SEDAR

Southeast Data, Assessment, and Review

Stock Assessment Report
of
SEDAR 7

Gulf of Mexico Red Snapper

SEDAR7
Assessment Report 1

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SEDAR 7 Gulf of Mexico Red Snapper
Complete Stock Assessment Report

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SouthEast Data, Assessment, and Review

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SECTION 1. Introduction

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1. SEDAR Overview

SEDAR (Southeast Data, Assessment and Review), is a process developed by the Southeast Fisheries Science Center and the South Atlantic Fishery Management Council to improve the quality and reliability of stock assessments and to ensure a robust and independent peer review of stock assessment products. SEDAR was expanded in 2003 to address the assessment needs of all three Fishery Management Council in the Southeast Region (South Atlantic, Gulf of Mexico, and Caribbean), and to provide a platform for reviewing assessments developed through the Atlantic and Gulf States Marine Fisheries Commissions and state agencies within the southeast.

SEDAR is organized around three workshops. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the Assessment workshop, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. Third and final is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. SEDAR workshops are organized by the SEDAR staff and the lead Council. Data and Assessment Workshops are chaired by the SEDAR coordinator. Participants are drawn from state and federal agencies, non-government organizations, Council members and advisors, and the fishing industry, with a goal of including a broad range of disciplines and perspectives. The Review Workshop is chaired by a scientist selected by the Center for Independent Experts, an organization that provides independent, expert review of stock assessments and related work. Other participants include one reviewer from the CIE, one from the SEFSC, one from NOAA fisheries, one NGO representative, one or more Council Advisory panel representatives, and one or more Council technical (SSC or other panel) representatives.

This assessment, eighth in the SEDAR series, is charged with assessing Caribbean stocks of yellowtail snapper and spiny lobster. The Review Workshop will also consider an assessment of Atlantic and Gulf of Mexico spiny lobster conducted by the State of Florida in a SEDAR workshop format and with assistance from the Councils and NOAA Fisheries.

2. Management Summary

2.1 INTRODUCTION

The Gulf of Mexico Fishery Management Council (Council), under provisions of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), is responsible for management of species within its geographic authority. To manage a given species (or group of species), the Council must first develop a fishery management plan (FMP) and submit it to the Secretary of Commerce (Secretary) for approval. The Reef Fish FMP was one of the first FMPs developed by the Council. It was submitted in August 1981, approved by the Secretary in June 1983, and implemented in November 1984. The goal identified in the FMP was “to manage the reef fish fishery of the United States waters of the Gulf of Mexico to attain the greatest overall benefits to the Nation with particular reference to food production and recreational opportunities on the basis of maximum sustainable yield (MSY) as modified by relevant economic, social, or ecological factors.” Pursuant to this goal, one of the primary objectives set forth in the FMP was to rebuild declining reef fish stocks wherever they occur in the fishery.

While encompassing a large number of species, much of the Council's reef fish management activities have pertained to red snapper. The fishery, which is targeted by commercial, for-hire, and recreational fishermen, is classified as overfished and undergoing overfishing. Evidence of a decline in the adult population was documented as early as the late 1980s during which time the fishery was primarily supported by age-1 to age-3 fish. The overfished status of the red snapper fishery is the result of not only an excessive amount of effort in the directed fishery, but also of a high level of bycatch mortality of juvenile red snapper associated with shrimp trawling.

When the Reef Fish FMP was implemented there was no attempt to directly limit effort in the fishery. However, when the first red snapper stock assessment was conducted in 1988 (Goodyear 1988[1]), the stock was determined to be so overfished that reductions in fishing mortality of 60 to 70 percent would be required to rebuild the stock. The assessment also confirmed that shrimp trawl bycatch was a significant source of juvenile red snapper mortality.

The following history of management only pertains to red snapper so some other reef fish amendments are not listed. Sections following historical implementation of the FMPs and Regulatory Amendments include the chronology of control dates to the fishery and tables summarizing bag limits, size limits, and fishing seasons (Tables 1-4). Also included in this report is the portion of the executive summary from Amendment 22 to the Reef Fish FMP (red snapper rebuilding plan). This summary provides the preferred alternatives selected by the Council for red snapper biological reference points and status determination criteria, a stock rebuilding plan, and bycatch reporting requirements as well as an overview of the rationale for their selection.

2.2 FISHERY MANAGEMENT PLANS AND REGULATORY AMENDMENTS

The Reef Fish FMP (with its associated environmental impact statement (EIS)) was implemented on November 8, 1984. The regulations, designed to rebuild declining reef fish stocks, included: (1) prohibitions on the use of fish traps, roller trawls, and power head-equipped spear guns within an inshore stressed area; (2) a minimum size limit of 12 inches fork length (FL) for red snapper with the exceptions that for-hire boats were exempted until May 8, 1987, and each angler could keep 5 undersize fish; and (3) the establishment of optimum yield (OY) for the snapper/grouper complex [49 FR 39548].

Amendment 1 to the Reef Fish FMP [with its associated environmental assessment (EA), regulatory impact review (RIR), and initial regulatory flexibility analysis (IRFA)], implemented on February 21, 1990, set as a primary objective of the FMP, the stabilization of long-term population levels of all reef fish species by establishing a survival rate of biomass into the stock of spawning age to achieve at least 20 percent spawning stock biomass per recruit (SSBR), relative to the SSBR that would occur with no fishing. It set a red snapper minimum size limit of 13 inches total length (TL) which is equivalent to the previous 12 inches FL, a 7-fish recreational bag limit and 3.1-million pound (MP) commercial quota that together were to reduce fishing mortality by 20 percent and begin a rebuilding program for that stock. A framework

[1] Goodyear, C.P. 1988. Recent trends in red snapper fishery of the Gulf of Mexico. NMFS. SEFSC. Miami FL. CRD 87/88-16. Memo. Rpt. 98p.

procedure for specification of total allowable catch (TAC) was created to allow for annual management changes, and a target date for achieving the 20 percent SSBR goal was set at January 1, 2000. This amendment also established a longline and buoy gear boundary inshore of which the directed harvest of reef fish with longlines and buoy gear was prohibited and the retention of reef fish captured incidentally in other longline operations (e.g., shark) was limited to the recreational bag limit. Subsequent changes to the longline/buoy boundary could be made through the framework procedure for specification of TAC [55 FR 2078].

A regulatory amendment implemented on March 11, 1991, set the red snapper TAC at 4.0 MP to be allocated with a commercial quota of 2.04 MP and a 7-fish recreational daily bag limit (1.96 MP allocation) beginning in 1991. This allocation of TAC was based on a provision in the framework procedure for specification of TAC which specified that commercial and recreational allocations be based on historical percentages harvested by each user group during the base period of 1979-87 (51 percent commercial, 49 percent recreational). The amendment also contained a proposal by the Council to effect a 50-percent reduction of red snapper bycatch in 1994 by the shrimp trawl fleet operating in the exclusive economic zone (EEZ), to occur through the mandatory use of finfish excluder devices on shrimp trawls, reductions in fishing effort, area or season closures of the shrimp fishery, or a combination of these actions. This combination of measures was projected to achieve a 20 percent SPR by the year 2007. The 2.04 MP quota was reached on August 24, 1991, and the red snapper fishery was closed to further commercial harvest in the EEZ for the remainder of the year.

At the direction of the Council, the Reef Fish Stock Assessment Panel (RFSAP) met in March 1990 and reviewed the 1990 red snapper stock assessment produced by NOAA Fisheries. The recommendation of the RFSAP at that time was to close the directed fishery because the Allowable Biological Catch (ABC) was being harvested as bycatch by the shrimp trawl fishery. No viable alternatives were identified that would achieve the 20-percent SPR goal by the year 2000 without closure of the directed fishery. This was because no means existed for reducing shrimp trawl bycatch that limited the ability of the stock to rebuild. As a result, **Amendment 3** (with its associated EA, RIR, and IRFA), implemented on July 29, 1991, provided additional flexibility in the annual framework procedure for specifying TAC by allowing the target date for rebuilding an overfished stock to be changed depending on changes in scientific advice, except that the rebuilding period cannot exceed 1.5 times the generation time of the species under consideration. It revised the FMP's primary objective, definitions of OY, overfishing, and framework procedure for TAC by replacing the 20 percent SSBR target with 20 percent SPR. The amendment also established a new red snapper rebuilding target year of 2007 for achieving the 20 percent SPR goal. In 1992, the commercial red snapper quota remained at 2.04 MP. However, extremely heavy harvest rates resulted in the quota being filled in just 53 days, and the commercial red snapper fishery was closed on February 22, 1992 [56 FR 33883]. An emergency rule [56 FR 30513], implemented in 1992 by NOAA Fisheries at the request of the Council, reopened the red snapper fishery from April 3, 1992, through May 14, 1992, with a 1,000-pound trip limit. This rule was implemented to alleviate economic and social upheavals that occurred as a result of the 1992 red snapper commercial quota being rapidly filled. Although this emergency rule resulted in a quota overrun of approximately 600,000 pounds, analysis by NOAA Fisheries' biologists determined that this one-time overrun would not prevent the red snapper stock from attaining its target SPR.

Amendment 4 (with its associated EA and RIR), implemented on May 8, 1992, established a moratorium on the issuance of new reef fish permits for a maximum period of three years. The moratorium was created to moderate short-term future increases in fishing effort and to attempt to stabilize fishing mortality while the Council considered a more comprehensive effort limitation program. It allowed the transfer of permits between vessels owned by the permittee or between individuals when the permitted vessel is transferred. Amendment 4 also changed the time of the year that TAC is specified from April to August and included additional species in the reef fish management unit [57 FR 11914].

An emergency rule effective December 30, 1992, created a red snapper endorsement to the reef fish permit for the start of the 1993 season. The endorsement was issued to owners or operators of federally permitted reef fish vessels who had annual landings of at least 5,000 pounds of red snapper in two of the three years from 1990 through 1992. For the duration of the emergency rule, while the commercial red snapper fishery was open, permitted vessels with red snapper endorsements were allowed a 2,000-pound possession limit of red snapper, and permitted vessels without the endorsement were allowed 200 pounds. This emergency action was initially effective for 90 days, and was extended for an additional 90 days with the concurrence of NOAA Fisheries and the Council. A related emergency rule delayed the opening of the 1993 commercial red snapper season until February 16 to allow time for NOAA Fisheries to process and issue the endorsements [59 FR 966].

A regulatory amendment implemented on March 23, 1993, raised the 1993 red snapper TAC from 4.0 MP to 6.0 MP to be allocated with a commercial quota of 3.06 MP and a recreational allocation of 2.94 MP (to be implemented by a 7-fish recreational daily bag limit). The amendment also changed the target year to achieve a 20 percent red snapper SPR from 2007 to 2009, based on the plan provision that the rebuilding period may not exceed 1.5 times the generation time of the stock and an estimated red snapper generation time of 13 years (Goodyear 1992) [58 FR 16371].

A regulatory amendment implemented on January 1, 1994, set the opening date of the 1994 commercial red snapper fishery as February 10, 1994, and restricted commercial vessels to landing no more than one trip limit per day. The purpose of this amendment was to facilitate enforcement of the trip limits, minimize fishing during hazardous winter weather, and ensure that the commercial red snapper fishery was open during Lent, when there is increased demand for seafood. The TAC was retained at the 1993 level of 6 MP, with a 3.06 MP commercial quota and 2.94 MP recreational allocation.

Amendment 5 (with its associated EIS, RIR, and IRFA), implemented on February 7, 1994, established restrictions on the use of fish traps in the Gulf EEZ, implemented a three-year moratorium on additional participation in the fishery by creating a fish trap endorsement and issuing the endorsement only to fishermen who had submitted logbook records of reef fish landings from fish traps between January 1, 1991, and November 19, 1992; created a special management zone (SMZ) with gear restrictions off the Alabama coast; created a framework procedure for establishing future SMZ's; required that all finfish except for oceanic migratory species be landed with head and fins attached; established a schedule to gradually raise the minimum size limit for red snapper from 13 inches TL to 16 inches TL over a period of five years; and closed the region of Riley's Hump (near Dry Tortugas, Florida) to all fishing during May and June to protect mutton snapper spawning aggregations.

Amendment 6 (with its associated EA and RIR), implemented on June 29, 1993, extended the provisions of the emergency rule for red snapper endorsements for the remainder of 1993 and 1994, unless replaced sooner by a comprehensive effort limitation program. In addition, it allowed the trip limits for qualifying and non-qualifying permitted vessels to be changed under the framework procedure for specification of TAC [58 FR 33025].

Amendment 7 (with its associated EA, RIR, and IRFA), implemented on February 7, 1994, established reef fish dealer permitting and record keeping requirements; allowed transfer of fish trap permits and endorsements between immediate family members during the fish trap permit moratorium; and allowed transfer of other reef fish permits or endorsements in the event of the death or disability of the person who was the qualifier for the permit or endorsement. A proposed provision of this amendment that would have required permitted vessels to sell harvested reef fish only to permitted dealers was disapproved by the Secretary of Commerce [59 FR 6588].

A regulatory amendment implemented on January 1, 1995, retained the 6 MP red snapper TAC and commercial trip limits and set the opening date of the 1995 commercial red snapper fishery as February 24, 1995. However, because the recreational sector exceeded its 2.94 MP red snapper allocation each year since 1992, this regulatory amendment reduced the daily bag limit from 7 fish to 5 fish, and increased the minimum size limit for recreational fishing from 14 inches to 15 inches one year ahead of the scheduled automatic increase [59 FR 67646].

Amendment 8 (with its associated EA, RIR, and IRFA), which proposed establishment of a red snapper Individual Transferable Quota (ITQ) system, was approved by NOAA Fisheries. The final rule was published in the *Federal Register* on November 29, 1995 [60 FR 61200]. This amendment provided for an initial allocation of percentage shares of the commercial red snapper quota to vessel owners and historical operators based on fishermen's historical participation in the fishery during the years 1990-1992, set a 4-year period for harvest under the ITQ system, during which time the Council and NOAA Fisheries would monitor and evaluate the program and decide whether to extend, terminate or modify it, and established a special appeals board, created by the Council, to consider requests by fishermen who contested their initial allocations of shares or determination of historical captain status. The appeals board was originally scheduled to meet during January 1996, with the ITQ system itself to become operational in April 1996. However, the federal government shutdown of December 1995-January 1996 forced an indefinite postponement of the appeals board meetings, and concerns about Congressional funding of the ITQ system made it inadvisable for the ITQ system to become operational, pending Congressional action. In October 1996, Congress, through re-authorization of the Magnuson-Stevens Act, repealed the red snapper ITQ system and prohibited Councils from submitting, or NOAA Fisheries from approving and implementing, any new individual fishing quota program before October 1, 2000.

Amendment 9 (with its associated EA and RIR), implemented on July 27, 1994, provided for collection of red snapper landings and eligibility data from commercial fishermen for the years 1990 through 1992. The purpose of this data collection was to evaluate the initial impacts of the limited access measures being considered under Amendment 8, and to identify fishermen who may qualify for initial participation under a limited access system. This amendment also extended the reef fish permit moratorium and red snapper endorsement system through December 31, 1995, in order to continue the existing interim management regime until longer term measures could be implemented. The Council received the results of the data collection in November 1994, at which time consideration of Amendment 8 resumed [59 FR 39301].

A regulatory amendment, implemented October 16, 1996, raised the red snapper TAC from 6 MP to 9.12 MP, with 4.65 MP allocated to the commercial sector and 4.47 MP allocated to the recreational sector. Recreational size and bag limits remained at 5 fish and 15 inches TL. The recovery target date to achieve 20 percent SPR was extended to the year 2019, based on new biological information that red snapper live longer and have a longer generation time than previously believed. A March 1996 addendum to the regulatory amendment split the 1996 and 1997 commercial red snapper quotas into two seasons each, with the first spring opening on February 1 with a 3.06 MP quota, and the fall season opening on September 15, with the remainder of the annual quota [61 FR 48641].

Amendment 11 (with its associated EA and RIR) was partially approved by NOAA Fisheries and implemented in January 1, 1996. Approved provisions included: (1) limit sale of Gulf reef fish by permitted vessels to permitted reef fish dealers; (2) require that permitted reef fish dealers purchase reef fish caught in Gulf federal waters only from permitted vessels; (3) allow transfer of reef fish permits and fish trap endorsements in the event of death or disability; (4) implement a new reef fish permit moratorium for no more than 5 years or until December 31, 2000, while the Council considers limited access for the reef fish fishery; (5) allow permit transfers to other persons with vessels by vessel owners (not operators) who qualified for their reef fish permit; (6) allow a one time transfer of existing fish trap endorsements to permitted reef fish vessels whose owners have landed reef fish from fish traps in federal waters, as reported on logbooks received by the Science and Research Director of NOAA Fisheries from November 20, 1992, through February 6, 1994; and (7) implemented a charter vessel/headboat permit [60 FR 64356].

The agency disapproved a proposal to redefine OY from 20 percent SPR (the same level as overfishing) to an SPR corresponding to a fishing mortality rate of $F_{0.1}$ until an alternative operational definition that optimizes ecological, economic, and social benefits to the Nation could be developed. In April 1997, the Council resubmitted the OY definition with a new proposal to redefine OY as 30 percent SPR. The re-submission document was disapproved by NOAA Fisheries. Following the Congressional repeal of the red snapper ITQ system in Amendment 8, an emergency interim action was published in the *Federal Register* on January 2, 1996, to extend the red snapper endorsement system for 90 days. That emergency action was superseded by another emergency action, published in the Federal Register on February 29, 1996, that extended the red snapper endorsement system through May 29, 1996, and subsequently, by agreement of NOAA Fisheries and the Council, for an additional 90 days until August 27, 1996.

Amendment 12 (with its associated EA and RIR), was implemented on January 15, 1997. NOAA Fisheries disapproved proposed provisions, for the commercial sector, to cancel the automatic red snapper size limit increases to 15 inches TL in 1996 and 16 inches TL in 1998 [61 FR 65983].

Amendment 13 (with its associated EA and RIR), implemented on September 15, 1996, further extended the red snapper endorsement system through the remainder of 1996 and, if necessary, through 1997, in order to give the Council time to develop a permanent limited access system that was in compliance with the new provisions of the Magnuson-Stevens Act [61 FR 48413].

A regulatory amendment implemented on March 17, 1997, changed the opening date of the fall 1997 commercial red snapper season from September 15 to September 2 at noon and closed the season on September 15 at noon; thereafter the commercial season was opened from noon of the first day to noon of the fifteenth day of each month until the 1997 quota was reached. It also complied with the new Magnuson-Stevens Act requirement that recreational red snapper be managed under a quota system by authorizing the NOAA Fisheries Regional Administrator (RA) to close the recreational fishery in the EEZ at such time as projected to be necessary to prevent the recreational sector from exceeding its allocation. Subsequent to implementation of a recreational red snapper quota, the recreational red snapper fishery filled its 1997 quota of 4.47 MP, and was closed on November 27, 1997, for the remainder of the calendar year [61 FR 46677 and 61 FR 48641].

A regulatory amendment implemented on January 1, 1998, canceled a planned increase in the red snapper recreational minimum size limit to 16 inches TL that had been implemented through Amendment 5, and retained the 15-inch TL minimum size limit [63 FR 443].

Amendment 14 (with its associated EA, RIR, and IRFA), implemented on March 25 and April 24, 1997, provided for a 10-year phase-out for the fish trap fishery; allowed transfer of fish trap endorsements for the first 2 years and thereafter, only upon death or disability of the endorsement holder, to another vessel owned by the same entity, or to any of the 56 individuals who were fishing traps after November 19, 1992, and were excluded by the moratorium; and prohibited the use of fish traps west of Cape San Blas, Florida. The amendment also provided the RA with authority to reopen a fishery prematurely closed before the allocation was reached and modified the provisions for transfer of commercial reef fish vessel permits [62 FR 13983].

Amendment 15 (with its associated EA, RIR, and IRFA), implemented on January 29, 1998, established a permanent two-tier red snapper license limitation system to replace the temporary red snapper endorsement system. Under the new system, Class 1 licenses and initial 2,000-pound trip limits were issued to red snapper endorsement holders as of March 1, 1997. Class 2 licenses, and initial 200-pound trip limits are issued to other holders of reef fish permits as of March 1, 1997, who had any landings of red snapper between January 1, 1990, and March 1, 1997. Vessels without a Class 1 or Class 2 red snapper license are prohibited from commercial harvest of red snapper, and licenses are fully transferable. The commercial red snapper season was split in two, with two-thirds of the quota allocated to a February 1 opening and the remaining quota to a September 1 opening. The commercial fishery was open from noon of the first day to noon of the fifteenth day of each month during the commercial season [62 FR 67714].

A regulatory amendment proposed maintaining the status quo red snapper TAC of 9.12 MP, but set a zero bag limit for the captain and crew of for-hire recreational vessels in order to extend the recreational red snapper quota season. NOAA Fisheries provisionally approved the TAC, releasing 6 MP, with release of all or part of the remaining 3.12 MP to be contingent upon the capability of shrimp BRDs devices to achieve better than a 50-percent reduction in juvenile red snapper shrimp trawl mortality. The zero bag limit for captain and crew of for-hire recreational vessels was not approved. Following an observer monitoring program of shrimp trawl BRDs conducted during the summer of 1998, NOAA Fisheries concluded that BRDs would be able to achieve the reduction in juvenile red snapper mortality needed for the red snapper recovery program to succeed, and the 3.12 MP of TAC held in reserve was released on September 1, 1998. In lieu of implementing the regulatory amendment, NOAA Fisheries implemented an interim rule effective April 14, 1998 (63 FR 18144) which initially allocated only 2/3 of the TAC of 9.12 MP and reduced the recreational red snapper bag limit from 5 to 4 fish for the period January 1 to August 30, 1998. A subsequent interim rule allocated the remainder of the TAC effective September 1, 1998.

An interim rule implemented by NOAA Fisheries in January 1999 reduced the recreational bag limit for red snapper from 5 to 4 fish per person and retained the 15-inch TL minimum size limit for both the commercial and recreational sectors. It also provided for the reopening of the recreational fishing season to commence in January 1999 [64 FR 47711]. A regulatory amendment implemented on October 1, 1999, maintained the status quo red snapper TAC of 9.12 MP; reduced the recreational bag limit for red snapper to 4 fish for recreational fishermen and zero fish for captain and crew of for-hire vessels (note: the zero fish bag limit for captain and crew was rescinded prior to its going into effect by a December 1999 interim rule); set the opening date of the recreational red snapper fishing season at March 1; reduced the minimum size limit for red snapper to 14 inches TL for both the commercial and recreational fisheries; and changed the opening criteria for the fall commercial red snapper fishing season from the first 15 days to the first 10 days of each month beginning September 1, until the sub-allocation is met or the season closes on December 31. This regulatory amendment followed up the same set of proposals requested under an emergency action, of which NOAA Fisheries approved only the proposal for a 4-fish bag limit.

Amendment 17 (with its associated EA and RIR) was implemented by NOAA Fisheries on August 2, 2000. It extends the reef fish permit moratorium for another five years, from the existing expiration date of December 31, 2000 to December 31, 2005, unless replaced sooner by a comprehensive controlled access system [65 FR 41016].

A regulatory amendment implemented on September 18, 2000, maintained the status quo red snapper TAC of 9.12 MP for the next two years, pending an annual review of the assessment; increased the red snapper recreational minimum size limit from 15 inches to 16 inches TL; set the red snapper recreational bag limit at 4 fish; reinstated the red snapper recreational bag limit for captain and crew of recreational for-hire vessels; set the recreational red snapper season to be April 15 through October 31, subject to revision by the RA to accommodate reinstating the bag limit for captain and crew; set the commercial red snapper spring season to open on February 1 and be open from noon on the 1st to noon on the 10th of each month until the spring sub-quota is reached; set the commercial red snapper fall season to open on October 1 and be open from noon on the 1st to noon on the 10th of each month until the remaining commercial quota is reached; retained the red snapper commercial minimum size limit at status quo 15 inches TL; and allocated the red snapper commercial season sub-quota at 2/3 of the commercial quota, with the fall season sub-quota as the remaining commercial quota [65 FR 50158]. These measures were first put in place by an interim rule from January 19 to June 19, 2000 [64 FR 71056], and continued through a second interim rule from June 19-December 16, 2000 [65 FR 36643].

Amendment 19, also know as the **Generic Amendment Addressing the Establishment of the Tortugas Marine Reserves** (with its associated EIS, RIR, and IRFA), was submitted to NOAA Fisheries in March 2001, and implemented on August 19, 2002. This amendment, affecting all FMPs for the Gulf fisheries (Amendment 19 to the Reef Fish FMP), establishes two marine reserve areas off the Tortugas area and prohibits fishing for any species and anchoring by fishing vessels inside the two marine reserves [67 FR 47467].

Amendment 20, also known as the **Charter/Headboat Moratorium Amendment** (with its associated EA and RIR), affects the Reef Fish FMP (Amendment 20), the Coastal Pelagic FMP (Amendment 14) was implemented by NOAA Fisheries on July 29, 2002, except for some provisions which will become effective on December 26, 2002. This amendment establishes a 3-year moratorium on the issuance of new charter and headboat vessel permits in the recreational for-hire fisheries (reef fish and coastal migratory pelagic fisheries only) in the Gulf EEZ. The purpose of this moratorium is to limit future expansion in the recreational for-hire fishery while the Council monitors the impact of the moratorium and considers the need for a more comprehensive effort management system in the for-hire recreational fishery. Although the control date notice which announced that a limited access system would be considered was dated November 18, 1998, the Council set a qualifying cut-off date of March 29, 2001, in order to include all currently permitted vessels and vessels which applied for a permit as of that date. The qualifying provisions also included persons who had a recreational for-hire vessel under construction prior to March 29, 2001, and who can show expenditures of at least five thousand dollars. In addition, persons who met the eligibility requirements to qualify as a historical captain will be issued a letter of eligibility, which will be replaced by a permit/endorsement valid only on the vessel that is operated by the historical captain [67 FR 43558].

Amendment 21 (with its EA, RIR, and IRFA) was approved in March 2004. The amendment will extend the Madison-Swanson and Steamboat Lumps marine reserves closures for an additional six years and modify fishing restrictions allowed within the reserves.

Proposed Amendment 22 (with its Draft Supplemental EIS (DSEIS), RIR, and IRFA) was submitted to NOAA Fisheries in June 2004 and is currently under review. It provides alternatives to set biological reference points and status determination criteria for red snapper, establish a rebuilding plan for the red snapper stock, and improve bycatch monitoring in the reef fish fishery. The specific proposed provisions of the rebuilding plan are:

Status Determination Criteria (based on the 1999 stock assessment, Schirripa and Legault 1999):

MSY = the yield associated with fishing at F_{MSY} = 41.13 million pounds (mp) whole weight (wwt), assuming low maximum recruitment and an initial steepness of 0.90 for the stock-recruitment relationship.

OY = the yield corresponding to fishing at F_{OY}, defined as: $F_{OY} = 0.75*F_{MSY} = 0.069$.

MSST = $(1-M) *B_{MSY}$ = 2,453 mp wwt where B_{MSY} = 2,726 mp wwt and M = 0.1.

MFMT = F_{MSY}

Rebuilding Strategy, Initial TAC, and Rebuilding Target Date: Maintain TAC at 9.12 mp wwt, end overfishing between 2009 and 2010, and rebuild red snapper by 2032. Review and adjust this policy, as necessary, through periodic assessments. Monitor annual landings to ensure quota is not exceeded.

In addition to the above, Amendment 22 contains a proposal to monitor bycatch in the reef fish commercial and for-hire recreational fisheries through a random selection observer program and by enhancing the MRFSS by including headboats using the same sampling methodology as used for charter vessels.

Amendment 26, currently under development, proposed to implement an individual fishing quota (IFQ) system for the commercial red snapper fishery.

Amendment 9 to the Shrimp FMP [with its associated SEIS, RIR, IRFA, and Social Impact Assessment (SIA)], approved in May 1998, required the use of a NOAA Fisheries-certified bycatch reduction devices (BRDs) in shrimp trawls used in the EEZ from Cape San Blas, Florida (85°30' W. Longitude) to the Texas/Mexico border and provided for the certification of the Fisheye BRD in the 30-mesh position. The purpose of this action was to reduce the bycatch mortality of juvenile red snapper by 44 percent from the average mortality for the years 1984-89. This amendment exempted shrimp trawling for royal red shrimp outside of 100 fathoms, as well as groundfish and butterfish trawls. It also excluded small try nets and no more than two ridged roller frame trawls that do not exceed 16 feet. Amendment 9 also provided mechanisms to change the bycatch reduction criterion and to certify additional BRDs [63 FR 18139].

Amendment 10 to the Shrimp FMP (with its associated EA, RIR, and IRFA), approved in March 2004, required the installation of a NOAA Fisheries-certified BRDs that reduces the bycatch of finfish by at least 30 percent by weight in each net used aboard vessels trawling for shrimp in the Gulf EEZ east of Cape San Blas, Florida (85° 30' W. Longitude). Vessels trawling for groundfish or butterfish are exempted. A single try net with a headrope length of 16 feet or less per vessel and no more than two rigid roller frame trawls limited to 16 feet or less, are also exempted [69 FR 1538].

2.3 Control Date Notices

Control date notices are used to inform fishermen that a license limitation system or other method of limiting access to a particular fishery or fishing method is under consideration by the Council. If a program to limit access is established, anyone not participating in the fishery or using the fishing method by the published control date may be ineligible for initial access to participate in the fishery or to use that fishing method. However, a person who does not receive an initial eligibility may be able to enter the fishery or fishing method after the limited access system is established by transfer of the eligibility from a current participant, provided the limited access system allows such transfer. Publication of a control date does not obligate the Council to use that date as an initial eligibility criteria. A different date could be used, and additional qualification criteria could be established. The announcement of a control date is primarily intended to discourage entry into the fishery or use of the gear based on economic speculation during the Council's deliberation on the issues. The following summarizes control dates that have been established for the Reef Fish FMP. A reference to the full *Federal Register* notice is included with each summary.

November 1, 1989 - Anyone entering the commercial reef fish fishery in the Gulf of Mexico and south Atlantic after November 1, 1989, may not be assured of future access to the reef fish resource if a management regime is developed and implemented that limits the number of participants in the fishery [54 FR 46755].

November 18, 1998 - The Council is considering whether there is a need to impose additional management measures limiting entry into the recreational-for-hire (i.e., charter vessel and headboat) fisheries for reef fish and coastal migratory pelagic fish in the EEZ of the Gulf of Mexico and, if there is a need, what management measures should be imposed. Possible measures include the establishment of a limited entry program to control participation or effort in the recreational-for-hire for reef fish and coastal migratory pelagics [63 FR 64031]. (In the Charter/Headboat Moratorium Amendment, approved by the Council for submission to NOAA Fisheries in March 2001, a qualifying date of March 29, 2001, was adopted.)

July 12, 2000 - The Council is considering whether there is a need to limit participation by gear type in the commercial reef fish fisheries in the EEZ of the Gulf of Mexico and, if there is a need, what management measures should be imposed to accomplish this. Possible measures include modifications to the existing limited entry program to control fishery participation, or effort, based on gear type, such as a requirement for a gear endorsement on the commercial reef fish vessel permit for the appropriate gear. Gear types which may be included are longlines, buoy gear, handlines, rod-and-reel, bandit gear, spearfishing gear, and powerheads used with spears [65 FR 42978].

March 29, 2001 - The Council is considering whether there is a need to limit participation for the reef fish and coastal migratory pelagics charter vessel and headboat fisheries. The intent of this notice is to inform the public that entrants into the charter vessel/headboat fisheries after this date may not be assured of a future access to the reef fish and/or coastal migratory pelagics resources if: 1) an effort limitation management regime is developed and implemented that limits the number of vessels or participants in the fishery; and 2) if the control date notice is used as criterion for eligibility [67 FR 32312].

December 6, 2003 - On April 29, 2003, NOAA Fisheries published an advanced notice of proposed rulemaking that established a control date of December 6, 2003, for the commercial shrimp fishery operating in the Gulf EEZ. By way of the notice, the public is advised that, in the future, the Council may consider management measures to limit entry into the shrimp fishery, and may use this control date as a qualifying criterion for participation in the fishery [68 FR 22667].

2.4 INDIVIDUAL FISHING QUOTA (IFQ) PROGRAM

Overall, it could be concluded that a “derby ” situation in the red snapper fishery had developed by 1992. Despite the aforementioned increase in regulations, initiated in an attempt to ameliorate the adverse affects of “derby” fishing, including the implementation of a two-tier system with differential trip limits and numerous seasonal closures, the fishery still harvests its quota in a relatively short time. In 2000, for example, the commercial fishery remained open for only 76 days despite a commercial quota of 4.65 MP. In essence, while the commercial quota has increased by 50 percent between 1990 and 2000 (i.e., 3.1 MP to 4.65 MP), the length of the season has been reduced by about three-quarters (from 365 days to 76 days). It is the results of the reduced season length, marketing conditions, and safety-at-sea issues that the Council is now developing options for an IFQ program for the Gulf of Mexico red snapper fishery.

2.5 RED SNAPPER REBUILDING PLAN

Executive Summary

The red snapper stock is in an overfished condition and undergoing overfishing. Currently this stock is under a rebuilding plan to restore the stock to 20 percent SPR by 2019. However, this plan is inconsistent with NOAA Fisheries National Standard Guidelines (NSGs). Definitions of stock size, the overfished threshold, and yield must be biomass-based, but overfishing definitions can be based on SPR proxies for the fishing mortality rate that would provide MSY. Therefore, before a rebuilding plan can be initiated to halt overfishing and rebuild a stock, overfished and overfishing targets and thresholds must be specified so that rebuilding goals are known.

For overfished stocks, a recovery plan must be developed to end overfishing and restore the stock to the biomass level capable of producing MSY on a continuing basis (B_{MSY}). This goal is more conservative than that currently specified (20 percent SPR), which is estimated to be the minimal level needed to prevent future declines in the stock. Rebuilding is to occur in as short a time period as possible, but should not exceed 10 years unless conditions dictate otherwise. For red snapper, it would take more than 10 years to rebuild the stock even if the directed fishery was closed. The longest rebuilding period recommended by the NSGs is the time to recover in the absence of fishing mortality (12 years) plus the mean generation time (19.6 years). This equals 31.6 years for red snapper. The Council did submit a recovery plan through a regulatory amendment that met the new guidelines in 2001. It set a recovery target of 2032 or earlier for the stock. However, this amendment was returned to the Council by NOAA Fisheries with a request to further explore alternative rebuilding plans based on realistic expectations for future reductions in shrimp trawl bycatch, and to more fully evaluate the effects of alternatives through a SEIS.

Additionally, the Magnuson-Stevens Act requires that FMPs establish a standardized methodology to assess the amount and type of bycatch occurring in the fishery and to identify and implement conservation measures that, to the extent practicable, minimize bycatch.

Therefore, the purpose of this amendment is to:

1) Review, and redefine as needed, biological reference points and status determination criteria;

2) Establish a plan to end overfishing and rebuild the red snapper stock to a level consistent with current fishery management standards;

3) Establish a standardized methodology to collect bycatch information in the directed red snapper fishery; and

4) Evaluate the practicability of additional measures to reduce bycatch and bycatch mortality in the directed red snapper fishery.

Description of Alternatives

Biological Reference Points and Status Determination Criteria

Status determination criteria are defined by 50 CFR '600.310 to include a minimum stock size threshold (MSST), i.e., the overfished criterion, and a maximum fishing mortality threshold (MFMT), i.e., the overfishing criterion. Together with MSY and optimum yield (OY), these parameters are intended to provide fishery managers with the tools to measure fishery status and performance.

Estimates of MSY, B_{MSY}, and the rate of fishing mortality that achieves MSY (F_{MSY}) provided by the most recent peer-reviewed stock assessment (Schirripa and Legault, 1999) serve as the foundation of the alternative bundles of reference points and status determination criteria considered in this amendment for red snapper. The 1999 assessment produced a range of point estimates for MSY based on various assumptions about the stock-recruitment relationship. These assumptions were defined by varying two parameters: (1) steepness and (2) estimated maximum recruitment. These parameters are used to make assumptions about or provide quantitative estimates of the productivity of a stock. The estimated productivity level of a stock increases and decreases in response to a respective increase or decrease in the values used for these parameters in the assessment model. Data from these assessment runs are used to calculate alternative definitions of OY, MSST, and MFMT.

The preferred alternative for the biological reference points and status criteria are as follows:

Alternative 2 (Preferred): **MSY for red snapper equals the yield associated with fishing at F_{MSY}, or 41.13 million pounds (MP) whole weight (wwt), assuming low maximum recruitment and an initial steepness of 0.90 for the stock-recruitment relationship.**

Until recovery, the harvest for red snapper will be defined as consistent with the rebuilding strategy selected in this amendment. After achieving the rebuilding target, the OY for red snapper shall correspond to a fishing mortality rate (F_{OY}) defined as:

$F_{OY} = 0.75*F_{MSY} = 0.069$

Red snapper MSST shall equal:

$(1\text{-}M) *B_{MSY} = 2{,}453$ MP wwt where $B_{MSY} = 2{,}726$ MP wwt and $M = 0.1$

Red snapper MFMT is equal to:

F_{MSY}.

The red snapper stock would be considered undergoing overfishing if F_{CURR} is greater than MFMT.

Plan to End Overfishing and Rebuild the Red Snapper Stock to B_{MSY}

The cause of the overfishing and overfished status of the red snapper fishery in the Gulf of Mexico is unique to many American fisheries. This status was not only the result of fishing mortality from the directed fishery, but also due to a high level of bycatch mortality on juvenile red snapper by the shrimp trawl fishery. This non-directed fishery catches substantial numbers of juvenile red snapper as bycatch such that without some reduction in bycatch, stock assessments have projected that the stock cannot rebuild to B_{MSY} even if no harvest was allowed by the directed fishery. Therefore, to end overfishing and rebuild the red snapper stock, large reductions in bycatch mortality from the shrimp fishery need to be achieved either through technological means such as bycatch reduction devices (BRD), or through a reduction in effort by the shrimp fishery. Currently, BRDs are estimated to achieve about a 40 percent reduction in red snapper bycatch. In addition, recent analyses of the economic performance of the shrimp fishery have indicated an economic downturn that will likely cause shrimp effort to decline.

Projections show that red snapper stock can rebuild within 31 years which is the longest recommended period by the NOAA Fisheries NSGs. Given the unique effect the Gulf shrimp fishery (one of the most economically important fisheries to the United States of which the Gulf of Mexico contributes over 70 percent to the total pounds landed (NOAA Fisheries, 2003a[2])) has on rebuilding the red snapper, the general guidance provided by the NSGs to assist with determining the rebuilding schedule may not apply. Therefore, rebuilding strategy alternatives based on longer rebuilding periods were also explored.

The alternative for ending overfishing and rebuilding the stock are as follows:

Alternative 2 (Preferred): Maintain TAC at 9.12 MP wwt, end overfishing between 2009 and 2010, and rebuild red snapper by 2032. Review and adjust this policy, as necessary, through periodic assessments. Monitor annual landings to ensure quota is not exceeded.

Bycatch Reporting Methodology

Current regulations require selected commercial and recreational for-hire participants in the Gulf reef fish fishery to maintain and submit a fishing record on forms provided by NOAA Fisheries. Bycatch is reported for the commercial fishery via the Coastal Fisheries Logbook Program (CFLP). The Marine Recreational Fisheries Statistical Survey (MRFSS) collects fishery information including bycatch data from private recreational vessels, as well as the recreational for-hire sector. Other methodologies including expanded reporting programs and observers, are ways to increase the scope of bycatch reporting. While data on bycatch in the Gulf of Mexico shrimp fishery are important to the understanding of the recovery rate of red snapper, it is beyond the scope of this amendment to include bycatch reporting methodologies for the shrimp fishery. Modifications to the bycatch reporting methodologies used in the shrimp fishery must to be addressed through an amendment to the Shrimp FMP. Currently such alternatives are being considered in Shrimp Amendment 13.

The Council chose two preferred alternatives for the commercial and for-hire fisheries. These will not replace existing methodologies over the short-term because a baseline needs to be maintained for comparative purposes.

Commercial and Recreational For-Hire Fisheries

Alternative 4 (Preferred). Develop an observer program managed by NOAA Fisheries for the reef fish fishery. NOAA Fisheries will develop a random selection procedure for determining vessels that will be required to carry observers in order to collect bycatch information. In selecting vessels, the agency will consider the suitability of the vessel for such purpose and ensure that the universe of vessels included are representative of all statistical sub-zones in the Gulf. Vessel permits will not be renewed for vessels that fail or refuse to carry observers in accordance with this process. The requirement for the observer program to be implemented is contingent on NOAA Fisheries obtaining sufficient funding for the program.

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[2]NOAA Fisheries. 2003. Fisheries of the United States, 2002. NOAA Fisheries, Silver Springs, MD. 126p

Alternative 6 (Preferred). Enhance the MRFSS by including headboats using the same sampling methodology as used for charter vessels.

Private Recreational Fishery

Alternative 1 (Preferred). No Action (status quo). Use the existing MRFSS catch and effort program to continue collecting bycatch information from the private recreational sector.

Bycatch Minimization Measures

The evaluation of the practicability of additional management measures to reduce bycatch and bycatch mortality considers the status of the stock, and the impacts of that bycatch from various fisheries. Anecdotal information suggests that the red snapper stock has improved since it was last assessed in 1999, and that red snapper bycatch mortality in the shrimp fishery has declined considerably (estimated 40 percent) due to the implementation of BRDs. The current assessment indicates that any action taken to reduce bycatch in the directed fishery would not likely effect the status of the red snapper stock. However, an assessment is due to be completed in 2004 and is expected to provide additional information on the implications of current bycatch mortality on the red snapper stock from the directed fishery.

The 2004 assessment will incorporate a great deal of new information, including five years of observer data on shrimp trawl bycatch, fishery-dependent data on observed changes in lengths of harvested fish, and estimates of changes in age-one recruitment from the Southeast Area Monitoring and Assessment Program (SEAMAP) data. Additionally, the results of new research into red snapper stock structure in the northern and western Gulf and new estimates of discard mortality should be available to use in the assessment. This new information, combined with four years of data on the fishery under the same management regulations, is expected to provide us with a better understanding of the impacts of BRDs, the effectiveness of regulations in the directed fishery, and the possible impacts of new regulations on the red snapper stock.

The Council plans to use the results of the 2004 assessment to develop logical and defensible measures to reduce shrimp trawl bycatch and/or directed fishery discards. Shrimp trawl bycatch must be addressed in the Shrimp FMP. Options for bycatch minimization are being considered in Amendment 14 of the Shrimp FMP.

The preliminary analysis of the practicability factors indicates that there would not likely be positive biological impacts associated with further reducing bycatch in the directed red snapper fishery unless the 2004 stock assessment shows a major increase in the relative proportion of bycatch taken in the directed fishery. Many of the minimization measures considered (e.g., minimum sizes, seasonal closures, education, and an individual fishing quota for the commercial fishery) would result in short-term adverse economic and social impacts. Consequently, the Council has concluded that it would not be practicable to take action to further reduce bycatch in the directed fishery at this time based on the best available scientific information. The Council will review this decision in Amendment 18 to the Reef Fish FMP and may wish to take further actions based on the results of the 2004 red snapper stock assessment.

Major Conclusions and Areas of Controversy

The selections by the Council for preferred alternatives for biological reference points and status determination criteria, rebuilding plans, and bycatch reporting methodology reflect positive actions in long-term managing of the red snapper stock and fishery. The Council selected the most precautionary alternative presented for MSY which results in the lowest estimate of stock production relative to the other alternatives. The potential disadvantage of this alternative is forgone yield should the stock be more productive. The advantage of using a more conservative estimate of stock productivity is that the chance of over harvesting the stock diminishes. Preferred alternatives for OY and status determination criteria follow NOAA Fisheries' technical guidance for precautionary approaches to these parameters.

Red snapper stock rebuilding cannot occur without reductions of juvenile red snapper bycatch by the shrimp fishery. Projections indicate that even with a 40 percent reduction of bycatch mortality by using BRDS, the stock cannot rebuild to B_{MSY}. The preferred rebuilding plan alternative selected by the Council takes into account predicted reductions in bycatch achieved through decreases in effort in the shrimp fishery. This plan is projected to rebuild the stock by holding TAC constant at 9.12 MP to B_{MSY} by 2032.

Bycatch reporting methodologies are required for FMPs. Data collected on bycatch is important for assessing stocks and developing appropriate management actions. The preferred alternatives selected by the Council for observers and expansion of the MRFSS survey to include headboats should enhance information needs for better management decisions. Observers improve the precision of catch and bycatch data; however, observer programs are expensive and funding would need to be identified before implementing a program. Currently, headboats are not sampled for bycatch, so adding this component of the recreational fishery to MRFSS should improve bycatch data. The Council determined that for the recreational fishery, the current MRFSS program was sufficient to obtain bycatch information.

3. Review Workshop Advisory Report

Assessment Summary Report
Gulf of Mexico Red Snapper
SEDAR 7

Stock Distribution:

- Red snapper are found throughout the Gulf of Mexico, the Caribbean Sea, and from the U.S. Atlantic Coast to northern South America. Major fisheries occur in both U.S. and Mexican waters of the Gulf of Mexico.
- This assessment addresses red snapper in the U.S. Gulf of Mexico. The stock is divided into eastern and western gulf components to allow application of area-specific life history characteristics, catch statistics, and survey indices. This assessment incorporates considerable new information available since the last assessment and includes an extended time series of catch (starting in 1872) derived to improve stock productivity estimates.

Assessment Methods & Data:

- Red snapper in the Gulf of Mexico were assessed with several models, including ASAP, SRA, VPA, and CATCHEM. Within each type of model various configurations were explored. Details of all models are available in the Stock Assessment Report and the Review Panel Consensus Summary.
- The Assessment Workshop chose the CATCHEM model to provide the base assessment results based on its flexibility and better mathematical rigor. The RW accepted this model with some structural modifications that are detailed in the Consensus Summary and summarized here in a subsequent section.
- Data sources include landings, age composition data , fishing effort, and relative abundance indicators from commercial and recreational, directed and bycatch fleets east and west of the Mississippi; multiple fishery-independent relative abundance measures; and recent information on growth and reproduction.

Catch Trends:

- Catch in numbers of fish is dominated by shrimp bycatch which mainly consists of age-0 and age-1 fish (Figure 1). The shrimp fishery annually removes roughly 25-45 million fish, mainly from the western Gulf in recent years. The recreational and commercial fisheries combined take roughly 3-4 million red snapper annually.
- Red snapper taken by the directed commercial and recreational fisheries dominate removals in weight, accounting for about 9 million pounds in recent years. In comparison, the annual weight of the shrimp bycatch returned to the sea was estimated to be roughly two to five million pounds (Figure 2).

Sources of Information:

- Results are summarized in the following bullets. Complete details are available in the SEDAR7 Assessment Report, the SEDAR 7 Review Panel Consensus Summary, and the many SEDAR 7 workshop working papers.
- Complete results of the CATCHEM model configuration preferred by the Review Panel are contained in the Appendix to the Stock Assessment Report.

Status Determination Criteria:

- The Assessment Workshop base case did not include removals of age-0 red snapper. The Review Workshop (RW) recommends including those removals in the assessment.
- The decision to include or exclude age-0 fish is based on assumptions about timing and strength of density dependent effects on survival (in other words, the point at which year-class strength is determined).
- Excluding age-0 removals (whether from landings or discard mortality) implies that, regardless of other factors, cohorts experience such strong compensatory density dependent natural mortality at age-0 that age-0 fishing mortality does not affect abundance at older ages. Including age-0 removals implies that there is no compensation for age-0 fishing mortality and therefore fishing mortality on age-0 affects abundance at older ages.
- Although considerable uncertainty remains regarding the recruitment dynamics of red snapper, the RW does not support assuming that mortality on age-0 fish is irrelevant, and thus does not support excluding age-0 fish from analysis. While some compensation may occur for age-0 fish, it seems unlikely that compensation is so strong that fishing mortality is irrelevant.
- MSY reference points upon which overfishing and overfished criteria and rebuilding plans are based are derived either from spawner-recruitment (S-R) functions or by assuming that MSY is associated with a specific level of spawning per recruit (expressed as a percentage of the unfished level and designed "SPR").
- The RW concurred with the AW that spawner per recruit (SPR) benchmark levels may be more robust to uncertainties regarding the true underlying stock-recruitment function and selectivity patterns in the fishery. $SPR_{30\%}$, which has already been employed by the Council, is relatively insensitive to benchmarks derived from a stock-recruitment function. The RW points out that SPR benchmarks are consistent with MSY concepts as estimates of both FMSY and BMSY can be inferred from any SPR.
- SPR based reference points are not robust to all aspects of recruitment uncertainty, and they are not entirely robust to size- or age-specific allocation decisions as discussed below.
- The RW did not recommend whether S-R or SPR based reference points should be applied in this case. The RW did agree that a stock-recruitment function with maximum recruitment based on the recent average recruitment was the most realistic function to use for projections. The RW also agreed that a similar approach should be used for MSY reference points, whether calculated through the S-R or SPR approach.
- The RW points out that both SPR and S-R based approaches require a S-R function to determine MSY and S_{msy}. While the spawning stock at MSY (Smsy) is independent of size or

age specific allocation, the biomass at MSY (Bmsy; total recruited biomass associated with MSY) is affected by allocation to some degree, and MSY can be sensitive to it when there are discards.

- Reference values derived through SPR and S-R approaches are dependent on the assumption that the recent average recruitment will continue in the future, with the exception of the value for Fmsy when based on SPR.
- The Council should carefully consider risk to the stock and the relative advantages and disadvantages offered by both MSY and SPR-based approaches when determining the appropriate Maximum Fishing Mortality Threshold (MFMT) and other reference points. Management strategy options and allocation decisions of the Council will influence benchmark values.
- Stock status benchmarks should be tested for robustness to sources of uncertainty within the assessment and to better define the management strategy for red snapper. This would help decrease the range of possible benchmarks for consideration.

Fishing Mortality:

- Fishing mortality is estimated by fleet for both eastern and western stock components.
- Fishing mortality of each fleet in the eastern stock component is below F=0.2 until the mid 1970's . Between 1975 and 1983 the recreational component increases considerably and exceeds F=1.0 in 1983, then remains generally high but variable. Commercial hook and line fishing mortality also increases noticeably after 1980, reaching nearly F=0.4 in 1990, but then returns to pre-1980 levels by the mid-1990s. (Figure 3).
- Bycatch fishing mortality dominates the Western stock component, with estimates increasing from just below F=0.2 in 1950 to nearly F=1 by the mid-1980's and later. Fishing mortality for the recreational fishery begins to increase by 1970, varies around F=0.4 through the 1980's, then declines to around F=0.1. Fishing mortality for the commercial hook and line increases to F=0.2 between 1980 and 1984 where it remains until the mid 1990's when it increases to around F=0.4.

Recruitment and Spawning Stock Level:

- Estimated recruitment for both stock components increases noticeably after 1980 and is generally above the long term average in recent years although spawning stock is estimated to be much lower than it was historically (Figure 4). Possible explanations of such a pattern were discussed but no single reason emerged as most probable. The Review Panel suggested further research of this issue.
- The panel considers it unlikely that future recruitment can be reasonably predicted from the observed long-term spawner-recruitment relationship and instead recommends basing stock projections on average recruitment estimated between 1984 and 2003.
- Spawning stock depletion in both the east and the west stock components is attributed to the combined effects of direct harvest and bycatch by the shrimp fleet. (Figure 4).

Stock Status:

- Gulf Red Snapper are overfished and overfishing was occurring in 2003 (Table 1, Figure 5). These conclusions are consistent with previous assessments despite changes in stock status criteria and assessment methods over the periods covered by those assessments.

Projections:

- Projections are derived from the area-specific model used to estimate stock status; however, results are also combined across regions to provide gulf-wide values for parameters such as total allowable catch (TAC) and productivity to accommodate the current management system (Table 1).
- Projection results presented are a subset of many possible scenarios considered during the Assessment and Review Workshops. Scenarios presented here were chosen to illustrate the trade-off between bycatch removals and directed harvest and to examine the feasibility of stock recovery within the rebuilding timeframe.
- The Review Panel considers future recruitment the greatest source of uncertainty in projections and recommends exploring several alternative future recruitment assumptions. Projections presented here are based on the base case, which assumes future recruitment will be the same as the average estimated recruitment for 1984-2003. Results of all projection scenarios are summarized in the Consensus Summary and detailed in the Stock Assessment Report Appendix.
- Higher directed fishery yield is feasible in future years if mortality from shrimp fishery bycatch is reduced below current levels (Table 1, Figure 6).
- The Gulf-wide SPR could exceed 30% by 2032 with long-term directed fishery yields ranging from 2-25 million pounds if shrimp fishery bycatch mortality is further reduced (Table 1, Figure 6). Long-term yields of 3 million pounds are feasible if shrimp bycatch mortality allocation is further reduced 40% and directed fishing continues at the $F_{30\%SPR}$ rate ; long-term yields of 6.3 million pounds are feasible if shrimp bycatch mortality allocation is further reduced 50% and directed fishing continues at the $F_{30\%SPR}$ rate, and long-term yields of 25 million pounds are feasible under the equal proportion mortality rate reduction scenario and directed fishing continues at the $F_{30\%SPR}$ rate.
- The Gulf-wide spawning stock could exceed the S_{msy} ($S_{5\%SPR}$) level fishing at $F_{5\%SPR}$ by 2023 with a resulting long-term directed fishery yield thereafter of MSY=11 million pounds under the 'current shrimp' allocation scenario. Gulf wide spawning stock could exceed the S_{msy} level by 2031 with directed fishery yields between 17 and 25 million pounds if shrimp fishery bycatch mortality allocation is further reduced (Table 1, Figure 6). Long-term yields of 17 million pounds are feasible if shrimp bycatch mortality allocation is reduced a further 40% (S_{msy}=$S_{7\%SPR}$) and directed fishing continues at the $F_{7\%SPR}$ rate; long-term yields of 18 million pounds are feasible if shrimp bycatch mortality allocation is reduced a further 50% (S_{msy}=$S_{8\%SPR}$) and directed fishing continues at the $F_{8\%SPR}$ rate, and long-term yields of 25 (S_{msy}=$S_{27\%SPR}$) million pounds are feasible if shrimp and directed fisheries are reduced equally and directed fishing continues at the $F_{27\%SPR}$ rate.

- The previous two statements refer to results combined for both the east and west stock components. However, if red snapper are treated as separate stocks in the eastern and western Gulf of Mexico, all projection scenarios indicate the eastern stock can recover with the allotted time, whereas the western stock may not rebuild in the allotted time frame under some projection scenarios. (see caption of Table 1).
- The outlook for each component differs if red snapper are considered separate stocks in the eastern and western Gulf of Mexico. For the western component, only the equal proportion reduction scenario provides recovery to $SPR_{30\%}$ by 2032, and the stock cannot reach $SPR_{30\%}$ under either the current shrimp or 40% shrimp reduction scenarios. The western component may reach S_{msy} between 2024 and 2032, depending upon which scenario is chosen. The eastern stock component can achieve $SPR_{30\%}$ by 2028 and S_{msy} by 2027 under all scenarios (Table 1).

Table 1. Summary of the status of red snapper in the Gulf of Mexico relative to MSY and $SPR_{30\%}$ criteria conditioned on four bycatch mortality scenarios: (1) directed fishery mortality rates reduced by same proportion, but bycatch mortality rates (shrimp and closed season) remain at current levels, (2) like 1, but shrimp bycatch mortality rates reduced by 40%, (3) like 1, but shrimp bycatch mortality rates reduced by 50%, and (4) mortality rates associated with all fleets (directed and bycatch) reduced by the same proportion. Note that the second scenario (40% reduction) reflects the expectations of an economic forecast, with the predicted reductions modeled to begin and continue after 2007. The third scenario (50% reduction) is shown because SPR values of 30% or higher could not be achieved for the western stock under a 40% reduction. The sections labeled 'East' and 'West' give the results expected when the two stocks will be managed independently. The section labeled 'Gulf' gives the results expected when the stocks are managed as a single unit. An asterisk (*) indicates that a sustainable directed fishery harvest at the $F_{30\%}$ level cannot be achieved. Note that the projections and status criteria assume future recruitment will follow a Beverton-Holt spawner-recruit relationship with virgin recruitment levels equal to the average recruitment estimated for 1984-2003 and steepness = 0.974. The statistic S_0 here represents the spawning potential of the stock under this new spawner-recruit relationship (rather than the historical virgin spawning potential).

		Shrimp fishery bycatch mortality reduction scenario			
Area	Benchmark statistic	Current shrimp	40% shrimp reduction	50% shrimp reduction	Equal proportion reduction
East	Yield at $F_{30\%}$ (mp)	3.1	3.9	4.1	6.4
	$F_{2003}/F_{30\%}$	8.2	6.6	6.3	4.1
	$S_{2003}/S_{30\%}$	0.11	0.11	0.11	0.11
	$S_{2010}/S_{30\%}$	0.33	0.32	0.31	0.37
	year $S/S_{30\%}$ = 1	2028	2028	2028	2027
	MSY (mp)	4.6	5.1	5.3	6.4
	F_{2003}/F_{MSY}	2.6	2.6	2.6	3.6
	S_{2003}/S_{MSY}	0.29	0.25	0.25	0.13
	S_{2010}/S_{MSY}	0.60	0.55	0.53	0.41
	year S/S_{MSY} = 1	2022	2022	2023	2027
	SPR at F_{MSY}	11%	13%	13%	26%
	S_{2003}/S_0	0.032	0.032	0.032	0.032
West	Yield at $F_{30\%}$ (mp)	*	*	1.2	18.9
	$F_{2003}/F_{30\%}$	*	*	61.9	4.3
	$S_{2003}/S_{30\%}$	*	*	0.04	0.04
	$S_{2010}/S_{30\%}$	*	*	0.15	0.21
	year $S/S_{30\%}$ = 1	*	*	>2032	2032
	MSY (mp)	6.8	11.4	12.9	19.0
	F_{2003}/F_{MSY}	2.2	2.1	2.0	3.9
	S_{2003}/S_{MSY}	0.29	0.19	0.17	0.04
	S_{2010}/S_{MSY}	0.64	0.43	0.40	0.22
	year S/S_{MSY} = 1	2024	2026	2027	2032
	SPR at F_{MSY}	4%	6%	7%	27%
	S_{2003}/S_0	0.011	0.011	0.011	0.011

Table 1 continued

Area	Benchmark statistic	Shrimp bycatch mortality reduction scenario: Current shrimp	40% shrimp reduction	50% shrimp reduction	Equal proportion reduction
Gulf	Yield at $F_{30\%}$ (mp)	*	3.0	6.3	25.3
	$F_{2003}/F_{30\%}$	*	35.7	18.8	4.3
	$S_{2003}/S_{30\%}$	*	0.05	0.05	0.05
	$S_{2010}/S_{30\%}$	*	0.19	0.19	0.24
	year $S/S_{30\%} = 1$	*	2032	2032	2031
	MSY (mp)	11.3	16.5	18.1	25.4
	F_{2003}/F_{MSY}	2.3	2.2	2.2	3.8
	S_{2003}/S_{MSY}	0.29	0.21	0.20	0.06
	S_{2010}/S_{MSY}	0.62	0.46	0.43	0.26
	year $S/S_{MSY} = 1$	2023	2026	2026	2031
	SPR at F_{MSY}	5%	7%	8%	27%
	S_{2003}/S_0	0.015	0.015	0.015	0.015

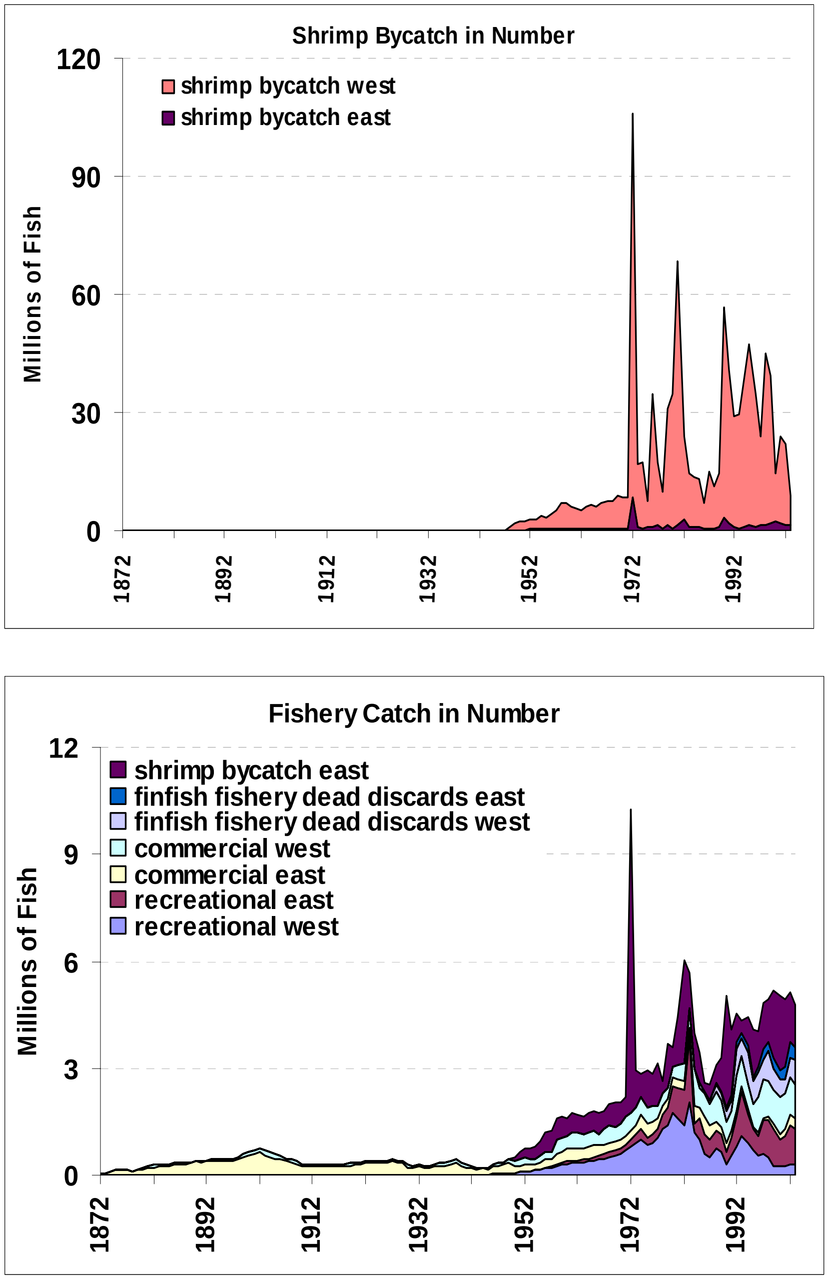

Figure 1. Estimated and calculated catch in number of red snapper from the shrimp fishery (upper panel, east and west) and the eastern shrimp fishery and the east and west finfish fisheries for 1872-2003. Note the differences in scale between the two panels.

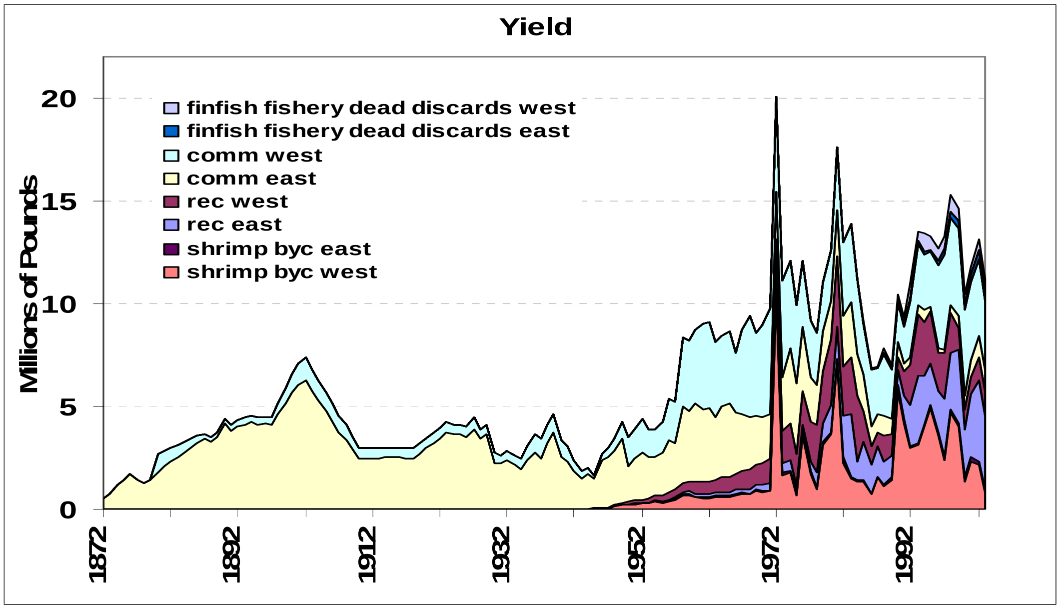

Figure 2. Recorded and calculated weight (pounds) of red snapper landed and discarded from the recreational, commercial, and shrimp fisheries during 1872-2003.

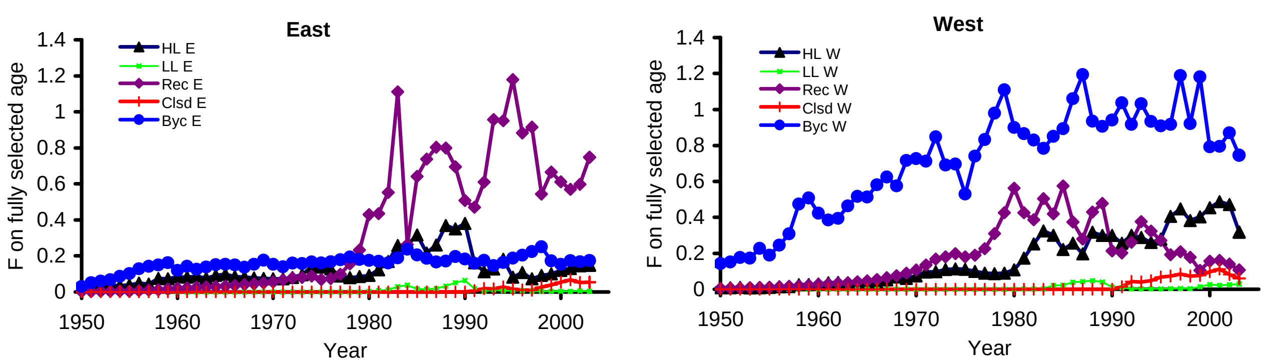

Figure 3. Trends in estimated fishing mortality rates for the most vulnerable age class for each fishing fleet modeled. Fleet designations are: HL handline, LL longline, Rec recreational, Clsd closed season, Byc shrimp bycatch. E designates eastern Gulf fleets and W designates western Gulf fleets.

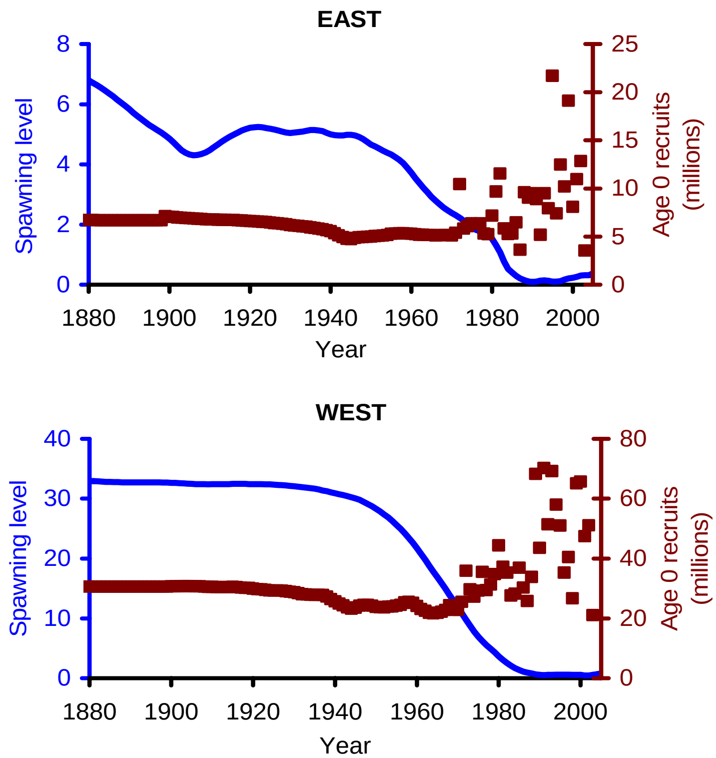

Figure 4. Estimated trends in red snapper spawning level (solid line) and recruitment (squares) for the eastern and western Gulf of Mexico.

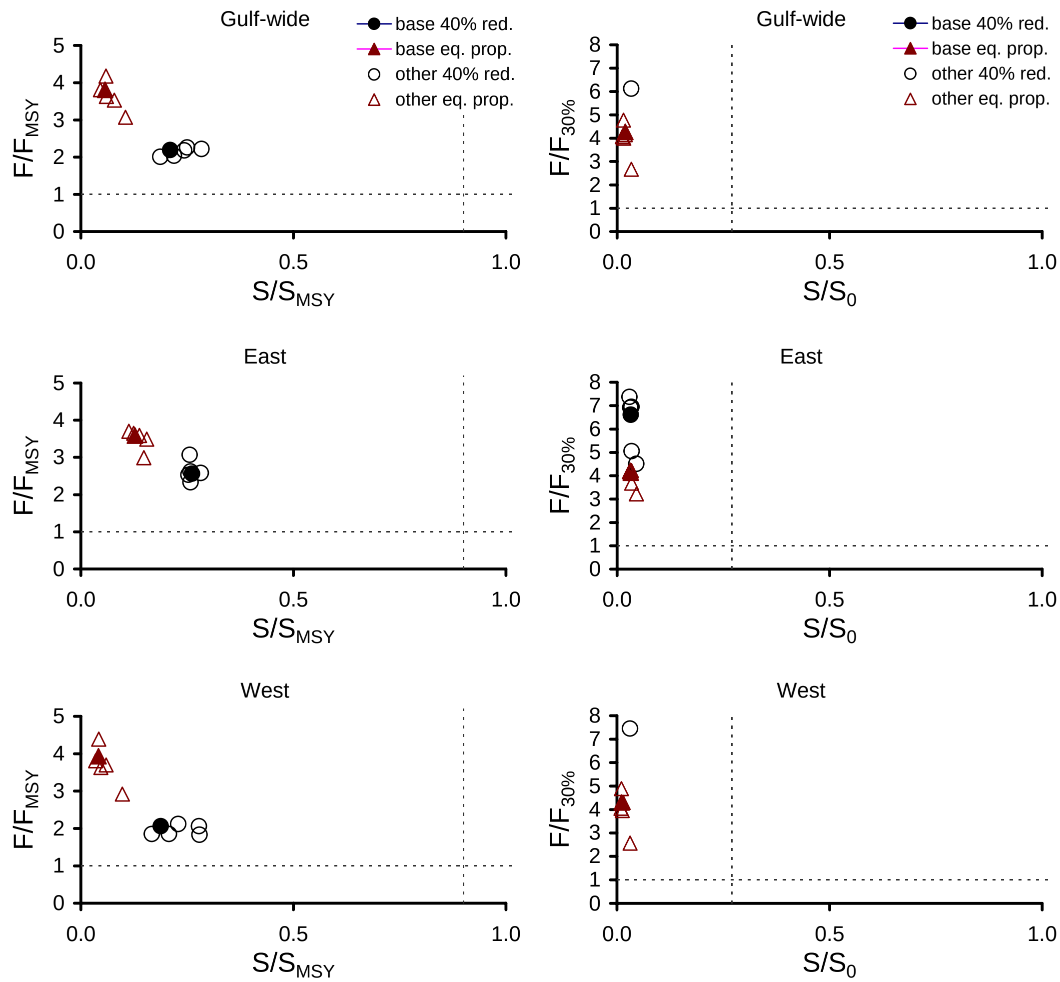

Figure 5. Status determinations for the base case assessment model applications (solid symbols) and for sensitivity analyses (hollow symbols). Left hand plates show results for F_{2003}/F_{MSY} (assuming either a 40% additional reduction in shrimping-induced mortality (circles) or equal proportional reduction in both shrimp and finfish fisheries mortality (triangles)). Right hand plates show $F_{2003}/F_{30\%SPR}$ and associated spawning potential relative to virgin conditions (S_{2003}/S_0) for the same model runs. Note that some model outcomes indicated $F_{30\%SPR}$ could not be sustained unless shrimping-induced mortality was reduced by more than 40% and are therefore not shown. Reference lines represent MSST (vertical) and MFMT (horizontal).

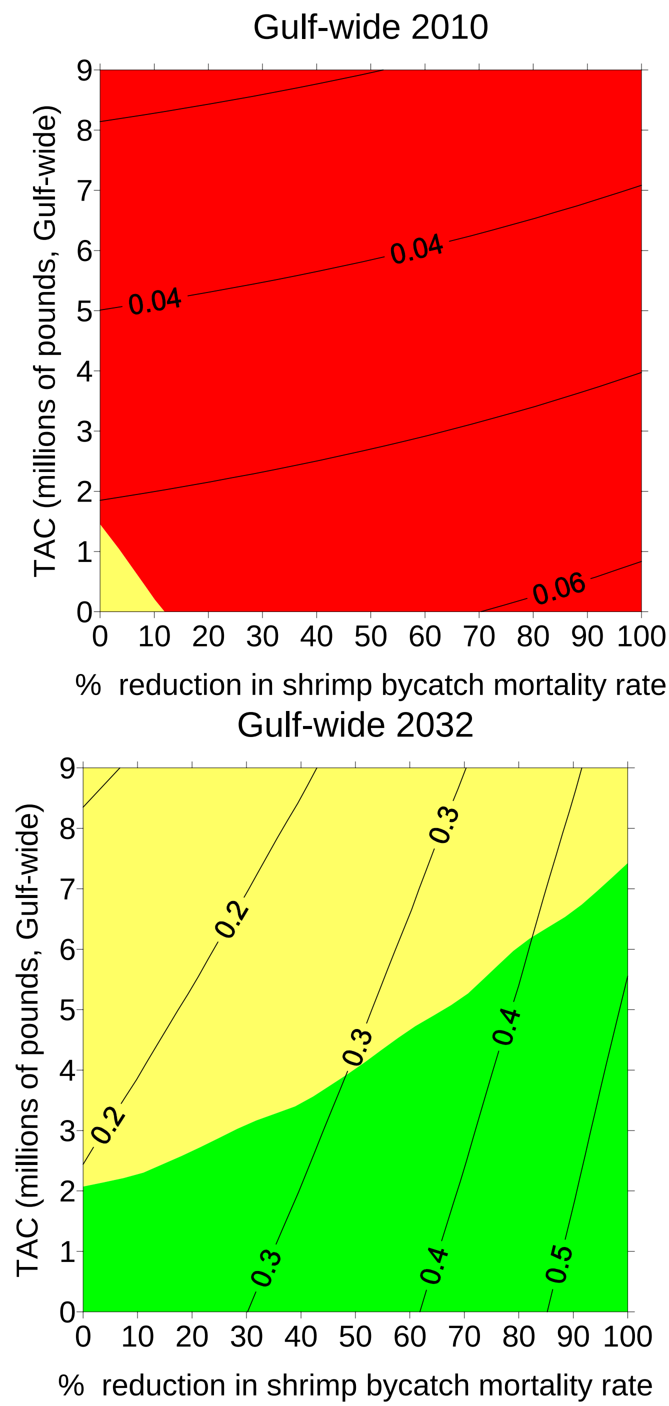

Figure 6. Isopleths of spawning potential in the year 2010 and 2032 relative to virgin levels (S_{2032}/S_0). These isopleths were determined assuming that future recruitments will follow a Beverton-Holt spawner-recruit relationship with virgin recruitment levels equal to the average recruitment estimated for 1984-2003. The horizontal axis refers to the projected shrimp bycatch mortality rate in terms of a *percentage reduction* from current levels and the vertical axis refers to the projected Gulf-wide TAC. The color shades on the graphs represent different levels of spawning potential relative to conditional MSY levels, where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{year}/S_{MSY} < 1$, yellow represents $1 < S_{year}/S_{MSY} < 4$, and green represents $S_{year}/S_{MSY} > 4$.

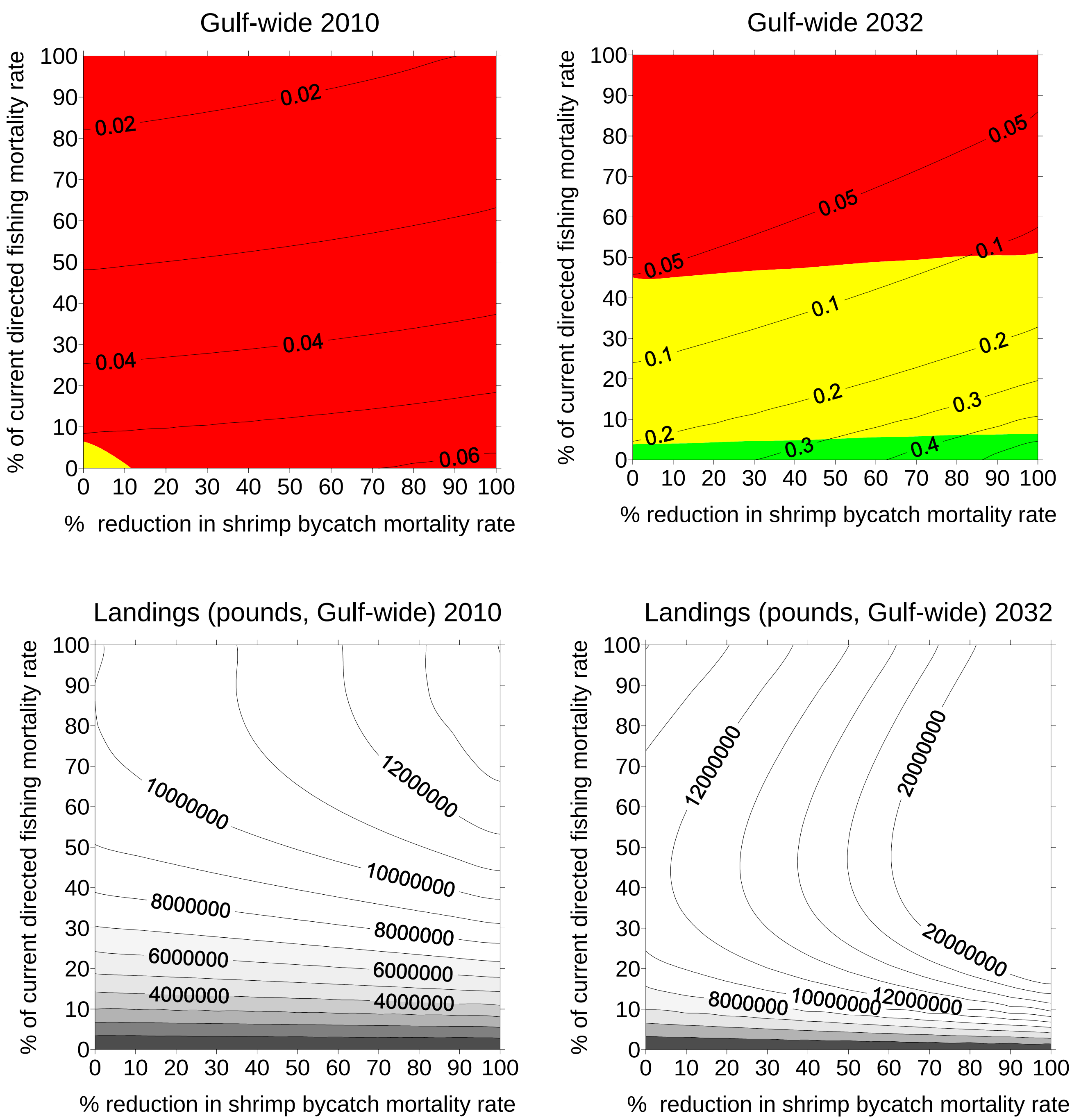

Figure 7. Isopleths of spawning potential relative to virgin levels (S_{2032}/S_0, top panels) and Gulf-wide landings (bottom panels) in the years 2010 and 2032. These isopleths were determined assuming that future recruitments will follow a Beverton-Holt spawner-recruit relationship with virgin recruitment levels equal to the average recruitment estimated for 1984-2003. The horizontal axis refers to the projected shrimp bycatch mortality rate in terms of a *percentage reduction from* current levels. The vertical axis refers to the projected directed fishery mortality rate as a *percentage of* current levels. The color shades on the upper graphs represent different levels of spawning potential relative to conditional MSY levels, where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{year}/S_{MSY} < 1$, yellow represents $1 < S_{year}/S_{MSY} < 4$, and green represents $S_{year}/S_{MSY} > 4$.

SEDAR

SouthEast Data, Assessment, and Review

Gulf of Mexico Red Snapper
Stock Assessment Report

SECTION 2. Data Workshop

SEDAR 7: Gulf of Mexico Red Snapper

RED SNAPPER DATA WORKSHOP REPORT

6/17/04

Introduction:

The Data Workshop for the red snapper SEDAR was held in New Orleans April 19-23, 2004. Participants are listed in Appendix 1. Initial data compilations and exploratory analyses for SEDAR assessments are requested from participants in the form of "working documents" to be submitted in advance and evaluated over the course of the workshop. A full list of papers submitted is presented in Appendix 2.

Among the Data Workshop participants, seven working groups were established to address development of available data for stock assessment. The working groups were: 1) life history, 2) commercial statistics, 3) recreational statistics, 4) fishery dependent indexes, 5) fishery independent indexes, 6) release mortality, and 7) shrimp fleet bycatch. Participants chose which group or groups to join, and group rapporteurs reported issues and progress to Data Workshop plenary sessions several times during the week. Written reports from each working group were substantially complete by week's end, although there has been some subsequent editing, and some further analyses sketched out during the Data Workshop have been added as planned. Some additional analyses recommended at the Data Workshop were too extensive to allow completion prior to circulation of the Data Workshop report. These will be reported and evaluated at the Assessment Workshop scheduled for August, 2004. Additionally, some of the working documents submitted (e.g. SEDAR7-DW-37, 50) address topics that will be covered in more detail at the Assessment Workshop.

This report is divided into seven sections, paralleling the choice to establish seven working groups. Structure within each section was determined by each working group, following some general guidelines derived from SEDAR's for other species. Red snapper has a long history of previous assessments, so this report tends to have expanded discussion on issues that had been difficult or controversial in past work, but is fairly brief on issues that are reasonably well settled. Figures and tables remain within the individual sections, and are numbered in "Section number.figure number" sequence. One section (5.) has appendixes of its own, which are located with that section's text. Lists of references to the general literature (i.e. papers other than the working documents submitted to this Workshop) also remain with the individual sections. Citations to papers submitted to this workshop as "working documents" are made in the text using the identifying numbers assigned by the SEDAR Coordinator (in the form SEDAR7-DW-xx), and refer to the list in Appendix 2.

As is customary for Data Workshop reports, several of the sections contain recommendations for future research efforts. Many of these recommendations are intended to be considered over the next several years, and are not recommendations for work to be completed prior to the Stock Assessment Workshop portion of the red snapper SEDAR in August. In general, the timeline intended is clear from the context of a recommendation, but the SEFSC has gone through the recommendations individually to identify those needing immediate attention. Many of the recommendations to be addressed prior to August relate to the details of estimating catch at age, which could not be addressed completely at the workshop for lack of time (see also SEDAR7-DW-45, 46, and 56) There are also a few issues identified in this report for which participants could not reach a satisfactory consensus. Most of these are tied to recommendations for additional analyses, which will be developed for presentation at the Assessment Workshop.

This report is a complete and final documentation of the activities, decisions, and recommendations of the Data Workshop. It will also serve as one of 4 components of the final SEDAR Assessment Report. The final SEDAR Assessment Report will be completed following the last workshop in the cycle, the Review Workshop, and will consist of the following sections: I) Introduction; II) Data Workshop Report; III) Assessment Workshop Report; and IV) Review Workshop Report.

TERMS OF REFERENCE:

1. Evaluate stock structure and develop a unit stock definition.
2. Evaluate the quality and reliability of life-history information (Age, growth, natural mortality, reproductive characteristics); develop models to describe growth, maturation, and fecundity by age, sex, or length as appropriate.
3. Evaluate the quality and reliability of fishery-independent measures of abundance; develop indices of population abundance by appropriate strata (e.g., age, size, and fishery) for use in assessment modeling.
4. Evaluate the quality and reliability of fishery-dependent measures of abundance; develop indices of population abundance by appropriate strata for use in assessment modeling.
5. Evaluate the quality and reliability of commercial and recreational fishery-dependent data for determining harvest and discard by species; develop estimates of total annual catch including both landings and discard removals.
6. Evaluate the quality and reliability of data available for characterizing the size and age distribution of the catch (landings and discard); characterize commercial and recreational landings and discards by size and age.
7. Evaluate the quality and reliability of available data for estimating the impacts of management actions.
8. Recommend assessment methods and models that are appropriate given the quality and scope of the data sets reviewed and management requirements.
9. Provide recommendations for future research (research, sampling, monitoring, and assessment).
10. Prepare complete documentation of workshop actions and decisions, and generate a data workshop report (Section II. of the SEDAR assessment report).

Contents:

1. Life History

1.1 Stock Definitions

The life history sub-group supported the development of a two stock (east vs. west of the Mississippi River) model for the Gulf of Mexico red snapper. This separation is supported by inferential (e.g., genetic, otolith constituent) and direct evidence, and also will allow the incorporation of potential life history differences that occur in these two regions. The group also discussed the possibility of further sub-dividing the western stock based on demographic results, which suggested differences between Louisiana and Texas fish. However, there was consensus that insufficient evidence was available about reproduction, recruitment, and habitat usage (especially for age-0 and -1 fish) to support further partitioning at this time. The observed demographic differences do not correspond to geographic isolation, according to the movement studies, and may be explained by environmental factors, including the possible influence of differential fishery exploitation. The sub-group also recognized that a single stock model will be developed and will prove useful for comparisions to the old assessment and could also help understand the impacts of treating Gulf of Mexico red snapper as one stock or two. A summary of the available evidence follows:

Genetic results: Analysis of neutral microsatellite markers in red snapper indicated spatial homogeneity across the northern Gulf. However, there were three types of demographic units based on variance effective size. Higher genetic effective population sizes were detected in Louisiana than in Texas or Alabama. Results from mt-DNA analysis were similar in that female effective population size was greater in Louisiana than Texas or Alabama (Gold 2003, although Gold also pointed out that the upper 95% confidence bounds for all three areas were essentially infinite). Nested Clade analysis shows a successive history of genetic expansion and isolation, with a geographic component to the cladogram (J.R. Gold, Texas A&M, personal communication, April 2004).

Otolith constituent analysis: Good nursery discrimination was found via otolith microchemical analysis (Patterson et al. 1998). Applied to adults, findings revealed that fish harvested from the north-central gulf Gulf (AL) had most likely recruited locally. In the northwestern gulf Gulf (LA), the nursery source was primarily local but some individuals were coming from southwestern Gulf nurseries (TX) and a few other adult fish (age-5) were coming across the Mississippi River from the north-central Gulf. In the southwestern Gulf however, there was evidence of extensive mixing, with individuals coming from both the northwestern and southwestern Gulf (Cowan et al. 2002). This provides strong evidence of the interaction of fish across the northern Gulf, but is not without potential misinterpretations. The analytical tool used to produce these estimates does not explicitly test for statistical significance of any observed differences. As a result, it does not distinguish between misclassification and migration. Nonetheless, the data were consistent with observed movements, including across age-classes.

Tagging and movements: Evidence was presented of longer migrations and lower site fidelity than previously estimated (Patterson et al. 2001; SEDAR7-DW-18)), at least in the eastern Gulf. Together, these results suggest more mixing is feasible, but tagging efforts to date have focused primarily on the eastern Gulf. . Those results generally show eastward and southeastward movement from north-central Gulf to the west Florida shelf. There was more limited evidence of movement from east to west (Patterson et al., 2001; SEDAR7-DW 18). It was recognized that site fidelity estimates vary and not all the factors affecting this are understood. There was some discussion about misreporting by fishermen which could affect site fidelity estimates. It was felt that routine checks on reporting could detect much of this problem and that more information coming from acoustic tagging results could elucidate fidelity estimates (by habitat etc.), at least for adult fish.

Demographic patterns: There was evidence that fish in the eastern Gulf may mature younger and smaller than fish in the western Gulf (Woods 2003, SEDAR7-DW-35 and addendum). There was also evidence for a higher abundance of older individuals in the west compared to the east based on aged samples from the commercial long-line fishery and scientific long-line survey (SEDAR7-DW-33 and -9). Unlike long-line trends, little difference in aggregated age structure was noted in the commercial hand-line and recreational age distributions east and west, which is not surprising considering that these fisheries generally catch younger individuals. Evidence existed for smaller size-at-age (age-2 to age-5) for fish in Texas waters compared to other states (SEDAR SEDAR7-DW-33 addendum, Cowan et al. 2002).

Other factors: The sub-group also discussed the east-west regional differences in habitat and the management issues associated with them. An example is the Texas shrimp fishery opening and its potential effect on age-0 red snapper, which is a unique western situation. Another example is the large area off Alabama that is effectively closed to trawling due to artificial reefs, which presents a unique eastern situation. These examples provided further compelling reasons to recommend regional partitions in the assessment model.

Several recommendations for future research were discussed. All of these are focused on long-term information needs, and none are a prerequisite to running the current assessment. 1) More movement information via tagging is needed from the western Gulf. There was discussion that a recreational tagging data base from the Coastal Conservation Association (CCA) may be available for this purpose. The sub-group recommended every effort be made to access and analyze this data base (by LSU researchers). 2) The results from the otolith microchemical analysis were compelling in providing estimates of mixing rates for the north-central, northwest, and southwestern Gulf. The sub-group recommends continued work to also derive mixing rates from the eastern Gulf (west Florida shelf). It was of great interest to determine if there was evidence for localized recruitment in the east or whether recruits were derived from other areas as suggested by tagging results. 3) Much more otolith microchemistry needs to be conducted on snapper off Texas, especially age 0 & 1 cohorts to aid in our understanding of the recruitment dynamics there. 4) There needs to be an examination of whether regional stock recruitment functions can be developed. It was recognized that trawl surveys, which have been previously relied upon for recruitment estimates, are conducted from Texas to the Florida/Alabama border and may not capture any localized recruitment which may occur on the west Florida Shelf. The sub-group recommended that other survey methods be examined for recruitment determination and the red snapper larval index was recognized as a candidate for this purpose.

1.2 Habitat Requirements

Most red snapper spawn from the late spring through the summer, and larvae spend their first 2 to 3 weeks or more in the plankton. An approximately 28 day PLD was identified off the Freeport Bathymetric High (Rooker et al. 2004). Fish metamorphose and drop out of the plankton to seek benthic habitat starting in late June, with recruitment continuing into September (Szedlmayer and Conti 1999). Peak settlement in Texas occurs between mid-July through August, with virtually none seen after 1 September (Rooker et al. 2004). New recruits can be found over a wide range of habitats, including open habitat (e.g., mud flats) and structured habitat (e.g., shell ridges, rock outcroppings). In the fall the growing fish move to more structured habitat, with few remaining over open habitat at the end of the first season (December). Structured habitat includes natural rock outcroppings, shell ridges, sand banks, and artificial reefs. Diet shifts occur with this shift in habitat, with significant increases in reef prey types as fish move to structured habitat (Szedlmayer and Lee 2004). Over much of the rest of the red snapper life history, fish are associated with structured habitat and show wide ranging prey types, including reef, sand, pelagic, and mixed prey types. Red snapper were also found to vary their diets with diel cycles (Ouzts and Szedlmayer 2003). New information from NMFS long-line survey suggests that larger older fish may become more independent of structured habitat and frequent open continental shelf (SEDAR7-DW-9).) This conclusion is also supported by tournament winning fish in Texas, where the winners generally come from mud bottoms with very small (<1m^2) structured relief (<0.5m) (Landre, personal observation).

1.3 Age

Numerous studies have used otoliths to age red snapper and provide basic information on growth and annulus formation (Futch and Bruger 1976, Bortone and Hollingsworth 1980, Nelson and Manooch 1982, Manooch and Potts 1997, Patterson et al. 2001,Wilson and Nieland 2001). For the 2004 assessment, three fishery-dependent data bases were combined to yield annual age structure information from 1980 and 1991-2002 (SEDAR-DW-33). Ages were derived from NMFS, Panama City laboratory (1980, 1991-2002), Louisiana State University (LSU) (1995-2002) and the Gulf States Fish Information Network (FIN)

(2002). Over 44,000 red snapper from the commercial and recreational fishery were aged from these sources. In addition, NMFS Panama City aged fish collected from fishery independent hand-line survey and from the NMFS Pascagoula long-line survey (1999-2002; SEDAR7-DW-9).

Red snapper ages ranged from 1 to 57 years. Each fishing mode caught a different range of red snapper ages, with the commercial long-line contributing the oldest individuals followed by the commercial hand-line and recreational fishery. Age distributions from the eastern and western Gulf were similar for the commercial hand-line and recreational fishery. However, the commercial long-line and fishery independent long-line survey yielded older fish in the western Gulf. Similarities in age-structure within modes was noted among years; however there was some evidence for strong year-classes in 1989 and 1995 based on age distributions in the directed fishery in both the eastern and western Gulf (SEDAR7-DW-33).

Because estimates of longevity were questioned in the last assessment, subsequent research used carbon14 bomb radiocarbon dating methods to validate longevities of 50+ years (Baker and Wilson 2001). Some aging concerns remain, including routine interpretation of annuli patterns (SEDAR7-DW-33, -34, -36, -55). In general, there was good precision among different aging facilities (average percent error about 5% or less) (SEDAR7-DW-34). However, it was noted that there were some difficulties in aging, primarily relating to the variable pattern of the first annulus. The sub-group recognized attempts to deal with this issue (marginal increment analysis, observed and back-calculated size at 1st annulus). A chemical marking experiment to examine and compare annulus formation from early and late spawned individuals was recommended as a future research objective. Dr. Steve Szedlmayer (Auburn University) indicated he had chemically marked age-0 red snapper off Alabama during August 2003. Recovery of these individuals may help elucidate the first annulus pattern. The sub-group recommended continued use of reference collections and training workshops to develop consistency, improve precision among readers and facilities, and to facilitate data corrections if current methods of interpretation change.

1.4 Growth

There have been several growth studies on red snapper in the Gulf of Mexico. Both recent and older studies have produced similar results regarding the growth coefficient K and maximum attainable size L_∞ (Patterson et al. 2001, Wilson and Nieland 2001). The sub-group recommended that in the future, growth parameters be fit with the available age data as needed for the assessment models (by region/strata). Growth models can be influenced by the use of size-biased samples, for example due to minimum size-limits. While useful for characterizing the age composition of the catch, they can be biased with respect to the underlying population growth characteristics and need to be considered with caution if being used to model population level productivity benchmarks.

1.5 Conversion Factors

Conversions for length and weight in English units were presented in the last stock assessment (Schirripa and Legault 1999) and are repeated here.

Length to weight conversions: Where required, total lengths (TL) were converted to pounds whole weight (WW) using the fitted model of Equation1. Fork lengths (FL) were converted to pounds whole weight using the model of Equation 2.

$$WW\ (lbs) = 4.40E\text{-}04 * TL\ (in) \wedge 3.056 \qquad (1)$$

$$WW\ (lbs) = 6.62E\text{-}04 * FL\ (in) \wedge 2.997 \qquad (2)$$

Commercial landings are often in gutted condition and conversions for total and fork lengths to gutted weight (GW) were also needed for several analyses. Data from the TIP samples were used to establish the relation between total length and gutted weight (Equation 3) and fork length and gutted weight (Equation 4). The resulting two equations were used to assign weights from lengths for the commercial samples, as appropriate.

$GW\ (lbs) = 3.51E\text{-}04 * TL\ (in) \wedge 3.114$ (3)

$GW\ (lbs) = 6.83E\text{-}04 * FL\ (in) \wedge 2.973$ (4)

Length conversions: Lengths were commonly recorded as either whole length or fork length. Most of the length observations from the commercial fishery were in units of fork length, as were most of the observations from the NMRFSS intercept sampling. However, other surveys took total length measurements. Conversions among length units used the regression equation of Equation 5. The few measurements of standard length in the available data that required conversion to total length used the regression of total length on standard length (SL) presented in Equation 6.

$TL\ (in) = 0.1729 + FL\ (in) * 1.059$ (5)

$TL(in) = 0.0291 + SL\ (in) * 1.278$ (6)

Weight conversions: In 1964 the then Bureau of Commercial Fisheries established a policy of recording finfish landings in units of whole weight (Udall 1964). Since most red snapper are landed in gutted condition, a conversion factor was required to convert the landed weight to its equivalent value in whole weight. A conversion factor of 1.11 was adopted for this purpose. The basis for this value is unknown. However, the Florida red snapper landings from 1986 to the present and those of all other states have been adjusted upward by this factor before entry into the computer files which constitute the historical data base for the red snapper fishery. Florida landings prior to 1986 were never converted from landed to whole weight (E. Snell, SEFSC, personal communication).

The same problem exists with other species in the data base. An evaluation of the correction factor being applied to grouper landings revealed that the conversion factor being used to convert red grouper from gutted to whole weight was in substantial error (Goodyear and Schirripa 1993). Consequently, the accuracy of the conversion factor for red snapper was evaluated by regressing total weight on gutted weight (Equation 7).

$GW\ (lbs) = 1.106 * WW(lbs) - 0.02$ (7)

The slope of the resulting model, 1.106 is an estimate of the conversion factor and is very close to the value currently being used. As a consequence, the conversion between whole and gutted weights used for analyses presented in this report retain the historically applied value of 1.11. This value is somewhat smaller than the value of 1.15 derived by Camber (1955). Anecdotal information suggests variability in the extent of evisceration among fishermen and variability in the ratio of gutted weight to whole weight across seasons. Consequently, additional data may lead to a better characterization the conversion rate for the commercial fishery for this stock.

Recent developed formulae for transforming length and total weight in metric units are presented in Wilson and Nieland (2001), Patterson et al. (2001), SEDAR7-DW-33 and SEDAR7-DW-52.

1.6 Reproduction

Since the 1999 Red Snapper Stock Assessment Report, new unpublished data has been produced on reproduction of red snapper in the northern Gulf (Woods 2003, SEDAR7-DW-35). It was generally recommended that these two data sets of similar methods and results be combined for use in the assessment as a more thorough analysis of reproductive biology. Care should be given to the types of samples used since size-biased sampling can lead to overestimation of reproductive output of young fish whose sizes are less than allowed for via landings.

Maturity: Based on the decision to partition the assessment model, it was recommended that maturity functions be developed for the east and west based on combining MARFIN and NMFS (Panama City) data. Doing so will give a broader geographic perspective within each region than would be allowed by each dataset alone. There was concern that reproductive output at age could be affected by selectivities for faster growing fish in the fishery-dependent samples (ultimately affecting maturity and batch fecundity at age). It was recognized that both data sets contained some fishery-independent samples that could be used to examine this effect. There was also discussion as to whether overlapping (recent) years (1999, 2000, 2001) should be examined to avoid any historical year effect that may be present. The sub-group recommendation was to examine and standardize both data sets for source (gear) and year effect. Table 1.1 and 1.2 indicate the sample sizes and states represented by both data sets for the years that overlap.

Batch Fecundity: The subgroup recommended use of the batch fecundity-at-age relationship. While not as directly predictive as length, it avoids the need to extrapolate age from length. The sub-group also recommended use of the power function of the Von Bert relationship (asymptotic). Akaike (AIC) information criteria indicated a better fit than the Beverton Holt function (addendum to SEDAR7-DW-35). It was recognized that a relatively small number of fish over age 15 (about 9 females) affect this choice, but this is a significant improvement in terms of available observations compared to those available for the last assessment. Therefore, the sub-group views the choice of an asymptotic function for age as a hypothesis until more information is available.

Spawning frequency: Spawning frequency was observed to increase with age to about age-6. Little information exists for examination beyond this age. The sub-group recommended to reexamine combined datasets and fit an asymptotic decay function to the data and further evaluate the need to incorporate spawning frequency into the assessment. There was a concern that a combined function should be weighted by abundance estimates. While recognizing that appropriate information may not be available, the recommendation was to further investigate possible weighting procedures, for example, based on fishery-independent surveys.

There was also a need to consider an estimate for spawning season duration. It was noted that annual estimates could vary based upon opportunistic sampling. The recommendation was to use a best estimate of 150 d (Woods 2003, SEDAR7-DW-35).

1.7 Stock-Recruitment Relationship

The stock-recruitment relationship may have a strong effect on the outcome of an assessment. The most recent assessment concluded “[T]he stock-recruitment relationship could not be well estimated given the short time series, most likely due to the lack of regression range” (Schirripa and Legault 1999, p. 26). As it proved impossible to estimate the stock-recruitment parameters from observed data, they ran the model with combinations of six steepness values (ranging from 0.8 to 0.99) and two different maximum recruitment parameter values (163 or 245 million age-0 recruits), the latter numbers representing an estimate of the maximum SEAMAP survey-based recruitment estimate (from 1972) and 2/3 that value (presumed to represent an average of several high years instead of a single peak). Their objective function, a measure of the fit of the model to observed data, was maximized at a steepness of 0.975 but this fit was influenced by the assumption of maximum recruitment. The Reef Fish Stock Assessment Panel (1999) raised a concern that this steepness value did not match those of other similar species, and so recommended focusing analysis on runs using either a steepness of 0.9 or 0.95.

Given the importance of this relationship to the results of the stock assessment and the difficulty in accurately estimating its parameters, it would be valuable to explore several possible means of constructing it. One possibility would be to recreate the options examined in the past assessment, in particular the version accepted in defining red snapper stock status reference points (steepness of 0.9 and maximum recruitment of 163 million).

Another approach would be to specify a prior distribution of the values of steepness informed by examining estimates from similar species, and then produce an estimate of maximum recruitment in the model itself. This approach would be facilitated by incorporating data on the abundance of young of year red snapper, which stretch back to 1972, into the estimation procedure. It might also benefit from an examination of historical landings dating back to the 1880s, although data prior to the 1970s is not considered as reliable as more current information (it, for example, could include substantial landings from Campeche Bank, Mexico). The prior distributions for steepness could come from any of at least three meta-analyses.

McAllister (SEDAR7-DW-13,26) examined the steepness values associated with all demersal species, excluding rockfishes (Subfamiy Sebastinae). Rockfishes were excluded because these species were considered to have distinctively long lifespans and low fecundities compared to *L. campechanus*. Excluding them from demersal species produces a median steepness of approximately 0.77 with a mean of 0.71. Porch (SEDAR7-DW-50) compiled a distribution of maximum lifetime fecundity parameters (α), which are directly related to steepness, using just periodic spawners (as defined by Rose et al. 2001) from a meta-analysis by Myers and colleagues (1999). A similar approach by Rose et al. (2001) identified a mean steepness of 0.7, with a median of approximately 0.75. Both of these approaches included one rockfish species (the Pacific Ocean perch, *Sebastes alutus*), which should be excluded for the reasons stated above. Excluding them produces summary statistics as follows: steepness mean = 0.696, median = 0.745; α mean = 17.985, median = 12.85.

While the analyses by Porch and Rose and co-authors are more focused than those performed by McAllister, they still include a wide range of species (from sardines to swordfish). The list of periodic species from Rose and colleagues (2001) can be further separated into those with basic similarities to red snapper (i.e., marine, demersal, and periodic spawners). This finer separation leaves 19 species in addition to red snapper, which should not be included for obvious reasons. These 19 species are characterized by the following summary statistics: steepness mean = 0.741, median = 0.81; α mean = 22.132, median = 18 (Fig. 1.1). This latter distribution made up of species with similar basic life history traits as red snapper could be used to formulate a prior distribution for steepness when running a Bayesian version of the red snapper assessment model. This approach will complement the approach used previously of examining a range of plausible steepness and maximum recruitment values.

1.8 MSY Reference Points

It is often perceived that the calculation of maximum sustainable yield (MSY) and corresponding reference points, the biomass B_{MSY} and fishing mortality rate F_{MSY}, is strictly a scientific exercise. This perception is correct in the sense that an MSY calculation does not explicitly take consideration of the specific goals and objective of a fishery (this process informs optimum yield). However, there are important policy implications, and thus value judgments, associated with calculation of MSY and the effort that produces MSY for age structured populations (see Goodyear 1996, for example- Goodyear, C. P.1996. Variability of fishing mortality by age: Consequences for MSY. North American Journal of Fisheries Management.. 16:8-13.). These manifest themselves in specifying the selectivity of the fishery, a characterization of the relative vulnerabilities of different age classes to fishing. MSY and F_{MSY} values for the same population will vary depending on the pattern of selectivities.

Myers and Mertz (1998) provided a good illustration of this point. They showed that if fisheries avoided all fish that were not yet mature, the stock could sustain very high fishing mortality rates (i.e., a high F_{MSY}) on the older age classes. The same fishery would be much more vulnerable at lower fishing mortality rates (i.e., a low F_{MSY}) if they applied to immature fish.

These MSY reference points for red snapper are sensitive to selectivity patterns because those patterns differ dramatically among different fishing sectors, especially between bycatch in the shrimp fishery and the directed fisheries. Shrimp bycatch selects primarily for age-0 and age-1 fish and does not contribute to yield, the recreational sector primarily for age-2 to -4 fish, the commercial handline sector primarily for age-3 to -5 fish, and the commercial longline for age-5 and older fish. The choice of a selectivity pattern when calculating MSY implies an allocation of effort among the fishing sectors. Such choices represent policy rather than analysis, and thus need to be informed by policymakers and the public. At best, analysts can illustrate the importance of this decision and potential implications by presenting a range of different scenarios as in past assessments (including yield foregone). The sub-group recommended several selectivity/ effort scenarios.

1) The last assessment held selectivity at an average of the 1995-1997 levels when calculating MSY. In effect this approach would assume that any increase or decrease in fishing mortality rates would affect each fishing sector, including the shrimp industry, equally. This method of estimation is problematic if it would be more desirable and practicable to regulate the bycatch sector to a

different degree than the sectors that target red snapper. However, it has the advantage from an analytic point of view that it does not present a bias towards favoring one sector over another– clearly a policy choice, not a scientific one.

2) The selectivity and effort patterns could be set according to anticipated or desired bycatch reductions in the shrimp fishery. Current economic conditions project that effort will drop substantially in the shrimp industry due to rising fuel costs and shrinking dockside prices for shrimp (NMFS 2004). These projections indicate that total shrimp effort is likely to drop by 40% within the next 10 years. Additional bycatch reductions may be expected due to the use of bycatch reduction devices (BRDs), which have been required in the western Gulf since 1999. Presently, BRDs may only reduce red snapper bycatch by 10-15% (Foster, SEDAR7-DW-29). Studies of red snapper and shrimp behavior or requirement of different existing BRD designs may improve effectiveness (Parsons SEDAR7-DW-4), but these improvements are still under development or complicated to deploy effectively in the field. Analysts could be charged with predicting the long-term effort of the shrimp fishery and likely maximum real-world BRD effectiveness. A selectivity/ shrimp effort pattern could then be constructed based on this level of bycatch.

3) The selectivity and effort patterns could be set under the assumption that all bycatch were eliminated. Although it is extremely unlikely that all bycatch could be eliminated, this scenario would represent an ideal but theoretical description of waste-free fisheries. Mandates to reduce bycatch to the extent practicable indicate a desire to minimize waste. However, given the inevitability of catching unmarketable red snapper in the shrimp fishery, this approach might be considered unachievable and therefore impracticable.

4) Extending item 3), one could use a simple knife-edge selection near the age of maximum biomass without fishing, and an F approximating the replacement curve at maximum surplus recruitment. This approach has the advantage of making MSY a property of the stock, rather than a property of the fishery; thereby moving any allocation and selectivity discussions to the realm of Optimum Yield. The disadvantage is that MSY might for some fisheries have little practical meaning as a desirable management target.

An alternative way to address bycatch was proposed by Powers (SEDAR7-DW-51). He assumed that if one reduced bycatch to the full extent practicable, MSY might be calculated based on the maximum yield that would be achievable in the directed fisheries. Powers suggested three possible ways to assign a fishing mortality rate for bycatch—as a proportion of the directed fishing mortality rate, as a constant independent of directed fishing, or as a proportion of the fishing mortality rate that would produce MSY in the absence of any bycatch mortality. The method of modeling bycatch had dramatic results on a whole host of MSY reference points (see SEDAR7-DW-51, Fig. 1). Of concern is the range of sensitivity in estimates of B_{msy} to one of the methods identified – which essentially treats bycatch F as a form of 'natural' mortality which cannot be controlled through management intervention, since the B_{msy} reference point is more a function of the underlying stock recruit relationship than the combined fishery selectivity. Because of its implications for achieving various management objectives, the methods outlined in SEDAR7-DW-51 would require input from policymakers prior to a specific allocation between fishery sectors being adopted. As with the three approaches identified above, this one could be illustrated and the implications described to policymakers to stimulate their consideration and inform their decision.

One other alternative for determining MSY would be an ecosystem-based energetics approach. Driggers (SEDAR7-DW-12) examined the amount of prey that would be required to support various stock sizes of red snapper based on a variety of mortality, catch, and energetic considerations. He was unable to come up with a single estimate due to parameter uncertainties, nor to test those predictions against real world prey biomass levels because that information is not yet known. As a result, this approach needs further development before it can provide useful benchmarks for calculating MSY and associated reference points. Even then, selectivity and effort allocation patterns will influence the reference points as described above.

<u>1.9 Natural Mortality</u>

Issues to be resolved before the August 2004 SEDAR Assessment workshop:

1. No resolution could be achieved over whether the previously applied values for the natural mortality rate for age 0 (M_0) and age 1 (M_1) should be updated. The previous values came from comparing model-based estimates of age distributions to data from surveys focusing on young fish. There was a good match for overall Z in 1995 when values of M_0 = 0.5 and M_1 = 0.3 were used. However, new data has come to light, for example, SEDAR7-DW-21, which presented a new estimate of Z_0 of 2.3 yr^{-1}. However, a number of problems were identified with the interpretation of this study (including immigration and emigration effects), leaving the question of whether the new evidence was sufficient to outweigh the approach used previously.

Proposed solutions:

a) Update the evaluation of the relationship between the Fall Groundfish and summer SEAMAP age 1 indices to estimate Z for age 1 (evaluation originally conducted in Goodyear 1995); compare this with ADAPT VPA predictions of Z for age 1 conditioned on a variety of values assumed for M_0 and M_1.

b) Gather more literature on the potential decay in M with juvenile fish size.

c) Formulate a prior probability distribution for M_0 and M_1 that accounts for the sources of uncertainty in estimates of these values and the available empirical information.

2. It was agreed that the 2004 assessment should test the sensitivity of stock assessment and projection results to assuming a range of plausible values for M_0 and M_1. However, it was not decided which values should be considered for this sensitivity test.

Proposed solutions:

a. Wait until there has been a decision on the base case values to adopt for M_0 and M_1, then make decisions about the values to consider in the sensitivity tests.

b. Use a wide range of plausible values, e.g., Goodyear (1995, 1996) had used 0 to 4 yr^{-1} for M_0 and 0 to 2 yr^{-1} for M_1.

A few papers, namely SEDAR7-DW-49 and -21, suggested some possible alternatives to the values for M applied in the Goodyear (1995) and Schirripa and Legault (1999) assessments. No consensus emerged over the question of adopting revised base case values for M for age 0 (M_0) and age 1 (M_1) year fish. Considerations regarding the options for specifying M at age based on the last several stock assessments and the new options provided by SEDAR7-DW-21 and -49 are summarized in Table 1.3. Nonetheless, the sub-group remained unconvinced that new information could justify an update of the value of natural mortality rate applied for ages 2+ (M_{2+}=0.1 yr^{-1}) used in Schirripa and Legault (1999). (There is in SEDAR7-DW-8 a catch curve from the fishery-independent longline survey that might provide an upper limit on adult M (7+). The estimated Z was 0.13 (one s.e., 0.01), essentially imply the same adult M used by Schirripa and Legault.)

The rationale that had been applied to support the values for M_0 and M_1 in the last few assessments was sought and is summarized below. The sub-group generally agreed that in the upcoming stock assessment, tests of the sensitivity of stock assessment results to alternative plausible values for M_0 and M_1 should be conducted. The particular sets of values to consider for these sensitivity tests however have yet to be agreed. Subsection 1 summarizes the discussion of SEADAR-7- DW-49's proposal for revised values for natural mortality rate at age. Subsection 2 summarizes the discussion of SEDAR7- DW-21's recent field experiment based estimate of natural mortality rate for M_0. Subsection 3 reviews rationale that had been applied to support the values for M_0 and M_1 in the last few assessments.

Discussion of SEDAR7-DW-49

Previous estimates of the rate of natural mortality rate (*M*) for (*L. campechanus*) were briefly reviewed in this paper, together with some common approaches to produce approximations of *M* such as Hoenig (1983) and Ralston (1987). The concept that natural mortality rate decays with age was also reviewed (e.g., Shepherd and Breen 1992). The paper proposed a new formula to compute natural mortality at age for age groups 0 to 4+ years with the values constant for ages 4+ years. A decay in *M* at age was modelled by a particular fixed proportion, *p*. Ralston's approach of assuming that *M* can be approximated by doubling the growth rate, *K*, was applied to estimate a mean value for *M* over ages 0 to 4+. The formula was applied to suggest particular values for M at age assuming a variety of decay rates, *p*. While the sub-group acknowledged that this offers one new potential mechanism to set values for *M* at age, the method for assigning values for *M* at age is still arbitrary. The approach is quite a marked departure from the values for *M* in applied the 1995 and 1999 assessments, especially in that the decay in *M* at age was extended to age 4 years. In contrast, the decay in the 1995 and 1999 assessment values is confined to ages from 0 to 2 years. Some suggestions were offered to have the asymptotic age for *M* to be set at some particular life history point at which *M* could be reasoned to be constant such as the age that fish become free swimming. However, this was countered by the suggestion that there may be a variety of reasons for *M* becoming constant with age at a variety of different points in the life history. Without any empirical support, such a new proposal would be no less arbitrary than the values for *M* in the last few assessments.

<u>Discussion of SEDAR7-DW-21</u>

This paper describes field experiments leading to a new estimate of the M_0. The experiment set up clusters of 2x2m shell and shell/concrete block artificial reefs at approximately 20 meter spacing. Plastic pillars were erected in spaces between the reefs to signal whether shrimp trawls had swept through the experimental reef sites. None were knocked down, indicating that in the duration of the experiment, no shrimp trawls had encroached upon the experimental sites. Anti-predator cages were placed on some reefs to evaluate whether predation might be reducing the number of fish on the reefs. Cages were placed in nearby areas with no reefs but no aggregations formed about these cages. Higher densities in the caged reefs suggested that predation could be reducing the abundance of fish on non-caged reefs. However, it was noted in the sub-group that shrimp bycatch and predation may also be occurring when fish foraged at night away from the artificial reefs. Field observations were gathered from a total of 94 artificial reefs between 1999 and 2004.

The abundance of age zero fish on shell reefs was estimated at the peak of abundance in July by in situ sampling and sampling with quadrats when abundances were high. Abundances of age 1 fish on nearby concrete block reefs in July of the same year were also estimated using the same techniques. Estimates of the rate of natural mortality rate for age 0 fish (M_0") in four successive years were obtained by evaluating the annual difference in abundance between age 0 fish and age 1 fish on these artificial reef sites. It was noted at the workshop that the estimates for each of the four years could be made more accurate by using the relative abundances of the same cohort, age 0 abundance in one year and then age 1 abundance in the next year rather than age 0 and age one abundance in the same year. However, this alternate technique was hampered by a year, mid experiment, when data could not be collected. As a result, there were only two cohorts that could be examined from one year to the next. The mean of the four annual estimates, 2.3 yr^{-1}, was offered as a new empirically derived estimate of annual mortality rate for age 0 fish. This suggests an annual survival rate of a fish from 2cm to 20 cm of about 10% (=exp(-2.3)), as opposed to 52% (=exp(-(0.5+0.3/2))) from the previous two stock assessments. However, the 52% figure only accounts for natural mortality. When estimated fishing mortality is also included, the survival rate is 18% (=exp(-(0.5+0.3/2+0.35+1.4/2)) using average estimated F rates from 1995-97). This level is more consistent with the experimental findings if one assumes the fish left reefs and became vulnerable to shrimp bycatch at night.

The sub-group discussed the following potential biases in this estimate. The new estimate of M_0 may be biased by immigration and emigration of age 0 fish to or from the artificial reef sites. Net immigration from, or net emigration to, the site following the initial July measurement, could bias the estimates of M_0 either too high or too low. Dr. Szedlmayer indicated however, that tagging of some individuals on the sites indicated some emigration and migration but not extensive rates of either [but the key question here is whether one can differentiate between mortality and migration, and it is not clear that a localized tagging experiment can make this distinction]. The habitat upon which the estimates were obtained is only one of several different types of habitat upon which age 0 fish are known to settle. This rate of natural mortality here thus might not be representative of the mean rate of natural mortality of age 0 fish when all habitats are considered. For example, a study of post-settlement red snapper in Texas showed that they grew faster and has lower mortality rates when living on nutrient-rich inshore mud bottoms than on shell ridges or offshore mud bottom (Landre, unpublished results), which could suggest the shell reef-based estimates could be too high Dispersion of age 1 fish off the reefs would also bias the estimates towards being too high.

Should assessment scientists wish to consider Szedlmayer's estimate further some additional considerations will need to be addressed. For example, M_0 in the stock assessment represents newly settled fish up to the end of the year. This may on average represent fish from a settlement in July to December. Thus M_0 would need to represent on average the rate of natural mortality for the first six months of settlement. The value derived from Szedlmayer's data represents M for the first year and thus would need to be partitioned between year 0, which encompasses the first six months, and the first half of year 1. Some assumed value would still be required to provide an annual value for M for the second half of year 1. Because it is generally regarded that the rate of natural mortality in newly settled juvenile fish must decay as the fish grows larger (as indicated in Rooker et al. 2004), then it is likely that the rate of natural mortality for the first six months of settlement would be larger than for the second six months. Thus rather than dividing Szedlymayer's value by two to obtain the value of M_0 for the first six months, some larger fraction of Szedlymayer's value might be assumed for the first six months. For example, if a value 67% of Szedlymayer's value was assumed for the first six months, then a value 33% of that would be assumed for the following six months. A value smaller than 33% Szedlymayer's value would need to be assumed for the latter six months of the first year. This example, is intended only as an illustration of how M_0 might be partitioned and a decay in M with size consistently incorporated.

A third study (Rooker et al. 2004) was briefly discussed in which an estimate of 0.12 d^{-1} for the first 10 days of settlement was obtained. This estimate was based on catch curves for age 47-57 day old yoy and, using a ~28 d PLD estimate, would make these cohorts between 20 to 30 days post-settlement. This implied a potentially much higher estimate of M_0. However, the extrapolation of this value to the remaining period of the year is not currently possible because this value is likely to decay as the fish grows larger and the rate of decay in M_0 over the first year is currently unknown.

Despite these limitations some members of the sub-group suggested that this new estimate be considered to formulate a revised base case input value of M_0 and M_1 for the stock assessment of red snapper. While biasing effects could occur due to migration or the age interval over which calculations are made and this site might not be representative, the experimental protocol applied was rigorous and the estimate provided was not implausible. Yet, no consensus could be reached at the meeting. It was suggested that before such a proposal could be considered, the rationale provided for the base case values of M_0 and M_1 in the 1995 and 1997 stock assessments be retrieved. It was agreed, however, that the sensitivity of stock assessment results to a range of possible values for M_0 and M_1 be evaluated in the upcoming stock assessment to account for potential effects of uncertainty in these values of stock assessment results. A set of potential values of M_0 and M_1 for this sensitivity analysis has yet to be recommended.

It was subsequently suggested that the available data be compiled to formulate a prior probability distribution for the parameters M_0 and M_1 that could be used in Bayesian stock assessment methods for red snapper (e.g., SEDAR7-DW-50). The prior would incorporate all available information and also reflect the uncertainty over the values for these parameters. It is intended that this prior be formulated to be ready for the August 2004 stock assessment.

Review of justifications for the values for M_0 and M_1 in Goodyear (1995)

A review of Goodyear (1995) revealed that the values, 0.5 and 0.3 yr^{-1}, adopted in this stock assessment for M_0 and M_1 appear to have been assumed initially and later checked against evidence. For example, on page 40 in the section on shrimp discard mortality it is stated that "Natural mortality was assumed to be 0.5 for age 0 and 0.3 for age 1". Similarly on p. 43, in the SPR analysis, it is stated "Analyses assume natural mortality (M) to be 0.5 at age 0, 0.3 at age 1, 0.1, 0.15 or 0.2 for ages 2-30." In the section on natural mortality on p. 7,8 (which appears to be largely repeated in Schirripa and Legault 1999), a variety of techniques are presented to utilize other life history and sample information to approximate Z for ages of two years and older; an approach for checking the consistency of the assumed values for M_0 and M_1 is provided on page 41.

On page 41, two different approaches are offered to estimate Z in the first year from the midpoint of the 2nd trimester to the midpoint of the 3rd trimester. One is a regression of fall groundfish survey catch rates on summer SEAMAP survey catch rates. It is assumed here that "if the catchability of age-1 red snapper is the same in the summer SEAMAP and Fall Groundfish surveys, the decay in their relative abundances between the two surveys would be an estimate of the mortality between the two periods." The slope estimate of 0.473 suggests a value for Z of 0.75 (0.75=-ln(-0.473)), for this particular period between the middle of the 2nd and middle of the 3rd trimesters. This trimesterly estimate expanded to an annual estimate this becomes 2.25 yr^{-1}. The second approach was to apply the ADAPT VPA method, assuming a value of M_0 = 0.5 and M_1 = 0.3, and M_{2+}=0.1 and the shrimp bycatch estimates. The reported estimate of Z for the same trimester period was 0.86 yr^{-1}. This gives an annual value of Z of about 2.58 yr^{-1} for age 1 fish. Assuming the same values for M_1, M_{2+}, but instead a value of 0.15 for M_0, the trimester value for Z was 0.79. Assuming a value of 0.2 for M_0, gave a trimester estimate of Z of 0.71. The extrapolated annual value of Z of 2.58 yr-1, assuming M_{2+} = 0.1, appears to be slightly higher than the annual estimates in Figure 82 of Goodyear (1995) which were estimated instead on a trimesterly basis. Thus the values of M_0 = 0.5 and M_1=0.3 give approximately consistent estimates of the trimester estimate of Z from the Fall Groundfish – summer SEAMAP index. Yet the annual extrapolated value for Z appears to be rather high. The sensitivity of ADAPT predictions of the trimester Z for age one fish to different values for M_0 and M_1 however were not reported.

In summary, this approach still provides a means to evaluate whether ADAPT VPA predictions of trimester Z for age 1, are consistent with predictions using the regression of summer SEAMAP survey cpue on Fall Groundfish survey cpue for age 1. Unless the VPA calculation applied has been misinterpreted, this method seems only to cross check the M_1 values assumed in the VPA. Because cohort abundances are back-calculated, this method still does not appear to provide a mechanism to ground truth assumed values for age 0 fish. Moreover, only the value of M_1 after the middle of the 2nd trimester are utilized in predicting the 2nd-3rd trimester Z value. If only this latter segment of the year is used to ground-truth values for M_1, this could potentially give a negatively biased estimate of M_1. This is because the rate of natural mortality could be expected to decay in fish between 6 months old (beginning of age 1 category in stock assessment model) to fish 18 months. This model-based approach to ground-truthing values for M_1 also assumes that the catchabilities of age 1 fish are the same between the Fall groundfish survey and the summer SEAMAP survey. Nonetheless, this approach still provides a mechanism to evaluate consistency of model predictions and observed catch per unit effort (CPUE) values for age 1. It is recommended that this analysis be updated using more up-to-date estimates of Summer SEAMAP survey and Fall Groundfish survey CPUE for age 1. It is also recommended that a wider variety of M_1 values be applied to check consistency of VPA predictions of 2nd-3rd trimester Z values for age 1 with the age 1 survey age catch rate estimates of this trimester Z. Further, it is recommended that additional trawl cpue data be compiled to obtain additional independent approximations of Z for early life history phases of red snapper, especially, phases earlier than those of age 1 fish in the mid 2nd trimester.

During plenary discussion it was pointed out that SEDAR7-DW-2 constructed similar estimates of Z_0 based on regressing fall (age 0) and subsequent summer surveys (age 1). Those results averaged over surveys since 1987 indicate an average Z of 1.8 largely representing the loss from age 0 to age 1. It was subsequently suggested that the newly compiled observer dataset on red snapper bycatch in the shrimp trawl fishery be considered to provide additional independent empirical annual and possibly monthly estimates of Z for age 0 fish. This is a dataset compiled from joint National Marine Fisheries Service and Gulf and South Atlantic Fisheries Foundation observer programs. The observers on board shrimp trawlers sampled all snapper bycatch in shrimp trawl hauls and the data have been compiled for thousands of hauls in Gulf waters. Average catch rates of age 0 and age 1 fish by location and month are available for several years. A catch-curve analysis of these data will permit estimation of Z over monthly intervals between

September when age 0 fish become fully susceptible to shrimp trawl gear and June before the age 1 fish migrate to habitats where they become less susceptible to shrimp trawl gear.

For the SPR analysis, projections and base case shrimp bycatch mortality rate estimates in Goodyear (1995), base case values of 0.5 and 0.3 were assumed for M_0 and M_1. In shrimp by-catch sensitivity tests, values ranging from 0 to 4 for M_0 and 0 to 2 for M_1 were considered. In the text on p. 41 it is stated that "Natural mortality for the cohort through the end of its first calendar year (age 0) was set to 2 times greater than during its second calendar year (age 1). This expansion permitted an expansion of the range of natural mortality considered for younger fish. This convention is purely arbitrary and does not reflect any particular expectation that the level of natural mortality is actually 2 times greater than in the older fish." Of these ranges of values it is stated on p. 42 that "it is likely that the actual natural mortality is well within the range of values examined." No further justifications for these particular values of 0.5 and 0.3 could be found in the Goodyear (1995) document. No such justification could be found either in the Schirripa and Legault (1999) document. It thus appears that the base case values of 0.5 and 0.3 originated from, and were justified in, Goodyear (1995) and have not been modified or updated since then. Neither has there been much attention given to the uncertainty in these values, except for the 1995 test of sensitivity of shrimp bycatch values to a range of values for M_0 and M_1.

The limited attention given to the assumed values for M in the 1995 stock assessment was addressed in McAllister's serving on the Science and Management Panel in the August 1997 Peer Review of Red Snapper (*Lutjanus campechanus*) Research and Management in the Gulf of Mexico. Commenting on the use of the assumed values of 0.5 and 0.3 for M_0 and M_1 in Goodyear's ADAPT sequential population analysis: Regarding the VPA projections,"… no sensitivity analysis was conducted on M for age 0 and age 1. [While] there is considerable uncertainty in these two quantities and unlike for the value of M for ages 2+, there was no empirical analysis presented to support these values. During the panel meetings Benny Galloway presented one laboratory study to indicate that these two values could be much larger. Reasonable alternative[s] could perhaps be 1.0 and 0.5. More work is needed to attempt to obtain better guesses at values for these quantities."

Natural Mortality Summary

With recent research on possible values for M for age 0 fish, scientists are now in a position to consider updating the previously assumed values for M_0 and M_1 with some empirically based estimates. Some further scrutiny of Szedlmayer's study (SEDAR7-DW-21) will be required before the new estimate in this study might be considered as a basis to provide updated base case values or prior probability density functions for M_0 and M_1. Considerations regarding the options for specifying M at age based on the last two stock assessments and the new options provided by SEDAR7-DW-21 and -49 are summarized in Table 1.3. The following points summarize the issues that remain to be resolved before the August 2004 stock assessment.

1. No resolution was achieved over whether the values assumed for the natural mortality rate for age 0 (M_0) and age 1 (M_1) should be updated.

•On Szedlmayers's paper #21 estimate of M_0 (2.3 yr^{-1}), it was recognized that the estimate could be biased by

•Immigration and emigration of age 0 fish to and from the study site

•The non-representative features of the artificial reefs employed (e.g., they could entail either higher or lower predation risk for age 0 fish when compared to natural sites).

•Use of same-year on site abundance estimates of age 0 and age 1 rather than cohort based estimates

Nonetheless, the overall Z values for the first full year post-settlement were relatively similar across a range of estimation procedures, including Szedlmayer's field work and Schirripa and Legault's model-based values used in the last red snapper assessment.

Proposed solutions:

•Update the regression of the age 1 fall groundfish survey cpue on the summer SEAMAP cpue age 1 index to approximate Z for age 1, and comparisons with VPA estimates of Z_1 (Goodyear 1995) (q assumed the same)

•For example Goodyear (1995) had obtained:

Z_1(VPA, M_1=0.3, M_0=0.5, M_{2+}=0.1)=2.52 yr^{-1}; Z_1(SEAMAP) =2.25 yr^{-1}

•In the updated analysis compare SEAMAP estimates of Z_1 with VPA predicted values for Z_1 using M_0 and M_1 set at different values.

•SEDAR7–DW-2 constructed similar estimates of Z_0 based on regressing fall (age 0) and subsequent summer survey; utilize these estimates also.

•Analyze the dataset compiled from joint National Marine Fisheries Service and Gulf and South Atlantic Fisheries Foundation observer programs to estimate Z_0 between September and July, and evaluate whether these data contain sufficient information to estimate trimester values for Z.

•Gather more literature on the potential decay in M with juvenile fish size.

•Formulate a prior probability distribution for M_0 and M_1 that accounts for the sources of uncertainty in estimates of these values and the available empirical information.

2. It was agreed that the 2004 assessment should test the sensitivity of stock assessment and projection results to assuming a range of plausible values for M_0 and M_1. However, it was not decided which values should be considered for this sensitivity test.

Proposed solutions:

•Wait until there has been a decision on the base case values to adopt for M_0 and M_1, then make decisions about the values to consider in the sensitivity tests.

•Use a wide range of plausible values, e.g., Goodyear (1995, 1996) had used 0 to 4 yr^{-1} for M_0 and 0 to 2 yr^{-1} for M_1.

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Table 1.1. Sample numbers of female red snapper for two maturation data sets by region and state from east to west, 1999-2001.

Region	State	NMFS 2004	Woods 2003
East	FL	200	
	AL	31	1029
	MS	16	
	East Total	247	1029
West	LA	68	653
	TX	105	
	West Total	173	
Total	Total	420	1692

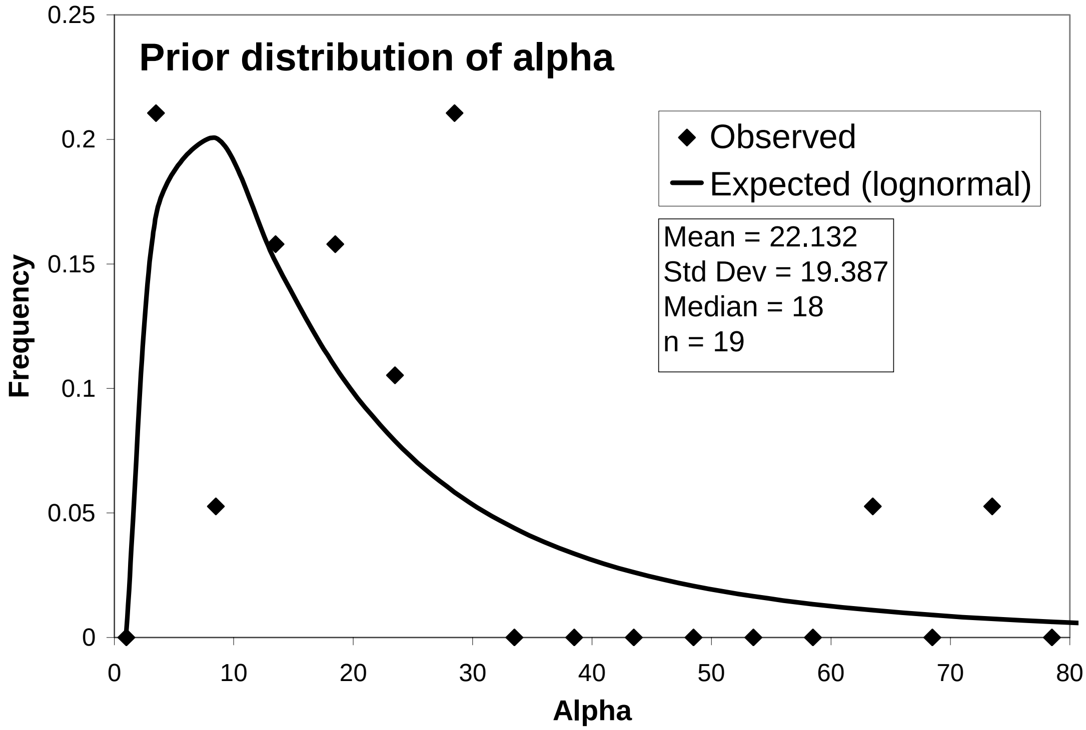
Table 1.2. Sample numbers of red snapper for 2 batch fecundity data sets by region and state from east to west, 1999-2001.

Region	State	NMFS 2004	Woods 2003
East	FL	43	
	AL	18	142
	MS	5	
	East Total	66	142
West	LA	9	81
	TX	19	
	West Total	28	81
Total	Total	94	223

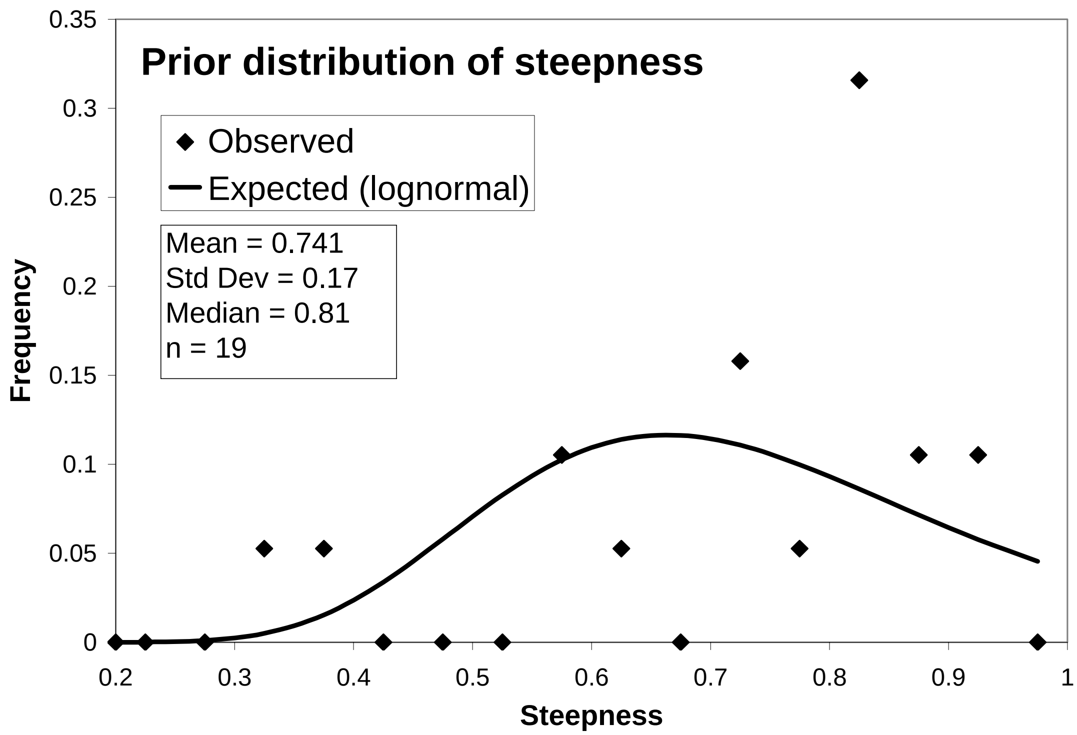
Table 1.3. Considerations regarding the options for specifying M at age based on the last two stock assessments (Goodyear 1995; Schirripa and Legault 1999) and the new options provided by SEDAR7 DW21 and SEDAR7 DW49 are summarized in Table 1.1.

Papers	Apparent base case values for M	Considerations	Sensitivity tests?
Goodyear (1995)	$M_0 = 0.5\ yr^{-1}$ $M_1 = 0.3\ yr^{-1}$ $M_{2+} = 0.15\ yr^{-1}$	Values for M_{2+} justified based on Pauly (1980) and Hoenig (1983) and sample and life history information for red snapper. No explicit justifications offered for the values assumed for M_0 and M_1. A belief is stated that the actual values for M_0 and M_1 should fall well within the range of values for these parameters in the sensitivity tests of shrimp bycatch mortality estimates. Because M_0 operates only for the first year, the annual survival rate of age 0 fish implied is exp(-(0.5+0.3/2) = 0.52. VPA predictions of the mid 2nd to mid third trimester Z (Z_{t23}) for age 1, utilizing the value of 0.3 for M_1 were cross checked with a prediction of Z for age 1 based on a regression of the Fall Ground fish survey cpue on the summer SEAMAP CPUE. When $M_{2+} = 0.1$, values of $Z_{t23} = 0.86$ and 0.75 were obtained was also incorporated. These values would need to be expanded to annual values to obtain annual Z's of approximately 2.58 and 2.25 yr^{-1}, respectively.	$M_{2+} = 0.10$ and 0.20 yr^{-1} also tried for SPR and stock projection analysis Sensitivity of Bycatch mortality estimates to values for M_1 from 0 to 2 yr^{-1} and M_0 from 0 to 4 yr^{-1} evaluated.
Schirripa and Legault (1999)	$M_0 = 0.5\ yr^{-1}$ $M_1 = 0.3\ yr^{-1}$ $M_{2+} = 0.1\ yr^{-1}$	Values for M_{2+} justified based on Pauly (1980) and Hoenig (1983) and updated sample and life history information for red snapper. No explicit justifications offered for the values assumed for M_0 and M_1.	No tests of sensitivity of stock assessment results to values for natural mortality
SEDAR7 DW49	A variety of options with M_0 starting at 0.4 and decreasing to 0.26 for age 4+ to M_0 starting at 1.28 and decreasing to 0.08 for ages 4+.	Values for average M at age justified based on Ralston (1987) and Hoenig (1983) and sample and life history information for red snapper. A decay function for M at age is proposed: $M_i =$ 2k(1-p)i-2 where k is the growth rate (0.16yr^{-1}) and p is an inputted parameter to specify the rate of decay in M with age. The paper offers an explicit and transparent quantitative rule for specifying a decay in natural mortality rate at age. However, justifications for the age at which natural mortality rate becomes asymptotic and the decay rate will be required. The equation does not permit empirical estimates of M at age to be incorporated.	Not applicable
SEDAR7 DW21	A field experiment was designed to provide an estimate of natural mortality rate for age 0 fish.	The experimental protocol was rigorously designed and executed. The estimate of M0 is obtained from averaging across annual estimates for four cohorts. Net emigration of age 0 fish away from the experimental site from after the age 0 census and before the age 1 census could positively bias estimates of M_0; net immigration of age 0 fish to the site after the age 0 census and before the age 1 census could negatively bias estimates of M_0. The sample site utilized artificial 2x2m shell reefs upon which age 0 fish settled and 2x2 concrete block/ shell reefs upon which age 1 fish settled. This artificial habitat may provide superior protection from predation relative to other habitats used by age 0 and age 1 fish and could negatively bias estimates of natural mortality. The value of 2.3 yr implies an annual survival rate of about 0.1 for fish between 2cm and 20cm.	Not Applicable

		Values for M_0 and M_1 would need to be derived from this annual estimate of 2.3 yr^{-1}, taking into account that M_0 in the first year is only for six months and the decay in natural mortality rate as fish size increases.	



a)



b)

Figure 1.1. Distributions of stock recruitment parameters from marine demersal species with a periodic life history. a) α, the maximum lifetime fecundity, and b) steepness, a representation of recruitment levels expected at low abundance. Points represent frequencies, lines represent fitted lognormal distributions.

2. Commercial Fishery Statistics

2.1 Commercial Landings

Commercial landings statistics are the quantities and value of seafood products sold to established (licensed) wholesale and retail seafood dealers. Currently, these data are collected by trip ticket programs managed by the state fishery agencies in Florida, Alabama, and Louisiana (SEDAR7-DW-20). Dealers in Mississippi and Texas are required to submit monthly reports that provide quantity and value by species. Prior to the implementation of the trip ticket programs, landings statistics were collected by NMFS/state employees that visited the seafood dealers monthly and recorded the quantities and value purchased for each species for a calendar month. In addition, the agents would assign an estimate of the type of gear and fishing area where the landings were caught.

The Southeast Fisheries Science Center (SEFSC) has maintained the commercial landings statistics (also know as, general canvass landings statistics) in a regional database since the mid 1980's. The states provide the landings statistics from their trip ticket or monthly program to the SEFSC and these data are summarized and maintained in the same format as the historical general canvass data. The objective of the SEDAR Data Workshop is to provide a final (agreed upon) data set that contains the landings at the following level of resolution - year, month, gear, fishing area (the NMFS statistical grids), and state/county where the fish were landed. The Panel also requested that the SEDAR landings data set for red snapper be extended as far back in time as possible. The Panel recognizes that landings data for the “older” years may not be available at the desired level of resolution, but the Panel still recommends that all historical data be included with explanations of the data limitation included.

As described in Working Paper, SEDAR-DW-22, the SEFSC maintains the general canvass database for the southeast region. The general canvass database includes landings data from 1962 through 2003. However, as noted in SEDAR-DW-22, there are several situations during the 1962-2003 time series that the data do not meet the desired level of resolution. The following identifies these situations:

1. only annual data are available for 1962 - 1977;
2. for Florida, gear and fishing area are not available for monthly data for 1977 - 1984;
3. for Louisiana, gear and fishing area are not available for 1990 - 1999,
4. for Texas, an unusually large of allocations of red snapper landings were assigned to shrimp trawl gear for 1978 - 1983;
5. for Texas, gear and fishing area are not available for 1990 - 2003.

The Workshop Panel recognized the lack of resolution for the 1962 - 1977 period; however, the Panel did not see a need to distribute the annual percentages by gear and fishing area by month for this time period.

For the landings on the west coast of Florida during the period 1977 - 1984, data on the allocation of landings gear and fishing area are available from the Florida annual general canvass data. The concern is whether landings are distributed evenly throughout the year or whether there are seasonal patterns which result in uneven landings by gear throughout the year. The monthly data from the Florida trip ticket program were analyzed to determine if the landings by gear are different throughout the year for handline and bottom longline gears. For both the period 1991 - 1995 and 1996 - 2003, the average percentages for these two gear types by month are very similar throughout the year. For example, the average percent of the landings by handline gear for 1991 - 1996 varies between 87.4 % and 98.3 % throughout the year. Given these similarities, the Panel agreed that the percentage allocations from the annual general canvass can be applied to the monthly general canvass data to provide the desired resolution for the SEDAR data base.

As noted in the 3rd item, gear allocations are not available for the Louisiana landings from 1990 through 1999. The Panel agreed that the percentages by gear from the SEFSC logbook program should be used. The Panel also noted that the logbook data are essentially the only alternative for gear allocations during this period.

The 4th item relates to the gear allocations for Texas landings during 1980 - 1983. For this 4 year period, approximately 50 to 60% of the landings were reported from shrimp trawls. The Panel agreed that such a large allocation to this gear type is highly unlikely. Several Panel members stated that the fishery for red snappers was undergoing a transitions during this period. The landings statistics from the 1962 - 1977 period show commercial landings of red snapper from shrimp trawl and it is likely that commercial landings of the shrimp trawl fishery continued through the 1978 - 1983 period. In 1984, a 12" minimum size limit went into effect and the commercial landings of red snapper from shrimp trawls decreased appreciably. In 1980, a small fleet of bottom longline vessels fished off the Texas coast and introduced bottom longlining to the fishery. Because shrimp trawlers were relatively easily re-rigged for bottom longline fishing, this provided these vessels with an alternative to shrimping during the off-season. The large percentages of the commercial landings during the 1978 - 1983 period suggests that these landings were not adequately allocated to either hook & line fishing or the newly introduced bottom longline fishery. The Panel notes that Goodyear, 1995, presents allocations by gear for a shrimp trawl index; however, the method used to allocate the red snapper landings by gear type was not described in the assessment. At this time, no reliable allocations by gear are available for this 4 year period.

The last item is similar to the 3rd item in which gear allocations are not available for Texas landings for the period 1990 - 2003. The Panel agreed that the gear allocations from the SEFSC logbook program should be used to provide the best estimate of the landings by gear for this period.

In summary, the Panel recommends that for 1990 and later the gear allocations available in the general canvass (trip ticket) data be retained and the gear allocations from the SEFSC logbook data be used for Louisiana (1990 - 1999, the Louisiana trip ticket data have gear designations for 2000 - 2003) and for Texas landings.

The Panel also considered the allocations of landings by fishing area (i.e., the statistical grid established by the NMFS). Because the logbook data are reported by fishermen and are likely to provide a more realistic distribution of fishing areas, the Panel recommends using the logbook data to identify the allocations of landings by fishing areas. It was noted that annual allocations provide a better distribution than monthly allocations because some areas and months may not be covered by the logbook reporting.

The SEFSC general canvass landings data will be the basis for the SEDAR landings data base for the red snapper assessment with the adjustments for gear and fishing area specifications as noted above. The annual landings of red snapper by gear categories are presented in Table 2.1 and the annual landings by east and west Gulf are presented in Table 2.2.

2.2 Size Frequency Data

Size frequency data are collected as part of the Trip Interview Program (TIP), as well as the biological component of GulfFIN. These programs are cooperative data collection activities between the NMFS/SEFSC and the coastal states along the Gulf of Mexico . Hard part (otoliths and spines) and tissue samples are also collected as part of both the TIP and the FIN. These data are used to estimate life history parameters and are discussed in that section of the SEDAR report.

The TIP began in 1984 and data from that year through 2002 are included in the SEDAR Workshop. A total of 174,185 red snapper were sampled (measured and/or weighed) from commercial fisheries during this period and are included in the size frequency analysis. Of those samples, 93.3% were caught from handline gear and 5.6% were caught by bottom longline gear. The numbers of trips from which samples were taken and the numbers of red snapper samples are presented in Table 2.1 and Table 2.2, respectively, in SEDAR-DW-45. It should be noted that only the samples where the area of catch was reported along with the size frequency sample are included in the size frequency analysis in SEDAR-DW-45. The conclusions from these analyses are:

- red snapper sampled from landings on the west coast of Florida that were caught in grids 1 - 7 had a consistently larger proportion of larger fish than landings that were caught in grids 8 - 10 off the Florida Panhandle;
- the differences in sizes of red snapper sampled from grids 1 - 7 and grids 8 - 12 could not be explained by the samples from vessels with a Class I permit endorsement vs a Class II permit endorsement; and
- red snapper samples landed on the Florida west coast with electric handlines (aka, bandit rigs) were larger than fish landed by manual handline gear for the period 1984 - 1988.

The Panel noted two possible explanations for the differences in size frequency distributions between the two strata for the eastern Gulf (first bullet). These differences may be due to a difference in the way the fishing is conducted in these two areas. In the southern area, grids 1-7, it appears that red snapper caught with handlines may be incidental to the grouper fisheries; whereas the fishery in the northern area, grids 8-12, may be from trips directed at red snapper. The second reason for considering the two strata for the eastern Gulf is the differences in sample sizes for the two areas. The influence of sample size on the size frequency distributions is analyzed in SEDAR-DW-43. The sample sizes of the individual trips in the grids 1-7 are generally smaller than the sample sizes for the trips in grids 8-12.

The size frequency data for red snapper samples suggest the following stratification for calculating catch-at-size distributions for the commercial harvest:

- For handline gear, which includes the manual and electric/power assisted reel in a single category, three area stratification can be considered. These strata are grids 1-7, grids 8-11 (or 12) and grids 12 (or 13) to 21.

- For bottom longline gear, the size frequency support two strata, grids 1 - 10 and grids 11 - 21.

The TIP data were analyzed to determine if species misidentification, i.e., other species being misidentified as red snapper or red snapper being identified as other species, in the SEDAR Working Paper, SEDAR-DW-44. The conclusions of this analysis show that neither of the two misidentification scenarios represent a significant portion of the red snapper landings during the period, 1994 - 2003.

2.3 Discards by the commercial directed fishery

In August 2001, the SEFSC initiated a program to collect information on the numbers of fish that are being discarded in the Gulf of Mexico reef fish and South Atlantic snapper-grouper fisheries. To collect this information, the SEFSC developed a form that supplements the existing vessel logbooks that are currently mandatory for these fisheries. The data reported from the supplemental discard reporting are presented in SEDAR-DW-22.

A generalized linear model (GLM) was used to estimate the statistical parameters that are significantly correlated with the numbers of red snapper that were discarded during the two years, 8/1/2001 - 7/31/2003. Separate GLM's were analyzed for the 3 major types of gear (bandit rigs, manual handline and bottom longline gear) used in the directed fishery for red snapper. The results of the GLM's provided the combinations of parameters that were to calculate the average numbers of red snapper discarded. From the average numbers of discards per trip and the numbers of trip reported during the period 8/1/2001 - 7/31/2002, a total of 738,900 red snapper were estimated to have been discarded during this 12 month period. From the estimated weights provided by the fishermen on the supplemental discard form, the mean weight of fish released by handline gear was 2.35 pounds, the mean for bandit rig vessels was 2.9 pounds and the mean weight for bottom longline vessels was 6.49 pounds. Using these means, the estimated weight of the red snapper discarded during the period 8/1/2004 - 7/31/2004 is 2.1 million pounds (i.e., 108.6 thousand at 2.35 pounds from Table 8, 623.8 thousand at 2.9 pounds from Table 9 and 6.5 thousand at 6.49 pounds from Table 10 of SEDAR-DW-22).

One recommendation from the Panel was to calculate the average weights for the red snapper discarded during the open and closed seasons separately. The concern is that a 2.35 to 2.9 pound fish is a legal size and it is unlikely that fish of this size would be discarded during the open season. For the period 8/1/2001 - 7/31/2003, the mean weight reported for the red snapper discarded during the open seasons was 1.96 pounds and the mean weight of the discarded red snapper during the closed seasons was 4.25 pounds.

From the research conducted by Nieland, Baker, Fischer and Wilson (presentation at the SEDAR meeting), an estimated 69% of the red snapper discarded were dead or remained on the surface. During the project, a total of 399 fish (25 potential discards per trip) were measured and aged. The mean length of these fish was 335 mm (TL) and the distribution by age was 7.3% age 1, 85.5% age 2, 6.8% age 3 and 0.5% age 4. It is assumed that the trips sampled in the LSU project were conducted during the open season and therefore, the vast majority of the red snapper discarded during the open season would have been age 2. Under that assumption, the study does not provide any data on discards during the closed seasons.

Table 2.1. Red snapper landings (whole weight, thousands of pounds) for the Gulf of Mexico by gear categories, 1996 - 2003*.

Year	Bandit Rig	General Handline	Bottom Longline	Other**	Unknown	Total
1962		12,231		241		12,472
1963		13,176		150		13,326
1964		13,758		294		14,053
1965		13,802		253		14,055
1966		12,770		328		13,098
1967		12,016		482		12,498
1968		10,522		604		11,126
1969		9,556		462		10,018
1970		8,245		717		8,963
1971		8,392		494		8,886
1972		8,276		634		8,910
1973		7,898		704		8,602
1974		8,374		564		8,938
1975		7,936		326		8,263
1976		7,224		306		7,530
1977		5,383		290		5,674
1978		4,504		153	388	5,045
1979		4,619		130	215	4,964
1980		4,351	139	403	119	5,012
1981		4,969	229	348	419	5,966
1982		5,321	298	526	264	6,409
1983		5,844	544	477	416	7,281
1984		4,453	1,133	156		5,742
1985		3,092	718	96	531	4,438
1986		2,566	887	102	410	3,965
1987		2,256	798	64	239	3,357
1988		2,894	741	92	333	4,060
1989		2,315	525	43	216	3,100
1990		2,036	226	28	372	2,662
1991	4	2,114	100	8	15	2,241
1992	9	2,974	44	15	0	3,043
1993	0	3,300	62	15	28	3,405
1994	0	2,981	109	9	152	3,252
1995	0	2,868	47	2	37	2,954
1996	0	4,261	34	55	1	4,351
1997	1	4,703	44	76	0	4,823
1998	10	4,608	35	39	1	4,694
1999	35	4,689	128	21	4	4,877
2000	1,320	3,320	192	7	5	4,844
2001	1,552	2,946	150	15	4	4,666
2002	2,168	2,469	149	36	1	4,823
2003	2,461	1,771	183	29	1	4,445

* Source: Southeast Fisheries Science Center, General Canvass Landings Statistics, Miami, FL 33149

** The "Other" category includes the lesser used types of gear such as: nets, shrimp trawls, etc.

Table 2.2. Red snapper landings (whole weight, thousand of pounds) for the Gulf of Mexico by eastern and western areas*, 1962 - 2003**.

Year	Eastern	Western	Outside	Unknown	Total
1962			14	12,457	12,472
1963	3,002	3,818	4,191	2,315	13,326
1964	3,607	3,590	6,856		14,053
1965	3,713	3,646	6,696		14,055
1966	3,099	3,041	6,958		13,098
1967	2,907	4,231	5,360		12,498
1968	2,618	5,161	3,347		11,126
1969	2,442	4,187	3,388		10,018
1970	2,309	4,653	2,000		8,963
1971	2,224	5,366	1,297		8,886
1972	2,374	4,842	1,694		8,910
1973	2,713	4,867	1,022		8,602
1974	3,768	4,434	737		8,938
1975	3,577	3,933	753		8,263
1976	3,288	3,327	915		7,530
1977	2,264	2,873	537		5,674
1978	2,016	2,677	353		5,045
1979	2,045	2,466	454		4,964
1980	1,990	2,561	462		5,012
1981	2,305	3,193	468	0	5,966
1982	2,516	3,733	160		6,409
1983	2,827	3,919	119	416	7,281
1984	2,000	3,669	73		5,742
1985	1,074	2,284	248	832	4,438
1986	614	2,667	233	451	3,965
1987	548	2,206	288	314	3,357
1988	687	2,969	81	323	4,060
1989	474	2,323	1	302	3,100
1990	503	1,501	14	643	2,662
1991	337	1,400	25	479	2,241
1992	365	2,050	10	618	3,043
1993	276	2,511	5	612	3,405
1994	278	2,381	21	572	3,252
1995	187	2,496	8	263	2,954
1996	296	4,026	26	2	4,351
1997	276	4,535	12	0	4,823
1998	406	4,275	12		4,694
1999	597	4,240	39	0	4,877
2000	695	4,141	7	0	4,844
2001	818	3,824	15	9	4,666
2002	1,132	3,661	20	10	4,823
2003	1,076	3,335	32	1	4,445

* Eastern Gulf is the area in statistical grids 1 through 12. Western Gulf is the area in statistical grids 13 through 21. The "Outside" is the area for fishing in grids greater than 21.

