Stock Assessment and Fishery Evaluation Report
for the
KING AND TANNER CRAB FISHERIES
of the
Bering Sea and Aleutian Islands Regions

2006 Crab SAFE

Compiled by

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of the Bering Sea and Aleutian Islands

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Executive Summary

The annual stock assessment and fishery evaluation (SAFE) report is a requirement of the North Pacific Fishery Management Council's *Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP)*, and a federal requirement [50 CFR Section 602.12(e)]. The SAFE summarizes the current biological and economic status of fisheries, total allowable catch (TAC), and analytical information used for management decisions. The report is assembled by the Crab Plan Team with contributions from the State of Alaska, Department of Fish and Game (ADF&G) and the National Marine Fisheries Service (NMFS), and is available to the public and presented to the North Pacific Fishery Management Council (NPFMC) on an annual basis. Additional information on Bering Sea/Aleutian Islands (BSAI) king and Tanner crab is available on the NMFS web page at www.fakr.noaa.gov and the ADF&G Westward Region web page at www.cf.adfg.state.ak.us/region4/rgn4home.htm.

Status of Annually Surveyed Crab Stocks

The FMP defines the minimum stock size threshold (MSST) and the maximum fishing mortality threshold (MFMT). These requirements are contained in the FMP and outlined in the following section, overfishing parameters. MSST is 50% of the mean total spawning biomass (SB = total biomass of mature males and females, also known as TMB = total mature biomass) for the period 1983-1997, upon which the maximum sustainable yield (MSY) was based. A stock is overfished if the SB is below MSST. MFMT is represented by the sustainable yield (SY) in a given year, which is the MSY rule applied to the current SB (the MSY control rule is F = 0.2 for king crabs, and F = 0.3 for Tanner and snow crabs). Overfishing occurs if the total allowable catch (TAC) exceeds the SY in one year. TACs are developed from joint NMFS and ADF&G assessment of stock conditions based on harvest strategies developed by ADF&G. Figures 1-6 depict each crab stock’s spawning biomass and catch history relative to overfishing.

Table 1. MSST, 2006 spawning biomass (SB), sustained yield (SY), and 2006/2007 Total allowable catch levels (TAC) for BSAI king and Tanner crab stocks. Values are in millions of pounds.

Stock	MSST	2006 SB	2006 SY	2006/2007 TAC
Bristol Bay red king	44.8	157.2	31.5	N/A
Pribilof Islands red king	3.3	19.0	3.8	N/A
Pribilof Islands blue king	6.6	1.6	0.3	N/A
Saint Matthew blue king	11.0	11.2	2.2	N/A
EBS Tanner	94.8	253.3	76.1	N/A
EBS snow	460.8	547.6	164.5	N/A

In addition to the Federal requirements, survey results for five stocks (Pribilof District blue king crab, Saint Matthew Island Section blue king crab, Bristol Bay red king crab, eastern Bering Sea Tanner crab, and eastern Bering Sea snow crab) are compared to thresholds established in State of Alaska harvest strategies and regulations. ADF&G uses these thresholds to determine if a fishery should be opened and to calculate the TAC.

Bering Sea Tanner crab (*Chionoecetes bairdi*):

Total mature biomass for this stock in 2006 is 253.3-million pounds, a significant increase above the 2005 estimate (162.0-million pounds) and above the B_{MSY} for the first time since the overfished declaration of 1998. Note that under the rebuilding plan established for this stock, this stock is considered rebuilt if total mature biomass is above the B_{MSY} level (189.6-million pounds) for two years in a row. If the stock is estimated above B_{MSY} in 2007 the stock would be considered rebuilt. For the first time since the overfished declaration, estimated TMB in the last 2 years has shown consistent sharp annual increases comparable to that seen in the mid-1980s.

ADF&G's area-swept estimates for mature-sized female abundance in the Eastern Subdistrict increased by approximately 50% between 2005 and 2006; from 42.513-million crabs in 2005 to 65.500-million crabs in 2006. Prior to the results for 2005, abundance estimates of mature-sized females have shown only minor fluctuations about depressed levels in the overall Eastern Subdistrict. Given the size frequency distribution of females in 2005, the increase in mature female abundance and biomass in 2006 is not entirely unexpected, although the level of increase is higher than was expected from the 2005 data. There is a relatively large mode at roughly 75-mm CW in the size frequency distributions for both males and females in 2006. That may provide continued recruitment into the mature size classes in the near-term future. However, unlike the size frequency distributions for the previous four year, there is very poor representation of males or females <50-mm CW in 2006 and that is not promising for continued recruitment to mature size classes in the long-term future.

The area-swept abundance estimates for mature-sized males in the Eastern Subdistrict has shown an increasing trend since 1997, with a marked increase between 2004 and 2005. Separate TACs are established for the areas east and west of 166° W longitude. Since at least 1996 through 2003, most of the mature-sized males in the Eastern Subdistrict occurred in the area east of 166° W longitude. Since 2004, however, a majority of the estimated mature-sized male abundance has occurred west of 166° W longitude; in 2006 two-thirds of the estimated abundance of mature-sized males was from the area west of 166° W longitude. Old-and-older shelled crabs dominated the legal-sized males in the Eastern Subdistrict during the 2006 survey; approximately 20% of the legal males were in old- or older-shell condition. Although, the high incidence of old- or older-shelled crab among the legal males may be due to later than usual molting associated with the cold water temperatures recorded during the 2006 summer survey, it is more likely that the old shell crabs represent males that terminally molted to maturity a year earlier. Hence, in terms of growth, low future productivity would be expected from the legal males (as well as from sublegal, mature-sized males).

Bering Sea snow crab (*Chionoecetes opilio*):

This stock in 2006 is, at 547.6-million pounds, above MSST but slightly below the estimate for 2005 (610.7-million pounds). The estimated TMB in 2006 remains below the rebuilt level (it is 59% of the 'rebuilt' level of 921.6-million pounds) and maintains the trend in TMB of 'hovering about' MSST for the last 8 surveys without any apparent trend towards rebuilding. Perhaps the most hopeful sign for rebuilding from the 2006 survey is that, since 1999, 2006 is the first year that estimated TMB has been above MSST for 2 years in a row.

The abundance estimate for males ≥4-inches CW in 2006 (143.89-million crabs) is by far the highest value since 1998 and twice the estimate for 2005 (72.1-million crabs). However, this area-swept estimate of abundance of males ≥4-inches in 2006 is associated with poor precision (±76.4% of the point estimate) and the doubling of abundance from 2005 is unexpected from the 2005 survey data; the 2006 snow crab model estimate for this value in 2006 is 80.9-million crabs. The Crab Plan Team supports this biomass estimate over the area-swept abundance estimate from the survey due to the poor precision in the survey estimate. The abundance estimate for males 78-101 (288.38-million crabs) is essentially the same as for 2005 (284.1-million crabs) and compares to annual estimates during 1999-2004 ranging from 106.2-million (for 2004) to 287.7-million (for 2001). Estimated abundance of males <78-mm CW (1,106.91-million crabs) is lower than the

2005 estimate (1,911.2-million); the 2006 estimate is greater than each of the annual estimates for 1997-2000, but is lower than 4 out of the 5 annual estimates for 2001-2005. The abundance estimate for females ≥50-mm CW in 2006 (1,045.53-million crabs) is 64% of the 2005 estimate and the abundance estimate for females <50-mm CW (669.77-million crabs) is 48% of the 2005 estimate. Since the 1999 survey, estimated abundance of females ≥50-mm CW has ranged from 510.5-million (for 2002) to 1,630.8-million (for 2005), whereas estimated abundance of females <50-mm CW has ranged from 180.5-million (for 2002) to 1,869.2-million (for 2004). Estimated mature female biomass in 2006 (214.7-million pounds) is lower than in 2005 (313.1-million pounds). Estimated mature male biomass in 2006 (332.9-million pounds) is up slightly from the 2005 estimate (297.6 million pounds), but more than half of that estimate (180.98-million pounds) is attributable to males ≥4-inches CW. So, regardless of the increase in estimated abundance of males ≥4-inches CW, the 2006 standard survey area-swept estimates provide no strong evidence that the stock currently or potentially rebuilding.

The 2006 trawl survey also performed tow in 29 ‘northern’ stations outside of the standard survey area. The northern area had been surveyed in 2001, 2004, and 2005 in an effort to better track the snow crab stock during a period when the stock distribution contracted from the more southern areas of the standard survey distribution. Recognizing that only 25 northern area stations were sampled in 2001, the following comparison is of area-swept estimates from 29 northern area stations. Males in the northern area are almost exclusively <78-mm CW. The 2006 abundance estimate for males <78-mm CW in the northern area is 950.56-million crabs. That is higher than the 2001 (432.4-million) and would be higher even if only the 2006 estimate from the 25 stations sampled in 2001 were considered (795.28-million crabs). However, estimated abundance of males <78-mm CW in the northern area for 2006 is low by comparison to 2005 (1,771.7-million) and, especially, by comparison to 2004 (2,922.4-million). The 2006 northern area abundance estimate for females <50-mm CW is 676.62-million crabs and for females ≥50-mm CW is 137.53-million crabs. Those estimates are high relative to 2001 (165.5-million females <50-mm CW and 64.2-million females ≥50-mm CW), but are slightly lower than for 2005 (760.5-million females <50-mm CW and 268.1-million females ≥50-mm CW) and 2004 (896.2-million females <50-mm CW and 152.5-million females ≥50-mm CW).

Bristol Bay red king crab (*Paralithodes camtschaticus*):

Estimated total mature biomass in 2006 (157.2-million pounds) is down slightly from the estimates of the preceding 3 years (approximately 180-million pounds). However, the stock remains well above MSST and B_{MSY}. The ADF&G length-based analysis (LBA) point estimates for mature-sized males and legal males in 2006 are both slightly higher than for 2005. The LBA model for 2006 estimates that mature-sized females increased to 40.469-million crabs in 2006 from 37.848-million in 2005, continuing a trend in annually increasing abundance since 2000. Although far below the levels estimated to have existed in the late 1970s, the 2006 LBA model estimates that mature males, mature females, effective spawning biomass and legal male abundance are each at their highest levels since the early 1980s.

As anticipated from the 2005 survey data, the 2006 LBA model estimated that recruits to the mature-sized female class in 2006 declined slightly from that of 2005. However, a mode of juvenile-sized crabs centered at approximately 72.5-mm CL in the 2005 male and female size-frequency distributions apparently tracked to a mode centered at approximately 87.5-mm CL in the size frequency distribution for each sex in 2006. Assuming that the 87.5-mm CL size mode continues to track into the future, it should provide good recruitment into the mature female size class (≥90-mm CL) in 2007, but would not provide strong recruitment to the mature male size class (≥120-mm CL) until 2008. Representation of juvenile crabs <70-mm CL, however, was poor for both sexes in the 2006 survey as compared to the 2002-2005 surveys.

Pribilof District red king crab (*Paralithodes camtschaticus*):

Because of the low precision of abundance estimates for this stock, stock levels and trends are difficult to evaluate. However, the consistency of trend in data for the previous five survey years indicated that the total mature biomass was in decline. Estimated total mature biomass declined annually from 25.5-million pounds in 2001 to 8.1-million pounds in 2005. However, total mature biomass in 2006 rose to 19.0-million pounds. ADF&G catch survey analysis (CSA)-estimated mature male abundance, on the other hand, has shown a declining trend since 2002 through 2006.

Mature-sized (≥120-mm CL) males captured in the 2006 trawl survey were largely legal sized (≥135-mm CL) and legal males were largely post-recruit-sized crabs ≥150-mm CL. The size-frequency distribution of males captured during the 2006 survey provides no expectation for significant recruitment to mature-sized males in 2006; after 2007, future declines in mature-size male abundance for this stock would be expected from the lack of sublegal-sized males <100-mm CL.

There is no harvest strategy for this stock in State regulation. The fishery was closed from 1999 through 2005/2006 due to the poor precision of the abundance estimates, poor performance of recent fisheries, concerns for bycatch of blue king crabs of the overfished Pribilof blue king crab stock.

Pribilof District blue king crab (*Paralithodes platypus*):

The stock remains in "overfished" condition for the fifth year in a row. This depressed stock continues to show declines with little indications for recovery in the near future. Estimated total mature biomass for 2006 is at, 1.6-million pounds, the same as in 2005 and at the second lowest on record. The ADF&G CSA estimates for abundance of mature males, legal males, and mature females in 2006 are the lowest estimated for the period 1975-2006. A continued decline in mature male and female abundance should be expected for at least the next two years. Although relatively high numbers of small crab (< 70 mm-CL) were caught, mainly at one haul, during the 2005 trawl survey, there is very little representation of juvenile crabs in the 2006 survey.

Because estimated total mature biomass in 2005 was less than 13.2-million pounds, the fishery on this stock cannot open for the 2006/2007 season under the State harvest strategy. Also, because estimated total mature biomass in 2006 was less than 13.2-million pounds, the fishery on this stock cannot open for the 2007/2008 season under the State harvest strategy. This fishery has been closed since 1999 through the 2005/2006 season.

Saint Matthew Island Section blue king crab (*Paralithodes platypus*):

Total mature biomass (TMB) in 2006 was estimated to be 11.2 million pounds, at its second highest level since the overfished declaration of 1999. However, the series of annually estimated TMB since 1999 shows at best a slow rate of stock recovery and TMB in 2006 is at approximately ½ the "rebuilt" level of 22.0-million pounds.

From all indications, this stock continues to remain at a depressed level, comparable to that of the mid-1980s. Unlike the mid-1980s, however, the stock is in a prolonged period (now in its seventh year) of depressed status. There are some promising indications for the stock in this year's survey data, however. Although low relative to pre-1999 levels, NOAA Fisheries area-swept estimates of sublegal, mature-sized males (105-119 mm CL) and legal-sized males (≥120-mm CL) in 2006 are, at 0.74-million and 1.38-million, both more than twice the estimates for 2005 (0.3-million and 0.6-million respectively). The current ADF&G CSA estimate of the mature-sized male abundance shows the first signs of improvement since the marked stock decline observed between the 1998 and 1999 surveys. The mode of small crab (approximately 65 to 70-mm CL) observed in 2003, apparently followed into 2004 (mode near 80 to 85-mm CL) and again into 2005 (mode between 90 to 95-mm CL). In 2006, that mode has apparently provided some recruitment into the mature size class. Males 80 to 104-mm CL that appeared in this year's survey may also provide recruitment in the next 2-3 years.

As always with this stock, forecasts of the stock's future, particularly the future recruitment into the mature size class, should be viewed with some skepticism. Abundance estimates are heavily influenced by the catch in relatively few tows and precision of estimates is generally poor. Bottom temperatures in the survey stations southwest of St. Matthew Island that are important for providing catches of male blue king crab during the trawl survey were much colder in 2006 than in recent years. Bottom temperatures may affect the distribution of blue king crab within the surveyed area and that could affect the susceptibility of crabs to be caught during the survey. Additionally, it's important to note that, although poorly estimated, female blue king crabs are showing no indications of increasing in abundance; NOAA Fisheries area-swept estimates of female size classes remain low and have declined from an estimate of 1.0-million females in 2003 to 0.4-million females in 2006.

Total mature biomass would need to increase nearly double to 22.0 million pounds from the 2006 estimate for the stock to be considered "rebuilt." Data from the 2006 survey do not provide any expectations for such an increase in the near-term future; the estimates from 1999 through 2006 indicate at best only a weakly increasing trend in total mature biomass. The fishery has been closed since 1999 through the 2005/2006 season.

Crab Stocks With No Annual Survey

Stock status for the following stocks are unknown due to a lack of survey data: Pribilof District golden king crab (*Lithodes aequispinus*); Saint Lawrence Island blue king crab; Northern District golden king crab; Aleutian Islands golden king crab; Western Aleutian Tanner crab *(C. bairdi*); Aleutian Islands (AI) scarlet king crab (*Lithodes couesi*); Bering Sea triangle Tanner crab (*Chionoecetes angulatus*); Eastern AI triangle Tanner crab; Eastern AI grooved Tanner crabs (*Chionoecetes tanneri*); Western AI grooved Tanner crabs and Bering Sea grooved Tanner crabs. The fisheries for the species identified in Table 3 occur under authority of an ADF&G commissioner's permit. Estimation of MSST for these stocks is not possible at this time because of insufficient data on the basic stock abundance.

Table 2. 2006/2007 Total allowable catch, or guideline harvest level, fishery status and MSY estimates for BSAI king and Tanner crab stocks that are surveyed on a limited basis.

Stock	TAC/GHL (millions of pounds)	Fishery/Season	MSY (millions of pounds)
WAI red king	Closed	10/15	1.5
EAI red king	Closed	Closed	NA
Norton Sound red king			0.5
Saint Lawrence blue king	None established	Permit	0.1
AI golden king	5.7 (TAC)	8/15	15.0
Pribilof golden king	0.15 (GHL)	Permit	0.3
Northern District golden king	0.01-0.02 (GHL)	Permit	0.3
AI scarlet king	Incidental harvest	Permit	NA
EBS scarlet king	Incidental harvest	Permit	NA
EAI Tanner	Stock status determ. pending	1/15	0.7
WAI Tanner	Closed	Closed	0.4
EAI triangle Tanner	Incidental harvest	Permit	1.0
EBS triangle Tanner	Incidental harvest	Permit	0.1
EAI grooved Tanner	0.05-0.2 (GHL)	Permit	1.8
EBS grooved Tanner	0.05-0.2 (GHL)	Permit	1.5
WAI grooved Tanner	Incidental harvest	Closed	0.2

NA: Indicates that insufficient data exists to generate an estimate.

Aleutian Islands red king crab: WAI (Adak or Petrel Bank) and EAI (Dutch Harbor). The GHL for the eastern portion is based on the results of surveys performed by ADF&G on a triennial basis; the most recent survey was performed in 2004. Few red king crabs have been caught in surveys of the eastern Aleutians since 1995. The eastern portion has been closed since 1983. Historically, the GHL for the western portion has been based on the most recent fishery performance. The western portion was closed for the 1996/97 and 1997/98 seasons due to poor performance and poor signs of recruitment during the 1995/96 season. The western portion was reopened for limited exploratory fishing in some areas in 1998/99. Based on the results of the 1998/99 season, the fishery in the western portion was closed in 1999/2000.

In 1999 the Crab Plan Team identified the need for standardized surveys in areas of historical production prior to reopening the fishery in the western portion; prior to that meeting, the western portion had not been surveyed since 1977. A cooperative ADF&G-Industry pot survey was performed in the Petrel Bank area under the provisions of a permit fishery in January-February and November of 2001. Results of those surveys showed high densities of legal crabs within limited portions of the surveyed area. Survey catches of females and prerecruit sized males were low. Based on results of the 2001 surveys and recommendations from ADF&G and the public, the Alaska Board of Fisheries adopted pot limits, and modified the season opening date.

A GHL of 0.5 million pounds was set for the 2002 season in the Petrel Bank area. Because only relative abundance information is available, ADF&G monitored the fishery utilizing inseason catch data. The management goal is to maintain a fishery CPUE of at least 10 legal crabs per pot lift. The 2002 fishery in the Petrel Bank area harvested 505,000 pounds. The fishery CPUE was 18 legal crabs per pot lift. Based on fishery performance, ADF&G announced a 0.5 million pound GHL for the 2003 fishery and the fleet harvested 479,000 pounds. The 2003 catch rate dropped to 10 legal crabs per pot lift. The fishery was closed in 2004 and 2005. The Petrel Bank red king crab fishery will not open in 2006 due to low stock size. An additional pot survey is planned for November 2006.

In order to assess red king crab in other portions of the western AI, during November 2002, a survey was conducted between 172° W longitude, and 179° W longitude (waters in the vicinity of Adak, Atka, and Amlia Islands). The survey of these waters yielded very few red king crabs and the area will remain closed until further notice.

Norton Sound red king crab The king crab population model estimated legal male crab abundance for the 2006 summer commercial crab fishery at 4.5 million pounds. This is down 27% from the 2005 model abundance estimate of 6.2 million pounds for legal male crab. It should be noted that this apparent 27% decline is due to a revision of the model following the 2005 season rather than an actual loss of crab in the population. The revised model estimated the 2005 population at 4.8 million pounds making the decline approximately 5%. Current size composition data from the 2006 winter pot study indicates that the portion of the crab population classified as recruits has decreased 9.8% since the 2005 winter survey and the post recruit male crab population has decreased 11.6%. The winter pot study also points to an above average prerecruit-1 and prerecruit-2 populations and a very small prerecruit-3 population. The prerecruit-1 crab will molt and become part of the legal population next year. These findings indicate the legal crab population has peaked and is expected to decrease in 2007 followed by an increase in 2008 and 2009.

A 10% exploitation rate on the legal population (over 4.75 inch carapace width) equates to a guideline harvest level of 454,000 pounds of crab. The CDQ allocation for 2006 was 34,050 pounds with the remaining 419,950 pounds allocated to the open access fishery. This follows the harvest strategy set by the Board of Fisheries and is the highest GHL since 1982.

In 2006, a total of 224 landings were made during the open access season for a harvest of 139,131 crabs and 419,191 pounds, equating to 99.8% of the open access quota. The CDQ catch was 32,557 pounds making the total crab harvest during the summer season 451,748 pounds.

Aleutian Islands golden king crab Prior to the 1996/97 season, the Aleutian Islands king crab fisheries were managed as two distinct areas: the Dutch Harbor Area (east of 171° W longitude) and the Adak Area (west of 171° W longitude). In 1996, the Alaska Board of Fisheries noted that the management boundary at 171° W longitude apparently bisected a single stock of golden king crab. At that meeting, the Board combined the Dutch Harbor and Adak Areas into a single management area. The Board also directed the department to conservatively manage golden king crab, east and west of 174° W longitude, as two distinct stocks. Prior to combining the two management areas, the Dutch Harbor Area had been managed on the basis of fishery performance with the historic average landings providing an informal harvest guideline. The Adak Area was formerly managed under a size-sex-season (3-S) policy.

To establish the 2006/07 TACs, fishery data, observer data, and tag recovery information were used in reviewing stock status, previously established guideline harvest levels (GHLs), and TACs. Fishery data, through the 2005/06 season, were examined for CPUE and geographic harvest trends. Observer data from the 1998/99 to 2005/06 seasons were examined for size composition of retained and discarded crabs, shell-age of male and female crabs, stock composition and reproductive condition of female crabs. With the implementation of rationalization during the 2005/06 season observer coverage changed. Catcher-only vessels are required to carry an observer for 50% of the total golden king crab harvest by each vessel during each of three trimesters (August 15 to November 15, November 16 to February 15, and February 16 to May 15). Catcher-processor vessels are required to carry an observer for 100% of the harvest.

In the Aleutian Islands east of 174 W longitude, the total number of crab per pot captured over the last eight seasons appears stable, although the legal-male catch rates have increased and sublegal and female crab have decreased. Legal male CPUE, based on fish ticket data, was 25 crabs per pot for the 2005/06 fishery, which is the highest on record and a 39% increase from the 2004/05 CPUE of 18 crabs per pot lift. The increase in CPUE is likely due to many factors including, but not limited to increased soak times, fewer pots being utilized, and fewer vessels participating. Escape mechanisms in golden king crab pots are very effective in allowing smaller golden king crabs to escape, especially with the longer soak times relative to other king crab fisheries. Sublegal male and female golden king crab also occur over a wider depth range than legal crab and may not be equally represented in the commercial catch. Recently, sublegal male CPUE has decreased and there are no indications that legal male CPUE will remain at the current high level if sublegal male CPUE is viewed as an index of possible future recruitment. Commercial fishery catch data does not provide adequate information to accurately predict future recruitment. Harvest level decisions are difficult to discern based solely on CPUE. A review of observer size frequency data and CPUE data are used in a qualitative measure to ensure there are no adverse effects from the current constant-catch harvest strategy. The constant-catch harvest strategy assumes that fishing mortality changes annually, however those changes are currently not measured in these golden king crab stocks. Currently, work is being completed on a catch-survey model that uses data from the commercial fishery and triennial surveys. Once completed, this model should provide managers with additional information to assess stock status and harvest rate. Based on a review of available data ADF&G set the 2006/07 TAC at 3.0 million-pound for the area east of 174 W longitude.

In the Aleutian Islands west of 174 W longitude, fishery and observer data did not demonstrate a compelling reason to change the TAC from the 2.7 million pound level set in 2005/06. Fishery catch statistics have not markedly changed since the GHL was developed in 1996/97. The size frequency of the retained catch continues to be stable though there appear to be fewer of the smaller pre-recruits. CPUE of pre-recruit and female crabs are also relatively stable in the catch. Most commercial fishing effort occurs at depths less than 200 fathoms. Deeper than 200 fathoms, the abundance of small male and female crab is generally greater than legal males. Recent fishery data from the western Aleutian Islands implies that the stock in that area is stable, catches of sublegal males have been steady and there are no indications of a strong recruitment episode.

Eastern Aleutian Islands Tanner crab: The Eastern Aleutian District (EAD) Tanner crab fishery began in 1973 and harvest peaked at 2.5 million pounds in 1977. Harvest decreased to a low of 0.05 million pounds in 1991 and increased to 0.17 million pounds in 1994. The fishery was closed from 1995 to 2003. The 1985 to 1994, 10-year average harvest is 0.18 million pounds.

The Alaska Department of Fish and game (ADF&G) conducted pot surveys targeting king and Tanner crabs in the EAD during 1979, 1984, 1986 and 1987. A partial pot survey targeting Tanner crabs was conducted in 2003. Pot survey results provide general information on relative abundance and distribution of Tanner crabs in the district; however no estimates of abundance have been made with their results. Prior to 1990, the fishery was managed under a size-sex-season (3S) policy. In most years, the season was open until the regulatory closure date. The closure date was formerly June 15, and is currently March 31.

Beginning in 1990, triennial trawl survey results were used to evaluate the health of the stock and Tanner crab abundance estimates were made for the areas surveyed. Results of the 1990 and 1991 trawl surveys provided impetus for setting a guideline harvest level (GHL) of 100,000 pounds for the EAD, however it is apparent from season length and commercial harvests in the 1990 to 1994 seasons that the 3S management policy was still being applied.

Based on results of the 2005 EAD trawl survey, only the Makushin/Skan Bay portion of the EAD met ADF&G criteria for opening the commercial fishery. A GHL of 87,241 pounds was set for Makushin/Skan Bays while the remainder of the district remained closed.

Data from the 2006 EAD trawl survey have yet to be analyzed and no stock status determination has been made at this time.

Overfishing Parameters

The FMP identifies the following overfishing definitions to provide objective and measurable criteria for identifying when the BSAI crab fisheries are overfished or overfishing is occurring, as required by the Magnuson-Stevens Fishery Conservation and Management Act. Table 3 provides the MSST, MSY, OY and maximum fishery mortality threshold (MFMT) control rule estimates for the BSAI king and Tanner crab stocks. The Crab Plan Team is currently studying revisions to the Overfishing Definitions.

Table 3. MSST, MSY, OY, and the MFMT values for BSAI king and Tanner crabs. Values in millions of pounds.

Stock	MSST	MSY	OY range	MFMT
WAI red king	NA	1.5	0-1.5	0.2
Bristol Bay red king	44.8	17.9	0-17.9	0.2
EAI red king	NA	NA	NA	0.2
Pribilof Islands red king	3.3	1.3	0-1.3	0.2
Norton Sound red king	NA	0.5	0-0.5	0.2
Pribilof Islands blue king	6.6	2.6	0-2.6	0.2
Saint Matthew blue king	11.0	4.4	0-4.4	0.2
Saint Lawrence blue king	NA	0.1	0-0.1	0.2
Aleutian Islands golden king	NA	15.0	0-15.0	0.2
Pribilof Islands golden king	NA	0.3	0-0.3	0.2
Northern District golden king	NA	0.3	0-0.3	0.2
Aleutian Islands scarlet king	NA	NA	NA	0.2
EBS scarlet king	NA	NA	NA	0.2
Total king crab		**43.9**	**0-43.9**	
Eastern Aleutian Tanner	NA	0.7	0-0.7	0.3
EBS Tanner	94.8	56.9	0-56.9	0.3
Western Aleutian Tanner	NA	0.4	0-0.4	0.3
Total Tanner		**58.0**	**0-58.0**	
EBS snow	460.8	276.5	0-276.5	0.3
Total snow		**276.5**	**0-276.5**	
Eastern Aleutian triangle Tanner	NA	1.0	0-1.0	0.3
EBS triangle Tanner	NA	0.3	0-0.3	0.3
Eastern Aleutian grooved Tanner	NA	1.8	0-1.8	0.3
EBS grooved Tanner	NA	1.5	0-1.5	0.3
Western Aleutian grooved Tanner	NA	0.2	0-0.2	0.3
Total other Tanner		**4.8**	**0-4.8**	

NA: Indicates that insufficient data exists to calculate value.

Maximum sustainable yield (MSY) is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. MSY is estimated from the best information available. Proxy stocks are used for BSAI crab stocks where insufficient scientific data exists to estimate biological reference points and stock dynamics are inadequately understood. MSY for crab species is computed on the basis of the estimated biomass of the mature portion of the male and female population or total spawning biomass (SB) of a stock. A fraction of the *SB* is considered sustained yield (*SY*) for a given year and the average of the *SY*s over a suitable period of time is considered the MSY.

Overfishing and Overfished: The term "overfishing" and "overfished" mean a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce MSY on a continuing basis. Overfishing is defined for king and Tanner crab stocks in the BSAI management area as any rate of fishing mortality in excess of the maximum fishing mortality threshold, F_{msy}, for a period of 1 year or more. Should the actual size of the stock in a given year fall below the minimum stock size threshold, the stock is considered overfished. If a stock or stock complex is considered overfished or if overfishing is occurring, the Secretary will notify the Council to take action to rebuild the stock or stock complex.

MSY control rule means a harvest strategy which, if implemented, would be expected to result in a long-term average catch approximating MSY. The MSY control rule for king and Tanner crabs is the mature biomass of a stock under prevailing environmental conditions, or proxy thereof, exploited at a fishing mortality rate equal to a conservative estimate of natural mortality. Sustainable yield (SY) in a given year is the MSY rule applied to the current spawning biomass. Overfishing occurs if the SY is exceeded for one year or more.

MSY stock size is the average size of the stock, measured in terms of mature biomass of a stock under prevailing environmental conditions, or a proxy thereof. It is the stock size that would be achieved under the MSY control rule. It is also the minimum standard for a rebuilding target when remedial management action is required. For king and Tanner crab, the MSY stock size is the average mature biomass observed over the 15 year period from 1983 to 1997.

Maximum fishing mortality threshold (MFMT) is defined by the MSY control rule, and is expressed as the fishing mortality rate. The MSY fishing mortality rate $F_{msy} = M$, is a conservative natural mortality value set equal to 0.20 for all species of king crab, and 0.30 for all *Chionoecetes* species.

Minimum stock size threshold (MSST) is whichever is greater: one half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years if the stock or stock complex were exploited at the maximum fishing mortality threshold. The minimum stock size threshold is expressed in terms of mature biomass of a stock under prevailing environmental conditions, or a proxy thereof

Management Programs

Crab Rationalization Program

The Crab Rationalization Program (Program) allocates BSAI crab resources among harvesters, processors, and coastal communities. The Council developed the Program over a 6-year period to accommodate the specific dynamics and needs of the BSAI crab fisheries. The Program balances the interests of several groups who depend on these fisheries. The Program addresses conservation and management issues associated with the derby fishery, and increases the safety of crab fishermen by ending the race for fish. Share allocations to harvesters and processors, together with incentives to participate in crab harvesting cooperatives, increase efficiencies, provide economic stability, and facilitate compensated reduction of excess capacities in the harvesting and processing sectors. Community interests are protected by Community Development Quota

(CDQ) allocations and regional landing and processing requirements, as well as by several community protection measures.

In January 2004, the U.S. Congress amended section 313(j) of the Magnuson-Stevens Act through the Consolidated Appropriations Act of 2004 (Public Law 108-199, section 801). As amended, section 313(j)(1) requires the Secretary of Commerce to approve and implement by regulation the Program, as it was approved by the Council. In June 2004, the Council consolidated its actions on the Program into Amendment 18 to the FMP. Additionally, in June 2004, the Council developed Amendment 19 to the FMP, which represents minor changes necessary to implement the Program. NMFS published a final rule to implement Amendments 18 and 19 on March 2, 2005 (70 FR 10174). Crab fishing under the Program began on August 15, 2005.

The Program applies to the following BSAI crab fisheries: Bristol Bay red king crab, Western Aleutian Islands (Adak) golden king crab - west of 174°W. long., Eastern Aleutian Islands (Dutch Harbor) golden king crab - east of 174°W. long., Western Aleutian Islands (Adak) red king crab - west of 179°W. long., Pribilof Islands blue king crab and red king crab, St. Matthew Island blue king crab, Bering Sea snow crab, and Bering Sea Tanner crab. A License Limitation Program (LLP) license is no longer required to participate in these crab fisheries.

Several crab fisheries under the FMP are excluded from the Program, including the Norton Sound red king crab fishery, which is operated under a "superexclusive" permit program intended to protect the interests of local, small-vessel participants. Also excluded from this Program are the Aleutian Islands Tanner crab fishery, Aleutian Islands red king crab fishery east of 179°W. long., and the Bering Sea golden king crab, scarlet king crab, triangle Tanner crab, and grooved Tanner crab fisheries. An LLP license is required to participate in the FMP crab fisheries excluded from the Program.

Since NMFS published the final rule implementing the Program, NMFS and the Council have made a number of changes to the implementing regulations. These changes include:

- Three technical corrections.
- Issuance of Tanner crab QS and PQS as two separate pools of east and west QS and PQS.
- New Arbitration System deadlines for establishing contracts and joining an Arbitration Organization.
- Application of Gulf of Alaska sideboards to federally permitted vessels fishing in the State of Alaska parallel.
- Change the economic data report submission deadline date from May 1 to June 28.

Community Development Quota and Adak Community Allocation Crab Fisheries

The Magnuson-Stevens Act mandated that the Council and NMFS establish the CDQ Program under which a percentage of the total allowable catch for Bering Sea and Aleutian Island crab fisheries is allocated to the CDQ program (16 U.S.C. 1855 (i)(1)(A)). The Council and NMFS deferred management authority of the BSAI king and Tanner crab fisheries, including the CDQ fisheries, to the State, within the FMP framework. The FMP specifies three categories of management measures, which provide the framework for Federal/State management of the crab fisheries, including the determination of the TACs and fishery seasons. Additionally, the FMP authorizes the State to recommend allocations of the crab CDQ reserve among CDQ groups and to manage crab harvesting activity of the BSAI CDQ groups (§8.1.4.2 of the FMP).

Sixty-five communities located along the Bering Sea are eligible for the CDQ program. These communities are aligned into six CDQ groups: Aleutian Pribilof Island Community Development Association (APICDA), Bristol Bay Economic Development Corporation (BBEDC), Central Bering Sea Fishermen's Association (CBSFA), Coastal Villages Regional Fund (CVRF), Norton Sound Economic Development Corporation

(NSEDC), and Yukon Delta Fisheries Development Association (YDFDA). The legislation that implemented the Crab Rationalization Program (Pub. L. No. 108-199, section 801) specified a CDQ reserve of 10.0% of the TAC for the crab fisheries assigned to the program. Additionally, the legislation assigned the Eastern Aleutian Island golden king crab fishery to the CDQ program. The following BSAI crab fisheries are assigned to the CDQ program: Eastern Aleutian Island golden king crab; Bristol Bay red king crab; Pribilof District red and blue king crab; Norton Sound red king crab; Saint Matthew Island Section blue king crab; Bering Sea snow crab; and Bering Sea Tanner crab.

Table 4. 2006/2007 CDQ reserve by fishery.

Fishery	CDQ reserve
Bristol Bay red king	Xx million pounds
Pribilof Islands king	Closed
Saint Matthew blue king	Closed
Norton Sound red king	Xx million pounds
EBS Tanner	Xx million pounds
EBS snow	Xx million pounds
EAI golden king	xx million pounds

The legislation implementing the Crab Rationalization Program (Pub. L. No. 108-199, section 801) allocated 10.0% of the Western Aleutian Island golden king crab fishery to an entity representing the community of Adak. This allocation is managed similar to allocations made under the CDQ program – ADF&G established criteria for the oversight and use of the allocation in coordination with NMFS. The entity representing Adak has been established and authorized by NMFS.

History Relative to Overfishing for the Surveyed Stocks

September 17, 2006

L. Rugolo

DRAFT: for Crab Plan Team Meeting, Sept. 13-15, 2006

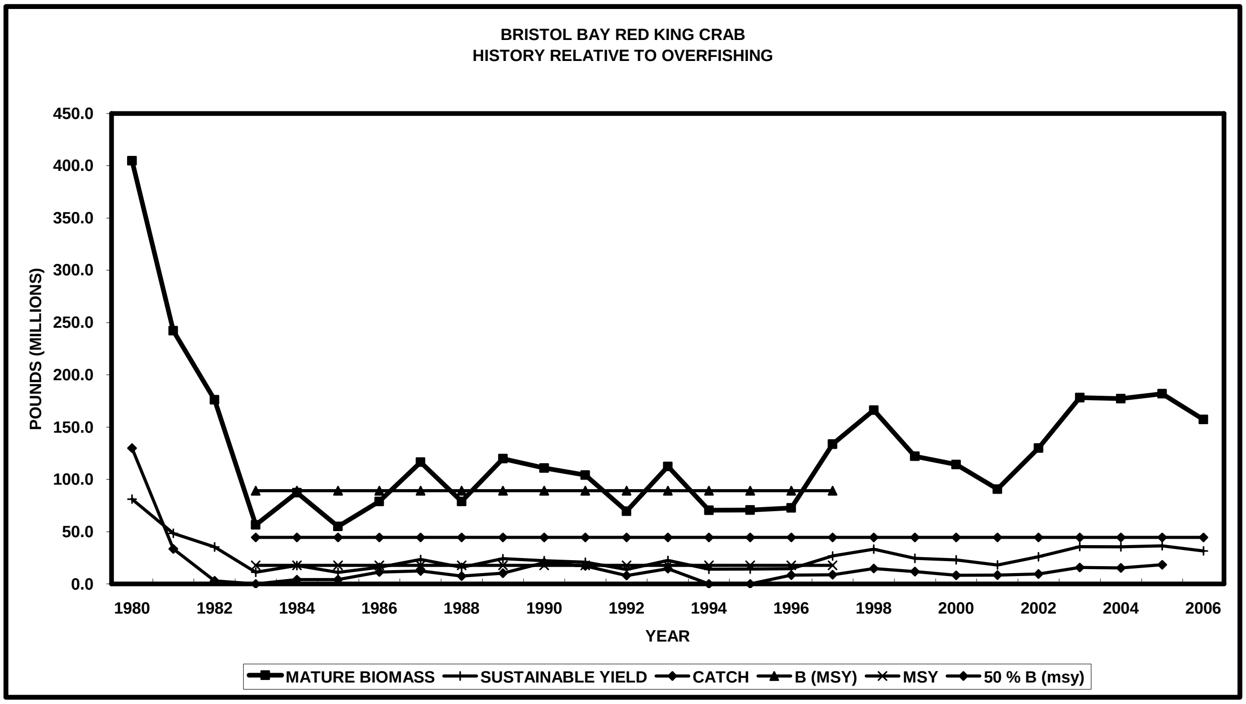
Status of Surveyed EBS King, Tanner and Snow Crab Stocks relative to FMP Overfished Levels in 2005.

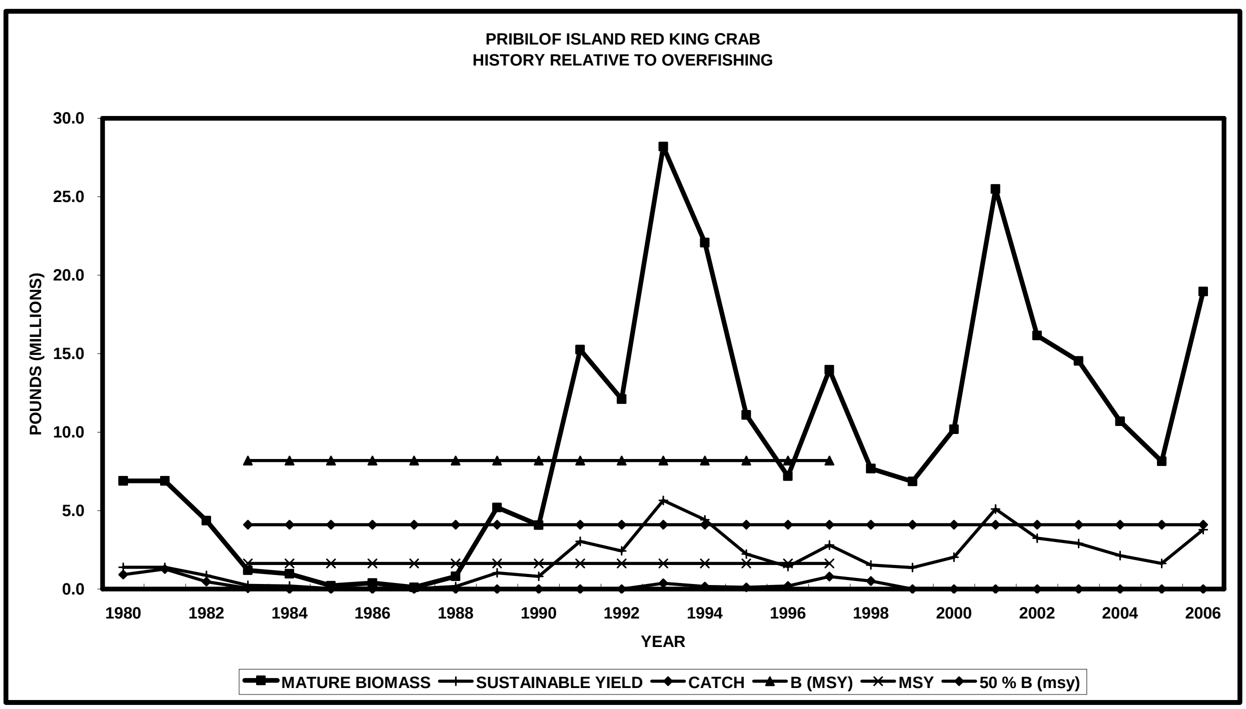
1) **General Notes**: The following documents survey based computations to date.

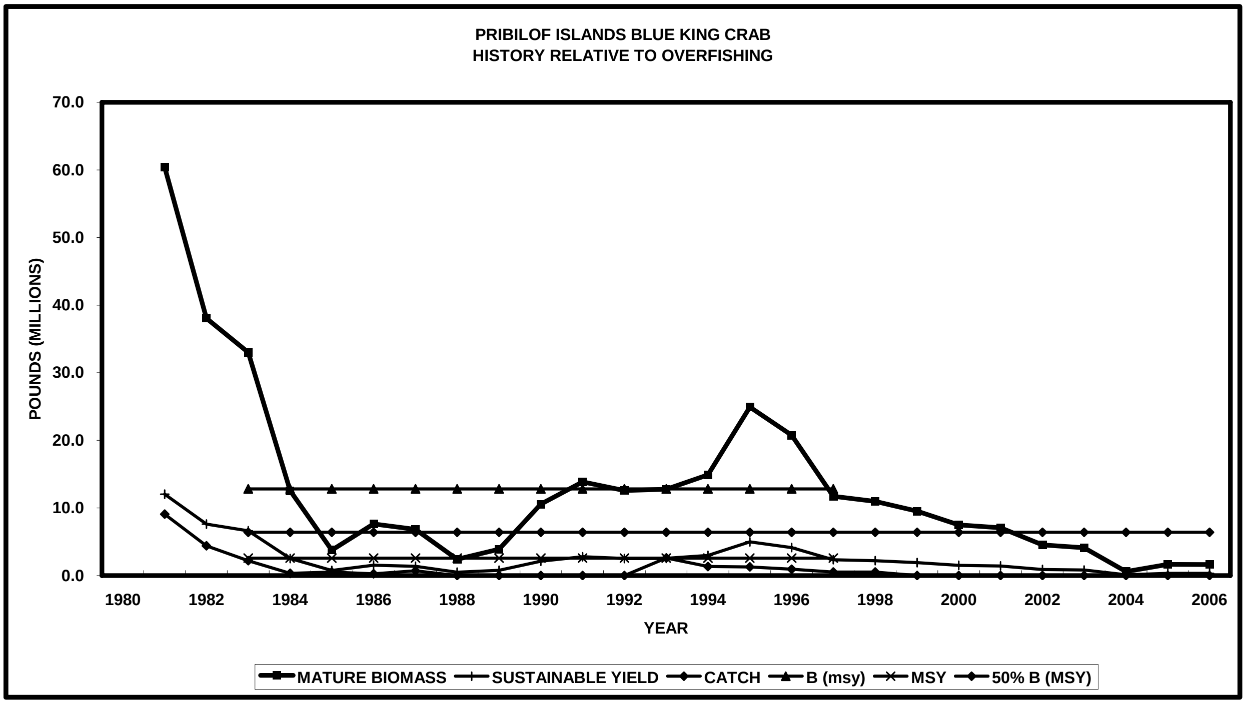
We are still in the process of revising our long term data series, so the diagrams below will change slightly in the future. Never the less, overfished levels or minimum stock size thresholds (MSST = 50 % B_{msy}) in the FMP are fixed values. It is most important, at this juncture, to consider the level of total mature biomass (TMB) relative to the overfished levels in the plan and with respect to various rebuilding plans. Here I simply present the calculations as a first step in the process of determining the status of these stocks in these regards.

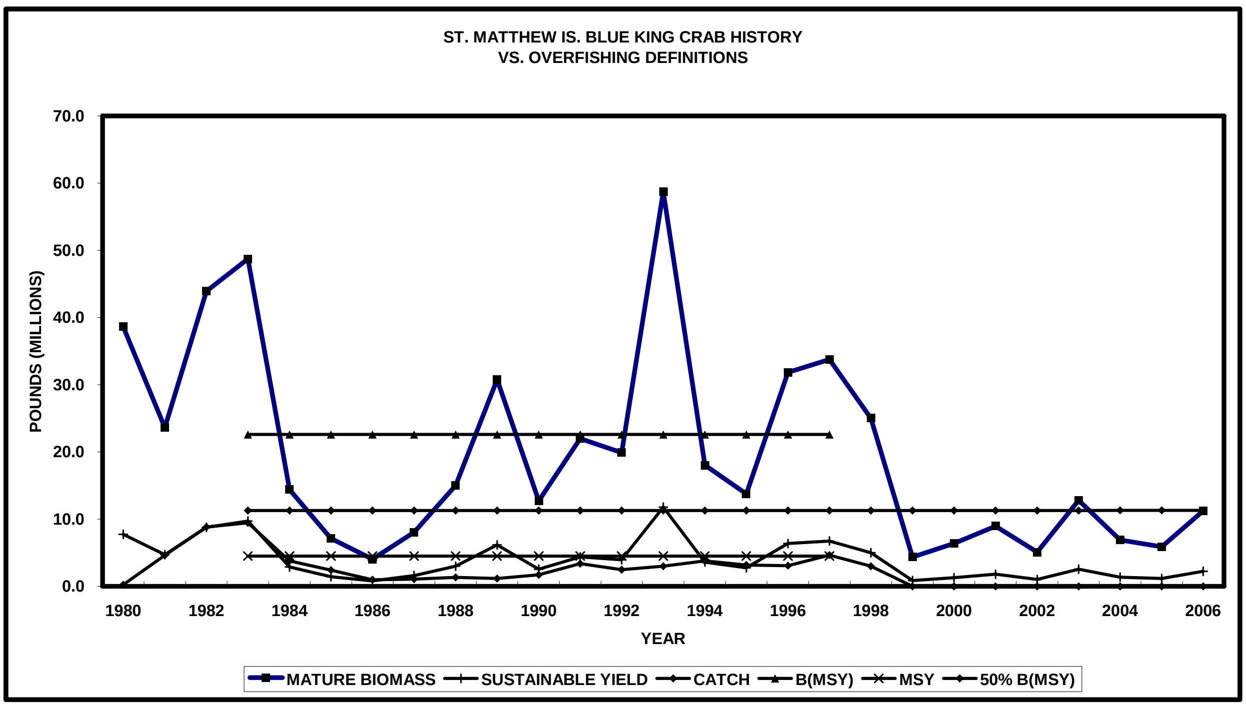
Stock	FMP Overfished Level (millions lbs)	Current Survey TMB (millions lbs)	+/- %
Bristol Bay Red King Crab	44.8	157.2	+ 251
Pribilof Is. Red King Crab	3.3	19.0	+ 476
Pribilof Is. Blue King Crab	6.6	1.6	- 76
St. Matthew Is. Blue King Crab	11.0	11.2	+ 2
EBS Tanner Crab	94.8	253.3	+ 167
EBS Snow Crab	460.8[1]	547.6	+ 19

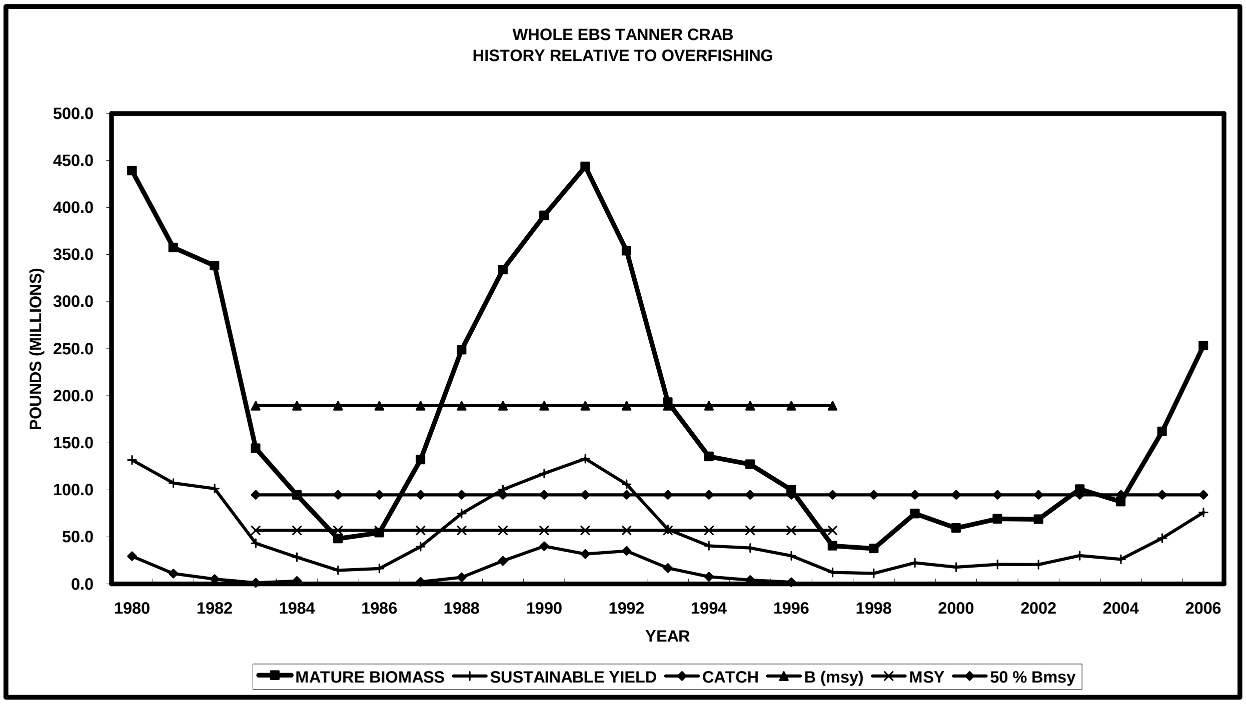
[1] This value was inadvertently omitted from the plan and is taken from the Regulatory Impact review.

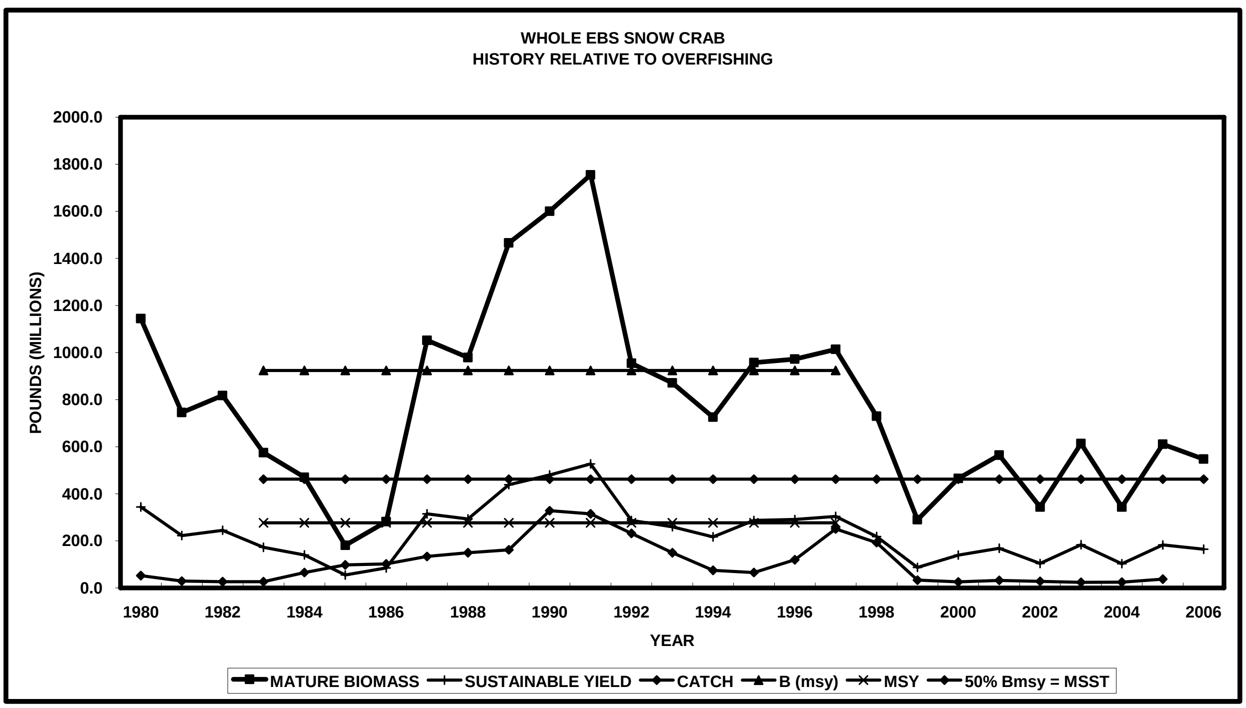

BRISTOL BAY RED KING CRAB
HISTORY RELATIVE TO OVERFISHING
POUNDS (MILLIONS)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
YEAR
MATURE BIOMASS
SUSTAINABLE YIELD
CATCH
B (MSY)
MSY
50 % B (msy)


PRIBILOF ISLAND RED KING CRAB
HISTORY RELATIVE TO OVERFISHING
POUNDS (MILLIONS)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
YEAR
MATURE BIOMASS
SUSTAINABLE YIELD
CATCH
B (MSY)
MSY
50 % B (msy)


PRIBILOF ISLANDS BLUE KING CRAB
HISTORY RELATIVE TO OVERFISHING
POUNDS (MILLIONS)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
YEAR
MATURE BIOMASS
SUSTAINABLE YIELD
CATCH
B (msy)
MSY
50% B (MSY)


ST. MATTHEW IS. BLUE KING CRAB HISTORY
VS. OVERFISHING DEFINITIONS
POUNDS (MILLIONS)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
YEAR
MATURE BIOMASS
SUSTAINABLE YIELD
CATCH
B(MSY)
MSY
50% B(MSY)


WHOLE EBS TANNER CRAB
HISTORY RELATIVE TO OVERFISHING
POUNDS (MILLIONS)
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
YEAR
MATURE BIOMASS
SUSTAINABLE YIELD
CATCH
B (msy)
MSY
50 % Bmsy


WHOLE EBS SNOW CRAB
HISTORY RELATIVE TO OVERFISHING
POUNDS (MILLIONS)
2000.0
1800.0
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
YEAR
MATURE BIOMASS
SUSTAINABLE YIELD
CATCH
B (msy)
MSY
50% Bmsy = MSST

RESULTS OF THE 2006 NMFS BERING SEA CRAB SURVEY

DRAFT EXECUTIVE SUMMARY

This document summarizes data presented in the Report to Industry on the 2006 National Marine Fisheries Service Eastern Bering Sea Trawl Survey. Numbers presented are trawl survey indices of population level and do not necessarily represent absolute abundance.

For further information, contact Dr. Louis Rugolo, NMFS, 301 Research Court, Kodiak, AK 99615. Phone (907) 481-1715. GHLs (Guideline Harvest Levels) are for the combined open-access and CDQ fisheries. This draft reflects data analysis and management decision making through 15 September 2006.

Red king crab (*Paralithodes camtschaticus)* Bristol Bay.
Legal males: 12.5 million crabs; 26% increase.
Pre-recruits: 7.4 million crabs; 28% decrease.
Large females: 24.4 million crabs; 43% decrease.
Status: Abundance of legal males increased and that of pre-recruit males declined. Abundance of mature females decreased substantially. Except for the legal male category, all sex-specific size categories declined relative to 2005; the overall population declined by 32%. Total males declined by 20%; that for females declined by 42%. Almost all new shell females carried new eggs. Estimated total mature biomass is above the minimum stock size threshold (MSST); the stock is not considered to be in the overfished level of abundance although it remains far below the peak population levels of the 1970s
GHL: Unknown at present.

Red king crab (*Paralithodes camtschaticus*) Pribilof District.
Legal males: 1.3 million crabs; 369% increase, low reliability.
Pre-recruits: 0.3 million crabs; 1242% increase, low reliability.
Large females: 0.9 million crabs; 33% decrease, low reliability.
Status: Crabs are highly concentrated, and indices of abundance have very low precision. Estimated total mature biomass is above the MSST; the stock is not considered to be in the overfished level of abundance. Future recruitment is difficult to discern. Red king crabs in the Pribilof Islands have been historically harvested along with blue king crabs and are currently the dominant of the two species. There are concerns as to the low reliability of estimates and that unacceptable levels of blue king crab incidental catch could occur in a red king crab fishery.
GHL: Unknown at present.

Pribilof Islands blue king crab *(P. platypus*) Pribilof District.
Legal males: 0.04 million crabs; 63% decrease, low reliability.
Pre-recruits: 0.04 million crabs; no change, low reliability.
Large females: 0.5 million crabs; 51% increase, low reliability.
Status: Population is low and trends are not easily detectable. Except for the large female category, all sex-specific size categories declined relative to 2005; the overall population declined by 86%. Little or no recruitment is apparent. The current assessment represents the lowest total population estimates on record. Estimated total mature biomass fell below the MSST in 2002 and has remained below threshold though 2006. The stock is considered to be in the overfished level of abundance.
GHL: Unknown at present.

St. Matthew blue king crab (*P. platypus*) Northern District.
Legal males: 1.4 million crabs; 151% increase.
Pre-recruits: 0.7 million crabs; 141% increase.
Large females: 0.3 million crabs; 26% decrease. Not well estimated.
Status: Indices of abundance are affected by the portion of the stock occupying inshore rocky untrawlable grounds. The population declined steeply in 1999 and estimated total mature biomass fell below the MSST threshold. Total mature biomass has remained below MSST since 1999 with the exception of 2002 where it was slightly above threshold. In 2006, total mature biomass is slightly below MSST. The stock continues to be in the overfished level of abundance. Assessment of this stock is clouded by large uncertainty in female abundance. The abundance of mature males is expected to be below the threshold for opening the fishery.
GHL: Unknown at present.

Tanner crab (*Chionoecetes bairdi*) Eastern District.
Legal males: 14.6 million crabs; 28% increase.
Pre-recruits: 73.3 million crabs; 41% increase.
Large females: 43.4 million crabs; 49% increase..
Status: Indices of abundance continue to increase and the population is demonstrating encouraging signs of recovery. With the exception of the small female category, all sex-specific size categories increased relative to 2005. A notable proportion of old to very old shell crab are observed in the male size distribution from 80mm carapace width and above. Estimated total mature biomass was below MSST from 1997-2002; it rose slightly above threshold in 2003 and fell slightly below in 2004. In 2005, the mature biomass index rose well above MSST. It rose again in 2006 to a level in excess of the biomass level indicative of a restored stock. Commencing in 2005, the stock is managed separately east and west of 166^0 W longitude.
GHL: Unknown at present.

Snow crab (*C. opilio*) All districts combined.
Large males: 143.9 million crabs; 100% increase.
Pre-recruits: 288.4 million crabs; 1.5% increase.
Large females: 1045.5 million crabs; 36% decrease.
Status: The abundance index of large males doubled relative to that in 2005. Pre-recruit male abundance was unchanged. Large female abundance decreased, and apparent recruitment to the female component of the stock is seen at the lower end of the mature size range. Except for the large and pre-recruit male categories, all sex-specific size categories declined relative to 2005; total males declined by 32%, females by 43%, and the overall population by 38%. Recruitment to female reproductive stock is evidenced by high frequencies of old and very old shell crab, which is of concern in terms of expected reproductive output. Estimated total mature biomass has been oscillating slightly above and below the MSST threshold since 1999. Mature biomass declined in 2006 relative to 2005 but remains above MSST. The stock is considered to be in the overfished level of abundance. Under the current rebuilding plan and harvest strategy the fishery would be closed if the stock fell below 50% MSST.
GHL: Unknown at present.

<u>Hair crab</u> (*Erimacrus isenbeckii*) All districts combined.
Legal males: 1.1 million crabs; 270% increase.
Large females: 3.8 million crabs; 341% increase. Not well estimated
Status: The population had been declining for several years through 2005. Abundance indices of all sex-specific size categories increased in 2006. Recruitment trends in this stock are unclear due to poor representation of small crabs in the survey.
GHL: Unknown at present.

Table 1. Total allowable catch (TAC) and combined IFQ and CDQ fishery harvest and for major Bering Sea/Aleutian Islands king and Tanner crab fisheries during the 2005/2006 seasons.

Fishery	TAC[a]	Harvest[a]
Aleutian Islands red king crab (Petrel Bank, 2005)	Fishery Closed	
Aleutian Islands golden king crab (2005/2006)	5.70	.5.52
Bering Sea snow crab (2005/2006)	37.18	36.80
Bering Sea Tanner crab (2005/2006)	1.62	0.97
Bristol Bay red king crab (2005/2006)	18.33	18.31
Pribilof Islands red king crab (2005/2006)	Fishery Closed	
Pribilof Islands blue king crab (2005/2006)	Fishery Closed	
Saint Matthew Island blue king crab (2005/2006)	Fishery Closed	

[a] Millions of pounds.

Table 2. Western Aleutian Islands red king crab fishery harvest (thousands of pounds) relative to guideline harvest level (GHL/TAC; thousands of pounds), 1993/94 season to 2005/06 season.

Year	GHL/TAC	Harvest
1993/94		698.1
1994/95		197.0
1995/96		38.9
1996/97		
1997/98		
1998/99	15.0	5.9
1999/00		
2000/01		
2001/02		
2002/03[a]	500.0	505.6
2003/04[a]	500.0	479.1
2004/05		
2005/06		

[a] Petrel Bank only.

Table 3. Aleutian Islands golden king crab fishery harvest (millions of pounds) relative to guideline harvest level (GHL; millions of pounds), 1993/94 season to 2005/2006 season.