** Source: Southeast Fisheries Science Center, General Canvass Landings Statistics, Miami. FL

3. Recreational Statistics

3.1 Recreational Landings

Recreational catch estimates are provided by the Marine Recreational Fishery Statistics Survey (MRFSS), NMFS Headboat Survey, and the Texas Parks and Wildlife Department Coastal Creel Survey (TPWD). Table 3.1 shows the annual estimated catch for red snapper from each survey.

There have been active discussions of MRFSS issues ongoing for some time (see e.g. SEDAR7-DW-27), and the working group spent a good deal of time addressing possible anomalies in the survey results.

After 1998, MRFSS implemented a new methodology to estimate charterboat effort (For-Hire-Survey, FHS). This change in methodology for effort estimation affects the catch estimates since they are the product of estimated effort and observed catch-per-unit effort. Estimates from the previously used method (MRFSS) and the new FHS can not be directly compared because estimates from the old methods have been shown to be biased. Conversion factors to correct for the bias are necessary in order to use Charterboat effort and landings from 1986-1997 and the FHS estimates for 1998-2003 as one time series. Conversion factors can be estimated based on ratios of estimates from old and new methodology which were made simultaneously starting in 1998. Note that from 1981 to 1985 charterboat and headboat were combined into one mode, thus conversion factors for charterboat estimates cannot be applied prior to 1986.

Two preliminary sets of conversion factors were estimated and used to convert 1986-1997 charterboat landings. The general approach to estimate the conversion factors was to use GLM to identify significant factors and predict conversion factor values. The first model included ZONE (Inshore, >3 miles and <3 miles) and WAVE as significant factors for the combined data from the states of LA, MS and AL and only ZONE for the data from FL (note that FL had to be treated separately because ZONE is defined as Inshore, >10 miles and <10 miles). The second model did not include the zone 'Inshore' and had WAVE as the only significant factor. The group agreed that further work is necessary to estimate better conversion factors and new estimates will be presented to the stock assessment working group.

An estimated directed catch-per-trip (cpue) analysis of red snapper by state and year revealed an outlier in Mississippi in 1989. The data in wave 5, Sep-Oct, 1989 contained two angler interviews from the same Private boat mode trip, each reporting 25 red snapper landed (type B1 catch), and a single Private boat mode angler-interview with 4 red snapper landed by 4 anglers (type A catch). The resultant catch per angler-trip was considerably higher than the typical and resulted in an unusually large estimate of red snapper harvest for the wave and the entire year. The group recommended substitution for the Private mode, wave 5, 1989, Mississippi catch estimate, replacing the estimated value with the average of wave 5, Private boat mode, 1988 and 1990. This substitution has been made in the annual estimated catch of red snapper (Table 3.1). Note that the group used catch-per-trip (cpue) analysis to identify outliers instead of examining catch estimates because the inter-annual variability of red snapper catch estimates made it difficult to identify data anomalies.

Complete coverage for estimating recreational catch in Gulf states began in 1986, with the Headboat Survey expanding to include the Gulf, the TPWD survey covering Texas, and MRFSS covering all but headboats in other states (SEDAR7-DW-19). Before 1986, MRFSS and TPWD surveys both operated intermittently and incompletely in TX. Consistent estimates of private boat and charterboat landings in the TPWD data are only available beginning in wave 3,1984 but headboats were sampled by TPWD only during wave 3, 1983 through wave 4, 1984. For the empty cells identified in the period 1981-85 for both MRFSS (including all modes and states in wave 1, 1981) and TPWD, possible substitution schemes need to be investigated.In addition, the group acknowledged that estimated MRFSS landings for the period 1981-1985 have a high degree of uncertainty due to the small number of fish sampled. The group recommended that the uncertainty resulting from low sample sizes and lack of data for both MRFSS and TPWD during 1981-1985 be taken into consideration in the construction of the stock assessment models.

In 2002, LA Headboat owners did not report catch and effort data. The reported catch/effort data from LA in 2001 were used by the Headboat Survey to estimate the LA landings for 2002. The LA red snapper landings are less than 7% of the total headboat red snapper landings in 2002. The group notes that TPWD landing estimates are not final and that new estimates for Texas will be provided which might result in significant changes for 1983-1997 and minor changes for 1998-2002. However, these estimates might not be available for this assessment.

3.2 Recreational Discards

Information about discards is routinely collected through the existing MRFSS methodology. At the present time, there are no estimates of live discards from Headboats and only limited data from TX. The group discussed using the discard estimates from a special study of Headboats in TX for the period August-September 1999 (Dorf 2003) to estimate discard ratios. It was concluded that Dorf's data might not be representative since it was collected close to the end of the fishing season when the proportion of undersized fish is thought to be higher. Campbell et al. presented discard ratios for TX for the period May 2003-present. The group recognized that Campbell's work will be valuable for future assessments. But Diaz (SEDAR7-DW-58) showed that discard ratios vary on an annual basis. Thus, the group was concerned about applying Campbell's discard ratios for years previous to 2003. The group recommended applying the MRFSS discard ratios estimated for the rest of the Gulf of Mexico (Table 3.2) to the TPWD and Headboat data series. The group also recommended that given some concerns raised by the SEDAR about appropriateness of applying MRFSS discard ratios to TPWD and Headbot surveys, an assessment run be conducted without discards to measure the sensitivity of the results to the discards estimates.

3.3 Recreational Sampling Intensity

The percentages of landings observed in the MRFSS, TX Parks and Wildlife and NMFS Headboat surveys were calculated using the observed (or reported) and estimated landings (Tables 3.3-5). The percentages are generally 0.1 to 1.3 annually in the MRFSS, 0.7 to 5.8 annually (2.9 overall) in the TPWD survey, and are typically above 80% in the Headboat Survey, particularly in TX, where most landings of red snapper from headboats occur.

The percentages of landings for which length was measured were also calculated (Tables 3.6-7). The percentages were highest in the Headboat survey (1.13 to 2.73% annually, 1.78% overall) and TPWD survey (0.35 to 2.53 annually, 1.16% overall). Annual percentages in the MRFSS were 0.02 to 0.8, 0.2 overall, but were above 0.5 since 1999 due mainly to increased charterboat sampling.

3.4 Recreational Catch-at-Length and Catch-at-Age

At the present time, very limited data on sizes of live discards are available. Dorf (2003) provided red snapper size composition caught by headboats operating in TX waters, but the temporal coverage of her study is limited (Aug-Sep 1999). Campbell et al. also presented preliminary results from TX for 2003-04. The group recognized that Campbell's work will be valuable for future assessments. However, the group did not recommend applying Campbell's 2003 discard size composition for years prior to 2002 since the 2003 data can not reflect the possible effect of year class strength on the size composition of prior years. The group emphasized the need for more systematic information on discards size composition.

The recreational size data from MRFSS, TPWD, and Headboat Survey indicated flexibility in estimating CAS for the entire Gulf or for east and west strata. The group decided not to make any specific recommendation on where to establish the boundary between east and west areas.

In developing the Catch-at-Age, available FIN size and age data will be reviewed and used in the calculations.

Table 3.1: Red snapper estimated landings (MRFSS is A+B1 and uses the charterboat estimates made with the old method).

YEAR	MRFSS	Headboat	TPWD	TOTAL
1981	1,874,662			1,874,662
1982	1,433,438			1,433,438
1983	2,618,628		254,713	2,873,341
1984	671,864		233,793	905,657
1985	890,249		45,945	936,194
1986	827,623	332,558	34,597	1,194,778
1987	782,174	329,156	49,007	1,160,337
1988	715,762	438,080	71,848	1,225,690
1989	563,132	383,521	97,644	1,044,297
1990	390,817	203,785	26,445	621,047
1991	639,731	280,509	49,099	969,339
1992	972,318	447,228	118,645	1,538,191
1993	1,494,515	496,472	292,264	2,283,251
1994	1,009,847	527,616	199,598	1,737,061
1995	772,112	377,995	72,029	1,222,136
1996	692,021	977,801	42,464	1,712,286
1997	1,126,242	396,121	87,383	1,609,746
1998	1,318,861	321,647	97,394	1,737,902
1999	1,207,474	166,305	54,171	1,427,950
2000	974,559	169,164	56,735	1,200,458
2001	1,087,575	167,700	67,320	1,322,595
2002	1,429,525	213,633	91,216	1,734,374
TOTAL	23,493,129	6,229,291	2,042,310	31,764,730

Table 3.2: Proportion of animal released alive (Type B2) to all catches (Type A + Type B1+Type B2) based on MRFSS catch estimates by year and state.

	State					
Year	TX	LA	MS	AL	FL	TOTAL
1981	0.01	0.01		0.04	0.08	0.03
1982		0.01	0.05	0.002	0.04	0.02
1983		0.001				0.001
1984					0.27	0.03
1985	0.52	0.12			0.06	0.17
1986		0.02		0.05	0.07	0.05
1987		0.07	0.29	0.15	0.06	0.09
1988		0.37	0.15	0.001	0.17	0.22
1989		0.37	0.27	0.05	0.40	0.35
1990		0.61	0.79	0.56	0.45	0.58
1991		0.53	0.60	0.62	0.53	0.58
1992		0.41	0.59	0.39	0.58	0.49
1993		0.39	0.58	0.43	0.2	0.39
1994		0.52	0.53	0.48	0.37	0.47
1995		0.57	0.45	0.43	0.41	0.49
1996		0.40	0.65	0.60	0.66	0.59
1997		0.38	0.76	0.64	0.60	0.62
1998		0.43	0.73	0.57	0.46	0.51
1999		0.71	0.54	0.60	0.62	0.62
2000		0.51	0.80	0.70	0.57	0.62
2001		0.47	0.75	0.70	0.61	0.65
2002		0.43	0.77	0.65	0.57	0.60
TOTAL	0.32	0.26	0.61	0.50	0.47	0.45

Table 3.3. Percent of estimated red snapper landings (A + B1) which were recorded in the MRFSS intercepts. Type A are seen by the sampler and Type B1 are self-reported by the fishers who are interviewed (Data for LA 2001 to be added).

	STATE OF INTERCEPT					
	AL	FL	LA	MS	TX	GULF TOTAL
	% Sampled	% Sampled	% Sampled	% Sampled	% Sampled	% Sampled
year						
1983	0.3046	0.1274	0.1171	0.0456	9.4241	.1927
1984	0.2640	0.2297	0.1960	7.7299	0.0619	0.2139
1985	0.0981	0.0744	0.0781	1.0174	0.0889	0.0868
1986	0.3733	0.2478	0.3470	8.3351	.	0.3047
1987	0.4361	0.3899	0.3578	1.6134	.	0.4254
1988	0.3044	0.0998	0.0526	0.5076	.	0.1382
1989	0.1980	0.0698	0.0513	0.1172	.	0.1069
1990	0.1905	0.2280	0.2263	1.1552	.	0.2559
1991	0.4311	0.9675	0.2612	0.2796	.	0.5323
1992	0.6190	0.6111	0.4644	0.3603	.	0.5280
1993	0.1587	0.1216	0.0754	0.1632	.	0.1294
1994	0.2382	0.2418	0.1246	0.1396	.	0.2026
1995	0.1620	0.0733	0.0905	0.7273	.	0.1488
1996	0.0922	0.1216	0.1525	0.2344	.	0.1260
1997	0.2247	0.2987	0.2559	0.1753	.	0.2504
1998	0.5809	0.3059	0.2775	0.2889	.	0.3784
1999	1.2414	0.7498	0.2918	0.5508	.	0.8779
2000	1.1667	1.5503	0.4163	1.0243	.	1.3230
2001	0.8030	0.8005	.	0.7268	.	.
2002	0.6777	1.0891	0.8047	0.5248	.	0.9075

Table 3.4. Percent of estimated red snapper landings which were recorded in the TX Parks and Wildlife Department recreational harvest survey. (TPWD estimates correspond to Type A catch in MRFSS.)

1983	4.548
1984	5.766
1985	3.141
1986	3.781
1987	3.563
1988	2.516
1989	1.194
1990	3.479
1991	2.475
1992	1.419
1993	0.695
1994	1.337
1995	4.271
1996	5.793
1997	3.222
1998	2.406
1999	2.632
2000	3.328
2001	3.749
2002	2.272
Total	2.921

Table 3.5. Percent of estimated red snapper landings which were recorded in the NMFS Headboat Survey logbooks. Logbooks were not available from vessels operating in Area 24 (LA) in 2002, but estimates were made by the survey using logbooks from 2001.
Area 23 = AL/NW FL, 24 = LA, 25-27 = SE-SW TX.

			Area			
	23	24	25	26	27	Total
1986	13.427	53.836	69.657	59.998	55.893	63.368
1987	36.247	37.940	96.387	69.020	76.224	86.096
1988	75.817	31.300	76.440	70.681	80.451	73.189
1989	74.713	86.992	90.273	73.699	84.490	86.386
1990	93.114	77.925	88.730	79.245	95.631	87.689
1991	85.849	87.847	86.838	59.166	93.750	82.086
1992	83.285	80.798	90.571	93.244	92.027	89.759
1993	87.647	60.455	90.681	88.785	92.848	87.218
1994	92.256	70.299	83.086	91.569	97.070	85.644
1995	91.758	81.388	80.370	93.824	91.981	85.428
1996	97.408	47.773	81.414	90.364	97.856	82.004
1997	91.863	76.084	65.754	69.176	98.097	72.528
1998	90.322	94.736	86.504	96.352	89.649	90.074
1999	90.923	46.753	96.912	97.840	88.034	87.556
2000	93.055	62.933	99.401	98.519	9.886	89.828
2001	92.742	52.945	99.916	88.777	92.339	90.076
2002	82.163	0.000	95.646	98.086	96.936	85.490
Total	86.506	64.908	84.225	85.065	84.826	83.179

Table 3.6. Percent of estimated red snapper landings which were measured (length) in MRFSS and TPWD surveys.

A. MRFSS intercepts. Landings estimates are for Type A+B1 (all fish killed, including discarded dead).

B. TX Parks and Wildlife recreational harvest survey. Landings estimates correspond to Type A (does not include those discarded dead).

	A. MRFSS						B. TPWD
	TX	LA	MS	AL	FL	Total	TX
1981	0.0168	0.0068		0.0299	0.0337	0.0175	
1982		0.0449	0.0485	0.0192	0.0396	0.0358	
1983	0.1769	0.0637	0.0456	0.0175	0.0970	0.0517	1.55665
1984	0.0619	0.0628	0.2089	0.0148	0.1056	0.0575	1.98979
1985	0.1555	0.0437	0.0462	0.0154	0.0129	0.0429	1.53880
1986		0.1746	1.1711	0.1142	0.0141	0.0731	1.06946
1987		0.2749	0.0647	0.2287	0.0624	0.1153	0.95088
1988		0.0336	0.3839	0.1600	0.0276	0.0657	0.67921
1989		0.0489	0.0204	0.0742	0.0182	0.0405	0.34616
1990		0.1243	0.1037	0.0911	0.0405	0.0888	1.43316
1991		0.1940	0.1344	0.3286	0.0296	0.1909	1.09778
1992		0.1810	0.2204	0.4204	0.1416	0.2778	0.53015
1993		0.0564	0.0886	0.0872	0.0629	0.0731	0.27749
1994		0.0775	0.0805	0.1174	0.0488	0.0856	0.52355
1995		0.0704	0.0719	0.0863	0.0601	0.0755	1.89229
1996		0.0926	0.1326	0.0710	0.0378	0.0714	2.53391
1997		0.0762	0.0981	0.1330	0.1685	0.1347	1.56209
1998		0.1555	0.1673	0.3748	0.2097	0.2486	1.35019
1999		0.1920	0.4039	1.0472	0.5475	0.6865	1.47496
2000		0.1049	0.8081	1.1498	0.8261	0.8496	1.95999
2001		0.0357	0.4826	0.7942	0.5952	0.6405	1.76173
2002		0.4595	0.4378	0.6059	0.5622	0.5715	1.18181
Total	0.0700	0.0535	0.1471	0.2757	0.2574	0.1983	1.15962

Table 3.7. Percent of estimated red snapper landings from the NMFS Headboat Survey logbooks which were measured (length). Although logbooks from vessels operating in Area 24 (LA) in 2002 were not available, dockside sampling was conducted.

	Area					
	27	26	25	24	23	Total
1986	3.05	10.34	0.81	1.66	0.96	1.93
1987	4.01	3.51	0.88	4.25	2.06	1.88
1988	2.94	2.80	0.25	1.94	1.51	1.13
1989	2.25	4.86	0.34	10.38	2.70	1.71
1990	4.06	2.54	0.96	5.16	2.14	2.28
1991	3.15	0.98	0.65	3.31	3.23	1.40
1992	5.59	1.23	1.35	5.05	2.13	1.99
1993	6.33	0.58	0.97	3.47	1.05	1.50
1994	4.75	0.81	0.91	1.80	2.80	1.41
1995	7.68	1.26	1.96	3.73	1.92	2.32
1996	4.44	1.03	1.06	2.66	1.75	1.52
1997	5.05	0.18	0.38	5.27	2.35	1.30
1998	3.70	2.60	1.52	8.76	2.82	2.73
1999	2.97	2.30	0.85	9.28	1.30	2.52
2000	4.07	0.35	0.05	19.38	2.00	2.58
2001	2.13	1.25	0.47	11.13	1.29	1.91
2002	3.77	1.42	0.15	6.83	1.67	1.70
Total	3.96	1.69	0.86	5.05	1.94	1.78

4. Fishery-Dependent Indexes

4.1 Commercial Fishery Catch Rates

4.1.1 Commercial Handline

SEDAR7-DW-47 used data from the National Marine Fisheries Service (NMFS) reef fish logbook program to develop two abundance indices for red snapper. Since no size data are available in the logbook data base, data from only those years of consistent minimum allowable size were included in the analyses (1996-2003). The first index used data collected from vessels with class 1 permits (allowing possession or landing of up to 2,000 pounds of red snapper) fishing during red snapper open seasons only. The pattern of open seasons has not been consistent during the time series examined.

The second index used an association statistic to identify species which are frequently caught along with red snapper; this statistic was then used to identify trips with a higher probability of catching red snapper, that is, trips which might be directed at species assemblages which include red snapper. Data from those trips were used to develop the second abundance index. The status of the season (open or closed) was considered as a factor.

The Fishery Dependent Indices Working Group had concerns regarding the utility of the commercial catch rates as indices of the population because of size and trip limits combined with the lack of discard information. However, size and trip limits have been consistent across the time period and are less restrictive than those of the recreational fishery, with the likely result that a lower proportion of fish are discarded. Therefore, the Working Group recommended that the index could be considered for use in the assessment, given that the available data may be analogous to that of an index derived using catch data from a (highly) size-selective gear.

It is not possible to distinguish between electric and non-electric handline in the data until 2001. If catch rates are different between the gears, it is possible that a changing proportion of effort split between these gears could have an influence which is not accounted for. It should be possible to evaluate any differences in catch rates in future years as more data become available.

The Working Group was also concerned about the potential impact of the current multiple, short open seasons on catch rates (as opposed to fewer, extended open seasons which occurred in the past). The Working Group investigated the possibility that the change to shorter open seasons may have reduced the duration of fishing trips, which in turn may have reduced the geographic coverage of the fishing effort. No evidence was found of such a decline in trip duration (Figure 4.1).

Due to the high proportion of trips with catch, a lognormal analysis might be more appropriate than a delta-lognormal analysis. The Working Group suggested that the lognormal approach should be employed when conducting revised analyses and that the diagnostics should be examined to confirm suitability of this approach.

The eastern and western Gulf nominal catch rate trends for Class I permitted vessels during open seasons were examined (Figure 4.2). The nominal catch rate trends are somewhat different (although a year*region interaction was not important in fitting the standardized index). The Working Group recommended that indices be calculated separately for the eastern and western Gulf to permit flexibility in the assessment and for use in sensitivity analyses.

The available fisheries data (including both commercial and recreational) include many trips with a low probability of catching red snapper due to unrecorded covariates such as depth, fishing location, bait, bottom type, gear configuration, weather, etc. The Working Group noted that each of the available papers presenting fishery dependent abundance indices included an analytical approach to identify trips likely to be directed at red snapper. These approaches eliminated trips which are unsuccessful in catching any member of an associated species assemblage and/or restricting to the most successful vessels. The

Working Group considered that these were reasonable treatments of the available data. However, the Working Group suggested that modifications to restrictions based upon the associated species assemblage could be explored. These modifications could include: 1) defining upper cutoffs (retaining trips only if species with a higher association statistic are caught) AND lower cutoffs (rejecting trips if any of these less associated species are caught), this could address possible split effort on trips, 2) utilizing biological/life history information to define association statistic cutoffs, and 3) setting cutoff levels independently between regions (as these association statistics are relative measures).

4.1.2 Commercial Landings from Shrimp Trawlers

Historically, red snapper of commercial size were taken as a bycatch in shrimp trawls and were commonly sold until the provisions of the Amendment 1 to the Reef Fish Fishery Management Plan became effective in 1990 (GFMFC 1989). These landings represented a small but consistent part of the commercial red snapper landings, and since they are taken incidental to the shrimp fishery, the catch rates should reflect the relative abundance of red snapper. Catch, effort and catch per effort for this component of the fishery are given in Figure 4.3. Effort is thousands of days fished offshore Alabama-Texas in depths from 5 to 50 fathoms. Catch per day- fished fluctuated at a level of about 3 kg from 1967-1974, declined to 0.47 kg, recovered to 1.43 kg in 1983 then continued to decline to a low of 0.13 kg in 1989.

The age composition of the fish sold from the shrimp trawls is unknown. Only 12 red snapper were sampled from this component of the fishery Figure 4.4). However, additional samples from the shrimp bycatch characterization studies are available for comparison. These were truncated to the minimum size observed in the TIP samples to eliminate fish that were too small to be sold (Figure 4.4). Both data sets suggest that the sold bycatch was made up mostly of small fish, but larger fish were occasionally found in the catch.

Although shrimp trawlers were exempted from possession limits of the Fisheries Management Plan (GMFMC 1981), red snapper had to be at least 30.5 cm (12 in) fork length to be sold. The FMP rules became effective in November 1984. Given the modal size of the small sample of Figure 4.4, it is likely that some or all of the decline observed after 1984 resulted from compliance with the minimum size. Amendment 1 to the FMP (GMFMC 1989) prohibited the sale of red snapper caught by shrimp trawls. If the decline after 1983 was the result of the minimum size then the decline from the early 1970s could be interpreted as a decline in recruitment because of the small size of the fish involved. The increased cpue observed in 1981 and 1983 would have been associated with the relatively strong year classes in 1979 and 1981 recruiting to the fishery at age 2.

Analyses corresponding to Figure 4.3 were presented in an earlier report (Goodyear and Phares 1990) and elicited comments from fishermen. Anecdotal reports and testimony of individuals before the Gulf of Mexico Fisheries Management Council suggested that some or most of these landings were the result of handline catches of the shrimp vessel crews while at anchor. Further, it was argued that some or even most of the subject landings were from Mexican waters prior to their closure to U.S. shrimpers. The likely effect of the former argument would be to change the units from days fished to days anchored which are probably highly correlated. Consequently, the basic trends in Figure 4.3 would not be altered. As for the latter argument, these analyses are restricted to catches that were believed to have been from U.S. waters by the port agents who assigned the areas of capture. Further, Bradley and Bryan (1975) found that shrimp fishermen marketed the larger snappers caught in their trawls and discarded those too small to sell. There is no basis apparent from the available data to support the contention that a significant proportion of the landings from shrimp vessels recorded as caught from US waters were actually caught by handlines or from Mexican waters.

However, at this writing, the Commercial Statistics working group has not able to reconcile the shrimp trawl landings values in Figure 4.3 with the current General Canvass data base. Efforts continue.

4.2 Recreational Fishery Catch Rates

4.2.1 MRFSS and Texas Parks and Wildlife Dept. Survey Catch Rates

SEDAR7-DW-41 used two sources of recreational catch rates to develop two alternative indices of abundance for red snapper: the Marine Recreational Fisheries Statistics Survey (MRFSS) and Texas Parks and Wildlife Department's Recreational Angler Creel Survey (TPWD).

The first index was intended to replicate the recreational index used during the most recent red snapper assessment (Schirripa and Legault 1999) using a similar technique. This index was constructed using MRFSS intercept data from 1981-2003 and TPWD catch and effort data from 1983-1989. TPWD data were not included after 1989 because strict minimum size and bag limits were mandated in 1990. Unlike MRFSS data which include fish landed and observed by the interviewer (A), dead fish not observed by the interviewer (B1; e.g., unavailable, filleted, used for bait, discarded dead at sea) and fish released alive (B2), TPWD data only record fish observed by the interviewer (A). TPWD data are not appropriate to combine with MRFSS intercept data after the 1990 regulations because the proportion of red snapper discarded by the recreational fishery may have increased significantly; it was presumed that prior to 1990 most landed fish were available for observation in the TPWD survey and that the number of discarded fish in the Texas fishery was negligible. All headboat, charter boat and private boat trips that fished in "oceanic" areas using hook and line gear were included in the dataset used to construct the first standardized index of abundance. Shore mode and inshore fishing trips were excluded as they very seldom land red snapper.

The second index was constructed using only MRFSS intercept data, applying the same restrictions as above. Trips were excluded if they did not catch a least one red snapper, or one of a species determined to typically be associated with red snapper in catches (using methodology similar to that of SEDAR7-DW-47). Texas data within the MRFSS data set were excluded from the analysis due to insufficient sampling (n=59).

The Working Group had several concerns regarding these indices. The Working Group discussed whether or not headboat data should be excluded from the analysis (it is only present 1981-1985). Although the potential effect of that mode may have been accounted for in the model, the analysis of the mode may be complicated by its presence only in the early period. The Working Group concluded that it was most appropriate to initially exclude the headboat data from future analyses. The headboat data could subsequently be included if determined to be statistically warranted.

The Working Group noted that the approach used to develop Index 1 (intended to replicate the methods of Schirripa and Legault, 1999) includes a great deal of effort not directed at red snapper (proportion positive < 10% in most years). Also, the binomial model component is most appropriate if proportion positive is between 20% and 80%. The Working Group therefore recommended that the index may not be appropriate for base case application.

The MRFSS data were examined and a considerable increase in the proportion of fish discarded (live or dead) over time was observed (Figure 4.5). This was likely the result of changes in management measures (bag and size limits). The increasing proportion discarded is likely the reason for the overall increasing trend. If the discard rates seen in the MRFSS data are reflective of the Texas fishery, the initial presumption that discard rates in Texas were negligible before 1990 appears to be invalid. MRFSS discard proportions were below 10% prior to 1988, but increased thereafter.

The eastern and western Gulf nominal catch rate trends were examined (Figure 4.6) and appear to be different. The indices are based upon MRFSS data from 1990 onward, which are derived mainly (and increasingly) from Alabama-Florida. The Working Group recommended that separate indices be calculated for the EAST and WEST and that the resulting indices be used for the assessment, as appropriate.

4.2.2 Headboat Survey Catch Rates

SEDAR7-DW-42 developed several indices using the NMFS's Beaufort Headboat Survey data from 1986-2002. For one set of analyses, indices were developed separately for EAST (Dry Tortugas – Alabama) and WEST (Louisiana – Texas) zones, as defined from the Headboat Survey statistical landings areas. Data were restricted to periods when the season was open. A subset of headboat vessels considered to be consistently directing effort at red snapper was defined by: 1) Ranking vessels within each year and zone by average catch rate, 2) keeping only vessels which appear in more than half the years of the survey, and 3) keeping only vessels which have an average CPUE rank above the median for the zone. These restrictions resulted in an analysis data set with 10 vessels in the WEST and 21 vessels in the EAST. A continuous variable was defined (bag limit * number of anglers); examination of frequency distributions indicated that the distribution of catches for individual trips was usually (although not always) truncated at this value. Unfortunately, there is no information on discards available in the Headboat survey data set.

An alternative analysis approach, in which more restrictive criteria were used to define trips likely to be directed at red snapper, was used to produce a third index. In this case, the EAST and WEST zones were ***not*** analyzed separately. Again, data were restricted to periods when the season was open. Data were further restricted to full day trips (3/4 – 1 day in length); red snapper catch rates were highest on these trips. Data were also restricted to trips on which the catch included red snapper or at least one of a (zone-specific) list of species typically associated with red snapper in the catch. A subset of headboat vessels considered to be consistently directing effort at red snapper was defined by the same approach taken in the first set of analyses. These restrictions resulted in an analysis data set with 29 vessels.

The Working Group considered that the headboat indices might have very limited utility, since the proportion of the catch discarded was almost certainly changing over time in response to management measures (changing bag limits and size limits) as well as stock abundance and size distribution changes. However, the analysis may be providing some insight into population and/or fishery trends. For example, it was noted that both nominal and standardized catch rate trends (for kept fish only) varied between the EAST and WEST zones; catch rates in the EAST tended to be lower, but increasing over time, whereas catch rates in the WEST tended to be higher, but decreasing over time.

The Working Group recommended that the headboat indices not be used for the assessment because of the expected effects of the changes in management measures.

4.3 References:

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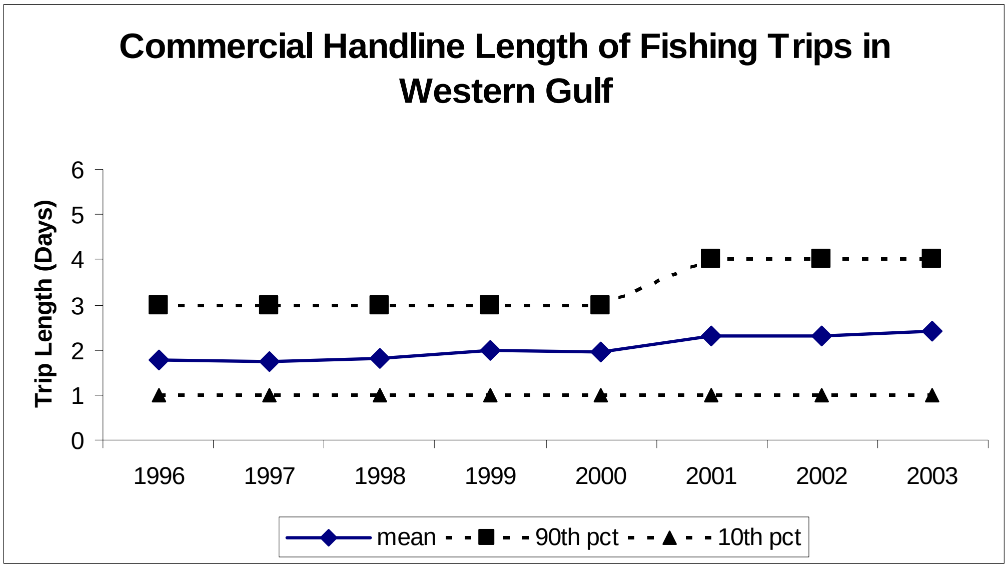

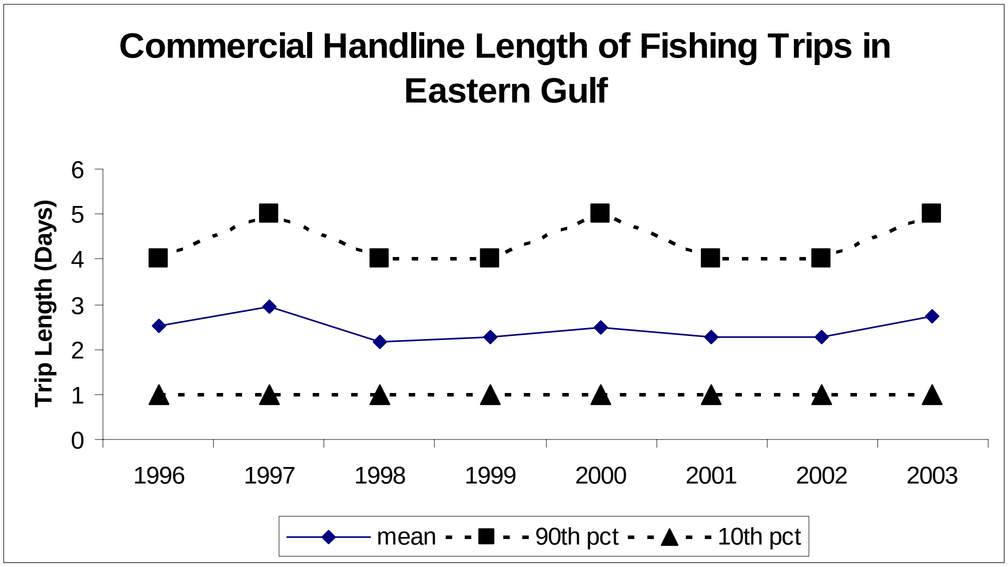

Figure 4.1: Historical trend in trip duration by Class I permitted vessels during open red snapper seasons.

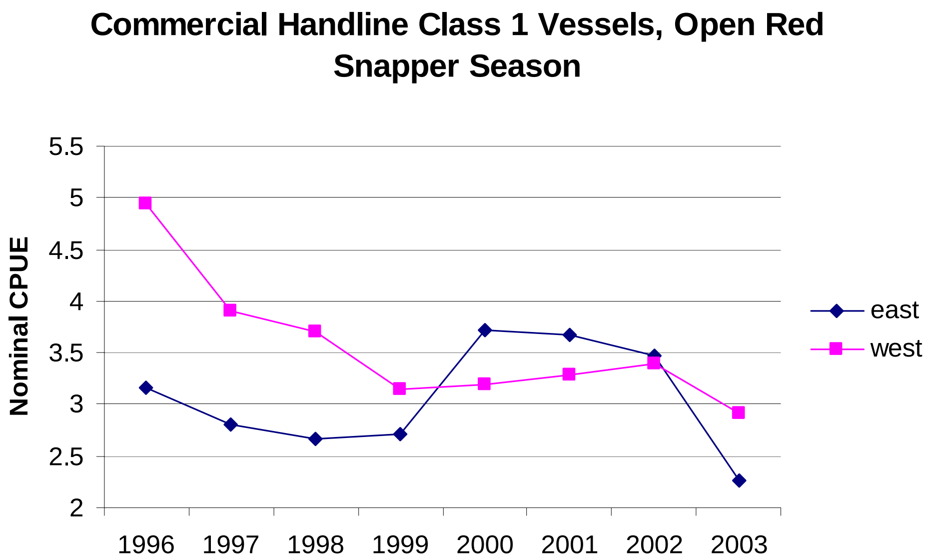

Figure 4.2: Historical trend in observed catch rates (eastern and western Gulf of Mexico) by Class I permitted vessels during open red snapper seasons.

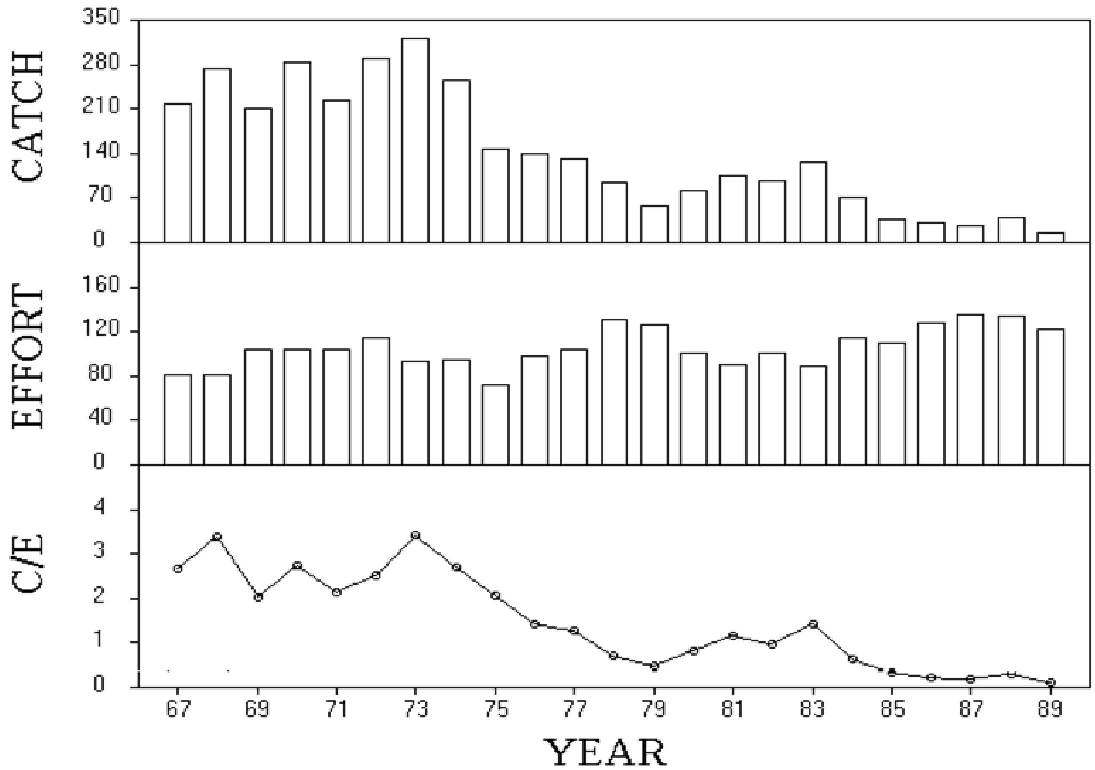

FIGURE FDI-3. Landings, effort, and catch per unit effort for red snapper sold from the bycatch of shrimp trawls 1967-1989.

Figure 4.3.

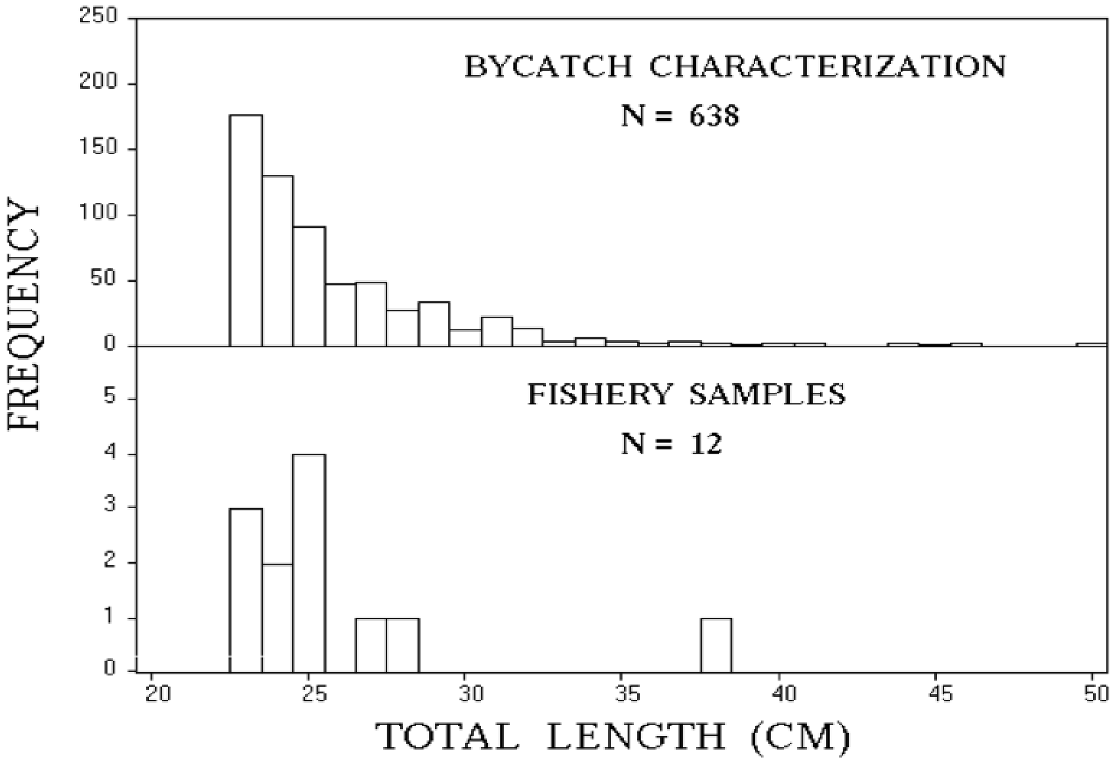

FIGURE FDI-4. Length frequencies for red snapper lengths from TIP samples and from bycatch characterization samples truncated at the minimum size observed in the TIP samples.

Figure 4.4.

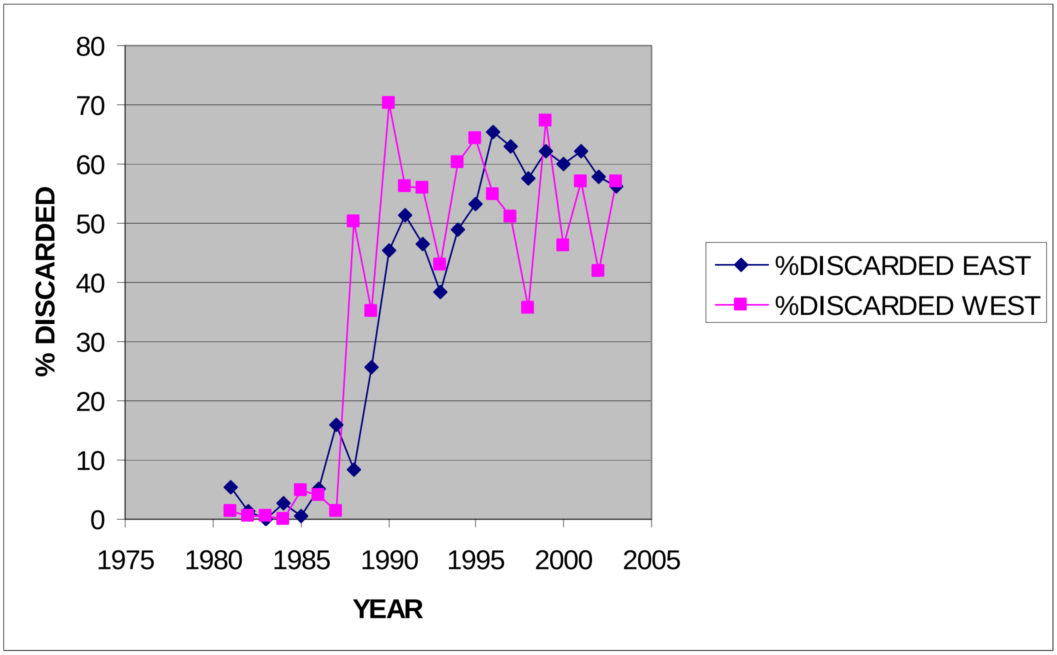

Figure 4.5: Historical trend in discarded catch (both live and dead discards) percentage from MRFSS data.

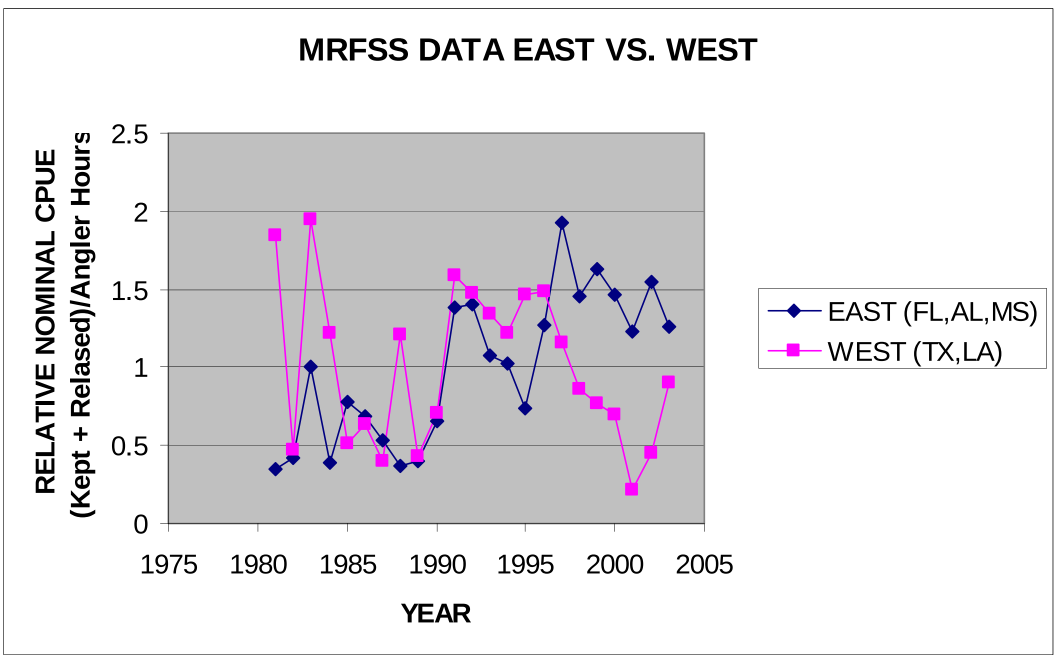

Figure 4.6: Historical trend in observed relative catch rates (eastern and western Gulf of Mexico) from MRFSS data (relative trend calculated by dividing each series by its mean).

5. Fishery-Independent Indexes

In preparation for the SEDAR, five fishery independent surveys were analyzed and indices of relative abundance developed. These were the National Marine Fisheries Service Southeast Area Monitoring and Assessment Program (SEAMAP) shrimp/bottomfish surveys, SEAMAP icthyoplankton surveys, SEAMAP reef fish survey, shark/snapper/grouper bottom longline survey, and the small pelagics trawl survey. An additional survey was conducted by Auburn University off the coast of Alabama. Of these surveys, only the shrimp/bottomfish index had been used in prior red snapper stock assessments. The remaining surveys were not included in earlier stock assessments for a variety of reasons.

Very little discussion centered on the use of SEAMAP shrimp/bottomfish surveys data, since indices of relative abundance derived from these surveys have been used in previous assessments. The data include density estimates (number caught per hour fished) from 1972 to 1986, in the northern Gulf of Mexico (between 88˚ 00´ and 91˚ 30´ W longitude, during the fall season in depths of 9.1 to 91.5 meters (5 to 50 fathoms), and survey from Mobile to Brownsville, fall 1987-2002, and summer 1982-2003. These data were collected with standard gear and survey methods, and are explained in detail in SEDAR7-DW-1. There is also a summary of fishing power issues available in SEDAR7-DW-53. Arithmetic means were used in previous assessments. We employed a Bayesian analysis here (SEDAR7-DW-2) to fill missing cells and link separate surveys. The Bayesian central tendency estimates closely mimic the arithmetic values, but the procedure produces estimates with nearly lognormal error distributions upon accounting for missing cells and surveys covering less than the full SEAMAP range. We discussed partitioning age classes 0 and 1, particularly for the summer survey, for better estimates of Z. This work will be based on the data processing reported in SEDAR7-DW-17, and will be continued prior to the assessment workshop.

Data from SEAMAP ichthyoplankton samples were not used in earlier assessments because larval red snapper could not be distinguished from other lutjanids. Recent advances in identification of larval red snapper have made it possible to develop time series back to the 1980s, and to develop annual indices of abundance for red snapper from fishery independent surveys (SEDAR7-DW-14). Annual indices of frequency of occurrence and abundance of red snapper larvae were developed for the SEAMAP summer bottomfish surveys (1982-2002), fall plankton surveys (1985-2002) and both survey combined (1982-2002) for both neuston net and bongo net collections. The initial recommendation was to use the annual frequency of occurrence of larvae in neuston samples from SEAMAP summer shrimp/bottomfish and fall plankton surveys combined. The recommendation was based on this index's high correlation with adult red snapper abundances over the time period 1984 to 1997 (SEDAR7-DW-14). The fishery independent indices working group examined all possible larval indices over the period 1982 to 2002 using all combinations of variables: Gulf region (east or west of 89.15 ° W longitude); gear (neuston or bongo); survey time frame (June/July or late August to mid October) in addition to the recommended index. Tables listing these indices are given in Appendix 5.1. It is evident that percent frequency of occurrence has increased over the time series for all the examined indices as did abundance of larvae in non-zero tows. The workgroup reviewed data of standardized abundance categories and the frequency of abundance categories for samples in which red snapper larvae were caught (positive catch samples). The plots indicate higher frequencies of the standardized abundance categories over the time series and an increase in the frequencies of the higher abundance categories for both the neuston and bongo collections (Appendix 2).

There was discussion whether to include both survey time frames (summer and fall) in formulating the larvae red snapper index. A combined survey index was favored because it would cover a greater portion of the red snapper spawning season and area. The workgroup also compared model-based (GLM mixed model) for the combined survey estimates of annual frequency of occurrence to design-based estimators for both the bongo and neuston gears and found little to no difference in the estimates (Table 5.1). Standard errors were somewhat greater for the model-based than the design-based estimators but the group considered the former to be more realistic and, therefore, recommends use of a model based larval red snapper index. At this time the group recommends that annual frequency of occurrence, and not mean abundance be the index metric used in the upcoming assessment. Stock size has been shown to be correlated with the geographic area occupied by eggs and larvae of Pacific sardine and northern anchovy (Mangel and Smith 1990; Hunter and Lo 1993). Assuming this is true for red snapper, it can be argued that larval occurrence would provide a more useful index of stock size than estimates of mean annual abundance which are, at present, unadjusted for age composition of larval catches. Prior to the assessment in August personnel at the Mississippi Labs will develop an age-corrected abundance index using the age/length relationship for red snapper larvae in Comyns (1992; Final Report MARFIN Grant No. NA37FF0050-02). This new index of larval red snapper abundance will then be evaluated. Also separate indices for the eastern and western Gulf will be developed prior the formal stock assessment this summer.

Data from SEAMAP reef fish survey were analyzed and red snapper abundance indices developed (SEDAR7-DW-15). This survey was designed to sample hard bottom habitat with relief; and although limited in spatial coverage, it samples a part of the population not covered by the other surveys. The biggest weakness of this survey is uncertainly about size and age of fish observed by the cameras. Although no red snapper were directly measured the workgroup recommended that size of individual red snappers be estimated by comparing sizes with other species of fishes either measured with lasers or captured in traps. Two indices of abundance were developed; frequency of occurrence and number of red snapper per sampling site. Two estimators were examined for each index as well, one using design-based estimates of mean number (or frequency) of red snapper and associated standard errors and a second using model-based estimates. The workgroup recommended that the model-based estimates of number of red snapper per site be used since it controlled the high survey mean value in 1992 that occurred as a result of a single large aggregation of red snapper being observed and that the estimated standard errors were much lower than those from the design-based estimates.

The working group concluded that the SEAMAP shrimp/bottomfish, ichthyoplankton and reef fish surveys would provide the most useful fisheries independent indices for the purposes of stock assessment at this time. These three indices correspond with each other giving us confidence that they reflect trends in red snapper abundance in the Gulf of Mexico (Figure 5.1).

Data from a relatively new shark/snapper/grouper longline survey were presented for the first time (SEDAR7-DW-9, see also 8 and 11). This survey consists of three years of data, and provides insights into the distribution and abundance of older, offshore stocks of large red snapper. The workgroup felt that a three-year time series was not appropriate for the current assessment, but noted that this survey would probably be valuable for future assessments. The most important contribution to the SEDAR from the longline survey is information pertaining to the previously undocumented age distribution of large red snapper in offshore waters and computed instantaneous mortality rates (0.13 per year, one std err 0.01), which may provide an upper limit on M for adult snapper.

Small pelagic survey data were analyzed and indices of abundance developed (SEDAR7-DW-10). Indices from these surveys were found to be correlated with shrimp/bottomfish surveys, but workgroup discussions suggested that this index did little to improve the overall estimates as surveys were spatially and temporally disjunct and differed with regard to methodologies and objectives. The group recommended that this index not be included in the final recommended fishery independent indices.

Additional data and information considered by the working group:

An additional data set concerning recruitment of juvenile red snapper to experimental artificial reef sites off Alabama was presented to the workgroup (SEDAR7-DW-21). Data indicate first recruits of red snapper quickly colonize artificial shell/block habitats. SCUBA visual surveys of age-0 to age-1 abundance were used to estimate mortality for 1998, 1999, and 2002, and in 2001 estimates were based on multiple surveys (n = 4) of the same age-0 year class. The workgroup felt that this data set might be useful to the life history group. However, as with the NMFS longline survey data, the group felt that this short time series in a localized area was not a particularly useful index of red snapper abundance for the current stock assessment.

A climatological model of mean monthly wind driven surface currents was applied to data on the location of capture of adult red snapper taken during NMFS shark/snapper/grouper longline survey (Dr. Don Johnson, pers. commun., Gulf Coast Research Laboratory, Ocean Springs, MS). The objective of this exercise was to track the movement of red snapper eggs and larvae assuming that spawning occurred at location of capture of adult red snapper. The model assumed larvae remained in the plankton for duration of 20 and 30 days at which time they presumably settled on nursery grounds. Net transport of larvae spawned on the Florida shelf was west of the adult collection sites. There was no indication of larval movement west of the DeSoto Canyon in the northern Gulf. Larval transport in the northcentral Gulf of Mexico, specifically the Mississippi Bight, showed a similar pattern of net westward movement. Net transport off the Florida Panhandle was offshore whereas fish spawned off Mobile Bay remained inshore of the 100 m isobath. The Mississippi River mouth did not appear to be a barrier to westward movement of larvae across the outflow of the River. Snapper spawned off Louisiana and Texas coasts remained inside the 100 m isobath west of Mobile Bay with the exception of an offshore of movement predicted for a limited number of larvae due south of the Mississippi River delta. These data suggest that there is little to no movement of larval red snapper from the western to the eastern Gulf of Mexico.

Literature Cited

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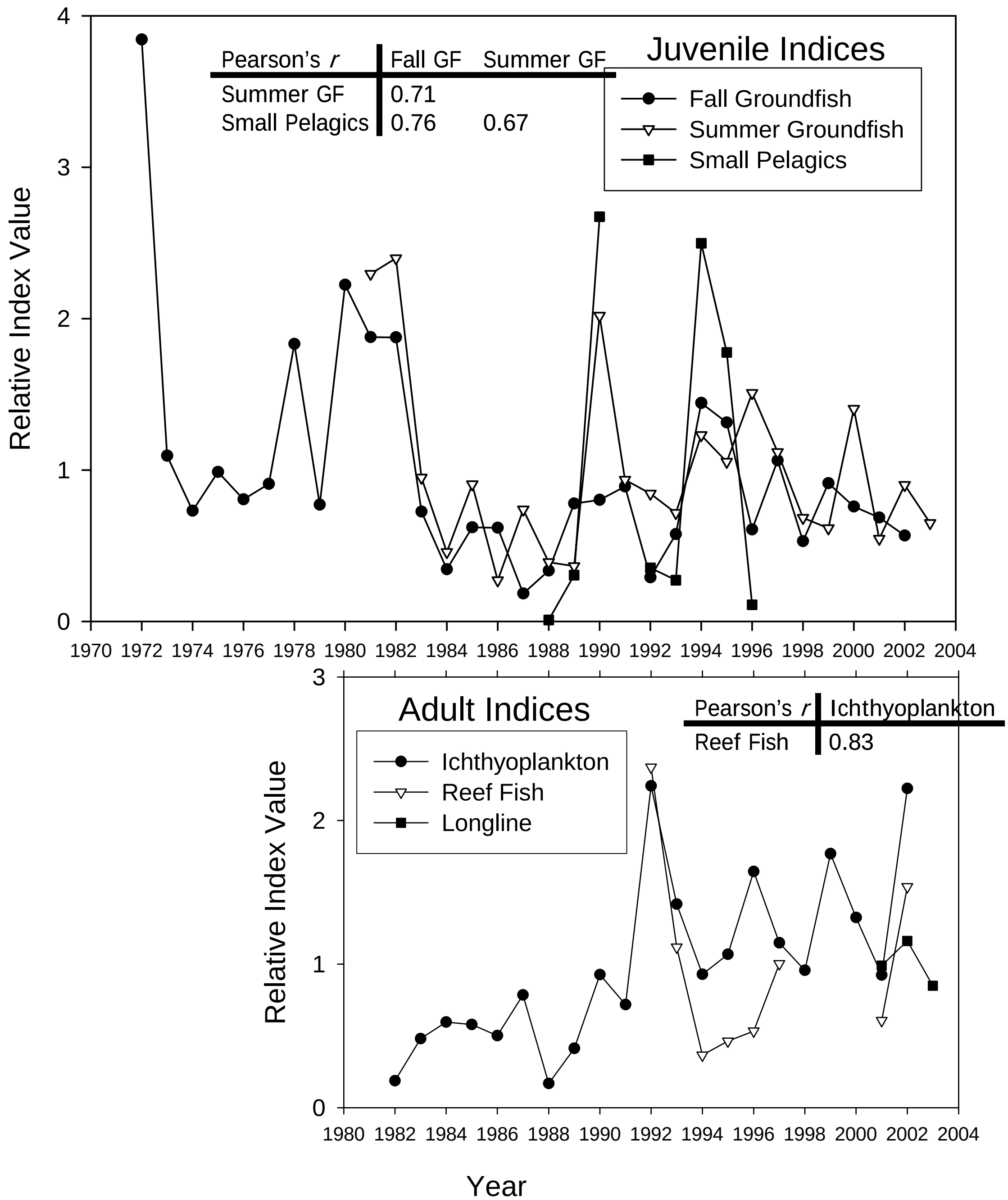

Figure 5.1. Comparison of standardized indices from fisheries-independent surveys. Correlation coefficients illustrate similarity in trends between surveys within each survey type (i.e. Juvenile and Adult Indices).

Table 5.1. Model- and design-based red snapper larval indices of annual frequency of occurrence from neuston and bongo net samples taken during SEAMAP Summer Shrimp/Bottomfish and Fall Ichthyoplankton surveys in the Gulf of Mexico, 1982 to 2002.

		Neuston Model-Based Estimators		Neuston Design-Based Estimators			Bongo Model-Based Estimators		Bongo Design-Based Estimators	
Year	**Number of Samples**	**% Frequency of Occurrence**	**Standard Error**	**% Frequency of Occurrence**	**Standard Error**	**Number of Samples**	**% Frequency of Occurrence**	**Standard Error**	**% Frequency of Occurrence**	**Standard Error**
1982	73	1.37	2.33	1.37	1.37	76	9.43	3.59	11.84	3.73
1983	57	3.51	3.51	3.51	2.46	59	5.34	3.38	6.78	3.30
1984	69	4.35	3.30	4.35	2.47	70	6.78	3.32	8.57	3.37
1985	71	4.23	3.20	4.23	2.40	91	7.73	2.96	8.79	2.98
1986	191	3.66	1.65	3.66	1.36	214	8.36	2.12	7.94	1.85
1987	192	5.73	1.94	5.73	1.68	215	7.33	2.08	6.98	1.74
1988	163	1.23	1.25	1.23	0.86	125	6.03	2.52	5.60	2.06
1989	166	3.01	1.66	3.01	1.33	128	9.17	3.05	8.59	2.49
1990	148	6.75	2.45	6.76	2.07	128	6.75	2.90	6.25	2.15
1991	172	5.23	2.00	5.23	1.70	129	10.45	3.23	10.08	2.66
1992	159	16.35	3.19	16.35	2.94	167	10.93	2.69	10.18	2.35
1993	174	10.34	2.58	10.34	2.32	175	6.80	2.39	6.29	1.84
1994	177	6.78	2.17	6.78	1.89	176	6.77	2.23	6.25	1.83
1995	154	7.79	2.50	7.79	2.17	153	14.05	3.43	12.42	2.67
1996	150	12.00	2.99	12.00	2.66	150	12.77	3.15	11.33	2.60
1997	179	8.38	2.34	8.38	2.08	179	16.08	3.13	15.08	2.68
1998	43	6.97	5.12	6.98	3.93	45	12.39	5.79	11.11	4.74
1999	186	12.90	2.73	12.90	2.46	186	13.68	2.84	12.37	2.42
2000	176	9.66	2.50	9.66	2.23	184	21.58	3.30	20.11	2.96
2001	178	6.74	2.17	6.74	1.88	175	16.12	3.14	14.86	2.70
2002	148	16.21	3.30	16.22	3.04	152	20.81	3.54	19.74	3.24

Appendix 5.1

Tables 5.1-18. Annual indices of frequency of occurrence, and mean abundance of red snapper larvae from SEAMAP plankton surveys for each combination of survey time frame (Summer Bottomfish, Fall Plankton and Summer Bottomfish/Fall Plankton combined), gear (neuston or bongo) and spatial area (entire GOM, western GOM and Eastern GOM). Number of Sampels (N), Mean abundance (A), standard error of abundance (A-SE), frequency of occurrence (F0), percent frequency of occurrence (%FO) and standard error of frequency of occurrence (FO-SE). Mean abundance is expresses as the number of larvae per 10 minute tow for neuston collections, and as the number of larvae under 10 m^2 of sea surface for bongo net collections. Percent frequency of occurrence (%FO) is the ration of positive samples to total samples.

Table 5.1.1. Neuston Summer Bottomfish.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	73	0.01370	0.01370	1	1.3699	1.3699
1983	57	0.12281	0.10641	2	3.5088	2.4588
1984	69	0.10145	0.06243	3	4.3478	2.4730
1985	61	0.06557	0.03959	3	4.9180	2.7917
1986	49	0.04082	0.04082	1	2.0408	2.0408
1987	62	0.17689	0.08119	6	9.6774	3.7854
1988	36	0.02662	0.02662	1	2.7778	2.7778
1989	41	0.00000	0.00000	0	0.0000	0.0000
1990	10	0.00000	0.00000	0	0.0000	0.0000
1991	46	0.21739	0.13871	4	8.6957	4.2004
1992	49	0.55102	0.39130	7	14.2857	5.0508
1993	49	0.22442	0.11760	5	10.2041	4.3691
1994	51	0.26799	0.17542	5	9.8039	4.2054
1995	30	0.00000	0.00000	0	0.0000	0.0000
1996	30	0.26501	0.20143	3	10.0000	5.5709
1997	56	0.37500	0.32189	4	7.1429	3.4727
1998	10	0.19868	0.19868	1	10.0000	10.0000
1999	44	0.22727	0.12535	5	11.3636	4.8398
2000	54	0.22063	0.15670	3	5.5556	3.1464
2001	47	1.32674	1.18045	5	10.6383	4.5460
2002	52	0.90059	0.48333	10	19.2308	5.5187

Table 5.1.2. Bongo Summer Bottomfish.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	76	0.3150	0.11086	9	11.8421	3.7309
1983	59	0.3415	0.16758	4	6.7797	3.3010
1984	70	0.3415	0.14135	6	8.5714	3.3701
1985	67	0.6589	0.26357	8	11.9403	3.9914
1986	73	0.7244	0.27844	9	12.3288	3.8746
1987	74	0.4335	0.20090	6	8.1081	3.1948
1988	37	0.6261	0.34004	4	10.8108	5.1753
1989	40	0.5237	0.31011	4	10.0000	4.8038
1990	37	0.1896	0.18959	1	2.7027	2.7027
1991	48	0.4346	0.23487	4	8.3333	4.0315
1992	50	1.8071	0.81302	9	18.0000	5.4884
1993	50	0.3668	0.27993	2	4.0000	2.7994
1994	50	0.7811	0.38992	5	10.0000	4.2857
1995	29	0.1806	0.18062	1	3.4483	3.4483
1996	30	3.2193	1.85679	6	20.0000	7.4278
1997	56	1.4573	0.68608	8	14.2857	4.7184
1998	10	12.6087	8.33579	3	30.0000	15.2753
1999	44	1.4021	0.50848	9	20.4545	6.1513
2000	54	2.3087	0.58215	15	27.7778	6.1524
2001	48	1.5023	0.53031	9	18.7500	5.6933
2002	51	2.3802	0.64982	15	29.4118	6.4438

Table 5.1.3. Neuston Fall Ichthyoplankton.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1985	10	0.00000	0.00000	0	0.0000	0.00000
1986	142	0.09859	0.04825	6	4.2254	1.69413
1987	130	0.15385	0.08562	5	3.8462	1.69317
1988	127	0.00787	0.00787	1	0.7874	0.78740
1989	125	0.20000	0.09837	5	4.0000	1.75977
1990	138	0.13516	0.05795	10	7.2464	2.21496
1991	126	0.07162	0.03771	5	3.9683	1.74603
1992	110	0.51059	0.14744	19	17.2727	3.62069
1993	125	0.28801	0.13335	13	10.4000	2.74132
1994	126	0.07937	0.03305	7	5.5556	2.04879
1995	124	1.29032	0.61686	12	9.6774	2.66579
1996	120	0.42042	0.16414	15	12.5000	3.03170
1997	123	0.39632	0.15855	11	8.9431	2.58357
1998	33	0.09091	0.06691	2	6.0606	4.21800
1999	142	0.57505	0.19324	19	13.3803	2.86702
2000	122	0.91803	0.37889	14	11.4754	2.89750
2001	131	0.08189	0.03381	7	5.3435	1.97250
2002	96	0.49705	0.20160	14	14.5833	3.62108

Table 5.1.4. Bongo Fall Ichthyoplankton.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1985	24	0.00000	0.00000	0	0.0000	0.00000
1986	141	0.27711	0.10275	8	5.6738	1.95518
1987	141	0.59565	0.28534	9	6.3830	2.06598
1988	88	0.21323	0.14119	3	3.4091	1.94548
1989	88	0.59051	0.22712	7	7.9545	2.90101
1990	91	0.44990	0.17575	7	7.6923	2.80883
1991	81	0.50529	0.17676	9	11.1111	3.51364
1992	117	0.36824	0.13645	8	6.8376	2.34338
1993	125	0.40297	0.15457	9	7.2000	2.32129
1994	126	0.52468	0.34959	6	4.7619	1.90476
1995	124	1.07801	0.33683	18	14.5161	3.17625
1996	120	1.06405	0.50993	11	9.1667	2.64518
1997	123	0.93805	0.25231	19	15.4472	3.27196
1998	35	0.15194	0.10715	2	5.7143	3.98075
1999	142	0.46209	0.13597	14	9.8592	2.51056
2000	130	1.40213	0.39742	22	16.9231	3.30130
2001	127	1.08859	0.39033	17	13.3858	3.03341
2002	101	1.08919	0.38726	15	14.8515	3.55610

Table 5.1.5. Neuston Summer Bottomfish and Fall Ichthyoplankton Survey Combined.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	73	0.01370	0.01370	1	1.3699	1.36986
1983	57	0.12281	0.10641	2	3.5088	2.45882
1984	69	0.10145	0.06243	3	4.3478	2.47303
1985	71	0.05634	0.03409	3	4.2254	2.40441
1986	191	0.08377	0.03736	7	3.6649	1.36316
1987	192	0.16129	0.06350	11	5.7292	1.68158
1988	163	0.01202	0.00847	2	1.2270	0.86493
1989	166	0.15060	0.07431	5	3.0120	1.33060
1990	148	0.12602	0.05409	10	6.7568	2.07023
1991	172	0.11060	0.04626	9	5.2326	1.70290
1992	159	0.52305	0.15720	26	16.3522	2.94230
1993	174	0.27011	0.10120	18	10.3448	2.31540
1994	177	0.13372	0.05579	12	6.7797	1.89497
1995	154	1.03896	0.49801	12	7.7922	2.16705
1996	150	0.38934	0.13719	18	12.0000	2.66219
1997	179	0.38965	0.14784	15	8.3799	2.07685
1998	43	0.11597	0.06807	3	6.9767	3.93095
1999	186	0.49278	0.15070	24	12.9032	2.46470
2000	176	0.70406	0.26773	17	9.6591	2.23301
2001	178	0.41059	0.31296	12	6.7416	1.88468
2002	148	0.63883	0.21393	24	16.2162	3.04016

Table 5.1.6. Bongo Summer Grounfish and Fall Ichthyoplankton Survey Combined.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	76	0.31498	0.11086	9	11.8421	3.73091
1983	59	0.34149	0.16758	4	6.7797	3.30100
1984	70	0.34151	0.14135	6	8.5714	3.37010
1985	91	0.48510	0.19607	8	8.7912	2.98484
1986	214	0.42968	0.11715	17	7.9439	1.85291
1987	215	0.53984	0.19924	15	6.9767	1.74147
1988	125	0.33545	0.14167	7	5.6000	2.06476
1989	128	0.56964	0.18311	11	8.5938	2.48701
1990	128	0.37465	0.13644	8	6.2500	2.14795
1991	129	0.47899	0.14074	13	10.0775	2.66076
1992	167	0.79903	0.26486	17	10.1796	2.34693
1993	175	0.39264	0.13589	11	6.2857	1.83995
1994	176	0.59752	0.27325	11	6.2500	1.82981
1995	153	0.90792	0.27633	19	12.4183	2.67495
1996	150	1.49509	0.55257	17	11.3333	2.59696
1997	179	1.10050	0.27533	27	15.0838	2.68251
1998	45	2.92011	1.94290	5	11.1111	4.73779
1999	186	0.68445	0.16074	23	12.3656	2.42024
2000	184	1.66817	0.32924	37	20.1087	2.96289
2001	175	1.20207	0.31796	26	14.8571	2.69629
2002	152	1.52236	0.33966	30	19.7368	3.23898

Table 5.1.7. Neuston Summer Bottomfish Western Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	53	0.01887	0.01887	1	1.8868	1.8868
1983	39	0.17949	0.15530	2	5.1282	3.5782
1984	54	0.12963	0.07951	3	5.5556	3.1464
1985	52	0.07692	0.04633	3	5.7692	3.2649
1986	39	0.05128	0.05128	1	2.5641	2.5641
1987	50	0.18000	0.09342	5	10.0000	4.2857
1988	31	0.03092	0.03092	1	3.2258	3.2258
1989	32	0.00000	0.00000	0	0.0000	0.0000
1990	7	0.00000	0.00000	0	0.0000	0.0000
1991	42	0.23810	0.15168	4	9.5238	4.5844
1992	44	0.61364	0.43525	7	15.9091	5.5778
1993	44	0.22727	0.12950	4	9.0909	4.3840
1994	46	0.23191	0.18991	3	6.5217	3.6807
1995	28	0.00000	0.00000	0	0.0000	0.0000
1996	25	0.31802	0.24111	3	12.0000	6.6332
1997	50	0.42000	0.36037	4	8.0000	3.8756
1998	8	0.24834	0.24834	1	12.5000	12.5000
1999	39	0.23077	0.13970	4	10.2564	4.9216
2000	50	0.23829	0.16911	3	6.0000	3.3927
2001	44	1.41720	1.26069	5	11.3636	4.8398
2002	45	1.04068	0.55640	10	22.2222	6.2675

Table 5.1.8. Bongo Summer Bottomfish Western Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	56	0.4275	0.1479	9	16.0714	4.9522
1983	39	0.5166	0.2499	4	10.2564	4.9216
1984	55	0.4346	0.1782	6	10.9091	4.2424
1985	57	0.7222	0.3054	7	12.2807	4.3860
1986	63	0.8393	0.3206	9	14.2857	4.4441
1987	62	0.5174	0.2386	6	9.6774	3.7854
1988	31	0.7473	0.4032	4	12.9032	6.1205
1989	31	0.5763	0.3896	3	9.6774	5.3978
1990	31	0.2263	0.2263	1	3.2258	3.2258
1991	44	0.4741	0.2556	4	9.0909	4.3840
1992	45	2.0079	0.8993	9	20.0000	6.0302
1993	45	0.4076	0.3108	2	4.4444	3.1068
1994	45	0.7713	0.4248	4	8.8889	4.2903
1995	27	0.1940	0.1940	1	3.7037	3.7037
1996	25	3.8631	2.2126	6	24.0000	8.7178
1997	50	1.5641	0.7653	7	14.0000	4.9570
1998	8	15.7609	10.2262	3	37.5000	18.2981
1999	39	1.5818	0.5680	9	23.0769	6.8348
2000	50	2.3600	0.6177	14	28.0000	6.4143
2001	44	1.5265	0.5705	8	18.1818	5.8818
2002	45	2.4814	0.7242	13	28.8889	6.8329

Table 5.1.9. Neuston Summer Bottomfish Eastern Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	20	0.00000	0.00000	0	0.0000	0.0000
1983	18	0.00000	0.00000	0	0.0000	0.0000
1984	15	0.00000	0.00000	0	0.0000	0.0000
1985	9	0.00000	0.00000	0	0.0000	0.0000
1986	10	0.00000	0.00000	0	0.0000	0.0000
1987	12	0.16393	0.16393	1	8.3333	8.3333
1988	5	0.00000	0.00000	0	0.0000	0.0000
1989	9	0.00000	0.00000	0	0.0000	0.0000
1990	3	0.00000	0.00000	0	0.0000	0.0000
1991	4	0.00000	0.00000	0	0.0000	0.0000
1992	5	0.00000	0.00000	0	0.0000	0.0000
1993	5	0.19934	0.19934	1	20.0000	20.0000
1994	5	0.60000	0.40000	2	40.0000	24.4949
1995	2	0.00000	0.00000	0	0.0000	0.0000
1996	5	0.00000	0.00000	0	0.0000	0.0000
1997	6	0.00000	0.00000	0	0.0000	0.0000
1998	2	0.00000	0.00000	0	0.0000	0.0000
1999	5	0.20000	0.20000	1	20.0000	20.0000
2000	4	0.00000	0.00000	0	0.0000	0.0000
2001	3	0.00000	0.00000	0	0.0000	0.0000
2002	7	0.00000	0.00000	0	0.0000	0.0000

Table 5.1.10. Bongo Summer Bottomfish Eastern Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	20	0.00000	0.00000	0	0.0000	0.0000
1983	20	0.00000	0.00000	0	0.0000	0.0000
1984	15	0.00000	0.00000	0	0.0000	0.0000
1985	10	0.29775	0.29775	1	10.0000	10.0000
1986	10	0.00000	0.00000	0	0.0000	0.0000
1987	12	0.00000	0.00000	0	0.0000	0.0000
1988	6	0.00000	0.00000	0	0.0000	0.0000
1989	9	0.34259	0.34259	1	11.1111	11.1111
1990	6	0.00000	0.00000	0	0.0000	0.0000
1991	4	0.00000	0.00000	0	0.0000	0.0000
1992	5	0.00000	0.00000	0	0.0000	0.0000
1993	5	0.00000	0.00000	0	0.0000	0.0000
1994	5	0.86957	0.86957	1	20.0000	20.0000
1995	2	0.00000	0.00000	0	0.0000	0.0000
1996	5	0.00000	0.00000	0	0.0000	0.0000
1997	6	0.56738	0.56738	1	16.6667	16.6667
1998	2	0.00000	0.00000	0	0.0000	0.0000
1999	5	0.00000	0.00000	0	0.0000	0.0000
2000	4	1.66667	1.66667	1	25.0000	25.0000
2001	4	1.23626	1.23626	1	25.0000	25.0000
2002	6	1.62152	1.07043	2	33.3333	21.0819

Table 5.1.11. Neuston Fall Ichthyoplankton Survey Western Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1985	10	0.00000	0.00000	0	0.0000	0.00000
1986	59	0.23729	0.11426	6	10.1695	3.96869
1987	56	0.08929	0.05270	3	5.3571	3.03619
1988	62	0.00000	0.00000	0	0.0000	0.00000
1989	62	0.40323	0.19575	5	8.0645	3.48631
1990	62	0.26857	0.12333	9	14.5161	4.51027
1991	63	0.12698	0.07330	4	6.3492	3.09685
1992	55	0.89556	0.27972	14	25.4545	5.92784
1993	63	0.52381	0.26082	10	15.8730	4.64089
1994	56	0.17857	0.07256	7	12.5000	4.45941
1995	56	2.80357	1.34416	10	17.8571	5.16428
1996	56	0.88304	0.34249	14	25.0000	5.83874
1997	55	0.74242	0.34052	7	12.7273	4.53534
1998	19	0.10526	0.10526	1	5.2632	5.26316
1999	68	0.87657	0.37187	11	16.1765	4.49870
2000	67	1.59701	0.67890	12	17.9104	4.71982
2001	58	0.11822	0.06436	4	6.8966	3.35631
2002	58	0.77019	0.32569	13	22.4138	5.52348

Table 5.1.12. Bongo Fall Ichthyoplankton Survey Western Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1985	24	0.00000	0.00000	0	0.0000	0.00000
1986	58	0.56269	0.22817	6	10.3448	4.03378
1987	67	1.12848	0.58948	7	10.4478	3.76511
1988	37	0.35417	0.30008	2	5.4054	3.76874
1989	36	1.32651	0.52292	6	16.6667	6.29941
1990	35	1.03456	0.42163	6	17.1429	6.46349
1991	35	0.87024	0.36577	6	17.1429	6.46349
1992	61	0.70630	0.25507	8	13.1148	4.35790
1993	63	0.79955	0.29948	9	14.2857	4.44408
1994	56	1.03334	0.77823	4	7.1429	3.47266
1995	56	2.14144	0.71293	14	25.0000	5.83874
1996	56	2.28011	1.07480	11	19.6429	5.35714
1997	55	1.95947	0.52939	16	29.0909	6.18063
1998	19	0.16129	0.16129	1	5.2632	5.26316
1999	70	0.58619	0.18171	10	14.2857	4.21263
2000	67	2.14205	0.72245	15	22.3881	5.13098
2001	57	2.05837	0.83919	12	21.0526	5.44789
2002	61	1.69997	0.62686	13	21.3115	5.28673

Table 5.1.13. Neuston Fall Ichthyoplankton Survey Eastern Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1986	83	0.00000	0.00000	0	0.0000	0.00000
1987	74	0.20270	0.14524	2	2.7027	1.89796
1988	65	0.01538	0.01538	1	1.5385	1.53846
1989	63	0.00000	0.00000	0	0.0000	0.00000
1990	76	0.02632	0.02632	1	1.3158	1.31579
1991	63	0.01625	0.01625	1	1.5873	1.58730
1992	55	0.12562	0.06345	5	9.0909	3.91210
1993	62	0.04841	0.02749	3	4.8387	2.74745
1994	70	0.00000	0.00000	0	0.0000	0.00000
1995	68	0.04412	0.03269	2	2.9412	2.06415
1996	64	0.01563	0.01563	1	1.5625	1.56250
1997	68	0.11639	0.06775	4	5.8824	2.87458
1998	14	0.07143	0.07143	1	7.1429	7.14286
1999	74	0.29798	0.13991	8	10.8108	3.63433
2000	55	0.09091	0.06499	2	3.6364	2.54738
2001	73	0.05303	0.03274	3	4.1096	2.33949
2002	38	0.08015	0.08015	1	2.6316	2.63158

Table 5.1.14. Bongo Fall Ichthyoplankton Survey East.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1986	83	0.07756	0.06442	2	2.4096	1.69345
1987	74	0.11323	0.07973	2	2.7027	1.89796
1988	51	0.11099	0.11099	1	1.9608	1.96078
1989	52	0.08097	0.08097	1	1.9231	1.92308
1990	56	0.08449	0.08449	1	1.7857	1.78571
1991	46	0.22761	0.13010	3	6.5217	3.68070
1992	56	0.00000	0.00000	0	0.0000	0.00000
1993	62	0.00000	0.00000	0	0.0000	0.00000
1994	70	0.11775	0.08314	2	2.8571	2.00561
1995	68	0.20225	0.10417	4	5.8824	2.87458
1996	64	0.00000	0.00000	0	0.0000	0.00000
1997	68	0.11190	0.06483	3	4.4118	2.50883
1998	16	0.14085	0.14085	1	6.2500	6.25000
1999	72	0.34144	0.20198	4	5.5556	2.71846
2000	63	0.61523	0.26047	7	11.1111	3.99123
2001	70	0.29891	0.13865	5	7.1429	3.10041
2002	40	0.15774	0.11058	2	5.0000	3.48991

Table 5.1.15. Neuston Summer Bottomfish and Fall Ichthyoplankton Survey Combined Western Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	53	0.01887	0.01887	1	1.8868	1.88679
1983	39	0.17949	0.15530	2	5.1282	3.57816
1984	54	0.12963	0.07951	3	5.5556	3.14640
1985	62	0.06452	0.03896	3	4.8387	2.74745
1986	98	0.16327	0.07208	7	7.1429	2.61492
1987	106	0.13208	0.05205	8	7.5472	2.57785
1988	93	0.01031	0.01031	1	1.0753	1.07527
1989	94	0.26596	0.13027	5	5.3191	2.32708
1990	69	0.24133	0.11116	9	13.0435	4.08407
1991	105	0.17143	0.07469	8	7.6190	2.60151
1992	99	0.77026	0.24718	21	21.2121	4.12961
1993	107	0.40187	0.16256	14	13.0841	3.27543
1994	102	0.20262	0.09396	10	9.8039	2.95892
1995	84	1.86905	0.90510	10	11.9048	3.55466
1996	81	0.70865	0.24897	17	20.9877	4.55286
1997	105	0.58889	0.24683	11	10.4762	3.00299
1998	27	0.14766	0.10238	2	7.4074	5.13611
1999	107	0.64118	0.24292	15	14.0187	3.37212
2000	117	1.01636	0.39903	15	12.8205	3.10407
2001	102	0.67856	0.54526	9	8.8235	2.82229
2002	103	0.88837	0.30315	23	22.3301	4.12355

Table 5.1.16. Bongo Summer Bottomfish and Fall Ichthyoplankton Survey Combined Western Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	56	0.42747	0.14789	9	16.0714	4.95223
1983	39	0.51661	0.24993	4	10.2564	4.92161
1984	55	0.43465	0.17816	6	10.9091	4.24242
1985	81	0.50823	0.21748	7	8.6420	3.14148
1986	121	0.70672	0.19915	15	12.3967	3.00831
1987	129	0.83478	0.32685	13	10.0775	2.66076
1988	68	0.53339	0.24513	6	8.8235	3.46517
1989	67	0.97941	0.33461	9	13.4328	4.19748
1990	66	0.65492	0.25083	7	10.6061	3.81922
1991	79	0.64962	0.21539	10	12.6582	3.76487
1992	106	1.25886	0.41135	17	16.0377	3.58112
1993	108	0.63622	0.21729	11	10.1852	2.92393
1994	101	0.91657	0.46930	8	7.9208	2.70063
1995	83	1.50794	0.49401	15	18.0723	4.24928
1996	81	2.76869	1.00451	17	20.9877	4.55286
1997	105	1.77119	0.45606	23	21.9048	4.05569
1998	27	4.78339	3.21036	4	14.8148	6.96696
1999	109	0.94243	0.23721	19	17.4312	3.65056
2000	117	2.23520	0.48891	29	24.7863	4.00890
2001	101	1.82666	0.53314	20	19.8020	3.98507
2002	106	2.03169	0.47323	26	24.5283	4.19886

Table 5.1.17. Neuston Summer Bottomfish and Fall Ichthyoplankton Survey Combined Eastern Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	20	0.00000	0.00000	0	0.0000	0.00000
1983	18	0.00000	0.00000	0	0.0000	0.00000
1984	15	0.00000	0.00000	0	0.0000	0.00000
1985	9	0.00000	0.00000	0	0.0000	0.00000
1986	93	0.00000	0.00000	0	0.0000	0.00000
1987	86	0.19729	0.12679	3	3.4884	1.99018
1988	70	0.01429	0.01429	1	1.4286	1.42857
1989	72	0.00000	0.00000	0	0.0000	0.00000
1990	79	0.02532	0.02532	1	1.2658	1.26582
1991	67	0.01528	0.01528	1	1.4925	1.49254
1992	60	0.11515	0.05830	5	8.3333	3.59823
1993	67	0.05968	0.02915	4	5.9701	2.91644
1994	75	0.04000	0.02965	2	2.6667	1.87283
1995	70	0.04286	0.03176	2	2.8571	2.00561
1996	69	0.01449	0.01449	1	1.4493	1.44928
1997	74	0.10695	0.06233	4	5.4054	2.64659
1998	16	0.06250	0.06250	1	6.2500	6.25000
1999	79	0.29178	0.13152	9	11.3924	3.59746
2000	59	0.08475	0.06062	2	3.3898	2.37622
2001	76	0.05094	0.03147	3	3.9474	2.24842
2002	45	0.06768	0.06768	1	2.2222	2.22222

Table 5.1.18. Bongo Summer Bottomfish and Fall Ichthyoplankton Survey Combined Eastern Gulf.

YEAR	N	A	A-SE	FO	%FO	FO-SE
1982	20	0.00000	0.00000	0	0.0000	0.0000
1983	20	0.00000	0.00000	0	0.0000	0.0000
1984	15	0.00000	0.00000	0	0.0000	0.0000
1985	10	0.29775	0.29775	1	10.0000	10.0000
1986	93	0.06922	0.05751	2	2.1505	1.5124
1987	86	0.09743	0.06867	2	2.3256	1.6347
1988	57	0.09930	0.09930	1	1.7544	1.7544
1989	61	0.11957	0.08487	2	3.2787	2.2990
1990	62	0.07631	0.07631	1	1.6129	1.6129
1991	50	0.20940	0.11991	3	6.0000	3.3927
1992	61	0.00000	0.00000	0	0.0000	0.0000
1993	67	0.00000	0.00000	0	0.0000	0.0000
1994	75	0.16787	0.09600	3	4.0000	2.2780
1995	70	0.19647	0.10126	4	5.7143	2.7943
1996	69	0.00000	0.00000	0	0.0000	0.0000
1997	74	0.14883	0.07446	4	5.4054	2.6466
1998	18	0.12520	0.12520	1	5.5556	5.5556
1999	77	0.31927	0.18902	4	5.1948	2.5456
2000	67	0.67800	0.26154	8	11.9403	3.9914
2001	74	0.34958	0.14560	6	8.1081	3.1948
2002	46	0.34867	0.17670	4	8.6957	4.2004

Appendix 5.2.

Figures 5.1-4. Red snapper frequency of abundance categories for positive catch stations by year, for bongo and nueston net collections from the Summer Bottomfish and Fall Ichthyoplankton surveys.

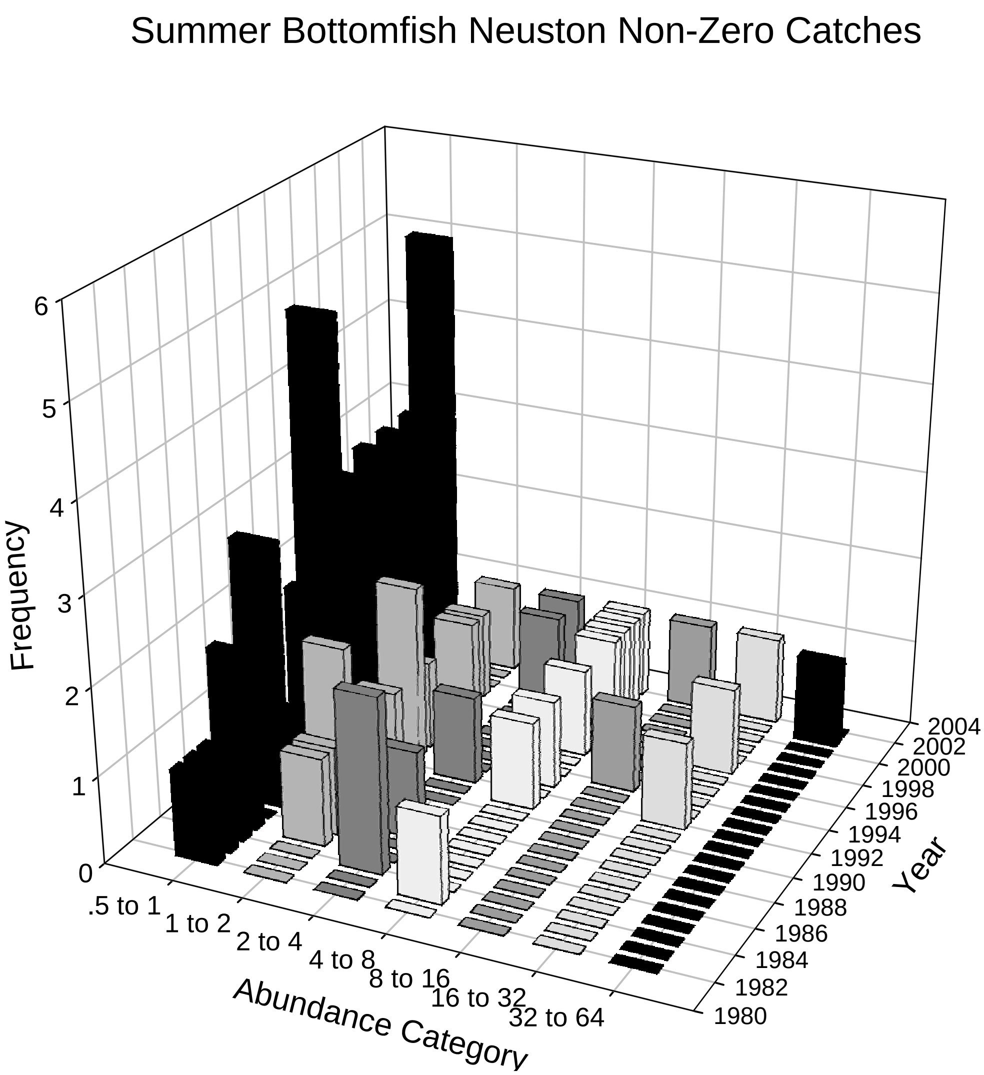

Figure 5.2.1. Frequency of standardized abundance categories for positive catch neuston stations by year for the SEAMAP Summer Bottomfish surveys. Abundance categories are in the number of larvae per 10 minute tow.

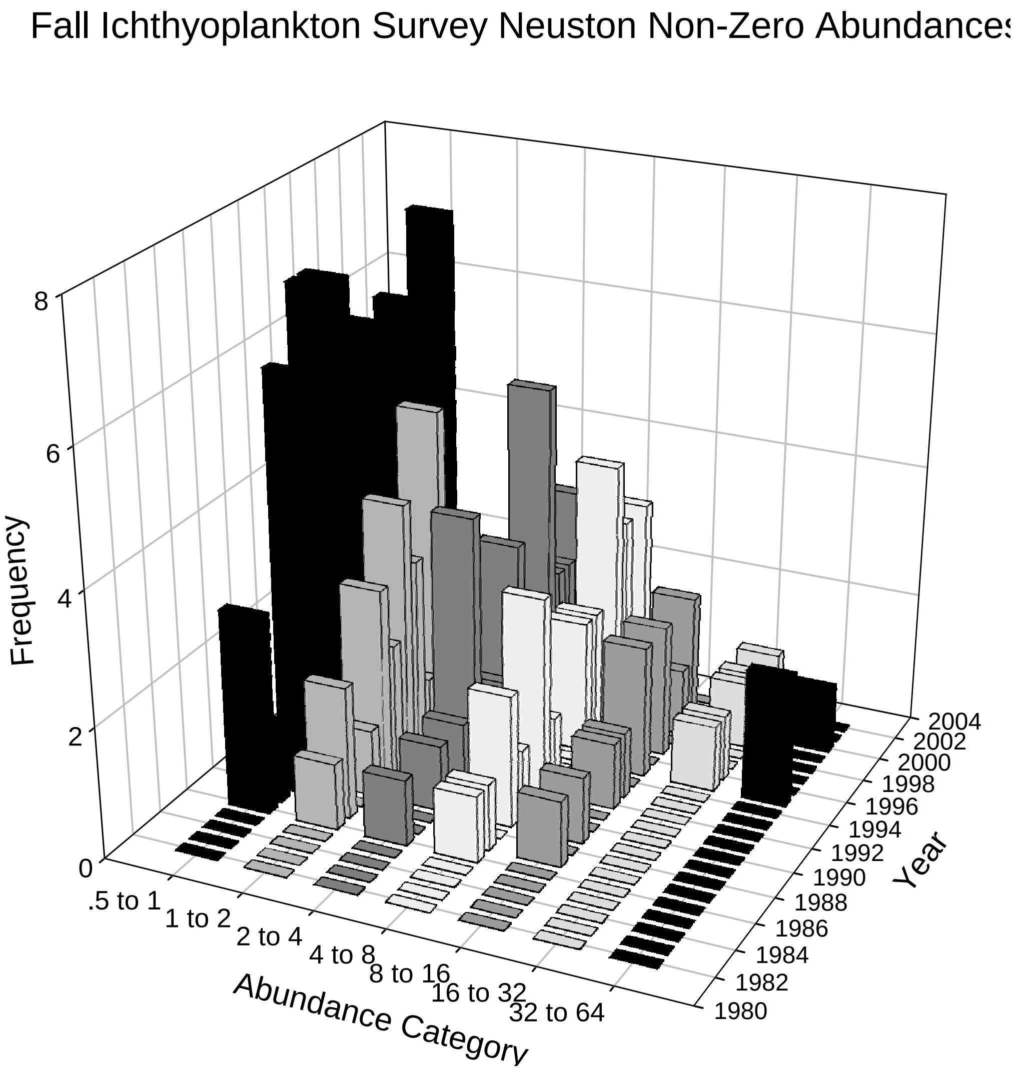

Figure 5.2.2. Frequency of standardized abundance categories for positive catch nueston stations by year for the SEAMAP Fall Ichthyoplankton surveys. Abundance categories are in the number of larvae per 10 minute tow.

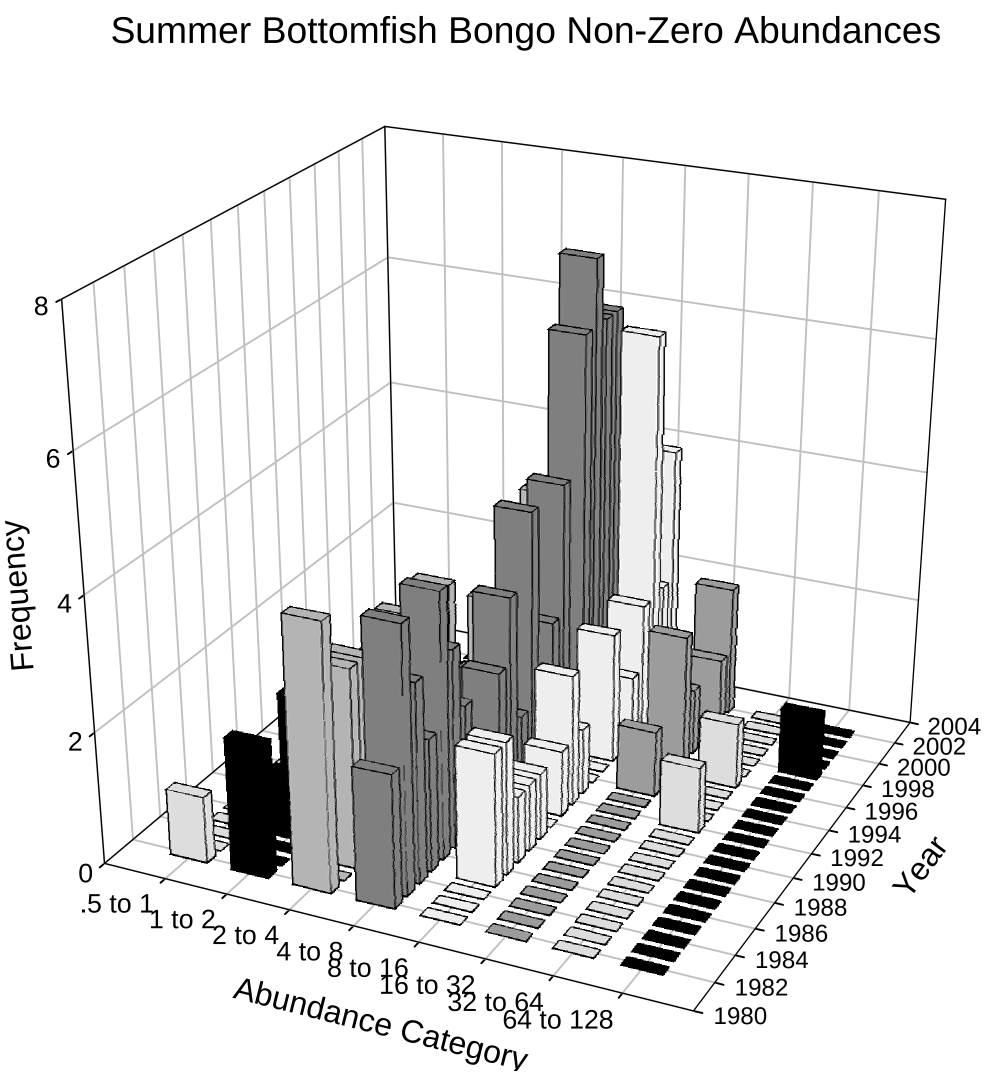

Figure 5.2.3. Frequency of standardized abundance categories for positive catch bongo stations by year for the SEAMAP Summer Bottomfish surveys. Abundance categories are in units of the number of larvae per 10 meters squared of sea surface.

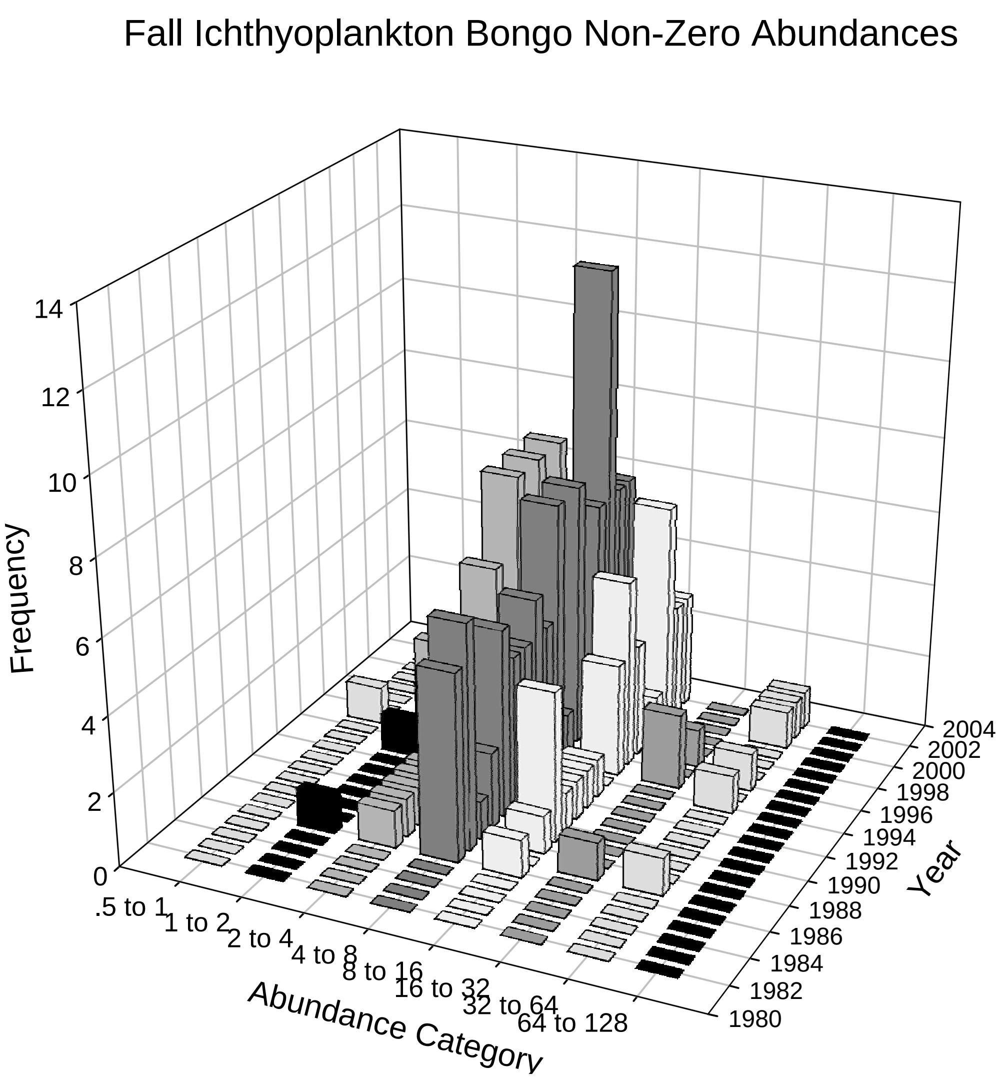

Figure 5.2.4. Frequency of standardized abundance categories for positive catch bongo stations by year for the SEAMAP Fall Ichthyoplankton surveys. Abundance categories are in units of the number of larvae per 10 meters squared of sea surface.

6. Release Mortality

6.1 Background

Gulf of Mexico red snapper are now protected from harvest by a size limit of 15 inches total length for the commercial fishery and 16 inches total length for the recreational fishery. The minimum size for recreational fisherman was increased to 18 inches for the last month of the recreational season in 1999. Anecdotal comments from fishermen attest to the consequence of this regulation i.e., significant numbers of undersize red snapper are caught and must be released. The mortality of released fish is an important consideration in evaluating the conservation effects of regulations that set minimum sizes and total allowable catch.

Data from some recent studies of the mortality of reef fishes after being caught and released were summarized by Parker (1991) who in an earlier report observed no immediate mortality of 30 red snapper (<16 in TL) caught from 30 m off the Texas coast and released at the surface (Parker 1985). That report also described experiments which found a mortality of 21% for red snapper that were caught from 22 m, returned to the capture depth and held in wire cages. A similar study at 30 m resulted in 11% mortality. Gitschlag and Renaud (1994) found that mortality of small (<32 cm) red snapper caught by hook and line off Texas and released at the surface was 1% at 21-24 m (n=138), 10% at 27-30 m (n=27), and 44% at 37-40 m (n=47). These authors also observed a mortality of 36% for red snapper that were caught from 50 m, returned to the capture depth and held in wire cages. Render and Wilson (1994) found mean mortality to be 20% for red snapper caught at 21 m and released at the surface into a 9-m-deep cage after 48 hours. Release mortality was higher in the fall than spring. Also, there was a nonsignificant increase in mortality with depth of capture.

Patterson et al. (2001) reported that of nearly 3,000 red snapper tagged and released in the north central Gulf, off Dauphin Island, 84% were released in “condition one,” defined as fish that immediately returned to the bottom, showing no signs of stress. These were assumed to have survived capture and tagging. This survival assumption is strengthened by subsequent recapture of more than 500 fish, some of which had been judged to have been more stressed than condition one. Of the recaptured fish, thirty-five were recaptured twice, and one fish was recaptured three times. These data further suggest that red snapper can survive the catch-and-release experience. The study was based on release depths of 21m, 27m, and 32m. Release mortality was estimated at 9%, 14%, and 18%, respectively. Subsequent to the published study, an additional 3,000+ snapper were tagged and released, but the tagging process was streamlined. The release mortality, based on the “condition” assessment was reduced to about 12% (Shipp, pers. comm.).

Further tagging efforts are reported in Burns et al. (2004), at depths of 13m to 66 m. Of 5470 releases, 435 total recaptures have been made, primarily at 20 to 40 m (the same depth where most of them were tagged). Of those recaptures, 20 were captured twice and 5 were recaptured 3 times. This provides additional evidence of red snapper surviving the capture event.

C. Koenig conducted capture-release mortality studies off Apalachicola and Caribelle, Florida during the fall and spring of 1999, 2000, and 2001 (reported in Burns et al. 2002). Small red snapper (<50 cm) were caught using electric reels aboard chartered commercial vessels. Ascent rate varied 1-2 m/sec. Standard J hooks were replaced by circle hooks to eliminate gut and gill hooked fish. Fish were not vented. Cages remained on the bottom for 5 – 8 days. There was a direct, strong relationship between depth related mortality and surface interval. At a 40 m capture depth, mortality varied from 20 % at a 3 minute surface interval to 100% for an 18 minute surface interval (Fig. 6.1). These results indicate that the faster fish are released and returned to the bottom, the higher the survival. Burns et al. (2002) suggest that the higher internal pressure relative to ambient is a major factor in the relationship between surface interval and mortality.

Dorf (2003) conducted a study of the recreational headboat discards at 3 ports in Texas (Galveston, Port Aransas, and Port Isabel) in August and September of 1999. Discard fate was determined for 3,851 fish (12.9% were kept and landed). Of those discarded, 60.6% were released alive and swam down, 22.8% were swimming erratically, 15.2% floating, and 1.4% were discarded dead. Fish released either dead or floating were caught at greater depths than fish which swam down or swam erratically on release. Depth ranged from 13.4 – 95.4 m. When snapper were discarded, 62.8% were released by hook removal without puncturing the swim bladder. The swim bladder was punctured along with hook removal for 36.2% of released snapper. Although hook type was not specifically documented, circle hooks are the predominant hook type on Texas headboats.

Burns et al. (2004) evaluated release mortality in 3 components: causes of acute mortality, hook related mortality with circle versus J hooks, and hyperbaric experiments to examine depth related mortality. Out of 266 undersized red snapper caught off Panama City, Daytona and St. Augustine, Florida, 171 (or 64.3%) suffered acute mortality (i.e., the fish were landed dead or died on deck before they could be returned to the water). Of the 171 acute mortalities, 49.1% of them were killed from hook induced mortality. Another 13.5% were killed due to depth related trauma, and the remainder died of "other" causes. At all depth categories, hooking mortality was the largest proportion of identified mortality causes. In addition, several snapper brought back to MML died of latent hook injuries.

Burns et al. (2004) evaluated depth related mortality by placing fish in hyperbaric chambers. Red snapper suffered no mortality when exposed to simulated depths of 21 or 27.4 m, while 40% died at 43 m and 45% died at 61 m.

Diamond et al. (2004) are conducting a study of Texas release mortality and discards. Preliminary results from a control study to evaluate delayed mortality found significant differences in mortality for the main effects (depth, season). The control studies were conducted at BP Oil platforms, and used cages to assess mortality over a 4 day period.
All fish were vented. Circle hooks were used (>90% of fish were hooked in mouth).
Deeper depths and increased temperatures caused an increase in mortality. Overall mortality for the control project was 64%. By depth, observed mortality was: 53% at 30 m, 71% at 45 m, and 69% at 50 m. With respect to temperature, the proportion of released fish that were classified as dead (by month) was: 90% in July, 63% in September, and 44% in October.

Wilson and Nieland (2004) are conducting studies of the fate of undersized red snapper caught on commercial vessels off central Louisiana. Overall, 16 trips with 273 fishing events were observed at depths ranging from 30-90 m. Undersized fish were released and their condition of release was categorized as 1) swam down vigorously; 2) swam down slowly; 3) alive, but remained at surface; 4) unresponsive or dead. Over the 2 year study period, 65-74% of discards were classified in categories 3 and 4. Fish in category 2 accounted for 15% of total discards. Circle hooks and bandit reels were the principle gear.

Recent studies have evaluated hooking mortality for circle versus J hooks. Circle hooks have a different pattern of hooking location, typically around the maxilla for red snapper (Dorf 2004). It is believed that circle hooks reduce hooking related mortality because of reduced hook swallowing and subsequent damage to internal organs. During 2003, a comparison of release mortality of circle and "J" hooks was conducted as part of a long term tag-recapture study (Shipp, pers. comm.). Release mortality was reduced by approximately 50% by capture with circle hooks (Shipp, pers. com.). An evaluation of tagged fish in the Burns et al. (2004) study caught initially on either circle or J hooks revealed similar recapture rates for both hook types (5.5% for circle, 7.2% for J) in the headboat fishery. Circle hooks distributed by Burns et al. did not have the hook offset, however it is not known if fishers manually offset any hooks or if fishers used their own circle hooks with an offset angle. In practice, the commercial fishery uses circle hooks, and in the recreational fishery, the trend is moving towards increased use of circle hooks.

In addition to the hooking and handling mortality, predation of released fish may be important in areas with significant concentrations of large predators. Parker (1985) noted 19.5% mortality of reef fish caught and released in 20-30m depths off Daytona, Florida due to predation. In contrast, Gitschlag and Renaud (1994) noted that predation was not apparent in their study. Burns et al. (2004) directly observed dolphin predation on 2.9% - 6.5% of discards, and dolphins were seen to pursue another 20%-21.7% of released fish although the actual take was not witnessed. Wilson and Nieland (2004) also noted predation by pelicans and dolphins, and Shipp (pers. comm.) noted that bottlenose dolphins occasionally appeared during tagging operations and were seen to actively pursue red snapper.

Preliminary data from a study conducted at Mote Marine Laboratory (Burns and Porch *in preparation*, Figure 6.2) suggest that venting increases survival in red snapper caught in deep water. This is in contrast to earlier studies by Render and Wilson (1993) and Gitschlag and Renaud (1994), who found no increase in survival from venting. The work by Burns and Porch (*in progress*) updates the study by Burns and Restrepo (1999), which had concluded no significant difference between vented and non-vented fish. It is believed that venting, when properly executed, can increase survival of released fish. Most commercial fishermen are not thought to vent. The extent of venting in the recreational fishery is unknown. Florida SeaGrant is distributing pamphlets and producing videos that demonstrate proper venting techniques, and they are providing free venting kits. A survey is suggested as a way of determining the fraction of fishermen that vent.

Temperature related effects were reported by Render and Wilson (1994) and Diamond et al. (2004). Both studies found release mortality to be lower in the fall than in the summer months.

6.2 <u>Derivation of estimates</u>

To derive estimates of release mortality by region (West Gulf = Texas and Louisiana, East Gulf = Mississippi, Alabama, and West Florida), the effort at which fishing occurred in each fishery was determined and this was then matched with study estimates of release mortality by depth. Table 6.1 summarizes study estimates of release mortality by depth.

For Texas headboat and charterboat fisheries, Diamond et al. (2004) sampled depth ranges of 10 to 115 m with a median of 43 m. Dorf (2003) also sampled the Texas headboat fishery, and the depths fished ranged from 13-95 m with an average of about 40 m. Dorf (2003) found release mortality to be 40% at this depth (Table 6.1), and this value included Categories 2-4. The study by Diamond et al. (2004) found release mortalities of 71% at 45 m. While the Diamond et al. estimates made observations after 4 days to account for delayed mortality, the value of 71% includes survival of both control fish and fish from which blood was drawn. It is suspected that mortality may be inflated due to the increased stress and handling for the blood-drawn fish, but further analysis of this data is required to assess that. As this project is still being conducted, no further results are anticipated prior to the stock assessment.

Effort in Louisiana is believed to be focused at depths similar to Texas. Thus, a release mortality of 40% is assumed for the western Gulf recreational fisheries.

The recreational fishery in the northeastern and north central Gulf of Mexico is prosecuted in relatively shallow water, usually at depths of less than 40m (Patterson et al. 2001). The bulk of observations in the study by Burns et al. (2004) were concentrated in 20 to 40 m depths along the panhandle and west and southwest coast of Florida, and the east coast of Florida from Daytona to northeast Florida. Studies conducted in the eastern Gulf (Table 6.1) found release mortalities of 8.9%-22% at these depths. These estimates are based on observation methods that included Cage+SCUBA and surface observations that included Categories 2-4 as mortalities. Averaging over that range, we obtain a value of approximately 15% for the eastern Gulf recreational fisheries.

A Gulf-wide estimate of release mortality in the recreational fishery can be obtained by multiplying the proportion of landings in each region by the corresponding estimate of release mortality. The average landings by each region was close to 50-50 until 1997. For the period 1997-2002, the average by region is about 77% for the eastern region and 23% for the western region. Two possible explanations for the observed change were suggested. First, a strong year class in 1995 would have recruited to the fishery landings in the period 1997-2002. Second, management actions that changed the quota and that closed the winter season during this period may help explain the reduction in proportional and total western regional landings. A Gulf-wide estimate of release mortality for the recreational fishery is 27.5% the period 1981-1996, and 21% for the period 1997-2002.

The only available depth information for the commercial fishery is provided by TIP, which records the minimum and maximum depths fished on a given trip. The midpoint of the reported depth range was used to represent depth fished on that trip. Depth fished was examined following the same regional delineation in the Gulf as was used in the recreational analysis, namely an eastern region consisting of Florida, Alabama, and Mississippi, and a western region comprised of Texas and Louisiana. The regional analysis was summarized according to the open versus closed commercial fishing season, because it is believed that fishing during the closed season occurs in deeper waters where release mortality is expected to be higher. The median of the depths fished by region and by open/closed season was matched to a release mortality estimate by examining scientific studies in the regions, and self-reported dead discards from the logbook program.

During the open season, the median depth for trips that landed red snapper was 55 m in the eastern Gulf and 58 m in the western Gulf. Because the commercial and recreational fisheries operate very differently, release mortality estimates were restricted to studies that sampled the commercial fishery. In the eastern Gulf, a study by Burns et al. (2002) fit a logit regression to estimate release mortality at depth. At 55m, the estimate from their equation predicts a release mortality of about 70%. In the western Gulf, the work by Wilson and Nieland (2004) found a release mortality of 85% (categories 2,3,4) for depths between 50 and 60 m. From self-reported discard records in the logbook program (Poffenberger and McCarthy, SEDAR7-DW-22), fish were classified into one of the following categories: All dead, Mostly dead, Mostly alive, All alive, Kept but not sold, Unable to determine. Although these categories do not match those of other studies, a reasonable approximation was to treat the sum of categories “All dead + Mostly dead + Mostly alive” as similar to categories 2-4 in the surface observation studies. Using this criterion, an estimate of release mortality from the logbook program is 72% in the east and 78% in the west. Averaging the estimates from the logbook program with regional estimates from scientific studies, the release mortalities assigned to the commercial fishery during the open season are 71% in the east and 82% in the west.

In the closed season, there are no red snapper trips recorded in the TIP database. Rather than look at depths for all trips in the closed season, it was decided that only trips that were likely to catch red snapper should be examined. To identify these trips, discard records from the logbook program that reported red snapper discard in the closed season were matched to landings of other species caught on those trips. The list of all species associated with trips discarding red snapper was reduced to those species that accounted for a substantial portion of total regional red snapper discards. The species in each region that were associated with trips likely to catch red snapper are reported in Table 6.3; in the western Gulf, the top two species were mackerel (king and cero) and vermilion snapper, while in the eastern Gulf, red and gag grouper were associated with the greatest amount of red snapper discard.

Trips that landed any of the species identified in Table 6.3 during the closed red snapper season were extracted from the TIP database. The median depth fished on these trips in the eastern Gulf was 55 m (the same as in the open season) and 83 m in the western Gulf. The list of species associates was evaluated to determine how sensitive the median estimate of depth fished was to the inclusion/exclusion of some species. In the east, only yellowtail snapper had a lower median depth fished of 23 m; all of the remaining fish were associated with depths of 42-68 m. In the west, only king and cero mackerel were caught at shallower depths (median 38 m), while the remaining species on the list were caught in the range of 83-101 m. From this, it was concluded that the median depth assigned to each region in the closed season was not sensitive to the species included in the analysis.

Release mortality in the eastern Gulf during the closed season is the same estimate as during the open season (71%) because the median depth fished was the same. In the western Gulf, Wilson and Nieland (2004) estimated release mortality to be about 97% for trips that fished at depths of 80-85 m. For the sake of comparison, the logit model of Burns et al. (2002) predicts a release mortality of 91% at 80m. Averaging the estimates in the western Gulf from the logbook program (78%) and from the study by Wilson and Nieland (97%), the release mortalities assigned to the commercial fishery during the closed season are 71% in the east and 88% in the west.

A Gulf-wide estimate of release mortality in the commercial fishery could be obtained by weighting the regional estimates according to regional proportional landings (total weight). Table 6.4 shows the proportional landings by region in the commercial fishery from 1962-2003. The average split in total landings by weight is 86% for the eastern Gulf and 14% for the western Gulf for the period 1962-1983, whereas the last ten years (1993-2003) show the opposite split (15% for the eastern Gulf and 85% for the western Gulf). For the intervening period, the landings by the eastern region declined steadily from a high of 68% to a low of 25%. A Gulf-wide estimate of release mortality is 73% for the period 1962-1983, and 80% for the period 1993-2003. For the period 1984-1992, the average split between the east and west is 43% for the east and 57% for the west. Applying these proportions, a weighted average for Gulf-wide release mortality is 77% for 1984-1992.

In the recreational fishery, the depths of fishing assigned to each region were derived from recent studies. The group discussed whether these depths could have varied over time. Because recreational effort directed towards red snapper is concentrated on structures (wrecks, reefs, rigs, etc.), it is not believed that fishing depth has changed over time. For the commercial fishery, reported depths from the TIP database were examined for a temporal trend in both the open and the closed season. No temporal trend was observed. In the east, the range was 50-60 m in the closed season and 41-64 meters in the open season. In the west, the range was 73-100 during the closed season and 34-79 during the open season.

As noted in several recent studies, predation on discarded fish by dolphins and pelicans is occurring in both the recreational and commercial fisheries. It is also being reported to occur on fish before they are landed. At present, there is no way of quantifying the mortality caused by predation, and the group does not recommend including an additional component of mortality due to predation. Estimates reported in the studies by surface observation method, which counted categories 2-4 as mortalities, would already account for predation on fish in these categories. It is felt that the estimates derived for regional, fishery specific release mortality represent a compromise on potential biases, both high and low. Two tagging studies (Burns et al. 2004, Bob Shipp *pers. comm.*) report recoveries of fish released in categories 2-4; there is no measure of delayed mortality or predation on category 1 fish; and underwater predation prior to landing fish cannot be quantified.

Point estimates of release mortalities assigned to each sector (recreational and commercial) and region, and the associated depths fished, are summarized in Table 6.5. Uncertainty associated with these estimates comes from having no depth observations in the recreational fishery and only very limited depth information for the commercial fishery, no estimates of variability for the release mortality values in the studies summarized in Table 6.1, no way of quantifying the distribution of handling time for each fishery, little or no information about venting practices by each fishery, as well as the aforementioned uncertainty in fish fate (based on surface observations) and unquantifiable predation. For these reasons, no attempt was made to provide a distribution for these point estimates. If sensitivity runs are desired, one might consider using the minimum and maximum observed estimates in Table 6.1 that are associated with each category in Table 6.5.

6.3 References

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Table 6.1. Summary of release mortality estimates by study, observation method, and area. (R&W refers to Render and Wilson; G&R refers to Gitschlag and Renaud).

Depth range (5 meter intervals)	Release Mortality	Method of Observation	Study	Area
<20 m	0%	Hyperbaric	Burns	Panama City, FL
	22%	Cage+SCUBA	Parker	Daytona,FL and Galveston
	21%	Cage	R&W	LA gas platforms
	1%	Cage	G&R	Galveston, TX
	8.9%	Surface Obs	Patterson	AL coast
	0%	Hyperbaric	Burns	Panama City, FL
25	41%	Surface Obs	Dorf	Texas ports
	11%	Cage+SCUBA	Parker	Daytona, FL and Galveston
	10%	Cage	G&R	Galveston, TX
	8.9%	Surface Obs	Patterson	AL coast
	0%	Hyperbaric	Burns	Panama City, FL
	53%	Cage	Diamond	Port Aransas, TX
30	47%	Surface Obs	Dorf	Texas ports
	13%	Surface Obs	Patterson	AL Coast
35	15%	Surface Obs	Dorf	Texas ports
	44%	Cage	G&R	Galveston, TX
40	40%	Surface Obs	Dorf	Texas ports
	40%	Hyperbaric	Burns	Panama City, FL
	71%	Cage	Diamond	Port Aransas, TX
45	63%	Surface Obs	Dorf	Texas ports
	36%	Cage	G&R	Galveston, TX
	69%	Cage	Diamond	Port Aransas, TX
50	61%	Surface Obs	Dorf	Texas ports
55	58%	Surface Obs	Dorf	Texas ports
	45%	Hyperbaric	Burns	Panama City, FL
60	38%	Surface Obs	Dorf	Texas ports
65	37%	Surface Obs	Dorf	Texas ports
70	33%	Surface Obs	Dorf	Texas ports
75	23%	Surface Obs	Dorf	Texas ports
80	47%	Surface Obs	Dorf	Texas ports
85				
90				
95	56%	Surface Obs	Dorf	Texas ports
100				

Table 6.2. Proportional landings by region in the Gulf of Mexico recreational fishery. Proportions were calculated from MRFSS (1981-2003), Headboat (1986-2002), and Texas Parks and Wildlife Division (1983-2002) data sets, which are summarized in SEDAR7-DW-58.

Year	FL+MS+AL	TX+LA
1981	0.40	0.60
1982	0.55	0.45
1983	0.38	0.62
1984	0.21	0.79
1985	0.50	0.50
1986	0.51	0.49
1987	0.60	0.40
1988	0.42	0.58
1989	0.45	0.55
1990	0.52	0.48
1991	0.52	0.48
1992	0.52	0.48
1993	0.53	0.47
1994	0.46	0.54
1995	0.41	0.59
1996	0.50	0.50
1997	0.64	0.36
1998	0.73	0.27
1999	0.84	0.16
2000	0.78	0.22
2001	0.82	0.18
2002	0.84	0.16

Table 6.3. Species associated with trips that reported red snapper discards during the closed season.

Eastern Gulf	**Proportion of total red snapper discard associated with trips catching species**
GROUPER,RED	0.141
GROUPER,GAG	0.101
SNAPPER,MANGROVE	0.084
SCAMP	0.058
GROUPER,BLACK	0.049
SNAPPER,YELLOWTAIL	0.046
SNAPPER,VERMILION	0.040
TRIGGERFISH,GRAY	0.038
Western Gulf	
MACKEREL,KING AND CERO	0.147
SNAPPER,VERMILION	0.073
SCAMP	0.049
TRIGGERFISH,GRAY	0.048
GREATER AMBERJACK	0.046
GROUPER,WARSAW	0.044

Table 6.4. Proportional landings (total weight) by region in the Gulf of Mexico commercial fishery. Proportions were calculated from Table 1 in SEDAR7-DW-23.

Year	FL+MS+AL	TX+LA
1962	0.80	0.20
1963	0.81	0.19
1964	0.82	0.18
1965	0.83	0.17
1966	0.86	0.14
1967	0.86	0.14
1968	0.87	0.13
1969	0.89	0.11
1970	0.87	0.13
1971	0.86	0.14
1972	0.83	0.17
1973	0.87	0.13
1974	0.88	0.12
1975	0.91	0.09
1976	0.93	0.07
1977	0.90	0.10
1978	0.91	0.09
1979	0.92	0.08
1980	0.89	0.11
1981	0.83	0.17
1982	0.83	0.17
1983	0.81	0.19
1984	0.68	0.32
1985	0.60	0.40
1986	0.43	0.57
1987	0.41	0.59
1988	0.34	0.66
1989	0.35	0.65
1990	0.41	0.59
1991	0.35	0.65
1992	0.25	0.75
1993	0.18	0.82
1994	0.20	0.80
1995	0.12	0.88
1996	0.11	0.89
1997	0.10	0.90

Year	FL+MS+AL	TX+LA
1998	0.10	0.90
1999	0.12	0.88
2000	0.16	0.84
2001	0.18	0.82
2002	0.24	0.76
2003	0.16	0.84
2003	0.16	0.84

Table 6.5. Summary of depths fished by fishery and by region in the Gulf of Mexico, and the estimate of release mortality assigned. Release mortality is expressed as the percent of discarded fish that were assumed to suffer mortality.

Recreational Fishery	**Depth**	**% Release Mortality**
Eastern Gulf	20-40 m	15%
Western Gulf	40 m	40%
Gulf-wide (1981-1996)		27.5 %
Gulf-wide (1997-2002)		21%
Commercial Fishery—Open Season		
Eastern Gulf	55 m	71%
Western Gulf	58 m	82%
Gulf-wide (1962-1983)		73%
Gulf-wide (1984-1992)		77%
Gulf-wide (1993-2003)		80%
Commercial Fishery—Closed Season		
Eastern Gulf	55 m	71%
Western Gulf	83 m	88%

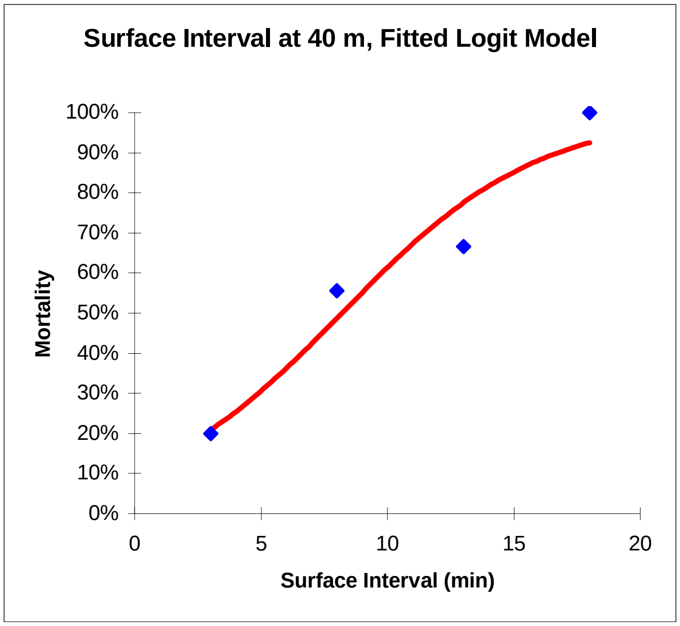

Figure 6.1. The relationship between surface interval of captured red grouper, red snapper, and gag and mortality at 40 m capture depth. (From Burns et al. 2002)

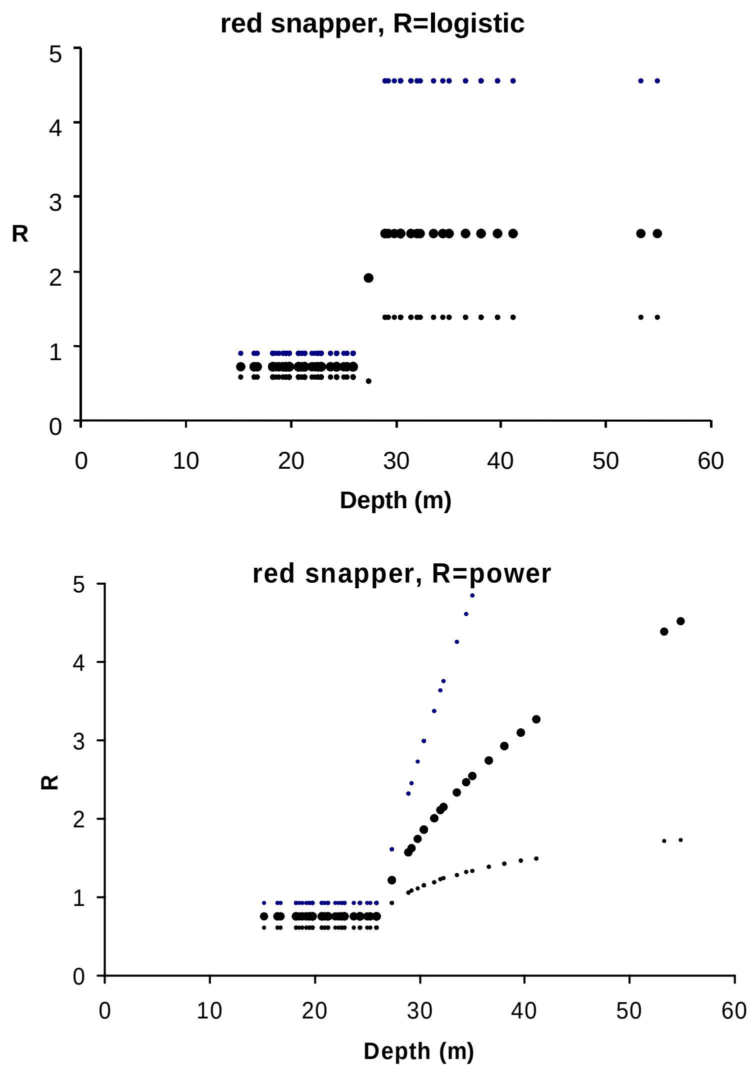

Figure 6.2. Estimated survival of vented red snapper relative to un-vented red snapper (R) as a function of depth with 80% confidence limits. A value of 1.0 would imply that venting has no effect on survival whereas a value less than 1.0 would imply that venting decreases survival. The logistic and power function expressions of R explain the data equally well (i.e., they have similar AIC values). (From *Burns and Porch, in progress*)

7. Shrimp Fleet Bycatch

7.1 Shrimp Effort Calculations

Allocation of Landing and CPUE

Allocation of landings and CPUE has been a concern relative to the estimation of shrimp effort in the Gulf of Mexico. Current shrimp effort estimations involve the assignment of shrimp landings and effort to one or more of 231 location cells by month. The allocations are based on information obtained through dockside interviews conducted by port agents. The current method (SEDAR7-DW-24) involves allocation to 21 statistical areas subdivided by 10 depth zones on a monthly basis. In location cells where no interview data are available, a General Linear Model (GLM) based on historical data, is used to estimate effort. For the 2004 assessment, this method will be used as a comparative or baseline run for the new assessment as described below.

Because of a reduction and possible misallocation to proper cells in dockside interviews over the past decade, alternative pooling methods will be used for the 2004 assessment. A determination was made by the group to pool data in a manner most applicable to the shrimp fishery as opposed to pooling for bycatch species (e.g., red snapper, king mackerel).

The consensus of the group was to pool location cells into larger units by collapsing interview and landings data into four statistical area groups (1-9; 10-12; 13-17; 18-21); two depth zones ($\leq$10, >10); and three-four month seasons (Jan-April; May-Aug; Sept-Dec). This "pooling scheme" is denoted as model SN (SEDAR7-DW-24).

Interview Representation

Concern related to interview data as being non-representative with respect to vessel size was addressed (SEDAR7-DW-6). The common consensus proposed to correct for this potential problem is to apply an alternative model where effort is estimated for non-interviewed vessels (Model 4, SEDAR7-DW-6). The effort estimates from this model will be used as an alternative scenario in the 2004 assessment.

By expanding or pooling, we reduce any allocation error made by port agents.
The selected or any other "pooling scheme" based upon the current data will not, however, address the underestimation of effort in nearshore and deep-water areas. Higher effort in deep-water has been reported recently; however the majority of effort still occurs in the 20-35 fathom zone, typically off statistical area 19. A recommendation was made to continue to partition by state (e.g. 18-21- TX) due to the radically different regulatory measures of each Gulf state. Differences in statistical areas 18 and 19 relative to habitat and fishery operations were explored. The uniqueness of statistical zones 1-3 when compared to zones 4-9 off Florida was discussed.

7.2 Red Snapper CPUE

Data Inputs

Data inputs for bycatch were discussed by the group. From group consensus, there were no issues of concern relative to SEAMAP (SEDAR7-DW-2) or to observer data (SEDAR7-DW-5).

Average Number of Nets

Methods of estimating bycatch have historically assumed an average of 2 nets was representative of the shrimp fishery. SEDAR7-DW-54 describes a functional-distribution approach (with variance estimates) to address the increase in total nets pulled on a per-tow basis from 1 to 4 over time. The group agreed to include a function describing the increase in the number of nets per vessel in the estimates of red snapper bycatch, as outlined in SEDAR7-DW-54.

Bycatch Models

In past stock assessments, a general linear model (GLM) has been used to estimate red snapper bycatch. However, this linear modeling technique did not generate a credible estimate of variance for these effort values. Because of the lack of the ability to estimate variance for the central tendencies of the data and the unbalanced nature of the data sets, this approach has been criticized during previous peer reviews. Therefore, a Bayesian model using Markov Chain Monte Carlo procedures was developed to estimate red snapper bycatch (SEDAR7-DW-3 and 54). This type of model provides for the ability to calculate variance for these estimates, while simultaneously addressing the lack of data in some of the cells

Two papers were submitted following up on suggestions to consider Small Area Estimation (SAE) from the Congressionally-mandated review in 1997. The original SAE suggestions were found to require too many ad hoc procedures to produce complete bycatch estimates (SEDAR7-DW-31). A spatial model that attempted to incorporate the spirit of the SAE suggestions was found to be beyond the current state of knowledge with respect to numerical analysis, and was unsuccessful.

Following detailed discussions of the Bayesian approach a consensus by the group was reached. Because of the ability of the Bayesian model to calculate variance terms while dealing with observations of zero, it was agreed to adopt this model (model 02 of SEDAR7-DW-3, as updated by 54) to generate estimates of bycatch for the red snapper stock assessment.

The current Bayesian model developed assumed a negative binomial error-distribution. It was proposed by the group that a comparative Bayesian model should be developed using the delta lognormal error-distribution. This additional model run will be compared to the negative binomial model.

Red Snapper Age Partitioning and Size Distributions

The group agreed to partition red snapper age distributions by trimester by year for all years. It was also agreed that for those cells not having data by trimester available, the average size distribution for that trimester during that year will be calculated for the entire Gulf and be used in lieu of those empty data cells.

It was agreed that all red snapper under 300 mm that are not age zero will be counted as age one. Further analysis of the data set will be conducted to determine at what size age zero and age one fish start to appear as bycatch, as well as the cut off size for age zero fish.

7.3 BRD Performance Projections

The status of Bycatch Reduction Device (BRD) performance in the north-central western Gulf of Mexico is presented in SEDAR7–DW-38 (see also SEDAR7-DW-57 for an update of the Foundation’s efforts). The results of the Red Snapper Initiative program 2001-2003 indicate a decline in performance since 1998. Several changes in fishing gear characteristics and practices in the fishery may be reducing fisheye performance. Fisheye performance appears to be highly variable over the range of vessels and gear configurations, but poor performance is most likely due to changes in fishing practices to minimize shrimp loss. A NOAA Fisheries/Industry meeting sponsored by the Gulf and South Atlantic Fisheries Foundation will be held on May 4-5, 2004, to present the status of fisheye performance and to elicit recommendations from the industry on means to improve BRD performance. The red snapper shrimp trawl bycatch reduction projection for the stock assessment model will be derived based on the results of the meeting.

7.4 Future Research Recommendations

Future recommendations for improved data collection methods related to shrimp effort estimation include implementation of the Electronic Logbook Program (ELB) for 3-5 years (SEDAR7-REF-1; SEDAR7-REF-2) in conjunction with the current (or some form of) port agent interview system. Amendment 13 to the Shrimp Fishery Management Plan will address vessel monitoring systems (VMS) or ELB approaches for the shrimp fishery to obtain better effort data. Considerations of who will pay and own units (VMS or ELB) were discussed. VMS units are approximately $1200 (+ monthly fee + maintenance) vs. ELB ($500).

The group strongly recommended a fully-funded shrimp trawl observer program to collect bycatch data as related to bycatch reporting requirements. This program would cost approximately $2.5 KK annually.

Work will continue on the new BRD designs using infrared observation technology (SEDAR7-DW-30). With this approach, we must encourage industry innovation by providing information to fishers for cooperative research to solve operational problems and maximize shrimp retention. The key to development of effective designs is getting new designs into the fleet, but this will result in innovation only if the industry has incentive to develop new technology. Consideration must also be given to the present certification protocol. BRD performance requirements will have to be re-examined based on performance projections of current BRD designs. BRD development should be focused on BRD designs which induce continuous and consistent bycatch escapement during variable environmental and commercial applications.

Appendix 1. List of Participants.

Allman, Robert
Atran, Steve
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Porch, Clay
Powers, Joe
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Shipp, Bob
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Steele, Phil
Szedlmayer, Steve
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Tuner, Steve
Walker, Bobbi
Werner, Wayne
Woods, Melissa
Zales II, Bob

Appendix 2. List of Working Documents.

Submitted Working Papers

Document #	Title	Authors
SEDAR7-DW-1	Derivation of Red Snapper Time Series from SEAMAP and Groundfish Trawl Surveys	Nichols, S.
SEDAR7-DW-2	Calibration Among the Separate Trawl Survey Programs to Extend the Time Series for Juvenile Snapper Indexes	Nichols, S.
SEDAR7-DW-3	Some Bayesian Approaches to Estimation of Shrimp Fleet Bycatch	Nichols, S.
SEDAR7-DW-4	Behavior and Swimming Performance of red Snapper: Its Application to Shrimp Trawl Bycatch Reduction	Parsons, G.
SEDAR7-DW-5	Observer Coverage of the US Gulf of Mexico and Southeastern Atlantic Shrimp Fishery, February 1992-December 2003 - Methods	Scott-Denton, E.
SEDAR7-DW-6	Discussion of Days Fished Expansion in the Gulf of Mexico Shrimp Fishery	Griffin, W.
SEDAR7-DW-7	Bioeconomic Simulation Analysis of Alternative Bycatch, Commercial, and Recreation Policies for the Recovery of Gulf of Mexico Red Snapper	Griffin, W.
SEDAR7-DW-8	Shark/Snapper/Grouper Longline Surveys	Henwood, T., W. Ingram, and M. Grace
SEDAR7-DW-9	Distribution, Abundance, and Age Structure of Red Snapper (Lutjanus campechanus) Caught on Research Longlines in U.S. Gulf of Mexico	Mitchell, K., T. Henwood, G. Fitzhugh, and R. Allman
SEDAR7-DW-10	Data Summary of Red Snapper (Lutjanus campechanus) Collected During Small Pelagic Trawl Surveys, 1988-1996	Ingram, W.
SEDAR7-DW-11	Assessment of the Distribution and Abundance of Coastal Sharks in the U.S. Gulf of Mexico and Eastern Seaboard, 1995 and 1996	Grace, M. and T. Henwood
SEDAR7-DW-12	Estimation of Prey Biomass Necessary to Maintain the Equilibrium Standing Stock Biomass of Red Snapper (Lutjanus campechanus), at Various Levels, in the Gulf of Mexico	Driggers, W.
SEDAR7-DW-13	The Steepness Stock-Recruit Parameter for Red Snapper in the Gulf of Mexico (Lutjanus campechanus): What Can Be Learned From Other Fish Stocks?	McAllister, M.
SEDAR7-DW-14	The Potential for Incorporating a Larval Index of Abundance for Stock Assessment of Red Snapper, Lutjanus Campechanus	Lyczkowski-Shultz, J., D. Hanisko, and W. Ingram
SEDAR7-DW-15	SEAMAP Reef Fish Survey of Offshore Banks	Gledhill, C. and W Ingram
SEDAR7-DW-16	Retrospective Coding of Dual Size Classes of Size Frequency Data for Red Snapper Collected During SEAMAP Shrimp/BottomFish Surveys	Pellegrin, G., N. Sanders, K. Johnson, and A. DeBose

SEDAR7-DW-17	Partitioning release mortality in the undersized red snapper bycatch: comparison of depth vs. hooking effects	Burns, K.M., N. F. Parnell, and R. R. Wilson
SEDAR7-DW-18	Red snapper movements based on tag recovery data.	Burns, K. M et al.
SEDAR7-DW-19	Estimating Catches and Fishing Effort of the Southeast United States Headboat Fleet, 1972-1982.	Dixon, R.L. and G.R. Huntsman
SEDAR7-DW-20	Overview of State Trip Ticket Programs in the Gulf of Mexico	Donaldson, D.
SEDAR7-DW-21	Fishery independent estimation of abundance, age frequency, growth rates, and mortality of red snapper *Lutjanus campechanus*, in the northeast Gulf of Mexico.	Szedlmayer, S., D. Moss, and M. Maceina.
SEDAR7-DW-22	Estimates of Red Snapper Discards by Vessels with a Federal Permit in the Gulf of Mexico	Poffenberger, J.
SEDAR7-DW-23	Commercial Landings Statistics –Red Snapper in the Gulf of Mexico	Poffenberger, J.
SEDAR7-DW-24	Estimation of Effort in the Offshore Shrimp Trawl Fishery of the Gulf of Mexico	Nance, J.
SEDAR7-DW-25	Using scenario-based population dynamics modeling to prioritize those parameters in Gulf of Mexico red snapper stock assessment where uncertainty should be taken into account	McAllister, M. K.
SEDAR7-DW-26	Using demographic analysis to evaluate the stock resilience implications and plausibility of life history parameter values assumed for Gulf of Mexico red snapper.	McAllister, M. K.
SEDAR7-DW-27	MARINE RECREATIONAL FISHING STATISTICAL SURVEY (MRFSS): One Constituent's Analysis	Zales, R. F. II.
SEDAR7-DW-28	Summary of Fishing Mortality for the Red Snapper Research Project off Alabama	Shipp, R. L.
SEDAR7-DW-29	NOT USED	
SEDAR7-DW-30	NOT USED	
SEDAR7-DW-31	EBLUP Small Area Estimation for Red Snapper Bycatch from the Gulf of Mexico Shrimp Fleet	Jones, B.
SEDAR7-DW-32	Spatial Modeling of Red Snapper Shrimp Fleet Bycatch in the Gulf of Mexico	Jones, B.
SEDAR7-DW-33	Red snapper (*Lutjanus campechanus*) otolith aging summary 1980 & 1991-2002. NOAA, NMFS, Panama City Laboratory. Contribution Series: 04-03.	Allman, R.J., G.R. Fitzhugh, W.A. Fable, L.A. Lombardi-Carlson and B.K. Barnett

SEDAR7-DW-33add	Addendum to Document 33.	
SEDAR7-DW-34	Precision of age estimation in red snapper (*Lutjanus campechanus*). NOAA, NMFS, Panama City Laboratory Contribution Series: 04-04.	Allman, R.J., G.R. Fitzhugh, K.J. Starzinger and R.A. Farsky
SEDAR7-DW-35	Characterization of red snapper (*Lutjanus campechanus)* reproduction: for the 2004 Gulf of Mexico SEDAR. NOAA, NMFS, Panama City Laboratory. Contribution Series: 04-01.	Fitzhugh, G.R., M.S. Duncan, L.A. Collins, W. T. Walling Jr., D.W. Oliver.
SEDAR7-DW-35add	Addendum to Document 35.	
SEDAR7-DW-36	Red snapper otoliths selected for aging at NMFS Panama City Laboratory and discussion of future sampling targets. NOAA, NMFS, Panama City Laboratory. Contribution Series: 04-02	Fitzhugh, G.R., L.A. Lombardi-Carlson, R.J. Allman and B. K. Barnett.
SEDAR7-DW-37	Analysis of Total Fishing Mortality for Gulf of Mexico Red Snapper Contributed by Shrimp Trawl Bycatch and Commercial and Recreational Fisheries (Including Discards)	McAllister, M. K.
SEDAR7-DW-38	Status of bycatch reduction device performance and research in Norh-Central and Western Gulf of Mexico	Foster, D. G. and Scott-Denton, E.
SEDAR7-DW-39	Florida Fishery Dependent Monitoring	Brown, S. E.
SEDAR7-DW-40	History of red snapper management in federal waters of the US Gulf of Mexico, 1984-2004.	Hood, P. and Steele, P.
SEDAR7-DW-41	Alternative catch rate indices for red snapper (Lutjanus campechanus) landed during 1981-2003 by the U.S. recreational fishery in the Gulf of Mexico using MRFSS and Texas Parks and Wildlife Department data sets.	Cass-Calay, S. L.
SEDAR7-DW-42	Standardized catch rates of red snapper (Lutjanus campechanus) from the United States headboat fishery in the Gulf of Mexico during 1986-2002	Brown, C. A. and S. L. Cass-Calay
SEDAR7-DW-43	Some problems with sampling commercial red snapper fisheries in the Gulf of Mexico.	Chih, C-P.
SEDAR7-DW-44	Estimation of species misidentification in the commercial landing data of red snappers in the Gulf of Mexico.	Chih, C-P.
SEDAR7-DW-45	Size frequency distribution of red snapper from dockside sampling of commercial landings in the Gulf of Mexico 1984-2003 (TIP size data)	Diaz, G.A., S. C. Turner, and C-P Chih.
SEDAR7-DW-46	Size frequency distribution of red snapper from dockside sampling of recreational landings in the Gulf of Mexico 1984-2003 (TXPW, MRFSS, and headboats size data)	Diaz, G. A.
SEDAR7-DW-47	Standardized catch rates of red snapper (Lutjanus campechanus) from the United States commercial handline fishery in the Gulf of Mexico during 1996-2003	McCarthy, K. J. and S. L. Cass-Calay
SEDAR7-DW-48	NOT USED	
SEDAR7-DW-49	A priori estimates of natural mortality rates and stock-recruitment curve steepness for Gulf of	Sladek Nowlis, J.

	Mexico red snapper	
SEDAR7-DW-50	An age-structured assessment model for red snapper that allows for multiple stocks, fleets, and habitats.	Porch, C. E.
SEDAR7-DW-51	MSY, Bycatch and Minimization to the "Extent Practicable"	Powers, J. E.
SEDAR7-DW-52	Length and weight conversions for Florida's recreationally important finfish species	Sauls, B., R. Beaver, and J. O'Hop
SEDAR7-DW-53	Comparisons of Relative Fishing Powers of Selected SEAMAP Survey Vessels	Pellegrin, G. Jr N. Sanders Jr; J. Hanifen; R. Waller; M. VanHoose
SEDAR7-DW-54	Update for the Bayesian estimation of shrimp fleet bycatch	Nichols, S.
SEDAR7-DW-55	An evaulation of the first annulus for red snapper off Alabama	Mareska, J.
SEDAR7-DW-56	Some methods of calculating catch at age of the directed fisheries for red snapper in the Gulf of Mexico, 1984-2002	Turner, S. C.
SEDAR7-DW-57	An Update of Shrimp Trawl Bycatch Reduction Efforts in the Gulf of Mexico	Graham, G.
Reference Documents Provided for Data Workshop		
NAJFM 2003 23:581-589 SEDAR7-REF1	Description of a simple electronic logbook designed to measure effort in the Gulf of Mexico shrimp fishery.	Gallaway, B. J., J. G. Cole, L. R. Martin, J. M. Nance, and M. Longnecker
NAJFM 2003 23:7987-809 SEDAR7-REF2	An evaluation of an electronic logbook (ELB) as a more accurate method of estimating spatial patterns of trawling effort and bycatch in the Gulf of Mexico shrimp fishery.	Gallaway, B. J., J. G. Cole, L. R. Martin, J. M. Nance, and M. Longnecker
GoM Science 1998(1):92-104 SEDAR1-REF3	Movement of red snapper, *Lutjanus campechanus*, in the North central Gulf of Mexico: Potential effects of hurricanes	Watterson, J. C., W. F. Patterson III, R. L. Shipp, and J. H. Cowan
TAFS 2001 130:533-545 SEDAR7-REF4	Movement of tagged red snapper in the Northern Gulf of Mexico	Patterson, W. F. III, J. C. Watterson, R. L. Shipp, and J. H. Cowan
MRAG Americas Inc. 1997 SEDAR7-REF5	Consolidated Report of the Peer Review of Red Snapper (*Lutjanus campechanus*) Research and Management in the Gulf of Mexico	anon.

MARFIN Final Report NA87FF0424 SEDAR7-REF6	Stock Structure of red snapper in the Northern Gulf of Mexico: Is there management as a single stock justified based on spatial and temporal patters of genetic variation, otolith microchemistry,and growth rates?	Gold, J. R.
AFS Symp. 36. 2003 SEDAR7-REF7	Red snapper discards in Texas coastal waters—a fishery dependent onboard survey of recreational headboat discards and landings. In:Stanley, D.R., Scarborough-Bull, A. (Eds.), Fisheries, reefs, and offshoredevelopment. American Fisheries Society, Symposium 36, Bethesda, Maryland, pp.155-166	Dorf, B.A.
Fish Bull 2001 99:617-621 SEDAR7-REF8	Age and growth of red snapper, *Lutjanus campechanus*, from an artificial reef area off Alabama in northern Gulf of Mexico	Patterson, W. F. III; J. H. Cowan, Jr; C. A. Wilson, R. L. Shipp
53 GFCI SEDAR7-REF9	Indirect estimatio of red snapper (*Lutjanus campechanus)* and gray triggerfish (*Balistes capriscus*) release mortality	Patterson, W. F. III; G. W. Ingram, Jr.; R. L. Shipp, J. H. Cowan, Jr.
AFS Symp. 2003 36:181-193 SEDAR7-REF10	Site fidelity and dispersion of red snapper associated with artificial reefs in the northern Gulf of Mexico	Patersonm, W. F. III; and J. H. Cowan

SEDAR

SouthEast Data, Assessment, and Review

Gulf of Mexico Red Snapper
Stock Assessment Report

SECTION 3. Assessment Workshop

SEDAR 7 Gulf of Mexico Red Snapper
Assessment Workshop Report

Contents

SEDAR 7
Gulf of Mexico Red Snapper

Assessment Workshop Overview

Introduction

Two assessment worskhops were conducted during SEDAR 7. The first convened at the SEFSC Laboratory in Miami FL from August 16-20, 2004. The second convened at the Wyndham Grand Bay in Coconut Grove, FL from December 14 – 17, 2004.

Terms of Reference

1. Select several appropriate modeling approaches based on: 1) available data sources, 2) parameters and values required to manage the stock, and 3) recommendations of the Data Workshop – especially including consideration of possible eastern and western stock units; develop and solve population models incorporating the most recent scientifically sound data.
2. Select a preferred model approach that will be used to provide estimates of population parameters and stock status; provide complete justification for the selected model as well as a review of those methods pursued but ultimately rejected as a preferred approach.
3. Provide measures of model performance, reliability, and goodness of fit.
4. Estimate values for and provide tables of relevant stock parameters (abundance, biomass, fishery selectivity, stock-recruitment relationship, etc; include values by age and year where appropriate).
5. Consider sources of uncertainty related to input data, modeling approach, and model configuration. Provide approporiate and representative measures of precision for stock parameter estimates.
6. Prepare sensitivity runs or consider other modeling approaches to examine the reliability of input data sources.
7. Provide Yield-per-Recruit and Stock-Recruitment analyses.
8. Provide complete SFA criteria: evaluate existing SFA benchmarks, estimate values for alternative SFA benchmarks if appropriate, and estimate SFA benchmarks (MSY, Fmsy, Bmsy, MSST, and MFMT) if not previously estimated; develop stock control rules.
9. Provide declarations of stock status relative to SFA benchmarks: MSY, Fmsy, Bmsy, MSST, MFMT (or their proxies if appropriate).
10. Estimate the Allowable Biological Catch (ABC) for each stock if appropriate.
11. Estimate probable future stock conditions and develop rebuilding schedules if warranted; include estimates of generation time. Calculate rebuilding analyses under the following future exploitation possibilities: F=0, F=current, F=current*0.25, F=current*0.5, F=current*0.75.
12. Evaluate the impacts of current management actions, with emphasis on determining progress toward stated management goals.
13. Provide recommendations for future research and data collection (field and assessment); be specific possible in describing sampling design and recommended sampling intensity.
14. Provide thorough justification for any deviations from recommendations of the Data Workshop or subsequent modification of data sources provided by the Data Workshop.
15. Fully and completely document all activities in writing:

    Draft Section III of the SEDAR Stock Assessment Report;

        Provide required tables of estimated values

Prepare a first draft of the Advisory Report based on the Assessment Workshop's recommended base assessment run for consideration by the Review Panel

Report Completion Schedule:

Draft of all text to SEDAR Secretary for formatting: 2 wks, September 8 2004.
(Will be sent to participants for content review during formatting)
Content Comments Due: 1 week, September 15, 2004
Final Draft to Panel for review: September 17, 2004
Final Comments to Staff: 1 week, September 24, 2004
Final Report Distributed to Review Panelists: October 1, 2004

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Baker, Pam	Environmental Defense
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Thompson, Nancy	NMFS/SEFSC Miami
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Williams, Roy	GMFMC

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Atran, Steven	GMFMC

Carmichael, John	SEDAR
Frapwell, Jennifer	SEDAR

List of Assessment Workshop Working Papers

Document Number	Document Title	Authors
SEDAR7-AW 1	Growth models for red snapper in U.S. Gulf of Mexico waters estimated from landings with minimum size limit restrictions	Diaz, Guillermo A., Clay E. Porch, and Mauricio Ortiz
SEDAR7-AW 2	Allometric relationships of Gulf of Mexico red snapper	Diaz, Guillermo A.
SEDAR7-AW 3	Estimated conversion factors for calibrating MRFSS charterboat landings and effort estimates for the Gulf of Mexico in 1981-1997 with For Hire Survey estimates with application to red snapper landings	Diaz, Guillermo A and Patty Phares
SEDAR7-AW 4	Revised catch rate indices for red snapper (*Lutjanus campechanus*) landed during 1981-2003 by the U.S. Gulf of Mexico recreational fishery - REVISED	Cass-Calay, Shannon L.
SEDAR7-AW 5	Batch-fecundity and maturity estimates for the 2004 assessment of red snapper in the Gulf of Mexico	Porch, Clay E.
SEDAR7-AW 6	An age-structured assessment model for red snapper that allows for multiple stocks, fleets and habitats	Porch, Clay E.
SEDAR7-AW6a	Calculation of relative length frequencies	Brooks, E.N.
SEDAR7-AW 7	Preliminary Trials Estimating M1 from Fall and Summer Trawl Surveys	Brooks, Elizabeth N. and Clay E. Porch
SEDAR7-AW 8	Red Snapper Compensation in the Stock-Recruitment Function and Bycatch Mortality	Powers, J.E. and E.N. Brooks
SEDAR7-AW 9	Standardized catch rates of red snapper (*Lutjanus campechanus*) from the United States commercial handline fishery in the Gulf of Mexico during 1996-2003: additional indices	McCarthy, Kevin J. and Shannon L. Cass-Calay
SEDAR7-AW 10	Not used	
SEDAR7-AW 11	A population dynamics model for Gulf of Mexico red snapper that uses a historically extended catch time series and alternative methods to calculate MSY	McAllister, Murdoch K.
SEDAR7-AW 12	Impact on Yield from Density Dependence of red Snapper Juvenile Life Stages	Gazey, W.J.
SEDAR7-AW 13	Brief Review of Red Snapper Data Workshop Report	McAllister, Murdoch K.
SEDAR7-AW 14	Identifying some approaches to formulating prior probability distributions for natural mortality rates in age zero and age one Gulf of Mexico red snapper	McAllister, Murdoch K.
SEDAR7-AW 15	Estimation of Juvenile M for Red Snapper Based on SEAMAP Survey Data	Nichols, Scott, Gilmore Pellegrin Jr. and G. Walter Ingram
SEDAR7-AW 16	Estimates of Historical Red Snapper Recreational Catch Levels Using US Census Data and Recreational Survey Information	Scott, Gerald P.
SEDAR7-AW 17	Documentation on the Preparation of the Database for the Red Snapper Stock Assessment SEDAR	Poffenberger, John and Stephen C. Turner

	Workshop	
SEDAR7-AW 18 revised	Modeled age composition of Gulf of Mexico Red Snapper 1984-2003	Turner, Stephen C., Elizabeth Brooks, Gerald P. Scott and Guillermo Diaz
SEDAR7-AW 19	Gulf of Mexico Red Snapper Observed Catch at Age	Sladek Nowlis, Josh
SEDAR7-AW 20	Estimating Catch at Age for Red Snapper in the Shrimp Fleet Bycatch	Nichols, Scott

Presented at Assessment Workshop Session 2, December 14 – 17, 2004:

SEDAR7-AW 21	A Summary of the August Assessment Workshop for Red Snapper	Anonymous
SEDAR7-AW 22	The commercial landings of red snapper in the Gulf of Mexico from 1872 to 1962	Porch, Clay E., Stephen C. Turner, and Michael J. Schirripa
SEDAR7-AW 23	Reconstructed time series of shrimp trawl effort in the Gulf of Mexico and the associated bycatch of red snapper from 1948 to 1972	Porch, Clay E. and Steve Turner
SEDAR7-AW 24	Additional information on modeled age composition of red snapper from the Gulf of Mexico 1984-2003	Turner, Stephen C., Elizabeth Brooks, and Guillermo Diaz
SEDAR7-AW 25	Alternative indices of abundance of juvenile red snapper from the Gulf of Mexico from SEAMAP surveys 1972-2003	Turner, Stephen C., and Clay E. Porch
SEDAR7-AW 26	An age-structured stock reduction analysis (SRA) model for the Gulf of Mexico red snapper that accounts for uncertainty in the age of density-dependent natural mortality	McAllister, Murdoch K.
SEDAR7-AW 27	An alternative assessment of the red snapper (*Lutjanus campechanus*) fishery in the U.S. Gulf of Mexico using a spatially-explicit age-structured assessment model: Preliminary results	Porch, Clay E.
SEDAR7-AW 28	Benchmarks and Estimated Status from a 1-fleet VPA projection for Red snapper (*Lutjanus campechanus*)	Brooks, Elizabeth N. and Steve Turner
SEDAR7-AW 29	VPA Evaluation of Projected SPR resulting from TAC and Bycatch Reduction for Red snapper (*Lutjanus campechanus*) in the Gulf of Mexico	Brooks, Elizabeth N. and Steve Turner
SEDAR7-AW 30	Assessments of Gulf of Mexico red snapper during 1984-2003 using a Gulfwide implementation of ASAP, including continuity cases	Cass-Calay, Shannon L. and Guillermo A. Diaz
SEDAR7-AW 31	Assessments of Gulf of Mexico red snapper during 1962-2003 using a Gulfwide implementation of an age-structured-assessment-program (ASAP)	Cass-Calay, Shannon L., Guillermo A. Diaz, and Joshua Sladek Nowlis

SEDAR7-AW 32	Draft: Bootstrapping a Gulfwide implementation of an age-structured-assessment-procedure (ASAP) for red snapper (*Lutjanus campechanus*) from 1962 to 2003	Sladek Nowlis, Joshua and Shannon L. Cass-Calay
SEDAR7-AW 33	Summary of all model runs and control rule plots	Brooks, Elizabeth N.
SEDAR7-AW 34	Assessments of red snapper stocks in the eastern and western Gulf of Mexico using an age-structured-assessment-procedure (ASAP)	Cass-Calay, Shannon L. and Mauricio Ortiz

After the December Asssessment Workshop some papers were substantially revised, one was newly developed and another paper was not formally presented to the workshop. These papers are listed below as RW (review workshop) documents.

SEDAR7-RW 1	Application of the age-structured assessment model CATCHEM to the U.S. Gulf of Mexico red snapper fishery since 1962	Porch, Clay E.
SEDAR7-RW 2	Revised Assessments of Gulf of Mexico red snapper during 1984-2003 using a Gulfwide implementation of ASAP	Cass-Calay, Shannon L. andGuillermo A. Diaz
SEDAR7-RW 3	Revised Assessments of Gulf of Mexico red snapper during 1962-2003 using a Gulfwide implementation of an age-structured-assessment-program (ASAP)	Cass-Calay, Shannon L., Guillermo A. Diaz, and Joshua Sladek Nowlis
SEDAR7-RW 4	Assessments of red snapper stocks in the eastern and western Gulf of Mexico using an age-structured-assessment-procedure (ASAP). Revised and updated analysis of results presented in SEDAR7-AW-32	Ortiz, Mauricio and Shannon L. Cass-Calay
SEDAR7-RW 5	Revised bootstrapping a Gulfwide implementation of an age-structured-assessment-procedure (ASAP) for red snapper (*Lutjanus campechanus*) from 1962 to 2003	Sladek Nowlis, Joshua and Shannon L. Cass-Calay
SEDAR7-RW 6	An age-structured stock reduction analysis (SRA) model for Gulf of Mexico red snapper that accounts for uncertainty over the ages of density-dependent natural mortality	McAllister, Murdoch K.
SEDAR7-RW 7	Alternative fishery independent larval indices of abundance for red snapper	Hanisko, D., J. Lyczkowski-Shultz, and W. Ingram

List of additional documents and appendices for this report.

Document number	Description
Proceedings document	Annotated proceedings of August and December assessment workshops
Appendix 1	Data inputs
Appendix 2	Overview of projection and assessment results
Appendix 3	Summary table of benchmarks and status all models (excel file)
Appendix 4	ASAP Gulf wide projection results
Appendix 5	ASAP East and West projection results
Appendix 6	VPA projection results
Appendix 7	SRA Results
Appendix 8	Assessment output
Appendix 9	Assessment programs and inputs

Overview Document

Red snapper has been the subject of five stock assessments since 1990, the last in 1999. That history has covered a large range of modeling decisions, what-if's, sensitivities, revisits to the primary data, and major external peer reviews. However, all past assessments have ultimately been limited by the same problem: it has been impossible to determine a convincing relationship between parent stock and subsequent juvenile recruitment. This is not an unusual problem in stock assessment, but the red snapper case has some unique features. After about 20 years of collecting detailed data and perhaps 20-fold variations in year class strength, parent stock size appears to have barely changed.

In recent stock assessment meetings, the problem has usually been discussed in terms of a model parameter called 'steepness,' often abbreviated as *h*. In its common usage, steepness is theoretically bounded by values of 0.2 and 1.0 and represents the number of recruits produced by a parental stock reduced by 80% relative to the number of recruits produced by an unfished parental stock. A high steepness value (*i.e*. approaching 1.0) actually implies that recruitment rates may remain high down to very low levels of parent stock abundance, only then 'steeply' declining. A lower value implies a longer, slower curvature to the relationship -- recruitments will tend to decline as parent stock declines, slowly early in the history of the fishery, then at an increasing rate if parent stocks continues to be reduced.

With red snapper, the assessment scientists have had a dilemma. Twenty years of red snapper data, taken at face value, suggested steepness is very high (above 0.95), higher than most scientists believe possible. Experience with stocks similar to red snapper suggested steepness should be nearer to 0.8 than 1.0. The different values have had important implications for long-term management advice. For red snapper, accepting the high steepness implied more drastic reductions were needed to make management targets within defined time frames, but opened the question of whether the targets were set unnecessarily high. Accepting the lower value implied that current restrictions could be closer to what is needed, that ultimate production might be much higher than ever seen, but that rebuilding could be prolonged.

There have been many advances in information available for the present assessment, but it was expected coming in that spawning stock abundance had still not moved enough since 1999 to improve our knowledge of stock-recruitment. Therefore, a different direction was suggested during the SEDAR process. Considerable effort was devoted to reconstructing a time series of catch estimates going back to the dawn of the fishery as recommended by the Data Workshop. By running the assessment models on this extended, 'ultra-historical' series, we hoped to develop enough contrast in spawning stock and recruitment to define the stock-recruitment relationship.

That effort is now complete. The extended analyses continue to support a very high estimate for steepness. In fact, results are consistent with recent recruitments being amongst the highest they ever have been, despite a spawning stock very depleted by most any standard. However, the 'ultra-historical' series has pinned down virgin stock sizes in such a way that stock status results are no longer as sensitive to steepness as they were in past assessments, at least in the context of the favored model. This is reassuring, but with the caveat that the ultimate productivity of the snapper stock is not a settled issue. Because of that, we urge readers to focus more on short term (5-10 yr) directions of management advice, and how to tend toward a more desired state, without unduly emphasizing specific targets and how to attain them.

Over the last 5 years, the scientific community has produced many major advances in the red snapper information base. Statistical coverage has improved, as has age and length sampling. Fishery independent surveys were expanded, the SEAMAP trap / video survey was resumed, and a new longline survey was initiated. Expanded sample processing led to major improvements in growth and fecundity information, and allowed derivation of SEAMAP larval indices. Analytical advances included improved evaluation of uncertainty, and improved age composition information for shrimp fleet bycatch and for SEAMAP trawl surveys. These in turn led to a better estimate of juvenile M. Large MARFIN research projects strengthened the plausibility of East and West substructure to the stock, provided interesting information on juvenile habitat utilization, and improved the knowledge base on release mortality. In order to accommodate and take advantage of these gains in information, a new assessment model (named CATCHEM) was developed, with much greater generality, better mathematical rigor, and the capability to handle geographic substructure. Although some fundamental uncertainty over stock productivity remains, many other areas of previous concern have been resolved, or at least uncertainty has been substantially reduced. All these advances should benefit future assessments of other stocks as well, as the data collection and analytical advances will largely be applicable.

This report and supporting information are organized in several layers. The discussion in this Overview Report relies largely on the CATCHEM models selected by the Assessment Workshop (AW) as the most appropriate. A write-up of the proceedings of the AW meetings follows as a separate report. During the AW, a number of other models were also used to evaluate the sensitivity to features about the modeling *per se* for which we have uncertainty. These other model are referred to as ASAP (for Age-Structured Assessment Procedure), SRA (for Stock Reduction Analysis), and VPA (for Virtual Population Analysis). Findings from other sensitivity runs are referred to in this Overview Report, and sketched out in the Proceedings Report, but most of the information about these runs has been collected in the Appendices, and in the AW-# working paper series. Of course, the SEDAR process also includes a major document summarizing the recommendations from the Data Workshop (DW), which is included. Electronic versions of documents submitted for consideration by AW and DW are also provided.

A word of warning is warranted concerning interpretation of the MSY benchmarks: In this arena the usage of the term MSY has evolved over the years such that it no longer refers to just a property of the stock, but has now become conditional on selectivity patterns within and among fisheries. Several participants in the AW do not favor this newer usage for the term MSY, feeling that selectivity modifications are more properly treated as part of OY considerations. However, all agree that reporting benchmark evaluations based on different selectivity scenarios provides important insight. Confusion may arise because making different choices about selectivity and benchmark construction leads to some of the biggest differences in statements about stock status in the results. These differences do not imply ‘uncertainty’ in the same sense that we speak of uncertainty due to imprecise knowledge of catches, or steepness, or M, for example. The “uncertainty” among the different MSY metrics is really an uncertainty about what strategies the Gulf of Mexico Fishery Management Council might consider possible or practical, and how they might choose to allocate among competing users. The biggest issue here is interpretation of the impact of the shrimp fishery. The Council may have the authority to decide what it considers ‘bycatch reduction to the extent practical’ per National Standard 9, and then consider status of the stock conditional on that decision. Using the term MSY in that context can result in stock status statements that may seem more ‘favorable’ than the Council is used to seeing for red snapper (although these status findings may be paired with more restrictive advice toward directed fishery futures), while the biological situation is very similar to what has been reported in the past. This usage will work as long as readers understand it, but readers must be 1) careful to recognize what type of benchmarks are being referred to in any instance, 2) understand what each implies about the sorts of management that might be considered, and 3) avoid comparing across benchmarks types using ‘better’ or ‘worse’ evaluations of stock status. To aid the reader and to provide a basis for comparing results of the assessment herein with prior assessment results, we have also provided Spawner per Recruit (SPR) metrics. In this way, it is easier to examine the implications of different allocations between fishing sectors on the current and longer-run depletion of spawning stock. Due to the uncertainty over the true underlying stock-recruitment relationship, SPR proxies for MSY benchmarks, which have been used by the Council, may in fact remain the most robust.

Data Issues and Deviations from Data Workshop Recommendations

All the technical papers in the AW-# series were developed after the data workshop (DW), but most address analyses developed following the DW’s guidance. For this section, comments are generally limited to topics that deviated from DW intent for some reason. For the ultra-historical data, there were no formal recommendations from the DW on how to construct it. (There was some discussion of trying for longer histories in the context of the DW biological parameters discussions to potentially provide an improved basis for estimating (from data) a stock-recruitment relationship, but it was not a topic the DW statistics groups highlighted in the DW report.)

1). Historic Time Series of landings: Details of the reconstruction of an 'ultra-historical' commercial catch series are available in AW-22. Ultra-historical shrimp effort reconstruction is described in AW-23. Figure 1, reproduced from AW-22, highlights the major features of the reconstruction. Based upon comments received and further investigation, there were changes from the 'first cut' at the extended time series available at the first AW session (from Schirripa and Legault 1999) to the time-series used in assessment modeling reported herein.

2). Catch at age modeling: The DW recommended that growth curves be fitted as needed for the AW to allow for region or stratum variations, and that two separate data sets on reproductive parameters be combined for a new analysis. New analyses following these guidelines were presented at the first AW session (as AW-1 and AW-5), and resulted in a picture with more potential production at younger ages than seen in previous assessments. The matrix of catches at age developed using Goodyear's (1997) procedure was compared with the weighted observed age composition (otolith samples available for the 1990s and particularly since the late 1990s); it was noted that the differences in proportions at age appeared larger for the commercial handline than for longline or recreational. It was noted that both the Goodyear probabilistic catches at age and observed catch at age (based on raw frequencies see AW 19) were used for the ASAP analyses while the VPA analyses only used the probabilistic catch at age and CATCHM analyses used on the observed age composition.

3) An alternative index of abundance from the SEAMAP trawl data was developed (AW-25). An index was needed in this form for the Goodyear catch at age procedure. The index was also more similar in nature to indexes used in past assessments than the AW-15 indexes, and so was useful for evaluating continuity using ASAP with updated data.

4) An estimate of M at age 1 was derived as a distribution in AW-15, based on SEAMAP trawl data. The central tendency of this distribution was a bit higher (~0.6 per year) than most participants at the DW had been considering (although the DW had not reached consensus on a value or set of values to recommend).

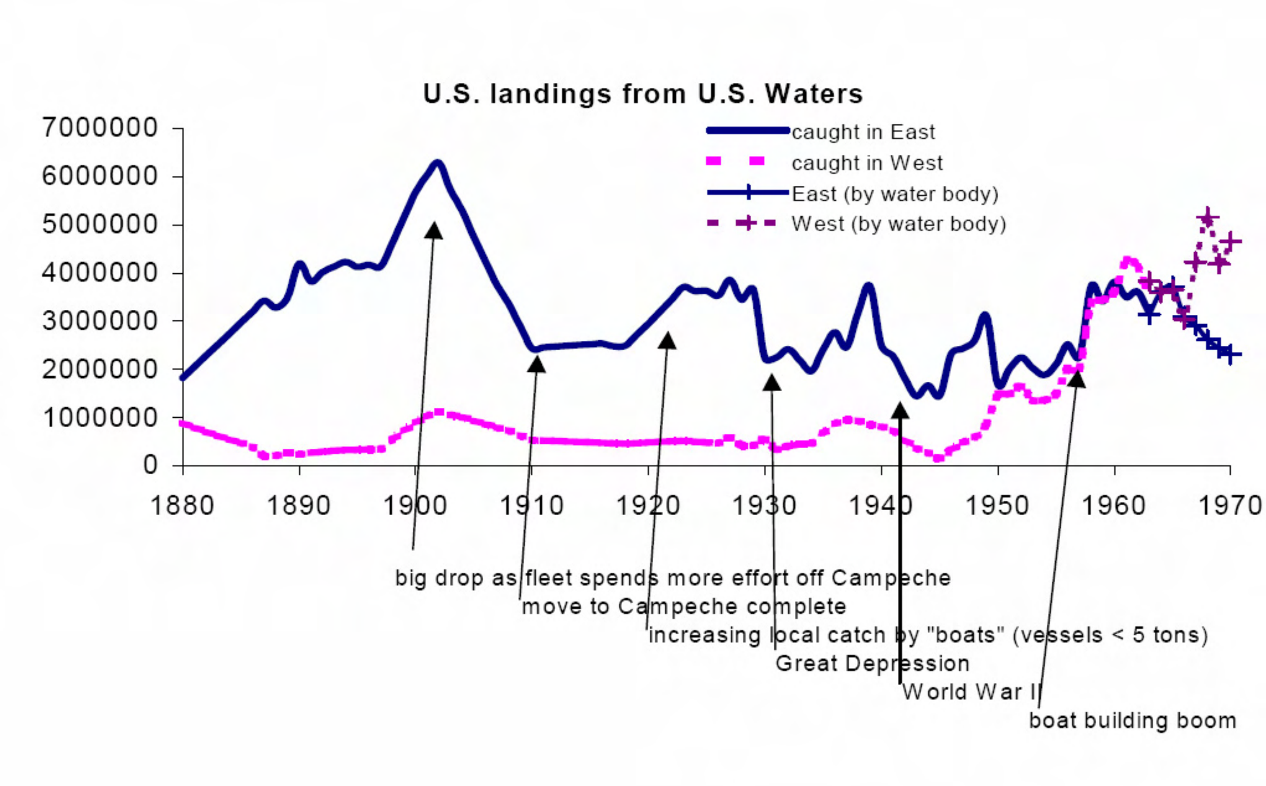

Figure 1. Reconstructed 'commercial' landings (pounds) of red snapper caught in the U.S. Gulf of Mexico (east or west of the Mississippi River) for the years 1872-1962 (lines without symbols) compared to similar statistics for 1963 through 1970 when water body information was recorded (lines with + symbols). Arrows connect trends with important historical events.

Stock Assessment Models and Status of Stock Results

The AW meeting was actually split into two sessions. The first session heard summary presentations of papers following up recommendations from the DW, and took a preliminary look at model results, mainly to understand the properties and sensitivities for the analyses to come later. The second session heard model results from interim analyses, and selected a set of final instructions to those running recommended approaches. For more details of the session discussions, see the "Proceedings" document that follows.

Several modeling approaches were considered, for which there are supporting documents in the Appendixes. In summary, the ASAP model used in the most recent assessments exhibited instability when used to address the "ultra-historical" time series and to a lesser extent with the shorter time series (1962-2003 and 1984-2003). Modifications to the ASAP code have reduced, but not eliminated that instability. The newly developed model, CATCHEM, was selected as the primary model by the AW. CATCHEM is in many ways a generalization of the ASAP approach, with more flexibility, better mathematical rigor due to internalizing the catch at age fitting, and the ability to model geographic substructure. Technical details for the CATCHEM model are described in AW- 6 and AW-27. Discussion during the first AW session about the dangers of confounding between changes in abundance and fluctuations in dome-shaped selectivity patterns resulted in a recommendation that any forward age-structured model results be compared with results from VPA models. The VPA models are described in AW-28 and AW-29. A stock reduction analysis (SRA, also referred to as the Gaming Model, see AW-26 and AW-11, with revisions) was considered, although the model's author (McAllister) recommended it be used primarily to gain insight, and not for management advice calculations. Nevertheless, the contrast between the SRA results and the preliminary results with other models using shorter time series provided impetus for the development of the 'ultra-historical' data series.

Ideally, comparisons among models would be made with identical inputs, but this was not completely possible due to the different modeling structures, and particularly with ASAP, the presence of legacy, 'hard-wired' components that made manipulation difficult. It was also impossible to compare models over every sensitivity case, *i.e*. a 'balanced' set of comparisons. Comparisons chosen reflected those deemed most important by the AW group for examining sensitivities, and for those done subsequent to the second AW meeting, by Miami assessment staff. During the second AW session, the group was satisfied by comparisons between VPA results and CATCHEM results, which indicated that serious confounding between abundance and selectivity changes were unlikely. CATCHEM and SRA results also matched within the limits expected, given the complex vs simple mechanistic structures modeled. Concern about the stability of ASAP, its inability to find a solution in the 'ultra-historical' cases examined, and the difficulties presented by the hard-wired components were important factors which led the AW group to select CATCHEM as the model of choice. However, CATCHEM has a disadvantage: run-times are long, sometimes exceeding 24 hours on even the newest computers. It was not practical to do all sensitivity comparisons suggested within CATCHEM in the available time. Therefore, some of the sensitivity cases were considered only within ASAP (some abundance index exclusions, juvenile M bootstrapping, some steepness values) or VPA (initial age 0 or 1).

CATCHEM model

The CATCHEM model was developed as an alternative to the two-step approach used in prior assessments where the number of fish discarded owing to minimum size limits are determined by use of the 'probabilistic' method of Goodyear (1997) and then used along with indices of abundance in an age-structured model (ASAP or VPA). Ideally, these two steps should not be independent because the indices of abundance contain information on relative cohort strength that is pertinent to the number discarded. Moreover, by accounting for the length structure of the population internally, the CATCHEM approach is able to track the abundance of the fraction of the population that can be landed (is above the size limit), which allows for the use of indices of landings per unit effort such as the time series based on handline logbooks. Another advantage of the CATCHEM approach is that it that can accommodate two (or more) stocks fished by multiple fleets in two (or more) areas. Finally, there are a number of features built into the existing code that were not used in the present assessment (such as fitting to length composition data and accommodating movements between areas) owing to other pressing issues for the current assessment. For further details on the model and statistical algorithm see AW-6 or AW-27. The AD Model Builder code for CATCHEM is listed in Appendix 9.

A number of different runs were made applying the CATCHEM algorithm to catch and effort data extending from 1872 to 2003 (summarized below and in AW-27). In addition, runs were made with shorter data streams, one using only data collected since 1962 and the other using data collected only since 1984, to examine the sensitivity of the outcomes to these variations in time series and assumptions. These are summarized below and presented in more detail in RW 1.

Methods

The CATCHEM algorithm was applied to information on red snapper populations in U.S. waters during the years from 1872 to 2003. Five fisheries were designated for each of two regions (east and west): handline, longline, recreational, closed season discards and shrimp bycatch. Three four-month seasons were modeled, starting in January. Spawning was assumed to occur during the second season. Spawning was also assumed to be independent of natal origins, *i.e.*, there is no site fidelity. Thirty age classes were modeled starting with age 1, with the number of age 1 fish being computed as a Beverton and Holt function of the spawn produced during the preceding year. This approach essentially assumes that the bycatch rate is negligible compared to mortality rate owing to natural density-dependent processes during the first year of life.

Data employed.

The commercial landings from 1963 to 2003 are discussed in AW 17, and the landings prior to 1963 are discussed in AW-22 (Appendix 1.Table 1). The annual recreational harvest since 1981 is based on the NMFS Marine Recreational Fishery Statistical Survey (MRFSS), Texas Parks and Wildlife Survey and NMFS headboat survey as described in AW 3 (Appendix 1.Table 2). The recreational harvest statistics used for earlier years (1946-1980) were reconstructions based on U.S. census data using methods described in AW 16 (Appendix 1.Table 2). It is assumed that prior to 1946 the recreational take was negligible in comparison to the commercial take owing to the relative inaccessibility of the fishing grounds (powered vessels were few and expensive, making offshore trips mostly a pastime for the wealthy). The bycatch of juveniles from the offshore shrimp fishery is based on the series produced in DW-54 and discussed by AW 23, which extends back to 1972 (Appendix 1.Table 4). A time series of offshore shrimping effort, which extends for the entire history of the fishery, was also used to tune the model (see AW-23) (Appendix 1.Table 4). The catch during the closed season was derived as described in AW 18 (Appendix 1.Table 3).

The discards from the recreational and commercial fleets during the open season were assumed to occur predominantly due to the regulations on minimum size. They were computed on a seasonal rather than annual basis to better accommodate the rapid growth exhibited by younger red snapper. The population growth curve and coefficient of variation of length about age were fixed to the values estimated in AW 1.

The CV's used to weight the landings data for model fitting were fixed at 0.1 (an arbitrary low value) for the commercial fleets inasmuch as they represent a near census. The exceptions are for years when no census was taken, in which case the effective CV's were computed from the census estimates immediately before and after the year in question (absolute difference divided by the mean); the reasoning being that the true value likely lies somewhere between those values. The CV's for the recreational catches after 1981 came from the variance estimates produced by the MRFSS (Diaz, pers. comm.); the CV's for the catch inputs prior to 1982 were assigned arbitrary high CVs (1.0) inasmuch as they were not actually observed., but extrapolated based on US human census estimates of Gulf states coastal county populations. The CV's for the shrimp bycatch are based on the CV's of the overall index (ages 0-2), but modified by the proportion that are not age zero (see AW 23). An additional process variance term was not included for the catch, it being assumed under the assumption that process variations in catch are adequately modeled by inter-annual deviations in recruitment and fishing mortality rates.

Ten indices of abundance were used, 5 for each region (east or west) (Appendix 1.Table 5). These include the handline CPUE series based on log books (DW-47), the MRFSS recreational indices (DW-41), SEAMAP larval indices (DW-14), SEAMAP trawl survey (DW 2) and video surveys (DW-15). The handline logbook indices were modeled in this case as landings per unit effort rather than catch per unit effort, thereby taking into account the potential discards owing to the minimum size limit and removing the major objection to their use by the August, 2004 SEDAR panel. The SEAMAP larval indices were assumed to index the effective number of spawners (abundance in number weighted by the relative fecundity at age) and the video surveys were assumed to index the overall stock. The CV's for the indices of abundance are based on the year-specific estimates that come from the GLM-based procedures used to standardize them (see the references cited above). These are regarded as representing observation variance. To this the model adds an internally-estimated process variance term, which is intended to represent random discrepancies between the trends in the indices and the trends in the actual population they purport to track.

The age composition (and effective sample sizes) used for the commercial and recreational fisheries is described in AW 19 and is presented in (Appendix 1, Tables 9 and 10). Inasmuch as the model makes seasonal calculations with spawning occurring during the second season (midyear), the data for each year were aggregated by the actual integer age in years (i.e., it is not necessary to shift the ages by 0.5 to track cohorts as VPA and ASAP must do). The age composition for the shrimp bycatch was based on model output from AW 20 (Appendix 1, Table 11). The age composition used for the closed season is described in AW 18 (Appendix 1, Table 7).

Parameter specifications

The vulnerability and catchability coefficients for each specific fleet were assumed to be relatively unchanged through time, but allowed to vary with age and among fleets. The relative effort of each fleet was allowed to vary by year essentially as a free parameter (thus the effective selectivity across the mix of fleets (*i.e.* the fishery as a whole) varied noticeably through the years). The vulnerability coefficients for the fishery independent surveys were fixed to 0 for age 1 and 1.0 for ages 2 and older (in the case of the larval indices which are taken as indicators of spawner abundance, the numbers at age are weighted by the fecundity at age vector). The release mortality rates for fish below the minimum size were the multi-year regional values shown in Table 6.5 of the Data Workshop Report.

Natural mortality was fixed to 0.6 yr^{-1} for age 1 and 0.1 yr^{-1} thereafter based on prior decisions of the AW participants. The fecundity at age (including maturity) was set to the vector derived from the age-conditioned model described by AW 5, normalized to a maximum value of 1 (at age 30). Thus, the spawning stock estimates, *S*, are *not* the actual number of eggs produced by the population, but should be interpreted as the effective number of fully-productive spawners, *i.e*. the number of eggs produced by the spawning population relative to the number that would have been produced if all of the spawners were 30 years old.

Likelihoods and priors.

The catch, effort, and relative abundance indices were assumed to be approximately lognormal distributed. Age composition was assumed to be multinomial distributed. For stock-recruitment, a lognormal prior (see DW 49) was imposed on the model parameter α (see AW 6 or AW 27) with a median value of 13.3 and log-scale variance of 1.28 (equivalent to a mean steepness of about .86). The remaining parameters were treated as free parameters constrained to lie with bounds that encompassed the range of plausible values (essentially the same as specifying uninformative priors over the feasible range).

Benchmark calculations.

As discussed earlier the potential and standard for recovery depends on the way the benchmark is defined. Several MSY and SPR-based benchmarks were examined here. In all cases the fleet-specific vulnerability patterns used in the projections were set equal to the estimated values (which in this case are constant through time) and the minimum size limits for each fleet were assumed to remain unchanged. Furthermore the relative allocation of effort between east and west is assumed to remain at current levels (2001-2003 average). Equilibrium recruitment is assumed to follow the pattern dictated by the estimated Beverton and Holt spawner-recruit relationship.

Three types of MSY-related reference points were considered. The first assumes that the effort of the directed fleets can be scaled down to maximize long-term landings, but that the shrimp bycatch and closed season discards will continue at current levels (i.e., are not controlled). Hereafter the yield associated with this long-term strategy shall be referred to as MSY{current-shrimp}. The second type defines MSY as the maximum long-term landings that could be achieved in the absence of offshore shrimp trawling, hereafter referred to as MSY{no-shrimp}. The third alternative defines MSY in terms of the entire fishery, assuming the effort of all fleets, both directed and undirected, can be scaled down simultaneously by the same proportion. In previous assessments this has been referred to as the “linked-selectivity” or “policy neutral” approach because all fleets endure the same proportional reduction in effort (technically this is policy-neutral only with respect to red snapper, other important concerns notwithstanding, but lacking a decision on allocations to be divided amongst the shrimp and directed fisheries for guidance). Hereafter this definition shall be referred to as MSY{linked}.

One disadvantage of MSY-based reference points, such as have been discussed so far, is that the corresponding biomass targets change with the vulnerability pattern. For example, the estimates for S_{MSY}{current-shrimp} turn out to be less than half of S_{MSY}{no-shrimp}. Clearly policies based on the former are more risk-prone relative to red snapper than policies based on the latter. Moreover, in cases where one stock is larger and more productive than another, MSY-based policies can sometimes lead to the extirpation of the less productive stock. A more stable and potentially less risky policy might be based on maintaining a particular spawning potential ratio (SPR). While the fishing mortality rate associated with a given SPR ($F_{\%SPR}$) depends on the current vulnerability pattern, the corresponding long-term spawning potential ($S_{\%SPR}$) does not. For this paper the value of $F_{\%SPR}$ is chosen so that the SPR value of the most affected stock is equal to the desired level; the SPR level achieved by the remaining stock being greater than or equal to the desired level.

Sensitivity analyses.

Seven models were considered. The first, model 1, was set up exactly as described above. This was the model selected as the base case by the stock assessment workshop participants. The six remaining models were the same as the base case except for the following changes:

(2) the natural mortality rate on age 1 was reduced to 0.3 yr^{-1}
(3) the logbook-based handline indices were dropped
(4) the length-based fecundity vector was used in place of the age-based version
(5) the steepness was fixed at 0.81
(6) the model was started in 1962
(7) the model was started in 1984.

Note that the use of shorter time series avoids the need for the ultra-historical commercial landings series and, in the case of the 1984-2003 run, also eliminates the need for the ultra-historical recreational harvest series. The disadvantage, of course, is that there is little contrast in the more recent data, making it difficult to obtain reliable estimates of stock status. Moreover, the use of the shorter time series requires information on (or assumptions about) the relative trends in fishing effort for the thirty years prior to the start of the period because the population cannot reasonably be assumed to be near virgin levels (as it was for the 1872 -2003 runs). Otherwise the specifications are the same as for the long time series model and the benchmarks are computed in the same way (defined above).

Results

Model fits to data.

The base model matched the total catch data quite well with the exception of certain unusually high values that happen to have high CV's associated with them (Figure 2). These include the 1983 peak in the eastern recreational catch series and the high shrimp bycatch during some of the early years. The model fit most of the indices of abundance reasonably well (Figure 3), but could not reconcile the increasing trend in the western larval index (representing spawners) with the flat or declining trends indicated by the other western indices. The model fits to the SEAMAP trawl series show a strong residual pattern where the predictions for the early years are considerably lower than the trawl values, but the predictions for the later years are considerably higher. The mismatch for the early years can be attributed the very high CV's associated with those data. The mismatch in more recent years reflects the influence of the bycatch data, which, in the context of relatively constant effort, suggests recruitment generally has increased in recent years. The shrimp effort series were fit very well (Figure 4) owing to the relatively low observation CV's assigned to those data (10%). The fits to the age composition data, aggregated over all years, appear to be quite good (Figure 5). It should be kept in mind, however, that the fits to individual years are noisier, particularly where the sample size was small.

The fits obtained with the six sensitivity models are not shown as they were essentially indistinguishable from the fits of the base model.

Parameter estimates.

The estimated vulnerability and apical fishing rates (*F)* for the base model are shown in Figure 6 (note that the fishing rate is somewhat greater than the fishing *mortality* rate unless all discarded fish die). In general, the vulnerability of red snapper to the recreational and commercial hand line fleets follows a dome-shaped pattern with a peak at age 1 or 2 for the former and at age 5 for the latter. (It should be reiterated that the vulnerability coefficients reflect the probability of being caught and includes undersized fish; the probability of being caught and landed is the vulnerability coefficient multiplied by the probability that a fish is greater than the size limit.) The vulnerability of red snapper to the commercial long line fleet follows a logistic pattern with older animals (10+) being the most vulnerable. The vulnerability patterns for the closed season "fleets" were between the hand line and longline. As expected, age1 fish were much more vulnerable to shrimp trawls than age 2 or older.

The estimated trends in apical fishing rates indicate persistent increase for all fleets. Although the recreational fishing rate in the east appears to have declined markedly in recent years, it remains at rather high levels. The highest rates were exhibited by the western shrimp fishery followed by the eastern recreational and western commercial handline fisheries. Note, however, that the high shrimp bycatch rates applies to a single age group with 100% mortality, whereas the lower apical *F*'s estimated for the handline and recreational fleets apply to multiple age classes where some of the undersized animals that are discarded survive. The trends in apical *F* and vulnerability for the four sensitivity runs were quite similar to the base model.

These data do not suggest a strong relationship between the number of recruits and the effective number of spawners (*S*) in the previous years (see Figure 7). In six of the seven runs the estimates of the maximum potential spawn per recruit (α) were near the limit of 151 imposed by the model, which translates to a steepness of 0.974 and in the seventh (1962-2003) the estimate was quite similar (0.96).

Estimated population trends.

The estimates of historical trends in the effective number of spawners and age 1 recruits are shown for the long time series in Figure 7. Under pristine conditions, the western population of red snapper in U.S. waters is estimated to have been about three times as large and three times as productive as the eastern population. The eastern population, which was fished hard early in the 1900's, shows the first signs of decline. The western population is not estimated to have declined substantially until the 1950's. By the 1980's both populations had been seriously depleted and were below the level required to maintain MSY. The extent of the depletion, of course, depends on the way in which MSY is defined (see results in the projection section). Table1 provides various stock status and fishing condition indicators.

The absolute estimates of the number of spawner and number of recruits from the shorter time series are quite similar to the estimates from the long time series (Figure 8). What differs is the perception of potential production and stock status. While all of the models estimate that steepness values of 0.96 or higher, the models based on the shorter time series give estimates of the virgin level of recruitment and MSY that are several times larger than the corresponding values estimated by the models based on the longer time series (see Table 1). On the other hand, the shorter time series also gave rise to higher estimates for S_{MSY}. In summary, the short time series suggest that the stock is much more productive, but also more heavily overfished.

Results More Directly Related to Management Advice

Existing Definitions and Standards

Status determination criteria include a Minimum Stock Size Threshold (MSST), *i.e.*, the overfished criterion, and a Maximum Fishing Mortality Threshold (MFMT), *i.e*, the overfishing criterion. Together with MSY and optimum yield (OY), these 2 parameters are intended to provide fishery managers with the tools to measure fishery status and performance.

Amendment 22 (May 2004) of the Gulf Council's Reef Fish Fishery Management Plan provides the preferred definitions of the overfishing criterion (MFMT) and overfished criterion (MSST) for the Gulf of Mexico red snapper resource. Within that amendment, red snapper MSST is defined as: (1-M) *B_{MSY}, where M is the adult natural mortality rate (0.1), and red snapper MFMT is equal to F_{MSY}. As such, the red snapper resource would be considered undergoing overfishing if F_{CURR} is greater than MFMT and the red snapper resource would be considered overfished if B_{CURR} is less than MSST.

For overfished stocks, a recovery plan must be developed to end overfishing and restore the stock to the biomass level (B_{MSY}) capable of producing maximum sustainable yield (MSY) on a continuing basis. Rebuilding is to occur in as short a time period as possible, but should not exceed 10 years unless conditions dictate otherwise.

Stock Status

Overfishing Definitions and Recommendations.

Under the Council's preferred definition for MFMT (overfishing criterion), the red snapper resource in the US Gulf of Mexico is considered to be undergoing overfishing as our best characterization of the resource from the base model results indicate $F_{2003}>F_{MSY}$ regardless of the form of benchmark calculation (Table 1). The *degree* of overfishing is sensitive to the form of benchmark calculation employed and also is sensitive to steepness and the length of the time-series of data used in the CATCHEM formulation (Figure 9). Other model applications which are not judged as adequate for this stock evaluation provide a broader set of status outcomes (see Appendices). Due to concern over our ability to estimate MSY related benchmarks for red snapper because the underlying stock-recruit relationship is not well determined, a proxy such as $F_{30\%SPR}$, which is consistent with the Council's generic F_{MSY} proxy used for other Reef Fish, may well be more robust for management purposes. In this case, the base model outcomes would still imply overfishing is occurring, although the degree of overfishing would generally be greater..

Overfished Definitions and Recommendations.

Under the Council's preferred definition for MSST (overfished criterion), the red snapper resource in the US Gulf of Mexico is considered to be overfished as the base model results indicate $S_{2003}<.9S_{MSY}$, regardless of the form of benchmark calculation (Table 1). The *degree* of depletion is sensitive to the form of MSY benchmark calculation and to the steepness and time-series of data assumed in the CATCHEM formulation (Figure 9). Other model applications which are not judged as adequate for this stock evaluation provide a broader set of status outcomes (see Appendices). As with the Overfishing Definition, there is concern over our ability to estimate MSY related benchmarks for red snapper because the underlying stock-recruit relationship is not well determined. As such, an MSST definition using a B_{MSY} proxy such as $B_{30\%SPR}$ ($S_{30\%SPR}$ in the CATCHEM jargon) may well be more robust for management purposes.

Control Rule and Recommendations

The rebuilding strategy now adopted by the Council calls for maintaining TAC at 9.12 mp, ending overfishing between 2009 and 2010, and rebuilding red snapper by 2032, with review and adjustment of this policy, as necessary, through periodic assessments while continuously monitoring annual landings to ensure quota is not exceeded. The current assessment indicates that the goals of this policy may not be met and adjustment could be necessary. Stock projections over a wide range of benchmark and future human-induced mortality scenarios are provided in the subsequent section.

Projection methods and assumptions.

The future course of the red snapper population and fishery was modeled through 2032 using the population dynamics equations described in AW-27. Only deterministic projections were made; the stock assessment workshop participants felt that stochastic projections would not be particularly helpful in view of the other uncertainties related to choice of models and reference points.

Future recruitment is assumed to follow the pattern dictated by the estimated Beverton and Holt spawner-recruit relationship. The fleet-specific vulnerability patterns used in the projections were set equal to the estimated values and the minimum size limits for each fleet were assumed to remain unchanged. Until 2007, the effort exerted by the directed fleets (commercial and recreational) was set so as to achieve landings equal to the current TAC of 9.12 million pounds (mp). Subsequently, effort was either fixed to various levels (including zero, "current", and several different benchmarks relating to MSY and spawning potential ratio) or determined numerically by matching an imposed catch quota (TAC) on the directed component of the fishery. In case of the latter, it was not always possible to achieve the higher TACs for all of the projection years. In such cases the model selects a catch schedule as close to the TAC as possible without completely extirpating the stock before 2032. In deriving this schedule, the model assumed that the fishery is more likely to attempt to meet the quota during the earliest years of the projections than in subsequent years.

The effort exerted by offshore shrimp trawlers was set equal to "current levels" (2001-2003 average). In some projections the shrimp effort (not bycatch) was reduced by various percentages beginning in 2007. Closed season effort was assumed to remain at the 2001-2003 average regardless of the way the directed fishery was managed. In point of fact the duration of the closed season will likely increase with decreases in TAC, so the number of red snapper discarded may also increase. However, the extent of the increase is unclear owing to the vagaries of human behavior. Inasmuch as the matter was not discussed by the assessment panel participants, it was assumed that closed season effort would be relatively unaffected by the magnitude of the TAC.

Projection results

Projected trends in the effective number of spawners and total landings from the base model are shown under various scenarios in Figure 10. The spawning stock reference points in this figure is S_{MSY}\{current-shrimp\}, which assumes only the effort of the directed fleets can be scaled down to maximize long-term landings while the shrimp bycatch and closed season discards continue at current levels. The corresponding values of MSY{current-shrimp} are estimated to be about 3million lbs for the east and 3.4 million lbs for the west (the value for the west is similar to the value for the east owing to the much larger western shrimp bycatch). The effective number of spawners in the eastern and western populations are estimated to have been reduced in 2003 to 39% and 50%, respectively, of S_{MSY}\{current-shrimp\}. The effective spawner levels associated with the S_{MSY}\{current-shrimp\} benchmark equates to 12.9% and 5.2% of unfished levels in the east and west, respectively. The effective spawner estimates for 2003 equate to ~5% in the east and ~2.5% in the west relative to unfished conditions (Table 1). The current fishing mortality rate exerted by the directed fleet is estimated to be about 2.3 times greater than F_{MSY}\{current-shrimp\}benchmark. Not surprisingly, the projections indicate that the current TAC of 9.12 million lbs (Figure 10a) is not sustainable. Current levels of effort (Figure 10b) may be sustainable, but the model predicts the population will be driven to even more dangerously low levels. The 9.12 million lb TAC may be sustainable with a severe reduction in shrimp bycatch (Figure 10c), but the spawning stock would remain well below S_{MSY}\{current-shrimp\}. On the other hand, the spawning stock is projected to recover to the S_{MSY}\{current-shrimp\} standard in less than ten years in the absence of any directed harvest (Figure 10d, assuming closed season discarding does not increase). Generally speaking, similar estimates of the current and projected status of the stock were obtained with the sensitivity models (see Table 1 and Figure 11).

As mentioned previously, the recovery targets depend on the way MSY is defined. In the results just considered (Figures 10 and 11), MSY was defined as the maximum long-term landings that could be achieved with current levels of offshore shrimp trawling and closed season bycatch, *i.e.*, MSY{current-shrimp}. An alternative is to define MSY as the maximum long-term landings that could be achieved in the absence of offshore shrimp trawling, *i.e.*, MSY{no-shrimp}. In that case the estimates for MSY{no-shrimp} are greater (3.7 million lbs for the east and 9.2 million lbs for the west), but the corresponding value of S_{MSY}\{no-shrimp\} is also greater (Figure 12a and Table 1). The effective spawner levels associated with the S_{MSY}\{no-shrimp\} benchmark equates to 13.6% and 11.3% of unfished levels in the east and west, respectively. As a result of using this benchmark definition, the stock condition is estimated as even more overfished; the estimates of the effective number of spawners in 2003 for the east and west are only 37% and 21% of S_{MSY}\{no-shrimp\}, respectively (Table 1). Current levels of directed fleet fishing mortality are estimated to be 2.1 times greater than F_{MSY}\{no-shrimp\}.

The third alternative, MSY{linked}, which scales the effort of all fleets (directed and bycatch) by the same proportion, paints an even less optimistic picture of stock status because it assumes closed season discards can also be scaled back. The estimates of MSY{linked} for the east and west are 3.7 and 8.4 million lbs, respectively. Spawning levels in 2003 for the east and west are estimated to be 16% and 10% of S_{MSY}\{linked\}. The effective spawner levels associated with the S_{MSY}\{linked\} benchmark equates to 30.3% and 24.3% of unfished levels in the east and west, respectively. Current levels of fishing mortality across all fleets (shrimp and directed) are estimated to be about 3.6 times greater than F_{MSY}\{linked\}.

Projections of the base model suggest that, whichever definition of MSY is adopted, the spawning stock will recover by 2032 (Figure 12a) provided the various fleets fish at the corresponding F_{MSY} level (Figure 12a). It must be emphasized, however, that this rate of recovery is made possible by the series of strong year classes (greater than expected from the spawner recruit relationship) estimated to have occurred over the last decade. If the recent recruitment levels are not as high as indicated, then recovery will take very much longer unless fishing is further reduced. Moreover, if the future effort levels for some components of the fishery are higher than those associated with F_{MSY}, then the initial recovery, if achieved, to S_{MSY} may not be sustainable. For example, if managers were to select MSY{no-shrimp} or MSY{linked} targets, but the shrimp fishery continued at current levels, then S_{MSY} will not be achieved (Figure 12b).

Trajectories of yield and relative spawning potential for SPR levels of 5%, 10% and 20% are shown in Figure 13. The trends under the F_{MSY}\{current-shrimp\} policy closely match the trends under an $F_{5\%SPR}$\{current-shrimp\}, while the trends for the F_{MSY}\{no-shrimp\} policy look more like the trends for the $F_{10\%SPR}$\{current-shrimp\} policy. SPR levels greater than 20% cannot be attained under current levels of offshore shrimp effort even with no directed harvest. Generally speaking, policies based on maintaining such low SPR values are regarded as extremely risk prone for most stocks.

As mentioned previously, the SEDAR stock assessment workshop participants selected Model 1 as the most plausible of the formulations presented. They requested additional projections of that model under various total allowable catch (TAC) and constant *F* scenarios. These are summarized as isopleths of S/S_{MSY} and S/S_0 (which is essentially the same as SPR for the high steepness cases). Figure 14 presents S/S_{MSY} and S/S_0 isopleths generated from short-term projections to the year 2010 under various levels of TAC (Gulf-wide total allowed landings) and percent reductions in effective offshore shrimp effort. Here MSY (and S_{MSY}) are conditioned on the current state of the fishery as described for MSY{current-shrimp}, except with a presumed reduction in offshore shrimp effort. In Figure 14a the presumed reduction in offshore shrimp effort used to compute MSY was fixed at 40% for all projections. Accordingly, the graph should be interpreted as an indication of what might happen if managers based the MSY definition on an assumed 40% reduction in shrimp effort but the actual reduction in shrimp effort was as indicated on the horizontal axis (note that, by this definition, MSY cannot be achieved unless the actual reduction in shrimp effort at least 40%). In Figure 14b, the presumed reduction in offshore shrimp effort used to compute MSY varied with the value indicated on the horizontal axis. Hence, the graph should be interpreted as an indication of what might happen if managers based the MSY definition on the actual reduction in offshore future shrimp effort (implying that managers can either control or accurately forecast future shrimp effort). The S/S_{MSY} isopleths in Figure 14b decrease with reduced shrimp effort rather than increase as in Figure 13a because the denominator S_{MSY} used to generate Figure 14b also increases with reduced shrimp effort (*i.e.* a changing baseline).

Figure 14 suggests that the current TAC of 9.12 million pounds cannot be sustained and will lead to continued depletion of the stock. Reductions in the offshore shrimp fleet have little impact on the projections for the east, but substantially impact the recovery in the west. However, even with zero shrimp effort, the TAC would need to be decreased to under 3 million lbs in order to bring about a full recovery within the next five years. Perhaps more importantly, the projected values of S/S_0 are very low and would not be expected to increase above 15 percent within 5 years even with no fishing. The situation is somewhat more optimistic with a longer recovery time (Figures 15a and 15b). The graphs suggest a full recovery is possible by 2032 if the TAC is reduced to about 6 million lbs regardless of what occurs in the shrimp fishery (slightly larger TACs may be permissible if the offshore shrimp fleet effort is reduced). Values of S/S_0 of 20% or better are possible be achieved in 2032 with TACs between 2 and 3 million pounds and shrimp effort reductions of 40% to 50%.

Figures 16 and 17 show isopleths similar to those above, but for various levels of directed fishery mortality rate (expressed as a fraction of current levels). The implications, of course, are similar to the TAC-based isopleths. Current levels of effort in the directed fishery will keep both the eastern and western stocks depressed below 5% of S_0 regardless of what happens in the offshore shrimp fishery. Modest S/S_0 values of even 20% cannot be achieved for the western stock by 2032 unless the directed fishing effort is reduced by 90% and the offshore shrimp effort is reduced by 80% or more (Figure 17).

Discussion

Previous assessments (since the early 1990's) of gulf red snapper indicated the stock was overfished and undergoing overfishing by different standards (either SPR or linked selectivity MSY benchmarks). Based on previous assessments, it was determined that even if the directed fishery was closed and all juvenile red snapper bycatch from the shrimp fishery was halted, rebuilding to B_{MSY} levels would exceed 10 years. The longest rebuilding period recommended by the National Standard Guidelines is the time to recover in the absence of fishing mortality plus the mean generation time which was previously estimated as 19.6 years for red snapper. The Gulf of Mexico Fishery Management Council thus set a recovery target date of 2032 or earlier for the stock. This rebuilding timeline and threshold replaced the previously (in 1996) established rebuilding schedule for red snapper, which required adjustment of total allowable catch (TAC) biannually to maintain a rebuilding trajectory that rebuilds the red snapper stock to 20 percent transitional SPR by 2019. The rebuilding strategy now adopted by the Council calls for maintaining TAC at 9.12 mp wwt (whole weight), ending overfishing between 2009 and 2010, and rebuilding red snapper by 2032, with review and adjustment of this policy, as necessary, through periodic assessments while continuously monitoring annual landings to ensure quota is not exceeded.

Depending upon the selectivity standard used for benchmark calculations, it is no longer clear that the red snapper resource would require more than 10 years to rebuild. This result was also evident in an independent assessment conducted by Rothschild *et.al.* (1997), which ignored shrimp bycatch. Rebuilding to the lowest biomass standards (those associated with the assumption that current shrimp mortality levels shall not be further reduced), could be achieved in the near future if the directed fishery were sufficiently restrained. However, this implies that the stock need only rebuild to about 5% of the unfished level in the west and about 13% in the east. As noted above such low percentages of the unfished condition are usually considered risky.

Other model results are available in the Appendices and the working documents. These other model applications, which were not judged by the AW participants as adequate for this stock evaluation, provide a broader set of status outcomes than the base model and its associated sensitivity evaluations described above. These results are used in the discussion that follows. More technical detail is available in the Appendices.

The CATCHEM base model fits almost all data presented to it very well. The primary exception is the West larval SEAMAP index, which indicates a strong increasing trend that runs counter to the direction indicated by the other indices. Also the model consistently underestimated the value of some of the higher bycatches. It was suggested that this could be an indicator of post-recruit density dependence, but the points that were poorly fit have very large variances and it is likely that pattern seen is partly a consequence of having to fit landings data with much smaller CVs Nevertheless, it appears that one does not need to invoke additional mechanisms to fit the existing data. CATCHEM appears to have finessed any post-recruitment density dependence with its age 1 start; the problems fitting the historical series without invoking density dependence encountered with the SRA models were not evident in the CATCHEM results. The cost is that any information (and potential production) associated with age 0 snapper is not available.

Nearly all of the CATCHEM runs estimated steepness values near 0.97, essentially the upper bound of the built-in constraints. However, one of the more interesting results with CATCHEM comes from a sensitivity run setting steepness=0.81, rather than allowing internal fitting. Stock status results are qualitatively similar with both steepness conditions within comparable benchmarks. Apparently, the ultra-historical approach has resulted in estimates of stock productivity that are much less sensitive to steepness than seen in past assessments. On the other hand, the estimates of productivity from the CATCHEM model are very sensitive to the duration of the time series used (1872, 1962, or 1984). The estimates of MSY{current-shrimp}, for example, were on the order of 6 mp (east and west combined) when the 1872-2003 time series was used and over 20 mp when the shorter time series were used. In the case of the latter, such high estimates for MSY are difficult to reconcile with the concomitant estimation of an overfished status because the landings in the historical records prior to 1962 are very much less than 20 mp. Hence, if the estimates from the shorter time series are to be believed, then either the historical landings were under-estimated several fold or else there has been a change in the underlying productivity of the stock. The first hypothesis seems unlikely owing to the limited number of fish houses extant prior to the 1960’s. On the other hand, mechanisms that would account for a four or five-fold increase in the productivity of the stock are also difficult to envisage. It should also be noted that the solution surfaces for the models based on the shorter time series do not appear as well behaved as those for the models based on the longer time series owing to the lack of contrast in the data; there appear to be several local minima with nearly the same value of the objective function, but very different implications for stock status. Hence, the absolute estimates of productivity from the short time series are rather uncertain and should be interpreted with caution. Nevertheless, the hypothesis that the productivity of the stock has increased in recent years is not inconsistent with the results from the models applied to the longer time series, which indicate that the recruitment levels over the last 20 years were the highest in the history of the fishery despite the very low number of spawners.

Within the ASAP assessment model framework, steepness was fixed at three values: 0.81, 0.90, and 0.95. Almost without exception, the status plots show that the point for steepness = 0.81 is the least overfished (relatively speaking) with the least amount of overfishing occurring. Status for higher steepness values veer diagonally up and to the left from steepness = 0.81 (i.e., toward more overfished and greater overfishing). This is logical, because a lower steepness indicates that the stock has greater potential to recover as stock size increases; or in other words, the higher the steepness value, the less distance there is between current recruitments and virgin recruitment levels. The extreme case is visible in the VPA runs, where steepness is ~1 (indicating near constant recruitment). The variability in VPA runs within a given plot and for a given age of recruitment (assumed to be 0 or 1) is due primarily to whether R_0 was estimated or fixed to a level that corresponds to 8.5 times the three year average low for the time series (1984-2003). In this case, the fixed R_0 sets the virgin benchmark higher, and therefore relative SSB values are shifted to the left (towards greater overfished status); there is much less vertical shift in the overfishing status. Within each fixed steepness, the whole-Gulf ASAP results suggest much less R_0 variation with starting year than CATCHEM for 1962 and 1984 starts, but ASAP could not reach a solution for the 1872 start. The age 0 (ASAP) vs age 1 (CATCHEM) starts may be some of the source of this differencing, but it seems likely that most of this variation represents different placement of some fundamental uncertainties or incompleteness by the two models.

The ASAP models suggest that the perception of stock status is rather sensitive to the level of natural mortality on juvenile (age 0 and 1) red snapper, particularly when steepness is low. The bootstrapping analyses of the ASAP applications to the 1962-2003 Gulf wide time series (RW-5) show that, in general, the status of the stock appears more to be overfished and overfishing appears more likely with increased M. The CATCHEM formulation was much less sensitive to changes in M, starting as it does with age 1 (rather than age 0). Both the CATCHEM and ASAP models provided the best fits to the data with higher levels of early natural mortality, irrespective of steepness values.

VPA was the only assessment model to explore two different ages of recruitment—age 0 or age 1. ASAP looked only at age 0, and CATCHEM looked only at age 1. Stock Reduction Analyses conducted at the AW meeting suggested this to be an important source of variability in status and benchmark estimation, but that work was conditioned upon the ASAP model outcomes, and so it is less clear if the results can be generalized. Modeling the population with recruitment at age 1 is a way of acknowledging that bycatch mortality on age 0, whether additive or compensatory, cannot be estimated apart from natural mortality; thus, all mortality between age 0 and 1 gets combined into the estimates of the stock recruit parameters. For Gulf-wide and East model applications, the status for assuming age 1 recruitment (ignoring age 0 fishery-induced mortality) is shifted to the right of age 0 points, i.e. less overfished. There is also a slight shift downward in the biomass status point, i.e. less overfishing, but this is much less than the shift in overfished status. The pattern in the west model is different, most likely because the western gulf is where the majority of the bycatch occurs. When R_0 is estimated, the status for the model application using age 1 recruitment is to the ***left*** (more overfished) of the age 0 recruitment point. A possible explanation for this is that when the model begins at age 1, it does not have information on the age 0 recruits lost to bycatch and therefore assumes a much less productive stock. The reverse pattern is seen when R_0 is fixed to 8.5 times the 3 year average low recruitment level. In these cases, the status estimated from models with age 1 recruitment is to the right (less overfished) of the age 0 models. This pattern is the opposite of when R_0 was estimated, but it is not a contradiction—in this case, the model already has information that recruitment productivity is high (because it is fixed high).

SRA results were conditional on several ASAP derived inputs, and therefore do not represent a completely independent set of results. However, the model was deemed to provide several important insights.

The SRA model could not fit a plausible trajectory for the 1872-forward period without invoking post-recruitment density dependence. Adding density dependence at either age 1 or age 2 did allow a plausible trajectory, and producing results similar to the ASAP and VPA results presented at the AW. With density dependence, shrimp bycatch reduction had little impact on future trajectories. Recovery by 2032 required a reduction in TAC, and failing to reduce TAC led to a collapse within the next 10 years under this model.

Comparison with past recommendations

Red snapper has been assessed since at least the early 1990s, and the Gulf of Mexico Fishery Management Council's Reef Fish Stock Assessment Panel (RFSAP) recommended appropriate biological catch (ABC) levels multiple times between 1990 and 1999 (Table 2; RFSAP 1990a, 1990b, 1992, 1993, 1995, 1999a and 1999b). Given assumed reductions in shrimp fishery bycatch of 40-50%, the RFSAP recommended ABCs ranging from 0 to 10 million pounds (most were 0 to 6mp) to be able to rebuild the spawning stock to the 20%-30% SPR level within one to three decades. The CATCHEM projections presented above are similar to several of those recommendations in that with 40-50% reductions in shrimp effort and a directed fishery TAC of 2 to 3 million pounds the spawning stock is projected to rebuild to 20% SPR by 2032. It is noteworthy that the shrimp fishery fishing mortality rate has already declined roughly 20% from the 1984-1989 level. Thus this assessment indicates that greater reductions in shrimp effort are needed than projected in the earlier assessments.

Issues of Particular Concern

The new CATCHEM results, which free the management advice to some extent from steepness assumptions, probably rest on the ultra-historical catch series. Supporting documents for the series were sparse, but it seems unlikely that any additional information exists to improve the series. However, the management advice, at least over the short term, appears reasonably consistent among different starting years for the models, and remains generally consistent with advice from past assessments. It therefore seems unlikely that there could be strong misleading guidance resulting from the new analysis. However, it was also clear that the question of the ultimate productivity attainable from this stock was not settled by the ultra-historical approach.

The unexpectedly high value for steepness, high estimates for recruitment since the 1970's, and the sensitivity of R_0 to starting year (but not to steepness) in CATCHEM suggests that there are still important, unmodeled dynamics affecting the long-term variation in snapper abundance. Several possible mechanisms were discussed at the workshop, but at present, all should be consider speculations. The mechanisms mentioned (not exhaustive) included density-dependent mortality in (post-recruit) juveniles; density-dependent mortality in adults; delayed density dependence (adults *vs.* juveniles); changing M over time, not related to snapper density (reduced predator abundances); increasing carrying capacity over time for pre-recruits (oceanographic regime change); increasing carrying capacity over time for adults (oil rigs or other habitat expansions); and stock extending geographically well beyond assumed range (Campeche connection). These are all valid research topics for the next several years, and at this point it seems premature to focus on one to the exclusion of the others. Current data seem unlikely to support serious estimation for any of these effects.

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Table 1. Management benchmarks and stock status indicators for red snapper in the eastern and western Gulf of Mexico from seven CATCHEM runs and under three benchmark selectivity patterns. from seven CATCHEM runs including the base case and six sensitivity tests.

					S/Smsy					F/Fmsy					S/S0					Benchmarks			Current Status	
Area	Model- run	assumption	Benchmark selectivity	Estimated R0 (millions)	1872	1962	1984	1999	2003	1872	1962	1984	1998	2003	1872	1962	1984	1998	2003	MSY (mp)	Smsy	SMSY/S0	Over- fished?	Over- fishing?
east	CATCHEM-1	Base	linked	2.2	3.35	1.03	0.17	0.09	0.16	0.06	1.52	4.99	2.69	3.59	1.00	0.31	0.05	0.03	0.05	3.73	1.80	0.30	yes	yes
east	CATCHEM-1	Base	no-shrimp	2.2	7.64	2.35	0.40	0.21	0.37	0.03	0.80	2.62	1.41	2.08	1.00	0.31	0.05	0.03	0.05	3.69	0.79	0.14	yes	yes
east	CATCHEM-1	Base	curr-shrimp	2.2	8.07	2.49	0.42	0.22	0.39	0.04	0.87	2.85	1.54	2.31	1.00	0.31	0.05	0.03	0.05	3.01	0.75	0.13	yes	yes
west	CATCHEM-1	Base	linked	6.8	4.20	1.97	0.24	0.11	0.10	0.00	0.51	2.89	2.78	3.59	1.00	0.47	0.06	0.03	0.02	8.37	4.53	0.24	yes	yes
west	CATCHEM-1	Base	no-shrimp	6.8	9.35	4.39	0.54	0.25	0.21	0.00	0.25	1.41	1.36	2.08	1.00	0.47	0.06	0.03	0.02	9.22	2.03	0.11	yes	yes
west	CATCHEM-1	Base	curr-shrimp	6.8	21.80	10.24	1.26	0.57	0.49	0.00	0.27	1.52	1.46	2.31	1.00	0.47	0.06	0.03	0.02	3.41	0.87	0.05	yes	yes
east	CATCHEM-2	M 0.3 on age 1	linked	1.6	3.45	1.07	0.19	0.09	0.17	0.06	1.37	4.36	2.78	3.59	1.00	0.31	0.06	0.03	0.05	3.91	1.79	0.29	yes	yes
east	CATCHEM-2	M 0.3 on age 1	no-shrimp	1.6	8.11	2.52	0.46	0.21	0.39	0.03	0.70	2.24	1.42	2.03	1.00	0.31	0.06	0.03	0.05	3.83	0.76	0.13	yes	yes
east	CATCHEM-2	M 0.3 on age 1	curr-shrimp	1.6	8.57	2.67	0.48	0.22	0.41	0.03	0.78	2.48	1.58	2.30	1.00	0.31	0.06	0.03	0.05	3.03	0.72	0.12	yes	yes
west	CATCHEM-2	M 0.3 on age 1	linked	5.7	4.09	1.95	0.23	0.10	0.09	0.00	0.49	2.96	2.86	3.59	1.00	0.48	0.06	0.02	0.02	9.01	5.23	0.25	yes	yes
west	CATCHEM-2	M 0.3 on age 1	no-shrimp	5.7	8.90	4.23	0.49	0.21	0.19	0.00	0.23	1.40	1.35	2.03	1.00	0.48	0.06	0.02	0.02	10.47	2.41	0.12	yes	yes
west	CATCHEM-2	M 0.3 on age 1	curr-shrimp	5.7	22.29	10.59	1.23	0.54	0.48	0.00	0.25	1.52	1.47	2.30	1.00	0.48	0.06	0.02	0.02	3.50	0.96	0.05	yes	yes
east	CATCHEM-3	No Logbook Indices	linked	2.2	3.52	1.03	0.18	0.10	0.17	0.07	1.65	5.17	2.49	3.43	1.00	0.29	0.05	0.03	0.05	0.00	1.68	0.29	yes	yes
east	CATCHEM-3	No Logbook Indices	no-shrimp	2.2	8.18	2.40	0.41	0.23	0.40	0.04	0.87	2.73	1.31	1.99	1.00	0.29	0.05	0.03	0.05	3.58	0.72	0.13	yes	yes
east	CATCHEM-3	No Logbook Indices	curr-shrimp	2.2	8.56	2.51	0.43	0.24	0.42	0.04	0.95	2.98	1.43	2.22	1.00	0.29	0.05	0.03	0.05	2.92	0.69	0.12	yes	yes
west	CATCHEM-3	No Logbook Indices	linked	6.8	4.09	1.95	0.24	0.11	0.10	0.00	0.52	2.95	2.79	3.43	1.00	0.48	0.06	0.03	0.02	0.00	4.68	0.25	yes	yes
west	CATCHEM-3	No Logbook Indices	no-shrimp	6.8	8.51	4.05	0.50	0.23	0.21	0.00	0.26	1.47	1.39	1.99	1.00	0.48	0.06	0.03	0.02	9.59	2.25	0.12	yes	yes
west	CATCHEM-3	No Logbook Indices	curr-shrimp	6.8	19.41	9.25	1.14	0.52	0.48	0.00	0.28	1.59	1.50	2.22	1.00	0.48	0.06	0.03	0.02	3.62	0.99	0.06	yes	yes
east	CATCHEM-4	Fecundity Calculation	linked	2.1	3.41	1.05	0.19	0.11	0.18	0.06	1.52	4.85	2.73	3.59	1.00	0.31	0.05	0.03	0.05	3.74	1.57	0.30	yes	yes
east	CATCHEM-4	Fecundity Calculation	no-shrimp	2.1	7.65	2.36	0.42	0.25	0.40	0.03	0.80	2.57	1.45	2.10	1.00	0.31	0.05	0.03	0.05	3.70	0.70	0.14	yes	yes
east	CATCHEM-4	Fecundity Calculation	curr-shrimp	2.1	8.09	2.50	0.44	0.26	0.42	0.04	0.88	2.81	1.58	2.33	1.00	0.31	0.05	0.03	0.05	3.01	0.66	0.13	yes	yes
west	CATCHEM-4	Fecundity Calculation	linked	6.8	4.28	2.05	0.26	0.12	0.11	0.00	0.51	2.86	2.76	3.59	1.00	0.48	0.06	0.03	0.03	8.39	3.95	0.24	yes	yes
west	CATCHEM-4	Fecundity Calculation	no-shrimp	6.8	9.42	4.51	0.57	0.26	0.24	0.00	0.25	1.41	1.36	2.10	1.00	0.48	0.06	0.03	0.03	9.19	1.80	0.11	yes	yes
west	CATCHEM-4	Fecundity Calculation	curr-shrimp	6.8	21.96	10.51	1.32	0.60	0.55	0.00	0.27	1.51	1.46	2.33	1.00	0.48	0.06	0.03	0.03	3.41	0.77	0.05	yes	yes
east	CATCHEM-5	low steepness	linked	2.8	3.10	0.98	0.20	0.10	0.19	0.07	1.64	4.53	2.16	3.11	1.00	0.31	0.06	0.03	0.06	3.38	2.55	0.36	yes	yes
east	CATCHEM-5	low steepness	no-shrimp	3.1	6.22	2.18	0.41	0.20	0.34	0.03	0.71	2.26	1.18	2.03	1.00	0.35	0.07	0.03	0.05	3.72	1.41	0.21	yes	yes
east	CATCHEM-5	low steepness	curr-shrimp	2.8	5.06	1.59	0.32	0.17	0.31	0.05	1.11	3.06	1.46	2.75	1.00	0.31	0.06	0.03	0.06	2.72	1.57	0.24	yes	yes
west	CATCHEM-5	low steepness	linked	7.8	3.44	1.79	0.30	0.12	0.14	0.00	0.51	3.05	2.97	3.11	1.00	0.52	0.09	0.04	0.04	6.36	6.38	0.33	yes	yes
west	CATCHEM-5	low steepness	no-shrimp	9.0	4.53	2.43	0.41	0.15	0.18	0.00	0.29	1.84	1.71	2.03	1.00	0.54	0.09	0.03	0.04	9.94	5.59	0.27	yes	yes
west	CATCHEM-5	low steepness	curr-shrimp	7.8	12.90	6.72	1.13	0.47	0.52	0.00	0.31	1.84	1.79	2.75	1.00	0.52	0.09	0.04	0.04	2.39	1.70	0.13	yes	yes
east	CATCHEM-6	Start in 1962	linked	5.0	-	0.08	0.06	0.03	0.06	-	6.30	6.10	3.61	4.39	-	0.03	0.02	0.01	0.02	9.33	4.74	0.34	yes	yes
east	CATCHEM-6	Start in 1962	no-shrimp	5.0	-	0.16	0.11	0.07	0.13	-	3.48	3.37	2.00	2.68	-	0.03	0.02	0.01	0.02	9.03	2.33	0.17	yes	yes
east	CATCHEM-6	Start in 1962	curr-shrimp	5.0	-	0.16	0.12	0.07	0.13	-	3.83	3.71	2.20	2.99	-	0.03	0.02	0.01	0.02	7.48	2.23	0.17	yes	yes
west	CATCHEM-6	Start in 1962	linked	25.3	-	0.03	0.04	0.02	0.02	-	4.83	3.94	3.03	4.39	-	0.01	0.01	0.01	0.00	35.59	17.14	0.25	yes	yes
west	CATCHEM-6	Start in 1962	no-shrimp	25.3	-	0.07	0.07	0.05	0.04	-	2.56	2.09	1.61	2.68	-	0.01	0.01	0.01	0.00	38.14	8.29	0.12	yes	yes
west	CATCHEM-6	Start in 1962	curr-shrimp	25.3	-	0.17	0.19	0.13	0.10	-	2.80	2.28	1.76	2.99	-	0.01	0.01	0.01	0.00	12.67	3.21	0.05	yes	yes
east	CATCHEM-7	Start in 1984	linked	5.8	-	-	0.05	0.03	0.06	-	-	4.98	5.27	4.18	-	-	0.02	0.01	0.02	10.68	5.81	0.36	yes	yes
east	CATCHEM-7	Start in 1984	no-shrimp	5.8	-	-	0.11	0.06	0.13	-	-	2.98	3.15	2.77	-	-	0.02	0.01	0.02	8.98	2.81	0.18	yes	yes
east	CATCHEM-7	Start in 1984	curr-shrimp	5.8	-	-	0.11	0.06	0.13	-	-	2.98	3.15	2.77	-	-	0.02	0.01	0.02	8.98	2.81	0.18	yes	yes
west	CATCHEM-7	Start in 1984	linked	31.5	-	-	0.04	0.02	0.02	-	-	3.23	2.97	4.18	-	-	0.01	0.00	0.00	43.80	20.89	0.24	yes	yes
west	CATCHEM-7	Start in 1984	no-shrimp	31.5	-	-	0.19	0.11	0.08	-	-	1.84	1.70	2.77	-	-	0.01	0.00	0.00	16.11	3.90	0.05	yes	yes
west	CATCHEM-7	Start in 1984	curr-shrimp	31.5	-	-	0.19	0.11	0.08	-	-	1.84	1.70	2.77	-	-	0.01	0.00	0.00	16.11	3.90	0.05	yes	yes

Table 2. TAC and ABC recommendations by the Gulf of Mexico Fishery Management Council's Reef Fish Stock Assessment Panel

	TAC or ABC recommendations			range of shrimp bycatch reductions considered		target		strategy	source
	lower	upper	for year	lower	upper	benchmark	year		
1990		0			0%	20% SPR	2000		RFSAP March 1990
1990		0			> 50%	20% SPR	2000		RFSAP June 1990 (revised shrimp bycatch estimates)
1992	4	6.0		40%	50%				RFSAP September 1992
1993	4	6.0			50%				RFSAP 1993
1994		6.0		50%					RFSAP September 1994
1995	6	10.0		50%					RFSAP 1995 October
1998	3	6.0		44%					RFSAP 1998 January and October
1998		0		0%					RFSAP 1998 January
1999	0	5.8		40%		20% SPR	2019	constant catch	RFSAP 1999 September
1999		0		40%		Bmsy	2031	constant catch	
1999	0	9.1		50%		20% SPR	2019	constant catch	
1999	0	2.8		50%		Bmsy	2031	constant catch	
1999	0	2.0	2000	40%		20% SPR	2019	constant F	
1999		0	2000	40%		Bmsy	2031	constant F	
1999	0	3.5	2000	50%		20% SPR	2019	constant F	
1999	0	0.4	2000	50%		Bmsy	2031	constant F	

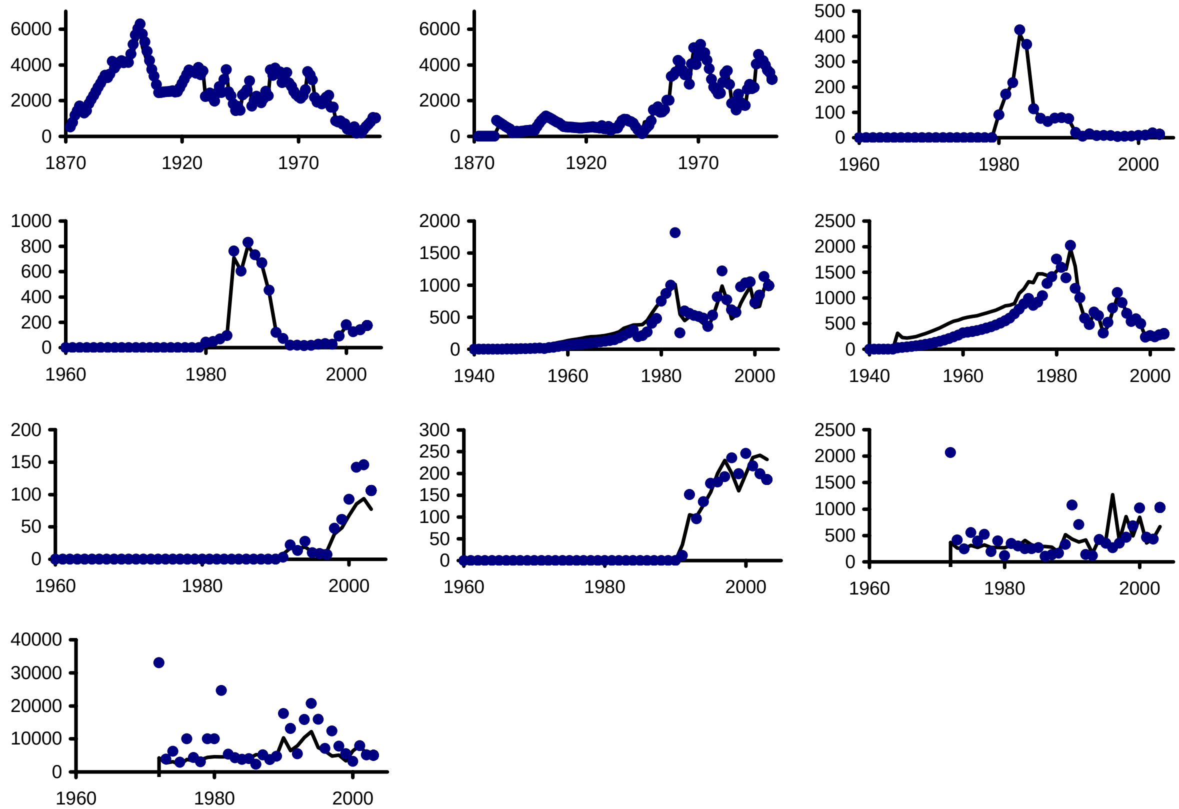

Figure 2. Model fits to the total landings in weight for the handline (HL) and longline (LL) fleets, total number landed for the recreational fleet (REC), and total number killed for the closed season (CS) and shrimp bycatch.

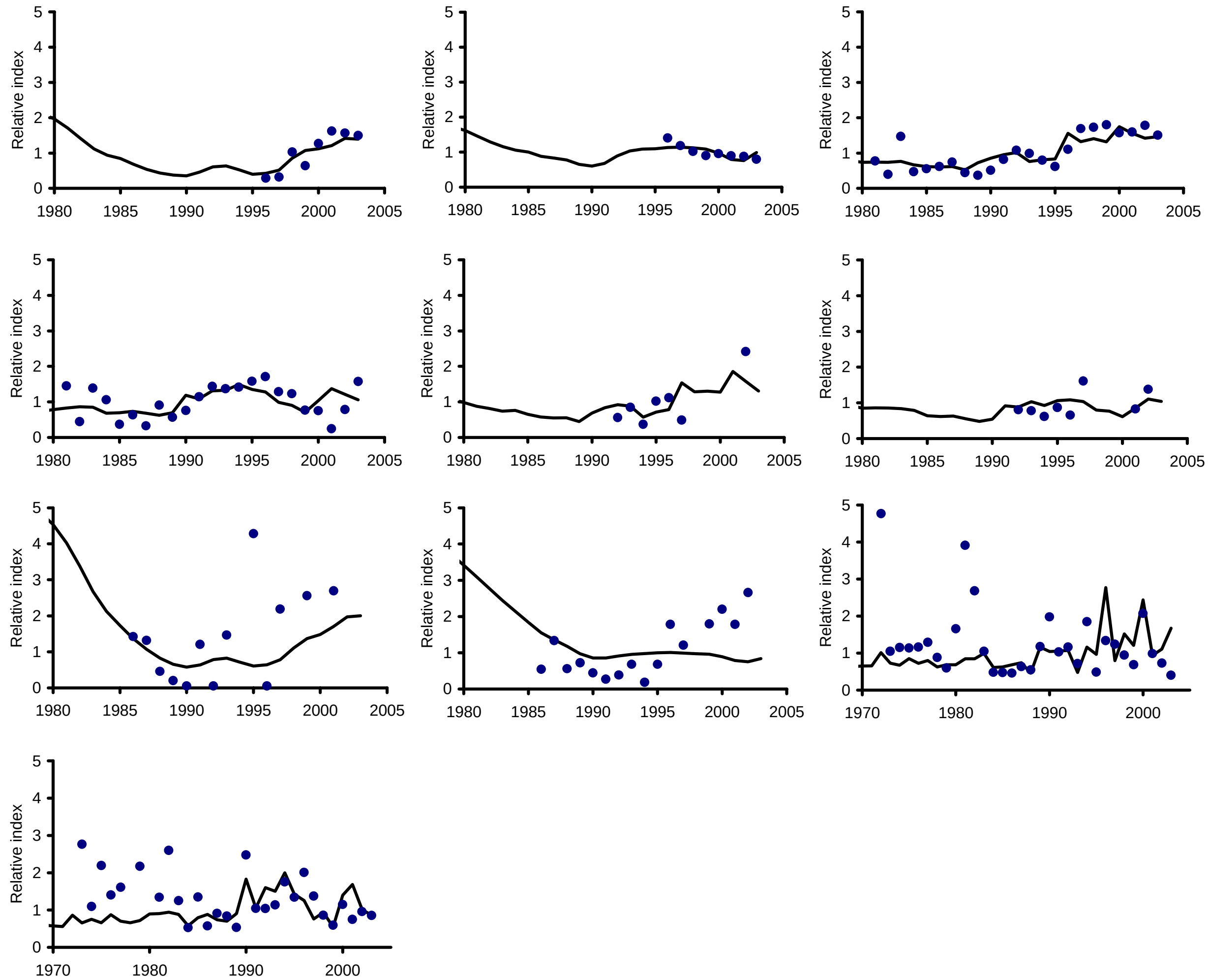

Figure 3. Model fits to indices of abundance (rescaled by the mean of the predicted values).

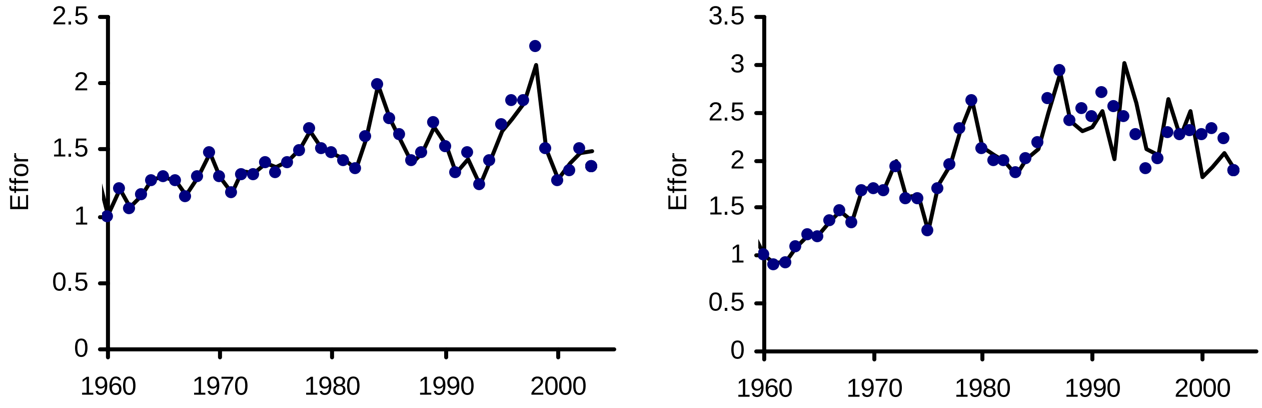

Figure 4. Model fits to the shrimp trawl effort series.

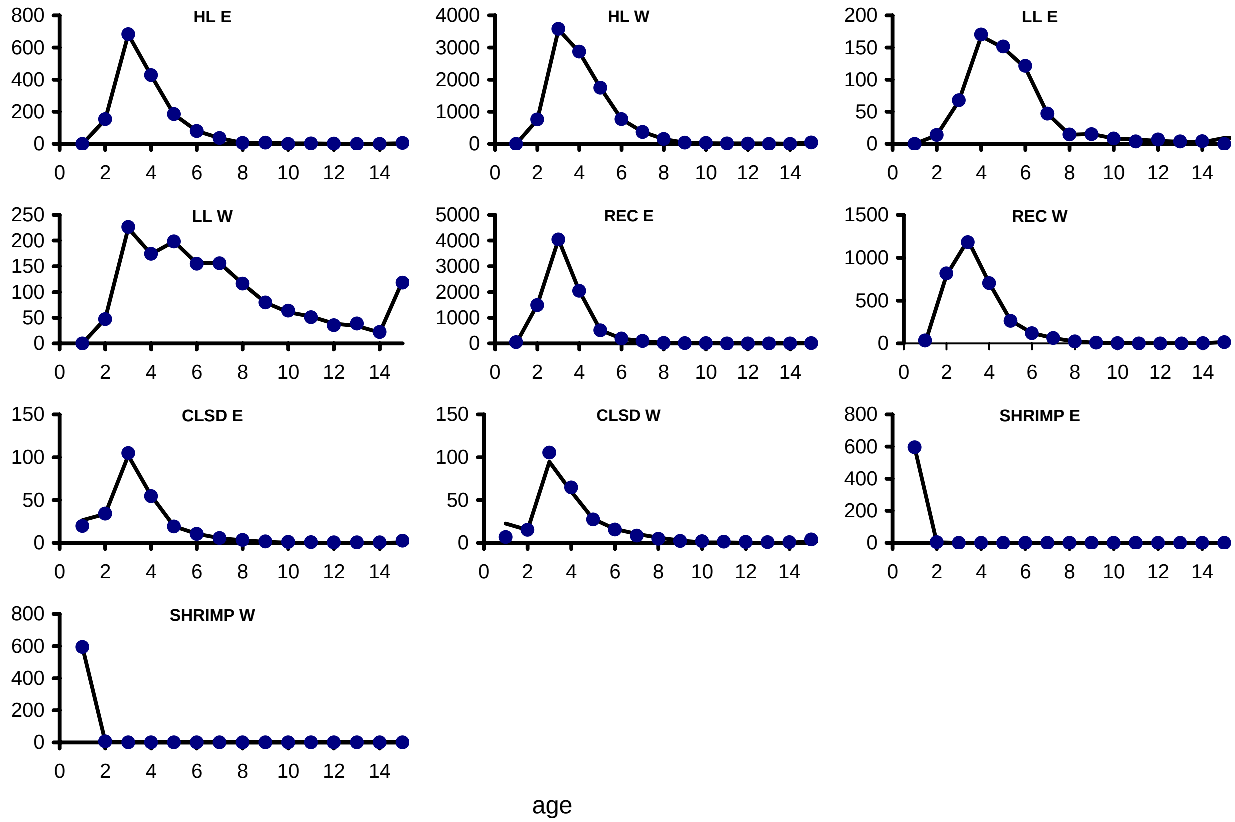

Figure 5. Model fits to the age composition data (aggregated across years).

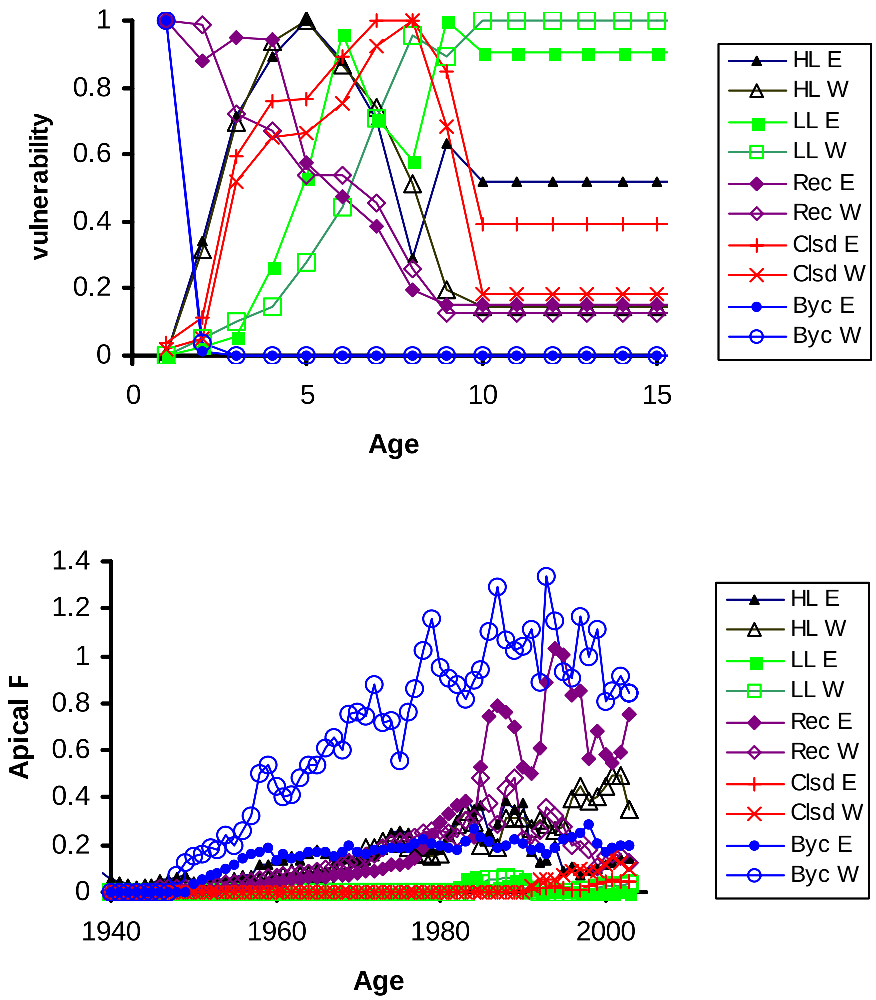

Figure 6. Model estimates of vulnerability and apical fishing rate for each fleet.

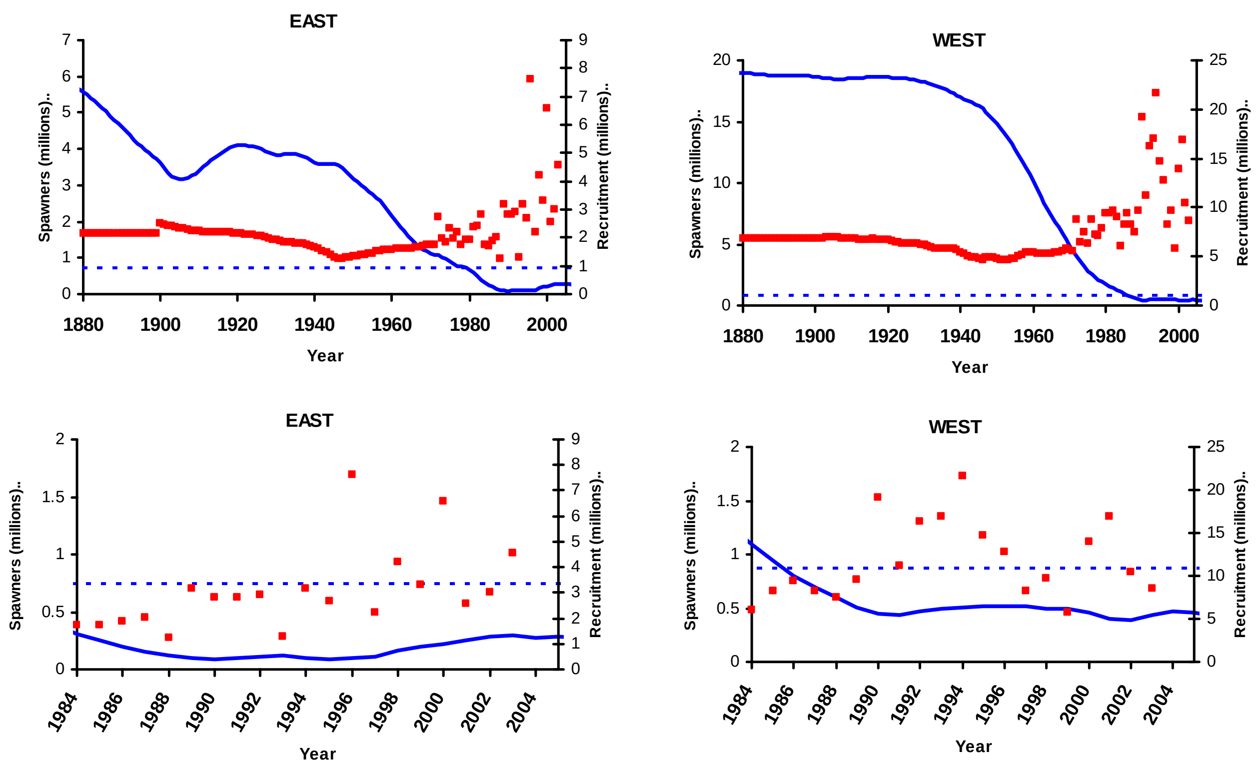

Figure 7. Model 1 estimates of the effective number of spawners (lines) and corresponding number of age 1 recruits (squares). The horizontal line gives the effective number of spawners associated with MSY{current-shrimp}. The upper panels are for 1880-2003 and the lower panels are for 1984-2003.

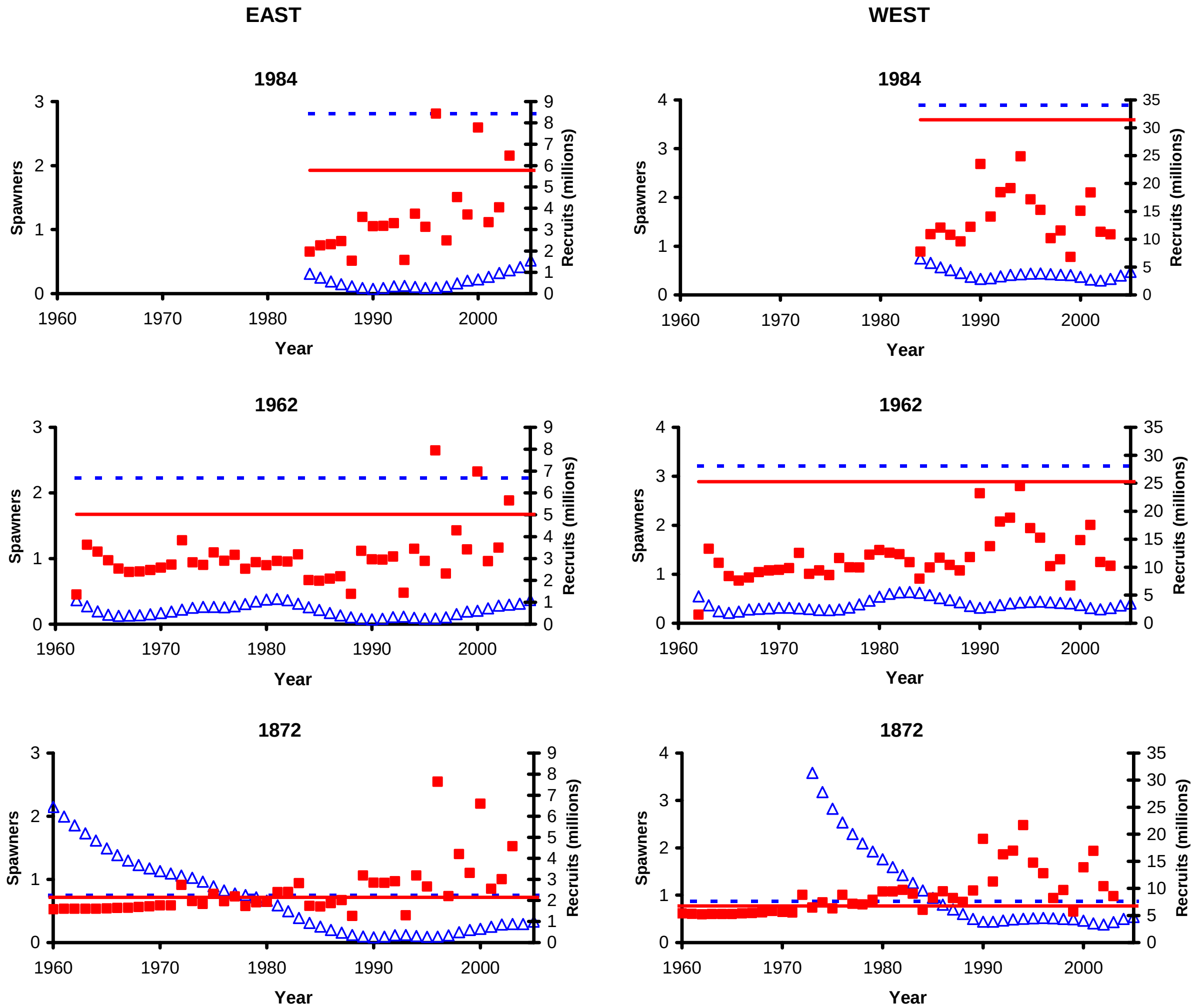

Figure 8. Comparison of model outputs for the three time series: 1872-2003, 1962-2003 and 1984-2003. The square symbols represent the estimates of the number of recruits (*R*) and the triangles represent the estimates of the effective number of spawners (*S*). The estimated effective number of spawners in the west from 1960 through the mid 1970s for the 1872-2003 runs was greater than 4 (see Figure 7) and are not shown.The solid and dashed horizontal lines represent the estimates of virgin recruitment (R_0) and S_{MSY}{current shrimp}, respectively.

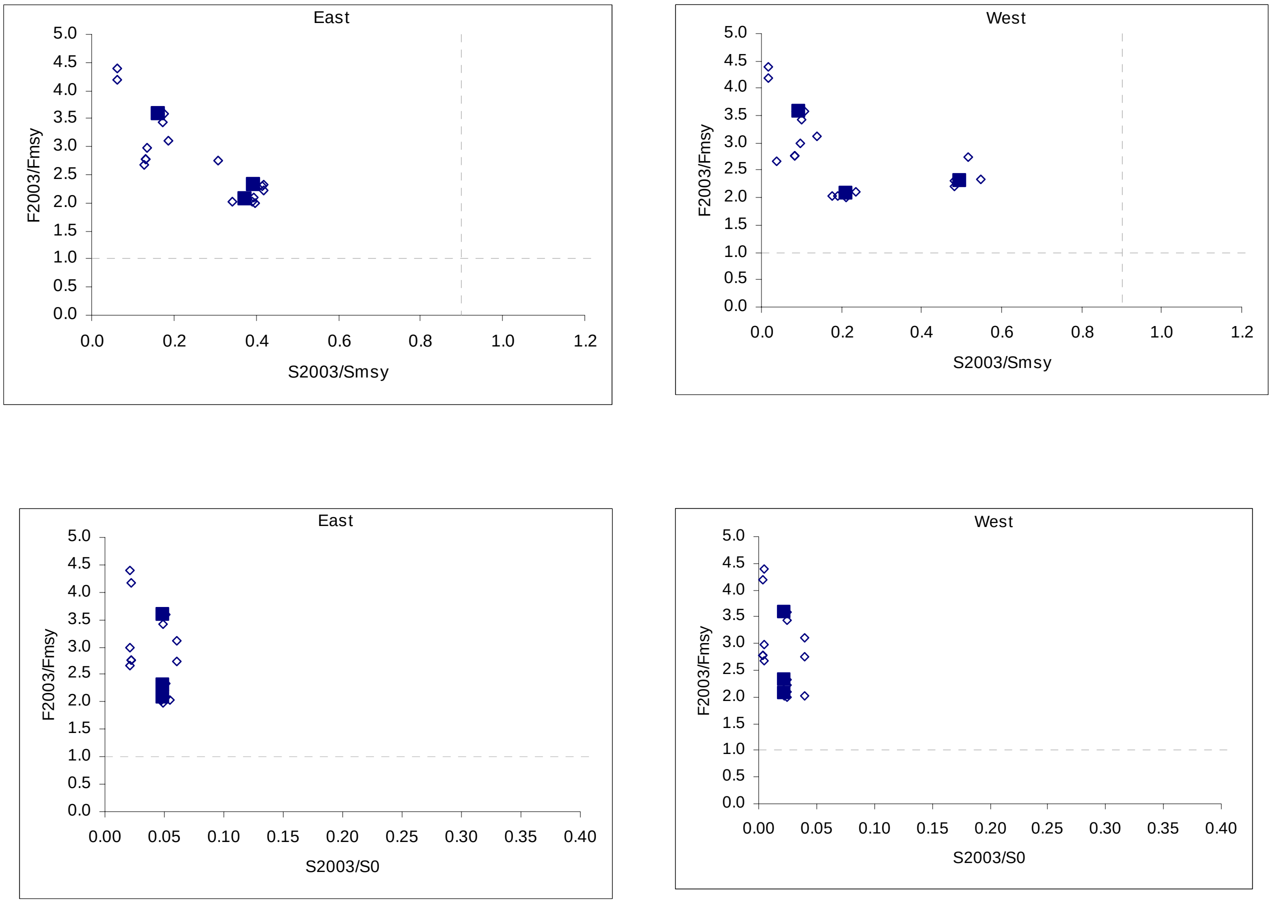

Figure 9. Status determinations for the base CATCHEM model applications (solid squares) and CATCHEM sensitivity analyses (open diamonds) using the 3 different selectivity alternatives for MSY Benchmark calculations. Dashed lines represent the Council's preferred definitions for MFMT (horizontal) and MSST (vertical) Upper plates show results for F_{2003}/F_{MSY} and S_{2003}/S_{MSY}. Lower plates show results for F_{2003}/F_{MSY} and S_{2003}/S_0 .

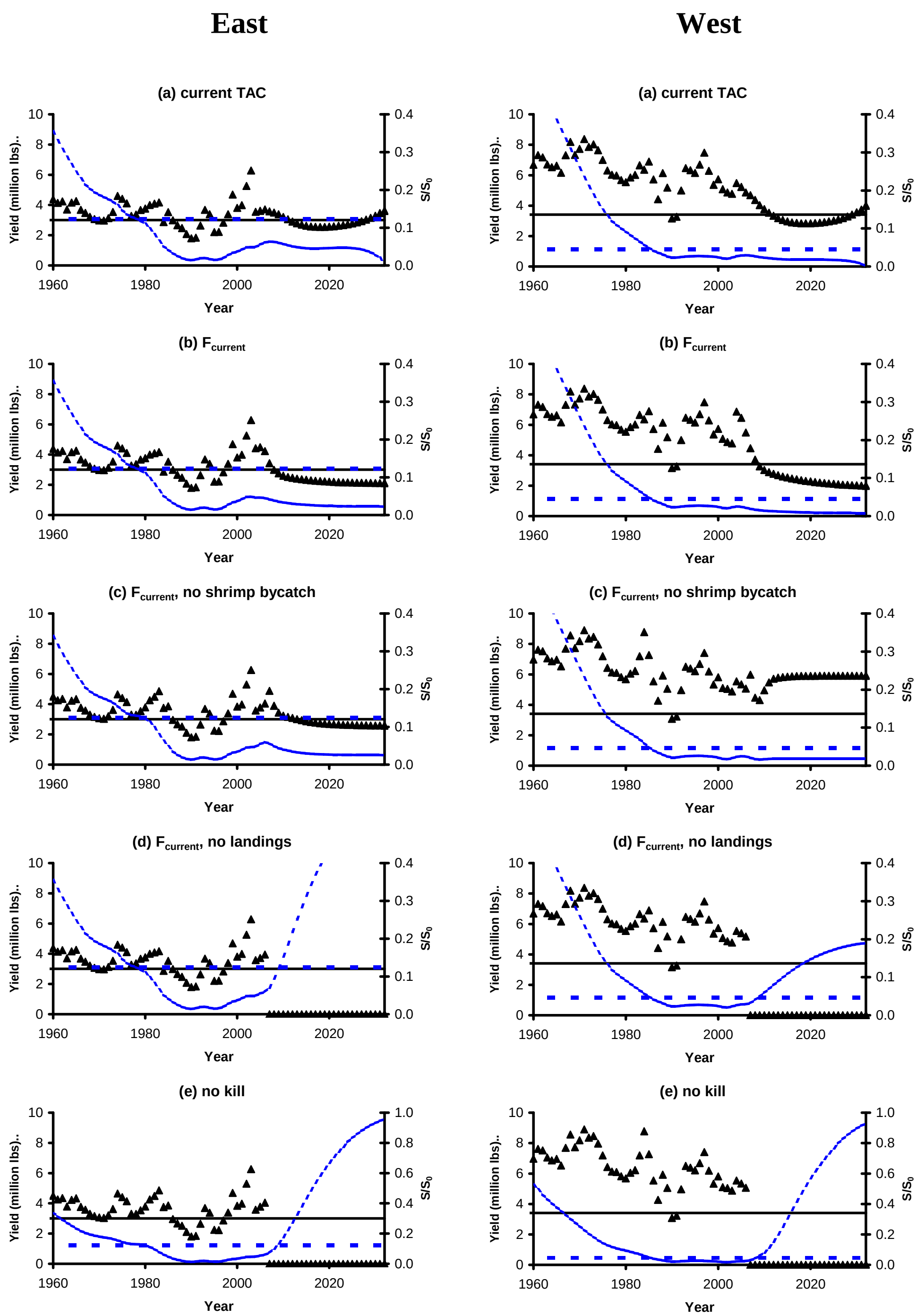

Figure 10 Projected trends in effective number spawners relative to virgin levels (S/S_0, lines lines) and landings (yield in weight, triangles) under (a) the current TAC of 9.12 mp, (b) current *F* levels, (c) current *F* levels except no shrimp bycatch, (d) current *F* levels except no landings and (e) no fishing. Horizontal lines represent MSY (solid) and S_{MSY} (dashed) conditioned on current levels of bycatch (shrimp and closed season).

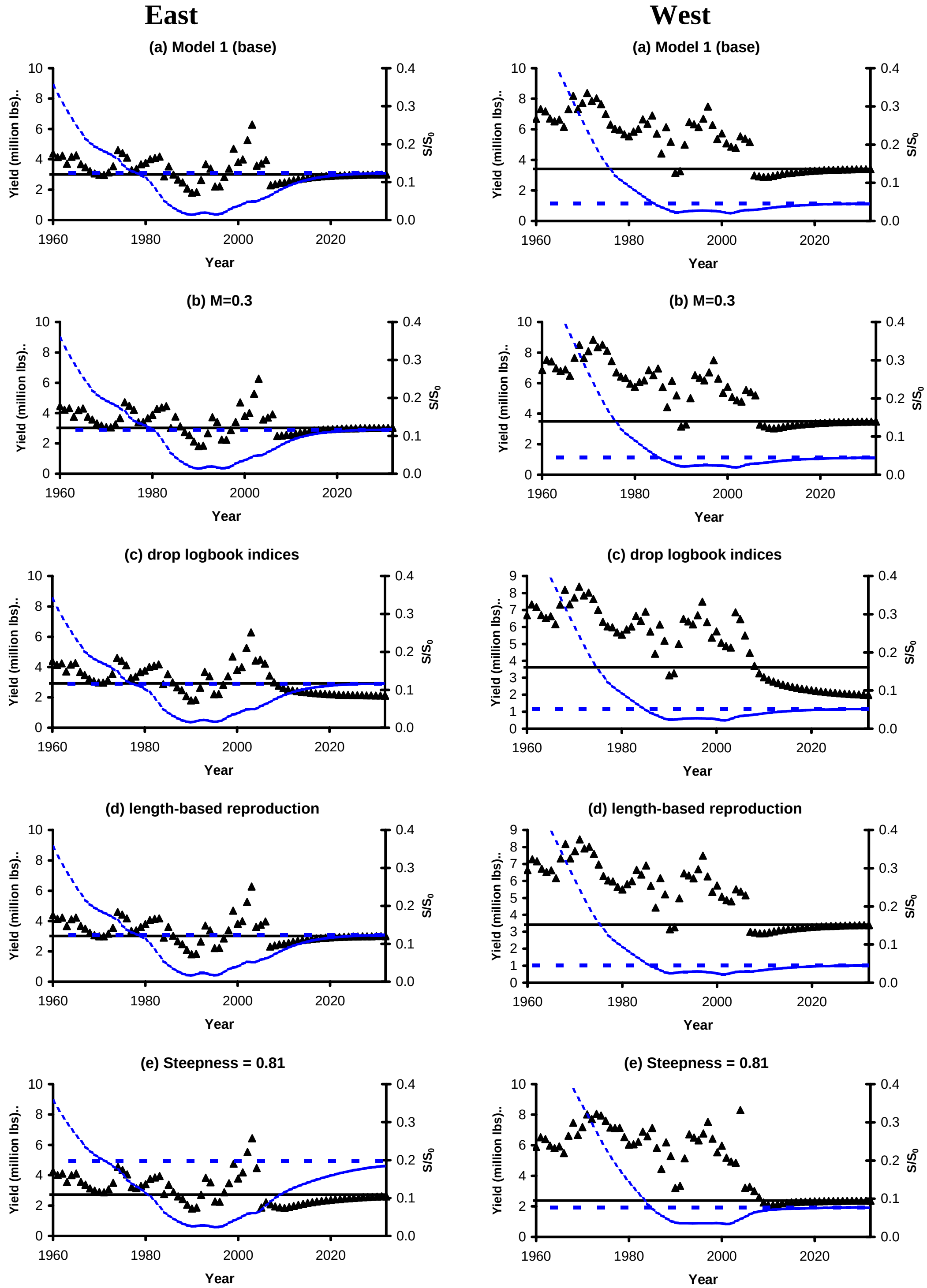

Figure 11. Projected trends in effective number spawners relative to virgin levels (S/S_0, solid lines) and landings (yield in weight, dashed lines) when closed season discards and shrimp effort continue at current rates and the directed fleet fishes at F_{MSY}\{current-shrimp\} assuming (a) model 1, the base model; (b) model 2, where M_1=0.3; (c) model 3, where the handline logbook indices are dropped; (d) model 4, with a length-based reproductive potential curve; and (e) model 5, with steepness fixed to 0.81.

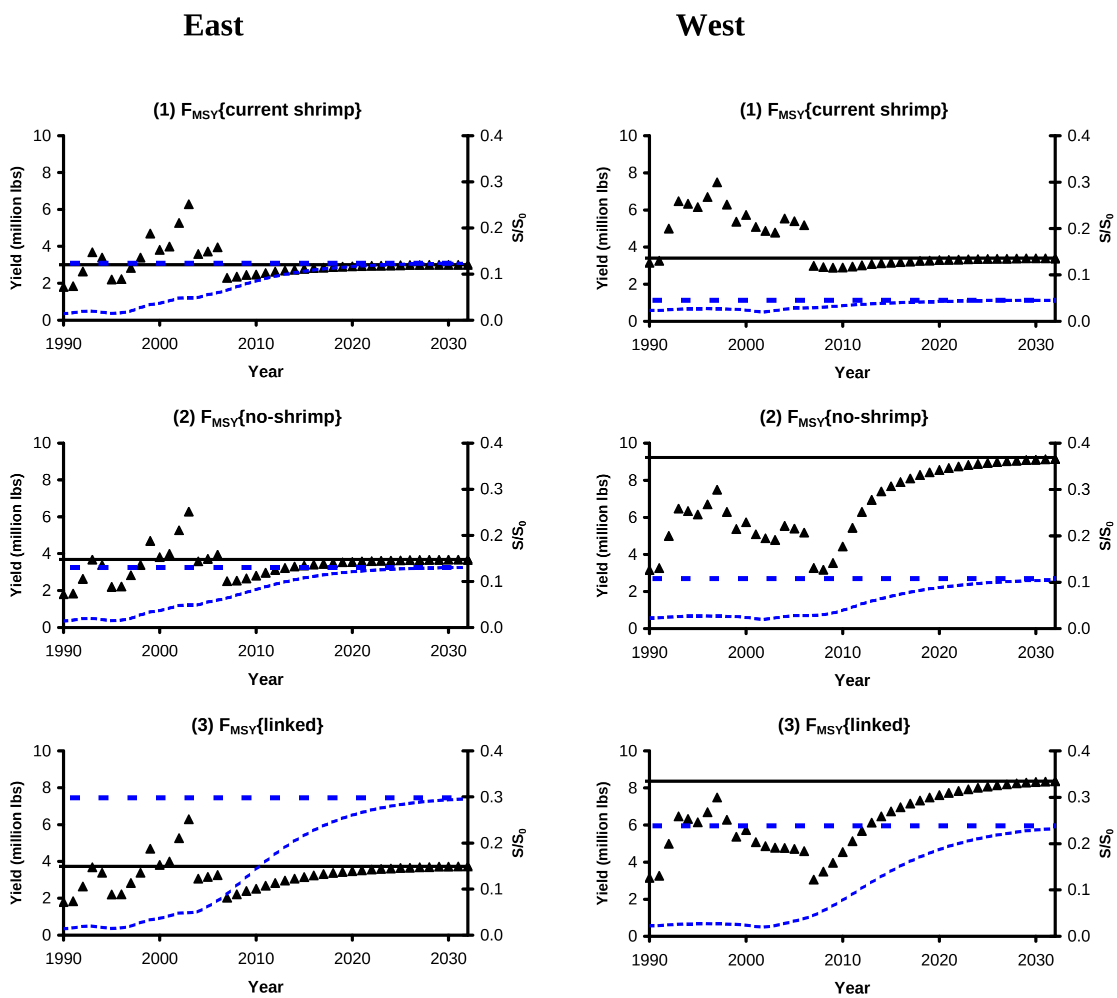

Figure 12a. Projected trends in effective number spawners relative to virgin levels (S/S_0, dashed lines) and landings (yield in weight, solid lines) when the respective fisheries operate according to three different management policies: (1) F_{MSY}\{current-shrimp\}, where closed-season and shrimp bycatch rates continue at current levels; (2) F_{MSY}\{no-shrimp\}, where closed-season bycatch continues at current levels and the offshore shrimp fishery is discontinued; and (3) F_{MSY}\{linked\}, where the reductions in bycatch are commensurate with the reduction in the effort of the directed fleets. Note that the yield statistic includes only the landings of the directed fleet. Horizontal lines represent the values associated with the different definitions of MSY (solid) and S_{MSY} (dashed).

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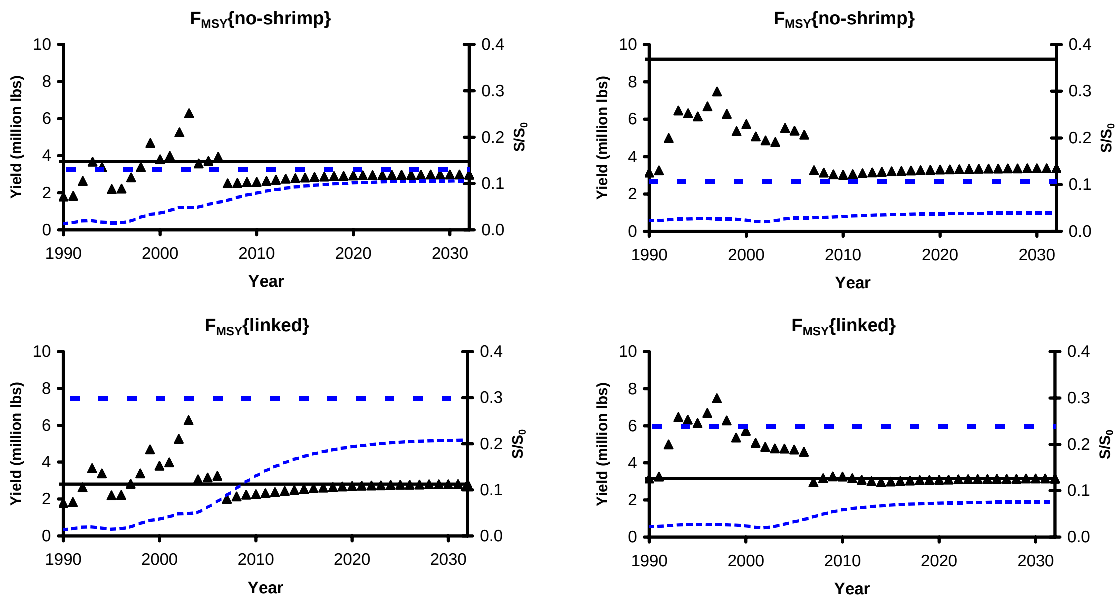


Figure 12b. Projected trends in effective number spawners relative to virgin levels (S/S_0, dashed lines) and landings (yield in weight, solid lines) when the benchmarks are based on MSY{no-shrimp} or MSY{linked} and the directed fisheries operate accordingly (fishing at F_{MSY}\{no-shrimp\} or F_{MSY}\{linked\}), but the shrimp bycatch is not reduced. Note that the yield statistic includes only the landings of the directed fleet. Horizontal lines represent the values associated with the different definitions of MSY (solid) and S_{MSY} (dashed).

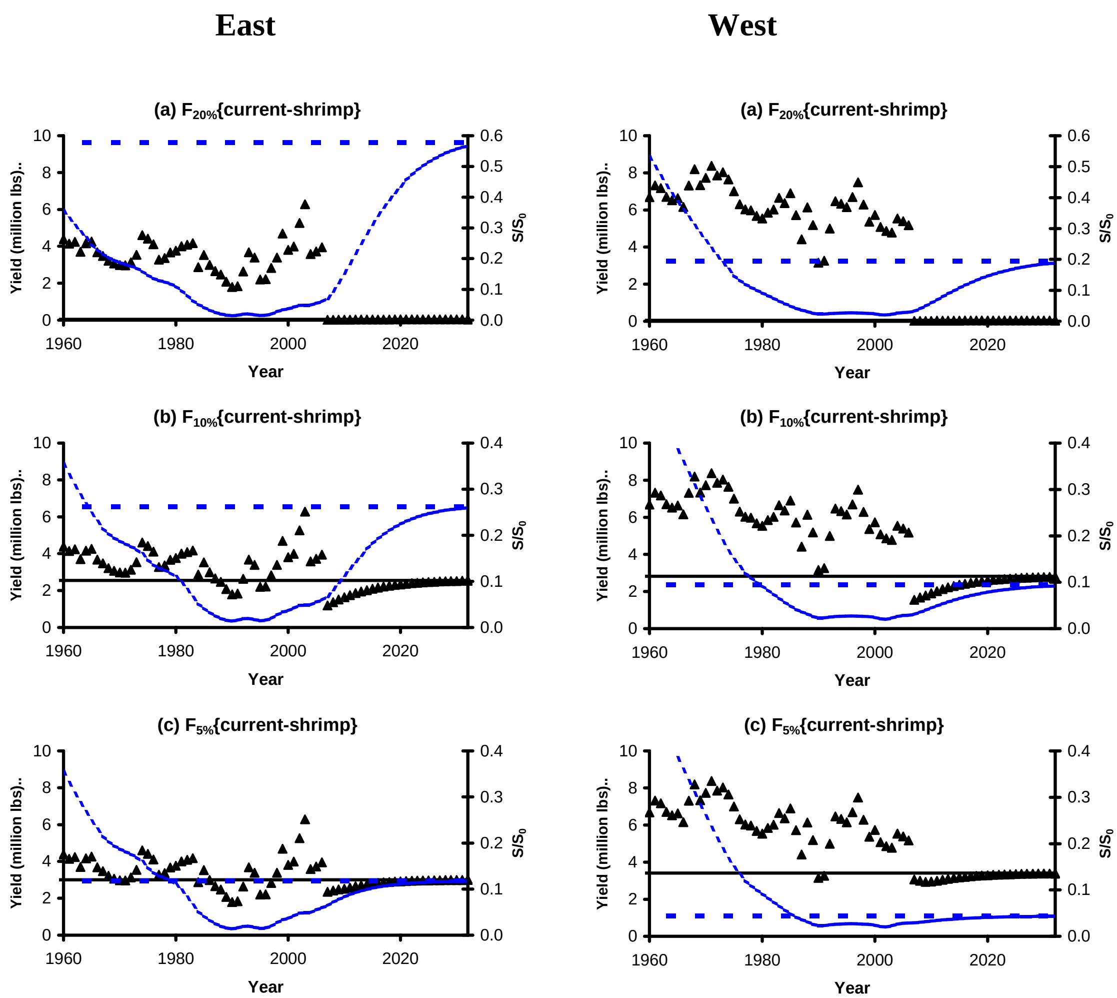


Figure 13. Projected trends in effective number spawners relative to virgin levels (S/S_0, solid lines) and landings (yield in weight, dashed lines) when closed season discards and shrimp effort continue at current rates and the directed fleet fishes at (a) $F_{20\%}$\{current-shrimp\}, (b) $F_{10\%}$\{current-shrimp\}, and (c) $F_{5\%}$\{current-shrimp\}.Horizontal lines represent the long-term yield (solid) and spawning potential (dashed) associated with the given SPR levels. Note that the yield under $F_{20\%}$\{current-shrimp\}is very low (about 9,000 lbs), but $S_{20\%}/S_0$ is high enough to necessitate a scale change.

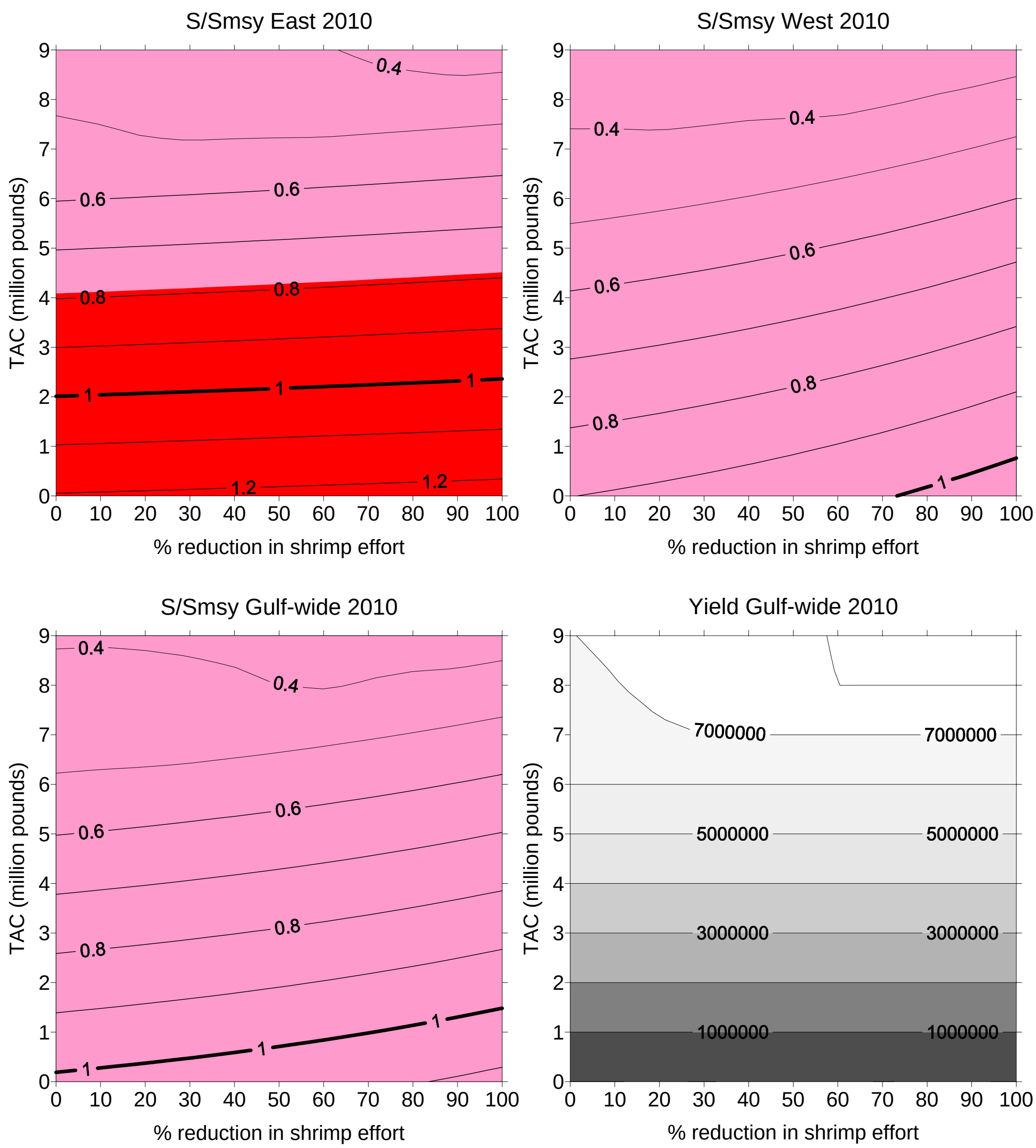


Figure 14a. Isopleths of effective number spawners in the year 2010 relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on an assumed 40 percent reduction in effective offshore shrimp effort. The horizontal axis refers to the projected percent reduction in shrimp effort and the vertical axis refers to the projected Gulfwide TAC (total allowed catch for the directed fishery in millions of pounds). The color shades on the graphs represent different levels of stock biomass relative to virgin conditions: pink shades represent $S/S_0<10\%$ and red shades represent $10\%\leq S/S_0<20\%$ (in these cases, stock biomass is not expected to exceed 15% of virgin level). Yield isopleths that do not coincide with the TAC labels (TACs above 6 million lbs) indicate that the higher TAC could not be sustained.

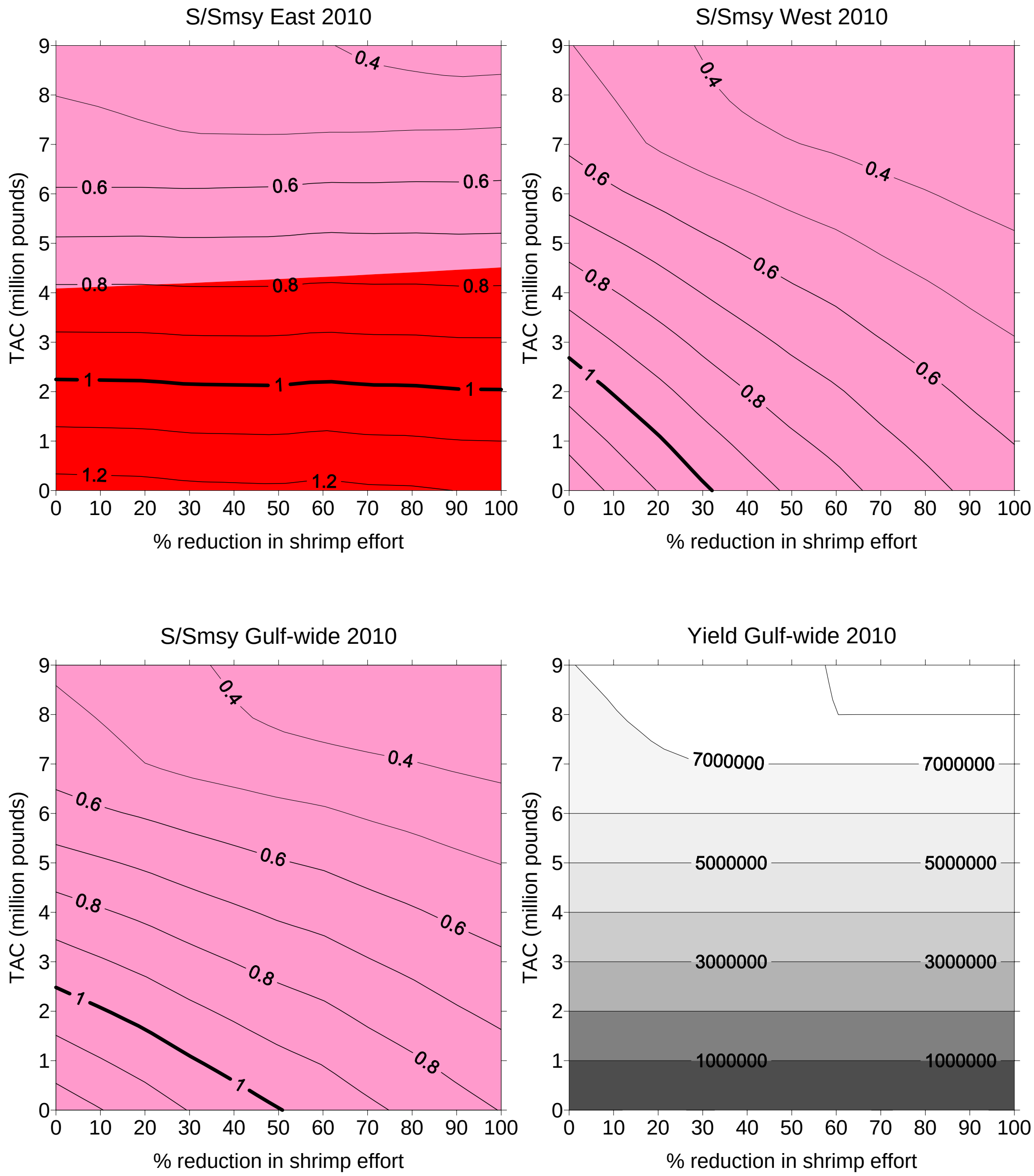


Figure 14b. Isopleths of effective number spawners in the year 2010 relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on the projected percent reduction in shrimp effort indicated on the horizontal axis. The vertical axis refers to the projected Gulfwide TAC (total allowed catch for the directed fishery in millions of pounds). The color shades on the graphs represent different levels of stock biomass relative to virgin conditions: pink shades represent S/S_0<10% and red shades represent 10%≤S/S_0<20% (in these cases, stock biomass is not expected to exceed 15% of virgin level). Yield isopleths that do not coincide with the TAC labels (TACs above 6 million lbs) indicate that the higher TAC could not be sustained.

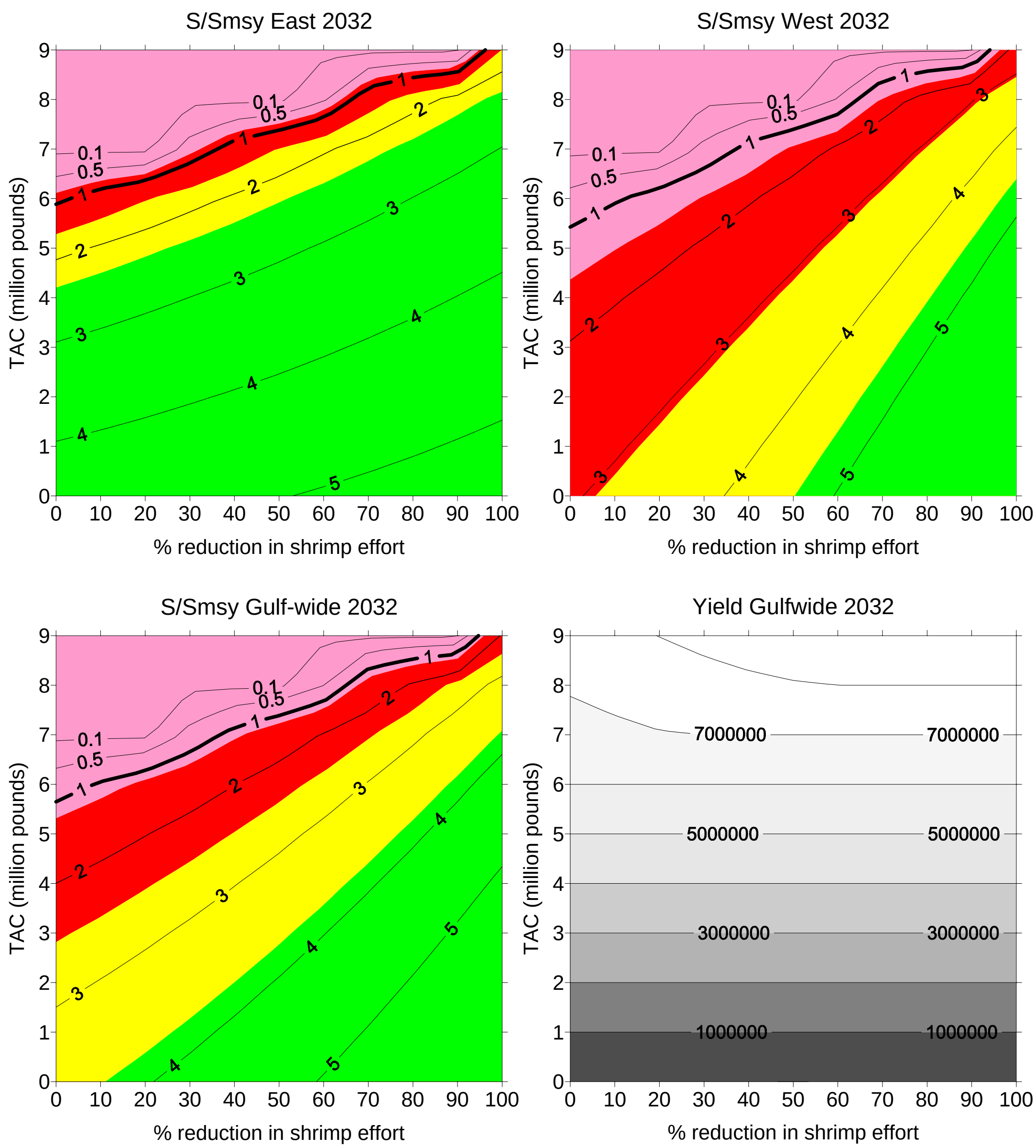


Figure 15a. Isopleths of effective number spawners in the year 2032 relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on an assumed 40 percent reduction in effective offshore shrimp effort. The horizontal axis refers to the projected percent reduction in shrimp effort and the vertical axis refers to the projected Gulfwide TAC (total allowed catch for the directed fishery in millions of pounds). The color shades on the graphs represent different levels of stock biomass relative to virgin conditions: pink represents $S/S_0<10\%$, red $10\%\leq S/S_0<20\%$, yellow $20\%\leq S/S_0<30\%$, and green $S/S_0\geq 30\%$. Yield isopleths that do not coincide with the TAC labels (TACs above 6 million lbs) indicate that the higher TAC could not be sustained.

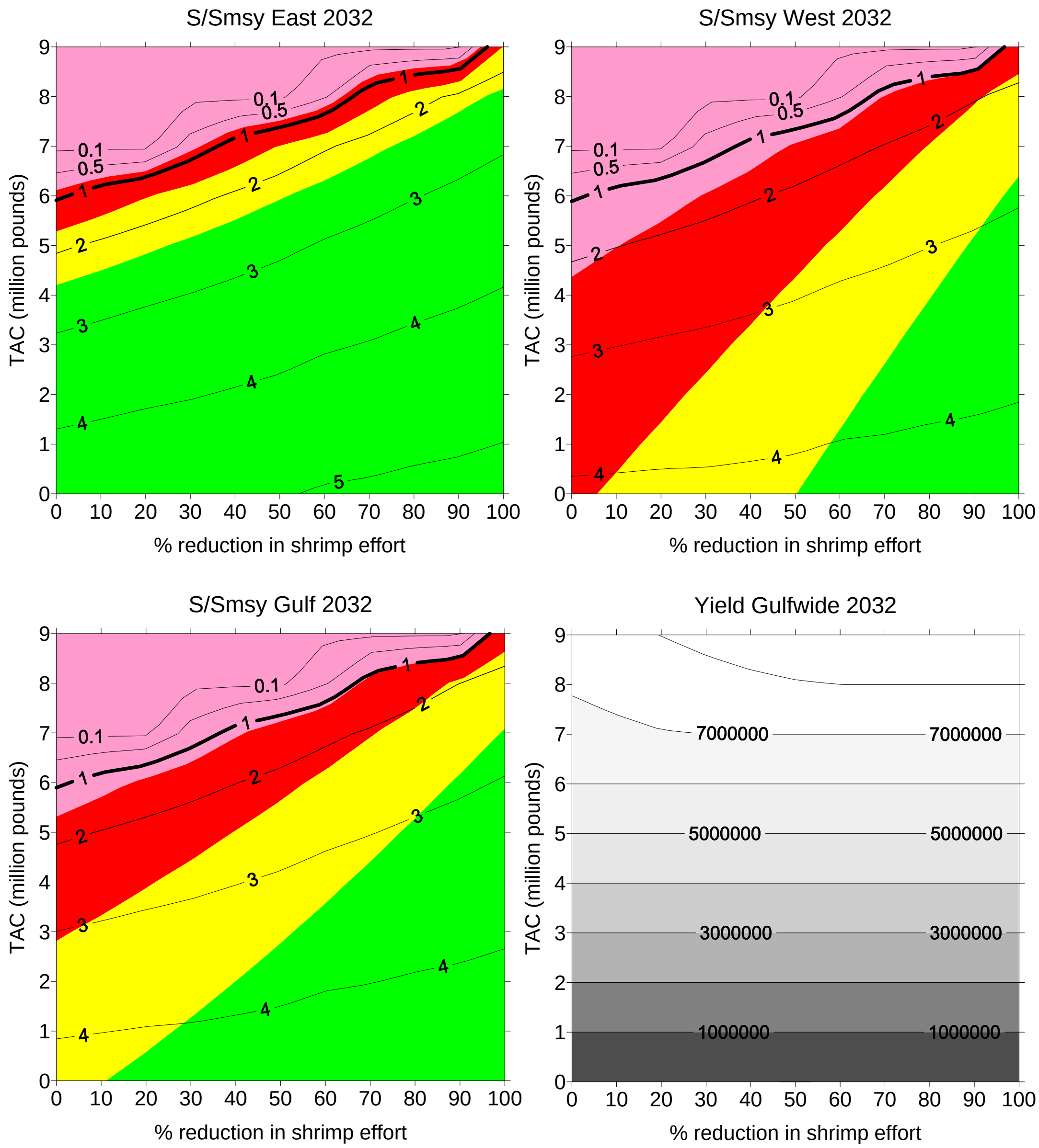


Figure 15b. Isopleths of effective number spawners in the year 2032 relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on the projected percent reduction in shrimp effort indicated on the horizontal axis. The vertical axis refers to the projected Gulfwide TAC (total allowed catch for the directed fishery in millions of pounds). The color shades on the graphs represent different levels of stock biomass relative to virgin conditions: pink represents S/S_0<10%, red 10%$\leq S/S_0$<20%, yellow 20%$\leq S/S_0$<30%, and green $S/S_0 \geq$30%. Yield isopleths that do not coincide with the TAC labels (TACs above 6 million lbs) indicate that the higher TAC could not be sustained.

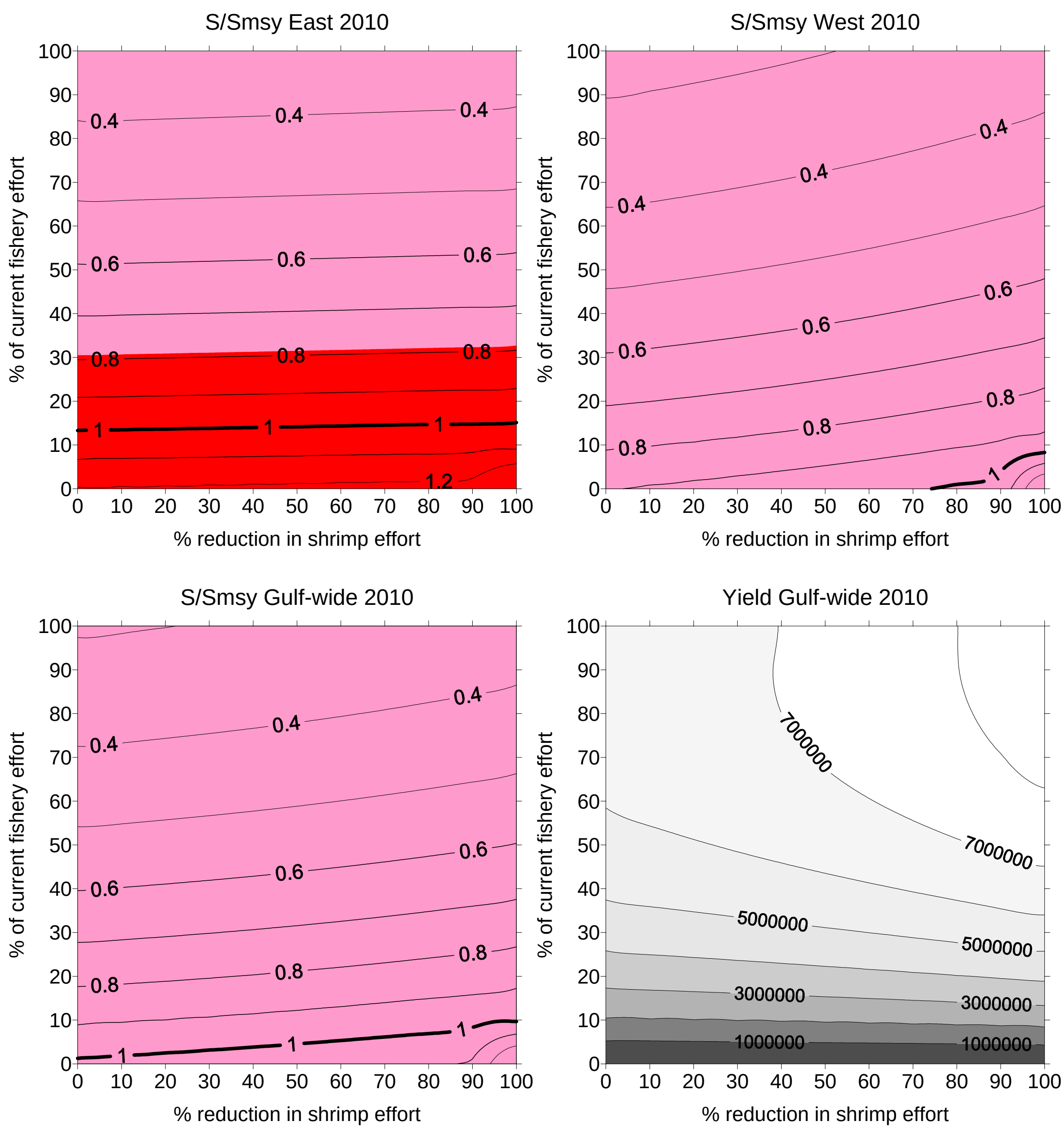


Figure 16a.. Isopleths of effective number spawners in the year 2010 relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on an assumed 40 percent reduction in effective offshore shrimp effort. The horizontal axis refers to the projected percent reduction in shrimp effort and the vertical axis refers to the projected fishing mortality rate of the directed fishery (expressed as a percentage of current levels). The color shades on the graphs represent different levels of stock biomass relative to virgin conditions: pink shades represent S/S_0<10% and red shades represent 10%$\leq S/S_0$<20% (in these cases, stock biomass is not expected to exceed 15% of virgin level.

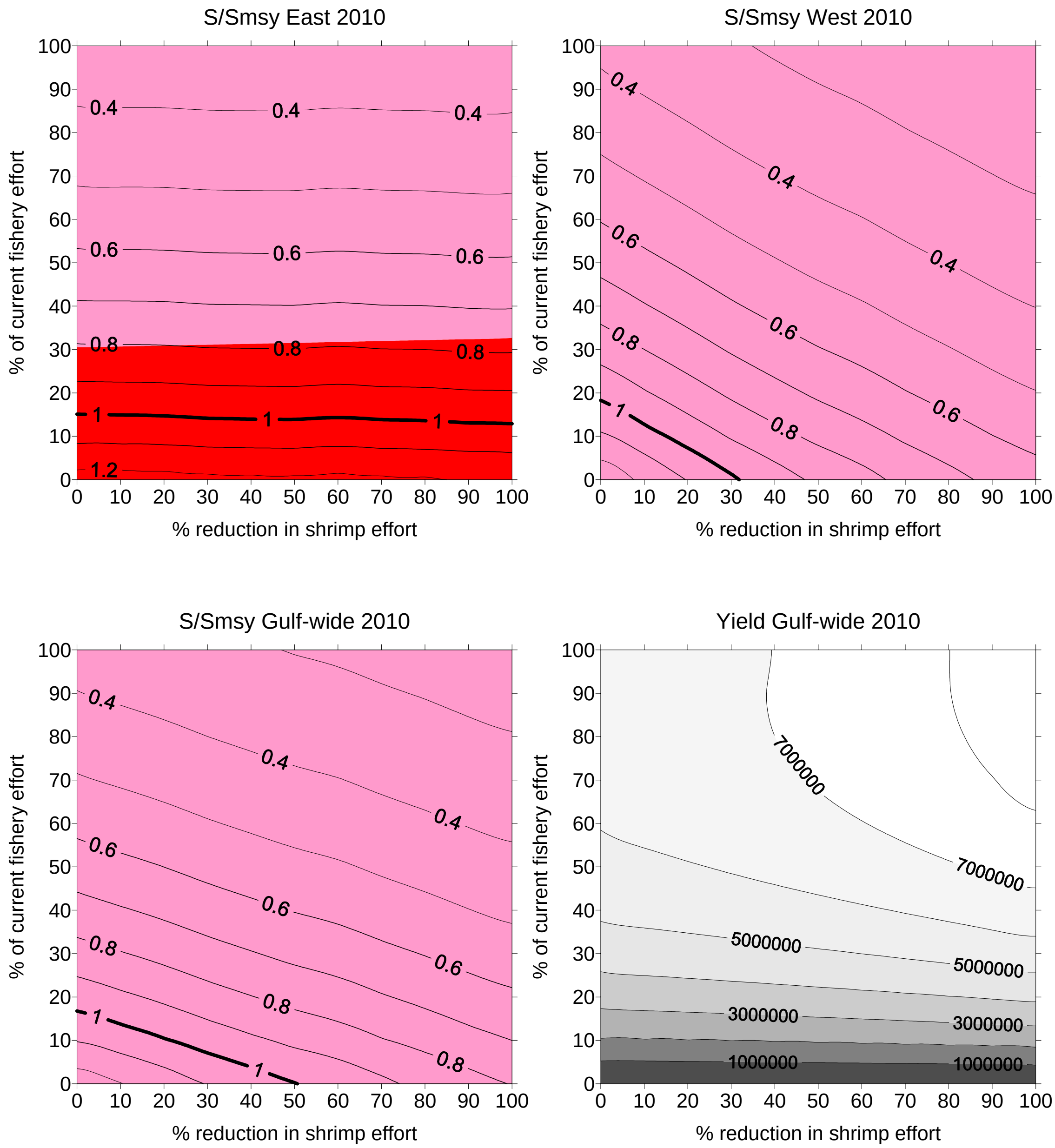


Figure 16b. Isopleths of effective number spawners in the year 2010 relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on the projected percent reduction in shrimp effort indicated on the horizontal axis. The vertical axis refers to the projected fishing mortality rate of the directed fishery (expressed as a percentage of current levels). The color shades on the graphs represent different levels of stock biomass relative to virgin conditions: pink shades represent $S/S_0<10\%$ and red shades represent $10\%\leq S/S_0<20\%$ (in these cases, stock biomass is not expected to exceed 15% of virgin level).

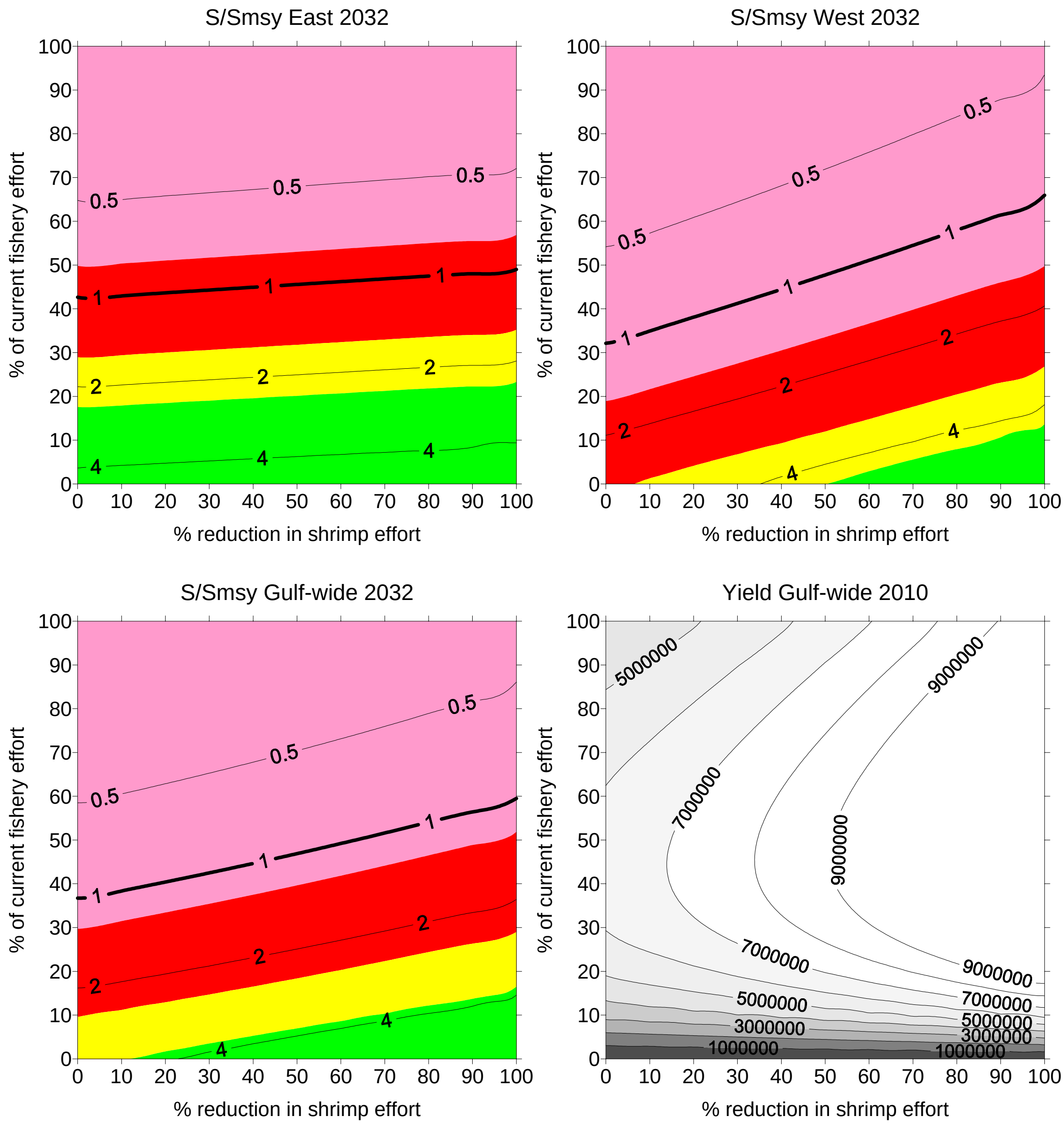


Figure 17a. Isopleths of effective number spawners in the year 2032 relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on an assumed 40 percent reduction in effective offshore shrimp effort. The horizontal axis refers to the projected percent reduction in shrimp effort and the vertical axis refers to the projected fishing mortality rate of the directed fishery (expressed as a percentage of current levels). The color shades on the graphs represent different levels of stock biomass relative to virgin conditions: pink represents $S/S_0<10\%$, red $10\%\leq S/S_0<20\%$, yellow $20\%\leq S/S_0<30\%$, and green $S/S_0\geq 30$

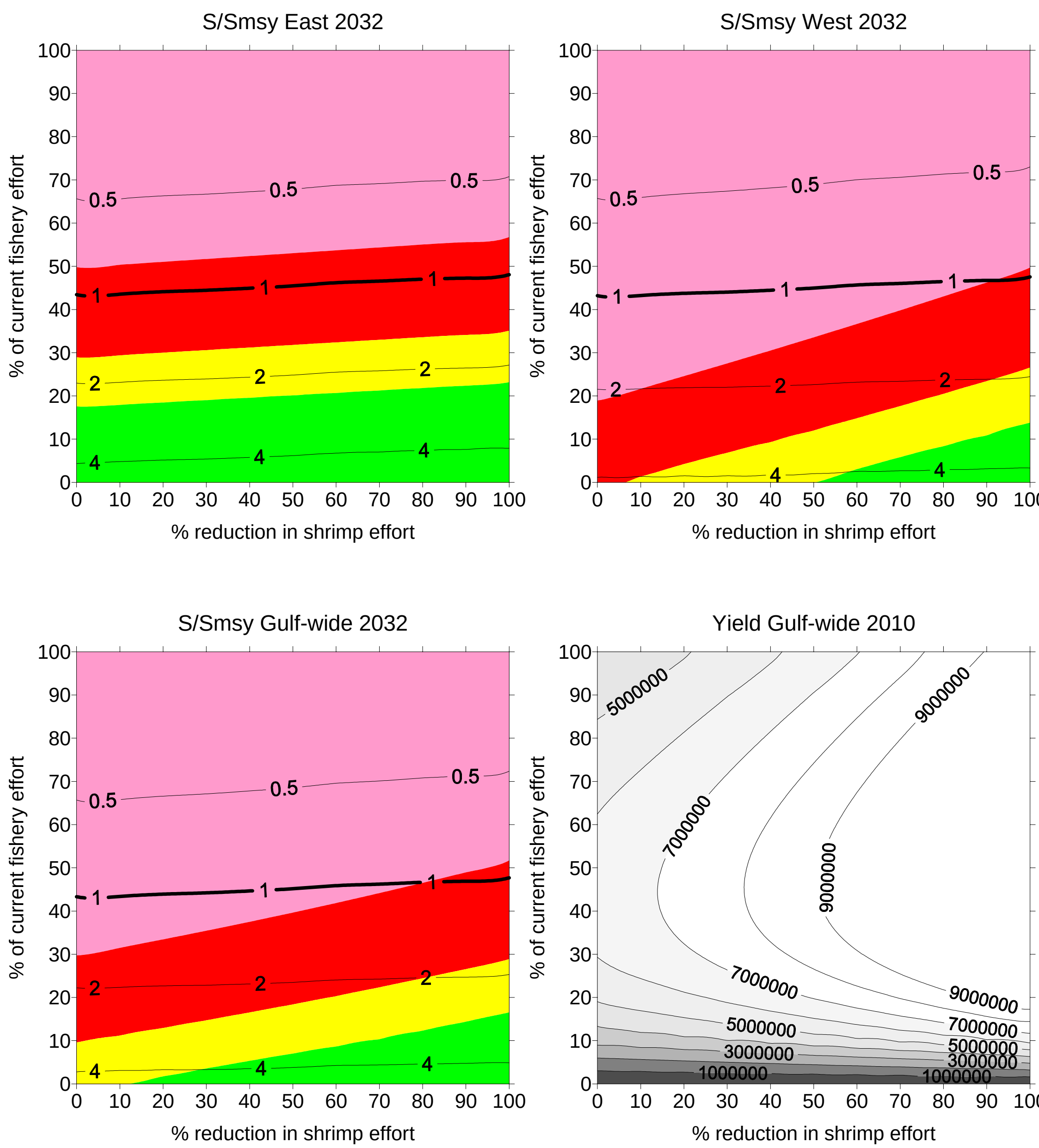


Figure 17b. Isopleths of effective number spawners in the year 2032 relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on the projected percent reduction in shrimp effort indicated on the horizontal axis. The vertical axis refers to the projected fishing mortality rate of the directed fishery (expressed as a percentage of current levels). The color shades on the graphs represent different levels of stock biomass relative to virgin conditions: pink represents $S/S_0<10\%$, red $10\% \leq S/S_0<20\%$, yellow $20\% \leq S/S_0<30\%$, and green $S/S_0 \geq 30\%$

SEDAR 7
Gulf of Mexico Red Snapper

Assessment Workshop Proceedings

Proceedings of the SEDAR7 Red Snapper Assessment Workshops

The Assessment Workshop portion of the red snapper SEDAR actually was spread over two week-long sessions; the first in August, the second in December. The volume of new and past work, the desire to develop an "ultra-historical" data base, and problems with the first choice for a lead assessment model (ASAP) made it impossible to complete an assessment in the time period that had been allotted to previous SEDARs. Indeed, even the second workshop session ended with what was largely a set of instructions to the Miami assessment staff to guide the final model runs, with final assessment results to be circulated to the group later by email.

There are separate sections to this report for each of the sessions. The report roughly follows the developments at the meetings chronologically. However, some topics came up repeatedly, or were discussed in fragments between evaluations of analytical results. For these, comments from the several times a topic was discussed have been brought together here. Additional comments offered by AW participants after the second session ended (beyond those meant to edit or clarify the session reports) are collected in a third section. The fourth and final section collects the research recommendations made over the course of the meetings.

The discussions at the AW sessions tended to be qualitative, and strategic in nature. Technical details are generally to be found in the supporting reports (AW-# series), in the Data Workshop report, and in the supporting documents from the Data Workshop (DW-# series). There were about 90 technical documents, by and large consisting of previously unpublished work, submitted to the DW and AW. Because of the volume of new material, we have opted here for a 'layered' report, simply summarizing key points and subsequent discussion, with citations to the primary submissions. Reviewers are invited to 'drill down' through the collected papers to consider any topic for which they want more technical detail.

August Session

The first portion of the SEDAR Assessment Workshop (AW) for red snapper was held at the SEFSC Miami facility Aug 16-20, 2004. The meeting began by reviewing issues from the April Data Workshop (DW). Twenty new papers were submitted, most of them either making recommendations on points left undecided at the DW, or presenting results of additional analyses recommended at the DW. Preliminary assessment model runs using ASAP were conducted, directed at examining properties of individual factors prior to establishing a 'base run' assessment. An overview of a spatially separate assessment model under development was provided. Other models discussed included McAllister's Gaming Model, and Walters' VPA investigation. Both of these models included exploration of 'ultra-historic' information – landings and effort estimates derived from the years prior to the current data collection programs for fisheries statistics. It was hoped that this consideration of the full history of exploitation could provide additional insight into some of the problematic areas in interpreting past assessments. The meeting began with brief presentations on the new papers, with each presentation followed by open discussion of any topics inspired by the paper. The order here follows the order of presentation at the workshop.