Season	GHL	Harvest
1993/94	None	5.55
1994/95	None	8.13
1995/96	None	6.89
1996/97	5.9	5.85
1997/98	5.9	5.95
1998/99	5.7	4.94
1999/00	5.7	5.84
2000/01	5.7	6.02
2001/02	5.7	5.89
2002/03	5.7	5.46
2003/04	5.7	5.67
2004/05	5.7	5.58
2005/06	5.7	5.52

Table 4. Eastern Bering Sea snow crab fishery harvest relative to harvest strategy target and guideline harvest level (GHL) or total allowable catch (TAC), 1994-2005/2006.

Fishery Year	Harvest Strategy Target[a]	Actual[b]	Mature Male Biomass[c]	GHL/ TAC[d]	Harvest[e]
1994	N/A[f]	36.3%	412.3	105.8	149.8
1995	N/A[f]	22.6%	332.9	55.7	75.3
1996	N/A[f]	13.9%	474.0	50.7	65.7
1997	N/A[f]	17.2%	694.4	117.0	119.5
1998	N/A[f]	34.6%	729.7	234.8	252.2
1999	N/A[f]	38.3%	502.6	195.9	192.3
2000	N/A[g]	16.9%	197.1	28.6	33.3
2001	14.7%	13.8%	182.8	27.3	25.3
2002	10.2%	10.6%	308.6	31.0	32.7
2003	11.5%	12.7%	224.9	25.8	28.5
2004	11.4%	13.1%	183.2	20.8	23.9
2005	12.0%	14.1%	176.4	20.9	24.8
2005/06	16.9%	12.4%	297.6	37.2	36.8

[a] Harvest strategy in effect since 2001 targets a percentage of the preseason survey estimate of mature male biomass (subject to cap on harvest rate on exploited legal males).
[b] Actual harvest as a percentage of the preseason survey estimate of mature male biomass.
[c] Preseason estimate of mature male biomass provided by NMFS (millions of pounds).
[d] GHL/TAC established preseason (millions of pounds).
[e] Actual harvest (millions of pounds).
[f] GHL established as 58% percentage of males >101-mm carapace width.
[g] GHL established as 22% percentage of males >101-mm carapace width.

Table 5. Bristol Bay red king crab fishery harvest relative to harvest strategy target and guideline harvest level (GHL) or total allowable catch (TAC), 1993-2005/2006.

Fishery Year	Harvest Strategy Target[a]	Actual[b]	Number of males >119 mm CL[c]	Number Harvested[d]	GHL/ TAC[e]	Harvest[f]
1993	20%	23.0%	9.85	2.26	16.8	14.6
1994	Fishery Closed		8.49	0.00	0	0
1995	Fishery Closed		9.37	0.00	0	0
1996	10%	12.1%	10.34	1.25	5.0	8.4
1997	10%	11.2%	11.78	1.32	7.0	8.8
1998	15%	14.3%	15.00	2.14	16.3	14.8
1999	10%	11.5%	15.74	1.81	10.7	11.7
2000	10%	8.9%	13.13	1.17	8.4	8.2
2001	10%	9.8%	12.15	1.20	7.2	8.4
2002	10%	9.8%	14.11	1.38	9.3	9.6
2003	15%	14.3%	16.37	2.34	15.7	15.7
2004	15%	14.0%	15.97	2.24	15.4	15.3
2005/06	15%	15.2%	18.04	27.3	18.3	18.3

[a] Harvest strategy targets 20% of abundance of males >119-mm carapace length (CL) as estimated from preseason survey.
[b] Actual number of legal males harvested as percentage of preseason estimated abundance of males >119-mm carapace length (CL).
[c] Estimated abundance of males >119-mm carapace length (CL) from preseason survey (millions of animals).
[d] Millions of animals.
[e] GHL/TAC established preseason (millions of pounds).
[f] Actual harvest (millions of pounds).

Table 6. Pribilof king crab fishery harvest relative to guideline harvest level (GHL) or total allowable catch (TAC), 1993-2005/2006.

		Harvest[a]		
Fishery Year	GHL[a]	Red King	Blue King	Total
1993	3.4[b]	2.61	0.00	2.61
1994	2[b]	1.34	0.00	1.34
1995	2.5[c]	0.87	1.27	2.14
1996	1.8[c]	0.20	0.94	1.14
1997	1.5[c]	0.76	0.51	1.27
1998	1.25[c]	0.51	0.52	1.03
1999		Fishery closed		
2000		Fishery closed		
2001		Fishery closed		
2002		Fishery closed		
2003		Fishery closed		
2004		Fishery closed		
2005/06		Fishery closed		

[a] Millions of pounds.
[b] GHL established only for red king crab; closed to blue king crab.
[c] GHL established for combined red and blue king crab.

Table 7. St. Matthew blue king crab fishery harvest relative to harvest strategy target and guideline harvest level (GHL), 1993-2004.

Fishery Year	Harvest Strategy Target[a]	Actual[b]	Number of males >104 mm CL[c]	Number Harvested[d]	GHL/ TAC[e]	Harvest[f]
1993	20%	16%	3.98	0.63	4.4	3.00
1994	20%	20%	4.11	0.83	3.0	3.76
1995	20%	17%	3.99	0.67	2.4	3.17
1996	20%	15%	4.38	0.66	4.3	3.08
1997	20%	20%	4.70	0.94	5.0	4.65
1998	20%	15%	4.13	0.63	4.0	2.87
1999	Fishery closed		1.01	0	0	0
2000	Fishery closed		1.21	0	0	0
2001	Fishery closed		1.34	0	0	0
2002	Fishery closed		1.47	0	0	0
2003	Fishery closed		1.33	0	0	0
2004	Fishery closed		1.29	0	0	0
2005	Fishery closed		1.02	0	0	0

[a] Harvest strategy in effect for 1993-1998 seasons targeted 20% of abundance of males >104-mm carapace length (CL) as estimated from preseason survey.
[b] Actual number of legal males harvested as percentage of preseason estimated abundance of males >104-mm carapace length (CL).
[c] Estimated abundance of males >104-mm carapace length (CL) from preseason survey (millions of animals).
[d] Millions of animals.
[e] GHL/TAC established preseason (millions of pounds).
[f] Actual harvest (millions of pounds).

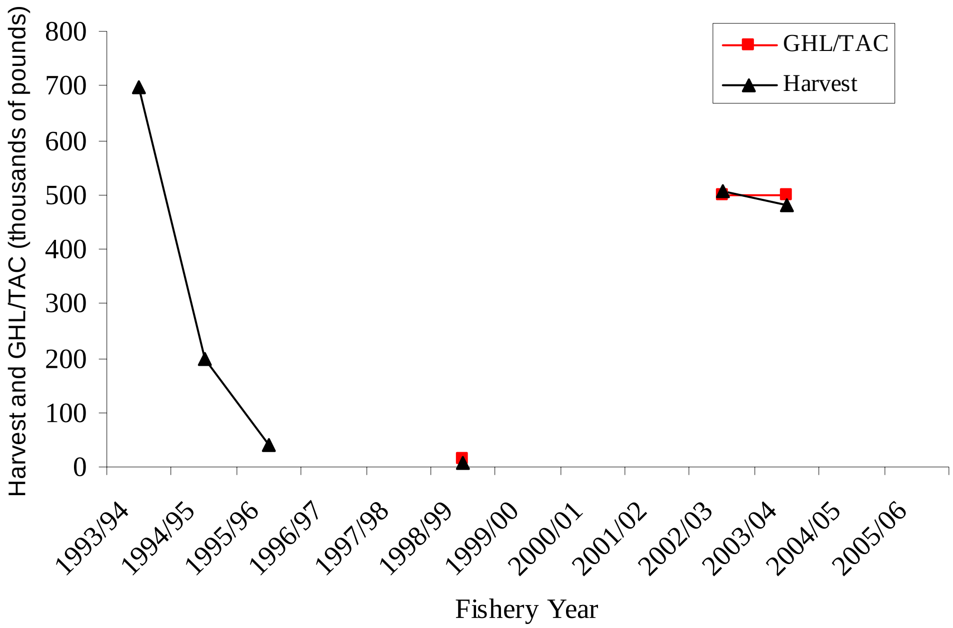


Figure 1. Western Aleutian Islands commercial red king crab fishery harvest and guideline harvest levels (GHLs), 1993/94-2005/06.

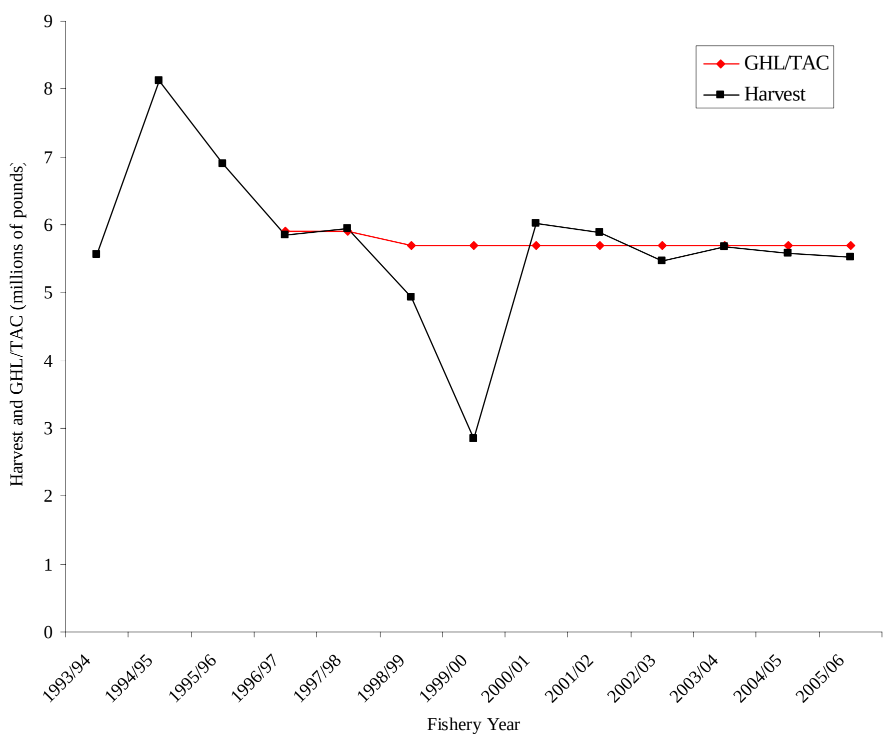


Figure 2. Aleutian Islands commercial golden king crab fishery harvest and guideline harvest levels (GHLs), 1993/94-2005/06

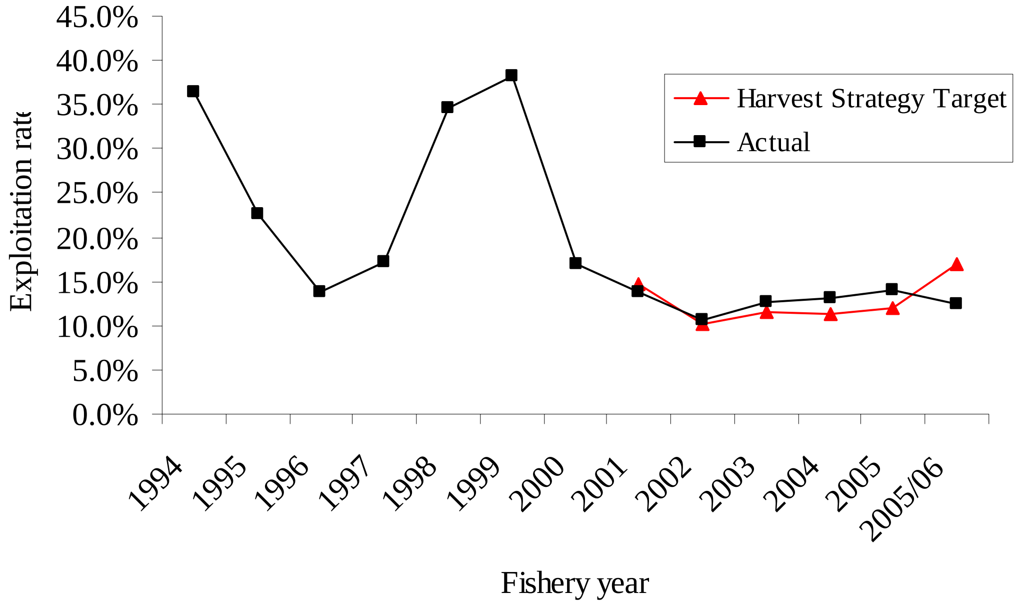


Figure 3. Comparison of harvest strategy specified and actual exploitation rates on mature male biomass in the Bering Sea commercial snow crab fishery, 1994-2005/2006.

Figure 4. Bering Sea commercial snow crab general/IFQ and CDQ fishery harvest and guideline harvest levels (GHLs) or total allowable catch (TAC), 1994-2005/2006.

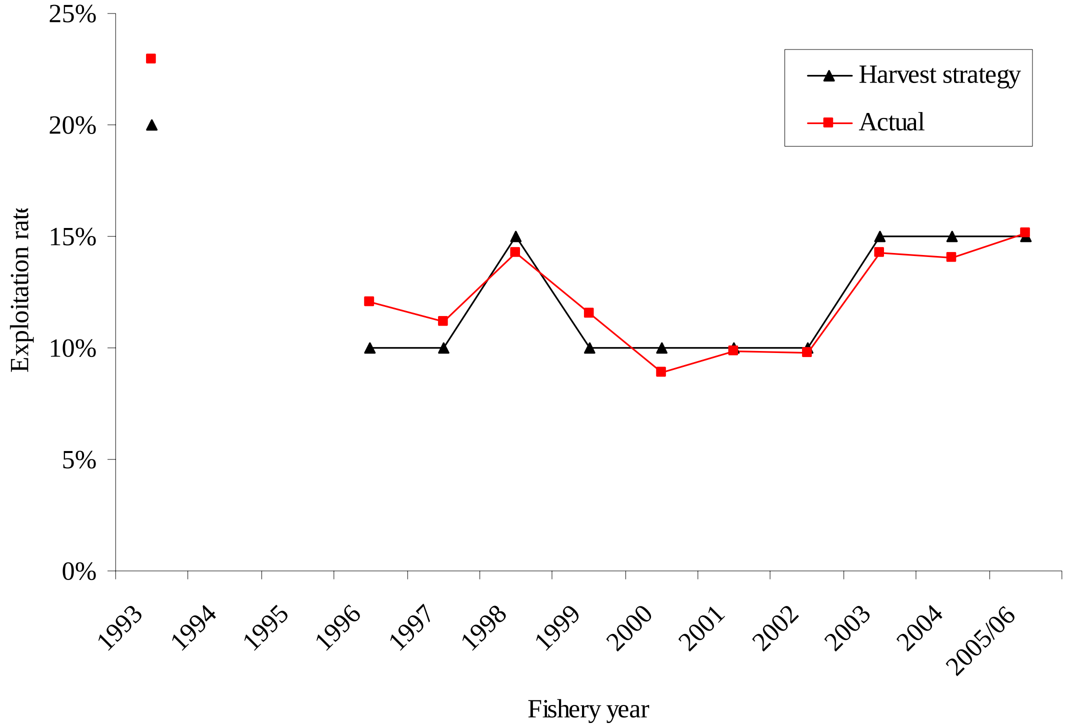


Figure 5. Comparison of harvest strategy specified and actual exploitation rates on males > 119-mm carapace length in the Bristol Bay red king crab commercial fishery, 1993-2005/2006.

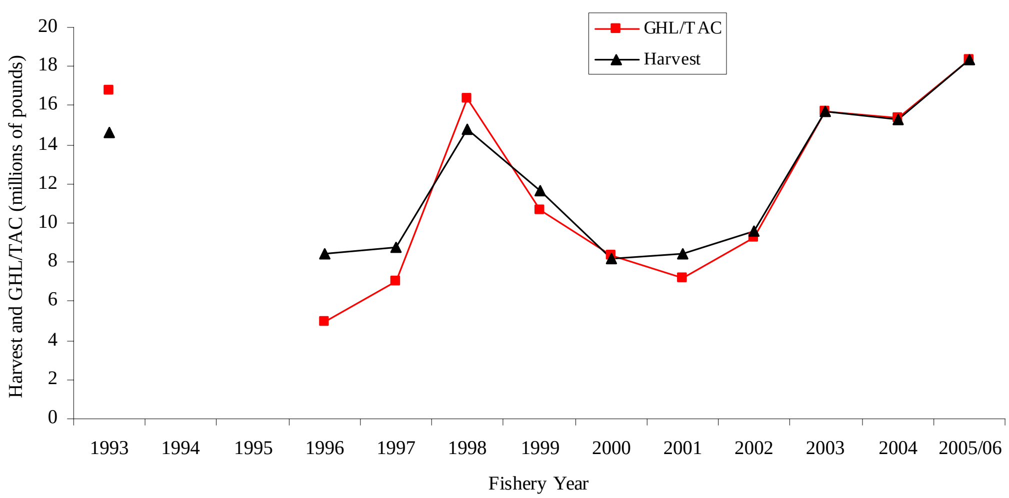


Figure 6. Bristol Bay commercial red king crab general/IFQ and CDQ fishery harvest and guideline harvest levels, 1993-2005/2006.

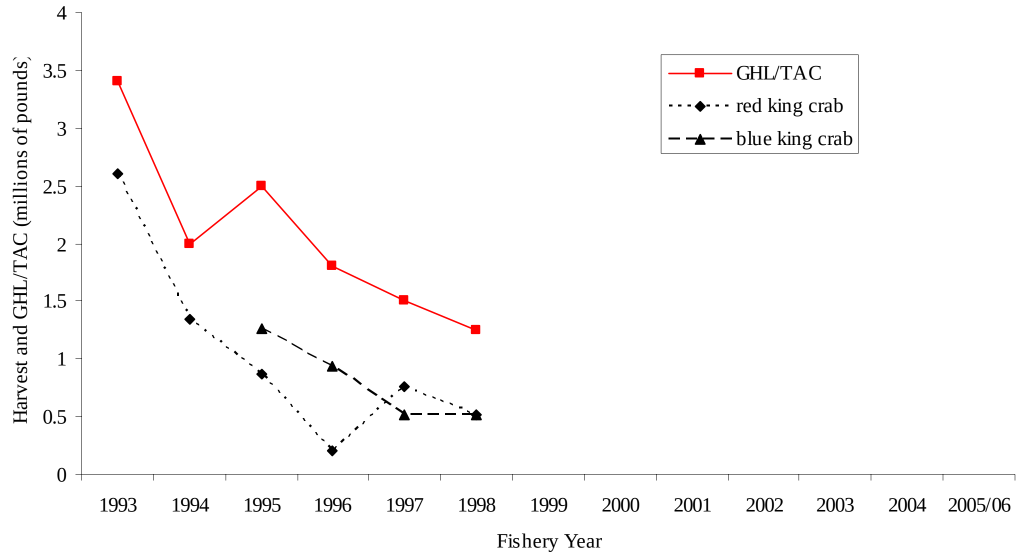


Figure 7. Pribilof District commercial red and blue king crab harvest and guideline harvest levels (GHLs) or total allowable catch (TAC), 1993-2005/2006.

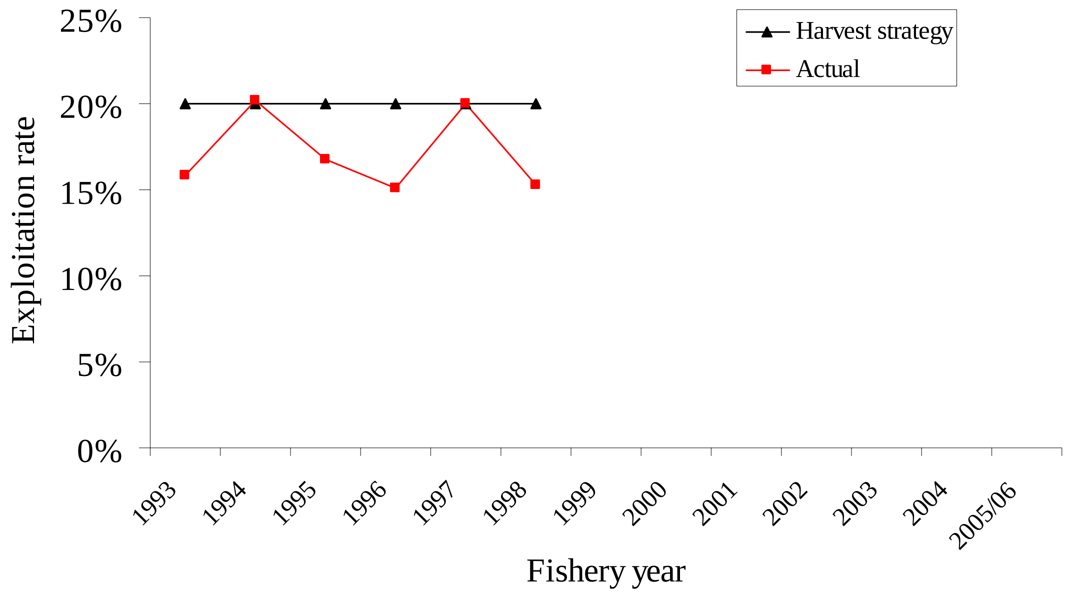


Figure 8. Comparison of harvest strategy specified and actual exploitation rates on mature-sized males (>104-mm carapace length) in the Saint Matthew Island Section commercial blue king crab fishery, 1993-2005/2006.

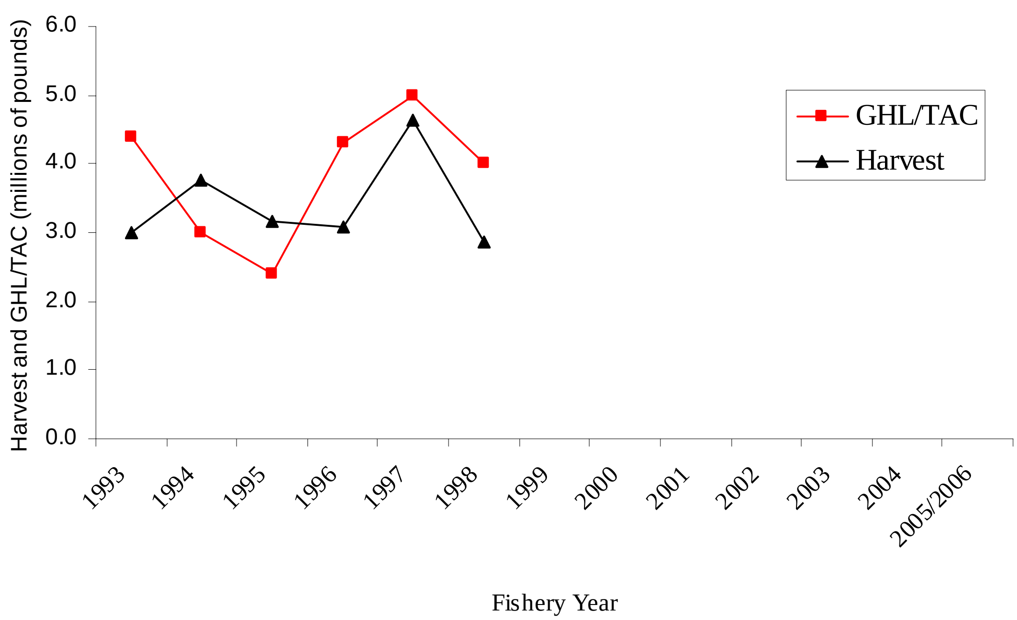


Figure 9. Saint Matthew Island Section commercial blue king crab harvest and guideline harvest levels (GHL) or total allowable catch (TAC), 1993-2005/2006.

BSAI Crab Bycatch

Diana Stram, Doug Pengilly and David Witherell

What is bycatch?

Bycatch of crab occurs in the directed crab pot fisheries and other fisheries, including groundfish and scallop fisheries. In the crab fisheries, crab bycatch includes females of target species, sublegal males of target species, and non-target crab. In all other fisheries, crabs are a prohibited species, so every crab caught incidentally is considered bycatch.

How many crabs are taken as bycatch?

The following tables show the numbers of crab taken as bycatch in these fisheries.

Bycatch of *C. opilio* crabs (numbers of crab) in Bering Sea fisheries, 1995-2005.

Year	Directed crab pot	Groundfish Trawl	Groundfish fixed gear	Scallop dredge	Total
1995	48,734,000	5,165,555	230,233	0	54,129,788
1996	56,570,785	3,643,612	267,395	104,836	60,586,628
1997	75,005,446	5,276,208	554,103	195,345	81,031,102
1998	51,591,453	4,122,648	549,139	232,911	56,496,151
1999	47,093,200	1,544,747	269,778	150,421	49,058,146
2000	5,020,800	2,207,279	270,000	105,602	7,603,681
2001	6,123,100	1,293,143	215,000	68,458	7,699,701
2002	15,823,300	882,967	n/a	70,795	n/a
2003	22,140,336	615,012	86,313	16,206	22,857,867
2004	4,800,043	1,693,101	140,428	3,843	6,637,415
2005[1]	4,530,514	3,292,520	124,171	5,211	7,952,425

Bycatch of St. Matthew blue king crabs (numbers of crab) in Bering Sea fisheries, 1995-2005.

Year	Directed crab pot	Groundfish Trawl	Groundfish fixed gear	Scallop dredge	Total
1995	confidential	2,725	47	0	n/a
1996	1,699,333	168	574	0	1,700,075
1997	confidential	8	187	0	n/a
1998	confidential	0	774	0	n/a
1999	n/a	0	4,983	0	n/a
2000	54,300	0	n/a	0	n/a
2001	1,300	0	n/a	0	n/a
2002	600	n/a	n/a	0	n/a
2003	0	855	1,263	0	2,118
2004	0	1,416	475	0	1,891
2005[2]	0	24	343	0	367

1 This estimate is from the 2005 Pre-rationalized opilio fishery and the 2005/2006 rationalized Bristol Bay red king crab seasons; does not include some bycatch during the 2005/2006 EBS snow and Tanner crab fisheries.
2 Does not include some bycatch in 2005 during the 2005/2006 rationalized EBS snow and Tanner crab fisheries.

Bycatch of Bristol Bay red king crabs (numbers of crab) in Bering Sea fisheries, 1995-2005.

Year	Directed crab pot	Groundfish Trawl	Groundfish fixed gear	Scallop dredge	Total
1995	0	44,934	3,257	0	48,191
1996	605,000	30,967	75,675	0	711,642
1997	985,000	50,711	25,579	0	1,061,290
1998	4,593,800	42,003	7,017	146	
1999	957,800	84,709	8,968	1	1,026,178
2000	1,701,000	70,787	39,754	2	1,653,542
2001	2,419,100	58,552	19,000	0	2,496,652
2002	1,677,800	89,955	27,477	2	1,795,234
2003	5,808,200	91,937	13,531	0	5,913,668
2004	2,470,868	78,742	15,014	0	2,564,624
2005[3]	5,724,919	111,249	19,723	2	5,855,893

Bycatch of *C. bairdi* crabs (numbers of crab) in Bering Sea fisheries, 1995-2005.

Year	Directed crab pot	Groundfish Trawl	Groundfish fixed gear	Scallop dredge	Total
1995	15,897,300	2,212,181	87,674	0	18,197,155
1996	4,588,000	1,836,031	279,560	17,000	6,930,591
1997	4,865,900	1,917,736	50,218	28,000	6,861,854
1998	4,293,800	1,477,816	46,552	36,000	5,854,168
1999	1,995,100	901,619	43,220	n/a	n/a
2000	491,000	1,002,074	140,453	53,614	1,539,141
2001	626,400	950,331	80,000	48,718	1,705,449
2002	1,282,600	1,086,286	98,848	48,053	2,515,787
2003	626,000	897,340	105,094	31,316	1,659,750
2004	334,593	800,794	38,592	15,303	2,849,032
2005[4]	708,290	1,569,613	122,167	15,529	2,415,599

Crab Bycatch Measures in Groundfish Fisheries

Various management measures have been enacted by the Council and the National Marine Fisheries Service over the years to limit the incidental catch of crab species in groundfish fisheries and to protect crab stocks and crab habitat.

Snow Crab Bycatch Limitation Zone

Bycatch limits for snow crab in groundfish trawl fisheries were established under BSAI groundfish FMP amendment 40, which became effective in 1998. Snow crab PSC limits are apportioned among fisheries in anticipation of their bycatch needs for the year. A PSC limit is established for snow crab in a defined

3 From the 2005/2006 rationalized BB red king crab fishery (Oct 15 2005 to January 15 2006) but little or no catch or effort from January 1-15. This does not include any bycatch from the rationalized 2005/2006 Tanner crab fishery.
4 This is from the pre-rationalized opilio fishery and the rationalized 2005/2006 BB re4d king crab fishery. This does not include bycatch during 2005 from the 2005/2006 EBS snow crab or direct3d Tanner crab fishery.

area that fluctuates with abundance except at high and low stock sizes. The PSC cap is established at 0.1133% of the total Bering Sea abundance (as indicated by the NMFS trawl survey), with a minimum PSC of 4.5 million snow crabs and a maximum PSC of 13 million snow crabs. Snow crab taken within the "C. opilio Bycatch Limitation Zone" (COBLZ) accrue towards the PSC limits established for individual trawl fisheries (Figure 1). Upon attainment of a snow crab PSC limit apportioned to a particular trawl target fishery, that fishery is prohibited from fishing within the COBLZ. In 1998 the bycatch limit for snow crab was further reduced by an additional 150,000 crabs as part of amendment 57.

The total snow crab limit in 2005 was established as 4,858,992 crabs. Fisheries in 2005 had the following bycatch (and associated fishery-specific limits) within the COBLZ (data from NMFS Catch Accounting).

Bycatch of EBS snow crabs in the COBLZ in 2005

Fishery	**Limit**	**Total Catch**
Pacific cod	139,331	31,865
Rockfish	44,945	0
Rock sole, flathead sole, other flatfish	1,082,528	197,350
Pollock, Atka Mackerel, other species	80,903	1,623
Yellowfin sole	3,101,915	3,006,557
Greenland turbot, Arrowtooth, Sablefish	44,946	0
Opilio crab PSQ (CDQ fishery)	364,424	7,558
Total	**4,858,992**	**3,244,954**

Under the proposed amendment 80, the current bycatch limits as established by amendment 40 for opilio will be changed. Under the preferred alternative for amendment 80, once annually calculated according to the formula noted above (0.1133% of the total Bering Sea abundance), 61.44% of the cap will be allocated to the head and gut (H&G) sector of the trawl fleet. To accommodate the potential PSC savings the sector will likely enjoy from development of cooperatives, the calculated allocation (61.44%) to the H&G sector will be reduced by 20%, which will be phased in at 5% per year over a four year-period starting in the second year of the program. The remaining sectors of the trawl fleet will be limited to their sideboard amounts. The overall effect of this adjustment (and the limitation by the AFA sector to their sideboards) will be a reduction in the total limit (and overall catch) for snow crab in the COBLZ. Additional information can be found in the EA/RIR/IRFA for Amendment 80.

Red King Crab Savings Area

The Red King Crab Savings Area (162° to 164° W, 56° to 57° N) is closed year-round to non-pelagic trawling (Figure 2). This was enacted under amendment 37 to the BSAI FMP with an effective implementation date of January 1, 1997. The intent of the extended duration of the closure period was to provide for increased protection of adult red king crab and their habitat. To allow some access to productive rock sole fishing areas, the area bounded by 56° to 56°10' N latitude remains pen during years in which a guideline harvest level for Bristol Bay red king crab is established. A separate bycatch limit for this area is established at no more than 35% of the red king crab prohibited species catch (PSC) limits apportioned to the rock sole fishery.

Nearshore Bristol Bay Closure

Nearshore waters of Bristol Bay the area east of 162° W are also closed to all trawling (Figure 3), with the exception of an area bounded by 159° to 160° W and 58° to 58°43' N that remains open to trawling during the period April 1 to June 15 each year. This closure was enacted to protect juvenile red king crab and critical rearing habitat while at the same time allow trawling in an area that can have high catches of flatfish and low bycatch of other species. The area north of 58°43' N was closed to reduce bycatch of herring, and also of halibut, which move into the nearshore area in June.

Crab and Halibut Protection Zone

The crab and halibut protection zone is closed to all trawling from January 1 to December 31 (Figure 4). For the period March 15 to June 15, the western border of the zone extends westward. For practical purposes this closure has been largely superceded by the Nearshore Bristol Bay closure with the exception of the western extension of the closure from March 15 to June 15.

Pribilof Islands Habitat Conservation Area

The Pribilof Islands Habitat Conservation Zone was established under amendment 21a to the BSAI FMP and became effective in January, 1995. All trawling is prohibited from the designated area (Figure 5). The purpose of the closure was to eliminate trawl activities in areas of importance to blue king crab and Korean hair crab stocks, as well as reducing the bycatch of juvenile halibut and crab and mitigate any unobserved mortality or habitat modification that occurred due to trawling. The closure area was selected as it surrounded the area with the highest blue king crab concentration.

Red King Crab PSC limits

Amendment 37 PSC limits for Zone 1 red king crab.

Abundance	PSC Limit
Below threshold or 14.5 million lbs of effective spawning biomass (ESB)	33,000 crabs
Above threshold, but below 55 million lbs of ESB	97,000 crabs
Above 55 million lbs of ESB	197,000 crabs

PSC limits are based on the abundance of Bristol Bay red king crab as shown in the adjacent table. In 1999, red king crab bycatch was reduced by an additional 3,000 crabs. In years when red king crab in Bristol Bay are below threshold of 8.4 million mature crabs, a PSC limit of 35,000 red king crab is established in Zone 1 (Figure 6). In years when the stock is above threshold but below the target rebuilding level of 55 million pounds of effective spawning biomass, a PSC limit of 97,000 red king crab is established. A 197,000 PSC limit is established in years when the Bristol Bay red king crab stock is rebuilt (above threshold and above 55 million pounds of effective spawning biomass). Based on the 2005 estimate of effective spawning biomass (68 million pounds), the PSC limit for 2006 is 197,000 red king crabs. The regulations also specify that up to 35% of the PSC apportioned to the rock sole fishery can be used in the 56º - 56º10'N strip of the Red King Crab Savings Area. The red king crab cap has generally been allocated among the pollock/mackerel/other species, Pacific cod, rock sole, and yellowfin sole fisheries. Once a fishery exceeds its red king crab PSC limit, Zone 1 is closed to that fishery for the remainder of the year, unless further allocated by season.

Bairdi PSC limits

PSC limits are also established for *bairdi* Tanner crab under amendment 41 to the BSAI FMP. These limits are established in Zones 1 and 2 based on total abundance of *bairdi* crab as indicated by the NMFS trawl survey (Figure 6). Based on 2005 abundance (763 million crabs), and an additional reduction implemented in 1999, the PSC limit for *C. bairdi* in 2006 will be 980,000 (1,000,000 minus 20,000) *bairdi* crabs in Zone 1 and 2,970,000 (3,000,000 minus 30,000) crabs in Zone 2.

PSC limits for bairdi Tanner crab.

Zone	Abundance	PSC Limit
Zone 1	0-150 million crabs	0.5% of abundance
	150-270 million crabs	750,000
	270-400 million crabs	850,000
	over 400 million crabs	1,000,000
Zone 2	0-175 million crabs	1.2% of abundance
	175-290 million crabs	2,100,000
	290-400 million crabs	2,550,000
	over 400 million crabs	3,000,000

Do all these crabs die?

Crab Fisheries

Some crabs taken as bycatch die due to handling mortality. Several laboratory and field studies have been conducted to determine mortality caused by handling juvenile and female crab taken in crab fisheries. There are a variety of effects caused by handling, ranging from sublethal (reduced growth rates, molting probabilities, decreased visual acuity from bright lights, and vigor) to lethal effects. Studies have shown a range of mortality due to handling based on gear type, species, molting stage, number of times handled, temperature, and exposure time (Murphy and Kruse 1995). Handling mortality may have contributed to what has been attributed to high natural mortality levels observed for Bristol Bay red king crab in the early 1980’s (65% for males and 82% for females), that along with high harvest rates, may have resulted in stock collapse (Zheng et al. 1995). However, another study concluded that handling mortality from deck impacts and temperature was not responsible for the decline on the red king crab fishery (Zhou and Shirley 1995, 1996).

Byersdorfer and Watson (1992, 1993) examined red king crab and Tanner crab taken as bycatch during the 1991 and 1992 red king crab test fisheries. Instantaneous handling mortality of red king crab was <1% in 1991, and 11.2% in 1992. Stevens and MacIntosh (1993) found average overall mortality of 5.2% for red king crabs and 11% for Tanner crabs on one commercial crab vessel. Authors recommend these results be viewed with caution, noting that experimental conditions were conservative; mortality in the fishery might be higher. Mortality for red king crab held 48 hours was 8% (Stevens and MacIntosh 1993, as cited in Queirolo et al. 1995). A laboratory study that examined the effects of multiple handling indicated that mortality of discarded red king crabs was negligible (2%), although body damage increased with handling (Zhou and Shirley 1995).

Delayed mortality due to handling does not appear to be influenced by method of release. In an experiment during a test fishery, red king crab thrown off the deck while the vessel was moving versus those gently placed back into the ocean had no differences in tag return rates (Watson and Pengilly 1994). Handling methods on mortality have been shown to be non-significant in laboratory experiments with red king crab (Zhou and Shirley 1995, 1996) and Tanner crab (MacIntosh et al. 1996). Although handling did not cause mortality, injury rates were directly related to the number of times handled.

Mortality of crabs is also related to time out of water and air temperature. A study of red king crabs and Tanner crabs found that crabs exposed to air exhibited reduced vigor and righting times, feeding rates (Tanner crabs), and growth (red king crabs) (Carls and O'Clair 1989). For surviving females, there was no impact on survival of eggs or larvae. Cold air resulted in leg loss or immediate mortality for Tanner crabs, whereas red king crabs exhibited delayed mortality that occurred during molting. A relationship was developed to predict mortality as the product of temperature and duration of exposure (measured as degree hours). Median lethal exposure was -8oC for red king crab and -4.3oC for Tanner crab. For example, if crabs were held on deck for 10 minutes and it was -23oC (10 degrees below zero Fahrenheit) outside, about 15% of the king crab and 50% of the Tanner crab would die of exposure. Because BSAI crab fisheries occur from November through March, cold exposure could cause significant handling mortality to crabs not immediately returned to the ocean. Zhou and Shirley (1995) observed that average time on deck was generally 2 to 3 minutes, and they concluded that handling mortality was not a significant source of mortality for red king crab.

Further research has indicated that windchill may be an important mortality factor. In 1997, a laboratory study examined the effects of cold windchill temperature on mortality, limb loss, and activity (righting response) for sublegal sized male Tanner crabs (Zhou and Kruse, 1998, Shirley 1998). The study found significant inverse relationships between windchill and crab mortality, limb loss, and activity. Crabs were exposed to combinations of temperatures and wind speeds for duration of 5 minutes, then placed in seawater tanks and held for 7 days. Zhou and Kruse (1998) found that virtually all crabs died when exposed to windspeeds greater than 7.7 m/s (15 nautical miles per hour) and air temperatures less than -10.4ºC (13.3oF). Stronger winds, even at warmer temperatures (but still below freezing), can have the same effect. Shirley (1998) reported that 50% of the Tanner crabs died in windchill temperatures of -11ºC (this windchill temperature can result from air temperatures of 21ºF and wind speeds of 30 nautical miles per hour). He concluded that "The effects of windchill on sublegal Tanner crabs is dramatic, and undoubtedly results in decreased recruitment to adult stocks".

Laboratory experiments found that snow crabs were more sensitive than either Tanner crabs (Shirley 1998) or red king crabs (Shirley 1999) and experienced 100% to 40% mortality within 7 days after exposure to windchill values from -16ºC to -10ºC (Warrenchuk and Shirley, 2002a). Snow crab males were exposed to wind speeds from 8 to 16 m/s and air temperatures from -2 to -10ºC for 5 minutes (corresponding to 16 to 32 mph and 28 to 14ºF, respectively). Reducing exposure time to 2.5 minutes significantly reduced mortality. Limb loss was variable, but pronounced at windchill values below -10ºC. Coordination of crabs (measured as an ability to right themselves) was impaired after all but the least severe treatment; concern for the crabs ability to avoid predation after exposure is warranted (Warrenchuk 2001; Warrenchuk and Shirley, 2002a). Warrenchuk and Shirley (2002b) applied the results from their laboratory study on the effects of windchill on snow crab mortality (Warrenchuk and Shirley 2002a) to estimate the mortality of snow crabs that were discarded during the 1998 EBS snow crab fishery. Mortality of non-retained snow crab during the 1998 fishery was estimated to be from 3.6% (windchill model) to 19.6% (temperature/windspeed model) (Warrenchuk and Shirley 2002b).

Although cold temperatures and windchill clearly have been shown to effect mortality, limb loss, and impaired righting response in snow and Tanner crabs, it remains uncertain how well experimental conditions used to estimate effects of wind chill reflect the exposure to discarded crabs during actual fishing conditions. For example, features of fishing vessels and fishing practices (e.g., shelter decks, storm walls, use of totes, and leeward alignment of vessels during gear retrieval) may provide some protection to captured and sorted crabs from windchill exposure. Additionally, observer data collected during the 1998 and 1999 snow crab seasons indicate that sorted bycatch typically is returned to the sea in less time than the 5 minutes that crabs were exposed to windchill during the laboratory study (Tracy and Byersdorfer 2000, Byersdorfer and Barnard 2002). Observers randomly chose pots fished during the 1998 general fishery, the 1998 CDQ season, the 1999 general fishery, and the 1999 CDQ fishery and recorded the maximum exposure time (i.e., the time from when a pot was lifted from the water until when the last non-retained crab in the pot was returned to the sea) from each pot. The means of the maximum exposure times were: 4.4 minutes for 1998 general fishery (n=1,548 pots; Tracy and Byersdorfer 2000), 6.1 minutes for the 1998 CDQ fishery (n=1,104 pots; Tracy and Byersdorfer 2000), 3.7 minutes for the 1999 general fishery (n=677 pots; Byersdorfer and Barnard 2002), and 5.1 minutes for the 1999 CDQ fishery (n=406 pots; Byersdorfer and Barnard 2002). Byersdorfer and Barnard (2002) noted that the mean maximum exposure times were influenced by outlying values and that the median of the maximum exposure times for the 1999 general fishery was 2.9 minutes and for the 1999 CDQ fishery was 3.8 minutes. It is also notable that deadloss during historic snow crab fisheries has been low, ranging from 0.7% to 2.0% of the total annually delivered crabs during the 1990 through 1998 seasons. Snow crabs delivered to processors during the 1990-1998 seasons were typically held in vessel holding tanks for one to three weeks prior to delivery (R. Morrison, ADF&G-retired, *pers. comm*.); i.e., for as long as or longer than the time that mortality due to windchill was exhibited in the laboratory studies on snow crabs (Warrenchuck and Shirley 2002a) and Tanner crabs (Shirley 1998). The applicability of deadloss rates to mortality rates in discarded crabs due to windchill exposure may be questionable, however, due to differences in exposure times between retained and non-retained crabs. Data collected from fishing vessels during the 1998 and 1999 seasons indicate that crew on 50-60% of vessels prioritize retrieving retainable crabs from pots before removing and discarding bycatch crabs Tracy and Byersdorfer 2000, Byersdorfer and Barnard 2002); on the remainder vessels release of bycatch crabs was either prioritized or there was no clear priority for either bycatch or retained crabs. Also, non-retained crabs are smaller and may lose heat quicker than retained crabs. Smaller crabs have a greater surface area to volume ratio and less thermal mass (Shirley 1999). Smaller juvenile Tanner crabs were more sensitive to cold aerial exposure than larger adults (Carls and O'Clair 1995) and adult Tanner crabs were more sensitive to exposure and windchill than larger red king crabs (Carls and O'Clair 1990; Shirley 1999).

In summary, the actual rates of mortality to captured crabs discarded during crab fisheries remains unknown. Deadloss rates in deliveries cannot be considered applicable because of differences between the treatment of retained and non-retained crabs. Retained crabs are dropped only a short distance directly into the holding tanks, while non-retained crabs may be thrown over the side of the vessel or swept along the deck into scuppers, which results in rougher and more prolonged handling. Additionally, mortality due to capture and discarding may not be exhibited under the conditions of a holding tank or within the time that crabs are held in tanks prior to delivery. The Crab Plan Team has estimated bycatch mortality to be higher in the snow and Tanner crab fisheries (24% and 20%, respectively) than in the king crab fisheries (8%) and that has been supported by higher incidence of pre-discard injuries during the snow crab fishery than in the red king crab fishery (Tracy and Byersdorfer 2000, Byersdorfer and Barnard 2002). Warrenchuck and Shirley (2002) estimated the bycatch mortality rate for crabs discarded during the 1998 EBS snow crab fishery to be 22.2%, which they considered to be in agreement with the rate of 25% assumed in analyses for the EBS snow crab rebuilding plan (NPFMC 2000). Given the uncertainty in true bycatch mortality rates and the sensitivity of conservation considerations to bycatch mortality rates, the Crab Plan Team's Working Group on overfishing definitions is currently (September 2005) assuming bycatch mortality rates of 20% for the red king crab fishery and 50% for the snow crab fishery.

Trawl Fisheries

The effect of crab bycatch on crab stocks is somewhat tempered by survival of discarded crabs. There have been numerous studies conducted on crab bycatch mortality, with each study having different objectives, methodology, and results. A summary of these studies is provided below, but many questions remain unanswered. Stevens (1990) found that 21% of the king crabs and 22% of the Tanner crabs captured incidentally in BSAI trawl fisheries survived at least 2 days following capture. Blackburn and Schmidt (1988) made observations on instantaneous mortality of crab taken by domestic trawl fisheries in the Kodiak area. They found acute mortality for softshell red king crab averaged 21%, hard shelled red king crab 1.2%, and 12.6% for Tanner crab. Another trawl study indicated that trawl induced mortalities aboard ship were 12% for Tanner crab and 19% for red king crab (Owen 1988). Fukuhara and Worlund (1973) observed an overall Tanner crab mortality of 60-70% in the foreign Bering Sea trawl fisheries. They also noted that mortality was higher in the summer (95%) than in the spring (50%). Hayes (1973) found that mortality of Tanner crab captured by trawl gear was due to time out of water, with 50% mortality after 12 hours. Natural Resource Consultants (1988) reported that overall survival of red king crab and Tanner crab bycaught and held in circulation tanks for 24-48 hours was <22%. In other analyses, the estimated mortality rate of trawl bycaught red king crab and Tanner crab was 80% (NPFMC 1993, 1995).

Other Groundfish Fisheries

Some crabs are caught incidentally by non-trawl gear in pursuit of groundfish, and a portion of these crabs die. No field or laboratory studies have been made to estimate mortality of crab discarded in these fisheries. However, based on condition factor information from the trawl survey, mortality of crab bycatch has been estimated and used in previous analyses (NPFMC 1993). Discard mortality rates for red king crab were estimated at 37% in longline fisheries and 37% in pot fisheries. Estimated bycatch mortality rates for Tanner crab were 45% in longline fisheries and 30% in pot fisheries. No observations had been made for snow crab, but mortality rates are likely similar to Tanner crab. In the analysis made for Amendment 37, a 37% mortality rate was assumed for red king crab taken in longline fisheries and an 8% rate for pot fisheries. Observer data on condition factors collected for crab during the 1991 domestic fisheries suggested lower mortality of red king crab taken in groundfish pot fisheries. Bycatch mortality rates used in the analysis of Amendment 37 (NPFMC 1996) for snow crabs were 45% in longline fisheries and 30% in pot fisheries.

Scallop Fishery

Observations from scallop fisheries across the state suggest that mortality of crab bycatch is low relative to trawl gear due to shorter tow times, shorter exposure times, and lower catch weight and volume. For crab taken as bycatch in the Gulf of Alaska weathervane scallop fishery, Hennick (1973) estimated that about 30% of Tanner crabs and 42% of the red king crabs bycaught in scallop dredges were killed or injured. Hammerstrom and Merrit (1985) estimated mortality of Tanner crab at 8% in Cook Inlet. Kaiser (1986) estimated mortality rates of 19% for Tanner crab and 48% for red king crab bycaught off Kodiak Island. Urban el al. (1994) reported that in 1992, 13%-35% of the Tanner crab bycaught were dead or moribund before being discarded, with the highest mortality rate occurring on small (<40 mm cw) and large (>120 mm cw) crabs. Delayed mortality resulting from injury or stress was not estimated. Mortality in the Bering Sea appears to be lower than in the Gulf of Alaska, in part due to different sizes of crab taken. Observations from the 1993 Bering Sea scallop fishery indicated lower bycatch mortality of red king crab (10%), Tanner crab (11%) and snow crab (19%). As with observations from the Gulf of

Alaska, mortality appeared to be related to size, with larger and smaller crabs having higher mortality rates on average than mid-sized crabs (D. Pengilly, ADF&G, unpublished data). Immediate mortality of Tanner crabs from the 1996 Bering Sea scallop fishery was 12.6% (Barnhart and Sagalkin 1998). Delayed mortality was not estimated. In the analysis made for Amendment 41, a 40% discard mortality rate (immediate and delayed mortality combined) was assumed for all crab species.

What are the population impacts of bycatch?

By applying mortality rates estimated from scientific observations to the number of crabs taken as bycatch, it is possible to estimate the relative impacts of bycatch on crab populations. Discard mortality rates have been established in previous analysis (NPFMC 1999), and may be species or fishery specific. Bycatch mortality rates in trawl, dredge, and fixed gear fisheries for all crab species were set at 80%, 40%, and 20% respectively. For crab fisheries, mortality rates were averaged across different fisheries. Rates used were 24% for *C. opilio*, 20% for *C. bairdi*, and 8% for blue king crab and red king crab. The following tables show the resulting discard mortality estimates, the estimated population size based on the NMFS trawl survey, and the percentage of the population removed due to bycatch mortality.

Total bycatch (numbers) mortality of red king crab in all fisheries in the Bristol Bay area, 1995-2004, and current years survey abundance estimate

Year	Total Bycatch	Bycatch mortality	Abundance (millions)	Mortality (as % of population)
1995	48,191	35,599	33.9	0.11
1996	711,642	88,309	53.3	0.17
1997	1,061,290	124,485	75.1	0.17
1998	4,642,966	402,568	75.6	0.52
1999	1,026,178	144,161	46.7	0.22
2000	1,653,542	200,661	50.0	0.40
2001	2,496,652	244,169	44.2	0.55
2002	1,795,234	206,188	78.3	0.26
2003	5,913,668	538,205	84.1	0.64
2004	2,564,624	263,666	104.8	0.25
2005	5,855,893	550,938	75.9	0.73

Total bycatch (numbers) mortality of blue king crab in all fisheries in the St. Matthew area, 1995-2004, and current years survey abundance estimate.

Year	Total Bycatch	Bycatch mortality	Abundance (millions)	Mortality (as % of population)
1995	n/a	conf	5.6	*
1996	1,700,075	136,196	10.0	1.36
1997	n/a	conf	10.0	*
1998	n/a	conf	8.4	*
1999	n/a	997	1.7	0.06
2000	n/a	n/a	1.7	*
2001	n/a	n/a	2.9	*
2002	n/a	48	1.2	0.001
2003	2,118	0	3.3	0
2004	1,891	1,228	2.7	0.045
2005	367	89	4.5	0.002

Total bycatch (numbers) mortality of Bairdi Tanner crab in all fisheries in the St. Matthew area, 1995-2004, and current years survey abundance estimate.

Year	Total Bycatch	Bycatch mortality	Abundance (millions)	Mortality (as % of population)
1995	18,197,155	4,966,740	189.9	2.62
1996	6,930,591	2,449,137	175.6	1.39
1999	6,861,854	2,528,612	159.0	1.59
1998	5,854,168	2,064,723	156.5	1.32
1999	n/a	n/a	349.5	*
2000	1,539,141	949,394	219.2	0.43
2001	1,705,449	921,032	600.1	0.15
2002	2,515,787	1,125,549	437.6	0.26
2003	1,659,750	843,072	448.1	0.19
2004	2,849,032	731,035	571.7	0.13
2005	2,415,599	1,427,993	866.3	0.16

Total bycatch mortality (numbers) of *C. opilio* in all fisheries in the Bering Sea, 1995-2004, and current years survey abundance estimate

Year	Total Bycatch	Bycatch mortality	Abundance (millions)	Mortality (as % of population)
1995	54,129,788	15,874,651	8,655.3	0.18
1996	60,586,628	16,587,291	5,424.9	0.31
1997	81,031,102	22,411,232	4,107.5	0.55
1998	56,496,151	15,883,059	3,233.3	0.49
1999	49,058,146	11,349,869	1,401.0	0.81
2000	7,603,681	3,067,056	3,241.2	0.09
2001	7,699,701	2,589,299	3,861.3	0.07
2002	n/a	4,503,965	1,517.7	0.30
2003	22,857,867	5,805,709	2,630.8	0.22
2004	6,637,415	2,531,803	4,420.7	0.06
2005	7,952,425	3,748,265	3,254.5	0.12

What about unobserved mortality?

In addition to those crabs that are captured as bycatch, fishing activities can also cause crab mortality in ways that cannot be directly observed. A summary of these potential unobserved mortalities are discussed below.

Crab Fishery

Catching mortality is ascribed to those crabs that enter a pot and are eaten by other pot inhabitants before the pot is retrieved. Catching mortality likely occurs during the molting period, when crabs are more susceptible to cannibalism. Most crab fisheries are set to occur outside of the molting season, and catching mortality in these fisheries may be limited to octopus or large fish entering a pot. Because no evidence of crab is left in the pot, these mortalities remain unassessed.

Mortality is also caused by ghost fishing of lost crab pots and groundfish pots. Ghost fishing is the term used to describe continued fishing by lost or derelict gear. The impact of ghost fishing on crab stocks remains unknown. It has been estimated that 10% to 20% of crab pots are lost each year (Meyer 1971, Kruse and Kimker 1993). Based on skipper interviews, about 10,000 pots were estimated lost in the 1992 Bristol Bay red king, and Bering Sea Tanner and snow crab fisheries (Tracy 1994). Fewer pots are expected to be lost under pot limit regulations and shorter seasons. Bob Schofield, a major crab pot manufacturer, testified at the January 1996 Council meeting that he was making fewer pots since inception of the pot limit. He estimated that 6,461 pots were replaced in 1995. It is not known how long lost pots may persist and continue to fish, or just litter the bottom.

A sonar survey of inner Chiniak Bay (Kodiak, Alaska) found a high density of lost crab pots (190 pots) in an area of about 4.5 km2 (Vining et al. 1997). Underwater observations indicated that crabs and fish were common residents of crab pots, whether or not the pot mesh was intact. Intact pots recovered from the Chiniak Bay study area often contained crabs (primarily Tanner crabs) and octopus. High (1985) and High and Worlund (1979) observed that 20% of legal sized male red king crab and 8% of the sublegals captured by lost pots failed to escape.

Crabs captured in lost pots may die of starvation or by predation. Captured crab are subject to cannibalism (Paul et al. 1993), and predation by octopus, halibut and Pacific cod (High 1976). Crabs may have limited abilities to withstand starvation. In a simulated field study, 39% mortality of Tanner crabs was observed after 119 days of starvation (Kimker 1994). In a laboratory study, 10% of the Tanner crabs tested died of starvation in 90 days. Of the 90% that had survived 90 days, all later died even though they were freely fed (Paul et al. 1993). However, highest survival rates for juvenile king crabs fed a variety of diets were from those treatments recieving no food, even for extended period of 3 to 4 months (Shirley, unpublished data). To reduce starvation mortality in lost pots, crab pots have been required to be fitted with degradable escape mechanisms. Regulations required #120 cotton thread from 1977-1993. Beginning in 1993, regulations required #30 cotton thread or 30-day galvanic timed release mechanisms. A #30 cotton thread section is also required in groundfish pots. The average time for #30 cotton twine to degrade is 89 days, and the galvanic timed release about 30 days to degrade. Pots fitted with an escape mechanism of #72 cotton twine had a fishable life of 3-8 years and documented retention of up to 100 crabs per lost pot (Meyer 1971). High and Wolund (1979) estimated an effective fishing life of 15 years for king crab pots. Pots without escape mechanisms could continue to catch and kill crabs for many years, however testimony from crabbers and pot manufacturers indicate that all pots currently fished in Bering Sea crab fisheries contain escape mechanisms.

Mortality of crab caused by ghost fishing is difficult to estimate with precision given existing information. Mortality caused by continuous fishing of lost pots has not been estimated, but unbaited crab pots continue to catch crabs (Breen 1987, Meyer 1971), and pots are subject to rebaiting due to capture of Pacific cod, halibut, sablefish, and flatfish. In addition to mortality of trapped crab by ghost pots, and predation by octopus and fish, pot mesh itself can kill crabs. Lost pots retrieved by NMFS trawl surveys occasionally contain dead crabs trapped in loose webbing (Brad Stevens, NMFS, pers. comm). Pot limits and escape mechanisms may have greatly minimized ghost fishing due to pot loss in recent years.

Another very minor source of human induced crab mortality is direct gear impacts. Direct gear impacts result from a pot landing on the ocean floor when it is being set, presumably damaging any crab on which it lands. With reasonable assumptions, direct gear impacts are only a very minor source of mortality, however. An estimate of this impact can be derived by multiplying the number of pot lifts, the area they occupy, and relative crab density within areas fished in the Bering Sea. Assuming that pots land on different areas after each lift, and crab pots are set non-randomly over areas with relatively high density of crabs in directed fisheries, the total number of crab impacted can be roughly estimated. For 1993 the red king crab fishery, assuming a density of 5,000 red king crab of all sizes per square mile (density data from Stevens et al. 1998), a maximum of about two thousand red king crab were impacted (NPFMC 1996). Similarly, a maximum of 9,000 Tanner crabs (assuming 10,000 crab/mile2) and 110 thousand snow crabs (assuming 75,000 crab/mile2) were impacted by direct gear impacts in respective crab fisheries in 1993. It is not known what proportion of these crab die when a crab pot lands on them.

Trawl Gear

Not all crabs in the path of a trawl are captured. Some crab pass under the gear, or pass through the trawl meshes. Non-retained crabs may be subject to mortality from contact with trawl doors, bridles, footrope, or trawl mesh, as well as exposure to silt clouds produced by trawl and dredge gear. Only a few studies have been conducted to estimate catchability of crabs by trawl gear, and these studies are summarized below.

In one experiment to measure non-observable mortality, 169 red king crabs were tethered in the path of an Aleutian combination trawl (Donaldson 1990). The trawl was equipped with a footrope constructed of 14 inch bobbins spaced every 3 feet, separated by 6.5 inch discs. Thirty-six crabs (21.3%) were recovered onboard the vessel in the trawl. Divers recovered 46.2% of the crabs not captured by the trawl. Another 32.5% were not recovered but assumed to have interacted with the trawl. Of the 78 crabs not retained in the trawl, but captured by divers, only 2.6% were injured. If all injured crabs die, the non-observable mortality rate for trawl gear on red king crabs is estimated at 2.6% (Donaldson 1990). It should be noted that hard shelled crabs were used in this experiment; higher impacts would be expected if softshelled crabs were tested. Additionally, some areas have had higher intensity of bottom trawling than other areas, thus potentially exposing some crabs to multiple interactions with trawl gear.

In 1995, NMFS used underwater video cameras to observe the interaction of trawl gear with king and Tanner crabs (Craig Rose, NMFS, unpublished data). The experiment was conducted in Bristol Bay in an area with large red king crabs and Tanner crabs. Three types of trawl footropes were examined and they are as follows: a footrope with 3-4 foot lengths of 6” discs separated by 10” discs (called disc gear), a footrope with 24” rollers (tire gear), and an experimental float/chain footrope with the groundgear suspended about 8” off the seafloor. For disc gear, preliminary analysis indicated that all red king crab encountered entered the trawl and about 76% of the Tanner crabs were caught. Tire gear captured fewer king crabs (42%) and Tanner crabs (1%). The float/chain gear did not catch any of the crabs encountered. At the December 1995 Council meeting, excerpts of the NMFS video were shown to the Council and public. Trawl industry representatives testified that groundgear used to harvest finfish in this area depended on target species and bottom type, with tire gear type footropes used in hard bottom areas, and disc type gear used on smooth bottom areas. Testimony also indicated that variability existed in groundgear used among vessels, but that on average, most gear used in Bristol Bay trawl fisheries would be comprised of groundgear with discs or rollers larger than the disc gear tested and smaller than the tire gear tested.

The NMFS underwater video observations were further analyzed to determine the proportion of red king crab that were injured by passage under bottom trawl footropes (Rose 1999). Injury rates of 5% to 10% were estimated for crabs that encountered, but were not captured, in the center section of the trawl.