Summary of Contributed Papers

AW-17 reported on an investigation of discrepancies in gear assignments of TX landings between past assessments and the current landings data files. A portion of the landings once attributed to the shrimp industry had been reclassified as longline (LL) landings in the commercial data files in the years since the CPUE index based on shrimper-landed snapper was first developed. Discussion revealed that there may well have been an expansion of the LL landings around that time, but no record supporting the reclassification of any particular amount of the catch to LL was ever found. The recommendation was that Texas data from the 1980-84 period be treated as unclassified as to gear, and the 1980-1984 period should be removed from the CPUE index derived from snapper landings by the shrimp fishery. Subsequent discussion touched on possible inclusion of landings from outside the US (believed by SEFSC scientists to have been adjusted in accord with all available evidence several years back for those years incorporated in the past assessments); the allocation of the 2003 catch between commercial handline (HL) and LL (currently based on logbook proportions);

the conversion factor between gutted and whole weight (currently 1.11 is used); and whether catches from outside the US are considered to come from a different stock (currently treated as coming from another stock.). Discussion later in the week reported on an AW recommendation to compare age composition in the purported shrimp trawler landings with trawl survey composition; it did appear there was an overlap. The allocation of catches between HL and LL came up at several times later in the meeting. The group recommendation was to investigate impacts of any possible misreporting by matching portions of the reported HL landings to LL size or age frequencies.

AW-3 reported on the calibration between 'old' and 'new' procedures for estimating charter boat catch in MRFSS. Questions arose about how Texas data fit into this issue. Texas has its own program, separate from MRFSS. The Texas system provides charterboat catch estimates, but these do not enter the ratios used to adjust MRFSS, and Texas catches are not adjusted using the MRFSS procedure. Uncertainties around the (estimated) adjustment ratios are not propagated forward into the estimates of uncertainty for MRFSS charterboat catches.

AW-2 updated the estimates of allometric conversion factors. Contrary to what was expected, significant differences were not found between east and west. There were also no significant differences from the factors used in the Goodyear assessments. The recommendation was to retain the size conversions used in the previous assessments.

AW-1 presented new growth results. Size at age has been clearly influenced by minimum size regulations, and the approach in this paper attempts to correct for that effect analytically. No east / west differences were evident in growth curves developed from data from any of the fisheries (commercial LL, HL; Recreational), so use of one Gulfwide curve was recommended. The parameter K was estimated to be somewhat higher than the value estimated in previous assessments (0.22 vs 0.16). This change appeared to be a consequence of the large increase in data available in recent years and changes in the minimum size, rather than a change in growth pattern over time.

AW-5 addressed fecundity and maturity estimation. This topic encompasses some of the largest biological differences from past assessments, and there are some real differences that result from choice of analytical method. Fecundity and maturity could be considered as direct functions of length, or as direct functions of age. Currently available modeling procedures ultimately require age-based functions, which means that if a direct function of length is assumed, an unbiased growth curve is a necessity. Or, a direct dependence on age could be assumed, bypassing the length to age conversion. The data base for reproductive biology was expanded considerably over the last few years. Results from two separate data sets were presented to the DW. The two sets analyzed separately led to somewhat different reproductive patterns, quite probably dominated by sampling differences. The DW recommended that simple combination of the two sets for a single analysis would be the best procedure. This has now been done. Analysis of the combined data found no east / west differences in either batch fecundity or fecundity*maturity, which was a bit of a surprise. However, the most important differences with the reproductive biology from past assessments (which assumed direct dependence on length) appear to be related to the new assumptions about growth. With the new curve, smaller fish are estimated to be more productive than in the previous stock assessment. However, a direct reproductive potential vs age function is now available also, so the AW has a choice. It was pointed out during discussion that separate age dependent and length dependent components might exist, and that relative strengths of the two possible components might differ among species. As this appeared to be a topic of some importance, without clear evidence within the data to indicate which method to favor, the AW felt that sensitivity work might be necessary. Discussion also mentioned the lack of information at present about frequency of spawning.

AW-16 considered use of U.S. Census data to lengthen the time series for the recreational fishery. A (log transformed) GLM related recreational catch to human population size, state, type of fishing, and year class strength (SEAMAP trawl survey), with interactions. Resulting parameters were used to predict catches prior to 1981.

AW-18 reviewed Goodyear's "probabilistic aging" method. The probabilistic procedure is known not to be mathematically rigorous (i.e. there is no mathematical basis to expect convergence as the number of iterations are increased), and modern assessment models do not require age composition vectors to match every catch. However, age data for the earlier years (1980s) are so sparse that incorporating probabilistic age estimates up front might have an advantage over leaving estimation of missing age compositions to an internal fitting in the assessment model. The analysis presented in AW-18 ran the Goodyear procedure for 3 iterations, and compared the results to similarly estimated age frequencies used in the previous assessment (Schirripa and Legault 1999) via bar graphs of percent age composition .Two stock structures were considered. The effect of the new (AW-1) growth curve appeared evident, particularly in the age 1 estimates.

AW-19 summarized the observed age composition data from otolith samples, and assembled age composition as matrices for 6 fisheries: commercial handline east (1991-2003), commercial handline west (1992-2003, less 1996-1997), commercial longline east (1991-2002), commercial longline west (1993, and 1998-2002), recreational handline east (1991-2003), and recreational handline west (1991-2003, less 1996-1997). It was noted that there were differences between the observed age composition and the probabilistic age composition.

At this point in the meeting, Clay Porch led a discussion of the Goodyear probabilistic aging method and the ASAP model. The discussion that followed covered a wide range of strategic issues for assessment models. Foremost was a debate over the virtue of stepwise incorporation and evaluation of changes from the 1999 assessment vs wholesale incorporation of new data, new estimation techniques, and modeling advances; with evaluation of differences to follow. The AW participants seemed to fall into two camps on this issue. However, as the ASAP model used in the previous assessment was known to require a number of isolated changes of ‘hardwired’ features to accommodate new information, a more stepwise approach was ultimately favored. A second important issue considered was the potential for misidentifying changes in abundance as changes in selectivity over time in age-structured models. Solutions offered included considering a VPA analysis as a check, and constraining changes in selectivity during model fitting. However, this was a contentious area, expected to require some time in evaluating model performance.

AW-20 covered the analysis recommended by the DW to develop age composition estimates for the shrimp fleet bycatch. The analysis showed considerable interannual variation in the age composition vector, a variation that was largely not present in the years available to assessments in the late 1990s. Some differences were noted in the amount of data used in AW-20 and in the data files held by LGL Consultants. These differences were found to be due to observations on trawls experimenting with or conducting certification testing on uncertified BRDs. As these BRDs were not in general use in the fishery, and in the case of certification testing, may have involved trawling selectively in areas of high snapper concentration, these trawls should not be considered representative of the overall fishery.

AW-15 presented an estimate for M at age 1 based on analysis of SEAMAP trawl survey data, using a method largely following a classical regression of Z vs effort. (This paper also covered the methods and data used in extracting separate CPUE indexes for age 0 and age 1 from the SEAMAP data.) AW-7 also considered estimation of M from the trawl survey data, based on an MLE programmed in AD Model Builder. It turned out that estimation was possible only by combining Fall-to-Summer and Summer-to-Fall estimates of Z in a single analysis, per AW-15. Without considering both seasons, there was insufficient contrast in the shrimp effort data to permit estimation. Later in the week, the AW group recommended using the 0.6 value derived in AW-15 as the point estimate of M at age 1. However, there may be as much of a message in the large confidence interval from AW-15 as in the point estimate itself.

AW-14 also considered juvenile M, in the sense of generating prior pdf’s. This approach was recommended more for subsequent assessments rather for use on the time scale available for the current assessment. During discussion, the allometric strategy proposed by Lorenzen was also introduced.

Papers AW-8 and AW-12 addressed possible density dependence in juvenile M. AW-8 provided a formal structure to incorporate the timing of density dependent effects in a Beverton-Holt context, and the effects of different timings on a set of equilibrium population statistics. AW-12 presented yield curves based a particular set of assumptions with and without post-recruitment density dependence. (AW-12 also addressed the issue of linking F’s from separate fisheries in MSY calculations.) Discussion of potential impacts of post-recruit density dependence occurred occasionally throughout the week. Those who had experimented with models incorporating “ultra-historic” data noted that it appeared difficult if not impossible to derive a realistic exploitation history without invoking additional density dependence. However, the group as a whole noted that there appeared to be no route available to estimate density dependence, or even decide upon its structure, based on existing data. Most all agreed that at the likely current levels of abundance, density dependent effects would not be immediately important in predicting population trends over the near future. However, the role, timing and strength of any density dependent effects could be very important over the longer term, particular regarding optimal allocation strategies.

There were some additional papers not covered by oral presentations during the paper presentation sessions. AW-4 and AW-9 presented updated indexes of abundance for the recreational and commercial handline fisheries, respectively, based on recommendations of the DW. There was also a short update paper on relative length frequency methods (AW-6a). The results from these papers were used in later discussions of indexes in the assessment models. Paper AW-13 was a commentary on the DW results, and many of its points came up in discussions throughout the week. Papers AW-6 and AW-11 covered modeling issues, and were addressed in the portion of the workshop looking at modeling results, so consideration of these papers appears in the next section. An additional 'paper' was available as a powerpoint presentation (.ppt format); this material was also covered during the discussion of modeling results.

Summary of Initial Modeling Results

The modeling efforts during the workshop began by establishing a 'continuity case' – a case matching as closely as possible the methods of the assessments of the 1990s, but including the data developed since that time. This analysis used the ASAP program, as did the most recent assessment. This continuity run was followed by considering a series of 'single step' changes, modifying items like fishery definitions, inclusion or exclusion of indexes, fixing and floating various parameters or constraints, considering alternative treatments that generate input data, etc., as suggested by the group. This process was aimed a getting an understanding the properties of the models and data prior to deciding on a 'base case' for the current assessment. Most of this effort was by necessity limited to the ASAP framework, but we were also able to consider results of a 'Gaming model' approach, and a classical, untuned VPA. Discussion of the data items in the submitted papers resulted in some new suggestions for analytical treatments, and the stepwise modeling changes proved time-consuming. By midweek, it was clear that one week would not be enough time to finish the assessment. The group continued investigation of modeling alternatives, but less driven toward reaching a full assessment or even a 'base case' by week's end, and more geared toward setting up what could be done prior to a second assessment workshop. The presentation of results here to capture only the more general discussions and results, in anticipation that a number of the runs presented during the week would be superseded by new material produced between the two workshops.

A recurrent, significant finding was that the ASAP model could not reliably fit both the steepness and virgin recruitment (R_{virgin})stock recruitment parameters if both were allowed to simultaneously estimated, at least if only the modern data were considered. The reason why was obvious: there has been a relatively large range in recruitment over the modern period, but an almost trivial range in spawning stock sizes. This was not a new discovery. The same problem has been discussed since at least the early 1990s. Although recruitment and spawning stock estimations are now available for many more years, it appears the spawning stock size has still not changed enough over that time for a reliable stock recruitment curve to be established. Many of the participants retained hope that inclusion of the "ultra-historic" data might provide some insight. There was hope the steepness and R_{virgin} might mainly impact the long term rebuilding issues – what the stock might be capable of producing near MSY. Shorter term advice might be less affected.

Another significant issue was the existence of differing directions of trends among several of the recent CPUE indexes. There was some measure of conflict noted between fishery dependent vs independent, and east vs west. There was general agreement that one should not simply include conflicting indexes in hopes the model fitting would sort things out. Results then would be driven by index weightings, and under most choices the result would be a flat 'average' that would be 'flat wrong.' There was a suggestion to contrast model runs containing only the upward trending indexes with runs containing only the downward trending indexes to bracket the uncertainty in the CPUE signals. This proposal seemed to obtain general support. There was an extended discussion of the extent of preference to be given to fishery independent information, with some participants preferring to use only fishery independent indexes when both independent and dependent indexes were available, and others recommending inclusion of both types. Consensus was less clear on this issue, but discussion ultimately trended more toward inclusion than exclusion. There was also some hope that the spatially structured model being developed could sort out differences that might be due to real east / west differences. However, it may be that the durations of the trends have not been sufficient to sort out true abundance changes in the most recent years from other possible causes.

Carl Walters expanded on results mentioned earlier in the meeting (no accompanying AW paper) using a classical VPA approach. Walters had been concerned that forward projecting age structured models may falsely interpret abundance changes as selectivity changes, especially with a dome-shaped selectivity pattern. His analysis found the expected peak in F at early ages, but also found traces of transient targeting of older fish. He felt that both factors present problems to models allowing fitting of selectivity. Waters also incorporated 'ultrahistoric' data into a stock reduction analysis, and suggested that it would very difficult to provide a plausible trajectory over the entire history of the fishery without adding additional dynamics like post-recruitment density dependence.

AW-6 laid out the structure for an assessment model (CATCHEM AD) that would allow consideration of multiple stocks, with movement among them. The model also has the potential to 'internalize' the probabilistic aging procedure in a more rigorous fashion and/or to use catch at age data. There was discussion about the ability to model any local depletions during development of the longline fishery, and for handling any changing vulnerabilities like those of Walters VPA by loosening selectivity constraints.

AW-11 summarized Murdoch McAllister's Gaming Model approach, with results from some trial runs, which by the second AW session, this model came to be referred to more often as the "SRA" (stock reduction analysis). Additional results were shown at the meeting, including incorporating density dependence at age 2. This model incorporated estimates of catch back to 1880. This model also had difficulty producing a trajectory going from an unfished state to current conditions with a single stock / recruitment function; adding post-recruitment compensation made the trajectories seem more plausible.

Approximately 3 dozen ASAP runs were completed during the course of the meeting. Most runs explored inclusion or exclusion of sets of CPUE indexes. These runs also explored the tension between R_{virgin} and Steepness by alternating fixing and fitting in the course of including indexes. Several of the runs looked at inclusion of data from the period prior to the current statistics programs. Four runs also incorporated the higher point estimates of juvenile M recommended during the meeting. . In general, inclusion or exclusion of any particular CPUE index did not change the results appreciably. Any model's evaluation of the status of the stock rested heavily on the treatment of steepness used.

The stock / recruitment problem remained a constant theme to the close of the meeting. Model estimates of recruitment (or inferences from CPUEs) suggest a relatively large range for recruitments since the 1970s, with stretches of several years with persistently higher or lower levels. Past discussions of evidence suggested recruitment may have been highest early in and just preceding the 'historical' period, but it now seems that ascribing any decline since then solely to changes in spawning stock size is incompatible with the lack of range of spawning stock during the historical period. Models using 'ultrahistoric' data suggested that it is difficult to get a time series of F that makes sense – smooth progressions with plausible assumptions about effort are either unresponsive, or too responsive, over some portion of the time series. The long age span of red snapper implies the adult population could be very slow in rebuilding age-sturcture and spawning biomass . Over the range of fishery information, the stock has seemed to become almost absent in the eastern portion of its historical range. In ASAP, fixing steepness in the range expected based on other species usually led to results suggesting a low (in some cases, an almost trivial) level of current F; in contrast, allowing steepness to be fit usually suggested very serious depletion. In sum, the results have not been entirely internally consistent. Adding additional dynamics might help, but there are multiple possibilities (e.g. post-recruitment density dependence, impacts of larger snapper on smaller snapper anywhere in the age range, M variation over time due changes in predator stock sizes, changing stock / recruitment parameters over time, grossly different selectivities over time, an outside source of new recruits). Most discussion at the meeting focused on compensation around age 2, but there is precious little evidence for or against that, or for or against any of the other possibilities at this time. We looked forward to December to learn if spatial subdivision and further development of the 'ultrahistoric' line of inquiry could provide any new insight into stock / recruitment.

December Session

The second portion of the SEDAR Assessment Workshop was held at the Wyndham Hotel in Miami, December 14-17, 2004. Discussion began with brief summaries of a new set of contributed papers, developed since the August meeting.

Summary of new contributions, and model development

Steve Turner began the discussion with an overview of progress since the August meeting. He introduced revisions to AW-18, which covered the modeling of the age composition used as input to ASAP. Catch at age matrixes were developed for multiple M's. He summarized the assessments that would be covered, emphasizing the advances in developing estimates of 'ultrahistoric' catches. He also cited two papers, AW-24 and AW-25, on ageing the closed season recreational catch and alternative juvenile trawl indexes, respectively.

Clay Porch covered reconstruction of a shrimp catch and effort time series (AW-23). The start of the offshore brown shrimp fishery relevant to snapper bycatch was taken to be 1948. The start of the Tortugas fishery was taken as 1950.

ASAP used catch estimates, whereas CATCHEM uses effort estimates as input for the prehistoric period. (For the shrimp fishery, the ultrahistoric period ends in 1960)

Clay Porch summarized the story of 'ultrahistoric' catch reconstruction for the commercial fishery (AW-22). Further investigation of the historical records since August resulted in several changes from the time series considered at the August meeting. There were scattered reports of local catches back to 1850, but the real beginning of the fishery was taken to be 1872, when 4 'smack' vessels began fishing inside 40 fm. The fishery grew rapidly, with first reports of local depletion appearing in 1885. Several sources were consulted to separate Campeche (off the Mexican Yucatan Peninsula) catches from catches from US waters. US statistics began recording water body in 1963. In the 1950s and 60s, there were major boat-building programs, leading to major increases in effort. There are no viable CPUEs available for the pre-historic period. Steve Turner answered questions about gutted vs whole weight. Gutting at sea apparently began in 1935, but the statistics reported were converted to whole weight. The statistics for 1955 stated that landings were expressed as whole weight; for 1956, the term 'landed weight' appeared instead. So, from 1956 on, weights reported were assumed to be gutted, with a 1.11 conversion factor.

Steve Turner summarized the runs to be presented:

VPA 1984 – forward
ASAP 1984 -- forward , 1962 – forward (ASAP 1872 – was not sucessful)
CATCHEM 1872 -- forward

Liz Brooks followed with a table of summary statistics for the runs made at that point (AW-33). A few possible transcription errors were noted by the group, to be checked later by Miami staff. This table became a 'living document' for additions and revisions made during and after the workshop. The current version is available as Table 2 of the overview report.

Liz Brooks presented results from two VPA papers (AW-28 and AW-29). Running VPAs was cited at the August session as a particularly important check on the validity of ASAP and CATCHEM given the domed-shaped selection pattern, which was deemed likely to enhance the danger of confounding selectivity changes and abundance changes. A number of projections forecasting future stock status were made. Technical details are available in the AW papers, with summary lines in Table 1 of the Overview Report.

Shannon Cass-Calay presented the ASAP results for 1984-forward (AW-30) and 1962-forward (AW-31). Two sets of 1984-forward runs were made: one set (the 'continuity' case) was most similar to the past assessments (with two indices of abundance used previously) and another set which used six indices. All the 1984-forward model had 6 fleets and , updated fecundity estimates. The parameter for (log) virgin stock size was estimated; steepness values (h) were fixed, with runs at h=0.81, 0.9, and 0.95. Fits to the catch data were generally good, except for bycatch, especially pre-1990. Gerry Scott commented that this run with updated data, modeled using logic very similar to previous assessments, gave results very similar to previous assessments.

Group discussion then centered on assumption used in projections. The projections presented used a scenario developed by economists, predicting declines in shrimping on the order of 40% over the next several years. Questions were raised about the review status of that report, and several participants expressed concern that they had not seen the source document. The advice ultimately given was to be sure to be clear about both what is assumed about shrimp effort trends, and what is assumed about survival from any F reduction in the shrimp fishery in any final presentations. No one advocated any single scenario for projections.

Shannon Cass-Calay presented results for the ASAP runs from 1962 forward, Gulfwide (AW 31). Mauricio Ortiz presented results of separate East and West ASAP analyses (again, for 1962 forward, AW 34). This effort proved difficult, with many prelimary runs required. There are no actual age data available pre-1984, and the model returned nonsensical results if none were input. To get a solution, age compositions averaged over 5 years from each fleet were calculated, and introduced into the analysis for the years lacking data. This allowed the model to reach a solution, but the model had an additional problem with catches of zero (some of the years were pre-longline, when catches of zero were correct for that fishery). Addressing this problem by substituting small positive numbers for catches of zero led to large differences in MSY depending on what small number was substituted. Although results were otherwise plausible, this 'instability' of the ASAP model was a serious concern (and later figured in the group's decisions to recommend the CATCHEM model). Carl Walters suggested the problems were related to the lack of information in changing, dome shaped vulnerabilities. Clay Porch disagreed, and felt that the problems were more likely related to the complex and *ad* *hoc* penalty structures hard-wired into the ASAP model, which were reasonable for the short time-series were possibly inappropriate for longer time-series of catch-effort data. (Further investigation was conducted in Miami after the meeting, and to date no fully satisfactory explanation for the instability has been found.)

Josh Sladek-Nowlis presented results of a bootstrap analysis of sensitivity to juvenile M requested at the August AW session (AW-32). ASAP was fitted with a front end that allowed recalculation of the full ASAP procedure with random draws from a distribution of juvenile M values approximating the uncertainty described in AW-15. Runs were made at three levels of steepness (h = 0.81, 0.9, and 0.95). Response to M variation was generally as expected. Benchmark responses were monotonic with M except for SS_{2004} / SS_{MSY} at the highest steepness. Qualitative descriptions of stock status remained similar throughout the range of M considered. The range of steepness considered varied the stock status results far more than the M range considered, and some interaction between steepness and juvenile M was evident.

Clay Porch presented results from the CATCHEM model for 1872 forward (AW 27). The model incorporates East and West geographic divisions (at the Mississippi River). The fishery was presumed to start from a virgin situation in 1872. Thirty ages are used, starting at age 1. There are three 4-month seasons as time steps. All spawning and recruitment is modeled to occur in the second season. A Beverton-Holt spawner / recruit structure is assumed. The parameter corresponding to steepness is a fitted parameter, with a prior; but all runs so far ended with steepness very near or at the upper bound allowed, ~0.97. The age-related fecundity description was taken as the primary, with a length-related function also run for sensitivity. M_1 was set at 0.6 per year; with 0.3 run made for sensitivity. The commercial HL fishery was started in 1872. The longline fishery started in 1980. The recreational fishery was assumed to start in 1946. The closed season commercial fishery (discards) was treated as a separate fishery for modeling purposes, beginning in 1991. Shrimp bycatch catches began in 1972, but shrimp effort data were incorporated back to 1960, and reconstructed effort estimates extended back to 1945. Indexes included handline (as Landings per unit effort), MRFSS, SEAMAP trawl at age 1, SEAMAP larval index, and the SEAMAP video index (Appendix 1. Table 5). Only observed age composition was used (Appendix 1. Table 8) . Commercial catches (presumed intended to be censuses) were assigned an arbitrarily low CV of 0.1. Weightings were all based on reported CVs for the data elements to which the model was fitted; in addition process variance was estimated for the relationship between the indices and abundance..

In general, the base CATCHEM model was able to fit the catch, effort, indexes, and composition data very well. Only the West larval index (with its increasing trend) failed to be fit. The F's reported in the presentation results were actually catch rates, not mortality rates (some discards live). The productivity of the West was estimated to be about 3 times the productivity of the East. Current catch levels in the East did not appear to be sustainable. The sensitivities considered modified results in the directions expected, although the magnitude of the changes was somewhat less than observed in other model applications.

Carl Waters commented that the CATCHEM results looked very similar to his VPA results. Murdoch McAllister also noted the similarities to his SRA results.

Murdoch McAllister provided an update to his SRA ("gaming") model (AW-26). He stressed that he felt the SRA model was appropriate for gaining insight, but not for making management predictions. The model did not fit catch at age directly, instead it uses average output from ASAP runs for selectivity and recruitment deviations. Basically, the model did not provide a plausible trajectory over the ultra-historical period unless a post-recruit density-dependent mortality mechanism was added to the model. Once density dependence was added, model results resembled the results from ASAP and CATCHEM presented at the second AW session.

The group discussion again visited density dependence discussion. The SRA approaches had difficulty fitting the pre-historical catch series without incorporating some post-recruitment density dependence. ASAP tended to underpredict the shrimp bycatch (which had high CVs in many or the earlier years of the time series), which McAllister suggested might be evidence of density dependence. Porch countered that a better fit to bycatch might simply mean that the trawl survey series were not fitted quite correctly. Consensus moved to starting the population modeling at age 1 (per CATCHEM). Information contained in age 0 catch-effort observations would be lost, but this might best deal with the problem of uncertainty about the timing of any density dependence. Discussion spread to the different modeling approaches in general, with participants citing their opinions on the pro's and con's of each approach. The similarity of the results between VPA and CATCHEM was noted as evidence that CATCHEM was not plagued by confusion between selectivity and mortality change. The lack of numerical instability in CATCHEM compared to ASAP was also reiterated. Finally, CATCHEM was endorsed by the group as the recommended model structure to apply for characterizing the status and likely future prospects of the Gulf red snapper resource.

Several possible alternative scenarios within CATCHEM were then discussed. Suggestions included:

1) revising the stock recruitment function to include a density dependent M component explicitly (deemed not doable in short term) as a longer-term research activity.
2) model a common larval pool (easy to do)
3) model the shorter time series
4) fix steepness at the central tendency of the prior (~0.8)
5) force the model to fit the shrimper landed CPUE index
6) consider a single index to eliminate the logbook index conflict (eventually decided against doing)

Most of the assessment staff returned to the lab to work on the alternative scenarios. The remaining AW participants discussed projections into the future and other issues. These topics are considered in a later section, as discussions and CATCHEM results presentations were interspersed over the remainder of the meeting. First, this report will summarize the CATCHEM results.

The CATCHEM run with the common larval pool was not run to completion. It was stopped once it was clear that results would be very similar to runs presented previously. Virgin recruitment in the east was raised slightly.

Fixing steepness at 0.81 fit the catch and index data about the same as the base case when compared by visual inspection. The ratio of virgin recruitment West:East dropped to 2:1 (was 3:1 in the base case).

Forcing the model to fit the shrimper CPUE was an attempt to mimic the logic used in the pre-1998 assessments, where recruitments in the 1960s and early 1970s were inferred to be much higher, and characteristic of near-virgin levels. This model predicted that an unrealistically large kill must have taken place in the recreational fishery in the period before recreational catch data were recorded. An alternative was suggested, setting R_0 to the $R_{1960's}$ level. This alternative also required very large recreational catches in the 1970s (well above levels expected in the historical reconstruction) to fit all other aspects of the data.

The shorter time series request was accidentally mis-specified in coding changes, and was deferred until after the meeting.

Collected summary of topics discussed

Discussion by AW participants not involved in running assessment models at the meeting covered a wide range of topics. Many of the key topics tended to come up repeatedly but intermittently as the group alternated between awaiting and wading through model results. A Presentation of these comments and discussions chronologically would be hard to follow, so this report isolates the major topic and collects points of view expressed over the duration of the meeting. Topics highlighted here are MSY definition, steepness, geographic structure, release mortality, management tools, future shrimping patterns, past treatment of stock / recruitment, most recent recruitments, abundance vs selectivity, and habitat enhancement and density dependence

MSY definition. Although the MSY concept and the uncertainty properties for its estimation have been discussed critically for many years; recent assessment developments have actually led to an increased ambiguity in the definition of MSY. With more detailed models better characterizing selectivity in individual fisheries, new definitions conditional on observed or targeted selectivities have emerged. This situation was discussed at length in the snapper SEDAR meetings (see particularly DW-51), but no consensus was reached. Some argued for keeping MSY as a property of the stock by use of simplified and standardized selectivity vectors. Others preferred definitions incorporating realistic selectivity expectations, with the advantage of keeping MSY benchmarks more meaningful to real fisheries. The most difficult issue for red snapper is accounting for extreme selectivity differences among the different fisheries, especially how to incorporate the shrimp fishery in snapper MSY calculations. Several participants stressed that no choice is truly "policy neutral." Recent previous assessments had used scenarios named 'linked' and 'unlinked,' with linked calculating MSY using proportional reductions set equal in all fisheries, and 'unlinked' setting the shrimp fishery to high, arbitrary reduction. The 'unlinked' terminology was also used to describe results of projections that varied the F's independently among fisheries, which became a source of confusion.

The CATCHEM-based assessments discusses stock status relative to 3 different selectivity structures, named pre-shrimp, post-shrimp, and linked. Pre-shrimp describes the case with F due to shrimp bycatch set to zero, with the name reflecting the rather late development of a significant shrimping mortality component in the history of the snapper fishery. Post-shrimp MSY benchmarks leave shrimping F at the status quo (average of 2001-2003), reflecting the possibility the 'reducing bycatch to the extent practical' has largely been reached. However, 'post-shrimp' also applies to future projections in which shrimp F may be manipulated separately from directed F's to anticipate future changes in shrimping effort or BRD technology. 'Linked' continues to refer to proportional changes in all partial F's, and is included largely for historical continuity.

It is very important to recognize that evaluation of stock status with respect to any MSY is very dependent on the choice of MSY definition used.

Steepness. The preliminary CATCHEM results were all consistent with steepness ~1. Steepness near 1 is still an unexpected result for many of the AW participants. There are several reasons why an assessment could produce a steepness near 1:

1) The assessment is correct; steepness really is very high
2) The historical catches were a great deal higher than recorded in the statistical reports and archives.
3) The portion of the results suggesting recruitments are near maximal today is an artifact of modeling very different types of information in different eras
4) There are important dynamics not modeled in the current assessment structure. The most likely possibilities include:
    a. Density dependent mortality in (post-recruit) juveniles
    b. Density dependent mortality in adults
    c. Delayed density dependence (adults vs juveniles)
    d. Changing M over time, not related to snapper density (reduced predators)
    e. Increasing carrying capacity over time for pre-recruits (regime change, artificial reefs)
    f. Increasing carrying capacity over time for adults (oil rigs)
    g. Stock extends geographically well beyond assumed range (Campeche connection)

Discussion by the AW included speculation on possible mechanisms for each (a few are listed parenthetically). Each AW participant had favorites, but the best advice at present is probably that all are speculative, and it would be a mistake to single out any possibility for further research or analytical focus, to the exclusion of any of the others. Remember also, that there is no need to invoke any of these mechanisms to fit the current data. The main reason for considering any of them is disbelief about the steepness result. It is certainly possible that the primary CATCHEM model could fit the data well, but be mechanistically incomplete. However, it seems inappropriate to simply force structures that include these potential dynamics into the current model at this time. It is unlikely that the current data could provide any realistic support for any of these postulated mechanisms. Improving our knowledge in all these areas should definitely be considered for future research.

Geographic structure. Perceived low mobility of juveniles and adults, possible geographic differences in vital rates, and especially, stable isotope evidence convinced the DW to recommend consideration of spatial substructure in this assessment. Interestingly, some of the follow-up analyses conducted after the DW did not support major rate differences between East and West. However, adding the geographic substructure has appeared to reduce the problem of conflicting CPUE indexes. The CATCHEM runs completed during the workshop did suggest plausible differences in the histories of East and West subdivisions of the population. CATCHEM could actually do a lot more with interchange rates in the adult phases, for which there was some evidence presented at the DW. However, exchange estimates available looked very cohort-specific, and estimates were available for very few year classes. The group decided it would be inappropriate to include rates for only that handful, with no acceptable way to predict the rest for this assessment, so exchange modeled was basically larval. This should be a project for the future, as data accumulate.

Release mortality. The DW report provided a thorough airing of what is known about release mortality, and recommended values to be used. However, the issue was brought up again at the second session of the AW. Some argued that the differences ascribed to recreational vs commercial release mortality are too large, because boats of both fleets are often seen in close proximity. Others argued that differences in practices, and differences in depth distributions for the two fleets taken in their entirety would dominate. Discussion ended without specific recommendations for values different from those recommended by the DW, but concern clearly remains that not enough is known about release mortality rates.

Management tools. Several of the constituents' representatives have asked for analyses to evaluate effectiveness of specific management tools (e.g. size limits, slot limits, bag limits, non-proportional F reductions, etc.), and understandably have expressed some frustration at repeated postponements of taking up these issues. Unfortunately, there is little value in running these types of analyses until we have completed the more general analyses about status of the stock. Because the time required to finish the status of stock modeling has extended so long, we have been unable to consider anything but the most basic management scenarios in time to be included in this report. Many of the requests for detailed management scenarios may have to be completed after the SEDAR RW.

Future shrimping patterns. The AW did not reach full consensus on future time series of shrimp F's to be considered in projections of future yields. All wanted to see a range of levels considered, such as is customary in isopleth diagrams of status metrics vs directed TAC vs shrimp F reduction. However, these diagrams contain no explicit time information. A scenario exists with a trajectory for shrimping effort, developed by economists. The group split somewhat on the potential use of that scenario, with some feeling it was a worthwhile to consider (but not as the only scenario), while others expressed concern that the scenario had not been reviewed at either the DW or AW.

Past treatments of stock / recruitment. As early as 1990, the scientific community was aware that the existing data would not support fitting a stock/recruitment function for red snapper. At a workshop held in Pascagoula in 1990, a stock / recruitment function was constructed for the purpose of forecasting stock sizes under hypothetical management scenarios. Three pieces of evidence were considered relevant to estimating recruitment prior to the earliest direct data available. First, The NMFS Fall Groundfish Survey (a predecessor of SEAMAP) extended back to 1972. The 1972 point was several-fold higher than any other point in the time series. (The raw data were consulted, and there were indeed many stations with elevated catches during the survey.) Second, a Landings Per Unit Effort index based on red snapper landed by shrimp trawlers had been constructed for the 1960s through the 1980s. (A the time, these were believed to have been trawl-caught, but limited to market size fished. Industry members later indicated a substantial portion of these fish may have been caught be hook and line during inactive periods on shrimping trips.) This index paralleled the Groundfish index very closely with a 1 or 2 year lag for years in common, and showed a level pre-1974 that was several times the 1980s level. The third piece of evidence was that red snapper total commercial landings dropped sharply in the early-mid 1970s. (There were no recreational data from that period.) The group concluded the recruitment must have been substantially higher from 1972 back at least through the 1960s than in the mid 1980's. Discussion centered around virgin recruitment being about a factor of 10x the recruitments of the mid 1980s. To pick a point for modeling, the 1970-74 shrimper CPUE index was divided by the shrimper CPUE index for 1984-88, and the result was 8.5. The group felt this was a conservative estimate of virgin recruitment, in that the long history of exploitation had probably reduced recruitment somewhat by 1970-74. After a few trials with simpler structure, a Beverton Holt S/R equation was developed by forcing the curve through 2 points: recruitment at 8.5x the mid-1980s level, spawning stock (as egg production) in equilibrium with that recruitment in the absence of fishing; and the mean of 1984-1988 recruitment (from Goodyear's assessment model), mean 1984-1988 spawning stock . The belief at the time was that increasing fishing pressure through the 1960s had reduced the spawning stock enough to compromise recruitment. Everyone recognized that the level of virgin recruitment was not certain, and thus the potential production at much reduced fishing levels was not certain, but unrecorded discussion suggested at least some participants would consider anything from 2x to 20x the recent recruitments as within the range of possibility.

This heuristic construction of a stock recruitment function was superseded in the late 1990s by analyses based on systematic alteration of the steepness parameter using the ASAP model. In that context, status inferences tended to be closely linked to steepness assumptions, and fairly large ranges in possible ABC were reported back to the Council. Results that predicted unexpectedly high standing stocks at MSY came under particular criticism, largely on energetic grounds. It now appears energetic considerations do not rule out many of the higher values (see DW-12), but with potential yields still predicted to be higher than ever believed to have occurred, the highest MSY outcomes remained suspect.

In the interim between the 1990s assessment and the present, some alteration to the data base regarding landings by gear in Texas occurred (see AW-17). No documentation for the changes was ever found, so the shrimping Landing per Unit effort index cannot now be considered reliable. The index remains reported here, but it did not play a role in fitting the assessment models.

Inclusion of the 'ultra-historical' data in the current assessment has now provided additional insight. Several attempts were made to 'force' a result simulating the 8.5x recruitment change between the late 1960s and mid-1980s using the CATCHEM model. The only outcomes that allowed recruitments at that level required unrealistically high recreational catches in the pre-MRFSS era. It was a bit surprising that the model did not support even temporarily high recruitments as consistent with all other data, but clearly, CATCHEM results at the AW did not support the idea that virginal recruitment was much higher than recruitments currently occurring. Although it might be conceivably possible to add new dynamics to CATCHEM that leads to a result more consistent with elevated recruitment in the past, the opinion of the AW was that a past, higher recruitment scenario should now be considered an unlikely scenario.

Most recent recruitments. Concern was expressed about declines in recruitment in the most recent 3-4 years evident in some model outputs. These results appeared most prominent in some of the VPA results, but were not a strong feature in others. All participants had some concern, and some participants expressed a lot of concern, but ultimately the group did not appear to consider this topic to be a central issue.

Abundance vs selectivity. The similarity of the CATCHEM and VPA results appeared sufficient to satisfy the group that seriously misleading outcomes due to confounding of abundance and selectivity changes, such as discussed at length in the first AW session, were sufficiently ruled out for the snapper assessment.

Density dependence and habitat enhancement. The possible importance of post-recruit density dependence has been a central topic at both sessions. An interesting, related issue raised by Carl Walters was that perhaps juvenile snapper survival may have been increased due to system changes induced by heavy trawling pressure. A subcommittee was formed to draft text covering these topics, and their contribution forms the remainder of this subsection. Notes made at the meeting suggest that there was less enthusiasm for the strength of evidence that trawling may have enhanced survival than implied here, but the AW group was certainly willing to air the viewpoint.

> At present, the red snapper assessment model recommended by the Assessment Workshop participants assumes that density dependent survival takes place prior to fishing impacts, as do most assessment model applications. However, the red snapper situation is complicated by the fact that fishing impacts occur at such young ages. Consequently, the common assumption is more tenuous here than elsewhere. At present adequate data are not available to resolve the period during which density-dependent survival takes place. From a policy perspective, perhaps the most significant implication of these unknowns is in our confidence of the effectiveness of bycatch reduction efforts, including bycatch reduction devices (BRDs). It is very unlikely that continued data collection of fishery independent and dependent information as currently being used in the assessments will resolve the uncertainty in the near future, due both to variability in the data and confounding of bycatch effects with other factors that may be causing recruitment changes (regime shifts, changes in stock size). The quickest and perhaps most economical way to determine the net impact of bycatch reduction measures would be to conduct a large-scale adaptive management experiment, involving closure of some areas to trawling and careful comparative monitoring of red snapper juvenile abundances in closed vs open areas.
>
> To the extent that existing data can provide insight, two lines of evidence suggest that current assumptions might be wrong, and that density-dependent mortality may take many of the juveniles "saved" through bycatch reduction measures:

1) long term population models (stock reduction analysis) indicate that historical fishing effects would have been minor if historical recruitments had been as high as would be expected from current bycatches;
2) the Seamap data is consistent with density-dependence in survival rate from age 0 to age 1 (Figure 1).

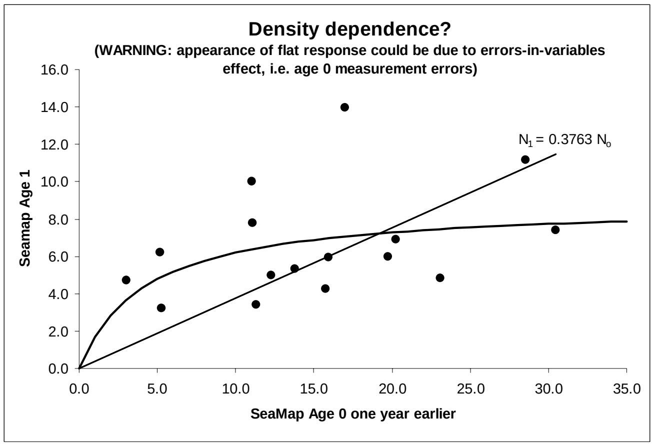
However, it is possible that historical recruitment rates were lower for some other reason (dome shaped recruitment, possible enhancing effects of shrimp trawling on snapper juvenile survival due to removal of predators, environmental regime changes), and the apparent density-dependence in juvenile survival could be an errors-in-variables effect (data show artificially high range of regression X values due to measurement errors in X).

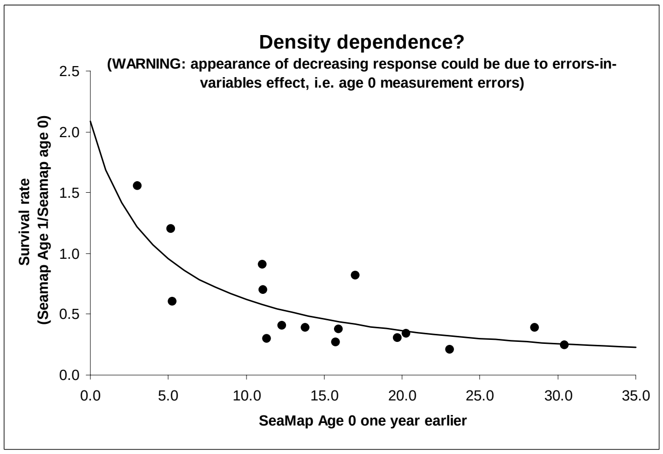
We should not be surprised to see continuing density-dependence in juvenile mortality rate over the ages intercepted by shrimp trawls. There are few published studies of timing of density-dependence in juvenile mortality (eg Myers and Cadigan 1993), but the evidence that is available indicates that density-dependent effects may occur until fish reach relatively large sizes (review in Rose et al. 2001). Models based on juvenile foraging behavior and associated predation risk predict continuing density-dependent effects until those ages where total M is quite low (Walters and Martell 2004). Observations of snapper behavior indicate, size-dependent spacing effects, with smaller fish being displaced to potentially less favorable sites when they encounter larger conspecifics. Such spacing effects are likely to result in density-dependent mortality due to predation risk during “forced” dispersal events (even if that predation risk is not cannibalism per se).

While density-dependent effects may prevent recruitment increases following implementation of policies aimed at bycatch reduction, recent data are consistent with an even more counter intuitive possibility: the habitat and fish community “disruption” effects of shrimp trawling may actually be resulting in improved juvenile survival of red snapper. There is a broad positive correlation between shrimp fishing effort and recruitment rates estimated using the CATCHEM long term model, and VPAs indicate a peak in recruitment during the early 1990s followed by reduced recruitments in the late 1990s following implementation of BRDs. However, this evidence is weak for two major reasons: (1) Most of the recruitment estimates from CATCHEM are modeled rather than observed, and could be highly sensitive to model assumptions. (2) Any suggestion of decline in recent recruitment are driven by three unusual years that do not correspond with the implementation of BRDs in 1998, including a spike in 1994 and 1995 and apparent dramatic drop in 2003. Nonetheless, it is a global expectation by shrimp fishers that trawling causes improved shrimp recruitment, most likely due to removal of competitor and predator fish species, and this expectation is supported by ecosystem models for one case situation (Great Barrier Reef lagoon area; Neil Gribble, Queensland DPI, pers. Comm.). Perhaps this same “cultivation” or enhancement effect has influenced the red snapper as well.

Whether because of density dependent mortality or reduced survival enhancement effects, there is risk that policies aimed at bycatch reduction have either negligible or the opposite effect from that intended. This means that even the direction of snapper response to bycatch and shrimp effort reduction is uncertain. It is unlikely that continued data collection of fishery independent and dependent information as currently being used in the assessments will resolve the uncertainty in the near future, due both to variability in the data and confounding of bycatch effects with other factors that may be causing recruitment changes (regime shifts, changes in stock size). An adaptive management experiment, as outlined above, would be the most effective way to gain insight into the strength of linkage between fishing impacts on young red snapper and the status of the red snapper population as a whole.

Figure 1. Evidence of density dependence in red snapper mortality rate from age 0 to age 1 is present in the Seamap data, when age 0 numbers are used to predict either age 1 numbers the next year (no density dependence would result in proportional response on average), or survival rate to age 1.





AW Participant Contributions after the Second Session

Murdoch McAllister was able to update his SRA results with using data revisions from the AW. He submitted a short document summarizing his methods and key findings, which has been added to the AW collection as AW-35. The description of results made at the AW held upon updating. The model could not fit a plausible trajectory for the 1872-forward period without invoking post-recruitment density dependence. Adding density dependence at either age 1 or age 2 did allow a plausible trajectory, and producing results similar to the ASAP and VPA results presented at the AW. With density dependence, shrimp bycatch reduction had little impact on future trajectories. Recovery by 2032 required a reduction in TAC, and failing to reduce TAC led to a collapse within the next 10 years under this model.

Research Recommendations

A subcommittee was formed at the second AW session to collect the research recommendations made over both sessions. They singled out several important items, and provided short write-ups on each on behalf of the AW group. (This list was developed to expand on several key items; other research recommendations brought up during the meetings remain worthy.)

The most important research needs are:

1) direct measurement of current fishing mortality rates,

2) experiments to determine the magnitude and timing of density dependent compensation in juveniles,
3) information on the effects on shrimp trawling on red snapper through community effects including nutrient cycling and changes in predation pressure,
4) continuation and expansion of the fishery-independent survey for adult red snapper,
5) more information on release mortality and discard rate by depth, season, and fishery,
6) additional alternatives for reducing bycatch such as closed areas etc.,
7) additional research such as simulation testing on the estimation properties of stock assessment methods and models,
8) distribution and mixing between the East an West.

Measurement of fishing mortality rates

A Gulf-wide mark-recapture program could provide a direct measure of current fishing mortality that would allow us to evaluate mortality estimates from the model, MSY, and risk in harvesting older fish through commercial longlining. Traditional tags such as spaghetti tags have a problem with tag shedding. Pit tags are sometimes missed in the recapture phase, and both types of tags cause disturbance to the fish during the tagging phase. A new type of tag that doesn't cause disturbance during tagging and that cannot be lost is a genetic tag, or an identification of the fish based on its DNA. A DNA sample is taken from a fish on the bottom using a special hook that bends, releasing the fish, and bringing up only a small piece of the flesh. The DNA sample is analyzed, and a catalog of individual DNA fingerprints is created. During the recapture phase, DNA samples are taken from harvested fish at fish houses or aboard commercial or recreational boats, and compared to the library of 'tagged' fish. With a large enough sample size of tagged and recaptured fish, then the fishing mortality rates can be calculated.

Density dependent compensation in juveniles

Past assessments assumed that the sole population control occurs at a life history stage before red snapper become vulnerable to shrimp trawling (at about 5 cm). Biological reproductive potential, some behavioral observations and evidence from stock reduction analysis suggest that compensatory mortality occurs during or after shrimp trawling. SEDAR7-AW-08 and SEDAR7-AW-12 make the case that the efficacy of bycatch reduction is significantly impacted if compensation occurs during or after the juvenile life stages. Experimentation with areas measure juvenile survival from the age-0 to age-1 year at different densities of juvenile abundance would provide the needed information.

Effects of shrimp trawling on red snapper

Possible enhancement effects of shrimp fishing may lead to uncertainty about efficacy of bycatch reduction policies. Direct assessment of juvenile survival responses to elimination of shrimp bycatch mortality can be achieved through the monitoring of several replicated pairs of experimental open and closed areas. The number of areas, the size of areas and the location of areas, monitoring methodology, variables to monitor and statistical design must all be determined. To test the hypothesis that red snapper production is actually enhanced by the release from predation that happens when bycatch removes a community that includes many species of predatory fishes, characterization data by observers aboard shrimp vessels on the individual species in the bycatch is needed. This type of data was formerly collected under the characterization program starting in 1992, but data collected since 1998 has been either specifically on red snapper or has been on BRD evaluations, which only collects data on 22 individual species of concern. Data on all species in the catch could be put into ecosystem models to evaluate the effects on red snapper of the removal of predators such as lizardfish, small flounders, Portunid crabs, sharks, and others.

Fishery-independent abundance index

Currently, NMFS's Pascagoula Laboratory conducts a long-line survey in the Northern Gulf of Mexico that could be expanded spatially to cover the red-snapper's range. The existing information should be used as pilot study to design a survey with adequate numbers of samples by season. This series would be more applicable i.e., fewer assumptions, than the larval survey that is currently used to index spawning biomass.

Release mortalities by sector, season, fish size, and depth

As regulations become more restrictive, more fish are released. For example the current assessments include an additional fishery – closed season discards. With the advent of biomass-based benchmarks, it is essential to account for the deaths of released fish. The SEDAR 7 Data Workshop Report examined the existing information on release mortality by sector and east vs. west Gulf concluded that commercial release mortality was 80% while recreational release mortality was 15% in the East and 40% in the West. The commercial estimate was based primarily on samples from Louisiana, which may not reflect the depth distribution of commercial fisheries in Texas or further east. The discrepancy between commercial and recreational release mortality and East and West release mortality that can not solely be explained by differences in depth need further exploration. Other difficulties are that many of the estimates were based on immediate sink or swim data, which may not be indicative of delayed mortality, that none of the estimates include increased natural mortality due to predation by dolphins or barracuda that eat fish before they can return to depth, and that most of the studies do not include differences in mortality of released fish based on size, season (either based on water temperature or closed vs. open seasons), or depth. Discard rate should also be related to recruitment indices one to two years previously, but there is not yet a time series of data built up to show this relationship.

Sampling for age composition of the catch.

Differences were observed between the observed age composition and the probabilistic age composition particularly for the commercial handline fishery. The intensive sampling otoliths from the fisheries which was initiated in the late 1990s should continue. A presentation by scientists from Louisiana State University on the age composition of red snapper discards from the directed red snapper handline fishery from late in 2001 through each 2003 indicated a younger age composition of open season discards than estimated in the probabilistic aging procedure. Such sampling should be continued and expanded to cover a larger fraction of the fishery.

Additional management measures to reduce bycatch

Recent onboard observations indicate that BRDs as actually used reduce bycatch of red snapper by only about 11%. Because fishermen tinker with their nets to reduce shrimp loss rather than to reduce bycatch, and because slight differences in BRD placement and fishing practices such as haulback procedures can have large effects on BRD efficacy, BRDs may not be able to reduce snapper bycatch as much as may be desired, and other alternatives such as closed areas, effort limitations, etc. may be desirable. More research is needed to explore these options and their potential for reducing bycatch in addition to BRDs.

Testing of the estimation procedures used in stock assessments

This assessment used a suite of methods – Virtual Population Analysis (backward), two statistical catch-at-age models (forward), and two stock reduction analysis (forward). A worthwhile exercise that would lend confidence to the assessment results is to simulate a test data set with known characteristics and to apply each of the models to that data set to see whether the methods can estimate the original parameters (N.R.C. 1997).

Mixing and dispersal

Due to differences in the effort, landings, stock structure and the potential for different stock dynamics, the recent stock assessment looked at the East and West Gulf separately. These models make some assumptions about mixing and migration of both adults and larvae. The Western Gulf appears to have higher landings and higher recruitment, and it is not know whether this stock acts as a source to provide larvae to the Eastern Gulf stock. More information on movements and dispersal of larvae based on the location of the spawning stock and physical oceanographic parameters would give insights into the metapopulation dynamics of red snapper and how the East and West runs should be linked. Similarly, the isotope research that suggests exchange among young (but recruited) fish should be continued.

Planning Workshops

The present assessment exercise can only identify the critical research needs and propose a general approach that may address the issue. We suggest two structured workshops to design and evaluate the feasibility of the programs. Simulation models should be constructed to ensure that the measured variables and analytical tools are capable of achieving the program objectives. The attendees of the workshop will be the relevant scientific experts as well as user group representatives.

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SEDAR 7
Gulf of Mexico Red Snapper

Assessment Workshop Report

Appendices

Appendix 1. Data inputs.

Historical commercial and recreational fishery catches from 1872-2003 used in the assessments are presented in Table 1. The commercial landings for 1872-1962 were developed in AW 22 and for 1963-2003 as reported in AW 17. The recreational yield for 1900-1980 was developed for the eastern and western Gulf of Mexico using the same methods as used to estimate recreational landings for the entire U.S. Gulf of Mexico (AW 16); the Gulf wide information reported here is the sum of east and west rather than the estimates reported in AW 16.. The recreational yield for 1981-2003 was calculated from recreational harvest (landings from headboat and Texas Parks and Wildlife surveys, A+B1 from MRFSS, Table 2) using an annual aggregated mean weight; use of mean weights stratified by year, region and mode (headboat, charter, private and headboat-charter for 1981-1985) produces alternative estimates which may better reflect the actual weight of the landings.

The CATCHEM and ASAP models and the derived aging system used recreational harvest (numbers of fish) rather than recreational yield as inputs. The recreational harvest is shown in Table 2. As with the yield the 1900-1980 values were developed for the eastern and western Gulf of Mexico using the same methods described in AW 16. The 1981-2003 harvest estimates were developed with the methods reported in AW 03 with the exception that 2003 charter and private mode catches were not available and so 1998-2002 means were substituted

The number of fish estimated to have been discarded dead from the commercial and recreational open and closed season fisheries is shown in Table 3. These estimates were developed as part of the probabilistic aging (AW 18).

The estimated bycatch from the shrimp fishery is presented in Table 4. The estimates for 1948-1971 are documented in AW 23. The methods used to develop the 1972-2003 estimates are presented in DW 3.

The indices of abundance available for the assessments are presented in Table 5. The source document numbers are provided for each index.

Annual length composition is presented in Table 6. The individual length samples with their landing date were used in the probabilistic aging procedure.

The catch at age calculated with the probabilistic method for is presented in Table 7 for a single Gulf wide stock using a natural mortality rate of 0.98 on age 0, 0.59 on age 1, and 0.1 on older ages as described in AW 18 and DW 56. Table 8 presents similar information calculated with natural mortality rates of 0.58 on age 0, 0.29 on age 1 and 0.1 on older ages. Similar information was calculated for the alternative two stock assumptions (east, west) and additional levels of natural mortality for use in the bootstrap analyses reported in AW 32).

The catch weighted ‘observed’ age composition from otolith samples is presented in Table 9 and the effective sample sizes used in CATCHEM to calculate weights for the observed age composition are presented in Table 10. AW 19 documents the procedures used in developing the age composition. In CATCHEM the maximum effective sample size was fixed at 200.

The age composition of the estimated shrimp fishery bycatch of red snapper is presented in Table 11. AW 20 documented the methods used to estimate that catch at age.

Table 12 provides growth and size conversion parameters as well as the age based fecundity vector and perhaps the parameters of the length based fecundity vector.

Appendix 1. Table 1. Commercial landings and recreational harvest (MRFSS A+B1, headboat and Texas PWD landings) of red snapper from the U.S. Gulf of Mexico in pounds whole weight as used in the assessments. These recreational yield estimates for 1981-2003 were made using un-stratified average weights; the use of stratified estimates of average weight might better reflect the weight of the actual landings.

	commercial									recreational			total		
	handline +			longline			total								
	west	east	total	west	east		west	east	total	west	east	total	west	east	total
1872	0	521,326	521,326	0	0	0	0	521,326	521,326				0	521,326	521,326
1873	0	781,989	781,989	0	0	0	0	781,989	781,989				0	781,989	781,989
1874	0	1,172,984	1,172,984	0	0	0	0	1,172,984	1,172,984				0	1,172,984	1,172,984
1875	0	1,433,647	1,433,647	0	0	0	0	1,433,647	1,433,647				0	1,433,647	1,433,647
1876	0	1,694,310	1,694,310	0	0	0	0	1,694,310	1,694,310				0	1,694,310	1,694,310
1877	0	1,433,647	1,433,647	0	0	0	0	1,433,647	1,433,647				0	1,433,647	1,433,647
1878	0	1,303,315	1,303,315	0	0	0	0	1,303,315	1,303,315				0	1,303,315	1,303,315
1879	0	1,433,647	1,433,647	0	0	0	0	1,433,647	1,433,647				0	1,433,647	1,433,647
1880	891,034	1,824,641	2,715,675	0	0	0	891034	1,824,641	2,715,675				891,034	1,824,641	2,715,675
1881	801,943	2,052,381	2,854,324	0	0	0	801943	2,052,381	2,854,324				801,943	2,052,381	2,854,324
1882	711,859	2,282,108	2,993,967	0	0	0	711859	2,282,108	2,993,967				711,859	2,282,108	2,993,967
1883	634,313	2,509,861	3,144,174	0	0	0	634313	2,509,861	3,144,174				634,313	2,509,861	3,144,174
1884	556,765	2,737,622	3,294,387	0	0	0	556765	2,737,622	3,294,387				556,765	2,737,622	3,294,387
1885	478,225	2,965,390	3,443,615	0	0	0	478225	2,965,390	3,443,615				478,225	2,965,390	3,443,615
1886	400,672	3,195,145	3,595,817	0	0	0	400672	3,195,145	3,595,817				400,672	3,195,145	3,595,817
1887	203,970	3,422,926	3,626,896	0	0	0	203970	3,422,926	3,626,896				203,970	3,422,926	3,626,896
1888	212,884	3,277,425	3,490,309	0	0	0	212884	3,277,425	3,490,309				212,884	3,277,425	3,490,309
1889	269,327	3,483,431	3,752,758	0	0	0	269327	3,483,431	3,752,758				269,327	3,483,431	3,752,758
1890	242,531	4,192,327	4,434,858	0	0	0	242531	4,192,327	4,434,858				242,531	4,192,327	4,434,858
1891	269,541	3,822,273	4,091,814	0	0	0	269541	3,822,273	4,091,814				269,541	3,822,273	4,091,814
1892	293,175	4,010,384	4,303,559	0	0	0	293175	4,010,384	4,303,559				293,175	4,010,384	4,303,559
1893	311,969	4,132,232	4,444,201	0	0	0	311969	4,132,232	4,444,201				311,969	4,132,232	4,444,201
1894	324,863	4,227,631	4,552,494	0	0	0	324863	4,227,631	4,552,494				324,863	4,227,631	4,552,494
1895	333,838	4,125,291	4,459,129	0	0	0	333838	4,125,291	4,459,129				333,838	4,125,291	4,459,129
1896	340,888	4,167,613	4,508,501	0	0	0	340888	4,167,613	4,508,501				340,888	4,167,613	4,508,501
1897	340,642	4,138,252	4,478,894	0	0	0	340642	4,138,252	4,478,894				340,642	4,138,252	4,478,894
1898	544,671	4,612,379	5,157,050	0	0	0	544671	4,612,379	5,157,050				544,671	4,612,379	5,157,050
1899	722,625	5,146,576	5,869,201	0	0	0	722625	5,146,576	5,869,201				722,625	5,146,576	5,869,201
1900	889,976	5,674,141	6,564,117	0	0	0	889976	5,674,141	6,564,117	297	0	297	890,273	5,674,141	6,564,414
1901	1,020,372	6,027,029	7,047,401	0	0	0	1020372	6,027,029	7,047,401	314	0	314	1,020,686	6,027,029	7,047,715
1902	1,126,034	6,283,575	7,409,609	0	0	0	1126034	6,283,575	7,409,609	331	0	332	1,126,365	6,283,575	7,409,941

	commercial									recreational			total		
	handline +			longline			total								
	west	east	total	west	east		west	east	total	west	east	total	west	east	total
1903	1,059,802	5,722,123	6,781,925	0	0	0	1059802	5,722,123	6,781,925	349	0	350	1,060,151	5,722,123	6,782,275
1904	1,011,726	5,286,731	6,298,457	0	0	0	1011726	5,286,731	6,298,457	368	1	368	1,012,094	5,286,732	6,298,825
1905	940,928	4,756,040	5,696,968	0	0	0	940928	4,756,040	5,696,968	387	1	388	941,315	4,756,041	5,697,356
1906	867,673	4,240,944	5,108,617	0	0	0	867673	4,240,944	5,108,617	407	1	408	868,080	4,240,945	5,109,025
1907	791,605	3,743,104	4,534,709	0	0	0	791605	3,743,104	4,534,709	427	1	428	792,032	3,743,105	4,535,137
1908	735,773	3,363,251	4,099,024	0	0	0	735773	3,363,251	4,099,024	448	1	449	736,221	3,363,252	4,099,473
1909	632,940	2,890,857	3,523,797	0	0	0	632940	2,890,857	3,523,797	469	2	471	633,409	2,890,859	3,524,268
1910	538,109	2,436,701	2,974,810	0	0	0	538109	2,436,701	2,974,810	491	2	493	538,600	2,436,703	2,975,303
1911	527,520	2,455,472	2,982,992	0	0	0	527520	2,455,472	2,982,992	438	2	440	527,958	2,455,474	2,983,432
1912	517,874	2,473,439	2,991,313	0	0	0	517874	2,473,439	2,991,313	391	3	394	518,265	2,473,442	2,991,707
1913	508,475	2,491,078	2,999,553	0	0	0	508475	2,491,078	2,999,553	352	3	355	508,827	2,491,081	2,999,908
1914	498,829	2,507,351	3,006,180	0	0	0	498829	2,507,351	3,006,180	319	4	323	499,148	2,507,355	3,006,503
1915	489,183	2,522,773	3,011,956	0	0	0	489183	2,522,773	3,011,956	291	5	296	489,474	2,522,778	3,012,252
1916	478,596	2,537,294	3,015,890	0	0	0	478596	2,537,294	3,015,890	269	6	275	478,865	2,537,300	3,016,165
1917	468,950	2,479,260	2,948,210	0	0	0	468950	2,479,260	2,948,210	253	7	260	469,203	2,479,267	2,948,470
1918	459,305	2,492,553	2,951,858	0	0	0	459305	2,492,553	2,951,858	242	8	250	459,547	2,492,561	2,952,108
1919	471,382	2,718,931	3,190,313	0	0	0	471382	2,718,931	3,190,313	236	10	246	471,618	2,718,941	3,190,559
1920	483,458	2,954,424	3,437,882	0	0	0	483458	2,954,424	3,437,882	236	12	247	483,694	2,954,436	3,438,129
1921	496,724	3,198,932	3,695,656	0	0	0	496724	3,198,932	3,695,656	307	14	321	497,031	3,198,946	3,695,977
1922	508,800	3,452,171	3,960,971	0	0	0	508800	3,452,171	3,960,971	405	17	422	509,205	3,452,188	3,961,393
1923	520,876	3,707,316	4,228,192	0	0	0	520876	3,707,316	4,228,192	539	20	560	521,415	3,707,336	4,228,752
1924	503,176	3,621,389	4,124,565	0	0	0	503176	3,621,389	4,124,565	720	24	744	503,896	3,621,413	4,125,309
1925	485,474	3,627,316	4,112,790	0	0	0	485474	3,627,316	4,112,790	961	29	990	486,435	3,627,345	4,113,780
1926	467,525	3,532,334	3,999,859	0	0	0	467525	3,532,334	3,999,859	1,276	35	1,310	468,801	3,532,369	4,001,169
1927	585,907	3,857,579	4,443,486	0	0	0	585907	3,857,579	4,443,486	1,684	41	1,725	587,591	3,857,620	4,445,211
1928	426,871	3,444,187	3,871,058	0	0	0	426871	3,444,187	3,871,058	2,206	49	2,255	429,077	3,444,236	3,873,313
1929	417,093	3,658,800	4,075,893	0	0	0	417093	3,658,800	4,075,893	2,866	58	2,923	419,959	3,658,858	4,078,816
1930	553,559	2,233,495	2,787,054	0	0	0	553559	2,233,495	2,787,054	3,689	68	3,758	557,248	2,233,563	2,790,812
1931	342,794	2,249,781	2,592,575	0	0	0	342794	2,249,781	2,592,575	4,138	81	4,219	346,932	2,249,862	2,596,794
1932	411,305	2,416,037	2,827,342	0	0	0	411305	2,416,037	2,827,342	4,625	96	4,721	415,930	2,416,133	2,832,063
1933	447,623	2,184,361	2,631,984	0	0	0	447623	2,184,361	2,631,984	5,151	113	5,265	452,774	2,184,474	2,637,249
1934	464,740	1,964,863	2,429,603	0	0	0	464740	1,964,863	2,429,603	5,719	134	5,853	470,459	1,964,997	2,435,456
1935	675,130	2,411,025	3,086,155	0	0	0	675130	2,411,025	3,086,155	6,330	158	6,487	681,460	2,411,183	3,092,642
1936	871,388	2,773,983	3,645,371	0	0	0	871388	2,773,983	3,645,371	6,984	185	7,170	878,372	2,774,168	3,652,541
1937	946,575	2,458,439	3,405,014	0	0	0	946575	2,458,439	3,405,014	7,685	218	7,902	954,260	2,458,657	3,412,916
1938	935,330	3,180,371	4,115,701	0	0	0	935330	3,180,371	4,115,701	8,432	255	8,687	943,762	3,180,626	4,124,388
1939	854,469	3,732,701	4,587,170	0	0	0	854469	3,732,701	4,587,170	9,226	298	9,525	863,695	3,732,999	4,596,695

	commercial									recreational			total		
	handline +			longline			total								
	west	east	total	west	east		west	east	total	west	east	total	west	east	total
1940	815,871	2,496,953	3,312,824	0	0	0	815871	2,496,953	3,312,824	10,069	349	10,418	825,940	2,497,302	3,323,242
1941	737,892	2,271,791	3,009,683	0	0	0	737892	2,271,791	3,009,683	13,580	523	14,103	751,472	2,272,314	3,023,786
1942	544,639	1,818,353	2,362,992	0	0	0	544639	1,818,353	2,362,992	18,058	770	18,828	562,697	1,819,123	2,381,820
1943	371,388	1,446,274	1,817,662	0	0	0	371388	1,446,274	1,817,662	23,697	1,116	24,814	395,085	1,447,390	1,842,476
1944	279,690	1,670,030	1,949,720	0	0	0	279690	1,670,030	1,949,720	30,718	1,594	32,312	310,408	1,671,624	1,982,032
1945	153,741	1,455,205	1,608,946	0	0	0	153741	1,455,205	1,608,946	39,364	2,244	41,609	193,105	1,457,449	1,650,555
1946	323,401	2,319,802	2,643,203	0	0	0	323401	2,319,802	2,643,203	49,907	3,121	53,028	373,308	2,322,923	2,696,231
1947	478,181	2,432,194	2,910,375	0	0	0	478181	2,432,194	2,910,375	62,642	4,291	66,933	540,823	2,436,485	2,977,308
1948	595,421	2,598,682	3,194,103	0	0	0	595421	2,598,682	3,194,103	77,892	5,838	83,729	673,313	2,604,520	3,277,832
1949	869,794	3,108,401	3,978,195	0	0	0	869794	3,108,401	3,978,195	96,004	7,865	103,869	965,798	3,116,266	4,082,064
1950	1,476,048	1,693,118	3,169,166	0	0	0	1476048	1,693,118	3,169,166	117,351	10,501	127,852	1,593,399	1,703,619	3,297,018
1951	1,477,540	2,016,917	3,494,457	0	0	0	1477540	2,016,917	3,494,457	140,469	13,713	154,182	1,618,009	2,030,630	3,648,639
1952	1,654,176	2,245,040	3,899,216	0	0	0	1654176	2,245,040	3,899,216	167,242	17,788	185,029	1,821,418	2,262,828	4,084,245
1953	1,358,592	2,026,470	3,385,062	0	0	0	1358592	2,026,470	3,385,062	198,120	22,927	221,047	1,556,712	2,049,397	3,606,109
1954	1,365,982	1,883,191	3,249,173	0	0	0	1365982	1,883,191	3,249,173	233,594	29,376	262,970	1,599,576	1,912,567	3,512,143
1955	1,492,039	2,106,652	3,598,691	0	0	0	1492039	2,106,652	3,598,691	274,194	37,429	311,623	1,766,233	2,144,081	3,910,314
1956	2,017,420	2,520,865	4,538,285	0	0	0	2017420	2,520,865	4,538,285	320,493	47,438	367,931	2,337,913	2,568,303	4,906,216
1957	2,013,517	2,261,891	4,275,408	0	0	0	2013517	2,261,891	4,275,408	373,105	59,825	432,931	2,386,622	2,321,716	4,708,339
1958	3,357,390	3,724,587	7,081,977	0	0	0	3357390	3,724,587	7,081,977	432,690	75,092	507,782	3,790,080	3,799,679	7,589,759
1959	3,431,602	3,407,851	6,839,453	0	0	0	3431602	3,407,851	6,839,453	499,948	93,834	593,782	3,931,550	3,501,685	7,433,235
1960	3,601,182	3,816,825	7,418,007	0	0	0	3601182	3,816,825	7,418,007	575,622	116,757	692,379	4,176,804	3,933,582	8,110,386
1961	4,248,967	3,504,256	7,753,223	0	0	0	4248967	3,504,256	7,753,223	597,999	126,432	724,431	4,846,966	3,630,688	8,477,654
1962	4,131,601	3,612,712	7,744,313	0	0	0	4131601	3,612,712	7,744,313	624,844	136,990	761,834	4,756,445	3,749,702	8,506,147
1963	3,677,162	3,009,957	6,687,119	0	0	0	3677162	3,009,957	6,687,119	656,883	148,525	805,408	4,334,045	3,158,482	7,492,527
1964	3,446,689	3,462,403	6,909,092	0	0	0	3446689	3,462,403	6,909,092	694,905	161,148	856,052	4,141,594	3,623,551	7,765,144
1965	3,500,238	3,564,061	7,064,299	0	0	0	3500238	3,564,061	7,064,299	739,757	174,981	914,738	4,239,995	3,739,042	7,979,037
1966	2,919,580	2,974,814	5,894,394	0	0	0	2919580	2,974,814	5,894,394	792,351	190,165	982,516	3,711,931	3,164,979	6,876,910
1967	4,061,713	2,790,666	6,852,379	0	0	0	4061713	2,790,666	6,852,379	853,653	206,859	1,060,512	4,915,366	2,997,525	7,912,891
1968	4,954,451	2,512,844	7,467,295	0	0	0	4954451	2,512,844	7,467,295	924,686	225,245	1,149,931	5,879,137	2,738,089	8,617,226
1969	4,019,962	2,344,264	6,364,226	0	0	0	4019962	2,344,264	6,364,226	1,006,524	245,527	1,252,051	5,026,486	2,589,791	7,616,277
1970	4,466,619	2,217,076	6,683,695	0	0	0	4466619	2,217,076	6,683,695	1,100,289	267,941	1,368,230	5,566,908	2,485,017	8,051,925
1971	5,151,388	2,134,626	7,286,014	0	0	0	5151388	2,134,626	7,286,014	1,251,223	320,579	1,571,802	6,402,611	2,455,205	8,857,816
1972	4,648,105	2,279,349	6,927,454	0	0	0	4648105	2,279,349	6,927,454	1,417,185	383,283	1,800,468	6,065,290	2,662,632	8,727,922
1973	4,672,509	2,604,511	7,277,020	0	0	0	4672509	2,604,511	7,277,020	1,599,018	457,955	2,056,973	6,271,527	3,062,466	9,333,993
1974	4,256,448	3,616,862	7,873,310	0	0	0	4256448	3,616,862	7,873,310	1,797,553	546,846	2,344,399	6,054,001	4,163,708	10,217,709
1975	3,775,645	3,433,559	7,209,204	0	0	0	3775645	3,433,559	7,209,204	1,547,024	353,487	1,900,511	5,322,669	3,787,046	9,109,715
1976	3,193,606	3,156,601	6,350,207	0	0	0	3193606	3,156,601	6,350,207	1,658,106	383,490	2,041,596	4,851,712	3,540,091	8,391,803

	commercial									recreational			total		
	handline +			longline			total								
	west	east	total	west	east		west	east	total	west	east	total	west	east	total
1977	2,758,173	2,173,199	4,931,372	0	0	0	2758173	2,173,199	4,931,372	1,892,603	485,039	2,377,642	4,650,776	2,658,238	7,309,014
1978	2,586,240	1,916,498	4,502,738	0	0	0	2586240	1,916,498	4,502,738	2,325,757	733,346	3,059,102	4,911,997	2,649,844	7,561,840
1979	2,373,583	1,956,379	4,329,962	0	0	0	2373583	1,956,379	4,329,962	2,562,428	865,684	3,428,112	4,936,011	2,822,063	7,758,074
1980	2,415,848	1,819,918	4,235,766	42,292	90,245	132,537	2458140	1,910,163	4,368,303	3,185,114	1,361,321	4,546,436	5,643,254	3,271,484	8,914,739
1981	3,017,571	2,041,270	5,058,841	47,291	171,385	218,676	3064862	2,212,655	5,277,517	2,846,681	1,281,548	4,128,229	5,911,543	3,494,203	9,405,746
1982	3,515,073	2,197,591	5,712,664	68,752	217,511	286,263	3583825	2,415,102	5,998,927	2,805,045	1,515,804	4,320,849	6,388,870	3,930,906	10,319,776
1983	3,667,340	2,288,680	5,956,020	94,787	425,542	520,329	3762127	2,714,222	6,476,349	2,155,410	1,006,531	3,161,941	5,917,537	3,720,753	9,638,290
1984	2,906,413	1,631,916	4,538,329	762,672	368,449	1,131,121	3669085	2,000,365	5,669,450	2,298,932	789,539	3,088,470	5,968,017	2,789,904	8,757,920
1985	1,846,048	1,623,814	3,469,862	604,890	114,341	719,231	2450938	1,738,155	4,189,093	1,457,091	1,530,519	2,987,609	3,908,029	3,268,674	7,176,702
1986	1,933,384	859,831	2,793,215	831,375	75,897	907,272	2764759	935,728	3,700,487	894,207	1,713,726	2,607,933	3,658,966	2,649,454	6,308,420
1987	1,474,284	796,819	2,271,103	734,038	63,474	797,512	2208322	860,293	3,068,615	658,651	1,407,954	2,066,606	2,866,973	2,268,247	5,135,221
1988	2,355,132	858,116	3,213,248	670,131	76,685	746,816	3025263	934,801	3,960,064	1,253,641	1,254,028	2,507,669	4,278,904	2,188,829	6,467,733
1989	1,891,961	673,521	2,565,482	454,743	78,572	533,315	2346704	752,093	3,098,797	1,102,542	1,180,214	2,282,757	3,449,246	1,932,307	5,381,554
1990	1,757,928	697,742	2,455,670	120,424	74,816	195,240	1878352	772,558	2,650,910	482,631	882,120	1,364,751	2,360,983	1,654,678	4,015,661
1991	1,724,747	395,205	2,119,952	72,593	20,709	93,302	1797340	415,914	2,213,254	963,167	1,134,678	2,097,845	2,760,507	1,550,592	4,311,099
1992	2,632,608	373,096	3,005,704	19,786	5,103	24,889	2652394	378,199	3,030,593	1,728,582	1,890,063	3,618,645	4,380,976	2,268,262	6,649,238
1993	2,901,388	436,988	3,338,376	20,291	15,236	35,527	2921679	452,224	3,373,903	2,585,718	2,986,881	5,572,599	5,507,397	3,439,105	8,946,502
1994	2,671,459	527,123	3,198,582	15,809	7,959	23,768	2687268	535,082	3,222,350	2,326,329	2,207,067	4,533,396	5,013,597	2,742,149	7,755,746
1995	2,735,402	172,740	2,908,142	17,506	8,459	25,965	2752908	181,199	2,934,107	2,024,996	1,668,961	3,693,957	4,777,904	1,850,160	6,628,064
1996	4,044,132	233,981	4,278,113	27,362	7,588	34,950	4071494	241,569	4,313,063	1,596,338	1,868,800	3,465,137	5,667,832	2,110,369	7,778,200
1997	4,589,368	184,406	4,773,774	31,496	4,626	36,122	4620864	189,032	4,809,896	1,816,201	2,554,039	4,370,240	6,437,065	2,743,071	9,180,136
1998	4,267,684	379,169	4,646,853	27,236	5,505	32,741	4294920	384,674	4,679,594	1,599,856	2,749,298	4,349,154	5,894,776	3,133,972	9,028,748
1999	4,229,058	537,490	4,766,548	91,741	6,623	98,364	4320799	544,113	4,864,912	963,764	3,388,118	4,351,882	5,284,563	3,932,231	9,216,794
2000	3,983,046	665,437	4,648,483	180,068	8,795	188,863	4163114	674,232	4,837,346	999,172	2,332,595	3,331,766	5,162,286	3,006,827	8,169,112
2001	3,691,045	798,080	4,489,125	126,099	10,133	136,232	3817144	808,213	4,625,357	774,554	2,790,165	3,564,719	4,591,698	3,598,378	8,190,076
2002	3,569,829	1,054,025	4,623,854	140,644	18,471	159,115	3710473	1,072,496	4,782,969	1,056,364	3,815,618	4,871,982	4,766,837	4,888,114	9,654,951
2003	3,196,720	1,022,378	4,219,098	175,144	13,027	188,171	3371864	1,035,405	4,407,269	1,187,570	3,409,657	4,597,227	4,559,434	4,445,062	9,004,496

Appendix 1. Table 2. Recreational catch (in number) of red snapper from the Gulf of Mexico as used in the assessments.

	west	east	Gulf wide
1900	164	0	164
1901	173	0	173
1902	183	0	183
1903	193	0	193
1904	203	0	203
1905	214	0	214
1906	224	0	225
1907	236	1	236
1908	247	1	248
1909	259	1	260
1910	271	1	272
1911	241	1	243
1912	216	2	217
1913	194	2	196
1914	176	2	178
1915	161	3	163
1916	149	3	152
1917	140	4	143
1918	133	5	138
1919	130	5	136
1920	130	6	136
1921	169	8	177
1922	224	9	233
1923	298	11	309
1924	397	13	411
1925	530	16	546
1926	704	19	723
1927	929	23	952
1928	1,217	27	1,244
1929	1,581	32	1,613
1930	2,035	38	2,073
1931	2,283	45	2,327
1932	2,551	53	2,604
1933	2,842	63	2,904
1934	3,155	74	3,229
1935	3,492	87	3,579
1936	3,853	102	3,955
1937	4,239	120	4,359
1938	4,651	141	4,792
1939	5,090	165	5,254
1940	5,555	192	5,747
1941	7,492	288	7,780
1942	9,962	425	10,387
1943	13,073	616	13,689
1944	16,946	879	17,825
1945	21,716	1,238	22,954
1946	27,532	1,722	29,254
1947	34,558	2,367	36,925
1948	42,970	3,220	46,191
1949	52,962	4,339	57,301
1950	64,739	5,793	70,532

	west	east	Gulf wide
1951	77,492	7,565	85,057
1952	92,262	9,813	102,074
1953	109,296	12,648	121,944
1954	128,866	16,206	145,072
1955	151,264	20,648	171,912
1956	176,805	26,170	202,975
1957	205,830	33,004	238,833
1958	238,701	41,426	280,126
1959	275,804	51,765	327,569
1960	317,551	64,411	381,962
1961	329,896	69,748	399,644
1962	344,705	75,573	420,278
1963	362,380	81,936	444,317
1964	383,355	88,900	472,255
1965	408,099	96,531	504,630
1966	437,113	104,908	542,021
1967	470,932	114,117	585,049
1968	510,118	124,260	634,378
1969	555,265	135,449	690,714
1970	606,992	147,814	754,806
1971	690,258	176,852	867,110
1972	781,813	211,444	993,258
1973	882,124	252,638	1,134,763
1974	991,649	301,676	1,293,326
1975	853,441	195,007	1,048,448
1976	914,721	211,559	1,126,280
1977	1,044,085	267,580	1,311,665
1978	1,283,042	404,562	1,687,604
1979	1,413,605	477,569	1,891,174
1980	1,757,120	750,995	2,508,115
1981	1,595,534	868,618	2,464,152
1982	1,392,181	999,005	2,391,186
1983	2,026,290	1,818,440	3,844,729
1984	1,186,171	255,805	1,441,977
1985	1,004,625	596,697	1,601,322
1986	606,398	558,138	1,164,537
1987	481,428	528,024	1,009,452
1988	725,783	510,400	1,236,183
1989	652,305	485,617	1,137,922
1990	312,485	357,062	669,547
1991	523,205	532,238	1,055,442
1992	802,595	817,218	1,619,813
1993	1,101,996	1,223,092	2,325,088
1994	909,572	770,601	1,680,172
1995	700,065	615,557	1,315,622
1996	539,430	577,035	1,116,464
1997	594,047	972,685	1,566,732
1998	496,566	1,034,766	1,531,333
1999	236,425	1,050,934	1,287,360
2000	266,197	726,813	993,010
2001	238,677	844,364	1,083,041
2002	277,089	1,133,563	1,410,652
2003	302,096	992,881	1,294,977

Appendix 1 Table 3. Dead discards (number of fish) from the commercial and recreational finfish fisheries as used in the assessments (from Gulf wide treatment with M = 0.59: generally less than 1% differences in annual totals between M of 0.59 and 0.29).

	open season discards														
	commercial									recreational			total		
	handline			longline			total			total					
	west	east	total	west	east	total	west	east	total	west	east	total	west	east	total
1981															
1982															
1983															
1984	799	279	1,078	22	4	26	821	283	1,104	0	3382	3,382	821	3,665	4,486
1985	35,243	8,128	43,371	2,221	56	2,277	37,464	8,184	45,648	124821	2484	127,305	162,285	10,668	172,953
1986	32,164	10,258	42,422	3,466	54	3,520	35,630	10,312	45,942	7502	5725	13,227	43,132	16,037	59,169
1987	72,757	30,578	103,335	6,194	46	6,240	78,951	30,624	109,575	11640	9990	21,630	90,591	40,614	131,205
1988	57,474	13,343	70,817	7,831	56	7,887	65,305	13,399	78,704	160484	9462	169,946	225,789	22,861	248,650
1989	72,021	20,015	92,036	6,851	165	7,016	78,872	20,180	99,052	143608	25460	169,068	222,480	45,640	268,120
1990	84,663	23,723	108,386	2,821	302	3,123	87,484	24,025	111,509	208323	64934	273,257	295,807	88,959	384,766
1991	62,267	19,452	81,719	434	27	461	62,701	19,479	82,180	252709	114412	367,121	315,410	133,891	449,301
1992	341,310	48,832	390,142	297	90	387	341,607	48,922	390,529	237289	120637	357,926	578,896	169,559	748,455
1993	96,538	15,744	112,282	201	35	236	96,739	15,779	112,518	301286	126441	427,727	398,025	142,220	540,245
1994	256,619	64,575	321,194	86	21	107	256,705	64,596	321,301	448289	101685	549,974	704,994	166,281	871,275
1995	112,507	6,622	119,129	46	44	90	112,553	6,666	119,219	378859	59033	437,892	491,412	65,699	557,111
1996	335,328	15,917	351,245	295	28	323	335,623	15,945	351,568	136797	130920	267,717	472,420	146,865	619,285
1997	224,412	9,599	234,011	44	15	59	224,456	9,614	234,070	140154	261647	401,801	364,610	271,261	635,871
1998	360,137	49,929	410,066	304	28	332	360,441	49,957	410,398	194391	181688	376,079	554,832	231,645	786,477
1999	144,556	22,770	167,326	769	48	817	145,325	22,818	168,143	270542	230035	500,577	415,867	252,853	668,720
2000	165,541	17,821	183,362	496	26	522	166,037	17,847	183,884	62812	146549	209,361	228,849	164,396	393,245
2001	146,473	20,405	166,878	84	14	98	146,557	20,419	166,976	66444	162085	228,529	213,001	182,504	395,505
2002	270,884	73,208	344,092	2,642	72	2,714	273,526	73,280	346,806	70405	219044	289,449	343,931	292,324	636,255
2003	126,561	40,540	167,101	87	78	165	126,648	40,618	167,266	331086	211205	542,291	457,734	251,823	709,557

	closed season discards														
	commercial									recreational			total		
	handline			longline			total			total					
	west	east	total	west	east	total	west	east	total	west	east	total	west	east	total
1981															
1982															
1983															
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	11453	3029	14482	164	31	195	11,617	3,060	14,677	0	0	0	11617	3060	14677
1992	162349	23542	185891	284	73	357	162,633	23,615	186,248	0	0	0	162633	23615	186248
1993	94972	13112	108084	273	148	421	95,245	13,260	108,505	0	0	0	95245	13260	108505
1994	159592	33034	192626	421	94	515	160,013	33,128	193,141	0	0	0	160013	33128	193141
1995	166801	9279	176080	451	159	610	167,252	9,438	176,690	0	0	0	167252	9438	176690
1996	186226	8727	194953	375	107	482	186,601	8,834	195,435	0	0	0	186601	8834	195435
1997	198877	7574	206451	405	46	451	199,282	7,620	206,902	0	0	0	199282	7620	206902
1998	243635	26302	269937	541	69	610	244,176	26,371	270,547	30143	25639	55782	274319	52010	326329
1999	164416	21005	185421	1921	107	2028	166,337	21,112	187,449	33629	40504	74133	199966	61616	261582
2000	196115	24545	220660	2744	146	2890	198,859	24,691	223,550	45301	67676	112977	244160	92367	336527
2001	145472	23324	168796	1341	119	1460	146,813	23,443	170,256	64478	117848	182326	211291	141291	352582
2002	157654	36563	194217	2865	172	3037	160,519	36,735	197,254	50687	110498	161185	211206	147233	358439
2003	110121	28664	138785	1318	152	1470	111,439	28,816	140,255	89576	74976	164552	201015	103792	304807

Appendix 1. Table 4. Estimated shrimp fishery bycatch of red snapper in the Gulf of Mexico as used in the assessments.

	Gulf wide				west				east			
	ages 0+		ages 1+		ages 0+		ages 1+		ages 0+		ages 1+	
	catch	CV	catch	CV	catch	CV	catch	CV	catch	CV	catch	CV
1948	6274751	1.0801	2215019	1.1906	7079343	1.1512	2499044	1.2554	0	0	0	0
1949	10137938	1.0801	3578744	1.1906	11437894	1.1512	4037635	1.2554	0	0	0	0
1950	15535623	1.0801	5484154	1.1906	13815286	1.1512	4876866	1.2554	854181	1.3686	301530	1.3360
1951	18546451	1.0801	6546991	1.1906	14528503	1.1512	5128635	1.2554	1471661	1.3686	519504	1.3360
1952	21895119	1.0801	7729089	1.1906	17143634	1.1512	6051790	1.2554	1739236	1.3686	613959	1.3360
1953	22220893	1.0801	7844088	1.1906	16720986	1.1512	5902593	1.2554	1921050	1.3686	678140	1.3360
1954	29038313	1.0801	10250672	1.1906	22056909	1.1512	7786201	1.2554	2463060	1.3686	869473	1.3360
1955	27337907	1.0801	9650420	1.1906	18200252	1.1512	6424782	1.2554	2909018	1.3686	1026898	1.3360
1956	35241241	1.0801	12440337	1.1906	23747499	1.1512	8382988	1.2554	3684299	1.3686	1300576	1.3360
1957	41927375	1.0801	14800577	1.1906	29770223	1.1512	10509040	1.2554	4034204	1.3686	1424095	1.3360
1958	57131480	1.0801	20167703	1.1906	45910070	1.1512	16206488	1.2554	4267475	1.3686	1506440	1.3360
1959	61318429	1.0801	21645717	1.1906	49053509	1.1512	17316138	1.2554	4631102	1.3686	1634803	1.3360
1960	49282119	1.0801	17396839	1.1906	40839877	1.1512	14416684	1.2554	3396441	1.3686	1198961	1.3360
1961	48445135	1.0801	17101379	1.1906	37002584	1.1512	13062100	1.2554	4062080	1.3686	1433935	1.3360
1962	47356231	1.0801	16716990	1.1906	37780092	1.1512	13336565	1.2554	3600516	1.3686	1271000	1.3360
1963	54581057	1.0801	19267391	1.1906	44434855	1.1512	15685730	1.2554	3944837	1.3686	1392547	1.3360
1964	60470141	1.0801	21346267	1.1906	49482073	1.1512	17467423	1.2554	4312287	1.3686	1522259	1.3360
1965	60302905	1.0801	21287232	1.1906	49015051	1.1512	17302562	1.2554	4376330	1.3686	1544867	1.3360
1966	65758562	1.0801	23213107	1.1906	55593359	1.1512	19624738	1.2554	4278983	1.3686	1510503	1.3360
1967	67794836	1.0801	23931922	1.1906	59439594	1.1512	20982479	1.2554	3922611	1.3686	1384702	1.3360
1968	65566834	1.0801	23145426	1.1906	54949537	1.1512	19397466	1.2554	4377347	1.3686	1545226	1.3360
1969	80062302	1.0801	28262400	1.1906	68514396	1.1512	24185930	1.2554	5019134	1.3686	1771780	1.3360
1970	78335050	1.0801	27652671	1.1906	69350219	1.1512	24480980	1.2554	4378443	1.3686	1545613	1.3360
1971	75619915	1.0801	26694215	1.1906	68030191	1.1512	24015003	1.2554	3977341	1.3686	1404022	1.3360
1972	110898000	0.8329	37720756	0.9851	97647000	0.9578	33044060	1.0911	8508600	0.7004	2069263	1.1241
1973	17515000	0.6120	4611455	0.9144	15652000	0.6595	3867906	0.9732	1018400	0.9615	413994	1.0960
1974	17954000	0.3835	6724230	0.6125	16743000	0.3998	6230104	0.6211	647960	0.9435	243952	1.1013
1975	7712600	0.7577	3581413	0.8500	6445500	0.9998	2877229	1.0754	1021180	0.3465	556026	0.5237
1976	35502000	0.2321	10801297	0.6321	33777000	0.2371	10016735	0.6417	891100	0.9182	393576	1.0380
1977	17847100	0.2463	5021253	0.6818	16184300	0.2582	4318224	0.7113	1187100	0.4949	521541	0.6941
1978	9876500	0.3740	3308577	0.6519	9316700	0.3912	3012651	0.6724	369350	0.6246	193829	0.7457
1979	31916000	0.9263	10777841	1.0670	29584000	0.9977	10045543	1.1254	1258500	0.8791	396273	1.1108
1980	35134100	0.3367	10323791	0.6957	34276200	0.3434	10019417	0.6957	559200	0.7239	117711	1.2473
1981	69367000	0.7797	25429623	0.9198	67066000	0.8255	24626047	0.9558	1366100	1.0116	347467	1.3153
1982	25231000	0.8346	6247684	1.1038	21059000	1.0531	5375300	1.2605	2894700	0.6803	298515	2.1821

	Gulf wide				west				east			
	ages 0+		ages 1+		ages 0+		ages 1+		ages 0+		ages 1+	
	catch	CV	catch	CV	catch	CV	catch	CV	catch	CV	catch	CV
1983	15504700	0.8939	4701018	1.0710	13763900	0.9944	4237501	1.1484	961930	1.0491	250361	1.3324
1984	14337100	0.8866	4365592	1.0635	12445700	0.9986	3785858	1.1555	987890	1.1047	248248	1.3944
1985	13873600	0.8740	4478889	1.0348	12355900	0.9728	3967867	1.1178	815310	0.9763	268897	1.1719
1986	7288100	0.8864	2513137	1.0270	6788100	0.9567	2306075	1.0892	268830	0.8575	107092	1.0117
1987	15371000	0.8850	5324387	1.0247	14537000	0.9407	5114483	1.0665	436050	0.9606	134143	1.1857
1988	11624700	0.8739	4044427	1.0139	10739900	0.9466	3709159	1.0762	485220	0.9129	167003	1.1042
1989	15259000	0.8571	5345006	0.9977	13398000	0.9519	4743294	1.0750	958570	1.0449	330605	1.2150
1990	59594000	0.8827	19700216	1.0353	53493000	0.9768	17650215	1.1142	3146200	1.0101	1072363	1.1890
1991	42635000	0.9040	14484196	1.0461	39074000	0.9802	13139196	1.1123	1827100	0.9325	706391	1.0842
1992	29339600	0.2171	5795620	0.2264	28167700	0.2275	5483345	0.2367	806560	0.5702	141611	0.6993
1993	29945000	0.1329	16012847	0.1348	29349000	0.1333	15825477	0.1353	383050	0.8236	117425	0.8576
1994	38799000	0.1751	21377975	0.1769	37600000	0.1765	20725461	0.1783	788660	0.7505	421553	0.7679
1995	48460000	0.2563	16604389	0.2590	45888000	0.2594	15901223	0.2619	1343800	1.1197	350936	1.3871
1996	35698000	0.7317	7487266	0.7833	33574000	0.7904	7091155	0.8418	991770	1.2439	268366	1.4736
1997	25169000	0.4177	13798007	0.4211	22578000	0.4330	12387151	0.4366	1318190	1.1019	354398	1.3589
1998	45490000	0.4680	8469666	0.4712	43964000	0.4841	7775591	0.4875	1178340	0.4689	464803	0.4827
1999	40705000	0.2996	6125553	0.3133	37476000	0.3116	5477621	0.3260	1879600	0.9031	679973	1.0793
2000	15107000	0.2319	4635069	0.2432	12620400	0.2611	3179514	0.2789	2110400	0.3212	1021275	0.3230
2001	24047000	0.2603	8551626	0.2687	21902000	0.2908	7930214	0.2994	1925200	0.2283	467171	0.2363
2002	21881000	0.1337	5575271	0.1343	20438000	0.1424	5132133	0.1430	1406700	0.1208	430345	0.1231
2003	9052000	0.2736	6291501	0.2749	7680000	0.3094	5041550	0.3112	1209200	0.2179	1028816	0.2185

Appendix 1. Table 5. Indices of abundance of Gulf of Mexico red snapper as used in the assessments.

	MRFSS SEDAR7 AW 4rev, age range = 1 - 15, Units = # fish						**LGBK_HL** SEDAR7 AW 9, age range = 2 - 15, Units = biomass (lb)				**Shrimp landed CPUE** Goodyear 1995 Fig 36, age range = 2 - 15, Units = biomass (kg)	
	Gulf wide		East		West		East		West			
YEAR	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1960												
1961												
1962												
1963												
1964												
1965												
1966												
1967											2.6790	1.0000
1968											3.3916	1.0000
1969											2.0330	1.0000
1970											2.7560	1.0000
1971											2.1512	1.0000
1972											2.5206	1.0000
1973											3.4071	1.0000
1974											2.6894	1.0000
1975											2.0636	1.0000
1976											1.4123	1.0000
1977											1.2610	1.0000
1978											0.7190	1.0000
1979											0.4694	1.0000
1980												
1981	0.6870	0.3649	0.5288	0.4423	0.4431	0.4476						
1982	0.3240	0.3338	0.2711	0.4077	0.1358	0.5404						
1983	1.0673	0.2770	1.0050	0.3748	0.4232	0.3819						
1984	0.5776	0.3251	0.3222	0.5212	0.3224	0.4049						
1985	0.3880	0.4381	0.3794	0.4427	0.1137	0.7588						
1986	0.4381	0.2559	0.4239	0.3008	0.1938	0.4484						
1987	0.4782	0.2892	0.5086	0.3157	0.0995	0.6767						
1988	0.4119	0.3190	0.3035	0.3590	0.2774	0.6386						
1989	0.2928	0.3738	0.2521	0.4249	0.1741	0.5864						
1990	0.4112	0.3337	0.3483	0.3751	0.2302	0.5018						
1991	0.6918	0.2840	0.5592	0.3128	0.3485	0.5443						

	MRFSS **SEDAR7 AW 4rev** **age range = 1 - 15** **Units = # fish**						**LGBK_HL** **SEDAR7 AW 9** **age range = 2 - 15** **Units = biomass (lb)**				**Shrimp landed CPUE** **Goodyear 1995 Fig 36** **age range = 2 - 15** **Units = biomass (kg)**	
	Gulf wide		East		West		East		West			
YEAR	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1992	0.8792	0.2370	0.7358	0.2712	0.4377	0.4696						
1993	0.8029	0.2466	0.6726	0.2780	0.4179	0.4830						
1994	0.6205	0.2568	0.5425	0.2900	0.4313	0.4269						
1995	0.5795	0.3074	0.4215	0.3511	0.4817	0.4938						
1996	0.8632	0.2624	0.7556	0.2844	0.5211	0.4607	0.0817	0.8317	4.8074	0.0221		
1997	1.2313	0.2129	1.1541	0.2456	0.3920	0.4460	0.0916	0.7823	4.0632	0.0214		
1998	1.1713	0.2035	1.1795	0.2359	0.3760	0.4802	0.2937	0.5321	3.5035	0.0213		
1999	1.2121	0.1977	1.2309	0.2341	0.2346	0.5046	0.1818	0.5886	3.0878	0.0223		
2000	0.9671	0.1980	1.0744	0.2363	0.2286	0.4578	0.3617	0.4809	3.2769	0.0232		
2001	0.9085	0.2038	1.0869	0.2375	0.0753	0.6682	0.4615	0.4490	3.0779	0.0231		
2002	1.0350	0.1947	1.2189	0.2322	0.2391	0.4215	0.4462	0.4490	3.0063	0.0234		
2003	1.0709	0.1948	1.0308	0.2337	0.4804	0.4021	0.4273	0.4436	2.7412	0.0243		

Appendix 1. Table 5. continued

	VIDEO						**LARV_B**						**SEAMAP_TRWL 87+**			
	SEDAR7 DW 15						**SEDAR7 DW14 and RW7**						**SEDAR7 DW 2**			
	age range = 2 - 15						**age range = 2 - 15**						**age range = 0-2**			
	Units = # fish						**Units = relative reproductive output**						**Units = # fish**			
	Gulf wide		East		West		Gulf wide		East		West		Gulf Wide		Gulf wide	
YEAR	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1960																
1961																
1962																
1963																
1964																
1965																
1966																
1967																
1968																
1969																
1970																
1971																
1972																
1973																
1974																
1975																
1976																
1977																
1978																
1979																
1980																
1981																
1982																
1983																
1984																
1985																
1986							5.5383	0.6676	0.7628	1.6272	8.5752	0.6873				
1987							10.0551	0.6637	0.7048	1.3165	20.9802	0.7314	3.0192	0.1739	4.0269	0.1826
1988							4.6066	0.5719	0.2457	2.0122	8.7646	0.5643	5.2646	0.1251	2.1073	0.2019
1989							6.1167	0.4950	0.1083	2.5832	11.3639	0.4644	17.1158	0.0996	1.9621	0.2108
1990							3.7273	0.5532	0.0000	0.0000	6.9512	0.5105	15.9267	0.0996	11.0674	0.1517
1991							2.8822	0.5409	0.6462	1.3320	4.1998	0.5472	19.7272	0.0959	4.7875	0.1694
1992	0.0457	0.4814	0.0178	1.0056	0.2518	0.28912	2.9519	0.5976	0.0000	0.0000	6.0715	0.5652	5.1655	0.1344	4.3536	0.1705

	VIDEO						**LARV_B**						**SEAMAP_TRWL 87+**			
	SEDAR7 DW 15						**SEDAR7 DW14 and RW7**						**SEDAR7 DW 2**			
	age range = 2 - 15						**age range = 2 - 15**						**age range = 0-2**			
	Units = # fish						**Units = relative reproductive output**						**Units = # fish**			
	Gulf wide		East		West		Gulf wide		East		West		Gulf Wide		Gulf wide	
YEAR	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1993	0.0723	0.5491	0.0269	0.7212	0.2440	0.38975	6.8454	0.6145	0.7846	1.6214	10.6809	0.6161	11.0342	0.1174	3.8690	0.1723
1994	0.0333	0.5015	0.0117	1.1368	0.1933	0.40197	3.3588	0.7491	3.9523	1.4526	2.9427	0.8028	30.4778	0.0966	6.5864	0.1627
1995	0.0686	0.42711	0.0324	0.6605	0.2709	0.26836	8.0168	0.5256	2.2913	1.0408	10.6688	0.5449	28.6743	0.0965	5.0988	0.1712
1996	0.0466	0.45494	0.0355	0.6563	0.2050	0.27268	13.6270	0.4953	0.0000	0.0000	28.0808	0.4503	11.1563	0.1092	8.2071	0.1641
1997	0.0973	0.38438	0.0155	0.7935	0.5024	0.14331	11.0610	0.4867	1.1718	1.0736	19.0106	0.4904	23.1501	0.0979	5.8416	0.1672
1998													11.2571	0.1207	3.6877	0.1993
1999							15.6005	0.4693	1.3697	1.2302	28.2644	0.4503	20.3687	0.1044	2.2691	0.1916
2000							25.5012	0.4283	9.5218	0.8377	34.6184	0.4300	15.7368	0.1058	4.8988	0.1736
2001					0.2582	0.36909	14.9447	0.4486	1.4414	0.9581	28.0846	0.4505	13.7908	0.1124	2.0419	0.2534
2002	0.1411	0.41318	0.0765	0.5699	0.4303	0.18824	22.6475	0.4322	2.7462	0.8544	41.8594	0.4393	12.2803	0.1108	4.3017	0.1759
2003															3.4799	0.2198

Appendix 1. Table 5. continued.

	SEAMAP_TRWL72+ (Miami) **SEDAR AW 25** **age range = 0** **Units = # fish**						**SEAMAP_TRWL72+ (Miami)** **SEDAR AW 25** **age range = 1** **Units = # fish**					
	Gulf wide		East		West		Gulf wide		East		West	
YEAR	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1960												
1961												
1962												
1963												
1964												
1965												
1966												
1967												
1968												
1969												
1970												
1971												
1972	79.5707	0.9492	44.5663	0.3670	95.9005	1.7309	34.6302	1.2330	21.3367	0.8646	44.5108	1.9251
1973	22.6706	0.9282	9.7783	0.2928	34.6053	1.6672	9.8665	1.2169	4.6815	0.8358	16.0615	1.8679
1974	15.1371	0.9276	10.7733	0.2882	13.7240	1.6803	6.5879	1.2164	5.1579	0.8342	6.3698	1.8796
1975	20.4430	0.9247	10.6245	0.2952	27.5097	1.6750	8.8971	1.2143	5.0866	0.8366	12.7682	1.8749
1976	16.6894	0.9238	10.8752	0.2814	17.6023	1.6672	7.2635	1.2135	5.2066	0.8318	8.1699	1.8679
1977	18.7942	0.9237	12.0818	0.2922	20.1673	1.6698	8.1795	1.2134	5.7843	0.8356	9.3604	1.8703
1978	37.9392	0.9298	8.2426	0.2945	76.1563	1.6698	16.5117	1.2181	3.9462	0.8364	35.3468	1.8703
1979	15.9615	0.9252	5.6154	0.2904	27.2541	1.6698	6.9467	1.2146	2.6885	0.8349	12.6496	1.8703
1980	46.0515	0.9285	15.4744	0.3025	80.3784	1.6724	20.0422	1.2171	7.4086	0.8392	37.3064	1.8726
1981	38.8776	0.9348	36.5509	0.2910	16.8002	1.6750	16.9201	1.2219	17.4992	0.8351	7.7976	1.8749
1982	38.8426	0.9315	35.3051	0.2773	19.3917	1.6672	16.8712	0.4314	12.0055	0.5361	15.1087	0.4208
1983	15.0231	0.9268	8.3836	0.3116	18.7306	1.6803	6.6347	0.4212	4.6981	0.4845	7.2690	0.6437
1984	7.1248	0.9382	5.6021	0.3116	5.3327	1.6987	3.1817	0.4483	2.1439	0.5347	3.0736	0.5167
1985	12.8744	0.9825	3.3581	0.3959	23.8429	1.7776	6.1377	0.4289	2.1198	0.4938	7.8273	0.7805
1986	12.8218	1.0627	6.7429	0.5934	15.1079	1.9690	3.0101	0.7468	2.0665	0.7155	3.3437	1.2240
1987	3.0308	1.0902	3.0581	0.3066	3.2052	0.1913	5.2867	0.2993	2.8374	0.3246	5.2969	0.1643
1988	5.2806	0.1299	4.7849	0.2898	5.3783	0.1336	4.7116	0.1288	2.4590	0.3930	4.8798	0.1320
1989	17.0033	0.1014	22.1582	0.2304	16.3230	0.1092	3.2048	0.1878	5.2764	0.6391	3.0912	0.1959
1990	15.9386	0.0991	18.4019	0.1845	15.6689	0.1063	13.9742	0.1276	8.8520	0.2634	14.4018	0.1319
1991	19.7256	0.0967	24.1858	0.1687	19.2625	0.1039	5.9638	0.1509	4.6194	0.3740	6.0748	0.1562
1992	5.1856	0.1357	3.9074	0.3090	5.2906	0.1388	5.9759	0.1370	5.2084	0.2572	6.0429	0.1422
1993	11.0378	0.1180	9.7569	0.2060	11.0863	0.1246	6.2188	0.1267	3.2154	0.2874	6.6184	0.1286
1994	30.4503	0.0948	6.2768	0.2187	32.8431	0.0969	10.0125	0.1267	8.2758	0.2034	10.1821	0.1342
1995	28.5393	0.0961	15.6900	0.1834	29.8200	0.0993	7.4076	0.1388	2.1792	0.5259	7.8244	0.1411
1996	11.1058	0.1111	6.2210	0.2264	11.5775	0.1156	11.1744	0.1279	5.9862	0.2307	11.6878	0.1320
1997	23.0754	0.0988	13.6112	0.2020	23.9509	0.1027	7.7787	0.1409	5.5379	0.3026	7.9873	0.1457
1998	11.3118	0.1214	4.1622	0.3203	11.8987	0.1248	4.8486	0.1634	4.2282	0.3058	5.0223	0.1690
1999	20.2554	0.1047	11.2240	0.2101	21.1022	0.1085	3.3961	0.1640	3.0751	0.4168	3.4511	0.1698
2000	15.7532	0.1052	14.7179	0.2099	15.7031	0.1123	6.8943	0.1367	9.2644	0.2523	6.6892	0.1444
2001	13.8036	0.1122	4.2910	0.3075	14.6171	0.1151	4.2541	0.1566	4.4146	0.2878	4.3670	0.1613
2002	12.2829	0.1124	7.1785	0.2245	12.7920	0.1162	5.3365	0.1522	3.2593	0.3187	5.5827	0.1571
2003	14.6814	0.1112	8.3147	0.2545	15.2226	0.1154	4.9740	0.2551	1.7943	0.6152	4.9705	0.2748

Appendix 1. Table 6. Annual numbers of fish at length (inches) by region and commercial gear (longline, or handline plus others) or recreational mode (headboat, charter, or private).

commercial handline southeast (statistical areas 1-7)

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	5	0	2	0	0	0	0	0	0
12	0	0	23	0	1	1	4	0	0	0	0	0	0	1	1	0	0	0	0	0
13	0	1	19	0	19	1	16	2	9	0	0	1	0	6	0	0	0	0	0	0
14	0	0	6	3	15	3	62	2	7	1	0	0	2	4	6	3	0	1	0	39
15	0	0	6	1	5	6	58	1	14	1	0	0	4	9	35	99	0	40	2	95
16	8	4	7	4	6	6	64	0	8	2	11	2	14	16	90	199	9	37	6	136
17	25	11	13	9	9	7	58	0	9	2	11	0	10	29	52	163	18	30	19	105
18	46	14	14	10	9	4	36	4	17	1	12	1	16	47	37	124	19	27	26	71
19	102	20	7	9	5	16	11	6	12	6	7	0	14	21	31	160	32	33	32	70
20	133	30	8	5	4	10	11	4	10	4	6	3	8	13	16	103	31	38	19	51
21	144	56	16	12	3	3	8	4	6	10	3	2	13	15	25	81	15	37	20	62
22	117	74	15	11	0	2	6	1	4	9	11	3	8	8	29	70	33	27	24	46
23	111	82	18	12	0	1	6	3	7	5	3	4	5	15	12	45	15	24	18	32
24	90	109	14	14	1	6	3	4	6	12	0	2	5	5	12	32	15	31	41	13
25	36	88	26	7	1	0	2	4	4	9	4	1	4	4	3	34	12	24	28	11
26	28	101	32	12	2	3	7	1	2	2	2	3	2	7	11	31	6	19	29	14
27	10	96	29	7	4	1	8	1	5	3	2	1	2	3	6	11	6	14	25	11
28	5	67	34	10	5	1	7	4	0	0	1	0	1	3	7	10	4	8	24	8
29	3	40	30	15	3	1	4	0	1	0	0	0	1	0	10	5	5	3	19	3
30	1	19	13	8	3	1	2	0	2	0	0	0	0	2	6	2	1	1	7	2
31	2	8	7	7	1	0	3	0	1	0	1	1	0	4	0	3	5	0	2	0
32	0	8	5	4	4	1	2	0	1	0	1	0	0	0	0	2	1	0	0	1
33	0	1	4	7	2	2	1	0	0	0	3	0	0	1	1	1	2	0	0	0
34	3	6	2	4	3	1	2	0	1	1	3	3	0	0	0	1	2	0	0	0
35	8	9	10	4	4	1	1	0	0	0	1	0	0	0	0	0	3	0	0	0
36	3	17	8	3	2	0	2	0	0	0	1	2	0	0	0	0	1	0	0	0
37	8	13	4	2	0	0	1	1	0	2	1	0	0	0	0	0	0	0	0	0
38	4	10	0	4	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
39	1	4	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40+	0	6	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
total	888	894	373	185	114	78	386	42	126	70	84	44	109	215	390	1179	235	394	341	770

Appendix 1. Table 6. continued.

commercial handline northeast (statistical areas 8-12)

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
9	2	0	10	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1
10	30	0	7	3	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	76	0	24	4	1	46	2	5	1	2	0	0	0	1	0	0	0	0	0	0
12	93	2	221	114	10	23	13	4	16	1	1	3	0	0	1	0	0	0	0	1
13	103	9	236	163	30	39	232	852	395	188	25	18	0	1	1	0	1	2	1	3
14	107	15	124	125	28	41	331	998	369	362	478	361	80	21	73	53	72	84	94	105
15	147	18	53	56	9	54	260	683	229	378	921	366	487	343	839	498	523	654	802	922
16	181	23	44	49	8	57	248	476	178	402	805	317	564	504	1021	639	802	703	1038	1049
17	140	24	31	44	11	25	169	321	138	329	528	285	337	334	580	574	595	597	881	756
18	85	28	11	21	14	23	117	173	95	216	298	256	241	281	390	477	481	522	554	488
19	75	38	5	21	5	29	128	138	42	157	195	210	182	177	200	348	373	406	340	404
20	49	27	14	6	7	23	121	81	39	77	188	135	127	152	117	244	248	307	223	264
21	36	23	8	6	7	14	83	38	11	68	132	129	134	107	94	197	236	242	216	215
22	41	18	11	5	12	7	52	29	25	49	99	97	123	78	67	139	178	168	161	124
23	38	7	8	5	7	8	49	11	5	36	68	75	97	59	52	95	155	146	126	103
24	24	9	6	6	5	4	37	21	2	30	60	56	98	50	31	64	130	119	103	79
25	14	11	1	4	5	1	32	21	1	21	43	42	64	33	33	39	92	91	71	60
26	8	9	0	2	3	2	29	15	8	19	30	36	55	26	32	51	92	70	61	66
27	10	1	3	0	2	3	22	23	2	11	24	31	42	37	28	41	60	59	38	56
28	6	3	0	4	1	5	7	13	1	15	21	19	28	34	28	51	51	50	42	27
29	4	4	0	1	1	1	9	3	0	12	18	21	20	17	14	32	29	43	33	32
30	9	3	0	0	1	4	4	10	0	9	12	13	15	11	9	15	21	25	20	22
31	6	4	0	0	0	0	6	6	2	2	7	20	13	11	12	10	10	19	21	15
32	3	8	0	0	0	1	14	3	2	5	5	14	8	1	5	8	9	9	9	8
33	7	5	0	1	0	2	2	3	0	1	2	7	4	3	12	2	5	9	8	3
34	7	4	0	0	0	2	5	2	2	1	1	7	5	0	5	6	2	5	4	6
35	7	2	1	0	0	2	0	0	0	0	2	2	3	1	4	4	1	1	1	1
36	3	1	0	0	0	0	5	0	0	1	1	2	0	0	2	4	0	2	0	3
37	0	0	0	0	0	0	2	1	0	0	0	3	0	0	1	0	0	1	0	1
38	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	1	0	0	0	0
39	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	2	0
40+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
total	1312	296	818	640	167	443	1982	3930	1567	2392	3964	2527	2728	2282	3651	3592	4167	4335	4849	4814

Appendix 1. Table 6. continued.

commercial handline west

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	28	4	2	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0
10	86	13	1	1	3	1	5	3	2	0	0	0	0	0	0	1	0	0	1	0
11	189	20	2	1	2	41	9	11	1	1	0	0	0	0	0	1	0	0	1	0
12	245	274	71	6	9	59	47	72	31	0	3	1	2	0	4	0	2	1	2	0
13	389	640	442	124	220	183	813	1092	1097	292	37	12	0	3	4	0	0	3	11	11
14	389	715	518	195	234	239	1222	1622	2220	952	511	438	82	41	73	57	47	52	218	308
15	284	534	372	132	98	189	998	1067	1990	1157	1093	885	1086	1558	1146	541	659	691	1589	1704
16	330	431	269	87	174	210	1023	932	1463	1226	1053	904	1666	2003	1836	979	895	904	1689	1786
17	269	239	198	59	77	160	705	622	1041	1147	846	778	1158	1719	1564	775	700	759	1317	1292
18	170	170	115	44	79	123	503	563	683	810	627	534	873	1121	983	636	476	531	847	929
19	173	140	150	44	47	63	453	445	503	809	488	446	718	954	917	498	372	436	620	648
20	105	116	75	30	53	95	353	309	279	507	326	303	527	769	722	345	258	260	403	453
21	86	132	78	19	55	54	184	233	232	438	249	288	455	709	646	331	173	221	296	328
22	68	95	61	14	29	51	176	142	162	286	241	283	345	553	451	279	118	162	239	249
23	28	84	44	6	18	37	114	121	106	223	183	210	207	383	371	221	87	124	185	194
24	36	86	49	14	27	23	102	114	137	203	160	211	190	333	304	213	93	100	180	175
25	38	67	45	5	22	36	71	78	72	111	131	154	111	220	212	152	86	75	135	129
26	41	70	34	13	25	35	66	87	68	98	75	137	95	203	225	133	68	64	111	101
27	47	55	23	4	13	8	37	47	46	60	100	142	108	164	164	125	50	56	102	87
28	14	35	21	4	8	17	42	44	51	53	56	101	98	143	146	112	56	49	69	64
29	20	57	24	7	7	10	43	48	49	63	53	97	118	144	111	91	40	45	49	39
30	24	42	10	3	12	4	16	51	29	30	27	91	75	126	86	64	37	36	29	43
31	16	64	29	1	4	4	10	44	32	37	31	56	51	82	87	63	23	20	31	18
32	11	50	18	3	7	2	10	36	17	19	14	18	19	64	62	28	11	16	14	14
33	18	33	20	5	7	2	11	31	9	11	16	6	5	29	26	17	6	5	10	8
34	12	37	24	3	5	0	11	29	10	7	10	4	2	13	22	5	2	1	4	7
35	7	14	17	1	1	0	6	15	4	7	8	7	4	5	8	0	3	3	3	1
36	2	8	7	0	1	0	6	20	3	6	5	4	1	4	6	1	1	2	2	5
37	2	3	3	0	1	1	3	6	1	2	1	3	0	2	1	1	0	0	0	0
38	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	2	0	0	1	0
39	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
40+	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
total	3127	4228	2722	825	1238	1647	7040	7886	10341	8555	6344	6113	7998	11345	10177	5671	4263	4616	8159	8593

Appendix 1. Table 6. continued

commercial longline east

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0
14	0	0	2	0	1	0	3	1	8	1	0	3	0	0	0	1	0	0	0	0
15	0	0	4	0	0	0	6	0	8	0	1	0	0	0	0	1	0	0	2	0
16	10	1	7	3	0	0	30	2	2	0	0	0	0	0	2	2	1	0	1	1
17	6	1	15	4	6	0	19	2	25	1	1	1	2	5	2	8	1	0	5	11
18	17	11	27	11	10	1	7	4	9	2	3	2	2	2	4	13	4	1	10	18
19	31	7	33	6	14	2	7	7	5	6	0	9	3	0	6	39	6	2	12	26
20	35	21	40	10	10	2	4	11	7	6	1	7	4	2	8	29	15	11	12	36
21	75	28	46	12	9	2	9	7	4	13	4	17	7	0	10	29	25	18	11	50
22	135	44	38	19	16	1	10	9	10	17	7	20	10	1	13	32	29	21	14	27
23	121	80	47	29	13	1	20	6	5	16	9	11	14	4	12	19	40	26	15	30
24	112	95	72	20	13	2	10	7	5	23	11	7	11	1	17	23	50	27	15	17
25	74	83	63	30	12	1	26	9	5	11	4	8	5	2	11	16	31	31	20	14
26	40	106	91	28	9	3	21	15	9	13	12	2	9	5	7	14	27	31	25	13
27	31	84	81	21	8	2	17	10	5	8	14	7	0	6	6	7	18	19	23	18
28	10	67	106	35	5	1	14	7	8	10	4	1	2	6	18	5	8	18	30	14
29	18	24	80	26	7	1	9	4	5	1	2	5	5	3	20	5	6	10	23	13
30	6	21	60	25	5	0	9	4	3	2	2	4	1	4	36	3	3	5	18	11
31	20	16	55	22	4	2	14	1	2	1	3	7	1	5	28	7	7	3	18	2
32	16	5	23	12	6	1	8	2	3	2	1	4	1	11	24	7	4	2	7	4
33	18	15	20	11	8	1	13	4	4	4	3	2	0	5	10	8	1	2	7	2
34	21	9	21	20	13	1	8	9	2	2	2	2	0	2	5	11	0	1	3	0
35	21	12	22	11	6	1	10	3	5	3	3	6	1	3	2	5	2	1	7	2
36	26	26	18	13	11	1	5	2	0	1	5	3	0	0	2	5	3	0	4	2
37	10	20	18	16	2	2	6	2	4	0	3	2	0	1	2	1	1	1	0	1
38	5	14	13	5	1	1	2	0	1	0	0	3	1	0	1	0	1	0	0	0
39	6	6	6	7	0	0	5	0	2	0	0	0	0	0	0	0	0	0	0	0
40+	0	5	3	1	0	0	3	2	1	0	0	0	0	0	0	0	0	1	0	0
total	864	801	1011	397	189	29	295	130	158	143	95	133	79	68	246	290	283	231	282	312

Appendix 1. Table 6. continued.

commercial longline west

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	2	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
12	7	4	2	1	0	0	35	0	0	0	0	0	0	0	0	0	0	0	0	0
13	17	5	26	0	29	37	76	29	4	0	0	0	0	0	0	0	0	0	0	0
14	36	11	23	7	15	42	45	36	16	1	0	0	0	0	0	0	0	0	19	0
15	26	43	15	0	2	13	56	16	7	6	0	0	3	0	4	2	10	0	65	0
16	26	43	15	8	8	37	28	19	4	11	0	0	1	0	6	15	16	0	88	0
17	34	40	13	4	12	28	36	12	7	7	0	1	0	0	15	28	12	1	81	0
18	24	35	13	0	17	35	12	5	2	4	0	4	0	0	7	17	2	3	83	0
19	26	44	10	2	9	10	14	11	5	4	0	1	0	0	6	6	3	3	79	0
20	39	40	8	2	14	26	9	10	2	1	0	1	1	1	12	5	8	6	60	2
21	24	32	10	4	9	27	7	9	1	4	0	3	0	3	10	3	19	8	44	6
22	17	31	10	5	15	31	5	7	6	2	1	6	0	0	18	7	27	5	37	2
23	19	24	2	2	3	3	9	7	1	1	1	10	0	1	22	4	27	11	27	6
24	16	20	4	1	7	18	15	5	9	0	1	16	0	4	42	15	25	15	14	12
25	13	25	4	4	5	15	10	4	5	0	0	9	0	4	28	23	25	10	28	18
26	13	23	5	2	4	16	11	8	4	1	0	5	0	5	28	25	43	10	21	12
27	16	14	5	1	2	2	2	47	1	2	0	2	1	9	29	25	61	10	25	18
28	4	15	4	0	1	6	5	20	10	0	0	6	0	8	28	18	61	11	27	28
29	27	11	4	3	2	12	4	17	10	2	0	2	0	12	22	6	60	11	39	33
30	28	23	6	1	1	7	6	9	8	2	0	3	1	3	23	7	37	28	35	32
31	52	34	6	3	3	2	3	6	8	1	0	0	1	6	26	5	32	26	37	30
32	85	43	8	2	0	1	5	37	16	1	0	1	1	6	15	1	29	19	26	22
33	74	45	13	4	0	1	1	5	1	7	0	0	2	0	7	4	21	7	16	24
34	67	48	13	3	0	3	3	9	3	1	0	4	0	1	7	2	14	5	7	5
35	30	19	6	2	0	1	2	8	3	0	0	0	0	0	1	0	7	0	4	7
36	11	11	3	0	0	0	4	1	0	2	0	0	0	0	0	0	1	1	0	2
37	3	4	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40+	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
total	737	689	229	62	158	373	408	338	134	61	3	74	11	63	358	218	540	192	862	259

Appendix 1. Table 6. continued.

recreational headboat east

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
9	0	1	2	3	0	6	0	0	0	0	4	0	0	0	0	0	0	0	0	0
10	0	0	4	7	1	10	1	1	4	0	4	0	1	1	0	1	1	0	0	0
11	1	1	15	16	8	29	3	2	1	2	1	0	0	1	0	0	1	0	0	0
12	1	0	19	23	18	46	4	19	15	9	1	1	0	0	1	0	0	1	0	0
13	1	0	24	26	38	37	75	116	128	61	60	4	4	3	1	0	0	0	0	0
14	2	0	16	25	29	16	67	94	146	106	287	31	43	103	52	4	1	0	0	1
15	1	1	18	22	23	20	63	91	144	77	336	100	112	430	585	113	73	16	27	14
16	1	0	16	13	20	18	40	56	128	41	197	100	101	265	660	210	362	195	354	300
17	3	1	11	9	17	20	19	37	79	27	154	64	80	123	433	212	251	147	364	313
18	0	1	11	12	6	21	14	43	42	28	128	42	40	57	203	118	150	68	196	168
19	3	2	10	7	11	22	13	32	32	23	104	19	47	48	113	79	95	75	156	99
20	0	0	5	6	4	8	6	21	20	25	68	18	18	31	53	45	61	50	66	58
21	2	2	3	6	3	10	9	11	10	15	48	17	20	16	20	34	36	36	21	46
22	2	2	0	6	6	6	5	14	17	11	48	11	9	15	16	24	26	23	16	28
23	0	1	1	1	3	5	5	7	8	6	35	10	7	17	9	15	22	7	9	26
24	1	0	4	0	5	3	4	3	5	1	40	7	10	14	13	17	21	8	12	17
25	0	0	2	3	0	0	0	3	5	3	34	3	3	8	5	4	8	3	12	9
26	0	1	1	0	1	3	1	4	5	4	19	1	5	5	6	5	3	4	8	5
27	0	1	0	0	1	4	1	5	2	2	18	4	6	2	4	4	12	4	1	4
28	0	0	0	0	0	1	0	1	2	0	15	1	3	3	2	1	3	9	0	3
29	0	0	2	1	1	0	1	0	0	0	16	2	2	1	2	0	5	2	4	6
30	0	0	1	2	0	1	1	0	1	0	9	2	1	1	2	1	4	2	1	0
31	0	0	1	1	1	0	0	0	0	0	4	3	1	0	0	2	0	0	1	1
32	0	0	0	1	0	0	0	0	0	0	3	0	0	0	1	0	0	3	1	1
33	0	0	0	0	0	0	0	0	1	0	2	0	1	1	0	0	0	1	0	0
34	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40+	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total	18	14	166	193	196	286	333	560	795	441	1636	443	514	1145	2181	889	1135	654	1250	1100

Appendix 1. Table 6. continued.

recreational charter east

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	10	0	1	2	0	0	0	0	1	0	0	0	0
9	0	0	0	2	2	0	0	17	7	0	6	1	0	2	0	0	0	0	0	0
10	0	0	1	10	8	0	1	36	5	2	6	1	0	0	0	2	1	0	0	0
11	3	0	7	48	19	3	4	96	23	12	19	5	0	0	2	4	4	2	0	0
12	12	0	9	25	31	3	3	200	140	67	24	8	2	4	4	5	8	2	1	2
13	37	1	15	39	54	22	32	3584	2946	1840	223	33	1	3	9	1	10	11	10	7
14	50	13	39	66	58	39	80	7140	4461	2695	1450	110	12	50	78	54	24	10	18	38
15	76	5	14	61	31	16	55	7236	3870	1823	2197	459	51	347	505	795	548	342	441	852
16	56	8	31	58	33	25	33	4541	2370	1223	2130	348	30	348	873	1645	2159	1763	2345	3925
17	46	0	10	33	46	15	27	2959	1602	815	1728	224	42	168	643	1499	1915	1285	2598	3675
18	34	1	13	30	19	8	13	1421	970	560	1184	137	29	85	380	1075	1147	846	2097	2607
19	41	4	10	27	23	13	11	989	757	463	865	120	38	52	259	850	783	654	1296	1759
20	21	0	4	8	15	6	5	495	483	298	496	89	17	44	143	637	496	469	720	1146
21	12	0	4	12	2	1	1	287	312	239	341	77	14	32	73	445	382	399	470	899
22	14	0	2	11	1	2	1	154	177	157	303	53	11	26	52	347	243	253	274	578
23	6	0	0	10	0	0	2	93	109	112	208	49	15	25	36	219	138	197	224	434
24	14	1	3	10	1	0	1	72	86	76	170	31	7	12	21	126	117	137	201	322
25	14	1	1	4	3	0	2	54	46	69	131	27	7	9	21	74	70	94	151	226
26	8	0	0	4	0	1	2	43	51	57	95	34	2	15	21	49	66	74	126	172
27	3	0	2	3	0	0	1	19	21	44	72	24	2	3	16	39	46	60	89	144
28	4	1	2	2	0	0	0	11	17	21	48	21	4	10	11	30	32	46	69	139
29	4	0	1	1	2	1	0	12	13	17	28	13	4	4	11	19	22	33	42	82
30	9	0	0	3	0	0	1	16	14	13	18	10	3	2	2	9	7	23	42	73
31	4	0	0	0	0	0	1	4	12	3	6	6	5	2	4	6	4	11	22	45
32	0	0	0	0	0	0	0	2	5	4	3	1	0	2	1	4	1	7	11	27
33	0	0	1	0	0	0	0	3	3	0	3	2	0	0	1	5	1	2	2	15
34	0	0	0	0	0	0	0	2	0	3	1	0	1	2	0	4	0	2	8	10
35	0	0	0	1	0	1	0	2	1	1	2	2	1	0	0	3	1	0	5	3
36	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	2	2	1	6
37	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	4
38	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	2	4
39	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
40+	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
total	468	35	169	468	348	156	276	29500	18503	10616	11782	1886	298	1247	3166	7948	8228	6725	11266	17198

Appendix 1. Table 6. continued.

recreational private east

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	5	1	0	2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
10	3	0	0	5	0	0	0	0	1	0	0	0	0	0	0	9	0	0	0	0
11	1	0	0	13	0	0	2	0	3	3	0	0	0	0	0	6	0	0	0	0
12	3	1	0	10	0	1	8	4	4	5	1	0	2	0	0	0	1	0	0	0
13	1	0	0	10	4	3	9	28	56	14	5	2	0	0	0	1	1	4	0	0
14	3	1	0	17	5	4	8	53	87	30	10	6	5	4	3	4	1	8	2	7
15	5	0	3	32	2	2	13	75	130	27	26	19	10	13	9	46	18	24	17	35
16	0	0	3	21	7	1	3	46	77	46	27	22	20	25	23	74	71	49	149	143
17	0	0	3	16	1	0	3	32	53	40	33	15	15	30	32	75	61	76	175	228
18	0	0	2	5	3	0	2	17	31	16	10	13	13	20	28	91	66	60	122	165
19	1	3	1	3	2	0	1	9	21	5	10	12	10	26	14	104	60	46	95	135
20	0	3	0	9	3	1	2	3	13	11	12	8	5	12	4	85	30	42	85	113
21	0	1	0	19	1	0	0	4	29	13	8	2	6	11	7	73	30	23	60	86
22	0	1	1	4	0	0	0	1	7	2	2	0	4	10	2	50	25	31	62	49
23	0	0	0	1	0	0	2	1	8	7	6	4	3	5	3	40	12	21	36	47
24	0	0	0	3	1	0	0	1	2	4	5	2	6	3	0	19	13	19	32	30
25	0	0	1	3	0	0	2	0	5	2	5	1	0	2	3	16	10	12	18	31
26	1	0	0	0	0	0	2	0	3	3	0	2	2	1	0	12	7	21	29	25
27	0	0	1	0	0	0	0	0	1	1	2	0	1	3	2	11	5	17	7	19
28	0	0	0	0	3	1	0	2	0	1	2	1	0	2	3	9	5	19	14	22
29	0	0	0	0	0	0	0	0	1	0	1	2	0	4	3	12	4	9	18	15
30	0	0	1	0	0	0	0	0	1	1	2	1	0	0	2	4	2	9	12	9
31	0	0	0	1	0	0	0	0	1	0	1	1	1	4	2	3	3	1	5	9
32	0	0	0	1	0	0	0	1	0	0	0	0	0	2	0	0	0	1	7	6
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	2	6	7
34	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	1	1	4
35	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
38	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	1	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
total	26	11	16	175	32	13	57	277	535	231	169	113	106	179	140	752	426	496	954	1191

Appendix 1. Table 6. continued.

recreational headboat west

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
7	6	0	12	4	2	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0
8	52	1	91	37	13	17	1	0	0	0	0	0	2	0	0	0	0	0	0	0
9	235	4	367	223	91	72	6	4	1	0	0	0	0	0	1	0	0	0	0	0
10	521	8	934	572	386	464	36	23	2	3	1	0	2	0	1	0	0	0	0	0
11	856	30	1142	1006	644	924	145	42	35	24	4	3	0	0	3	0	0	0	0	0
12	961	17	1125	1196	825	1188	533	180	116	123	19	4	4	0	1	0	0	0	0	0
13	748	22	837	1017	732	1122	1063	1170	865	921	309	8	10	4	5	0	1	3	3	2
14	387	43	594	734	591	859	1018	1535	1904	1599	1490	354	56	41	184	11	17	35	11	4
15	197	11	330	395	422	643	625	966	2086	1508	1822	1603	778	592	1147	221	149	244	112	115
16	106	17	224	244	297	328	431	529	1422	1139	1211	1954	1228	727	1345	360	755	547	363	538
17	72	21	153	143	179	223	204	537	831	652	740	1381	956	552	1067	363	729	424	456	424
18	43	11	109	128	123	147	141	241	403	469	411	902	592	417	685	445	445	285	353	331
19	21	7	74	62	84	80	91	169	316	355	297	607	521	368	487	454	315	253	324	257
20	26	5	47	51	39	43	80	69	182	276	205	341	299	293	316	348	204	194	207	125
21	9	1	51	28	37	35	49	26	111	224	175	213	215	243	242	248	134	117	148	92
22	10	3	42	27	43	27	17	23	90	138	122	175	142	198	250	192	82	105	97	45
23	8	0	19	21	26	10	16	33	85	108	96	130	95	156	145	119	73	73	91	37
24	3	0	14	22	17	9	10	14	54	125	87	125	73	93	135	86	72	56	64	39
25	5	0	15	14	15	6	9	9	45	93	66	98	41	75	91	85	40	39	49	20
26	3	0	9	12	19	12	8	8	40	54	38	59	41	59	96	59	39	43	48	18
27	0	0	12	10	24	18	8	12	42	60	48	67	40	59	79	47	41	29	38	29
28	2	0	8	6	35	17	6	10	37	30	42	84	32	30	76	50	24	20	24	17
29	0	0	14	8	19	9	4	5	37	37	37	94	28	20	73	42	24	28	18	22
30	2	0	3	8	22	10	4	10	30	32	23	74	38	26	44	47	23	12	28	17
31	2	0	6	6	12	5	0	4	18	12	19	57	33	21	34	35	13	12	18	15
32	2	0	8	3	11	7	1	5	9	8	7	20	20	5	44	38	7	3	8	20
33	0	0	2	1	6	7	3	3	2	5	4	19	8	10	19	17	4	5	9	9
34	0	0	1	3	3	1	2	1	4	4	3	10	7	4	20	8	4	2	2	4
35	0	0	3	0	3	1	2	0	6	6	2	2	2	1	7	5	0	1	3	0
36	0	0	1	0	4	0	1	0	1	1	0	1	2	1	11	3	0	1	4	0
37	0	0	3	1	1	0	3	1	0	0	0	0	0	1	5	1	0	0	1	0
38	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	1	1
39	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
40+	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total	4277	202	6251	5982	4726	6287	4517	5629	8775	8006	7278	8386	5270	3996	6614	3284	3195	2531	2480	2181

Appendix 1. Table 6. continued.

recreational charter west

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	8	20	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	7	18	63	30	10	2	0	0	1	0	1	0	0	0	0	0	0	0	0	0
12	9	42	54	42	2	1	2	7	9	4	1	0	0	0	0	0	0	0	0	0
13	15	42	52	33	2	2	9	65	133	36	9	3	0	1	2	0	0	1	1	0
14	9	23	77	59	5	8	19	84	227	87	19	14	5	1	5	2	0	3	2	10
15	13	20	33	37	1	5	4	50	143	100	29	42	18	5	30	18	8	33	29	67
16	51	12	15	18	0	3	6	26	78	44	27	39	40	18	37	16	45	91	119	146
17	48	6	18	9	0	2	2	16	86	19	21	31	35	17	42	21	33	62	114	160
18	12	4	4	6	0	0	1	9	44	26	15	22	19	15	50	8	15	47	92	105
19	15	4	1	2	1	1	1	9	42	25	6	25	27	15	29	13	18	35	51	50
20	8	1	1	5	0	0	2	3	19	9	3	6	12	12	27	12	12	17	55	41
21	3	1	1	3	1	1	0	3	16	16	3	6	11	17	20	9	9	12	29	47
22	5	1	1	3	1	2	0	7	12	8	4	4	6	12	12	5	7	19	22	21
23	4	0	1	0	2	0	0	6	9	6	4	1	7	13	10	4	5	4	15	17
24	2	0	1	1	0	0	1	4	6	5	10	7	5	6	5	1	1	4	14	11
25	3	2	1	0	1	0	0	3	3	8	3	6	4	1	9	0	11	4	13	15
26	2	3	1	1	0	1	0	1	7	5	3	2	4	0	7	5	4	3	14	25
27	0	0	2	0	0	1	0	4	10	3	6	2	5	6	4	8	4	2	12	25
28	0	0	0	1	0	0	0	1	9	2	5	1	3	0	3	0	3	0	15	33
29	5	2	0	4	1	0	0	3	5	0	3	7	3	1	4	1	1	1	10	24
30	0	0	0	0	0	0	0	3	7	1	2	1	3	1	0	4	4	1	9	16
31	1	3	1	1	0	0	0	5	3	2	1	3	1	0	0	1	1	1	4	8
32	0	0	3	0	0	0	0	3	3	0	2	2	0	0	1	3	1	0	2	4
33	0	1	1	0	0	0	0	0	0	1	1	1	0	1	0	1	1	0	2	2
34	0	0	1	0	1	0	0	1	3	0	1	0	0	1	0	0	1	0	0	1
35	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40+	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total	219	196	358	259	29	29	48	314	875	407	180	226	208	143	297	132	187	340	624	828

Appendix 1. Table 6. continued.

recreational private west

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	9	5	2	5	1	4	1	0	0	0	2	0	0	0	0	0	0	0	0	0
8	26	15	16	30	10	12	6	3	1	0	2	1	1	0	1	0	1	0	0	0
9	50	45	29	63	29	19	12	9	1	4	5	1	1	0	2	0	3	1	0	0
10	31	54	32	56	41	32	29	9	1	5	1	3	1	0	0	1	3	0	2	0
11	37	116	64	65	56	33	40	18	2	6	11	8	0	0	1	3	4	0	1	0
12	54	152	64	36	91	52	58	44	36	51	26	15	2	4	13	7	1	1	0	0
13	60	119	66	60	87	64	75	166	104	183	119	64	5	14	19	8	10	3	4	2
14	46	63	48	48	66	57	49	107	137	137	218	200	67	72	95	50	55	33	30	50
15	29	45	31	27	33	39	44	58	118	106	175	264	151	218	207	171	230	175	149	150
16	24	14	17	19	25	25	30	47	61	72	119	205	154	238	143	137	185	204	294	220
17	12	13	5	8	17	11	9	14	36	37	83	145	167	183	142	92	149	155	237	182
18	10	8	7	8	16	11	6	11	20	41	68	114	148	144	114	88	100	86	185	180
19	5	3	9	5	8	7	8	6	36	42	53	95	100	128	113	52	85	56	138	112
20	11	10	5	3	8	5	5	10	31	52	40	59	72	85	76	40	66	46	101	90
21	5	1	5	6	2	0	6	3	21	39	27	47	41	75	53	32	30	19	71	80
22	6	2	3	3	3	3	7	7	11	36	21	27	40	42	46	29	21	13	49	60
23	4	6	1	2	0	0	2	4	6	20	23	32	27	27	29	15	18	13	28	50
24	4	5	2	1	7	5	1	1	2	15	14	25	28	22	31	14	16	9	22	68
25	2	3	2	2	4	3	4	4	3	6	17	21	12	22	33	14	5	8	21	48
26	2	4	0	1	2	0	1	2	0	6	19	11	8	16	22	10	5	5	21	28
27	1	2	1	2	1	1	0	4	3	4	14	16	5	15	25	11	10	5	11	36
28	1	0	0	3	4	2	0	2	0	2	14	11	5	5	16	8	11	6	11	28
29	1	0	1	1	0	1	0	0	1	2	10	12	10	12	9	16	6	7	8	35
30	3	0	2	1	0	0	0	0	0	2	5	5	8	7	8	6	3	5	7	30
31	1	0	0	0	0	1	0	0	1	0	1	2	3	2	10	6	5	6	2	22
32	2	0	1	0	1	1	0	0	1	1	0	0	0	2	4	4	1	6	6	12
33	2	0	1	0	1	0	1	0	2	0	1	1	1	0	5	1	1	2	2	12
34	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	1	0	0	1	4
35	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total	439	685	414	455	514	388	394	529	635	869	1088	1385	1057	1333	1222	818	1025	864	1401	1505

Appendix 1. Table 7. Derived age composition calculated from landings (commercial, weight) and catch (recreational, n fish), length frequency of the landed catches, modeling of discards and estimates of mortality rates and recruitment patterns. This set of derived age composition was calculated assuming a single Gulf wide stock and a natural mortality rate of 0.59.

commercial handline landings east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	17	55960	155774	92844	62684	12381	17672	5637	3454	3082	1732	2028	5692	4634	23308
1985	0	0	4655	24365	66252	49092	37769	8657	14273	5153	3465	3310	1953	2369	6834	35007
1986	0	284	315837	52028	29937	28764	13689	9120	1988	3196	1137	757	717	420	508	8798
1987	0	0	5015	252289	30016	23130	25199	12523	8470	1862	3014	1083	726	692	408	9018
1988	0	0	48326	59944	53315	8325	10866	17458	11132	8833	2158	3753	1419	989	968	13848
1989	0	0	52215	87984	25090	20171	3019	4054	6966	4808	4114	1074	1969	777	561	9094
1990	0	2	18072	93982	40497	11089	11082	2000	3056	5711	4161	3695	989	1848	741	9384
1991	0	0	8946	65421	62889	18086	4053	3776	675	1040	1962	1440	1284	345	645	3446
1992	0	0	629	132116	17189	15857	6041	1648	1721	329	530	1031	773	704	191	2300
1993	0	0	1755	31828	80556	6471	7342	3756	1314	1659	365	653	1375	1097	1043	4062
1994	0	0	586	72342	29500	47339	3931	4778	2617	976	1305	301	562	1221	999	4836
1995	0	0	2304	9951	15366	3485	6672	692	1007	636	266	390	97	191	436	2274
1996	0	0	1206	21681	10515	11694	2986	6427	720	1090	702	295	431	106	209	2817
1997	0	0	1446	11822	19206	4903	4980	1288	2891	340	538	359	156	233	59	1697
1998	0	0	1437	68054	23001	13826	3292	3673	1052	2583	329	558	394	179	278	2259
1999	0	0	1227	28670	72345	14506	10233	2923	3692	1141	2938	389	674	484	223	3141
2000	0	0	1429	24099	46166	58784	11109	8274	2506	3325	1066	2825	383	676	493	3398
2001	0	0	7976	30801	45108	39205	47390	9121	6924	2147	2921	958	2593	359	642	3685
2002	0	0	3148	126799	39266	30438	26588	35299	7330	5889	1909	2690	907	2508	353	4235
2003	0	0	9240	58672	137961	20661	16203	15416	21968	4805	4014	1342	1941	667	1872	3516

commercial handline landings west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	353	212019	392526	158817	85971	16357	24387	8238	5291	4880	2802	3328	9419	7709	39076
1985	0	0	54819	145751	129973	53785	34497	7660	12811	4726	3236	3130	1862	2272	6574	33842
1986	0	193	106987	117674	92791	89446	41593	27664	6169	10281	3797	2614	2545	1526	1874	33788
1987	0	0	65611	270528	32564	29503	36932	20297	14785	3436	5795	2145	1471	1424	849	19275
1988	0	0	98028	215390	181815	23084	27039	41689	26387	21080	5207	9152	3492	2453	2415	35067
1989	0	0	61165	274984	82054	69330	10811	14674	24790	16562	13650	3435	6101	2344	1655	25023
1990	0	67	55884	292575	122059	30084	27850	4799	7102	12938	9224	8039	2119	3906	1549	18953
1991	0	0	64877	152732	167314	60484	15936	16445	3161	5164	10228	7810	7196	1984	3786	21490
1992	0	0	1556	630615	103068	105552	44394	13275	14956	3030	5097	10245	7872	7281	2008	24890
1993	0	0	1723	147775	487449	44930	53600	27824	9780	12364	2723	4867	10244	8155	7750	29997
1994	0	0	221	238792	119934	222639	20595	27011	15542	5974	8133	1900	3557	7762	6361	30798
1995	0	0	8727	122612	226306	54701	113258	12529	18893	12073	5020	7263	1777	3449	7735	38531
1996	0	0	12297	350101	200934	208791	49134	101819	11311	17197	11135	4705	6919	1720	3382	45739
1997	0	0	20139	225841	392762	109993	119072	32140	74566	9022	14606	9921	4355	6601	1683	49640
1998	0	0	6249	375265	202671	168761	48058	58763	17611	44192	5692	9660	6813	3082	4786	38394
1999	0	0	6610	148496	423063	101360	84376	27105	36950	11968	31722	4269	7480	5410	2495	35395
2000	0	0	16794	200626	291683	329727	58539	43070	13184	17765	5778	15486	2117	3765	2759	19258
2001	0	0	57448	180550	224412	178746	205408	38674	29236	9099	12445	4103	11151	1545	2778	16008
2002	0	0	9958	432854	156540	118664	98613	125505	25262	19848	6331	8820	2948	8101	1134	13455
2003	0	0	20299	161368	463881	69579	53702	50351	70873	15347	12719	4223	6079	2080	5822	10837

Appendix 1. Table 7.

commercial longline landings east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	11	1910	6634	9019	2404	4033	1432	951	904	534	651	1885	1573	8368
1985	0	0	0	67	810	1454	1829	533	988	379	265	260	157	194	566	3012
1986	0	0	25	125	357	920	870	899	259	501	203	148	150	92	115	2169
1987	0	0	3	143	98	269	670	576	571	165	327	137	103	107	67	1753
1988	0	0	0	91	895	283	496	961	723	670	187	364	151	113	116	1921
1989	0	0	5	531	436	673	159	295	646	538	533	156	311	132	100	1879
1990	0	0	49	1001	718	364	584	146	281	626	521	512	148	294	123	1779
1991	0	0	0	38	264	253	121	179	43	80	174	142	138	39	78	480
1992	0	0	0	201	50	76	47	20	28	7	14	31	26	26	8	113
1993	0	0	5	29	452	123	246	168	69	97	23	43	95	78	76	313
1994	0	0	1	13	27	181	34	66	48	22	34	9	18	41	35	193
1995	0	0	12	30	160	71	194	25	45	33	16	25	7	14	33	187
1996	0	0	0	18	77	242	94	243	30	48	32	14	21	5	11	148
1997	0	0	0	15	29	18	42	19	64	10	19	15	7	12	3	108
1998	0	0	0	28	31	54	28	55	23	71	11	20	15	7	12	106
1999	0	0	1	30	293	105	103	36	54	19	56	8	15	11	5	87
2000	0	0	0	12	108	417	133	126	43	62	21	58	8	15	11	80
2001	0	0	0	4	61	178	418	114	105	37	54	18	52	7	13	82
2002	0	0	1	96	74	132	229	490	140	139	52	82	30	88	13	171
2003	0	0	1	55	488	150	172	206	342	83	75	26	40	14	41	81

commercial longline landings west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	2187	10389	7179	5723	1652	3785	1807	1488	1633	1060	1375	4153	3567	20055
1985	0	0	505	5794	12319	7992	6543	1773	3560	1525	1169	1229	777	991	2964	16372
1986	0	0	7762	14955	14949	17272	9420	7639	2102	4182	1765	1339	1397	881	1123	21860
1987	0	0	1525	20452	4577	6301	10900	7816	7160	2002	3887	1597	1183	1212	755	18907
1988	0	0	30875	26292	37870	6764	9068	14599	9289	7345	1786	3088	1161	805	784	11011
1989	0	0	6172	26315	12368	14111	2593	3884	7013	4915	4197	1085	1966	767	548	8550
1990	0	3	6770	11434	3665	1041	1202	250	428	874	682	637	177	341	140	1877
1991	0	0	719	1027	1195	610	278	463	124	252	575	483	475	137	270	1661
1992	0	0	2	517	93	173	137	69	113	30	60	138	116	116	34	475
1993	0	0	1	264	1109	101	129	85	41	68	19	40	95	84	86	414
1994	0	0	0	24	254	1310	167	236	134	50	65	15	27	57	45	209
1995	0	0	0	11	195	177	665	94	157	106	46	68	17	33	75	384
1996	0	0	0	625	222	200	66	259	50	111	93	47	79	21	45	709
1997	0	0	0	21	167	164	405	179	562	82	150	111	52	82	22	689
1998	0	0	6	283	216	404	203	357	135	392	56	102	75	35	56	484
1999	0	0	0	514	3227	1246	1707	717	1114	386	1065	147	261	191	89	1282
2000	0	0	35	498	966	3482	1559	2017	865	1440	538	1587	232	433	329	2514
2001	0	0	0	21	275	891	2740	1003	1164	478	787	295	877	130	245	1593
2002	0	0	1	4173	2725	2570	2618	4252	1080	1022	375	579	209	607	89	1159
2003	0	0	0	19	528	363	799	1555	3598	1091	1140	446	721	269	802	1745

Appendix 1. Table 7. continued.

recreational harvest east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	39349	70416	73929	28793	17019	3486	5386	1838	1178	1078	614	724	2036	1658	8301
1985	0	273477	84778	71366	75123	35744	22652	4637	7024	2364	1500	1365	775	912	2566	12412
1986	0	59169	273167	51061	41270	48813	26283	18825	4283	7070	2555	1717	1635	962	1163	20164
1987	0	149112	132110	138255	15469	16581	24033	14466	11066	2635	4497	1674	1152	1117	667	15190
1988	0	130923	199450	72471	49935	6493	7847	12330	7859	6274	1544	2700	1025	717	704	10128
1989	0	118839	208316	82870	17706	15598	2726	4158	7772	5644	4976	1322	2450	974	707	11559
1990	0	161464	68645	64295	20851	5913	6735	1390	2367	4800	3714	3446	953	1825	745	9915
1991	0	76824	336824	42328	36295	14021	4044	4460	891	1483	2957	2260	2078	572	1088	6114
1992	0	133298	207508	379653	25994	25806	12119	4027	4913	1055	1855	3854	3039	2868	804	10425
1993	0	176241	574375	137256	220200	19266	24691	14020	5339	7206	1672	3114	6772	5533	5367	22040
1994	0	93687	174771	276525	56103	98820	9618	13317	8046	3229	4562	1100	2115	4718	3937	20051
1995	0	41548	290297	100165	86306	19171	39170	4308	6509	4197	1768	2594	644	1265	2868	14749
1996	0	26673	149018	205471	52453	52876	13808	31686	3833	6271	4331	1936	2989	774	1575	23343
1997	0	67474	542973	136159	96198	26028	31487	9502	24058	3112	5308	3757	1705	2653	691	21579
1998	0	14338	290962	543685	80754	46649	11939	14205	4244	10704	1389	2377	1690	770	1204	9856
1999	0	13906	161595	315484	386016	65505	43606	12091	15075	4647	12019	1601	2800	2029	940	13622
2000	0	18460	148620	194131	142592	149022	25744	18050	5268	6849	2175	5743	778	1376	1005	7000
2001	0	8825	335807	116591	95675	86128	115987	24227	19448	6277	8800	2954	8146	1142	2073	12283
2002	0	12634	170977	556775	89721	68748	64806	92241	20242	16996	5708	8281	2857	8053	1150	14373
2003	0	6535	288333	194352	274702	42048	36141	37469	57375	13322	11697	4073	6097	2154	6188	12397

recreational harvest west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	289265	363791	300893	97003	49529	9361	14113	4879	3244	3126	1885	2350	6962	5937	33835
1985	0	526201	186680	119754	89094	33631	18821	3660	5508	1890	1239	1172	692	844	2452	12989
1986	0	258142	255287	23137	16653	19334	10147	7168	1637	2745	1012	694	673	403	494	8871
1987	0	230689	141907	76083	5810	5115	6854	4040	3095	743	1280	480	333	324	195	4479
1988	0	283466	285390	61723	35494	4774	6409	11251	7895	6815	1784	3275	1292	931	936	14351
1989	0	199125	296112	91121	15767	12809	2220	3447	6597	4897	4397	1185	2222	891	651	10862
1990	0	141637	71239	65847	17755	3834	3414	585	871	1604	1158	1021	272	506	202	2540
1991	0	100427	326678	28686	24382	10454	3451	4343	971	1767	3780	3051	2927	832	1625	9830
1992	0	106231	232336	372286	22917	22153	10655	3707	4757	1071	1958	4203	3403	3280	935	12702
1993	0	152242	510109	125535	207455	18261	23212	13047	4930	6619	1531	2846	6181	5046	4894	20087
1994	0	127593	267105	295573	53205	92526	9265	13269	8240	3372	4829	1175	2273	5090	4260	21798
1995	0	41835	306342	121752	104178	23085	48555	5544	8654	5720	2454	3649	914	1809	4123	21451
1996	0	23873	154776	207021	47516	43483	10622	23329	2732	4349	2930	1281	1939	494	990	14096
1997	0	11530	271004	107692	89850	25376	29884	8591	20750	2580	4266	2947	1312	2013	518	15732
1998	0	7135	118335	238595	44441	31801	9468	12468	4000	10633	1437	2537	1848	859	1363	11646
1999	0	1696	32571	60810	80962	15894	12834	4297	6248	2163	6089	863	1580	1184	562	8672
2000	0	7564	51283	63201	49023	56713	11019	8624	2762	3871	1304	3607	507	922	689	5108
2001	0	3826	113861	32960	24056	19962	25597	5223	4160	1342	1888	636	1763	248	452	2704
2002	0	2767	38233	130567	22035	17626	17313	25525	5760	4942	1688	2480	864	2455	353	4478
2003	0	1927	82454	58323	80359	12550	11435	12663	20496	4959	4483	1593	2418	863	2496	5075

Appendix 1. Table 7. continued.

commercial handline open season discards east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	266	11	2	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	5793	1955	291	70	7	6	1	0	0	0	0	0	2
1986	0	0	0	9333	739	153	24	7	1	1	0	0	0	0	0	0
1987	0	0	0	29697	700	122	43	9	4	0	0	0	0	0	0	0
1988	0	0	0	11780	1472	48	20	14	4	2	0	0	0	0	0	1
1989	0	0	0	19163	719	118	6	3	3	1	1	0	0	0	0	0
1990	0	0	0	22464	1167	65	20	1	1	1	1	0	0	0	0	0
1991	0	0	0	17273	2048	119	8	3	0	0	0	0	0	0	0	0
1992	0	0	0	47961	727	127	14	1	1	0	0	0	0	0	0	0
1993	0	0	0	12419	3253	49	17	4	1	0	0	0	0	0	0	0
1994	0	0	0	61254	2498	789	19	10	3	1	0	0	0	0	0	1
1995	0	0	0	5217	1293	67	41	2	1	0	0	0	0	0	0	0
1996	0	0	0	14738	920	222	18	16	1	1	0	0	0	0	0	0
1997	0	0	0	7819	1651	90	29	3	4	0	0	0	0	0	0	0
1998	0	0	0	47622	2013	260	19	10	1	2	0	0	0	0	0	0
1999	0	0	0	16714	5728	254	58	7	5	1	1	0	0	0	0	0
2000	0	0	0	13168	3553	1009	62	20	3	2	1	1	0	0	0	0
2001	0	0	0	16121	3331	656	260	21	9	2	1	0	1	0	0	1
2002	0	0	0	69523	2931	508	146	84	9	5	1	1	0	1	0	1
2003	0	0	0	30135	9908	338	87	36	28	3	2	0	1	0	0	1

commercial handline open season discards west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	773	23	3	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	30940	3869	345	71	7	6	1	1	1	0	0	1	2
1986	0	0	0	28562	2898	583	86	25	3	3	1	0	0	0	0	2
1987	0	0	0	71394	1058	197	78	18	7	1	1	0	0	0	0	1
1988	0	0	0	51450	5753	153	57	38	13	6	1	1	0	0	0	2
1989	0	0	0	68821	2676	465	23	13	12	5	3	1	1	0	0	2
1990	0	0	0	80340	4044	203	59	4	3	4	2	1	0	0	0	1
1991	0	0	0	54898	6822	482	38	17	2	2	2	1	1	0	0	1
1992	0	0	0	334794	5364	1000	122	15	8	1	1	2	1	1	0	2
1993	0	0	0	72604	23346	400	141	30	5	4	1	1	1	1	1	2
1994	0	0	0	240035	12016	4348	120	64	19	4	4	1	1	2	1	4
1995	0	0	0	87080	23267	1245	817	38	30	12	3	4	1	1	2	8
1996	0	0	0	308874	21113	4637	344	302	18	16	7	2	3	1	1	10
1997	0	0	0	181401	39582	2370	813	93	114	9	10	5	2	2	0	10
1998	0	0	0	334280	21485	3768	337	175	27	42	4	5	3	1	1	8
1999	0	0	0	102275	39476	2073	555	77	55	11	20	2	3	2	1	7
2000	0	0	0	132415	26055	6523	376	120	20	16	4	7	1	1	1	4
2001	0	0	0	121586	19893	3507	1310	107	43	8	8	2	4	1	1	3
2002	0	0	0	254447	13150	2259	617	342	37	18	4	4	1	3	0	3
2003	0	0	0	87384	37280	1296	332	136	103	14	8	2	2	1	2	2

Appendix 1. Table 7. continued.

commercial longline open season discards east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	19	24	9	3	0	0	0	0	0	0	0	0	0
1986	0	0	0	35	11	5	2	1	0	0	0	0	0	0	0	0
1987	0	0	0	40	3	2	1	0	0	0	0	0	0	0	0	0
1988	0	0	0	25	27	2	1	1	0	0	0	0	0	0	0	0
1989	0	0	0	147	13	4	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	277	22	2	1	0	0	0	0	0	0	0	0	0
1991	0	0	0	15	10	2	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	87	2	1	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	14	19	1	1	0	0	0	0	0	0	0	0	0
1994	0	0	0	15	2	3	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	24	16	1	1	0	0	0	0	0	0	0	0	0
1996	0	0	0	15	7	5	1	1	0	0	0	0	0	0	0	0
1997	0	0	0	11	3	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	24	3	1	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	20	25	2	1	0	0	0	0	0	0	0	0	0
2000	0	0	0	8	9	7	1	0	0	0	0	0	0	0	0	0
2001	0	0	0	3	5	3	2	0	0	0	0	0	0	0	0	0
2002	0	0	0	62	6	2	1	1	0	0	0	0	0	0	0	0
2003	0	0	0	35	38	3	1	0	0	0	0	0	0	0	0	0

commercial longline open season discards west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	20	1	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	1723	423	55	14	2	2	0	0	0	0	0	0	1
1986	0	0	0	2878	445	112	20	7	1	1	0	0	0	0	0	2
1987	0	0	0	5956	157	43	23	7	4	1	1	0	0	0	0	1
1988	0	0	0	6483	1261	46	19	13	5	2	0	0	0	0	0	1
1989	0	0	0	6337	403	95	6	4	3	1	1	0	0	0	0	1
1990	0	0	0	2696	114	7	3	0	0	0	0	0	0	0	0	0
1991	0	0	0	378	50	5	1	0	0	0	0	0	0	0	0	0
1992	0	0	0	290	5	2	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	146	54	1	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	31	27	26	1	1	0	0	0	0	0	0	0	0
1995	0	0	0	13	23	4	5	0	0	0	0	0	0	0	0	0
1996	0	0	0	273	16	4	0	1	0	0	0	0	0	0	0	0
1997	0	0	0	18	17	4	3	1	1	0	0	0	0	0	0	0
1998	0	0	0	268	23	9	1	1	0	0	0	0	0	0	0	0
1999	0	0	0	413	314	26	11	2	2	0	1	0	0	0	0	0
2000	0	0	0	317	88	71	10	6	1	1	0	1	0	0	0	0
2001	0	0	0	16	26	18	18	3	2	0	1	0	0	0	0	0
2002	0	0	0	2328	233	50	17	12	2	1	0	0	0	0	0	0
2003	0	0	0	14	48	7	5	4	5	1	1	0	0	0	0	0

Appendix 1. Table 7. continued.

commercial closed season discards east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	134	1351	993	278	63	60	11	16	32	23	21	6	11	58
1992	0	0	59	18844	1721	1518	575	158	165	32	51	100	75	69	19	228
1993	0	0	139	3912	6785	528	604	312	109	140	31	55	117	93	88	347
1994	0	0	74	19985	4164	6126	502	612	336	126	168	39	73	159	130	633
1995	0	0	404	3034	3035	638	1210	125	184	117	49	73	18	36	82	430
1996	0	0	126	4450	1246	1284	326	702	78	120	77	32	47	13	23	310
1997	0	0	173	2730	2575	602	605	156	354	41	66	44	20	29	7	216
1998	0	0	197	18595	3559	1960	461	515	148	366	46	80	56	25	41	325
1999	0	0	148	6286	9710	1800	1252	357	452	139	361	48	83	59	28	389
2000	0	0	185	5523	6640	7847	1467	1091	331	438	141	374	50	90	65	450
2001	0	0	814	5460	5088	4114	4916	946	719	223	303	100	270	38	66	385
2002	0	0	294	21060	4072	2931	2531	3363	700	565	184	260	88	243	34	413
2003	0	0	745	8164	12297	1716	1331	1265	1803	395	330	110	160	54	154	291

commercial closed season discards west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	1222	4122	3296	1149	303	316	61	101	202	155	143	40	76	432
1992	0	0	182	121437	12813	12490	5218	1560	1761	357	602	1213	934	863	239	2963
1993	0	0	169	23255	50790	4471	5294	2744	965	1222	270	482	1015	809	769	2988
1994	0	0	35	82996	21058	35798	3264	4266	2451	942	1281	299	560	1221	1000	4842
1995	0	0	1890	49566	55212	12217	24893	2744	4134	2641	1098	1589	389	754	1692	8431
1996	0	0	1597	94499	29466	27874	6444	13303	1478	2250	1459	617	909	226	445	6033
1997	0	0	2980	66159	65289	16729	17826	4800	11137	1348	2185	1485	653	989	252	7449
1998	0	0	1066	133569	39058	29623	8298	10115	3031	7609	981	1665	1175	532	826	6630
1999	0	0	985	40879	70778	15676	12935	4161	5684	1844	4891	659	1154	835	385	5468
2000	0	0	2700	58235	52064	54746	9717	7258	2258	3084	1014	2741	377	674	496	3493
2001	0	0	7266	41592	31489	23263	26530	5035	3851	1213	1675	556	1522	211	382	2227
2002	0	0	1156	87065	20378	14397	11838	15110	3063	2425	779	1091	366	1011	142	1697
2003	0	0	2029	26790	50980	7151	5490	5206	7458	1645	1387	467	680	235	662	1258

Appendix 1. Table 7. continued.

recreational open season discards east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	1646	1439	280	15	2	0	0	0	0	0	0	0	0	0	0
1985	0	1975	429	68	10	1	0	0	0	0	0	0	0	0	0	0
1986	0	2380	3250	82	9	3	1	0	0	0	0	0	0	0	0	0
1987	0	6970	2581	428	7	2	1	0	0	0	0	0	0	0	0	0
1988	0	5516	3731	196	19	1	0	0	0	0	0	0	0	0	0	0
1989	0	11919	12533	972	30	6	0	0	0	0	0	0	0	0	0	0
1990	0	57593	6103	1177	56	3	1	0	0	0	0	0	0	0	0	0
1991	0	48789	64381	1095	130	12	1	1	0	0	0	0	0	0	0	0
1992	0	79490	31139	9881	98	23	4	1	1	0	0	0	0	0	0	0
1993	0	68619	55179	2175	453	8	4	1	0	0	0	0	0	0	0	0
1994	0	70246	25498	5716	158	62	2	2	1	0	0	0	0	0	0	0
1995	0	23904	32431	2360	308	16	12	1	1	0	0	0	0	0	0	0
1996	0	71913	48528	10057	333	72	7	8	1	1	1	0	0	0	0	0
1997	0	64256	186377	10029	906	48	20	3	5	1	1	0	0	0	0	0
1998	0	46682	99062	34942	855	121	12	8	2	4	0	0	0	0	0	0
1999	0	65476	127432	31627	5218	204	54	8	8	2	5	0	0	0	0	0
2000	0	69251	57063	17251	2277	630	47	19	4	5	2	0	0	0	0	0
2001	0	29739	122943	8119	965	195	101	11	7	2	3	0	0	0	0	0
2002	0	74995	91219	51142	1271	235	89	71	11	9	3	0	0	0	0	0
2003	0	55491	137955	14409	3127	118	42	25	28	6	5	0	0	0	0	0

recreational open season discards west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	99253	21575	3442	482	52	13	2	2	1	0	0	0	0	0	0
1986	0	3119	4259	107	12	3	1	0	0	0	0	0	0	0	0	0
1987	0	8122	3008	499	8	2	1	0	0	0	0	0	0	0	0	0
1988	0	93550	63275	3316	318	10	5	5	2	2	0	0	0	0	0	0
1989	0	67227	70692	5480	167	33	2	2	2	2	1	0	0	0	0	0
1990	0	184769	19579	3776	181	11	4	0	1	1	1	0	0	0	0	0
1991	0	107764	142204	2419	288	27	3	2	0	1	1	0	0	0	0	0
1992	0	156354	61250	19436	192	45	9	2	2	0	1	0	0	0	0	0
1993	0	163508	131481	5184	1080	20	10	3	1	1	0	0	0	0	0	0
1994	0	309688	112409	25200	696	272	10	8	3	1	2	0	0	0	0	0
1995	0	153411	208132	15145	1979	100	78	5	5	3	1	0	0	0	0	0
1996	0	75140	50707	10508	348	75	7	9	1	1	1	0	0	0	0	0
1997	0	34420	99834	5372	486	26	11	2	3	0	0	0	0	0	0	0
1998	0	49946	105988	37385	915	130	13	8	2	4	0	0	0	0	0	0
1999	0	77006	149872	37197	6136	240	64	10	9	3	6	0	0	0	0	0
2000	0	29682	24457	7394	976	270	20	8	2	2	1	0	0	0	0	0
2001	0	12191	50398	3328	396	80	41	5	3	1	1	0	0	0	0	0
2002	0	24105	29319	16438	409	76	29	23	4	3	1	0	0	0	0	0
2003	0	86988	216259	22588	4901	185	66	39	44	9	8	0	0	0	0	0

Appendix 1. Table 7. continued.

recreational closed season discards east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	3732	10907	8903	991	544	138	163	49	123	16	27	19	9	14	4
1999	0	7092	15921	8288	6626	1053	692	191	238	73	190	25	44	32	15	23
2000	0	19145	21095	12326	6291	6110	1039	725	211	274	87	229	31	55	40	19
2001	0	12749	71134	10510	6286	5383	7182	1496	1200	387	543	182	502	70	128	95
2002	0	21940	33347	38424	4203	3010	2799	3968	870	730	245	354	122	345	49	91
2003	0	11813	37906	9113	9274	1344	1143	1181	1806	419	368	128	191	68	194	28

recreational closed season discards west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	4097	11896	10305	1450	997	295	388	124	330	45	79	57	27	42	11
1999	0	7217	15133	5715	3578	613	483	161	233	81	227	32	59	44	21	34
2000	0	8852	12171	8843	5571	6213	1198	936	300	420	141	391	55	100	75	35
2001	0	5496	38431	6614	4013	3231	4118	839	668	215	303	102	282	40	72	54
2002	0	7111	12583	19367	2601	2010	1961	2886	651	558	191	280	98	277	40	74
2003	0	17468	49609	9139	7373	1036	923	1016	1641	397	358	127	193	69	199	29

Appendix 1. Table 8. Derived age composition calculated from landings (commercial, weight) and catch (recreational, n fish), length frequency of the landed catches, modeling of discards and estimates of mortality rates and recruitment patterns. This set of derived age composition was calculated assuming a natural mortality rate of 0.29.

commercial handline landings east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	19	55908	155809	92831	62656	12359	17636	5630	3449	3079	1732	2027	5694	4635	23437
1985	0	0	4649	24369	66245	49071	37699	8637	14247	5141	3460	3307	1951	2369	6831	35178
1986	0	307	318565	50457	29396	28375	13553	9039	1972	3176	1132	754	715	419	507	8815
1987	0	0	5001	254643	29080	22597	24720	12333	8353	1839	2983	1073	721	688	405	9010
1988	0	0	48071	60250	54666	8108	10620	17079	10919	8679	2123	3698	1400	976	959	13783
1989	0	0	52582	87528	25473	20745	2924	3929	6755	4674	4008	1047	1924	762	551	8994
1990	0	2	17481	95119	40252	11263	11398	1939	2963	5533	4039	3593	963	1801	724	9240
1991	0	0	8951	63903	64584	18084	4117	3873	651	1003	1890	1389	1241	334	624	3364
1992	0	0	619	132045	16842	16367	6074	1682	1770	317	510	990	745	677	185	2235
1993	0	0	1835	30969	81216	6391	7637	3804	1351	1720	355	634	1331	1062	1011	3963
1994	0	0	553	74145	27979	47120	3856	4949	2646	1002	1351	293	544	1181	967	4707
1995	0	0	2300	9567	16001	3316	6632	677	1041	642	273	405	94	186	421	2213
1996	0	0	1203	21613	10180	12291	2860	6414	707	1129	708	302	446	103	202	2724
1997	0	0	1529	11733	19139	4764	5260	1240	2898	336	559	363	159	241	57	1640
1998	0	0	1380	69742	21932	13382	3138	3827	1002	2568	323	577	397	183	287	2176
1999	0	0	1204	27920	74513	13770	9830	2763	3812	1075	2895	378	690	483	225	3025
2000	0	0	1412	23772	45416	61074	10595	7942	2359	3410	997	2758	369	686	487	3254
2001	0	0	8218	30358	44658	38812	49506	8717	6648	2016	2984	892	2515	343	647	3514
2002	0	0	3021	128836	38105	29803	26143	36687	6983	5630	1784	2734	839	2416	336	4043
2003	0	0	9405	56820	141180	20030	15773	15070	22700	4546	3812	1246	1959	612	1792	3329

commercial handline landings west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	399	211791	392659	158816	85938	16327	24330	8223	5280	4873	2800	3325	9420	7710	39283
1985	0	0	54754	145792	129982	53771	34435	7642	12785	4715	3230	3126	1860	2271	6571	34005
1986	0	200	109271	116382	92384	89058	41452	27552	6144	10249	3788	2608	2543	1524	1875	33913
1987	0	0	65522	273858	31538	28789	36182	19962	14563	3389	5729	2124	1458	1416	843	19243
1988	0	0	97546	216043	185563	22361	26312	40660	25828	20683	5117	9013	3446	2421	2393	34911
1989	0	0	61797	273909	83302	71379	10494	14259	24086	16124	13308	3353	5959	2295	1621	24693
1990	0	72	54029	296165	121238	30493	28563	4634	6858	12484	8916	7781	2053	3788	1506	18567
1991	0	0	64916	149155	171675	60491	16208	16907	3059	5000	9898	7574	6989	1929	3685	21121
1992	0	0	1499	630132	100952	108951	44670	13569	15425	2936	4933	9887	7612	7046	1945	24283
1993	0	0	1833	143702	490688	44309	55690	28152	10045	12812	2647	4724	9909	7900	7511	29260
1994	0	0	205	245047	114116	222252	20253	28034	15740	6143	8438	1849	3453	7515	6167	30009
1995	0	0	8688	117517	235230	52037	112701	12289	19570	12206	5153	7522	1726	3341	7474	37421
1996	0	0	12261	348699	194481	219613	47083	101692	11116	17820	11250	4824	7154	1667	3269	44257
1997	0	0	21495	224289	391307	106816	125671	30920	74736	8901	15169	10042	4472	6841	1633	48050
1998	0	0	6003	386414	195595	165340	46258	61681	16870	44150	5600	10017	6886	3160	4953	37070
1999	0	0	6493	144589	436057	96695	81659	25830	38434	11364	31471	4173	7708	5431	2543	34251
2000	0	0	16588	198142	287288	342885	55878	41395	12437	18268	5416	15164	2044	3830	2734	18483
2001	0	0	59238	177781	222204	177065	214729	36993	28099	8552	12729	3820	10828	1480	2803	15278
2002	0	0	9554	440073	152152	116340	97044	130497	24070	18976	5916	8963	2726	7802	1078	12844
2003	0	0	20677	156063	473968	67385	52251	49203	73221	14520	12077	3923	6136	1910	5569	10259

Appendix 1. Table 8. continued.

commercial longline landings east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	11	1910	6630	9010	2399	4023	1429	949	903	534	650	1884	1572	8408
1985	0	0	0	67	809	1453	1824	532	986	378	264	260	157	193	566	3026
1986	0	0	25	125	357	918	868	896	258	500	202	147	149	92	115	2177
1987	0	0	3	148	97	269	668	574	568	164	326	136	103	107	67	1758
1988	0	0	0	92	927	279	491	951	717	665	186	362	150	112	116	1925
1989	0	0	5	532	447	701	156	290	636	531	526	154	308	130	99	1878
1990	0	0	47	1011	717	374	610	143	277	616	513	505	146	290	122	1774
1991	0	0	0	36	270	255	124	186	42	78	170	139	135	39	76	477
1992	0	0	0	201	49	78	48	20	29	7	13	30	25	25	7	111
1993	0	0	5	28	453	121	256	170	71	101	22	42	92	76	74	306
1994	0	0	1	14	26	182	34	69	49	22	35	8	17	40	34	189
1995	0	0	12	28	166	68	193	25	47	33	16	26	7	13	32	183
1996	0	0	0	18	74	253	90	242	29	50	33	14	22	5	10	143
1997	0	0	0	15	29	18	44	19	65	10	20	15	7	12	3	105
1998	0	0	0	30	30	53	27	58	22	71	10	21	15	7	12	103
1999	0	0	1	30	304	101	100	35	57	18	56	8	16	12	6	85
2000	0	0	0	12	106	435	127	122	41	64	20	57	8	15	11	77
2001	0	0	0	4	60	176	437	109	101	34	55	17	50	7	14	78
2002	0	0	1	98	73	131	228	514	134	134	49	84	28	85	12	165
2003	0	0	1	53	501	146	168	203	356	79	72	25	41	13	39	78

commercial longline landings west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	2184	10390	7177	5717	1646	3769	1800	1481	1627	1057	1371	4145	3560	20127
1985	0	0	504	5794	12318	7988	6528	1768	3549	1520	1165	1226	775	989	2958	16430
1986	0	0	7921	14864	14930	17235	9402	7614	2093	4168	1760	1335	1395	879	1122	21927
1987	0	0	1521	20788	4476	6227	10811	7770	7118	1991	3870	1592	1179	1212	753	18964
1988	0	0	30750	26503	38940	6598	8868	14285	9110	7215	1757	3043	1145	794	776	10954
1989	0	0	6225	26214	12569	14577	2529	3795	6854	4814	4118	1065	1932	756	540	8493
1990	0	3	6599	11647	3654	1062	1243	244	418	854	667	624	174	334	137	1861
1991	0	0	720	1003	1227	614	287	485	122	248	566	476	468	135	267	1652
1992	0	0	2	517	91	179	140	72	119	29	59	135	114	113	33	470
1993	0	0	1	256	1116	99	135	87	42	71	18	39	94	83	85	411
1994	0	0	0	25	244	1316	165	245	136	51	67	14	26	55	44	202
1995	0	0	0	10	203	170	667	92	164	108	47	70	16	32	73	374
1996	0	0	0	624	216	211	63	261	49	116	95	49	82	21	44	694
1997	0	0	0	20	165	159	427	173	564	81	156	113	53	85	21	668
1998	0	0	6	293	210	399	196	376	130	394	55	106	76	36	59	469
1999	0	0	0	497	3323	1206	1679	692	1171	370	1064	144	271	193	91	1247
2000	0	0	35	493	953	3658	1514	1973	830	1505	512	1577	227	447	331	2442
2001	0	0	0	21	271	882	2884	971	1135	456	817	279	865	126	251	1542
2002	0	0	1	4262	2661	2530	2589	4452	1038	987	354	595	195	591	85	1118
2003	0	0	0	18	547	358	793	1549	3788	1052	1102	421	741	251	780	1676

Appendix 1. Table 8. continued.

recreational harvest east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	40939	69272	73574	28718	16985	3476	5370	1834	1175	1077	614	724	2038	1659	8351
1985	0	283714	79393	68963	73628	35239	22372	4587	6960	2344	1489	1357	770	907	2554	12420
1986	0	62154	274825	49442	40298	47801	25828	18524	4221	6981	2527	1700	1622	954	1155	20108
1987	0	152114	130257	139739	14940	16095	23388	14120	10812	2578	4409	1644	1132	1101	657	15039
1988	0	134917	195777	72854	51029	6266	7575	11895	7595	6072	1495	2620	996	697	687	9923
1989	0	122312	206676	81560	17862	15994	2638	4029	7531	5481	4839	1286	2387	951	691	11379
1990	0	165624	64621	64726	20718	6014	6939	1348	2296	4652	3604	3348	927	1776	727	9740
1991	0	81320	332508	41244	37429	14115	4134	4598	863	1433	2851	2180	2006	552	1051	5955
1992	0	140570	198881	380659	25605	26821	12275	4138	5087	1025	1797	3721	2938	2773	778	10147
1993	0	183263	578569	128913	217812	18839	25539	14144	5469	7448	1620	3013	6529	5341	5183	21410
1994	0	98194	165192	285812	53223	98072	9400	13739	8101	3301	4706	1064	2041	4540	3794	19422
1995	0	44667	287025	96762	90851	18424	39217	4238	6749	4242	1813	2682	624	1222	2764	14281
1996	0	28348	147572	204404	50915	55910	13307	31814	3784	6526	4394	1993	3102	753	1528	22685
1997	0	69746	551403	129346	93128	24840	32874	9073	23977	3056	5489	3788	1744	2739	668	20813
1998	0	15158	282942	558666	76343	44530	11213	14589	3987	10502	1344	2426	1682	778	1227	9380
1999	0	14249	159188	309766	400747	62294	41698	11330	15387	4327	11692	1535	2831	1999	940	12952
2000	0	19591	146537	192245	141301	155927	24646	17323	4944	6988	2019	5561	742	1382	983	6624
2001	0	9139	340960	112993	93757	84818	120798	23094	18614	5870	8947	2733	7855	1086	2075	11621
2002	0	13251	165268	568068	86903	67048	63443	95440	19196	16174	5310	8377	2630	7720	1088	13646
2003	0	6764	291746	187764	281515	40828	35206	36616	59235	12591	11093	3779	6145	1975	5911	11713

recreational harvest west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	300789	355179	298571	96579	49368	9325	14059	4864	3234	3119	1881	2345	6954	5930	33974
1985	0	539549	178130	117072	87725	33219	18604	3621	5460	1875	1231	1166	688	840	2441	13006
1986	0	264275	251439	22088	16195	18928	9977	7060	1615	2713	1002	688	669	400	491	8859
1987	0	235003	138713	76023	5540	4909	6609	3916	3008	724	1250	470	326	319	191	4426
1988	0	291100	278239	61725	36210	4621	6227	10952	7711	6671	1749	3217	1272	917	925	14249
1989	0	204182	293171	89430	15860	13121	2150	3346	6409	4769	4289	1157	2173	874	639	10735
1990	0	144706	67746	66644	17619	3871	3480	560	834	1533	1108	978	261	486	195	2463
1991	0	106415	320994	27874	25122	10535	3540	4500	946	1721	3675	2969	2851	811	1584	9668
1992	0	112928	223496	374055	22612	23061	10814	3819	4942	1044	1905	4078	3306	3188	909	12436
1993	0	157927	513752	118148	205780	17898	24053	13181	5057	6850	1485	2757	5966	4877	4731	19534
1994	0	134451	253337	306235	50546	91954	9071	13716	8313	3454	4991	1139	2197	4908	4112	21148
1995	0	45358	302684	117606	109643	22184	48634	5459	8983	5790	2520	3779	887	1751	3980	20808
1996	0	25812	153207	205936	46146	46015	10246	23440	2699	4526	2971	1318	2010	480	959	13667
1997	0	11958	277348	103362	87721	24363	31324	8226	20719	2537	4416	2973	1343	2079	501	15176
1998	0	7519	115121	245546	42242	30614	8976	12921	3791	10522	1401	2610	1854	874	1401	11175
1999	0	1789	32101	59701	84101	15173	12377	4075	6467	2044	6015	840	1622	1185	571	8364
2000	0	8020	50548	62568	48565	59358	10564	8300	2603	3969	1217	3515	487	933	679	4871
2001	0	3958	115457	31867	23515	19614	26608	4971	3977	1255	1919	589	1700	236	452	2560
2002	0	2894	36968	133236	21352	17204	16968	26447	5471	4711	1573	2513	797	2358	334	4259
2003	0	1996	83455	56359	82378	12198	11163	12413	21236	4705	4268	1483	2446	794	2392	4809

Appendix 1. Table 8. continued.

commercial handline open season discards east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	266	11	2	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	5794	1955	291	69	7	6	1	0	0	0	0	0	2
1986	0	0	0	9138	731	151	24	7	1	1	0	0	0	0	0	0
1987	0	0	0	30165	682	120	43	9	4	0	0	0	0	0	0	0
1988	0	0	0	11833	1511	47	20	14	4	2	0	0	0	0	0	1
1989	0	0	0	19102	730	122	6	3	2	1	1	0	0	0	0	0
1990	0	0	0	22717	1160	66	21	1	1	1	1	0	0	0	0	0
1991	0	0	0	16824	2099	118	9	3	0	0	0	0	0	0	0	0
1992	0	0	0	47916	713	131	14	1	1	0	0	0	0	0	0	0
1993	0	0	0	12070	3278	49	18	4	1	0	0	0	0	0	0	0
1994	0	0	0	62965	2374	786	19	10	3	1	1	0	0	0	0	1
1995	0	0	0	4984	1342	64	41	2	1	0	0	0	0	0	0	0
1996	0	0	0	14684	890	232	17	16	1	1	0	0	0	0	0	0
1997	0	0	0	7765	1646	88	31	3	4	0	0	0	0	0	0	0
1998	0	0	0	48894	1923	253	18	10	1	2	0	0	0	0	0	0
1999	0	0	0	16266	5898	241	56	7	5	1	1	0	0	0	0	0
2000	0	0	0	12976	3493	1048	59	19	3	2	0	1	0	0	0	0
2001	0	0	0	15885	3297	649	272	20	9	1	1	0	1	0	0	1
2002	0	0	0	70712	2847	498	142	87	9	5	1	1	0	1	0	1
2003	0	0	0	29164	10135	328	85	36	29	3	2	0	1	0	0	1

commercial handline open season discards west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	774	23	3	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	30944	3869	345	71	7	6	1	1	1	0	0	1	2
1986	0	0	0	28310	2889	581	86	25	3	3	1	0	0	0	0	2
1987	0	0	0	72368	1026	192	76	18	7	1	1	0	0	0	0	1
1988	0	0	0	51617	5875	148	55	37	12	6	1	1	0	0	0	2
1989	0	0	0	68593	2717	479	22	13	12	5	3	1	1	0	0	2
1990	0	0	0	81249	4017	205	60	4	3	4	2	1	0	0	0	1
1991	0	0	0	53521	6992	482	39	17	2	2	2	1	1	0	0	1
1992	0	0	0	334461	5253	1032	122	15	9	1	1	2	1	1	0	2
1993	0	0	0	70542	23493	395	146	30	6	4	1	1	1	1	1	2
1994	0	0	0	247107	11449	4343	118	66	19	4	4	1	1	2	1	4
1995	0	0	0	83061	24131	1183	813	37	31	12	3	4	1	1	2	8
1996	0	0	0	307542	20430	4877	329	301	17	17	7	2	3	1	1	9
1997	0	0	0	180163	39433	2302	858	90	115	8	10	5	2	2	0	10
1998	0	0	0	344610	20750	3693	325	183	26	42	4	5	3	1	1	7
1999	0	0	0	99490	40681	1977	537	73	58	11	20	2	3	2	1	7
2000	0	0	0	130674	25648	6781	359	115	18	17	3	7	1	1	1	4
2001	0	0	0	119770	19697	3474	1370	102	41	8	8	2	4	0	1	3
2002	0	0	0	259106	12797	2216	607	356	35	17	4	4	1	3	0	3
2003	0	0	0	84428	38069	1255	323	133	106	13	8	2	2	1	2	2

Appendix 1. Table 8. continued.

commercial longline open season discards east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	19	24	9	3	0	0	0	0	0	0	0	0	0
1986	0	0	0	35	11	5	2	1	0	0	0	0	0	0	0	0
1987	0	0	0	41	3	2	1	0	0	0	0	0	0	0	0	0
1988	0	0	0	25	28	2	1	1	0	0	0	0	0	0	0	0
1989	0	0	0	147	13	4	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	280	22	2	1	0	0	0	0	0	0	0	0	0
1991	0	0	0	14	10	2	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	87	2	1	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	13	19	1	1	0	0	0	0	0	0	0	0	0
1994	0	0	0	15	2	3	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	23	17	1	1	0	0	0	0	0	0	0	0	0
1996	0	0	0	15	7	5	1	1	0	0	0	0	0	0	0	0
1997	0	0	0	11	3	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	25	3	1	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	20	25	2	1	0	0	0	0	0	0	0	0	0
2000	0	0	0	8	9	8	1	0	0	0	0	0	0	0	0	0
2001	0	0	0	3	5	3	2	0	0	0	0	0	0	0	0	0
2002	0	0	0	63	6	2	1	1	0	0	0	0	0	0	0	0
2003	0	0	0	34	39	2	1	0	0	0	0	0	0	0	0	0

commercial longline open season discards west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	20	1	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	1723	423	55	14	2	2	0	0	0	0	0	0	1
1986	0	0	0	2858	444	112	20	7	1	1	0	0	0	0	0	2
1987	0	0	0	6061	154	43	23	7	3	1	1	0	0	0	0	1
1988	0	0	0	6532	1297	45	19	13	4	2	0	0	0	0	0	1
1989	0	0	0	6311	410	98	5	3	3	1	1	0	0	0	0	1
1990	0	0	0	2733	114	7	3	0	0	0	0	0	0	0	0	0
1991	0	0	0	369	51	5	1	0	0	0	0	0	0	0	0	0
1992	0	0	0	290	5	2	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	141	55	1	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	32	26	26	1	1	0	0	0	0	0	0	0	0
1995	0	0	0	12	24	4	5	0	0	0	0	0	0	0	0	0
1996	0	0	0	273	16	4	0	1	0	0	0	0	0	0	0	0
1997	0	0	0	18	17	3	3	1	1	0	0	0	0	0	0	0
1998	0	0	0	277	23	9	1	1	0	0	0	0	0	0	0	0
1999	0	0	0	399	323	25	11	2	2	0	1	0	0	0	0	0
2000	0	0	0	314	87	74	10	6	1	1	0	1	0	0	0	0
2001	0	0	0	16	25	18	19	3	2	0	1	0	0	0	0	0
2002	0	0	0	2386	227	49	16	12	2	1	0	0	0	0	0	0
2003	0	0	0	14	50	7	5	4	6	1	1	0	0	0	0	0

Appendix 1. Table 8. continued.

commercial closed season discards east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	134	1314	1017	278	64	61	11	16	31	23	21	6	11	57
1992	0	0	58	18816	1685	1565	579	161	169	30	49	97	72	65	19	220
1993	0	0	145	3796	6822	521	626	314	113	144	30	54	113	90	86	338
1994	0	0	70	20643	3974	6137	496	638	342	130	175	38	71	154	127	621
1995	0	0	402	2896	3145	605	1197	122	189	118	50	75	17	34	80	417
1996	0	0	125	4427	1204	1347	311	698	77	123	77	34	48	12	22	300
1997	0	0	182	2706	2561	585	637	150	354	41	68	45	20	29	7	208
1998	0	0	191	19196	3416	1909	442	539	142	366	45	83	57	27	42	315
1999	0	0	145	6107	9981	1705	1202	337	465	132	355	46	85	59	28	374
2000	0	0	182	5434	6517	8137	1396	1045	310	449	132	364	48	91	64	430
2001	0	0	836	5369	5026	4062	5124	901	689	210	310	93	261	36	67	365
2002	0	0	283	21465	3962	2877	2496	3504	670	542	173	265	81	235	33	395
2003	0	0	757	7883	12551	1660	1293	1233	1858	372	312	102	161	50	147	273

commercial closed season discards west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	1220	4013	3374	1147	307	324	59	98	195	150	139	39	74	424
1992	0	0	175	121230	12539	12882	5246	1593	1815	346	583	1170	901	835	231	2889
1993	0	0	180	22548	50995	4398	5486	2771	989	1263	261	467	980	782	744	2907
1994	0	0	32	85844	20163	35958	3230	4456	2497	974	1337	293	547	1190	976	4747
1995	0	0	1873	47172	57099	11566	24652	2679	4262	2657	1122	1637	376	727	1628	8149
1996	0	0	1589	93932	28467	29264	6163	13262	1450	2327	1471	632	939	219	430	5828
1997	0	0	3175	65598	64940	16219	18784	4610	11144	1328	2266	1501	669	1024	244	7199
1998	0	0	1031	138510	37941	29210	8039	10686	2922	7652	971	1738	1195	548	860	6443
1999	0	0	966	39700	72793	14926	12496	3958	5901	1747	4843	643	1187	837	392	5281
2000	0	0	2662	57374	51170	56818	9260	6967	2128	3169	950	2682	363	685	491	3351
2001	0	0	7475	40871	31109	22993	27675	4807	3695	1138	1711	517	1476	203	386	2123
2002	0	0	1112	88816	19864	14154	11683	15756	2927	2326	730	1113	340	977	135	1625
2003	0	0	2062	25830	51949	6908	5329	5077	7692	1554	1315	433	686	216	633	1190

Appendix 1. Table 8. continued.

recreational open season discards east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	1766	1338	261	14	2	0	0	0	0	0	0	0	0	0	0
1985	0	2030	383	61	9	1	0	0	0	0	0	0	0	0	0	0
1986	0	2501	3137	75	8	2	1	0	0	0	0	0	0	0	0	0
1987	0	7154	2421	406	6	1	1	0	0	0	0	0	0	0	0	0
1988	0	5742	3514	187	18	1	0	0	0	0	0	0	0	0	0	0
1989	0	12411	12096	918	28	6	0	0	0	0	0	0	0	0	0	0
1990	0	58325	5443	1109	52	3	1	0	0	0	0	0	0	0	0	0
1991	0	51754	61487	1026	129	12	1	1	0	0	0	0	0	0	0	0
1992	0	83065	28148	9306	90	22	4	1	1	0	0	0	0	0	0	0
1993	0	70573	53499	1935	421	8	4	1	0	0	0	0	0	0	0	0
1994	0	72926	22943	5611	142	58	2	2	1	0	0	0	0	0	0	0
1995	0	25600	30897	2195	313	14	12	1	1	0	0	0	0	0	0	0
1996	0	75701	45399	9427	305	72	6	8	1	1	1	0	0	0	0	0
1997	0	66000	185591	9155	830	43	19	3	5	1	1	0	0	0	0	0
1998	0	49202	95806	35740	802	114	11	8	2	4	0	0	0	0	0	0
1999	0	69393	124174	30819	5382	192	51	8	8	2	5	0	0	0	0	0
2000	0	72405	54635	16600	2195	642	43	18	4	5	1	0	0	0	0	0
2001	0	30593	122612	7656	916	186	101	10	6	2	2	0	0	0	0	0
2002	0	78186	87438	51794	1220	227	86	72	11	8	2	0	0	0	0	0
2003	0	56911	137305	13642	3134	112	40	23	28	5	4	0	0	0	0	0

recreational open season discards west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	102032	19224	3073	430	46	12	1	2	1	0	0	0	0	0	0
1986	0	3278	4111	98	11	3	1	0	0	0	0	0	0	0	0	0
1987	0	8336	2821	473	7	2	1	0	0	0	0	0	0	0	0	0
1988	0	97388	59602	3165	307	9	5	4	2	2	0	0	0	0	0	0
1989	0	70004	68225	5179	160	32	2	2	2	1	1	0	0	0	0	0
1990	0	187118	17464	3558	167	10	4	0	1	1	1	0	0	0	0	0
1991	0	114313	135810	2267	285	26	3	2	0	0	1	0	0	0	0	0
1992	0	163386	55366	18304	178	44	8	2	1	0	0	0	0	0	0	0
1993	0	168163	127477	4612	1002	18	9	3	1	1	0	0	0	0	0	0
1994	0	321502	101148	24737	625	255	9	7	3	1	2	0	0	0	0	0
1995	0	164295	198286	14086	2010	93	75	4	5	3	1	0	0	0	0	0
1996	0	79099	47437	9850	319	75	7	8	1	1	1	0	0	0	0	0
1997	0	35354	99413	4904	445	23	10	1	3	0	0	0	0	0	0	0
1998	0	52642	102504	38239	858	122	12	8	2	4	0	0	0	0	0	0
1999	0	81613	146041	36246	6330	226	60	9	9	2	6	0	0	0	0	0
2000	0	31033	23417	7115	941	275	19	8	2	2	1	0	0	0	0	0
2001	0	12541	50263	3139	375	76	41	4	3	1	1	0	0	0	0	0
2002	0	25130	28104	16648	392	73	28	23	3	3	1	0	0	0	0	0
2003	0	89215	215241	21385	4912	176	62	37	44	8	7	0	0	0	0	0

Appendix 1. Table 8. continued.

recreational closed season discards east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	3934	10566	9136	936	519	129	168	46	121	15	28	19	9	14	3
1999	0	7509	15541	8113	6875	1001	662	179	243	68	185	24	45	31	15	24
2000	0	20028	20366	12078	6218	6388	994	695	198	280	81	222	30	55	39	19
2001	0	13119	71316	10099	6148	5298	7478	1426	1149	362	552	168	484	67	128	93
2002	0	22877	32024	39094	4068	2934	2740	4106	825	695	228	359	113	330	47	90
2003	0	12118	37877	8745	9489	1305	1113	1154	1865	396	349	119	193	62	185	27

recreational closed season discards west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	4318	11526	10587	1378	960	279	402	118	327	44	81	58	27	43	11
1999	0	7648	14759	5585	3713	585	466	152	241	76	224	31	60	44	21	35
2000	0	9267	11810	8699	5512	6500	1149	901	282	430	132	381	53	101	74	35
2001	0	5658	38632	6363	3918	3173	4280	798	638	201	308	94	272	38	72	53
2002	0	7415	12098	19727	2520	1962	1922	2990	618	532	178	284	90	266	38	74
2003	0	17916	49486	8744	7536	1006	901	996	1699	376	341	118	195	63	190	27

Appendix 1. Table 9. Proportions of observed age composition from otolith samples of red snapper in the Gulf of Mexico by gear and region assuming a January 1 birth date.

commercial handline east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1991	0	0.116	0.585	0.167	0.071	0.045	0.015	0	0	0	0	0	0	0	0	0
1992	0	0.010	0.554	0.225	0.149	0.012	0.012	0.010	0.010	0.019	0	0	0	0	0	0
1993	0	0.030	0.392	0.439	0.084	0.024	0.018	0	0	0	0.006	0	0	0	0	0.006
1994	0	0	0.381	0.295	0.180	0.087	0.046	0	0	0	0	0	0.006	0	0	0.006
1995	0	0.158	0.463	0.240	0.077	0.034	0.007	0	0	0	0.020	0	0	0	0	0
1996	0	0	0.636	0.231	0.114	0.016	0.003	0	0	0	0	0	0	0	0	0
1997	0	0	0.296	0.492	0.069	0.079	0.034	0	0.029	0	0	0	0	0	0	0
1998	0	0	0.046	0.615	0.215	0.095	0.013	0.008	0.008	0	0	0	0	0	0	0
1999	0	0	0.123	0.462	0.303	0.073	0.032	0.007	0	0	0	0	0	0	0	0
2000	0	0.002	0.265	0.350	0.261	0.082	0.026	0.008	0.006	0	0	0	0	0	0	0
2001	0	0.017	0.167	0.322	0.223	0.202	0.040	0.007	0.007	0.006	0.003	0.001	0	0	0	0.004
2002	0	0.013	0.398	0.343	0.142	0.049	0.045	0.005	0	0	0.002	0	0	0	0	0.002
2003	0	0.025	0.257	0.394	0.125	0.084	0.042	0.014	0.007	0.004	0.004	0.011	0.004	0	0	0.032

commercial handline west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1991																
1992	0	0.005	0.575	0.173	0.107	0.051	0.051	0.019	0	0.009	0	0	0	0	0	0.009
1993	0	0.023	0.339	0.444	0.135	0.029	0.018	0.003	0	0	0	0	0	0	0	0.009
1994	0	0.038	0.315	0.303	0.235	0.056	0.022	0.014	0.006	0.002	0.002	0	0	0	0	0.006
1995	0	0.007	0.306	0.403	0.132	0.118	0.028	0	0	0	0	0	0	0.007	0	0
1996																
1997																
1998	0	0.008	0.053	0.416	0.277	0.142	0.037	0.030	0.017	0.005	0.003	0.001	0.002	0	0	0.010
1999	0	0.002	0.176	0.401	0.249	0.103	0.047	0.012	0.005	0.003	0.001	0	0	0	0	0.002
2000	0	0.007	0.265	0.381	0.200	0.089	0.037	0.013	0.003	0.002	0.001	0.001	0	0	0	0.001
2001	0	0.015	0.164	0.307	0.239	0.145	0.074	0.029	0.014	0.007	0.002	0.002	0	0.001	0	0.003
2002	0.007	0.105	0.364	0.250	0.140	0.068	0.035	0.015	0.006	0.002	0.002	0.001	0.000	0.001	0	0.004
2003	0.006	0.071	0.364	0.338	0.123	0.045	0.013	0.006	0.006	0	0	0.006	0	0	0	0.019

commercial longline east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1991	0	0.083	0.667	0.083	0.083	0	0	0	0	0	0	0	0	0	0.083	0
1992	0	0	0	0.267	0.067	0.333	0.067	0.133	0	0	0.067	0	0	0	0	0.067
1993	0	0	0.133	0.200	0.367	0.100	0.033	0.067	0	0	0.033	0	0	0.033	0	0.033
1994	0	0	0.125	0.375	0.250	0.125	0	0	0.125	0	0	0	0	0	0	0
1995	0	0	0.053	0.421	0.421	0.053	0	0	0.053	0	0	0	0	0	0	0
1996	0	0	0	0	0.333	0.500	0.167	0	0	0	0	0	0	0	0	0
1997	0	0.100	0.200	0.400	0.200	0.100	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0.040	0.240	0.400	0.240	0.080	0	0	0	0	0	0	0	0
1999	0	0	0.020	0.363	0.304	0.196	0.088	0	0.020	0	0	0	0	0	0	0.010
2000	0	0	0.008	0.069	0.153	0.153	0.115	0.076	0.046	0.023	0.031	0.031	0.023	0.015	0.015	0.244
2001	0	0	0.022	0.099	0.308	0.352	0.165	0.022	0.022	0	0	0	0	0	0	0.011
2002	0	0.028	0.078	0.196	0.201	0.223	0.140	0.039	0.022	0.011	0.011	0	0	0	0.006	0.045
2003																

Appendix 1. Table 9. continued.

commercial longline west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1991																
1992																
1993	0	0.034	0.931	0.034	0	0	0	0	0	0	0	0	0	0	0	0
1994																
1995																
1996																
1997																
1998	0	0	0.009	0.089	0.144	0.190	0.069	0.052	0.063	0.052	0.066	0.049	0.043	0.043	0.026	0.106
1999	0	0	0.263	0.539	0.118	0.066	0	0.013	0	0	0	0	0	0	0	0
2000	0	0	0.003	0.027	0.064	0.195	0.225	0.174	0.117	0.044	0.037	0.034	0.020	0.013	0.003	0.044
2001	0	0	0	0.017	0.061	0.240	0.179	0.117	0.078	0.073	0.039	0.039	0.028	0.022	0.017	0.089
2002	0.004	0.074	0.258	0.127	0.109	0.053	0.082	0.058	0.034	0.036	0.025	0.015	0.018	0.018	0.015	0.074
2003																

recreational east

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1991	0	0.082	0.524	0.330	0.053	0.012	0	0	0	0	0	0	0	0	0	0
1992	0	0.172	0.289	0.413	0.093	0.022	0.007	0.003	0	0	0	0	0	0	0	0
1993	0	0.075	0.457	0.283	0.124	0.045	0.004	0.009	0	0	0	0.002	0	0	0	0
1994	0.000	0.074	0.348	0.333	0.142	0.070	0.027	0.002	0.002	0	0	0	0	0	0	0
1995	0.003	0.196	0.232	0.250	0.160	0.085	0.043	0.008	0.005	0.013	0	0	0	0	0	0.005
1996	0.019	0.141	0.569	0.173	0.031	0.010	0.009	0.019	0	0.028	0	0	0	0	0	0
1997	0	0	0.733	0.110	0.088	0.018	0.051	0	0	0	0	0	0	0	0	0
1998	0	0.014	0.307	0.491	0.158	0.022	0.005	0.001	0.001	0.000	0	0	0	0	0	0
1999	0	0.002	0.203	0.436	0.321	0.028	0.007	0.001	0	0	0.000	0	0	0	0	0.001
2000	0	0.04	0.494	0.337	0.113	0.014	0.002	0	0	0	0	0	0	0	0	0
2001	0	0.076	0.557	0.249	0.092	0.017	0.005	0	0.000	0.002	0	0	0	0	0	0
2002	0.001	0.048	0.263	0.406	0.175	0.060	0.028	0.013	0.002	0.000	0.000	0.000	0.000	0.001	0	0.001
2003	0.000	0.026	0.253	0.407	0.225	0.048	0.025	0.011	0.004	0.000	0.000	0	0.000	0	0	0.002

recreational west

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8	age 9	age 10	age 11	age 12	age 13	age 14	age 15+
1991	0	0.002	0.593	0.310	0.049	0.026	0.015	0.005	0	0	0	0	0	0	0	0
1992	0	0.024	0.367	0.451	0.082	0.028	0.028	0	0	0	0	0	0	0	0	0.020
1993	0	0.067	0.633	0.229	0.054	0.013	0.003	0.001	0.000	0	0	0	0	0	0	0
1994	0.000	0.028	0.42	0.286	0.158	0.054	0.018	0.014	0.001	0.000	0.010	0.000	0.000	0.000	0.000	0.010
1995	0.000	0.014	0.704	0.145	0.066	0.021	0.012	0.014	0.001	0.000	0.010	0.000	0.000	0.000	0.000	0.011
1996																
1997																
1998	0	0.029	0.177	0.332	0.259	0.114	0.050	0.022	0.007	0.002	0.001	0.001	0	0	0	0.007
1999	0	0.009	0.106	0.417	0.311	0.093	0.040	0.008	0.005	0.003	0	0.002	0	0	0	0.008
2000	0	0.018	0.300	0.233	0.043	0.040	0.040	0.119	0.003	0.003	0.097	0.002	0	0	0	0.102
2001	0.000	0.021	0.311	0.237	0.148	0.074	0.078	0.061	0.008	0.007	0.017	0.013	0.000	0.000	0.000	0.024
2002	0.003	0.110	0.337	0.339	0.116	0.042	0.021	0.018	0.003	0.002	0	0	0	0.002	0.003	0.002
2003	0	0.019	0.449	0.284	0.146	0.048	0.020	0.008	0.018	0.002	0.000	0.001	0.001	0.002	0.001	0.001

Appendix 1. Table 10. Effective sample size of observed age composition derived from the distribution of sampled otoliths within sub-stratified regions (commercial handline east was sub-stratified geographically and recreational east and west were sub-stratified by mode) for years starting January 1.

	commercial				recreational	
	handline		longline			
	west	east	west	east	west	east
1991	0	64	0	12	336	251
1992	214	94	0	15	94	382
1993	342	76	29	30	559	460
1994	498	91	0	8	5	461
1995	144	34	0	19	4	374
1996	0	10	0	6	0	112
1997	0	32	0	10	0	62
1998	1246	80	348	25	1029	1399
1999	1986	252	76	102	381	1394
2000	1424	93	298	131	18	582
2001	1327	164	179	91	4	439
2002	3046	529	551	179	607	2373
2003	154	78	0	0	207	182

Appendix 1. Table 11. Shrimp bycatch of red snapper from the Gulf of Mexico by year and age. Estimates were made separately for each region and are not additive, and are rescaled to the total catch.

	gulf wide			west			east		
	age 0	age 1	age 2	age 0	age 1	age 2	age 0	age 1	age 2
1972	73,177,244	37,705,239	15,518	64,602,940	33,038,926	5,134	6,439,337	2,065,818	3,445
1973	12,903,545	4,610,378	1,077	11,784,094	3,866,605	1,300	604,406	413,320	674
1974	11,229,770	6,723,067	1,163	10,512,896	6,223,835	6,269	404,008	243,556	395
1975	4,131,187	3,581,000	413	3,568,271	2,876,717	512	465,154	555,728	297
1976	24,700,703	10,799,337	1,960	23,760,265	10,015,516	1,219	497,524	392,925	651
1977	12,825,847	5,018,686	2,567	11,866,076	4,316,783	1,441	665,559	520,000	1,540
1978	6,567,923	3,308,103	474	6,304,049	3,012,047	604	175,521	193,235	594
1979	21,138,159	10,773,533	4,308	19,538,457	10,042,512	3,031	862,227	395,297	976
1980	24,810,309	10,321,557	2,234	24,256,783	10,010,295	9,122	441,489	117,263	448
1981	43,937,377	25,424,167	5,456	42,439,953	24,576,518	49,528	1,018,633	345,783	1,685
1982	18,983,316	6,241,574	6,110	15,683,700	5,373,952	1,348	2,596,185	297,870	645
1983	10,803,682	4,698,752	2,266	9,526,399	4,236,120	1,381	711,569	249,719	642
1984	9,971,508	4,363,068	2,524	8,659,842	3,785,197	661	739,642	247,582	666
1985	9,394,711	4,477,004	1,884	8,388,033	3,966,692	1,175	546,413	268,197	700
1986	4,774,963	2,512,406	730	4,482,025	2,305,416	659	161,738	106,808	284
1987	10,046,613	5,323,343	1,044	9,422,517	5,113,048	1,436	301,907	133,704	439
1988	7,580,273	4,043,067	1,360	7,030,741	3,708,193	966	318,217	166,601	402
1989	9,913,994	5,343,494	1,512	8,654,706	4,742,088	1,206	627,965	330,044	560
1990	39,893,784	19,694,271	5,945	35,842,785	17,644,636	5,579	2,073,837	1,070,587	1,776
1991	28,150,804	14,480,782	3,413	25,934,804	13,135,986	3,211	1,120,709	705,198	1,193
1992	23,543,980	5,572,176	223,444	22,684,355	5,268,929	214,416	664,949	141,362	249
1993	13,932,153	16,008,301	4,545	13,523,523	15,820,981	4,495	265,625	117,141	284
1994	17,421,025	21,360,580	17,394	16,874,539	20,708,845	16,617	367,107	412,185	9,368
1995	31,855,611	16,594,588	9,802	29,986,777	15,891,700	9,523	992,864	350,584	352
1996	28,210,734	7,470,769	16,497	26,482,845	7,076,113	15,043	723,404	267,720	646
1997	11,370,993	13,703,088	94,919	10,190,849	12,308,314	78,837	963,792	353,862	536
1998	37,020,334	8,462,146	7,520	36,188,409	7,768,384	7,207	713,537	463,218	1,585
1999	34,579,447	6,122,458	3,094	31,998,379	5,474,789	2,833	1,199,627	678,593	1,380
2000	10,471,931	4,613,689	21,379	9,440,886	3,165,147	14,367	1,089,125	1,015,398	5,877
2001	15,495,374	8,486,984	64,642	13,971,786	7,866,925	63,289	1,458,029	465,208	1,962
2002	16,305,729	5,448,117	127,154	15,305,867	5,011,868	120,265	976,355	423,302	7,043
2003	2,760,499	6,056,424	235,077	2,638,450	4,837,118	204,432	180,384	998,898	29,917

Appendix 1. Table 12. Size and age conversion parameters and relative fecundity vector used in the assessment of red snapper in United States waters of the Gulf of Mexico.

von Bertalanffy growth equation

L_{inf} (inches)	34.522
k	0.220
t_0	0.366

age	relative fecundity
0	0.0000
1	0.0000
2	0.0054
3	0.0342
4	0.1023
5	0.2066
6	0.3311
7	0.4582
8	0.5838
9	0.6824
10	0.7630
11	0.8269
12	0.8763
13	0.9139
14	0.9422
15+	1.0000

size lenth and weight conversion equations

length to length and weight to weight ($y = a + bx$)

	a	b
fork length to total length (in.)	0.17291	1.059
standard length to total length (in.)	0.02906	1.278
maximum length to total length (in.)	0.08664	0.973
gutted weight to whole weight (lb)	0	1.11

length to weight ($y = a*x^b$)

	a	b
total length (in.) to whole weight (lb)	0.0004398	3.056
fork length (in.) to whole weight (lb)	0.0006615	2.997

Appendix 2. Assessment Summary

Several population models were used to assess the status of red snapper: VPA, ASAP, CATCHEM and SRA. The ASAP model had been used in the most recent assessment (Schirripa and Legault 1999), but exhibited instability when used to address the very long time series (1872-2003) and to a lesser extent with the shorter time series (1962-2003 and 1984-2003). Modifications to the ASAP code have reduced, but not eliminated that instability. The newly developed program CATCHEM was created to be able to model fish discarded due to a minimum size internally as opposed to the external manner in which discard estimates have been made in past red snapper assessments (as part of the probabilistic aging procedure). CATCHEM also can be used to simultaneously model multiple fleets (which VPA cannot do, but ASAP can) and multiple stocks with possible mixing (which ASAP cannot do). CATCHEM was used in this assessment primarily to explore the long time series (1872-2003), but the shorter time series were also examined. The use of VPA was recommended at the August assessment workshop to examine vulnerability patterns. (It is worth noting that two different VPA programs were employed at the August meeting and some differences were observed in the results. Since then it has been determined that those differences were generally due to differences in input parameters). The simplicity of the VPA model permitted its use in examining the potential effects of multiple assumptions including: different stock structure assumptions (one Gulf wide stock or separate eastern and western stocks), different natural mortality rates on the youngest ages and the impacts of different ages at recruitment. The SRA model also was generally used for guidance on the effects of data and model assumptions rather than to develop management advice. Results from the SRA model are presented in the file Appendix 3 Table Summarizing All Models, however they are conditioned on some earlier (November) results from other models which have since been updated.

CATCHEM was selected in place of ASAP as the primary model by the AW. CATCHEM is in many ways a generalization of the ASAP approach, with more flexibility and the ability to model geographic substructure. One of the more important differences between the two models lies in the way the age structure of the population in the first year is estimated. The initial age structure is modeled in ASAP as deviations from the equilibrium age structure expected under virgin conditions, in which case the estimated deviations and virgin status will be correlated. If there is little information in the data concerning the initial conditions, the starting age structure will be forced to resemble the virgin condition even if the population has been heavily exploited. On the other hand, if there is some information on the initial age structure in the data, then this construct will cause the model to adjust both the deviations and the virgin condition, possibly biasing subsequent MSY benchmarks. This is especially problematic for the 1962-2003 ASAP runs, which substitute an ‘average’ age composition in place of the missing values for earlier years. In the CATCHEM model the initial age structure is set to virgin levels for the 1872-2003 series, but estimated independent of the virgin condition for the shorter time series. The latter is accomplished by estimating a ‘prehistoric’ recruitment level and utilizing an input relative effort series to compute the fishing mortality rate on those ‘prehistoric’ cohorts until the first year of data. If recruitment varies strongly over the 30 year prehistoric period or the input effort series trends are grossly in error, then the initial conditions established by CATCHEM for the shorter time series may be biased.

Another important difference between the two models is the first age class, which is age 0 in ASAP and age 1 in CATCHEM. Both models assume a Beverton and Holt spawner recruit relationship, therefore starting with age 0 implies all of the density dependent effects occur very early in the life history of the animal and subsequent mortality occurs because of shrimp bycatch and density independent natural causes (M_0=0.98yr^{-1}). Starting with age 1, on the other hand, implies that the density dependent processes dominate mortality over the first year of life such that shrimp bycatch of age 0 fish can be ignored. Stock reduction analyses on similar data suggest that stock appraisals become less optimistic as density dependence extends to older ages, which consistent with the difference between ASAP and CATCHEM (the VPA results, however, suggest the opposite is true). To date these differences have not yet been explored in either CATCHEM or ASAP.

Other differences between ASAP and CATCHEM exist, but are probably less important. They include:

(1) the use by ASAP of age composition data derived from length by use of the Goodyear (1997) procedure (see Turner et al. 2004), which is quite different from the observed age composition data discussed by Nowlis (2004).
(2) different indices of abundance
(3) the use by CATCHEM of data on offshore shrimp trawl effort from 1962-2003 (see Porch and Turner 2004)
(4) the use by ASAP of a manufactured (not observed) time series of shrimp bycatches from 1962-1972 (see Porch and Turner 2004)
(5) Discarded fish are modeled internally by CATCHEM, rather than read as inputs in ASAP
(6) CATCHEM models the east and west populations simultaneously, i.e., in a single run. The MSY benchmarks in CATCHEM maximize the Gulf-wide long-term yield and assume that the proportional change in effort will be the same for the eastern and western fleets, which implies that the east and west will be managed as a single unit (as they are presently). In contrast, ASAP models the east and west populations one at a time, i.e., in two separate runs. The MSY benchmarks in ASAP therefore maximize the long-term yields of east and west independently with no linkage between the effort exerted by the respective fleets, which implies that the east and west will be managed separately with their own MSY targets.

After the December Assessment workshop the probabilistic age composition was recalculated and all CATCHEM, ASAP and VPA analyses were re-run. The recalculation of the age composition corrected the recreational minimum size for 2000-2003 from 15” to 16”. The ASAP runs incorporated that change and were made with a modification to the program that allowed the plus-group to deviate from virgin conditions, thereby reducing some, but not all of the instability previously observed in the runs with the short time series; an average age composition was still needed for years when no age composition was available but catches were recorded.

Summary of estimated stock status from all model runs
Liz Brooks and Clay Porch

Overall, several general patterns can be detected in the summary plots. First, it is important to note that the perceptions of stock status depend on the way the MSY-related benchmarks are defined. In general, the perceptions were far more optimistic when the MSY benchmarks were conditioned on the current level of shrimp bycatch ("current shrimp" scenario) than when the MSY benchmarks were conditioned on zero shrimp bycatch ("no shrimp" scenario) or conditioned on reductions in bycatch effort that are commensurate with the reductions in directed effort (the "linked" scenario). The term "optimistic" is relative, however, because more than half of the "current shrimp" model runs still identify the stock as overfished and many of those also suggest that overfishing is occurring. Nearly all models showed a greater proportional change in the relative biomass indicator (towards less overfished) than in the relative F indicator (towards less overfishing) when the MSY definition was changed from linked to conditional on current shrimp bycatch.

Two other factors that seem to explain much of the spread in the results are steepness and the length of the time series of data (particularly the use of the ultra-historical landings information, i.e., the 1872-2003 series). In the case of the ASAP assessment model framework, steepness was considered difficult to estimate and was therefore fixed at three values: 0.81, 0.90, and 0.95. In the Gulfwide and Western model runs, the status plots show that the point for steepness = 0.81 is the least overfished (relatively speaking) with the least amount of overfishing occurring, and the status for higher steepness values veer diagonally up and to the left from steepness = 0.81 (i.e., more overfished and greater overfishing) (Figs 1,2,5,6). In the Eastern model runs, the pattern is reversed for the low M cases (steepness=0.95 is the least overfished); in the high M cases the intermediate steepness (h=0.90) is the least overfished, although the value is similar to h=0.81 (Figs 3,4). In the case of the CATCHEM framework, the results with the shorter time series were also sensitive to the level of steepness, but the opposite trend was observed in that the stocks were estimated to be in even worse (perhaps unrealistically worse) shape with lower steepness. It must be reiterated, however, that all of the CATCHEM runs began with age 1, whereas all of the ASAP runs began with age 0. Moreover, the solution surface with the shorter time series was not well-behaved and both the ASAP and CATCHEM models had difficulty navigating it. Both found local minima with similar objective function values, but very different implications. Hence, one should be careful not to over-interpret the results based on the shorter time series. The CATCHEM runs with the longer time series were much less sensitive to the value of steepness. Although the model estimated steepness to lie near the imposed upper limit of 0.97, the perception of stock status was almost unchanged when steepness was fixed to 0.81.

It was also noted by the AW that the CATCHEM estimates of virgin recruitment (R_0) and MSY obtained with the shorter (1962 and 1984) time series were several times greater than those obtained with the longer time series, which some have interpreted as suggesting an increase in the productivity of the stock over the last few decades. An alternative interpretation is that the lack of contrast in the shorter time series is responsible for the larger R_0 estimate. At this time, neither interpretation can be ruled out.

The assumed magnitude of the natural mortality rate on age 1 seems to have had a relatively minor impact on most of the appraisals of stock status. Generally the low M ASAP and CATCHEM models estimated a slightly less overfished stock with perhaps less overfishing as compared to the high M runs. Interestingly, the opposite appeared to be true for the VPA runs; going from a high M to a low M model led to a more overfished status with greater overfishing.

In the VPA runs (which used only the shortest time series, 1984-2003, computed only the linked MSY scenario, and indicated steepness was ~1), the main sources of variability in estimated stock status were the assumed age of recruitment (either 0 or 1) and whether R0 was estimated or fixed to a level that corresponds to 8.5 times the three year average low for the time series (1984-2003). In models with recruitment at age 1, the stock is almost always estimated to be less overfished than indicated by the corresponding models with recruitment at age 0. When R0 is fixed, it sets the virgin benchmark higher, and the stock is estimated to be more overfished.

For the 1962 and 1984 time series, the ASAP models which are most comparable with CATCHEM are the east and west runs with high M and steepness of 0.81 and 0.95. The models were mostly in agreement on overfishing and overfished status, although CATCHEM was always more overfished than ASAP outcomes. This could be due to the assumed age of recruitment (CATCHEM assumes age 1 while ASAP assumes age 0), as the SRA results suggest, however it is the opposite of the pattern observed for the VPA (which found that age 1 recruitment models were less overfished than age 0 recruitment models). For the 1984 time series, the VPA models with recruitment at age 1 and the linked MSY benchmark scenario are most comparable with CATCHEM as far as model assumptions, although structurally the two models are very different. Of the four models that might be compared, three of the VPA runs estimate the stock to be either not overfished or not undergoing overfishing.

All CATCHEM models estimated the stock to be overfished with overfishing occurring, whereas several VPA and ASAP models estimated the stock to be in fine shape (not overfished and/or no overfishing). As noted previously, the more optimistic ASAP runs resulted from the “current shrimp” scenario and usually assumed lower steepness values. However, in the west ASAP model runs, even the high steepness estimated no overfishing for the “current shrimp” scenario. A possible reason why this differs from CATCHEM is that ASAP, by including age 0, gives added importance to the shrimp bycatch relative to the directed fleet. Therefore, when the MSY benchmark is conditioned on current shrimp bycatch levels, the remaining directed fishing mortality is estimated to be just a fraction of Fmsy.

Key for model abbreviations in Figure Legends

A=ASAP
V=VPA
C=CATCHEM
L=Linked
c-s=current shrimp
n-s=no shrimp (CATCHEM only)
M=high mortality
m=low mortality

81,90,95,97 are steepness values
r=estimated recruitment (VPA)
R=fixed recruitment 8.5X (VPA)
0=age 0 recruitment (VPA)
1=age 1 recruitment (VPA)

_62, _84 are time series (VPA and ASAP)
1872, 1962, 1984 are time series (CATCHEM)

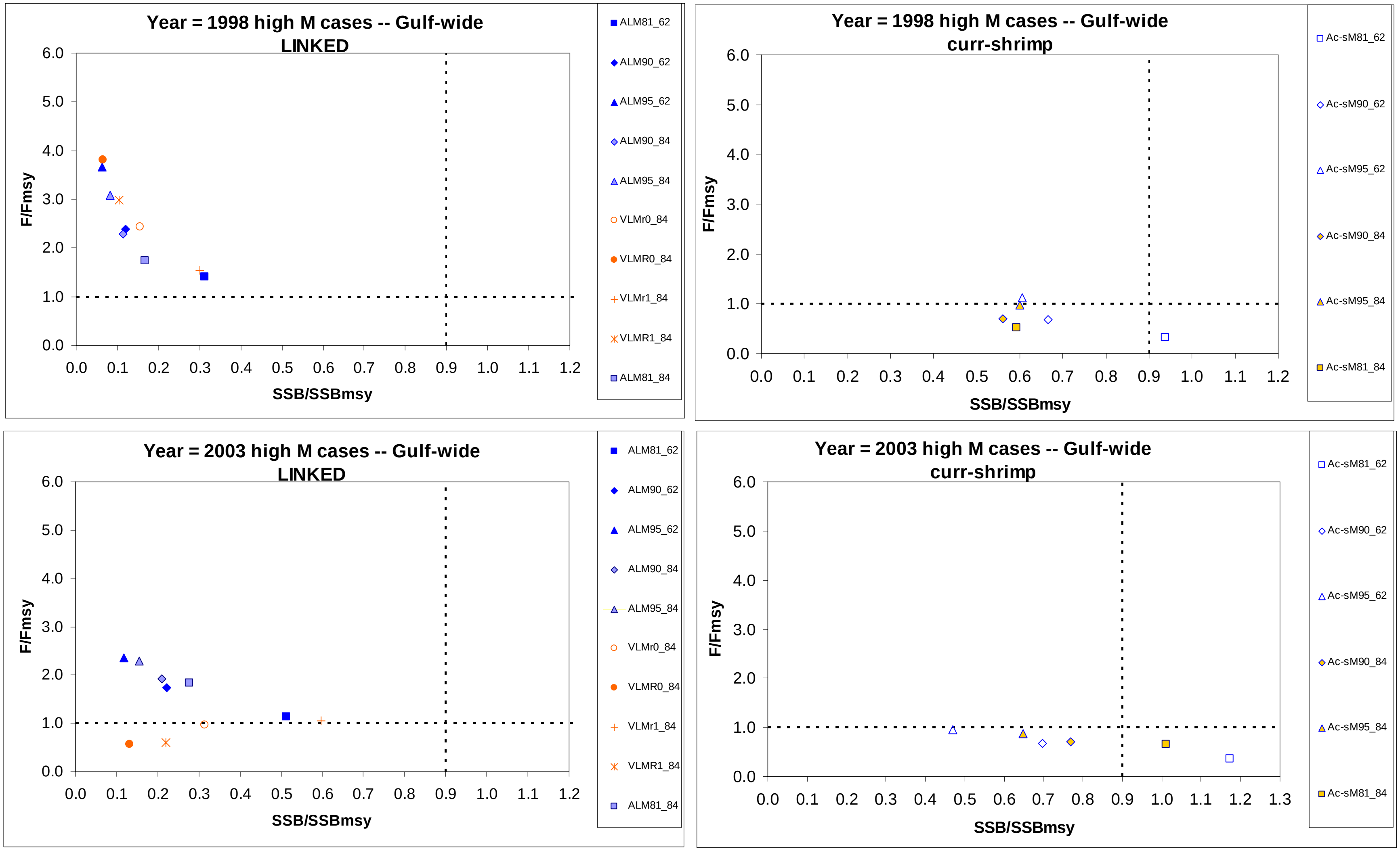


Figure 1. Gulfwide models of stock status with high natural mortality (M_0=0.98, M_1=0.59, M_{2+}=0.1).

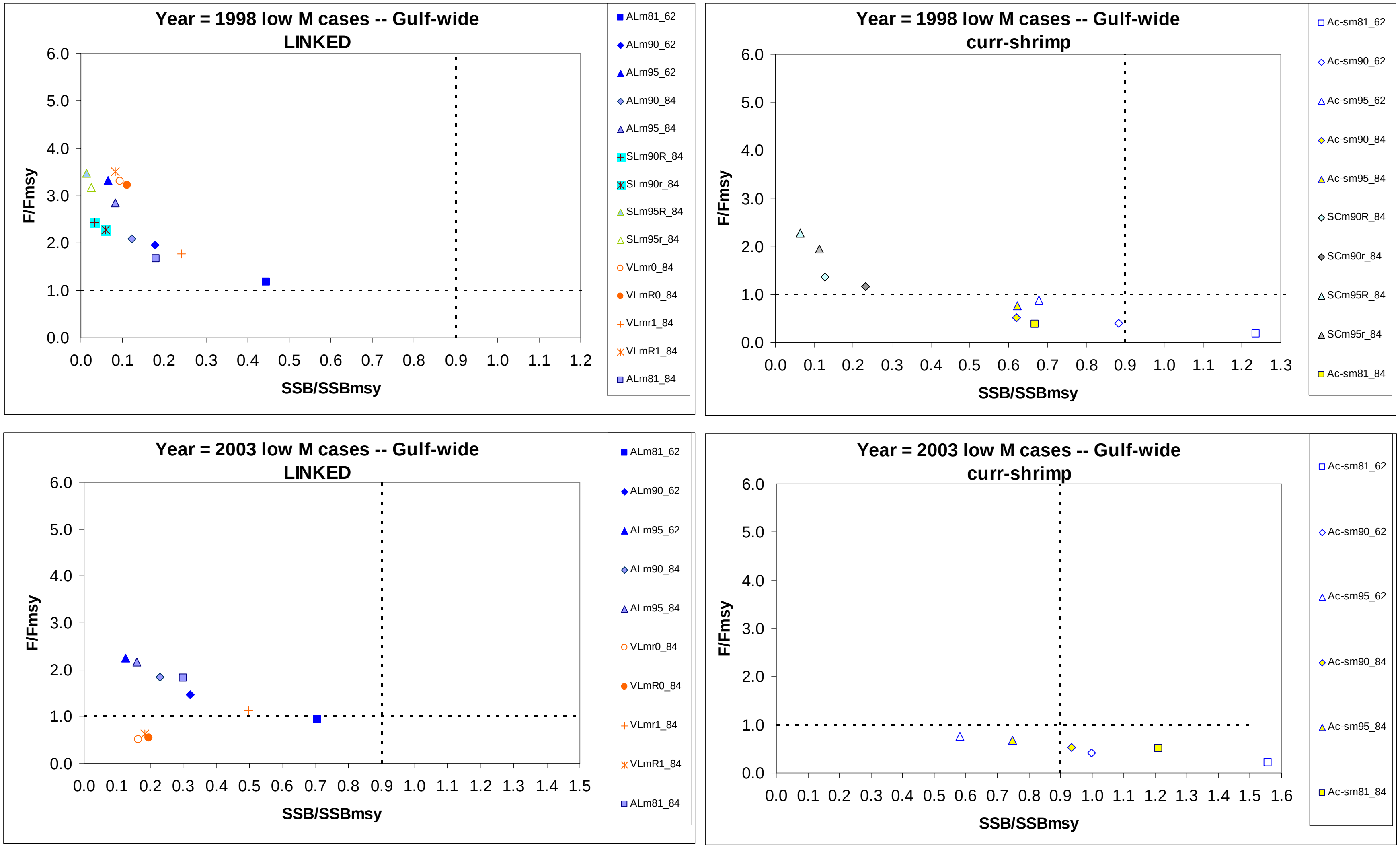


Figure 2. Gulfwide models of stock status with low natural mortality (M_0=0.48, M_1=0.29, M_{2+}=0.1).

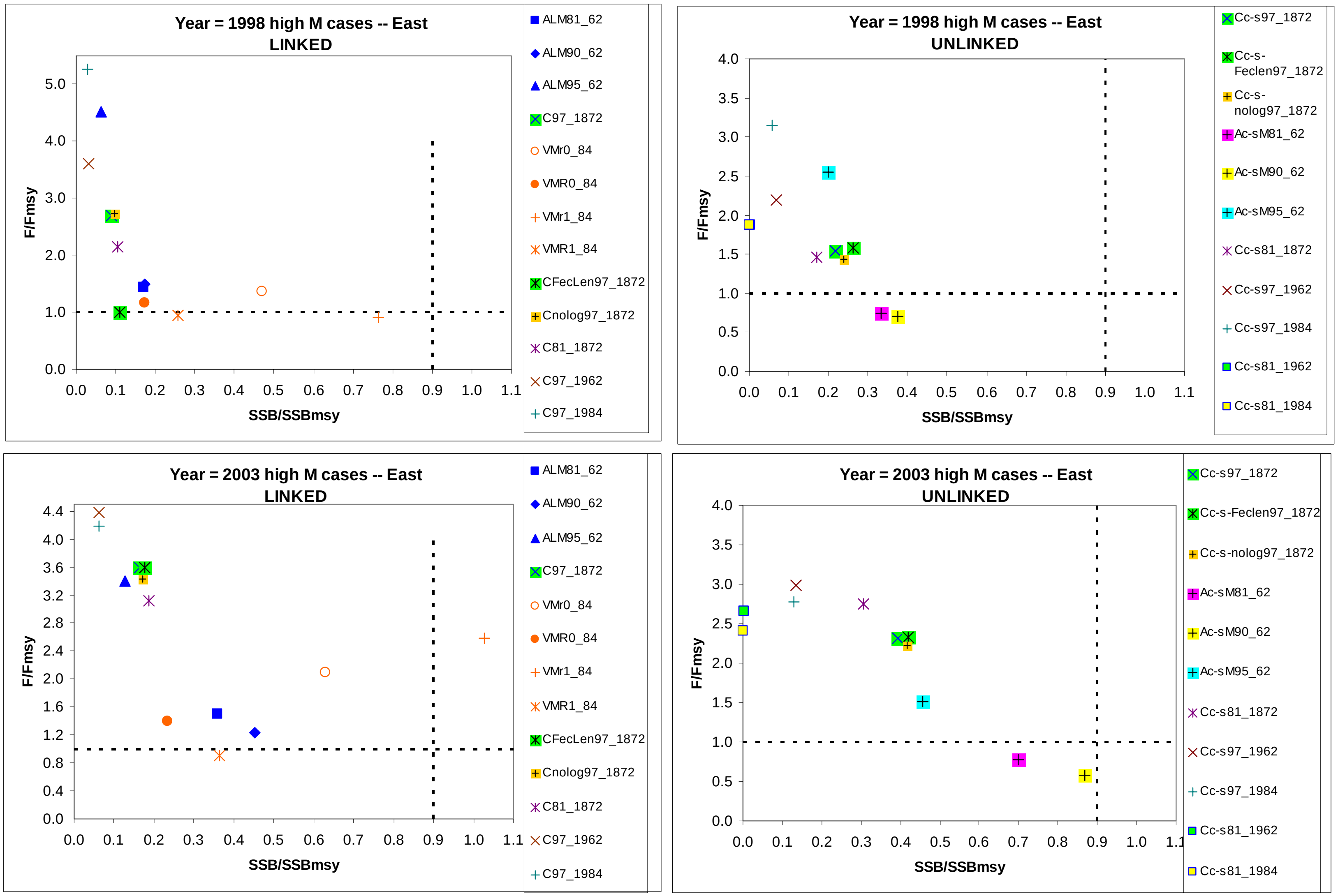


Figure 3. East models of stock status with high natural mortality (M_0=0.98, M_1=0.59, M_{2+}=0.1).

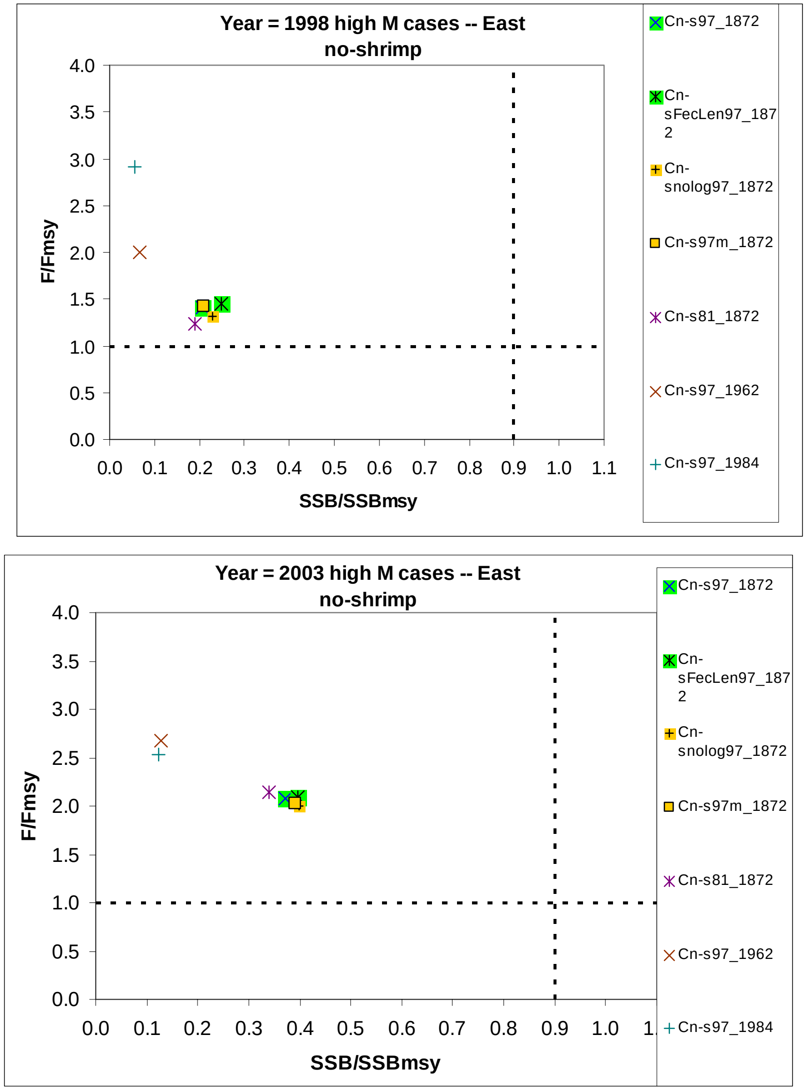


Figure 3. (cont.)

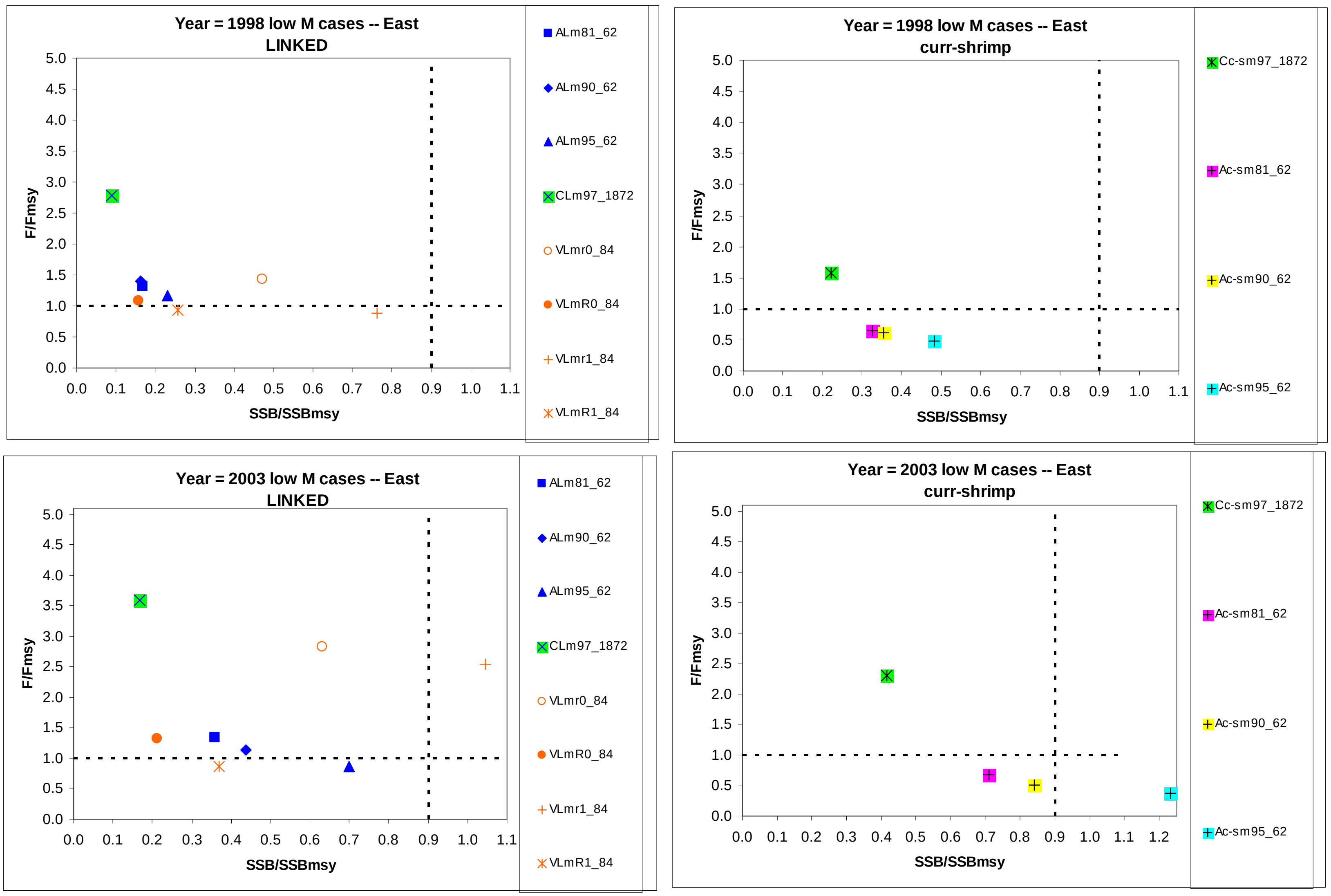


Figure 4. East models of stock status with low natural mortality (M_0=0.48, M_1=0.29, M_{2+}=0.1).

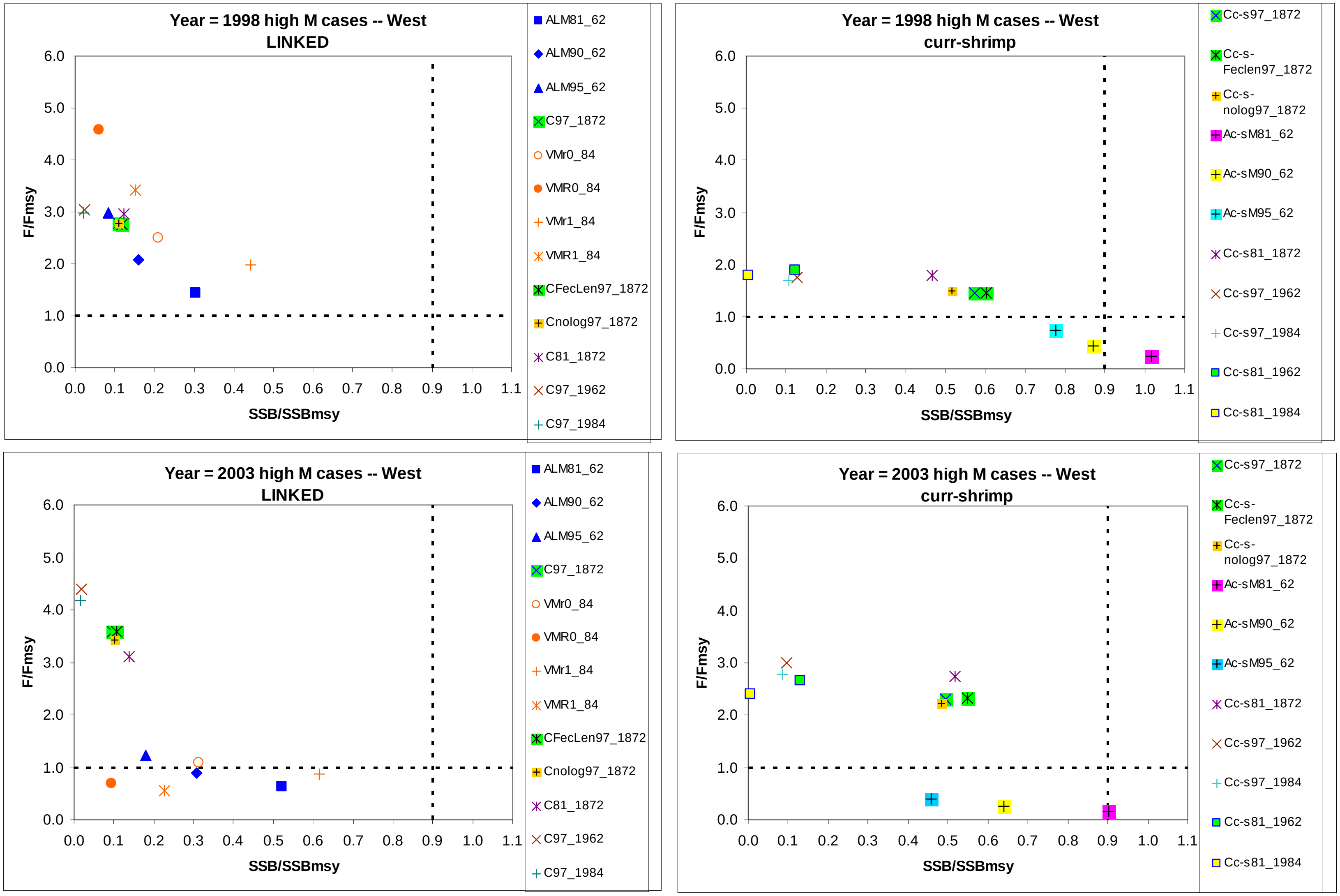
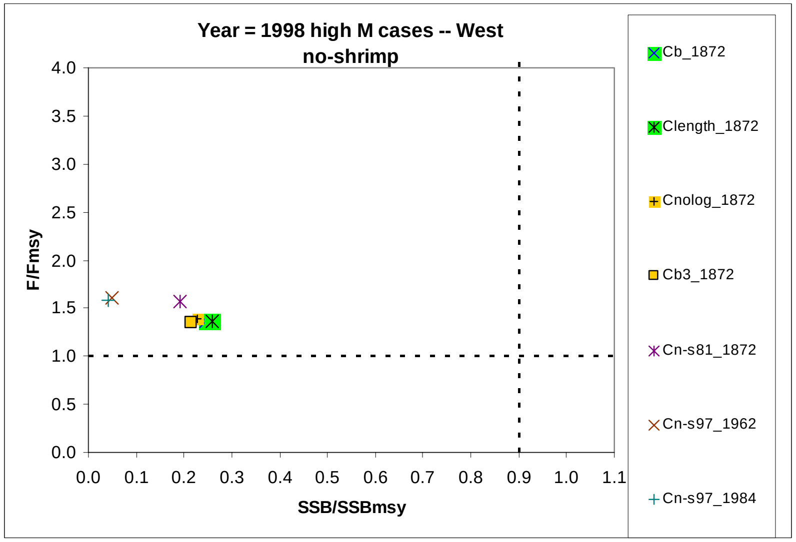


Figure 5. West models of stock status with high natural mortality (M_0=0.98, M_1=0.59, M_{2+}=0.1).



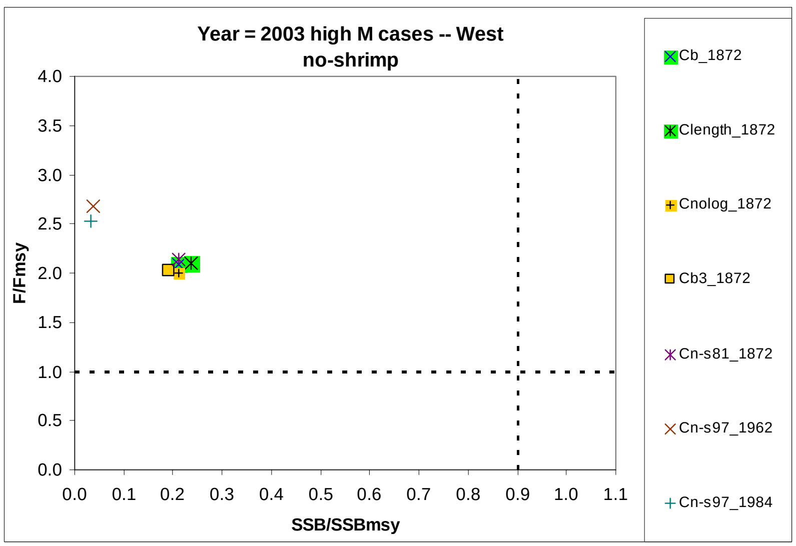


Figure 5. (cont.)

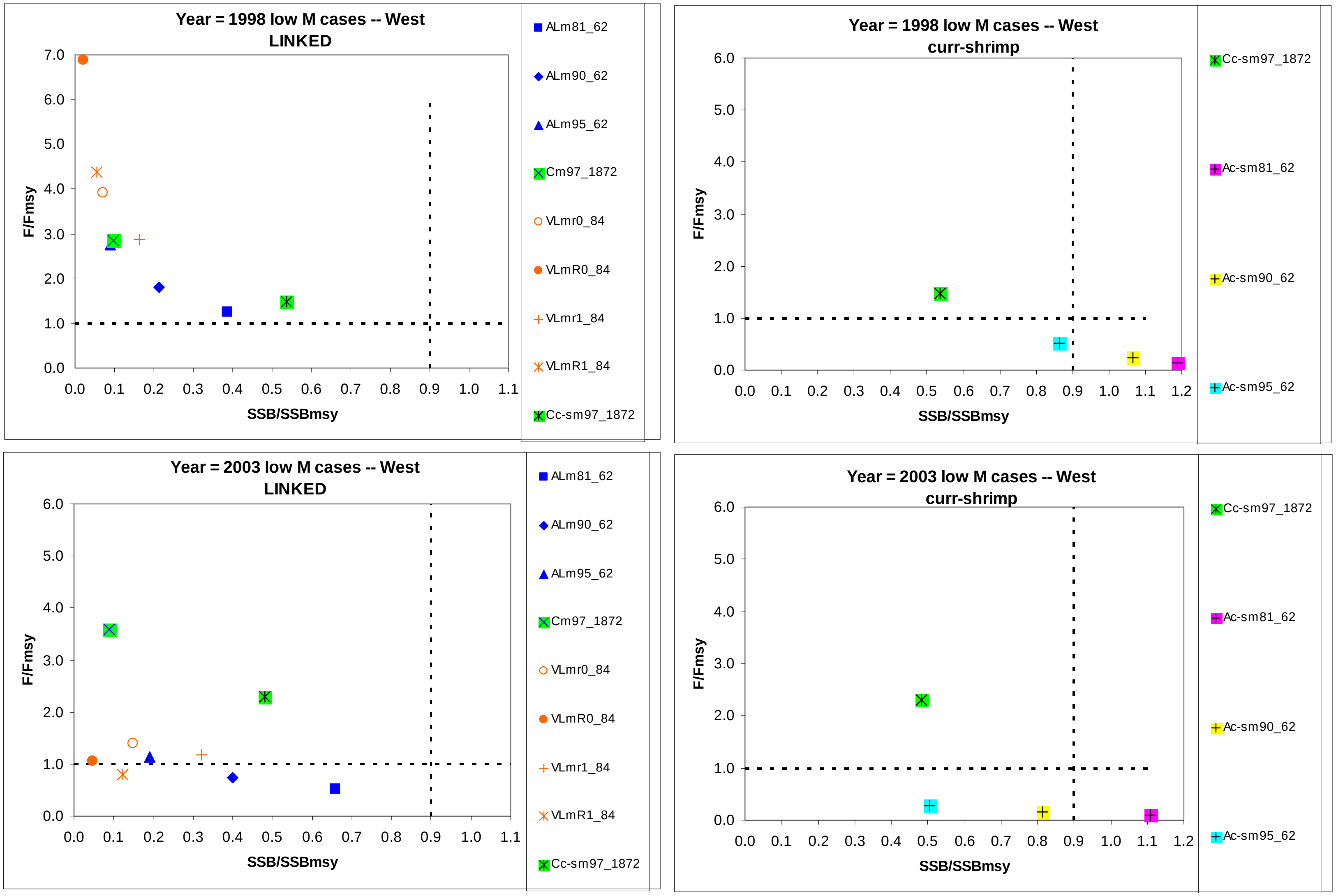


Figure 6. West models of stock status with low natural mortality (M_0=0.48, M_1=0.29, M_{2+}=0.1).

Appendix 3.

Summary of benchmarks and status results

To view file, click here :

(Requires Microsoft Excel)

This appendix is provided as a separate file on CD versions of the workshop report.

Appendix 4. ASAP Gulf wide projection results

METHODS

Projections were made from each of the "unlinked" (current-shrimp) ASAP runs (SEDAR7-RW-2; SEDAR7-RW-3) to predict the outcome of various management decisions. Isopleths of projected transitional SPR (tSPR), spawning stock status (S/Smsy) and yield during 2010 and 2032 were constructed using total allowable catches (TAC) ranging from 0 to 20 million pounds and shrimp effort reductions ranging from 0 to 100%. Similar isopleth diagrams were constructed using % current directed F and shrimp effort reductions both ranging from 0 to 100%. For all projections, the closed season commercial discards and shrimp bycatch fleets were specified as unlinked, and changes in TAC, directed F and shrimp bycatch commenced in 2007. For the years 2004-2006, the current TAC of 9.12 million pounds was used for the projection.

Current TAC for the Gulf of Mexico red snapper stock is 9.12 million pounds. "Current" levels of directed F and shrimp bycatch were defined using the three-year average during 2001-2003. Current shrimp bycatch is equivalent to a 0% reduction. A 100% reduction implies the termination of red snapper bycatch by the shrimp fleet beginning in 2007. Bycatch reductions can result from direct management measures (e.g. effort controls, bycatch reduction devices) or from indirect factors (e.g. effort reductions caused by economic factors, gear changes).

Annual MSY estimates are not static. Instead, MSY is reestimated at each level of shrimp effort reduction. MSY estimates in 2010 and 2032 increase with reductions in shrimp effort (applied in 2007).

RESULTS AND DISCUSSION

ASAP Gulf-wide 1962-2003 Projections

Steepness = 0.81

At steepness = 0.81, $tSPR_{2003}$ was 0.32. It is possible to achieve tSPR > 0.3 in 2010 at TACs up to 20 million pounds (Fig 1A) or 100% of current directed fishing mortality (Fig. 1C) without reducing shrimp effort. S/Smsy was 1.17 in 2003, and is maintained at that level in 2010 without reductions in TAC or shrimp effort (Fig 1B). In 2010, S/Smsy is maximal at a 0% reduction in shrimp effort because MSY_{2010} increases with reductions in shrimp effort. A yield greater than 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 1D).

In 2032, tSPR > 0.3 can be achieved at TACs up to 17 million pounds (Fig 2A) and at 100% of current directed F (Fig 2C) without reducing shrimp effort. A TAC of 20 million pounds will permit tSPR > 0.3 if shrimp effort is reduced by approximately 20% (Fig. 2A). At current fishing levels, projected S/Smsy in 2032 is approximately 1.9 and tSPR > 0.3 (Fig. 2B). Higher levels are possible with reductions in TAC or shrimp effort. A yield in excess of 9.12 million pounds can be achieved in 2032 without reducing directed F or shrimp effort (Fig 2D).

Steepness = 0.90

At steepness = 0.90, $tSPR_{2003}$ was 0.14. It is not possible to achieve tSPR > 0.2 in 2010 (Figs. 3A-C). S/Smsy was 0.7 in 2003, and is maintained at that level in 2010 without reductions in TAC or shrimp effort (Fig 3B). A yield of 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 3D).

Transitional SPR > 0.3 can be achieved and maintained through 2032 by reducing TAC to 5 million pounds (Fig 4A), by reducing directed F to about 30% of 2001-2003 levels (Fig 4C), or by reducing shrimp effort by 20-40% (Figs 4A-C). Smaller reductions in both directed fishing and shrimp effort can also allow tSPR > 0.3. Transitional SPR > 0.2 can be achieved with essentially no reduction in TAC, directed F or shrimp effort (Figs 4A-C). At current fishing levels, projected S/Smsy in 2032 is approximately 1.7, and tSPR is about 0.25 (Fig. 4B). Higher levels are possible with reductions in TAC or shrimp effort. A yield of 9.12 million pounds can be achieved in 2032 without reducing directed F or shrimp effort (Fig 4D).

Steepness = 0.95

At steepness = 0.95, $tSPR_{2003}$ was 0.06. It is not possible to achieve tSPR > 0.2 in 2010, but levels lower than 0.1 are avoided if TAC is reduced to 5 million pounds (Fig 5A) or if directed fishing is reduced to 50% of 2001-2003 levels (Fig 5C). S/Smsy was 0.47 in 2003, and is maintained at that level in 2010 without reductions in TAC or shrimp effort (Fig 5B). A yield of 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 5D).

Transitional SPR > 0.3 can be achieved and maintained through 2032 by eliminating the directed fishery (Fig 6A-C), or by reducing shrimp effort by >40% (Figs 6A). Smaller reductions in both directed fishing and shrimp effort can also allow tSPR > 0.3. For example, a 25% reduction in shrimp effort and a TAC of 5 million pounds is sufficient (Fig 6A). Transitional SPR > 0.2 can be achieved by reducing TAC to 7 million pounds (Fig 6A), by reducing directed fishing mortality to 40% of 2001-2003 levels, or with smaller reductions and a concurrent reduction in shrimp effort. At current fishing levels, projected S/Smsy in 2032 is approximately 1.7, but tSPR is less than 0.2 (Fig. 6B). A yield greater than 9.12 million pounds can be achieved in 2032 without reducing directed F or shrimp effort (Fig 6D), but yields in excess of 20 million pounds are possible with moderate reductions in shrimp effort.

ASAP Gulf-wide 1984-2003 Projections

Steepness = 0.81

At steepness = 0.81, $tSPR_{2003}$ was 0.23. It is not possible to achieve tSPR > 0.3 in 2010, but tSPR > 0.2 is possible at TACs up to 20 million pounds (Fig 7A) or 100% of current directed fishing mortality (Fig. 7C) without reducing shrimp effort. S/Smsy was 1.0 in 2003, and is maintained near that level in 2010 without reductions in TAC or shrimp effort (Fig 7B). In 2010, S/Smsy is maximal at a 0% reduction in shrimp effort because the 2010 MSY estimate increases with shrimp reduction. Yields near 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 7D).

In 2032, tSPR > 0.3 can be achieved with moderate (30%) reductions in TAC (or directed F) and shrimp effort (Fig 8A-C). Transitional SPR > 0.2 can be achieved without reductions. At current fishing levels, projected S/Smsy in 2032 is approximately 1.2 and tSPR is approximately 0.2 (Fig. 8B). Projected yield in 2032 is greater than 9.12 million pounds without reductions in fishing effort.

Steepness = 0.90

At steepness = 0.90, $tSPR_{2003}$ was 0.13. It is not possible to achieve tSPR > 0.1 in 2010 (Figs. 9A-C). S/Smsy was 0.77 in 2003, and is maintained at that level in 2010 without reductions in TAC or shrimp effort (Fig 9B). A yield of 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 9D).

Transitional SPR > 0.3 cannot be achieved in 2032 without moderate (30%) reductions in TAC (or directed F) and shrimp effort (Fig. 10A-C). Transitional SPR > 0.2 can be achieved with minimal reductions (10-30%) in TAC, directed F or shrimp effort (Figs 10A-C). At current fishing levels, projected S/Smsy in 2032 is approximately 1.5, and tSPR is about 0.19 (Fig. 10B). A yield of 9.12 million pounds can be achieved in 2032 without reducing directed F or shrimp effort, but higher yields are possible with modest reductions in shrimp effort (Fig 10D).

Steepness = 0.95

At steepness = 0.95, $tSPR_{2003}$ was 0.07. It is not possible to achieve tSPR > 0.2 in 2010, but levels lower than 0.1 are avoided if TAC is reduced to 6.5 million pounds (Fig 11A) or if directed fishing is reduced to 70% of 2001-2003 levels (Fig 11C). S/Smsy was 0.65 in 2003, and is maintained at that level in 2010 without reductions in TAC or shrimp effort (Fig 11B). A yield of 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 11D).

Transitional SPR > 0.3 can be achieved and maintained through 2032 by eliminating the directed fishery (Fig 12A-C), or by reducing shrimp effort by >40% (Figs 12A). Smaller reductions in both directed fishing and shrimp effort can also allow tSPR > 0.3. For example, a 30% reduction in shrimp effort and a TAC of 5 million pounds is sufficient (Fig 12A). Transitional SPR > 0.2 can be achieved by reducing TAC to 6 million pounds (Fig 12A), by reducing directed fishing mortality to 35% of 2001-2003 levels (Fig 12C), or with smaller reductions and a concurrent reduction in shrimp effort. At current fishing levels, projected S/Smsy in 2032 is approximately 1.25, but tSPR is less than 0.2 (Fig. 12B). A yield greater than 9.12 million pounds can be achieved in 2032 without reducing directed F or shrimp effort (Fig 12D), but yields in excess of 20 million pounds are possible with moderate reductions in shrimp effort.

Gulfwide ASAP 1962-2003; High Mortality (M_1 = 0.59)
Steepness = 0.81
A) B)

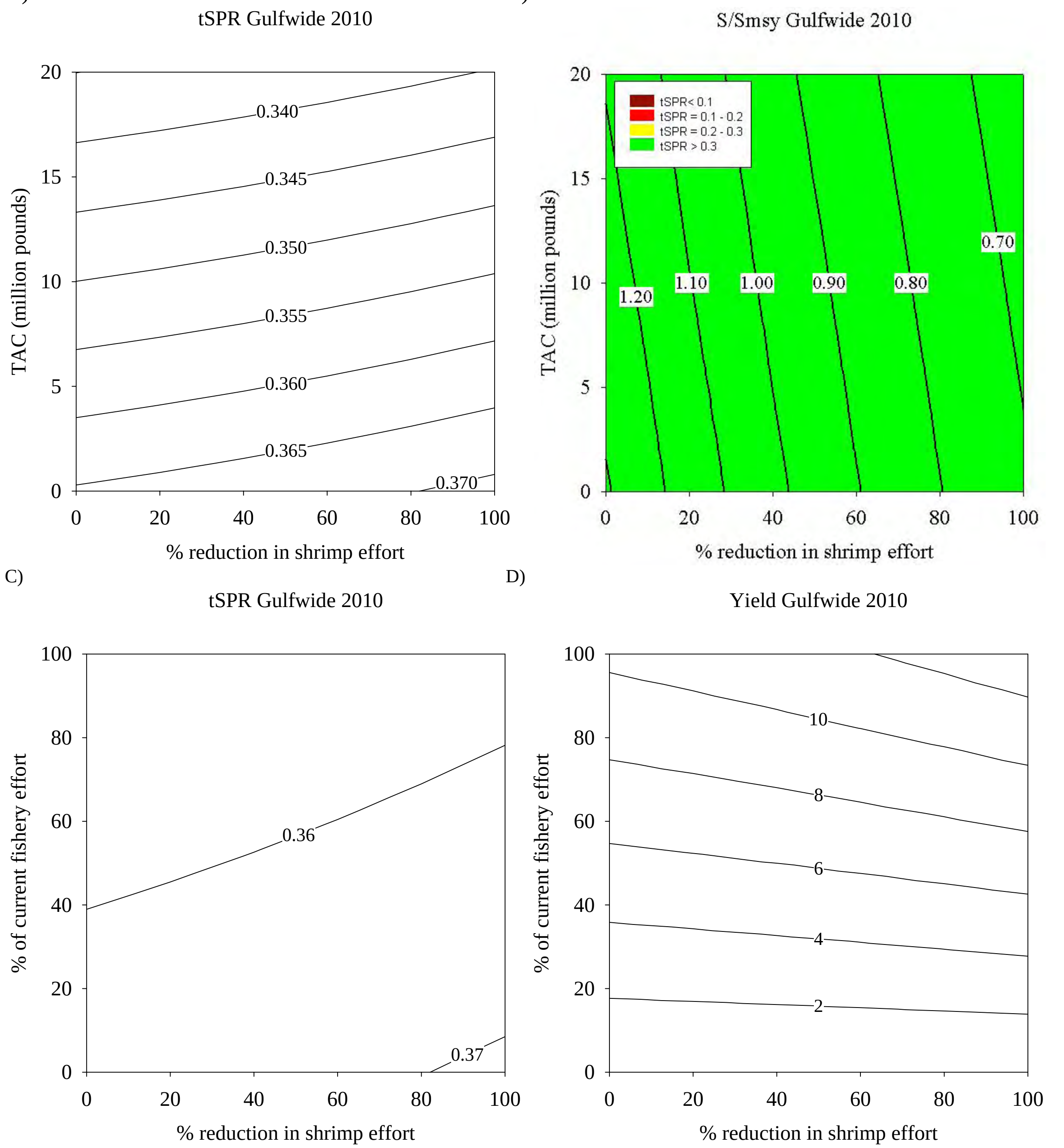


Figure 1. Projected isopleths of tSPR, SS_{2010}/SS_{MSY} and yield in the year 2010 assuming steepness -= 0.81. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2010}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2010} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1962-2003; High Mortality (M_1 = 0.59)
Steepness = 0.81

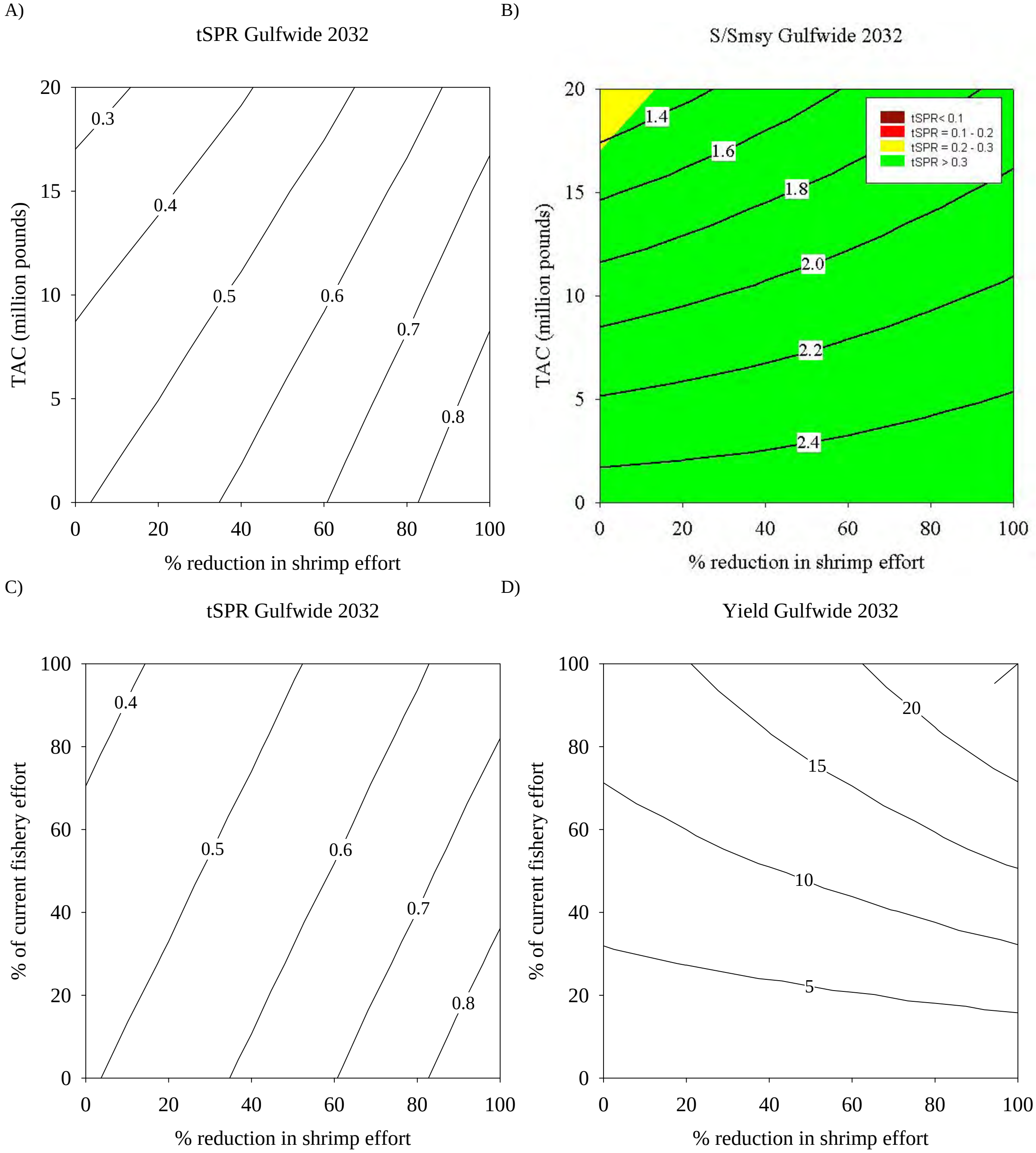


Figure 2. Projected isopleths of tSPR, SS_{2032}/SS_{MSY} and yield in the year 2032 assuming steepness -= 0.81. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2032}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2032} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1962-2003; High Mortality (M_1 = 0.59)
Steepness = 0.90

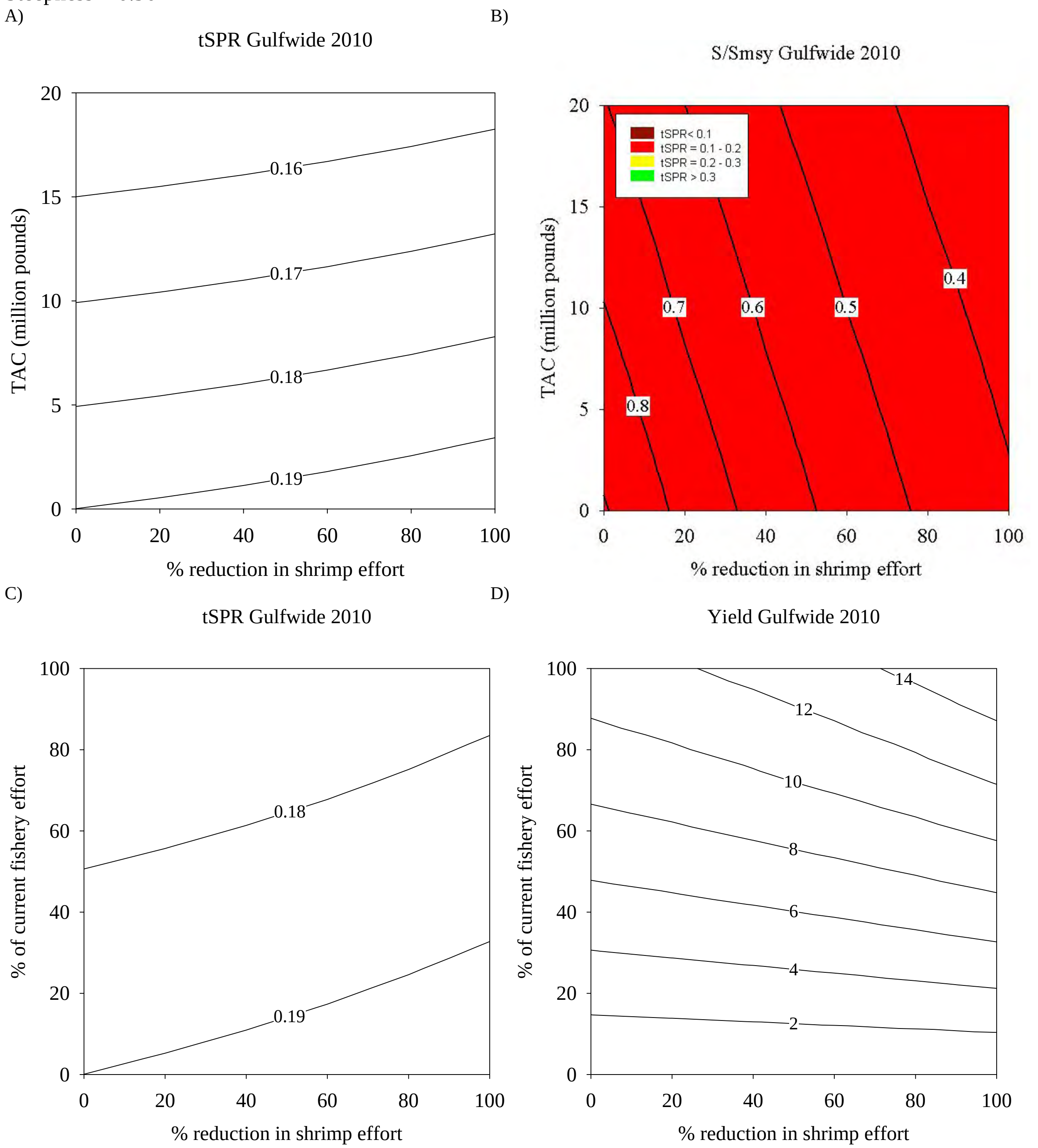
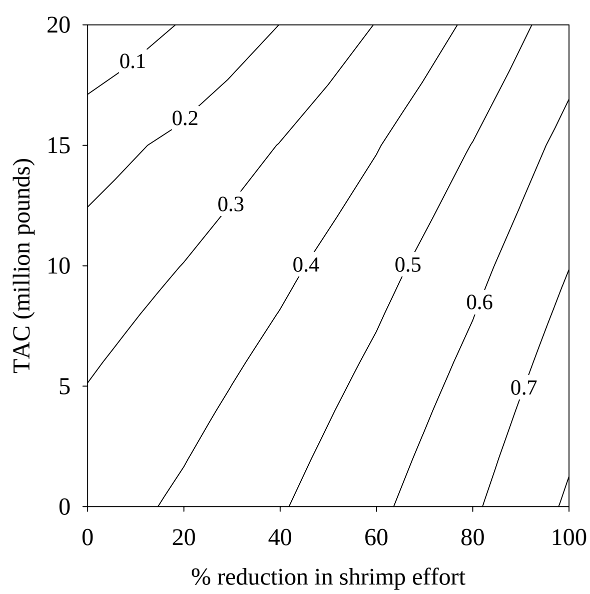


Figure 3. Projected isopleths of tSPR, SS_{2010}/SS_{MSY} and yield in the year 2010 assuming steepness -= 0.90. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2010}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2010} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1962-2003; High Mortality (M_1 = 0.59)
Steepness = 0.90

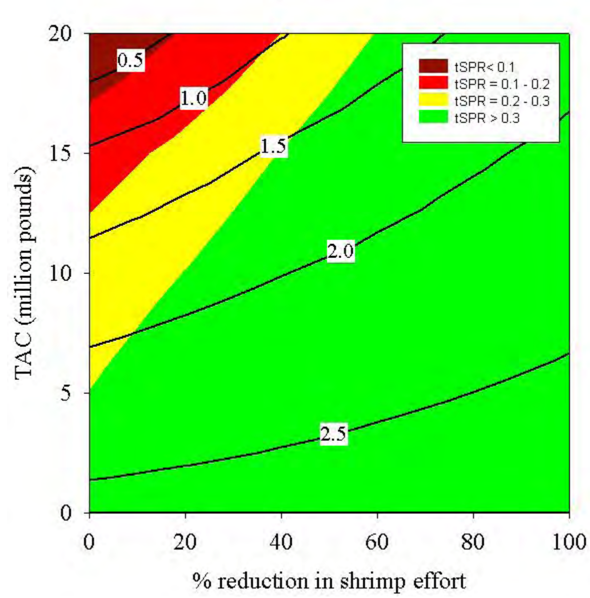
A)

tSPR Gulfwide 2032



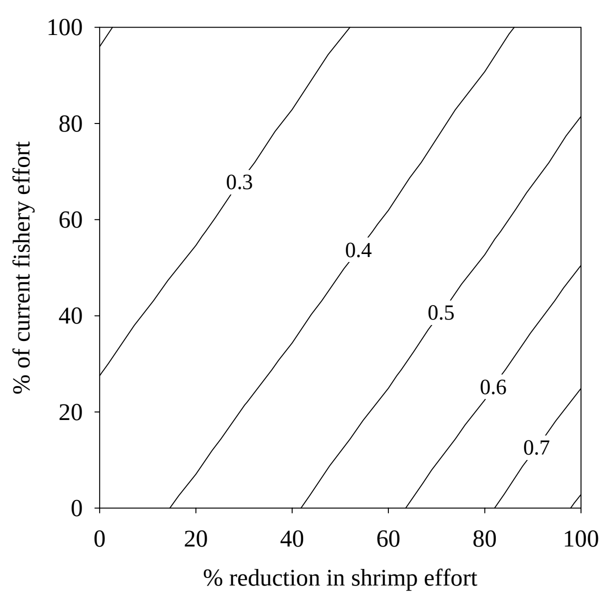
B)

S/Smsy Gulfwide 2032



C)

tSPR Gulfwide 2032



D)

Yield Gulfwide 2032

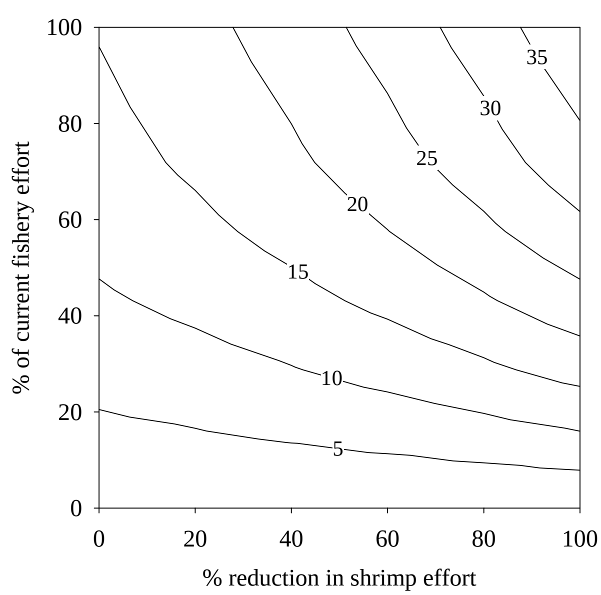


Figure 4. Projected isopleths of tSPR, SS_{2032}/SS_{MSY} and yield in the year 2032 assuming steepness -= 0.90. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2032}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2032} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1962-2003; High Mortality (M_1 = 0.59)
Steepness = 0.95

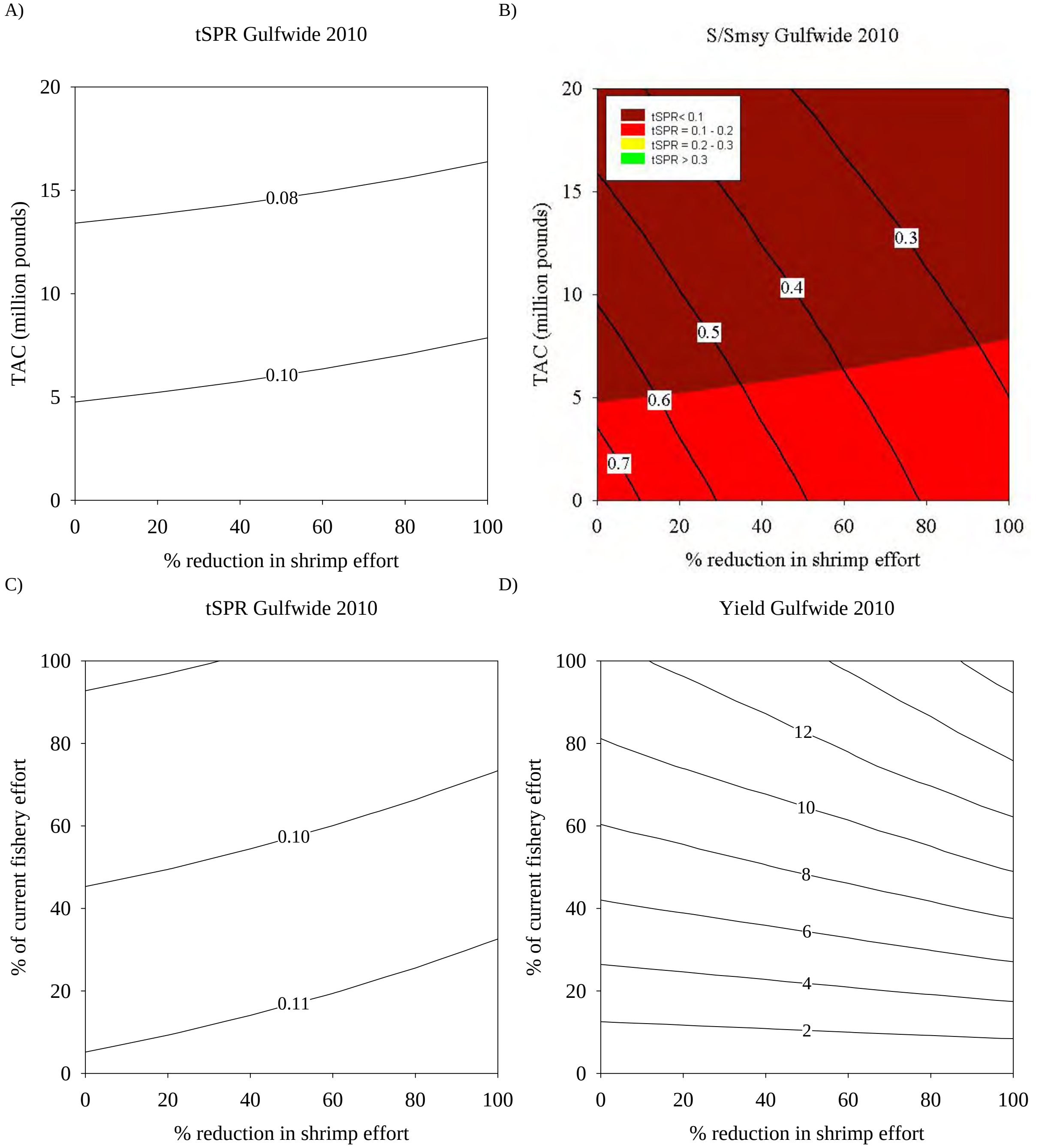


Figure 5. Projected isopleths of tSPR, SS_{2010}/SS_{MSY} and yield in the year 2010 assuming steepness -= 0.95. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2010}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2010} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1962-2003; High Mortality (M_1 = 0.59)
Steepness = 0.95

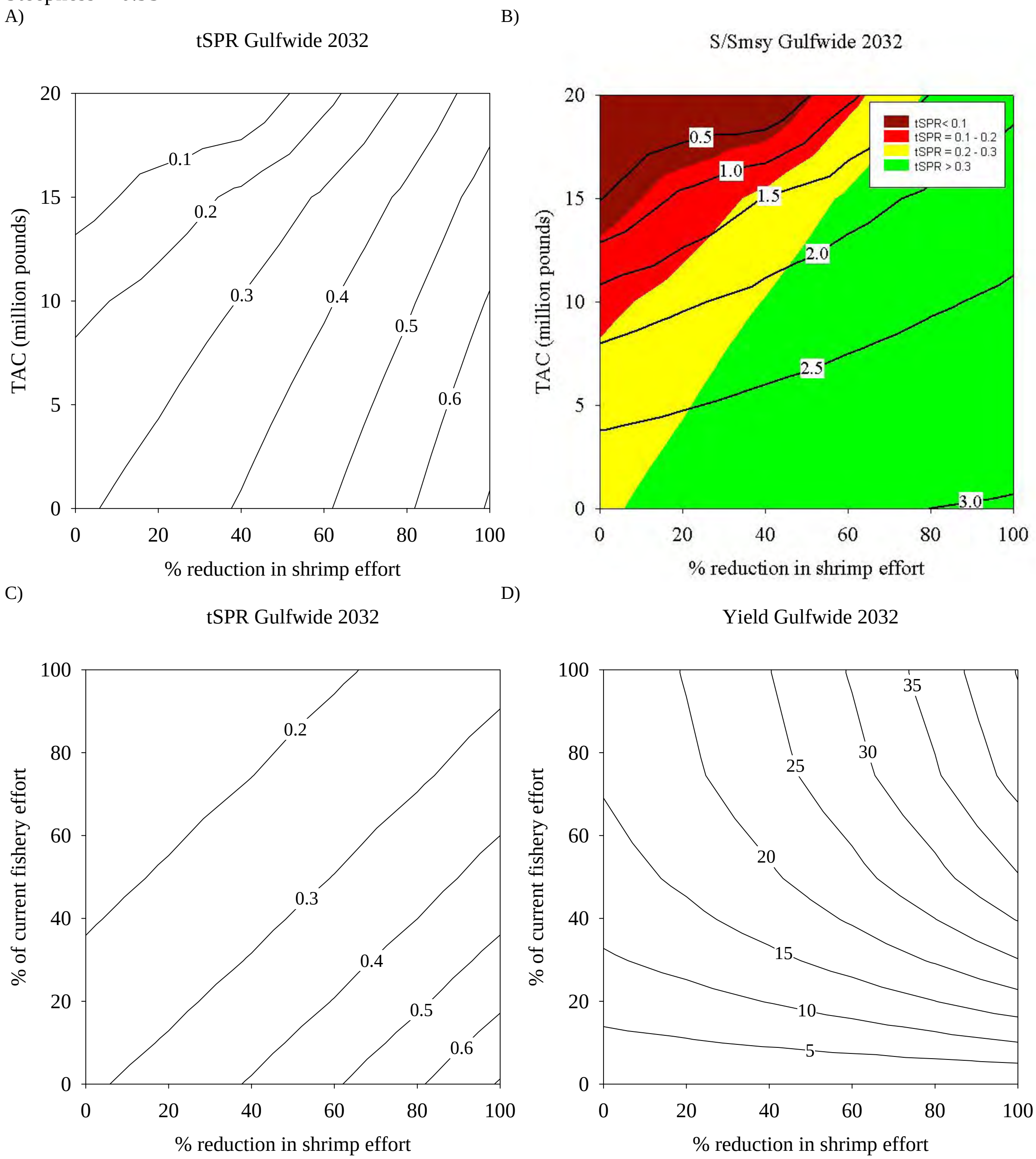


Figure 6. Projected isopleths of tSPR, SS_{2032}/SS_{MSY} and yield in the year 2032 assuming steepness -= 0.95. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2032}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2032} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1984-2003; High Mortality ($M_1 = 0.59$)
Steepness = 0.81

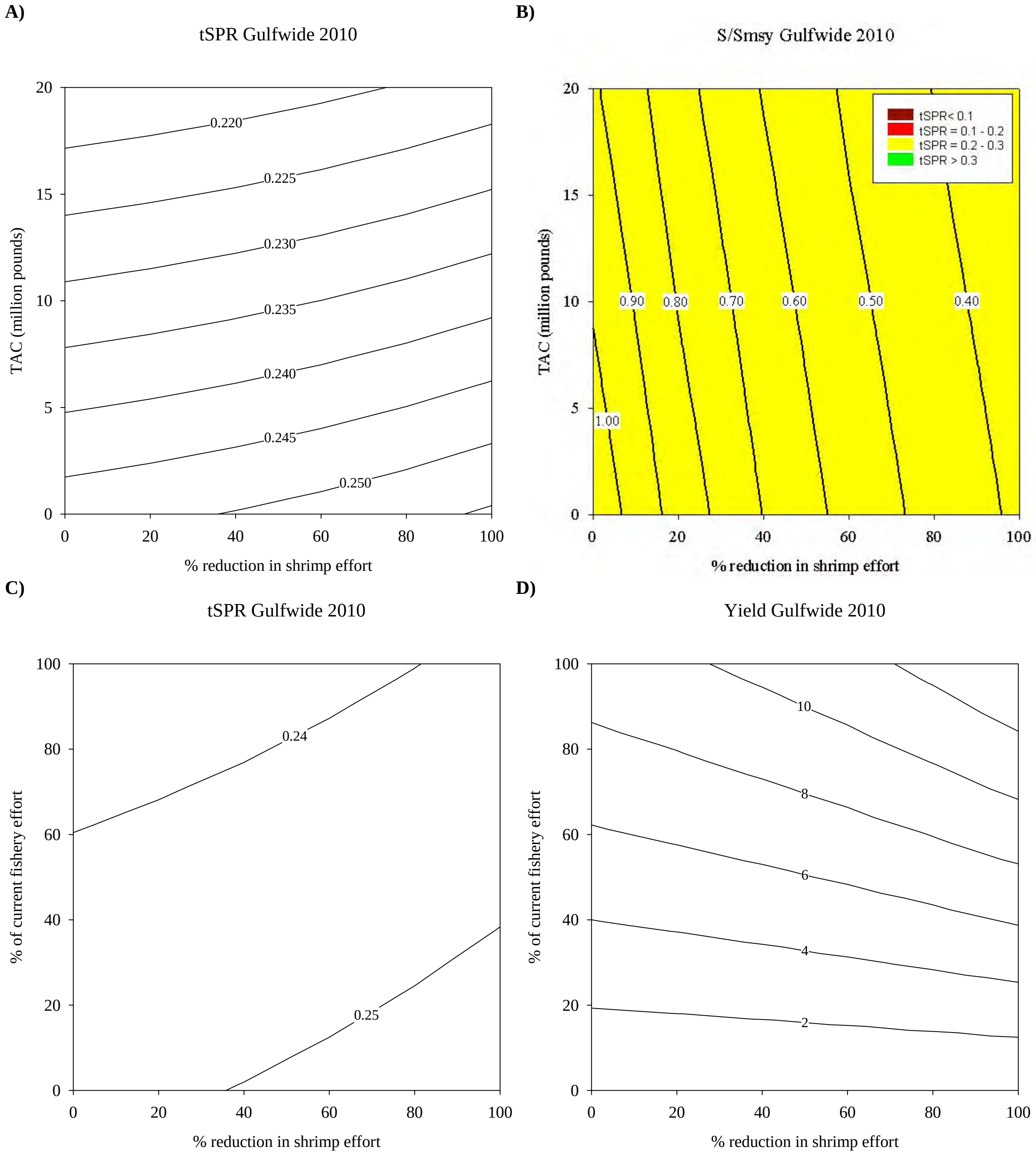


Figure 7. Projected isopleths of tSPR, SS_{2010}/SS_{MSY} and yield in the year 2010 assuming steepness -= 0.81. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2010}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2010} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1984-2003; High Mortality (M_1 = 0.59)
Steepness = 0.81

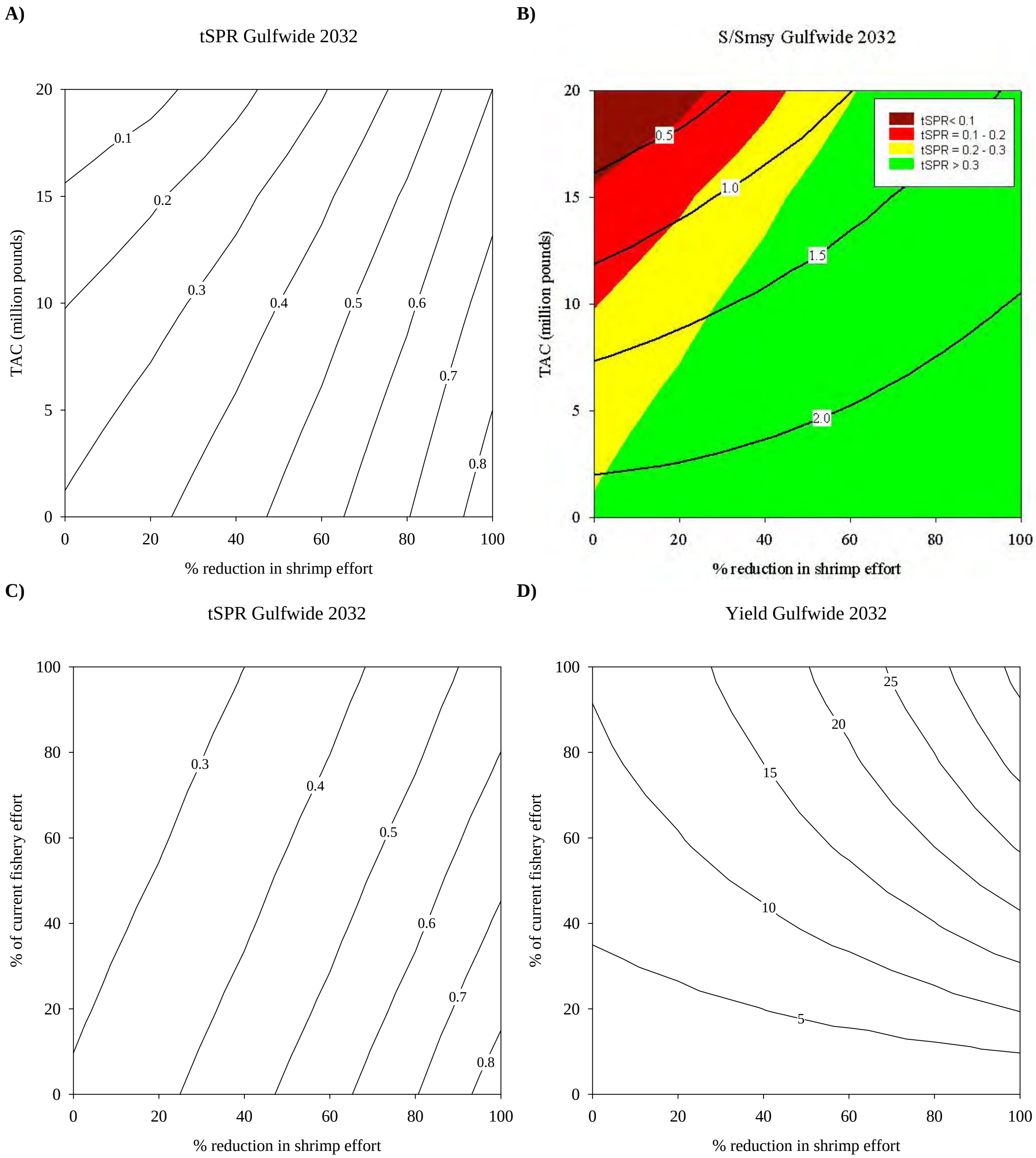


Figure 8. Projected isopleths of tSPR, SS_{2032}/SS_{MSY} and yield in the year 2032 assuming steepness -= 0.81. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2032}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2032} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1984-2003; High Mortality (M_1 = 0.59)
Steepness = 0.90

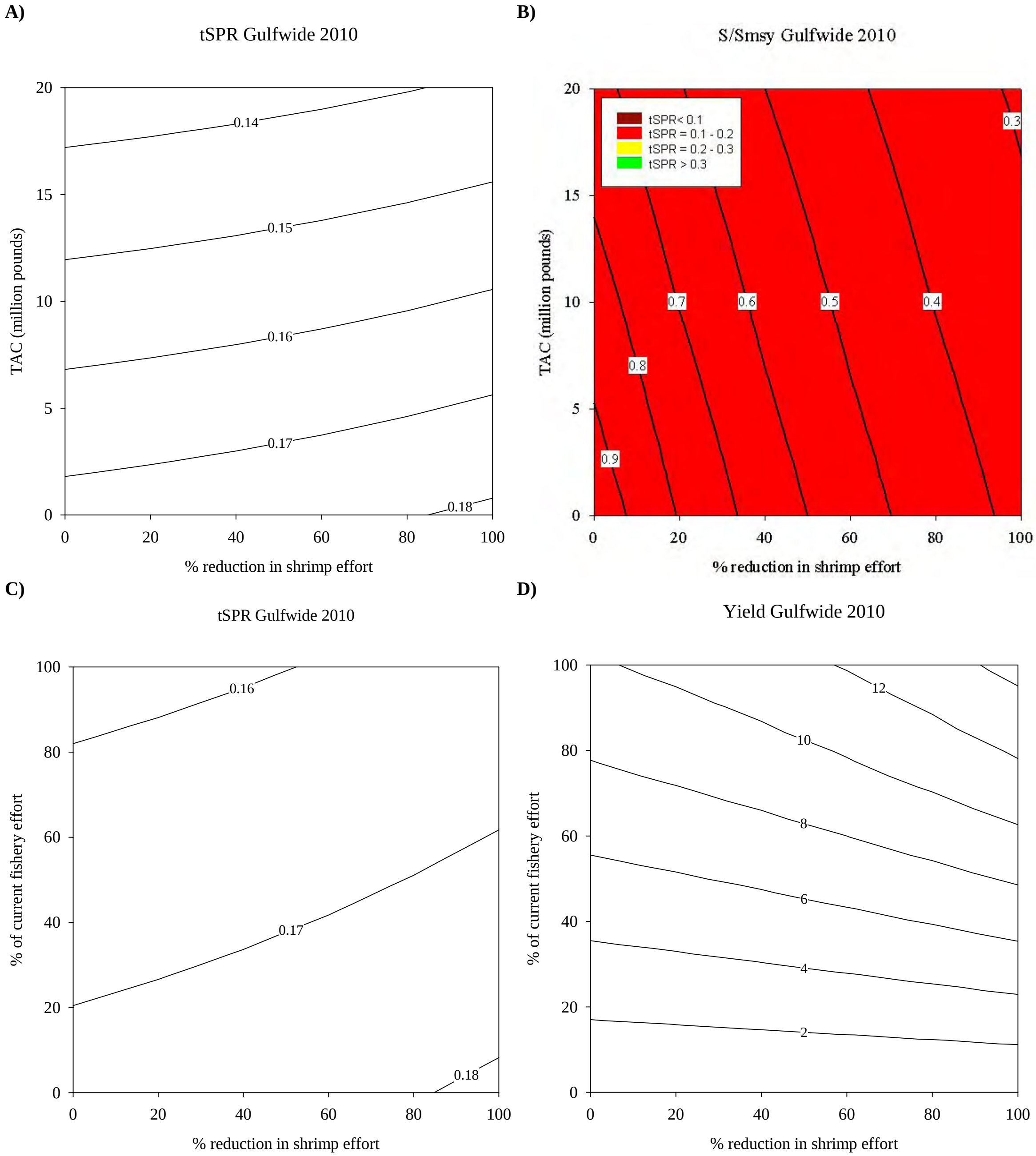


Figure 9. Projected isopleths of tSPR, SS_{2010}/SS_{MSY} and yield in the year 2010 assuming steepness -= 0.90. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2010}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2010} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1984-2003; High Mortality (M_1 = 0.59)
Steepness = 0.90

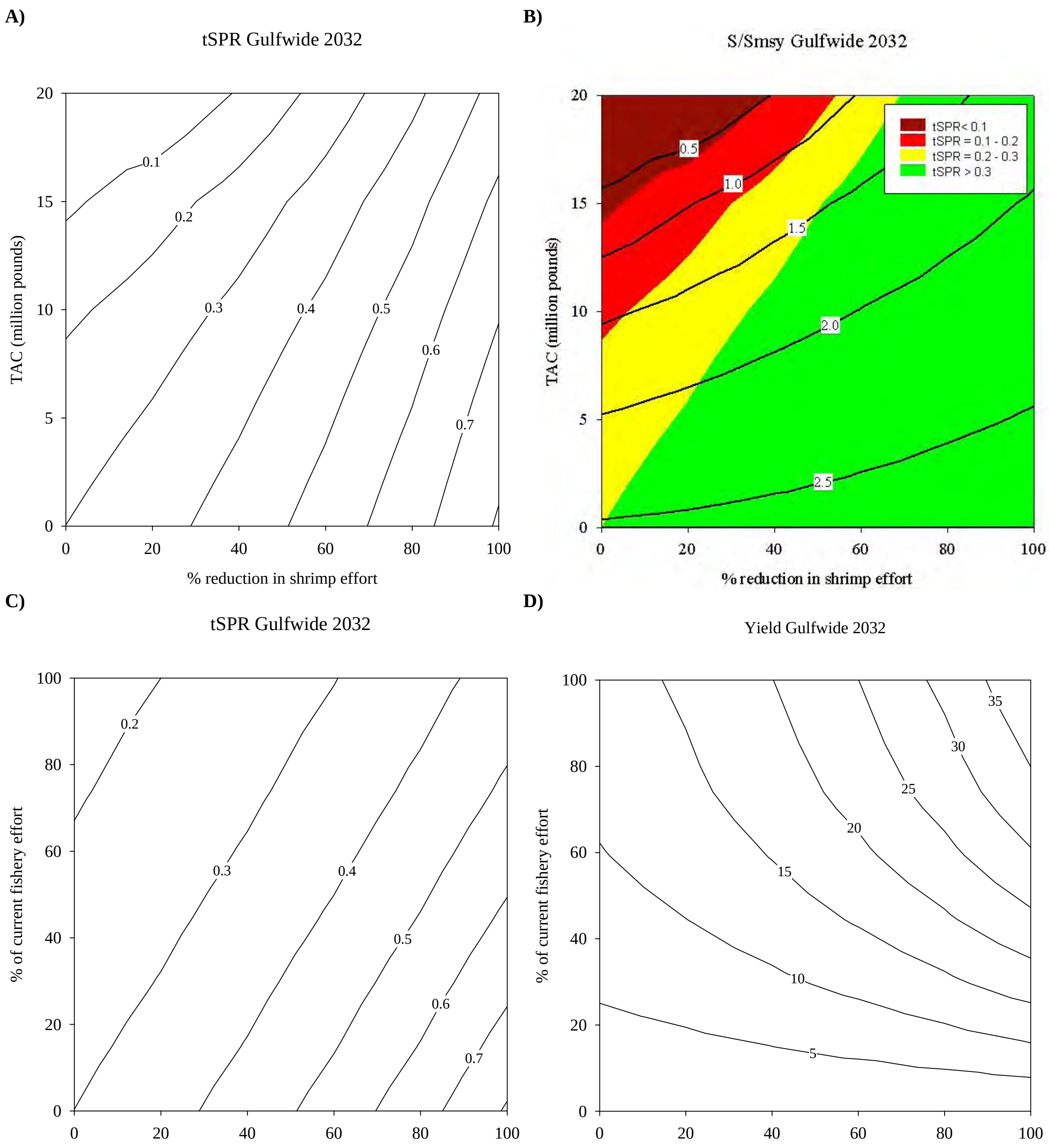


Figure 10. Projected isopleths of tSPR, SS_{2032}/SS_{MSY} and yield in the year 2032 assuming steepness -= 0.90. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2032}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2032} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1984-2003; High Mortality ($M_1 = 0.59$)
Steepness = 0.95

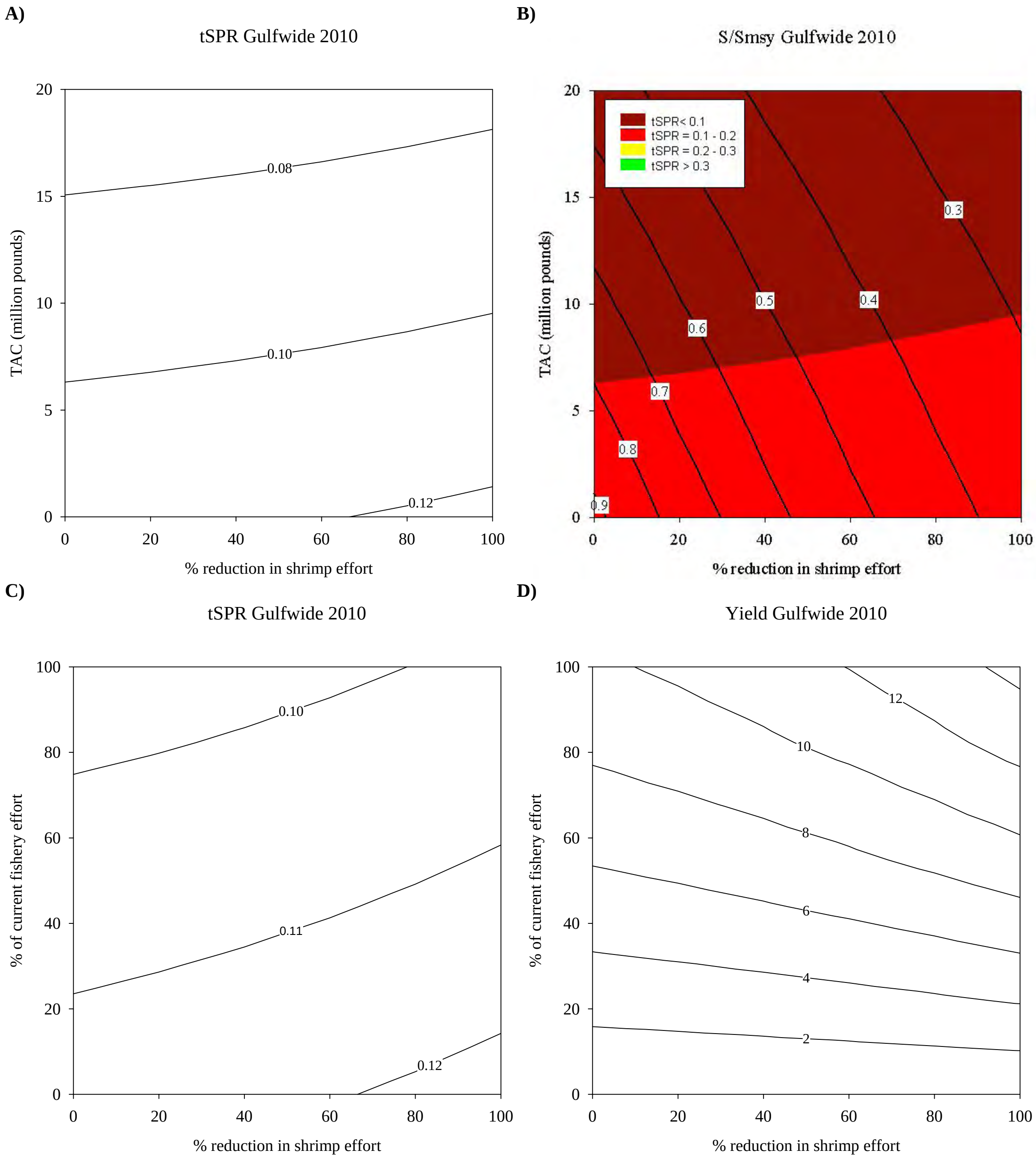


Figure 11. Projected isopleths of tSPR, SS_{2010}/SS_{MSY} and yield in the year 2010 assuming steepness -= 0.95. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2010}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2010} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Gulfwide ASAP 1984-2003; High Mortality ($M_1 = 0.59$)
Steepness = 0.95

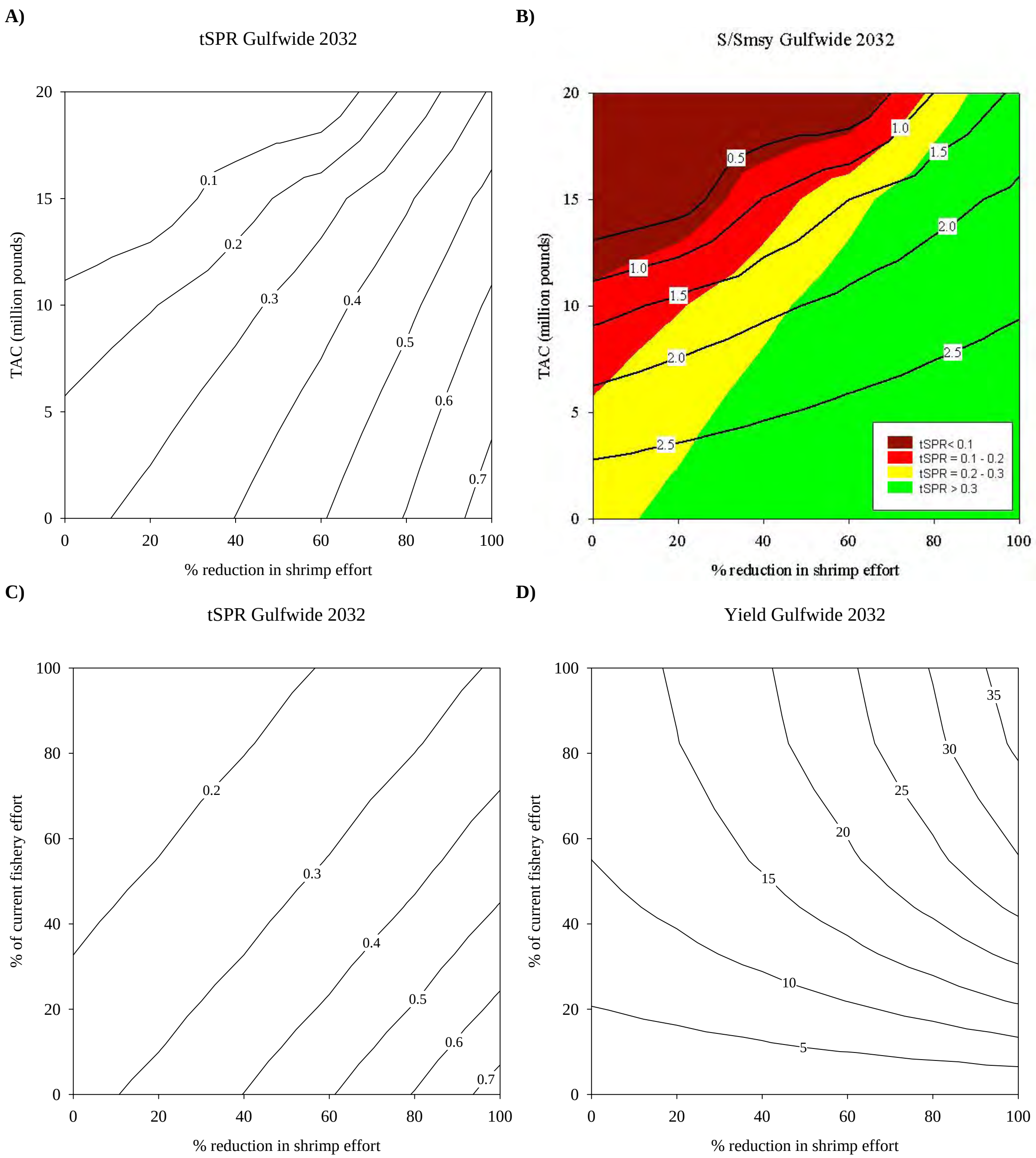


Figure 12. Projected isopleths of tSPR, SS_{2032}/SS_{MSY} and yield in the year 2032 assuming steepness -= 0.95. **Panels A and B:** Isopleths of tSPR **(A)** and SS_{2032}/SS_{MSY} with tSPR overlaid **(B)** as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated MSY_{2032} increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR **(C)** and yield in millions of pounds **(D)** as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

Addendum 5. ASAP East & West projections.

Projections of the East and West Gulf of Mexico red snapper stocks were carried out for the ASAP model evaluations. Two main groups of projections are presented: a) projections under a constant catch quota (TAC) and different levels of shrimp bycatch fishing mortality reduction, and b) projections under a constant fishing mortality of the directed fisheries and different levels of shrimp bycatch F reduction.

The projections discussed here corresponded to ASAP model assessments which considered catch and effort data starting in 1962 and ending in year 2003, with projections beginning in 2004 through 2032. For the period of 2004 through 2006, a Gulf-wide directed fishery TAC of 9.12 million pounds was equally split between East and West fisheries, while the current fishing mortality rates (averaged over the last three years of the assessment) were applied for the non-directed fisheries (shrimp bycatch and closed season). Beginning in year 2007 the different projection scenarios were then implemented. The mortality rates associated with closed season discarding in the recreational and commercial fishing sectors were held at the current levels throughout the projection period, as it is unclear what future scenarios would result under different management regimes. Projections were done for three levels of assumed steepness in the stock-recruitment relationship for both eastern and western stock assumptions (values of 0.81, 0.90, and 0.95 were applied), and assuming a high natural mortality vector (Age 0 = 0.98, Age 1 = 0.59, Age 2+ = 0.1). It is important to point out that these projections as well as the ASAP assessment treat the East and West GOM red snapper as completely independent stocks, with not relation between them at all what so ever. This is completely different modeling approach as the CATCHEM model program, which also considers East and West GOM red snapper evaluations (Ref).

For the East stock, projections of constant harvest were implemented for TACs of 0, 2, 4, 6, and 8 million pounds, with reductions of shrimp bycatch of 0, 20, 40, 60, 80 and 100% compared to the average of the most recent 3-year (2001-2003) estimated levels. Because the stock evaluations indicated higher overall productivity in the west, for the West stock, projections of constant harvest were implemented for TACs of 0, 2, 4, 6, 8, 10, 12, 14 and 18 MP, with reductions of shrimp bycatch from 0, 20, 40, 60, 80 and 100%. For both stocks, projections of directed fishery mortality rates were also conducted over the range of status quo levels to 0. The results of these projections were then contoured to provide a basis for interpolating projection outcomes over the range of catch, directed effort, and bycatch reduction levels specified.

Results and Discussion

Reinstating the assessment general results, the analysis of East and West independent stocks with ASAP indicated that the West stock is much more larger than the East component, about 6 to 7 times larger, depending on the assumed steepness (See table # Report ###). This is due primarily to the comparatively large shrimp bycatch observed in the West GOM compared to the East. Thus, everything else equal, the ASAP model interprets that the West stock must be much greater in biomass as a stock in order to produce the observed bycatch levels, particularly in the early years (1962-1975). This of course is also reflected in the projections of the East and West stocks. Overall, the East stock is over-exploited, with lower spawning stock compared to MSY levels (SS/SS_{MSY}), and low spawning potential ratios (transitional SPR) at the end of 2003, particularly for the assumed higher steepness (0.95) runs. For the West stock, at 2003 the stock is overexploited, with spawning stock below to MSY levels (SS/SS_{MSY}), and spawning potential ratios between 33% and 9% (depending on assumed steepness). However for the West stock, ASAP results indicated that the directed fishing mortality rates are low and shrimp bycatch is the main mortality component in this stock. Also, estimates of MSY for the west stock are much greater than any catch observed historically.

Projection results are grouped by the assumed steepness (0.81, 0.90, 0.95) and by year 2010 and 2032 (Figures 1 to 6). In general, reduction of shrimp bycatch has a larger effect in the West compared to the East stock. The slopes of the tSPR isopleths in the West are much higher than in the East, particularly at 2032. Assumed steepness has also an impact in the current status and projections of the East and West stocks. The East stock, at the lower steepness (0.81, 0.90) show higher tSPR values in 2010 and 2032 compared to the high steepness (0.95) projections. For the East stock Spawning stock would reach SS_{MSY} levels in 2032 with a 4 MP TAC and no bycatch reduction, or 5 MP TAC and 100% reduction of bycatch, at the 0.95 assumed steepness (Fig 6), however at this levels, still tSPR would be below 20%. Yield isopleths indicated that greater catches will be likely at about 70% of current directed fishing rates and complete reduction of shrimp bycatch (Fig 6). Under the lower steepness assumption (0.90 and 0.81), the East stock could reach SSMSY levels in 2032 with TAC between 4.5 and 5.8 MP and no bycatch reduction. However in these cases, tSPR is higher, above 20%.

For the West stock, projections indicated that it can support greater yields in the order of 20 to 30 MP depending on the assumed steepness. Higher yield would be expected with higher shrimp bycatch reductions. West spawning stock biomass in 2032 would be above SS_{MSY} levels at any steepness, with TACs below 18 MP and no bycatch reduction, and tSPR levels would also be above 30%. Estimates of MSY change with shrimp bycatch reduction. Estimated MSY increases as shrimp bycatch decreases. Estimates of SS_{MSY} and the corresponding fishing mortality benchmarks are also recalculated. During the projections, implementation of TAC and shrimp bycatch reduction takes place in 2007. Therefore, the results in 2010, only three years later, , reflect transitional effects of the stock. For example the 2010 SS/SS_{MSY} isopleths show a different trend than the 2032 SS/SS_{MSY} isopleths. The 2010 plots indicate that higher SS/SS_{MSY} ratios are achieved by decreasing TAC and maintaining current shrimp bycatch levels. While in 2032, plots indicate that higher SS/SS_{MSY} ratios are achieved by decreasing TACs and reducing shrimp bycatch effort. This occurs because SS_{2010} is relatively similar among the different shrimp bycatch reduction projection scenarios, (only three years after the scenario is implemented) while the target value, in this case $SS_{MSY,}$ increases substantially as shrimp bycatch effort decreases. Therefore the ratio SS_{2010}/SS_{MSY} is greater for high bycatch levels simply because the denominator is smaller. When the stock has passed several years, so that the dynamic equilibrium is reached (2032), then the trends of the isopleths reflect the true effects of bycatch reduction and constant catch projections.