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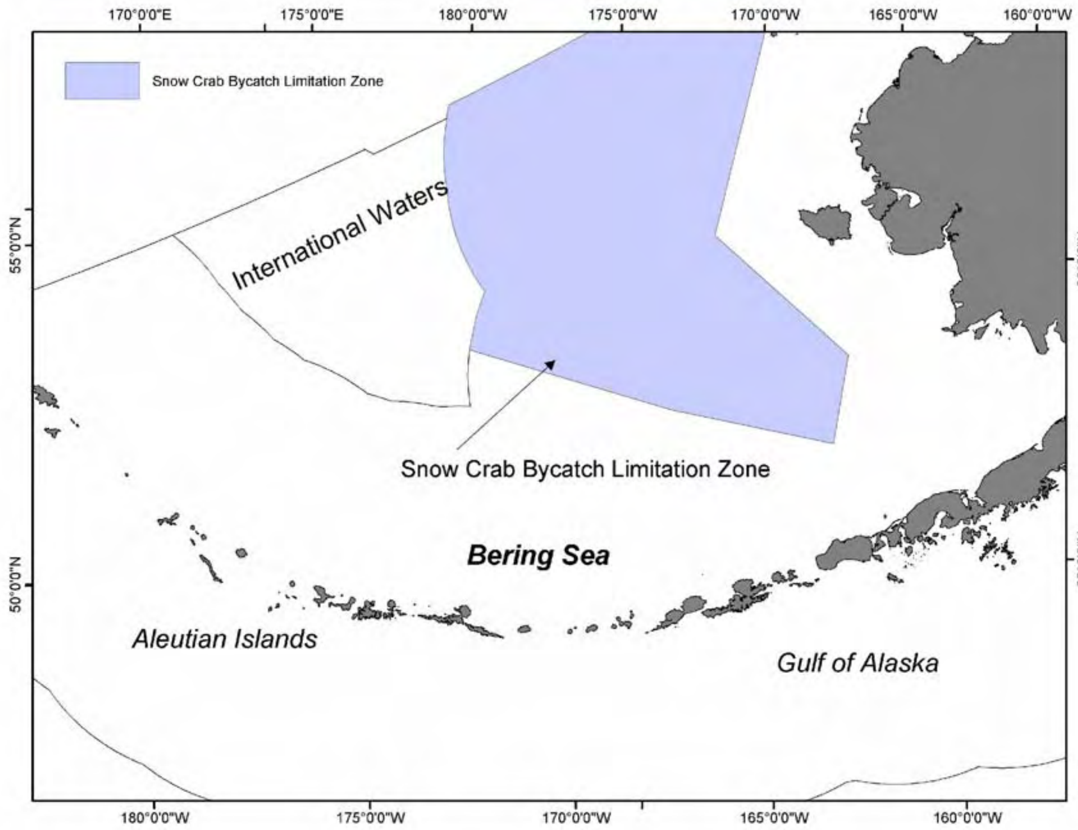

Figure 1. *Chionoecetes opilio* Bycatch Limitation Zone

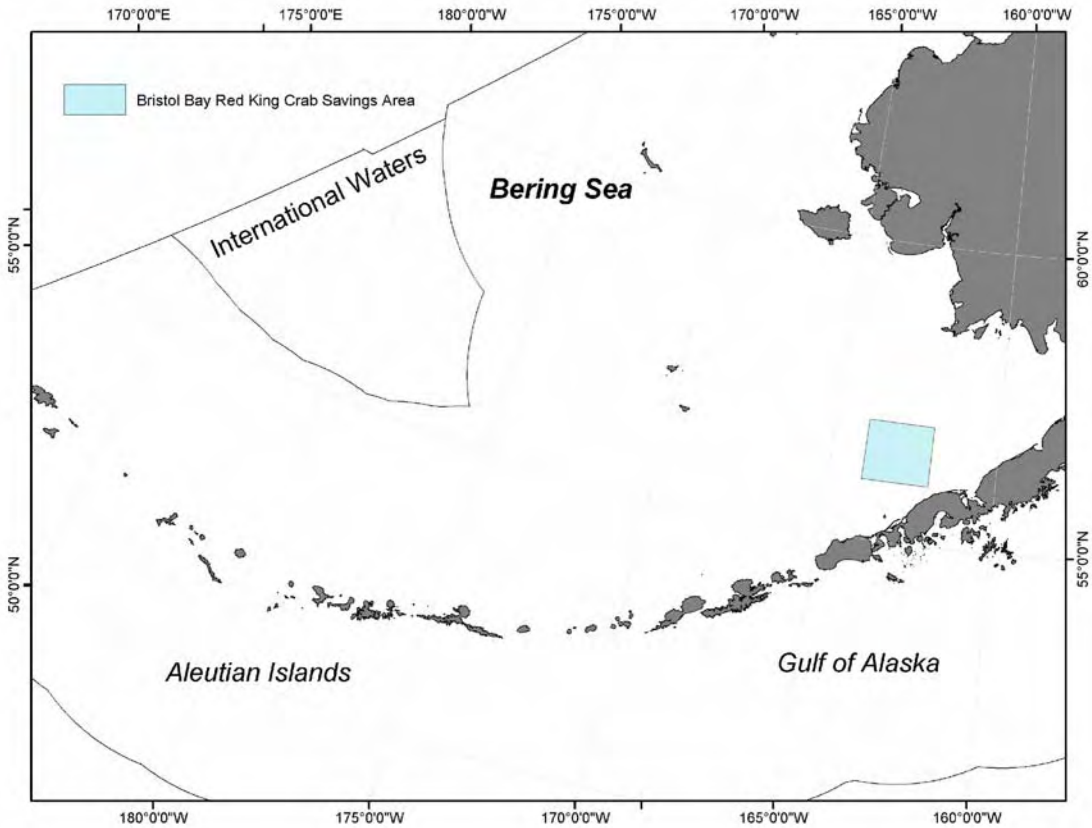

Figure 2. Red King Crab Savings Area

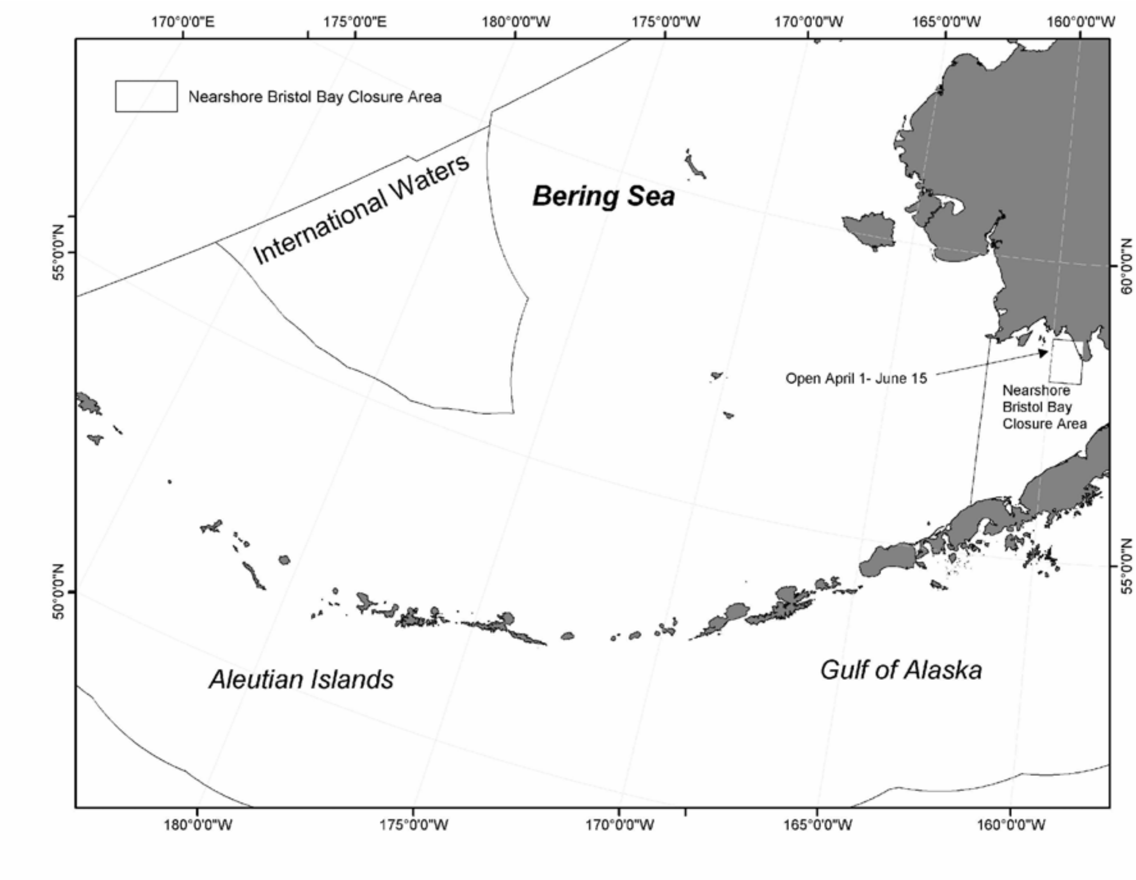

Figure 3 Nearshore Bristol Bay Closure

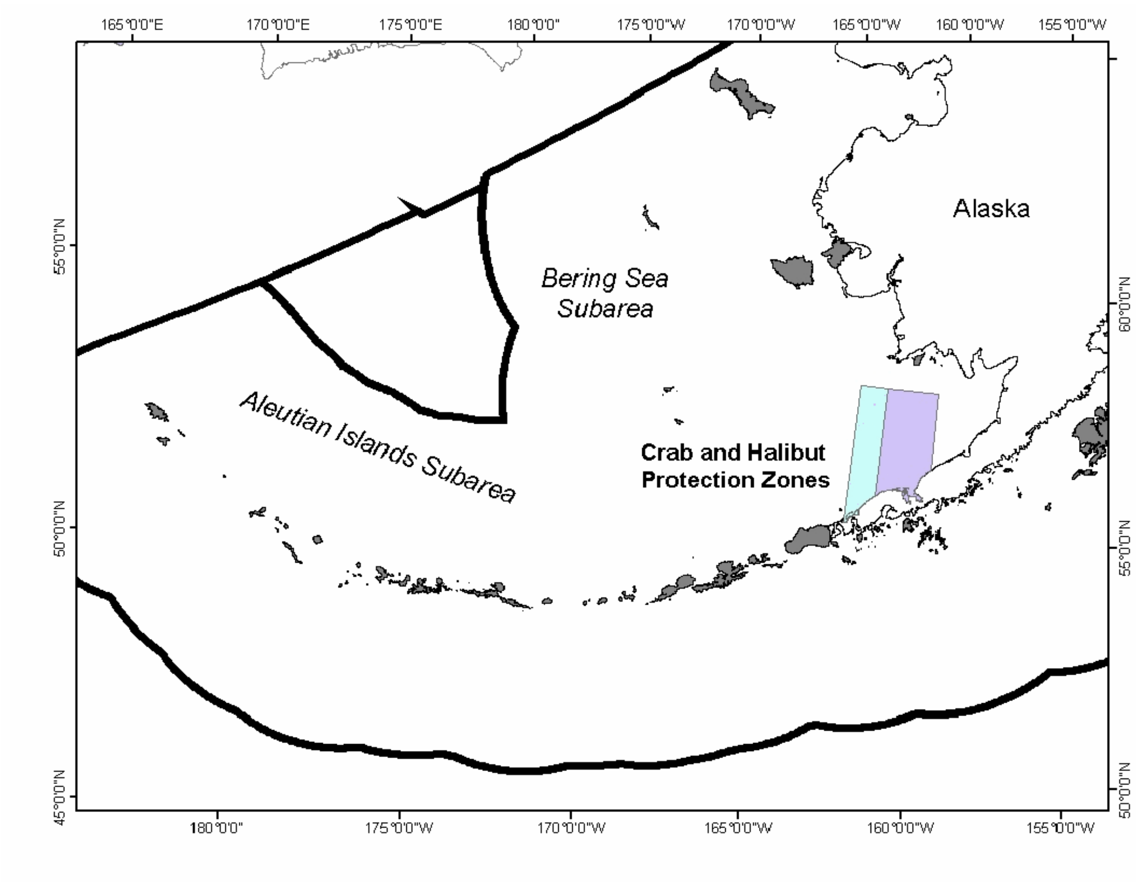

Figure 4. Crab and Halibut Protection Zones

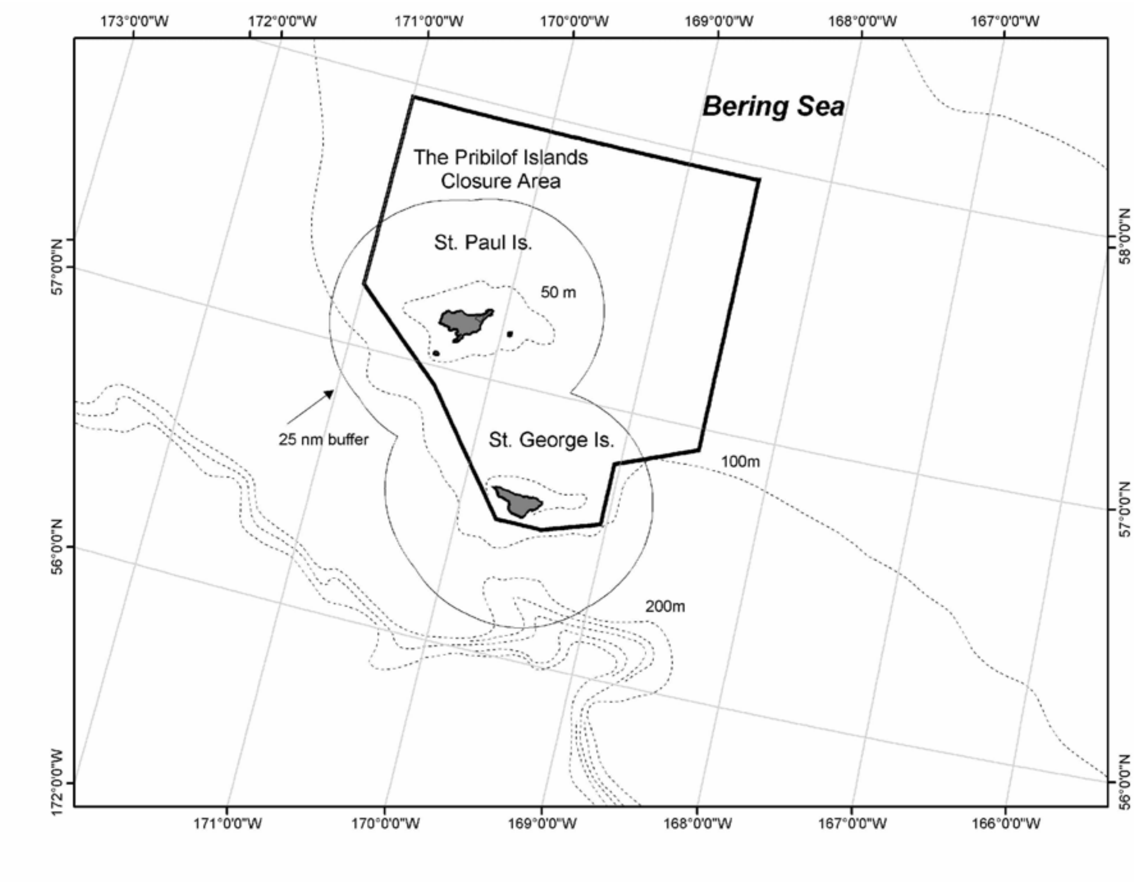

Figure 5. Pribilof Islands Habitat Conservation Zone

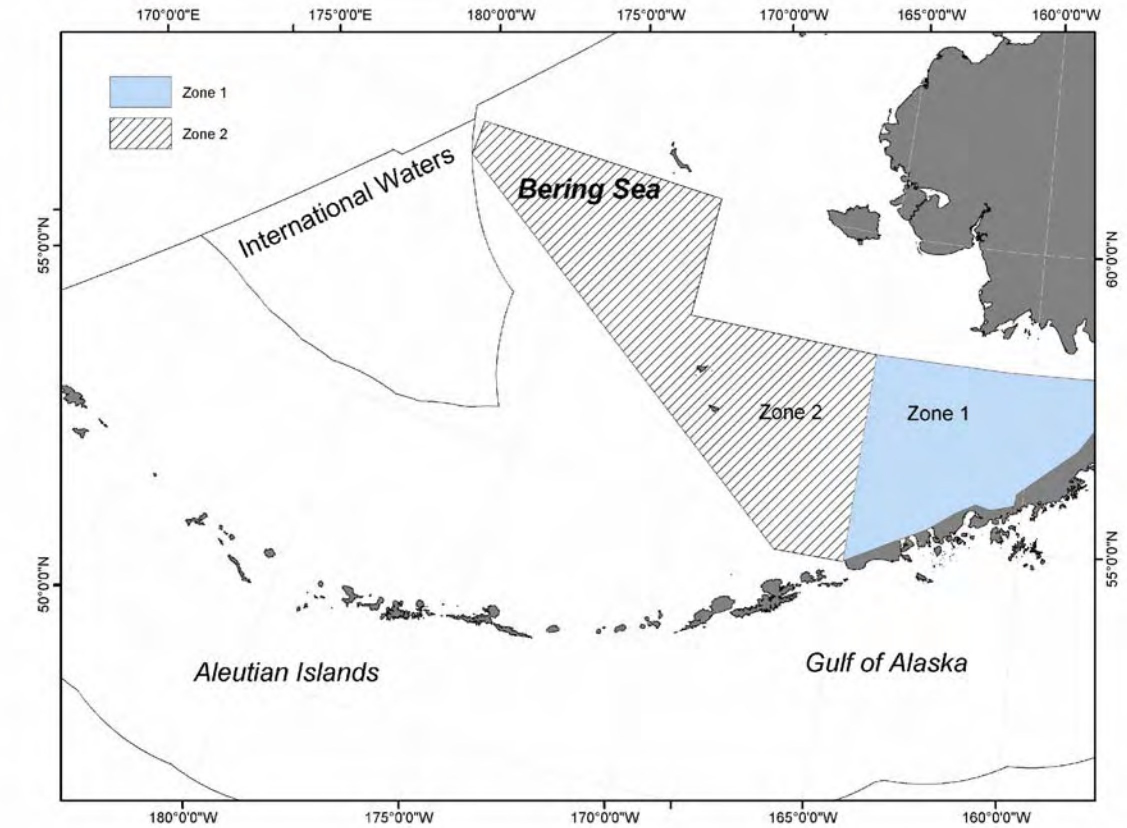

Figure 6. Zones 1 and 2 for PSC limits for red king crab and Tanner crab

Draft commercial fishery data tables for crab stocks included in the Fishery Management Plan for Bering Sea/Aleutian Islands king and Tanner crabs

Note: The following tables will be included in the Annual Management report for Bering Sea/Aleutian Islands king and Tanner crab that is prepared by ADF&G. The full report will be available in November 2006.

Table 2-1.-Bristol Bay commercial red king crab fishery harvest data, 1966-2005.

	Number of				Number of Pots			
Year	Vessels[d]	Landings	Crabs[a]	Harvest[a,b]	Registered	Pulled	CPUE[c]	Deadloss[b]
1966	9	15	140,554	997,321	NA	2,720	52	NA
1967	20	61	397,307	3,102,443	NA	10,621	37	NA
1968	59	261	1,278,592	8,686,546	NA	47,496	27	NA
1969	65	377	1,749,022	10,403,283	NA	98,426	18	NA
1970	51	309	1,682,591	8,559,178	NA	96,658	17	NA
1971	52	394	2,404,681	12,955,776	NA	118,522	20	NA
1972	64	611	3,994,356	21,744,924	NA	205,045	19	NA
1973	67	441	4,825,963	26,913,636	NA	194,095	25	NA
1974	104	605	7,710,317	42,266,274	NA	212,915	36	NA
1975	102	592	8,745,294	51,326,259	NA	205,096	43	1,639,483
1976	141	984	10,603,367	63,919,728	NA	321,010	33	875,327
1977	130	1,020	11,733,101	69,967,868	NA	451,273	26	730,279
1978	162	926	14,745,709	87,618,320	NA	406,165	36	1,273,037
1979	236	889	16,808,605	107,828,057	NA	315,226	53	3,555,891
1980	236	1,251	20,845,350	129,948,463	78,352	567,292	37	1,858,668
1981	177	1,013	5,273,530	33,372,832	75,756	536,646	10	706,489
1982	89	253	538,925	2,990,082	36,166	140,492	4	95,834
1983				FISHERY CLOSED				
1984	89	133	793,046	4,083,612	21,762	107,406	7	35,101
1985	128	130	780,791	4,090,305	30,117	84,443	9	6,436
1986	159	229	2,083,496	11,306,084	32,468	175,753	12	284,126
1987	236	311	2,122,341	12,289,067	63,000	220,971	10	120,388
1988	200	201	1,231,731	7,361,026	50,099	146,179	8	23,537
1989	211	287	1,667,405	10,156,849	55,000	205,528	8	81,334

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Table 2-1.-(Page 2 of 2)

Year	Number of Vessels[d]	Number of Landings	Number of Crabs[a]	Harvest[a,b]	Number of Pots Registered	Number of Pots Pulled	CPUE[c]	Deadloss[b]
1990	240	331	3,134,082	20,443,043	69,906	262,761	12	141,067
1991	302	322	2,597,994	16,971,365	89,068	227,555	12	106,853
1992	281	288	1,189,443	7,996,040	68,189	206,172	6	6,000
1993	292	360	2,254,989	14,587,704	58,881	253,794	9	133,314
1994				FISHERY CLOSED				
1995				FISHERY CLOSED				
1996	196	198	1,249,005	8,405,614	39,461	76,433	16	24,166
1997	256	265	1,315,969	8,756,490	27,499	90,427	15	13,771
1998	274	284	2,140,604	14,290,271	56,420	141,707	15	53,716
1999	257	268	1,812,357	11,070,729	42,403	146,997	12	44,132
2000	246	256	1,166,796	7,546,145	26,352	98,694	12	32,118
2001	230	238	1,196,469	7,786,446	24,571	63,242	19	57,294
2002	242	254	1,377,922	8,856,828	25,833	68,328	20	32,177
2003	252	275	2,344,436	14,529,124	46,964	128,430	18	228,270
2004	251	270	2,075,622	14,112,438	49,506	90,976	23	160,563
2005[e]	89	264	2,460,856	16,478,458	15,713	99,573	25	77,507

[a]General fishery only. Deadloss included.
[b]In pounds.
[c]Number of legal crabs per pot lift.
[d]Vessel totals are vessels that registered but may not have actively participated in the fishery.
[e]IFQ fishery beginning in 2005.
NA = Not available.

Table 2-2.-Bristol Bay commercial red king crab fishery economic data, 1980-2005.

Year	GHL/TAC[a]	Value		Season Length	
		Ex-vessel[b]	Total[c]	Days	Dates
1980	70-120	$0.90	$115.3	40	09/10-10/20
1981	70-100	$1.50	$49.3	91	09/10-12/15
1982	10-20[d]	$3.05	$8.9	30	09/10-10/10
1983		FISHERY CLOSED			
1984	2.5- 6.0	$2.60	$10.8	15	10/01-10/16
1985	3.0-5.0	$2.90	$12.1	8	09/25-10/02
1986	6.0-13.0	$4.05	$45.0	13	09/25-10/07
1987	8.5-17.7	$4.00	$48.7	12	09/25-10/06
1988	7.5	$5.10	$37.6	8	09/25-10/02
1989	16.5	$5.00	$50.9	12	09/25-10/06
1990	17.1	$5.00	$101.2	12	11/01-11/13
1991	18.0	$3.00	$51.2	7	11/01-11-08
1992	10.3	$5.00	$40.2	7	11/01-11/08
1993	16.8	$3.80	$55.1	9	11/01-11/10
1994		FISHERY CLOSED			
1995		FISHERY CLOSED			
1996	5.0	$4.01	$33.6	4	11/01-11/05
1997	7.0	$3.26	$28.5	4	11/01-11/05
1998	15.8	$2.64	$37.4	5	11/01-11/06
1999	10.1	$6.26	$69.1	5	10/15-10/20
2000	7.7	$4.81	$36.0	4	10/16-10/20[e]
2001	6.6	$4.81	$37.5	3.3	10/15-10/18
2002	8.6	$6.14	$54.2	2.8	10/15-10/18
2003	14.5	$5.08	$72.7	5.1	10/15-10/20
2004	14.3	$4.71	$65.7	3.3	10/15-10/18
2005	16.5	$4.24	$69.5	93	10/15-1/15

[a]Guideline harvest level for general fishery only, millions of pounds. Total allowable catch for IFQ fishery beginning in 2005.
[b]Average price per pound.
[c]Millions of dollars.
[d]Inseason revision to 4.7 million pounds.
[e]Delayed start due to weather.

Table 2-3.-Bristol Bay commercial red king crab fishery harvest and effort by week, 2005/06.

Week ending	Number of Vessels	Number of Landings	Crabs[a]	Harvest[a,b]	Pot pulls	CPUE[c]	Deadloss[b]
15-Oct	1			CONFIDENTIAL			
22-Oct	1			CONFIDENTIAL			
29-Oct	8	10	99,136	649,485	3,065	32	1,804
5-Nov	51	62	739,680	4,939,460	21,375	35	31,779
12-Nov	47	53	626,516	4,149,785	22,928	27	16,132
19-Nov	29	38	291,946	1,967,513	13,635	22	8,053
26-Nov	28	36	290,145	1,956,429	14,144	21	10,472
3-Dec	20	23	179,356	1,218,879	10,081	18	4,474
10-Dec	13	16	122,762	840,157	7,499	16	1,716
17-Dec	7	8	44,294	303,673	2,292	18	122
24-Dec	8	9	38,138	261,018	2,923	13	2,637
7-Jan	3	3	6,552	44,859	538	12	148
14-Jan	1			CONFIDENTIAL			
Total	89	264	2,460,856	16,478,458	99,573	25	77,507

[a]Deadloss included.

[b]In Pounds.

[c]Number of legal crabs per pot lift.

Table 2-4.-Bristol Bay commercial red king crab fishery catch by statistical area, 2005.

Statistical	Number of				Average		
Area	Landings	Crabs[a]	Pots Lifted	Harvest[a,b]	Weight[b]	CPUE[c]	Deadloss[b]
615630	8	8,629	929	56,338	6.5	9	135
625600	53	73,256	2,843	476,409	6.5	26	1,532
625630	39	90,915	3,212	597,427	6.6	28	4,489
635530	10	10,607	840	70,100	6.6	13	361
635600	203	1,345,175	50,549	8,933,961	6.6	27	41,327
635630	93	217,345	11,061	1,436,529	6.6	20	4,807
645600	87	293,876	11,340	2,060,652	7.0	26	12,836
645630	97	415,050	18,224	2,805,886	6.8	23	11,591
Other[d]	19	6,003	575	41,156	6.9	10	428
Total	609[e]	2,460,856	99,573	16,478,458	6.7	25	77,507

[a]Deadloss included.

[b]In pounds.

[c]Number of legal crabs per pot lift.

[d]Combination of eight statistical areas from which less than three vessels made landings.

[e]Number of statistical area landings is greater than the total number of landings because a single vessel may fish in several statistical areas.

Table 2-5.-Bristol Bay red king crab cost-recovery harvest data, 1990-2005.

Year[a]	Number of Landings	Number of Crabs[b]	Number of Pots Lifted	Harvest[b,c]	Average Weight[c]	CPUE[d]	Deadloss[c]
1990	3	9,567	870	80,701	5.9	16	24,540
1991	2	30,351	518	205,851	6.4	62	12,817
1992	1	11,213	670	74,089	6.3	17	3,000
1993	1	8,384	464	53,200	6.3	18	800
1994	1	14,806	732	93,336	6.0	21	4,500
1995	2	14,123	564	80,158	5.5	26	2,339
1996	3	15,390	355	107,955	6.9	44	1,918
1997	4	21,698	658	154,739	6.3	37	18,040
1998	2	22,230	738	188,176	7.0	36	32,564
1999[e]	4	29,368	1,239	185,944	6.3	24	410
2000[f]	2	14,196	702	86,218	6.1	20	347
2001[e]	3	17,605	597	120,435	6.8	29	138
2002[e]	2	14,528	277	96,221	6.6	52	181
2003[f,g]	1	5,327	584	33,817	6.4	9	143
2004[e]	3	29,733	1,286	201,579	6.8	23	638
2005[e]	4	30,585	1,376	208,828	6.8	22	1,500

[a]All cost recovery from 1990-1998 was conducted to fund the Bering Sea and Aleutian Islands shellfish research program.
[b]Deadloss included.
[c]In pounds.
[d]Number of legal crabs per pot lift.
[e]Bering Sea and Aleutian Islands shellfish research and observer program cost recovery.
[f]Bering Sea and Aleutian Islands shellfish research program cost recovery.
[g]Includes 1,222 pounds harvested in the Pribilof District.

Table 2-6.-Bristol Bay red king crab cost-recovery economic performance data, 1990-2005.

Year[a]	Harvest[b]	Value		Charter dates	Charter length[d]
		Ex-vessel[c]	Total		
1990	56,161	$5.10	$286,421	8/7-9/7	30
1991	193,034	$3.75	$723,878	9/2-10/7	35
1992	71,089	$5.24	$372,506	10/8-10/23	15
1993	52,400	$6.57	$344,268	8/20-9/20	31
1994	88,836	$5.21	$462,836	9/25-10/25	30
1995	77,819	$6.65	$517,496	8/1-8/31	31
1996	106,037	$4.53	$480,348	8/1-8/31	31
1997	136,699	$3.55	$485,281	7/25-8/21	28
1998	155,612	$3.25	$505,739	8/1-8/28	28
1999[e]	185,944	$6.18	$1,148,695	9/25-10/11,10/25-11/10	34
2000[f]	85,871	$5.82	$499,769	9/20-10/04	15
2001[e]	120,297	$5.18	$623,138	9/22-10/10, 10/23-11/8	36
2002[e]	96,087	$6.45	$619,761	9/23-10/9, 10/17-10/27	27
2003[f,g]	33,674	$5.56	$187,227	9/1-10/4	34
2004[e]	200,941	$4.98	$1,000,686	10/21-10/25,10/23-10/31,10/27-11/01	20
2005[e]	208,828	$5.07	$1,051,153	11/12-12/2	19

[a]All cost recovery from 1990-1998 was conducted to fund the Bering Sea and Aleutian Islands shellfish research program.
[b]In pounds. Deadloss not included.
[c]Average price per pound.
[d]In days.
[e]Bering Sea and Aleutian Islands shellfish research and observer program cost recovery.
[f]Bering Sea and Aleutian Islands shellfish research program cost recovery.
[g]Includes 1,204 pounds harvested in the Pribilof District.

Table 2-7.-Bristol Bay commercial red king crab fishery harvest composition by fishing season, 1973-2005/06.

Season	Percent Recruit	Percent Postrecruit[a]	Size Limit[b]	Average Weight[c]	Average Length[d]	% Old Shell
1973	63	37	6¼	5.6	NA	NA
1974	60	40	6¼	5.5	NA	NA
1975	21	79	6¼[e]	5.7	NA	NA
1976	56	44	6½	6.0	148	27.4
1977	67	33	6½	5.9	148	13.0
1978	75	25	6½	5.9	147	6.9
1979	47	53	6½	6.4	152	10.4
1980	44	56	6½	6.2	151	11.0
1981	14	86	6½[f]	6.3	151	47.4
1982	68	32	6½	5.5	145	24.6
1983			FISHERY CLOSED			
1984	59	41	6½	5.2	142	26.5
1985	66	34	6½	5.2	142	25.8
1986	65	35	6½	5.4	142	25.5
1987	77	23	6½	5.8	145	19.0
1988	59	41	6½	6.0	147	15.1
1989	58	42	6½	6.1	148	17.7
1990	49	51	6½	6.5	152	14.7
1991	44	56	6½	6.5	152	12.1
1992	33	67	6½	6.7	153	22.3
1993	33	67	6½	6.5	152	15.2
1994			FISHERY CLOSED			
1995			FISHERY CLOSED			
1996	31	69	6½	6.7	153	24.3
1997	28	72	6½	6.7	152	11.0
1998	40	60	6½	6.7	152	19.1
1999	72	28	6½	6.1	148	6.3
2000	65	35	6½	6.5	151	16.3
2001	54	46	6½	6.5	151	22.3
2002	61	39	6½	6.4	151	22.2
2003	72	28	6½	6.2	149	21.9
2004	52	48	6½	6.8	154	21.2
2005	57	43	6½	6.7	152	21.4

[a]Legal sized old and new shell greater than 153mm carapace length defined as postrecruits.
[b]Minimum carapace width in inches.
[c]In pounds.
[d]Carapace length in millimeters.
[e]6½ inches after 11/01.
[f]7 inches after 10/20.
NA = Not Available.

Table 2-8.-Pribilof District commercial red and blue king crab fishery data, 1973/74-2005/06.

	Number of				Number of Pots		Average			
Year[a]	Vessels	Landings	Crabs[b]	Harvest[b,c]	Registered	Pulled	Weight[c]	CPUE[d]	Length[e]	Deadloss[c]
1973/74	8	13	174,420	1,276,533	NA	6,814	7.3	26	NA	NA
1974/75	70	101	908,072	7,107,294	NA	45,518	7.8	20	157.8	NA
1975/76	20	54	314,931	2,433,714	NA	16,297	7.7	19	159.1	NA
1976/77	47	113	855,505	6,611,084	NA	71,738	7.7	12	158.1	NA
1977/78	34	104	807,092	6,456,738	NA	106,983	7.9	8	158.9	159,269
1978/79	58	154	797,364	6,395,512	NA	101,117	8.1	8	159.3	63,140
1979/80	46	115	815,557	5,995,231	NA	83,527	7.7	10	155.9	284,555
1980/81	110	258	1,497,101	10,970,346	31,636	167,684	7.3	9	155.7	287,285
1981/82	99	312	1,202,499	9,080,729	25,408	176,168	7.6	7	158.2	250,699
1982/83	122	281	587,908	4,405,353	34,429	127,728	7.5	5	159.8	51,703
1983/84	126	221	276,364	2,193,395	36,439	86,428	7.9	3	159.9	4,562
1984/85	16	25	40,427	306,699	3,122	15,147	7.6	3	155.5	NA
1985/86	26	49	76,945	528,164	6,038	23,062	6.9	3	146.5	7,500
1986/87	16	25	36,988	258,939	4,376	15,740	7.0	2	NA	5,450
1987/88	38	68	95,130	701,337	9,594	40,707	7.4	2	152.7	9,910
1988/89-92/93				F I S H E R Y CLOSED						
1993[f]	112	135	380,286	2,608,106	4,860	35,942	6.9	11	154.4	472
1994[f]	104	121	167,520	1,338,953	4,675	28,976	8.0	6	162.1	2,929
1995[f]	117	151	110,834	897,979		34,885	8.1	3	162.5	15,348
1995[g]	119	152	190,951	1,384,674		36,878	7.3	5	N/A	71,333
1995[h]	127	162	301,785	2,282,653	5,400	37,643	NA	8		86,681
1996[f]	66	90	25,383	200,304		29,411	7.9	<1	161.0	319
1996[g]	66	92	127,712	937,032		30,607	7.3	4	153.1	14,997
1996[h]	66	92	153,095	1,137,336	2,730	30,607	7.4	3		15,316

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Year[a]	Number of Vessels	Number of Landings	Number of Crabs[b]	Harvest[b,c]	Number of Pots Registered	Number of Pots Pulled	Average Weight[c]	Average CPUE[d]	Average Length[e]	Deadloss[c]
1997[f]	53	110	90,641	756,818		28,458	8.4	3	164.3	18,807
1997[g]	51	105	68,603	512,374		27,652	7.5	3	163.6	16,747
1997[h]	53	110	159,244	1,269,192	2,230	30,400	8.0	5		35,554
1998[f]	57	84	68,129	510,365		23,381	7.5	3	158.8	8,703
1998[g]	57	83	68,419	516,306		22,965	7.5	3	156.1	21,599
1998[h]	57	84	136,548	1,026,671	2,398	23,381	7.5	3		30,302
1999-2005					F I S H E R Y	CLOSED				

[a]Blue king crab, 1973 - 1988.

[b]Deadloss included.

[c]In pounds

[d]Number of legal crabs per pot lift.

[e]Carapace length in millimeters.

[f]Red king crab.

[g]Blue king crab.

[h]Blue and red king crab fisheries combined.

NA = Not available.

Table 2-9.-Guideline harvest level (GHL), economic performance and season length summary for the Pribilof District commercial red and blue king crab fishery, 1980/81-2005/06.

		Value		Season Length	
Year[a]	GHL/TAC[b]	Ex-vessel[c]	Total[d]	Days	Dates
1980/81	5.0-8.0	$0.90	$9.6	60	09/15-11/15
1981/82	5.0-8.0	$1.50	$13.6	47	09/10-10/28
1982/83	5.0-8.0	$3.05	$13.4	15	09/10-09/25
1983/84	4.0[e]	$3.00	$6.6	10	09/01-09/11
1984/85	0.5-1.0	$2.50	$0.1	15	09/01-09/16
1985/86	0.3-0.8	$2.90	$1.4	26	09/25-10/21
1986/87	0.3-0.8	$4.05	$1.2	55	09/25-11/20
1987/88	0.3-1.7	$4.00	$2.8	86	09/25-12/20
1988/89-92/93		FISHERY CLOSED			
1993[f]	3.4	$4.98	$13.0	6	09/15-09/21
1994[f]	2.0[e]	$6.45	$8.6	6	09/15-09/21
1995[f]	2.5[h]	$3.37	$2.9	7	09/15-09/22
1995[g]	2.5[h]	$2.92	$3.9	7	09/15-09/22
1996[f]	1.8[h]	$2.76	$0.6	11	09/15-09/26
1996[g]	1.8[h]	$2.65	$2.4	11	09/15-09/26
1997[f]	1.5[h]	$3.09	$2.3	14	09/15-09/29
1997[g]	1.5[h]	$2.82	$1.4	14	09/15-09/29
1998[f]	1.25[h,i]	$2.39	$1.2	13	09/15-09/28
1998[g]	1.25[h,i]	$2.34	$1.2	13	09/15-09/28
1999-2005		FISHERY CLOSED			

[a]Blue king crab, 1980-1988.

[b]Guideline harvest level, millions of pounds. Total allowable catch for IFQ fishery beginning in 2005.

[c]Average price per pound.

[d]Millions of dollars.

[e]Set not to exceed.

[f]Red king crab.

[g]Blue king crab.

[h]Combined red and blue king crab.

[i]General fishery only.

Table 2-10.-Saint Matthew Island Section commercial blue king crab fishery data, 1977-2005/06.

	Number of				Number of Pots		Percent	Average			
Year	Vessels	Landings	Crabs[a]	Harvest[a,b]	Registered	Pulled	Recruits	Weight[b]	CPUE[c]	Length[d]	Deadloss[b]
1977	10	24	281,665	1,202,066		17,370	7	4.3	16	130.4	129,148
1978	22	70	436,126	1,984,251		43,754	NA	4.5	10	132.2	116,037
1979	18	25	52,966	210,819		9,877	81	4.0	5	128.8	128.8
1980					C O N F I D E N T I A L						
1981	31	119	1,045,619	4,627,761		58,550	NA	4.4	18	NA	53,355
1982	96	269	1,935,886	8,844,789		165,618	20	4.6	12	135.1	142,973
1983	164	235	1,931,990	9,454,323	38,000	133,944	27	4.8	14	137.2	828,994
1984	90	169	841,017	3,764,592	14,800	73,320	34	4.5	11	135.5	31,983
1985	79	103	441,479	2,200,781	13,000	47,748	9	5.0	9	139	2,613
1986	38	43	219,548	1,003,162	5,600	22,073	10	4.6	10	134.3	32,560
1987	61	62	227,447	1,039,779	9,370	28,230	5	4.6	8	134.1	600
1988	46	46	302,098	1,325,185	7,780	23,058	65	4.4	30	133.3	10,160
1989	69	69	247,641	1,166,258	11,983	30,803	9	4.7	8	134.6	3,754
1990	31	38	391,405	1,725,349	6,000	26,264	4	4.4	15	134.3	17,416
1991	68	69	726,519	3,372,066	13,100	37,104	12	4.6	20	134.1	216,459
1992	174	179	545,222	2,475,916	17,400	56,630	9	4.6	10	134.1	1,836
1993	92	136	630,353	3,003,089	5,895	58,647	6	4.8	11	135.4	3,168
1994	87	133	827,015	3,764,262	5,685	60,860	60	4.6	14	133.3	46,699
1995	90	111	666,905	3,166,093	5,970	48,560	45	4.8	14	135	90,191
1996	122	189	660,665	3,078,959	8,010	91,085	47	4.7	7	134.6	36,892
1997	117	166	939,822	4,649,660	7,650	81,117	31	4.9	12	139.5	209,490
1998	131	255	612,440	2,869,655	8,561	89,500	46	4.7	7	135.8	15,107
1999-2005					F I S H E R Y C L O S E D						

[a]Deadloss included.

[b]In pounds.

[c]Number of legal crabs per pot lift.

[d]Carapace length in millimeters.

NA = Not available.

Table 2-11.-Guideline harvest level (GHL), economic performance and season length summary for the Saint Matthew Island Section commercial blue king crab fishery, 1983-2005/06.

		Value		Season Length	
Year	GHL/TAC[a]	Ex-vessel[b]	Total[c]	Days	Dates
1983	8	$3.00	$25.80	17	08/20-09/06
1984	2.0-4.0	$1.75	$6.50	7	09/01-09/08
1985	0.9-1.9	$1.60	$3.80	5	09/01-09/06
1986	0.2-0.5	$3.20	$3.20	5	09/01-09/06
1987	0.6-1.3	$2.85	$3.10	4	09/01-09/05
1988	0.7-1.5	$3.10	$4.00	4	09/01-09/05
1989	1.7	$2.90	$3.50	3[d]	09/01-09/04
1990	1.9	$3.35	$5.70	6	09/01-09/07
1991	3.2	$2.80	$9.00	4	09/16-09/20
1992	3.1	$3.00	$7.40	3[d]	09/04-09/07
1993	4.4	$3.23	$9.70	6	09/15-09/21
1994	3.0	$4.00	$15.00	7	09/15-09/22
1995	2.4	$2.32	$7.10	5	09/15-09/20
1996	4.3	$2.20	$6.70	8	09/15-09/23
1997	5.0	$2.21	$9.80	7	09/15-09/22
1998	4.0[e]	$1.87	$5.34	11	09/15-09/26
1999-2005			FISHERY CLOSED		

[a]Guideline harvest level in millions of pounds. Total allowable catch fro IFQ beginning in 2005.

[b]Average price per pound.

[c]Millions of dollars.

[d]Actual length - 60 hours.

[e]General fishery only.

Table 2-12.-Commercial harvest of blue king crabs by season for the St. Matthew Island Section, 1977-2005/06.

Season	Date		Harvest[a]	Minimum	Price per
	Opened	Closed		Size[b]	Pound
1977	Jun-07	Aug. 16	1,202,066	5 1/2	$1.00
1978	Jul-15	Sept. 3	1,984,251	5 1/2	$0.95
1979	Jul-15	Aug. 24	210,819	5 1/2	$0.70
1980	Jul-15	Sept. 3	CONFIDENTIAL	5 1/2	CONFIDENTIAL
1981	Jul-15	Aug. 21	4,627,761	5 1/2	$0.90
1982	Aug-01	Aug. 16	8,844,789	5 1/2	$2.00
1983[c,d]	Aug-20	Sept. 6[c]	9,506,880[d]	5 1/2	$3.00
1984	Aug-01	Sept. 8	3,764,592	5 1/2	$1.75
1985	Sep-01	Sept. 6	2,200,781	5 1/2	$1.60
1986	Sep-01	Sept. 6	1,003,162	5 1/2	$3.20
1987	Sep-01	Sep-05	1,039,779	5 1/2	$2.85
1988	Sep-01	Sep-05	1,325,185	5 1/2	$3.10
1989	Jan-01	Sep-04	1,166,258	5 1/2	$2.90
1990	Sep-01	Sep-07	1,725,349	5 1/2	$3.35
1991	Sep-16	Sep-20	3,372,066	5 1/2	$2.80
1992	Sep-04	Sep-07	2,475,916	5 1/2	$3.00
1993	Sep-15	Sep-21	3,003,089	5 1/2	$3.23
1994	Sep-15	Sep-22	3,764,262	5 1/2	$4.00
1995	Sep-15	Sep-22	3,166,093	5 1/2	$2.32
1996	Sep-15	Sep-16	3,078,959	5 1/2	$2.20
1997	Sep-15	Sep-22	4,649,660	5 1/2	$2.21
1998	Sep-15	Sep-26	2,869,655	5 1/2	$1.87
1999-2005		F I S H E R Y C L O S E D			

[a]In pounds, deadloss included.

[b]Carapace width in inches.

[c]Part of Northern District open until September 20.

[d]St. Lawrence Island harvest of 52,557 pounds included.

Table 2-13.-Pribilof District golden king crab fishery harvest data, 1981/82-2005 seasons.

	Number of					Average			
Season	Vessels	Landings	Crabs[a]	Pots lifted	Harvest[a,b]	Weight[b]	CPUE[c]	Length[d]	Deadloss[b]
1981/82	2				CONFIDENTIAL				
1982/83	10	19	15,330	5,252	69,970	4.6	3	151	570
1983/84	50	115	253,162	26,035	856,475	3.4	10	127	20,041
1984				NO LANDINGS					
1985	1				CONFIDENTIAL				
1986					NO LANDINGS				
1987	1				CONFIDENTIAL				
1988	2				CONFIDENTIAL				
1989	2				CONFIDENTIAL				
1990					NO LANDINGS				
1991					NO LANDINGS				
1992					NO LANDINGS				
1993	5	15	17,643	15,395	67,458	3.8	1	NA	0
1994	3	5	21,477	1,845	88,985	4.1	12	NA	730
1995	7	22	82,489	9,551	341,908	4.1	9	NA	716
1996	6	32	91,947	9,952	329,009	3.6	9	NA	3,570
1997	7	23	43,305	4,673	179,249	4.1	9	NA	5,554
1998	3	9	9,205	1,530	35,722	3.9	6	NA	474
1999	3	9	44,098	2,995	177,108	4.0	15	NA	319
2000	7	19	29,145	5,450	127,217	4.4	5	NA	4,599
2001	6	14	33,723	4,262	145,876	4.3	8	143	8,227
2002	8	20	34,860	5,279	150,434	4.3	6	144	8,984
2003	3				CONFIDENTIAL				
2004	5				CONFIDENTIAL				
2005	4				CONFIDENTIAL				

[a]Deadloss included.
[b]In pounds.
[c]Number of legal crabs per pot lift.
[d]Carapace length in millimeters.
NA = Not available.
Confidential = Less than three vessels or processors participated in the fishery.

Table 2-14.-Pribilof District golden king crab fishery economic data, 1991-2005 seasons.

Season	Value		Season Length	
	Ex-vessel[a]	Total	Days	Dates
1991	NO LANDINGS		365	1/1-12/31
1992	NO LANDINGS		365	1/1-12/31
1993	$2.42	$163,248	365	1/1-12/31
1994	$3.99	$355,050	365	1/1-12/31
1995	$3.23	$1,104,363	365	1/1-12/31
1996	$2.10	$690,919	365	1/1-12/31
1997	$2.23	$387,340	365	1/1-12/31
1998	$2.06	$72,611	365	1/1-12/31
1999	$2.34	$413,686	162	1/1-6/10
2000	$3.22	$392,436	365	1/1-12/31
2001	$3.12	$429,464	105	1/1-4/15
2002	$3.10	$438,495	134	1/1-5/14
2003	CONFIDENTIAL		121	1/1-5/1
2004	CONFIDENTIAL		72	1/1-3/12
2005	CONFIDENTIAL		365	1/1-12/31

[a]Average price per pound.

Confidential = Less than three vessels or processors participated in fishery.

Table 2-15.-Saint Matthew Island Section commercial golden king crab fishery harvest data,1982/83-2005 seasons.

Season	Number of					Average			
	Vessels	Landings	Crabs[a]	Pots lifted	Harvest[a,b]	Weight[b]	CPUE[c]	Length[d]	Deadloss[b]
1982/83	22	30	51,714	7,825	193,507	3.7	7	138	957
1983/84				NO LANDINGS					
1985				NO LANDINGS					
1986				NO LANDINGS					
1987	10	28	99,101	13,825	414,034	4.2	7	142	12,750
1988	10	22	36,470	11,672	160,441	4.4	3	150	14,000
1989	2			CONFIDENTIAL					
1990				NO LANDINGS					
1991				NO LANDINGS					
1992	1			CONFIDENTIAL					
1993				NO LANDINGS					
1994	1			CONFIDENTIAL					
1995	5	5	212	313	992	4.7	1	NA	0
1996	1			CONFIDENTIAL					
1997-2000				NO LANDINGS					
2001	1			CONFIDENTIAL					
2002				NO LANDINGS					
2003	1			CONFIDENTIAL					
2004				NO LANDINGS					
2005				NO LANDINGS					

[a]Deadloss included.

[b]In pounds.

[c]Number of legal crabs per pot lift.

[d]Carapace length in millimeters.

NA = Not available.

Confidential = Less than three vessels or processors participated in the fishery.

Table 2-16.-Saint Matthew Island Section commercial golden king crab fishery economic data, 1991-2005 seasons.

Season	Value		Season Length	
	Ex-vessel[a]	Total	Days	Dates
1991	NO LANDINGS		365	1/1-12/31
1992	CONFIDENTIAL		365	1/1-12/31
1993	NO LANDINGS		365	1/1-12/31
1994	CONFIDENTIAL		365	1/1-12/31
1995	$2.77	$2,748	365	1/1-12/31
1996	CONFIDENTIAL		365	1/1-12/31
1997-2000	NO LANDINGS		365	1/1-12/31
2001	CONFIDENTIAL		365	1/1-12/31
2002	NO LANDINGS		365	1/1-12/31
2003	CONFIDENTIAL		365	1/1-12/31
2004	NO LANDINGS		365	1/1-12/31
2005	NO LANDINGS		366	1/1-12/32

[a]Average price per pound.

Confidential = Less than three vessels or processors participated in the fishery.

Table 2-17.-King crab Registration Area Q commercial scarlet king crab fishery data, 1992-2005.

Year	Number of		Harvest[a,b]	Average		Value		Deadloss[a]
	Vessels	Pots Lifted		Weight[a]	CPUE[c]	Ex-vessel[d]	Total[e]	
1992-94			NO LANDINGS					
1995	4	24,551	26,684	2.4	1	$2.45	$65.38	465
1996	2		CONFIDENTIAL					
1997- 99			NO LANDINGS					
2000[f]	1		CONFIDENTIAL					
2001[f]	1		CONFIDENTIAL					
2002[f]			NO LANDINGS					
2003[f]	1		CONFIDENTIAL					
2004	3		CONFIDENTIAL					
2005	1		CONFIDENTIAL					

[a]In pounds.
[b]Deadloss included.
[c]Number of legal crabs per pot lift.
[d]Average price per pound.
[e]Thousands of dollars.
[f]Restricted to incidental harvest during Bering Sea golden king and grooved Tanner crab fisheries.
Confidential = Less than three vessels or processors participated in fishery.

Table 2-18.-Bering Sea District commercial Tanner crab fishery harvest data, 1969-2005/06.

	Number of				Number of Pots			
Year	Vessels	Landings	Crabs[a]	Harvest[a,b]	Registered	Pulled	CPUE[c]	Deadloss[b]
1969	NA	131	353,300	1,008,900	NA	29,800	12	NA
1970	NA	66	482,300	1,014,700	NA	16,400	29	NA
1971	NA	22	61,300	166,100	NA	7,300	8	NA
1972	NA	14	42,061	107,761	NA	4,260	10	NA
1973	NA	44	93,595	231,668	NA	15,730	6	NA
1974	NA	69	2,531,825	5,044,197	NA	22,014	115	NA
1974/75	28	80	2,773,770	7,028,378	NA	38,462	72	NA
1975/76	66	304	8,956,036	22,358,107	NA	141,206	63	NA
1976/77	83	541	20,251,508	51,455,221	NA	297,471	68	NA
1977/78	120	861	26,350,688	66,648,954	NA	516,350	51	218,099
1978/79	144	817	16,726,518	42,547,174	NA	402,697	42	76,000
1979/80	152	804	14,685,611	36,614,315	40,273	488,434	30	56,446
1981	165	761	11,845,958	29,630,492	42,910	559,626	21	101,594
1982	125	791	4,830,980	11,008,779	36,396	490,099	10	138,159
1983	108	448	2,286,756	5,273,881	15,255	282,006	8	60,029
1984	41	134	516,877	1,208,223	9,851	61,357	8	5,025
1985	44	166	1,272,501	3,036,935	15,325	94,532	12	14,096
1986				FISHERY CLOSED				
1987				FISHERY CLOSED				
1988	98	248	957,318	2,294,997	38,765	114,384	8	10,724
1989	109	359	2,894,480	6,982,865	43,607	183,692	16	34,664
1990	179	1,032	9,800,763	22,417,047	46,440	657,541	15	82,443
1990/91	255	1,756	16,608,625	40,081,555	75,356	883,391	19	210,769
1991/92	285	2,339	12,924,102	31,794,382	85,401	1,244,899	10	279,741

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Year	Number of Vessels	Number of Landings	Number of Crabs[a]	Harvest[a,b]	Number of Pots Registered	Number of Pots Pulled	CPUE[c]	Deadloss[b]
1992/93	294	2,084	15,265,865	35,130,831	71,481	1,200,385	13	343,955
1993/94	296	862	7,235,898	16,892,320	116,039	576,464	13	259,389
1994	183	349	3,351,639	7,766,886	38,670	249,536	13	132,780
1995	196	256	1,877,303	4,233,061	40,827	247,853	8	44,508
1996[d]	196	347	734,296	1,806,077	68,602	149,275	5	14,608
1997 to 2004				FISHERY CLOSED				
2005/06[e]	43	77	368,292	791,315	545	29,693	12	14,563

[a]Deadloss included.

[b]In pounds.

[c]Number of legal crabs per pot lift.

[d]Includes incidental harvest with Bristol Bay red king crab and Tanner crab directed fishery totals.

[e]Includes incidental harvest with Bering Sea snow crab and directed Tanner crab fishery totals.
NA = Not available.

Table 2-19.-Bering Sea District commercial Tanner crab fishery catch by subdistrict, 1974/75-2005/06.

		Number of					Average		
Season	Subdistrict[a]	Vessels	Landings	Crabs[b]	Pots Lifted	Harvest[b,c]	Weight[c]	CPUE[d]	Deadloss[c]
1974/75	Southeastern		72	2,526,687	32,275	6,504,984	2.6	78	0
	Pribilofs		8	247,083	3,923	523,394	2.1	63	0
	TOTAL	28	80	2,773,770	38,462	7,028,378	2.5	72	0
1975/76	Southeastern		230	6,682,232	106,445	16,643,194	2.5	63	0
	Pribilofs		74	2,273,804	34,761	5,714,913	2.5	65	0
	TOTAL	66	304	8,956,036	141,206	22,358,107	2.5	63	0
1976/77	Southeastern		437	16,089,057	233,667	41,007,736	2.6	69	0
	Pribilofs		104	4,162,451	63,804	10,447,485	2.5	65	0
	TOTAL	83	541	20,251,508	297,471	51,455,221	2.5	68	0
1977/78	Southeastern		706	21,055,527	408,437	53,278,012	2.5	52	0
	Pribilofs		155	5,210,170	107,913	13,152,843	2.5	48	0
	TOTAL	120	861	26,350,688	516,350	66,648,954	2.5	51	218,099
1978/79	Southeastern		758	15,601,891	356,594	39,694,205	2.5	44	75,400
	Pribilofs		59	1,124,627	46,103	2,852,969	2.5	24	600
	TOTAL	144	817	16,726,518	402,697	42,547,174	2.5	42	76,000
1979/80	Southeastern		789	14,329,889	476,410	35,724,003	2.5	30	56,446
	Pribilofs		15	355,722	12,024	890,312	2.5	30	0
	TOTAL	152	804	14,685,611	488,434	36,614,315	2.5	30	56,446

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Table 2-19.-(page 2 of 4)

Season	Subdistrict[a]	Number of Vessels	Number of Landings	Number of Crabs[b]	Number of Pots Lifted	Harvest[b,c]	Average Weight[c]	Average CPUE[d]	Deadloss[c]
1981	Southeastern		674	10,532,007	496,751	26,684,956	2.5	21	97,398
	Pribilofs		87	1,313,951	62,875	2,945,536	2.5	21	4,196
	TOTAL	165	761	11,845,958	559,626	29,630,492	2.5	21	101,594
1982	Southeastern		539	3,825,433	322,634	8,812,302	2.3	12	69,829
	Pribilofs		252	1,005,547	167,465	2,196,477	2.2	6	68,330
	TOTAL	125	791	4,830,980	490,099	11,008,779	2.3	10	138,159
1983	Northern		10	29,478	5,950	48,454	1.7	5	167
	Southeastern		287	1,984,673	192,538	4,633,354	2.3	10	52,879
	Pribilofs		151	272,505	83,528	592,073	2.2	3	6,983
	TOTAL	108	448	2,286,756	282,006	5,273,881	2.3	8	60,029
1984	Southeastern		91	470,181	44,546	1,099,142	2.3	11	4,688
	Pribilofs		43	46,759	16,811	109,081	2.3	3	337
	TOTAL	41	134	516,877	61,357	1,208,223	2.3	8	5,025
1985	Southeastern	38	143	1,266,567	85,926	3,023,193	2.4	13	14,096
	Pribilofs	15	23	5,934	8,606	13,742	2.3	1	0
	TOTAL	44	166	1,272,501	94,532	3,036,935	2.4	12	14,096
1986	F I S H E R Y C L O S E D								
1987	F I S H E R Y C L O S E D								

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Season	Subdistrict[a]	Number of Vessels	Number of Landings	Number of Crabs[b]	Number of Pots Lifted	Harvest[b,c]	Average Weight[c]	Average CPUE[d]	Deadloss[c]
1988	Eastern	98	248	957,318	114,384	2,294,997	2.5	8	10,724
	Western	0	0	0	0	0	0	0	0
	TOTAL	98	248	957,318	114,384	2,294,997	2.5	8	10,724
1989	Eastern	109	359	2,894,480	183,692	6,982,865	2.4	16	34,664
	Western	0	0	0	0	0	0	0	0
	TOTAL	109	359	2,894,480	183,692	6,982,865	2.4	16	34,664
1990	Eastern		1,105	972,788	647,993	22,399,091	2.3	15	82,443
	Western		17	7,975	9,548	17,956	2.3	1	0
	TOTAL	179	1,032	980,763	657,541	22,417,047	2.3	15	82,443
1990/91	Eastern	255	1,756	16,608,625	883,391	40,081,555	2.4	19	210,769
	Western	0	0	0	0	0	0	0	0
	TOTAL	255	1,756	16,608,625	883,391	40,081,555	2.4	19	210,769
1991/92	Eastern	285	2,339	12,924,102	1,224,899	31,794,382	2.5	10	279,741
1992/93	Eastern	293	2,011	15,074,069	1,150,334	34,821,008	2.3	13	340,955
	Western	70	96	191,796	50,051	309,823	1.6	4	3,000
	TOTAL	294	2,084	15,265,865	1,200,385	35,130,831	2.3	13	343,955
1993/94	East of 168°[e]	283	347	1,696,830	250,501	4,115,949	2.4	7	104,715
	163° to 173°[f]	261	515	5,539,068	325,963	12,776,371	2.3	17	154,674
	TOTAL	296	862	7,235,898	576,464	16,892,320	2.3	13	259,389

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Table 2-19.-(page 4 of 4)

Season	Subdistrict[a]	Number of Vessels	Number of Landings	Number of Crabs[b]	Number of Pots Lifted	Harvest[b,c]	Average Weight[c]	Average CPUE[d]	Deadloss[c]
1994	163° to 173°	183	349	3,351,639	249,536	7,766,886	2.3	13	132,780
1995	163° to 173°	196	256	1,877,303	247,853	4,233,061	2.3	8	44,508
1996	East of 168°[e]	192	195	393,257	75,753	994,776	2.5	5	8,464
	163° to 173°[f]	135	152	341,039	73,522	811,301	2.4	5	6,144
	TOTAL	196	347	734,296	149,275	1,806,077	2.5	5	14,608
1997 to 2004				FISHERY CLOSED					
2005/06[g]	West of 166°	43	77	368,292	29,693	791,315	2.2	12	14,563

[a]Prior to 1988, the subdistricts were: Southeastern, Pribilof, and Northern (includes the Norton Sound and General Sections).

[b]Deadloss included.

[c]In pounds.

[d]Number of legal crabs per pot lift.

[e]Incidental harvest in Bristol Bay red king crab fishery.

[f]Directed Tanner crab fishery.

[g]Includes incidental harvest with Bering Sea snow crab and directed Tanner crab fishery totals.

Table 2-20.-Bering Sea District commercial Tanner crab fishery economic data, 1979/80-2005/06.

		Value		Season Length	
Year	GHL/TAC[a]	Ex-vessel[b]	Total[c]	Days	Dates
1979/80	28-36	$0.52	$19.0	189	11/01-05/11
1981	28-36	$0.58	$17.2	88	01/15-04/15
1982	12-16	$1.06	$11.5	118	02/15-06/15
1983	5.6	$1.20	$6.2	118	02/15-06/15
1984	7.1	$0.95	$1.1	118	02/15-06/15
1985	3	$1.40	$4.3	149	01/15-06/15
1986			FISHERY CLOSED		
1987			FISHERY CLOSED		
1988	5.6	$2.17	$4.8	93	01/15-04/20
1989	13.5	$2.90	$20.3	110	01/15-05/07
1990[d]	29.5	$1.85	$45.3	89	01/15-04/24
1990/91	42.8	$1.12	$44.5	126	11/20-03/25
1991/92	32.8	$1.50	$47.3	137	11/15-03/31
1992/93	39.2	$1.69	$58.8	137	11/15-03/31
1993[e]	10.7	$1.90	$7.6	10	11/01-11/10
1993/94[f]	9.1	$1.90	$24.0	42	11/20-01/01
1994[f]	7.5	$3.75	$28.5	20	11/01-11/21
1995[f]	5.5	$2.80	$11.7	15	11/01-11/16
1996[e]	2.2	$2.51	$2.5	4	11/01-11/05
1996[f]	6.2	$2.48	$2.0	12	11/15-11/27
1997 to 2004			FISHERY CLOSED		
2005/06	1.5	$1.28	$0.9	168	10/15-3/31

[a]Guideline harvest level (total allowable catch from 2005/06 forward), millions of pounds.

[b]Average price per pound.

[c]Millions of dollars.

[d]Winter fishery.

[e]East of 168° West longitude (incidental to Bristol Bay red king crab).

[f]163° -173° West longitude (directed fishery).

Table 2-21.-Bering Sea District commercial Tanner crab fishery harvest by statistical area, 2005/06 season.

	Number of				Average		
Statistical area	Landings[a]	Crabs[b]	Pots Lifted	Harvest[b,c]	Weight[c]	CPUE[d]	Deadloss[c]
665530	3	4,944	139	11,485	2.3	35	92
685630	4	4,656	523	9,944	2.1	9	52
695631	34	290,323	6,058	619,731	2.1	48	12452
705600	6	3,163	782	6,972	2.2	4	4
705630	22	31,080	2,154	67,843	2.2	14	425
705701	5	980	148	2,104	2.2	7	14
715600	4	100	80	228	2.3	3	0
715630	28	6,307	6,510	13,774	2.2	1	492
715700	17	3,871	2,294	8,214	2.1	2	58
715730	5	1,371	1,247	2,896	2.1	1	343
725630	10	915	1,851	1,935	2.1	1	4
725700	8	313	634	676	2.2	1	0
725730	8	1,639	228	3,524	2.2	7	31
735800	8	362	1,395	763	2.1	0	75
735830	9	59	1,973	126	2.1	0	100
745830	7	19	1,124	44	2.3	0	44
745900	3	2	565	4	1.6	0	4
Other[e]	24	18,188	1,988	41,052	2.3	9	372
Total	205	368,292	29,693	791,315	2.2	12	14,563

[a]Number of statistical area landings is greater than the total number of landings because a single vessel may fish in several statistical areas.

[b]Deadloss included.

[c]In pounds.

[d]Number of legal crabs per pot lift.

[e]Combination of 14 statistical areas where less than three vessels made landings.

Table 2-22.-Bering Sea District commercial Tanner crab fishery harvest composition by fishing season, 1972-2005/06.

Season	Average Weight[a]	Average Width[b]	% New Shell
1972[c]	2.6	NA	NA
1973[c]	2.5	NA	NA
1974[c]	2	NA	NA
1974/75	2.5	NA	NA
1975/76	2.5	NA	NA
1976/77	2.5	NA	NA
1977/78	2.5	152.8	88.0
1978/79	2.5	152.7	95.0
1979/80	2.5	151.4	90.0
1981	2.5	149.4	86.6
1982	2.3	148.8	85.4
1983[d]	2.3	148.8	70.5
1984	2.3	146.5	40.0
1985	2.4	150.0	65.0
1986	FISHERY CLOSED		
1987	FISHERY CLOSED		
1988	2.5	143.5	70.2
1989	2.4	149.4	80.8
1990	2.3	148.1	96.5
1990/91	2.4	149.7	95.3
1991/92	2.5	150.4	93.2
1992/93	2.3	148.0	90.5
1993/94	2.4	150.7	93.9
1994	2.3	150.0	92.5
1995	2.3	149.3	58.6
1996[e]	2.5	152.1	46.6
1997 to 2004	FISHERY CLOSED		
2005/06	2.2	144.5	92.1

[a]In pounds.
[b]Carapace width in millimeters.
[c]Incidental to the king crab fishery.
[d]Partial Bering Sea closure.
[e]Includes incidental catch with Bristol Bay red king crab and Tanner crab directed fishery totals.
NA = Not available.

Table 2-23.-Bering Sea District commercial snow crab fishery harvest data, 1978/79-2005/06.

Year	GHL/TAC[a]	Number of Vessels[h]	Landings	Crabs[b]	Pots Lifted	Harvest[b,c]	CPUE[d]	Deadloss[c]
1978/79		102	490	22,118,498	190,746	32,187,039	116	759,137
1979/80		134	597	25,286,777	255,102	39,572,668	99	228,345
1981	39.5-91.0	153	867	34,415,322	435,742	52,750,034	79	2,269,979
1982	16.0-22.0	122	803	24,089,562	469,091	29,355,374	51	1,092,655
1983[e]	15.8	109	461	23,853,647	287,127	26,128,410	83	1,324,466
1984[e]	49.0	52	367	24,009,935	173,591	26,813,074	138	798,795
1985[e]	98.0	75	718	52,394,686	370,082	65,362,866	142	1,060,784
1986[e]	57.0	88	992	76,319,307	542,346	97,684,139	141	1,378,533
1987[e]	56.4	103	1,038	81,307,659	616,113	101,903,388	132	978,449
1988[e]	110.7	171	1,285	105,933,542	747,395	134,241,728	142	3,424,021
1989[e]	132.0	168	1,300	112,704,215	665,242	148,306,262	169	1,940,482
1990[e]	139.8	189	1,563	128,931,026	911,303	161,765,415	141	1,796,664
1991[e]	315.0	220	2,788	265,123,960	1,391,463	328,647,269	191	3,464,036
1992	333.0	250	2,763	227,376,582	1,281,796	315,302,034	177	2,325,852
1993	207.2	254	1,835	169,535,617	970,646	230,754,253	175	1,573,952
1994	105.8	272	1,293	114,810,186	716,524	149,792,718	160	1,799,763
1995	55.7	253	870	60,658,899	507,603	75,309,187	120	1,289,169
1996	50.7	234	771	52,892,320	520,671	65,696,173	102	1,333,015
1997	117.0	226	1,127	100,013,816	754,140	199,589,339	133	2,351,555
1998[f]	225.9	229	1,767	186,643,538	891,219	243,492,577	209	2,896,374
1999[f]	186.2	241	1,631	143,469,440	899,308	184,735,011	160	1,828,540
2000[f]	26.4	229	288	23,265,802	170,064	30,774,838	137	330,896
2001[f]	25.3	207	293	17,185,523	176,930	23,382,046	97	429,884
2002[f]	28.5	191	403	23,281,441	308,132	30,233,494	76	585,288
2003[f,g]	23.7	192	256	21,504,969	139,279	26,198,024	154	662,409
2004[f]	19.3	189	240	17,331,514	110,087	22,170,150	157	224,377
2005[f]	19.4	169	196	16,684,751	69,863	23,036,287	239	224,193
2005/06[i]	33.5	78	310	22,080,235	108,320	33,256,146	204	322,595

[a]Guideline harvest level, millions of pounds. Total allowable catch from 2005/06 forward.
[b]Deadloss included.
[c]In pounds.
[d]Number of legal crabs per pot lift.
[e]Partial district and subdistrict closures, see Table 2-26.
[f]General fishery only.
[g]Includes 181,457 pounds illegally taken in Russian waters.
[h]Vessel totals are vessels that registered but may not have actively participated in the fishery.
[i]IFQ fishery only.

Table 2-24.-Bering Sea District commercial snow crab fishery season dates and area closures, 1977/78-2005/06.

Season	Opened	Closed	Comments
1977/78	09/15/77	09/23/78	Bering Sea District closure[a]
1978/79	11/01/78	09/03/79	Bering Sea District closure[a]
1979/80	11/01/79	08/15/80	Bering Sea District state closure
		09/03/80	Bering Sea District federal closure
1981	01/15/81	09/01/81	Bering Sea District closure[b]
1982	02/15/82	08/01/82	Bering Sea District closure[b]
1983	02/15/83	05/22/83	Bering Sea District closure south of 57°30' N. lat. [b]
		08/01/83	Bering Sea District closure north of 57°30' N. lat. [b]
1984	02/15/84	08/01/84	Bering Sea District closure south of 58° N. lat.[b]
		08/22/84	Bering Sea District closure north of 58° N. lat. to allow an orderly start to king crab season[b]
	09/15/84	12/31/84	Bering Sea District closure north of 58°N. lat. reopened after king season and Bering Sea District closure[b]
1985	01/15/85	05/08/85	Pribilof Subdistrict closure south of 58° N. lat.[b]
		08/01/85	Bering Sea District closure south of 58°39' N. lat.[b]
		08/22/85	Northern Subdistrict closure to allow an orderly start to king crab season[b]
	10/09/85	01/15/86	*Bering Sea District reopened, except east of 164° W. long. in Southeastern Subdistrict, *fishery was scheduled to close 12/31/85 but did not, it remained open until the start of the 1986 fishery
1986	01/15/86	04/21/86	Southeastern Subdistrict closure west of 164° W long.[b]
		06/01/86	Pribilof Subdistrict closure[b]
		08/01/86	Northern Subdistrict closure east of 175° W. long.[b]
		08/24/86	Northern Subdistrict closure west of 175° W. long.[b]
1987	01/15/87	04/12/87	Southeastern Subdistrict west of 164° W. long., and Pribilof Subdistrict closure
		06/01/87	Northern Subdistrict south of 60°30' N lat. and east of 178° W. long. closure

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Table 2-24.-(page 2 of 2).

Season	Opened	Closed	Comments
1987 (cont.)	01/15/87	06/22/87	Northern Subdistrict north of 60°30’ N lat. and west of 178° W. long. closure
1988	01/15/88	03/29/88	Bering Sea District closure (Western Subdistrict to assist in an orderly closure)
	05/15/88	06/30/88	Western Subdistrict reopen and closure
1989	01/15/89	03/26/89	Eastern Subdistrict closure
		05/07/89	Western Subdistrict closure
1990	01/15/90	04/09/90	Eastern Subdistrict east of 165° W. long. closure
		04/24/90	Eastern Subdistrict west of 165° W. long. closure
		06/12/90	Western Subdistrict closure
1991	01/15/91	05/05/91	Eastern Subdistrict closure
		06/23/91	Western Subdistrict closure
1992	01/15/92	04/22/92	Bering Sea District closure
1993	01/15/93	03/15/93	Bering Sea District closure
1994	01/15/94	03/01/94	Bering Sea District closure
1995	01/15/95	02/17/95	Bering Sea District closure
1996	01/15/96	02/29/96	Bering Sea District closure
1997	01/15/97	03/21/97	Bering Sea District closure
1998	01/15/98	03/20/98	Bering Sea District closure
1999	01/15/99	03/22/99	Bering Sea District closure
2000	04/01/00	04/08/00	Bering Sea District closure
2001	01/15/01	02/14/01	Bering Sea District closure
2002	01/15/02	02/08/02	Bering Sea District closure
2003	01/15/03	01/25/03	Bering Sea District closure
2004	01/15/04	01/23/04	Bering Sea District closure
2005/06	10/15/05	05/15/06	Eastern Subdistrict closure
		05/31/06	Western Subdistrict closure

[a]State managed domestic fishery.

[b]Concurrent state and federal date.

Table 2-25.-Bering Sea commercial snow crab fishery harvest and effort by week, 2005/06 season.

	Number of						
Week ending	Vessels	Landings	Crabs[a]	Harvest[a,b]	Pot pulls	CPUE[c]	Deadloss[b]
22-Oct	1			CONFIDENTIAL			
26-Nov	1			CONFIDENTIAL			
10-Dec	1			CONFIDENTIAL			
17-Dec	1			CONFIDENTIAL			
24-Dec	1			CONFIDENTIAL			
31-Dec	2			CONFIDENTIAL			
7-Jan	6	6	488,819	781,571	2,389	205	4,152
14-Jan	20	23	1,995,485	3,023,674	10,297	194	30,648
21-Jan	17	19	1,586,537	2,436,898	9,941	160	24,653
28-Jan	24	26	2,157,237	3,305,062	13,062	165	30,246
4-Feb	16	19	1,144,117	1,760,438	6,156	186	16,315
11-Feb	16	17	879,336	1,366,407	6,803	129	10,314
18-Feb	12	16	1,335,499	2,031,997	5,126	261	16,492
25-Feb	13	16	1,368,876	2,036,111	5,018	273	18,990
4-Mar	15	17	1,754,913	2,627,268	6,322	278	24,245
11-Mar	20	25	1,631,892	2,389,927	7,149	228	27,023
18-Mar	28	38	2,581,263	3,751,736	10,674	242	43,748
25-Mar	14	17	1,091,093	1,596,580	4,619	236	15,128
1-Apr	13	21	1,338,359	1,962,938	5,243	255	17,651
8-Apr	14	19	1,173,395	1,741,607	5,739	204	21,982
15-Apr	5	7	202,786	315,602	1,517	134	3,420
22-Apr	4	5	446,581	694,488	2,529	177	8,930
29-Apr	1			CONFIDENTIAL			
6-May	1			CONFIDENTIAL			
13-May	4	4	325,875	538,672	1,484	220	5,817
20-May							
27-May	1			CONFIDENTIAL			
Total	78	310	22,080,235	33,256,146	108,320	204	322,595

[a]Deadloss included.
[b]In Pounds.
[c]Number of legal crabs per pot lift.

Table 2-26.-Bering Sea District commercial snow crab harvest by season and subdistrict, 1977/78-2005/06.

		Number of					Average		
Season	Subdistrict	Vessels[a,b]	Landings[c]	Crabs[d]	Pots Lifted	Harvest[d,e]	Weight[e]	CPUE[f]	Deadloss[e]
1977/78	Southeastern		33	1,063,872	11,560	1,439,959	1.4	92	NA
	Pribilof		5	203,674	1,687	276,165	1.4	121	NA
	TOTAL	15	38	1,267,546	13,247	1,716,124	1.4	96	NA
1978/79	Southeastern	101	476	21,279,794	184,491	31,102,832	1.5	115	659,137
	Pribilof	10	14	838,704	6,225	1,084,039	1.5	135	100,000
	TOTAL	102	490	22,118,498	190,746	32,187,039	1.5	116	759,137
1979/80	Southeastern	133	561	23,199,446	237,375	36,406,391	1.6	98	187,945
	Pribilof	19	36	2,087,331	17,727	3,166,777	1.5	118	40,400
	TOTAL	134	597	25,286,777	255,102	39,572,668	1.6	99	228,345
1981	Southeastern		624	24,498,642	309,304	37,866,229	1.6	79	1,475,078
	Pribilof		243	9,916,617	126,438	14,886,705	1.5	78	794,901
	TOTAL	153	867	34,415,322	435,742	52,750,034	1.5	79	2,269,979
1982	Southeastern		468	10,207,174	257,193	13,079,583	1.3	40	422,979
	Pribilof		335	13,882,388	211,898	16,276,421	1.2	66	669,676
	TOTAL	122	803	24,089,562	469,091	29,355,374	1.2	51	1,092,655
1983	Southeastern		153	3,553,281	94,470	4,197,304	1.2	38	165,298
	Pribilof		239	19,076,553	153,458	20,514,000	1.0	124	1,078,643
	Northern		69	1,223,813	39,199	1,417,106	1.1	31	80,525
	TOTAL	109	461	23,853,647	287,127	26,128,410	1.1	83	1,324,466

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Table 2-26.-(page 2 of 5)

Season	Subdistrict	Number of Vessels[a,b]	Landings[c]	Crabs[d]	Pots Lifted	Harvest[d,e]	Average Weight[e]	CPUE[f]	Deadloss[e]
1984	Southeastern		76	3,534,370	33,091	3,990,621	1.1	107	54,678
	Pribilof		230	17,909,096	112,078	19,727,493	1.1	160	708,706
	Northern		61	2,566,469	28,422	3,094,960	1.2	90	35,411
	TOTAL	52	367	24,009,935	173,591	26,813,074	1.1	138	798,795
1985	Southeastern	55	301	21,963,882	158,819	27,373,232	1.4	138	461,001
	Pribilof	60	301	24,089,526	142,937	29,804,093	1.2	169	505,146
	Northern	24	116	6,849,838	70,289	8,821,550	1.3	97	98,037
	TOTAL	75	718	52,903,246	372,045	65,998,875	1.3	142	1,064,184
1986	Southeastern	47	112	8,491,694	63,889	10,957,578	1.3	133	44,755
	Pribilof	80	508	39,851,767	281,337	50,525,150	1.3	142	472,342
	Northern	67	372	28,155,662	198,518	36,501,811	1.3	142	861,436
	TOTAL	88	992	76,499,123	543,744	97,984,539	1.3	141	1,378,533
1987	Southeastern	28	64	4,116,778	24,619	5,106,473	1.2	167	24,619
	Pribilof	94	458	38,604,802	261,337	47,676,734	1.2	148	261,337
	Northern	99	516	38,586,079	330,157	49,120,181	1.2	117	330,157
	TOTAL	103	1,038	81,307,659	616,113	101,903,388	1.2	132	978,449
1988	Eastern	162	771	60,019,586	423,919	75,926,942	1.3	142	740,976
	Western	151	518	45,913,956	323,476	58,314,786	1.3	142	2,501,693
	TOTAL	171	1,285	105,933,542	747,395	134,241,728	1.3	142	3,424,021
1989	Eastern	164	872	77,717,813	393,251	103,163,307	1.3	198	1,137,971
	Western	127	470	34,986,402	271,991	45,142,955	1.3	129	802,511
	TOTAL	168	1,300	112,704,215	665,242	148,306,262	1.3	169	1,940,482

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Table 2-26.-(page 3 of 5)

Season	Subdistrict	Number of Vessels[a,b]	Landings[c]	Crabs[d]	Pots Lifted	Harvest[d,e]	Average Weight[e]	CPUE[f]	Deadloss[e]
1990	Eastern	177	956	76,285,217	511,949	94,775,962	1.2	149	1,010,755
	Western	152	659	52,645,809	399,354	66,989,453	1.3	132	785,909
	TOTAL	189	1,563	128,931,026	911,303	161,765,415	1.3	141	1,796,664
1991	Eastern	218	2,013	190,139,612	912,631	240,090,666	1.3	208	1,593,021
	Western	185	867	74,984,348	478,832	88,556,603	1.2	157	1,871,015
	TOTAL	220	2,788	265,123,960	1,391,463	328,647,269	1.2	191	3,464,036
1992	Eastern	248	2696	217,376,231	1,228,280	302,364,005	1.4	177	2,269,467
	Western	55	152	10,000,351	56,385	12,938,029	1.3	187	56,385
	TOTAL	250	2,763	227,376,582	2,325,852	315,302,034	1.4	177	2,325,852
1993	Eastern	251	1,383	110,756,768	675,936	151,324,024	1.4	164	1,108,520
	Western	185	632	58,778,849	294,710	79,430,229	1.4	199	465,432
	TOTAL	254	1,835	169,535,617	970,646	230,754,253	1.4	175	1,573,952
1994	Eastern	219	820	56,012,433	375,928	72,008,424	1.3	149	901,674
	Western	171	586	58,797,753	340,596	77,784,294	1.3	173	898,089
	TOTAL	273	1,293	114,810,186	716,524	149,792,718	1.3	160	1,799,763
1995	Eastern	217	628	32,677,836	314,711	39,793,496	1.2	104	659,051
	Western	153	357	27,981,053	192,892	35,515,691	1.3	145	630,118
	TOTAL	253	870	60,658,899	659,051	75,309,187	1.2	120	1,289,169
1996	Eastern	161	465	23,663,995	252,159	28,232,574	1.2	94	555,326
	Western	146	354	29,228,325	268,512	37,463,599	1.3	109	777,689
	TOTAL	234	771	52,892,320	520,671	65,696,173	1.2	102	1,333,015

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Table 2-26.-(page 4 of 5)

Season	Subdistrict	Number of Vessels[a,b]	Landings[c]	Crabs[d]	Pots Lifted	Harvest[d,e]	Average Weight[e]	CPUE[f]	Deadloss[e]
1997	Eastern	225	1,041	88,524,929	649,319	105,695,147	1.2	136	2,115,217
	Western	83	164	11,488,887	104,821	13,894,192	1.2	110	236,338
	TOTAL	226	1,127	100,013,816	754,140	119,589,339	1.2	133	2,351,555
1998[g]	Eastern	228	1,724	177,994,288	855,869	232,772,054	1.3	208	2,789,721
	Western	43	87	8,649,250	35,350	8,649,250	1.2	245	106,653
	TOTAL	229	1,767	186,643,538	891,219	186,643,538	1.3	209	2,896,374
1999[g]	Eastern	236	1,387	103,230,699	656,541	135,454,092	1.3	157	1,237,997
	Western	121	388	40,238,741	242,767	49,280,919	1.2	166	590,543
	TOTAL	241	1,631	143,469,440	899,308	184,735,011	1.3	160	1,828,540
2000[g]	Eastern	170	217	15,269,109	110,127	20,941,389	1.4	139	196,610
	Western	82	92	7,996,693	59,937	9,833,449	1.2	133	134,286
	TOTAL	229	288	23,265,802	170,064	30,774,838	1.3	137	330,896
2001[g]	Eastern	162	218	8,864,497	113,954	12,557,788	1.4	78	223,861
	Western	85	115	8,321,026	62,976	10,824,258	1.3	132	206,023
	TOTAL	207	293	17,185,523	176,930	23,382,046	1.4	97	429,884
2002[g]	Eastern	144	274	10,403,159	162,729	13,554,037	1.3	64	300,716
	Western	108	192	12,878,282	145,403	16,679,457	1.3	89	284,572
	TOTAL[h]	191	403	23,281,441	308,132	30,233,494	1.3	76	585,288

-Continued-

Table 2-26.-(page 5 of 5)

Season	Subdistrict	Number of Vessels[a,b]	Number of Landings[c]	Number of Crabs[d]	Number of Pots Lifted	Harvest[d,e]	Average Weight[e]	Average CPUE[f]	Deadloss[e]
2003[g]	Eastern	58	75	391,324	29,305	4,856,607	1.2	134	106,594
	Western	159	216	17,573,645	109,974	21,341,417	1.2	160	555,815
	TOTAL[i]	192	256	21,504,969	139,279	26,198,024	1.2	154	662,409
2004[g]	Eastern	59	75	2,127,631	16,539	2,764,695	1.3	129	28,211
	Western	170	209	15,203,883	93,548	19,405,455	1.3	163	196,166
	TOTAL	189	240	17,331,514	110,087	22,170,150	1.3	157	224,377
2005[g]	Eastern	61	84	5,505,532	18,822	7,798,629	1.4	293	54,539
	Western	128	136	11,179,219	51,041	15,237,658	1.4	219	169,654
	TOTAL	169	196	16,684,751	69,863	23,036,287	1.4	239	224,193
2005/06[j]	Eastern	NA	566	14,193,844	77,311	21,741,637	1.5	184	202,154
	Western	NA	263	7,886,391	31,009	11,514,505	1.5	254	120,440
	TOTAL	78	829	22,080,235	108,320	33,256,142	1.5	204	322,594

[a]Vessels by subdistrict are vessels that actively participated in the fishery.
[b]Vessel totals are vessels that registered but may not have actively participated in the fishery.
[c]Number of subdistrict landings is greater than the total number of vessel landings because a single vessel may fish in several statistical areas.
[d]Deadloss included.
[e]In pounds.
[f]Number of legal crabs per pot lift.
[g]General fishery only.
[h]Total harvest includes 30,919 pounds taken from an unidentified statistical area.
[i]Includes 181,457 pounds illegally taken in Russian waters.
[j]IFQ fishery only.
NA = Not Available.

Table 2-27.-Bering Sea District commercial snow crab fishery catch by statistical area, 2005/06.

Area	Number of Landings[a]	Number of Crabs[b]	Number of Pots Lifted	Harvest[b,c]	Average Weight[c]	Average CPUE[d]	Deadloss[c]
EASTERN SUBDISTRICT AREAS							
675530	4	1,471	157	2,486	1.7	9	19
675600	4	757	100	1,202	1.6	8	15
685600	6	1,887	202	3,055	1.6	9	28
685630	7	67,989	788	104,458	1.5	86	1,075
695631	19	66,171	3,818	102,428	1.5	17	1,036
705600	11	125,390	1,009	183,698	1.5	124	2,169
705630	19	31,243	1,981	49,120	1.6	16	488
705701	11	146,062	946	238,249	1.6	154	1,936
715600	14	283,325	849	445,263	1.6	334	4,374
715630	95	3,519,696	17,814	5,470,027	1.6	198	52,837
715700	71	1,581,489	8,399	2,485,297	1.6	188	22,829
715730	58	2,235,351	8,283	3,372,267	1.5	270	31,991
725630	64	1,704,753	10,941	2,582,277	1.5	156	23,239
725700	51	1,013,554	6,408	1,582,523	1.6	158	13,196
725730	82	2,566,233	11,150	3,857,108	1.5	230	34,143
725800	35	753,003	3,233	1,120,672	1.5	233	10,964
Other[e]	15	95,470	1,233	141,507	1.5	77	1,815
Subtotal	566	14,193,844	77,311	21,741,637	1.5	184	202,154
WESTERN SUBDISTRICT AREAS							
735700	4	21,695	192	37,472	1.7	113	299
735730	21	210,447	1,722	320,467	1.5	122	2,649
735800	43	1,752,666	6,934	2,591,097	1.5	253	28,665
735830	55	1,992,448	7,794	2,864,950	1.4	256	32,451
735900	21	491,516	2,062	715,195	1.5	238	6,179
745800	4	27,346	123	39,210	1.4	222	500
745830	55	2,028,717	6,234	2,945,288	1.5	325	28,567
745900	38	1,271,293	5,056	1,868,191	1.5	251	18,564
745930	5	23,233	142	34,921	1.5	164	496
755900	7	33,539	405	48,394	1.4	83	948
Other[f]	10	33,491	345	49,320	1.5	97	1,122
Subtotal	263	7,886,391	31,009	11,514,505	1.5	254	120,440
Total	829	22,080,235	108,320	33,256,142	1.5	204	322,594

[a]Number of statistical area landings is greater than the total number of landings because a single vessel may fish in several statistical areas.

[b]Deadloss included.

[c]In pounds.

[d]Number of legal crabs per pot lift.

[e]Includes 10 statistical areas where less than three vessels made landings.

[f]Includes 5 statistical areas where less than three vessels made landings.

Table 2-28.-Bering Sea District commercial snow crab fishery economic data 1979/80-2005/06.

Year	Value		Registered	Season
	Ex-vessel[a]	Total[b]	Pots[c]	Length[d]
1979/80	$0.21	$ 82.50	35,503	307
1981	$0.26	$ 13.10	39,789	229
1982	$0.73	$ 20.70	35,522	167
1983[e]	$0.35	$ 8.70	15,396	120
1984[e]	$0.30	$ 7.80	12,493	320
1985[e]	$0.30	$ 19.50	15,325	333
1986[e]	$0.60	$ 60.00	13,750	252
1987[e]	$0.75	$ 75.70	19,386	158
1988[e]	$0.77	$ 100.70	38,765	120
1989[e]	$0.75	$ 110.70	43,607	112
1990[e]	$0.64	$ 102.30	46,440	148
1991[e]	$0.50	$ 162.60	76,056	159
1992	$0.50	$ 156.50	77,858	97
1993	$0.75	$ 171.90	65,081	59
1994	$1.30	$ 192.40	54,837	45
1995	$2.43	$ 180.00	53,707	33
1996	$1.33	$ 85.60	50,169	45
1997	$0.79	$ 92.60	47,036	65
1998[f]	$0.56	$ 134.65	47,909	64
1999[f]	$0.88	$ 160.78	50,173	66
2000[f]	$1.81	$ 55.09	43,407	7
2001[f]	$1.53	$ 32.12	40,379	30
2002[f]	$1.49	$ 44.20	37,807	24
2003[f]	$1.83	$ 46.98	20,452	9
2004[f]	$2.05	$ 44.99	14,444	8
2005[f]	$1.80	$ 41.47	12,840	6
2005/06[g]	$0.84	$ 27.66	13,734	229

[a]Average price per pound.
[b]Millions of dollars.
[c]Prior to 1992 includes Tanner crab gear.
[d]In days.
[e]Partial district and subdistrict closures, see Table 2-24.
[f]General fishery only.
[g]IFQ fishery only.

Table 2-29.-Bering Sea District commercial snow crab fishery harvest composition by fishing season, 1978/79-2005/06.

Season	Average		Percent new	Percent <102 mm cw
	Weight[a]	Width[b]	shell	landed
1978/79	1.5	113.1	83.0	NA
1979/80	1.6	118.1	90.0	NA
1981	1.5	117.0	79.2	NA
1982	1.2	109.4	78.0	NA
1983[c]	1.1	NA	NA	NA
1984[c]	1.1	105.4	78.0	NA
1985[c]	1.3	108.0	80.0	NA
1986[c]	1.3	109.5	73.7	NA
1987[c]	1.2	108.9	84.0	NA
1988[c]	1.3	109.5	71.2	NA
1989[c]	1.3	111.2	85.2	NA
1990[c]	1.3	109.1	97.4	NA
1991[c]	1.2	110.2	95.1	NA
1992	1.4	111.7	97.6	NA
1993	1.4	111.6	92.5	NA
1994	1.3	110.4	93.1	11.3
1995	1.2	108.6	89.6	17.2
1996	1.2	107.5	75.8	19.7
1997	1.2	107.3	96.5	17.3
1998[d]	1.3	111.1	97.0	7.3
1999[d]	1.3	110.3	97.7	8.0
2000[d]	1.3	111.3	95.2	6.5
2001[d]	1.4	111.3	95.2	5.3
2002[d]	1.3	110.4	69.0	12.2
2003[d]	1.2	107.2	83.8	10.2
2004[d]	1.3	110.4	86.0	10.2
2005[d]	1.4	113.6	88.1	7.9
2005/06[e]	1.5	116.6	81.4	1.8

[a]In pounds.
[b]Carapace width in millimeters.
[c]Partial district and subdistrict closures, see Table 2-24.
[d]General fishery only.
[e]IFQ fishery only.
NA = Not available.

Table 2-30.-Bering Sea District commercial grooved Tanner crab fishery harvest data, 1992-2005.

Year	Number of				Average		Value		
	Vessels	Crabs[a]	Pots Lifted	Harvest[a,b]	Weight[b]	CPUE[c]	Ex-vessel[d]	Total[e]	Deadloss[b]
1992				CONFIDENTIAL					
1993	6	342,095	35,650	658,796	1.9	9	$0.92	$0.61	71,000
1994	4	165,365	13,739	322,444	2.0	11	$2.65	$0.85	30,585
1995	8	461,401	59,028	984,648	2.1	7	$2.09	$2.06	67,329
1996	3	46,338	10,802	95,795	2.1	4	$1.12	$0.11	11,120
1997-1999				NO LANDINGS					
2000	1			CONFIDENTIAL					
2001	1			CONFIDENTIAL					
2002				NO LANDINGS					
2003	1			CONFIDENTIAL					
2004	4			CONFIDENTIAL					
2005	1			CONFIDENTIAL					

[a]Deadloss included.

[b]In pounds.

[c]Number of legal crabs per pot lift.

[d]Average price per pound.

[e]Millions of dollars.

Table 2-31.-Bering Sea District commercial triangle Tanner crab fishery harvest data, 1992-2005.

Year	Number of				Average		Value		
	Vessels	Crabs[a]	Pots Lifted	Harvest[a,b]	Weight[b]	CPUE[c]	Ex-vessel[d]	Total[e]	Deadloss[b]
1992-1994				NO LANDINGS					
1995	4	35,236	21,070	40,991	1.2	1	$1.45	$0.06	11,943
1996	1			CONFIDENTIAL					
1997-1999				NO LANDINGS					
2000[f]	1			CONFIDENTIAL					
2001[f]	1			CONFIDENTIAL					
2002[f]				NO LANDINGS					
2003[f]	1			CONFIDENTIAL					
2004[f]	4			CONFIDENTIAL					
2005[f]				NO LANDINGS					

[a]Deadloss included.

[b]In pounds.

[c]Number of legal crabs per pot lift.

[d]Average price per pound.

[e]Millions of dollars.

[f]Restricted to incidental harvest during grooved Tanner crab fishery.

Confidential = Less than three vessels or processors participated in the fishery.

Table 2-32.-Community Development Quota (CDQ) program percent allocation by fishery to each participating CDQ group, 2004-2005/06 seasons.

Fishery	Group[a]					
	APICDA	BBEDC	CBSFA	CVRF	NSEDC	YDFDA
Western Aleutian Islands red king crab	8	18	21	18	21	14
Eastern Aleutian Islands golden king crab	8	18	21	18	21	14
Bristol Bay Red King Crab	17	19	10	18	18	18
Pribilof Red & Blue King Crab	0	0	100	0	0	0
St. Mathew Blue King Crab	50	12	0	12	14	12
Bering Sea Tanner Crab	10	19	19	17	18	17
Bering Sea Snow Crab	8	20	20	17	18	17

[a]APICDA (Aleutian Pribilof Island Community Development Association).
BBEDC (Bristol Bay Economic Development Corporation).
CBSFA (Central Bering Sea Fishermen's Association).
CVRF (Coastal Villages Region Fund).
NSEDC (Norton Sound Economic Development Corporation).
YDFDA (Yukon Delta Fisheries Development Association).

Table 2-33.-Commity Development Quota (CDQ) Program crab fishery data, 1998-2005/06.

Fishery	Allocation[a]	Number of Vessels	Number of Landings	Number of Crabs[ab]	Harvest[a,b]	Deadloss[a]	CPUE[c]
			Bristol Bay Red King Crab				
1998	525,115		Confidential				23
1999	580,641		Confidential				29
2000	610,265		Confidential				20
2001	617,623		Confidential				29
2002	714,239		Confidential				30
2003	1,167,040	13	20	174,907	1,166,662	2,197	31
2004	1,135,326	12	21	166,829	1,133,013	2,549	31
2005/06	1,832,900		Confidential				
			Pribilof Red King Crab				
1998	35,958 [d]		Confidential				6
1999-2005/06			Fishery Closed				
			Pribilof Blue King Crab				
1998	35,958 [d]		Confidential				6
1999-2005/06			Fishery Closed				
			St. Matthew Blue King Crab				
1998	99,512		Confidential				10
1999-2005/06			Fishery Closed				
			Bering Sea Snow Crab				
1998	8,886,634	20	86	6,975,242	8,846,977	134,898	176
1999	9,674,326	23	104	7,747,876	9,670,084	92,871	167
2000	2,518,760		Confidential				144
2001	1,878,070		Confidential				98
2002	2,458,565	11	33	1,873,443	2,399,289	73,130	100
2003	2,120,637	10	29	1,747,935	2,118,899	18,378	120
2004	1,782,081	10	25	1,338,077	1,772,222	24,199	98
2005	1,856,337	9	23	1,325,601	1,855,841	11,286	389
2005/06	3,718,400	15	40	2,470,956	3,717,744	34,605	203
			Bering Sea Tanner Crab				
1998-2004			Fishery Closed				
2005/06	162,000	6	10	75,686	161,572	611	373
			Western Aleutian Islands red king crab				
2005/06			Fishery Closed				
			Eastern Aleutian Islands golden king crab				
2005/06	300,000		Confidential				

[a]In pounds.

[b]Deadloss inlcuded.

[c]Number of legal crabs per pot pull.

[d]Fishery was executed with an overall quota for both Pribilof red and blue king crab, harvest was tracked by species

Table 2-34.-Economic overview of the Bering Sea crab Community Development Quota fisheries, 1998-2005/06

Fishery	Harvest[ab]	Ex-vessel Value[c]	Fishery Value[d]	Average Weight[a]	Pots Registered	Pots Lifted
			Bristol Bay Red King Crab			
1998-2002			Confidential			
2003	1,164,465	$ 4.67	$ 5,438,052	6.7	2,470	5,704
2004	1,130,464	$ 3.97	$ 4,487,942	6.8	2,258	5,359
2005/06			Confidential			
			Pribilof Red King Crab			
1998			Confidential			
1999-2005/06			Fishery Closed			
			Pribilof Blue King Crab			
1998			Confidential			
1999-2005/06			Fishery Closed			
			St. Matthew Blue King Crab			
1998			Confidential			
1999-2005/06			Fishery Closed			
			Bering Sea Snow Crab			
1998	8,712,079	$ 0.54	$ 4,704,523	1.3	4,016	39,575
1999	9,577,213	$ 0.85	$ 8,140,631	1.2	5,250	46,490
2000			Confidential			
2001			Confidential			
2002	2,326,159	$ 1.33	$ 3,093,791	1.3	2,100	18,786
2003	2,100,521	$ 1.80	$ 3,780,938	1.2	1,670	14,583
2004	1,748,023	$ 1.99	$ 3,478,566	1.3	1428	13,622
2005	1,855,841	$ 1.80	$ 3,340,514	1.4	1140	3,345
2005/06	3,683,795	$ 0.65	$ 2,394,466	1.5	12192	
			Bering Sea Tanner Crab			
1998-2004			Fishery Closed			
2005/06	160,961	$ 1.25	$ 201,201	2.1	681	2,024
			Western Aleutian Islands red king crab			
2005/06			Fishery Closed			
			Eastern Aleutian Islands golden king crab			
2005/06			Confidential			

[a]In pounds.
[b]Deadloss not included.
[c]Average price per pound.
[d]CDQ group portion estimated at 20 to 30% of fishery value.

Market Models for Alaska Snow Crab and King Crab: The Affects of Foreign Competition

September 14, 2006

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Alaska crab fisheries have historically provided great economic benefits to harvesters, processors and coastal communities. However, declines to biomass and landings levels for most Alaska crab species, as well as changing market conditions, have greatly challenged the crab industries continued prosperity. The industry has had to transit to world crab markets that are now dominated by snow crab and king crab from Canada, Russia and Greenland. In addition to these major changes, the industry is now confronted with a new rights based fishery rationalization program that introduces to the major Alaska crab fisheries transferable rights to crab harvests and processing. Given the fundamental changes to industry structure, both in how the fishery is prosecuted and how exvessel prices are set, and the international snow crab and king crab markets, it is timely to develop an equilibrium supply and demand model of international snow crab and king crab markets for the pre-rationalization period. The model presented here is an extension of a past snow crab market model study the authors reported in the 2005 BSAI Crab SAFE.

The specific objectives of this study are to construct, estimate and perform sensitivity analysis on an international econometric model of the supply and demand for king and snow crab to (1) target the primary and most important determinants of market demand, (2) estimate the relationship between North America crab landings and the resulting prices and revenues received for the crab, (3) set a foundation that can be used to study the effects on industry revenues of crab rationalization.

An important recent development in world crab markets has been the emergence of a major commercial red king crab fishery in the Barents Sea. The Russian king crab fishery has historically occurred in the Russian Far-East. However, Russian scientist introduced red king crab to the Barents Sea in the 1960s. Since then the Barents Sea red king crab stock has greatly increased in numbers and range of distribution (Fisheries. No 2006). The fishery is currently co-managed by Russia and Norway. A research fishery occurred from 1994 to 2001, and a commercial fishery has been in place since 2002 (NMFCA 2006a). The quota for the Russian fishery in the current year is 3 million crab and the Norwegian quota is for an additional 300,000 animals (NMFCA 2006b). The Barents Sea red king crab fishery has been noted for producing particularly large crab with an average weight of 10 pounds (Welch 2006). In addition to the large size of the crab, the fishery has been noted for producing high quality product due to American supplied equipment and supervision. The sudden emergence of this large scale king crab fishery has been viewed by one fisheries consultant as being a major drag on world red king crab prices across size categories. Furthermore, the fishery is viewed as very healthy and capable of supporting a growing future commercial harvest (Sackton 2006). Because the commercial fishery did not emerge until 2002, its affects to crab markets are largely absent for the time period modeled in this study. However, this fishery is of great potential importance to world crab markets and the economic returns to the Alaska crab industry.

Methods

To determine the most important supply and demand factors influencing the prices and revenues for Alaska snow crab and king crab we developed an integrated market model. This model includes the major crab supplier countries of Alaska, Canada, Russia and Greenland and the major markets, the United States and Japan. This is the first model of its kind where the international allocation and demand for king crab and snow crab are simultaneously modeled in a partial equilibrium framework. Our modeling effort here is directed toward explaining long term movement in snow crab and king crab prices. We are interested in explaining and forecasting price trends rather than predicting prices at some particular point in time. The flowchart in Figure 1 presents the framework that informed our crab market model.

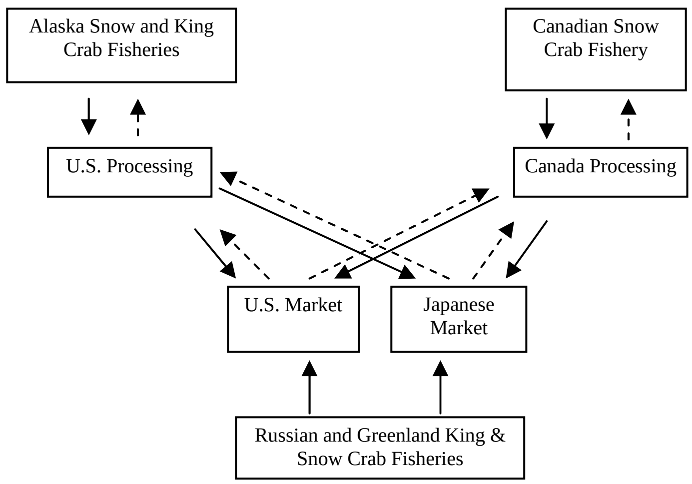

Figure 1. Market model flowchart for king crab and snow crab (The solid arrows represent modeled product flow and the dashed arrows represent modeled money flow).

The international supply and demand equilibrium model for Alaska king crab and snow crab and Canadian snow crab consists of 12 behavioral equations and 17 market clearing identities. The complete system of equations includes twenty-nine endogenous variables and equations. The behavioral structural equations include the Alaska allocation of snow (and Tanner) crab and king crab to Japan and the United States, the U.S. demand for Alaska and Canadian snow crab (and other crab) and Alaska king crab, the Alaska exvessel price of snow crab and king crab, the Canadian allocation of snow crab (and other crab) to Japan and the U.S. and Japanese demand for Alaska and Canadian snow crab and Alaska king crab, and the Canadian exvessel price of snow crab. The model was estimated using 3SLS with data for the period 1984-2004 for the snow crab portion of the model and 1980-2004 for the king crab portion of the model.

Through model estimation we found statistical evidence that the U.S. demand for Alaska and Canadian snow crab are affected by the competing countries snow crab prices and the imports of Russian and Greenland snow crab as well as Russian king crab. The Japanese demand for Alaska and Canadian snow crab are similarly affected by the competing countries snow crab prices and Japanese imports of Russian and Greenland snow crab and Russian king crab. In the U.S. and Japanese demand for king crab, it was found that not only was there competition from the Russian and Greenland crab, but that the substantial quantities of snow crab from Canada and the United States (at wholesale prices well below that of king crab) had influenced Alaska king crab wholesale prices. The model portrays an international crab market where competition between king and snow crab species from the various producing countries interact and ultimately affect wholesale and exvessel prices for Alaska crab. The statistical relationships among these competing sources of crab are strong.

Simulations

Model simulations were conducted to examine the affects of Alaska crab landings (volume) to prices and revenues and to examine the affects of foreign competition to Alaska crab prices and exvessel revenues. The simulation results portray world crab markets where Alaska has been relegated to being a price taker in markets now dominated by foreign snow crab and king crab. Alaska wholesale and exvessel prices were found to be relatively elastic with respect to changes in Alaska landings from current levels (simulated based on 2004 market conditions). Alaska product is now a minor contributor to world markets that appear to be less discriminating with respect to the supply source of the crab. In the model simulations, the domestic crab landings have a much less pronounced ability to influence world prices. Accordingly, the simulations reveal that it would take substantial increases in Alaska supplies (at current world supply levels) before a point is reached where further Alaska landings would diminish Alaska revenues. For Alaska snow crab it is estimated that at current world supply levels, Alaska landings could expand over six-fold before the international markets would respond in a such a manner that Alaska snow crab revenue would decline (before the negative impact to revenues from declining prices would swamp the positive impacts to revenues as snow crab volume increases). For Alaska king crab, it is estimated that at current world supply levels Alaska landings could expand nearly four-fold before revenue would decline. The implication to fishery management is that any biologically supported harvest increase will boost industry revenues and the resulting revenue increases should well exceed any incremental increase in harvesting and processing costs.

It should be noted that the results presented here are not based on a bioeconomic model; accordingly only a partial picture is presented with respect to the affects of changing harvest levels to industry performance. This analysis cannot address optimal harvest rates and does not link current harvest levels to future fishery recruitment and harvests. However, the model can be used to project how changes to biologically based fishery harvest quotas will impact prices and revenues. In addition, the model can be employed simulate price and revenues responses to changes in other exogenous market variables.

The affects of a rapidly expanding Canadian snow crab fishery to the Alaska snow crab industry were examined by setting Canadian snow crab harvest in simulations to a lower level representative of this industry's performance prior to its dramatic expansion in the 1990s. The total revenue curve for the Alaska 2004 snow crab season under varying harvest levels was simulated fixing the Canadian snow crab harvest at its 1989 level of 49.3 million pounds. This total revenue curve was compared to the simulated total revenue curve when Canadian landings were at their 2004 levels. The comparison of these simulations is illustrated in Figure 1.

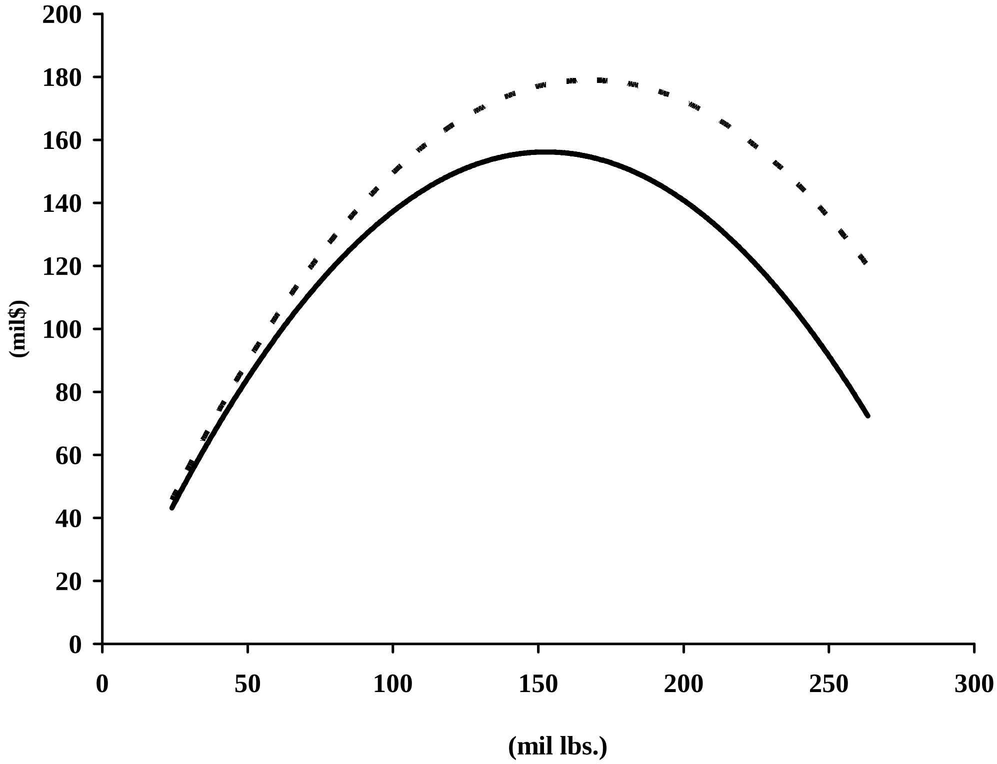

Figure 1. Simulated 2004 Alaska snow crab exvessel revenues for changes in Alaska snow crab landings (solid line) and with Canadian landings fixed at 1989 level of 49.3 million pounds (dashed line).

The simulated decrease in the 2004 Alaska snow crab price due to Canadian snow crab harvests being increased from their 1989 levels to their current levels is $0.11 per pound, which translates to a $2.64 million decline in exvessel revenue. At the lower level of Canadian harvest the model simulates an Alaska exvessel revenue curve that is maximized at Alaska landings of 167.6 million pounds. This would maximize the simulated exvessel revenue at $179.0 million with an exvessel price of $1.07/lb. This simulated Alaska exvessel revenue maximum is $22.8 million greater than that achieved with Canadian snow crab harvest at its 2004 level.

The impacts Russian crab exports to the Alaska crab industry was also investigated through model simulations. Specifically, crab exports from Russia (and Greenland) are set in simulations at 50% of the 2004 level while varying Alaska king crab landings. The Alaska king crab exvessel revenue curves simulated under actual and reduced Russian (and Greenland) export scenarios is presented in Figure 2.

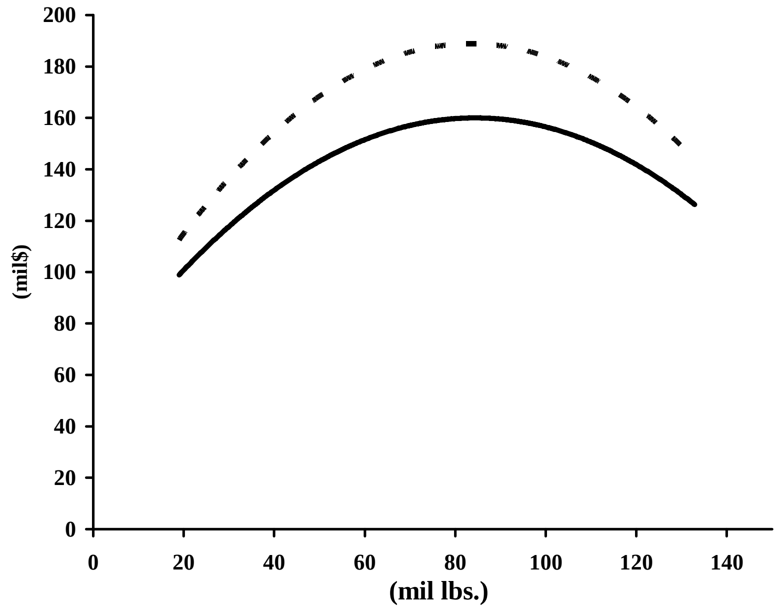

Figure 2. Simulated 2004 Alaska king crab exvessel revenues for changes in Alaska king crab landings (solid line) and with Russian and Greenland crab exports to Japan and the United States fixed at 50% of their 2004 level (dashed line).

The substantial amount of king crab and snow crab that Russia harvests and exports to Japan and the United States ultimately put significant downward pressure on Alaska king crab exvessel revenues. For example, in model simulations, Alaska king crab revenues would have been $19.5 million higher in 2004 if Russian and Greenland crab exports to the two major markets (U.S. and Japan) had been reduced in half. The simulated Alaska king crab exvessel revenues (at the reduced Russia and Greenland exports) is maximized at 70.3 million pounds at a price of $2.66/lb. and an exvessel revenue of $186.9 million. This simulated Alaska exvessel revenue maximum is $28.3 million greater than that achieved with the current (2004) level of Russian and Greenland crab exports.

Conclusions

In regard to the Alaska snow crab fishery revenue, given current world market conditions where Alaska is no longer the leading supplying nation of snow crab and where Alaska harvests have been well below historical peaks, the demand for Alaska snow crab is price elastic. This implies that world market prices are not sensitive to changes in Alaska snow crab production and there is room in crab markets for substantial growth in Alaska snow crab harvests. Biologically supported increases in Alaska snow crab harvests will increase snow crab revenue. This also implies that the Alaska crab industry can no longer rely on increased snow crab prices to mitigate the economic affects of decreased harvests. Decreases in Alaska snow crab harvests will decrease industry revenues.

In regard to the Alaska king crab fishery, the conclusions with regard to fishery revenue are similar to those stated above for snow crab. The Alaska king crab fishery is no longer the dominant supply source of king crab to world markets. Russia has assumed the role of the primary supplier of king crab to Japan, the traditional primary market for high valued Alaska red king crab. The result is that world king crab prices are not very responsive to changes in Alaska king crab harvest levels, i.e. world demand for Alaska king crab is price elastic. Accordingly, biologically supported increases in Alaska king crab harvests will increase industry revenue.

The Alaska snow crab industry is confronted with major competition from Canadian snow crab, Russian and Greenland snow crab and Russian king crab. Simulation results show that snow crab revenue to the Alaska crab industry have been severely impacted by the dramatic increases in snow crab from Canada. Furthermore the recent emergence of Greenland and Russia as major crab producers has acted as a further drag on Alaska snow crab prices and revenues.

The Alaska king crab industry is confronted with major competition from Russia king crab. Simulation results show Alaska king crab revenue to have been significantly depressed by the past decades growth in crab exports from Russia and Greenland. The competition from Russia may be intensifying as increased product flows from its Barents Sea fishery to world crab markets. Historically Russian king crab has been of lower quality than Alaska king crab and considered an inferior product. However, the Barents Sea king crab fishery produces large, high quality king crab that may be a very close substitute to Alaska king crab in world markets, and particularly in the U.S. market. The future performance of the Barents Sea king crab fishery and its potential affects to the Alaska crab industry deserves further study.

The opportunity for substantial economic improvement for Alaska snow and king crab prices, in lieu of a significant boost from crab rationalization, are not foreseen for the near future. The Alaska crab industry has been relegated to being a market follower in world crab markets and has limited ability to influence world snow crab and king crab prices. Major factors affecting world crab prices are exogenous to the Alaska crab industry.

All of the conclusions presented here are predicated on all other factor in the world crab markets remaining the same. If major market changes occur, for example should Canadian snow crab or Russian king crab harvests significantly decline then Alaska crab revenues would rise and Alaska crab harvests would become a much more prominent determinants of world crab prices.

For a more complete presentation of this study see:

> Hermann, M., and J. Greenberg, 2006. “An International Market Model for Red King (*Paralithodes camtschaticus*), Blue King (*P. platypus*), Golden King (*Lithodes aequispinus*), Tanner (*Chinoecetes Bairdi*) and Snow (*Chinoecetes opilio*) Crab. North Pacific Research Board Project Final Report. June.

Copies of this report are available from the authors, contact: j.greenberg@uaf.edu

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Stock Assessment of Eastern Bering Sea Snow Crab

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September 5, 2006

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SSC comments June 2006

1. There are troublesome trends in the residuals from the model fits. In particular, there is an unusual number of positive residuals in the period 1987 – 2001 (e.g., Figure 2), such that the model consistently underestimates biomass. The document would benefit from a more formal residuals analysis, in which deviations on a log scale are presented. The author should investigate the sensitivity of the model to the low biomass data from the 1985 and 1986 surveys. The author should investigate alternative weighting scenarios in addition to inverse variance weighting. Finally, retrospective analysis may assist in determining whether bias exists in the model.
2. The male maturity data needs additional examination. The logistic curve fitted to maturity of new-shell males does not fit well at smaller sizes. Better justification should be given for the logistic curve, or else a curve that matches the data should be used. A comparison of early and late survey data with respect to maturity is needed. Because the early surveys were restricted to the south, the survey range may affect the time series of maturity.
3. The document should explain the current rebuilding plan and gauge population status in regard to rebuilding goals.
4. The SSC agrees that shell condition may not be an accurate measure of age and awaits further investigation and resolution of this issue.
5. Having separate recruitment parameters by sex does not seem biologically plausible, unless there is evidence of differential mortality in the early life history. Only in 1981 is there any difference in estimated male and female recruitment, and this may be an artifact of uncertainty in the early data sources. Better justification is needed beyond the enhanced fit, or else separate parameters by sex should not be used.
6. The results from the spawner-recruit curve are not plausible, in that biomass during the entire time has been below the estimated B_{msy} level, even when the population boomed during two different cycles. This could be a consequence of the very high recruitment event of 1981. The sensitivity of B_{msy} to this data point should be investigated, as well as alternative spawner-recruit relationships.
7. Because the fishery occurs toward the south (in winter) but the population in the summer is more northward, it is unclear whether there may be differential exploitation by area. The author should further justify a single-area model and consider whether a spatial model or analysis is feasible.
8. The SSC recommends using points for observed values and lines for model values in figures.
9. More detail should be provided about the number of model parameters used and how many data points were used to fit the model. The model has a high number of estimated parameters. Efforts should be made to reduce this number.
10. A sensitivity analysis of the model to life history features should be undertaken.
11. A research priority should be fieldwork to understand variations in size, sex, and season, so that inferences about movement during the year and relative to the fishery can be made.
12. A sensitivity analysis should be conducted to examine the effects of the assumption that catchability is equal to 1.
13. Differential estimates of longevity were presented for males (18-20 years) and females (13-15 years), however the same natural mortality rate was used for both sexes. Therefore, a higher mortality rate for females than males seems appropriate, as was recommended during the February workshop. The effect of using a somewhat higher natural mortality rate for females should be explored through a sensitivity analysis. The model consistently estimates more large females than seen in the survey. Examination of residuals should be included in the sensitivity analysis.

Changes to the Model

The 1984, 1985 and 1986 survey biomass estimates were given less weight in the fitting procedure resulting in improved fit to the survey data (SSC comment 1). The inverse of the variance has been used in past assessments and is used in the present assessment to weight biomass in the fitting procedure (SSC comment 1). Other changes to the model also improved the fit to the survey data and the pattern of residuals.

The probability of maturing was estimated to match the observed fraction mature for all mature males and females observed in the survey data (SSC comment 2). While the fraction of all animals that are mature is fit well, the fraction of crab that are old shell is greater than in the survey data. The authors agree with SSC comment 4 that shell condition may not be an accurate measure of shell age and needs further investigation.

A figure and text concerning the rebuilding progress has been added to the document (SSC comment 3).

The number of parameters in the model was reduced by estimating recruitment to be equal for males and females and by estimating one set of fishery selectivities rather than allowing selectivity to change over time (SSC comments 5 and 9) .

The measure of spawning biomass used in the harvest strategy has been changed to mature male biomass at time of mating. Harvest strategies based on proposed tier 3 control rules with F35% and F40% are presented, using B35% and B40% respectively in the control rule (SSC comment 6), rather than attempting to fit a spawner recruit curve. The change in measure of biomass and the use of spr rates results in values for reference points within the range of estimated mature male biomass.

Points are used for observed values and lines for model fit (SSC comment 8).

Sensitivity analyses and alternative runs will be conducted in future. Time constraints between when survey data are available and when the assessment must completed in the late summer do not allow sufficient time for these investigations (SSC comments 7, 10,12 and 13).

The authors agree with SSC comment 11 that field research is needed on movement and distribution of crab by size and sex during different seasons.

A weight-length relationship for mature females and juvenile females was added to the model, which has been used in estimation of observed mature female survey biomass in the computer program used by NMFS in Kodiak.

Growth of females was constrained to be lower than in previous models taking into account growth information from Canadian female snow crab.

SUMMARY

A size based model was developed for eastern Bering Sea snow crab (*Chionoecetes opilio*) to estimate population biomass and harvest levels. Model estimates of mature biomass of snow crab increased from the early 1980’s to a peak in 1990 of about 1,946 million lbs. Biomass declined in the late 1990’s to about 798 million lbs. in 1999. The stock was declared overfished in 1999 because the survey estimate of

mature biomass was below the minimum stock size threshold (MSST = 460 million lbs). A rebuilding plan was implemented in 2000. Despite the imposition of the rebuilding plan, model estimates of mature biomass continued to decline to 499 million lbs in 2003, however, biomass then increased to 614 million lbs in 2006. Observed survey total mature biomass in 2006 was estimated at 519.5 million lbs, about 56% of Bmsy (921.6) estimated from average survey biomass 1983 to 1997. The observed survey estimate of males greater than 101 mm increased from about 69 million in 2005 to 135 million in 2006. There is a high degree of uncertainty in the estimated large male numbers. One survey tow accounted for 50 million males > 101 mm. The highest three tows accounted for 79 million males > 101 mm. The estimated 95% confidence interval for the observed survey large males was +/-76% of the estimate. Model estimates of large males were about 89 million crab in 2005 and 2006.

Catch has followed survey abundance estimates of large males, since the survey estimates have been the basis for calculating the GHL (Guideline Harvest Level for retained catch). Retained catches increased from about 6.7 million lbs at the beginning of the directed fishery in 1973 to a peak of 328 million lbs in 1991, declined thereafter, then increased to another peak of 243 million lbs in 1998. Retained catch in the 2000 fishery was reduced to 33.5 million lbs due to the low abundance estimated by the 1999 survey. A harvest strategy was developed using a simulation model previous to the development of the current model (Zheng et al. 2002), that has been used to set the most recent GHL's. Retained catch in the 2004 fishery was 23.66 million lbs, about 14% above the GHL of 20.8 million lbs. The 2004 total catch (retained plus discard) was estimated at 27.54 million lbs. Retained catch in the 2005 fishery was about 25 million lbs, about 20% above the GHL of 20.9 million lb. Retained catch in the 2006 fishery as 37 million lbs, equal to the preseason TAC.

Estimated discard (mostly undersized males and old shell males) in the directed pot fishery has averaged about 33% of the retained catch biomass since 1992 when observers were first placed on crab vessels. Discards prior to 1992 were estimated based on fishery selectivities estimated for the period with observer data. Discard mortality was assumed to be 50%.

Projected catch and biomass was estimated using mature male biomass at the time of mating, instead of total effective mature biomass using a mating ratio and old shell mature males used in the 2005 assessment. Spawning biomass per recruit values, F40% and F35% were used to project biomass and catches.

The survey biomass estimate for total mature biomass in 2006 was 56% (519 million lbs) of Bmsy (921.6 million lbs). The 2006 mature male biomass at mating time is projected to be at 61% of B40% and 68% of B35%. Using a harvest control rule with B40% and F40%, the 2007 retained catch is estimated at 21 million lbs (F = 0.4). Using a harvest control rule with B35% and F35%, the 2007 retained catch is estimated at 30 million lbs (F = 0.59).

The 2006 retained catch using the current ADF&G harvest strategy with observed mature male survey biomass (330.5 million lbs) is estimated at 52 million lbs(F = 1.2). The exploitation rate cap of 58% on the new shell males >101 plus 25% of old shell males >101 mm estimated from the survey (at the time of the survey) does not restrict the TAC. The total number of males >101mm estimated from the survey in 2006 was 135 million crab.

The rebuilding plan developed for snow crab projected a 50% probability of rebuilding by 2010. The probability of rebuilding to the total survey biomass Bmsy of 921.6 million lbs is 14% in 2010, fishing at F40% in fishery seasons 2007 to 2010 (55% probability in 2012). The probability of rebuilding is 10% in 2010, fishing at F35%, and 52% by 2013. The probability of rebuilding to Bmsy defined as 921.6 million lbs of total mature biomass under the current ADF&G harvest strategy is 13% in 2010 (51% in 2012).

Exploitation rates in the southern portion of the range of snow crab have been higher than target rates estimated using abundances in the geographic distribution of the stock due the majority of catch occurring in the southern portion of the snow crab range. This prominent feature of the fishery for Bering Sea snow crab has possibly contributed to the shift in distribution to less productive waters in the north. Computing the catch based on the complete survey biomass results in exploitation rates higher than the target rate on crabs in the southern area of the distribution. One solution would be to split the catch into two regions, north and south, according to the percent distribution of the survey estimate of large males or mature males from those regions. This would require knowing the location of catch inseason. Two other approaches would not require knowledge on inseason catch location. One would be to compute the catch from that portion of the stock where most of the catch is extracted. Another approach would be to compute a catch that would result in the target harvest rate for the southern portion of the stock and increase that catch according to the percent catch in the north. Splitting the catch by area would result in about 28% of the catch south of 58.5 deg N and 72% north. In 2003 and 2004, 26% and 24% respectively of male biomass greater than 101 mm measure in the survey was south of 58.5 deg N. Accounting for the population distribution and catch distribution would result in an expected exploitation rate in the southern portion of the snow crab range closer to the target rate.

Biomass is expected to increase in the next few years due to recent higher recruitment. The amount of increase may change in future assessments as more data on the strength of the recent recruitments is obtained.

INTRODUCTION

Snow crab (*Chionoecetes opilio*) are distributed on the continental shelf of the Bering Sea, Chukchi Sea, and in the western Atlantic Ocean as far south as Maine. In the Bering Sea, snow crab are common at depths less than about 200 meters. The eastern Bering Sea population within U.S. waters is managed as a single stock, however, the distribution of the population may extend into Russian waters to an unknown degree.

CATCH HISTORY

Snow crab were harvested in the Bering Sea by the Japanese from the 1960s until 1980 when the Magnuson Act prohibited foreign fishing. Retained catch in the domestic fishery increased in the late 1980’s to a high of about 328 million lbs in 1991, declined to 65 million lbs in 1996, increased to 243 million lbs in 1998 then declined to 33.5 million lbs in the 2000 fishery (Table 1, Figure 1). Due to low abundance and a reduced harvest rate, retained catches remained low and were 32.7 million lbs in the 2002 fishery (36.2 million lbs total catch), 28.3 million lbs of retained catch in 2003 (39 million lbs total catch). Retained catch in the 2005 fishery was 26 million lbs and 37 million lbs in 2006.

Discard from the directed pot fishery was estimated from observer data since 1992 and ranged from 11% to 64% (averaged about 33%) of the retained catch of male crab biomass (Table 1). Female discard catch is very low and not a significant source of mortality. In 1992 trawl discard mortality was about 9 million lbs, then declined to about 2 to 3 million lbs until 1998, when it declined to below 1 million lbs. Most discard for the period 1997 to 2002 in groundfish fisheries came from the yellowfin sole trawl fishery, flathead sole trawl fishery, Pacific cod bottom trawl fishery, rock sole trawl fishery and the Pacific cod hook and line and pot fisheries in decreasing order of catch.

Size frequency data and catch per pot have been collected by observers on snow crab fishery vessels since 1992. Observer coverage was 10% on catcher vessels larger than 125 ft (since 2001), and 100% coverage on catcher processors (since 1992). In the 2002 fishery about 0.5% of the total pot lifts were observed (Neufeld and Barnard 2003).

The average size of retained crabs has remained fairly constant over time ranging between 105 mm and 118 mm, and most recently about 110 mm to 111 mm. The percent new shell animals in the catch has varied between 69% (2002 fishery) to 98% (1999), and was 87% for the 2006 fishery. The average weight of retained crab has varied between 1.1 lbs (1983-1984) and 1.6 lbs(1979), and 1.3 lbs in the recent fisheries.

Several modifications to pot gear have been introduced to reduce bycatch mortality. In the 1978/79 season, pots used in the snow crab fishery first contained escape panels to prevent ghost fishing. Escape panels consisted of an opening with one-half the perimeter of the tunnel eye laced with untreated cotton twine. The size of the cotton laced panel to prevent ghost fishing was increased in 1991 to at least 18 inches in length. No escape mechanisms for undersized crab were required until the 1997 season when at least one-third of one vertical surface had to contain not less than 5 inches stretched mesh webbing or have no less than four circular rings of no less than 3 3/4 inches inside diameter. In the 2001 season the escapement for undersize crab was increased to at least eight escape rings of no less than 4 inches placed within one mesh measurement from the bottom of the pot, with four escape rings on each side of the two sides of a four-sided pot, or one-half of one side of the pot must have a side panel composed of not less than 5 1/4 inch stretched mesh webbing.

Harvest rates

The Harvest rate used to set the GHL (Guideline harvest level of retained crab only) previous to 2000 was 58% of the number of male crab over 101 mm carapace width estimated from the survey (Anonymous, 2000). The minimum legal size limit for snow crab is 78 mm, however, the snow crab market generally accepts animals greater than 101 mm. In 2000, due to the decline in abundance and the declaration of the stock as overfished, the harvest rate for calculation of the GHL was reduced to 20% of male crab over 101 mm. After 2000, a harvest strategy was developed based on simulations by Zheng (2002).