Stock assessment and projection results of East and West stocks with the current ASAP program are sensitive to initial conditions and user settings regarding relative weighting factors, as indicated in the manual (Legault and Restrepo 1998).

Steepness 0.81 2010

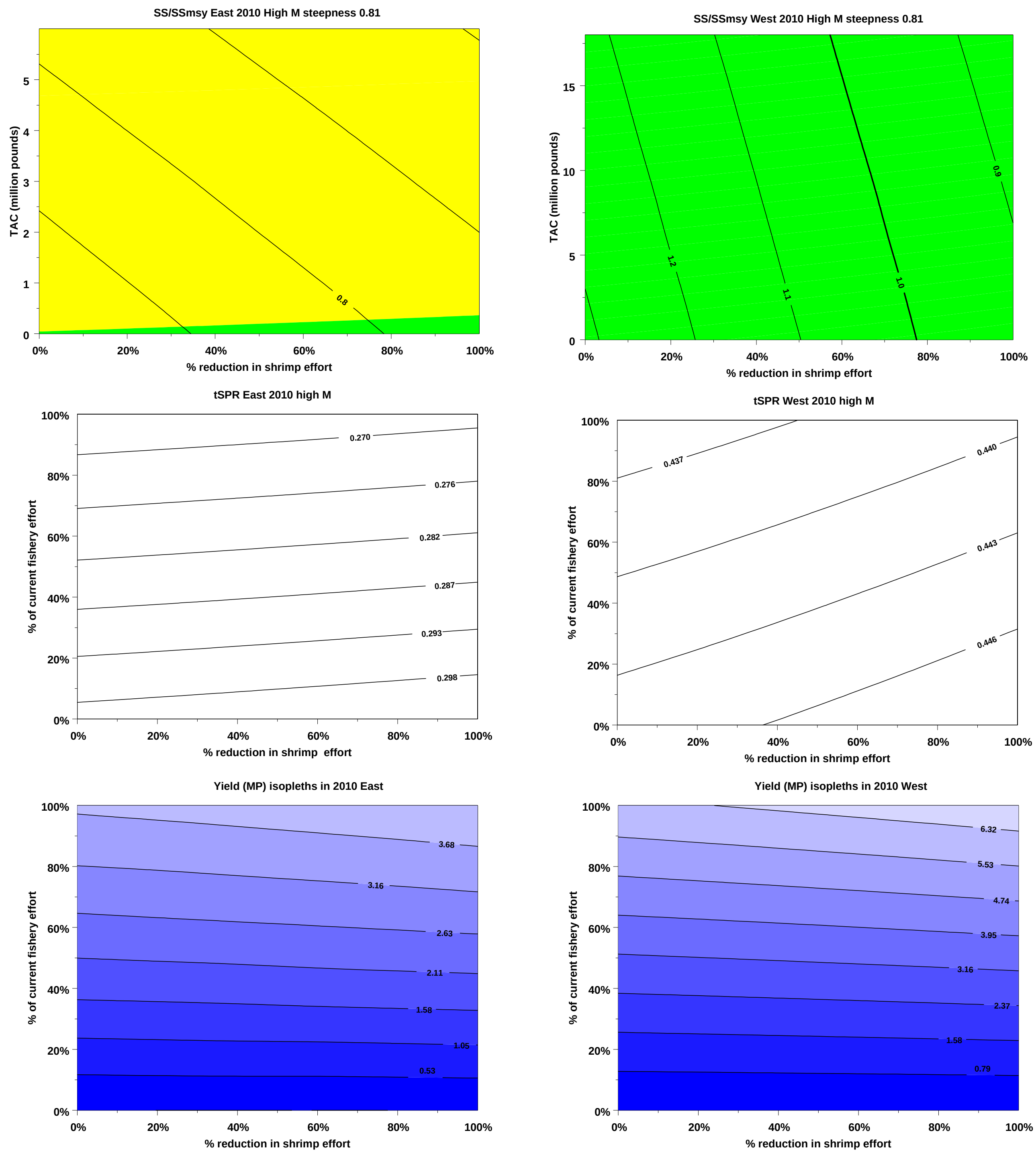


Figure 1. Top row: Isopleths of number of spawners in 2010 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.81.

Steepness 0.81 2032

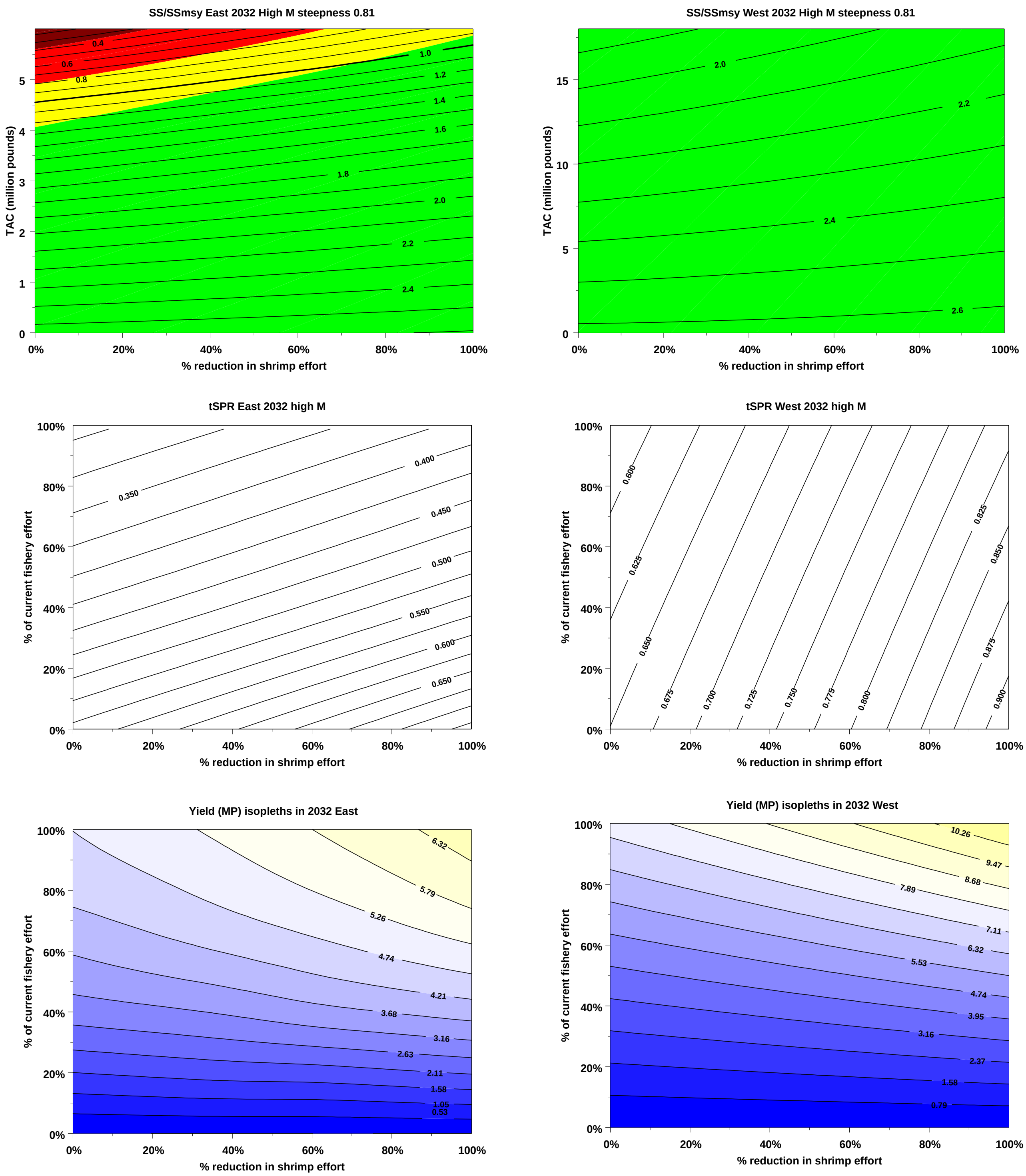


Figure 2. Top row: Isopleths of number of spawners in 2032 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.81.

Steepness 0.90 2010

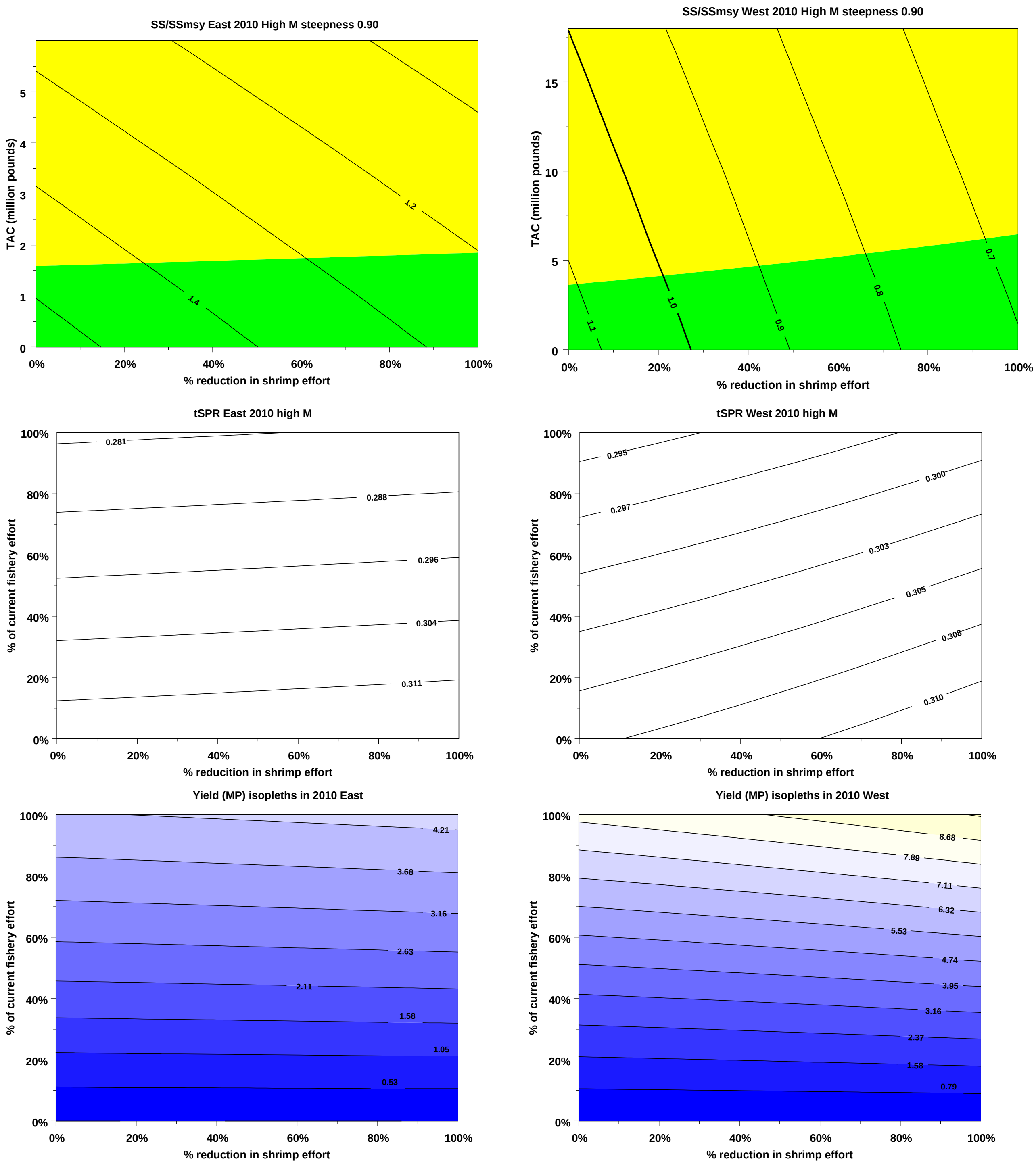


Figure 3. Top row: Isopleths of number of spawners in 2010 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.90.

Steepness 0.90 2032

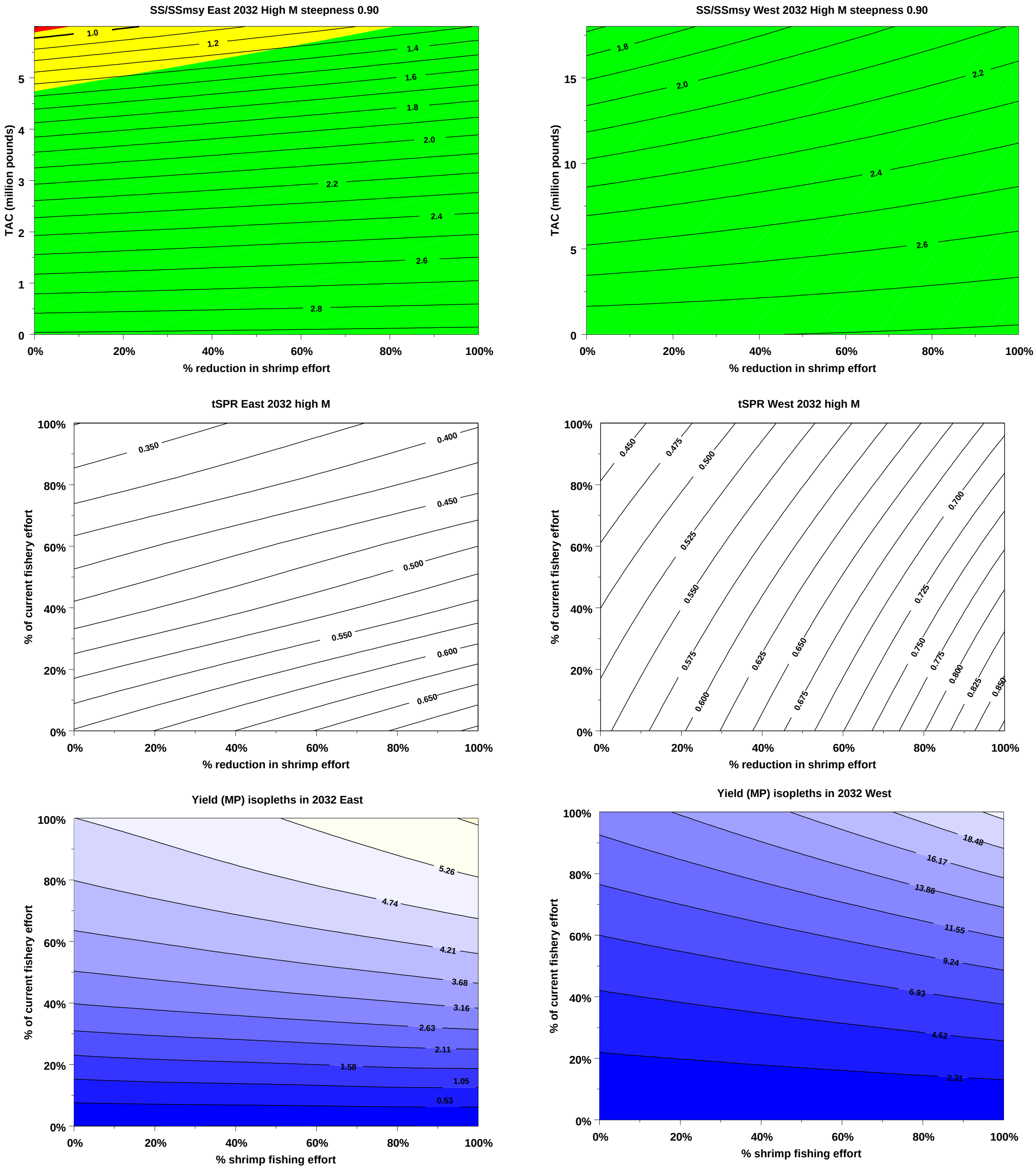


Figure 4. Top row: Isopleths of number of spawners in 2032 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.90.

Steepness 0.95 2010

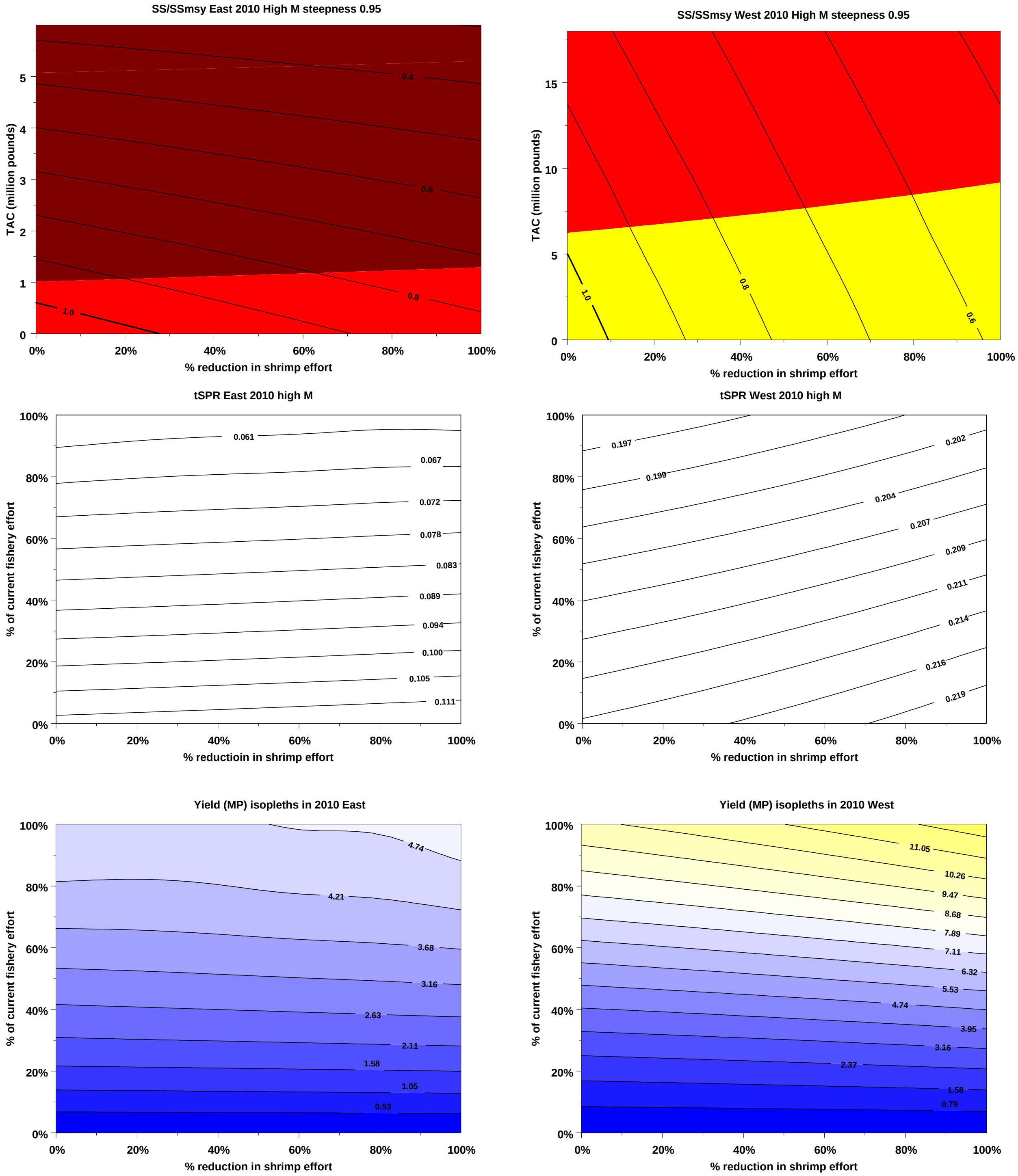


Figure 5. Top row: Isopleths of number of spawners in 2010 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.95.

Steepness 0.95 2032

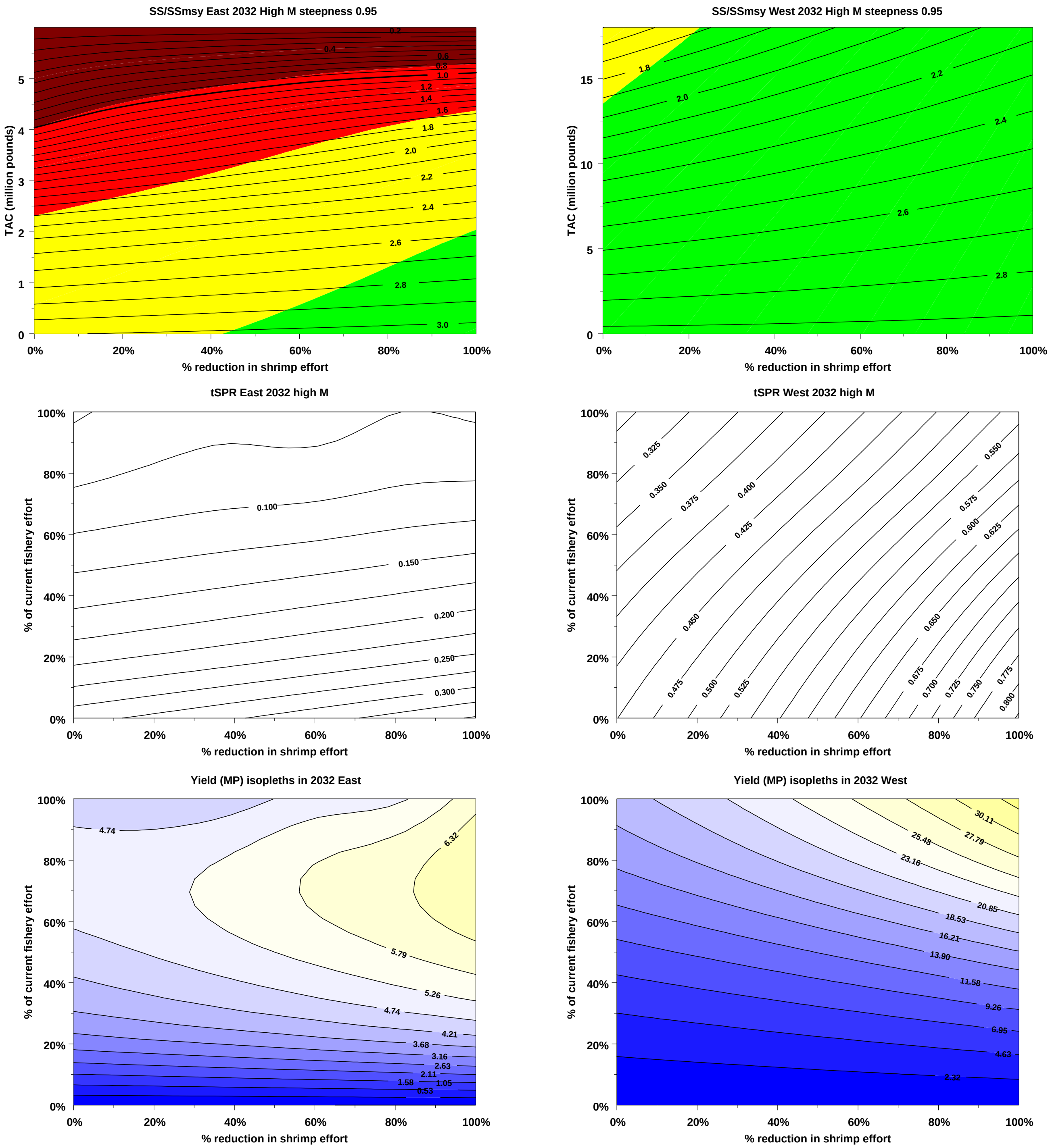


Figure 6. Top row: Isopleths of number of spawners in 2032 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.95.

Appendix 6. VPA Projection Results

Methods

A 2-fleet, tuned VPA was implemented, where the catch at age (CAA) for fleet 1 represented total directed catch and discards for Handline, Longline, and Recreational fisheries, and fleet 2 represented shrimp bycatch. Modeled ages were 0-15+ or 1-15+. Natural mortality at age was: M_0=1.0, M_1=0.6, $M_{2\text{-}15+}$=0.1. A moderate penalty was imposed to link selectivities ($s_{a,y}$) in the final 3 years. The estimate of annual fishing on the oldest age group ($F_{15+,y}$) was constrained to be equal to the estimate of $F_{14,y}$ for all years. Five regional indices (units) were used for tuning, where the region was Gulfwide, Eastern Gulf, or Western Gulf: MRFSS (numbers), Video (numbers), Larval (reproductive biomass—used as index of SSB), Fall Trawl Survey (numbers), Summer Trawl Survey (numbers). For cases where the modeled age of recruitment was 1, the Fall Trawl Survey was not used as it indexes age 0 fish. All indices were given equal weighting.

The VPA estimates of fishing mortality at age and year, and estimated abundance at age and year, were used in a set of factorial projections for the years 2004-2032. The following specifications were common to all projections:

- selectivity was fixed at the geometric mean of the last 3 years (2001-2003)
- with respect to benchmark estimation, all projections represent the "linked" scenario
- discard proportion for the directed fleet was fixed at the geometric mean of the last 3 years (2001-2003)
- the last 3 years of recruitments (2001-2003) were replaced with values predicted from the fitted Beverton-Holt
- F values in 2004-2006 were set to the 2003 estimates
- TAC, directed F, and bycatch reduction scenarios were implemented in 2007

Results

Updated benchmarks for the VPA projections are given in Table 1. Because the VPA modeling framework does not explicitly allow for closed seasons, the estimates of MSY include the weight of closed season discards by the directed fleet. Weights of 0 at all ages were specified for the shrimp bycatch fleet, so the MSY does not include any mass due to shrimp bycatch.

<u>Age 0</u>

Model responses to reduction in shrimp effort varied by region. Isopleths for transitional SPR (tSPR) were less steep in the east models, suggesting less sensitivity to reductions in shrimp effort. If half of the 9.12 million pound Gulfwide TAC (i.e. 4.56 mp) is applied in the east model, then shrimp effort would have to be reduced by about 60% to achieve a 20% tSPR by 2032 (Fig. 1, 2). A tSPR of 30% in 2032 is not achievable, even if shrimp effort were eliminated. With no shrimp reduction, a 4.56 TAC achieves 0.2 S/S_{MSY}, while a TAC of about 3 achieves S/S_{MSY}=1.0. The western gulf model suggests that the stock can support a larger TAC than the eastern gulf. If shrimp effort is eliminated, a TAC of up to 20 mp would achieve tSPR of 0.3; if shrimp effort is not reduced, a TAC of 12 mp achieves tSPR=0.2 by 2032. With no shrimp effort reduction, a TAC of about 5 mp achieves S/S_{MSY}=1.0. In the Gulf-wide model, a TAC of 9.12 mp yields tSPR values that are ≥0.3. With no shrimp effort reduction, a TAC of about 18 mp achieves S/S_{MSY}=1.0. (Fig. 1, 2).

With respect to isopleths where effort reductions in both fleets were explored, East model runs that apply 40-85% of current fishing effort would achieve tSPR in the range of 20-30% for all shrimp reduction scenarios (Fig. 3, 4). Current directed fishing effort would produce tSPR of 15-20% by 2032. The directed fishery realizes very little gain in yield from reducing shrimp effort if current fishing effort is reduced by half (or more)—even if shrimp effort is completely reduced. In the west, current directed fishing effort maintains tSPR ≥ 20% for all shrimp effort reductions. Fishing at levels less than 30% of current directed effort does not lead to substantial gains in yield from reduced shrimp effort. In the Gulf, current directed fishing effort maintains tSPR ≥ 20% for all shrimp effort reductions. Gains in yield resulting from reduced shrimp effort are marginal if fishing effort is less than 30% of current levels (Fig. 3,4).

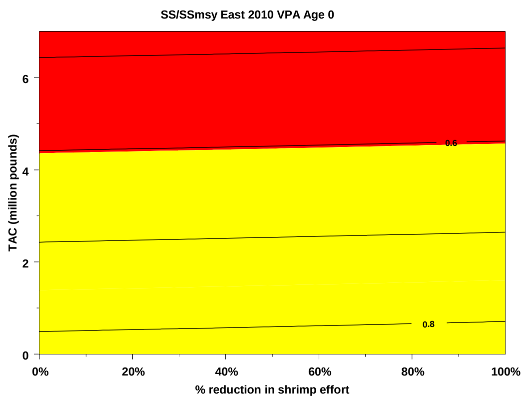
Age 1

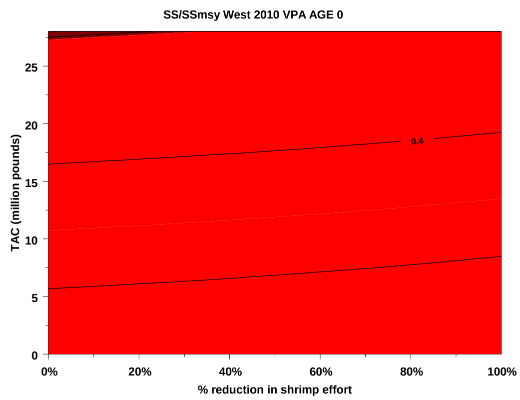
In the east, applying a TAC of 4.56 mp does not achieve a tSPR of 20% by 2032, although TACs in the range of 3-3.5 mp do (Fig. 5, 6). A TAC of <3 mp is needed to achieve S/S_{MSY}=1.0. In the west, a TAC < 11 mp always maintains tSPR ≥ 20%; larger TACs in the range of 12-15 mp are only possible with shrimp effort reductions > 40%. A TAC of approximately 7.5 mp is needed to achieve S/S_{MSY}=1.0. In the gulf-wide model, TACs in the range of 12.5-15.5 mp generally maintain tSPRs of 20-30%; larger TACs are possible only if shrimp effort is greatly reduced. A TAC of about 12 mp is needed to achieve S/S_{MSY}=1.0.

With respect to isopleths where effort reductions in both fleets were explored, East model runs with directed fishing at 80-85% of current levels would ensure tSPR ≥ 20% for all shrimp effort reduction scenarios, while fishing at <40% of current levels shows little gain in yield from shrimp effort reduction (Fig. 7, 8). In the west, current fishing effort can maintain tSPR of at least 20% for all shrimp effort reduction scenarios. Fishing at 40% or less of current levels shows little yield gain from shrimp effort reduction. In the gulf-wide model, current fishing effort can maintain tSPR of at least 20% for all shrimp effort reduction scenarios, while fishing at 40% or less of current levels does not show substantial yield gains from reduced shrimp effort.

Table 1. Benchmarks for VPA runs.

MEASURE	Gulf age 0 high M R0 est	East age 0 high M R0 est	West age 0 high M R0 est	Gulf age 1 high M R0 est	East age 1 high M R0 est	West age 1 high M R0 est
F at MSY	0.33	0.20	0.41	0.44	0.29	0.52
MSY	27100	4183	13710	13990	3041	8992
Y/R at MSY	0.23	0.33	0.20	0.66	0.84	0.52
S/R at MSY	0.39	0.38	0.38	0.97	0.85	0.97
SPR AT MSY	0.34	0.33	0.33	0.32	0.28	0.32
SSB AT MSY	45390	4855	26280	20790	3074	16730
F at max. Y/R	0.35	0.23	0.41	0.44	0.29	0.52
Y/R max.	0.24	0.33	0.20	0.66	0.84	0.52
S/R at Fmax	0.37	0.32	0.38	0.97	0.85	0.97
SPR at Fmax	0.32	0.28	0.33	0.32	0.28	0.32
SSB at Fmax	42580	4032	26280	20790	3074	16730
F 0.1	0.27	0.17	0.32	0.34	0.22	0.40
Y/R at F0.1	0.23	0.32	0.19	0.64	0.81	0.51
S/R at F0.1	0.48	0.44	0.49	1.27	1.17	1.26
SPR at F0.1	0.42	0.38	0.43	0.42	0.38	0.41
SSB at F0.1	56040	5714	33810	27090	4221	21700
F 20% SPR	0.50	0.29	0.60	0.63	0.37	0.72
Y/R at F20	0.22	0.32	0.18	0.62	0.82	0.50
S/R at F20	0.23	0.23	0.23	0.61	0.62	0.64
SSB at F20	25740	2731	15990	13100	2229	10900
F 30% SPR	0.37	0.22	0.45	0.46	0.27	0.55
Y/R at F30	0.23	0.33	0.20	0.65	0.84	0.52
S/R at F30	0.34	0.35	0.34	0.92	0.92	0.92
SSB at F30	39550	4362	23900	19620	3333	15790
F 40% SPR	0.28	0.16	0.34	0.35	0.21	0.42
Y/R at F40	0.23	0.32	0.19	0.64	0.80	0.51
S/R at F40	0.46	0.46	0.46	1.22	1.23	1.23
SSB at F40	53480	5993	31890	26140	4446	21050





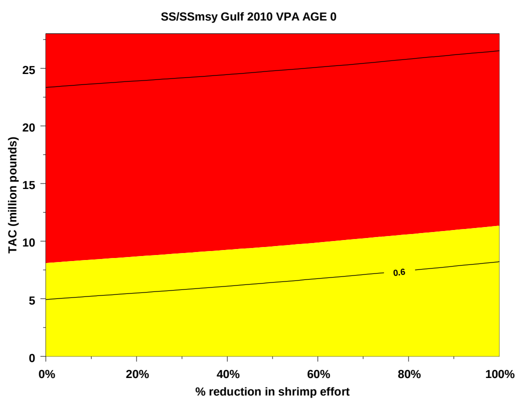


Figure 1. Projected isopleths of tSPR, $SS./SS_{MSY}$ resulting from TAC on the directed fishery and effort reduction for the shrimp fishery. Color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR >0.3. $SS./SS_{MSY}$ is overlayed as lines on the color contours.

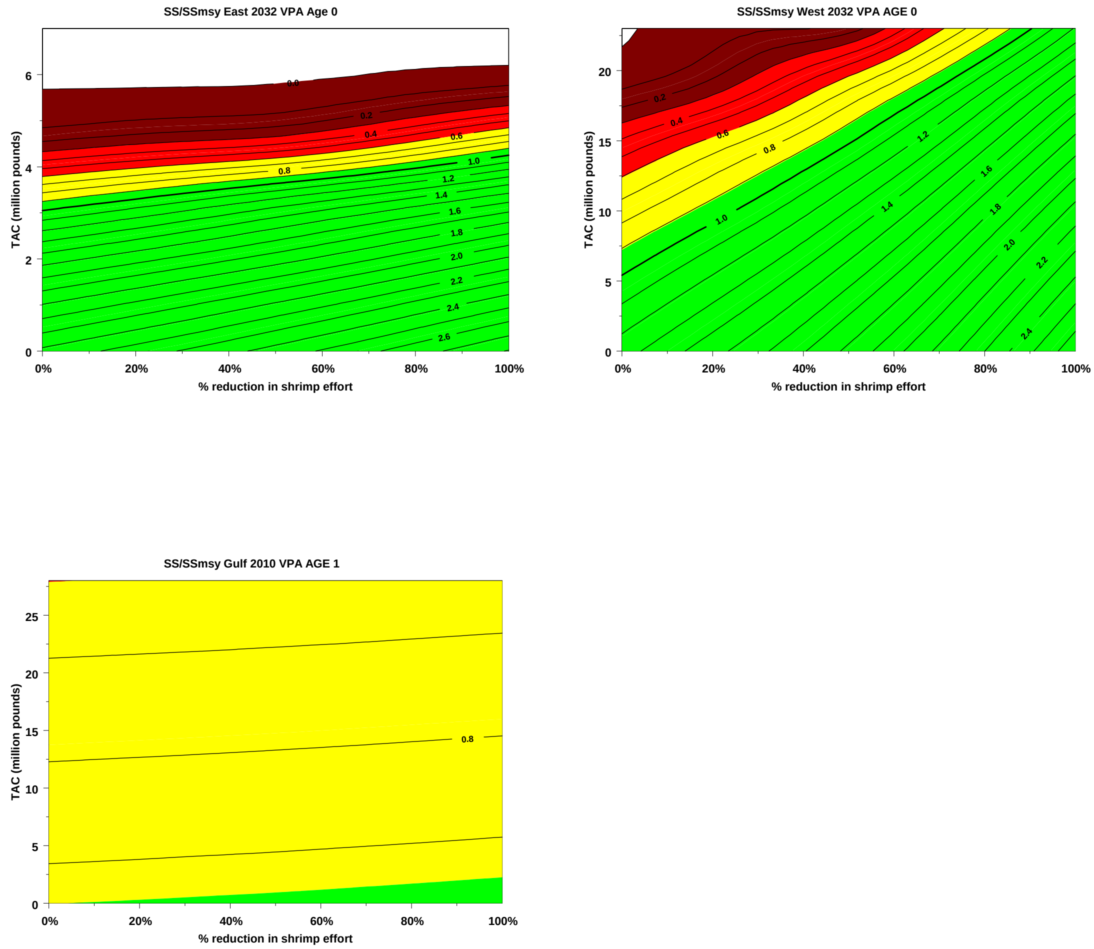


Figure 2. Projected isopleths of tSPR, SS./SS_{MSY} resulting from TAC on the directed fishery and effort reduction for the shrimp fishery. Color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR >0.3. SS./SS_{MSY} is overlayed as lines on the color contours.

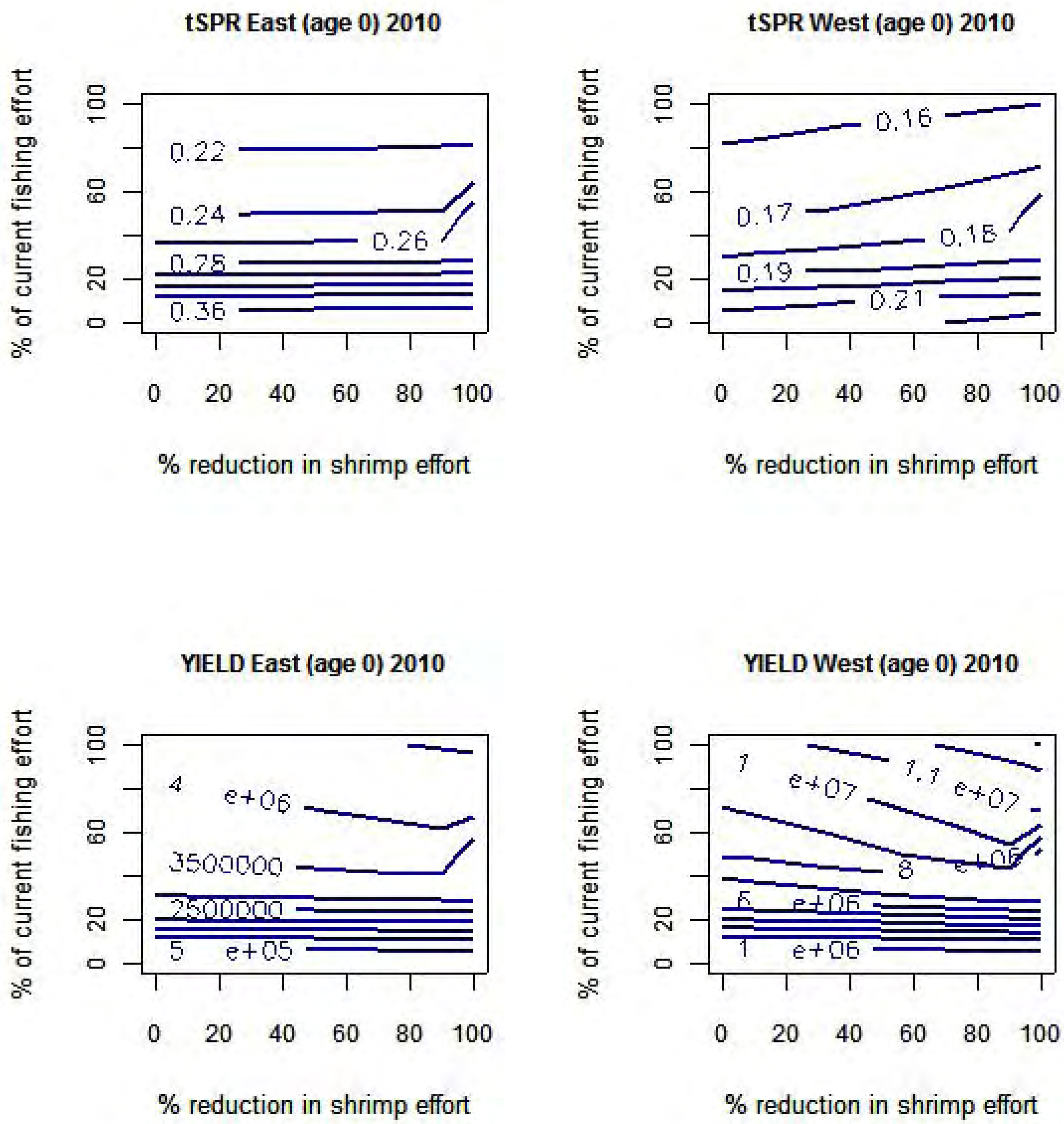
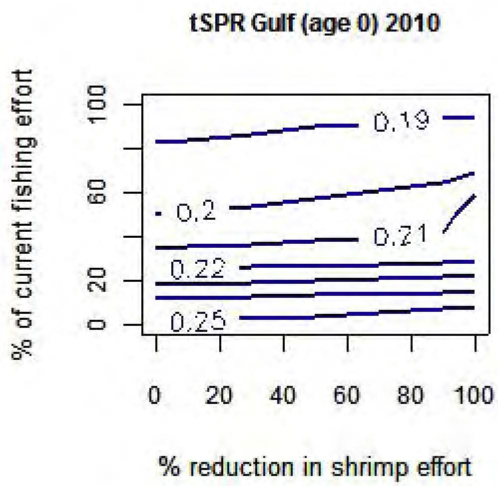
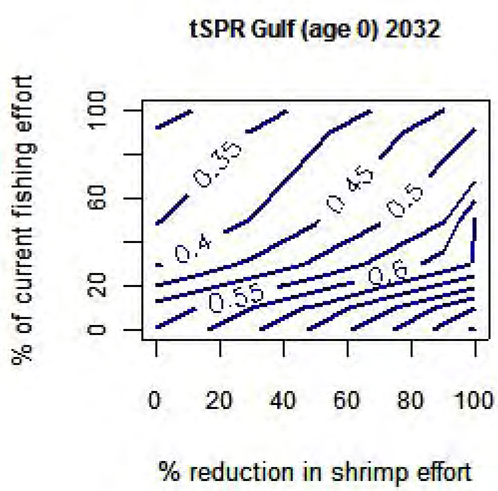


Figure 3. Projected isopleths of tSPR and yield to the directed fishery resulting from reductions in effort by the directed fishery and the shrimp fishery.





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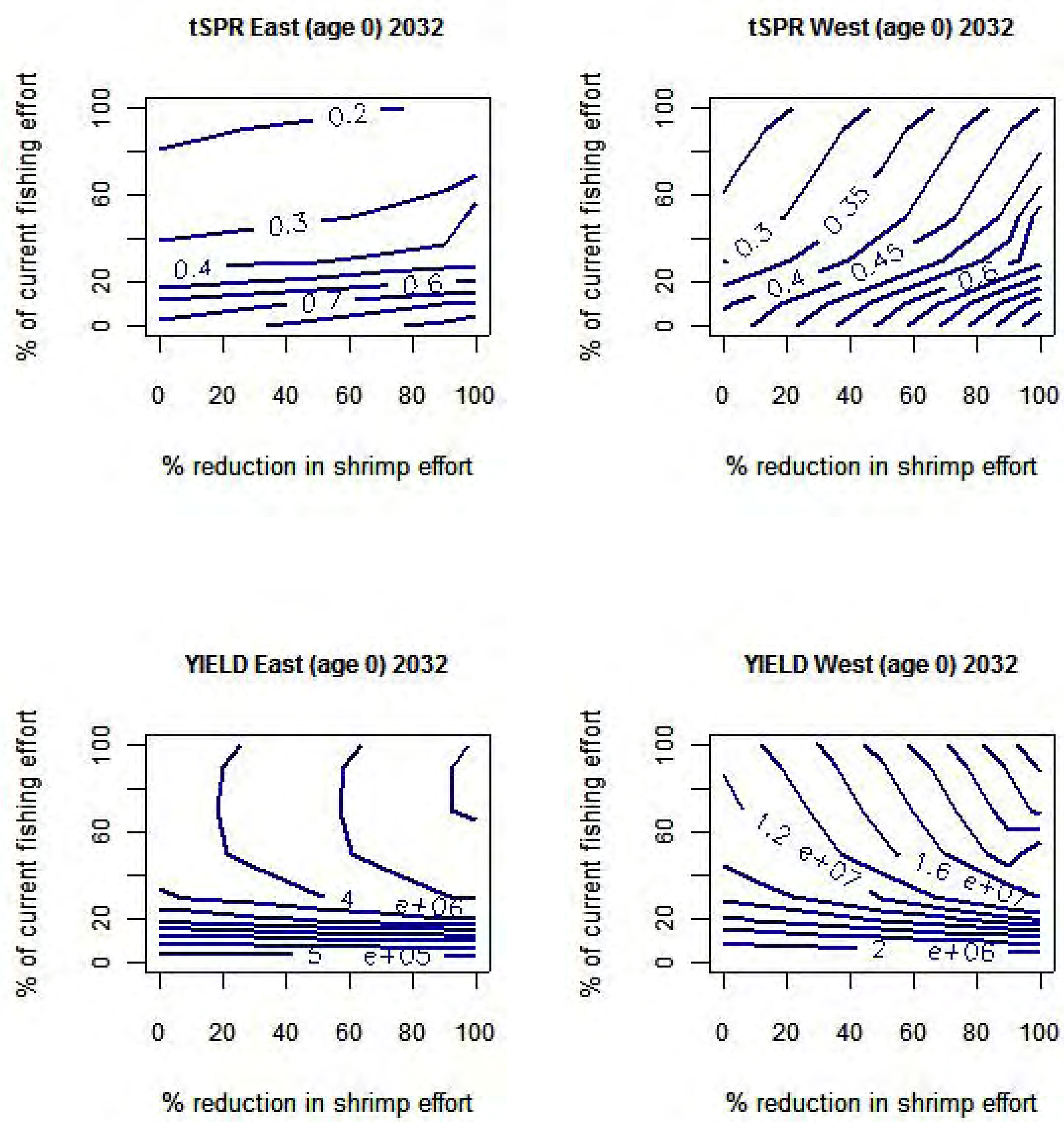
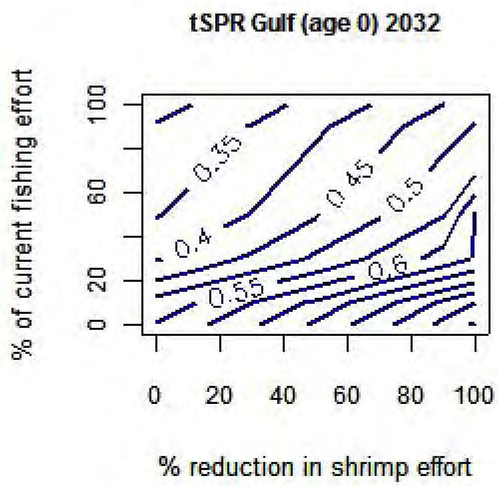
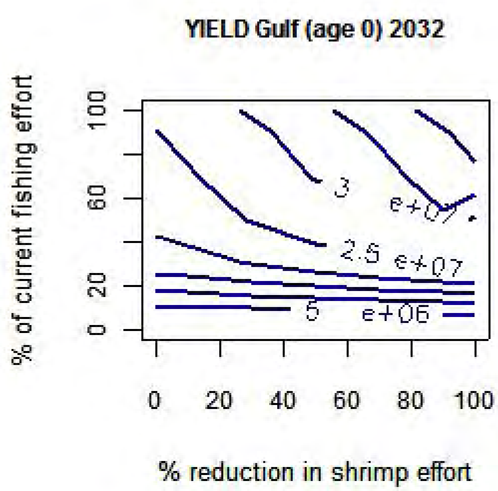


Figure 4. Projected isopleths of tSPR and yield to the directed fishery resulting from reductions in effort by the directed fishery and the shrimp fishery.





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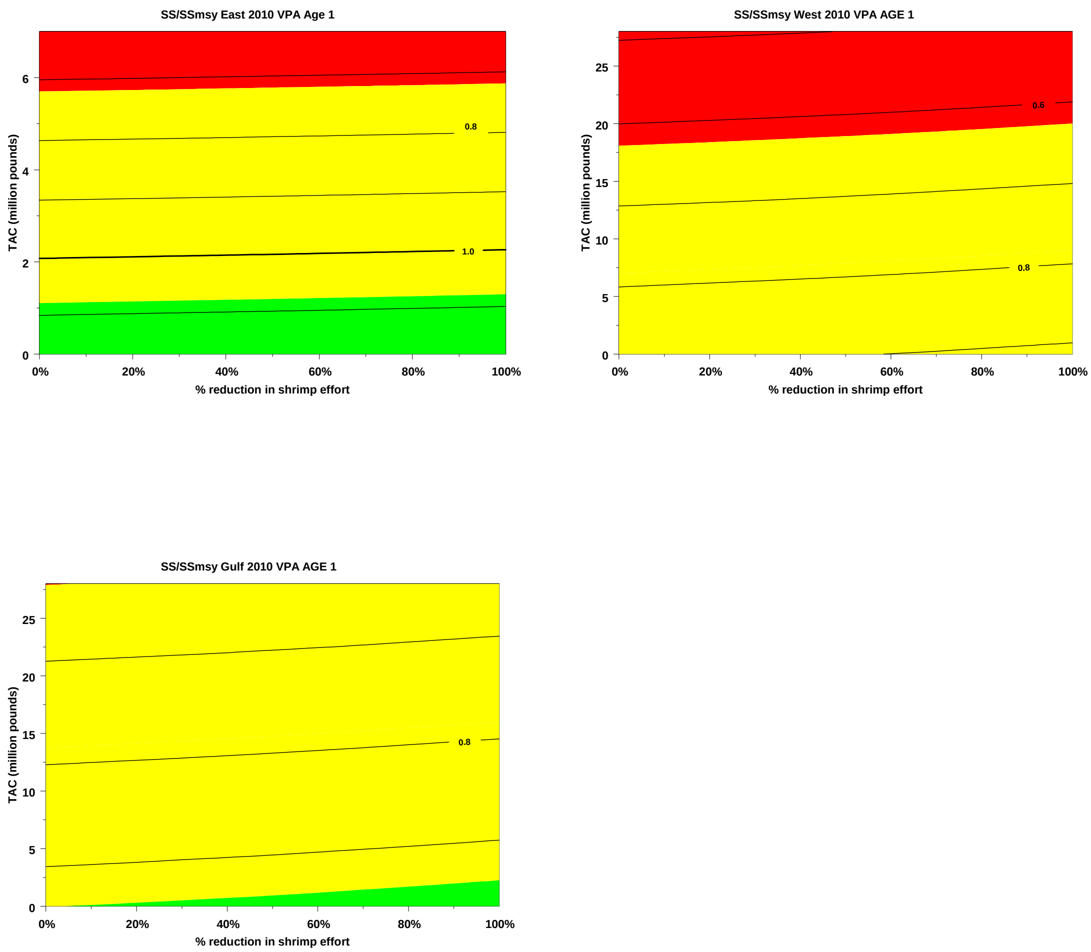
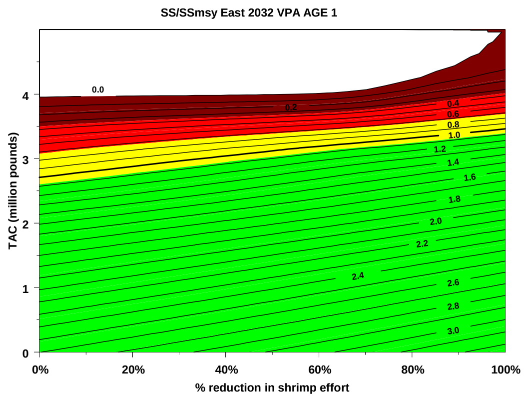
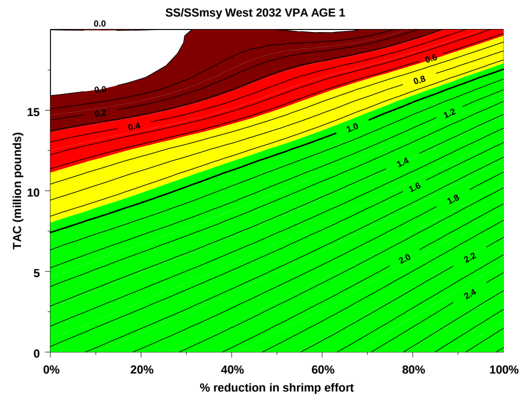


Figure 5. Projected isopleths of tSPR, SS./SS_{MSY} resulting from TAC on the directed fishery and effort reduction for the shrimp fishery. Color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR >0.3. SS./SS_{MSY} is overlayed as lines on the color contours.





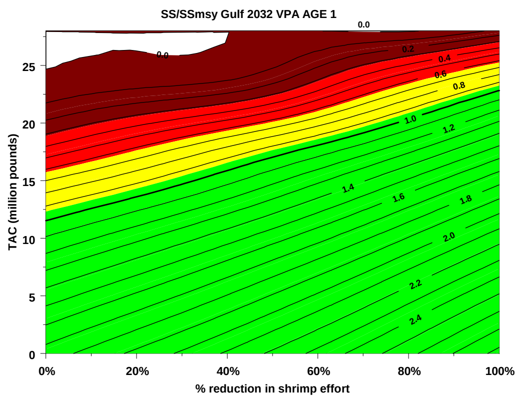


Figure 6. Projected isopleths of tSPR, SS./SS_{MSY} resulting from TAC on the directed fishery and effort reduction for the shrimp fishery. Color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR >0.3. SS./SS_{MSY} is overlayed as lines on the color contours.

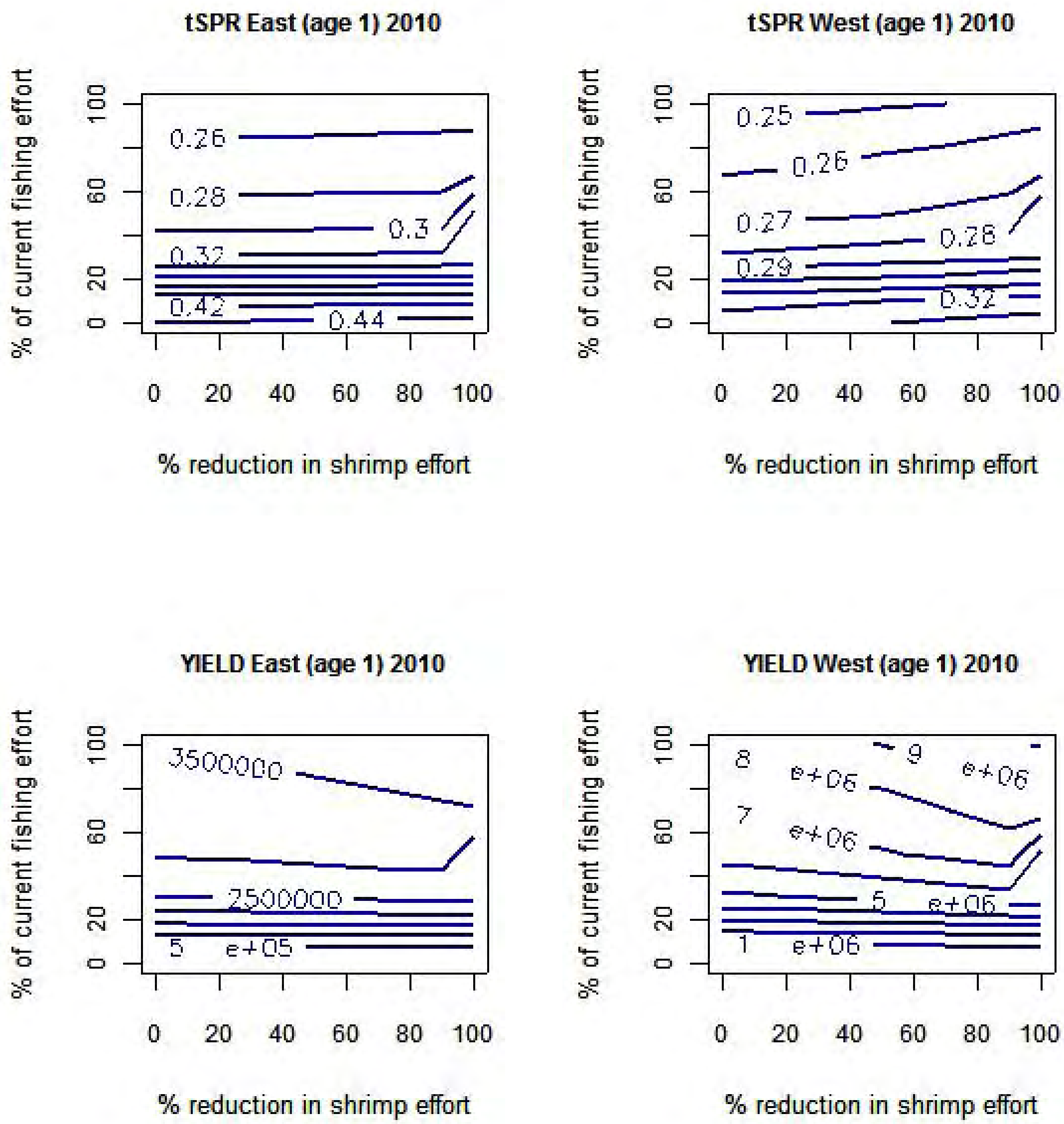
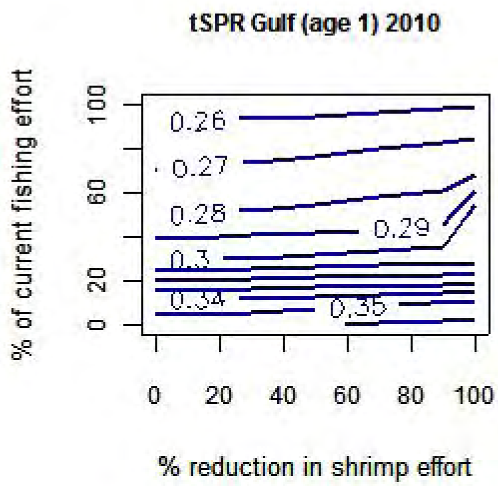
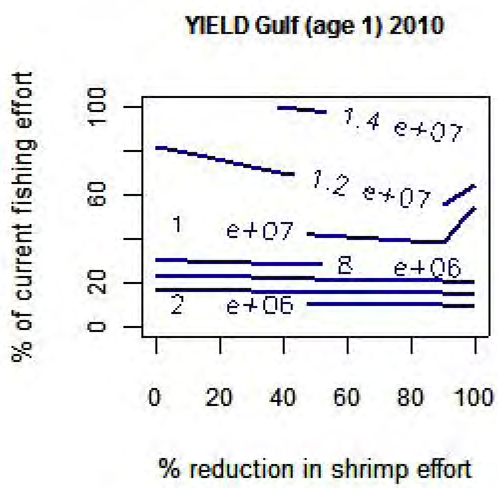


Figure 7. Projected isopleths of tSPR and yield to the directed fishery resulting from reductions in effort by the directed fishery and the shrimp fishery.





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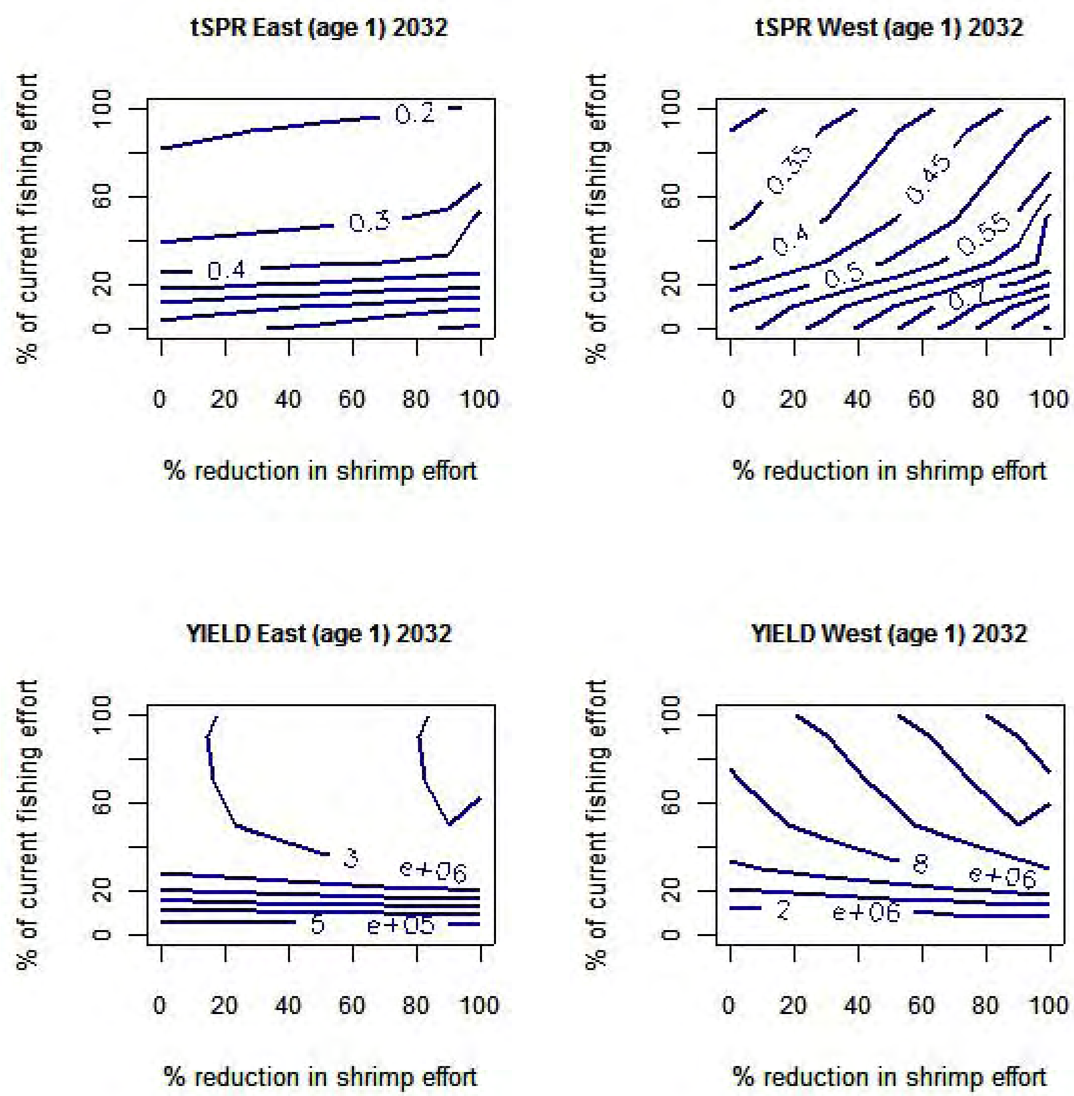
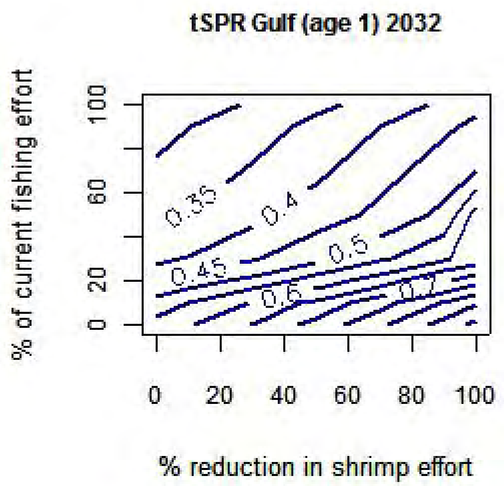
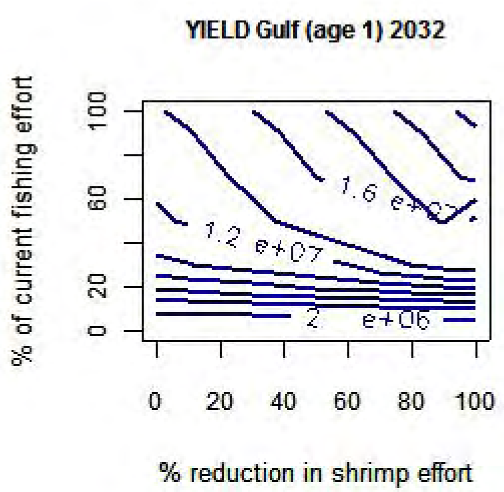


Figure 8. Projected isopleths of tSPR and yield to the directed fishery resulting from reductions in effort by the directed fishery and the shrimp fishery.





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Appendix 7. SRA results

Stock Reduction Analysis (SRA) Model: A brief description and summary of results for Gulf of Mexico red snapper

Provided by Murdoch McAllister

The description of the SRA model and summary of results is provided at the request of the red snapper SEDAR assessment group because it is one of the several models considered for the stock assessment.

The stock reduction analysis does the following.

1. The method starts the population at projected unfished conditions (based on data derived from historical documents dating back to 1872) and projects the population to the present time taking into account the fishery removals from the population.

2. The model uses a stock-recruit function that can incorporate density dependence in survival rates for the juvenile phases of the fish's life history. Density dependence can be specified to occur just before the shrimp trawl bycatch of age-0 fish, just after the first six months after emergence (called age-1), or just after the first 18 months following shrimp trawl bycatch of age 1 fish (called age-2).

3. The model requires life history parameter inputs such as mass at age, fecundity at age, steepness in the stock-recruit function and natural mortality rate at age which are provided by NMFS and agreed to by SEDAR participants

4. The model requires fishery inputs such as observed bycatch, landings for recreational and commercial fisheries, out of season discards for recreational and commercial fisheries, selectivity at age for each of the different fisheries modelled, including the selectivity of discarded fish, relative to the landed fish. Selectivity at age for shrimp trawl bycatch has been computed separately for the years before 1999 and then after 1999 to take into account the introduction of bycatch reduction devices late in 1998. These are provided by NMFS and agreed to by SEDAR participants.

5. The model can be fitted to relative abundance indices by estimating average unfished recruitment (R_0) and the constants of proportionality (i.e., factors that scale model predicted abundance to each abundance index) for each index of abundance. The model finds the best fit of the predicted abundance trends to the observed abundance trends. Catch-age estimates of stock-recruit deviates can also be included to account for variation in cohort strength. The model can also be constrained to fit recent estimates of fishing mortality rates obtained from other analyses (e.g., ASAP, CATCHEM).

6. Density-dependent survival rate implies that the average survival rate of individuals of a given age group in a population depends on the abundance of conspecifics of that age group; higher abundance will tend to lower the survival rate for example due to increased exposure to predation when the availability of hiding spots is limited. When density dependent survival rate is specified to occur at either age-one or two years the model calculates density independent survival of eggs to age-0 just at settlement and applies the density-independent rates of natural mortality for each age that have been previously specified in the data workshop. The model uses the initial slope of the stock recruit function under the age-0

density dependent scenario to obtain the number of age-0 fish in models with density dependence at either age-1 or 2 years. This permits the model to account for shrimp bycatch removals, directed fishery bycatch and natural mortality regardless of the age at which density dependence is assumed to occur.

7. Once a value for R_0 is obtained, the model can be projected from unfished conditions in 1872 to the present and then from the present into the future to evaluate the potential consequences of alternative fishery management options.

<u>The general advantages of the stock reduction analysis are as follows</u>:

1. The model runs very fast (a few seconds to do an estimation and projection) and permits a "gaming" approach in which a large variety of model assumptions and input settings can be efficiently evaluated. This is facilitated because the model has on-screen graphics to show the fit of the model to the abundance indices and the results of model projections. This permits quick learning about the sensitivity of assessment model results to different input assumptions.

2. The model permits an evaluation of the plausibility of stock-recruit parameter estimates obtained in catch-age analyses of the last few decades in over a century of exploitation of this fish stock. Specifically, the appropriateness of specific catch-age estimated R_0 and steepness values can be evaluated based on the criteria that subsequent model outputs should be consistent with the historical record. For example, if the modelled stock hardly depletes at all with these inputs, this model prediction is inconsistent with the high values of fishing mortality rate implied in the catch-age data and this provides reason to question the credibility of the catch-age stock-recruit parameter estimates and assumptions.

3. The model permits an evaluation of the credibility of alternative assumptions about where in the life history density dependence occurs. The model can be fitted to indices of abundance and catch-age fishing mortality rate estimates under the different assumptions about the ages of density dependence. The goodness of fits of the model to the data under the different assumptions about the age of density dependence can be assessed.

4. Because this model runs very fast, it would permit simulation testing of the accuracy of the model or extension so that it could be applied in Bayesian probabilistic calculations to take into account parameter uncertainty. These extensions may be implemented at some later date to test the accuracy of the estimation and provide measures of the uncertainty in estimated quantities.

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5. The model computes an Akaike Information Criterion (AIC) to permit evaluations of the goodness of fit of the different model assumptions to the data and model selection, taking into account differences in the numbers of parameters estimated.

6. The model computes MSY reference points to permit evaluations of stock status and future states of the stock under different management methods with respect to MSY reference points.

7. The program is written in Visual Basic and can be easily learned and modified by those who know VB.

<u>Some of the limitations of SRA analysis are as follows</u>:

1. The model currently does not permit computation of probability intervals or confidence intervals of modelled quantities which should normally be done for any stock assessment method to allow inspection of the statistical uncertainty in parameter estimates. This

capability will be included in the near future. Providing confidence intervals will not change the point estimates much at all but will provide indications of the relative amount of uncertainty in them given the fit of the model to the available data.

2. The model depends upon outputs from catch-age analyses for selectivity functions and stock-recruit function deviates. This could increase potential biases in model outputs in some runs when settings (e.g., natural mortality rate at age and steepness) different from the catch-age analysis are applied. Such biases could be reduced by updating the SRA analysis to estimate stock-recruit deviates and fishery selectivity parameters and by fitting the SRA model to additional age-structured datasets.

3. The SRA models mortality as a discrete process in the year rather than as a continuous process and could introduce some biases. Although mortality rates occur as continuous processes over time, it is computationally more efficient to model them as discrete processes that occur at a specific point within each year. Previous modelling work, however, demonstrates that under most conditions, representing mortality rate as events at discrete points in time produces similar results as the full continuous case.

4. It is most likely that density dependence in survival rate occurs over a range of ages rather than at one single age. To increase computational efficiency and maintain a simple approach to keeping track of mortality rates from fishing, density independent natural mortality rates, fishing mortality rates and shrimp trawl bycatch, the density dependence in survival rate is modelled to occur at a single age, rather than as a continuous process and this could introduce bias in estimates of abundance and abundance trends. The direction and magnitude of the bias introduced by the simplifying assumption is not immediately obvious. However, the basic effects on the stock assessment of assuming different mean ages over which density dependence occurs can still be readily evaluated with the current model.

5. The SRA does not compute SPR reference points (due to lack of time to implement these).

6. The model assumes stationarity in most parameters over time. For example, it assumes that the fisheries' catchabilities, the carrying capacity and selectivity functions for the commercial and recreational fisheries have remained constant over time. However, the introduction of additional offshore oil and gas platforms could mean that the stock has become more resilient to exploitation if carrying capacity is increased– or it may mean that it is more susceptible because it aggregates snapper making them easy to find for even novice fishermen. The assumption of stationarity in the SRA model could thus lead to underestimates of the recent potentially higher values for carrying capacity and MSY (average unfished recruitment) or underestimates of potential recent increases in catchability. These assumptions could be modified however to evaluate the sensitivity of model results to such alternative hypotheses.

7. The SRA model assumes that the inputted catches are known without error, when in fact there may be pronounced observation error in some of the catch time series such as the bycatch time series and earlier parts of the commercial and recreational catch time series.

<u>Key results</u>

1. Under density dependence at age 0, and using the 1999 ASAP settings (most recent past stock assessment settings) for steepness (h), average unfished recruitment (R_0) natural mortality rates, and stock-recruit deviates, the SRA model was run from 1872 to the present. This was done to evaluate the plausibility of stock-recruit parameter estimates obtained in the 1999 stock assessment and others presented at SEDAR when the stock assessments fitted to shorter time series. According to the SRA model, it was not possible to obtain values for fishing mortality rates as high as those from current and past ASAP or

VPA. If h is set at 0.95 and R_0 is set at 245 million (obtained from the 1999 stock assessment), then the computed fishing mortality rates were very low (e.g., 0.002 yr^{-1} for the average F for age 3 for years 1987-1998 ($F_{3, 87\text{-}89}$)) compared to about 0.47 yr^{-1} in the 2005 ASAP assessment. In this case, the estimate of spawner potential in 2004 ($Eggs_{04}/Eggs_{unfished}$) turned out to be implausible, i.e., at 110% of unfished conditions. This value resulted because the ASAP stock-recruit residuals for the 1990s were strongly positive and the fishery removals were insufficient to appreciably reduce the stock at the R_0 of 245 million fish and steepness of 0.95. The main conclusion that can be drawn is that stock-recruit parameter estimates obtained by fitting a model to data obtained at the end of a time series of exploitation such as has been done in the 1999 and 2004 ASAP assessments, can produce stock-recruit parameter estimates that are inconsistent with the longer historical time series and possibly highly biased.

2. The sensitivity of stock assessment model output to differing assumptions about the age at which density dependent survival rate occurs was evaluated. With density dependence set at age 0 years, as in the 1999 and 2004 ASAP assessment, and when R_0 and constants of proportionality for abundance indices were estimated and the model was fitted to the relative abundance indices, it was not possible to find parameters values that achieved estimates of depletion and fishing mortality rates as high as the values found in the 1999 and 2004 ASAP and 2004 VPA assessments. For example, under a variety of conditions, and different sets of abundance indices used, the estimates of $Eggs_{04}/Eggs_{unfished}$ were between 33% and 89% and $F_{3, 87\text{-}89}$ were between 0.004 and 0.04 yr^{-1}. Thus, the SRA model results indicate that 1999 ASAP settings for density dependence at age 0 and average unfished recruitment (both the low and high values assumed) are inconsistent with the historical record of catch removals -- and that the 1999 ASAP results which are based on the assumptions that density dependence occurs at age 0 and that recruitment was either near to unfished conditions in 1971 or near to unfished conditions in the mid to late 1970s should not be applied to provide management advice.

3. With density dependence set at either age 1 or age 2 years (both are equally plausible given current knowledge) rather than age 0, it became possible to obtain estimates of current stock status similar to those obtained in the ASAP and VPA assessments of the recent catch-age data. This provides empirical support in favour of the hypothesis that density dependence occurs at age 1 or 2 years rather than at age 0. Estimates of $Eggs_{04}/Eggs_{unfished}$ ranged between 8% and 37% and $F_{3,87\text{-}89}$ ranged between 0.09 and 0.18 yr^{-1}. The MSY values estimated under these more plausible settings were far lower than those under density dependence at age 0, and indicate that the current TAC may be higher than the MSY.

4. Under projections with density dependence at age 1 or age 2 years, the projected recovery time was highly sensitive to the TAC but relatively insensitive to different future values for shrimp trawl bycatch (STBC) removals. For example, under the scenarios and constant TAC policies evaluated (ranging between 0 and 9 million pounds per year), future annual STBC from zero to 25 million age 0 to 2 year fish changed stock recovery rates relatively little.

5. The projections changed very little when minimum size limits were removed in the recreational and commercial fisheries. This was partly because the low capture induced mortality rates for fish released by the recreational sector permitted the majority of these fish to survive and contribute the annual catch at later ages and larger sizes. The average age of fish discarded in the recreational fishery was one year (as opposed to two years for the commercial fishery), and a far larger number of fish are discarded in the recreational

fishery. In contrast, if all of the discarded recreational fish are retained, then due to the small size of recreational discards, the number of fish killed before the TAC is met can be nearly as high or higher than when discarding is permitted. Thus, the high survival rate of fish discarded from the recreational fishery and the larger numbers of small fish required to make up the TAC reduced considerably the potential positive effects of eliminating the minimum size limits in both the commercial and recreational fisheries.

6. Under the scenarios (which) considered, stock recovery to B_{MSY} before 2032 could only be achieved only by reducing the TAC. TACs between about 2.0 and 4.5 mp permitted recovery to B_{msy} before 2032. Failure to reduce the TAC by about half resulted in projected stock collapse within the next 10 years.

Appendix 8.

Available electronically.

This appendix is provided on CD versions of the workshop report.

Appendix 9.

Available electronically.

This appendix is provided on CD versions of the workshop report.

SEDAR

SouthEast Data, Assessment, and Review

Gulf of Mexico Red Snapper
Stock Assessment Report

SECTION 4. Review Workshop

Gulf of Mexico Red Snapper
Consensus Summary Report

Prepared by the SEDAR 7 Review Panel for the Gulf of Mexico Fishery Management Council

Edited by P.L. Cordue for
SEDAR 7, 4-7 April 2005
New Orleans, LA

Executive summary

The SEDAR 7 Review Workshop met in New Orleans, LA from April 4–7, 2005 to review the stock assessment of red snapper in the Gulf of Mexico. The first day consisted primarily of presentations by the Assessment Team covering the Data Workshop, the two Assessment Workshops, and their preferred base case assessment. During the second and third days, the workshop reviewed the assessment by addressing the terms of reference for the Review Workshop, including the consideration of additional model runs. On the final day, preliminary drafts of the Consensus Summary Report and the Advisory Report were reviewed.

The SEDAR for red snapper has extended over more than 12 months, during which time the Assessment Team and other Data Workshop and Assessment Workshop participants have worked towards producing a credible and reliable stock assessment. The red snapper assessment has been more challenging than the original participants could have envisaged. There were many challenges: being able to fully understand and duplicate the methods and data used in 1999 assessment; exploring alternative stock hypotheses and eventually moving from a single stock model to a two stock model; collating and analyzing the many relevant data sources to provide indices appropriate to single stock and two stock models; constructing a catch history (for multiple fisheries, including discard estimates) extending to the "dawn" of the fishery (1872); undertaking numerous assessment runs using four different stock assessment methods; and choosing a base case assessment to further develop and present to the Review Workshop.

The Review Panel was impressed by the quantity and quality of the work which had gone into the red snapper stock assessment. The presentations of the Assessment Team on the first day were well structured and clear. The information provided, through the presentations, and in response to questions, gave an excellent basis for the Panel's subsequent deliberations and collaboration with the Assessment Team.

Two changes to the base case assessment were made during the Review Workshop. These were suggested by the Panel and agreed to by the Assessment Team. First, age-0 snapper were reintroduced into the model. The Panel understood the argument in support of excluding this age class in that density dependent compensation could extend to even higher ages. However, in the scientific judgment of the Panel, it is not prudent to assume that density dependent compensation can completely override the mortality induced by the shrimp fishery on age-0 red snapper.

The second change was to include higher recruitment scenarios in the projections of the base case. Recruitment estimates over the last 20 years are highly variable, but on average are above the level predicted by the stock-recruitment relationship. Three alternative recruitment scenarios were recommended for projections, using either: the spawner-recruitment relationship; recent average recruitment (last 20 years); or an even higher average recruitment level (obtained from a sensitivity run). In terms of predicting short-term future recruitment levels, the Panel preferred, on the balance of probabilities, the use of average estimated recruitment over the last 20 years (with benchmarks recalculated to be consistent with that level).

The Advisory Report was finalized after the Review Workshop by the Assessment Team. Runs without age-0 snapper are included in that report together with the Review Workshop's base case. The Assessment Team included the runs to honor the Assessment Workshop agreement. The Review Panel believe that these runs are useful to illustrate the sensitivity of the assessment results to the exclusion of age-0 snapper but should not be used for the baseline assessment from which management advice is derived.

1. Introduction

1.1 Time and Place

The SEDAR 7 Review Workshop (RW) met in New Orleans, LA from April 4–7, 2005.

1.2 Terms of Reference for the Review Workshop

1. Evaluate the adequacy and appropriateness of all data used in the assessment and state whether or not the data are scientifically sound;

2. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation and state whether or not the methods are scientifically sound;

3. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (*e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies*) and required management parameters (*e.g., ABC*) and state whether or not the methods are scientifically sound;

4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound;

5. Ensure that required assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Review Panel's decisions regarding adequacy, appropriateness, and application of the data and methods;

6. Evaluate the performance of the Data and Assessment Workshops with regard to their respective Terms of Reference, and state whether or not the Terms of Reference for those previous workshops are adequately addressed in the Stock Assessment Report;

7. Review data and assessment workshop research and monitoring recommendations and make any additional recommendations warranted;

8. Prepare a Peer Review Consensus Report summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. (Drafted by the Panel during the Review Workshop with a final report due three weeks after the workshop ends.)

1.3 List of Participants

Panelists	Affiliation
Cordue, Patrick (Chair)	CIE
Babcock, Elizabeth	NGO; Univ. Miami
Blanchet, Harry	GMFMC SAP; LA DFW
Murphy, Mike	GMFMC SAP; FL FWCC
Nugent, Mike	GMFMC AP
Pilling, Graham	CIE
Prager, Michael	NMFS/SEFSC Beaufort
Rose, Kenneth	GMFMC SAP; LSU
Sissenwine, Michael	NOAA Fisheries

Presenters	
Brooks, Liz	NMFS/SEFSC Miami
Cass-Calay, Shannon	NMFS/SEFSC Miami
Nichols, Scott	NMFS/Pascagoula Lab
Porch, Clay	NMFS/SEFSC Miami
Scott, Jerry	SEFSC
Turner, Steve	NMFS/SEFSC Miami

Council Members	Affiliation
Minton, Vernon	GMFMC/Alabama DNR
Walker, Bobbi	GMFMC

Staff	Affiliation
John Carmichael	SEDAR Coordinator
Dawn Aring	GMFMC
Steven Atran	GMFMC
Loyd Darby	SEFSC

Observers	Affiliation
Bailey, Danica	Louisiana Dept. of Wildlife & Fisheries
Crabtree, Roy	NMFS/SERO
Cufone, Marianne	Gulf Restoration Network
Hano, Brett	Louisiana Dept. of Wildlife & Fisheries
Merriner, John	NMFS/Beaufort Lab
Nance, Jim	NMFS/Galveston
Powers, Joseph	NMFS/SEFSC Miami
Steele, Phil	NMFS/SERO
Thompson, Nancy	NMFS/SEFSC Miami
Viles, Aaron	Gulf Restoration Network
Zales II, Bob	Panama City Boatmen’s Association

1.4 Review Workshop working papers

Document Number	Document Title	Authors
SEDAR7-RW 1	Application of the age-structured assessment model CATCHEM to the U.S. Gulf of Mexico red snapper fishery since 1962.	Porch, C. E.
SEDAR7-RW 2	Revised assessments of Gulf of Mexico red snapper during 1984-2003 using a gulf-wide implementation of ASAP	Cass-Calay, S. L. and G. A. Diaz.
SEDAR7-RW 3	Revised assessments of Gulf of Mexico red snapper during 1962-2003 using a gulf-wide implementation of an age-structured assessment program (ASAP).	Cass-Calay, S. L., G. A. Diaz, and J. S. Nowlis.
SEDAR7-RW 4	Assessments of red snapper stocks in the eastern and western Gulf of Mexico using an age structured assessment procedure (ASAP)	Ortiz, M. and S. L. Cass-Calay.
SEDAR7-RW 5	Revised bootstrapping of a gulf-wide implementation of an age-structured assessment procedure (ASAP) for red snapper (*Lutjanus campechanus*) from 1962 to 2003.	Nowlis, J. S. and S. L. Cass Calay.
SEDAR7-RW 6	An age-structured stock reduction analysis (SRA) model for Gulf of Mexico red snapper that accounts for uncertainty over the ages of density-dependent natural mortality.	McAllister, M. K.
SEDAR7-RW 7	Alternate fishery-independent larval indices of abundance for red snapper.	Hanisko, D. S., J. Lyczkowski-Shultz, and W. Ingram.
SEDAR7-RW 8	Alternative estimates of the yield of red snapper from the Gulf of Mexico recreational fishery.	Turner, S. C.

2. Terms of Reference

2.1 Background

The RW is usually the third meeting in the SEDAR process. However, for red snapper, the Data Workshop (DW) was followed by *two* Assessment Workshops (AW). The SEDAR for red snapper has extended over more than 12 months, during which time the Assessment Team and other DW and AW participants have worked towards producing a credible and reliable stock assessment. The red snapper assessment has been more challenging than the original participants could have envisaged.

There were many challenges: being able to fully understand and duplicate methods and data used in the 1999 assessment; exploring alternative stock hypotheses and eventually moving from a single stock model to a two stock model; collating and analyzing the many relevant data sources to provide indices appropriate to single stock and two stock models; constructing a catch history (for multiple fisheries, including discard estimates) extending to the "dawn" of the fishery (1872); undertaking numerous assessment runs using four different stock assessment methods; choosing a base case assessment to further develop and present to the Review Workshop.

The Panel was impressed by the quantity and quality of the work which had gone into the red snapper stock assessment. The presentations of the Assessment Team on the RW's first day were well structured and clear. The information provided, through the presentations, and in response to questions, gave an excellent basis for the Panel's subsequent deliberations and collaboration with the Assessment Team.

During the RW some small deficiencies were noted by the Panel in the proposed base case assessment. The Assessment Team were willing and able, during the RW, to make the minor changes to the base case necessary to address the Panel's concerns. The changes were minor in terms of implementation, although potentially quite important for projections and evaluation of management options. The changes to the assessment are discussed in the following section under the appropriate terms of reference.

2.2 Review of the Panel's deliberations

This section addresses, in order, each of the eight Terms of Reference for the RW (see Section 1.2).

1. Evaluate the adequacy and appropriateness of all data used in the assessment and state whether or not the data are scientifically sound;

The RW's overall conclusion was that the SEDAR process had thoroughly considered the full range of potential sources of data. The flexibility of the AW's preferred assessment method, CATCHEM, allows the unusually complex and diverse array of available data to be assimilated within the assessment model. The RW did not identify inappropriate use of data (i.e., in this sense the data are scientifically sound), except with regard to the issue of choice of the youngest age within the model and its justification (see the discussion on the stock-recruitment relationship below).

The red snapper assessment uses information on (1) distribution and stock structure, (2) growth and reproduction, (3) natural mortality, (4) stock and recruitment relationship, (5) fishery landings and bycatch/discards, (6) age composition of catches and bycatch, and (7) indices of abundance. There is a complex and varied array of data available to address these information categories, but in most cases the available data are incomplete (e.g., in terms of temporal or spatial coverage) such that it is necessary to impute some missing data, and innovative approaches are needed to derive information. In some cases, such derived information is commonly observed for other fisheries, which is preferable (e.g., observations of discards including samples of age composition).

Distribution and stock structure: There are major fishing grounds in the eastern Gulf of Mexico (GoM), western GoM, and Campeche Bank off Mexico. At present, the US fishery is excluded from the fishing ground off Mexico, although historically, it was a major source of US landings. There is sufficient inferential information (e.g., genetics, otolith microchemistry) to support treating these as separate stocks, although the degree of reproductive isolation and mixing of fishes originating from the three areas is unknown.

Growth and reproduction: Since the late 1990s, there has been a tremendous increase in the number of age determinations of red snappers. These data provided a strong basis for estimating a new growth function, which was done taking account of the potential biasing effect of minimum size regulations. However, the relatively short period of time over which a large number of aging samples were collected means that for most years in the assessment, ages needed to be inferred, thus introducing uncertainty. Relatively few of the age samples collected for 2003 were available for inclusion in the assessment.

Another concern is that age sampling, in some years, may not be sufficiently representative of the catch. Also, a portion of the age and length sampling, in some years, has been taken on an opportunistic basis, rather than as part of a program to broadly and representatively sample the overall harvest. Effects of changes in sampling regimes as well as the ability of opportunistic sampling to characterize the size or age of harvest in a fishery have not been closely examined in this process.

Since the previous assessment, new data have been produced on the fecundity of red snapper, although older fish are poorly represented. Little difference between the eastern and western GoM was detected. A single fecundity at age function was fitted and used in the assessment.

Natural mortality: The assessment used instantaneous natural mortality rates of 1.0, 0.6 and 0.1 for ages 0, 1, and 2 years old and older (2+). The 2+ estimate is based on the longevity of the species (over 50 years) and has not changed in the current assessment. The DW reviewed new analyses on the mortality rate of age-0 and age-1 fish. While none of these analyses were conclusive, the DW agreed that the evidence was sufficient to use natural mortality rates for age-0 and age-1 fish (as given above) that are double the rates used in the previous assessment. While the RW accepted the rationale for increasing the estimates of age-0 and age-1 natural mortality, it noted that these changes were important as they lessen the impact of bycatch of young fish relative to the impact of directed fishing.

Stock-recruitment relationship: As is almost always the case, the stock-recruitment (S-R) relationship is empirically estimated by fitting to derived estimates of spawning stock size (S) and recruitment (R). In the case of the red snapper assessment, the fitting is done within the CATCHEM model, with several assumptions (consistent with previous assessments) to constrain the fit. However, it is necessary to specify the age at which recruitment occurs. The AW specified the age at recruitment as age 1 (compared to age 0 for previous assessments). The AW report (page 13, Methods) states that this approach "essentially assumes that the bycatch mortality rate is negligible compared to mortality rate owing to natural density-dependent processes during the first year of life." The DW did not identify data that was relevant to this assumption, nor does the AW report justify it. However, the RW was informed that there is evidence that the period of density dependent compensation extends through age 0 and possibly age 1. Thus treating mortality during age 0, but not age 1, as part of the compensatory recruitment process was considered a compromise. However, the RW included the age-0 bycatch in the base case due to the factors discussed under RW-TOR 2 below.

Fishery landings and bycatch/discards: Commercial landings and recreational catches have been reasonably well documented by systematic data collection programs since 1963 and 1981, respectively. In response to a recommendation of the DW, sporadic sources of commercial landings data were used to construct a catch history beginning in 1872 when the fishery is presumed to have begun. Recreational catches prior to 1981 were inferred by assuming that catches were proportional to human population in coastal areas, estimated from census data from 1900. In the assessment model, recreational catches were assumed to begin in 1946. While estimates prior to systematic data collection programs are particularly uncertain, the RW accepted them as being plausible and useful, and it did not suggest any alternatives.

It is noteworthy that shrimp fishing effort data is usually not available at the relatively precise depth and location scales necessary for direct bycatch estimation, which means that effort must be estimated using catch per unit effort data from interviewed fishing trips. The recent decline in the number of interviews and differences of the spatial distribution of the fishing trips those interviews cover over time is a concern. Also, it appears that estimates of fishing effort and fishing power are confounded such that it is difficult to estimate trends in the latter, although they have almost certainly occurred.

Unfortunately, there is relatively little data on discards, such as from scientific observers aboard fishing vessels. Closed season logbook data in 2001-2002 was deemed to provide some useful information on discards, although the quality of data from "self reporting" is difficult to judge. Data on recreational discards is routinely collected by interviewing "intercepted" anglers (also a form of self reporting). In general, discard estimates for commercial finfish and shrimp fisheries had to be derived from a relatively sparse set of data on discards based on assumptions that are difficult to verify. However, the RW accepted the estimates as a necessary and appropriate use of the data in order to take account of discards in the assessment.

Age composition of catches and bycatch: Age composition data have been collected sporadically, with a large number of samples collected during 1998-2002. The available data were used in the assessment. Fortunately, CATCHEM is flexible enough to not require complete age composition data. Thus, age compositions are derived within the model constrained by data when and where it is available. The RW accepted this approach and expressed concern that the extent, representativeness, and efficiency of the current sampling design should be examined.

Indices of abundance: Three fishery independent (larval survey, trawl survey, video survey) and two fishery dependent (recreational fishery, commercial longline fishery) indices of abundance are currently available. An additional longline survey was available for only a limited time period, so was not included in the base model. Separate indices were constructed for the western and eastern GoM. Trawl survey data for the eastern GoM is limited because of "hard bottom" that is not suitable for trawling. Thus, alternative fishery independent indices are desirable for the east. Fishery dependent indices were standardized using a commonly used General Linear Modeling framework. The RW agreed that the indices were appropriate for use in the assessment. However, it noted that the true uncertainty in the relationship between the larval index and spawning stock size is likely to be larger than is captured by the sampling coefficient of variation.

General comment about data collection: The RW noted that there are many sources of useful data, and that recent enhancements to data collection programs are encouraging. Unfortunately, it also noted that relatively short term data collection efforts (e.g., it appears that enhancements begun in the late 1990s may be dissipating) are less valuable than long term systematic commitments to building the time series that are the backbone of assessments. Fortunately, a flexible modeling framework is available for the red snapper assessment. In effect, missing data is imputed within the assessment model. However, data based on direct observations are more reliable. The lack of observer data on discards is a particular concern.

2. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation and state whether or not the methods are scientifically sound;

The Panel generally endorsed the methods used in the assessment and considered them to be scientifically sound. The one important exception was the decision of the AW to omit age-0 red snapper from the assessment model (see shrimp bycatch discussion below). The Panel was impressed by the large number of runs which had been performed and the use of multiple assessment methods.

The AW considered results from four different assessment methods: ASAP, SRA, VPA, and CATCHEM. The SRA and VPA models were primarily used in exploratory analysis. ASAP was used in previous red snapper assessments and the original intention of the AW was to update the assessment using a modified version of ASAP. Modifications to ASAP were needed to accommodate new data, and in particular the “ultra-historical” catch series (i.e., starting in 1872). Unfortunately, ASAP exhibited instability when it used the ultra-historical catch series and to a lesser extent the shorter time series (1962-2003 and 1984-2003). Further modifications to ASAP, reduced, but did not eliminate the instability. The AW chose CATCHEM to provide the base case stock assessment.

CATCHEM is in many ways a generalization of the ASAP approach, with more flexibility, better mathematical rigor due to internalizing the catch-at-age fitting, and the ability to model geographic substructure. In particular, it can deal with multiple time series with limited spatial and temporal coverage. Parameter estimates are obtained from a modified maximum likelihood best fit to the data. When fully developed, it is anticipated that CATCHEM will be able to provide fully Bayesian stock assessments for red snapper (with interval estimates obtained from marginal posterior distributions). However, the current assessment provided only point estimates (from the mode of the joint posterior distribution).

The AW report contained relatively few diagnostics and several of the Panel’s requests to the Assessment Team related to the provision of further diagnostics (see Section 3 and Appendix A).

Two stock model: The AW chose to adopt a two-stock model with separate eastern and western stocks. No mixing is assumed between the stocks. This is a model assumption that may be violated, but there is little data currently available for estimating mixing rates.

Goodness-of-fit: Fishery landings were closely matched by the model, an expected feature due to the low CVs of most of these data sets. In general, the model provided good fits to the fishery-dependent and fishery-independent abundance indices, although the shrimp by-catch was not fitted well in early years when CVs were high; and larval indices were generally poorly fitted.

Stock-recruitment relation: The RW shared the concern of the AW over the reliability of the estimated relationship between spawners and recruits, given that estimates of recruitment are highest when the stock is thought to be most depleted. The RW speculated that the stock recruitment function could be quite different today than it was 100 years ago.

Capture (fishing) rates: The estimated age composition of the catch was highly truncated in all but the longline fishery samples. The assessment model attributed much of this to strongly peaked selectivities in all but the longline fishery that displayed a logistic selectivity pattern. The RW investigated estimates of age- and year-specific fishing rates for each of the fisheries to inspect if they were at realistic levels to explain the age composition data. Discussions about the age-composition and fishing rates included thoughts about whether older fish were historically found in near shore waters and were vulnerable to the fishery during the ultra-historic period or whether there is a natural ontogenetic movement of fish to deeper water as they age.

Shrimp by-catch of age-0 fish: The base case recommended by the AW did not include age-0 red snapper. The RW examined the effect of including these fish in the analysis. The logic behind the decision to include or exclude these from the analysis is based on beliefs about the timing and strength of density dependent effects on survival. The RW was unable to comment on the age at which compensatory recruitment processes are complete. However, even if there were data that provided sound evidence that compensation occurs throughout age 0, it would be inappropriate to conclude that bycatch mortality of age-0 fish is insignificant. Doing so, not only requires that compensatory recruitment processes extend through age 0, but also that these processes assert such strong control that the fit of the S-R function would be expected to be extremely tight. Clearly, this is not true for red snapper (probably not for any species). Furthermore, it assumes that S is in the asymptotic region of the S-R function where density dependent compensation is strong, not at low levels of S where compensation is weak. The RW also noted that it is not aware of any other assessment where the possibility that density dependent compensatory processes occurring simultaneously with density independent mortality from fishing (either discards or retained catch) was considered justification for treating the mortality from fishing as insignificant, nor is there a reason to think that the red snapper situation is unique. The RW concluded that the base case model should include age-0 snapper. The RW recommends that future assessments model post-recruitment density dependent mortality, as this is critical for determining the impact of shrimp trawl bycatch on red snapper rebuilding.

3. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies) and required management parameters (e.g., ABC) and state whether or not the methods are scientifically sound;

The RW agreed that the methods used to derive population benchmarks by the AW were appropriate and scientifically sound. The RW endorsed the AW's view that the actual benchmarks are an emergent property of the harvest strategy; the value of MSY is conditional on selectivity patterns of the gears used in the fishery. Choices about selectivity and benchmark construction lead to some of the biggest differences in statements on stock status in the results. As a result, it is necessary to state clearly what the selected benchmark values are conditional upon.

MSY and SPR benchmarks for the RW base case are provided in the Advisory Report. The RW noted that the particular population benchmarks to be applied are policy dependent. The strategies defined by the Gulf of Mexico Fishery Management Council as possible or practical, and how the Council allocates quota among competing user groups, will define the final benchmarks to be calculated for assessment.

The RW concurred with the conclusion of the AW that, due to uncertainties over the true underlying stock-recruitment function and the underlying patterns in the fishery, spawner per recruit (SPR) benchmark levels may be more robust to these uncertainties. 30%SPR, which has already been employed by the Council, is relatively insensitive to benchmarks derived from a stock-recruitment function. Note, SPR benchmarks are consistent with MSY concepts as estimates of both F_{MSY} and B_{MSY} can be inferred from an SPR.

There is a need to test whether selected or alternative benchmarks are robust to sources of uncertainty within the process. The use of management strategy evaluation would be useful to identify alternative robust red snapper population benchmarks. See recommendations for future work.

4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound;

The AW report presented a number of projections from the CATCHEM base case. Only deterministic projections were presented, calculated at the mode of the joint posterior distribution, and using the estimated S-R function to predict future recruitments. These projections were done with several scenarios about the amount of future effort in the shrimp trawl fishery: (1) no shrimp, implying that there would be no snapper bycatch in the shrimp trawl fishery; (2) linked, implying that the effort in the directed and bycatch fisheries would remain at their current proportions; and (3) current shrimp, implying that the effort in the shrimp trawl fishery and the closed season handline fishery would remain at current levels, while the directed fisheries would be reduced proportionally. For isopleth calculations, additional levels of shrimp bycatch reduction were considered, including a 40% reduction in the shrimp effort.

The methods used to project population status and evaluate rebuilding were adequate, appropriate and scientifically sound, and were presented clearly. Ideally, the projections should be stochastic, so that it is possible to estimate probabilities of rebuilding and other performance indicators, but the RW recognizes that the stochastic and deterministic projections generally result in similar management advice. The AW did not calculate an Acceptable Biological Catch (ABC) for each stock as required by their terms of reference. However, the RW considers that it will not be possible to calculate the ABCs without clear guidance from the Council on the level of shrimp trawl bycatch that should be assumed in the calculations. In evaluating rebuilding, the AW should also have recalculated the mean generation time with the new biological information available since the last assessment.

The RW considered that the greatest source of uncertainty in the projections was the assumption that was made about future recruitments. The assessment estimated recruitments that were higher than the estimated pristine recruitment (R_0) in recent years when the spawning stock biomass was very low. Thus, using the estimated S-R function to predict future recruitments implies that future recruitments will be lower than the recruitments seen in the last two decades. To address this uncertainty, the Panel requested that projections be done with three different assumed stock recruitment relationships: (1) R_0 predicted from the base case model fit; (2) R_0 set equal to the average of recruitments from 1984–2003; (3) R_0 set equal to the value estimated in the sensitivity analysis run which began in 1984. In each case, steepness should be kept at the value estimated in the base case. Scenarios 2 and 3 are intended to address the possibility that the recent high recruitments were caused by a long-term shift toward higher productivity of red snapper. To be consistent, the benchmarks were calculated based on the assumed S-R function in each scenario. The Panel considered that the scenario based on recent average recruitments was most likely, and should be considered the base case for the projections. However, the RW was not confident that the actual stock recruit dynamics are well represented by any of the scenarios. Therefore, these projections should only be considered plausible in the short time frame (5 to 10 years). The three scenarios should provide reasonable bounds on the uncertainty about future recruitments.

5. Ensure that required assessment results (as listed in the SEDAR Stock Assessment Report Outline) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Review Panel's decisions regarding adequacy, appropriateness, and application of the data and methods;

The RW commends the AW for a clear and well-written report that concisely reflected a very complicated set of analyses and a complex set of deliberations.

The AW report generally followed the suggested report outline. The RW noted that the report was well-written and was mostly clear in what decisions were made and the rationales for these decisions. The AW report was concise, considering the complexity of the assessment workshop deliberations, and clearly cited the supporting documents at appropriate places. The report appeared to be well-balanced.

The Panel had several minor editorial comments about the Stock Assessment Report. These minor comments included: the need for more detailed discussion related to the use of SPR rather than biomass-based benchmarks, more information on why age-0 red snapper by-catch was not explicitly included, a simple statement of recommended ABC, and a clear explanation of how (effective) spawning biomass was computed. The RW also noted that the research recommendations were scattered among various sections, with only those related to shrimp by-catch explicitly noted in the table of contents.

The RW noted that the wording of RW-TOR 5 was somewhat confusing. Above, we have addressed whether the AW report followed the SEDAR Stock Assessment Report Outline, and "clearly and accurately presented" stock assessment results. The remainder of TOR 5, requires that we address if "such results are consistent with the Review Panel's decisions regarding adequacy, appropriateness, and application of the data and methods". However, the assessment results presented in the AW report pre-date the decisions of the RW. We suggest that TOR 5 be reviewed (see Section 5).

6. Evaluate the performance of the Data and Assessment Workshops with regard to their respective Terms of Reference, and state whether or not the Terms of Reference for those previous workshops are adequately addressed in the Stock Assessment Report;

Data Workshop Terms of Reference

The DW participants compiled and reviewed a truly voluminous amount of information on red snapper biology and fisheries in the GoM. Their report discussed in detail the appropriate terms of reference. They discussed the quality and reliability of the available data, considered alternative assessment methods, and provided research recommendations. The details of the workshop process overall were well-documented in the DW Report. Given the diverse sources and forms of information available and the time allotted, the consensus of the RW was that the DW report adequately addressed its Terms of Reference.

Each DW term of reference is considered below.

1. Evaluate stock structure and develop a unit stock definition.

The life history sub-group of the DW supported development of a two-stock model for GoM red snapper, supported by evidence from several sources. That discussion is well-documented in the DW report.

2. Evaluate the quality and reliability of life-history information (age, growth, natural mortality, reproductive characteristics); develop models to describe growth, maturation, and fecundity by age, sex, or length as appropriate.

This was generally well done. The RW noted that the derivation of the ultra-historical time series was motivated by trying to obtain better contrast to estimate steepness in the S-R function. Assuming constant life history parameters over such an extended timeframe is of course problematic, as is estimating natural mortality for ages 0 and 1.

3. Evaluate the quality and reliability of fishery-independent measures of abundance; develop indices of population abundance by appropriate strata (e.g., age, size, and fishery) for use in assessment modeling.

The RW noted that the indices of abundance seemed to treat variability only as sample variability, not considering other sources of variation. The RW mentioned the changing geographic range of the SEAMAP survey as one potential source – it is preferable that surveys cover the entire range of the species, so that variability across the range can be captured, as well as density values in specific portions of the range.

4. Evaluate the quality and reliability of fishery-dependent measures of abundance; develop indices of population abundance by appropriate strata for use in assessment modeling.

The DW did not directly address issues regarding changes in catchability due to technological improvement in recreational or commercial fisheries over time, which the RW considered to be a potentially significant factor. Sensitivity runs during the RW were not able to resolve the importance of this factor, but it is taken to be a subject for future research.

5. Evaluate the quality and reliability of commercial and recreational fishery-dependent data for determining harvest and discard by species; develop estimates of total annual catch including both landings and discard removals.

The DW participants spent considerable energy constructing a reasonable long term history of catch in the fishery to help assess the status of the current stock against the unfished condition. The RW noted that fishery-dependent data on discards is problematic, since it is self-reported except in the cases of direct observer data. Self-reporting can be biased in either direction, and for many causes.

6. Evaluate the quality and reliability of data available for characterizing the size and age distribution of the catch (landings and discard); characterize commercial and recreational landings and discards by size and age.

This was done. The available data from recreational and commercial fisheries were compiled for the assessment.

7. Evaluate the quality and reliability of available data for estimating the impacts of management actions.

This term of reference was not directly addressed in the DW report and it was not entirely clear to the RW how it should have been. Clearly, management actions can affect data and its interpretation (e.g., changes in minimum sizes affect interpretation of size and age frequencies and must be accounted for in an assessment model), but it is less clear what type of data, by itself, can be used to estimate the effects of management actions. Certainly, an assessment model, using whatever data are available, can be used to investigate whether management actions have had a measurable impact on a stock. However, in order to be able to measure the effects of a management action, it is necessary for the action to have greater effect than the noise in the signal. In the presence of noisy data, that may require management actions with a larger impact than have been seen in the past.

The effect of management actions on the shrimp fishery, with the introduction of BRDs, was noted as one data set relevant to this term of reference. The DW had identified this and the model used fleets with and without BRDs.

8. Recommend assessment methods and models that are appropriate given the quality and scope of the data sets reviewed and management requirements.

This was adequately, though not explicitly, covered in the DW report. The RW noted that the DW and AWs were part of a “continuum” – data and methods are inextricably linked.

9. Provide recommendations for future research (research, sampling, monitoring, and assessment).

Three recommendations were noted in the DW report by the RW.

10. Prepare complete documentation of workshop actions and decisions, and generate a data workshop report (Section II. of the SEDAR assessment report).

The RW noted that the DW report was adequate in respect of this rather ambitious term of reference ("complete" is never really achieved).

<u>Assessment Workshop</u>

The AW participants collectively spent more effort and utilized more information in the current analysis than has been done for any prior red snapper assessment, and possibly for any assessment of any kind in the GoM. The details of the workshop process overall were well-documented in the AW Report and the excellent accompanying Proceedings document. Several alternative models were developed and reviewed, with reports available in the AW documents. Given the diverse sources and forms of information available and the time allotted, the consensus of the RW was that the AW report more than adequately addressed the Terms of Reference. A few minor editorial changes were suggested for the report, but that was not seen as a significant factor.

Each AW term of reference is considered below.

> *1. Select several appropriate modeling approaches based on: 1) available data sources, 2) parameters and values required to manage the stock, and 3) recommendations of the Data Workshop – especially including consideration of possible eastern and western stock units; develop and solve population models incorporating the most recent scientifically sound data.*

The RW was impressed with the range of methods considered and employed during the AWs.

> *2. Select a preferred model approach that will be used to provide estimates of population parameters and stock status; provide complete justification for the selected model as well as a review of those methods pursued but ultimately rejected as a preferred approach.*

The selected model is based on well-developed theory and was reviewed by several independent assessment experts during the two AWs and the RW. The RW noted that CATCHEM, the method used in base case assessments, was not fully developed. It preferred that development of the model be more complete (e.g., including standard diagnostics and stochastic projection options) before being used in an actual stock assessment. However, the RW accepted that in the current case and circumstances it was necessary to use CATCHEM since alternative models had unacceptable limitations, such as being unstable when the entire history of the fishery was included in the analysis.

Past assessments concluded that the status of the stock had varied little in the recent time period, the period from which the majority of information was available for input into stock assessments. The AW participants evaluated several methods to construct a reasonable assessment of the status of the current stock against the unfished condition. The limited information available for the early period of these fisheries was found to create problems for the ASAP model used in prior assessments. Another approach, stock reduction analysis (SRA) was attempted, but was not recommended for use when making management recommendations. Rather, it was seen as a useful exploration tool for testing alternative assumptions. The preferred model, CATCHEM, is a more generalized form of ASAP, with greater ability to include information from multiple sources and to include different fleets fishing at different rates on different segments of the stock.

The AW preferred this model because, among other properties, it was able to reasonably model the fishery over the entire history without additional ad hoc inputs.

3. Provide measures of model performance, reliability, and goodness of fit.

Standardized residuals were not provided in the AW report, but some information was provided at the RW. The multinomial assumption for catch at age data appeared to be violated. This should be addressed in future assessments. Reliability of model output needs to be based on reliability of estimation procedures, and how usable it is for providing estimates of future stock structure. (Simulation studies could improve measures, but some sensitivities have been run during the RW to measure stability relative to some input assumptions.) In the view of the Panel the existing AW report was somewhat deficient with regard to diagnostics.

4. Estimate values for and provide tables of relevant stock parameters (abundance, biomass, fishery selectivity, stock-recruitment relationship, etc; include values by age and year where appropriate).

This was adequately done in the AW report.

5. Consider sources of uncertainty related to input data, modeling approach, and model configuration. Provide appropriate and representative measures of precision for stock parameter estimates.

The first part of this term of reference was well addressed by the AWs. However, interval estimates were not provided for parameters. The current implementation of CATCHEM is somewhat inefficient and given the current speed of available computers it is not possible, in a reasonable timeframe, to provide marginal posterior distributions (and hence creditability intervals) for parameters.

6. Prepare sensitivity runs or consider other modeling approaches to examine the reliability of input data sources.

This term of reference perhaps needs to be reworded to clarify how model runs can test the "reliability" as opposed to the "consistency" of input data. However, the RW comment with regard to the AW performance on this term of reference follows.

It is important to understand which indices and other data have greatest influence on the outputs. If precision is poor, but outputs are strongly influenced by that input, then there should be reservations about those outputs. Sensitivity runs to examine the robustness and reliability of the estimates with respect to the input data sets are important. A paragraph or two that stated why the data provided the results they did would have been useful in the AW report.

7. Provide Yield-per-Recruit and Stock-Recruitment analyses.

This was done.

8. Provide complete SFA criteria: evaluate existing SFA benchmarks, estimate values for alternative SFA benchmarks if appropriate, and estimate SFA benchmarks (MSY, Fmsy, Bmsy, MSST, and MFMT) if not previously estimated; develop stock control rules.

The AW report went to some pains to describe implications of different selectivities on SFA benchmarks, ABC, and future stock conditions. There were three sets of SFA benchmarks provided. While the information on the implications of these benchmarks was provided in the report in the form of isopleth diagrams, the RW felt that tabular formulation of a subset of benchmarks would also be useful. The rebuilding schedule is dependent on policy decision on appropriate reference points. Policy decisions make important differences in terms of distribution of TAC. If projections had been developed, they would need to have been done for each possible policy selection, which was thought to be beyond the purview of the AW. Full development of rebuilding plans would have been inefficient prior to selection of appropriate reference points by the Council, and is easily and swiftly done after that selection.

> *9. Provide declarations of stock status relative to SFA benchmarks: MSY, Fmsy, Bmsy, MSST, MFMT (or their proxies if appropriate).*

This was adequately addressed.

> *10. Estimate the Allowable Biological Catch (ABC) for each stock if appropriate.*

This was addressed. No singular value was estimated, but several acceptable catch scenarios were presented, including an infinite number in isopleth diagrams.

> *11. Estimate probable future stock conditions and develop rebuilding schedules if warranted; include estimates of generation time. Calculate rebuilding analyses under the following future exploitation possibilities: F=0, F=current, F=current*0.25, F=current*0.5, F=current*0.75.*

In the AW base case, future recruitment was modeled deterministically at the level of the estimated S-R function. Rebuilding plans were not explicitly examined, but were implicit in the isopleth diagrams for the many scenarios which were evaluated. Rebuilding schedules are dependent on policy decision and their associated reference points. Full development of a rebuilding plan would have been inefficient prior to a policy decision, but is easily done after that selection. Mean generation time was not re-calculated (but will be).

The Panel was satisfied that this term of reference was adequately addressed, but did request that projections be done at two alternative higher levels of mean recruitment (and evaluated relative to benchmarks consistent with the higher recruitment levels).

> *12. Evaluate the impacts of current management actions, with emphasis on determining progress toward stated management goals.*

Current policies were included as one of the many scenarios evaluated in the AW report.

> *13. Provide recommendations for future research and data collection (field and assessment); be specific if possible in describing sampling design and recommended sampling intensity.*

The RW noted various recommendations in the AW report.

14. Provide thorough justification for any deviations from recommendations of the Data Workshop or subsequent modification of data sources provided by the Data Workshop.

Deviations were adequately documented.

15. Fully and completely document all activities in writing:
Draft Section III of the SEDAR Stock Assessment Report;
Provide required tables of estimated values;
Prepare a first draft of the Advisory Report based on the Assessment Workshop's recommended base assessment run for consideration by the Review Panel

All reports and documentation were fully accomplished, except that development of the first draft of the Advisory Report was continued during the RW. This was to accommodate extra work performed after the second AW and during the RW.

7. Review data and assessment workshop research and monitoring recommendations and make any additional recommendations warranted;

The RW reviewed recommendations of the DW and AW, and has also made its own recommendations for research that could improve future assessments. The RW joins the AW in emphasizing that it is critical that suitable planning be done before large-scale research programs are conducted. Initial planning workshops and simulation studies can ensure that subsequent research will contribute the information most needed to resolve important questions in red snapper assessment. The more complex or expensive the proposed research, the more important this recommendation becomes.

Some of the following research recommendations are marked [D] or [A] or both. The symbol indicates that all or part of the corresponding recommendation was adapted from recommendations of the SEDAR 7 Data Workshop or Assessment Workshop.

1. *Data on shrimp fishery*. The RW recognized the importance of obtaining better estimates of fishing effort in the shrimp fishery, which might be done through vessel monitoring systems, electronic logbooks, or otherwise [A]. Also, the RW recommends that the statistical design and extent of the shrimp-trawl observer program be reviewed to ensure that the bycatch data collected are appropriate and sufficient for stock assessment.

2. *Independent estimates of mortality rates*. Direct estimation of mortality rates through tagging would reduce uncertainty in future assessments [A].

3. *Fishing power*. Research is recommended to estimate (independently of any stock assessment) changes in catchability q by gear over time. The RW believes that the introduction of GPS and marine chart-plotting equipment is likely to have increased fishing power substantially for some modes of fishing. Independent collection of data on fishing effort would provide valuable data for assessment and relieve the need to estimate catchability changes.

4. *Stock structure*. Research (e.g., tagging, otolith analysis) is recommended to better describe stock structure and mixing rates. Research should include a review of oceanographic data to see whether transport from the Campeche Banks could reasonably be supplying important numbers of larvae to the western Gulf stock [A].

5. *Spawning-stock index*. Given the many factors that can mask relationship of larvae to spawners, the value of the larval indices should be reviewed.

6. *Spatial distribution at age*. The RW recommends study of the age structure observed from longlines (survey and fishery), to clarify geographic distribution of fish as they age.

7. *Density dependence*. Research could clarify the magnitude and timing of density dependent compensation in juveniles by estimating survival (from age-0 to age-1 year) at different densities of juvenile abundance [A].

8. *Ecosystem concerns*. The RW recommends that the management objectives for the fishery complex (shrimp, red snapper, vermilion snapper, etc.) be formalized. Simulation studies could usefully identify and evaluate appropriate management strategies (including use of various reference points) and corresponding assessment modeling approaches. Research could also test the hypothesis that red snapper production is enhanced in some way by increased shrimp trawling [A].

9. *Assessment modeling*. The RW's recommendations for assessment modeling are made while recognizing that technology is currently limiting (the power of current small computers is marginal for the given model complexity). (a) Future assessments should include interval estimates on parameters and status indicators. (b) More diagnostic and output information should be provided in future assessment reports (e.g., plots or tables of F at age and plots of standardized residuals). (c) Extensive simulation tests of assessment models are recommended to examine accuracy, precision, and robustness [A].

10. *Age sampling*. The RW recommends that representative sampling of age- and length-composition of red snapper be conducted consistently across area, time, and gear.

11. *Fecundity at age*. The RW noted that few fecundity samples were available from older fish, and recommends that more such samples be collected.

12. *Model implementation*. The RW recommends that the assessment model's recruitment submodel be generalized to allow various options on the timing of bycatch mortality relative to density dependent compensation (see AW-8).

8. Prepare a Peer Review Consensus Report summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. (Drafted by the Panel during the Review Workshop with a final report due three weeks after the workshop ends.)

A first draft was completed during the RW. All Panel members contributed sections and the Assessment Team provided text and plots related to requests during (and after) the RW (see Appendix A). The report was finalized by email after the RW.

3. Additional comments

Model runs which excluded age-0 snapper were included in the Advisory Report, after the RW, by the Assessment Team. The Panel wished to emphasize their preference for the inclusion of age-0 snapper in the assessment and requested results for the RW's base case for inclusion in the Consensus Summary Report. These results are briefly discussed below.

The benchmarks are dependent on the assumed effort allocation and this must be kept in mind when considering the RW's base case results (Table 1). Note, the benchmarks have been calculated, and projections have been done, assuming that recruitment is equal to the average of the base case estimates from 1984–2003. Under the linked effort scenario, the SPR at F_{MSY} is 27% and hence the 30%-SPR results are very similar to results for runs where MSY was the benchmark (Table 1). For the current shrimp scenario and the 40% shrimp effort reduction, the rebuild to MSY levels occurs much more quickly than for the linked scenario (Table 1). However, this is because the target levels are much lower (5-10% SPR compared to 27% SPR, see Table 1). Note, SPR values of 30% or higher can only be achieved under the linked scenario.

The RW noted that although there were periods of time when there was good sampling coverage from a range of sources and fisheries, this was generally not the rule for red snapper (e.g., patchy age data with missing years). The consistent and sustained collection of data for stock assessment purposes is a generic issue for GoM species. Good quality data over an extended timeframe needs to be available for monitoring purposes and for stock assessment as the need arises. We understand that work is currently underway to address sampling needs for a range of species. The RW supports such statistical studies to provide sampling specifications to data providers, so that sufficient age- and length-composition data are available for assessments. It may also be timely to review protocols for ensuring random (representative) sampling in the various fisheries and monitoring programs.

The Panel made several requests of the Assessment Team for additional analyses, including some additional model runs. The requests are listed below. Further details, the results, and discussion of the results are given in Appendix A.

<u>Model runs</u>

1. Initial base case with high virgin recruitment and constrained directed catch history

2. ASAP run with revised and expanded input data (1984 time series) and revised parameters but the same approach as the 1999 assessment

3. All remaining runs for combinations of:

{1872 time series, 1984 time series} × {const q, random q} × {age 0, age 1}

The shorthand "random q" refers to allowing a random walk in the catchability coefficients of the directed fisheries; "const q" denotes constant catchability in the directed fisheries. For x = 0 or 1, "age x" denotes age-x red snapper as the minimum age class in the model. Three of these runs had already been completed. The remaining runs were prioritized with the two runs "1984 time series – random q – { age 0, age 1}" given the lowest priority.

4. Projections from the base case using higher average future recruitment

The Panel requested additional projections for the base case where future recruitment and MSY calculations were predicated on higher values for R_0 than the estimated value. The requested alternative values for R_0 were (a) the average of the estimates from 1984 to 2003 and (b) the value estimated with the 1984 time series. Two sets of deterministic projections, based on recruitment scenario (a), were completed in time to be shown to the group prior to the close of the RW meeting.

<u>Diagnostics</u>

1. Standardized residuals: Q-Q plots and standard deviation of standardized residuals

2. Capture rate (catch + discards) at-age trajectories

3. Spawner-recruitment relationship

<u>Miscellaneous requests</u>

1. Mature biomass trajectories in contrast to effective-spawner trajectories

2. Virgin predicted selected age frequencies (by fishery) contrasted with average observed age frequency

There were two minor analyses which were undertaken by Panel members.

1. The absence of a plus-group, at the maximum age of 30 years, in the population model was of concern because of the relatively low assumed adult natural mortality (0.1). It was possible that the cumulative number of fish aged 31 years or older might be sufficiently large to unduly bias estimates of ratios involving the virgin stock. However, when this was checked, for effective spawners, the bias was found to be only 10%, which is inconsequential for the current assessment.

2. The figures and tables in workshop documents presenting catch-at-age estimates were not adequate for the purpose of checking, by eye, for the presence of consistently strong or weak cohorts. To alleviate the workload of the Assessment Team, a Panel member produced bubble plots of age vs cohort and presented them to the RW. By eye, it was difficult to detect any consistently strong or weak cohorts. The presentation was ideal, and illustrated the strongly domed selectivity pattern in the main fisheries. However, a domed selection pattern reduces the number of times that a cohort is seen in a fishery and this obscures consistent strength or weakness. That said, it was not obvious that the observed data were entirely consistent with the highly variable pattern of recruitment estimates in the assessment runs. There is a case for further investigation of residual patterns for the catch-at-age data to check, amongst other things, that recruitment estimates are being driven by appropriate time series (i.e., not by random fluctuations in abundance times series).

4. Stakeholder comments

As an industry representative of the for-hire fishery to the Review Panel and chairman of the GMFMC’s Red Snapper Advisory Panel, here are my non-scientific feelings about the meeting.

The most disturbing thing that I encountered was the fact that the AW had decided to use a model that failed to include age-0 red snapper. The rationale was that due to high natural mortality rates of age-0 fish it was best, from a modeling standpoint, to begin the process with age-1 red snapper. The problem that I, and other non-scientists, have with this approach is that for the past twenty years we have been told that due to the high (80%) rate of shrimp by-catch mortality inflicted on the age-0 red snapper, rebuilding the stock could never be accomplished without very significant shrimp trawl by-catch reduction, regardless of what the directed fishery did or did not do.

Because of this, I am totally opposed to an assessment being released that omits the age-0 fish. The reason being that no matter how little effect age-0 omission would have on the actual model, it has the potential to have a huge effect on user group allocations when the Council begins using assessment to manage the red snapper stock.

Another thing that puzzles me as a non-modeler is the steepness of the recruitment curve. In an effort to understand and/or deal with or modify this recruitment steepness, there have been numerous runs and re-runs with different things factored in. The one thing that was never brought up is that maybe the stock has more spawners in it than are being accounted for and hence, at least in my mind, maybe the stock is in better condition then the model is showing. One of the Panel observed that it was hard for him to acknowledge the presence of an overfished stock with the recruitment steepness being shown by the model.

Another thing that I would like to speak about is the shrimp effort and/or by-catch reduction. While it is evident that BRD reduction rates are much lower then was hoped for and predicted, it seems to me that we must, somehow, find a way to incorporate the massive reductions (25%) of effort because of the economic upheavals in the shrimp fleet. These factors being high fuel costs, low shrimp prices, low performances of BRDs and the market glut of foreign and pond-raised shrimp. It seems to me that with the myriad of things that can be formulated and injected into the model, that this effort reduction can be computed as well.

Another concept that I feel is worthy of consideration is that possibly a reduction or elimination of minimum lengths might provide enough benefits in bycatch reduction and therefore by-catch mortality, particularly in the recreational sector, to offset the increased harvest that might result from such an action.

Mike Nugent, Chairman
Red Snapper Advisory Panel

5. Recommendations for future workshops

The RW has two major and two minor recommendations for future SEDARs. The recommendations are listed below followed by their justification.

1. *Change the Review Panel instructions to specifically allow minor changes to the assessment in collaboration with the Assessment Team.*

During the RW the Panel identified what were, in their opinion, deficiencies in the assessment. A strict interpretation of the Panel's instructions would have required that the shortcomings be noted in the Consensus Summary Report together with suggested remedial actions. According to their instructions the Panel was not able to request an alternative assessment. However, the remedial actions were minor in nature, and the Assessment Team were willing to make the changes during the RW. The alternative of reconvening the AW and the RW in the future would have been inefficient in terms of time and money.

The RW acknowledges that by opening the door to "minor changes" that a grey area is introduced. However, the Panel believe that future Review Panels should be attributed with sufficient common sense to allow them some latitude. They should always be guided by whether changes to the assessment can be made "safely" (without an undue possibility of errors being made), are in the spirit of the assessment (i.e., not using a different method or model), and are agreed to by the Assessment Team and the SEDAR Coordinator.

2. Review RW Term of Reference 5 to bring the Advisory Report back into the RW Terms of Reference.

The RW Term of Reference 5 has two parts. First, there is a check that the "Stock Assessment Report" is consistent with the required outline. Second, there is a check that the results are consistent with the Panel's decisions regarding adequacy and appropriateness. The second part creates some problems if an RW finds any deficiencies with the assessment which are addressed during the RW. Should the Assessment Report be revised to include the new results? This Term of Reference makes more sense if an RW is not a workshop, but simply an "accept" or "reject" forum.

The assessment goes forward into the Advisory Report, but an RW does not consider the Advisory Report in any of its Terms of Reference. During this RW, the base case and sensitivity runs to be presented in the Advisory Report were recommended by the Panel and agreed to by the Assessment Team (although the Assessment Team also included runs in the Advisory Report that the AW had agreed upon). The RW spent some time reviewing the Advisory Report (although the full set of results were not available). We took this approach because it seemed appropriate that an RW's decisions are necessarily reflected in the Advisory Report. That is, the possibility of a disjunction between an RW's decisions and the Advisory Report should be minimized.

3. Clarify Data Workshop and Assessment Workshop Terms of Reference

The RW had some difficulty in understanding the exact purpose and meaning of some of the DW and AW terms of reference. We suggest a brief review of these terms of reference.

4. Send documents as electronic copies, with hard copies of the main reports only.

This would provide some cost savings without detracting from the information available to participants. If a participant really does require all documents in hardcopy, they could still be provided on request.

Appendix A: Summary of Assessment Team results in response to Panel requests

Model runs

1. Initial base case with high virgin recruitment and constrained directed catch history

The Panel wanted some confirmation of why the input data necessarily lead to high current depletion. In an attempt to clarify this issue we requested a model run which fixed virgin recruitment at a much higher level than was estimated in the initial base case. The CVs on the directed catch history were modified to force the directed catches to be taken. The expectation, of some Panel members, was that there would be a bad fit to some, or most, of the abundance indices (showing that the indices were incompatible with a much larger virgin stock size).

The model found a best fit to the data by estimating a long series of poor recruitment from the beginning of the fishery (1872) up to near the beginning of the available abundance data. Predicted shrimp bycatch was reduced but the fit to other data was similar to the initial base case. The Panel did not pursue further runs aimed at understanding why the data were producing the high current depletion. We concluded, that with flat or increasing abundance indices in recent times, that fishing down had to have occurred before the period of the abundance indices, and that recent high catches were necessarily supported by good recruitment. The level of depletion was probably dictated by the extent of truncation in the catch-at-age data.

2. ASAP run with revised and expanded input data (1984 time series) and revised parameters but the same approach as the 1999 assessment

The Panel wanted to understand what the primary differences were between the previous assessment results in 1999, and the current assessment results, and whether the differences were due to a change of model or data. A single extra run was proposed, termed the “continuity run”. This was specified to incorporate all input data (1984 time series) and parameter changes adopted in the current assessment, but to use the model (ASAP) and “logic” of the 1999 assessment.

There are a number of difficulties when making comparisons with the 1999 assessment results. First, there were “low” and “high” recruitment scenarios considered in 1999. For the continuity run, the same logic was applied, as in 1999, to derive low and high recruitment runs for comparison. However, the logic of 1999 delivered different values of R_0, than those obtained in 1999, for “low” and “high” recruitment. Secondly, ASAP and CATCHEM have different definitions of effective spawners. Comparisons between ratios are appropriate, but absolute values cannot be compared. For this reason, absolute comparisons were made using mature biomass. Lastly, the CATCHEM base case has eastern and western stocks, but in 1999 there was a single stock assumption. Comparisons are made, where appropriate, by summing eastern and western estimates.

The continuity run with high recruitment gave almost identical estimates of depletion to the 1999 high recruitment run (Figure 1). The low recruitment runs gave similar estimates of depletion, in an absolute sense, but showed different trends (Figure 1). When considered relative to an S_{MSY} benchmark the continuity runs are somewhat different to the 1999 runs, in an absolute sense, but show very similar trends (Figures 2 & 3). The CATCHEM base case shows less depletion than the ASAP runs, ranging from 1–8% of virgin effective spawners (Figure 4). However, all of the runs show high levels of depletion (less than 10% of virgin effective spawners, see Figures 1 &

4). In terms of mature biomass, large differences are seen between the 1999 ASAP runs, the continuity runs, and the CATCHEM base case (Figure 5). The CATCHEM run shows the lowest estimated levels (from 1989 onwards), with the 1999 ASAP runs being higher by a factor of 3–4 (Figure 5). About half of the difference is accounted for by the change in the maturity and mean weight-at-age vectors (see Figure 6).

3. All remaining runs for combinations of:

{1872 time series, 1984 time series} x {const q, random q} x {age 0, age 1}

The shorthand "random q" refers to allowing a random walk in the catchability coefficients of the directed fisheries; "const q" denotes constant catchability in the directed fisheries. For x = 0 or 1, "age x" denotes age-x red snapper as the minimum age class in the model. Three of these runs had already been completed. The remaining runs were prioritized with the two runs "1984 time series – random q – { age 0, age 1}" given the lowest priority.

The three dimensions of the eight runs were identified as the primary "dimensions of choice", and the RW agreed that one of these runs would be selected as a base case (such a selection was a milestone in the draft RW Agenda). The length of the time series (primarily catch history) is an important choice because it must be acknowledged that the early catch history, although based on best available data, has uncertainties associated with it which cannot adequately be captured by assigning relatively arbitrary (but high) CVs. The 1984 time series option uses only actual observations. The random walk q was investigated as there undoubtedly have been changes in catchability (due to technology improvements). There was concern that the higher recent recruitment estimates could be an artifact of the model assumption that restricted catchability to a constant level. The issue of age-0 fish being included or not is clearly important (see Section 2.2).

The two random q runs with the long catch history were found to be very similar to the constant q runs. While these sensitivities suggested that catchability may have been changing, any conclusions are weak because of the lack of direct observations on fishing effort. The sensitivity runs made no substantial difference in the estimated recruitment pattern. Because of these results, the request for the two low priority runs was withdrawn

The length of the time series made some difference to the absolute level of biomass (and hence long term yields) but gave similar results with regard to depletion level. The previously observed instability of the solution to the 1984 time series was still present, and the likelihood surface was perceived as being much "flatter". The omission or not of the age-0 red snapper in the model made little difference to a qualitative assessment of the results. The RW chose as a base case the 1872 time series, with constant q, and inclusion of the age-0 red snapper. The 1984 time series, with constant q, and inclusion of age-0 red snapper was recommended as a sensitivity run to be taken forward to the Advisory Report.

4. Projections from the base case using higher average future recruitment

The Panel requested additional projections for the base case where future recruitment and MSY calculations were predicated on higher values for R_0 than the estimated value. The requested alternative values for R_0 were (a) the average of the estimates from 1984 to 2003, to reflect the possibility that the more recent values may provide a better reflection of recruitment in the near future, and (b) the value estimated with the 1984 time series, ostensibly as an upper bound. These requests required non-trivial changes to the existing code, which were accomplished towards the end of the meeting. Two sets of deterministic projections, based on recruitment scenario (a), were completed in time to be presented to the meeting.

The first set assumed a 40% reduction in shrimp bycatch rates beginning in 2007 and various levels of constant catch from the directed fishery. The results indicated that the stock could recover to MSY levels by as early as 2017 even with the current TAC, provided shrimp bycatch is in fact reduced by 40% (and provided post-settlement compensatory mortality effects are unimportant relative to shrimp bycatch). The second set of projections assumed current shrimp bycatch rates would continue into the future and the effort of the directed fisheries would be reduced to F_{MSY}. Under those conditions the stock could recover to MSY levels by 2025, but the initial TAC would have to be reduced to about 7 million pounds.

<u>Diagnostics</u>

1. Standardized residuals

The original assessment was rather weak on the provision of diagnostics. The Panel was interested in whether the residuals were consistent with the model's assumed (and estimated, through a common variance term) CVs and the statistical error structures: lognormal for catch, effort, and abundance indices; and multinomial for catch-at-age.

The production of quantile to quantile (Q-Q) plots was requested for the RW base case together with the standard deviations of the standardized residuals (sdsr). If the assumptions of the model are satisfied then Q-Q plots should show the residual distribution near the y=x line, and the sdsr values should be near to 1.

Most Q-Q plots showed good agreement with the lognormal assumption. The multinomial assumption for the catch-at-age data did not appear to be satisfied (Figure 7). The distribution of catch-at-age residuals was skewed with a standard deviation much greater than 1 (Table 2). Most other time series had residuals consistent with their CVs, the exceptions being the two handline time series (which were fitted too well relative to their CVs) and the larval-E time series (which was fitted badly relative to the CVs).

The Panel did not consider these results to be a problem for this assessment. Rather, they viewed the further development of diagnostics as work for the future.

2. Capture rate (catch + discards) at-age trajectories

The Panel debated what would be a useful diagnostic for a reality check on the estimated catch levels. The question is whether estimated catch levels are credible given the available biomass. The Panel requested time trajectories of (instantaneous) capture rate (catch plus discards) at age by stock.

The two stocks showed different patterns at age as would be expected given different levels of shrimp bycatch and the somewhat different selectivity patterns of the fisheries (Figure 8). The eastern stock had lowest rates on ages 0–2 years, with highest rates on ages 3–5 years (Figure 8a). In contrast, the western stock had its highest rate on age-1, with lowest rates on the oldest age classes; the age-0 red snapper had rates similar to ages 3-7 years (Figure 8b). The credibility of any of these rates was not addressed by the RW as there is currently insufficient understanding of the distribution of age classes relative to the effort in the fisheries.

3. Spawner-recruitment relationship

The Panel requested, for this report, a plot of the estimated recruitment used in the RW base case, together with the predicted average future recruitment from the S-R function (Figure 9). This plot illustrates, for both stocks, that the past and future recruitment from the S-R function is lower than average estimated recruitment over the last 20 years. This is why, on the balance of probabilities, the Panel prefer the use of mean estimated recent recruitment to predict future recruitment levels.

<u>Miscellaneous requests</u>

1. Mature biomass trajectories in contrast to effective-spawner trajectories

The Panel wanted some idea of the effect of increasing egg-production at age on the perception of stock depletion. That is, what proportion of the high level of depletion in the total egg production (as measured by effective age-30 spawners), was due to the loss of older, larger, fish (females), and what was due to depletion of mature biomass.

The Assessment Team produced plots of mature biomass trajectories (as a proportion of virgin) for each stock which were based on mean weight-at-age from catch data, which was only available up to age 15. The comparison of mature biomass with effective spawners showed a divergence between the trajectories for the western stock early in the time frame (1870–2003) which was not present for the eastern stock. The RW concluded that the stock difference may have been an artifact of the use of mean weights from catch data. A more appropriate method of calculating mature biomass was pursued after the RW.

2. Virgin predicted selected age frequencies (by fishery) contrasted with average observed age frequency

The Assessment Team suggested it would be useful to contrast age frequencies for selected biomass in the virgin population with the average observed age frequency. The Panel agreed that this could provide some insight into how the observed age frequencies were influencing the estimates of depletion.

There is strong contrast between the virgin and exploited age frequencies even for the fisheries with highly domed selectivity patterns (Figure 10).

Table 1. Summary of results for the eastern and western stocks for the RW base case (age 0 included, 1872-2003 time series, R_0 = average recruitment from 1984-2003) for F_{MSY} and $F_{30\%}$ under the current shrimp effort, a 40% reduction in shrimp effort, and the current effort proportions ("linked"). SPR values of 30% or higher could not be achieved for the current shrimp and 40% shrimp reduction scenarios.

Area	Benchmark statistic	Effort allocation schedule: Current shrimp	40% shrimp reduction	Linked
East	MSY (mp)	4.6	5.4	6.6
	F_{2003}/F_{MSY}	2.3	2.1	3.8
	S_{2003}/S_{MSY}	0.34	0.34	0.12
	S_{2010}/S_{MSY}	0.7	0.67	0.42
	year $S/S_{MSY} = 1$	2020	2020	2027
	SPR at F_{MSY}	10%	10%	27%
	Yield at $F_{30\%}$ (mp)			6.6
	$F_{2003}/F_{30\%}$			4.1
	$S_{2003}/S_{30\%}$			0.11
	$S_{2010}/S_{30\%}$			0.39
	year $S/S_{30\%} = 1$			2027
West	MSY (mp)	7.1	12.1	19.9
	F_{2003}/F_{MSY}	2.3	2.1	3.8
	S_{2003}/S_{MSY}	0.26	0.17	0.04
	S_{2010}/S_{MSY}	0.62	0.42	0.24
	year $S/S_{MSY} = 1$	2025	2027	2032
	SPR at F_{MSY}	5%	7%	27%
	Yield at $F_{30\%}$ (mp)			19.8
	$F_{2003}/F_{30\%}$			4.1
	$S_{2003}/S_{30\%}$			0.04
	$S_{2010}/S_{30\%}$			0.22
	year $S/S_{30\%} = 1$			2032

Table 2. Standard deviation of the standardized residuals for each index and for all catch-at-age residuals. There are east (E) and west (W) series for each index (HL=hand line; LARV=larval survey; REC=recreational; TRW0=trawl survey age-0; TRW1=trawl survey age-1; VID=video survey).

Index	Standard deviation of standardized residuals
HL-E	0.53
HL-W	0.54
LARV-E	1.98
LARV-W	1.51
REC-E	0.71
REC-W	0.84
TRW0-E	1.47
TRW0-W	1.32
TRW1-E	1.08
TRW1-W	1.08
VID-E	0.81
VID-W	0.80
Catch-at-age	3.48

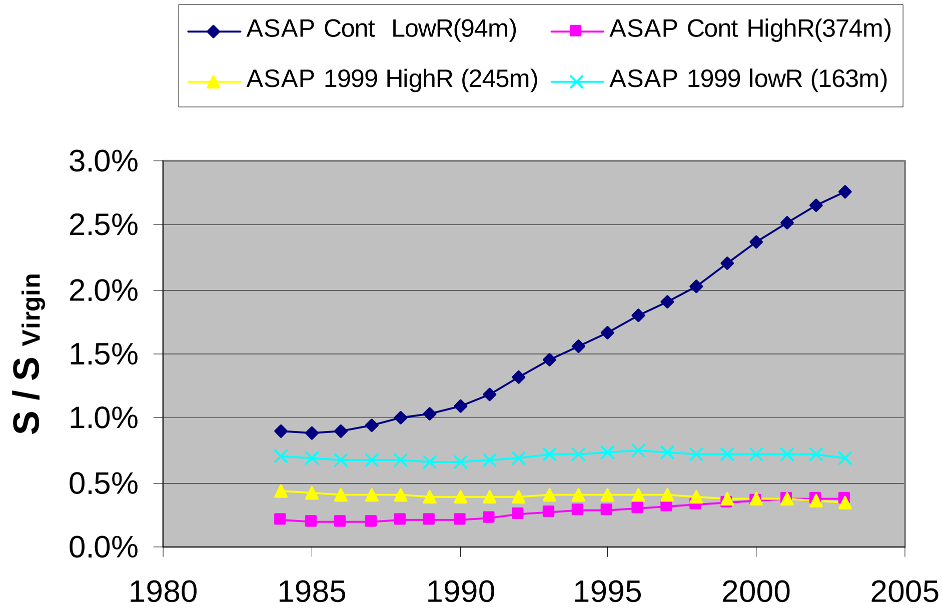


Figure 1: Effective spawners as a percentage of virgin from 1984–2003 for the 1999 ASAP assessment (ASAP 1999) and the RW continuity run (ASAP Cont). There are low and high recruitment scenarios for each case. Values of R_0 for the continuity run were derived using the same logic as the 1999 assessment.

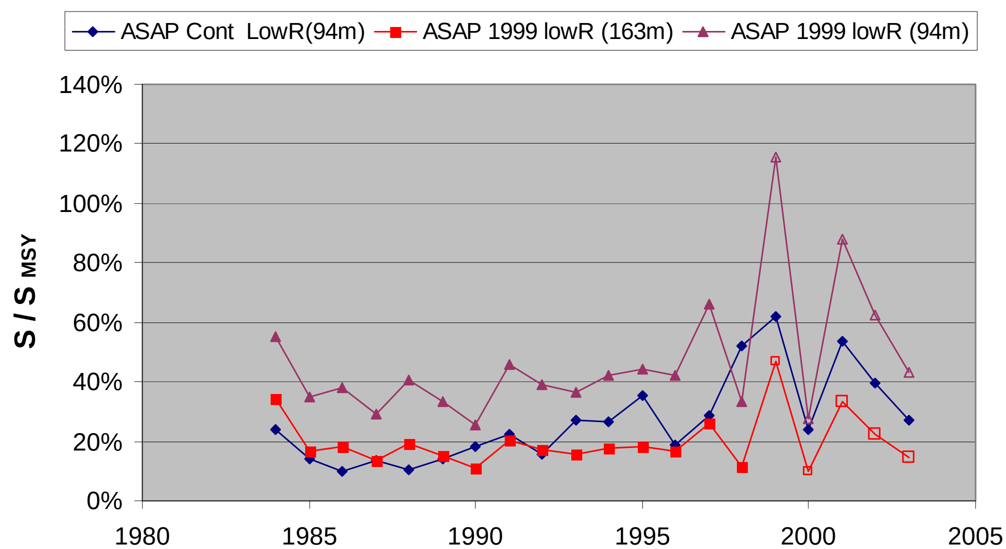


Figure 2: Effective spawners as a percentage of S_{MSY} for low recruitment cases. ASAP 1999 values for 1999–2003 are from a projection using observed directed yield and shrimp bycatch (indicated by open symbols).

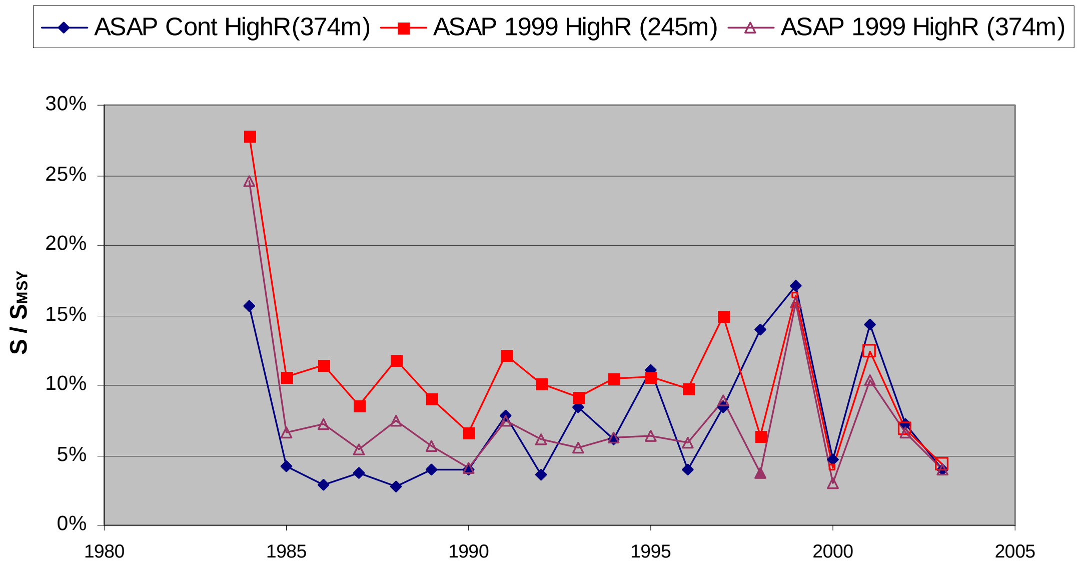


Figure 3: Effective spawners as a percentage of S_{MSY} for high recruitment cases. ASAP 1999 values for 1999–2003 are from a projection using observed directed yield and shrimp bycatch (indicated by open symbols).

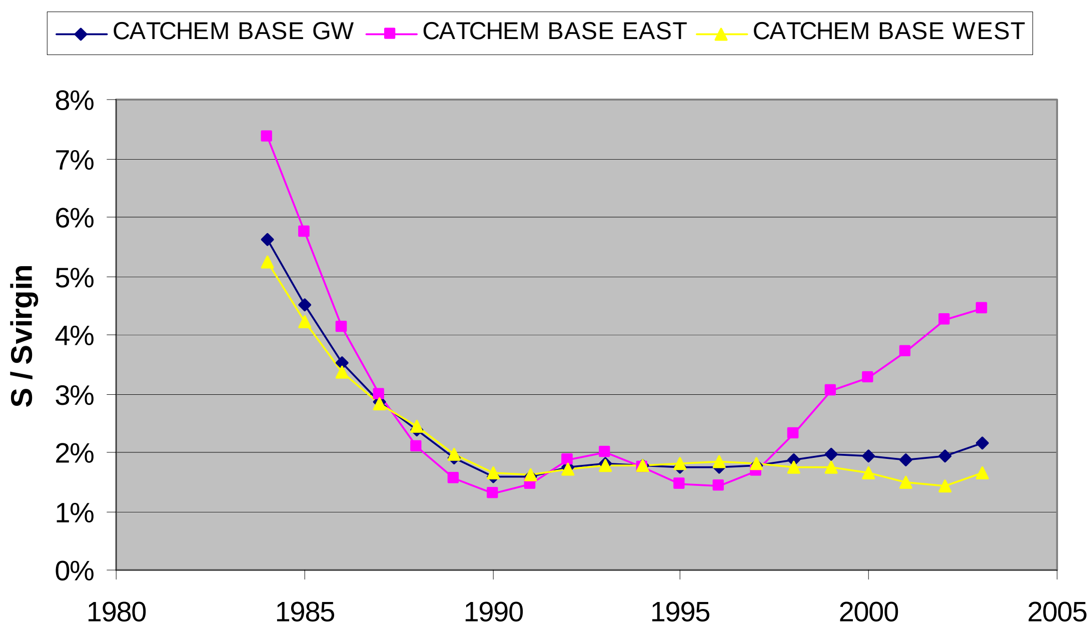


Figure 4: Effective spawners as a percentage of virgin from 1984–2003 for the CATCHEM RW base case. Results are shown for the eastern and western stocks separately and for the sum of the two stocks (GW).

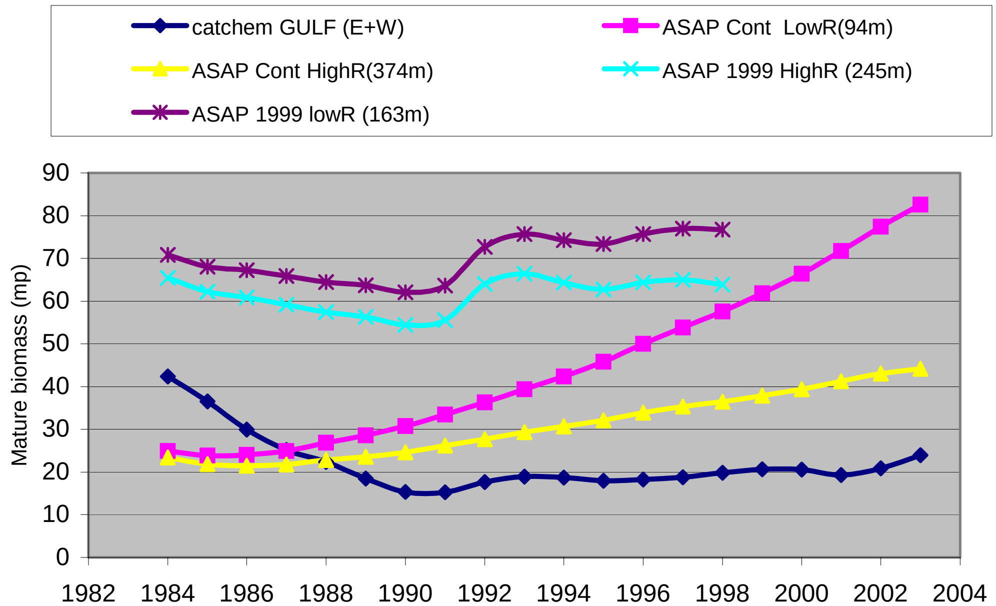


Figure 5: Mature biomass from 1984–2003 for the CATCHEM and ASAP continuity runs and for 1984–1998 for the 1999 ASAP low and high recruitment runs. Maturity and mean weight-at-age vectors used for the 1999 ASAP runs were consistent with assumptions in 1999.

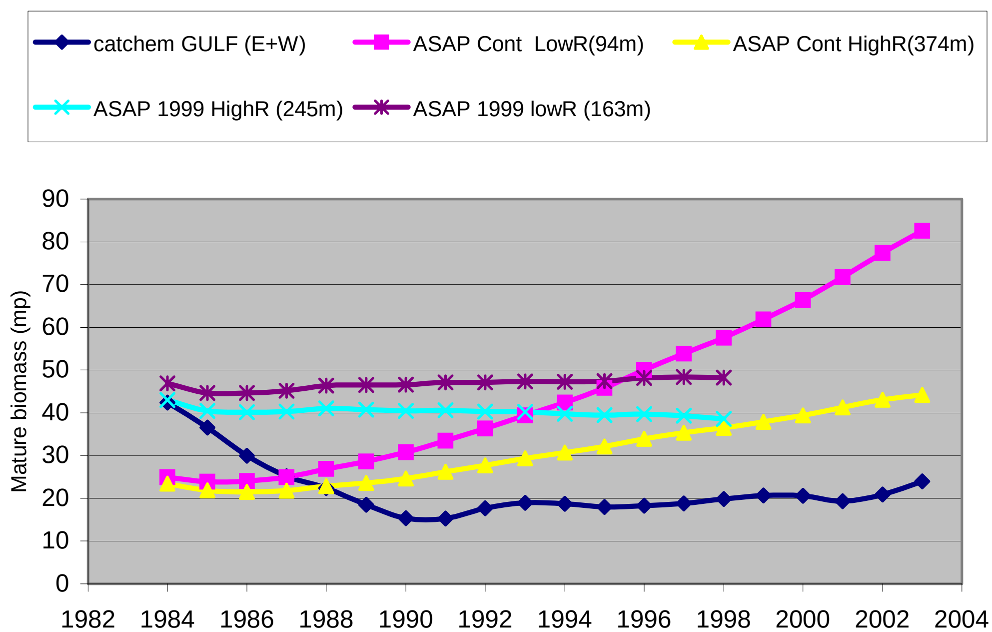


Figure 6: Mature biomass from 1984–2003 for the CATCHEM and ASAP continuity runs and from 1984–1998 for the 1999 ASAP low and high recruitment runs. The CATCHEM maturity and mean weight-at-age vectors were used for all runs.