The actual retained catch typically exceeds the GHL, resulting in exploitation rates for the retained catch (using survey numbers) ranging from about 60% to 100% for most years (Figure 4). The exploitation fraction is calculated using the abundance for male crab over 101 mm estimated from the survey data reduced by the natural mortality from the time of the survey until the fishery occurs, approximately 7 months later, since the late 1980's. The historical GHL calculation did not include the correction for time lapsed between the survey and the fishery. Catches were greater than the abundance estimates from the survey because some crabs are retained that are less than 102 mm, discard mortality of small crabs is also included, and survey catchability may be less than 1.0. The exploitation fraction using the total catch divided by the mature male biomass estimated from the model, ranged from 10% to 50% (Figure 5). The exploitation fraction estimated by dividing the total catch by the model estimate of the crabs over 101 mm ranged from about 15% to 80% (Figure 5). The total exploitation rate on males > 101 mm was 50% to 75% for 1986 to 1994 and near 70% for 1998 and 1999 (year when fishery occurred).

Bmsy (921.6 million lbs) is defined in the current crab FMP as the average total mature biomass (males and females) estimated from the survey for the years 1983 to 1997 (BSAI crab FMP 1998). MSST was defined as 50% of the Bmsy value (MSST=460 million lbs of total mature biomass). The current harvest strategy uses a retained crab harvest rate on the mature male biomass of 0.10 on levels of total mature biomass greater than ½ MSST (230 million lbs), increasing linearly to 0.225 when biomass is equal to or greater than Bmsy (921.6 million lbs) (Zheng 2002). The GHL is actually set as the number of retained crab allowed in the harvest, calculated by dividing the GHL in lbs by the average weight of a male crab > 101 mm. If the GHL in numbers is greater than 58% of the estimated number of new shell crabs greater than 101 mm plus 25% of the old shell crab greater than 101 mm, the GHL is capped at 58%. If natural mortality is 0.2, then this actually results in a realized exploitation rate cap for the retained catch of 66% at the time of the fishery, occurring approximately 7 months after the survey. The fishing mortality rate that results from this harvest strategy depends on the relationship between mature male size numbers and male numbers greater than 101 mm. The maximum full selection fishing mortality rate is close to 1.0 under the current harvest strategy at the maximum harvest rate of 0.225 of mature male biomass.

ABUNDANCE TRENDS

Survey Biomass

Abundance is estimated from the annual Bering Sea bottom trawl survey conducted by NMFS (see Rugolo et al. 2003 for design and methods). Since 1989, the survey has sampled stations farther north than previous years. In 1982 the survey net was changed resulting in a change in catchability. Juvenile crabs tend to occupy more inshore northern regions (up to about 63 degrees N) and mature crabs deeper areas to the south of the juveniles (Zheng et al. 2001).

The total mature biomass estimated from the survey declined to a low of 188 million lbs in 1985, increased to a high of 1,775 million lbs in 1991, then declined to 330 million lbs in 1999, when the stock was declared overfished (Table 2 and Figure 2). The mature biomass increased in 2000 and 2001, mainly due to a few large catches of mature females. Survey estimates of total mature biomass increased to 551 million lbs in 2005, then decreased to 519 million lbs in 2006. The total mature biomass includes all sizes of mature females and morphometrically mature males.

The term mature for male snow crab will be used here to mean morphometrically mature. Morphometric maturity for males refers to a marked change in chelae size (thereafter termed “large claw”), after which males are assumed to be effective at mating. Males are functionally mature at smaller sizes than when they become morphometrically mature, although the contribution of these “small-clawed” males to annual reproductive output is negligible. The minimum legal size limit for the snow crab fishery is 78 mm, however the size for males that are generally excepted by the fishery is >101mm. The historical quotas were based on the survey abundance of large males (>101mm).

Survey Size Composition

Carapace width is measured on snow crab and shell condition noted in the survey and the fishery. Snow crab cannot be aged at present (except by radiometric aging of the shell since last molt), however, shell condition has been used as a proxy for age. Based on protocols adopted in the NMFS EBS trawl survey, shell condition class and presumptive age are as follows: soft shell (SC1) (less than three months from molting), new shell (SC2) (three months to less than one year from molting), old shell (SC3) (two years to three years from molting), very old shell (SC4) (three years to four years form molting), and very very old shell (SC5) (four years or longer from molting). Radiometric aging of shells from terminal molt male crabs (after the last molt of their lifetime) elucidated the relationship between shell condition and presumptive age, which will be discussed in a later section (Nevissi et al 1995 and Orensanz unpub. Data).

Survey abundance by size for males and females indicate a moderate recruitment of small crab in 2004 and 2005 (Figures 6 through 9). High numbers of small crab in the late 1970's did not follow through the population to the mid-1980's. The high numbers of small crab in the late 1980's resulted in the high biomass levels of the early 1990's and subsequent high catches. Moderate increase in numbers can also be seen in the mid 1990's.

Spatial distribution of catch and survey abundance

In 2003 and 2004, the majority of the fishery catch occurred south of 58.5 deg N., even though ice cover did not restrict the fishery moving farther north. In past years, most of the fishery catch occurred in the southern portion of the snow crab range possibly due to ice cover and proximity to port and practical constraints of meeting delivery schedules. In 2003, 66% of the catch was south of 58.5 deg N. (Figure 10), and in 2004 78% of the catch was south of 58.5 deg N. (Figure 11). In 2003 and 2004 the ice edge was farther north than past years, allowing some fishing to occur as far north as 60-61 deg N.

Summer survey data show that approximately 75% of the mature male snow crab population resides in a region outside of the fishery zone (north of 58.5 deg N Latitude). The 2003 survey estimated about 24% of the male snow crab >101mm were south of 58.5 deg N. About 48% of those males were estimated to be new shell. In 2004 about 26 % of the survey abundance of male snow crab > 101 mm and the mature male biomass were south of 58.5 deg N. latitude (Figures 12 and 14). About 53% of those males south of 58.5 deg N. were estimated to be new shell (which are preferred by the fishery). The 2004 fishery retained about 19 million crab of which about 14.8 million were caught south of 58.5 deg south (about 78%). At the time of the fishery, although these new shell males are morphometrically mature (i.e., large clawed), they are subject to exploitation prior recruiting to the reproductive stock – i.e., mating once. The 2003 survey estimate of new shell male crab > 101 mm was about 7.6 million south of 58.5 deg N. which would have been fished on in the 2004 fishery. In the 2004 survey about 9.5 million new shell males >101mm were estimated south of 58.5 deg N. This indicates that survey catchability may be less than 1.0 and/or some movement occurs between the summer survey and the winter fishery. However, the exploitation rate on males south of 58.5 deg N exceeds the target rate, possibly resulting in a depletion of males from the southern part of their range. Snow crab larvae probably drift north and east after hatching in spring. Snow crab appear to move south and west as they age, however, no tagging studies have been conducted to fully characterize the ontogenetic or annual migration patterns of this stock. High exploitation rates in the southern area may have resulted in a northward shift in snow crab distribution. Lower egg production in the south from lower clutch fullness and higher percent barren females possibly due to insufficient males for mating may drive a change in distribution to the north. The northward shift in mature females is particularly problematic in terms of annual reproductive output due to lowered productivity from the shift to biennial spawning of animals in waters < 1.5 deg C in the north. The lack of males in the southern areas at mating time (after the fishery occurs) may result in insufficient males for mating.

The spatial distribution of snow crab in the 2005 survey was similar to 2004 (Figures 12 through 17). Female crab > 49 mm occurred in higher concentration in generally three areas, just north of the Pribilof Islands, just south and west of St. Matthews Island, and to the north and west of St. Matthew Island. Males > 78 mm were distributed in similar areas to females, except the highest concentrations were between the Pribilof Islands and St. Matthews Island.

Armstrong and Ernst (in press) found the centroids of survey summer distributions have moved to the north over time (Figures 18 and 19). In the early 1980's the centroids of mature female distribution were near 58.5 deg N, in the 1990's the centroids were about 59.5 deg N. The centroids of old shell male distribution was south of 58 deg N in the early 1980's, moved north in the late 1980's and early 1990's then shifted back to the south in the late 1990's (Figure 19). The distribution of males>101 mm was about at 58 deg N in the early 1980's, then was farther north (58.5 to 59 deg N) in the late 1980's and early 1990's, went back south in 1996 and 1997 then has moved north with the centroid of the distribution in 2001 just north of 59 deg N.(Figure 19). The centroids of the catch are generally south of 58 deg N, except in 1987 (Figure 19). The centroids of catch also moved north in the late 1980's and most of the 1990's. The centroids of the catch were about at 56.5 deg N in 1997 and 1998, then moved north to above 58.5 deg in 2002.

ANALYTIC APPROACH

Data Sources

Catch data and size frequencies of retained crab from the directed snow crab pot fishery from 1978 to the 2006 season were used in this analysis. Observers were placed on directed crab fishery vessels starting in 1990. Size frequency data on the total catch (retained plus discarded) in the directed crab fishery were available from 1992 to 2006. However, the overall rate of observer coverage is low for this fishery – e.g., 0.5% of total snow crab pot lifts were observed in 2002 (Neufeld and Barnard 2003). Total discarded catch was estimated from observer data from 1992 to 2006(Table 1). The discarded male catch was estimated for 1978 to 1991 in the model using the estimated fishery selectivities based on the observer data for the period 1992 to 2006. The discard catch estimate was multiplied by the assumed mortality of discards from the pot fishery. The mortality of discarded crab was assumed to be 50%. The current harvest strategy assumes a discard mortality of 25% (Zheng 2002). The discard mortality assumptions will be discussed in a later section. The estimated discards previous to 1992 may be underestimates due to the lack of escape mechanisms for undersized crab in the pots prior to 1997.

The following table contains the various data components used in the model,

Data component	**Years**
Retained male crab pot fishery size frequency by shell condition	1978-2006 (year when fishery actually occurred)
Discarded male and female crab pot fishery size frequency	1992-2006
Trawl fishery bycatch size frequencies by sex	1990-2005
Survey size frequencies by sex and shell condition	1978-2006
Retained catch estimates	1978-2006
Discard catch estimates from snow crab pot fishery	1992-2006 from observer data
Trawl bycatch estimates	1973-2005
Total survey biomass estimates and coefficients of variation	1978-2006

Model Structure

The model structure was developed following Fournier and Archibald's (1982) methods, with many similarities to Methot (1990). The model was implemented using automatic differentiation software developed as a set of libraries under C++ (ADModel Builder). ADModel Builder can estimate a large number of parameters in a non-linear model using automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries. This software provides the derivative calculations needed for finding the objective function via a quasi-Newton function minimization routine (e.g., Press et al. 1992). The model implementation language (ADModel Builder) gives simple and rapid access to these routines and provides the ability to estimate the variance-covariance matrix for all parameters of interest.

Details of the population dynamics and estimation equations, description of variables and likelihood equations are presented in Appendix A (Tables A.1, A.2 and A.3). The population dynamics equations, incorporating the growth transition matrix and molting probabilities are similar to other size based crab models (Zheng et al. 1995 and 1998). There were a total of 227 parameters estimated in the model (Table A.4) for the 29 year range of data (1978-2006). The 87 fishing mortality parameters (one set for the male catch, one set for the female discard catch, and one set for the trawl fishery bycatch) estimated in the model were constrained so that the estimated catch fit the observed catch closely. There were 29 recruitment parameters estimated in the model, one for the mean recruitment, 28 for each year from 1979 to 2006 (male and female recruitment were fixed to be equal). There were 10 fishery selectivity parameters that did not change over time as in previous assessments. Survey selectivity was estimated for three different periods resulting in 7 parameters estimated. One parameter was estimated to fit the pot fishery cpue time series.

Molting probabilities for mature males and females were fixed at 0, i.e., growth ceases at maturity which is consistent with the terminal molt paradigm (Rugolo et al. 2005 and Tamone et al. 2005). Molting probabilities were fixed at 1.0 for immature females and males. The intercept and slope of the linear growth function of postmolt relative to premolt size were estimated in the model using parmeters estimated from growth measurements for Bering Sea snow crab as prior distributions (4 parameters, Table A.5). A gamma distribution was used in the growth transition matrix with the beta parameters fixed at 0.75 for male and females.

The model separates crabs into mature, immature, new shell and old shell, and male and female for the population dynamics. The model estimate of survey mature biomass is fit to the observed survey mature biomass time series by sex. The model fits the size frequencies of the survey by new and old shell, immature and mature, and by sex. It also fits the size frequencies for the pot fishery catch by new and old shell and by sex.

Crabs 25 mm CW (carapace width) and larger were included in the model, divided into 22 size bins of 5 mm each, from 25-29 mm to a plus group at 130-135mm. In this report the term size as well as length will be considered synonymous with CW. Recruits were distributed in the first few size bins using a two parameter gamma distribution with the parameters estimated in the model. The alpha parameter of the distribution was estimated in the model and the beta parameter was fixed at 1.5. Eighty-eight parameters were estimated for the initial population size composition of new and old shell males and females in 1978. No spawner-recruit relationship was used in the population dynamics part of the model. Recruitments for each year were estimated in the model to fit the data.

The NMFS trawl survey occurs in summer each year, generally in June-July. In the model, the time of the survey is considered to be the start of the year (July), rather than January. The modern directed snow crab pot fishery has occurred generally in the winter months (January to February) over a short period of time. In contrast, in the early years the fishery occurred over a longer time period. The mean time of the fishery weighted by the catch was estimated for each year and the fishing mortality applied all at once at the mean time for that year. Natural mortality is applied to the population from the time the survey occurs until the fishery occurs, then catch is removed. After the fishery occurs, growth and recruitment take place (in spring), with the remainder of the natural mortality through the end of the year as defined above.

Weight–Size

The weight (kg) – size (mm) relationship was estimated from survey data, where weight = a* size^b. Juvenile female a= 0.00000253, b=2.56472, mature female a=0.000675 b=2.943352, and males, a= 0.00000023, b=3.12948 (Figure 20).

Maturity

Maturity for females was determined by visual examination during the survey and used to determine the fraction of females mature by size for each year. Female maturity was determined by the shape of the abdomen, by the presence of brooded eggs or egg remnants.

Morphometric maturity for males is determined by chela height measurements, which are available starting from the 1989 survey (Otto 1998). The number of males with chela height measurements has varied between about 3,000 and 7,000 per year. In this report a mature male refers to a morphometrically mature male.

One maturity curve for males was estimated and applied to all years of survey data to estimate mature survey numbers. A two-parameter logistic function fit the fraction mature for larger new shell males well, resulting in size at 50% mature for new shell males of 88 mm CW with a slope of 0.12. The separation of mature and immature males by chela height at small widths may not be adequately refined given the current measurement to the nearest millimeter. Chela height measured to the nearest tenth of a millimeter (by Canadian researchers on North Atlantic snow crab) shows a clear break in chela height at small and large widths and shows fewer mature animals at small widths than the Bering sea data measured to the nearest millimeter. Measurements taken in 2004-2005 on Bering sea snow crab chela to the nearest tenth of a millimeter show a similar break in chela height to the Canadian data (Lou Rugolo et al. 2005).

The average fraction mature for old shell males was used as the maturity curve for all years for old shell males. Maturity for old shell males is zero below 40 mm, increases from 83% at 45 mm to 95% at 115 mm.

The probability of a new shell crab maturing was estimated outside the model to move crab from immature to mature in the model. The probability of maturing was estimated to match the observed fraction mature for all mature males and females observed in the survey data. While the fraction of all animals that are mature is fit well, the fraction of crab that are old shell is greater than in the survey data. The authors agree with SSC comment 4 that shell condition may not be an accurate measure of shell age and needs further investigation. The probability of maturing by size for female crab was about 50% at about 50 mm and increased to 100% at 80mm (Figure 21). The probability of maturing for male crab was 20% at 80 mm, increased to 50% at 100mm, about 905 at 120mm and 100% at 135 mm.

Selectivity

Selectivity curves for the retained and total catch were estimated as two-parameter ascending logistic curves (Figure 22). The probability of retaining crabs by size and shell condition was estimated as an ascending logistic function. The selectivities for the retained catch were estimated by multiplying the retention curve by the selectivities for the retained plus discarded size compositions.

The selectivities for the survey and trawl bycatch were estimated with two-parameter, ascending logistic functions (Figure 23). Survey selectivities were set equal for males and females. Separate survey selectivities were estimated for the period 1978 to 1981, 1982 to 1988, and 1989 to the present. The maximum selectivity was fixed at 1.0. The separate selectivities were used due to the change in catchability in 1982 from the survey net change, and the addition of more survey stations to the north of the survey area after 1988. Survey selectivities have been estimated for Bering Sea snow crab from underbag trawl experiments (Somerton and Otto 1999) (Figure 23). A bag underneath the regular trawl was used to catch animals that escaped under the footrope of the regular trawl, and was assumed to have selectivity equal to 1.0 for all sizes. The selectivity was estimated to be 50% at about 74 mm, 0.73 at 102 mm, and reached about 0.88 at the maximum size in the model of 135 mm.

Growth

Very little information exists on growth for Bering Sea snow crab. Tagging experiments were conducted on snow crab in 1980 with recoveries occurring in the Tanner crab (*Chionoecetes bairdi*) fishery in 1980 to 1982 (Mcbride 1982). All tagged crabs were males greater than 80mm CW, which were released in late may of 1980. Forty-nine tagged crabs were recovered in the Tanner crab fishery in the spring of 1981 of which only 5 had increased in carapace width. It is not known if the tags inhibited molting or resulted in mortality during molting, or the extent of tag retention. One crab was recovered after 15 days in the 1980 fishery, which apparently grew from 108 mm to 123 mm carapace width. One crab was recovered in 1982 after almost 2 years at sea that increased from 97 to 107 mm.

Growth data from 14 male crabs collected in March of 2003 that molted soon after being captured were used to estimate a linear function between premolt and postmolt width (Lou Rugolo unpublished data, Figure 23). The crabs were measured when shells were still soft because all died after molting, so measurements are probably underestimates of postmolt width (Rugolo, pers. com.). Growth appears to be greater than growth of some North Atlantic snow crab stocks (Sainte-Marie 1995). Growth from the 1980 tagging of snow crab was not used due to uncertainty about the effect of tagging on growth. No growth measurements exist for Bering Sea snow crab females. North Atlantic growth data indicate growth is slightly less for females than males.

Growth was modeled using a linear function to estimate the mean width after molting given the mean width before molting (Figure 24),

$$\text{Width}_{t+1} = a + b^* \text{ width}_t$$

The parameters a and b estimated from the observed growth data for Bering sea snow crabs were used as prior means for the growth parameters estimated in the model.
Crab were assigned to 5mm width bins using a gamma distribution with mean equal to the growth increment by sex and length bin and a beta parameter (which determines the variance),

$$Gr_{s,l\to l'} = \int_{l'-2.5}^{l'+2.5} Gamma(\alpha_{s,l}, \beta_s)$$

Where Gr is the growth transition matrix for sex, s and length bin l (premolt size). l’ is the postmolt size. The Gamma distribution is,

$$g(x \mid \alpha_{s,l}, \beta_s) = \frac{x^{\alpha_{s.l}-1} e^{-\frac{x}{\beta_s}}}{\beta^{\alpha_{s,l}} \Gamma(\alpha_{s,l})} \quad .$$

Where x is length and alpha and beta are parameters. Beta for both males and females was fixed in the model at 0.75.

Natural Mortality

Natural mortality is an essential control variable in population dynamic modeling, and may have a large influence on derived optimal harvest rates. Natural mortality rates estimated in a population dynamics model may have high uncertainty and it may be correlated with other parameters, and therefore is usually fixed. However, a large portion of the uncertainty in model results (e.g. current biomass), will be attributed to uncertainty in natural mortality, when natural mortality is estimated in the model. The ability to estimate natural mortality in a population dynamics model depends on how the true value varies over time as well as other factors (Fu and Quinn 2000, Schnute and Richards 1995).

Estimation Techniques

Hoenig, 5% Rule and maximum age

In the 2004 snow crab SAFE, natural mortality was assumed to be between 0.2 for males and females. A maximum age of 20 years would result from an M of about 0.21 (Table 5) (Hoenig 1983). A natural mortality of 0.3 would indicate a maximum age of about 14 years (Hoenig 1983). Anthony (1982) proposed that the 95% percentile of age be used to limit the maximum age in yield modeling. This procedure would result in an M of 0.2 for a maximum observed age of 15 years. A natural mortality of 0.3 results in about 5% of animals remaining after 10 yrs of age. Research is currently underway to assess a method using lipofuscin for age determination (Se-Jong, et al. 1999). A maximum age of about 13 years for females and 19 years for males has been hypothesized for North Atlantic snow crab by Comeau, et al (1998) based on size frequency analysis and growth data. Sainte-Marie, et al (1995) estimated an age of about 9 years for a 95 mm male snow crab and 11 years for a 131 mm crab for a different sub-population of Atlantic snow crab than Comeau, et al (1998) using size frequency analysis and growth data. A maximum time at large of 8 years for tag returns of terminally molted mature male snow crab in the North Atlantic has been recorded since tagging started about 1993 (Sainte-Marie, pers. comm.).

Model based

Otto (1998) estimated natural mortality of male snow crab based on survey data and retained catches to be greater than 1.0. The snow crab fishery generally occurs over a short time span, about 7 months after the survey. Otto (1998) overestimates M because the method assumed no time lapse between the survey and the fishery removals (during which natural mortality would be occurring) and no bycatch mortality. Otto (1998) assumed that shell condition is an accurate indicator of age since last molt (new shell less than one year, old shell crabs more than one, but less than two years from molting), and that new and old shell crabs were accurately categorized by shell condition. Radiometric aging and tagging data indicate shell condition is not an accurate measure of shell age (discussed in Maximum post-terminal molt age and shell classification section).

Zheng (unpub) investigated natural mortality of Bering Sea snow crab using a modeling approach, accounting for natural mortality between the time of the survey and the fishery. Estimates of natural mortality ranged from 0.0 to 0.97, depending on assumptions made for molting probabilities, growth per molt and survey selectivities (Zheng unpub.).

Tanner crab

Tanner crab have a similar life history to snow crab and probably have similar longevity. Zheng et al. (1998) estimated natural mortality and bycatch mortality together to be about 0.5 for male and female Bering Sea Tanner crab (*Chionecites bairdi*) in a population dynamics model. He did not estimate bycatch mortality separately, but, natural mortality would have been less than the reported 0.5 value. Somerton (1981) estimated natural mortality for male Tanner crab less than commercial size to be 0.35. M was estimated to be between 0.13 and 0.28 for commercial size male Tanner crab (Somerton 1981).

Maximum age post-terminal molt and shell classification

Crab are classified by shell condition at the time of the survey. SC1 crab are soft shell crab indicating they have recently molted. SC2 crab (new shell) have clean, hard shells. SC3 crab (old shell) show some wear and scratches and encrusting organisms are frequently present. SC4 crab (very old shell) have more wear and growth on the shell and encrusting organisms are almost always present. SC5 (very very old shell) have shells extensively stained and usually with extensive cover of encrusting organisms.

Orensanz (unpub.) used radiometric techniques to estimate shell age from last molt (Table 4). The total sample size was 21 male crabs (a combination of Tanner and snow crab) from a collection of 105 male crabs from various hauls in the 1992 and 1993 NMFS Bering sea survey. Representative samples for the 5 shell condition categories were collected that made up the 105 samples. The oldest looking crab within shell conditions 4 and 5 were selected from the total sample of SC4 and SC5 crabs to radiometrically age (Orensanz, pers comm.). Shell condition 5 crab (SC5 = very, very old shell) had a maximum age of 6.85 years (s.d. 0.58, 95% CI approximately 5.69 to 8.01 years). The average age of 6 crabs with SC4 (very old shell) and SC5, was 4.95 years. The range of ages was 2.70 to 6.85 years for those same crabs. Given the small sample size, crabs older than the maximum age of 7 to 8 years are reasonably expected in the population. Maximum life span defined for a virgin stock is reasonably expected to be longer than these observed maximum ages of exploited populations.

Male snow crab during the mid to late 1980's were subjected to increasing exploitation with the maximum catch occurring in 1991. The maximum age in the sample of 6.85 years would be the result of fishing mortality as well as natural mortality. Using this maximum age would result in an upper bound on natural mortality. If crabs mature at about age 7 to 9, an additional 7 or 8 years gives a maximum total age of about 14 to 17 years. However, due to exploitation occurring at the same time, the maximum age that would occur due to M alone would be greater than 14 to 17 years.

Tag recovery data for Bristol Bay red king crab males in the 1968 Japanese fishery contains shell condition and carapace length at time of tagging and time of recapture (INPFC 1969). Thirty two of 98 animals tagged in July to August, 1967 and recaptured May to October 1968 did not grow, however, were assigned shell condition 2 (new shell) at recapture. Those 32 animals were 12 to 18 months from molting, if they had molted in spring of 1967. This would indicate that about 33% of animals that are clean shell (SC2) are actually more than a year from molting. There were 47 crabs assigned new shell of 52 animals that were at large more than two years that did not grow (tagged in 1966 and recaptured in 1968). These animals would have been at least 2 years from molting. Tagging of Bristol Bay male red king crab was also conducted in 1990, 1991 and 1993. Recoveries occurred in the fishery that took place in October to November of each year. Recovery information was recorded primarily by ADF&G research staff, dockside samplers and observers on board vessels. Only the 1991 tagging data had sufficient recaptures in 1992 and 1993 for analysis. There were 56 animals that were recaptured in November, 1992 that were tagged in September to October, 1991 that had carapace length measured and were recorded as new shell at recapture. Of those 56 new shell animals, 21 did not grow in the 1 year between tagging and recapture. Those 21 animals (37.5 % of the new shell animals) were more than 1 ½ years from molting and were recorded as new shell. This is similar to the results from the 1968 tag recaptures, indicating that shell condition as prescribed is suspect as a rigorously quantified index of shell age. Based on these results, molting probabilities and natural mortality will be overestimated by using shell condition as an index of true shell age.

We examined the empirical evidence for reliable estimates of oldest observed age for male snow crab. Radiometric aging of male snow crab carapaces sampled in the Bering Sea stock in 1992 and 1993, as well as the ongoing tag recovery evidence from eastern Canada reveal observed maximum ages in exploited populations of 17-19 years (Orensanz, et al 20??, St. Marie 20??). We reasoned that in a virgin population of snow crab, longevity would be at least 20 years. Hence, we used 20 years as a proxy for longevity and assumed that this age would represent the upper 99th percentile of the distribution of ages in an unexploited population if observable. Under negative exponential depletion, the 99th percentile corresponding to age 20 of an unexploited population corresponds to a natural mortality rate of 0.23. M=0.23 was used in all model runs presented here.

Molting probability

Female and male snow crab have a terminal molt to maturity. Many papers have dealt with the question of terminal molt for Atlantic Ocean mature male snow crab (e.g., Dawe, et al. 1991). A laboratory study of morphometrically mature male Tanner crab, which were also believed to have a terminal molt, found all crabs molted after two years (Paul and Paul 1995). Bering Sea male snow crab appear to have a terminal molt based on recent data on hormone levels (Sherry Tamone, per. comm.) and findings from molt stage analysis via setagenesis (Lou Rugolo, pers. comm.). The models presented here have a terminal molt for both males and females.

Male Tanner and snow crabs that do not molt (old shell) may be important in reproduction. Paul, et al (1995) found that old shell mature male Tanner crab out-competed new shell crab of the same size in breeding in a laboratory study. Recently molted males did not breed even with no competition and may not breed until after about 100 days from molting (Paul, et al. 1995). Sainte-Marie (2002) states that only old shell males take part in mating for North Atlantic snow crab. If molting precludes males from breeding for a three month period, then males that are new shell at the time of the survey (June to July), would have molted during the preceding spring (March to April), and would not have participated in mating. The fishery targets new shell males, resulting in those animals that molted to maturity and to a size acceptable to the fishery of being removed from the population before the chance to mate. Animals that molt to maturity at a size smaller than what is acceptable to the fishery may be subjected to fishery mortality from being caught and discarded before they have a chance to mate.

Crabs in their first few years of life may molt more than once per year, however, the smallest crabs included in the model are probably 3 or 4 years old and would be expected to molt annually.

The growth transition matrix was applied to animals that grow, resulting in new shell animals. Those animals that don't grow become old shell animals. Animals that are classified as new shell in the survey are assumed to have molted during the last year. The assumption is that shell condition (new and old) is an accurate measure of whether animals have molted during the previous year. The relationship between shell condition and time from last molt needs to be investigated further. Additional radiometric aging for male and female snow crab shells is being investigated to improve the estimate of radiometric ages from Orensanz (unpub. data).

Mating ratio and reproductive success

Full clutches of unfertilized eggs may be extruded and appear normal to visual examination, and may be retained for several weeks or months by snow crab (Rugolo, pers. comm., Alaska Fisheries Science Center, Seattle, Wa.). Resorbtion of eggs may occur if not all eggs are extruded resulting in less than a full clutch. Female snow crab at the time of the survey may have a full clutch of eggs that are unfertilized, resulting in overestimation of reproductive potential. Male snow crab are sperm conservers, using less than 4% of their sperm at each mating. Females also will mate with more than one male. The amount of stored sperm and clutch fullness varies with sex ratio (Sainte-Marie 2002). If mating with only one male is inadequate to fertilize a full clutch, then females will need to mate with more than one male, necessitating a sex ratio closer to 1:1 in the mature population, than if one male is assumed to be able to adequately fertilize multiple females.

The fraction barren females and clutch fullness observed in the survey increased in the early 1990’s then decreased in the mid- 1990’s then increased again in the late 1990’s (Figures 25 and 26). The highest levels of barren females coincides with the peaks in catch and exploitation rates that occurred in 1992 and 1993 fishery seasons and the 1998 and 1999 fishery seasons. While the biomass of mature females was high in the early 1990’s, the rate of production from the stock may have been reduced due to the spatial distribution of the catch relative and the resulting sex ratio in areas of highest reproductive potential.

The fraction of barren females in the 2003 and 2004 survey south of 58.5 deg N latitude was generally higher than north of 58.5 deg N latitude (Figures 27 and 28). In 2004 the fraction barren females south of 58.5 deg N latitude was greater for all shell conditions. In 2003, the fraction barren was greater for new shell and very very old shell south of 58.5 deg N latitude.

Female snow crab in waters less than 1.5 deg C and colder have been determined to be biennial spawners in the Bering Sea (Lou Rugolo, pers. comm.). Future recruitment may be affected by the fraction of biennial spawning females in the population as well as the estimated fecundity of females, which may depend on water temperature.

An index of reproductive potential for crab stocks needs to be defined that includes spawning biomass, fecundity, fertilization rates and frequency of spawning. In most animals, spawning biomass is a sufficient index of reproductive potential because it addresses size related impacts on fecundity, and because the fertilization rates and frequency of spawning are relatively constant over time. This is not the case for snow crab.

The centroids of the cold pool (<2.0 deg C) were estimated from the summer survey data for 1982 to 2003 (Figure 29). The centroid is the average latitude and average longitude. In the 1980’s the cold pool was farther south(about 58 to 59 deg N latitude) except for 1987 when the centroid shifted to north of 60 deg N latitude. The cold pool moved north from about 58 deg N latitude in 1999 to about 60.5 deg N latitude in 2003. The cold pool was farthest south in 1989, 1999 and 1982 and farthest north in 1987, 1998, 2002 and 2003.

The clutch fullness and fraction of unmated females however, does not account for the fraction of females that may have unfertilized eggs. The fraction of barren females observed in the survey may not be an accurate measure of fertilization success because females may retain unfertilized eggs for months after extrusion. Rugolo (pers. comm.) sampled mature females from the Bering sea in winter and held them in tanks until their eggs hatched in March. All females then extruded a new clutch of eggs in the absence of males. All eggs were retained until the crabs were sacrificed near the end of August. Approximately 20% of the females had full clutches of unfertilized eggs. The unfertilized eggs could not be distinguished from fertilized eggs by visual inspection at the time they were sacrificed. Indices of fertilized females based on the visual inspection method of assessing clutch fullness and percent unmated females may overestimate fertilized females and not an accurate index of reproductive success.

McMullen and Yoshihara (1969) examined female red king crab around Kodiak Island in 1968 and found high percentages of females without eggs in areas of most intense fishing (up to 72%). Females that did not extrude eggs and mate were found to resorb their eggs in the ovaries over a period of several months. One trawl haul captured 651 post-molt females and nine male red king crab during the period April to May 1968. Seventy-six percent of the 651 females were not carrying eggs. Ten females were collected that were carrying eggs and had firm post-molt shells. The eggs were sampled 8 and 10 days after capture and were examined microscopically. All eggs examined were found to be infertile. This indicates that all ten females had extruded and held egg clutches without mating. Eggs of females sampled in October of 1968 appear to have been all fertile from a table of results in McMullen and Yoshihara(1969), however the results are not discussed in the text, so this is unclear. This may mean that extruded eggs that are unfertilized are lost between May and October.

Discard mortality was assumed to be 50% for this assessment. The fishery for snow crabs occurs in winter when low temperatures and wind may result in freezing of crabs on deck before they are returned to the sea. Short term mortality may occur due to exposure, which has been demonstrated in laboratory experiments Zhou and Kruse (1998) and Shirley (1998), where 100% mortality occurred under temperature and wind conditions that may occur in the fishery. Even if damage did not result in short term mortality, immature crabs that are discarded may experience mortality during molting some time later in their life.

RESULTS

The total mature biomass increased from about 858 million lbs (328,000 t) in 1978 to the peak biomass of 1,824 million lbs in 1990. Biomass declined sharply after 1997 to about 499 million lbs in 2003, then increased slightly to 614 million lbs in 2006 (Table 3 and Figure 2). The model is constrained by the population dynamics structure, including natural mortality, the growth and selectivity parameters and the fishery catches. The low observed survey abundance in the mid-1980’s were followed by an abrupt increase in the survey abundance of animals in 1987, which followed through the population and resulted in the highest catches recorded in the early 1990’s.

Average discard catch mortality for 1978 to 2003 was estimated to be about 44% of the retained catch, a little higher than the observed discards from 1992 to 2003 (33%) (Table 1 and Figure 31). Parameter estimates for the 50% discard mortality model are in Table 7. During the last four years (2000 to 2003 fishery seasons) model estimates of discard mortality averaged 34% of the retained catch. Estimates of discard mortality ranged from 14% of the retained catch to 69% of the retained catch.

Mature male and female biomass show similar trends (Table 3 and Figures 32 and 33). Mature male biomass increased from 293 million lbs in 2005 to 322 million lbs in 2006, while observed survey mature male biomass increased from 295 million lbs to 331 million lbs. Model estimates of mature female biomass increased from 264 million lbs in 2005 to 292 million lbs in 2006. Mature female biomass observed from the survey declined from 257 million lbs in 2005 to 189 million lbs in 2006.

Fishery selectivities and retention curves were estimated using ascending logistic curves (Figure 22, 23 and 34). Selectivities for trawl bycatch were estimated as ascending logistic curves (Figure 35). Plots of model fits to the survey size frequency data are presented in Figures 36 and 38 by sex for shell conditions combined. The model estimates higher numbers of mature old shell male and female crabs and lower numbers of new shell mature male and female crabs than observed from the survey. This could be due the size at maturity, which determines when males and females stop growing, or that shell condition is not an accurate estimator of shell age. Tagging results presented earlier indicate that animals that are more than one year from molting may be underestimated by using shell as a proxy for shell age. A method of verifying shell age is needed for all crab species.

Survey selectivities for the period 1978 to 1981 were estimated at about 30% at 27.5 mm and reached 100% at about 60mm (Figure 23). Survey selectivities for the period 1982 to 1988 were estimated at 50% at about 50 mm and reached a maximum of 95% at 135 mm. Survey selectivities for the period 1989 to the present were estimated at 65% at about 27.5 mm and reached a maximum of 94% 135 mm. These selectivities were the best fit determined by the model. An underbag experiment estimated survey selectivity of 50% at 78 mm and a maimum of about 89% at 135 mm (Somerton and Otto 1998) with the survey net in use since 1982. The survey selectivities are multiplied by the population numbers by length to estimate survey numbers for fitting to the survey data.

The estimated number of males > 101mm generally follows the observed survey numbers except for a few peak survey years where the model estimates are lower than the survey estimates (Figure 40). The observed survey estimate of males greater than 101 mm increased from about 69 million in 2005 to 135 million in 2006. There is a high degree of uncertainty in the estimated large male numbers. One survey tow accounted for 50 million males > 101 mm. The highest three tows accounted for 79 million males > 101 mm. The estimated 95% confidence interval for the observed survey large males was +/-76% of the estimate. Model estimates of large males were about 89 million crab in 2005 and 2006.

Two main periods of high recruitment were estimated by the model, in 1980-1983 (fertilization year) and in 1987-1988 (Figure 41). Recruits are 25mm to about 40 mm and may be about 4 years from hatching, 5 years from fertilization (Figure 42, although age is approximated). Low recruitments were estimated from 1990 to 1997 and in 2000 to 2004. The 1998 and 1999 year classes appear to be medium size recruitments that have resulted in an increase in biomass in 2006. The estimated recruitments lagged by 5 years (approximate fertilization year) from the model coincide with the higher survey estimates of abundance of females with eggs and abundance of females with eggs multiplied by the fraction full clutch from 1975 to 1987 (Figure 43). Recruitment was low from 1988 to 1998, showing no relationship to the reproductive index. Exploitation rates were generally higher in 1986 to 1994, and in 1998-99 than prior to 1986 (Figure 4).

The size at 50% selected for the pot fishery was 102 mm for new shell males and 122 mm for old shell males (Figure 21). Retention for old shell males was less than for new shell males (Figure 33). The fishery generally targets new shell animals with clean hard shells and all legs intact. The fits to the fishery size frequencies are in Figures 44 through 48. Fits to the trawl fishery bycatch size frequency data are in figures 49 and 50.

Fishing mortality rates ranged from about 0.26 to 3.0 (Figure 51). Fishing mortality rates were 0.75 to 1.9, for the 1986 to 2003 fishery seasons (except F=3.0 in 1999). F was 0.53 for 2004, F = 0.47 for 2005, and F = 0.80 for the 2006 (year fishery occurred).

Harvest Strategy and Projected Catch

Current Harvest Strategy

Harvest strategy simulations are reported by Zheng et al. (2002) based on a model with structure and parameter values different than the model presented here. The harvest strategy by Zheng et al. (2002) was developed for use with survey biomass estimates and was applied to survey biomass estimates to calculate the 2007 fishery season catch. Bmsy is defined in the current crab FMP as the average total mature survey biomass for 1983 to 1997. MSST is defined as ½ Bmsy. The harvest strategy consists of a threshold for opening the fishery (230.4 million lbs of total mature biomass(TMB), 0.25*Bmsy), a minimum GHL of 15 million lbs for opening the fishery, and rules for computing the GHL.

Under current FMP (Fishery Management Plan) definitions for MSY biomass (B_{MSY} = 921.6 million pounds TMB) and overfishing rate (F_{MSY} =M=0.3), the exploitation rate to apply to current mature male biomass (MMB), is determined as a function of TMB as,

$$E = \frac{0.75 * Fmsy * \left[\frac{TMB}{Bmsy} - \alpha \right]}{(1-\alpha)}$$

for TMB ≥ 0.25*Bmsy and TMB<Bmsy, where α = -0.35, and,

- E = (Fmsy * 0.75) = 0.225, for TMB ≥ Bmsy, and E = 0 for TMB < 0.25*Bmsy.

The maximum for a GHL_{max} is determined by using the E determined from the control rule as an exploitation rate on mature male biomass at the time of the survey,

- GHL_{max} = E•MMB.

There is a 58% maximum harvest rate on exploited legal male abundance. Exploited legal male abundance is defined as the estimated abundance of all new shell legal males >=4.0-in (102 mm) CW plus a percentage of the estimated abundance of old shell legal males >=4.0-in CW. The percentage to be used is determined using fishery selectivities for old shell males.

Alternative Overfishing Control Rules

An alternative overfishing control rule based on spawning biomass per recruit reference points follows those developed for North Pacific groundfish stocks (SAFE 2004) (Figure 54).

$$F = \frac{F\% * \left[\frac{MMB}{B\%} - \alpha \right]}{(1-\alpha)}$$

MMB is mature male biomass at the time of mating. Two alternatives for the maximum fishing mortality were estimated, F40% and F35% (Table 6). F40% was estimated at 0.79 and B40% at 192,000 tons. B40% was estimated using average recruitment and spawning biomass per recruit for males fishing at

F40%. α = 0.05, and the F is set to zero when total effective spawning biomass is below 25% of Bmsy (Figure 54).

Estimated fishing mortality from 1980 fishing season to 2005 have been above the F40% control rule except for two years (1983 and 1984) (Figure 54). The target F historically (pre-2000 fishery season) was about 1.1 which was exceeded in many years. The last two fishery seasons F was estimated at 0.47 and 0.80, also above the F% control rule.

The catch using the control rule is estimated by the following equation,

$$catch = \sum_{s}\sum_{l} \; (1 - e^{-(F*Sel_{S,i})}) w_l N_{S,l} \; e^{-M*.62}$$

Where $N_{S,l}$ is the 2006 numbers at length(l) for males by shell condition(s) at the time of the survey estimated from the population dynamics model, M is natural mortality, 0.62 is the time elapsed (in years) from when the survey occurs to the fishery, F is the value estimated from the harvest control rule using the 2006 mature male biomass projected forward to the time of mating time (spring 2007), and w_l is weight at length. $Sel_{S,l}$ are the fishery selectivities by length and shell condition for the total catch (retained plus discard) or for the retained catch estimated from the population dynamics model (Figure 24).

Fishing mortality, biomass values and total and retained catches were projected for the 2007 to 2011 fishery seasons (Table 6). The survey biomass estimate for total mature biomass in 2006 was 519 million lbs (56% of Bmsy =921.6 million lbs) and mature male biomass was 330 million lbs. The MMB in spring 2007 is estimated to be at 61% of B40%. The 2007 F40% retained catch was estimated at 21 million lbs. The F35% retained catch for 2007 was estimated at 30 million lbs. The MMB in spring 2007 is estimated to be at 68% of B35%.

The 2007 catch using the current harvest strategy with estimates of Fmsy = M = 0.3 and Bmsy = 921.6 million lbs was calculated using 2006 survey mature biomass estimates. The exploitation rate on survey mature male biomass for 2007 estimated from the harvest control rule with Fmsy = 0.3, Bmsy = 921.6 million lbs and α = -0.35, was 0.157, resulting in an estimated 2007 catch of 52 million lbs. A 2007 catch of 52 million lbs would result in a full selection fishing mortality estimated by the model for 2007 of 1.2.

Computing the catch based on the complete survey biomass may result in exploitation rates higher than the target rate on crabs in the southern area of the distribution. One solution would be to split the catch into two regions, north and south, according to the percent distribution of the survey estimate of large males or mature males from those regions. This would require knowing the location of catch inseason. Two other approaches would not require knowledge on inseason catch location. One approach would be to compute the catch from that portion of the stock where most of the catch is extracted. Another approach would be to compute a catch that would result in the target harvest rate for the southern portion of the stock and increase that catch according to the percent catch in the north.

Projections and Rebuilding Scenarios

Projections and rebuilding trajectories were estimated using simulation with several harvest control rules and lognormally distributed, autocorrelated recruitment (cv recruitment =0.86, autocorrelation = 0.6). The rebuilding plan developed for snow crab projected a 50% probability of rebuilding by 2010. The probability of rebuilding to the total survey biomass Bmsy of 921.6 million lbs is 14% in 2010, fishing at

F40% in fishery seasons 2007 to 2010 (55% probability in 2012) (Table 6). The probability of rebuilding is 10% in 2010, fishing at F35%, and 52% by 2013. The probability of rebuilding to Bmsy defined as 921.6 million lbs of total mature biomass under the current ADF&G harvest strategy is 13% in 2010 (51% in 2012).

Projections of biomass and retained catch for various control rules indicate that biomass is expected to increase through 2010. Retained catch and large male abundance increase to the 2009 fishery season (2010 for ADF&G strategy) then decline. Future survey data will reduce uncertainty in the estimate of the strength of recent recruitments.

Conservation concerns

- The Bering Sea snow crab survey estimates of total mature biomass are currently at 56% of the survey Bmsy.
- Moderate recruitment is estimated in 1997-1998 fertilization year, however, in general recruitment has been at low levels in the last 10 years (since 1994). Survey total mature biomass declined in 2006, however, biomass is expected to increase in the next few years. The projected increase in biomass relies on the 1997-1998 recruitment remaining a moderately strong recruitment.
- There is uncertainty in discard mortality due to low coverage of total pot lifts and only 10% coverage of catcher vessels which only started in 2001. Higher discard mortality would necessitate lower retained catches.
- Exploitation rates in the southern portion of the range of snow crab may have been higher than target rates, possibly contributing to the shift in distribution to less productive waters in the north.

Research Needs

Research is needed to improve our knowledge of snow crab life history and population dynamics to reduce uncertainty in the estimation of current stock size, stock status and optimum harvest rates.

Tagging programs need to be initiated to estimate longevity and migrations. Studies and analyses are needed to estimate natural mortality. Additional sampling of crabs that are close to molting is needed to estimate growth for immature males and females.

The lower number of mature old shell male crabs in the observed survey compared to what are expected in the model needs to be reconciled. Harvest rates and status of the stock are highly dependent on what the discrepancy is due to. The differences could be due to higher fishery discard mortality, higher natural mortality of mature animals, differential catchability of new and old shell animals in the survey, or the estimation of when maturity occurs, which determines when animals stop growing and subsequently move from new shell to old shell animals. In addition, the assignment of crabs to new and old shell condition used in the survey data may not be an accurate measure of time from the last molt.

Increased observer coverage is needed on catcher vessels in the directed snow crab fishery to improve estimates of discards. Field studies are needed to estimate mortality of discards in the winter snow crab pot fisheries where freezing temperatures and wind chill are important factors.

Some method of aging crab needs to be developed. Current research is being conducted using lipofuscin to age crabs and continued radiometric aging of shells of mature crabs is also being conducted (results may be available the end of 2004). However, at this time it is not known if the lipofuscin method will be successful, and radiometric aging is time consuming, so only small numbers of animals can be aged at present. Aging methods will provide information to assess the accuracy of assumed ages from assigned shell conditions (i.e. new, old, very old, etc), which have not been verified, except with the 21 radiometric ages reported here from Orensanz (unpub data).

Techniques for determining which males are effective at mating and how many females they can successfully mate with in a mating season are needed to estimate population dynamics and optimum harvest rates. At the present time it is assumed that when males reach morphometric maturity they stop growing and they are effective at mating. Field studies are needed to determine how morphometric maturity corresponds to male effectiveness in mating. In addition the uncertainty associated with the determination of morphometric maturity (the measurement of chelae height and the discriminate analysis to separate crabs into mature and immature) needs to be analyzed and incorporated into the determination of the maturity by length for male snow crab.

The experiment to estimate catchability of the survey trawl net needs to be repeated with larger sample sizes to allow the estimation of catchability by length, sex and shell condition for snow crab (and Tanner crab). This is needed to determine if the number of mature old shell crabs in the observed survey (which are lower than expected in the model) are due to mortality (fishery discard or natural mortality) or due to lower catchability in the trawl survey.

Female opilio in waters less than 1.5 deg C and colder have been determined to be biennial spawners in the Bering Sea (Lou Rugolo, pers. comm.). Future recruitment may be affected by the fraction of biennial spawning females in the population as well as the estimated fecundity of females, which may depend on water temperature.

Analysis needs to be conducted to determine a method of accounting for the spatial distribution of the catch and abundance in computing quotas.

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Table 1. Catch (1,000s of lbs) for the snow crab pot fishery and groundfish trawl bycatch. Retained catch for 1973 to 1981 contain Japanese directed fishing. Observed discarded catch is the total estimate of discards before applying mortality. Discards from 1992 to 2006 were estimated from observer data. Model estimates of male discard include a 50% mortality of discarded crab.

Year fishery occurred	retained catch(1,000s of lbs)	Observed Discard male catch	Retained + discard male catch	Model estimate of male discard	Discard female catch	Year of trawl bycatch	trawl bycatch
1973	6,711					1973	30,046
1974	5,033					1974	41,582
1975	8,250					1975	16,096
1976	10,050					1976	6,975
1977	16,284					1977	4,722
1978-79	52,272			7,096	73	1978	5,422
1979-80	75,025			7,297	91	1979	4,331
1980-81	66,933			7,647	81	1980	3,150
1982	29,355			6,933	46	1981	1,314
1983	26,128			4,933	62	1982	535
1984	26,813			2,872	44	1983	689
1985	65,999			7,265	43	1984	732
1986	97,984			14,553	44	1985	628
1987	101,903			17,347	96	1986	2,699
1988	135,355			20,362	139	1987	8
1989	149,456			34,597	148	1988	968
1990	161,821			44,071	192	1989	1,124
1991	328,647			63,983	204	1990	860
1992	315,302	96,214	402,897	49,555	234	1991	9,401
1993	230,787	124,865	355,652	37,964	481	1992	4,552
1994	149,776	38,922	188,698	21,943	321	1993	2,892
1995	75,253	29,436	104,689	12,602	232	1994	3,219
1996	65,713	42,104	107,817	19,988	63	1995	1,794
1997	119,543	54,391	173,934	28,675	277	1996	2,063
1998	243,342	41,982	294,171	38,828	22	1997	2,884
1999	194,000	34,158	228,358	26,429	26	1998	2,146
2000	33,500	3,790	37,081	3,888	2	1999	788
2001	25,256	4,537	29,794	2,607	2	2000	611
2002	32,722	13,824	46,546	5,861	17	2001	376
2003	28,307	9,938	38,245	6,015	3	2002	217
2004	23,663	4,196	27,859	3,426	6	2003	174
2005	24,560	3,716	28,276	2,710	3	2004	455
2006	37,000	9,965	46,965	4,263	12	2005	500

Table 2. Observed survey female, male and total spawning biomass(millions of lbs) and numbers of males > 101mm (millions of crab).

Year	Observed survey female mature biomass	Observed survey male mature biomass	Observed survey total mature biomass	Observed number of males > 101mm (millions)
1978	336.6	424.9	761.5	163.4
1979	712.2	528.7	1,240.9	169.1
1980	894.8	385.1	1,279.9	109.0
1981	480.2	262.1	742.3	45.4
1982	507.0	403.0	910.1	65.0
1983	316.6	355.3	671.9	71.5
1984	145.2	387.5	532.6	154.2
1985	21.2	167.2	188.4	78.2
1986	55.8	200.9	256.7	80.0
1987	448.4	462.2	910.6	141.9
1988	556.1	538.8	1,094.9	167.3
1989	1,006.2	712.3	1,718.4	175.4
1990	649.6	905.4	1,555.0	407.2
1991	793.0	981.8	1,774.8	466.6
1992	463.9	574.8	1,038.8	251.4
1993	505.0	545.3	1,050.3	140.8
1994	473.6	379.4	853.0	80.3
1995	622.0	507.8	1,129.8	69.0
1996	435.0	744.9	1,179.9	170.1
1997	387.6	663.5	1,051.2	308.5
1998	285.4	529.3	814.7	244.0
1999	113.5	216.6	330.1	92.2
2000	374.7	227.1	601.8	75.6
2001	318.4	339.2	657.5	79.4
2002	120.5	232.8	353.3	73.5
2003	130.2	197.8	328.0	64.6
2004	194.3	196.6	390.9	65.8
2005	256.7	294.8	551.4	68.9
2006	188.9	330.5	519.5	135.3

Table 3. Model estimates of population biomass, population numbers, male, female and total mature biomass (million lbs) and number of males greater than 101 mm in millions. Recruits enter the population in the spring of the survey year.

Year	Biomass (million lbs 25mm+)	numbers (million crabs 25mm+)	female mature biomass	Male mature biomass	total mature biomass	Number of males >101mm (millions)	Recruitment (millions, 25 mm to 50 mm)	Male mature biomass at mating time	Ratio mature females to mature males
1978	1,157	7,734	383	475	858	155	618	347	
1979	1,187	6,711	515	450	965	151	986	299	3.1
1980	1,115	6,253	585	368	953	111	1,024	242	4.5
1981	1,030	5,931	601	310	911	76	1,731	230	5.5
1982	1,038	6,408	578	343	921	101	1,709	263	5.4
1983	1,088	6,773	546	416	962	152	1,203	322	4.6
1984	1,123	6,560	523	479	1,003	179	3,559	332	3.8
1985	1,190	8,712	507	502	1,009	180	5,162	337	3.4
1986	1,334	11,994	520	528	1,048	188	3,143	359	3.2
1987	1,494	12,572	594	596	1,190	211	2,272	398	3.0
1988	1,622	12,137	692	666	1,358	197	1,246	426	3.0
1989	1,760	10,724	760	808	1,568	242	600	554	2.9
1990	1,946	8,930	768	1,056	1,824	401	752	609	2.6
1991	1,829	7,506	720	1,026	1,746	386	3,000	587	2.4
1992	1,629	8,657	643	851	1,495	289	2,771	521	2.3
1993	1,445	9,420	594	667	1,262	195	1,131	446	2.3
1994	1,308	8,475	592	552	1,144	126	392	409	2.5
1995	1,259	7,050	599	551	1,150	110	220	422	2.6
1996	1,296	5,741	574	661	1,235	190	211	473	2.5
1997	1,301	4,640	515	753	1,268	280	568	443	2.3
1998	1,064	4,026	441	591	1,032	198	591	345	2.2
1999	798	3,618	373	386	759	88	556	305	2.3
2000	699	3,402	323	332	655	75	300	254	2.3
2001	615	2,981	288	290	578	62	618	220	2.3
2002	562	2,953	259	262	521	59	1,750	203	2.4
2003	578	4,067	235	263	499	72	2,057	208	2.4
2004	634	5,267	234	278	512	88	451	218	2.3
2005	660	4,614	264	293	557	89	761	220	2.3
2006	696	4,395	292	322	614	89	618	235	2.5

Table 4. Radiometric ages for male crabs for shell conditions 1 through 5. Data from Orensanz (unpub).

				Radiometric age	
Shell Condition	description	sample size	Mean	minimum	maximum
1	soft	6	0.15	0.05	0.25
2	new	6	0.69	0.33	1.07
3	old	3	1.02	0.92	1.1
4	very old	3	5.31	4.43	6.6
5	very very old	3	4.59	2.7	6.85

Table 5. Natural mortality estimates for Hoenig (1983) and the 5% rule given the oldest observed age.

	Natural Mortality	
oldest observed age	Hoenig (1983) empirical	5% rule
10	0.42	0.3
15	0.28	0.2
17	0.25	0.18
20	0.21	0.15

Table 6. Projections using F40%, F35% and the current ADF&G control rules for 2006 to 2010 (2007 to 2011 fishery season catches). Mature male and female biomass is at time of mating (millions of lbs). Large male numbers are at beginning of the fishery (millions of crab). Survey total mature biomass is at the time of the survey (millions of lbs).

F40%	total catch	mature males	mature females	Large males	retained catch	F	survey total mature biomass	Probability of rebuilding to Bmsy (921.6 mill lbs)
Survey year								
2006	29	257	253	77	21	0.40	519	0
2007	76	317	260	132	60	0.60	604	0
2008	118	367	277	198	99	0.69	710	0
2009	102	379	316	192	83	0.69	748	4
2010	85	393	366	153	63	0.70	784	14
F35%								
Survey year	total catch	Mature males	mature females	large males	retained catch	F	survey total mature biomass	
2006	41	248	253	77	30	0.59	519	0
2007	93	295	260	124	73	0.82	593	0
2008	135	329	276	181	113	0.91	682	0
2009	110	334	314	166	90	0.90	705	2
2010	95	349	361	127	67	0.91	735	10
ADFG								
Survey year	total catch	Mature males	mature females	large males	retained catch	F	survey total mature biomass	
2006	73	224	253	77	52	1.21	519	0
2007	70	285	260	105	54	0.65	564	0
2008	95	357	276	179	79	0.57	678	0
2009	105	371	314	191	87	0.72	741	3
2010	90	381	361	150	67	0.76	771	13

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Table 7. Parameters values for the model, excluding recruitments and fishing mortality parameters.

Natural Mortality	0.23
Female intercept (a) growth	5.099041
Male intercept(a) growth	8.430236
Female slope(b) growth	1.071008
Male slope (b) growth	1.123168
Alpha for gamma distribution of recruits	12.0
Beta for gamma distribution of recruits	1.5
Beta for gamma distribution female growth	0.75
Beta for gamma distribution male growth	0.75
Fishery selectivity total new slope	0.191203
Fishery selectivity total new length at 50%	102.1
Fishery selectivity total old slope	0.135171
Fishery selectivity total old length at 50%	122.4
Fishery selectivity retention curve new shell slope	0.253183
Fishery selectivity retention curve new shell length at 50%	96.04901
Fishery selectivity retention curve old shell slope	0.293564
Fishery selectivity retention curve old shell length at 50%	93.99332
Pot Fishery discard selectivity female slope	0.327537
Pot Fishery discard selectivity female length at 50%	60.88347
Trawl Fishery selectivity slope	0.072201
Trawl Fishery selectivity length at 50%	85.02528
Survey Q 1978-1981	1
Survey 1978-1981 length at 95% selected	50.51482
Survey 1978-1981 length at 50% selected	32.1194
Survey Q 1982-1988	1
Survey 1982-1988 length at 95% selected	133.4116
Survey 1982-1988 length at 50% selected	48.41813
Survey Q 1989-present	1
Survey 1989-present, length at 95% selected	143.8417
Survey 1989-present length at 50% selected	0.0
Fishery cpue q	0.000893

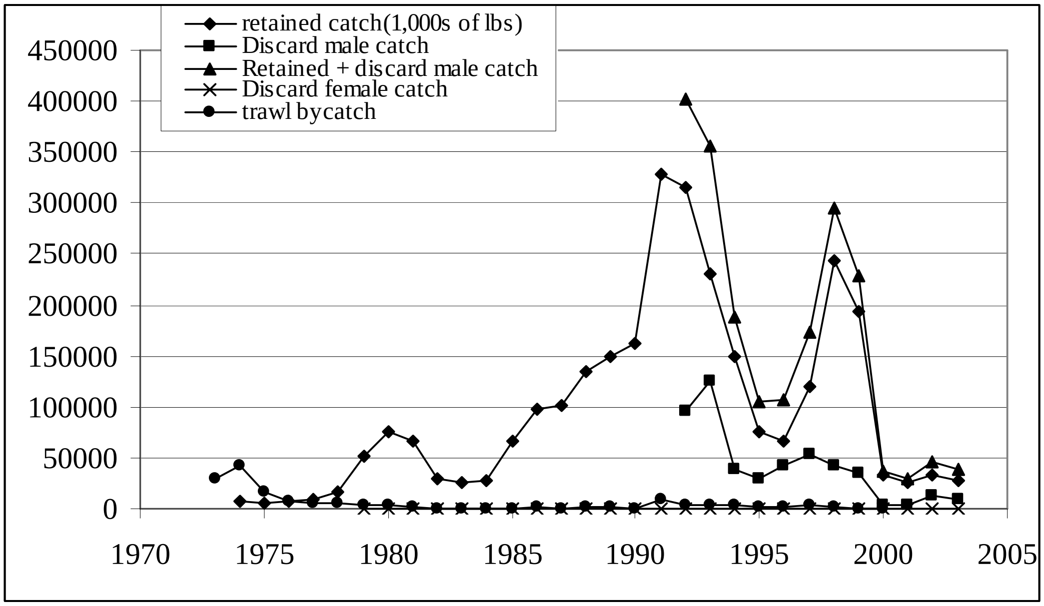

Figure 1. Catch (1,000s lbs) from the directed snow crab pot fishery and groundfish trawl bycatch. Retained catch is males only, discard the directed pot fishery is smaller males, females, old shell males and males with missing limbs. Trawl bycatch is male and female bycatch from groundfish trawl fisheries.

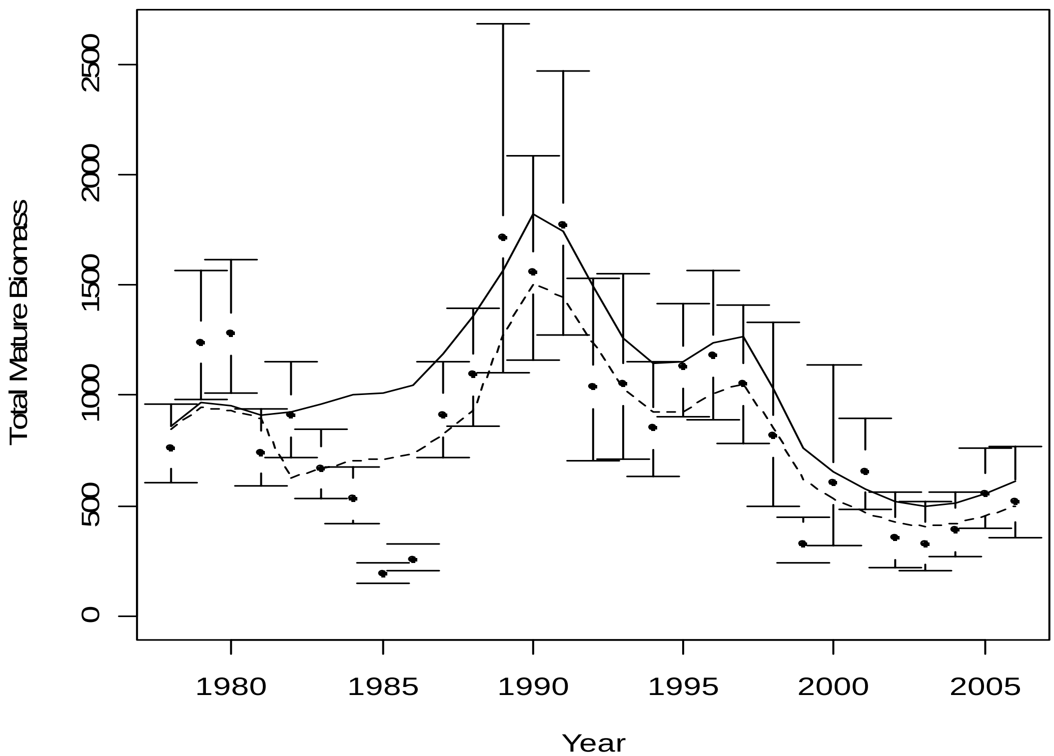

Figure 2. Population total mature biomass (millions of pounds, solid line), model estimate of survey mature biomass (dotted line) and observed survey mature biomass with approximate lognormal 95% confidence intervals.

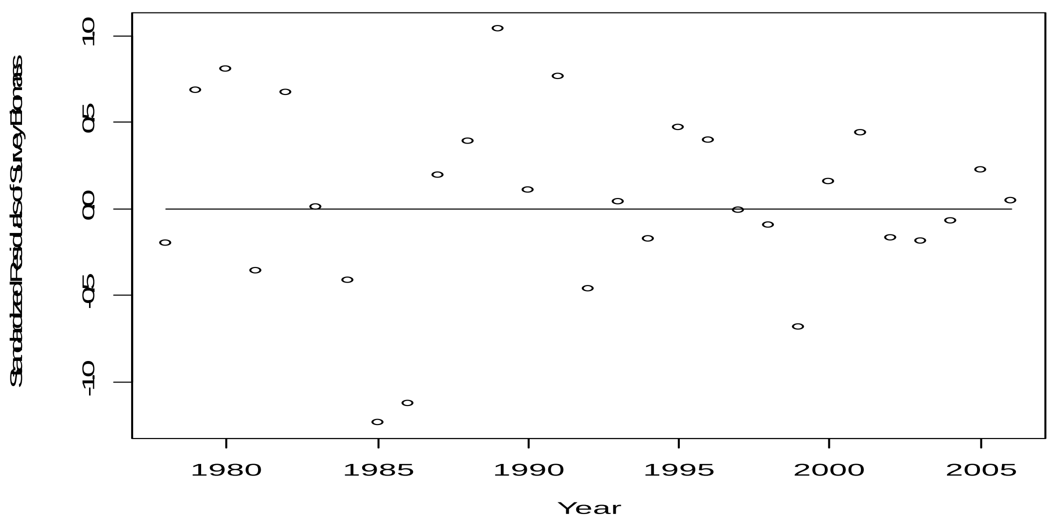

Figure 3. Standardized residuals for model fit to total mature biomass from Figure 2.

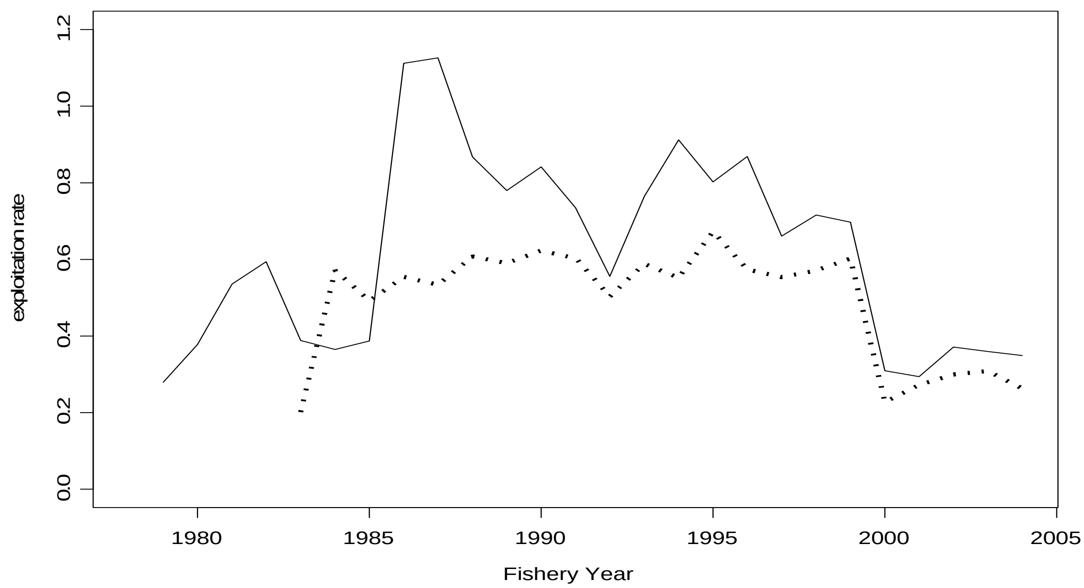

Figure 4. Exploitation rate estimated as the preseason GHL divided by the survey estimate of large male biomass (>101 mm) at the time the survey occurs (dotted line). The solid line is the retained catch divided by the survey estimate of large male biomass at the time the fishery occurs. Year is the year the fishery occurred.

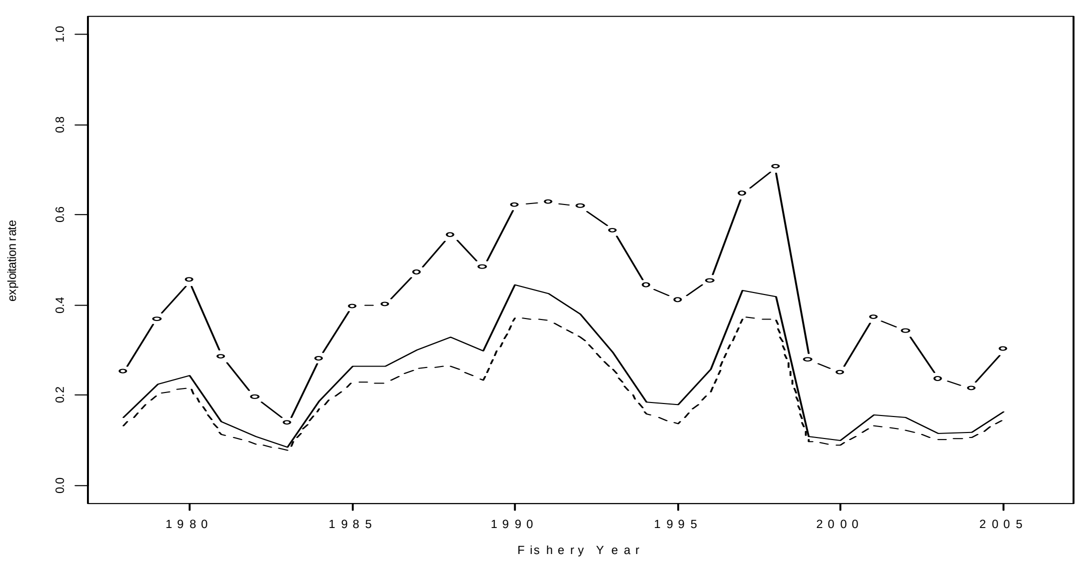

Figure 5. Exploitation fraction estimated as the catch biomass (total or retained) divided by the mature male biomass from the model at the time of the fishery (solid line and dotted line). The exploitation rate for total catch divided by the male biomass greater than 101 mm is the solid line with dots. Year is the year of the fishery.

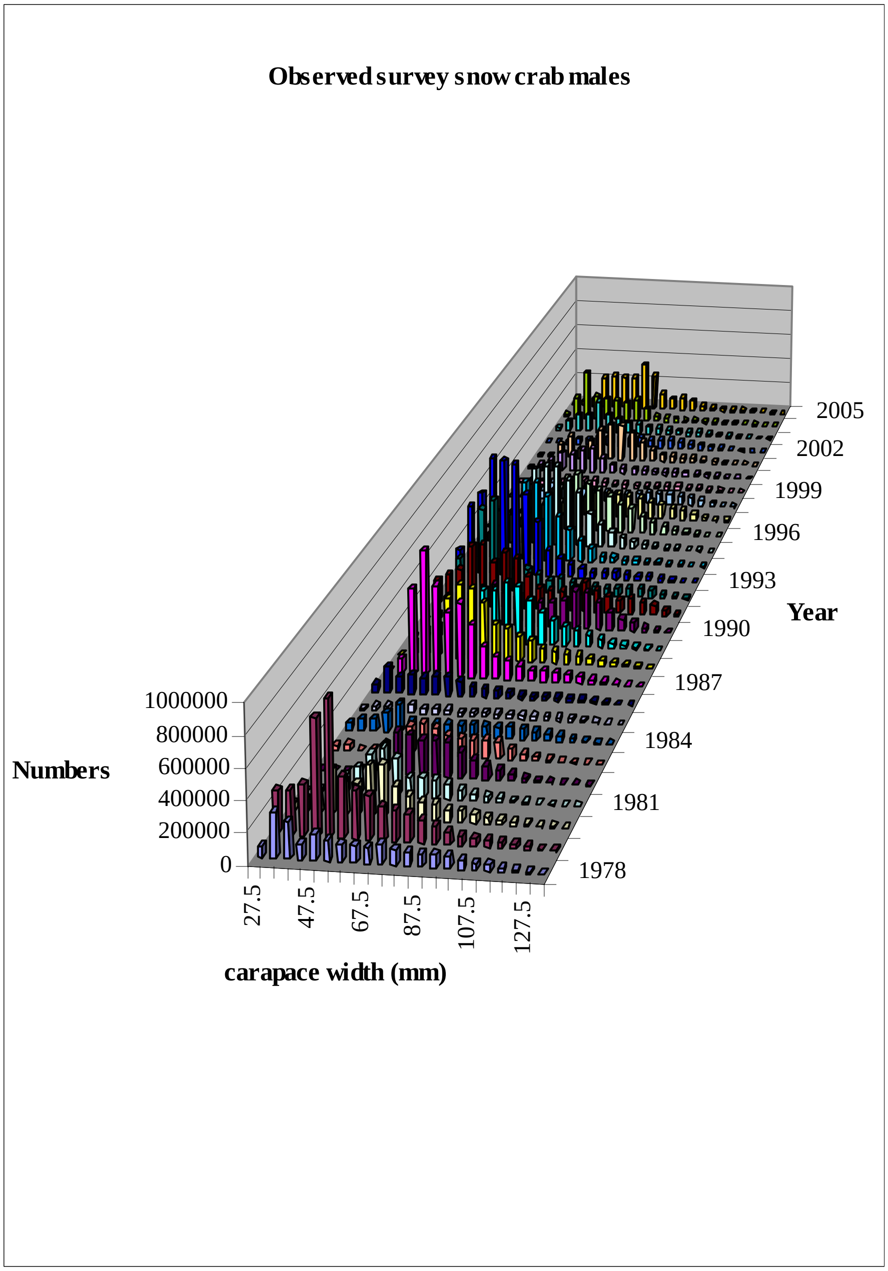

Figure 6. Observed survey numbers (1000's of crab) by carapace width and year for male snow crab.

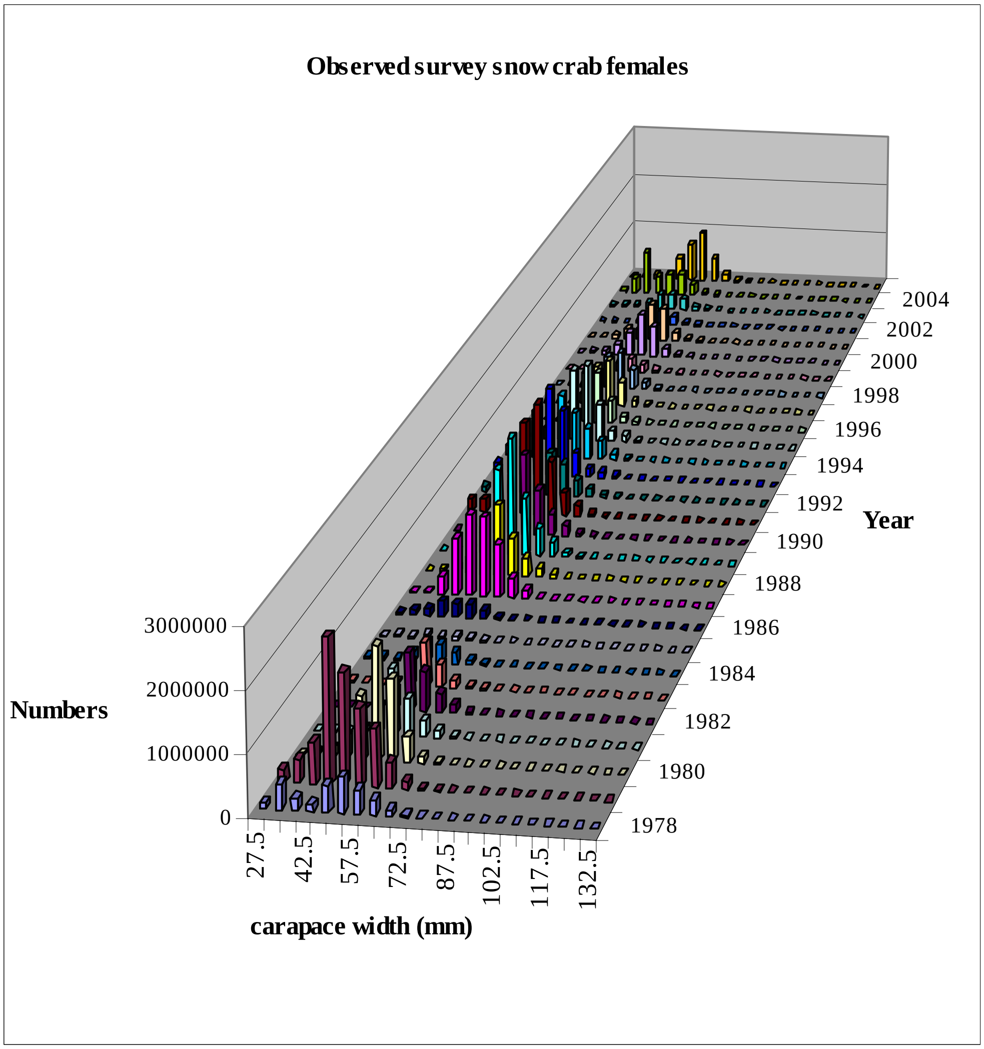

Figure 7. Observed survey numbers (1000's of crab) by carapace width and year for female snow crab.

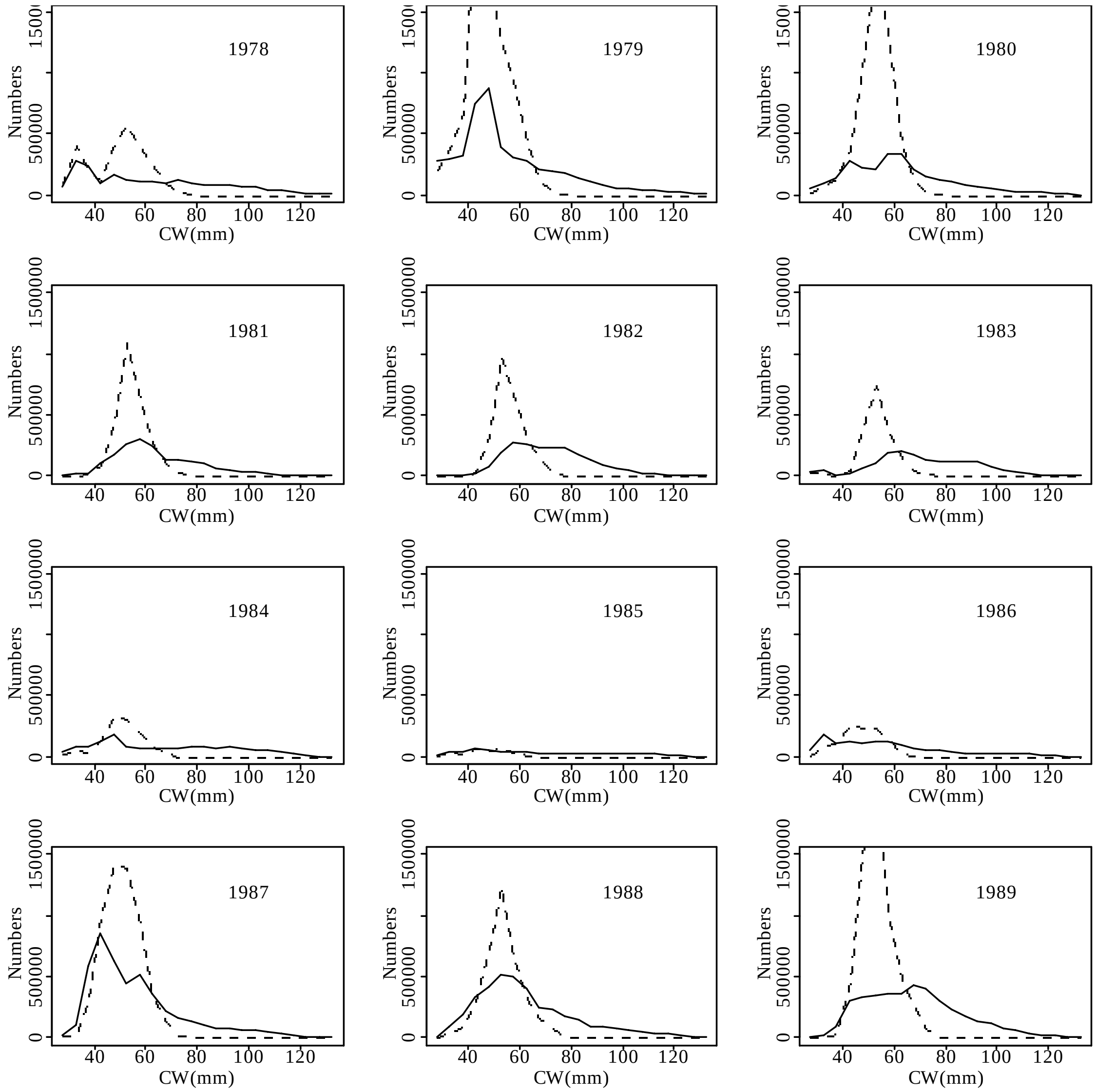

Figure 8. Survey numbers by length, females dashed line, males solid line.

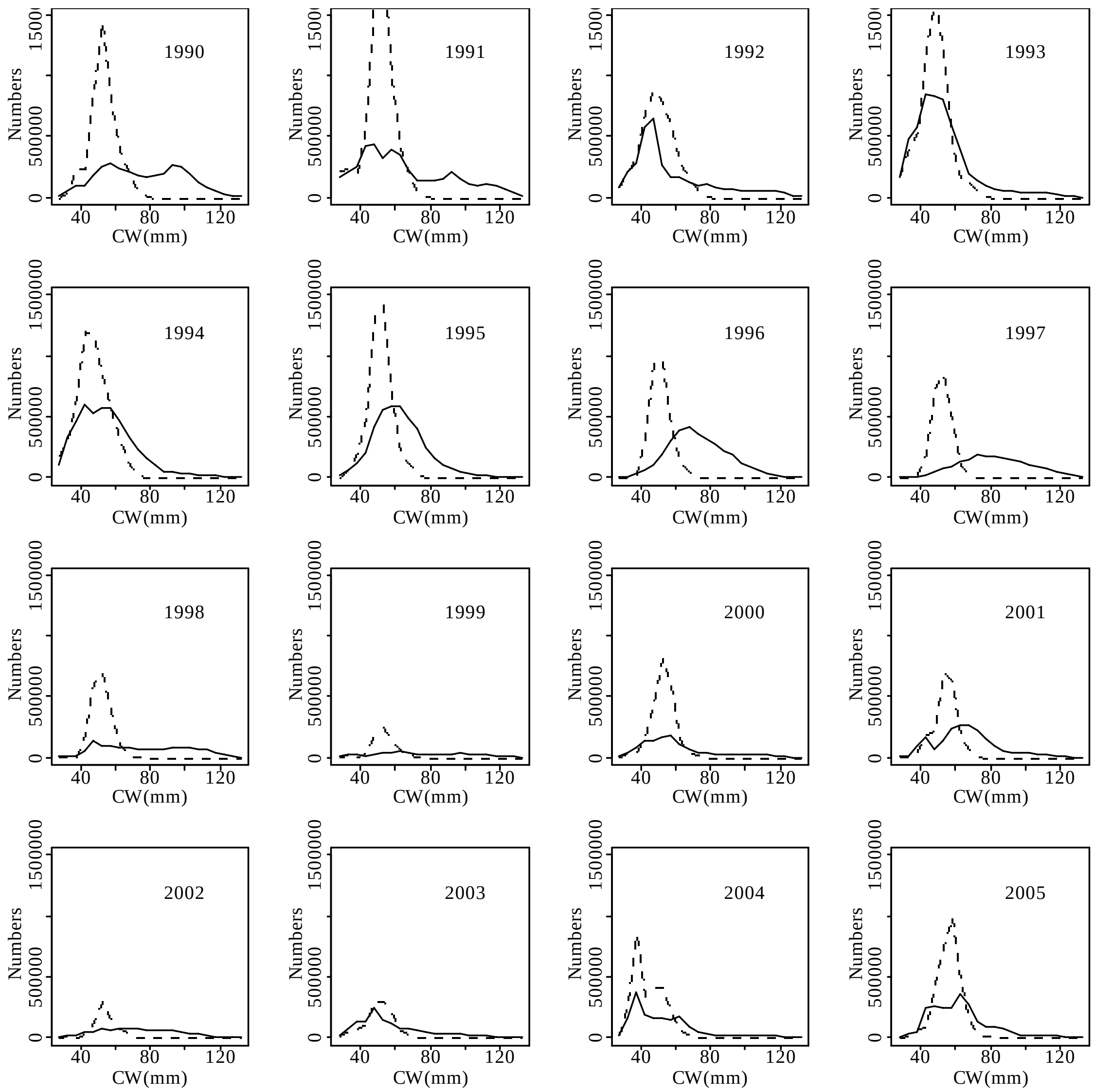

Figure 9. Survey numbers by length, females dashed line, males solid line.

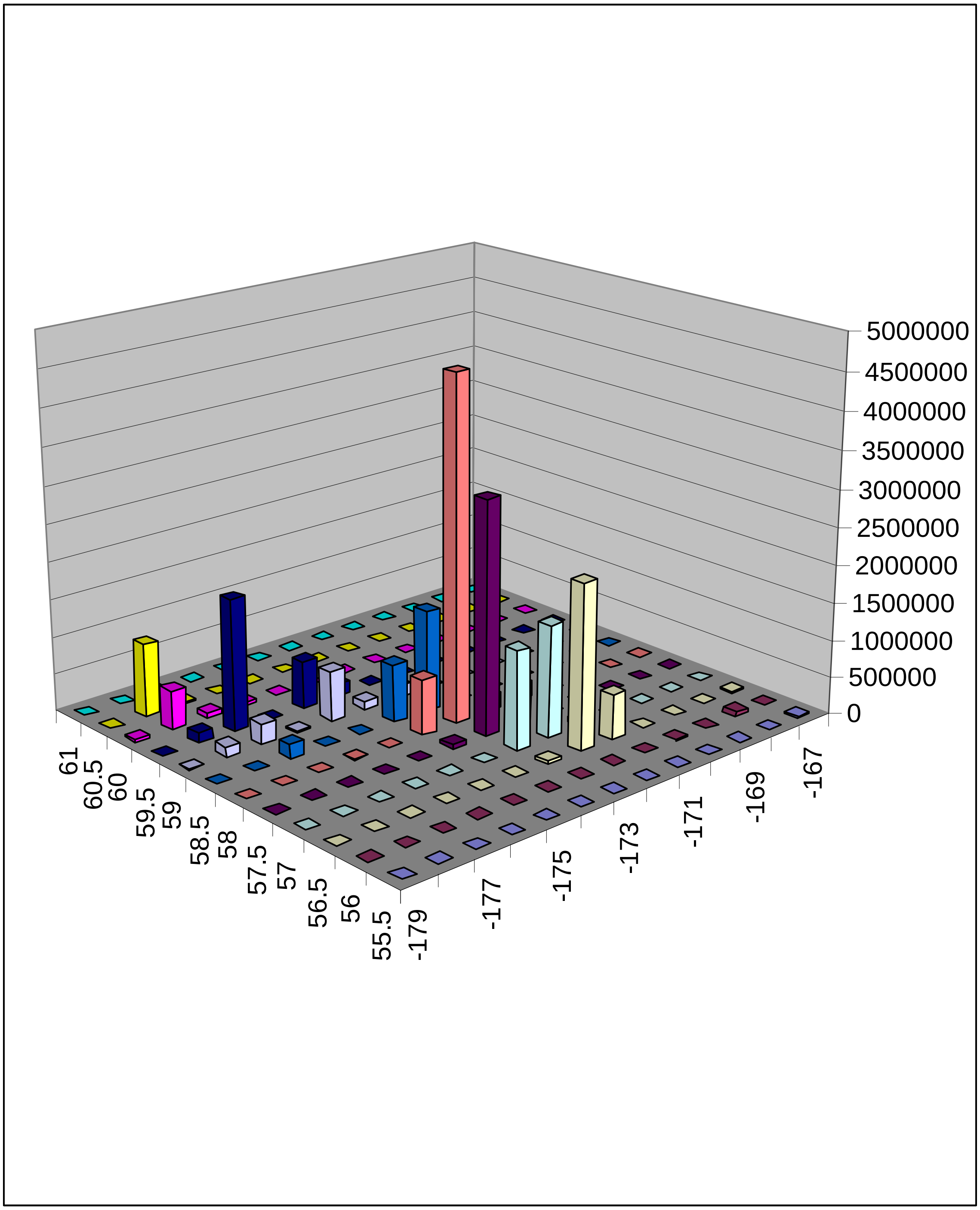

Figure 10. 2003 pot fishery retained catch in numbers by statistical area. Longitude in negative degrees. Areas are 1 degree longitude by 0.5 degree latitude.

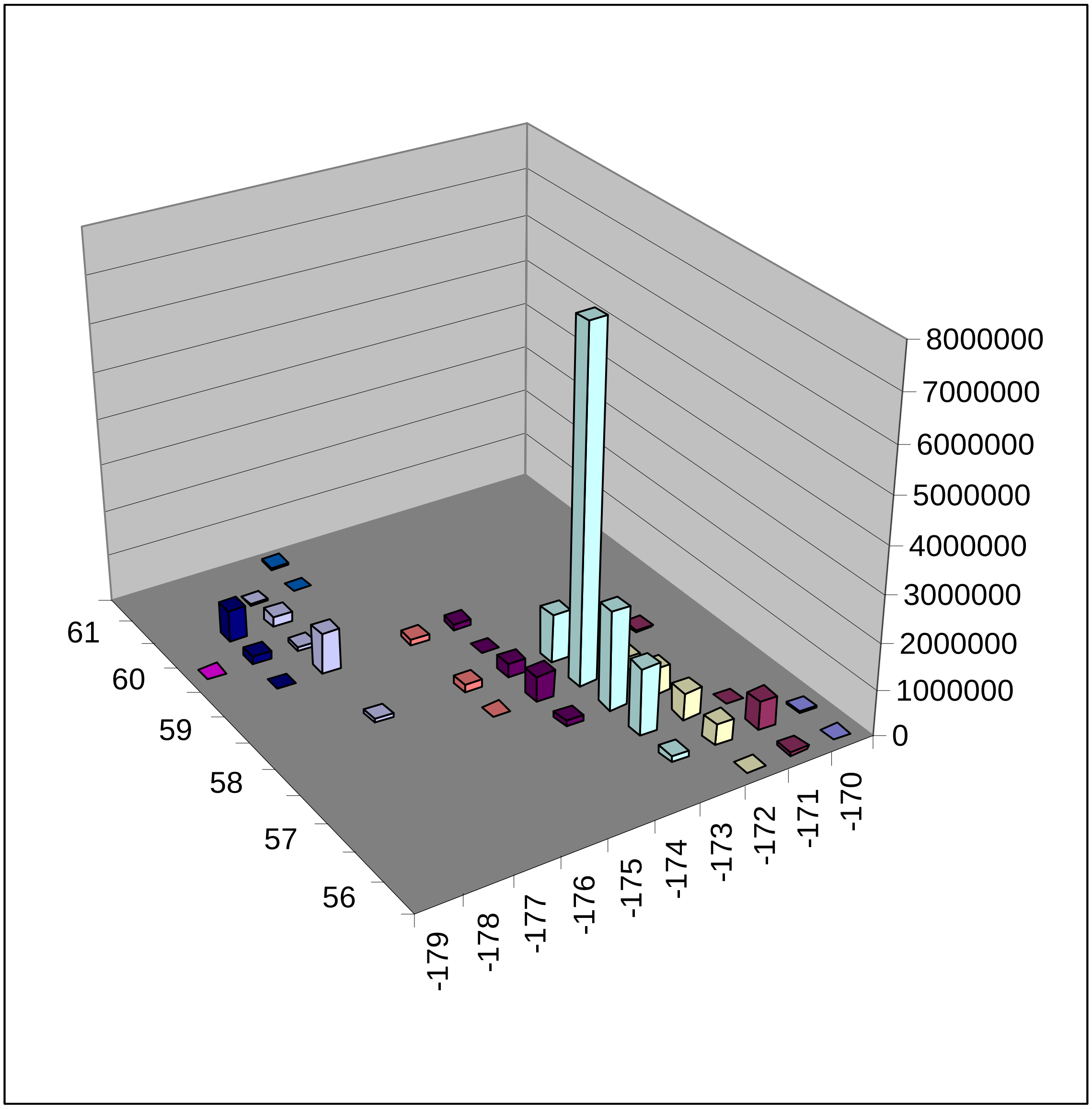

Figure 11. 2004 pot fishery retained catch in numbers by statistical area. Longitude in negative degrees. Areas are 1 degree longitude by 0.5 degree latitude.

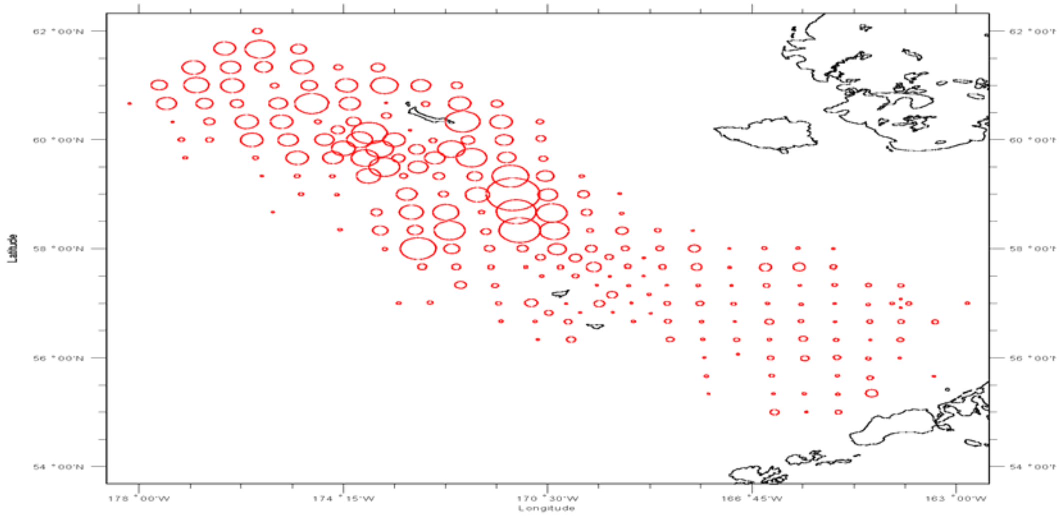

Figure 12. 2004 Survey abundance of males > 79 mm (approximately mature abundance) by tow. Abundance is proportional to the area of the circle (not on same scale as female abundance in Figure 51).

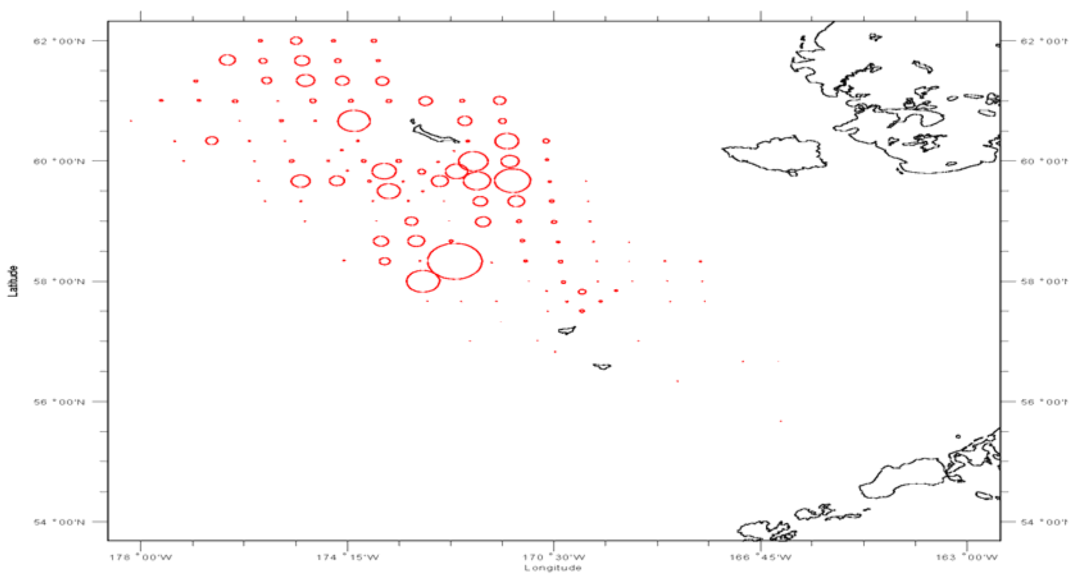

Figure 13. 2004 Survey abundance of females > 49 mm (approximately mature abundance) by tow. Abundance is proportional to the area of the circle (not on the same scale as male abundance in Figure 9).

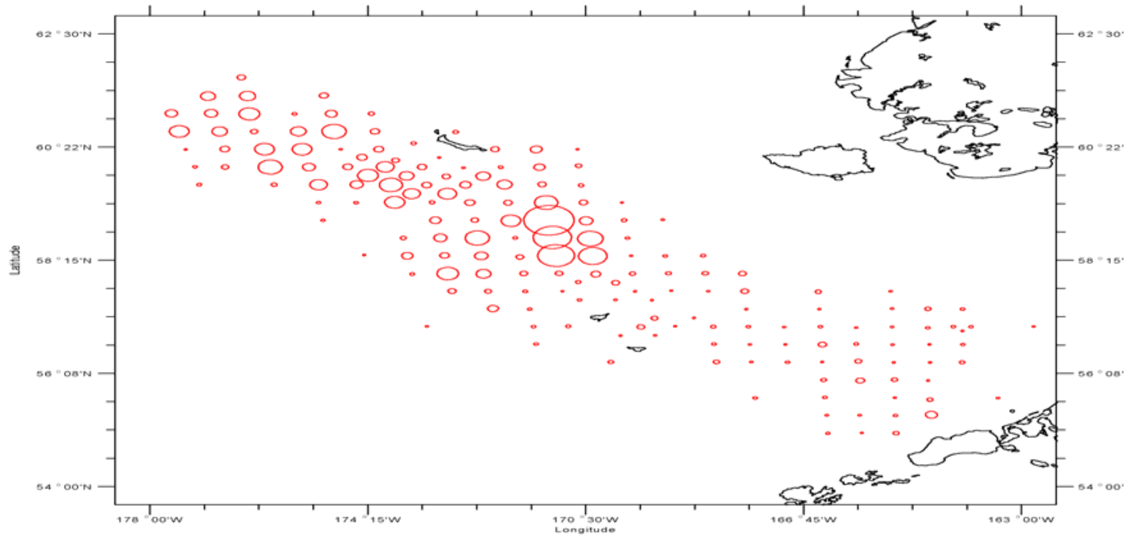

Figure 14. 2004 Survey abundance of males > 101 mm by tow. Abundance is proportional to the area of the circle.

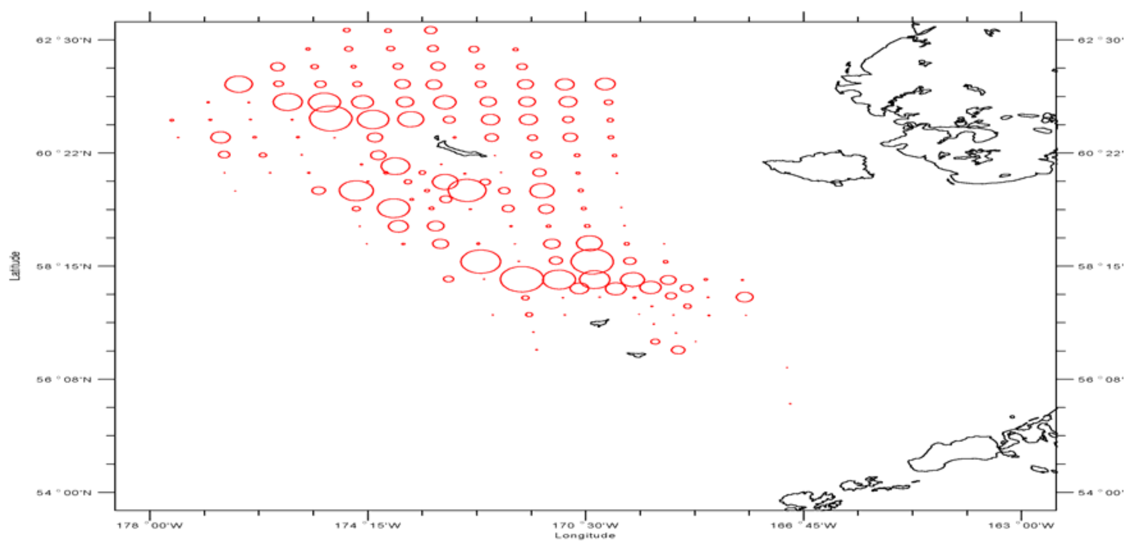

Figure 15. 2005 Survey abundance of females > 49 mm (approximately mature abundance) by tow. Abundance is proportional to the area of the circle (not on the same scale as male abundance in Figure 54). Includes stations to the north of the standard survey area.

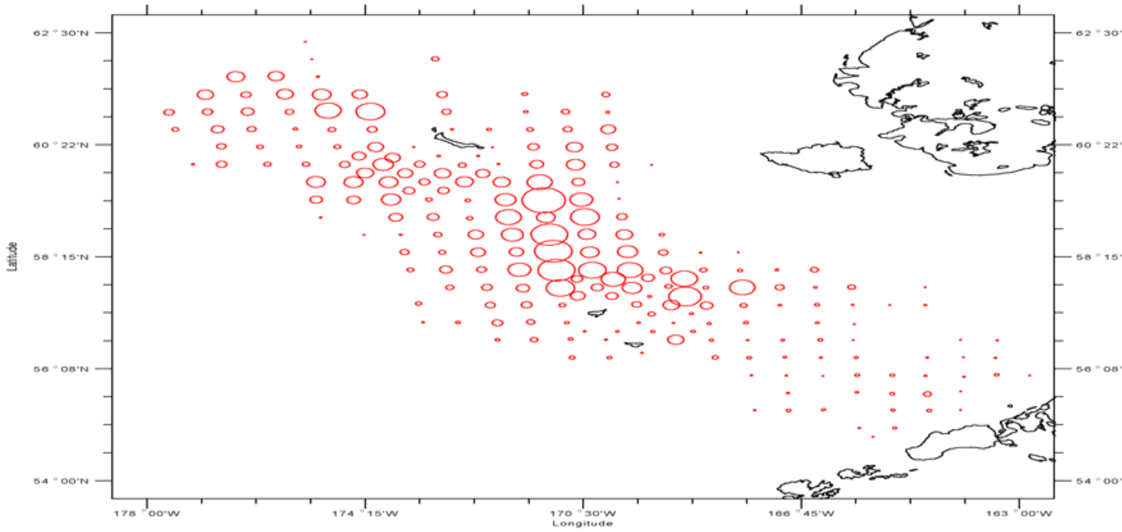

Figure 16. 2005 Survey abundance of males > 79 mm (approximately mature abundance) by tow. Abundance is proportional to the area of the circle (not on same scale as female abundance in Figure 53).

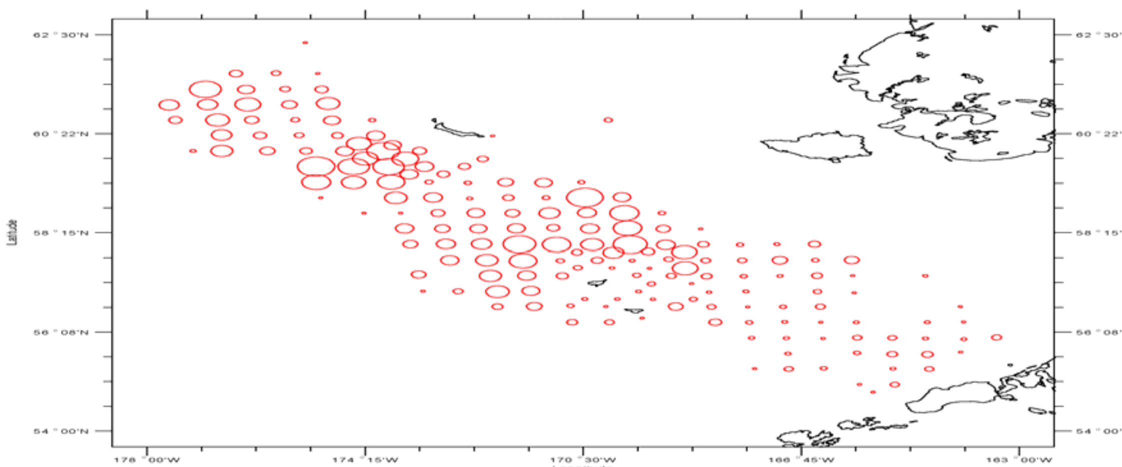

Figure 17. 2005 Survey abundance of males > 101 mm by tow. Abundance is proportional to the area of the circle.

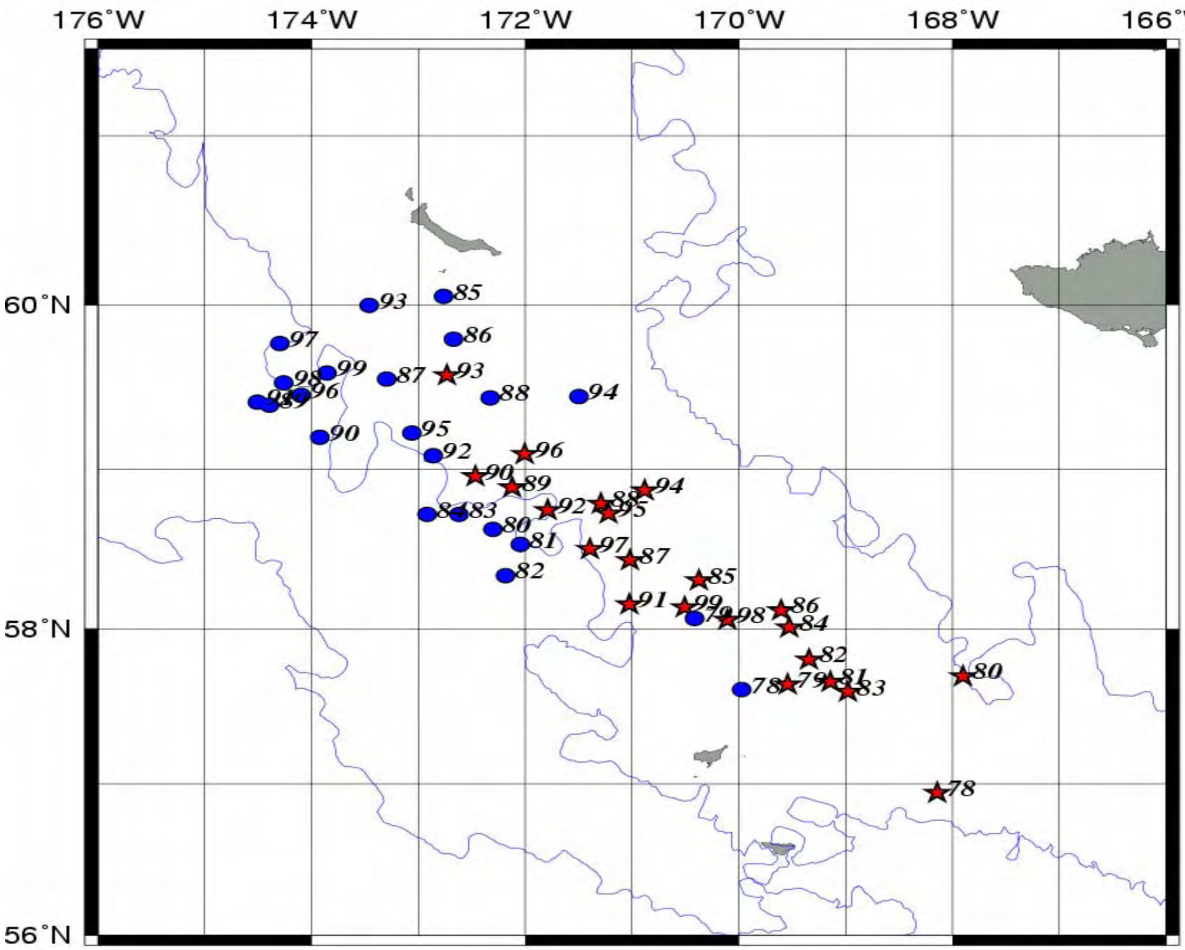

Figure 18. Centroids of abundance of mature female snow crabs (shell condition 2+) in blue circles and mature males (shell condition 3+) in red stars. Reprinted from Orensanz, Armstong and Ernst (in press).

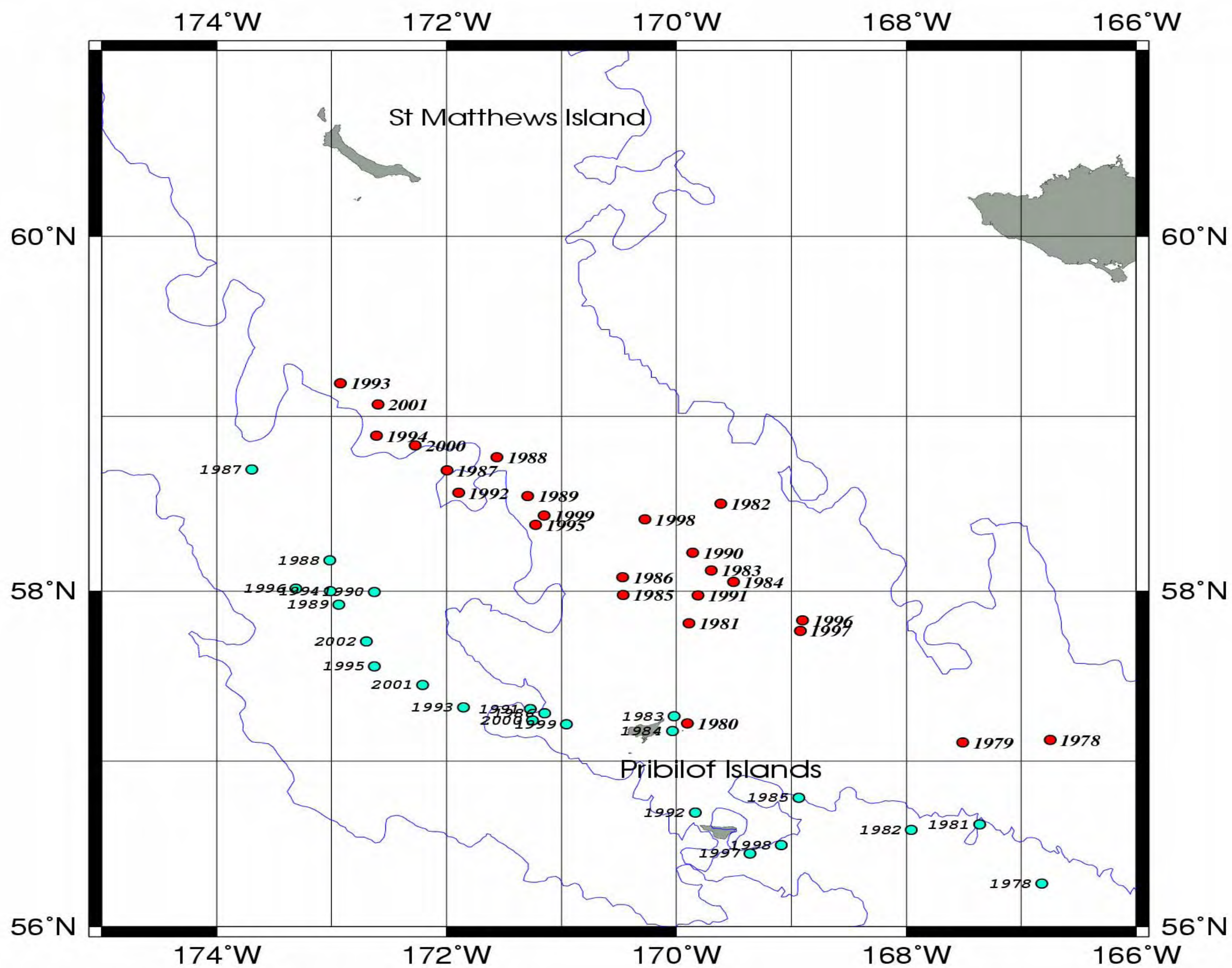

Figure 19. Centroids abundance (numbers) of snow crab males > 101 mm from the summer NMFS trawl survey (red) and from the winter fishery (blue-green), from Orensanz, Armstong and Ernst (in press).

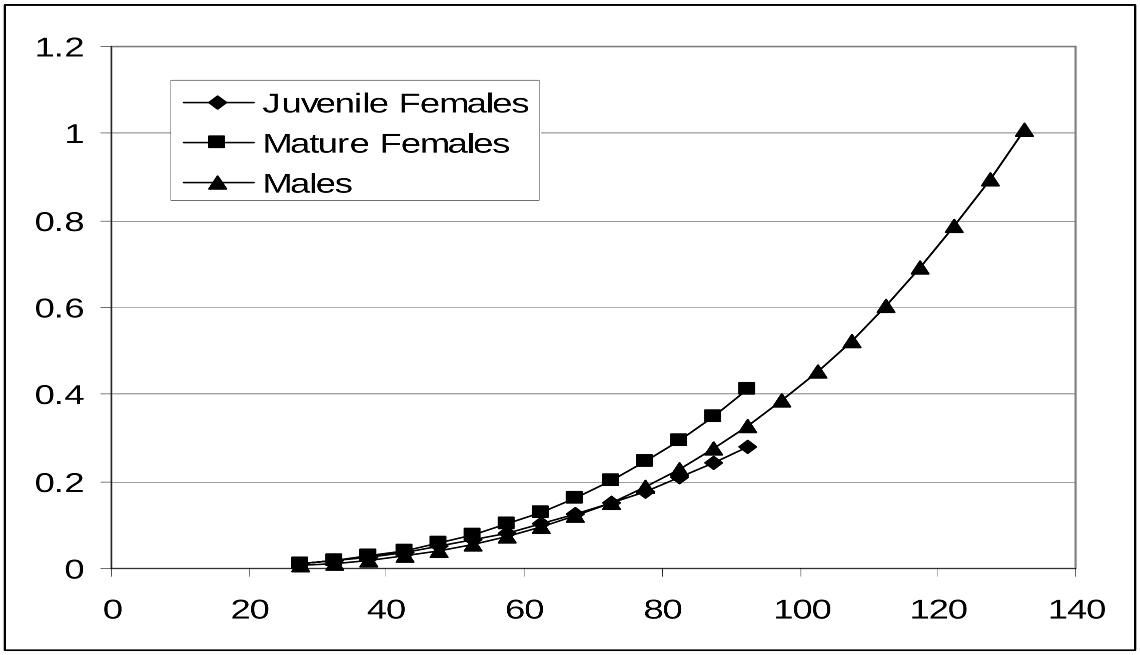

Figure 20. Weight (kg) – size (mm) relationship for male, juvenile female and mature female snow crab.

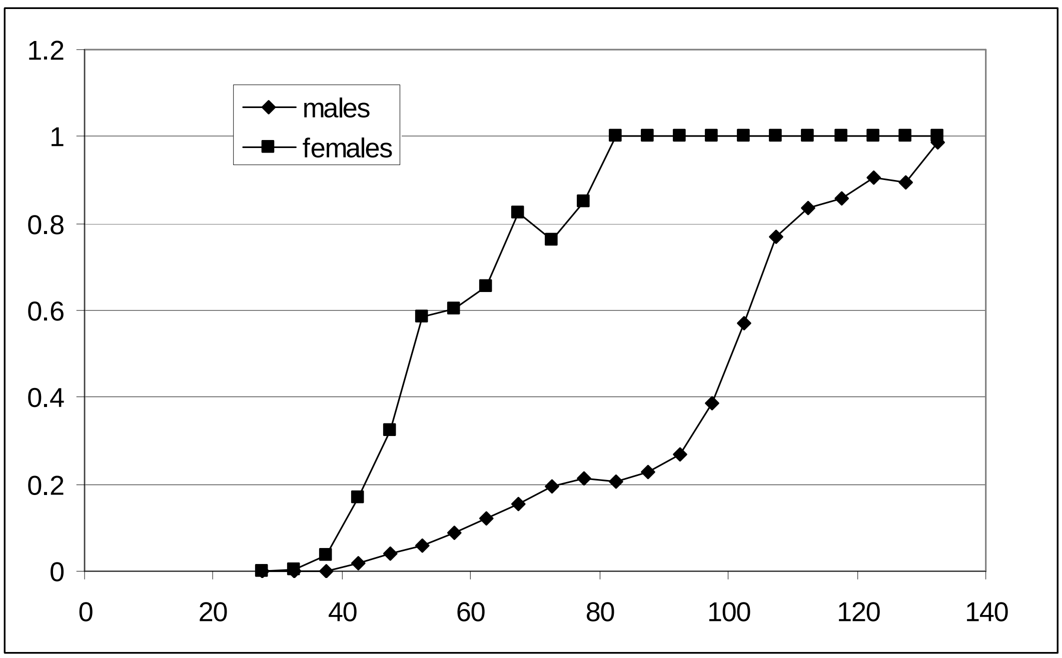

Figure 21. Probability of maturing by size for male and female snow crab (<u>not</u> the average fraction mature).

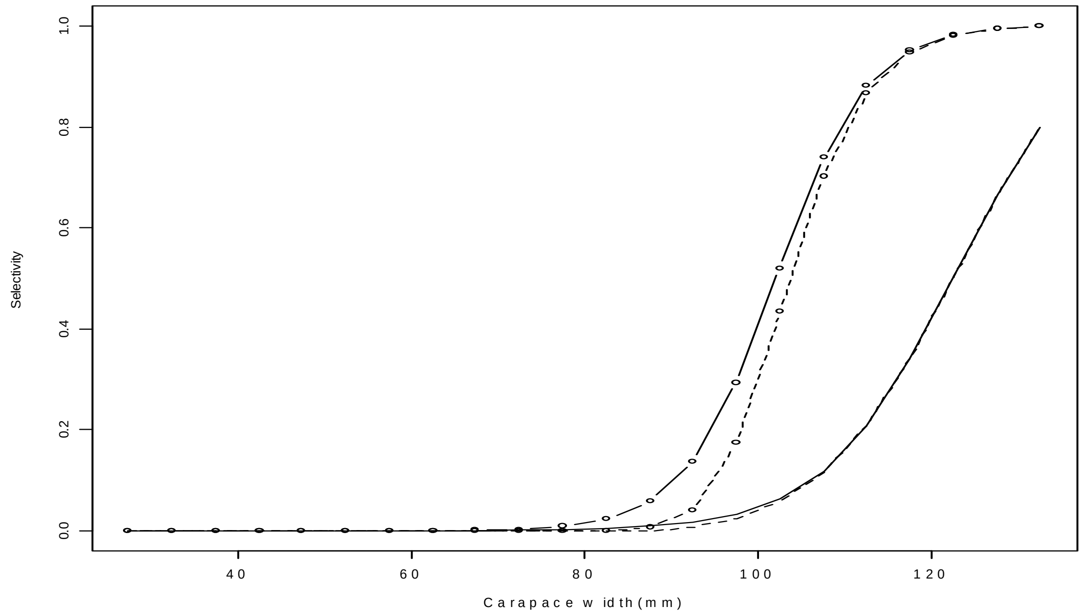

Figure 22. Selectivity curve for total catch (discard plus retained) for new shell males (solid line with filled circles) and retained catch of male snow crab by new (dotted line with filled circles) and old shell condition (dotted line). Solid line is total selectivity (discard plus retained) for old shell males.

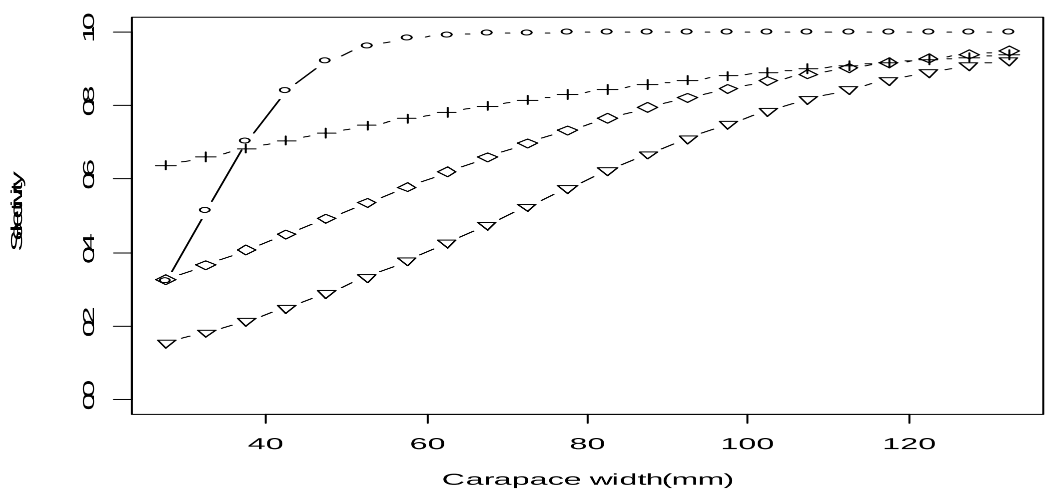

Figure 23. Survey selectivity curves for female and male snow crab estimated by the model for 1978-1981 (solid line with circles), for 1982 to 1988 (solid line with diamonds), and 1989 to present (solid line with pluses). Survey selectivities estimated by Somerton and Otto (1998) are the solid line with triangles.

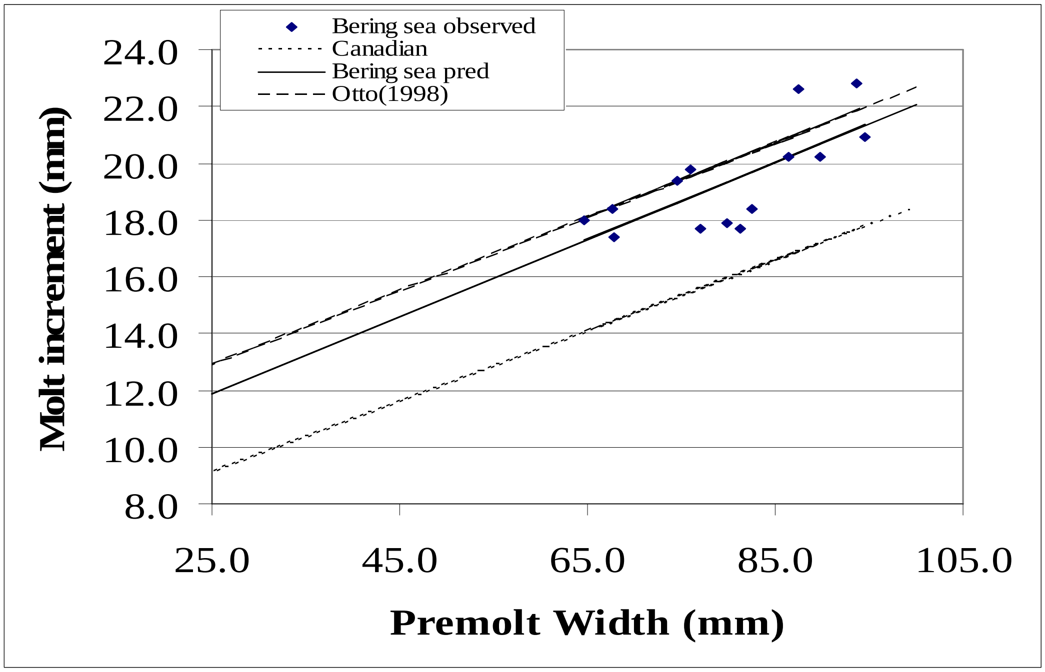

Figure 24. Growth increment as a function of premolt size for male snow crab. Points labeled Bering sea observed are observed growth increments from Rugolo (unpub data). The line labeled Bering sea pred is the predicted line from the Bering sea observed growth, which is used as a prior for the growth parameters estimated in the model. The line labeled Canadian is estimated from Atlantic snow crab (Sainte-Marie data). The line labeled Otto(1998) was estimated from tagging data from Atlantic snow crab less than 67 mm, from a different area from Sainte-Marie data.

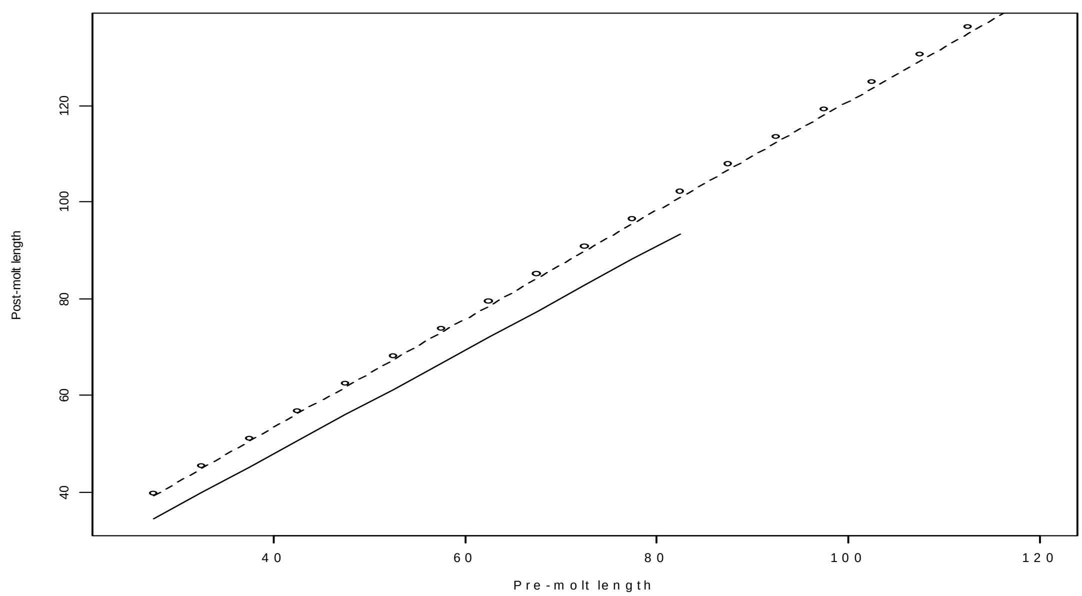

Figure 25. Growth (mm) for male (dotted line) and female snow crab (solid line) estimated from the model. Circles are the observed growth curve.

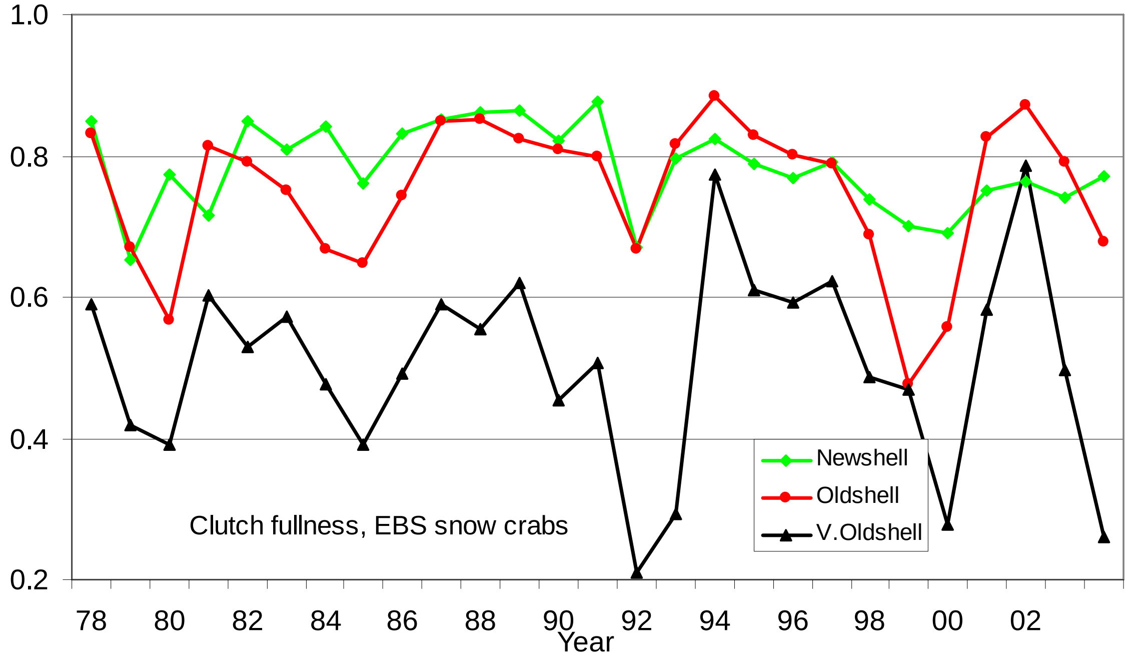

Figure 26. Clutch fullness for Bering sea snow crab survey data by shell condition for 1978 to 2004.