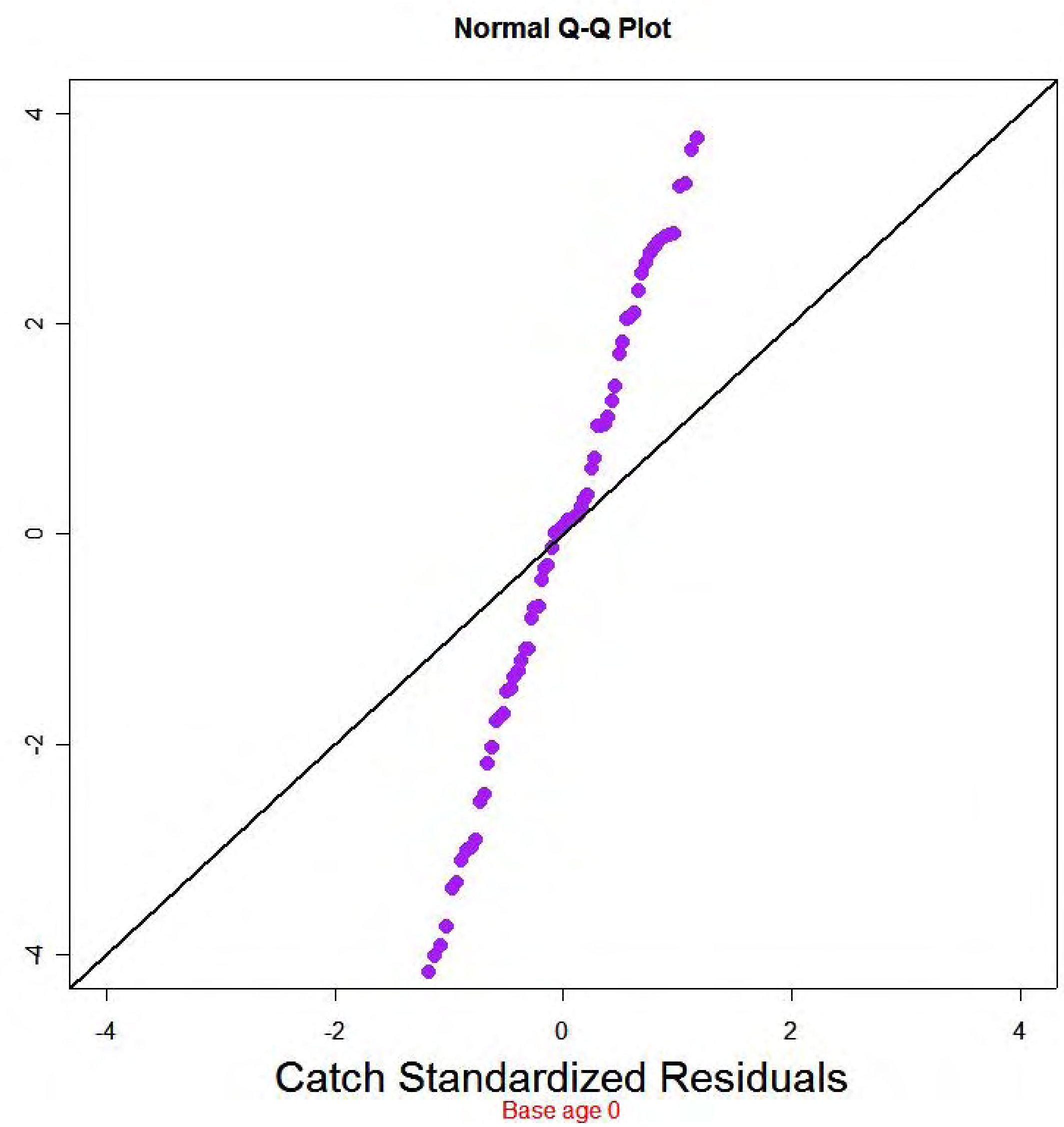


Figure 7. Q-Q plot of standardized residuals for the RW base case fit to observed catch-at-age (mean = -0.084, standard deviation = 3.48) showing highly skewed and over-dispersed residuals

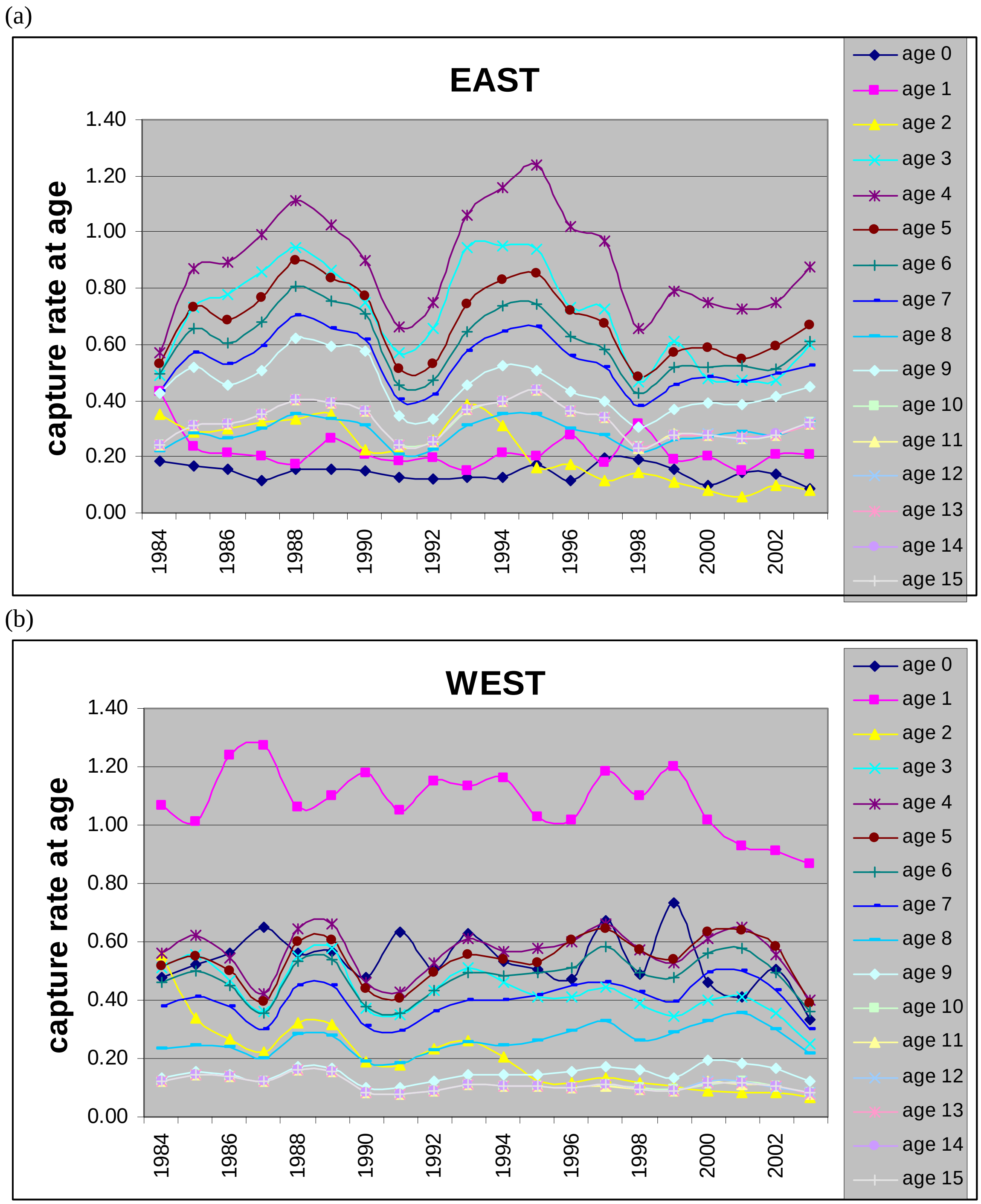
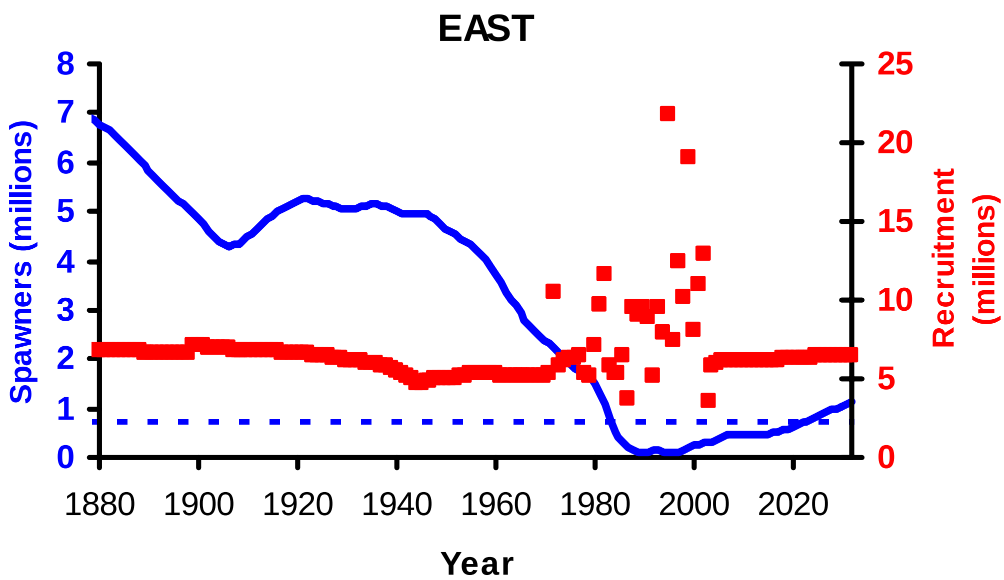


Figure 8. Capture rate at age in the east (a) and west (b) from 1984-2003. Capture rate reflects the instantaneous rate for fish that were caught (this includes landings as well as discards due to size limits and closed seasons). Age 15 is a plus group.

(a)



(b)

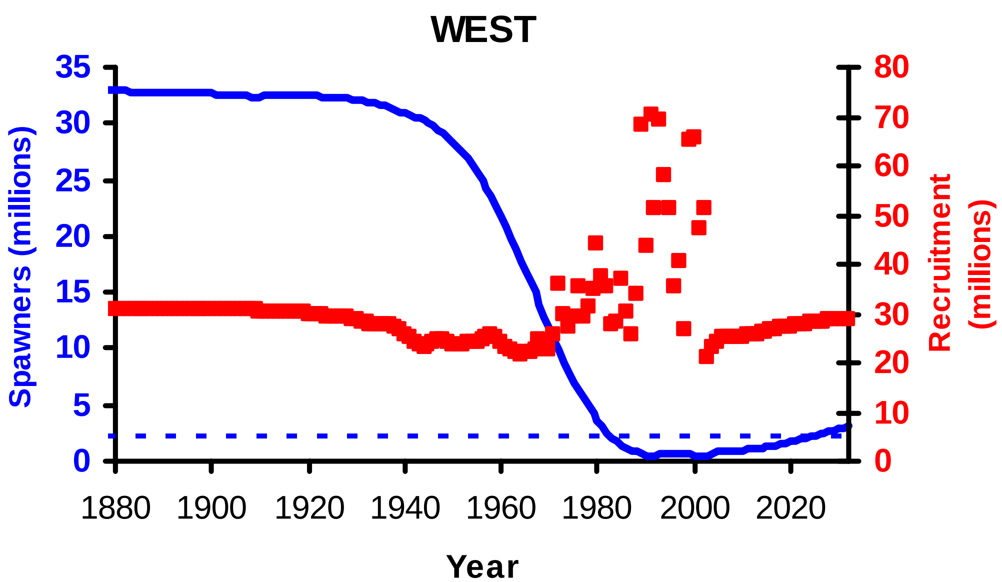
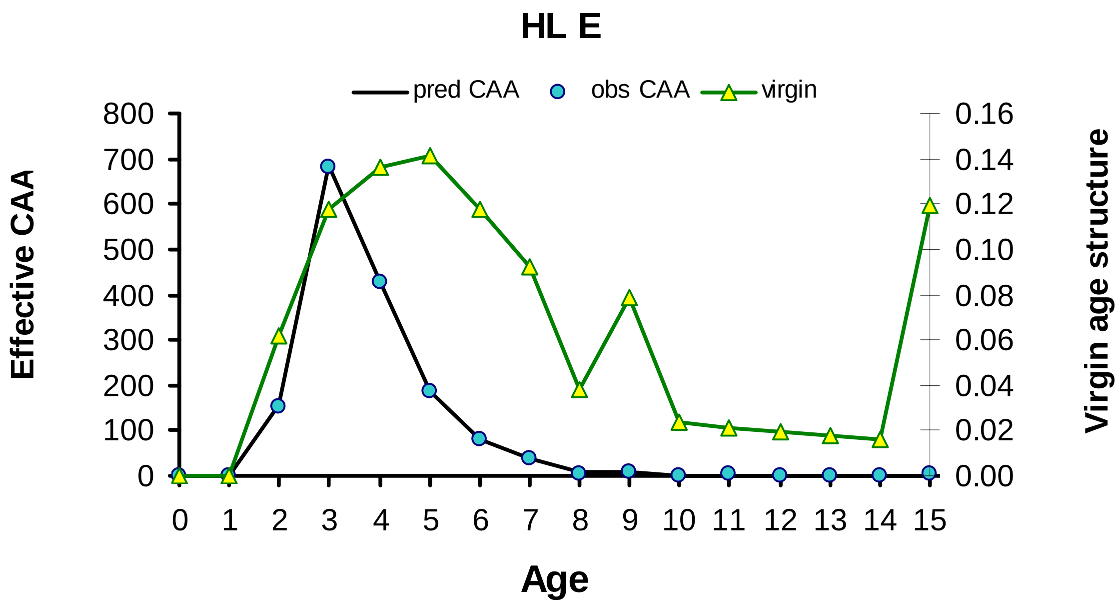


Figure 9. Trajectory of estimated effective spawners and predicted recruits in the east (a) and west (b) from 1872-2032. The dashed line is the effective spawners corresponding to 30%SPR.

(a)



(b)

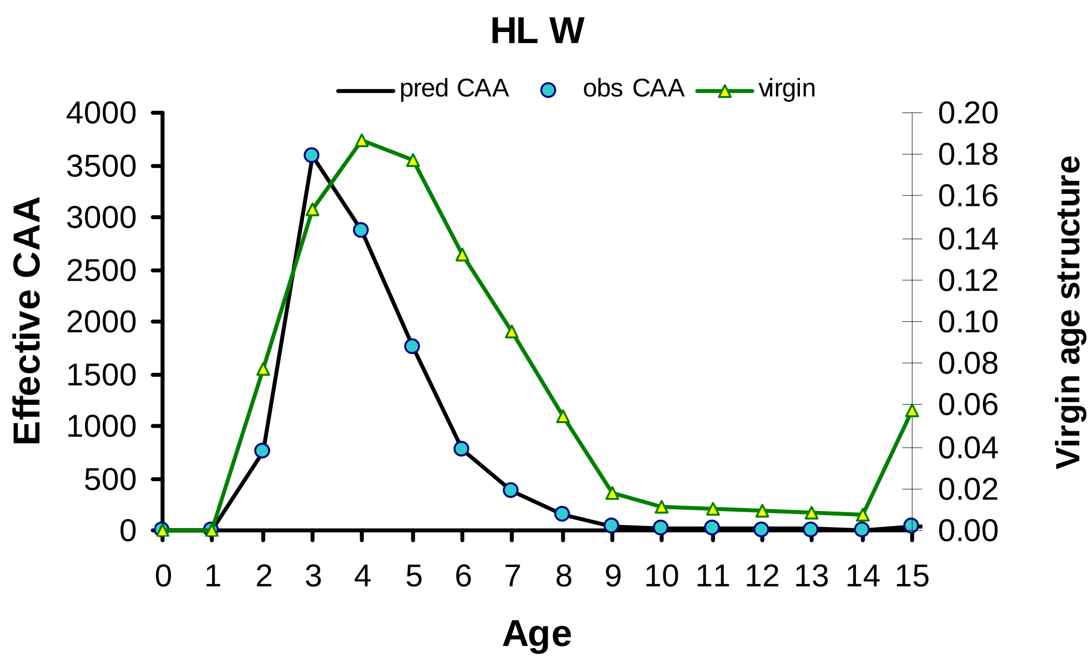


Figure 10. Unexploited age frequency (virgin) versus exploited age frequency (observed averaged across years, and predicted averaged across years) for the handline fisheries in the east (a) and west (b). Age 15 is a plus group.

SEDAR 7
Gulf of Mexico Red Snapper

Review Workshop Report

2. Reports submitted to the CIE by the Chair and CIE Reviewer

NOTE: The following are excerpts. Materials and sections that are duplicated elsewhere in this report, such as workshop attendance lists, agendas, and document lists are omitted here.

CHAIR REPORT ON THE

SEDAR 7 REVIEW WORKSHOP

APRIL 4–7, 2005

NEW ORLEANS, LOUISIANA

Prepared by

Patrick Cordue
Fisheries Consultant
New Zealand

for

University of Miami
Independent System for Peer Review

29 April 2005

EXECUTIVE SUMMARY

The SEDAR 7 Review Workshop for Gulf of Mexico red snapper was held in New Orleans from 4-7 April 2005. The SEDAR process normally involves a Data Workshop, an Assessment Workshop, and a Review Workshop. For red snapper, the process involved two Assessment Workshops and spanned more than 12 months. This was due to the complex nature of the red snapper assessment and because of problems encountered with the original choice of assessment method.

The draft agenda was reasonably closely followed during the meeting. On the first day, the Assessment Team made their main presentations. The morning of the second day saw discussion of, and agreement on, a set of model runs to be done (working towards a milestone in the draft agenda: “identify preferred model configuration”). Over the remainder of the second day, and during the third day, the Review Panel formally addressed their terms of reference. New assessment results were presented by the Assessment Team and discussed by the meeting as they became available. On the last day, the Panel reviewed preliminary drafts of the Consensus Summary Report (prepared by the Panel) and the Advisory Report (prepared by the Assessment Team). Also, further results were presented and discussed when they were available. After the meeting, via email, the Consensus Summary Report was completed by the Panel and the Advisory Report was completed by the Assessment Team.

Two issues of process arose during the meeting. First, there was a conflict between the draft agenda and the Review Panel’s instructions. The Panel’s written instructions strongly implied a “review only” role, but the draft agenda implied an active role in choosing a base case assessment. The issue was discussed at the meeting and it was concluded that it was better to follow the agenda, even if it lead to a somewhat altered assessment. The alternative appeared to be reconvening the Review Workshop at a later date.

The second issue was that the Advisory Report was not part of the Review Workshop’s terms of reference. This was also discussed at the meeting and it was agreed that the Review Panel should provide some guidance to the Assessment Team on the model runs to include in the Advisory Report.

The model run selected by the Review Panel as a base case assessment differed from the assessment presented to the meeting by the Assessment Team. The second Assessment Workshop had agreed to exclude age-0 red snapper from the assessment despite the bycatch of age-0 (and age-1) red snapper in the shrimp fishery. This is valid if density dependent mortality effects are so strong on age-0 snapper that the bycatch from the shrimp fishery is insignificant. The Review Panel did not accept this argument and selected a base case that included age-0 red snapper. The Advisory Report contains an equal number of model runs with and without age-0 red snapper. The Assessment Team included the age-1 snapper runs as they viewed the Advisory Report primarily as a product of the Assessment Workshops. However, they did indicate the Review Panel’s strong preference for the age-0 snapper runs.

There is a need to clarify some aspects of the SEDAR process and in particular the role and authority of the Review Workshop. Clarity of the process, to all parties involved, is perhaps more important than the specific details of the process.

INTRODUCTION

The SEDAR 7 Review Workshop (RW) for Gulf of Mexico red snapper was held in New Orleans from 4-7 April 2005. The SEDAR process normally involves a Data Workshop (DW), an Assessment Workshop (AW), and an RW. For red snapper, the process involved two AWs, and spanned more than 12 months. This was due to the complex nature of the red snapper assessment and because of problems encountered with the original choice of assessment method.

SUMMARY OF MEETING

The meeting convened in New Orleans at 8.30 am on 4 April and concluded at 6.30 pm on 7 April. After convening, there were opening remarks from the SEDAR Coordinator and then the draft agenda was briefly considered. There was a minor change with consideration of possible sensitivity runs at the end of the first day. The draft agenda was reasonably closely followed during the meeting (see Appendix 1). The first day was used for presentations by the Assessment Team. The morning of the second day saw discussion of and agreement on a set of model runs to be done (working towards a milestone in the draft agenda: "Identify preferred model configuration"). Over the remainder of the second day, and during the third day, the Review Panel addressed the RW's terms of reference 1–7 (see Appendix 1). New assessment results were presented by the Assessment Team and discussed by the RW as they became available. On the last day, the Panel reviewed preliminary drafts of the Consensus Summary Report (prepared by the Panel) and the Advisory Report (prepared by the Assessment Team). Also, further new results were presented and discussed when they were available. After the meeting, via email, the Consensus Summary Report (CSR) was completed by the Panel (with help from the Assessment Team, through provision of results and figures) and the Advisory Report was completed by the Assessment Team.

4 April 2005

There were the initial preliminaries: round-the-table introductions, a brief consideration of the draft agenda, and the assignment of writing tasks to the technical members of the Panel. The Assessment Team then made presentations summarizing the DW, the two AWs, previous assessment recommendations, and the current red snapper assessment.

The presentations were well structured, and well delivered. The information presented, and the answers provided to questions, provided a good foundation for the Panel's subsequent deliberations.

Key points with regard to the DW:

- the move from a single-stock to a two-stock hypothesis, east & west of the Mississippi;
- the many and varied data sources, but relatively sparse data;
- compilation of data into appropriate formats for two-stock or previous single-stock models;
- no data prior to the presumed fishing down period (based on previous assessments);
- the high level of estimated steepness (previous assessments) which motivated the construction of an "ultra-historical" catch history (back to the start of the fishery in 1872);

- the key importance of the shrimp fishery due to the bycatch of age-0 and age-1 red snapper;
- the consequent importance of natural mortality at age-0 and age-1, new estimates of which are double previous estimates; and
- the importance of the timing of density dependent mortality.

Key points with regard to the AWs and assessment:

- four different modeling approaches were used;
- an enormous number of model runs were performed;
- there were two AWs, but the agreed assessment was not presented to the second AW - there was only agreement on the assessment specification. the assessment was performed after the second AW;
- the previous assessment model (ASAP) could not cope with the ultra-historical catch history;
- also, ASAP was unstable with some shorter catch histories/data sets;
- the move to CATCHEM was necessary because it could deal with the relative sparseness of the available data and the ultra-historical catch history;
- CATCHEM is a generalization of ASAP, both are age-based, observation error models, using a "best fit" approach (Bayesian in the case of CATCHEM);
- although CATCHEM is age-based, it does generate length frequencies as needed;
- CATCHEM runs take a long time to converge (up to 24 hours if length frequency data are used, and several hours otherwise);
- age-0 red snapper were excluded from the model in the AW base case – assuming density dependent compensation effects override fishing mortality of age-0 snapper;
- inclusion of age-0 snapper qualitatively makes little difference to the assessment results (but could be important in terms of policy decisions on resource allocation);
- the ultra-historical catch history did not reduce the very high steepness in the stock-recruitment relationship; and
- the estimated recruitment since 1985 was, on average, higher than virgin recruitment despite the stock being estimated as highly depleted.

The first day concluded with a brief discussion of possible sensitivity runs that could be started that night (because of the long run times for CATCHEM). There was a suggestion to consider possible changes in catchability for the directed fisheries, which might account for the high estimated recruitment in recent times (i.e., improved technology delivering higher catch rates). This suggestion led to the subsequent "random-walk q" runs (a catchability parameter q is allowed to vary as a random walk over time).

5 April 2005

The main focus of the morning was specification of the CATCHEM runs that needed to be completed during the RW. The option of interval estimation was not available for this assessment, so uncertainty had to be described using a base case together with a number of sensitivity runs. There was agreement that only CATCHEM runs would be used to describe the uncertainty in the assessment. Also, there was agreement that a "continuity run" would be performed using ASAP to illustrate which changes in the assessment results were due to changes in data (and updated parameters) and which were due to changes in model (from ASAP to CATCHEM).

Three dimensions were identified to define a set of CATCHEM runs from which the base case and sensitivities would be chosen. The dimensions were: length of time series; constant or random walk q; and age-0 snapper included or not. In order to restrict the number of runs the first dimension was limited to the 1872-2003 option or the 1984-2003 option. In the former, there is the advantage of the "full" catch history; in the latter, only real data are used. Note that three of the eight runs had already been done.

During the discussion of the potential runs, one member of the Panel alerted the meeting to the possibility that we were overstepping our terms of reference. The question raised was whether we were changing the assessment. In the brief discussion that followed there was general agreement that we needed to look at a range of runs and identify an appropriate base case (as per the agenda: "identify preferred model configuration").

Also, there was discussion about which diagnostics should be produced for each of the runs. The Panel requested that standardized residuals be produced and presented in Q-Q plots (to test distributional assumptions) and that their standard deviations be tabulated (to test for over- or under-fitting relative to their assumed variances).

In the afternoon, the Panel addressed the RW's terms of reference with regard to "scientific soundness" of data and methods, the presentation of results in the Assessment Report, and whether the DW and AW had addressed their terms of reference. The Panel concluded that overall the DW and AWs had done a good job and had more than adequately addressed their terms of reference. Two deficiencies were noted: inadequate diagnostics for the model runs, and insufficient explanation of why age-0 snapper were omitted from the model. The RW was told that the omission of age-0 snapper was a compromise; there were those at the AW who argued that density dependent compensation effects could extend to higher ages, perhaps up to age-2 or even age-3 (so that omission of age-0 *and* age-1 was a possible option).

6 April 2005

During the previous evening, I had reviewed the RWs terms of reference, the Panel's instructions, and the draft agenda. In the morning, I asked the meeting to again consider whether it was appropriate for the RW to choose a base case that might differ from the assessment proposed by the Assessment Team. The Review Panel instructions were quite clear: "… the Chair may request a reasonable number of sensitivity runs…However, the review panel is not authorized to conduct an alternative assessment nor to request an alternative assessment…". Against that, we had an agenda milestone: "identify preferred model configuration".

The Panel discussion was similar to the previous day, but better focused. We apparently had two alternatives. These were to either note the deficiencies in the assessment and reconvene the RW at a later date after remedial actions had been taken, or to address the deficiencies at the current meeting. Since the Assessment Team were able to make the desired changes to the assessment at the current meeting, and they could do so without undue haste, it was agreed that we would proceed with the choice of a base case.

New model results were presented, and the RW chose as the base case the 1872-2003 time series, with a constant q, and the age-0 snapper included. The analogous, 1984-2003 time series run was chosen as a sensitivity test. Projections were requested for three future recruitment scenarios: using the stock-recruitment relationship; using the average of the last 20 years estimated recruitment; and using the (much higher) average from the 1984-2003 run. The idea was to bound the likely future average recruitment. Different shrimp bycatch options were also to be considered.

Diagnostics were reviewed for the base case. They looked acceptable, but the standardized residuals for catch-at-age data were yet to be produced. I consulted further with the Assessment Team to explain how to use the normal approximation to the binomial to check the multinomial assumption for the catch-at-age data.

In the afternoon, the Panel considered the RW's remaining terms of reference: projections and benchmarks, and research recommendations. We also "previewed" the Advisory Report. This was another area where the agenda was in conflict with the terms of reference. The Advisory report was not mentioned in the terms of reference, but there was an agenda item to review a draft. Since the RW had made changes to the assessment and recommended sensitivity runs it seemed appropriate that we agree with the Assessment Team what would appear in the Advisory report, hence the "preview".

7 April 2005

During the day, results from requested analyses or runs were presented as available. This included the continuity run, which showed that the new data and updated parameter values gave similar results to the previous ASAP assessment in 1999. There was also little qualitative difference between the CATCHEM base case and the updated ASAP run in terms of depletion level.

The Panel had written their individual sections for the CSR outside of the normal meeting hours. In the afternoon, the pieces were compiled into a single document for review. Panelists were given some time to read each other's sections, and then we reviewed the document as a group. The objective was to agree on the sense of the text rather than the exact wording.

Diagnostics for the base case were again presented, but this time with the catch-at-age residuals. Most diagnostics were acceptable, but the catch-at-age data were not consistent with the model assumptions of a multinomial distribution with the assumed effective sample sizes. Perhaps this was not a serious problem, but certainly it is something to be looked at for future assessments.

Two sets of projections were presented near the close of the meeting. Qualitatively, the results were very similar to the original assessment presented to the RW on the first day.

11-27 April 2005 (New Zealand)

I revised the preliminary draft of the CSR as soon as possible after the RW. Most sections had to be revised and reorganized to some extent. Text had to be inserted to provide linkage between sections and most of the text describing the Panel's requests of the Assessment Team and the subsequent results had to be written (a section on projection results was provided by the Assessment Team). A tidy draft was circulated to the Panel by email on 15 April (copied to the Assessment Team leader and the SEDAR Coordinator). It included everything except the plots and text for the comparison of the continuity run with the 1999 ASAP run and the RW base case. These were still being prepared by the Assessment Team.

Over the next few days the Panel provided what were mainly editorial suggestions on the tidy draft. There were two substantive issues. First, the reduction in sampling in 2003 reported in the draft was actually a timing issue in that the data had been collected but were not available for the assessment. Second, there was a suggestion to include more results with regard to the RW's base case. One panelist suggested some text be inserted and another suggested that a table of results be provided for a range of effort allocation scenarios. I was not initially supportive of these suggestions as I considered that the appropriate results would be contained in the Advisory Report.

After several emails, it was established that the Assessment Team were including, in the Advisory Report, runs additional to those recommended by the Panel. The point at issue was the inclusion or not of age-0 snapper in the assessment model. The AW had recommended that the model start with age-1 snapper, whereas the RW had recommended that age-0 snapper be included. The Assessment Team were planning to include equal numbers of age-0 and age-1 runs in the Advisory Report whilst indicating that the preference of the RW was for the age-0 runs. I then felt obliged to include the RW's base case results in the CSR to emphasize the preference of the Review Panel. I requested the results from the Assessment Team.

A revised version of the CSR was circulated on 22 April. Its contents were complete, including the requested assessment results and the plots missing from the previous draft. Parts of the text were revised to ensure consistency with the contents of the Advisory Report, in particular noting the strong preference of the Panel for the inclusion of age-0 snapper. Final editorial revisions were made on 28 April and the CSR (Appendix 3) was distributed (before the 29 April deadline).

VIEWS ON THE MEETING PROCESS

Meeting Process

Two important issues of process arose during the RW. First, there was a conflict between the draft agenda and the Panel instructions. Second, the Advisory report was outside the RW's Terms of Reference.

The Panelists were explicitly instructed that their primary duty was to review the assessment presented (see Appendix 1, "Draft Terms of Reference and Panel Instructions"). They were not to conduct an alternative assessment or to request an alternative assessment from the Assessment Team. If the Panel found that the assessment was unacceptable, then they were to outline, in the CSR, the remedial actions required to address the shortcomings. This was quite at odds with the draft agenda (see Appendix 1), which included a milestone to "identify preferred model configuration" with preliminary items which included, "identify corrections and adjustments".

The RW followed the draft agenda and we identified a base case that was different from the AW's recommendation. The Assessment Team were able to produce results for the new base case during the RW. We therefore proceeded to produce a new assessment, in direct contravention of the Panel Instructions. This caused some anxiety for the Chair and perhaps for some other participants, but the alternative appeared to be that the AW and the RW would need to be reconvened in the future.

The conflict between the draft agenda and the instructions would not have created a problem if the Panel had been in full agreement with the AW recommended assessment. However, the SEDAR process must be able to cope with such disagreements. There needs to be more clarity with regard to the exact role of the RW and the authority of the RW.

The role of the RW implied by the Panel Instructions is of an "accept or reject" nature. The draft agenda, implied an extension of the AW with fine tuning of an existing assessment, which could result in a "new" assessment (i.e., different from the AW assessment). But what is the authority of the RW? If the assessment had been rejected, would it have necessitated reconvening the AW and RW until there was an acceptable assessment, or would an Advisory Report have been produced by the Assessment Team simply noting the RW's concerns? What power does the RW have and indeed what power should it be given?

The fact that the Advisory Report is not currently in the RW's Terms of Reference creates a difficulty, which was encountered during the red snapper RW. The Assessment Team can produce an Advisory Report that ignores, to some extent, the RW's recommendations. The red snapper assessment was changed by the RW, and the Assessment Team produced an Advisory Report that could be seen as containing "competing" assessments: the RW base case and the AW base case. An alternative view is that the extra runs help to capture an appropriate level of assessment uncertainty. Ideally, the latter view will be the basis of any presentations of the Advisory Report to fishery managers. Managers are put in a difficult position if they have to choose between competing assessments. An avoidance of exactly that situation is no doubt partly the reason for the instructions to the Panel.

For management purposes, the ideal output from a stock assessment process is a single base case with an appropriate description of uncertainty. It must be clear in the SEDAR process where the authority to approve an assessment is vested.

It could be given to the AW. An RW would then provide quality control on the documentation, while occasionally eliminating any assessments with serious technical flaws. An Advisory Report would be produced by the Assessment Team with due recognition of comments from the RW, but the assessment would be a product of the AW.

The RW could be given the authority. An Advisory Report would then be a product of the RW and would contain an assessment approved by the RW. The assessment need not be a product of the RW. In general it would still be a product of an AW. One could allow for minor modification of an assessment at the RW along the lines recommended by the red snapper RW.

It is not clear to me which process is better. Either could work well provided that the process is made clear to all participants. There must be provision made in either process for appropriate handling of disagreements between the RW and the AW and it must be made clear who has ownership of the Advisory Report. If disagreements are settled at a later meeting (e.g., SSC), then representatives of the AW and the RW should be allowed to present their arguments.

Outcomes of the Meeting

The red snapper RW was successful in that preliminary drafts of the CSR and the Advisory Report were produced at the meeting and were subsequently finalized within the required deadlines (I assume this was the case for the Advisory Report – I have not seen the finalized version). It remains to be seen whether the meeting was successful in terms of its role in the delivery of appropriate scientific advice to fisheries managers. This will depend on the contents of the Advisory Report and the nature of the presentation of the Advisory Report to the Gulf of Mexico Fishery Management Council. The disagreement between the AW and the RW on the issue of inclusion or exclusion of age-0 red snapper may create a problem.

Materials provided

The materials provided were more than adequate. However, hardcopy is not needed for all documents. The red snapper RW Panelists could not possibly have read all of the documents before the meeting (there were so many of them – see Appendix 2). It would make sense to supply all documents electronically with only essential reading provided as hardcopy.

The provision of the source code for the models was useful. I was able to check the (CATCHEM) equations which were actually used rather than relying on the documentation (which did contain some errors).

Guidance provided to the Chair

Appropriate guidance was available to the Chair as required. The SEDAR Coordinator was at hand to provide advice on a number of issues and did so clearly and efficiently.

OTHER OBSERVATIONS ON THE MEETING PROCESS

There are two related issues on which I would like to briefly comment.

The red snapper assessment had not been updated since 1999. The DW, AWs, and RW to update the assessment have spanned more than a year. The whole process was delayed because of problems encountered with the previous assessment method when new data were added. Had a ”simple” update been possible there would not have been the need for two AW's, and the full results would have been presented to an AW, rather than only becoming available at the RW. There is perhaps a lesson here. A simple update was not the objective of the first AW given the ambitions of the DW to produce and use an ultra-historical catch history. Simple updates can be done in a timely manner to provide appropriate advice to fisheries managers. However, with such a large gap between assessments, it was unlikely that a simple update would eventuate.

In terms of providing timely scientific advice to fisheries managers, I have long advocated that there should be two asynchronous processes. Management advice should be provided by “simple” updates of stock assessments as required. The development of assessment methods and the substantial modification of data sets should be done in a separate process – it is harder and the timelines cannot be guaranteed. Scientific disagreements can also be dealt with outside of the management process.

Review of 2005 SEDAR Panel for Red Snapper

for

University of Miami Independent System for Peer Review

April 2005

CEFAS Contract C2327

COMMERCIAL IN CONFIDENCE

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Executive Summary

The SEDAR review panel examined the 2004 assessment of red snapper (*Lutjanus campechanus*). The review was held April 4th to 7th 2005 at the Country Inn and Suites hotel in New Orleans, Louisiana. The assessment data, model structure and results were presented to the Panel, and issues evaluated through open discussion. A decision was reached on the data set and assessment model to be used as a basis for management of the fishery. Recommendations for future red snapper data and assessment workshops were made.

The quantity and quality of work performed during the data and assessment workshops, and by the assessment team during the review workshop was highly impressive, and represents a considerable increase in knowledge since the last assessment. As a result, the data used within the assessment represent the best scientific information available, and the assessment approach, despite uncertainties, is adequate for the current stock assessment.

1. Adequacy and appropriateness of data

For the 2004 assessment, the time-series of catch data was extended back to the dawn of the fishery in 1872, using information available from various literature sources. This catch was divided between eastern and western regions of the Gulf. The review workshop (RW) considered that these data represented the best possible information available. The division of historical catch between areas, rather than absolute annual catch level, was considered a greater source of uncertainty. Sensitivity analyses examining the effect of different divisions of catch between east and west areas are recommended. Use of this extended time-series also required the strong assumption that biological processes remained constant over this time. Sensitivity analyses on the potential impact of temporal changes in biological parameters on the assessment are recommended.

Offshore longline catches exhibited a much older age composition than those of commercial and recreational fisheries operating inshore. This raises questions about stock spatial distribution and larval settlement, and whether the offshore component is the source of recent high recruitments despite inshore depletion. The implications of potential distributions of larvae and adults on the assessment (through the stock recruitment relationship) should be investigated. Suggestions for areas of study are made in the conclusions and recommendations section of this report.

Serial depletion of areas, as seen historically, may erroneously bolster CPUE levels, maintaining abundance level indices. This has been seen in commercial data from snapper fisheries in the Pacific, where serial depletion of sea-mounts has occurred. Available information on catch location should be examined for localized depletion.

Discard (release) mortality rates were related to depth. Fish caught in deeper waters experienced greater mortality on release. A single release mortality value was used, although a range may be more appropriate to incorporate potential stochasticity. Discard mortality will also interact with natural mortality at younger ages. An examination of the sensitivity of assessment results to different values of release mortality rate, and interaction between natural mortality and release mortality values at younger ages is recommended.

2. Adequacy, appropriateness and application of assessment methods
CATCHEM_AD, an age-structured model constructed in AD Model Builder, was used in the 2004 assessment; the ASAP model used in the 1999 assessment failed to converge when applied to the extended time-series of data. CATCHEM has the advantage of being more flexible than ASAP, allowing further factors to be incorporated (e.g. inclusion of eastern and western Gulf stocks, multiple fleets, etc.) and has better mathematical rigour owing to internalization of the catch-at-age fitting. The general perception of estimated stock status was comparable between the two models, when the short time-series of data were used. Estimated fishing mortality levels may be quite different between the two models, however. Fishing mortality estimates for the short time period run should be examined to identify differences in this metric.

CATCHEM consistently indicated that the stock was in a depleted state, but abundance indices were relatively constant, or increased slightly. Comparison of estimated unexploited age structures with current age structures did suggest that the inshore stock was depleted, supported by the high western Gulf effort level. The general perception of stock status was also unchanged between short and long time-series CATCHEM runs. The long time-series was selected as the base case, as it represents the best scientific information available. It is recommended that limited projections be performed using the short time period run to identify any differences in expected recovery period (with due consideration to management benchmarks).

While CATCHEM allows the eastern and western Gulf units to be modelled, it does not include migration rates between areas. Inclusion of migration should be considered and its potential impact examined.

The RW recommended that the base-case model include age 0 fish, as this age class is caught in an active fishery (the shrimp trawl fishery), and management may wish to explore options to control this bycatch. This reviewer fully supports the recommendation. The related issue of density dependence warrants further examination, however, since SEDAR7-RW 06 notes that its inclusion may result in considerably different perceptions of stock status and recovery trajectories.

The stock recruitment relationship remains an area of considerable uncertainty, with model fits indicating very high steepness. Examination of available data on the dynamics of the offshore, less exploited ‘stock’ (see above) might help explain this. Confidence limits on recruit estimates should be presented in model outputs.

High recruitment estimates in recent years may result from the model’s assumption of constant q, which may have increased over time. The RW recommended that attempts to estimate effort directly be made.

A number of model diagnostics were requested by the RW, including standardized residuals. Further diagnostic approaches are recommended and suggested in the conclusions and recommendations section of this report.

3. Adequacy, appropriateness and application of population benchmark estimation methods

Management benchmarks were driven by gear selectivity patterns and the stock recruitment relationship, and hence were strongly influenced by management decisions. Identification of benchmarks more robust to these factors through management strategy simulation is recommended. Consideration should also be given to inclusion of all related fisheries in assessments, and area-based management policies.

4. Adequacy, appropriateness and application of projection methods

Deterministic projections based upon the Beverton and Holt stock recruit relationship were presented. The RW recommended that the mean of recent high recruitments also be used during projections. Stochastic projections with suitable diagnostics for recovery are recommended where possible.

5. Assessment results are clearly and accurately presented in the Stock Assessment Report

The assessment report was well written, and generally clear in detailing the decisions made and rationale for those decisions. The production of a document detailing the proceedings of the assessment workshops was particularly helpful. A number of minor comments are noted in this report.

6. Performance of data and assessment workshops against respective Terms of Reference

The majority of the Terms of Reference for the data and assessment workshops were completed fully. Areas where further work could be performed to fully complete the terms of reference are noted in this report.

7. Recommendations

Recommendations have been noted throughout this report, and are clearly detailed in the Conclusions and Recommendations section.

Background

South East Data, Assessment, and Review (SEDAR) is a joint process for stock assessment and review of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; NOAA Fisheries, SEFSC and SERO; and the Atlantic and Gulf States Marine Fisheries Commissions. SEDAR is organized around three workshops: data, assessment, and review. Input data are compiled during the data workshop, population models are developed during the assessment workshop, and an independent peer review of the data and assessment models is provided by the review workshop. The assessment review panel is composed of stock assessment experts, other scientists, and representatives of councils, fishing industries, and non-governmental conservation organizations. Final SEDAR documents include a data report produced by the data workshop, a stock assessment report produced by the assessment workshops, a review consensus report evaluating the assessment and drafted during the assessment review panel workshop, and the collected stock assessment documents considered in the SEDAR process.

This report reviews the results of the data and stock assessment panels held under the SEDAR process for Gulf of Mexico red snapper (*Lutjanus campechanus*), at the request of the Center for Independent Experts (see Appendix 1). This stock is within the jurisdiction of the Gulf of Mexico Fishery Management Council and respective southeastern states. The author was provided with data review and stock assessment panel review documents, files and reports (see bibliography), and participated in the SEDAR review panel process.

Description of review activities

The review was undertaken by Dr Graham Pilling at CEFAS (Lowestoft, UK) and during the SEDAR panel review held in New Orleans, Louisiana, at the Country Inn and Suites hotel. The SEDAR panel was convened during April 4th to 7th 2005. The panel membership is listed in Appendix 2.

The documentation (see bibliography) was reviewed at CEFAS. Dr Pilling actively participated in the SEDAR panel meeting in New Orleans and assisted with the development of the SEDAR review panel meeting report. This separate report to CIE was completed on return to CEFAS.

Observers, including members of the fishing industry, attended the SEDAR panel meeting. The draft assessment was presented to the panel and other attendees, and the issues evaluated through open discussion. A decision was then reached on the data set and assessment model to be used as a basis for management of the fishery. Recommendations for future red snapper data and assessment workshops were made.

Summary of findings

The meeting of the SEDAR review panel for the 2004 red snapper assessment represented the culmination of over a year of scientific analysis, and data and assessment meetings. The resulting assessment, while presenting a similar picture to that of the 1999 assessment, is quite different in its specifics. These differences include both the model itself, and the data to which the model was applied. Overall, the data workshop (DW) and assessment workshops (AW) should be commended in developing an assessment based upon the best scientific information available.

The CIE reviewer's views on uncertainties in the data and modelling approach, and recommendations for future work, were fully incorporated in the SEDAR review panel consensus report. The strengths, weaknesses and uncertainties inherent in the approach are described below within relevant sections, addressing points 1-7 under the SEDAR assessment review panel tasks. Numbered recommendations (in bold) refer to the conclusions and recommendations section of the current report.

1. Adequacy and appropriateness of data
Many sources of useful data were available. While the data collection programmes were effective in recent years, the resulting time period of data was short. Long-term systematic sampling needs to continue so that the value of these data sets can be fully realized.

Commercial landings and recreational catch data have been documented through systematic data collection since 1962 and 1984, respectively. For the 2004 assessment, a catch history beginning in 1872 (the presumed start of the fishery) was constructed using information available from various literature sources. Recreational catches prior to 1981 were inferred, under the assumption that catches were proportional to human population census data from 1900. In the assessment model, however, recreational catches were assumed to start in 1946. Total annual catch was divided between eastern and western regions of the Gulf, since both genetic and otolith microchemistry studies indicated a division into these stock units. The RW considered that, despite the uncertainties, these data represented the best possible information available for the fishery. A number of assumptions were required to divide the catches between east and west regions, and it was indicated during the RW that the division of catch between areas, rather than the absolute catch level in the historical period, was the greater source of uncertainty. **See recommendation 1**. It was hoped that this extended time-series would provide a better contrast in the data, and that unexploited biomass indices could be better estimated as a result. Unfortunately, extending the time-series did not achieve this.

When using extended time-series within models, the strong assumption is made that biological processes have remained constant over this time. This is particularly relevant when considering the difference in recruitments estimated by the model in recent times compared with historical recruitments (see below). It is unlikely that additional biological information for earlier in the time-series (particularly in the 'ultra-historic' period) will become available, however. **See recommendation 2**.

Limited age composition data were available, although large numbers of samples had been collected during the period 1998-2002. There is a need to continue this sampling, ensuring appropriate statistical coverage of the population over space and time. Offshore longline catches exhibited a much older age composition than those obtained in commercial and recreational fisheries operating inshore. This raises an issue over spatial distribution and settlement: is settlement of larvae purely inshore followed by ontogenetic migration offshore, or is settlement more uniform across depth ranges in the Gulf? These two different settlement patterns have very different consequences. In the former, young fish are subject to fishing mortality from an early age from the commercial and recreational gears, which they must survive before moving offshore. In the latter, a source of relatively unexploited fish exists further offshore which are unaffected by commercial gears until older, and might contribute to inshore recruitment. Given indications that the Campeche Bank stock was quite heavily exploited, this offshore component might represent the source of high recruitments in recent years despite localized inshore depletion. **See recommendation 3**.

Historically, the fishery has exhibited serial depletion. If sufficient areas with potential for high catch rates still remain, movement of vessels between areas following serial depletion could bolster the CPUE level and mask continued depletion of the stock. **See recommendation 4**.

Many different values for natural mortality were estimated through a range of scientific studies. Despite the availability of such information, the value of M remains a source of considerable uncertainty. Its value was increased markedly in the current assessment (the rate doubled at age 0 and 1 years compared to the 1999 assessment). The change from 0.3 to 0.6 on age 1 had little qualitative influence on the results of the assessment. There may be interactions between the natural mortality rate set for younger individuals and the impact of the shrimp trawl fishery, however. The value set for adult natural mortality and the resulting implications of the lack of a plus group in the model was commented upon during the meeting by the CIE chair.

Commercial logbook and recreational fishery interviews were used to gather information on discards. Despite efforts, discard estimates were developed from sparse data based upon assumptions that are difficult to verify. Discards need to be taken into account in the assessment, however, and these data represent the best information available. Experimental studies indicated that discard mortality rates were related to depth. Individuals caught in deeper waters experienced a greater mortality on release. Using the relationship with depth, an overall discard mortality rate was set for the east and west areas of the Gulf, based upon average fishing depth. The value used was a point estimate, although use of a range may be more appropriate to incorporate the potential stochasticity. The discard mortality rate will also interact with the value of natural mortality at younger ages. **See recommendation 5**.

Estimates of fecundity at age (expressed as relative *per capita* production) were higher in the current assessment than those of Shirripa and Legault (1999). There was little difference between the rates up to ~4 years, but they diverged notably after this age, converging again in fish older than 25 years. As a result, the rate of recovery may be faster when based upon the current assessment settings than when based on those used in 1999.

2. Adequacy, appropriateness and application of assessment methods

The model used in the 1999 assessment of Gulf of Mexico red snapper – ASAP – was not used in the current assessment. When the extended data series was applied to ASAP, the model failed to converge. This was in contrast to ASAP's general behaviour when applied to the shorter time-series of data. The reason for the failure in convergence was not identified, but it does suggest a problem with the model. As a result of this, CATCHEM_AD, an age-structured model constructed in AD Model Builder, was developed. While the application of a new model for assessment purposes is not generally desirable, it was necessary in this case owing to the extraordinary circumstances. The model was also tested as far as possible prior to the assessment. CATCHEM has the advantage of being more flexible than ASAP, allowing further factors to be incorporated (e.g. the inclusion of stock structure by splitting stocks between the eastern and western Gulf, plus multiple fleets) and has better mathematical rigour owing to internalization of the catch-at-age fitting.

Although the model consistently indicated that the stock was in a depleted state, it was initially difficult to identify the information driving that result. Abundance indices were relatively constant. The exception was the larval indices, which showed marked increases from the mid-1990s, and the recreational fishery in the east, which also indicated an increase during this period. Constant abundance indices suggest that the stock could be consistently over- or underexploited, and its size is not changing rapidly. Comparison of estimated unexploited age structures with current age structures did suggested a depleted state for the stock exploited by the inshore fishery. This is supported by the high effort in the western Gulf.

It was gratifying to note that in the continuity runs requested by the RW, the general perception of estimated stock status was comparable between ASAP and CATCHEM (when the short time-series of data were used). In both cases, the stock was heavily exploited. The resulting fishing mortality levels might be quite different between the two models, however, despite the similarity in the level of 'spawning stock' as a percentage of unexploited levels. **See recommendation 6**.

The general perception of stock status was also unchanged between short and long time-series runs from CATCHEM. Although the review panel selected the long time-series run in CATCHEM as being the base model (because it represents the best scientific information available), the short time-series has the advantage of being based upon observed data only. **See recommendation 7**.

As noted, CATCHEM allows the red snapper stock to be assessed as eastern and western Gulf units. Currently, the model does not allow migration rates to be included between areas. **See recommendation 8**.

In the base-case model selected by the AW, age 0 fish were excluded. Given that this age class is caught in an active fishery (the shrimp trawl fishery), and that management may wish to explore options to control this bycatch, the key assumption of the AW-recommended base case (all processes were compensated for under natural mortality at age 0) is very strong. The RW panel opted for the inclusion of age 0 fish as the base-case model setting, which this reviewer fully supports. While inclusion of age 0 fish did not make a large difference to the perception of current stock status, it was noted that its inclusion in the model made it much easier to explain to interested parties, particularly given the perceived importance of the shrimp bycatch fishery. The issue of density dependence must be considered further, however, since SEDAR7-RW 06 noted that its inclusion could significantly affect the perception of stock status and recovery. **See recommendation 9**.

An area of considerable uncertainty remains the stock-recruitment relationship for red snapper, and in particular the steepness value. In CATCHEM, separate Beverton and Holt stock recruitment relationships are used for the east and west stocks. The results of model fits suggest that in the recent time period, recruitments are relatively high (greater than the estimated virgin recruitment, R_0), but the model estimates of 'spawning potential' are at their lowest. This results in a very high steepness estimate (near 1). If correct, and not a product of the model formulation, potential hypotheses for the cause are a regime shift in recent years (as compared with the ultra-historic period), or the recruitment of young from other areas (e.g. the 'Campeche Bank connection', or recruitment from the offshore spawning stock). **See recommendations 3 and 10**. Investigations undertaken during the RW raised some questions as to the source of the information driving this variable but high recruitment in recent years. Age composition information indicated few startlingly strong age classes, although variability in this information may be damped by dome-shaped selectivity patterns. There remains the possibility that the information is actually coming from fluctuations in the abundance time-series. This issue needs careful examination.

High recruitments estimated by the model in recent years may result from the assumption of constant *q*. Realistically, *q* may have increased in recent years, as a consequence of technological creep, e.g. the fitting of GPS, the advent of fish finders. During the RW, a model run was performed with increased CVs on *q*. The results suggested that *q* in the commercial fleet was increasing over time, but that recreational *q* levels were decreasing, and that recent recruitment levels were relatively high. Effort is being estimated from CPUE data within the model, however, which may confound changes in *q*. The RW recommended that attempts be made to estimate effort directly.

Despite the use of Bayesian priors in the model, the current assessment provided only point estimates for parameters from the posterior distribution. This was mostly because of the complexity of the model, and the resulting time needed to perform a single assessment. Sensitivity analyses were requested during the review to examine changes in data time-series, inclusion/exclusion of age 0, and *q*. A number of diagnostics were requested to judge model outputs better and to check the internal assumptions of the model. Standardized residuals (and quantile-quantile plots) were requested, and produced during the RW. The results suggested that the catch-at-age structure violated the assumption of a multinomial distribution. The larval index also did not comply with the assumption of normality. **See recommendation 11**.

3. Adequacy, appropriateness and application of population benchmark estimation methods

Management benchmarks were noted to be 'an emergent property of the harvest strategy', being driven by the selectivity pattern of gears in the fishery and the stock recruitment relationship. Benchmark values are therefore strongly influenced by the management decisions made. As a result, specific MSY and SPR proxy benchmarks were given for three separate scenarios of management action – linked (all fisheries catching red snapper are increased or decreased by the same percentage), no shrimp (shrimp bycatch is eliminated in the shrimp fishery) or current shrimp (shrimp bycatch and closed season bycatch remain the same, regardless of changes made to effort in the other fisheries). The interaction between management and stock status meant that further communication was needed between the management and stock assessment fora before final status and recovery scenarios could be estimated. **See recommendations 12 to 14**.

4. Adequacy, appropriateness and application of projection methods

Deterministic projections were presented, indicating likely recovery rates for the stock relative to management benchmarks. The methods used were scientifically sound and appropriate given their deterministic nature. Future recruitment levels were based upon the Beverton and Holt stock recruit relationship, and hence assumed that the recent time-series of very high recruitments would not continue. This assumption on future recruitments represents a significant source of uncertainty. The RW recommended that the mean of recent high recruitments also be used during projections. **See recommendation 15**. The RW also considered that the actual stock recruit dynamics were not well understood. As a result, the panel indicated that only short-term projections should be considered, with the different R_0 settings providing a suitable bound on recruitment uncertainty.

5. Assessment results are clearly and accurately presented in the Stock Assessment report

The assessment report was well written, and generally clear in detailing the decisions made and the rationale for those decisions. This was greatly helped by the production of a document detailing the proceedings of the assessment workshops.

A number of minor comments on additional requirements for the stock assessment report were noted by the RW, which this reviewer endorses:

- more detailed discussion related to the use of SPR rather than biomass-based benchmarks;
- more information on why age-0 red snapper by-catch was not explicitly included in the model. Furthermore, more information is required on the potential impacts of these decisions on projected stock status;
- a statement of recommended ABC;
- an explanation of the methods used to compute effective spawning stock biomass.

6. Performance of data and assessment workshops against respective Terms of Reference

The majority of the Terms of Reference for the data and assessment workshops were completed fully, to the best of the ability of the workshops. Noted below are the few areas where further effort was needed to complete their terms of reference:

Data workshop:

- ToR 3. The fishery-independent measures of abundance appeared to take into account only sample variability, ignoring other sources of variation.
- ToR 4. Changes in catchability were not assessed. This is a potentially important factor in the model.

Assessment workshop:

- ToR 3. A number of approaches to assess model performance, reliability and goodness of fit were not examined by the AW. Approaches were recommended by the RW and where possible, implemented during the review panel. Further recommendations are made in the RW report, and in this report.
- ToR 5. Interval estimates were not provided for parameters. See recommendations in this report.
- ToR 6. Sensitivity runs to identify which indices and data had the strongest influence on model results were recommended by the RW.

7. Recommendations

Recommendations were noted in the RW report. That report also reviewed those made by the DW and AW. Specific recommendations from this reviewer are noted in the following section.

Conclusions and recommendations

The quantity and quality of work performed during the data workshop, assessment workshops, and by the assessment team during the review workshop was impressive and highlight the considerable increase in knowledge since the last assessment. As a result, the data used within the assessment represent the best scientific information available, and the assessment approach, despite uncertainties, is adequate for the current stock assessment.

A number of areas for future work in the data and assessment processes are highlighted in the section above, and the specific recommendations are presented here. In many cases, sensitivity analyses are suggested. These, and other simulation testing, will help to identify areas in which specific research effort needs to be concentrated to improve estimates of key parameters in the model.

Adequacy and appropriateness of data

The data inputs for the assessment model cover a wide range of biological processes, at different spatial and temporal scales. A particular area of uncertainty was the assumptions that accompanied the use of the extended time-series of catches. Recommendations are:

Recommendation 1: Perform sensitivity analyses to examine the effect of different historical catch divisions between east and west areas of the Gulf on the assessment.

Recommendation 2: Perform sensitivity analyses to examine the impact of potential changes in biological parameters over time on the assessment.

Recommendation 3: Examine the implications of the different potential distributions of larvae and adults for the assessment. Are there areas offshore suitable for juvenile settlement? Is the offshore age structure consistent with recruitment directly to deeper waters, or ontogenetic migration? Does oceanographic information suggest that larval movements of this type are realistic? Consider tagging programmes to examine the movement of juveniles and adults offshore/onshore and between east and west regions of the Gulf (see also recommendation 8).

Recommendation 4: Consider the examination of available information on fishing position through logbooks (if sufficiently accurate) or observer programmes (if available) for serial depletion. Recommendations by the RW to examine the feasibility of VMS may need to be initiated before this can be investigated further.

Recommendation 5: Examine the sensitivity of assessment results to different values of release mortality rate (within the bounds indicated by the existing research). Investigate the interaction between natural mortality values and release mortality rates at younger ages.

Adequacy, appropriateness and application of assessment methods

The model represents a change from that applied during the 1999 assessment. Recommendations arise as result of this change, settings within the assessment, and particular assessment results:

Recommendation 6: Examine the fishing mortality levels output from ASAP and CATCHEM for the short time period run to identify any differences and trends in this metric.

Recommendation 7: Perform projections based upon the CATCHEM outputs from the short time period run to identify whether there are quantitative differences in expected recovery period. This will also require consideration of the management benchmarks resulting from changes in the estimated stock recruitment relationship, which may result in more significant differences.

Recommendation 8: Consider the inclusion of migration between east and west areas of the Gulf in the model. Parameterization might be based upon available information (if sufficient) or through new tagging studies (if feasible).

Recommendation 9: Examine the issue of density dependence and its effect on stock status and recovery further. Consider results in terms of risk to the population.

Recommendation 10: Present confidence limits on the recent recruitment levels estimated by the model, so that statistical differences between recruitments in the recent past and the ultra-historical period can be identified.

Recommendation 11: Develop further diagnostic approaches to assess the performance of the model. Present interval estimates for output parameters, or examine posterior distributions, as many of the estimates may be against their bounds (a count of the number of parameters against their bounds could be another diagnostic). Examine the shape of the response surface to assess whether local maxima are being identified. Perform retrospective analyses to assess model stability.

Adequacy, appropriateness and application of population benchmark estimation methods

Management benchmarks for these projections were highly sensitive to management decisions and biological assumptions. Recommendations are:

Recommendation 12: Identify benchmarks that are more robust to changes in management levels and the stock-recruitment relationship, through management strategy evaluation simulations.

Recommendation 13: Consider whether there is a need specifically to examine the red grouper/vermillion snapper fisheries (closed-season bycatch) along with the shrimp bycatch fishery and the targeted fisheries in assessments and management. Evaluate multispecies benchmarks.

Recommendation 14: While the RW was not tasked to look at management issues, the division of the stock between east and west areas of the Gulf within the assessment allows separate management to be applied within these areas, rather than the current strategy of producing Gulf-wide management (TACs). Indeed, given that the eastern stock appears to be less productive than the western stock, Gulf-wide management has the potential to reduce the eastern stock to very low levels. This needs to be presented to managers for consideration.

Adequacy, appropriateness and application of projection methods
The methods used to project population status were appropriate. The projections from the model were deterministic, however.

Recommendation 15: Consider performing stochastic projections and providing management with suitable diagnostics for recovery (e.g. the likelihood of recovery within particular time periods).

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SEDAR

SouthEast Data, Assessment, and Review

Gulf of Mexico Red Snapper
Stock Assessment Report

SECTION 5. Addenda & Errata

CONTENTS

Addendum 1. CATCHEM Runs Documentation.

APPENDIX : DOCUMENTATION OF CATCHEM RUNS THAT MODEL AGE 0 RED SNAPPER EXPLICITLY AND PROJECTIONS OF MODEL AGE 0 AND AGE 1 RESULTS UNDER DIFFERENT FUTURE RECRUITMENT SCENARIOS

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Porch (2004) assessed the status of red snapper in the U.S. Gulf of Mexico by use of various configurations of the age-structured statistical model CATCHEM. The results from that assessment consistently indicated that the stock was overfished and that overfishing was still occurring even when the definition of MSY was conditioned on current levels of offshore shrimp effort. In contrast, recent applications of the model ASAP sometimes indicated that the stock was not overfished and often indicated that overfishing was no longer occurring (Cass-Calay et al. 2005, Cass-Calay and Diaz 2005, Ortiz and Cass-Calay 2005). There are several differences between the CATCHEM and ASAP applications examined during the SEDAR7 process, both in terms of the data used and the underlying structure of the models. Two of the more glaring differences were the length of the time series used and the explicit use of the bycatch of age 0 animals by the offshore shrimp fishery. The CATCHEM runs in Porch (2004) were based on landings data extending back to 1872 and used data pertaining to age 1 and older red snapper; the implicit assumption being that the bycatch–related mortality of age 0 was negligible in comparison to natural, density-dependent effects. The ASAP runs were based on data extending back only to 1984 or 1962 and used data pertaining to age 0; the implicit assumption being that density-dependent mortality is limited to the larval phase. Unfortunately, it proved difficult to apply the ASAP model to the longer time series or data limited to age 1 and older. This appendix documents the application of the CATCHEM model to data that include age 0 animals.

Methods

The data employed and model structures used are essentially the same as described in Porch (2004) and Porch (2005) except that they explicitly incorporate age 0 animals. Thus, the bycatch time series now includes age 0 animals and the SEAMAP trawl indices for age 0 (Table x in the AW report) have been added. The SEAMAP trawl indices for age 1 were also used, but only after the mid 1980s when reliable age composition data were collected. The Beverton and Holt spawner recruit relationship was assumed, but with the understanding that it now links age 0 recruits to the spawning population during the same year. Thus, the density-dependent effects modeled by the Beverton and Holt function are essentially limited to the larval or settlement stages. Subsequent (post-settlement) mortality during the first year of life is modeled by a density-independent mortality rate coefficient (M_0) fixed at 0.98 yr^{-1}. This is in contrast to the age 1 formulation, in which case the density dependent effects are assumed to be important throughout the first year of life and are estimated.

Results

Two runs were made with age 0 modeled explicitly, one with the entire 1872 – 2003 time series (model A) and one beginning in 1984 (model B).

Model fits to data. Model A matched the total catch data quite well with the exception of the high shrimp bycatch values during some of the early years, which happen to have high CV's associated with them (Figure 1). The model fit most of the indices of abundance reasonably well (Figure 2), but could not reconcile the increasing trend in the western larval index (representing spawners) with the flat or declining trends indicated by the other western indices. The model fits to the SEAMAP trawl series show a strong residual pattern where the predictions for the early years are considerably lower than the trawl index values, and, in the case of the eastern stock, the predictions for the later years are considerably higher than the trawl index values. The mismatch for the early years can be attributed the very high CV's associated with those data. The mismatch in more recent years reflects the influence of the bycatch data, which, in the context of relatively constant effort, suggests recruitment generally has increased in the east in recent years. The shrimp effort series were fit very well (Figure 3) owing to the rather low observation CV's assigned to those data (10%). The fits to the age composition data, aggregated over all years, appear to be quite good (Figure 4). It should be kept in mind, however, that the fits to individual years are noisier, particularly where the sample size was small.

The model B fits to the data were quite similar to model A, and therefore not shown.

Parameter estimates. The estimated vulnerability and fishing mortality rates *F* for model A are shown in Figure 5 (patterns are similar for model B and therefore not shown). In general, the vulnerability of red snapper to the recreational and commercial hand line fleets follows a dome-shaped pattern with a peak at age 1 or 2 for the former and at age 5 for the latter. (Recall that the vulnerability coefficients reflect the probability of being caught and include undersized fish; the probability of being caught and landed is the vulnerability coefficient multiplied by the probability that a fish is greater than the size limit.) The vulnerability of red snapper to the commercial long line fleet follows a logistic pattern with older animals (10+) being the most vulnerable. The vulnerability patterns for the closed season "fleets" were between those of the hand line and longline fleets. As expected, age 0 and age 1 fish were much more vulnerable to shrimp trawls than age 2 or older.

The estimated trends in apical fishing mortality rates (the *F* on the most vulnerable age class) indicate persistent increases for all fleets. Although the recreational *F* in the east appears to have declined markedly in recent years, it remains at rather high levels. The highest fishing mortality rates were associated with the western shrimp fishery followed by the eastern recreational and western commercial handline fisheries. Of course the high shrimp bycatch rate essentially applies to only two age groups, whereas the lower apical *F*'s estimated for the handline and recreational fleets apply to multiple age classes.

There does not appear to be a strong relationship between the number of recruits and the effective number of spawners (*S*) in the previous years (see Figures 6 and 7). The estimates of the maximum potential spawn per recruit (α) were near the limit of 151 imposed by the model, which translates to steepness values of 0.974.

Estimated population trends. The Model A estimates of historical trends in the relative spawning potential and age 0 recruits are shown in Figure 6. The Model B estimates are shown in Figure 7. Under pristine conditions, the western population of red snapper in U.S. waters is estimated to have been about five times larger than the eastern population. Both populations are estimated to have been heavily overfished by 1962, consistent with the results obtained with the age-1 runs (i.e., when the age 0 animals were omitted).

Interestingly, the estimates of recruitment during the latter part of the time series are substantially larger than the estimates of virgin recruitment R_0. Numerous mechanisms that could account for such a change were discussed during the SEDAR assessment and review workshops, including density-dependent mortality effects; reduced predators; more favorable oceanographic conditions; increased pre-recruit habitat (oil rigs, artificial reefs and other habitat expansions); and the possibility that the stocks extends geographically well beyond the U.S. Gulf of Mexico (e.g., Campeche Banks). These are all valid research topics for the next several years, and at this point it seems premature to focus on one to the exclusion of the others. Current data seem unlikely to support serious estimation for any of these effects.

The main differences between Models A and B are attributable to the estimates of virgin recruitment R_0. In the case of Model A, the estimates were 6.7 and 30.6 million for the east and west, respectively. In the case of Model B, they are several times higher at 16.6 and 230 million (Figure 7). Accordingly, the estimates of MSY from Model B are also several times higher than for Model A. For example, consider the case where MSY is conditioned the estimated spawner-recruit relationship and current (2001-2003 average) levels of bycatch effort (offshore shrimp trawling and closed season), hereafter referred to as MSY{current shrimp}. Under Model A, MSY{current-shrimp} is estimated to be 3.3 mp for the east and 4.5 mp for the west, but under Model B, MSY{current-shrimp} is estimated to be about 9 mp in the East and 31 mp in the West. On the other hand, the relative condition of the stock appears worse under Model B. Under model A, the current fishing mortality rate is estimated to be about 2.4 times F_{MSY}{current-shrimp} and the relative spawning potential of the east and west stocks in 2003 is estimated to be 45% and 37% of S_{MSY}{current-shrimp}, respectively. Under model B, the current fishing mortality rate is estimated to be about 2.9 times F_{MSY}{current-shrimp} and spawning in the east and west is estimated to be 14% and 5% of S_{MSY}{current-shrimp}, respectively. The reader should keep in mind, however, that model B had some difficulty finding a global minimum; sometimes settling on local minima with nearly the same objective function values but very different implications (including solutions with highly unrealistic levels of virgin recruitment and MSY, as was also the case with the ASAP model used during the previous assessment). For this reason, the RW did not consider Model B further and all subsequent discourse will refer to Model A except as otherwise noted.

Choice of reference points. The potential for recovery of course depends on the way the benchmark is defined. To this point only *F* and *S* levels associated with MSY{current-shrimp} have been shown. The use of this reference point assumes, among other things, that (a) the relative allocation of effort among directed fleets remains constant at current levels, (b) the absolute allocation of effort among offshore shrimp trawlers and closed season fishing operations remains the same, and (c) future recruitment will generally be in accordance with the estimated spawner-recruit relationship. One alternative is to modify assumption (b) to reflect a prescribed reduction in offshore shrimp trawling relative to current (2001-2003) levels. The RW supposed that the most likely reduction would be about 40% in accordance with the results of a recent economic forecast (Travis and Griffin, 2004). In that case the equilibrium landings, hereafter referred to as MSY{40% reduced-shrimp}, amount to 3.7 million lbs for the east and 7.8 million lbs for the west. Spawning levels in the east and west are estimated to be 44% and 24% of S_{MSY}{40% reduced -shrimp}. Current levels of fishing mortality are estimated to be 2.1 times greater than F_{MSY}{40% reduced-shrimp}. Another alternative is to define MSY in terms of the entire fishery, assuming the effort of all fleets, both directed and undirected, can be scaled down by the same proportion (i.e., all fleets, directed and bycatch, are governed by assumption a). In previous assessments this has been referred to as the “linked-selectivity” or “policy neutral” approach because all fleets endure the same proportional reduction in effort (technically this is policy-neutral only with respect to red snapper, other important concerns notwithstanding). The corresponding equilibrium landings, hereafter referred to as MSY{equal-proportions}, are 5.2 and 15.6 million lbs for the east and west, respectively. Spawning levels in the east and west are estimated to be 16% and 6% of S_{MSY}{equal-proportions}.

Plots of stock status with respect to the benchmarks discussed above are compared with the corresponding plots for the age-1 model in Figure 8. Overall, the results for the models with and without age 0 are very similar; the stocks in the east and the west are estimated to be overfished regardless of the benchmark used. The degree to which each stock is overfished depends, of course, on the choice of benchmarks used to define MSST. The perception of stock status is least optimistic when the reference point used is S_{MSY}{equal-proportions}, which tends to be between 25 and 30% of S_0. The perception of stock status is better (less-overfished) when S_{MSY}{current-shrimp}or S_{MSY}{40% reduced-shrimp} are used as reference points inasmuch as they are a much lower fraction of S_0. The values of S_{MSY}{current-shrimp}and S_{MSY}{40% reduced-shrimp} for the east are both about 10% of S_0 because the bycatch of red snapper in that region is relatively small. The values of S_{MSY}{current-shrimp}and S_{MSY}{40% reduced-shrimp} are lower for the west (about 5% and 7%, respectively) because the bycatch there constitutes a much larger fraction of the total kill.

Other alternative definitions of MSY can be devised based on modifications to assumption (c), which concerns future recruitment. The Review Workshop recommended that MSY-related benchmark statistics and advisory forecasts reflect the apparent increase in recent recruitment over the levels expected based on the estimates of R_0. Specifically, they recommended determining future recruitments using a Beverton-Holt spawner recruit curve with the estimated steepness of 0.974, but a new R_0 equal to the average of the recruitment estimates for the period from 1984 to 2003. This approach, of course, implies that the mechanisms bolstering recent recruitment will continue into the foreseeable future. Plots of stock status when recent levels of recruitment are used to define the benchmark are shown for the three MSY allocation strategies discussed above in Figure 9. Again, the results for the models with and without age 0 are very similar; the stocks in the east and the west are estimated to be overfished regardless of the benchmark used. More importantly, the extent to which the stock appears overfished is greater under the "recent R_0" scenario than under the "estimated R_0" scenario (Figure 8) because the future productivity of the stock is deemed to have increased. In other words, both S_0 and S_{MSY} increase in proportion to the increase in R_0 (the steepness being near 1), therefore both S_{2003}/S_0 and S_{2003}/S_{MSY} decrease.

A more stable and potentially less risky policy than MSY might be based on maintaining a particular spawning potential ratio (SPR). While the fishing mortality rate associated with a given SPR ($F_{\%SPR}$) depends on the current vulnerability pattern, the corresponding long-term spawning potential ($S_{\%SPR}$) does not. For this paper the value of $F_{\%SPR}$ is chosen so that the SPR value of the most affected stock is equal to the desired level; the SPR level achieved by the remaining stock being greater than or equal to the desired level. Inasmuch as the steepness is near 1, the value of S/S_0 and SPR are nearly equivalent. Hence, stock status with respect to a 30% SPR policy can be inferred from the horizontal line at $S/S_0 = 0.3$ in Figures 8 and 9. Note that 30% SPR levels cannot be attained even in the absence of any directed harvest unless offshore shrimp effort is reduced from current levels by more than 40%.

Projections. The RW in fact identified three possible scenarios for future recruitment. Each scenario employed the Beverton-Holt relationship with a steepness of 0.974, but the level of virgin recruitment R_0 was set to one of three values: (1) the 'historical' level estimated with the long time series, i.e., Model A; (2) the 'recent' average of the recruitment estimates for 1984-2003 from Model A; and (3) the 'high' values estimated with the short time series, i.e., Model B (as an upper limit). Projected trends in the relative spawning potential S/S_0 are shown for Model A under various levels of total allowable catch (TAC) in Figure 10. In all cases the current TAC of 9.12 mp is projected to permit recovery to MSY{40% reduced} by 2032, but in no case will the stock in the west recover to values of S/S_0 equal to 0.3 (with high steepness the value of S/S_0 is roughly equivalent to the value of SPR). For comparison, similar TAC plots are shown in Figure 11 for the equivalent age-1 model. In this case, the current TAC is projected to lead to near extirpation of the stock unless recent levels of recruitment persist into the future.

Figures 12-15 present S/S_{MSY} and S/S_0 isopleths generated from projections to the years 2010 and 2032 under various levels of directed harvest (Gulf-wide total allowed landings or directed fishing mortality rate) and percent reductions in effective offshore shrimp effort (relative to current, 2001-2003, levels). The numbered contour lines represent the value of S/S_0 expected during the given year (2010 or 2032). The colors represent the magnitude of S/S_{MSY}: Red indicates that the value of S/S_{MSY} is less than 1.0 (not yet recovered); yellow indicates S/S_{MSY} is at least 1.0, but less than 4.0; and green indicates S/S_{MSY} is greater than 4.0. value. Here S_{MSY} is conditioned on the current state of the fishery as described for S_{MSY}{40% reduced-shrimp}, except with a percent reduction in offshore shrimp effort equal to the value given on the horizontal axis. For example, one can infer by moving upwards along the left axis of Figure 12b that a Gulf-wide TAC of 7 mp would be expected allow *S* to recover to just above S_{MSY}{current-shrimp} by 2032 if the age-0 model is correct and future recruitment is governed by the 'historical R_0' scenario. The value of S/S_0 at that point, however, is only about 10%, which is rather low in comparison to the standards suggested for other long-lived species. If one were to adopt a higher standard, say $S_{30\%}$, then the effort of the offshore shrimp fishery would need to be reduced by more than 70% in order for the western stock to recover under a 7 mp Gulf-wide TAC.

It is evident from the isopleths that a wide range of TACs could allow recovery, depending on the standard the stocks are expected to recover to and the allocation between the directed and bycatch fleets. Higher TACs depend upon lowering the effective shrimp mortality of red snapper. It is therefore impossible to recommend TACs without clear guidance from the Council on the most appropriate reference point or level of shrimp trawl bycatch that should be assumed in the calculations. However, it is recommended that due to uncertainty over the current stock-recruitment relationship and due to the large differences in biomass levels which would associate with long-term maximum yields (*i.e*. landed weight) by the fisheries under certain methods for benchmark calculations, that MSY proxies based on SPR of 30% be applied in this case.

Assuming future recruitment remains, on average, at recent levels, projections of the model formulation which includes age 0 catch indicates Gulf-wide 30% SPR could be achieved by 2032 under TACs ranging from 2-9 million pounds if shrimp effort could be further reduced by 40-70%, respectively, from recent levels (Figure 13a). Ignoring age 0 catch and assuming recent recruitment levels into the future indicates Gulf-wide 30% SPR could be achieved by 2032 under somewhat lower TACs ranging from 2-7 million pounds, if shrimp effort could be further reduced by 40-70%, respectively, from recent levels (Figure 14a). Should future recruitment return to lower, historical levels, somewhat lower TACs would be required to achieve the recommended benchmark for equivalent additional reductions in shrimp effort in the same time-frame.

Summary

The age-0 model preferred by the RW, by virtue of its use of the Beverton-Holt curve to relate age 0 recruits to spawning potential in the same year, makes the implicit assumption that density-dependent natural mortality processes are important only in the planktonic phase and are otherwise unimportant compared to shrimp bycatch. It also makes the explicit assumption that the density-independent natural mortality rate M_0 is about 0.98 yr^{-1}. In contrast, the age-1 model, by virtue of its use of the Beverton-Holt curve to relate age 1 recruits to spawning potential in the previous year, makes the implicit assumption that density-dependent natural mortality processes are more important than shrimp bycatch during the first year of life. Moreover, the density-independent natural mortality rate M_0 is essentially estimated as part of the Beverton-Holt spawner-recruit relationship, rather than fixed to 0.98 yr^{-1}. Not surprisingly, the age-0 model attributes greater importance to the shrimp fishery than does the age-1 model, as evidenced by the steeper isopleths in Figures 12-13 compared with those of Figures 14-15. Both models suggest that the stock will not recover to an SPR of 30% by 2032 unless offshore shrimp trawling is reduced by an additional 50 percent. The two models differ, however, on the level of TAC needed to achieve a recovery. For example, if future recruitment follows the estimated “historical’ Beverton and Holt relationships, then the age-1 model suggests the TAC would need to be reduced to about 3 mp with a 70% reduction in shrimp effort (Figure 14b) whereas the age-0 model suggests that a TAC of about 6 mp would suffice (Figure 12b).

The RW also recommended that future recruitment levels in the projections be conditioned on relatively high recruitments estimated for the last two decades (1984-2003). This of course implies that the high recent recruitments resulted from a change in the environment and that this change would likely persist into the foreseeable future. Previously, it had been assumed that the recent high recruitments were anomalous and that future recruitment would be more likely to follow the estimated “historical’ Beverton and Holt relationships. As might be expected, the shift to projecting recent recruitment levels had little effect on the advice given in regards to reductions in directed effort (compare for example, Figures 12d and 13d) or shrimp trawl effort (the results still suggest the stock will not recover to an SPR of 30% by 2032 unless offshore shrimp trawling is reduced by an additional 50 percent). On the other hand, the shift to projecting recent recruitment levels has a great impact on the advice generated in regards to a TAC. This is easily seen in Figures 10 and 11, where a 9 million pound TAC is projected to allow a rapid increase in stock size when high recruitment levels are assumed and little increase (age-0) or a decline (age-1) when ‘historical’ recruitment levels are assumed. Essentially, a given level of TAC corresponds to much reduced fishing effort in the new, higher recruitment regime.

Finally, it is important to emphasize that the perception of recovery depends greatly on the reference point being used as the standard. One option is to base the MSST on an MSY-based reference point that is conditioned on current shrimp bycatch rates or some prescribed reduction thereof. When this is done, and the shrimp bycatch is reduced to the degree expected, the stock can attain MSY by 2032 with little or no reduction in TAC (depending on the choice of models). However, economic forecasts of the potential reduction in shrimp bycatch are only about 40%, in which case the SPR values associated with the conditional MSYs are on the order of 10 percent or less. Such low values of SPR are considered very risky for long-lived species in most other arenas. If, on the other hand, a more reasonable SPR of 30% were targeted, then the current 9.12 mp TAC would not be justifiable unless offshore shrimp trawl effort were reduced by at least 70% from current levels. The TAC required to achieve a given SPR depends on whether the objective is to achieve that SPR on a Gulf wide basis or for each stock independently. Due to the greater impact of the shrimp fishery in the western Gulf, a lower TAC is required to ensure the recovery of the western stock than for the eastern Gulf or both stocks combined. If the management goal is to rebuild the each stock to an SPR of 30% by 2032, then the TAC and shrimp reduction levels be based on the stock specific isopleth diagrams. For example if the shrimp trawl effort were reduced by 60%, then the TAC that would allow recovery would be expected to lie between 1 mp (age 1, historical recruitment levels, Fig. 14b) and about 8 mp (age 0 model, recent recruitment levels, 13b). However it is important to remember that the economic forecast (Travis and Griffin 2004) project much less than a 60% reduction in shrimp effort.

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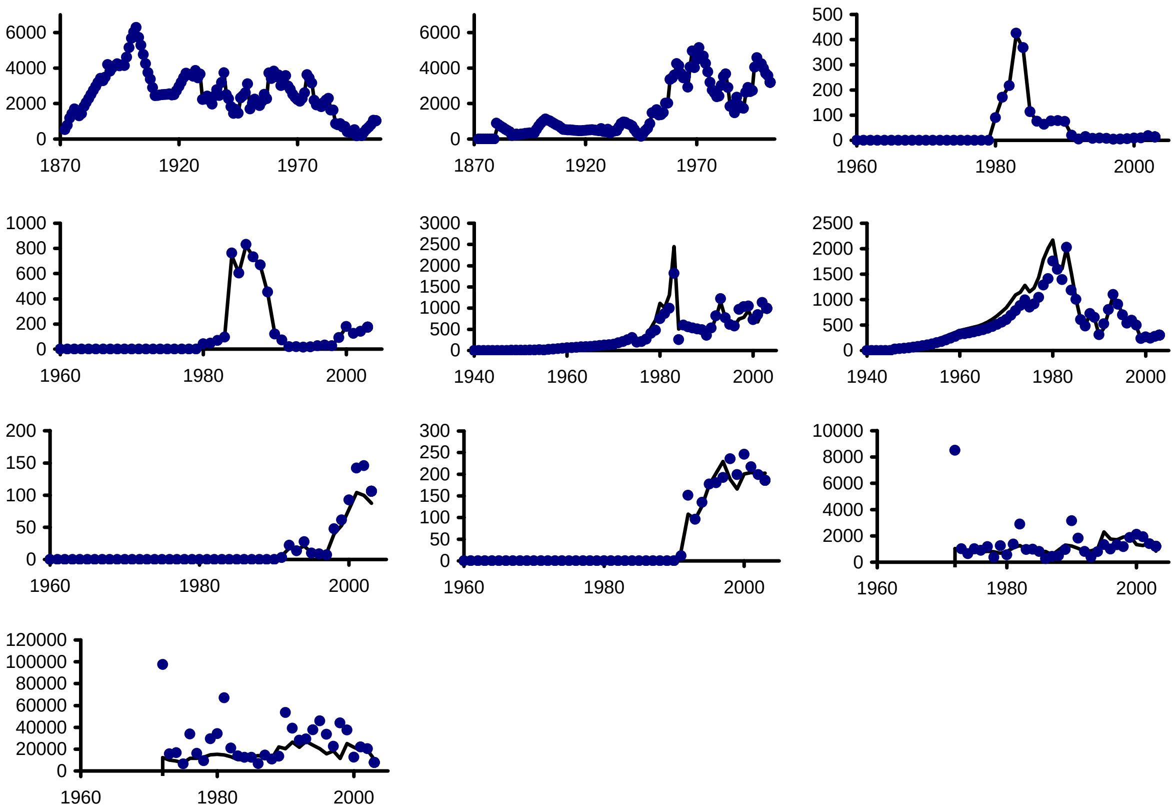


Figure 1. Model A (1872-2003) fits to the total landings in weight for the handline (HL) and longline (LL) fleets, total number landed for the recreational fleet (REC), and total number killed for the closed season (CLSD) and shrimp bycatch for east E and west W.

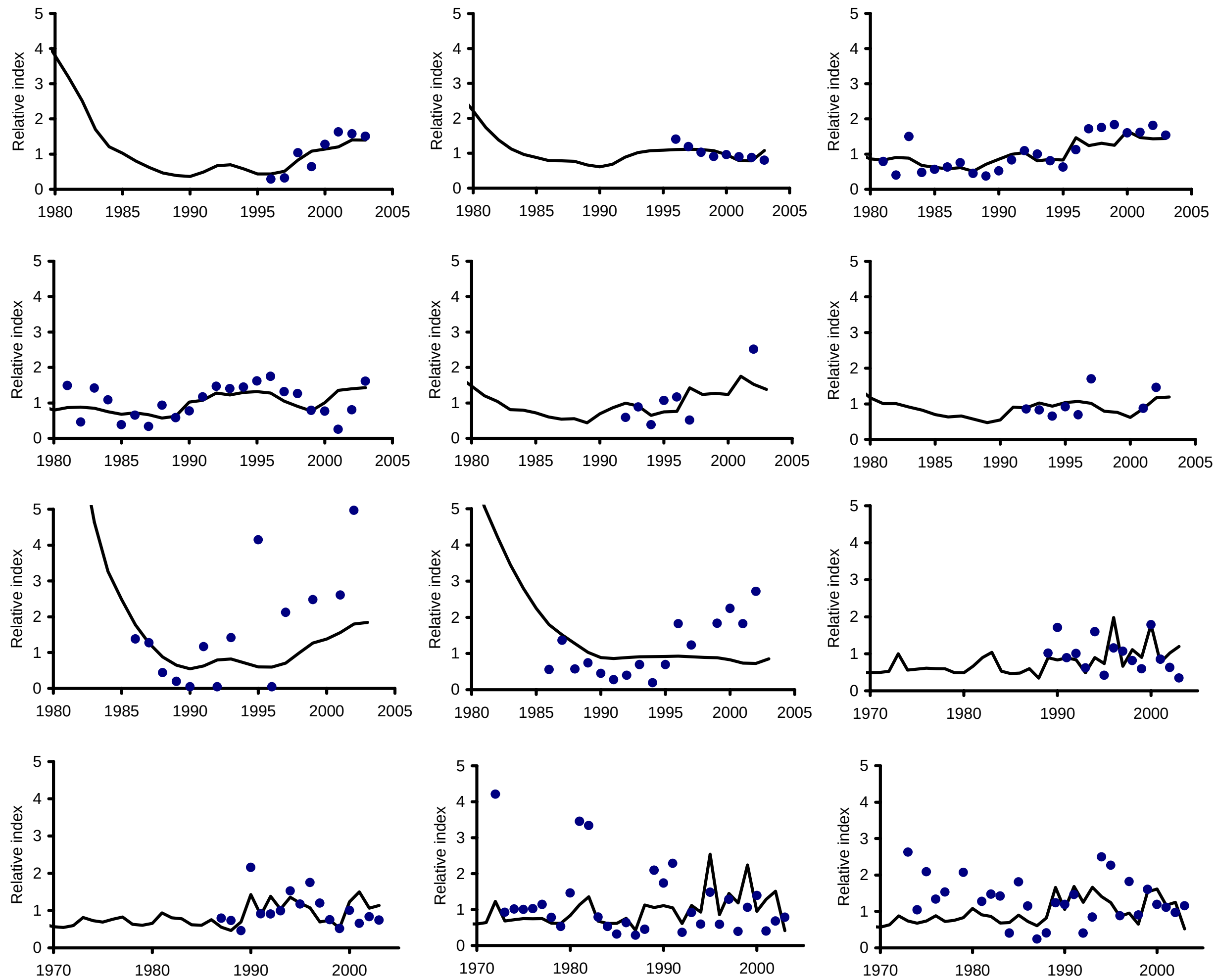


Figure 2. Model A (1872-2003) fits to indices of abundance (rescaled by the mean of the predicted values).

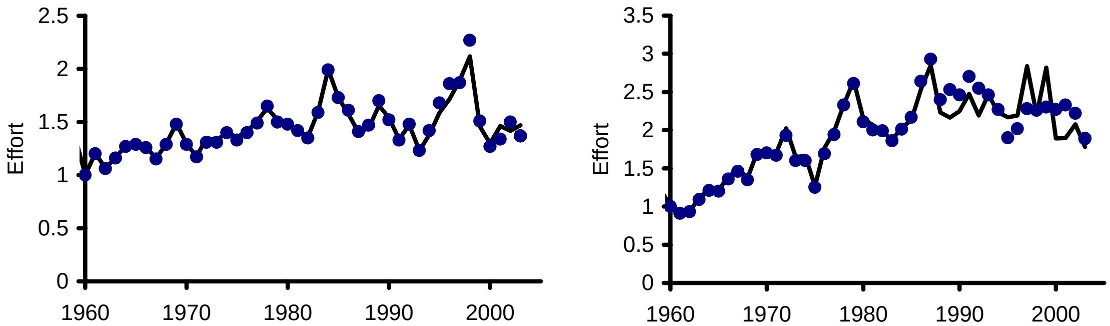


Figure 3. Model A (1872-2003) fits to the shrimp trawl effort series.

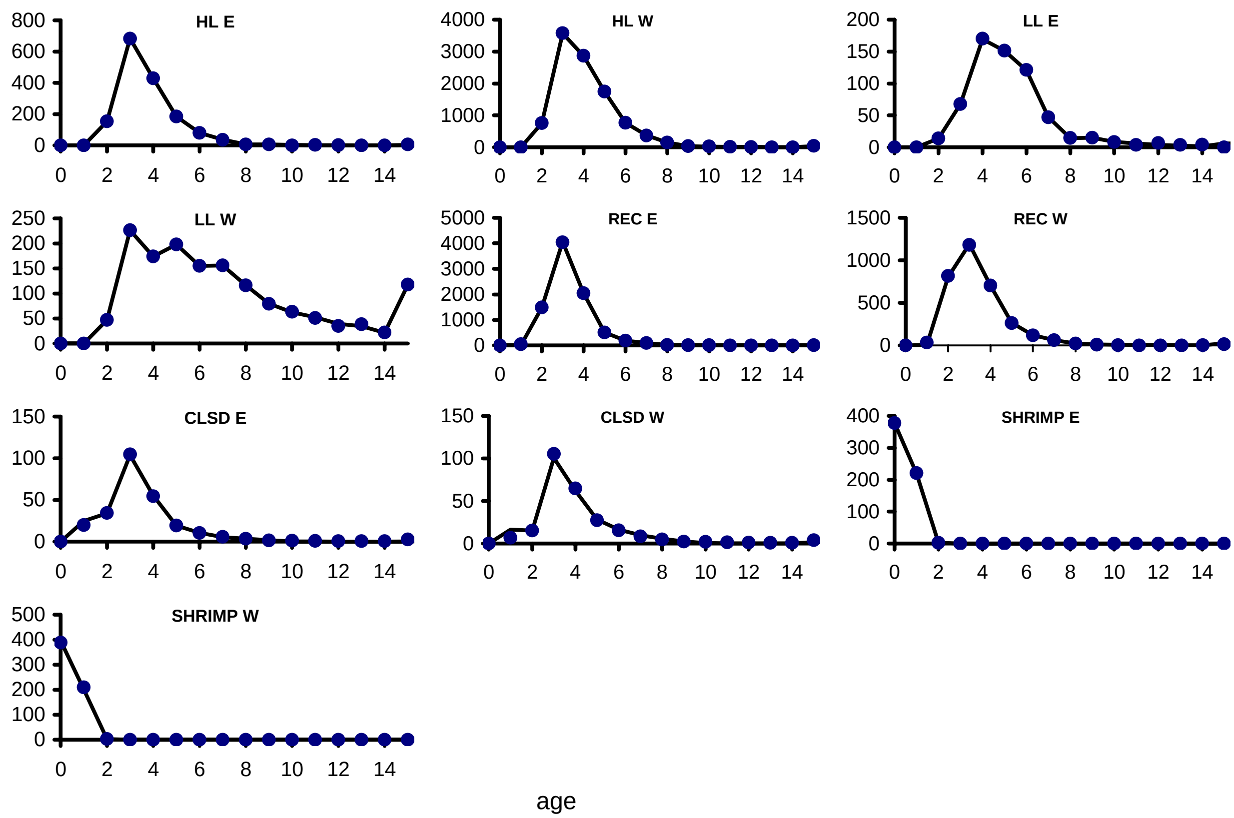


Figure 4. Model A (1872-2003) fits to the age composition data (aggregated across years).

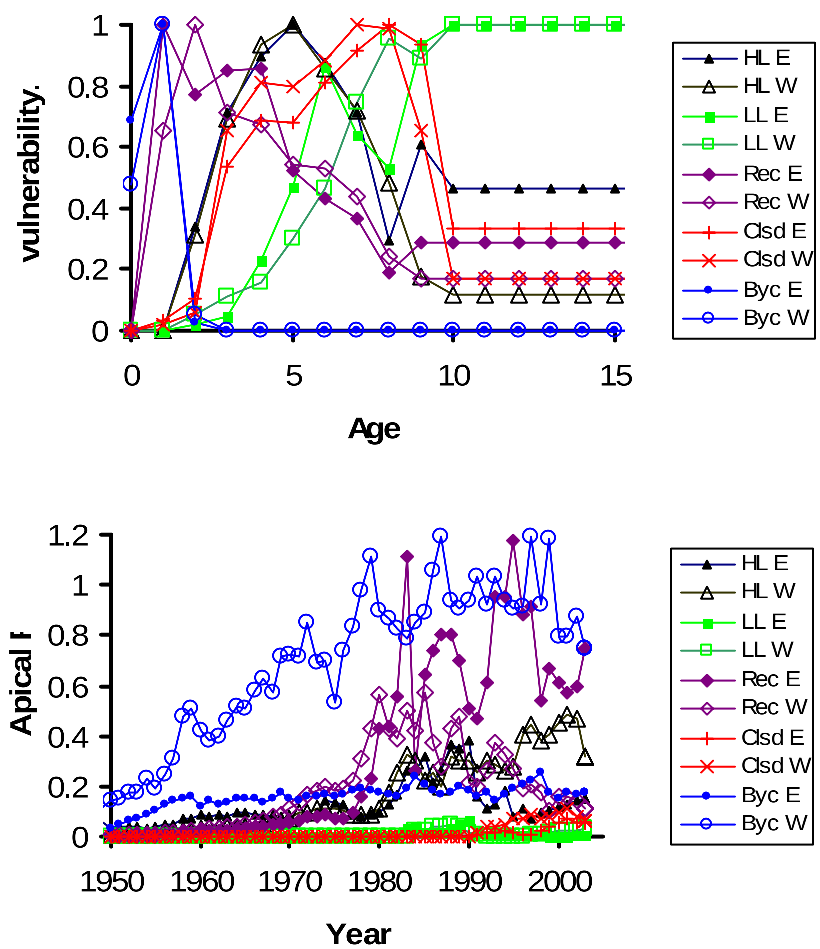


Figure 5. Model A (1872-2003) estimates of vulnerability and apical fishing rate by fleet.

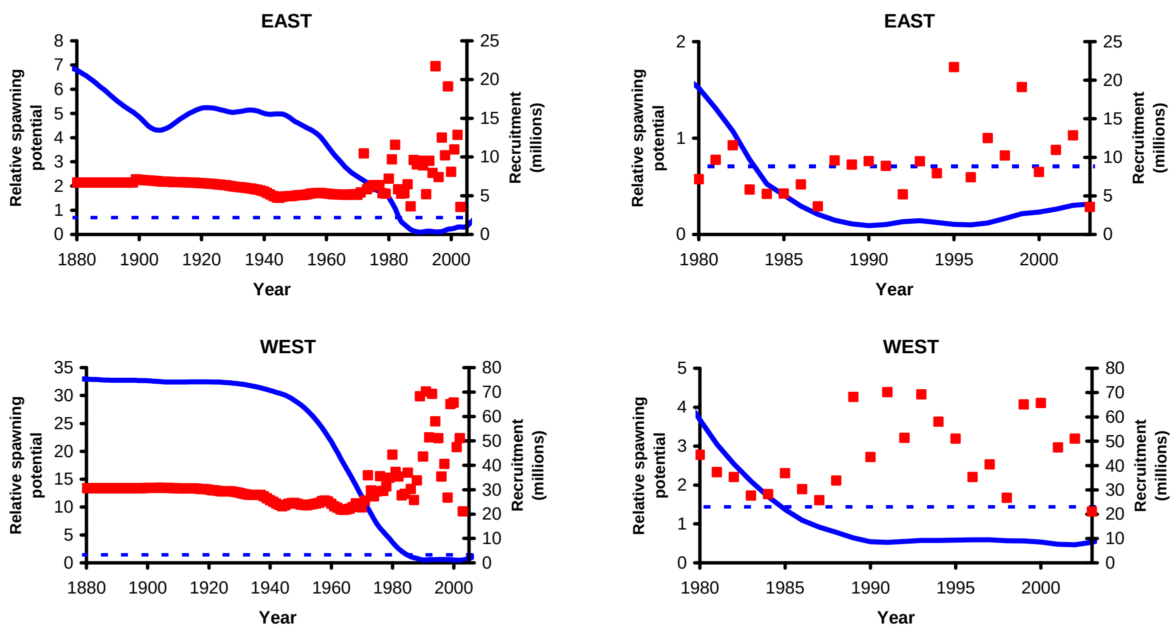


Figure 6. Model A (1872-2003 time series) estimates of the relative spawning potential (lines) and corresponding number of age 0 recruits (squares). The horizontal line gives the relative spawning potential associated with MSY{current-shrimp}. Panels to the right focus on the latter part of the time series.

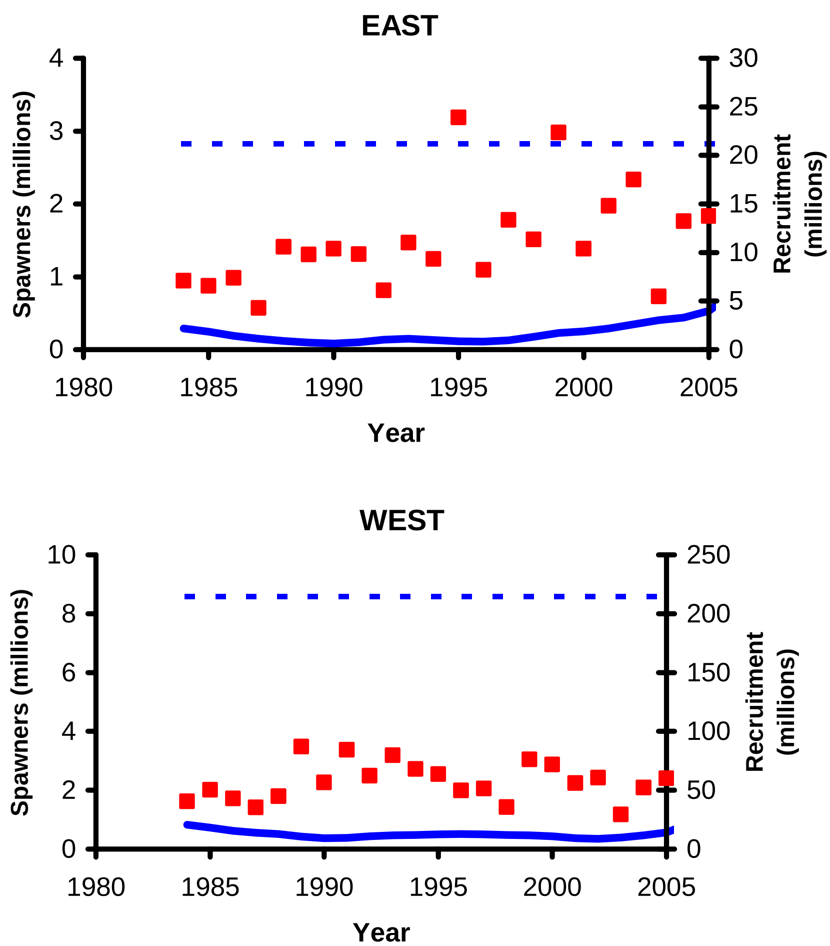


Figure 7. Model B (1984-2003 time series) estimates of the relative spawning potential (lines) and corresponding number of age 0 recruits (squares). The horizontal line gives the relative spawning potential associated with MSY{current-shrimp}.

R$_0$ = model estimate

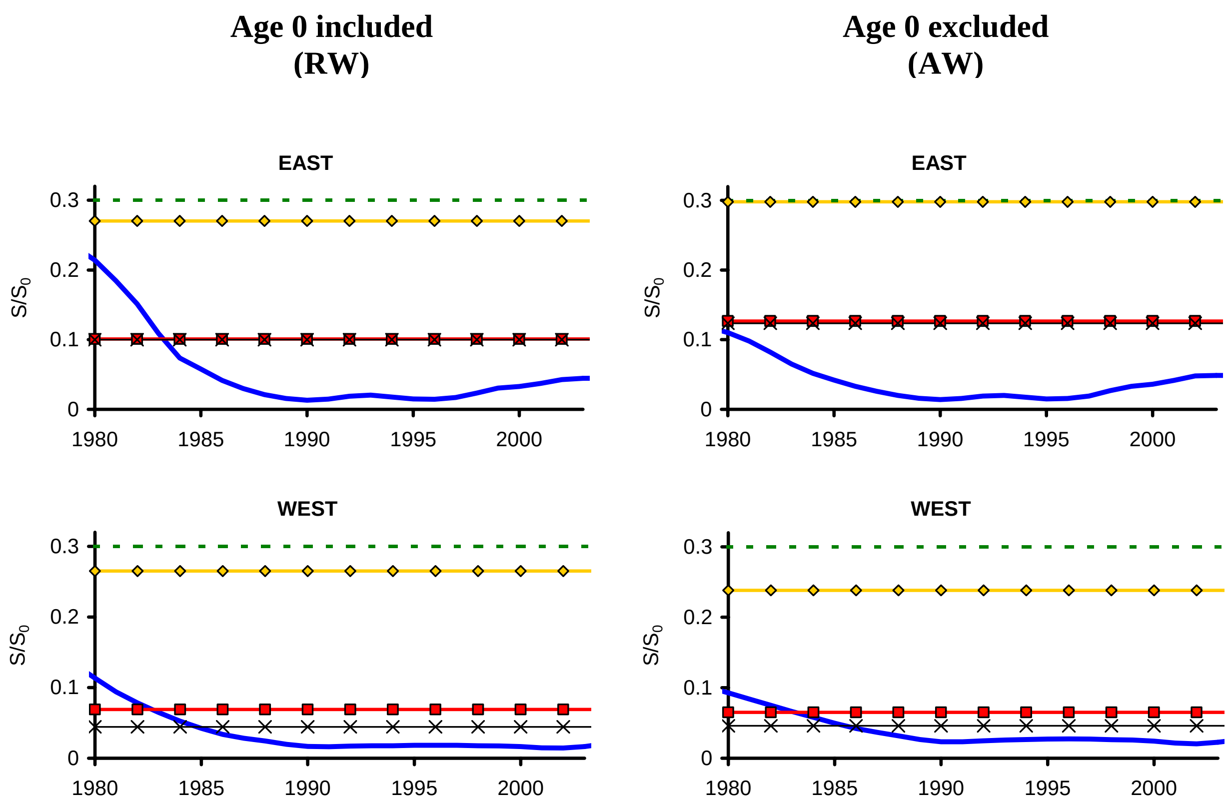


Figure 8. Trends in spawning potential relative to virgin levels (S/S$_0$, blue curve) compared with four benchmarks based on the estimated spawner-recruit relationship: $S_{30\%}$ = dashed green line; S_{MSY}\{equal proportions\} = gold diamonds; S_{MSY}\{40% reduced shrimp\} = red circles; and S_{MSY}\{current shrimp\} = black x's. The panels on the left give the results obtained when age 0 fish are modeled explicitly, with the implication that accounting for the bycatch of age 0 is more important than accounting for post-settlement density-dependent processes. The panels on the right give the results obtained when age 0 fish are *not* modeled explicitly, with the implication that accounting for the bycatch of age 0 is less important than accounting for post-settlement density-dependent processes.

R_0 = recent recruitments

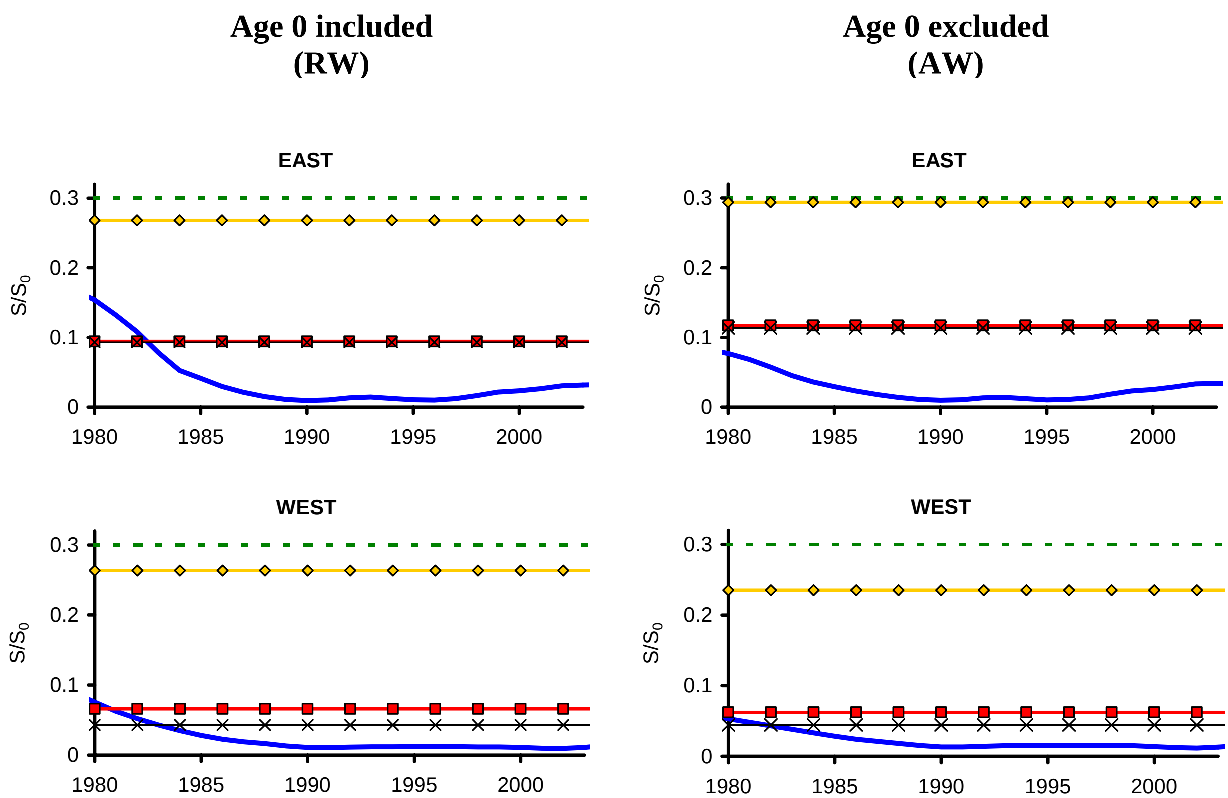


Figure 9. Trends in spawning potential relative to virgin levels (S/S_0, blue curve) compared with four benchmarks based on recent recruitment estimates: $S_{30\%}$ = dashed green line; S_{MSY}\{equal proportions\} = gold diamonds; S_{MSY}\{40% reduced shrimp\} = red circles; and S_{MSY}\{current shrimp\} = black x's. The panels on the left give the results obtained when age 0 fish are modeled explicitly, with the implication that accounting for the bycatch of age 0 is more important than accounting for post-settlement density-dependent processes. The panels on the right give the results obtained when age 0 fish are *not* modeled explicitly, with the implication that accounting for the bycatch of age 0 is less important than accounting for post-settlement density-dependent processes.

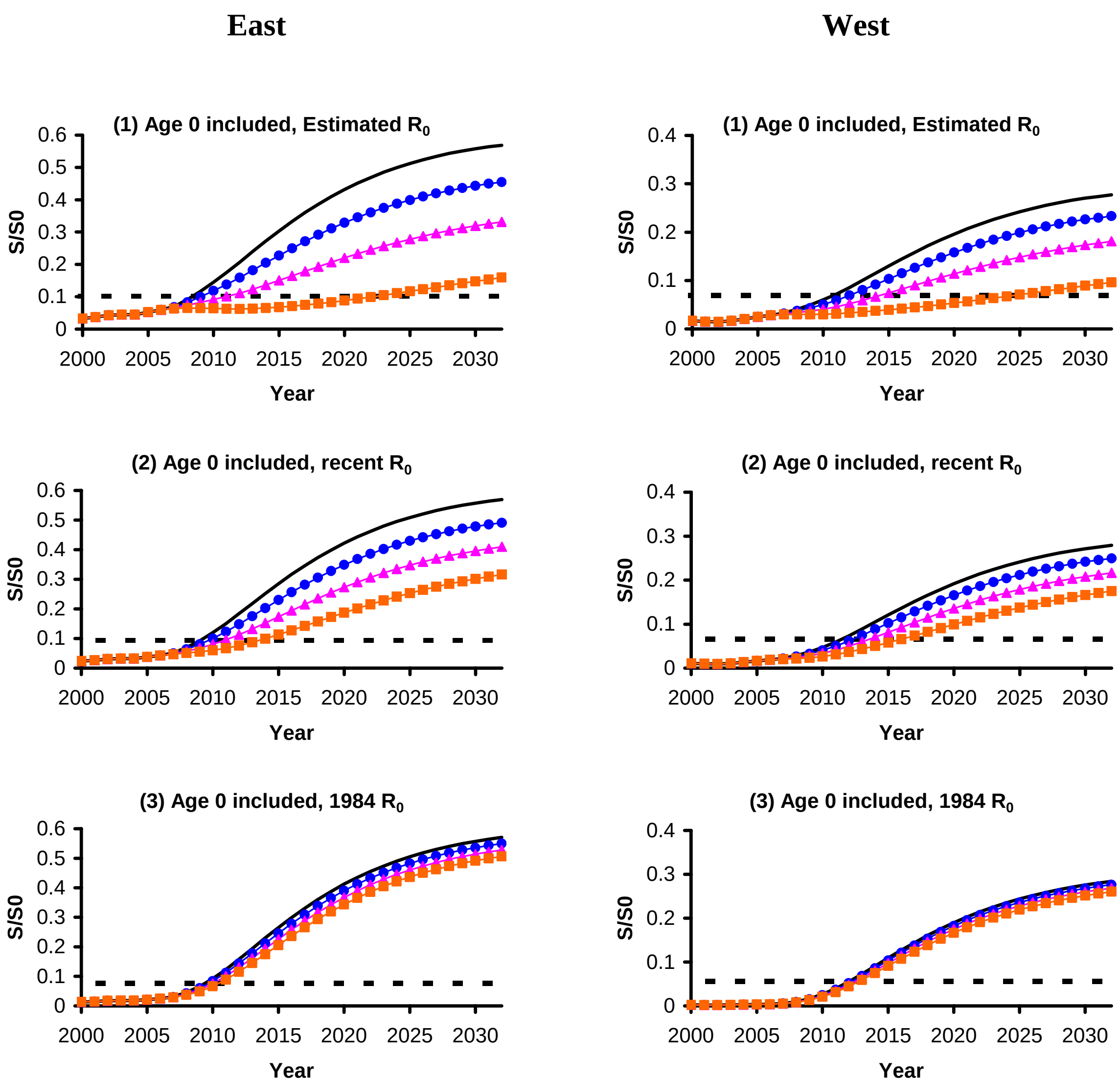


Figure 10. Projections of relative spawning potential based on Model A (age 0 included, long-time series) under various levels of TAC: 0 mp (black line), 3 mp (blue circles), 6 mp (pink triangles), and 9 mp (orange squares). Offshore shrimp trawling effort is reduced by 40% beginning in 2007. Future recruitment is assumed to follow a Beverton-Holt relationship with a steepness of 0.974 and values of R_0 set equal to (1) the model A estimates of R_0, (2) the average of the recruitment estimates from model A for 1984-2003 and (3) the model B (short-time series) estimates of R_0.

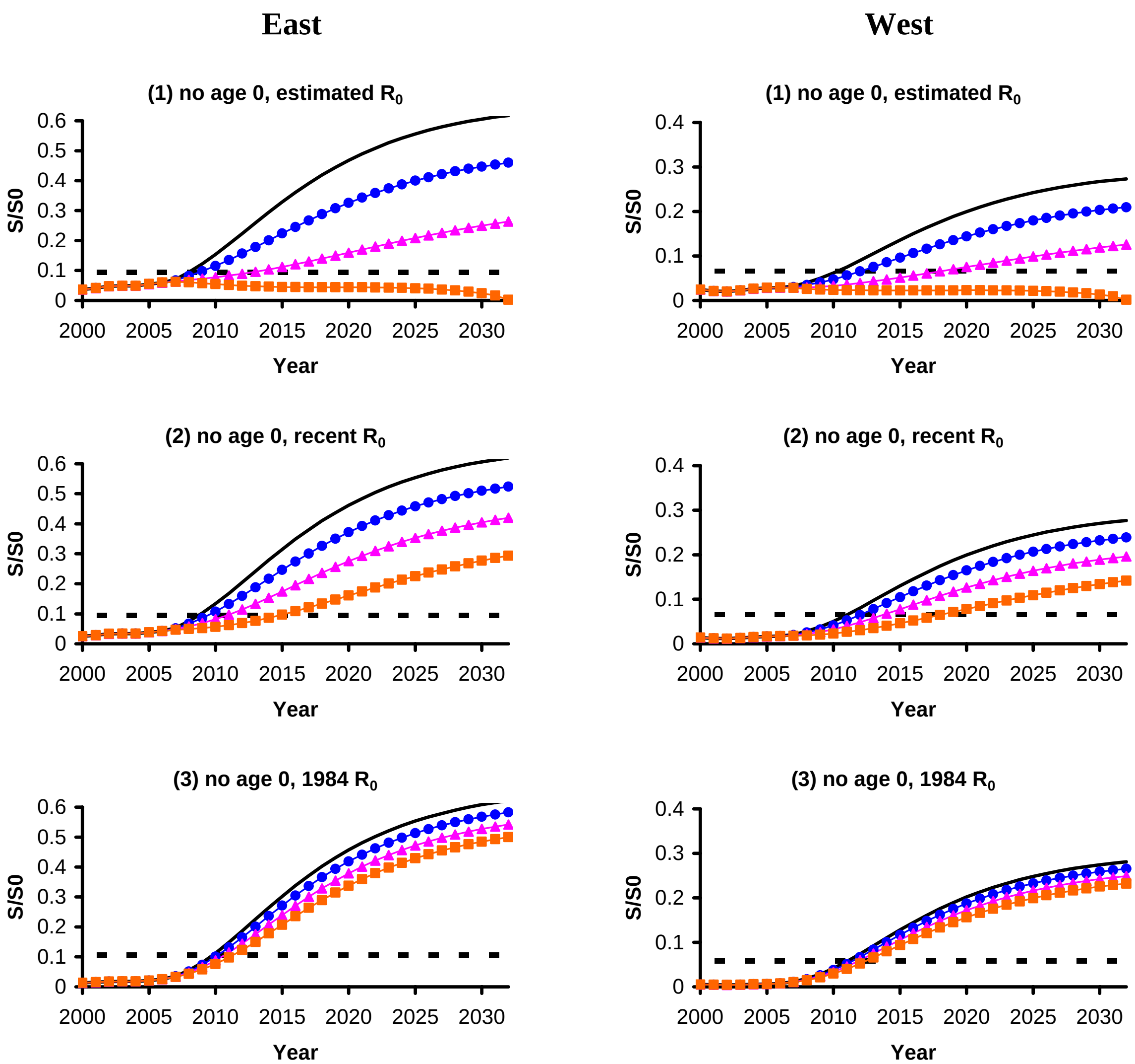


Figure 11. Projections of relative spawning potential based on the age-1 counterpart to model A, which does not include age 0, under various levels of TAC: 0 mp (black line), 3 mp (blue circles), 6 mp (pink triangles), and 9 mp (orange squares). Offshore shrimp trawling effort is reduced by 40% beginning in 2007. Future recruitment is assumed to follow a Beverton-Holt relationship with a steepness of 0.974 and values of R_0 set equal to (1) the model A estimates of R_0, (2) the average of the recruitment estimates from model A for 1984-2003 and (3) the model B (short-time series) estimates of R_0.

RW Age 0, historical R_0
(2010, TAC)

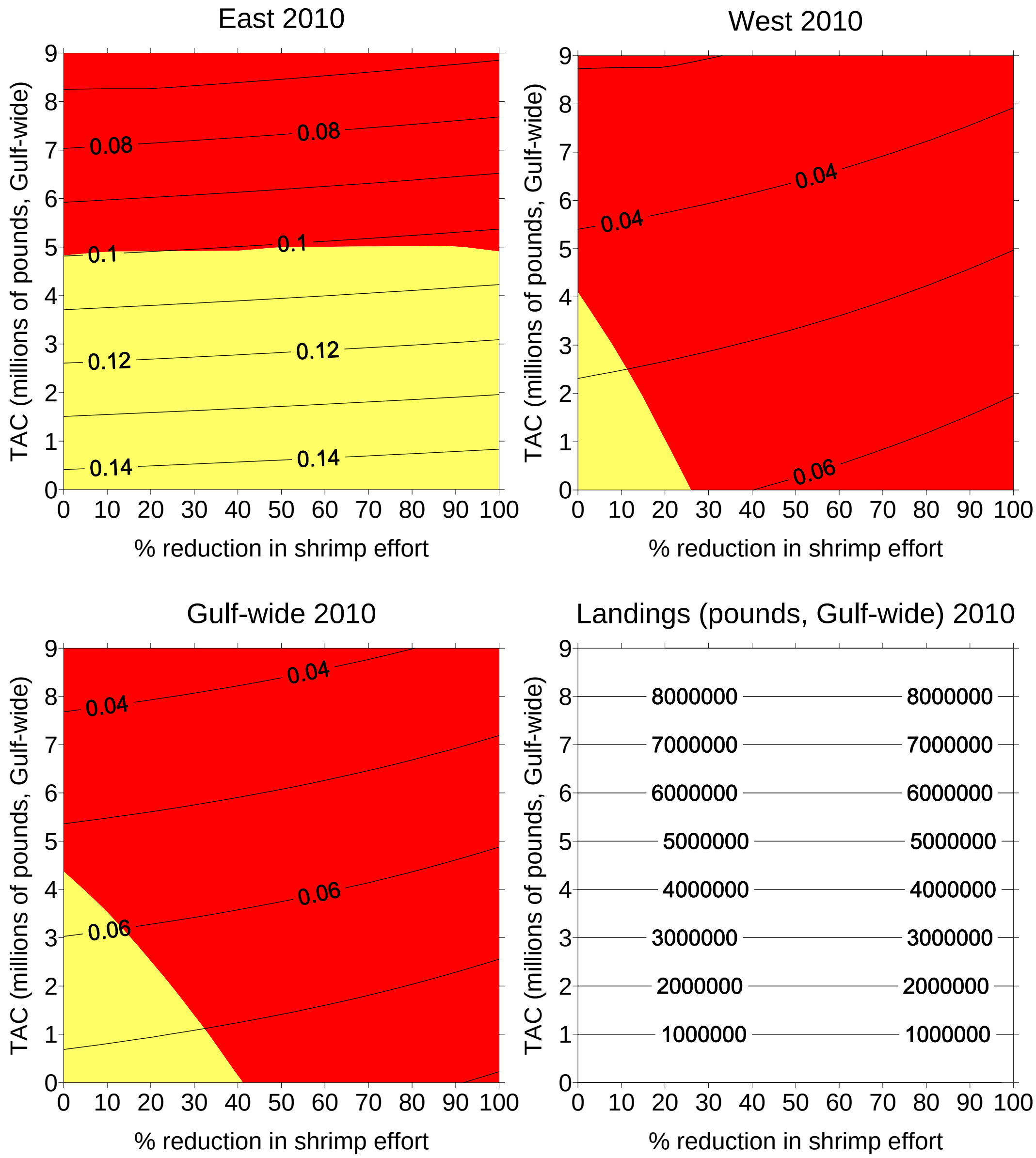


Figure 12a. Isopleths of spawning potential in the year 2010 relative to virgin levels (S_{2010}/S_0) obtained from the RW base model (age 0 included) when the model estimates of R_0 are used. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the projected Gulf-wide TAC. The color shades on the graphs represent different levels of spawning potential relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2010}/S_{MSY}<1$, yellow represents $1 \leq S_{2010}/S_{MSY}<4$, and green represents $S_{2010}/S_{MSY} > 4$.

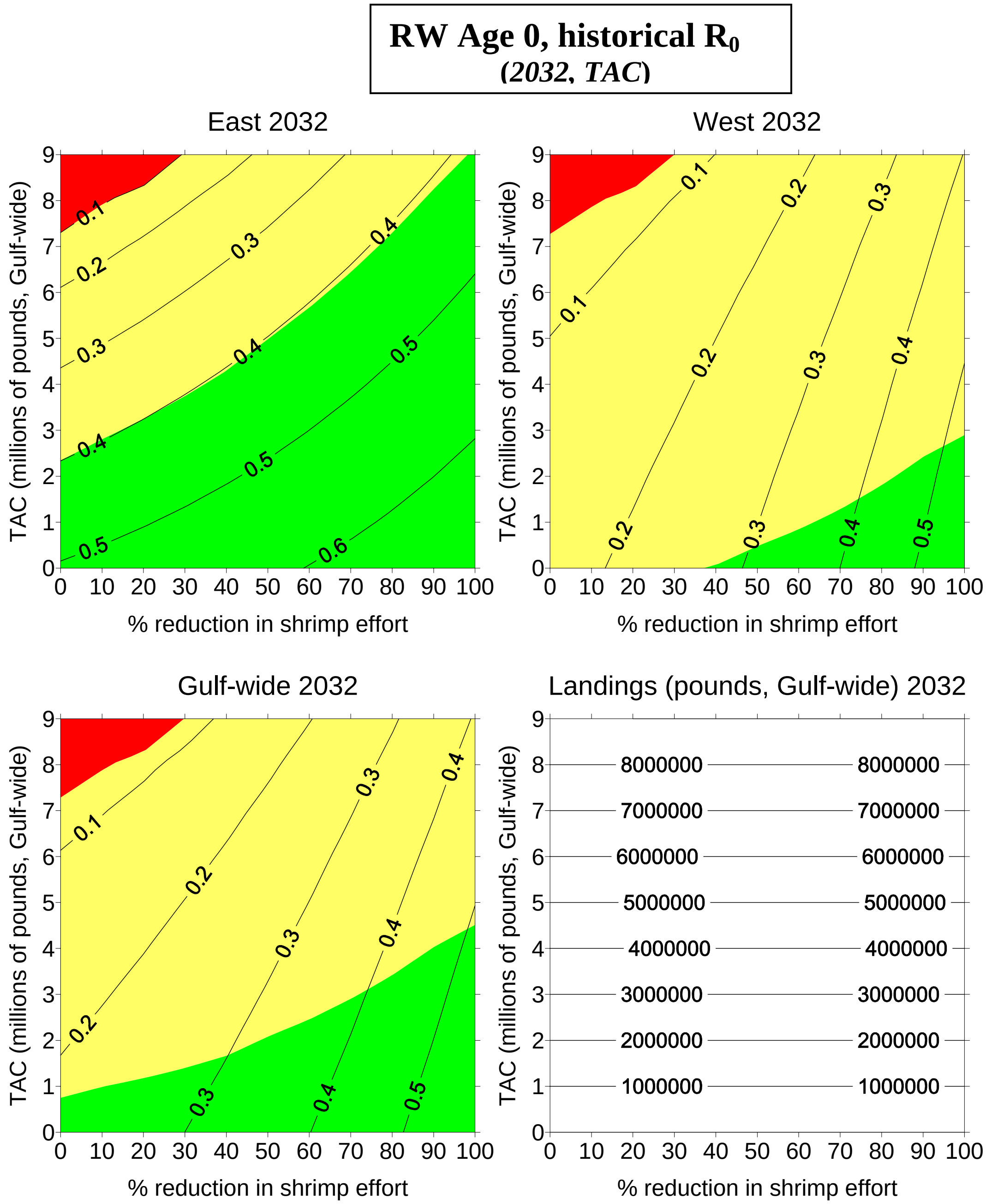


Figure 12b. Isopleths of spawning potential in the year 2032 relative to virgin levels (S_{2032}/S_0) obtained from the RW base model (age 0 included) when the model estimates of R_0 are used. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the projected Gulf-wide TAC. The color shades on the graphs represent different levels of spawning potential relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2032}/S_{MSY}<1$, yellow represents $1 \leq S_{2032}/S_{MSY}<4$, and green represents $S_{2032}/S_{MSY} > 4$.

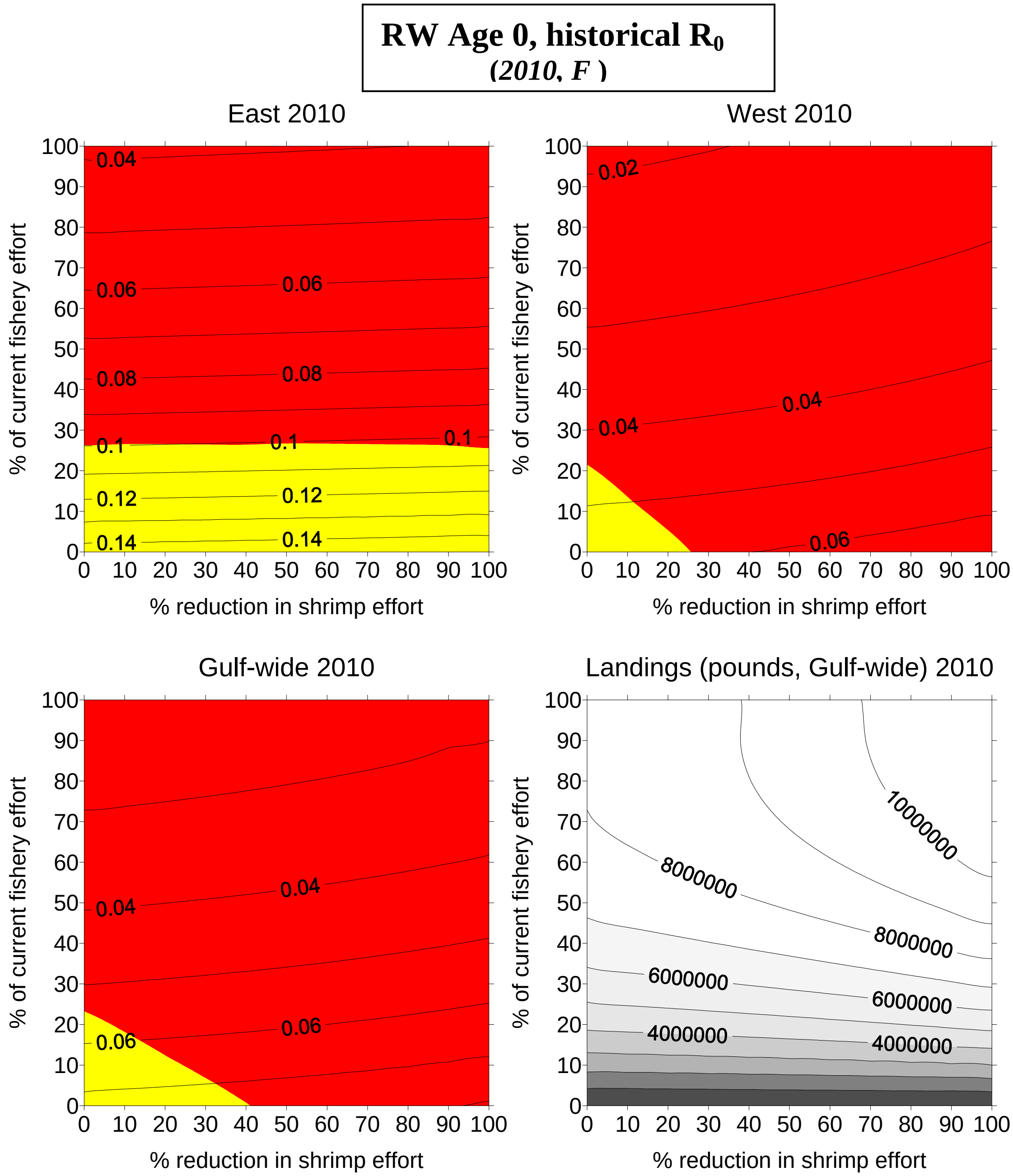


Figure 12c. Isopleths of spawning potential in the year 2010 relative to virgin levels (S_{2010}/S_0) obtained from the RW base model (age 0 included) when the model estimates of R_0 are used. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the fishing mortality rate (as a percent of current levels). The color shades on the graphs represent different levels of spawning potential relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2010}/S_{MSY}<1$, yellow represents $1 \leq S_{2010}/S_{MSY}<4$, and green represents $S_{2010}/S_{MSY} > 4$.

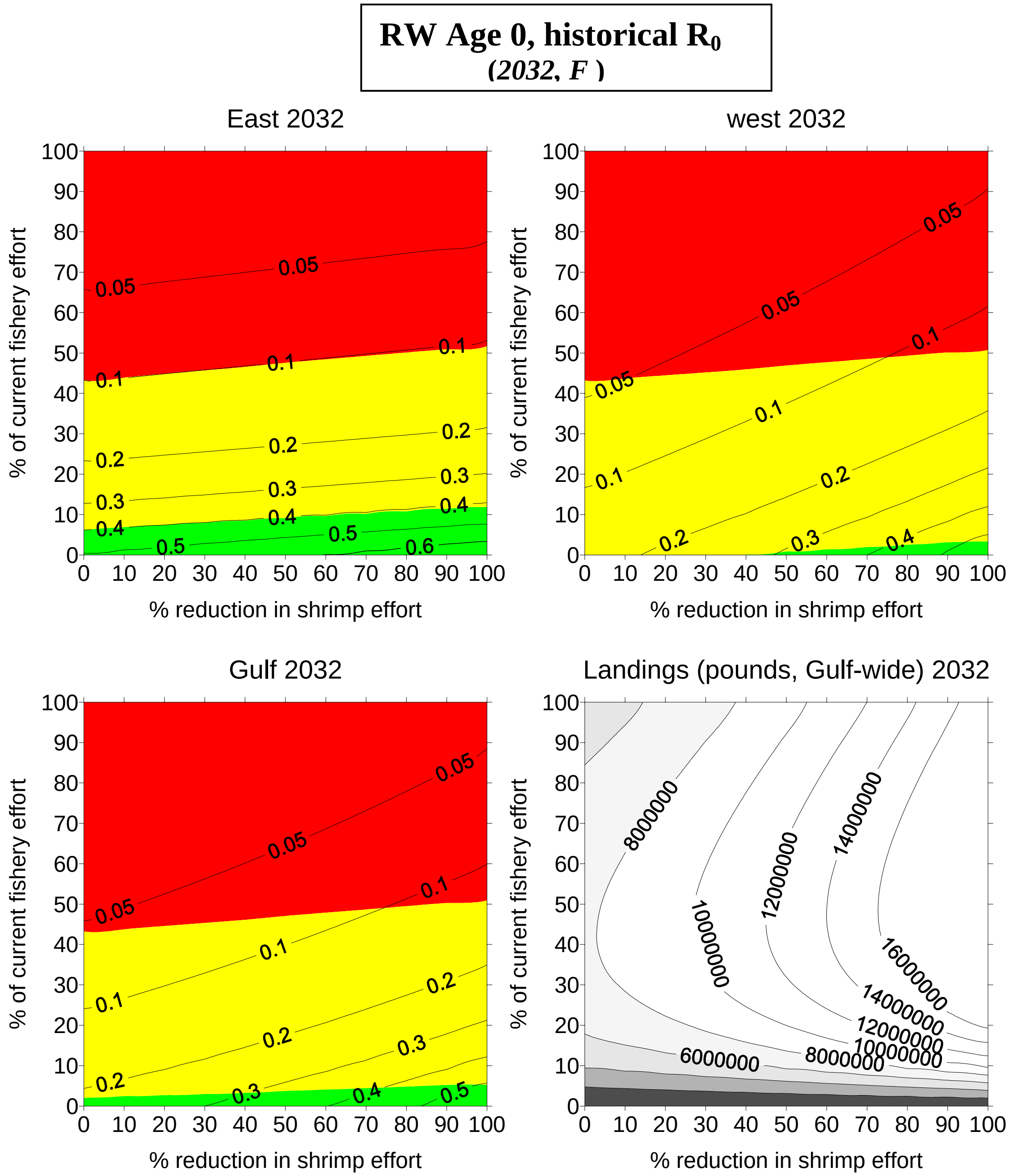


Figure 12d. Isopleths of spawning potential in the year 2032 relative to virgin levels (S_{2032}/S_0) obtained from the RW base model (age 0 included) when the model estimates of R_0 are used. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the fishing mortality rate (as a percent of current levels). The color shades on the graphs represent different levels of spawning potential relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2032}/S_{MSY}<1$, yellow represents $1 \leq S_{2032}/S_{MSY}<4$, and green represents $S_{2032}/S_{MSY} > 4$.

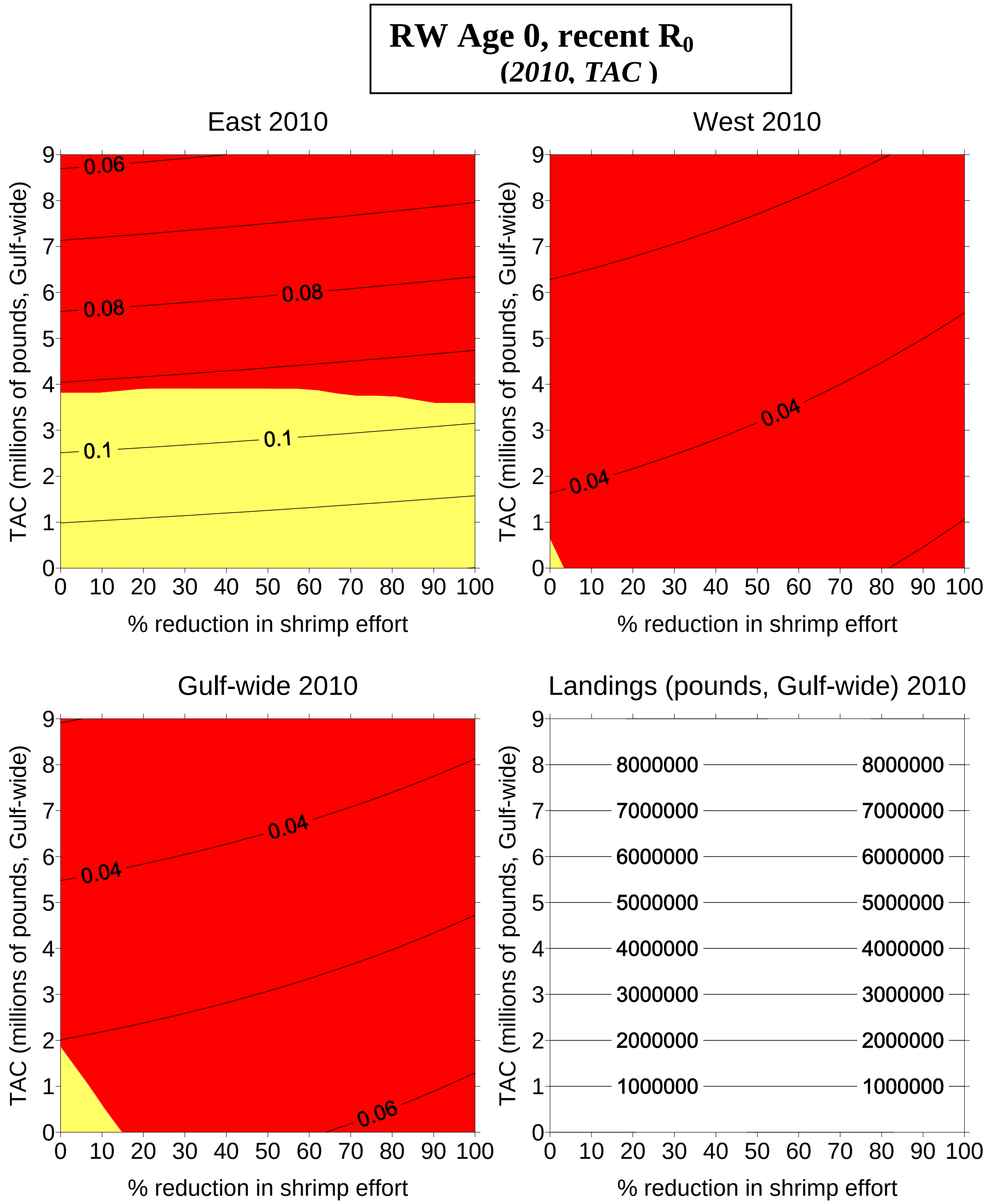


Figure 13a. Isopleths of spawning potential in the year 2010 relative to virgin levels (S_{2010}/S_0) obtained from the RW base model (age 0 included) when R_0 is set to the average of the recruitment estimates from 1984-2003. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the projected Gulf-wide TAC. The color shades represent different levels of spawning potential relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2010}/S_{MSY}<1$, yellow represents $1 \leq S_{2010}/S_{MSY}<4$, and green represents $S_{2010}/S_{MSY} > 4$.

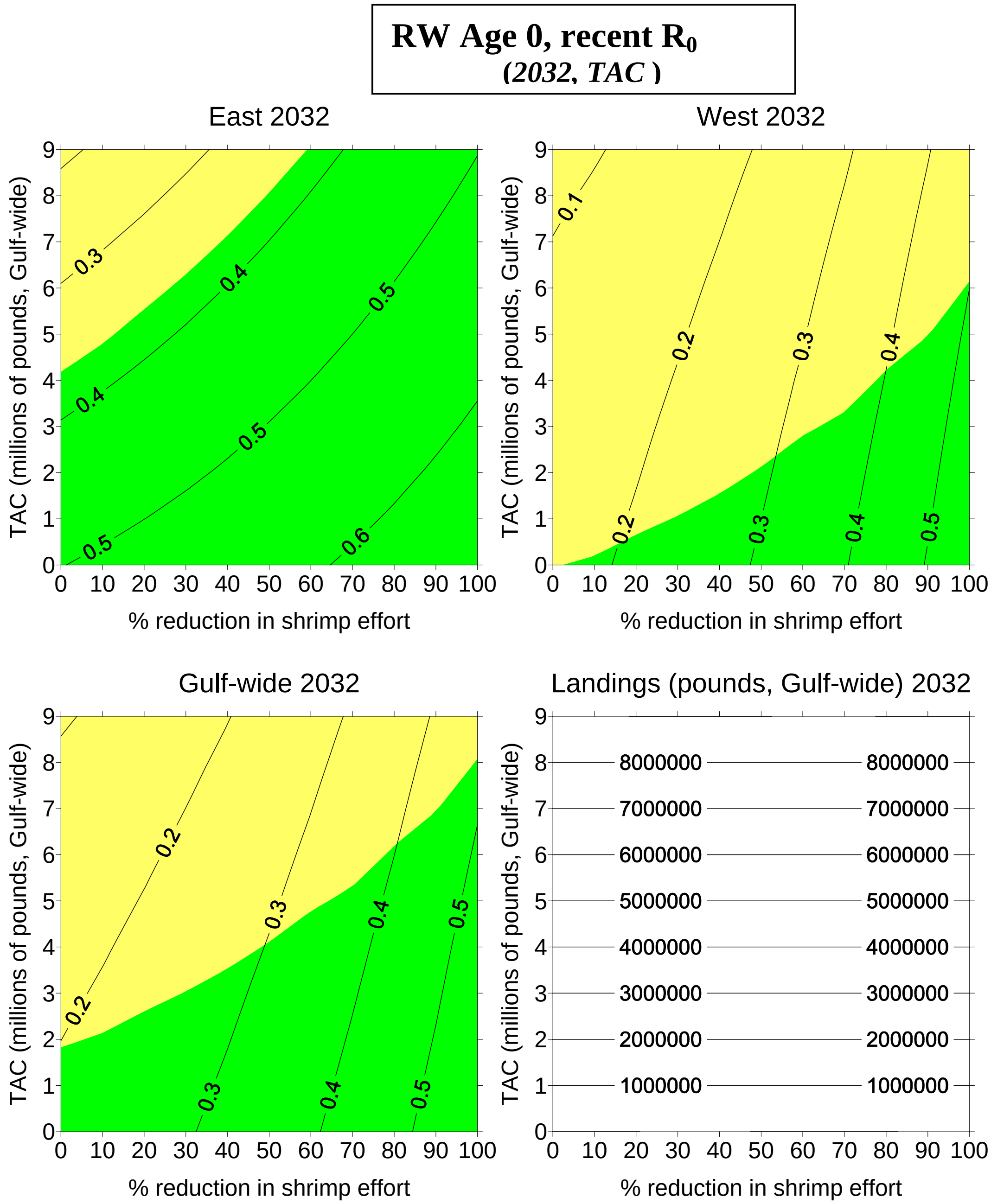


Figure 13b. Isopleths of spawning potential in the year 2032 relative to virgin levels (S_{2032}/S_0) obtained from the RW base model (age 0 included) when R_0 is set to the average of the recruitment estimates from 1984-2003. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the projected Gulf-wide TAC. The color shades represent different levels of spawning potential relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2032}/S_{MSY}<1$, yellow represents $1 \leq S_{2032}/S_{MSY}<4$, and green represents $S_{2032}/S_{MSY} > 4$.

RW Age 0, recent R_0

(2010, F)

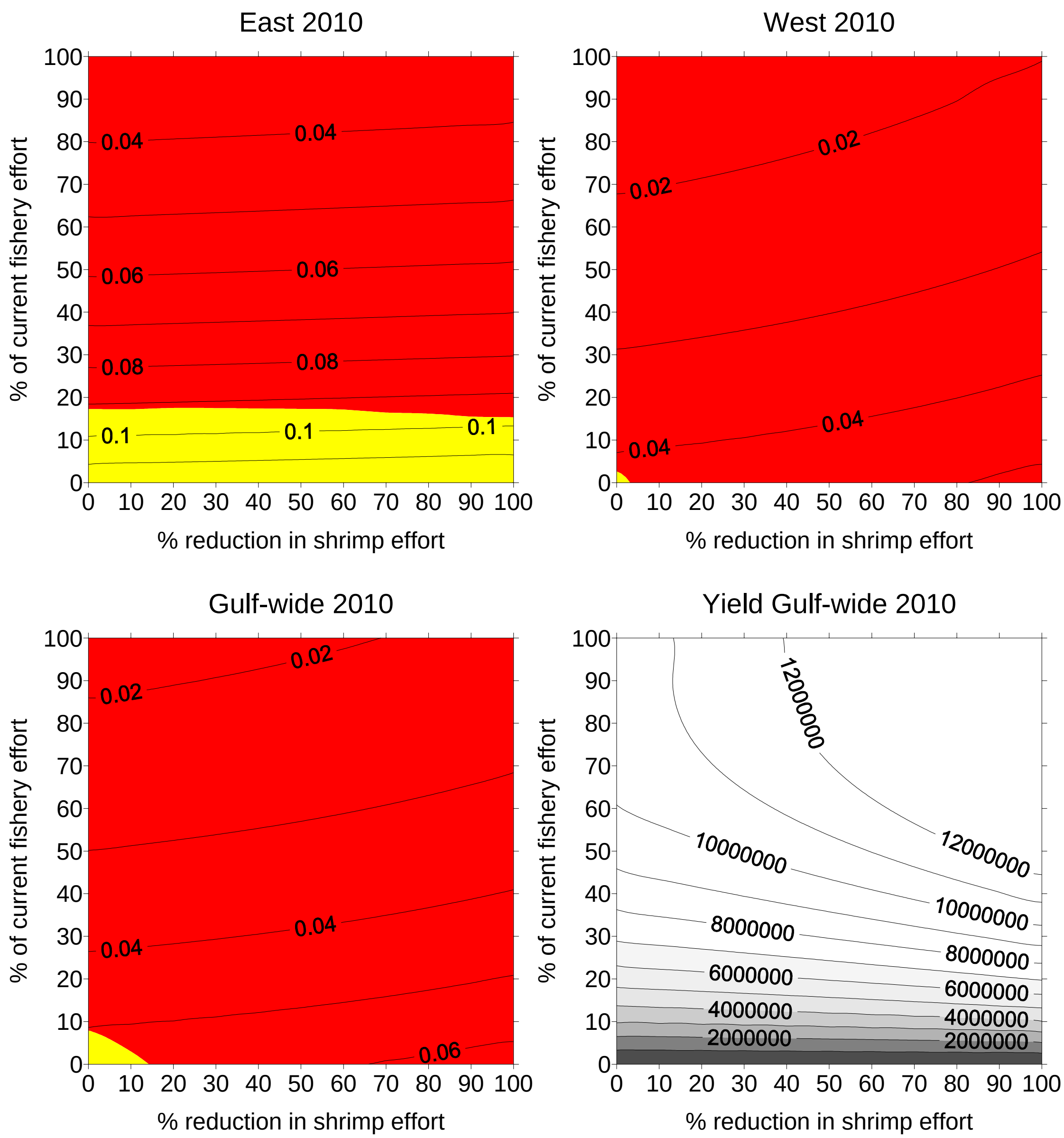


Figure 13c. Isopleths of spawning potential in the year 2010 relative to virgin levels (S_{2010}/S_0) obtained from the RW base model (age 0 included) when R_0 is set to the average of the recruitment estimates from 1984-2003. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the fishing mortality rate (as a percent of current levels). Colors represent spawning potential relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2010}/S_{MSY}<1$, yellow represents $1 \leq S_{2010}/S_{MSY}<4$, and green represents $S_{2010}/S_{MSY} > 4$.

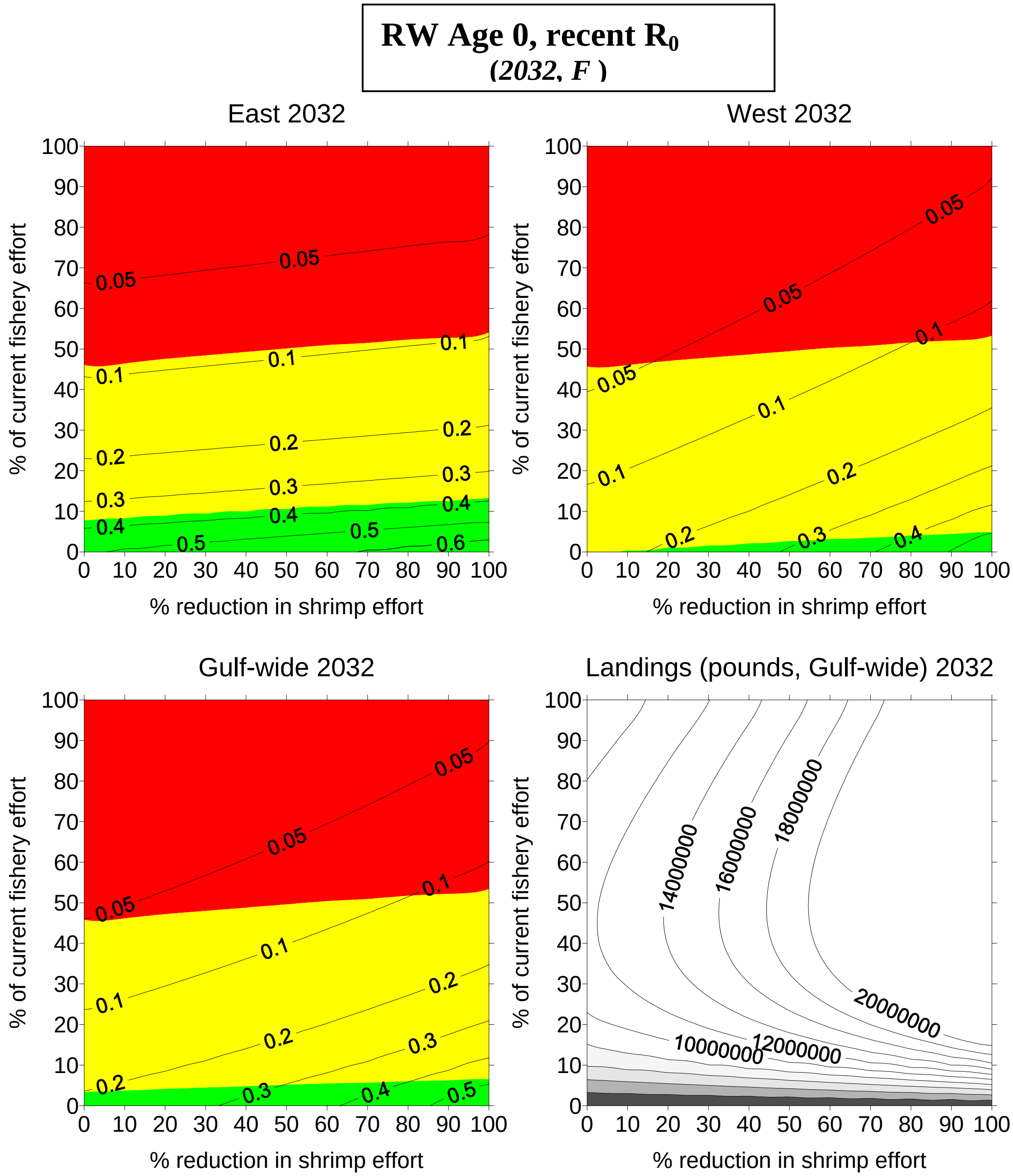


Figure 13d. Isopleths of spawning potential in the year 2032 relative to virgin levels (S_{2032}/S_0) obtained from the RW base model (age 0 included) when R_0 is set to the average of the recruitment estimates from 1984-2003. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the fishing mortality rate (as a percent of current levels). Colors represent spawning potential relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2032}/S_{MSY}<1$, yellow represents $1 \leq S_{2032}/S_{MSY}<4$, and green represents $S_{2032}/S_{MSY} > 4$.

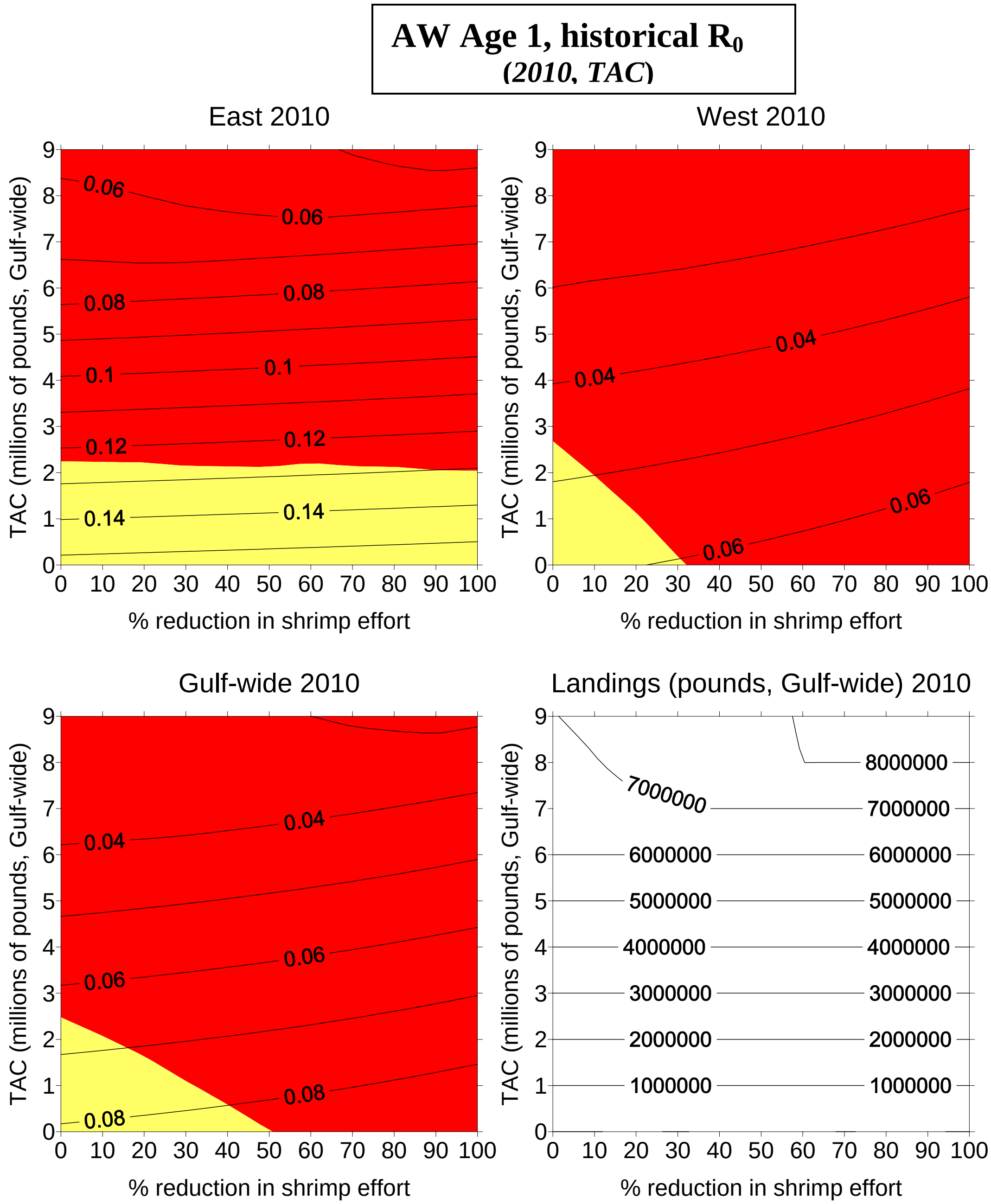


Figure 14a. Isopleths of spawning potential in the year 2010 relative to virgin levels (S_{2010}/S_0) obtained from the AW base model (no age 0) when the model estimates of R_0 are used. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the projected Gulf-wide TAC. Colors represent S_{2010}/S_{MSY}, where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2010}/S_{MSY}<1$, yellow represents $1 \leq S_{2010}/S_{MSY}<4$, and green $S_{2010}/S_{MSY} > 4$. Landings isopleths that do not coincide with the TAC labels indicate that the particular TAC could not be sustained.

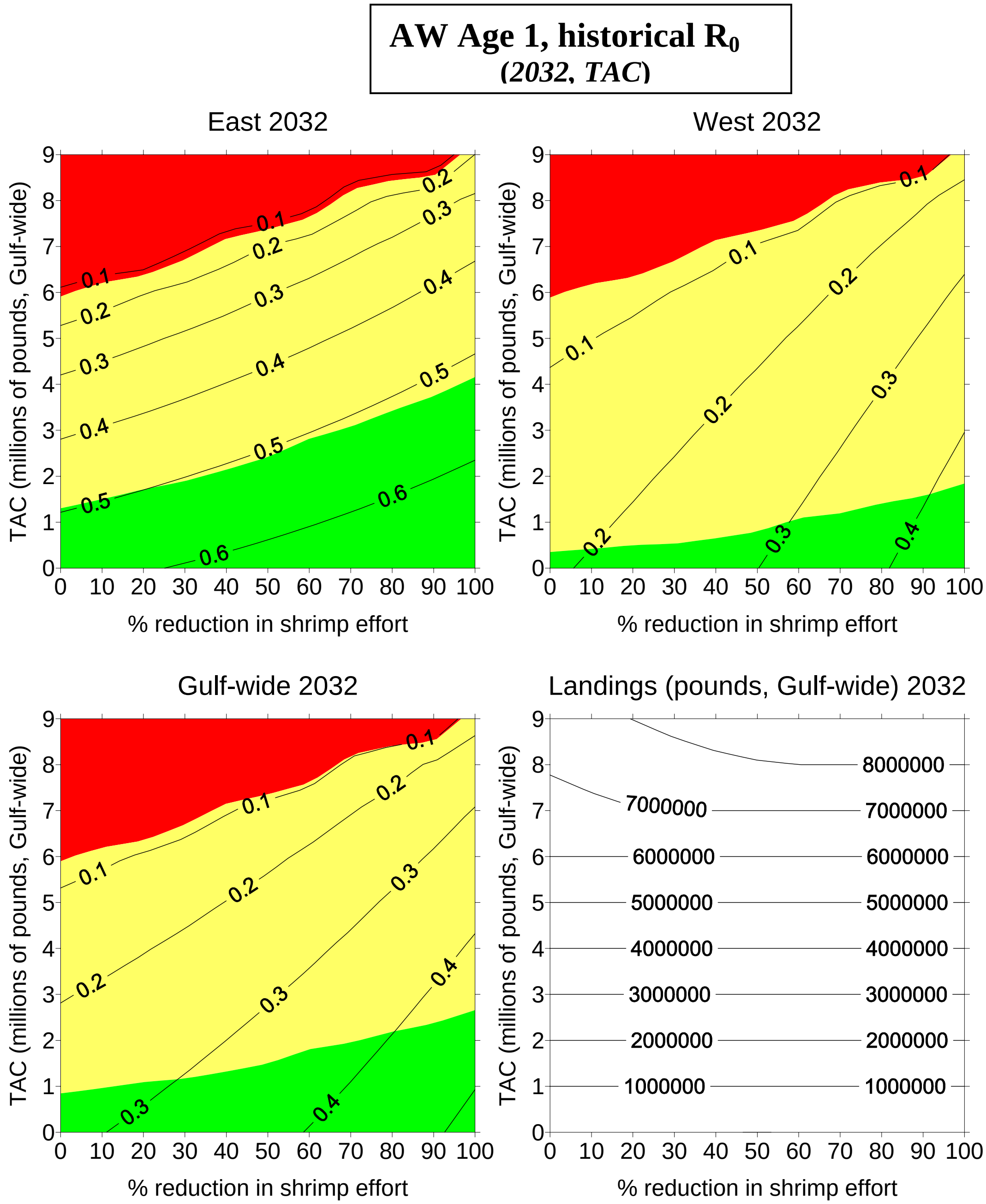


Figure 14b. Isopleths of spawning potential in the year 2032 relative to virgin levels (S_{2032}/S_0) obtained from the AW base model (no age 0) when the model estimates of R_0 are used. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the projected Gulf-wide TAC. Colors represent S_{2032}/S_{MSY}, where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2032}/S_{MSY}<1$, yellow represents $1 \leq S_{2032}/S_{MSY}<4$, and green $S_{2032}/S_{MSY} > 4$. Landings isopleths that do not coincide with the TAC labels indicate that the particular TAC could not be sustained.