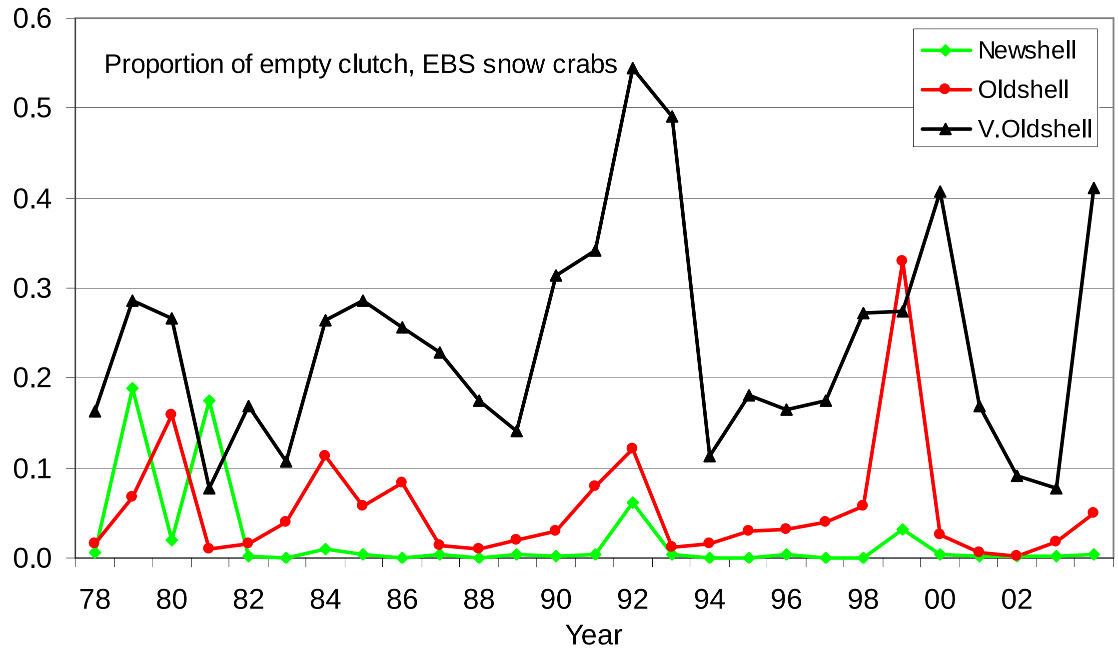

Figure 27. Proportion of barren females by shell condition from survey data 1978 to 2004.

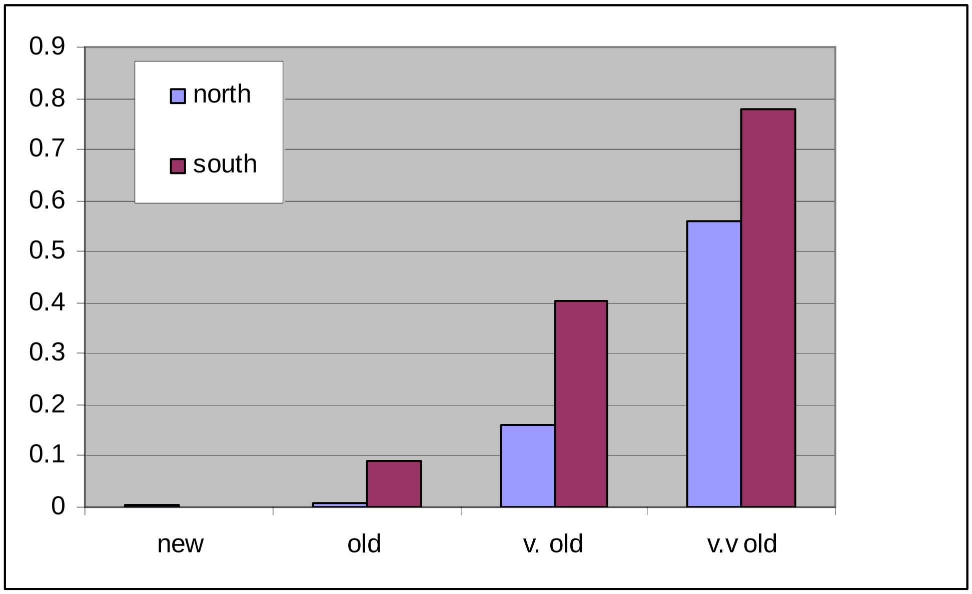

Figure 28. Fraction of barren females in the 2004 survey by shell condition and area north of 58.5 deg N and south of 58.5 deg N.

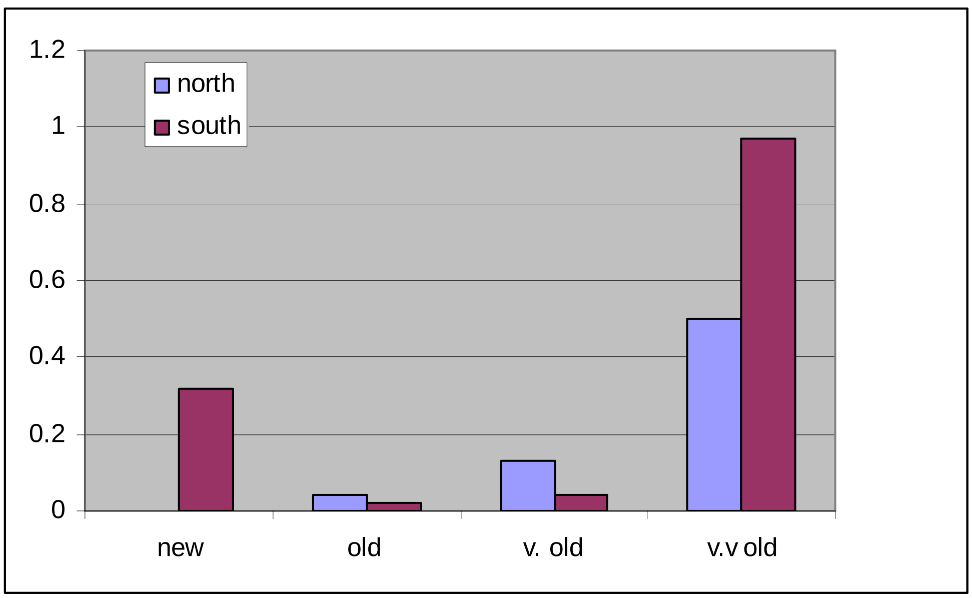

Figure 29. Fraction of barren females in the 2003 survey by shell condition and area north of 58.5 deg N and south of 58.5 deg N. The number of new shell mature females south of 58.5 deg N was very small in 2003.

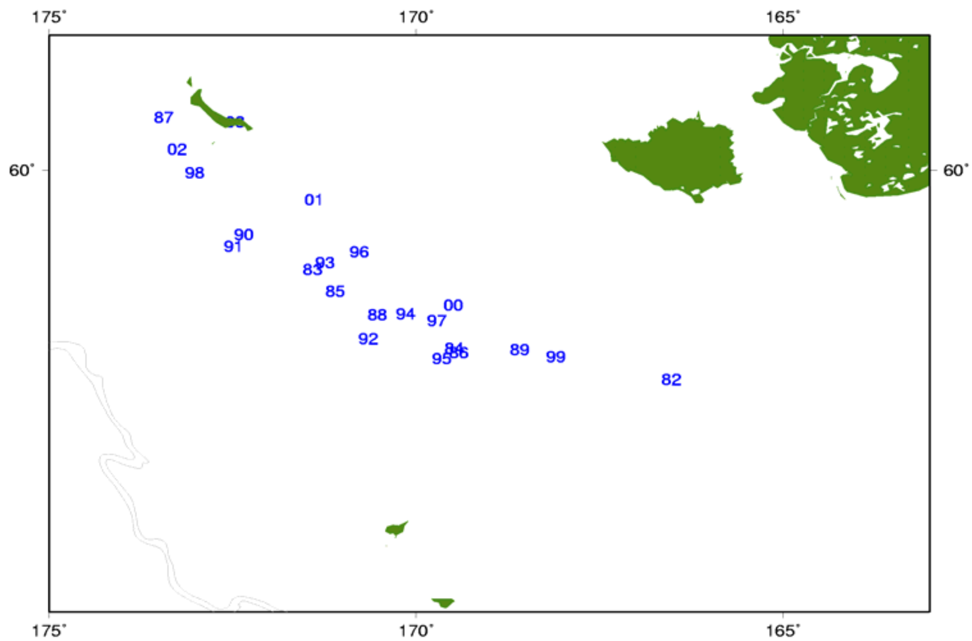

Figure 30. Centroids of cold pool (<2.0 deg C). Centroids are average latitude and longitude.

Figure 31. Estimated total catch (discard + retained) (solid line), observed total catch (solid line with circles) (assuming 50% mortality of discarded crab) and observed retained catch (dotted line) for 1979 to 2006 fishery seasons.

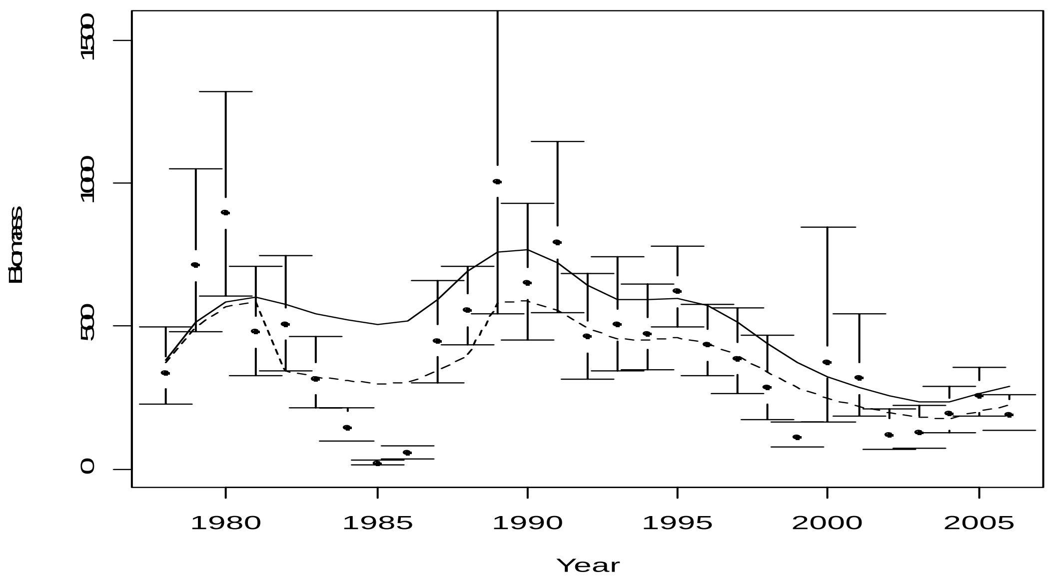

Figure 32. Population female mature biomass (millions of pounds, solid line), model estimate of survey female mature biomass (dotted line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.

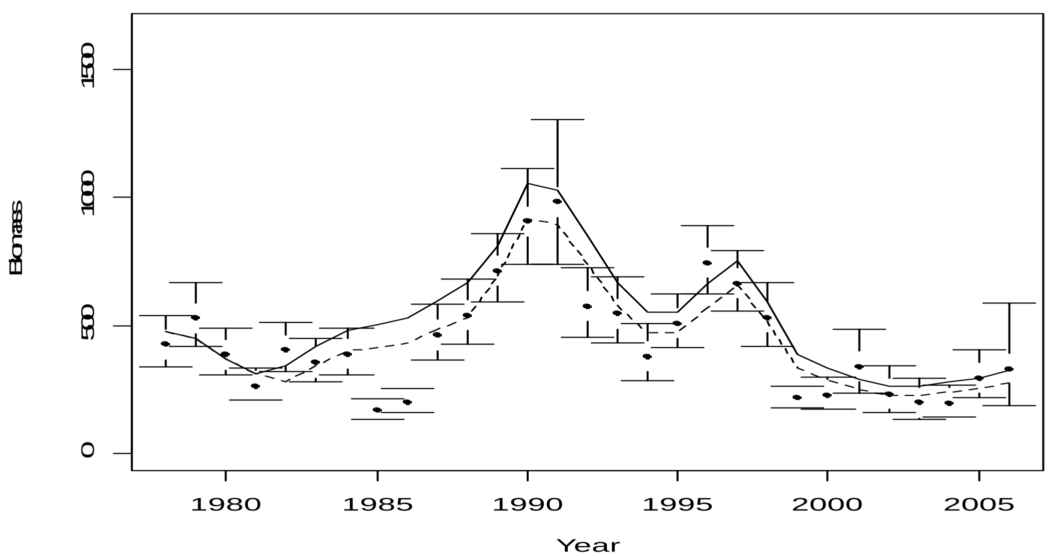

Figure 33. Population male mature biomass (millions of pounds, solid line), model estimate of survey male mature biomass (dotted line) and observed survey male mature biomass with approximate lognormal 95% confidence intervals.

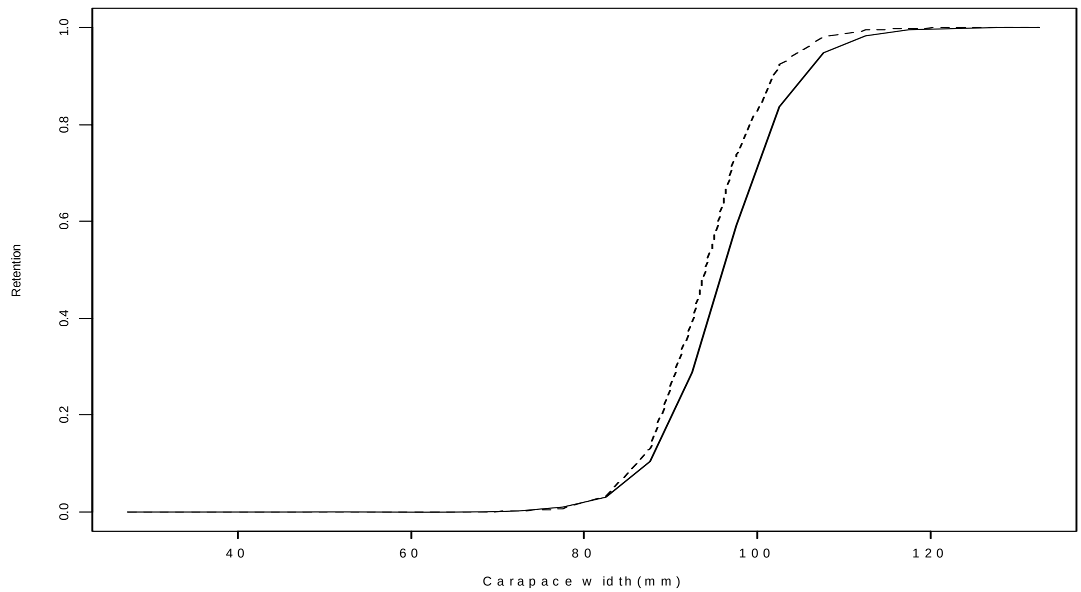

Figure 34. Model estimated fraction of the total catch that is retained by size for new (solid line) and old (dotted line) shell male snow crab.

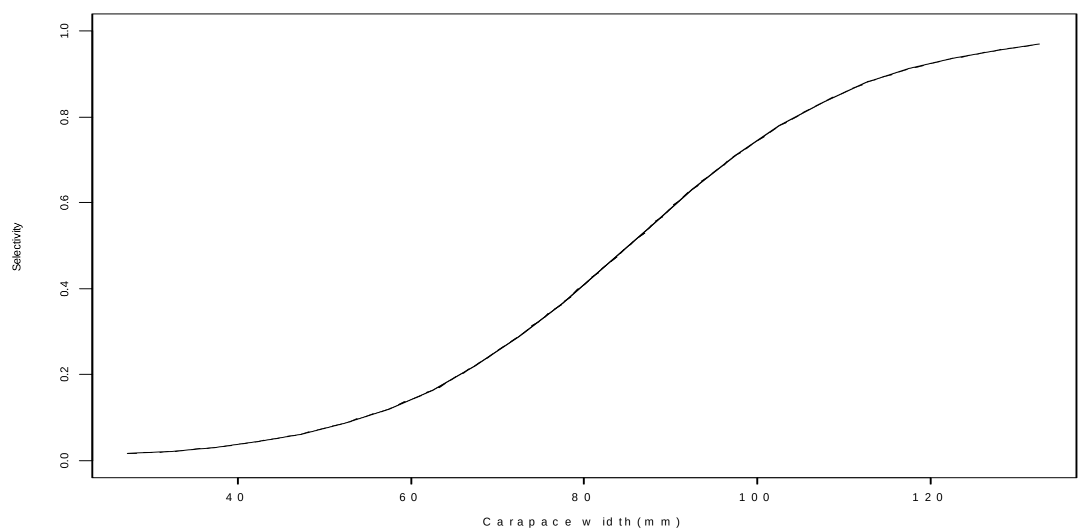

Figure 35. Selectivity curve estimated by the model for bycatch in the groundfish trawl fishery for females and males.

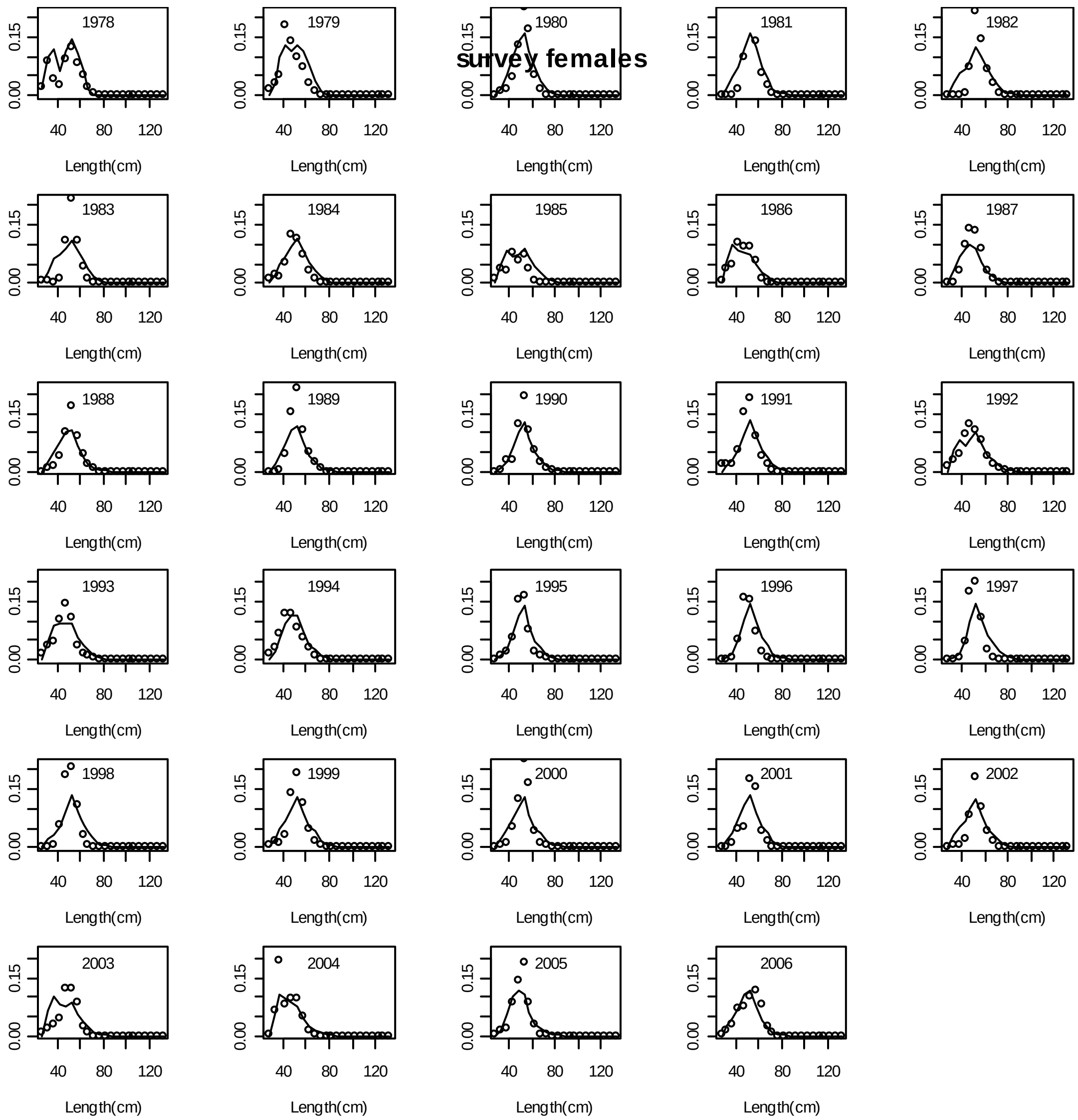

Figure 36. Model fit to the survey female size frequency data. Circles are observed survey data. Solid line is the model fit.

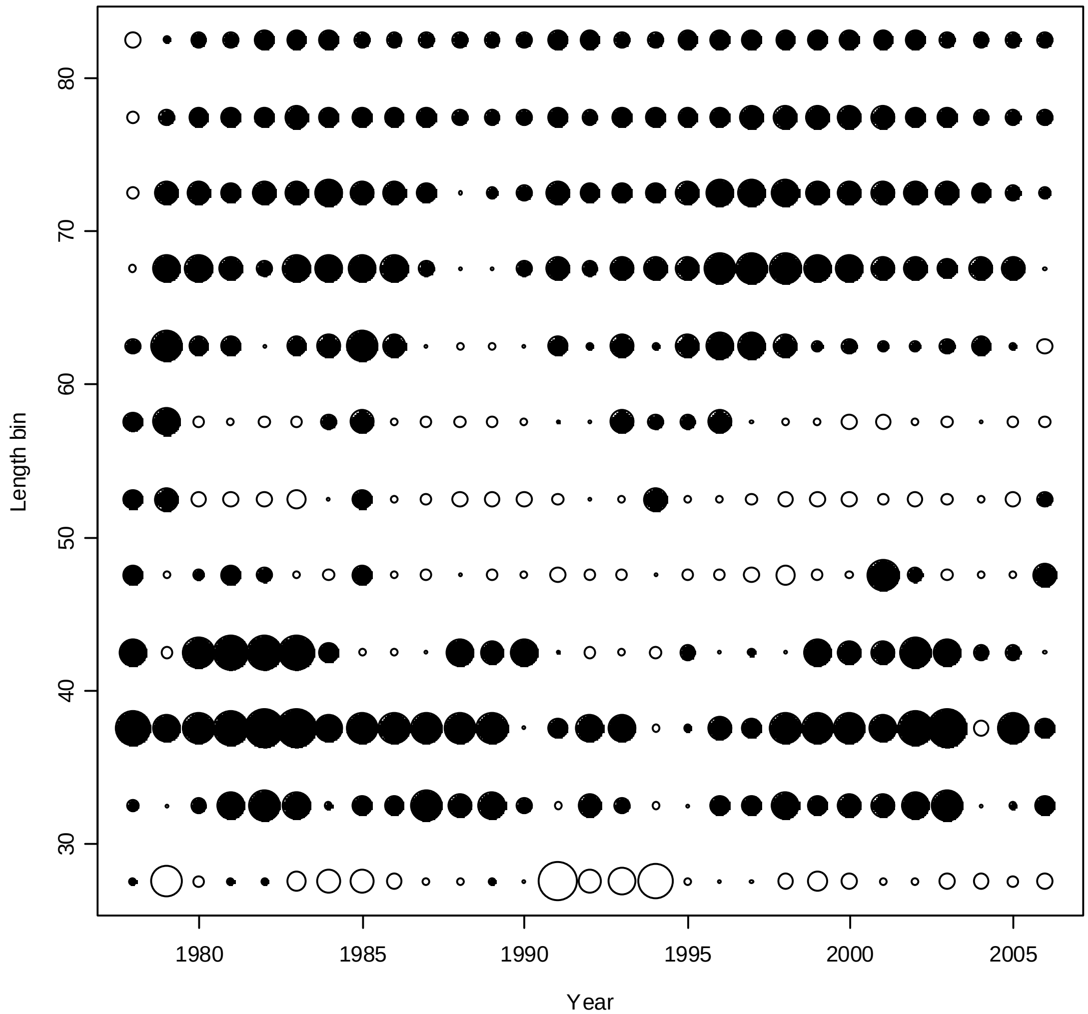

Figure 37. Residuals of fit to survey female size frequency. Filled circles are negative residuals.

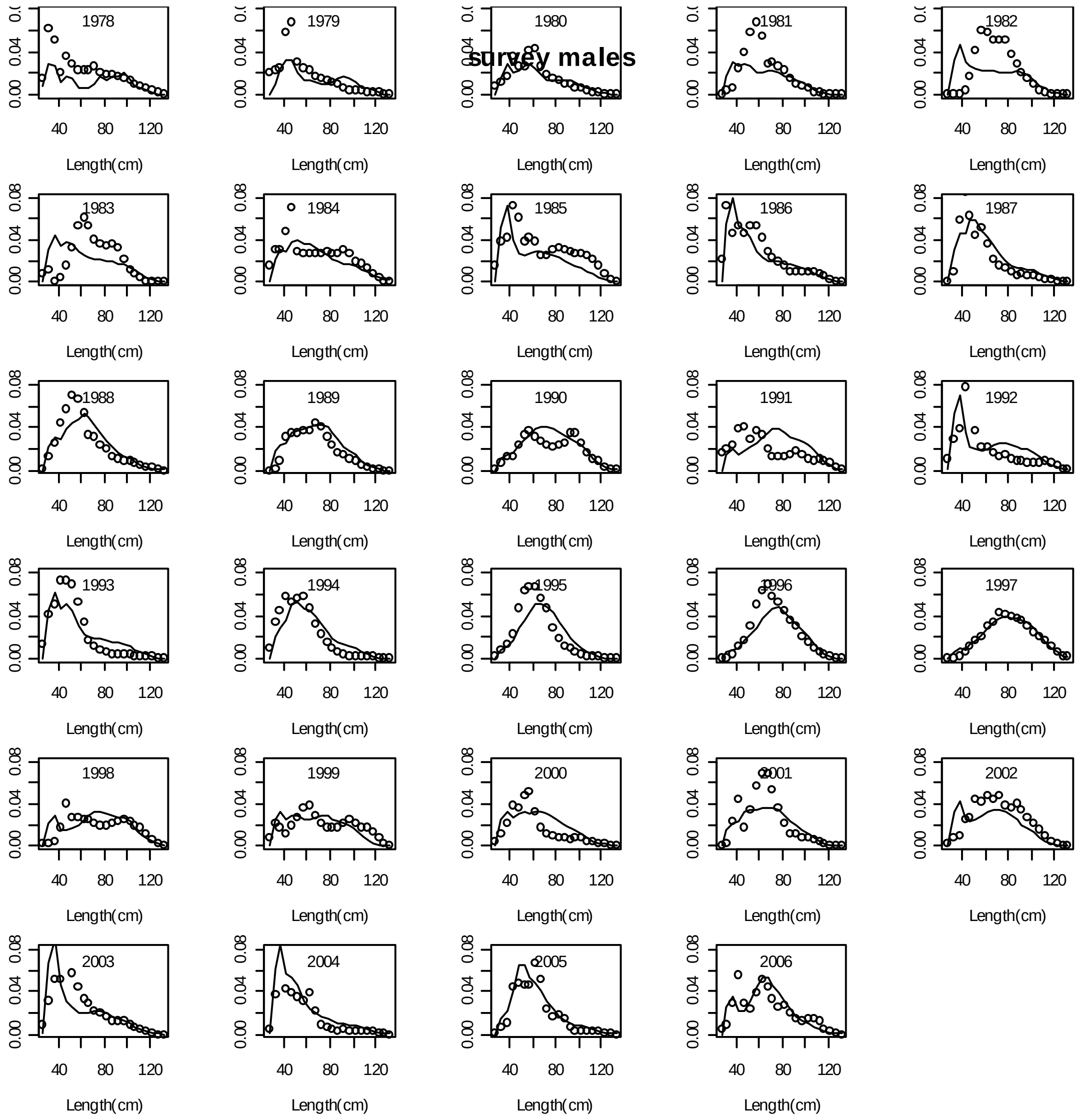

Figure 38. Model fit to the survey male size frequency data. Circles are observed survey data. Solid line is the model fit.

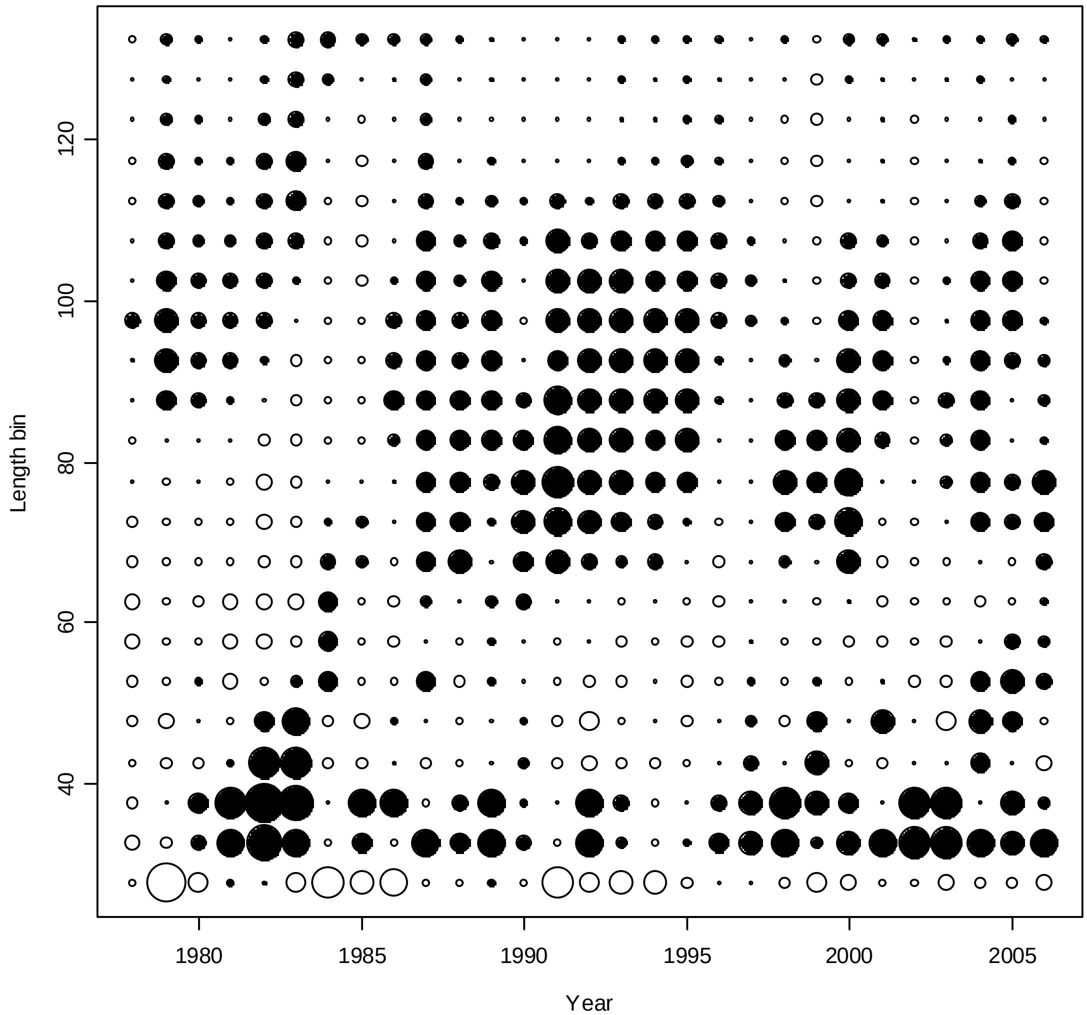

Figure 39. Residuals for fit to survey male size frequency. Filled circles are negative residuals.

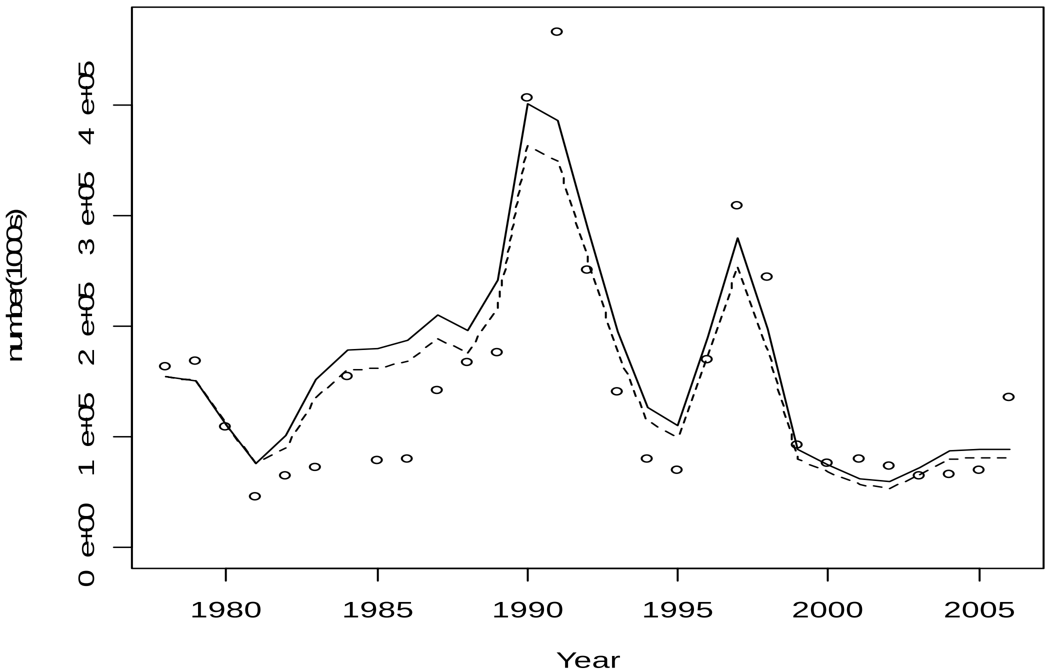

Figure 40. Observed survey numbers of males >101mm (circles), model estimates of the population number of males >101mm (solid line) and model estimates of survey numbers of males >101 mm (dotted line).

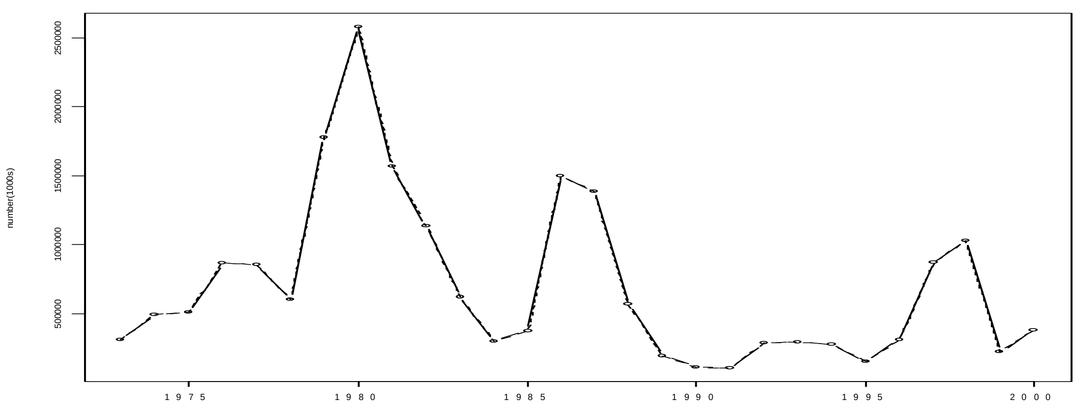

Figure 41. Recruitment to the model for crab 25 mm to 50 mm. Total recruitment is 2 times recruitment. Male and female recruitment fixed to be equal.

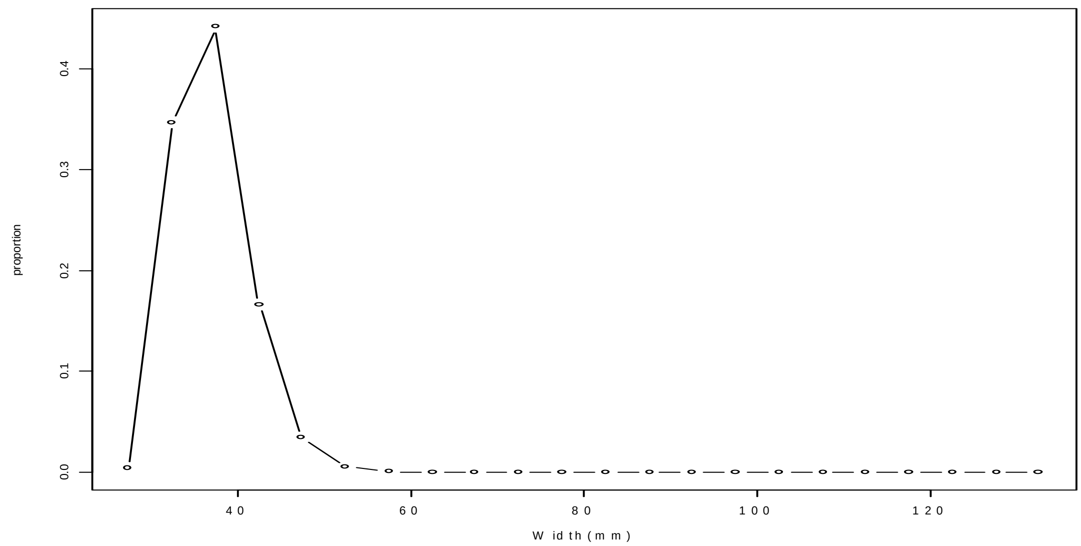

Figure 42. Distribution of recruits to length bins estimated by the model.

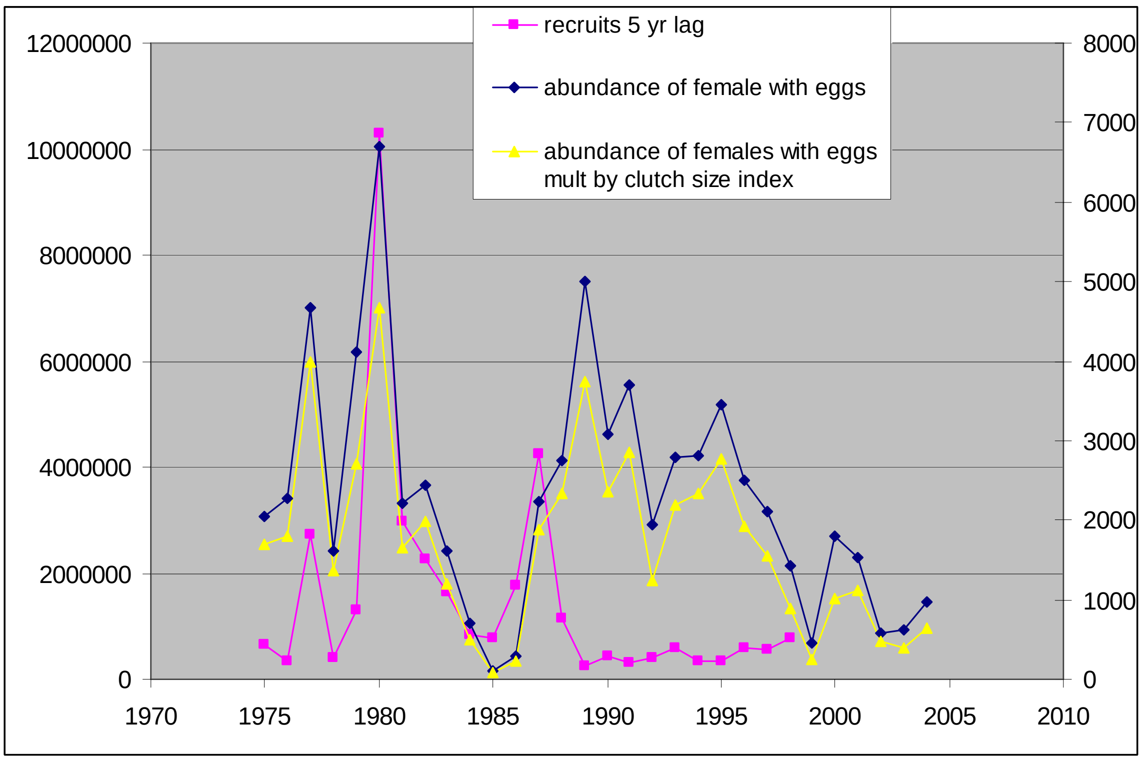

Figure 43. Model estimates of recruitment (fertilization year), survey abundance of females with eggs, and abundance of females with eggs multiplied by the fraction of full clutch from 1975 to 2004(from D:\crab\crab.adm\survey2004\clutch.xls).

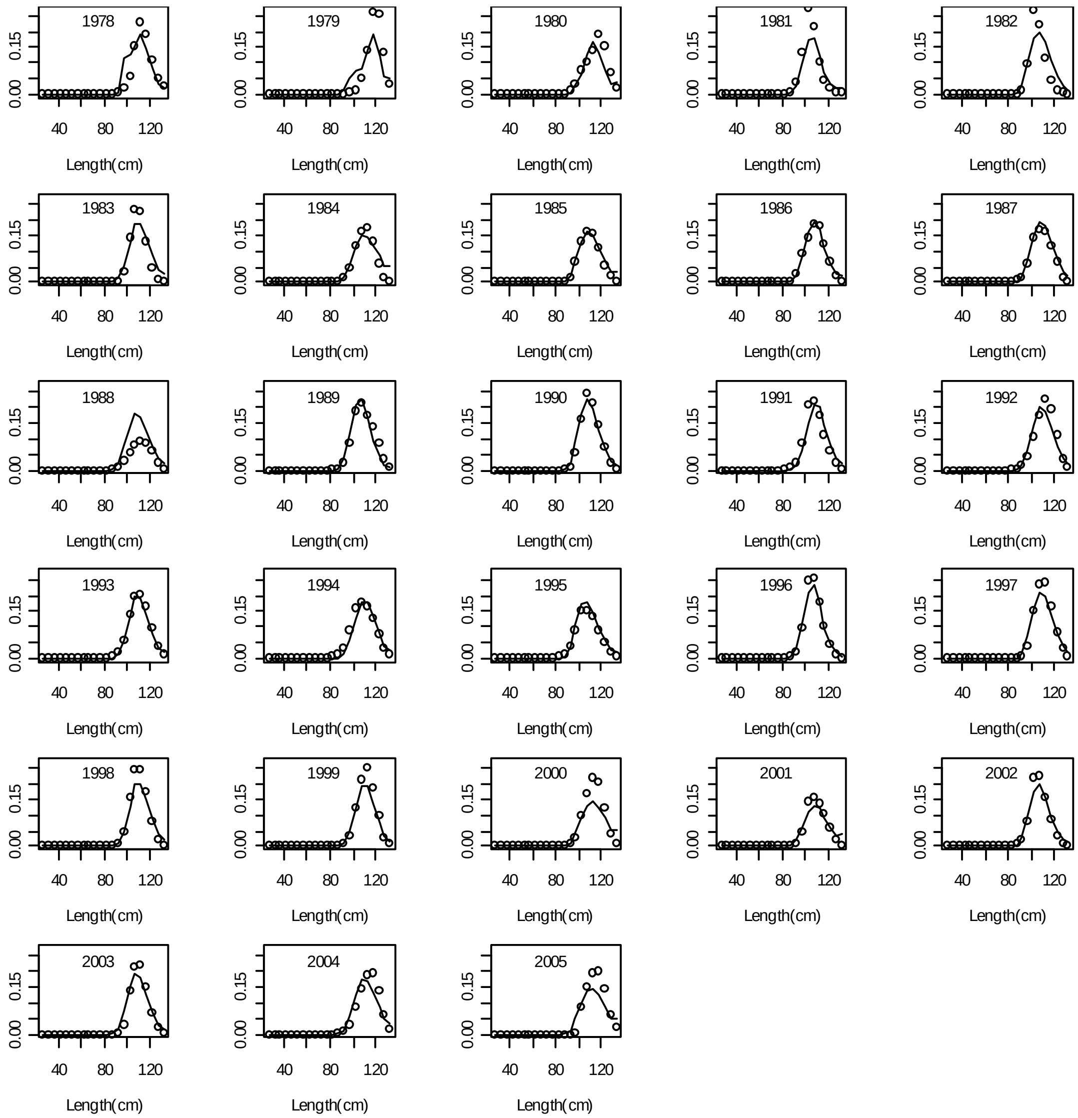

Figure 44. Model fit to the retained male new shell size frequency data. Solid line is the model fit. Circles are observed data. Year is the survey year.

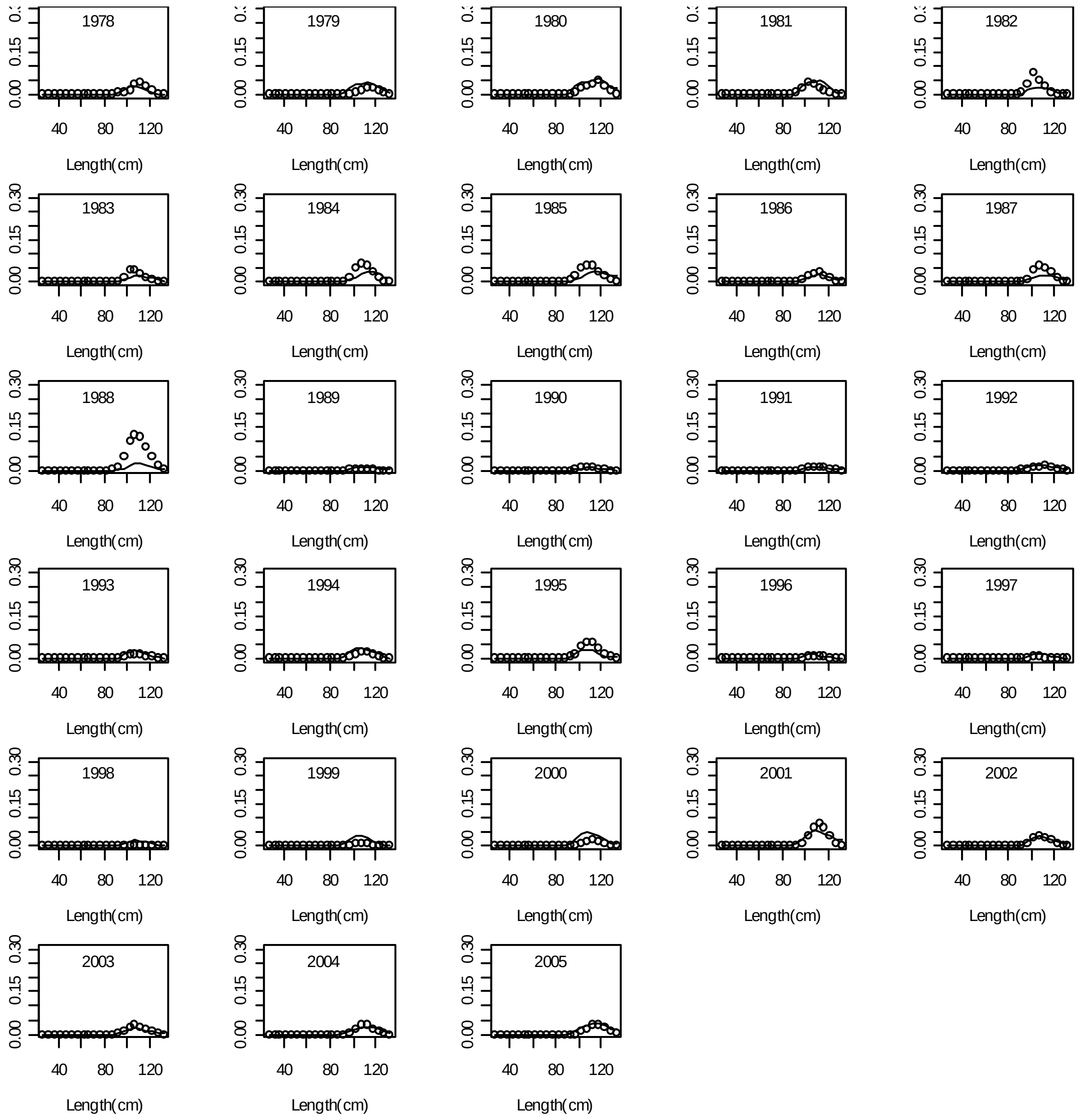

Figure 45. Model fit to the retained male old shell size frequency data. Solid line is the model fit. Circles are observed data. Year is the survey year.

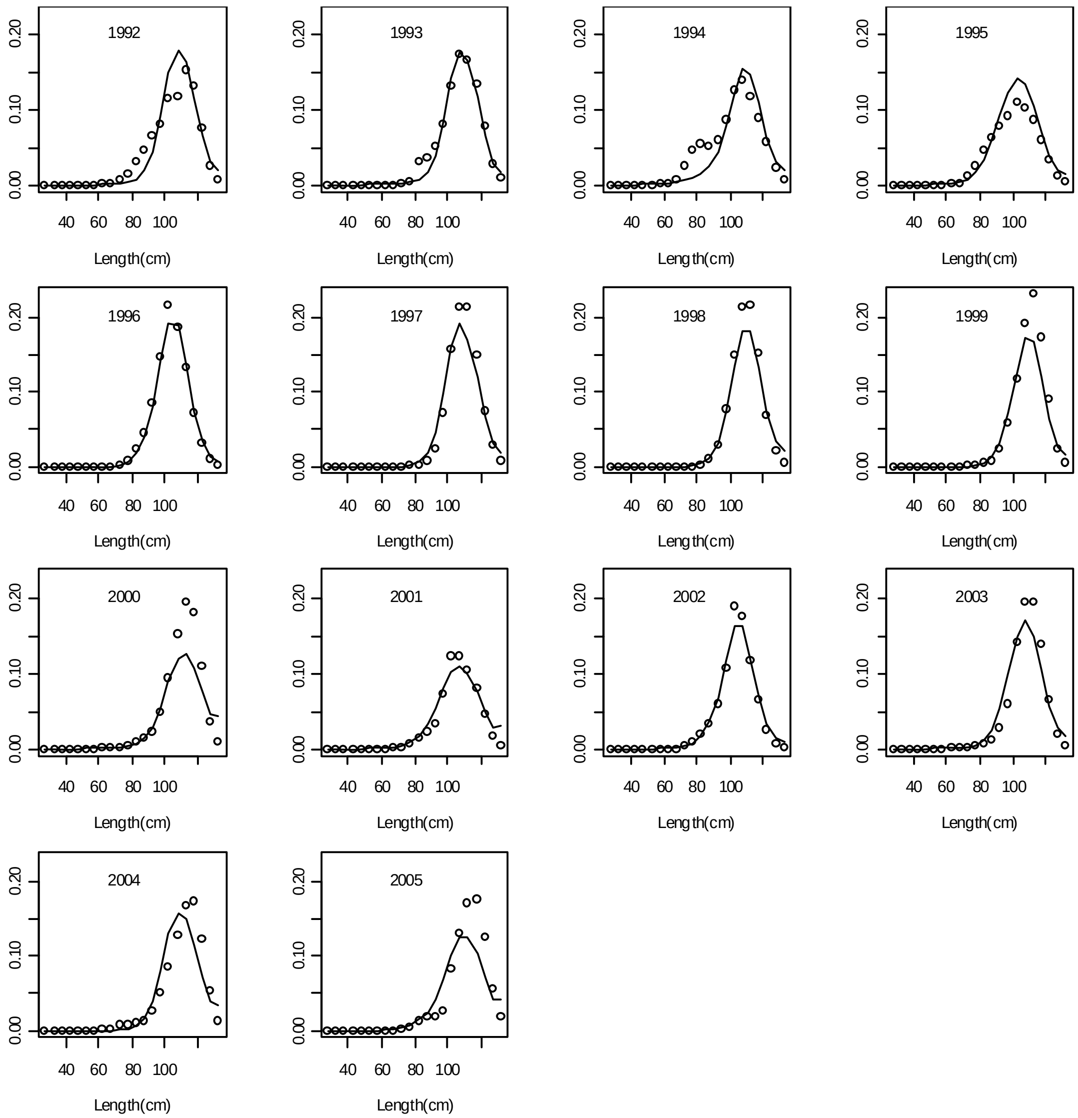

Figure 46. Model fit to the total (discard plus retained) male new shell size frequency data. Solid line is the model fit. Circles are observed data. Year is the survey year.

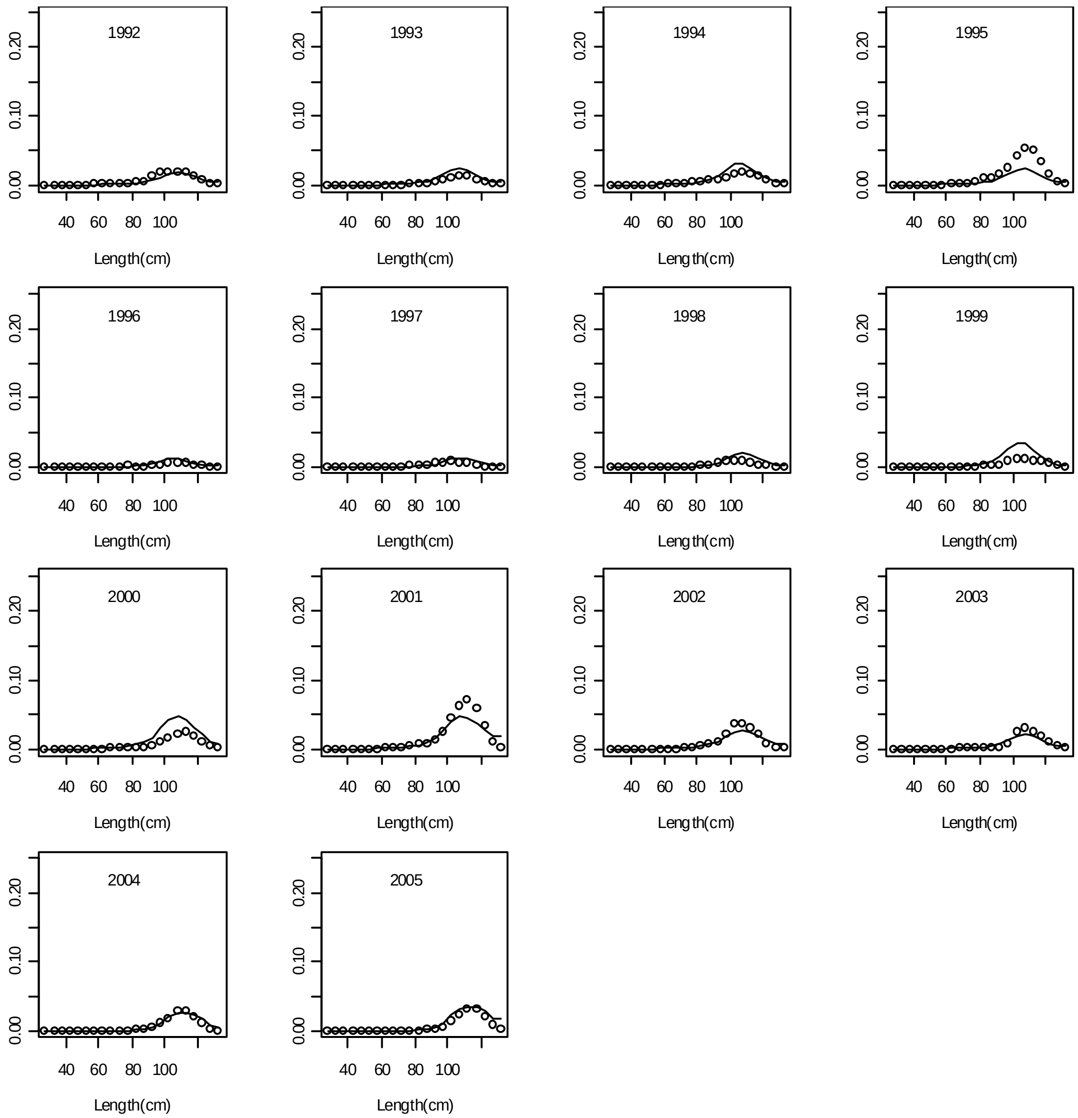

Figure 47. Model fit to the total (discard plus retained) male old shell size frequency data. Solid line is the model fit. Circles are observed data. Year is the survey year.

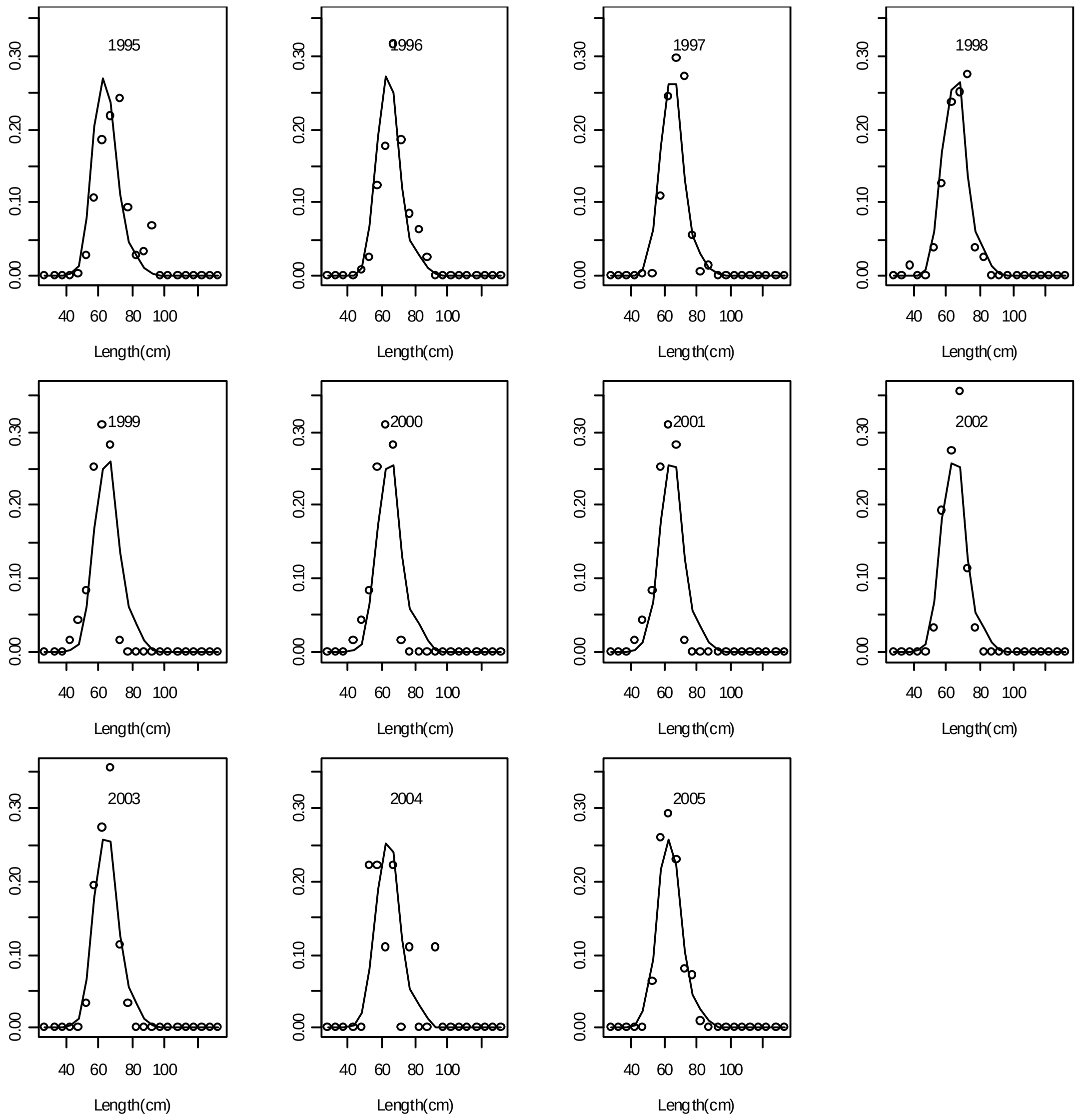

Figure 48. Model fit to the discard female size frequency data. Solid line is the model fit. Circles are observed data. Year is the survey year.

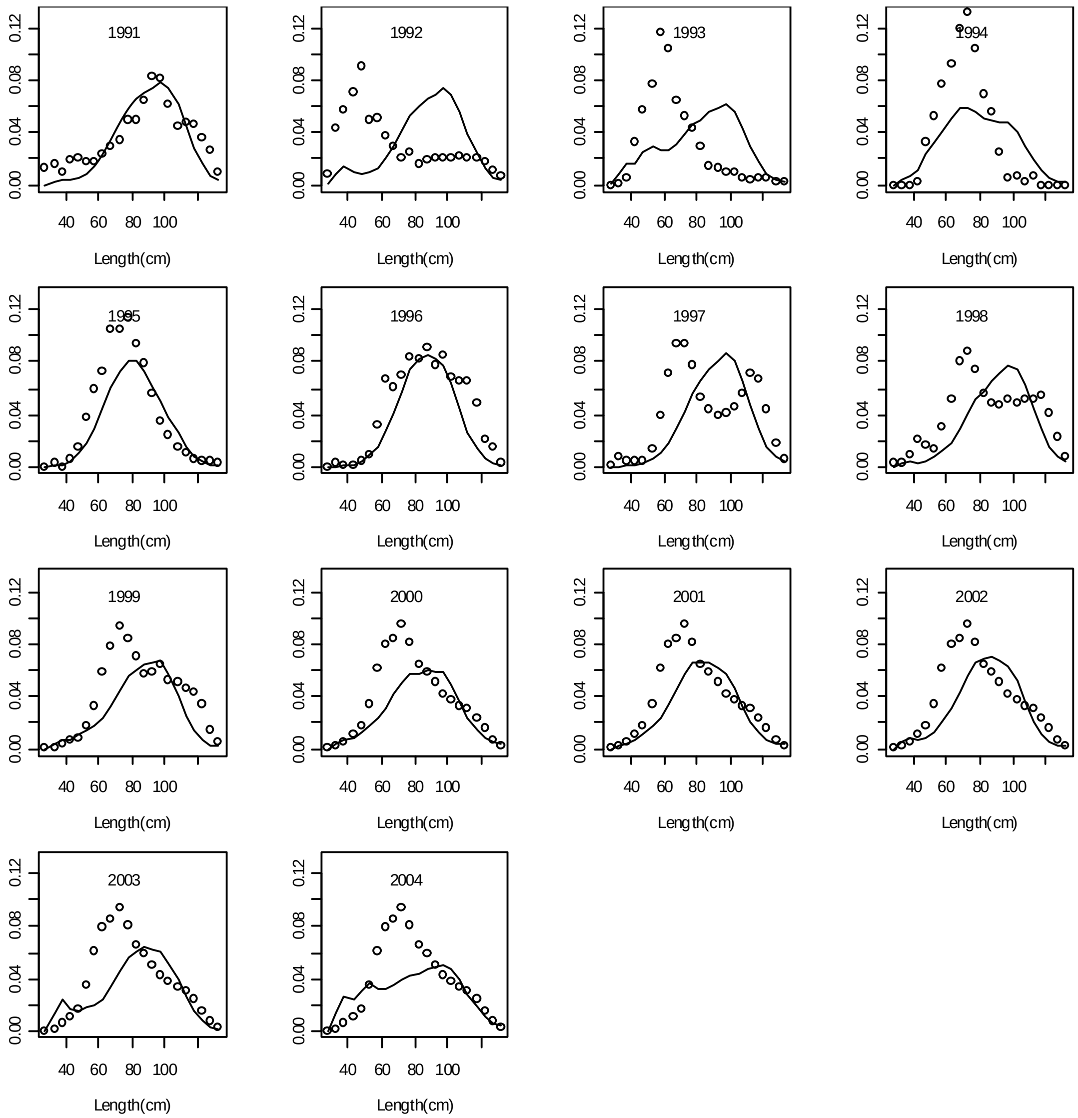

Figure 49. Model fit to the groundfish trawl discard male size frequency data. Solid line is the model fit. Circles are observed data. Year is the survey year.