AW Age 1, historical R_0
(2010, F)

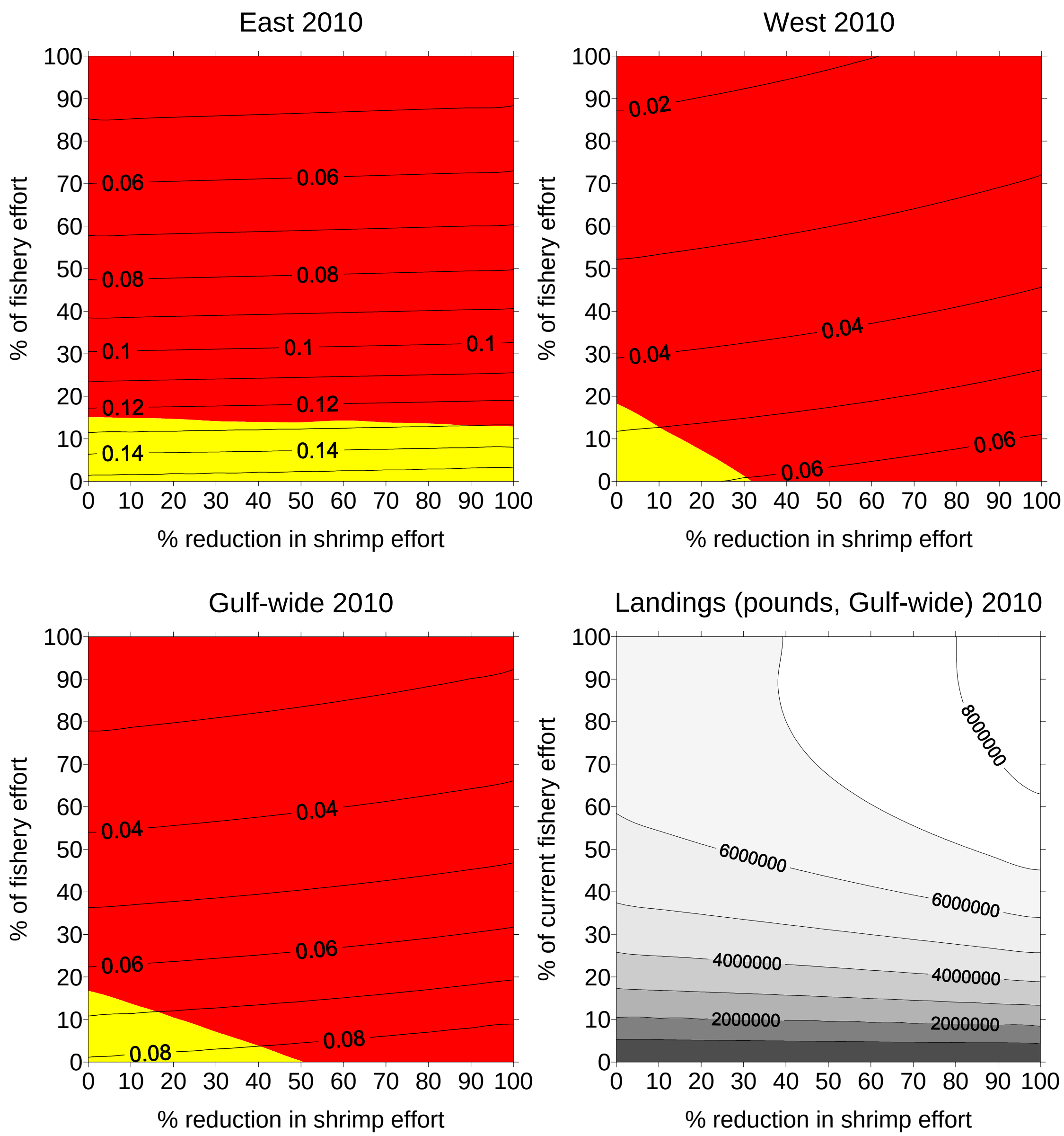


Figure 14c. Isopleths of spawning potential in the year 2010 relative to virgin levels (S_{2010}/S_0) obtained from the AW base model (no age 0) when the model estimates of R_0 are used. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the fishing mortality rate (as a percent of current levels). The color shades on the graphs represent different levels of spawning potential relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2010}/S_{MSY}<1$, yellow represents $1 \leq S_{2010}/S_{MSY}<4$, and green represents $S_{2010}/S_{MSY} > 4$.

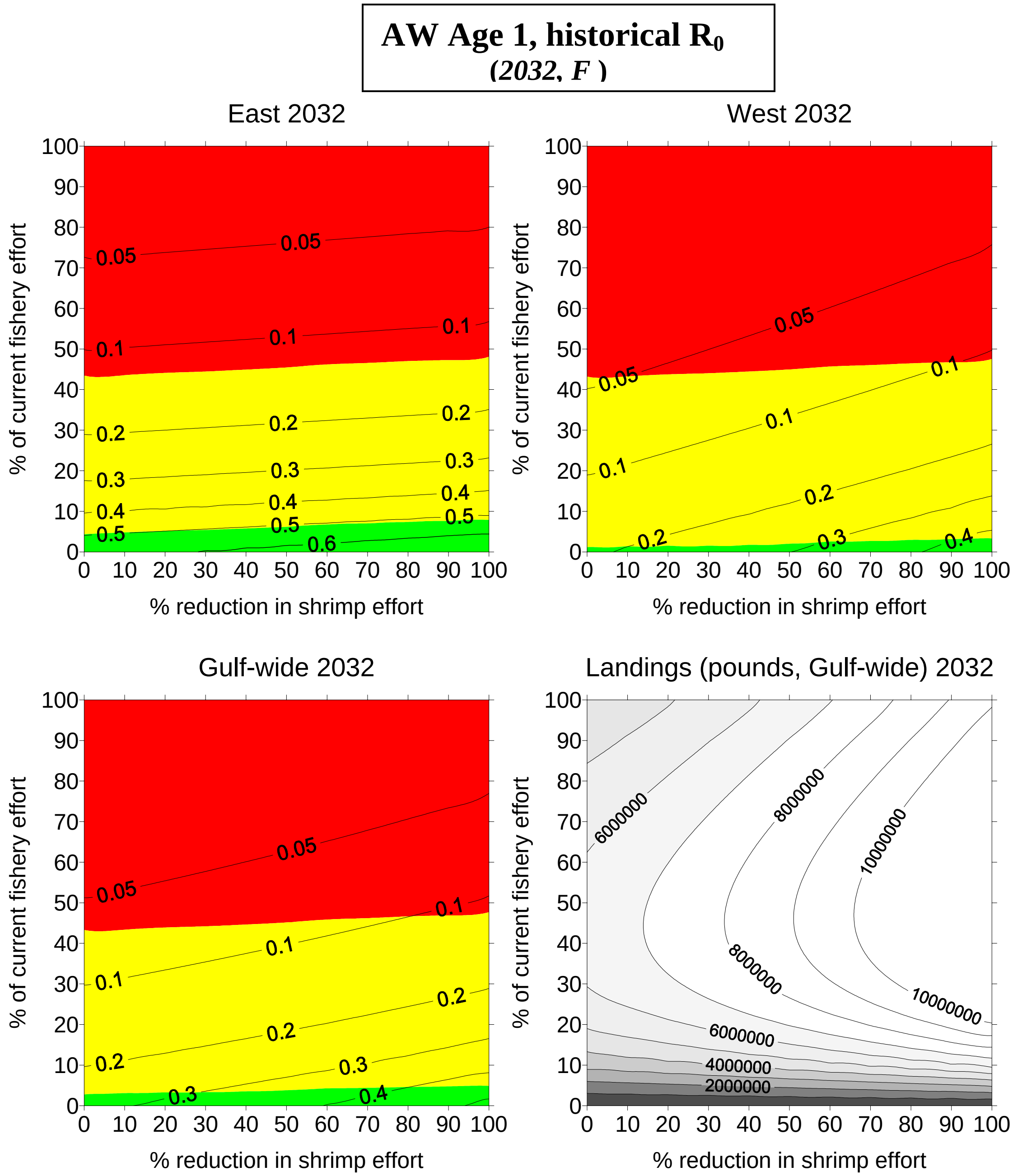


Figure 14d. Isopleths of spawning potential in the year 2032 relative to virgin levels (S_{2032}/S_0) obtained from the AW base model (no age 0) when the model estimates of R_0 are used. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the fishing mortality rate (as a percent of current levels). Colors represent spawning potential relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2032}/S_{MSY}<1$, yellow represents $1 \leq S_{2032}/S_{MSY}<4$, and green represents $S_{2032}/S_{MSY} > 4$.

AW Age 1, recent R_0
(2010, TAC)

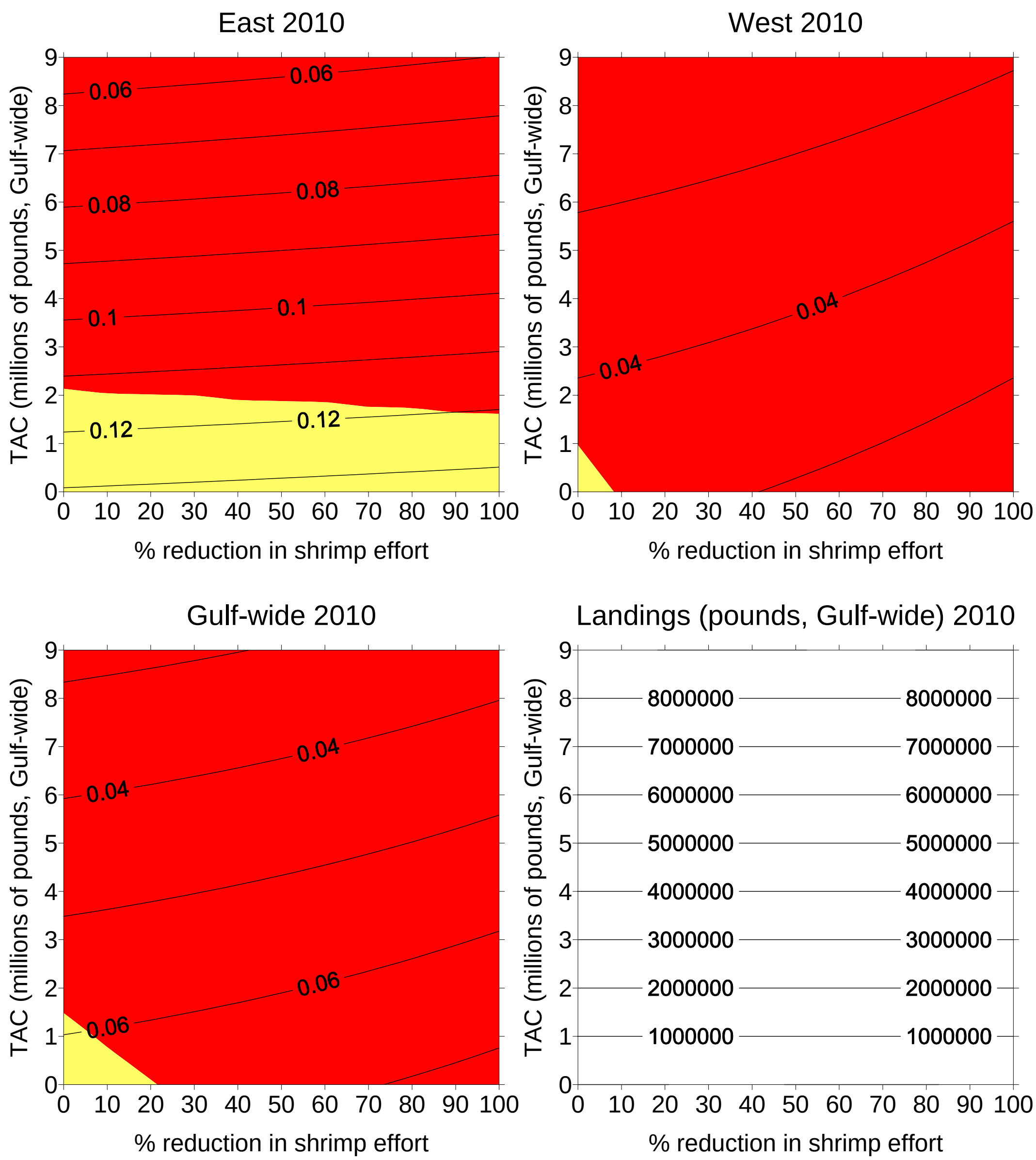


Figure 15a. Isopleths of spawning potential in the year 2010 relative to virgin levels (S_{2010}/S_0) obtained from the AW base model (no age 0) when R_0 is set to the average of the recruitment estimates from 1984-2003. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the projected Gulf-wide TAC. The color shades on the graphs represent different levels of spawning potential relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2010}/S_{MSY}<1$, yellow represents $1 \leq S_{2010}/S_{MSY}<4$, and green represents $S_{2010}/S_{MSY} > 4$.

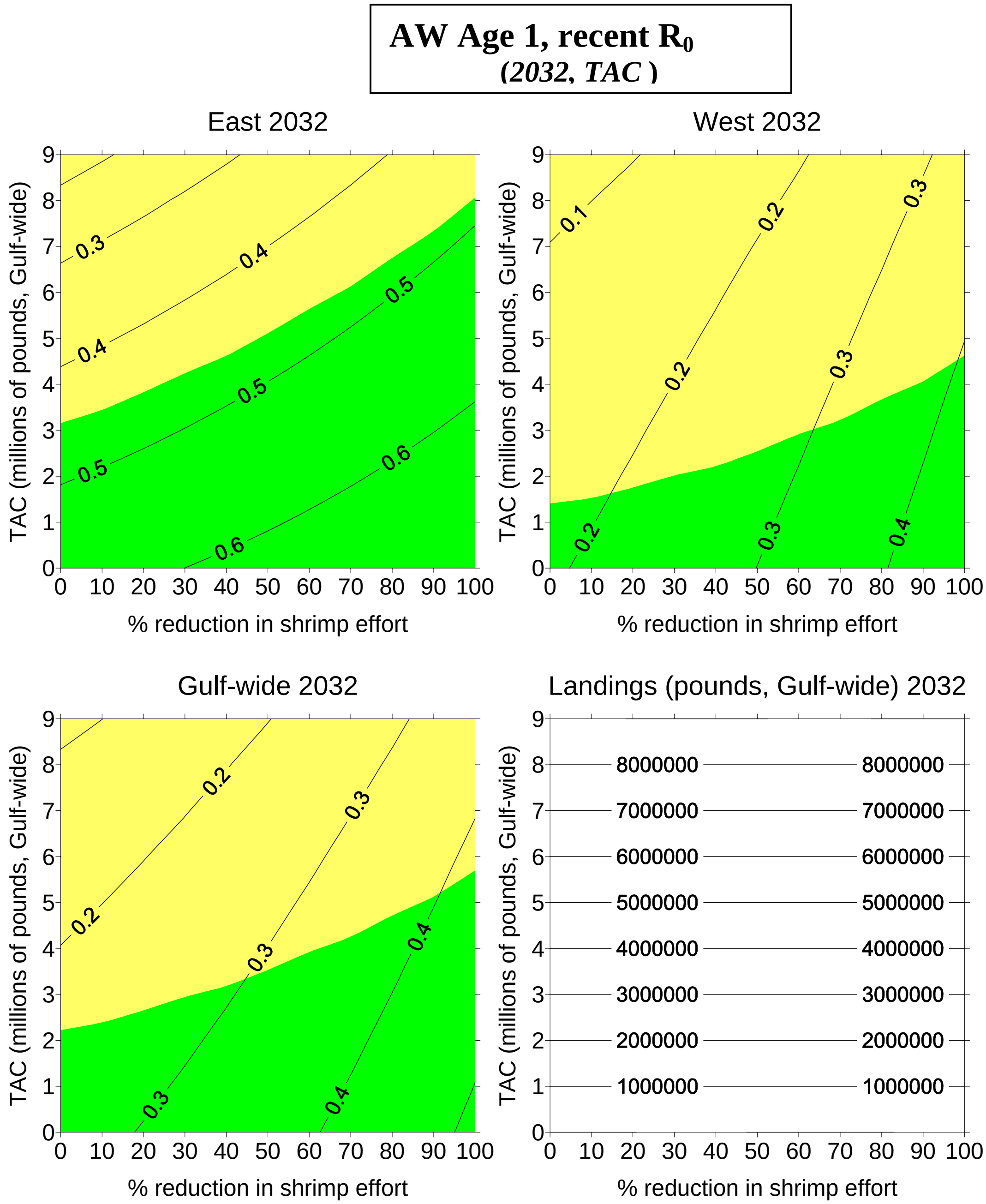


Figure 15b. Isopleths of spawning potential in the year 2032 relative to virgin levels (S_{2032}/S_0) obtained from the AW base model (no age 0) when R_0 is set to the average of the recruitment estimates from 1984-2003. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the projected Gulf-wide TAC. The color shades on the graphs represent different levels of spawning potential relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2032}/S_{MSY}<1$, yellow represents $1 \leq S_{2032}/S_{MSY}<4$, and green represents $S_{2032}/S_{MSY} > 4$.

AW Age 1, recent R_0
(2010, F)

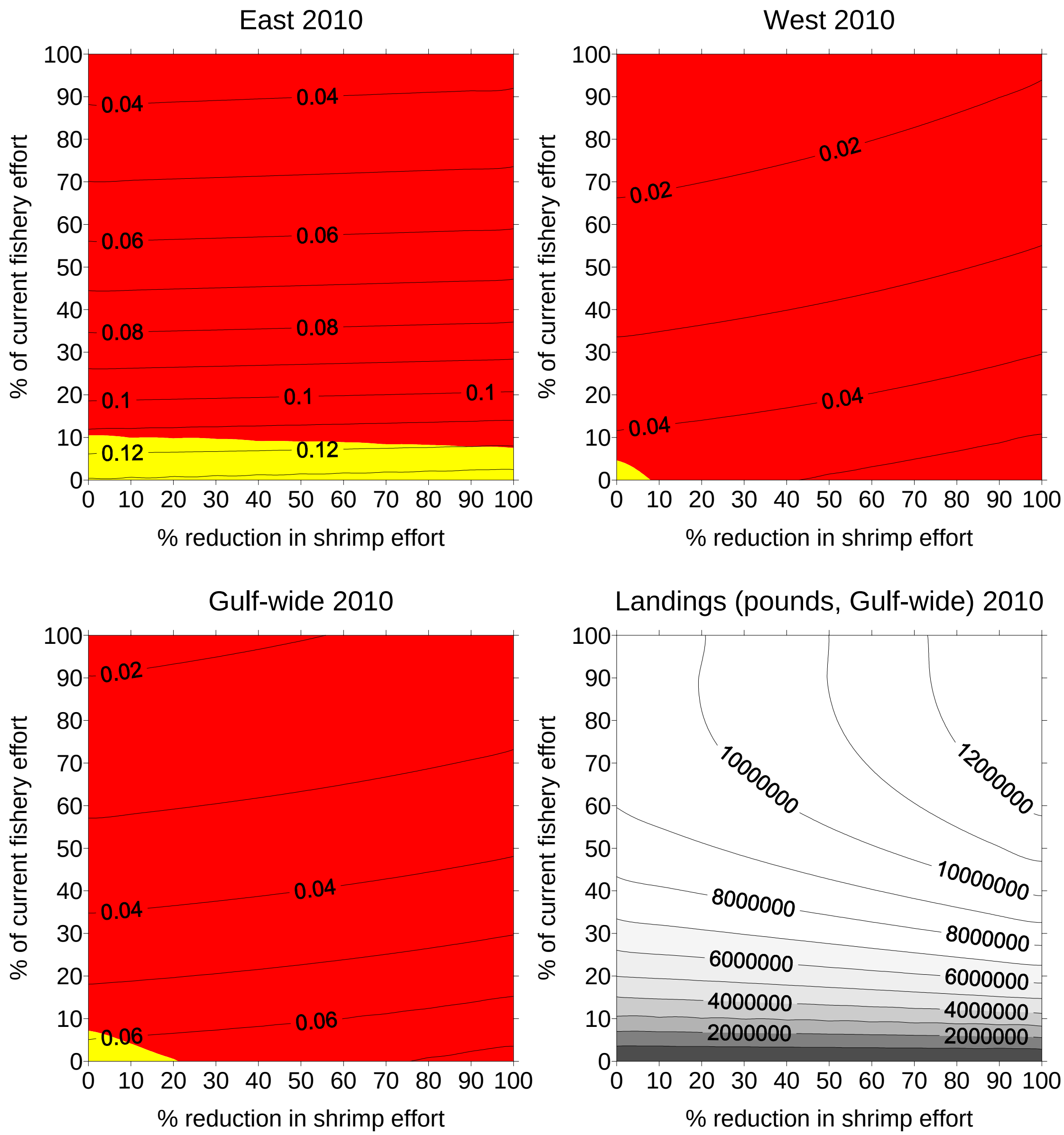


Figure 15c. Isopleths of spawning potential in the year 2010 relative to virgin levels (S_{2010}/S_0) obtained from the AW base model (no age 0) when R_0 is set to the average of the recruitment estimates from 1984-2003. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the fishing mortality rate (as a percent of current levels). Colors represent spawning potential relative to MSY levels (S_{2010}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2010}/S_{MSY}<1$, yellow represents $1 \leq S_{2010}/S_{MSY}<4$, and green represents $S_{2010}/S_{MSY} > 4$.

AW Age 1, recent R_0
(2032, F)

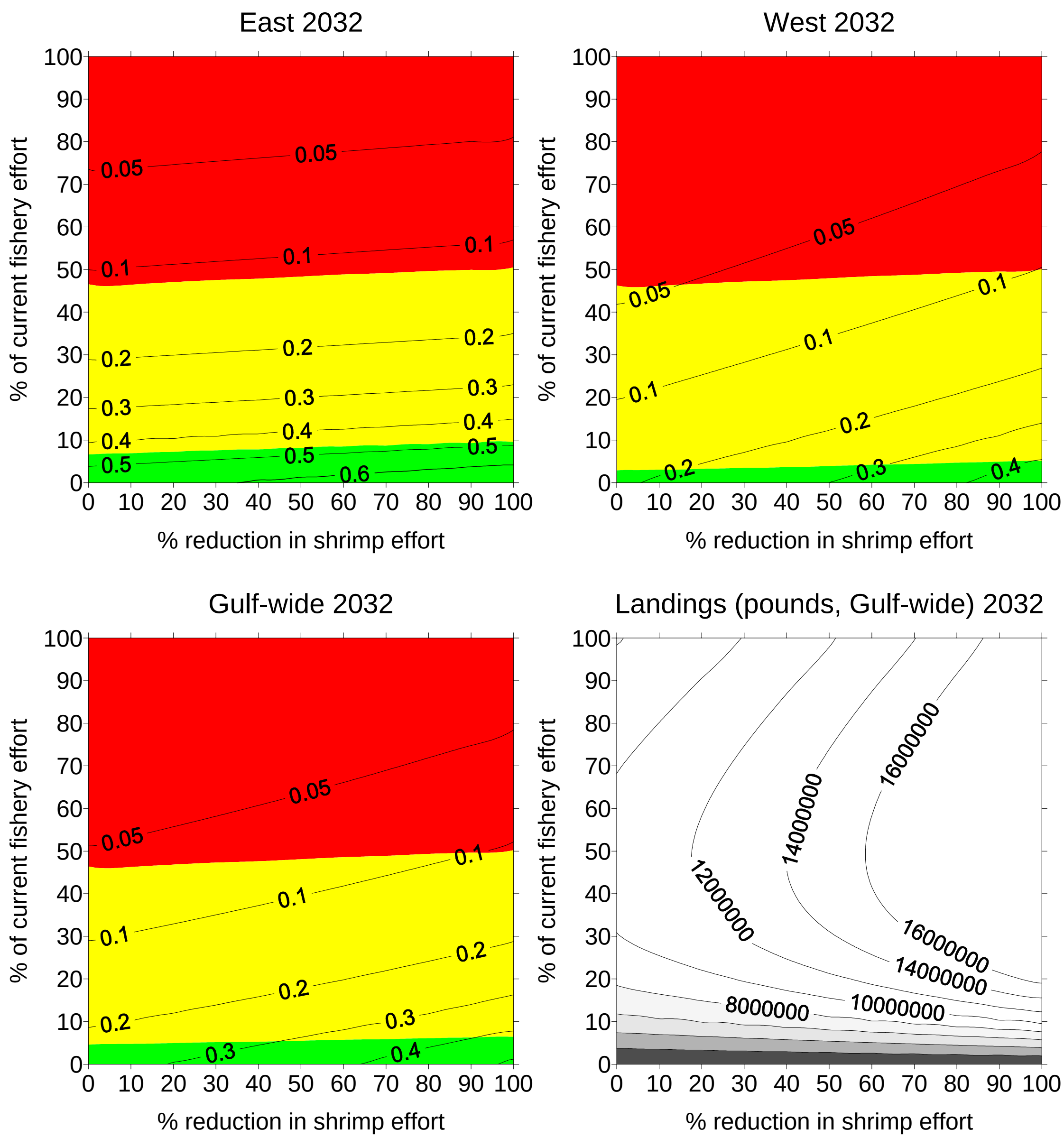


Figure 15d. Isopleths of spawning potential in the year 2032 relative to virgin levels (S_{2032}/S_0) obtained from the AW base model (no age 0) when R_0 is set to the average of the recruitment estimates from 1984-2003. The horizontal axis refers to the projected percent reduction in shrimp effort from current (2001-2003) levels (current levels are estimated to have been reduced by 11% in the east and 17% in the west relative to the estimates for 1984-89). The vertical axis refers to the fishing mortality rate (as a percent of current levels). Colors represent spawning potential relative to MSY levels (S_{2032}/S_{MSY}), where MSY is conditioned on the indicated reduction in shrimp effort. Red represents $S_{2032}/S_{MSY}<1$, yellow represents $1 \leq S_{2032}/S_{MSY}<4$, and green represents $S_{2032}/S_{MSY} > 4$.

APPENDIX – ADDITIONAL DIAGNOSTICS

At the request of the Review Workshop Panel, qq and other diagnostic plots and tables for the RW preferred base model results were prepared to permit evaluation of the appropriateness of the statistical model assumptions used and to examine the relative contribution of age structure vs relative abundance information to the stock status outcomes. These follow

Table AD1. Standard deviation of the standardized residuals for each index and for the observed catch at age. There was a region-specific series for each index (HL=Hand line; LARV=Larval survey; REC=recreational; TRW0=Trawl survey age 0's; TRW1=Trawl survey age 1's; VID=video survey).

Index	**Standard deviation of standardized residuals**
HL-E	0.53
HL-W	0.54
LARV-E	1.98
LARV-W	1.51
REC-E	0.71
REC-W	0.84
TRW0-E	1.47
TRW0-W	1.32
TRW1-E	1.08
TRW1-W	1.08
VID-E	0.81
VID-W	0.80
Catch at age	3.48

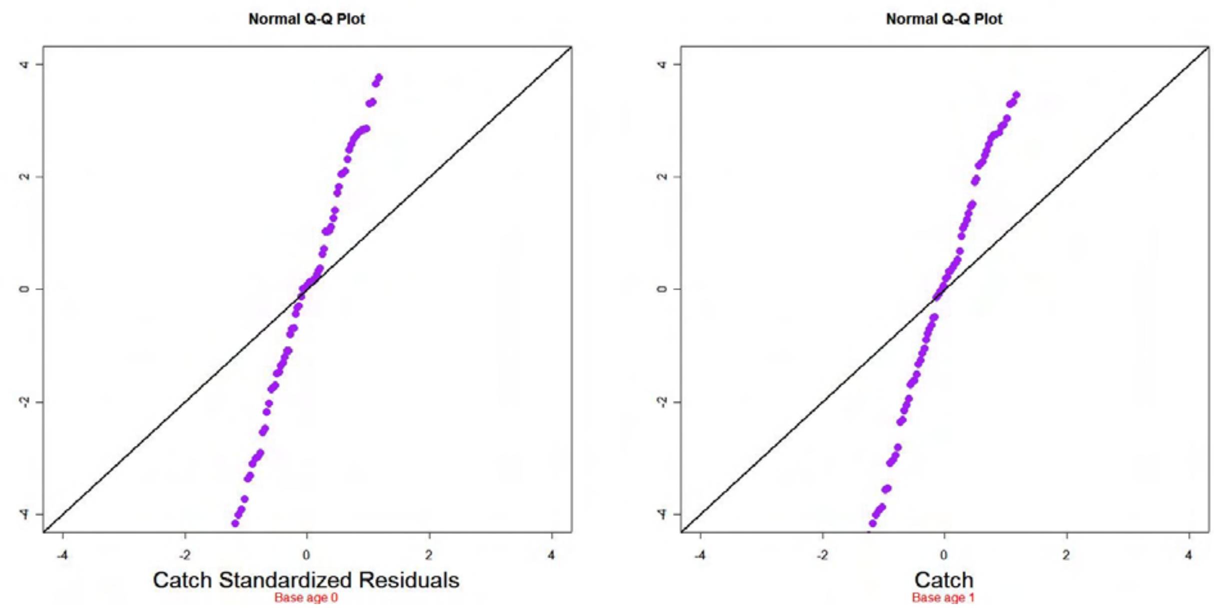


Figure AD1. Q-Q plot of standardized residuals from model fits to observed catch at age (mean = -0.084, standard deviation = 3.48) for models with and without age 0.

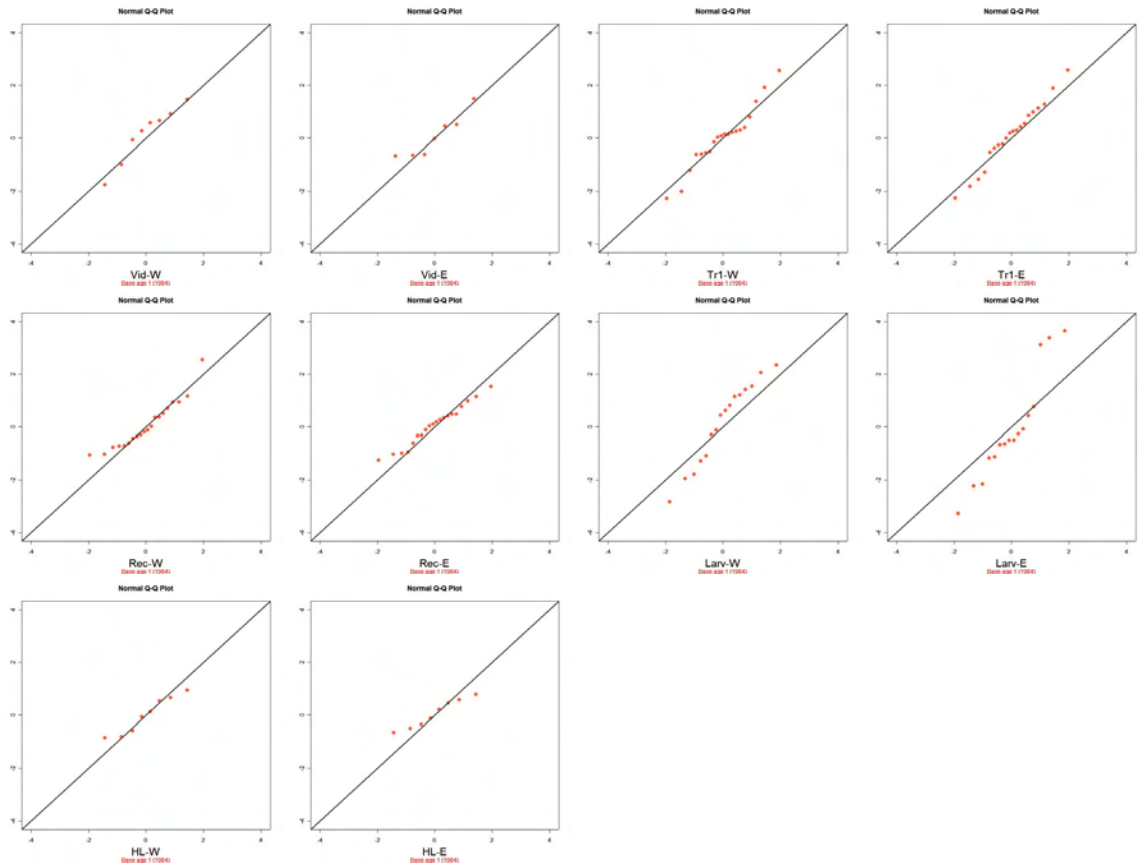


Figure AD2a. Q-Q plot of standardized residuals from model fits to indices of abundance for model based on age-1 model using the short time series (1984-2003).

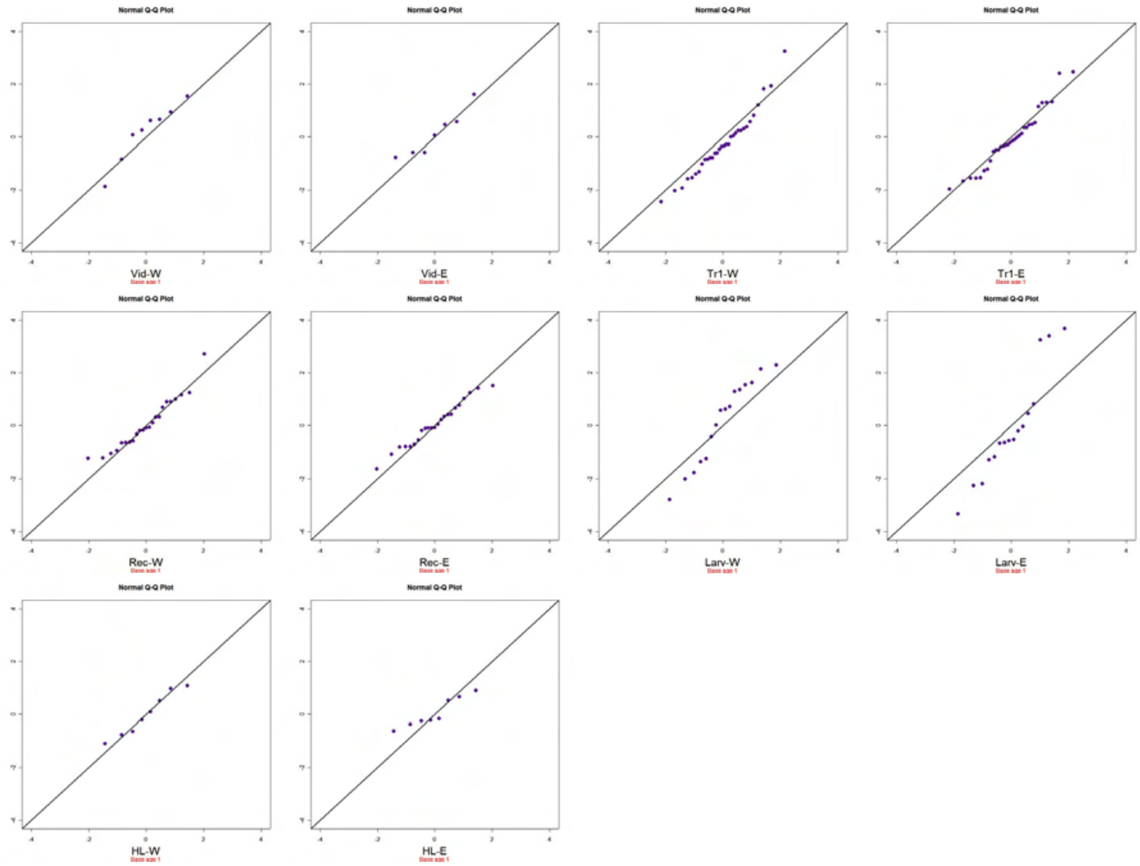


Figure AD2b. Q-Q plot of standardized residuals from model fits to indices of abundance for model based on age-1 model using the long time series (1872-2003).

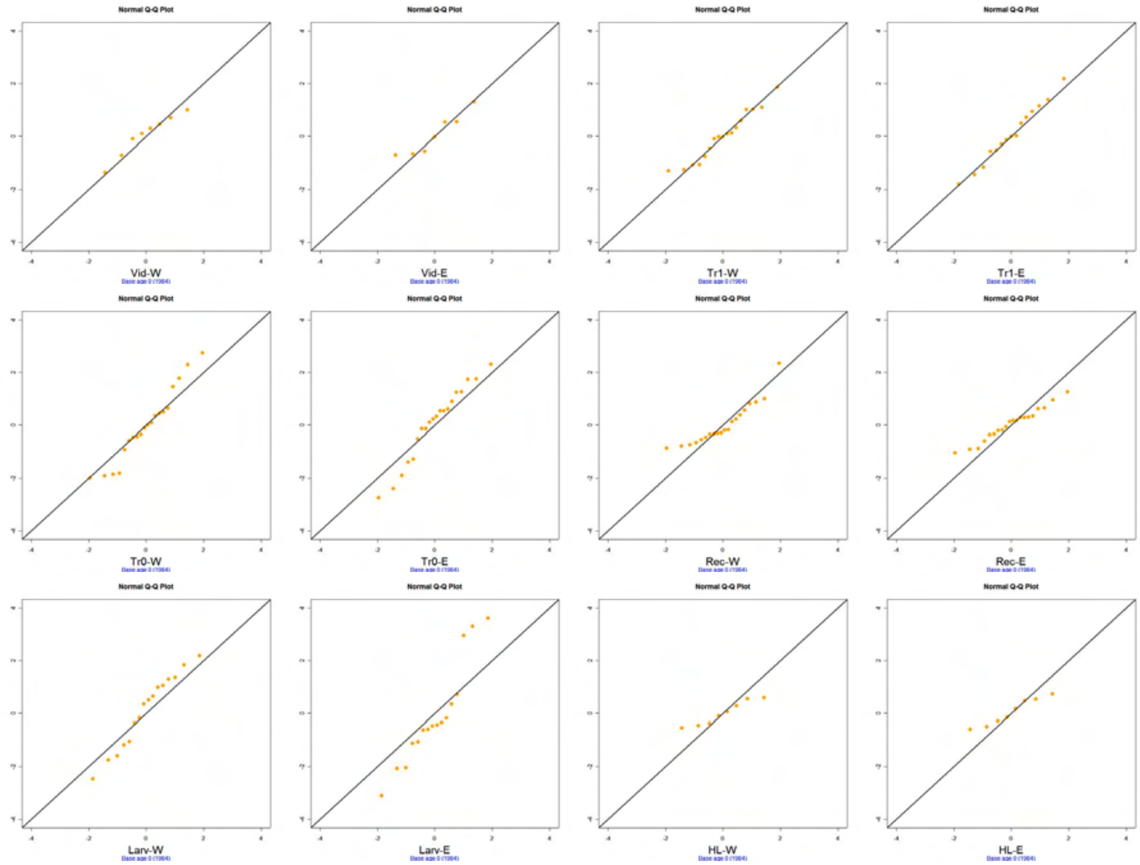


Figure AD2c. Q-Q plot of standardized residuals from model fits to indices of abundance for model based on age-0 model using the short time series (1984-2003).

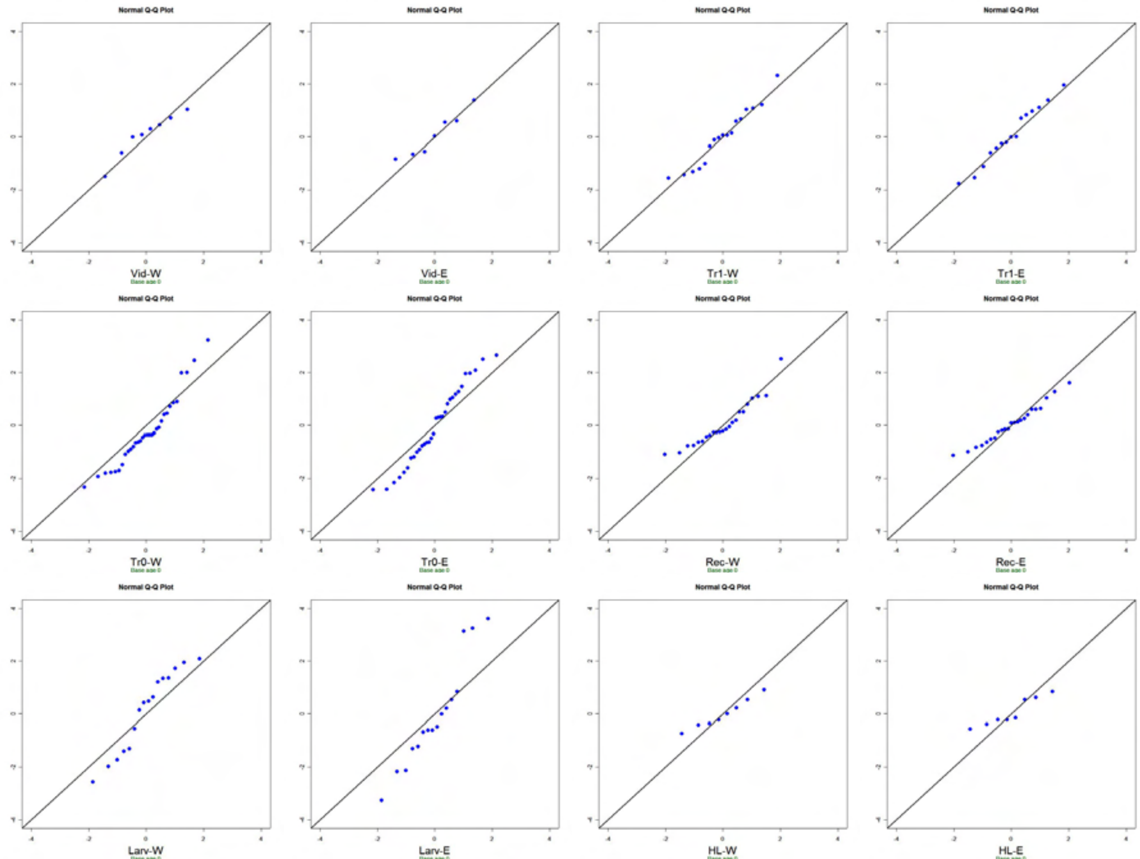
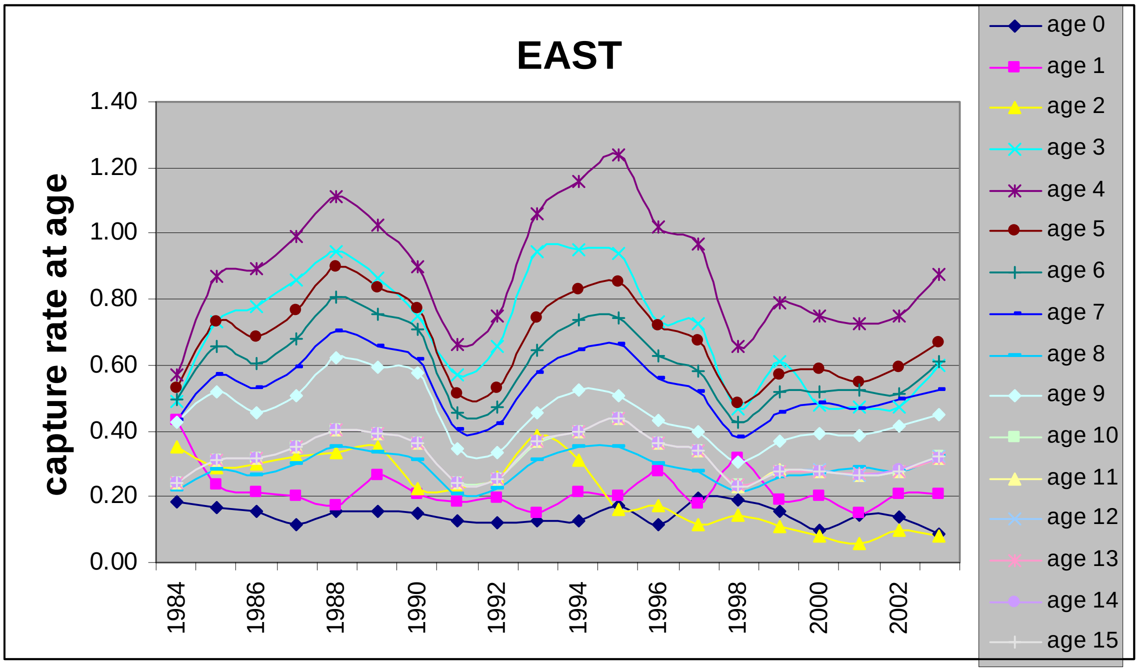


Figure AD2d. Q-Q plot of standardized residuals from model fits to indices of abundance for model based on age-0 model using the long time series (1872-2003).

(a)



(b)

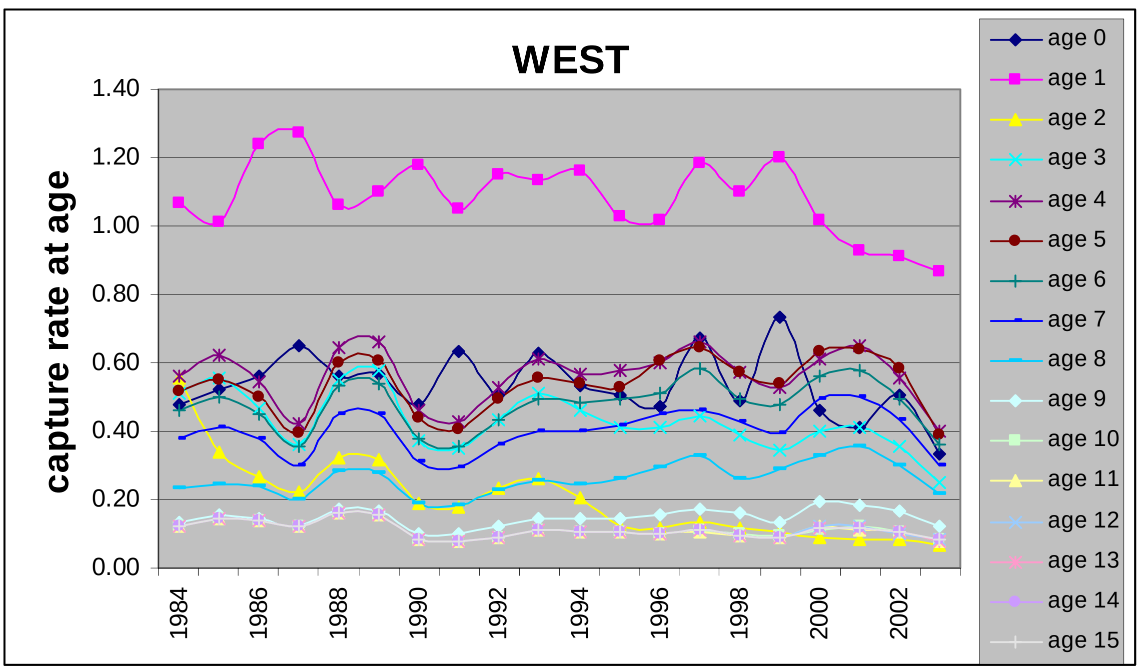
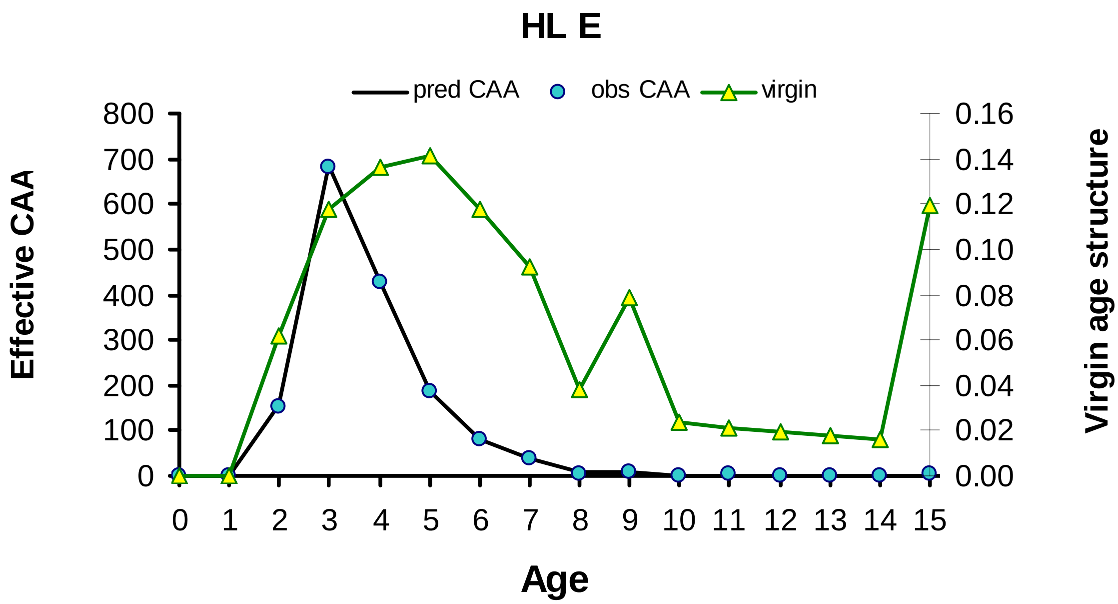


Figure AD3. Capture rate at age in the East (a) and West (b) from 1984-2003. Capture rate reflects the instantaneous rate for fish that were caught (this includes landings as well as discards due to size limits and closed seasons). Age 15 is a plus group.

(a)



(b)

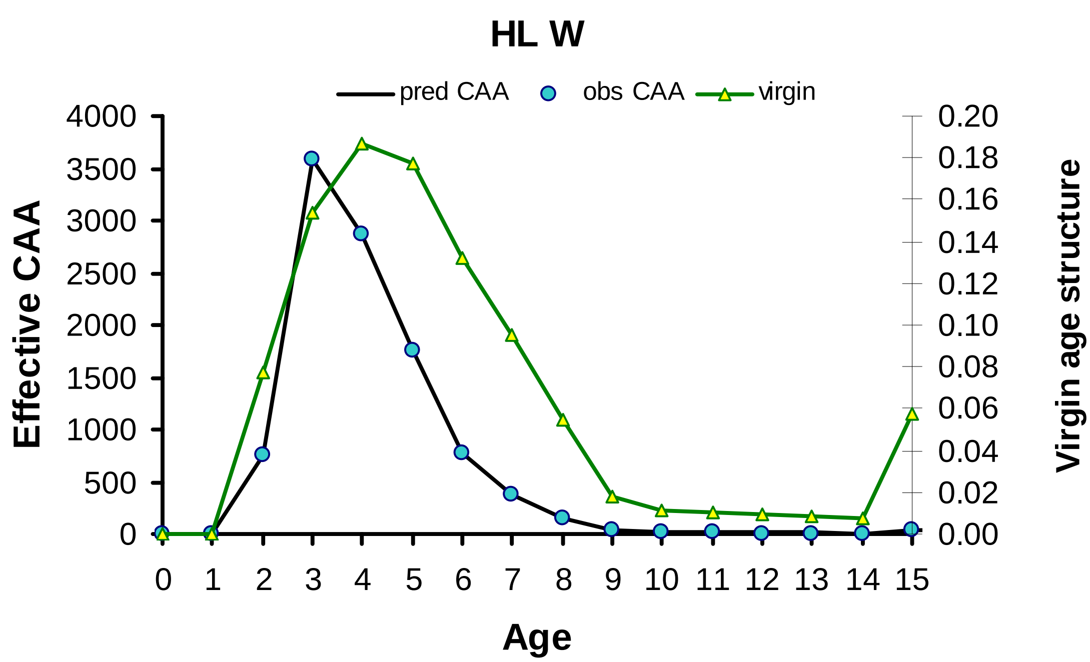


Figure AD4. Unexploited age frequency (virgin) versus exploited age frequency for the handline fishery in the East (a) and West (b). Age 15 is a plus group.

APPENDIX Generation Time & Spawning Abundance Comparisons

The attached spreadsheet gen time & ssb plots.xls provide calculations related to these issues.

Access Appendix Generation Time by Selecting Icon:
(Requries MS Excel)

APPENDIX CATCHEM Results

The attached spreadsheet Results.xls provide basic inputs and results for the CATCHEM age 0 and CATCHEM age 1

Access Appendix CATCHEM results by selecting icon:
(Requires MS Excel)

Addendum 2. CIE chair and reviewer reports pertaining to the post-review workshop finalization of the Assessment Summary (Section 1.3)

REVIEW OF ADVISORY REPORT

FROM

SEDAR 7 REVIEW WORKSHOP

APRIL 4–7, 2005

NEW ORLEANS, LOUISIANA

Prepared by

Patrick Cordue
Fisheries Consultant
New Zealand

for

University of Miami
Independent System for Peer Review

17 June 2005

EXECUTIVE SUMMARY

The SEDAR 7 Review Workshop for Gulf of Mexico red snapper was held in New Orleans from 4-7 April 2005. The Review Workshop Panel recommended that age-0 snapper be included in the assessment base case to account for bycatch mortality in the shrimp fishery. This was contrary to the recommendation of the Assessment Workshop, which had argued that shrimp bycatch mortality on age-0 snapper was insignificant due to strong density-dependent natural mortality. In their initial draft of the advisory report, the Assessment Team presented two sets of model runs, those supported by the Review Workshop and those supported by the Assessment Workshop.

Subsequently, a revised advisory report that used only age-0 snapper runs was written by the Assessment Team. NMFS-SEFSC requested that the SEDAR 7 Review Panel consider the revised report. The Terms of Reference supplied by email with the revised advisory report were: (1) review the red snapper assessment summary report and determine whether the report accurately represents the recommendations of the Review Workshop Panel; (2) review the advisory report recommendations for Sustainable Fisheries Act management criteria and determine whether the relative merits and risks of alternative criteria are accurately presented; (3) if the Panel determines that the advisory report is insufficient with regard to TOR (1) or (2), outline specific actions necessary to correct the deficiencies.

The revised report was reviewed by the Panel via email during the week of 13-17 June 2005. The revised report uses only age-0 based runs and the projections use the average of recent recruitment as recommended by the Panel. Therefore, I consider that the report is consistent with the Panel's previous recommendations and satisfies TOR 1. The revised report uses benchmarks based on $SPR_{30\%}$ rather than yield per recruit based F_{MSY} and B_{MSY}. I support the proposed $SPR_{30\%}$ based benchmarks. I see them as consistent with MSY concepts and believe that the 30% level is appropriate for red snapper. In my opinion, given the required brevity of the document, the brief wording in the revised report under "Status Determination Criteria" adequately satisfies TOR 2.

BACKGROUND

The SEDAR 7 Review Workshop for Gulf of Mexico red snapper was held in New Orleans from 4-7 April 2005. The SEDAR process normally involves a Data Workshop, an Assessment Workshop, and a Review Workshop (RW). For red snapper, the process involved two Assessment Workshops and spanned more than 12 months. This was due to the complex nature of the red snapper assessment and the problems encountered with the original choice of assessment method.

Two reports were produced subsequent to the RW: the Consensus Summary Report (prepared by the RW Panel) and the Advisory Report (prepared by the Assessment Team). The Advisory Report was not part of the RW's terms of reference. However, the Review Panel did provide some guidance to the Assessment Team on the model runs to include in the Advisory Report. The model run selected by the Review Panel as a base case assessment differed from the assessment presented to the meeting by the Assessment Team. The second Assessment Workshop had agreed to exclude age-0 red snapper from the assessment despite the bycatch of age-0 (and age-1) red snapper in the shrimp fishery. This is valid if density dependent mortality effects are so strong on age-0 snapper that the bycatch from the shrimp fishery is insignificant. The Review Panel did not accept this argument and selected a base case which included age-0 red snapper. The Advisory Report, as first drafted by the Assessment Team, contained an equal number of model runs with and without age-0 red snapper (Anon. draft c.) This was contrary to the Panel's recommendation during the RW.

Subsequently, a revised advisory report that uses only age-0 snapper runs was written by the Assessment Team (Anon. draft a & b). NMFS-SEFSC requested that the SEDAR 7 Review Panel consider the revised report: 1) review the revised assessment summary report to evaluate consistency with the Review Panel's previous recommendations, and 2) recommend a preferred benchmark that is appropriate for the advisory report under the Sustainable Fisheries Act.

REVIEW ACTIVITIES

I received the revised draft advisory report by email on 12 June 2005 (Anon. draft a.). The first email correspondence from a member of the Review Panel was on 15 June from Graham Pilling. Amongst other questions, he asked which results were actually in the revised report – were they the age-0 snapper runs? The Assessment Team leader promptly replied with answers to the questions and with additional material (Anon. draft b., draft c., Porch 2005, and spreadsheets). I read the Consensus summary Report to refresh my memory with regard to the Panel's recommendations (Cordue et al. 2005) and made my first email contribution later that day. I indicated that, in my opinion, the revised report did follow the recommendations of the Panel and that the suggested reference points (based on $SPR_{30\%}$) were appropriate. Graham later added his support to my position. Graham and I each made some editorial suggestions (e.g., Graham wanted explicit text indicating that age-0 snapper had been used).

Subsequent emails from Panel members indicated general acceptance that the report did follow the Panel's main recommendations. There were various editorial suggestions. There was general support for more explicit reference to the use of age-0 snapper in the model runs. One Panelist suggested a paragraph which was highly technical and I suggested that plainer language should be used. I also indicated that editing the report was outside of our TOR, and all such editorial suggestions should simply be taken as such when the Assessment Team leader did a final edit of the report.

SUMMARY OF FINDINGS

The main TOR for this review were:

(1) Review the red snapper assessment summary report and determine whether the report accurately represents the recommendations made by the Review Panel during the April 4-8, 2005 Review Workshop.

(2) Review the assessment summary report recommendations for Sustainable Fisheries Act management criteria and determine whether the relative merits and risks of alternative criteria are accurately and thoroughly presented.

The first TOR is definitely satisfied in that the report uses only the age-0 snapper runs as recommended by the Panel. Also, the projections use average recent recruitment as recommended by the Panel.

The second TOR is somewhat problematic in its wording. I do not think that it is possible in such a brief document to "accurately and thoroughly" present the "relative merits and risks of alternative criteria". The revised report uses benchmarks based on $SPR_{30\%}$ rather than yield per recruit based F_{MSY} and B_{MSY}. It is correctly argued that such benchmarks are less sensitive to the stock-recruitment relationship (which is poorly estimated) and the overall fishery selectivity pattern (which is defined by effort allocation amongst competing user groups). I support the proposed $SPR_{30\%}$ based benchmarks. I see them as consistent with MSY concepts and believe that the 30% level is appropriate for red snapper. Certainly, such benchmarks are much more precautionary than those that can result from yield per recruit analysis for stocks with very high (assumed/estimated) steepness in the stock-recruitment relationship. In my opinion, given the required brevity of the document, the brief wording in the revised document under "Status Determination Criteria" adequately satisfies TOR 2.

CONCLUSIONS AND RECOMMENDATIONS

The revised advisory report satisfies the TOR of this review in that it follows the recommendations of the SEDAR 7 Review Panel and it proposes sensible benchmark calculations. The document should be edited taking account of the comments provided by the Review Panel during the email discussions of 13-17 June 2005.

REFERENCES

(see Appendix 1 for further references)

Cordue, P.L. et al. 2005. Gulf of Mexico Red Snapper Consensus Summary Report. Prepared by the SEDAR 7 Review Panel for the Gulf of Mexico Fishery Management Council. SEDAR 7, 4-7 April 2005, New Orleans, LA

APPENDIX 1: MATERIAL PROVIDED

In addition to the following documents, two spreadsheets which contained detailed model results and plots were also provided.

Anon. (draft) a. 2005 Gulf red snapper advisory report. SEDAR 7 advisory report, draft 10 June. 10 p.

Anon. (draft) b. 2005 Gulf red snapper advisory report. SEDAR 7 advisory report with line numbers, draft 14 June. 10 p.

Anon. (draft) c. 2005 Gulf red snapper assessment summary. SEDAR 7 report, draft 6 June. 16 p.

Porch, C.E. 2005. Documentation of CATCHEM runs that model age 0 red snapper explicitly and projections of model age 0 and age 1 results under different future recruitment scenarios. Appendix to Anon. (draft) c. 45 p.

APPENDIX 2: STATEMENT OF WORK

Consulting Agreement between the University of Miami and Patrick Cordue

Statement of Work

Background

South East Data, Assessment, and Review (SEDAR) is a joint process for stock assessment and review of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; NOAA Fisheries, SEFSC and SERO; and the Atlantic and Gulf States Marine Fisheries Commissions. SEDAR is organized around three workshops: data, assessment, and review. Input data are compiled during the data workshop, population models are developed during the assessment workshop, and an independent peer review of the data and assessment models is provided by the review workshop. The assessment review panel is composed of stock assessment experts, other scientists, and representatives of councils, fishing industries, and non-governmental conservation organizations. Final SEDAR documents include a data report produced by the data workshop, a stock assessment report produced by the assessment workshops, an advisory report and a review consensus report evaluating the assessment and drafted during the assessment review panel workshop, and the collected stock assessment documents considered in the SEDAR process.

The review workshop for SEDAR 7, Gulf Red Snapper, took place at the Holiday Inn Chateau Le Moyne in New Orleans, Louisiana, from April 4 through April 8, 2005. The Center for Independent Experts (CIE) provided a chair and a technical reviewer for the SEDAR 7 review workshop. At that time, the review panel decided that a different assessment approach should be used. Subsequently, a revised assessment summary report that follows this recommendation was developed by the assessment team.

NMFS-SEFSC requests the additional assistance of the two assessment scientists from the CIE who previously worked on the SEDAR 7 review panel. There are two requirements: 1) review the revised assessment summary report to evaluate consistency with review panel's previous recommendations, and 2) recommend a preferred benchmark that is appropriate for the advisory report under the Sustainable Fisheries Act. No consensus opinion between the two CIE consultants is sought.

The activities required under this Statement of Work shall be conducted electronically, so no travel is needed.

Statement of Tasks

The roles and responsibilities of each CIE designee are described in the tasks below.

(1) Review the red snapper assessment summary report and determine whether the report accurately represents the recommendations made by the review panel during the April 4 - 8, 2005 review workshop.

(2) Review the assessment summary report recommendations for Sustainable Fisheries Act management criteria and determine whether the relative merits and risks of alternative criteria are accurately and thoroughly presented.

(3) If the panel determines that the advisory report is insufficient with regard to Tasks 1 or 2, outline specific actions necessary to correct the deficiencies.

(4) Participate in e-mail exchanges with the other peer-review panelists that address Tasks 1-3 above.

(5) Provide to the CIE a report addressing Tasks 1-4 above. The report shall consist of background, description of review activities, summary of findings, conclusions/recommendations, and references. The report shall also include as separate appendices the bibliography of all materials provided and a copy of the statement of work.

Schedule

It is estimated that the duties of each CIE consultant will require a maximum of five work days. The revised red snapper assessment report will be provided via e-mail to the CIE consultants no later than June 13, 2005. Please contact John Carmichael (SEDAR Coordinator; 843-571-4366 or John.Carmichael@safmc.net) for additional details. The e-mail exchanges of Task 4 shall take place during the week of June 13-17, 2005. Each consultant shall provide their individual written report for Task 5 to Dr. David Sampson, via e-mail to David.Sampson@oregonstate.edu, and to Mr. Manoj Shivlani, via e-mail to mshivlani@rsmas.miami.edu no later than the close of business on June 17, 2005.

Submission and Acceptance of CIE Reports

The CIE shall provide the final consultants' reports in pdf format for approval by NOAA Fisheries to the COTR, Dr. Stephen K. Brown, no later than July 1, 2005. The COTR shall notify the CIE via e-mail regarding acceptance of the consultants' reports. Following the COTR's approval, the CIE shall provide the COTR with digital copies of the consultants' reports with digital signed cover letters, both in pdf format.

CEFAS
The Centre for Environment, Fisheries & Aquaculture Science

Review of 2005 Red Snapper revised Assessment Summary Report

for

University of Miami Independent System for Peer Review

June 2005

CEFAS Contract C2327

COMMERCIAL IN CONFIDENCE

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Executive Summary

The review workshop for SEDAR 7, Gulf of Mexico Red Snapper (*Lutjanus campechanus*), took place in New Orleans, Louisiana, from April 4 through April 7, 2005. At that time, the review panel decided that a different assessment approach should be used. Subsequently, the assessment team developed a revised assessment summary report that follows this recommendation. This report reviews the revised assessment summary report to evaluate consistency with review panel's previous recommendations, at the request of the Center for Independent Experts. The report also reviews the assessment summary report's recommendations for management criteria under the Sustainable Fisheries Act.

(1) Review the red snapper assessment summary report and determine whether the report accurately represents the recommendations made by the review panel during the April 4 - 7, 2005 review workshop.

The review panel had two main findings: 1) that age-0 snapper be reintroduced into the model; 2) that the average estimated recruitment over the last 20 years be used in projections (with benchmarks recalculated to be consistent with that level).

The inclusion of age-0 individuals in the model runs presented in the assessment summary report could not be identified from the information presented in that report. Confirmation that age-0 individuals were included, as recommended by the Review Workshop, was obtained through communication with the NMFS Assessment Team. ***The inclusion of age-0 individuals within the model runs needed to be explicitly stated within the document to clarify the settings of the run that the reader was examining.***

The assessment summary report explicitly stated that the projections were based upon the use of average estimated recruitment over the last 20 years, as requested by the review panel. No action was therefore necessary.

(2) Review the assessment summary report recommendations for Sustainable Fisheries Act management criteria and determine whether the relative merits and risks of alternative criteria are accurately and thoroughly presented.

The assessment summary report followed the suggestions and discussions of the review panel. 30%SPR was used as a benchmark in the assessment summary report. Its use is consistent with MSY concepts (estimates of both F_{MSY} and B_{MSY} can be inferred from SPR).

As the Assessment Workshop noted, and the Review Workshop concurred, SPR benchmark levels are generally robust to fishery selectivity patterns: the value of MSY is conditional on selectivity patterns of the gears used in the fishery, which are affected by decisions of the Gulf of Mexico Fishery Management Council. Furthermore, given uncertainties over the true underlying stock-recruitment function, SPR benchmarks have the additional advantage of being less sensitive to stock-recruit uncertainties when compared to benchmarks derived from a stock-recruitment function.

Given the high levels of shrimp bycatch, it seems unlikely that 30%SPR will approximate MSY conditions. Despite this, the fact that 30%SPR has previously been used by the Council, and the fact that 30% is suitably high to ensure sustainability, makes its use appropriate.

(3) If the panel determines that the advisory report is insufficient with regard to Tasks 1 or 2, outline specific actions necessary to correct the deficiencies.

In general, the assessment summary report adequately communicated the assessment results and findings. There were areas that needed further clarification, as noted during the panel's e-mail discussions. These are detailed within the recommendation section of this report. Some minor editorial suggestions were also made, although they were outside the ToR. These are listed in the recommendations section of this report.

(4) Participate in e-mail exchanges with the other peer-review panellists that address Tasks 1-3 above.

The e-mail review was carried out during the period of the 13th to 17th June 2005. A number of issues were raised both within and outside the scope of work detailed above. The main points raised by this reviewer are summarised in this report.

Background

South East Data, Assessment, and Review (SEDAR) is a joint process for stock assessment and review of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; NOAA Fisheries, SEFSC and SERO; and the Atlantic and Gulf States Marine Fisheries Commissions. SEDAR is organized around three workshops: data, assessment, and review. Input data are compiled during the data workshop, population models are developed during the assessment workshop, and an independent peer review of the data and assessment models is provided by the review workshop. The assessment review panel is composed of stock assessment experts, other scientists, and representatives of councils, fishing industries, and non-governmental conservation organizations. Final SEDAR documents include a data report produced by the data workshop, a stock assessment report produced by the assessment workshops, an advisory report and a review consensus report evaluating the assessment and drafted during the assessment review panel workshop, and the collected stock assessment documents considered in the SEDAR process.

The review workshop for SEDAR 7, Gulf of Mexico Red Snapper (*Lutjanus campechanus*), took place at the Country Inn and Suites hotel in New Orleans, Louisiana, from April 4 through April 7, 2005. The Center for Independent Experts (CIE) provided a chair and a technical reviewer for the SEDAR 7 review workshop. At that time, the review panel decided that a different assessment approach should be used. Subsequently, the assessment team developed a revised assessment summary report that follows this recommendation.

This report reviews the revised assessment summary report to evaluate consistency with review panel's previous recommendations, at the request of the Center for Independent Experts (see Appendix 1). The report also reviews the assessment summary report's recommendations for management criteria under the Sustainable Fisheries Act.

Description of review activities

Dr Graham Pilling undertook the review at CEFAS (Lowestoft, UK). Dr John Carmichael provided the assessment summary report, by e-mail. During the week of the 13th June 2005, the report was discussed via e-mail by the SEDAR 7 review panel. Recommendations for modifications to the report were made direct to the NMFS Assessment Team in light of the terms of reference of the virtual panel. This separate report to CIE was completed during the week of the 27th June 2005.

Summary of findings

The findings of the CIE reviewer are presented by ToR task.

(1) Review the red snapper assessment summary report and determine whether the report accurately represents the recommendations made by the review panel during the April 4 - 7, 2005 review workshop.

The main recommendations from the Review Workshop were:

- Age-0 snapper are reintroduced into the model. The Panel understood the argument in support of excluding this age class in that density dependent compensation could extend to even higher ages. However, in the scientific judgment of the Panel, it is not prudent to assume that density dependent compensation can completely override the mortality induced by the shrimp fishery on age-0 red snapper.

- Higher recruitment scenarios are included in the projections of the base case. Recruitment estimates over the last 20 years are highly variable, but on average are above the level predicted by the stock-recruitment relationship. Three alternative recruitment scenarios were recommended for projections, using either: the spawner-recruitment relationship; recent average recruitment (last 20 years); or an even higher average recruitment level (obtained from a sensitivity run). In terms of predicting short-term future recruitment levels, the Panel preferred, on the balance of probabilities, the use of average estimated recruitment over the last 20 years (with benchmarks recalculated to be consistent with that level).

The inclusion of age-0 individuals in the model runs presented in the assessment summary report could not be identified from the information presented in that report. Confirmation that age-0 individuals were included, as recommended by the Review Workshop, was obtained through communication with the NMFS Assessment Team. A request was made that their inclusion be specifically stated within the document (see recommendations).

The assessment summary report explicitly stated that the projections were based upon the use of average estimated recruitment over the last 20 years, as requested by the review panel. No action was therefore necessary.

(2) Review the assessment summary report recommendations for Sustainable Fisheries Act management criteria and determine whether the relative merits and risks of alternative criteria are accurately and thoroughly presented.

The assessment summary report followed the suggestions and discussions of the review panel. 30%SPR was used as a benchmark in the assessment summary report. Its use is consistent with MSY concepts (estimates of both F_{MSY} and B_{MSY} can be inferred from SPR).

As the Assessment Workshop noted, and the Review Workshop concurred, SPR benchmark levels are generally robust to fishery selectivity patterns: the value of MSY is conditional on selectivity patterns of the gears used in the fishery, which are affected by decisions of the Gulf of Mexico Fishery Management Council. Furthermore, given uncertainties over the true underlying stock-recruitment function, SPR benchmarks have the additional advantage of being less sensitive to stock-recruit uncertainties when compared to benchmarks derived from a stock-recruitment function.

Given the high levels of shrimp bycatch, it seems unlikely that 30%SPR will approximate MSY conditions. Despite this, the fact that 30%SPR has previously been used by the Council, and the fact that 30% is suitably high to ensure sustainability, makes its use appropriate.

The assessment summary report also noted that, as suggested by the review workshop, there is a need to test whether selected or alternative benchmarks are robust to sources of uncertainty within the process. The use of management strategy evaluation would be useful to identify alternative robust red snapper population benchmarks.

(3) If the panel determines that the advisory report is insufficient with regard to Tasks 1 or 2, outline specific actions necessary to correct the deficiencies.

In general, the assessment summary report adequately communicated the assessment results and findings. There were areas that needed further clarification, as noted during the panel's e-mail discussions. These are detailed within the recommendation section of this report.

(4) Participate in e-mail exchanges with the other peer-review panellists that address Tasks 1-3 above.

The e-mail review was carried out during the period of the 13th to 17th June 2005. A number of issues were raised both within and outside the scope of work detailed above. The main points raised by this reviewer are summarised above.

Conclusions and recommendations

The assessment summary report was necessarily short and non-technical, as appropriate for its target audience.

The main 'substantive' recommendation with direct relevance to the ToR was that the inclusion of age-0 individuals within the model runs needed to be explicitly stated within the document, to clarify the settings of the run that the reader was examining.

A number of additional points can be raised, which mainly focus on clarifying the contents of the report and drawing attention to key issues.

- Table 1 of the assessment summary report reflects stock-specific calculations. This approach is sensible (and indeed, recommended in the Review Panel report of this CIE reviewer) since a sustainable scenario for one 'stock' might not be sustainable for the other. However, this change from previous reports needs to be clearly indicated when referring to this table.

- The Review Workshop did not examine a '50% shrimp reduction' allocation, as presented in table 1 of the assessment summary report, since 'Gulf-wide' results were given (see above). The stock-specific results were included in the assessment summary report since the western stock did not recover under the 40% shrimp mortality reduction scenario (although when considered as a Gulf-wide stock, recovery occurs within the target timescale of 2032). The fact that 30%SPR was not achieved by the western stock within the given time frame when stocks are considered separately should be stressed in the text to ensure managers consider this.

- Some explanation for differences in the recovery trajectories when compared to previous reports would be appropriate, to explain how changes in the model settings have influenced stock recovery. For example, it is worth noting that the average recruitment scenario recommended by the review workshop is about 50% higher than that estimated from the historical catch-effort information, 'kick-starting' rebuilding.

Bibliography

NMFS (2005). 2005 Gulf Red Snapper Advisory Report. 10p.

NMFS (2005). 2005 SEDAR 7 Assessment Summary Report. 16p.

Porch, C.E. (2005). SEDAR 7 Appendix. Documentation of CATCHEM runs that model age 0 red snapper explicitly and projections of model age 0 and age 1 results under different future recruitment scenarios. 45p.

Appendix 1. Statement of work

Subcontract between the University of Miami and CEFAS (Dr. Graham Pilling)

Statement of Work

Background

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<u>Schedule</u>

It is estimated that the duties of each CIE consultant will require a maximum of five work days. The revised red snapper assessment report will be provided via e-mail to the CIE consultants no later than June 13, 2005. Please contact John Carmichael (SEDAR Coordinator; 843-571-4366 or John.Carmichael@safmc.net) for additional details. The e-mail exchanges of Task 4 shall take place during the week of June 13-17, 2005. Each consultant shall provide their individual written report for Task 5 to Dr. David Sampson, via e-mail to David.Sampson@oregonstate.edu, and to Mr. Manoj Shivlani, via e-mail to mshivlani@rsmas.miami.edu no later than the close of business on June 17, 2005.

<u>Submission and Acceptance of CIE Reports</u>

The CIE shall provide the final consultants' reports in pdf format for approval by NOAA Fisheries to the COTR, Dr. Stephen K. Brown, no later than July 1, 2005. The COTR shall notify the CIE via e-mail regarding acceptance of the consultants' reports. Following the COTR's approval, the CIE shall provide the COTR with digital copies of the consultants' reports with digital signed cover letters, both in pdf format.

Addendum 3. Updated CATCHEM Results

Right Click on the Icon below to access the embedded excel file containing CATCHEM results for the updated model.

Addendum 4. Updated Red Snapper Projections

16 September 2005 Letter from Nancy Thompson, Director SEFSC, to Julie Morris, Gulf Council Chair.

And attachment:

PROJECTED EFFECTS OF CHANGES IN MINIMUM SIZE REGULATIONS ON THE FUTURE STATUS OF THE RED SNAPPER (*LUTJANUS CAMPECHANUS*) FISHERY IN THE U.S. GULF OF MEXICO
Porch, C. E.
September, 2005.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

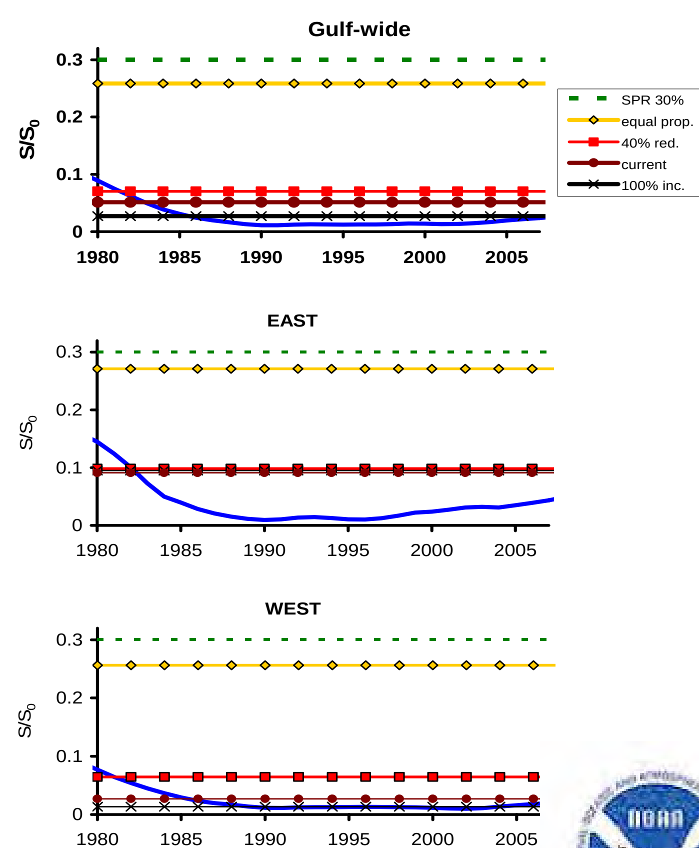
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, FL 33149

16 September 2005

Julie Morris, Chairwoman
Gulf of Mexico Fishery Management Council
Airport Executive Center
2203 N. Lois Avenue, Suite 1100,
Tampa, FL 33607

Dear Ms. Morris,

In response to your letter of 17 August, my staff has prepared the following materials regarding Gulf red snapper. For background and to place the requested analyses into perspective, some introductory material is provided below, followed by the requested projections.



The figure on the right shows estimated red snapper spawner abundance since 1980, expressed relative to unfished conditions (S/S_0). Also shown are various biomass reference levels related to SPR, including 30% S/S_0 (dashed horizontal), the estimated MSY biomass level from the assumed stock-recruitment relationship based upon the entire human-induced mortality selectivity vector (*i.e.* equal prop., horizontal with yellow diamonds), the relative biomass associated with marginally maximizing yield given an additional 40% reduction in shrimp bycatch mortality rate (*i.e.* 40% red., horizontal with red squares), the relative biomass associated with marginally maximizing yield with no additional reduction in shrimp bycatch mortality rate (*i.e.* current, horizontal with brown circles), and the relative biomass associated with marginally maximizing yield after doubling current shrimp bycatch mortality rate (*i.e.* 100% inc., horizontal with black x's). This figure contrasts the estimates of current and recent red snapper spawning stock abundance relative to a range of biomass levels referred to in the projections described below.

In your letter, you note that "Council is requesting additional analyses be conducted and presented in order to evaluate TACs under several management scenarios. These scenarios should be evaluated under both a separate east and west Gulf population basis and under a Gulf-wide basis.

> For constant F scenarios: Look at yield streams from production and bycatch F's from a 10% to 60% reduction, and look at that alone and also in a linked or proportional fashion; "

The figure and tables below show projected yield and spawner index projected trajectories while fishing under the indicated constant F levels and given the indicated additional reductions in shrimp bycatch mortality rates from the base case assessment model.

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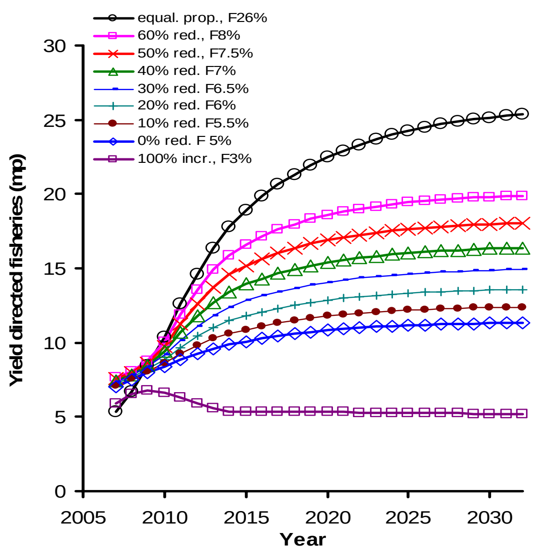


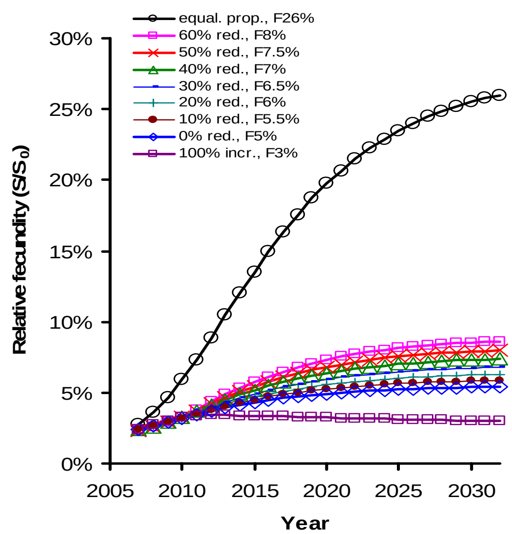


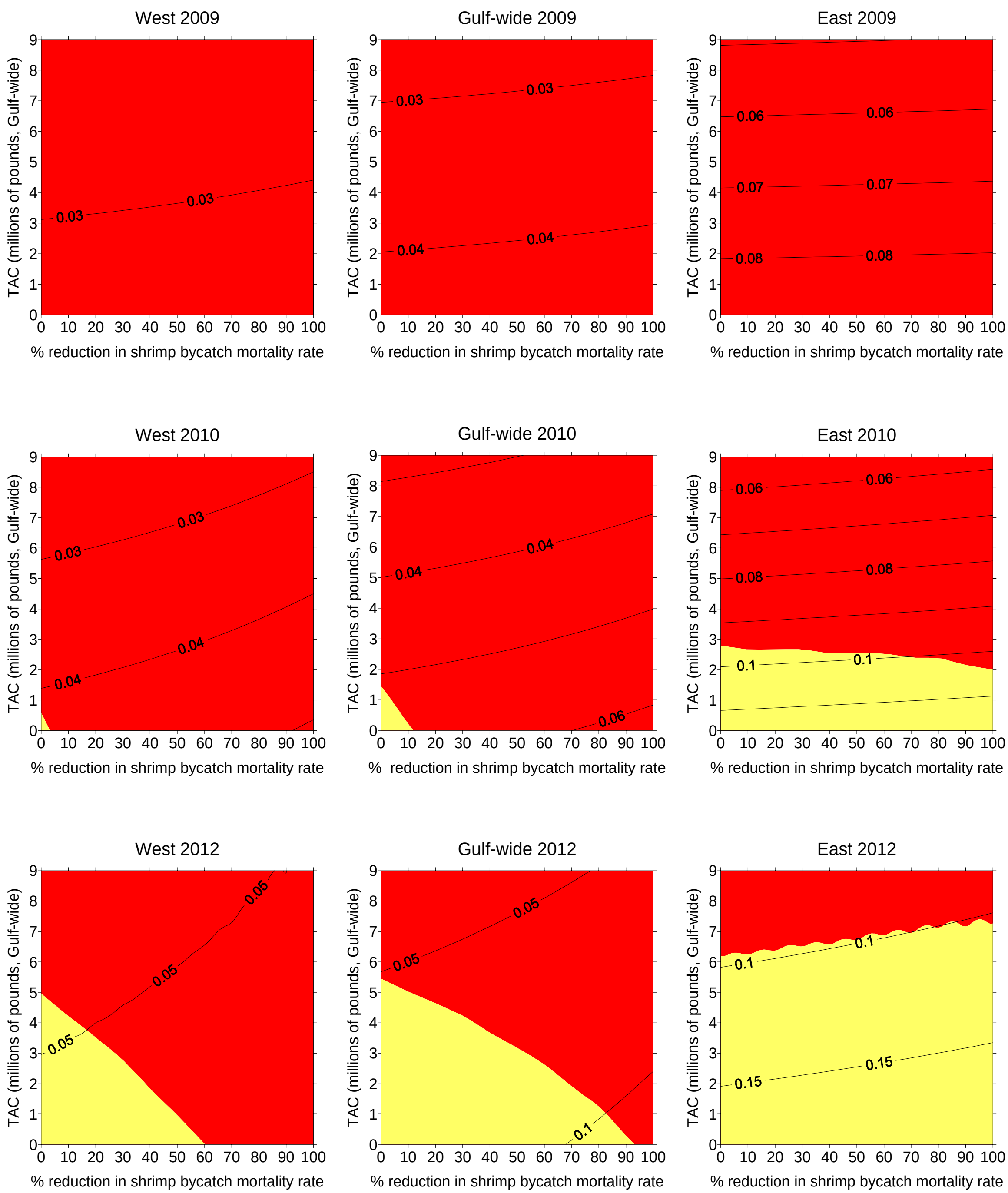
Table. Yield (mp) stream projections for F maximizing long-term yield for base age 0 model conditioned on indicated shrimp bycatch mortality rate changes and future recruitment eaual to recent average.

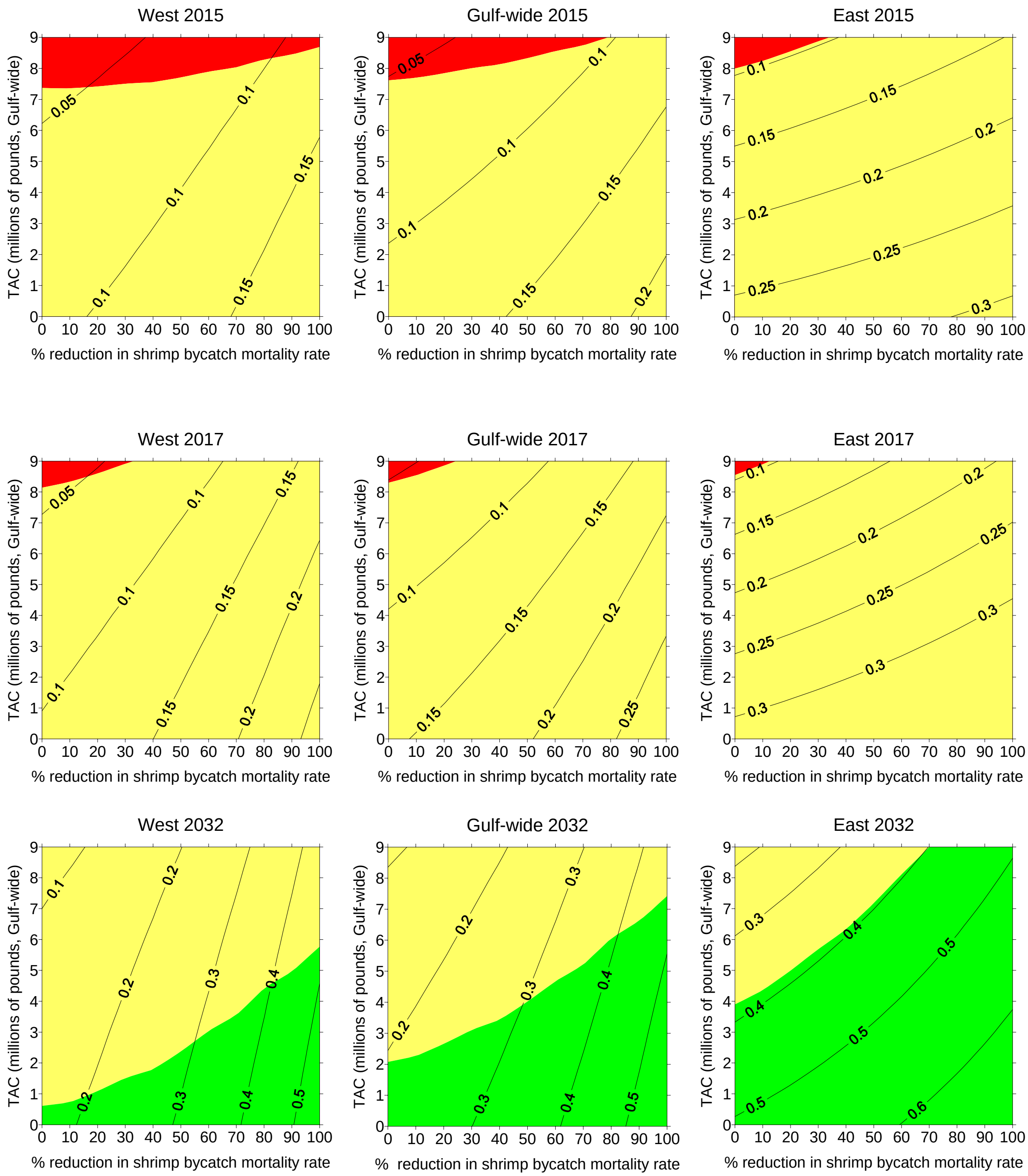
Year	% change in shrimp bycatch mortality rate: 0	-10	-20	-30	-40	-50	-60	+100	Equal Proportional Reduction
2007	7.0	7.1	7.2	7.4	7.4	7.5	7.7	5.9	5.3
2008	7.5	7.6	7.7	7.8	7.8	8.0	8.1	6.5	6.7
2009	8.0	8.1	8.2	8.4	8.5	8.6	8.8	6.8	8.4
2010	8.4	8.6	8.9	9.2	9.4	9.7	10.1	6.7	10.4
2011	8.9	9.3	9.7	10.2	10.7	11.2	11.9	6.3	12.6
2012	9.3	9.8	10.4	11.1	11.8	12.6	13.5	5.9	14.6
2013	9.6	10.3	11.0	11.8	12.7	13.7	14.9	5.6	16.4
2014	9.9	10.6	11.5	12.4	13.4	14.6	15.9	5.4	17.8
2015	10.1	10.9	11.8	12.8	13.9	15.2	16.6	5.3	18.9
2016	10.3	11.1	12.1	13.1	14.3	15.7	17.2	5.3	19.9
2017	10.5	11.3	12.3	13.4	14.6	16.0	17.6	5.3	20.6
2018	10.6	11.5	12.5	13.7	14.9	16.4	18.0	5.3	21.3
2019	10.7	11.6	12.7	13.9	15.2	16.7	18.3	5.3	21.9
2020	10.8	11.8	12.8	14.0	15.4	16.9	18.6	5.3	22.5
2021	10.9	11.9	13.0	14.2	15.6	17.1	18.8	5.3	22.9
2022	11.0	12.0	13.1	14.3	15.7	17.3	19.0	5.3	23.3
2023	11.1	12.1	13.2	14.4	15.8	17.4	19.2	5.3	23.7
2024	11.1	12.1	13.3	14.5	15.9	17.5	19.3	5.3	24.0
2025	11.2	12.2	13.3	14.6	16.0	17.6	19.4	5.3	24.3
2026	11.2	12.2	13.4	14.7	16.1	17.7	19.5	5.3	24.5
2027	11.2	12.3	13.4	14.7	16.2	17.8	19.6	5.2	24.7
2028	11.3	12.3	13.5	14.8	16.2	17.9	19.7	5.2	24.9
2029	11.3	12.3	13.5	14.8	16.3	17.9	19.8	5.2	25.0
2030	11.3	12.4	13.5	14.9	16.3	18.0	19.8	5.2	25.2
2031	11.3	12.4	13.6	14.9	16.4	18.0	19.9	5.2	25.3
2032	11.3	12.4	13.6	14.9	16.4	18.0	19.9	5.2	25.4
Maximum Long-term Yield:	11.3	12.4	13.6	15.0	16.5	18.1	20.0	5.0	25.4
SPR in 2032	5%	6%	6%	7%	7%	8%	9%	3%	26%

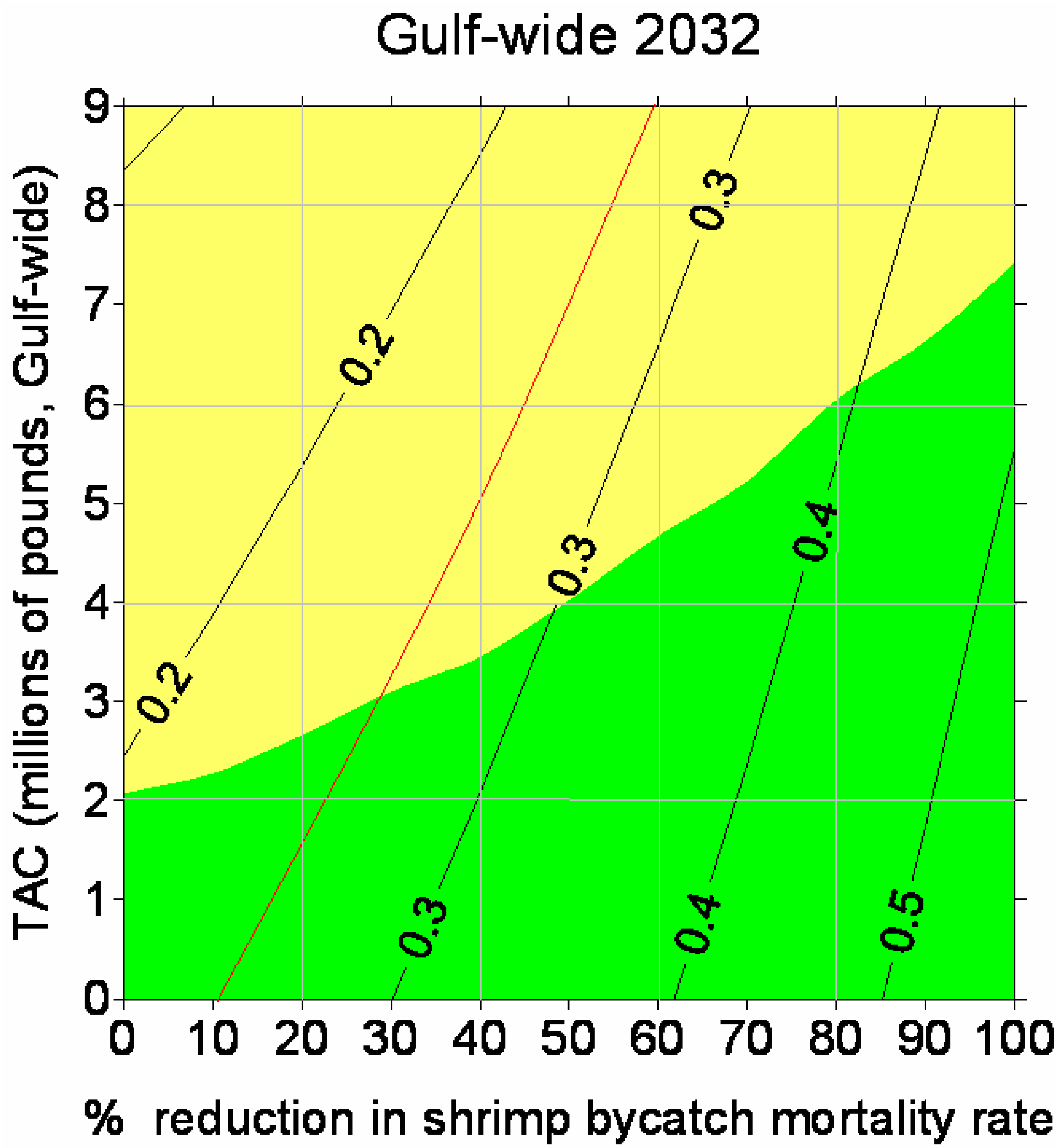
Table. Spawner abundance index (S/S0) projections for F maximizing long-term yield for base age 0 model conditioned on indicated shrimp bycatch mortality rate changes and future recruitment equal to recent average									
	% change in shrimp bycatch mortality rate								
Year	0	-10	-20	-30	-40	-50	-60	+100	Equal Proportional Reduction
2007	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.8%
2008	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%	2.7%	3.6%
2009	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	3.0%	4.6%
2010	3.2%	3.2%	3.2%	3.2%	3.3%	3.3%	3.3%	3.3%	5.9%
2011	3.5%	3.5%	3.6%	3.6%	3.7%	3.7%	3.8%	3.4%	7.3%
2012	3.7%	3.8%	3.9%	4.0%	4.1%	4.2%	4.3%	3.4%	8.9%
2013	3.9%	4.1%	4.2%	4.3%	4.5%	4.7%	4.9%	3.4%	10.5%
2014	4.1%	4.3%	4.5%	4.6%	4.9%	5.1%	5.3%	3.4%	12.0%
2015	4.3%	4.5%	4.7%	4.9%	5.2%	5.5%	5.8%	3.4%	13.5%
2016	4.5%	4.7%	4.9%	5.2%	5.5%	5.8%	6.1%	3.4%	15.0%
2017	4.6%	4.9%	5.1%	5.4%	5.7%	6.1%	6.5%	3.3%	16.3%
2018	4.7%	5.0%	5.3%	5.6%	6.0%	6.4%	6.8%	3.3%	17.6%
2019	4.8%	5.1%	5.4%	5.8%	6.2%	6.6%	7.1%	3.3%	18.7%
2020	4.9%	5.2%	5.6%	5.9%	6.4%	6.8%	7.3%	3.2%	19.7%
2021	5.0%	5.3%	5.7%	6.1%	6.5%	7.0%	7.5%	3.2%	20.7%
2022	5.1%	5.4%	5.8%	6.2%	6.7%	7.2%	7.7%	3.2%	21.5%
2023	5.1%	5.5%	5.9%	6.3%	6.8%	7.3%	7.9%	3.2%	22.2%
2024	5.2%	5.6%	6.0%	6.4%	6.9%	7.4%	8.0%	3.1%	22.9%
2025	5.2%	5.6%	6.0%	6.5%	7.0%	7.5%	8.1%	3.1%	23.5%
2026	5.3%	5.7%	6.1%	6.5%	7.1%	7.6%	8.2%	3.1%	24.0%
2027	5.3%	5.7%	6.1%	6.6%	7.2%	7.7%	8.3%	3.1%	24.5%
2028	5.3%	5.8%	6.2%	6.6%	7.2%	7.8%	8.4%	3.1%	24.9%
2029	5.4%	5.8%	6.2%	6.7%	7.3%	7.8%	8.5%	3.1%	25.2%
2030	5.4%	5.8%	6.2%	6.7%	7.3%	7.9%	8.5%	3.0%	25.5%
2031	5.4%	5.8%	6.3%	6.8%	7.3%	7.9%	8.6%	3.0%	25.7%
2032	5.4%	5.9%	6.3%	6.8%	7.4%	8.0%	8.6%	3.0%	26.0%
SPR @Fref	5%	6%	6%	6%	7%	8%	8%	3%	26%

You also requested a number of constant catch scenarios (3, 6, 9 million pounds), and also, "what level of TAC (or TAC yield streams) and shrimp trawl bycatch mortality reduction is needed to reach the rebuilding goals of either $B_{30\%SPR}$ or B_{MSY} on or before 2032?" Note that the equal proportional reduction case represents one time trajectory leading to rebuilding to the estimated MSY biomass level given the assumed stock-recruitment relationship and based upon the entire human-induced mortality selectivity vector. Intermediate year target SPR levels can be obtained from the graphs below to examine the range of constant catch and additional shrimp bycatch reduction scenarios which could lead to a rebuilt stock in 2032. Those combinations are shown in the 2032 isopleth diagram below.

The isopleth figures below show constant catch and TAC combinations that permit achieving a wide range of SPR levels in different years are shown in the following figures. These show the progression of projected S/S_0 for constant TACs indicated over a range of further reductions in shrimp bycatch mortality rate starting in year 2007 for years 2009, 2010, 2012, 2015, 2017, and 2032. In these figures, red shading indicates SPR levels lower than the relative biomass associated with marginally maximizing yield given the additional reduction in shrimp bycatch mortality rate indicated on the x-axis. Yellow shades indicate SPR levels from 1 to 4 times those levels, and green shades indicate levels >4 times those levels. In all cases number labels for the isopleths represent SPR values in the indicated year for the corresponding TAC and percentage additional reduction in shrimp bycatch mortality rate.


West 2009
Gulf-wide 2009
East 2009
West 2010
Gulf-wide 2010
East 2010
West 2012
Gulf-wide 2012
East 2012
TAC (millions of pounds, Gulf-wide)
% reduction in shrimp bycatch mortality rate
0.03
0.04
0.05
0.06
0.07
0.08
0.1
0.15

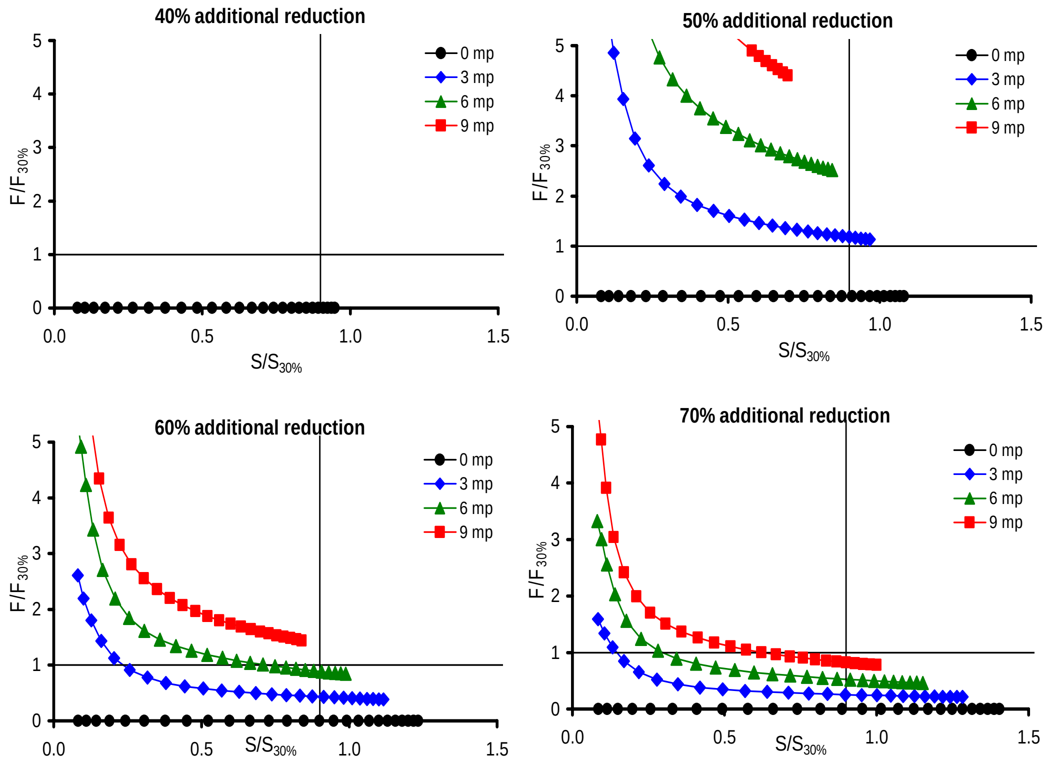

West 2015
Gulf-wide 2015
East 2015
West 2017
Gulf-wide 2017
East 2017
West 2032
Gulf-wide 2032
East 2032
TAC (millions of pounds, Gulf-wide)
% reduction in shrimp bycatch mortality rate



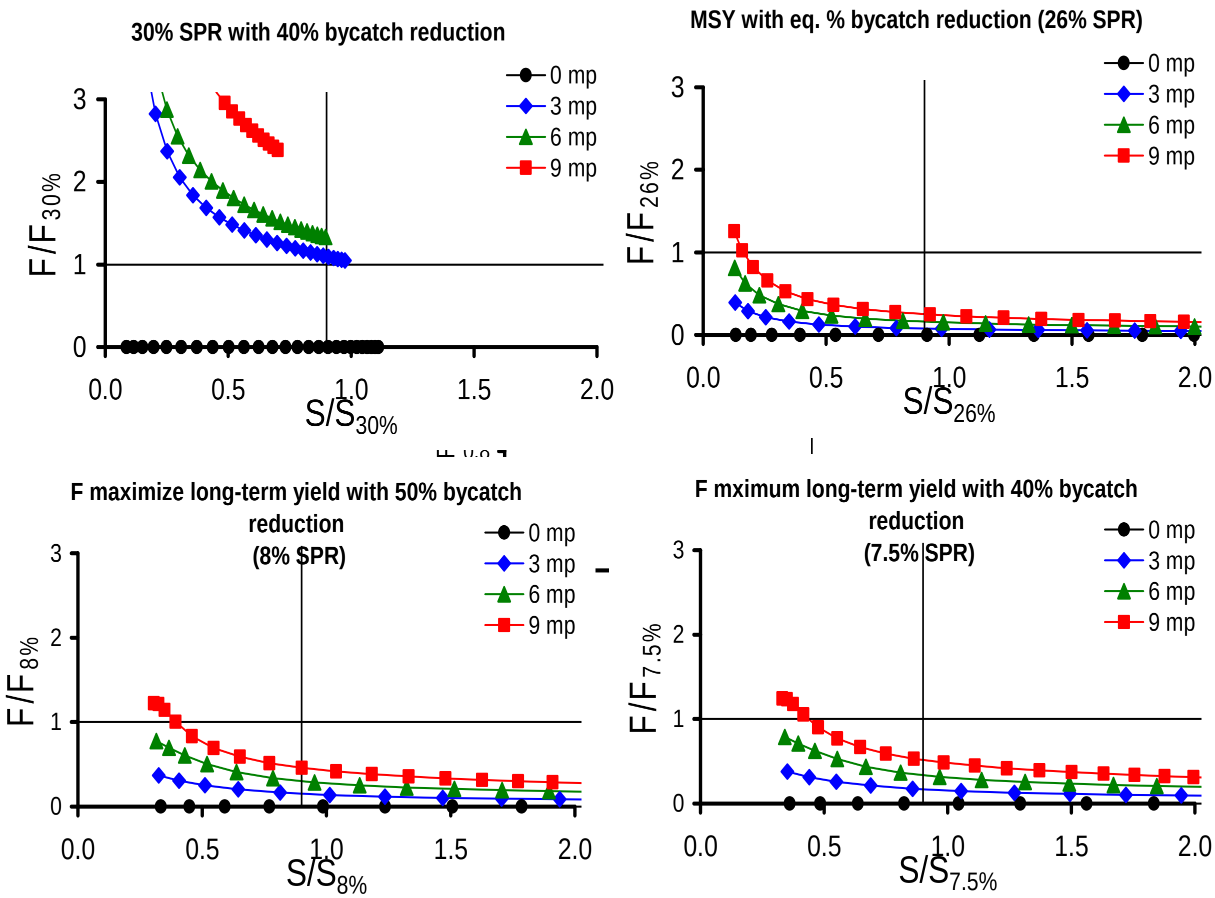
As shown in the above figure, there are a large number of TAC and shrimp reduction scenario combinations that could result in $B_{30\%SPR}$ by 2032 for the Gulf-wide case. $B_{30\%SPR}$ is not projected to be achievable Gulf-wide with less than an additional 30% reduction in shrimp bycatch mortality rate. At that level of bycatch mortality rate reduction, there would be no directed fishery TAC. Assuming additional shrimp bycatch mortality rate reductions from 40-60% starting in 2007, TAC could range from about 2-6.5mp annually, respectively. In order to rebuild to the estimated MSY biomass level from the assumed stock-recruitment relationship based upon the entire human-induced mortality selectivity vector (*i.e.* equal % reduction scenario, 26% SPR solid red isopleth above), with additional shrimp bycatch mortality rate reductions from 40-60%, TAC could range from about 5.2-9mp annually, respectively. Achieving lower SPR levels such as those associated with marginally maximizing yield given an additional 40%-60%

reduction in shrimp bycatch mortality rate would be possible with higher annual TACs because the SPR levels to which rebuilding would proceed would be lower.

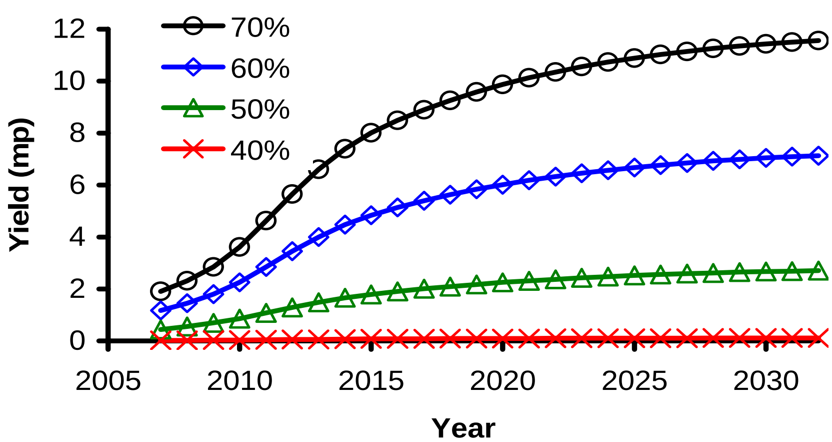
Under constant catch projections, the fishing mortality rate declines as stock abundance increases. For constant catch levels of 3, 6, and 9 million pounds, the progression of F relative to $F_{30\%}$ and S relative to $S_{30\%}$ under several constant TAC and several different levels of additional bycatch mortality rate reduction is shown below.



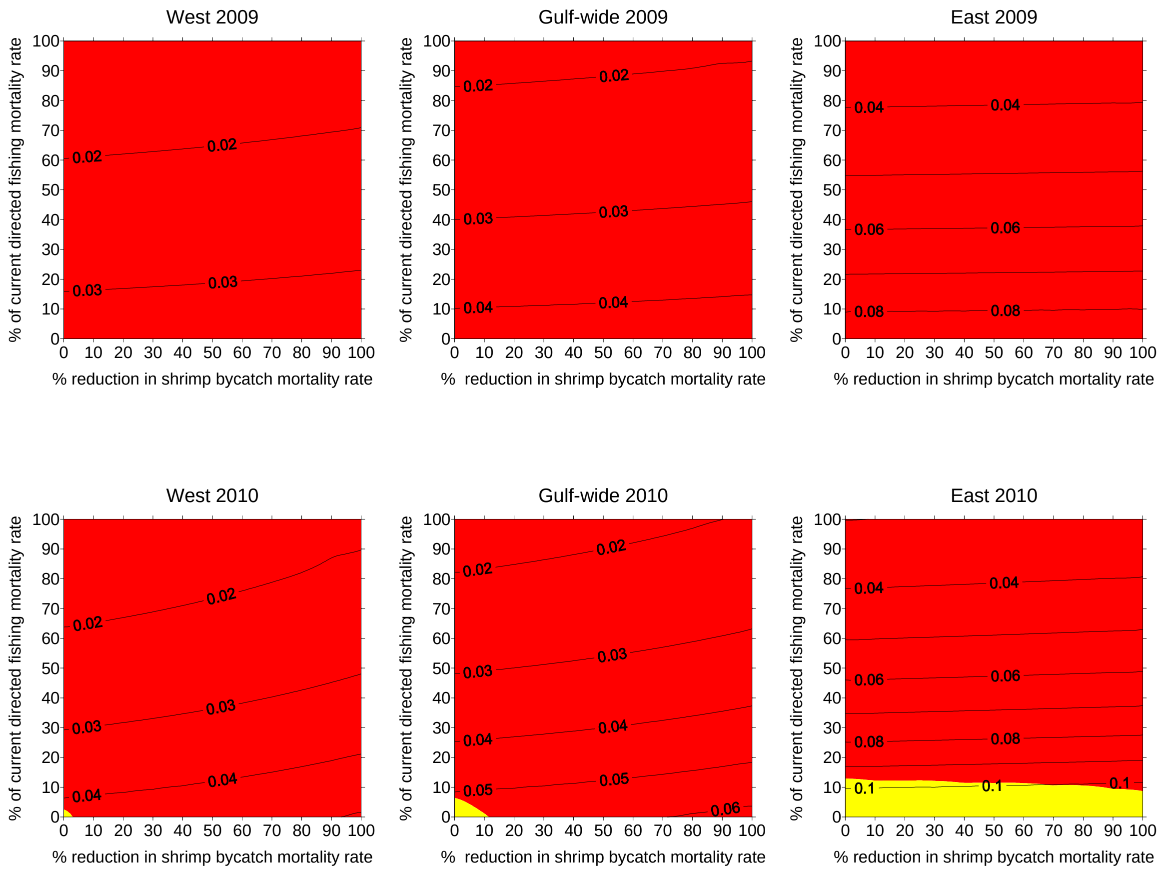
For comparison, the progression of F and S relative to different benchmarks under several constant TAC and several different levels of additional bycatch mortality rate reduction is shown below. From these figures it is clear that with lower standards, there is a quicker approach to those standards with higher TAC and lower shrimp bycatch mortality rate reductions.

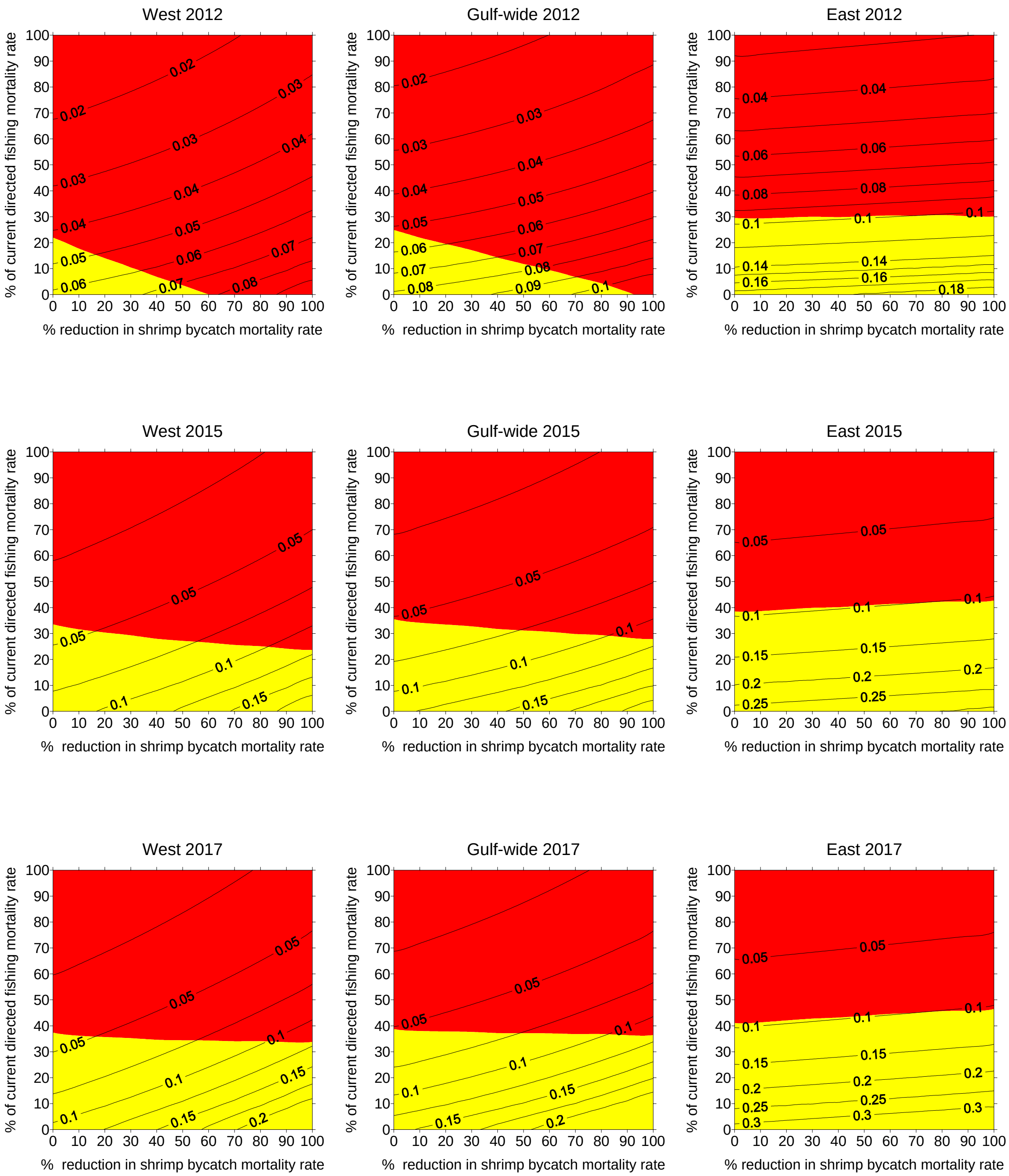


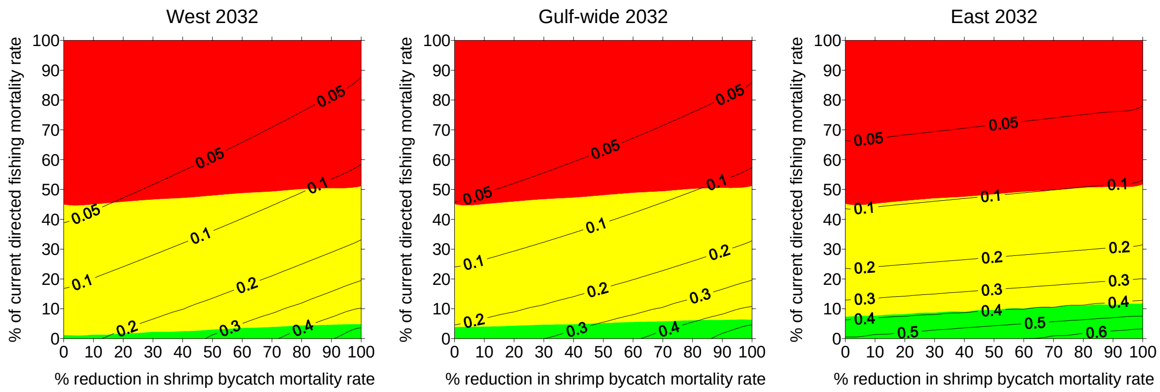
You also noted "Council also discussed the objective of ending overfishing over a one or two year period. Overfishing means fishing at a rate above MFMT, which is currently defined as $F_{30\%\ SPR}$" and asked "What actions would be necessary (in both the bycatch and directed fisheries) to end overfishing after one year, and after two years? Would these actions be consistent with the rebuilding scenarios described above?" Constant F projections have the quality of permitting yield to increase with abundance while fishing mortality rate remains the same. The time trends in expected TAC under a directed fishery $F_{30\%SPR}$ harvest strategy, which would end overfishing in 2007 and lead to rebuilding, conditioned given the indicated additional reduction in shrimp bycatch mortality rate, is shown in the following figure.



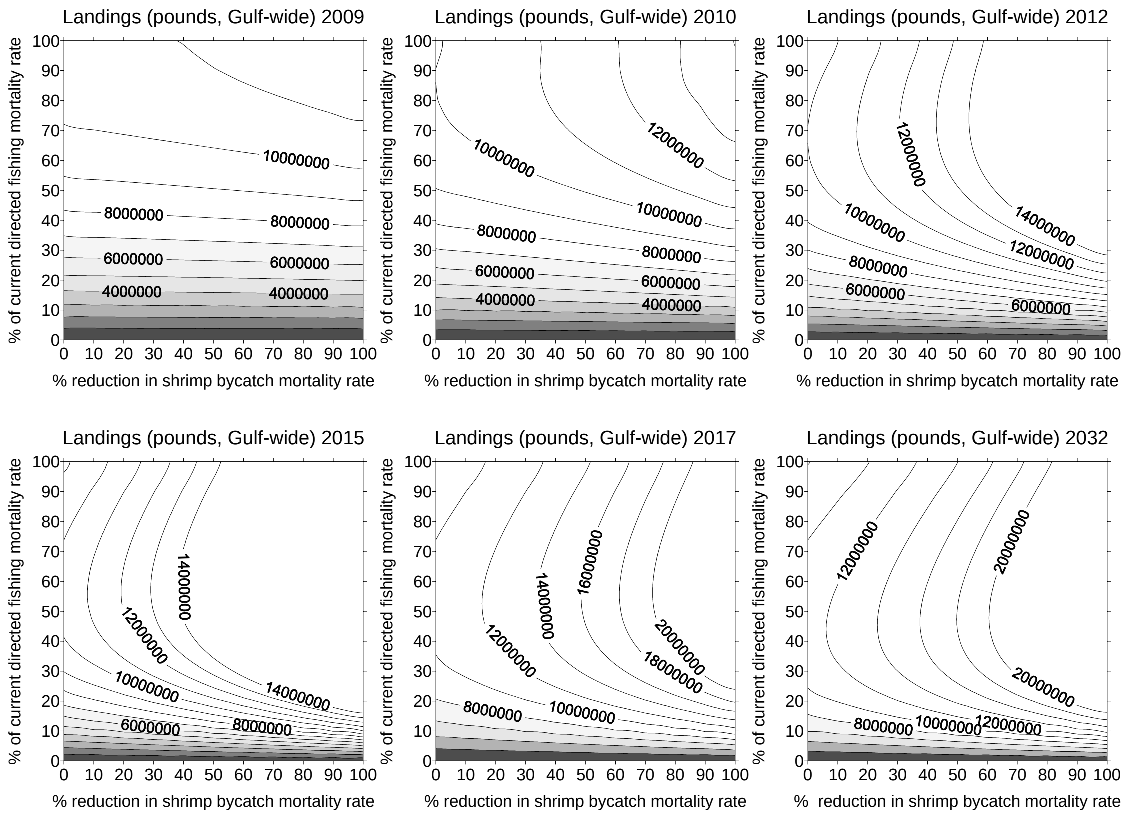
The isopleths below show the progression of projected S/S_0 for constant finfish fishing mortality rates expressed as a percentage of current fleet-wide fishing mortality rate over a range of further reductions in shrimp bycatch mortality rate starting in year 2007 for the years indicated.As before, red shading indicates SPR levels lower than the relative biomass associated with marginally maximizing yield given the additional reduction in shrimp bycatch mortality rate indicated on the x-axis. Yellow shades indicate SPR levels from 1 to 4 times those levels, and green shades indicate levels >4 times those levels.



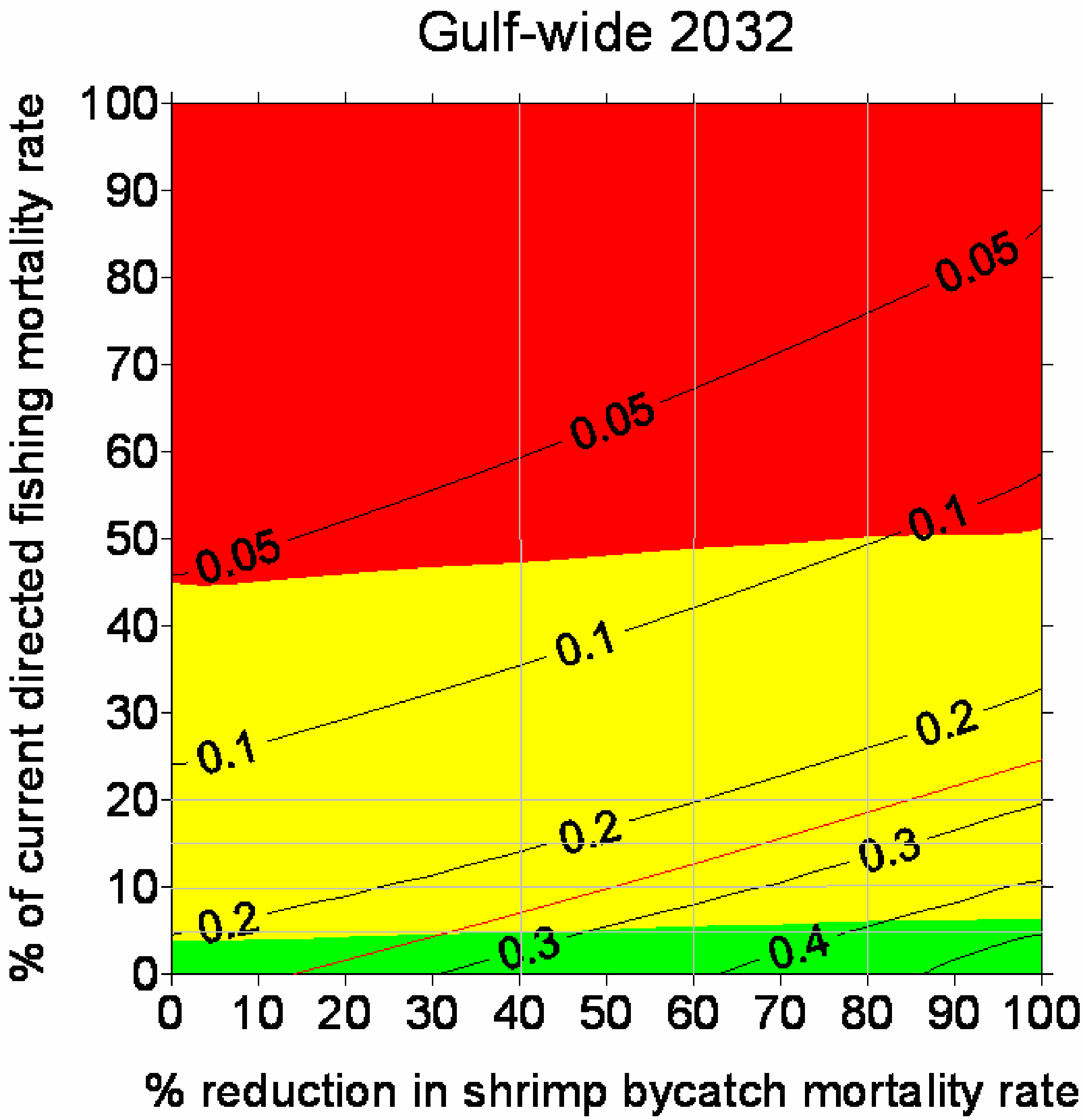

West 2012
Gulf-wide 2012
East 2012
West 2015
Gulf-wide 2015
East 2015
West 2017
Gulf-wide 2017
East 2017
% of current directed fishing mortality rate
% reduction in shrimp bycatch mortality rate

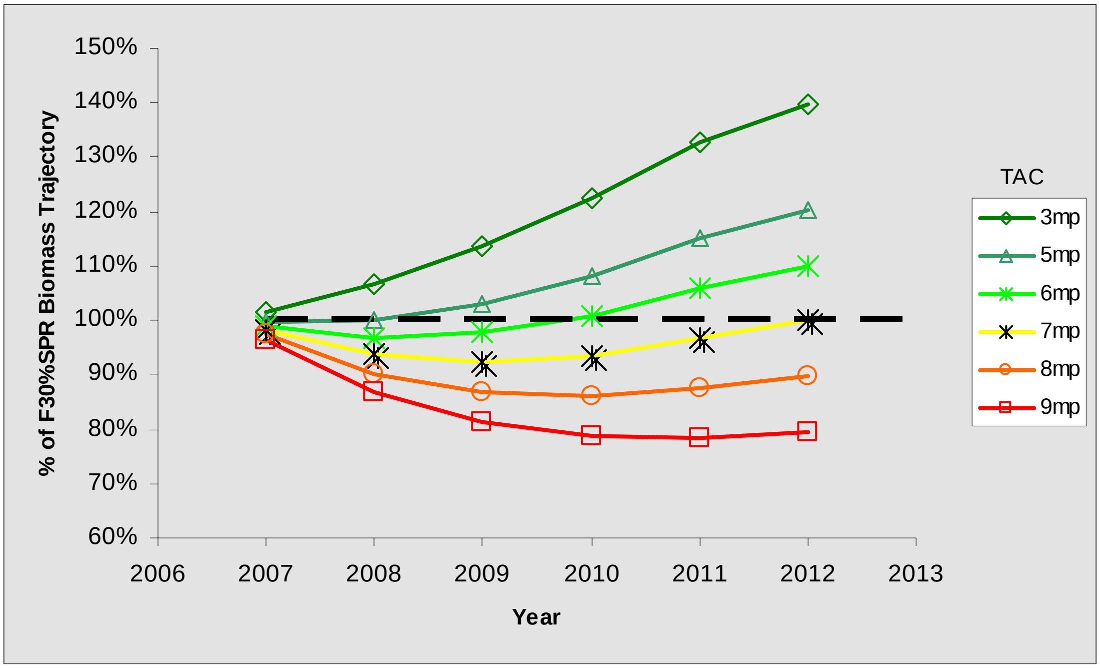

West 2032
Gulf-wide 2032
East 2032
% of current directed fishing mortality rate
% reduction in shrimp bycatch mortality rate
0.05
0.1
0.2
0.3
0.4
0.5
0.6

The progression of expected landed catch in the indicated year for constant F (expressed as a percentage of current directed fishing mortality rate) projections for the Gulf over a range of additional reductions in shrimp bycatch mortality rate starting in 2007 is shown below.



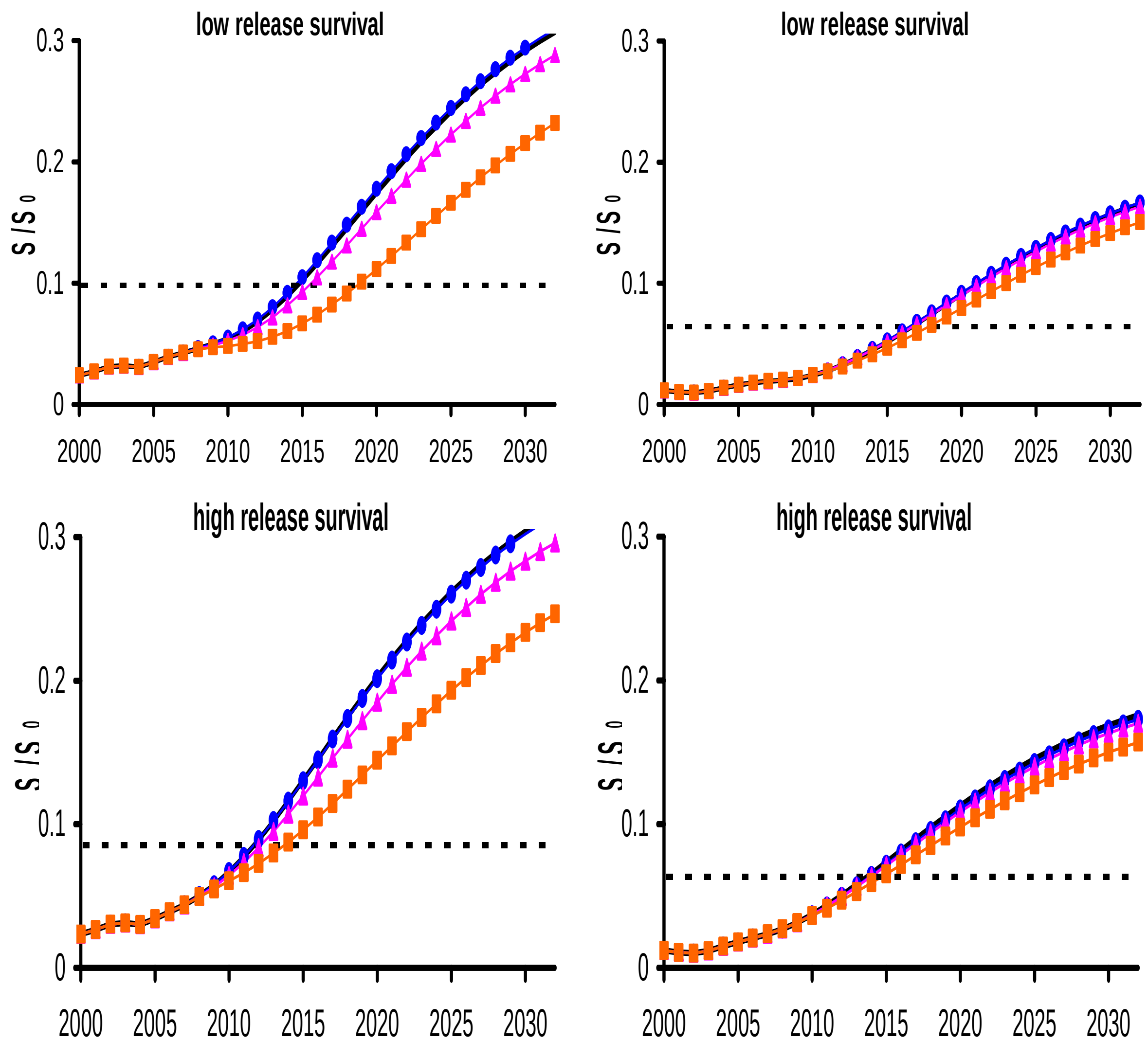
As with the constant catch projections, there are a relatively broad range of combinations of shrimp bycatch mortality rate reductions and reductions in directed fishery F that could result in $B_{30\%SPR}$ by 2032 for the Gulf-wide case and immediately (in 2007) end overfishing. This level of stock rebuilding would not be expected by 2032 with less than an 80% reduction in directed fishery F levels. Rebuilding to the estimated MSY biomass level from the assumed stock-recruitment relationship based upon the entire human-induced mortality selectivity vector (*i.e.* equal % reduction scenario, 26% SPR solid red isopleth below), would not be expected with less than a 75% reduction in directed fishing mortality rate.


Gulf-wide 2032
% of current directed fishing mortality rate
% reduction in shrimp bycatch mortality rate
0
10
20
30
40
50
60
70
80
90
100
0.05
0.1
0.2
0.3
0.4



The accumulation of SPR during the rebuilding projections occurs more quickly as new recruits grow into the spawning population; a lag of several years. Much of the initial rebuilding potential is due to recent high recruitment estimates. Because of this feature, in the short-run, SPR trajectories are relatively insensitive to the future decreases in shrimp bycatch mortality rates. The figure above contrasts the deviations from a projected $F_{30\%SPR}$ biomass rebuilding trajectory (dashed line) compared to the expected trajectories of SPR under constant catch scenarios from 3-9 million pounds per year for the projection period of 2007-2011. Constant catches from 2007-2011 greater than 7 million pounds are not projected to permit the Gulf-wide stock to attain the expected $F_{30\%SPR}$ trajectory by 2012. A 5-year constant catch of 5 million or less pounds would permit the stock to rebuild at a rate greater than expected under an $F_{30\%\ SPR}$ harvest strategy.

Lastly, you note "Bycatch mortality in the directed red snapper fishery has been an ongoing cause of concern, and it is even more so in the current red snapper assessment. The current size limits of 15 inches total length for the commercial fishery and 16 inches total length for the recreational fishery were adopted under assumed release mortalities of 33% commercial and 20% recreational. The current stock assessment uses recreational release mortality rates of 15% (eastern Gulf) and 40% (western Gulf), and commercial release mortality rates of 71% (eastern Gulf) and 82% (western Gulf) (Table 6.5 in the SEDAR 7 Red Snapper Data Workshop Report). The Council therefore requests that a range of size limits be analyzed for their potential effects on TAC and on bycatch mortality reduction. Specifically, a no size limit and a 13-inch total length size limit should be included in the analyses." In response, please find an attached manuscript by Dr. Clay Porch on the implications of changing the current minimum size on red snapper rebuilding prospects.



The figure above shows projected trends in spawning potential relative to unfished levels (S/S_0) for East (left panels) and West (right panels) Gulf red snapper based on the age-0 model with future recruitment set at 1984-2003 average levels, constant harvest of 9 mp and an additional 40% reduction in shrimp bycatch mortality rate. The top panels refer to the current base case, which has relatively low discard survival rates, and the bottom panels refer to the same model run with the relatively higher discard survival rates used during the 1999 assessment. The four scenarios run are status-quo (heavy black line), no commercial limit (blue circles, which is generally very close to and sometimes obscures the status-quo projection), 13 inch commercial and recreational limit (pink triangles) and no limit for commercial or recreational (orange squares). The dashed line in this case is the equilibrium spawning potential at marginal long-term maximum yield assuming an additional 40% reduction in shrimp bycatch mortality rate.

In summary, the results of this analysis indicate that if the survival rates of discarded red snapper are within the range examined, then the current 15 inch commercial limit offers little, if any, additional protection to the stock because the released fish mostly die rather than contribute towards filling the quota. The 16 inch recreational limit, on the other hand, would afford some protection because a larger fraction of the recreational discards survive to spawn or contribute later towards filling the quota as heavier animals.

Sincerely,

Nancy B. Thompson, PhD
Director
Southeast Fisheries Science Center

Attachment: Porch MS.

Cc: F/SER – Crabtree; F/SEC – Chester, Scott, Porch, Turner; Gulf Council – Swingle, Atran

PROJECTED EFFECTS OF CHANGES IN MINIMUM SIZE REGULATIONS ON THE FUTURE STATUS OF THE RED SNAPPER (*LUTJANUS CAMPECHANUS*) FISHERY IN THE U.S. GULF OF MEXICO

Clay E. Porch

September, 2005

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Sustainable Fisheries Division Contribution No. SFD-2005-009

Introduction

This paper projects various future size limit scenarios put forward by the participants of the 2004 SEDAR stock assessment workshop for Gulf of Mexico red snapper (SEDAR 7 AW) and at the August 8-12, 2005 Gulf of Mexico Fishery Management Council meeting in Fort Myers Beach.

Methods

Model equations

The basic population structures in the model are discussed thoroughly in Porch (2004) and will not be reviewed here. Instead the focus will be placed on the main point of interest here, which is the modeling of discards attributable to the minimum size limit. For clarity the subscripts relating to stock and habitat (region) have been omitted.

The equation for the total catch (landings plus discards) for each fleet is

$$(1) \qquad C_{i,s\{c,a\},y\{c,a\}} = \frac{F_{iasy}}{\xi_{iay} Z_{asy}} \tilde{N}_{ca} (1 - e^{-Z_{asy}})$$

where season *s* and year *y* are inferred from cohort *c* and age-class *a*. The instantaneous mortality rate *Z* is modeled as the sum of coefficients reflecting natural (*M*) and fishing-related (*F*) causes:

$$(2) \quad Z_{asy} = M_a + \sum_i F_{iasy}$$

where *i* indexes a particular source of fishing mortality, hereafter referred to as a fleet. The fishing mortality rate parameters are further decomposed into separable age-dependent and time-dependent effects:

$$(3) \quad F_{iasy} = q_{iy} v_{ia} f_{iy} \xi_{iay}$$

where *q* represents the catchability of the most vulnerable age-class, v_a represents the relative vulnerability of the remaining age-classes, *f* is the total effort exerted by the fleet, and ξ is the probability that a fish will die once it is caught (landed or released but died later).

Under the presumption that discarded fish are mostly below the size limit *L* ,

$$(4) \quad \xi_{iay} = 1 - (1 - d_{ias}) G_{L|a}$$

where *d* is the fraction of released fish that die and $G_{L|a}$ is the probability that a captured fish will be smaller than the size limit given that it is age *a*. Estimates of the number landed (harvest *H*) and number discarded (*D*) are therefore

$$(5a) \quad H_{iasy} = (1 - G_{L|a}) C_{iasy}$$

$$(5b) \quad D_{iasy} = G_{L|a} C_{iasy}$$

The corresponding number discarded dead (*DD*) and total number killed (*K*) are

$$(5c) \quad DD_{iasy} = d_{ias} D_{iasy}$$

$$(5d) \quad K_{iasy} = H_{iasy} + DD_{iasy}$$

Projections of the effects of any suite of future minimum size limits are easily accomplished by simply applying the equations above with assumed levels of effort, catchability and vulnerability (typically averages of the last few years). The effect of the size limit is reflected in the probability *G*, which we assume to be zero-truncated normal with a constant CV of 0.16 (see Diaz et al., 2004).

Application to red snapper

The SEDAR Assessment Workshop (AW) participants requested projections of the base-case model assuming:

a. Status quo; total allowed landings (TAC) of 9.12 million lbs, shrimp bycatch and closed season discards at current effort levels (average of last three years), and minimum size limits of 15 inches for the commercial fleets and 16 inches for the recreational fleets.
b. Status quo, except 13 inch limit on both sectors
c. Status quo, except no size limit on either sector
d. Status quo, except no commercial size limit

It was noted by some workshop participants that red snapper below 12 inches are not considered marketable and would not be retained commercially. Accordingly, it was assumed that, in the absence of size limit regulations (cases c and d), the effective size limit for the commercial fishery was 12 inches. Some recreational anglers would likely keep red snapper smaller than 12 inches if retention were allowed, but few would catch and keep fish under six inches. Therefore the effective minimum size for the recreational fishery in case (c) was set to six inches. For these projections, changes in the minimum size limits were assumed to begin in 2007.

The base model selected by the SEDAR Assessment Workshop (AW, December 2004) participants expressed the recruitment of 1 year-old fish to the population as a Beverton-Holt function of the spawning potential during the previous year (See Porch 2004 for details). Forecasts were based on a scenario where future recruitment varied with projected spawning potential according to the estimated ‘historical’ Beverton-Holt relationship. Subsequently, SEDAR Review Workshop (RW, April 2005) participants favored a reformulation of that model which expressed the recruitment of age 0 as

Beverton-Holt function of the spawning potential during the same year and incorporated estimates of the bycatch of age 0 animals by offshore shrimp trawlers. The RW also recommended conducting forecasts where the future recruitment followed more recent trends (see SEDAR 2005 for details). Accordingly, the impact of changing the minimum size limits was evaluated under four scenarios: (a) age 1 model, historical recruitment trends; (b) age 1 model, recent recruitment trends; (c) age 0 model, historical recruitment trends; (d) age 1 model, recent recruitment trends.

In some cases the current TAC of 9.12 million lbs was not sustainable over the time period of the projections (to the year 2032). The routine used finds the scenario with the time series of landings that comes the closest to the time series of TACs. This approach allows the stock to be driven to very low levels, but avoids the unlikely scenario of abruptly driving it to extinction. Finally, a 40% reduction in offshore shrimp trawl effort was assumed beginning in 2007, in accordance with the recommendations of the RW, which were based on the economic forecasts of Travis and Griffin (2004).

Results and discussion

The projected trends in S/S_0 under each minimum size scenario are shown for the four combinations of model type (age-0 versus age-1) and future recruitment (historical versus recent R_0) in Figure 1. In no case did the western stock recover to a level of spawning potential commensurate with an SPR of 30%. This would require a reduction in shrimp effort in the west of more than 40% relative to current levels (see SEDAR 2005). However, it was possible in some cases to recover to the spawning potential associated with the marginal long-term maximum yield conditional on the presumed 40% reduction in offshore shrimp trawling effort, S_{LTMY}{40% reduced shrimp}. If future recruitments remain at current high levels, then both the eastern and western stocks are projected to recover to S_{LTMY}{40% reduced shrimp} before 2032, regardless of the size limits imposed (although the recovery is markedly slower without size limits). The forecasts are less optimistic when future recruitments follow more historical trends. In the case of the age-1 model, neither stock was projected to recover regardless of the size limits imposed. In the case of the age-0 model, both stocks were projected to recover by 2032 except when no size limit was in place for either fishery.

The projected recovery rate was slightly faster without the commercial size limit, but increasingly slowed by smaller recreational limits. The recreational limit is estimated to be more effective than the commercial limit owing largely to the ***assumption*** that red snapper discarded by recreational anglers have a much higher survival rate (85% in the eastern Gulf and 60% in the western Gulf) than those discarded by commercial fishers (29% in the eastern Gulf and 18% in the western Gulf). The discard survival rates assumed during the prior assessment were higher and not so disparate between sectors (67% commercial, 80% recreational). When these higher survival values are used (in both the assessment and associated projections), the projected recovery rate was slightly slower without the commercial size limit (Figure 2). However, as before, the recovery rate was affected more by decreasing the recreational size limit than by decreasing the commercial limit. This is true partly because the commercial discard-survival rate used, although higher than before, was still somewhat lower than the recreational rate. Moreover, the relative change from current limits to no limit was less for the commercial

fishery than for the recreational fishery because the commercial fishery had a one inch lower size limit (15 versus 16 inches) and a six inch higher implicit size limit (12 versus 6 inches).

If the survival rates of discarded red snapper are within the range examined here, then the current 15 inch commercial limit offers little, if any, additional protection to the stock because the released fish mostly die rather than contribute towards filling the quota and thereby shortening the open season. The 16 inch recreational limit, on the other hand, would afford some protection because a larger fraction of the recreational discards survive to spawn or contribute later towards the quota as heavier animals. Future analyses should probably focus on determining the true magnitude of the discard survival rates rather than simulating the effects of a range of the minimum size limits.

Literature cited

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Legault, C.M and V.R. Restrepo. 1998. A flexible forward age-structured assessment program. ICCAT. Col. Vol. Sci. Pap.49: 246-253.

Porch, C. E. 2004. An alternative assessment of the red snapper (*Lutjanus campechanus*) fishery in the U.S. Gulf of Mexico using a spatially-explicit age-structured assessment model. Sustainable Fisheries Division Contribution No. SFD-2004-058. (SEDAR-AW-27-Revised)

SEDAR. 2005. Advisory Report of the SEDAR7 Review Workshop……

Travis, MD, WL Griffin. 2004. Update on the Economic Status of the Gulf of Mexico Commercial Shrimp Fishery. SERO-ECON-04-01, National Marine Fisheries Service, St. Petersburg, FL. 13 p.

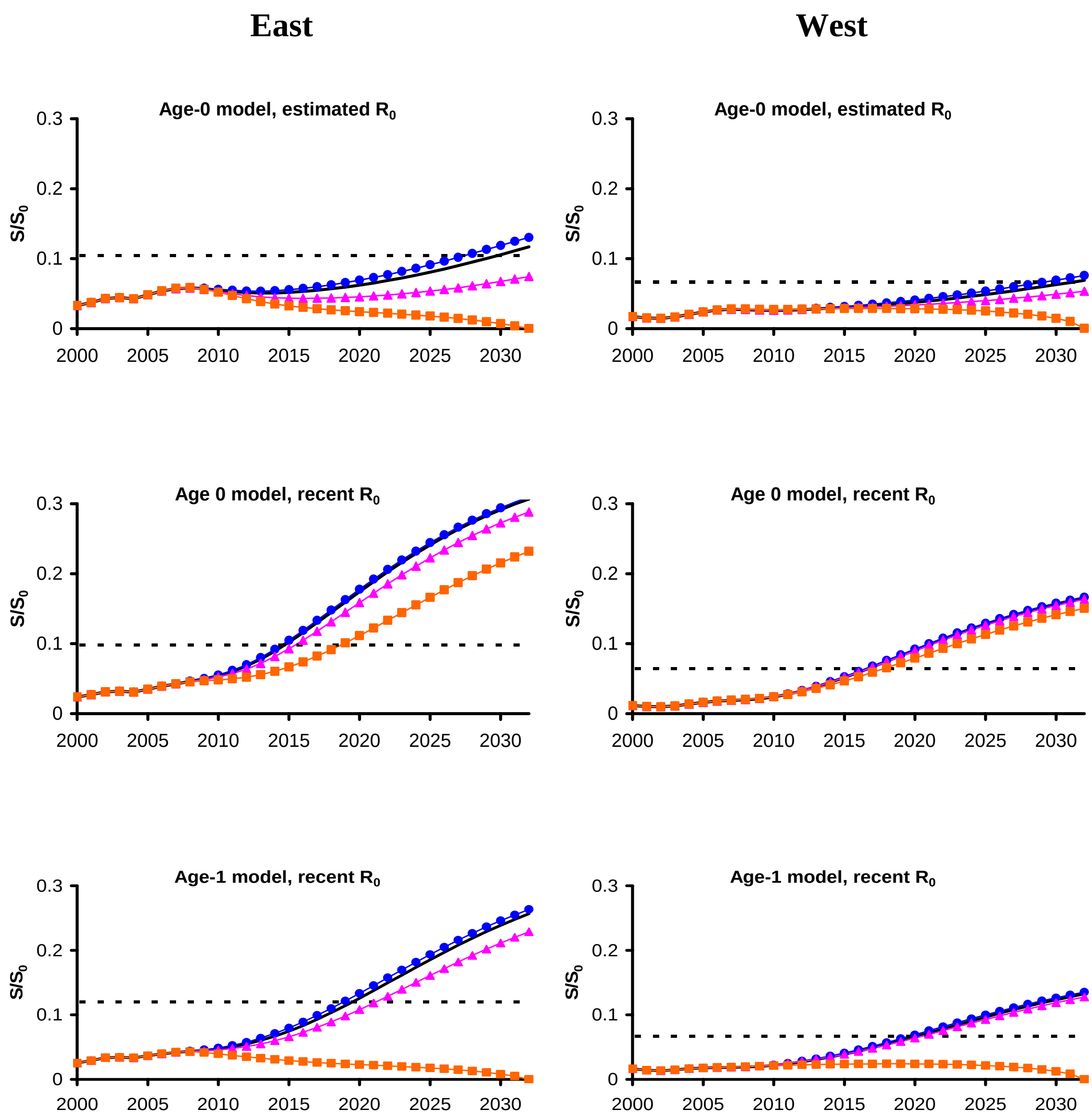

Figure 1. Projected trends in spawning potential relative to unfished levels (S/S_0) based on the age-0 and age-1 models when future recruitment is dictated by the 'historical' spawner-recruit relationship (estimated R0) or the 1984-2003 average levels (recent R0). The four scenarios are status-quo (heavy black line), no commercial limit (blue circles), 13 inch commercial and recreational limit (pink triangles) and no limit for commercial or recreational (orange squares). Dashed line is the equilibrium spawning potential at marginal long-term maximum yield relative to unfished levels (S_{LTMY}/S_0).

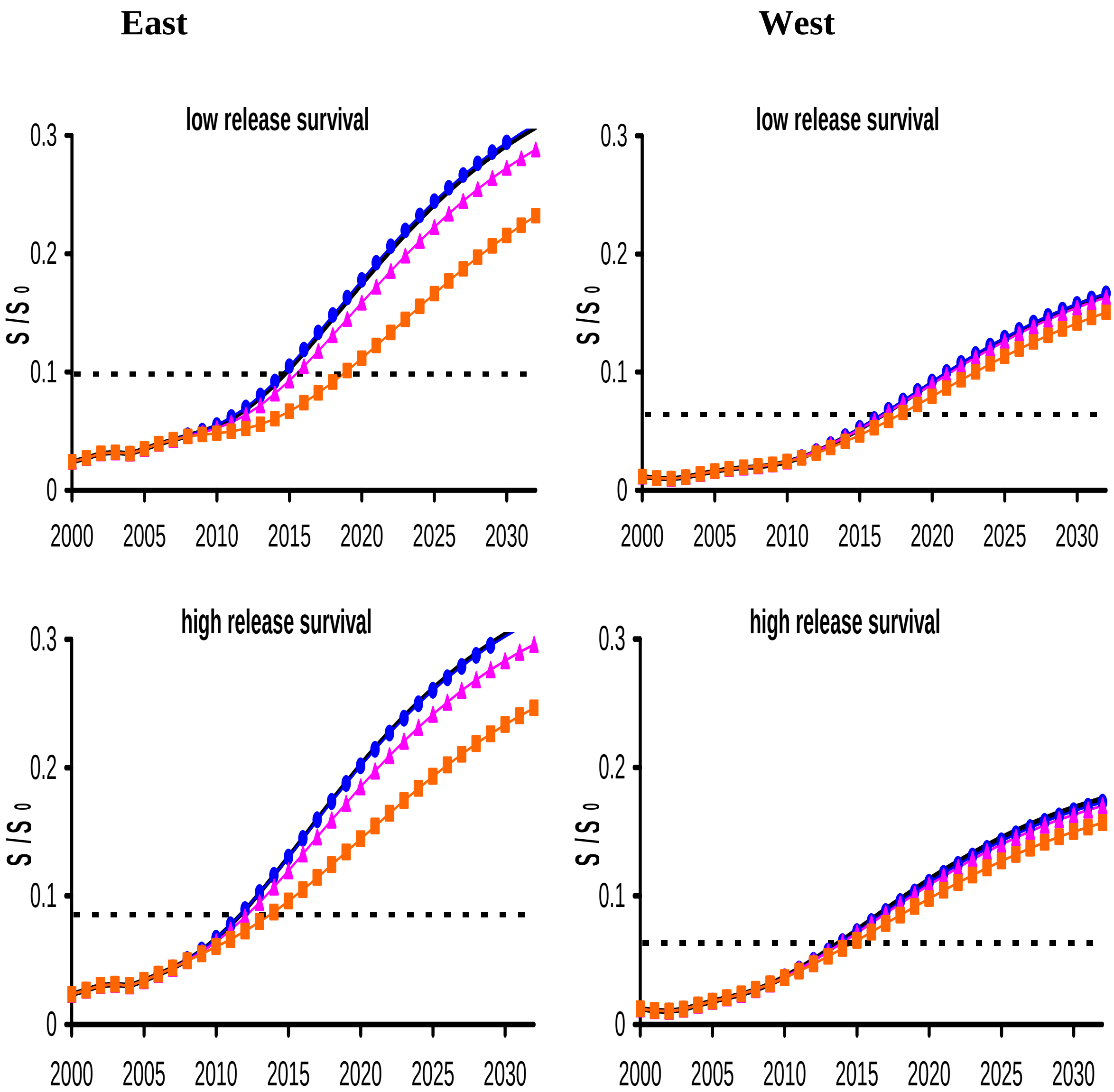

Figure 2. Projected trends in spawning potential relative to unfished levels (S/S_0) based on the age-0 model with future recruitment dictated by the 1984-2003 average levels (recent R0). The top panels refer to the current base case, which has relatively low discard survival rates, and the bottom panels refer to the same model run with the relatively higher discard survival rates used during the 1999 assessment. The four scenarios are status-quo (heavy black line), no commercial limit (blue circles), 13 inch commercial and recreational limit (pink triangles) and no limit for commercial or recreational (orange squares). Dashed line is the equilibrium spawning potential at marginal long-term maximum yield relative to unfished levels (S_{LTMY}/S_0).