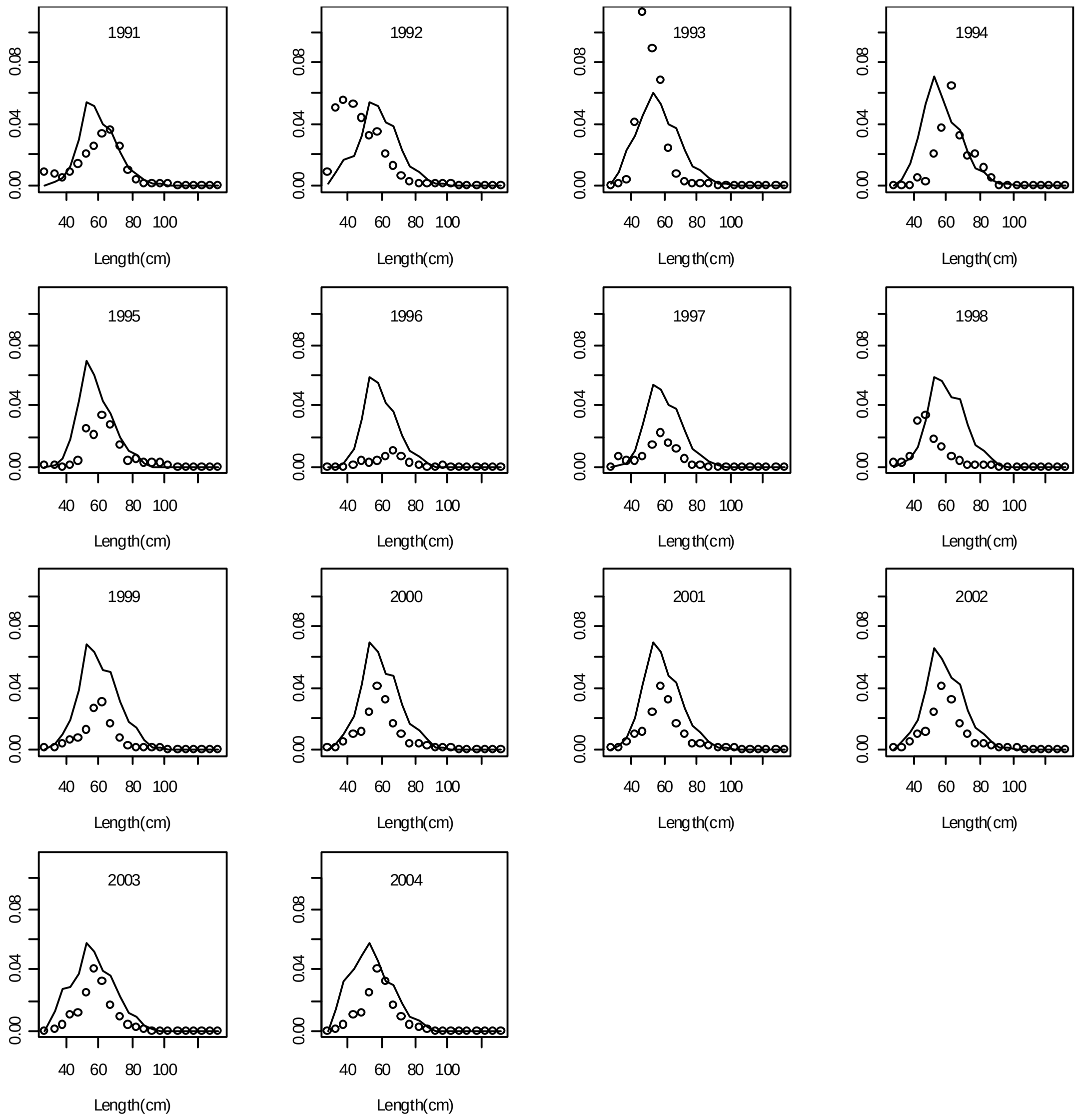

Figure 50. Model fit to the groundfish trawl discard female size frequency data. Solid line is the model fit. Circles are observed data.

Figure 51. Full selection fishing mortality estimated in the model from 1979 to 2006 fishery seasons.

Figure 52. Fit to pot fishery cpue for retained males. Solid line is observed fishery cpue, dotted line model fit.

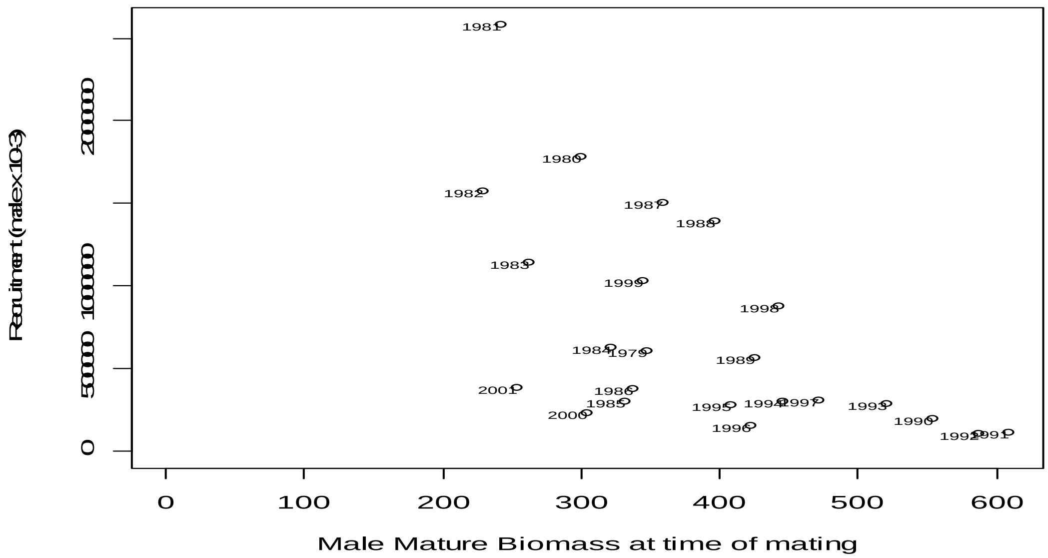

Figure 53. Spawner-recruit estimates using male mature biomass at time of mating. Recruitment is half total recruits x 10-3.

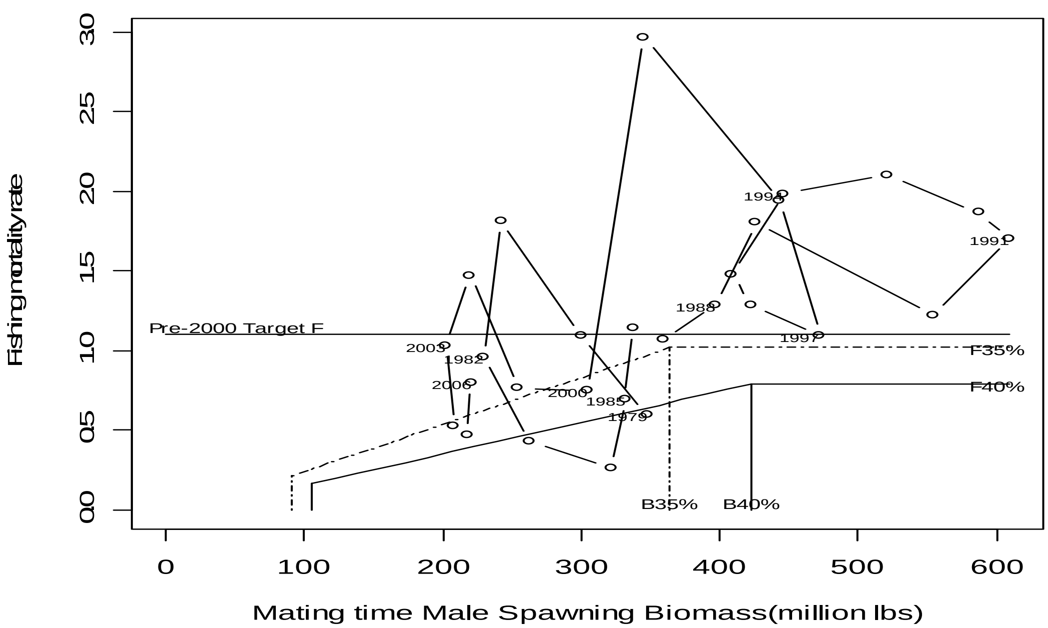

Figure 54. Harvest control rules. Two control rules are shown, one for F40% and one for F35% with alpha = 0.05. The pre-2000 target F of about 1.1 was the target F that resulted from the harvest strategy used before the 2000 fishery season. Vertical lines labeled B40% and B35% are estimated from the product of spawning biomass per recruit fishing at F40% or F35% respectively and mean recruitment from the stock assessment model.

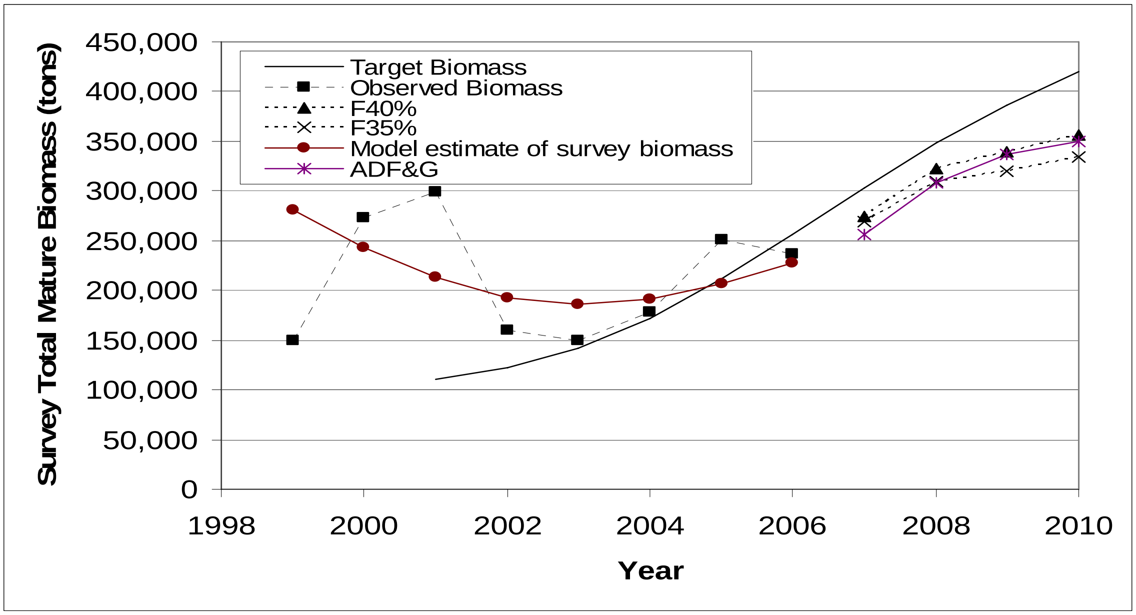

Figure 55. Target survey total mature biomass by year from rebuilding plan simulations, observed survey total mature biomass and model estimates of survey total mature biomass for the current ADF&G harvest strategy, F40% and F35% harvest strategies. 2010 is 10 years from the start of the rebuilding plan

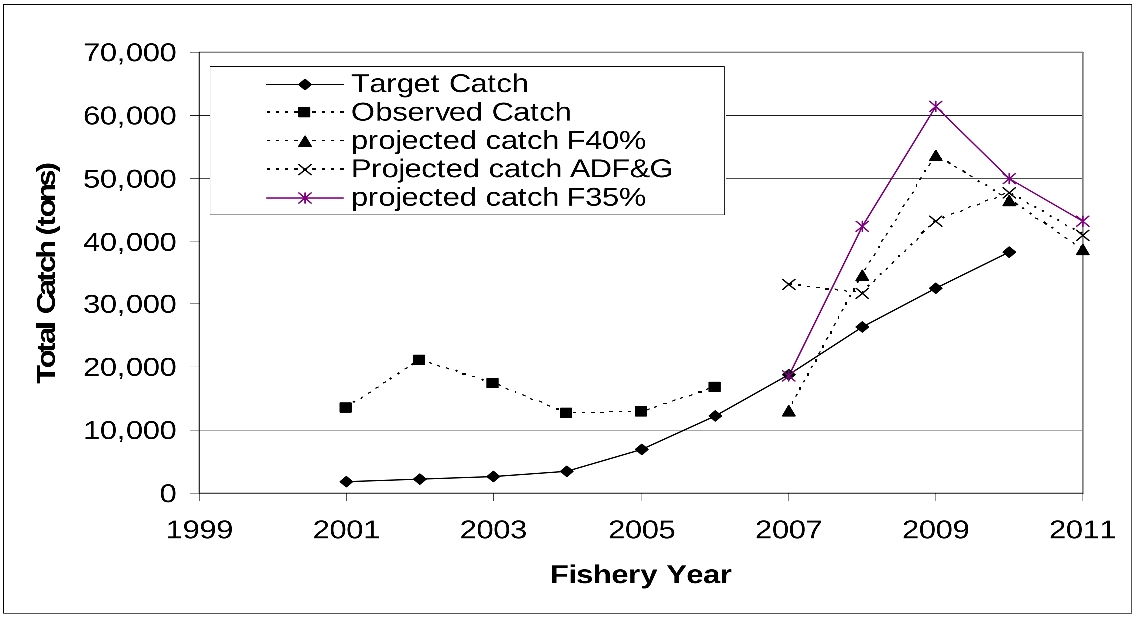

Figure 56. Target average total catch(discard plus retained)by year from rebuilding plan simulations, observed total catch for 2001 to 2006, and projected total catch for 2006 to 2010 using the current ADF&G harvest strategy, F40% and F35% harvest strategies.

Table A.1. Model equations describing the population dynamics.

$N_{s,t,1} = pr_l \, R_{0,s} e^{\tau_{s,t}}$	$\tau_{s,t} \sim N(0,\sigma_R^2$	Recruitment
TOTAL POT CATCH $C_{t,totalpotfishery,s,sh,l} = \sum_{mature,immature} \frac{F_{s,totalpotfishery,mat,sh,t,l}}{F_{s,mat,sh,t,l}} (1-e^{-F_{s,mat,sh,t,l}}) e^{-M_{s,mat,sh} Cmid_t} N_{s,mat,sh,t,l}$ RETAINED POT CATCH $C_{t,retainedfishery,s,sh,l} = \sum_{mature,immature} \frac{F_{s,retainedfishery,mat,sh,t}}{F_{s,mat,sh,t,l}} (1-e^{-F_{s,mat,sh,t,l}}) e^{-M_{s,mat,sh} Cmid_t} N_{s,mat,sh,t,l}$ TRAWL BYCATCH $C_{t,trawlfishery,s,sh,l} = \sum_{mature,immature} \frac{F_{s,ftrawlishery,mat,sh,t,l}}{F_{s,mat,sh,t,l}} (1-e^{-F_{s,mat,sh,t,l}}) e^{-M_{s,mat,sh} Cmid_t} N_{s,mat,sh,t,l}$	$1 \le t \le$ $1 \le l \le$	Catch taken as a pulse fishery at midpoint of catch (survey is considered start of the year).
$Nimmature_{new,t+1,s,l+1} =$ $(Nimmature_{new,t,s,l} e^{-Zimmat_{new,t,s,l}}) Gr_{s,l} (1-\phi_{s,l})$ $Nmature_{new,t+1,s,l+1} =$ $(Nimmature_{new,t,s,l} e^{-Zimmat_{new,t,s,l}}) Gr_{s,l} (\phi_{s,l})$ $Nmature_{old,t+1,s,l+1} =$ $(Nmature_{new,t,s,l} e^{-Zmat_{new,t,s,l}}) + (Nmature_{old,t,s,l} e^{-Zmat_{old,t,s,l}})$	$1 \le t <$ $1 \le l \le$	Numbers at size
$SB_{t,s} = \sum_{l=1}^{L} w_{s,l} (Nmature_{new,t,s,l} + Nmature_{old,t,s,l})$		spawning biomass by sex
$Z_{t,s,sh,l} = \sum_{fishery} F_{t,fishery,s,sh,l} + M$		Total Mortality
$C_{t,fishery} = \sum_{s} \sum_{sh} \sum_{l} C_{t,fishery,s,sh,l}$		Total Catch in numbers
$p_{t,sh,l} = C_{t,sh,l} / C_t$		proportion at size in the catch
$Y_t = \sum_{l=1}^{L} w_{t,l} C_{t,l}$		Catch biomass
$F_{t,fishery,s,sh,l} = s_{t,s,sh,l} F_{t,fishery}$		Fishing mortality

Table A.1. continued.

$F_{t,s,sh,l} = \sum_{fishery} F_{t,fishery,s,sh.l}$		Total F over all fisheries (total pot and trawl fisheries)
$S_{t,s,sh,l} = \frac{1}{1+e^{-a_{s,sh}(l-b_{t,s,sh})}}$		Fishery selectivity for total catch sex or shell condition s and size bin l. The 50% parameter changes over time.
$S_{male,t,sh,l} = \frac{1}{1+e^{-a_{male,sh}(l-b_{t,male,sh})}} \frac{1}{1+e^{-c_{sh}(l-d_{sh})}}$		Fishery selectivity for male retained catch by shell condition sh and size bin l is the selectivity for total catch multiplied by the retention curve
$S_{surv,l} = q \frac{1}{1+e^{-a_{surv}(l-b_{surv})}}$		Survey selectivity by size – same for males and females
$S_{trawl,s,l} = \frac{1}{1+e^{-a_{s,trawl}(l-b_{s,trawl})}}$		Trawl bycatch selectivity by size and sex
$SB_{s,t} = \sum_{s} \sum_{l=1}^{L} w_{s,l} s_{surv,l} N_{s,t,l}$		Total Survey biomass
$Gr_{s,l \to l'} = \int_{l'-2.5}^{l'+2.5} Gamma(\alpha_{s,l}, \beta_s)$		Growth transition matrix using a Gamma distribution
$width_{t+1} = a_s + b_s width_t$		Mean post-molt width given pre- molt width

Table A.2. Negative log likelihood components.

$\lambda \sum_{t=1}^{T} \left[\log(C_{t,fishery,obs}) - \log(C_{t,fishery.pred}) \right]^2$	Catch using a lognormal distribution.
$-\sum_{t=1}^{T} \sum_{l=1}^{L} nsamp_t * p_{obs,t,l} \log(p_{pred,t,l})$ - offset	size compositions using a multinomial distribution. Nsamp is the observed sample size. Offset is a constant term based on the multinomial distribution.
offset = $\sum_{t=1}^{T} \sum_{a=1}^{A} nsamp_t * p_{obs,t,a} \log(p_{obs,t,a})$	the offset constant is calculated from the observed proportions and the sample sizes.
$\sum_{t=1}^{ts} \left[\frac{\log\left[\frac{SB_{obs,t}}{SB_{pred,t}}\right]}{sqrt(2) * s.d.(\log(SB_{obs,t}))} \right]^2$	Survey biomass using a lognormal distribution, ts is the number of years of surveys.
$s.d.(\log(SB_{obs,t})) = sqrt(\log((cv(SB_{obs,t}))^2 + 1))$	
$\lambda \sum_{s=1}^{2} \sum_{t=1}^{T} (e^{\tau_{s,t}})^2$	Recruitment, where $\tau_{s,t} \sim N(0, \sigma_R^2)$
$\lambda \sum_{t} \left[\log(\frac{R_{male,t}}{R_{female,t}}) \right]^2$	Sex ratio penalty
$\lambda \sum_{t=1}^{t=T-1} \left[\log(s_{50\%,sh,t+1}) - \log(s_{50\%,sh,t}) \right]^2$	Constraint on size at 50% for fishery selectivity

Table A.3. List of variables and their definitions used in the model.

Variable	Definition
T	number of years in the model (t=1 is 1978 and t=T is 2006
L	number of size classes (L =22)
W_l	mean body weight(kg) of crabs in size group l.
ϕ_l	proportion mature at size l.
R_t	Recruitment in year t
R_0	Geometric mean value of recruitment
τ_t	Recruitment deviation in year t
$N_{l,a}$	number of fish in size group l in year t
pr_l	Fraction of annual recruitment (Rt) distributed to length bin l
$C_{t,l}$	catch number of size group l in year t
$p_{t,l}$	proportion of the total catch in year t that is in size group l
C_t	Total catch in year t
Y_t	total yield in year t
$F_{t,s,sh,l}$	Instantaneous fishing mortality rate for size group l, sex s, shell condition sh, in year t
M	Instantaneous natural mortality rate
E_t	average fishing mortality in year t
ε_t	Deviations in fishing mortality rate in year t
$Z_{t,l}$	Instantaneous total mortality for size group l in year t
GR	Growth transition matrix
$S_{s,l}$	selectivity for size group l, sex or shell condition s.

Table A.4. Estimated parameters for the model.

Parameter	Description
$\log(R_0)$	log of the geometric mean value of recruitment, one parameter
τ_t $1978 \le t \le 2006$, 29 parameters	Recruitment deviation in year t
Initial numbers by length for each sex and shell condition, 88 parameters.	Initial numbers by length
$\log(f_0)$	log of the geometric mean value of fishing mortality
ε_t $1978 \le t \le 2006$, 29 parameters, one set for retained catch, one set for female discard, and one set for trawl bycatch equals 97 total.	deviations in fishing mortality rate in year t
Slope and 50% selected parameters of the logistic curve	selectivity parameters for the total catch (retained plus discard) of new and old shell males.
Slope and 50% selected parameters of the logistic curve (2 parameters new shell, 2 parameters old shell)	Retention curve parameters for the retained males.
Slope and 50% selected parameters of the logistic curve (6 parameters)	Selectivity parameters for survey male and female crabs for three survey periods (1978-81, 82-88, 89-present).
Slope and 50% selected parameters of the logistic curve (2 parameters male, 2 parameters female)	Selectivity parameters for trawl bycatch male and female
Slope and 50% selected parameters of the logistic curve(2 parameters)	Selectivity parameters for crab fishery female bycatch
M	Natural mortality
Q = 1.0 for 1982 to present surveys	Survey catchability
Parameters for the linear growth function, intercept a and slope b (2 parameters male, 2 parameters female). Standard deviation of size at the first size bin and standard deviation of size for the last size bin.	Growth parameters estimated from Bering sea snow crab data (14 observations).

Draft

Bristol Bay Red King Crab Stock Assessment In 2006

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EXECUTIVE SUMMARY

Two length-based models were applied to eastern Bering Sea trawl survey, catch sampling, and commercial catch data to estimate stock abundance of Bristol Bay red king crabs (*Paralithodes camtschaticus*) during 1972-2006. Model A is the current stock assessment model, which assumes the trawl survey selectivities/catchability to be 1 for mature crabs and estimates natural mortality. The model was modified this year to include discarded bycatch. Two scenarios with different levels of natural mortality were compared for Model A: the base scenario with 3 levels of male natural mortality and 4 levels of female natural mortality over time and an alternative scenario with 2 levels of male and female natural mortality over time. Model B is a research model, which assumes a constant natural mortality (0.18) and estimates trawl survey selectivities. The number of estimated parameters for Model A is several times less than that for Model B. The base model fit the data very well, and its results were used to construct stock–recruitment relationships and determine the preseason total allowable catch (TAC).

Due to above average year classes 1990, 1994 and 1997, abundances of mature males, legal males, and mature females all increased in 2006 from 2005 and are at the highest levels since 1982. Abundance of mature males increased from 16.2 million in 2005 to 17.4 million in 2006, and legal male abundance increased from 9.5 million in 2005 to 10.5 million in 2006. Mature female abundance increased from 37.8 million in 2005 to 40.5 million crabs in 2006, and effective spawning biomass increased from 61.4 to 67.2 million pounds from 2005 to 2006, above the target rebuilding level of 55 million pounds.

INTRODUCTION

Stock Structure

Red king crabs (RKC), *Paralithodes camtschaticus*, are found in several areas of the Aleutian Islands and eastern Bering Sea. The State of Alaska divides the Aleutian Islands and eastern Bering Sea into three management registration areas to manage RKC fisheries: Aleutian Islands, Bristol Bay, and Bering Sea (ADF&G 2005). The Aleutian Islands area covers two stocks, Adak and Dutch Harbor, and the Bering Sea area contains two other stocks, the Pribilof Islands and Norton Sound. The largest stock is found in the Bristol Bay Area, which includes all waters north of the latitude of

Cape Sarichef (54°36' N lat.), east of 168° W long., and south of the latitude of Cape Newneham (58°39' N lat.) (ADF&G 2005). Besides these five stocks, RKC stocks elsewhere in the Aleutian Islands and eastern Bering Sea are currently too small to support a commercial fishery. This report summarizes the stock assessment results for the Bristol Bay RKC stock.

Fishery

The RKC stock in Bristol Bay, Alaska, supports one of the most valuable fisheries in the United States (Bowers et al. 2005). The Japanese fleet started the fishery in the early 1930s, stopped fishing from 1940 to 1952, and resumed the fishery from 1953 until 1974 (Bowers et al. 2005). The Russian fleet fished for RKC from 1959 through 1971. The Japanese fleet employed primarily tanglenets with a very small proportion of catch caught by trawl and pots. The Russian fleet used only tanglenets. U.S. trawlers started to fish for Bristol Bay RKC in 1947, and effort and catch declined in the 1950s (Bowers et al. 2005). The domestic RKC fishery began to expand in the late 1960s and peaked in 1980 with a catch of 59,000 t, worth an estimated $115.3 million ex-vessel value (Bowers et al. 2005). The catch declined dramatically in the early 1980s and has stayed at low levels during the last two decades (Table 1). After the stock collapse in the early 1980s, the Bristol Bay RKC fishery took place during a short period in the fall (usually lasting about a week), and the catch quota is based on the stock assessment conducted in the previous summer (Zheng and Kruse 2002a). As a result of new regulations for crab rationalization, the fishery was longer beginning with the 2005/2006 season, which was open for three months from October 15, 2005 to January 15, 2006. With the implementation of crab rationalization, historical guideline harvest levels (GHL) were changed to a total allowable catch (TAC). GHL/TAC and actual catch are compared in Table 2. The implementation errors are quite high for some years, and total actual catch from 1980 to 2005 is about 7% less than the GHL/TAC (Table 2).

Fisheries Management

King and Tanner crab stocks in the Bering Sea and Aleutian Islands are managed by the State of Alaska through a federal king and Tanner crab fishery management plan (FMP). Under the FMP, management measures are divided into three categories: (1) fixed in the FMP, (2) frameworked in the FMP, and (3) discretion of the State of Alaska. The State of Alaska is responsible for developing harvest strategies to determine GHL/TAC under the framework in the FMP.

Harvest strategies for the Bristol Bay RKC fishery have changed over time. Two major management objectives for the fishery are to maintain a healthy stock that ensures reproductive viability and to provide for sustained levels of harvest over the long term (ADF&G 2005). In attempting to meet these objectives, the GHL/TAC are coupled with size-sex-season restrictions. Only males ≥6.5-in carapace width (equivalent to 135-mm carapace length, CL) may be harvested and no fishing is allowed during molting and mating periods (ADF&G 2005). Specification of TAC is based on a harvest rate strategy. Before 1990, harvest rates on legal males were based on population size, abundance of prerecruits to the fishery, and postrecruit abundance, and varied from less than 20% to 60% (Schmidt and Pengilly 1990). In 1990, the harvest strategy was modified, and a 20% mature male harvest rate was applied to the abundance of mature-sized (≥120-mm CL) males with a maximum 60% harvest rate cap of legal (≥135-mm CL) males (Pengilly and Schmidt 1995). In addition, a threshold of 8.4 million mature-sized females (≥90-mm CL) was added to existing management measures to avoid recruitment overfishing (Pengilly and Schmidt 1995). Based on a new assessment model and research findings (Zheng et al. 1995a, 1995b, 1997a, 1997b), the Alaska Board of Fisheries adopted a new harvest strategy in 1996. That strategy had two mature male harvest rates: 10% when effective spawning biomass (ESB) is between 14.5 and 55 million pounds and 15% when ESB is at or above 55 million pounds (Zheng el al. 1996). The maximum harvest rate cap of legal males was changed from 60% to 50%. An additional threshold of 14.5 million pounds of ESB was also added. In 1997, a minimum threshold of 4 million pounds was established as the minimum GHL for opening the fishery and maintaining fishery manageability when the stock abundance is low. In 2003, the Board modified the current harvest strategy by adding a mature harvest rate of 12.5% when the stock is between 34.75 and 55 million pounds of ESB. The current harvest strategy is illustrated in Figure 1.

The purpose of this report is to document the stock assessments for Bristol Bay RKC. This report includes (1) all data used to conduct the stock assessments, (2) details of the analytic approach, (3) an evaluation of the assessment results, and (4) the future outlook.

DATA

Catch Data

Landings of Bristol Bay RKC by length and year and catch per unit effort data were obtained from annual reports of the International North Pacific Fisheries Commission from 1960 to 1973 (Hoopes et al. 1972; Jackson 1974; Phinney 1975) and from the Alaska Department of Fish and Game from 1974 to 2005 (Bowers et al. 2005). Bycatch data are available starting from 1990 and were obtained from the ADF&G observer database and reports (Bowers et al. 2005; Burt and Barnard 2006). Sample sizes for catch by length and shell condition are summarized in Table 3. Relatively large samples were taken from the retained catch each year. Sample sizes for trawl bycatch were the annual sums of length frequency samples in the National Marine Fisheries Service (NMFS) database.

Catch Biomass

Retained catch and estimated bycatch biomasses are summarized in Table 1. Retained catch and estimated bycatch from the directed fishery include both the general open access (i.e., harvest not allocated to CDQ groups) fishery and the CDQ fishery. Starting in 1973, the fishery generally occurred during the late summer and fall. Before 1973, a small portion of retained catch in some years was caught from April to June. Because most crab bycatch from the groundfish trawl fisheries occurred during the spring, the years in Table 1 are one year less than those from the NMFS trawl bycatch database to approximate the annual bycatch for seasons defined as June 1 to May 31; e.g., year 2002 in Table 1 corresponds to what is reported for year 2003 in the NMFS database. Catch biomass is shown in Figure 2.

Catch Size Composition

Retained catch by length and shell condition and bycatch by length, shell condition, and sex were obtained for stock assessments. From 1960 to 1966, only retained catch length compositions from the Japanese fishery were available. Retained catches from the Russian and U.S. fisheries were assumed to have the same length compositions as the Japanese fishery during this period. From 1967 to 1969, the length compositions from the Russian fishery were assumed to be the same as those from the Japanese and U.S. fisheries. After 1969, foreign catch declined sharply and only length compositions from the U.S. fishery were used to distribute catch by length.

Catch per Unit Effort

Catch per unit effort (CPUE) is defined as number of retained crabs per tan (a unit fishing effort for tanglenets) for the Japanese and Russian fisheries and number of retained crabs per potlift for the U.S. fishery (Table 4). Although soak time is an important factor influencing CPUE, it is difficult to standardize it. Furthermore, complete historical soak time data from the U.S. fishery are not available. Based on the approach of Balsiger (1974), all fishing efforts from Japan, Russia, and U.S. were standardized as the Japanese tanglenet from 1960 to 1971, and the CPUE was standardized as crabs per tan. The U.S. CPUE data have similar trends as survey legal abundance after 1971 (Figure 3).

Survey Data

NMFS has performed annual trawl surveys of the eastern Bering Sea since 1968. Two vessels, each equipped with an eastern otter trawl with an 83 ft headrope and a 112 ft footrope, conduct this multispecies, crab-groundfish survey during the summer. Stations are sampled in the center of a systematic 20 X 20 nm grid overlaid in an area of ≈140,000 nm^2. Since 1972 the trawl survey has covered the full stock distribution. The survey on Bristol Bay area occurs primarily during late May and June. Tow-by-tow trawl survey data for Bristol Bay RKC during 1975-2006 were provided by NMFS.

Abundance estimates by sex, carapace length, and shell condition were derived from survey data using an area-swept approach without post-stratification (Figure 4). If multiple tows were made for a single station in a given year, the average of the abundances from all tows was used as the estimate of abundance for that station. NMFS used a post-stratification approach until the late 1980s and has assumed Bristol Bay as a single stratum since then. If more than one tow is conducted in a station because of high RKC abundance (i.e., the station is a “hot spot”), NMFS regards the station as a separate stratum. Due to poor documentation, it is difficult to duplicate NMFS post-stratifications. A “hot spot” was not surveyed with multiple tows during the early years. Two such “hot spots” affected the survey abundance estimates greatly: station H13 in 1984 (mostly juvenile crabs 75-90 mm CL) and station F06 in 1991 (mostly newshell legal males). The tow at station F06 was discarded in the NMFS abundance estimates (Stevens et al. 1991). In this study, the average abundances from all tows in the 9 stations (the station itself and the 8 adjacent stations) were used as the estimates of abundance for station H13 in 1984 and station F06 in 1991.

The approach here results in estimates close to those made by NMFS with some exceptions (Figure 5). Two surveys were conducted for Bristol Bay red king crabs in 1999, 2000 and 2006: the standard survey that was performed in late May and early June (about two weeks earlier than historic surveys) in 1999 and 2000 and the standard survey that was performed in early June in 2006 and a resurvey of 31 stations (1999), 23 stations (2000) and 31 stations (2006, 1 bad tow and 30 valid tows) with high female density that was performed in late July, about six weeks after the standard survey. The resurveys were necessary because most females had not yet molted or mated prior to the standard surveys (Figure 6). Tow-by-tow estimates of survey abundance for the 30 valid resurvey stations in 2006 are summarized in Table 5. Differences in area-swept estimates of abundance between the standard surveys and resurveys of these same stations can be attributed to survey measurement errors or, possibly, to seasonal changes in distribution between survey and resurvey. The size distribution of females was significantly larger in the resurveys than during the standard surveys in 1999 and 2000 because most mature females had not molted prior to the standard surveys. Area-swept estimates of males >89 mm CL, mature males and legal males within the 30 resurvey stations in 2006 are not statistically significantly different between the standard survey and resurvey (p=0.96, 0.47 and 0.17) based on the t-test of paired two sample for means. However, area-swept estimates of mature females within the 30 resurvey stations in 2006 are significantly different between the standard survey and resurvey (p=0.04) based on the t-test. NMFS included all survey tows in its estimates in 1999 and 2000. To maximize use of the survey data, I used data from both surveys to assess male abundance but only the resurvey data, plus the standard survey data outside the resurveyed stations, to assess female abundance during these three years.

For 1968-1970 and 1972-1974, abundance estimates were obtained from NMFS directly because the original survey data by tow are not currently available. There were spring and fall surveys in 1968 and 1969. The average of estimated abundances from spring and fall surveys was used for those two years. Different catchabilities were assumed for survey data before 1973 because of an apparent change in survey catchability. A footrope chain was added to the trawl gear starting in 1973, and the crab abundances in all length classes in 1973 and beyond were much greater than those estimated prior to 1973 (Reeves et al. 1977).

ANALYTIC APPROACH

To reduce annual measurement errors associated with abundance estimates derived from the area-swept method, the Alaska Department of Fish and Game developed a length-based analysis (LBA) in 1994 that incorporates multiple years of data and multiple data sources in the estimation procedure. Annual abundance estimates of the Bristol Bay RKC stock from the LBA have been used to manage the directed crab fishery and to set crab bycatch limits in the groundfish fisheries since 1995 (Figure 1). The current stock assessment model is named Model A in this report and is the base model used to set TAC. An alternative LBA (research model) was developed in 2004 to include small size groups and extend to the data before 1972. In this report, the research model was to fit to the data only from 1985 to 2006. This research model is named Model B in this report. A stock-recruitment (S-R) relationship, estimated from the results of the base model (Model A), was used to develop the current harvest strategy.

Models and Scenarios

Two models: stock assessment model (Model A) used since 1995 and research model (Model B) developed in 2004 are reported. Two scenarios were run for model A; the results for each scenario and model were compared:

Model A(1): 4 levels of *M* for females and 3 levels of *M* for males over time,
Model A(2): 2 levels of *M* for both males and females over time, and
Model B: research model, a constant *M* and constant length-specific molting probabilities over time.

The results from scenario Model A(1) have been used for management during the last 12 years and are referred as the base scenario in this report.

Population Model

The original LBA model that was described in detail by Zheng et al. (1995a, 1995b) and Zheng and Kruse (2002a) was modified to include fishery discarded bycatch this year. Pulse fishing was assumed for the model. Male crab abundances by carapace length and shell condition in any one year are modeled to result from abundances in the previous year minus catch and handling and natural mortalities, plus recruitment and additions to or losses from each length class due to growth:

$$N_{l+1,t+1} = \sum_{l'=1}^{l'=l+1} \{P_{l',l+1}\,[(N_{l',t} + O_{l',t})\,e^{-M_t} - (C_{l',t} + D_{l,t})\,e^{(y_t-1)M_t}]\,m_{l',t}\} + R_{l+1,t+1}\,, \qquad (1)$$

$$O_{l+1,t+1} = [(N_{l+1,t} + O_{l+1,t})\,e^{-M_t} - (C_{l+1,t} + D_{l+1,t})\,e^{(y_t-1)M_t}]\,(1 - m_{l+1,t}),$$

where

- $N_{l,t}$ is newshell crab abundance in length class *l* and year *t*,
- $O_{l,t}$ is oldshell crab abundances in length class *l* and year *t*,
- M_t is the instantaneous natural mortality in year *t*,
- $m_{l,t}$ is the molting probability for length class *l* in year *t*,
- $R_{l,t}$ is recruitment into length class *l* in year *t*,
- y_t is the lag in years between assessment survey and the fishery in year *t*,
- $P_{l',l}$ is the proportion of molting crabs growing from length class *l'* to *l* after one molt,
- $C_{l,t}$ is the retained catch of length class *l* in year *t*, and
- $D_{l,t}$ is the discarded mortality catch of length class *l* in year *t*, including pot and trawl bycatch.

The minimum carapace length for males is set at 95 mm for Model A and 65 mm for Model B, and crab abundance is modeled with a length-class interval of 5 mm. The last length class includes all crabs ≥160-mm CL. There are 14 length classes/groups (1-14) for Model A and 20 length classes/groups for Model B. $P_{l',l}$, $m_{l,t}$, $R_{l,t}$, $C_{l,t}$, and $D_{l,t}$ are computed as follows.

Mean growth increment per molt is assumed to be a linear function of pre-molt length:

$$G_l = a + b\,\iota, \qquad (2)$$

where *a* and *b* are constants. Growth increment per molt is assumed to follow a gamma distribution:

$$g(x \mid \alpha_l, \beta) = x^{\alpha_l - 1}\ e^{-x/\beta} / [\beta^{\alpha_l}\ \Gamma(\alpha_l)]. \qquad (3)$$

The expected proportion of molting individuals growing from length class l_1 to length class l_2 after one molt is equal to the sum of probabilities within length range [ι_1, ι_2) of the receiving length class l_2 at the beginning of the next year:

$$P_{l_1,l_2} = \int_{\iota_1-\iota}^{\iota_2-\iota} g(x \mid \alpha_l, \beta)dx, \qquad (4)$$

where ι is the mid-length of length class l_1. For the last length class L, $P_{L,L}$ = 1.

The molting probability for a given length class *l* and time *t* is modeled by an inverse logistic function:

$$m_{l,t} = 1 - \frac{1}{1 + e^{-\beta_t (l - L_{50_t})}}, \qquad (5)$$

where

β_t, L_{50t} are parameters, and
ι is the mid-length of length class *l*.

Three logistic functions were used to describe the molting probability during different periods for Model A (Zheng et al. 1995a): high molting probabilities with α_1 and β_1 during 1972-1979, low molting probabilities with α_2 and β_2 during 1980-1984, 1992-1995, 1997, and 1999-2001, and intermediate molting probabilities with α_3 and β_3 during 1985-1991, 1996, 1998, and 2002-2006. Grouping of years for molting probabilities is based on the fit of newshell and oldshell crab abundances. Constant length-specific molting probabilities were assumed for Model B from 1985 to 2006.

Recruitment is defined as recruitment to the model and survey gear rather than recruitment to the fishery. Recruitment is separated into a time-dependent variable, R_t, and size-dependent variables, U_l, representing the proportion of recruits belonging to each length class. R_t was assumed to consist of crabs at the recruiting age with different lengths and thus represents year class strength for year *t*. $R_{l,t}$ is computed as

$$R_{l,t} = R_t U_l, \qquad (6)$$

where U_l is described by a gamma distribution similar to equations (3) and (4) with a set of parameters α_r and β_r.

Model A assumes observed retained catch and discarded mortality bycatch to be accurate. Before 1990, no observed bycatch data were available in the directed pot fishery; the crabs that were discarded and died in those years were estimated as the product of handling mortality rate, legal harvest rates, and mean length-specific selectivities. Mean length-specific fishery selectivities for retained males, discarded males and discarded females in the pot fishery were estimated by dividing the catch and bycatch by length by their corresponding estimated abundances and averaging over time. For Model B, all fishery catch and discarded mortality bycatch were estimated as:

$$C_{l,t} \; or \; D_{l,t} = (N_{l,t} + O_{l,t})\, e^{-y_t M_t} (1 - e^{-s_{l,t} F_t}) \qquad (7)$$

where

$s_{l,t}$ is selectivity for retained, pot or trawl discarded mortality catch of length class *l* in year *t*, and

F_t is full fishing mortality of retained, pot or trawl discarded mortality catch in year *t*.

The female crab model is the same as the male crab model except that the retained catch equals zero and molting probability equals 1.0 to reflect annual molting (Powell 1967). The minimum carapace length is set at 90 mm for females for Model A and 65 mm for Model B, and the last length class includes all crab ≥140-mm CL, corresponding to length groups 1-11 with 5 mm length intervals for Model A and to length groups 1-16 for Model B.

Fisheries Selectivities for Model B

Retained selectivity, pot female bycatch selectivity, and both male and female trawl bycatch selectivity are estimated as a function of length with annual lengths at 50% selectivity following a random walk process:

$$s_{l,t} = \frac{1}{1 + e^{-\beta\,(\iota - L_{50,t})}},$$
$$L_{50,t} = \overline{L}_{50} e^{\delta_t}, \quad \delta_t - \delta_{t+1} \sim N(0, \sigma_\delta^2) \qquad (8)$$

Different sets of parameters (β, $L_{50,t}$) are estimated for retained males, pot female bycatch, and trawl male and female bycatch.

Pot male bycatch selectivity is modeled by two linear functions:

$$s_l = \varphi + \kappa\iota, \quad if \; \iota < 135\,\text{mm CL},$$
$$s_l = s_{l-1} - 5\gamma, \quad if \; \iota > 134\,\text{mm CL} \qquad (9)$$

Where

φ, κ, γ are parameters.

In the 2005 pot fishery, a portion of legal males were also discarded. The selectivity for this highgrading was estimated to be the retained selectivity in 2005 times a highgrading parameter, *hg*.

Trawl Survey Selectivities/Catchability

Trawl survey selectivities/catchability were fixed at 1 for Model A. For Model B, survey selectivities/catchability were estimated as

$$s_l = \frac{A}{1 + e^{-\beta\ (l - L_{50})}}, \qquad (11)$$

Different sets of parameters (β, L_{50}) are estimated for males and females. Survey selectivity for the first length group (67.5 mm) was assumed to be the same for both males and females, so only three parameters (β, L_{50} for females and L_{50} for males) were estimated in the model. Parameter *A* is set to be 0.774 for females and 0.896 for males based on a trawl experiment Weinberg et al. (2004, Figure 7).

Natural Mortality

Four levels of *M* for females and three levels of *M* for males were estimated for Model A(1) over time. Two levels of *M* were estimated separately for males and females for Model A(2). Based on an assumed maximum age of 25 years and 1% rule, *M* was estimated to be 0.18 for both males and females for Model B.

Parameters Estimated Independently

Length-weight relationships and mean growth increments per molt were estimated independently outside of the model. Mean length of recruits to the model depends on growth and was assumed to be 95 mm for females and 102 mm for males for Model A and 72.5 for both males and females for Model B.

Length-weight Relationship

Length-weight relationships for males and females were as follows:

Immature Females: $W = 0.010271\ L^{2.388}$,
Ovigerous Females: $W = 0.02286\ L^{2.234}$, (10)
Males: $W = 0.000361\ L^{3.16}$,

where
W is weight in grams, and
L is CL in mm.

Growth Increment per Molt

A variety of data are available to estimate male mean growth increment per molt for Bristol Bay RKC. Tagging studies were conducted during the 1950s, the 1960s and the 1990s, and mean growth increment per molt data from these tagging studies in the 1950s and the 1960s were analyzed by Weber and Miyahara (1962) and Balsiger

(1974). Modal analyses were conducted for the data during 1957-1961 and the 1990s (Weber 1967; Loher et al. 2001). Mean growth increment per molt may be a function of body size and shell condition and vary over time (Balsiger 1974; McCaughran and Powell 1977); however, for simplicity, mean growth increment per molt was assumed to be only a function of body size in the models. Tagging data were used to estimate mean growth increment per molt as a function of pre-molt length for males (Figure 8). The results from modal analyses of 1957-1961 and the 1990s were used to estimate mean growth increment per molt for immature females, and the data presented in Gray (1963) were used to estimate those for mature females (Figure 8). To make a smooth transition of growth increment per molt from immature to mature females, weighted growth increment averages of 70% and 30% at 92.5 mm CL pre-molt length and 90% and 10% at 97.5 mm CL were used respectively, for mature and immature females. These percentages are roughly close to the composition of maturity. Once mature, the growth increment per molt for male crabs decreases slightly and annual molting probability decreases, whereas the growth increment for female crabs decreases dramatically but annual molting probability remains constant at 1.0 (Powell 1967).

Parameters Estimated Conditionally

For Model A, the following model parameters were estimated separately for male and female crabs: recruits for each year (year class strength R_t for t = 1973 to 2006), total abundance in the first year (1972), parameters β and β_r, and instantaneous natural mortality M_t (2 to 4 levels of M). Molting probability parameters α_1, α_2, α_3, β_1, β_2, and β_3 were also estimated for male crabs. Total number of parameters to be estimated is 87 for Model A(1) and 84 for Model A(2).

For Model B, the following model parameters were estimated for male and female crabs: total recruits for each year (year class strength R_t for t = 1985 to 2006), total abundance in the first year (1985), growth parameter β and recruitment parameter β_r for males and females separately. Molting probability parameters β and L_{50} were also estimated for male crabs. Estimated parameters also include β for retained selectivity, β for pot-discarded female selectivity, β for groundfish trawl discarded selectivity, φ, κ and γ for pot-discarded male selectivity, β and L_{50} for trawl survey selectivity, and *hg* for highgrading. Annual L_{50}s were estimated for retained selectivity (1985-1993, 1996-2005), pot-discarded female selectivity (1990-1993, 1996-2005), and groundfish trawl discarded male and female selectivity (1985-2005). Annual fishing mortalities were also estimated separately for retained males (1985-1993, 1996-2005), pot-discarded males (1990-1993, 1996-2005), pot-discarded females (1990-1993, 1996-2005), and groundifsh trawl discarded males and females (1985-2005). Total number of parameters to be estimated is 212. Many estimated parameters were constrained in the model. For example, male and female recruitment estimates were forced to be close to each other for a given year, and annual deviations on lengths at 50% selectivity were penalized in the model.

To increase the efficiency of the parameter-estimation algorithm, I assumed that the relative frequencies of length and shell classes from survey year 1972 for Model A and survey year 1985 for Model B approximate the true relative frequencies within sexes. Thus, only total abundances of males and females for the first year were estimated; 3n unknown parameters, where n is the number of length-classes, for the abundances in the first year were reduced to 2 under this assumption.

Parameter Estimation

For Model A, measurement errors were assumed to be log-normally distributed, and parameters of the model were estimated using a robust maximum likelihood approach:

$$Ln(L) = -\frac{0.5}{CV^2}\sum_{l,t}\{[\ln(N_{l,t}+\kappa) - \ln(\tilde{N}_{l,t}+\kappa)]^2 + [\ln(O_{l,t}+\kappa) - \ln(\tilde{O}_{l,t}+\kappa)]^2\}, \qquad (12)$$

where

$\tilde{N}_{l,t}, \tilde{O}_{l,t}$ are area-swept estimates of abundances of newshell and oldshell crabs in length class *l* and year *t* from trawl survey data, and

κ is a constant set equal to 0.1 millions of crabs (<0.7% and 0.3% of the largest observed male and female abundances by length).

Constant κ was used to prevent taking the logarithm of zero and to reduce the effect of length classes with zero or very low abundances on parameter estimation. A smaller κ gives a heavier weight for low abundances, and vice versa. This constant functions similar to the constant used in the robust likelihood function by Fournier et al. (1990).

Variance of population abundance can be estimated annually. However, because red king crabs are not uniformly distributed within Bristol Bay, variance estimates depend on how the survey data are stratified. For the stock assessment in 2006, CV is assumed to be 0.2 for all survey data.

For Model B, a Bayesian approach was used to estimate parameters. For length compositions ($p_{l,t,s,sh}$), the likelihood functions are :

$$Rf = \prod_{l=1}^{L}\prod_{t=1}^{T}\prod_{s=1}^{2}\prod_{sh=1}^{2}\frac{\left\{\exp\left[-\frac{(p_{l,t,s,sh}-\hat{p}_{l,t,s,sh})^2}{2\sigma^2}\right]+0.01\right\}}{\sqrt{2\pi\sigma^2}}, \qquad (13)$$

$$\sigma^2 = \left[\hat{p}_{l,t,s,sh}(1-\hat{p}_{l,t,s,sh})+0.1/L\right]/n,$$

where

L is the number of length groups,

T is the number of years, and

n is the effective sample size, which was assumed to be 500 for retained males, 200 for trawl survey and 100 for bycatch length composition data.

The weighted negative log-likelihood functions are:

$$\begin{array}{ll} \text{Length compositions:} & -\sum \ln(Rf_i) \\ \text{Biomasses:} & \lambda_j \sum \left[\ln(B_t / \hat{B}_t)^2 \right] \\ \text{Other components:} & R \text{ variation, } R \text{ sex ratio, annual } L_{50} \text{ variations} \end{array} \quad (14)$$

Weighted λ_j are assumed to be 800 for retained catch biomass, 300 for survey biomass, and 50 for all other biomasses, 2 for recruitment variation, 10 for recruitment sex ratio, and 0.1 for all annual changes in length of 50% selectivity. These λ_j values represent prior assumptions about the accuracy of the observed biomass data and about the variances of these random variables.

S-R MODELS

The results from Model A(1) (base scenario) were used to estimate the parameters of S-R models. I followed Zheng et al. (1995a) and Zheng and Kruse (2003) to estimate effective spawning biomass for Bristol Bay RKC. Male reproductive potential is defined as the mature male abundance by carapace length multiplied by the maximum number of females with which a male of a particular length can mate (Zheng et al. 1995a; Table 6). The maximum mating ratios (Table 6) used in this study are conservative and less than those observed in the laboratory studies (Powell and Nickerson 1965; Powell et al. 1974; Paul and Paul 1990, 1997). If mature female abundance was less than male reproductive potential, then mature female abundance was used as female spawning abundance. Otherwise, female spawning abundance was set equal to the male reproductive potential. The female spawning abundance was converted to biomass, defined as the effective spawning biomass SP_t. The S–R relationships of Bristol Bay RKC were modeled using a general Ricker curve:

$$R_t = SP_{t-k}^{r1} \, e^{r2 - r3 \, SP_{t-k} + v_t}, \quad (15)$$

and an autocorrelated Ricker curve:

$$R_t = SP_{t-k} \; e^{r2 - r3 \, SP_{t-k} + \upsilon_t}, \quad (16)$$

where

$\upsilon_t = \delta_t + a1 \, \upsilon_{t-1}$,

v_t, δ_t are environmental noises assumed to follow a normal distribution $N(0,\sigma^2)$,

$r1$, $r2$, $r3$, and $a1$ are constants.

Equation (15) was linearized as

$$\ln(R_t) = r2 + r1 \, \ln(SP_{t-k}) - r3 \; SP_{t-k} + v_t, \quad (17)$$

and equation (16) as

$$\ln(R_t / SP_{t-k}) = r2 - r3 \; SP_{t-k} + \upsilon_t. \quad (18)$$

An ordinary linear regression was applied to equation (17) to estimate model parameters *r*1*, r*2 and *r*3, and an autocorrelation regression (procedure AUTOREG, SAS Institute Inc. 1988) with a maximum likelihood method was used to estimate parameters *r*2*, r*3 and *a*1 for equation (18). A time lag of 8 years from mating to recruitment was used (Loher et al. 2001; Zheng and Kruse 2003).

To include the maximum range of available S–R data in the study of S–R relationships, I estimated the effective spawning biomass from 1968 to 1971 using survey abundance and the estimated survey catchability in 1972. The catchability for the survey gear in 1972 was estimated by comparing survey and model estimates. I assumed that the catchability for the survey gears in 1968-1971 was the same as in 1972 because the survey gears and methods were identical during these years (Reeves et al. 1977). Thus, the relative abundances from 1968 to 1971 were divided by the estimated catchability in 1972 to obtain the absolute abundances. The absolute abundances from 1968 to 2006 were used to construct S-R relationships.

Because of the regime shift in climate and physical oceanography that occurred in 1976–77 (Hare and Mantua 2000), it may not be realistic to expect the strong recruitment from hatching years before 1976 to occur in the near future. Also the Crab Plan Team does not consider levels of mature biomass prior to 1983 to be representative of that attainable under the current environmental conditions (NPFMC 1998). Therefore, a normal Ricker S–R curve was also fit to the S–R data after 1976 to estimate an alternative S–R relationship under the current environmental conditions.

As a comparison, mature male biomass on February 15 was also used as an alternative spawning stock index for the S–R relationships. Population abundance at survey time was projected forward to February 15 after adjusting fishing and natural mortalities. February 15 is near the peak of the primiparous female mating, prior to the molting of mature males, and after the fishery. This is about the lowest mature male biomass in a given year and is a conservative spawning biomass index.

RESULTS FOR MODEL A

Stock Assessment Model Evaluation

Model parameter estimates for Model A(1) and A(2) are summarized in Table 7, and estimated mature male and female abundances are compared in Figures 9 and 10. Common features of the two scenarios were strong recruitment in the 1970s and relatively weak recruitment during the last 20 years. Model A(2) fit the male abundance nearly as well as Model A(1) except that the estimated abundance was slightly lower during the 1970s, higher during the early 1980s, and lower in the last three years than the fit of Model A(1) (Figures 9 and 10). Model A(1) fit the female abundance (Ln(L) = -582.8) much better than Model A(2) (Ln(L) = -902.8).

Population Abundance

LBA estimates of Bristol Bay RKC abundance and 95% bootstrap confidence limits for 2006 under the base model (Model A(1)) are shown in Table 8. Mature crab abundance increased to a peak in the late 1970s, decreased dramatically in the early 1980s, remained at low levels during the 1980s and early 1990s, and increased somewhat since the mid 1990s due to the above average year classes (termed the 1990, 1994 and 1997 year classes in this report based on estimated hatching year). As most male crabs from these three above average year classes entered the legal-sized population, abundance of large-size groups continued to increase slightly from last year. Mature male abundance increased from 16.2 million to 17.4 million crabs, and legal males increased from 9.5 million to 10.5 million from 2005 to 2006 (Table 8). Due to the above average year class 1997, mature female abundance also continued to increase from last year (40.5 million crabs in 2006 from 37.8 million crabs in 2005). Effective spawning biomass in 2006 (67.2 million pounds) was higher than that in 2005 (61.4 million pounds).

Model A(1) closely fit the survey abundance by length, shell condition, and sex (Figure 11). It appeared that model estimates of oldshell male crabs in 1974, 1980, 1985, 1988, 2001, 2004 and 2006 were much higher than those of the survey. The abundance of newshell males was much higher than the oldshell males in the 1970s.

Molting Probabilities

Three levels of molting probabilities were estimated for different periods. Molting probabilities were very high during 1972-1979, low during 1980-1984, 1992-1995 and 1999-2001, and intermediate during 1985-1991 and 2002-2006 (Figure 12). Estimated molting probabilities during these periods were consistent with that estimated from the 1966-1969 tagging data (Balsiger 1974) but lower than those estimated from the tagging data during 1954-1961 (Balsiger 1974) (Figure 12).

Natural Mortality

Estimated natural mortality overall was much higher for females than males. For the base scenario, estimated natural mortality was very high in the early 1980s and very low in the mid 1990s and the recent years (Table 7). The high natural mortality is consistent with survey data (Figure 4), which show a sharp decline of crab abundances in the early 1980s. Factors causing the high natural mortality are not clear. Physical environmental conditions, predation, disease, and handling mortality or a combination of all these factors may have contributed to high natural mortality (Otto 1986; Blau 1986). Senescence may also play a role for high natural mortality (Stevens 1990); however, high mortality seems to occur for almost all sizes of crabs in the early 1980s.

Exploitation

The RKC fishery in Bristol Bay harvests only legal crabs. Mature male and legal male harvest rates were computed by dividing total catch by the mature male abundance and legal crab abundance estimated in the base scenario at the survey time, respectively. The legal male harvest rates ranged from 0.20 to 0.58 in the 1970s and the early 1980s and fluctuated around 0.21 since the current harvest strategy was adopted in 1996 (Figure 13). After 1995, application of the maximum mature harvest rate of 15% in 1998 and 2003-2005 resulted in a mean legal harvest rate of 0.27 (Figure 13). The mature male harvest rates were close to 0.2 in the early and middle 1970s and peaked at 0.35 in 1980 (Figure 13). These high harvest rates and legal crab abundances produced the record catches in the late 1970s and early 1980s, which were followed by the quick collapse of the population. Harvest not only removes legal male crabs but also reduces abundances of sublegal male and female crabs through handling mortality. Although the bycatch mortality biomass was very low relative to the retained catch biomass based on the assumed handling mortality rates (Figure 2), the bycatch handling mortality rate could be higher than those assumed during some extremely cold years (Carls and O'Clair 1990). In summary, it appears that high natural mortality coupled with high harvest rates may have contributed to the collapse of the Bristol Bay RKC population in the early 1980s. The current conservative harvest strategy (low harvest rates) and low natural mortality since the mid 1990s may be assisting the gradual recovery of the stock.

One assumption needed to estimate natural mortality from the survey data is that trawl catchability is equal to 1 during 1973-2006. The recent experiment shows that survey catchability may be less than 1 (Figure 7). Harvest rates would be lower than estimated in Figure 13 if the real catchability is lower than our assumption. Model B will assume a constant natural mortality to estimate survey selectivities/catchability.

Fishery Selectivities

Fishery selectivities for retained males, discarded males and discarded females in the pot fishery can be estimated by dividing the catch and bycatch by their corresponding estimated abundances and averaging over time (Figure 14). Based on data availability, retained selectivities were averaged from 1972 to 2005, and female bycatch selectivities were averaged from 1990 to 2005, and male bycatch selectivties were averaged from 1990 to 2004. Mean selectivity for female bycatch was generally much lower than those for male bycatch.

Retrospective Analysis

Past assessments were summarized for a retrospective analysis. The assessment under the base scenario (Model A(1)) in 2006 serves as the baseline estimates. The long-term trends of abundance estimates made by LBA assessments in terminal years 1994-2006 were similar (Figures 15 and 16). Abundance increased sharply from the early 1970s to the late 1970s and then dropped dramatically during the early 1980s. Abundance fluctuated around a low level during the last two decades.

The baseline total abundance estimates and the estimates made for terminal years 1994-2006 differed. The biggest difference for total abundance occurred in 1996 with a -19.8% relative error. In addition to the survey measurement errors, this difference may also be due to assumptions about natural mortality (i.e., process errors). Natural mortality from 1985 to 1997 was assumed constant for the stock assessments conducted before 1998 (Zheng et al. 1997). Consistently lower model estimates than area-swept estimates of large-sized crab abundance from 1995 to 1997 (Figure 15) prompted reevaluation of the assumption of natural mortality. In the 1998 and 1999 assessments, a new level of natural mortality was estimated after 1993, which was much lower than estimated natural mortalities from 1972 to 1993 (Zheng et al. 1998; Zheng and Kruse 1999). Overestimates of 1994-1997 natural mortality during the assessments in terminal years 1995-1997 partially caused underestimates of large-sized crab abundance in those terminal years.

Relative errors for Bristol Bay RKC stock estimates are smaller than those for many groundfish stock estimates. Relative errors range from –19.8% to 14.6% for total crab abundance, whereas relative errors of biomass could range from –57% to 27% for some eastern Bering Sea groundfish stocks (Zheng and Kruse 2002a; Ianelli et al. 2003). In a retrospective catch-at-age analysis for Pacific halibut (*Hippoglossus stenolepis*) from 1944 to 1990, Parma (1993) indicated that historical estimates could be several times higher than the most recent estimates. As a contrast to the results by Parma (1993) that historical assessments tended to greatly overestimate Pacific halibut abundance during the 1960s and 1970s, historical assessments substantially underestimated pollock abundance in the eastern Bering Sea (Ianelli et al. 2003). In both stocks, historical errors in abundance estimates were highly autocorrelated over time. Such large errors were most likely caused by mis-specification of survey or fishery catchabilities (Parma 1993).

Even though the estimated historical errors of total crab abundance estimates are relatively small, their impacts on annual GHL or TAC can be substantial (Zheng and Kruse 2002a). Mature female abundance assessed in 1995 was close to the threshold level, and the fishery was closed due to conservation concerns. Under the current model assessment of abundance in 1995, the fishery would have been opened. The estimated mature male harvest rates are close to the targeted rates in 1996, 1997, and 1999, but are much higher in 1998. Because the step harvest rates are based on effective spawning biomass (Figure 1), the higher estimated effective spawning biomass in 1998 resulted in a target rate of 15%. The current model assessment would have triggered a target rate of 10%. Model assessment errors could greatly affect annual GHL/TAC if effective spawning biomass is near transition points between 0% and 10% and 10% and 15% harvest rates, as in 1995 and 1998. However, over a period of years, total GHL/TAC may not be affected much by assessment errors: total estimated GHL/TAC from 1994 to 2004 is very close to that derived from the current model assessment (Zheng 2004).

Overall, abundance estimates by the length-based model and area-swept method had the same trends over time (Zheng et al. 1995a, 1995b; Zheng and Kruse 2002a). The model provides smoother, more consistent abundance estimates than the area-swept method, and it is considered to be an improvement over a single-year point estimate of abundance derived from the area-swept method. The reduction of annual assessment error estimates with the model decreases estimated errors in setting annual GHL/TAC.

RESULTS FOR MODEL B

The model fit the fishery biomasses very well and fit the survey biomass reasonably well (Figures 17 and 18). Because the model estimates annual fishing mortality for retained catch and each kind of mortality bycatch, the deviations of observed and predicted (estimated) fishery biomasses are mainly due to size compositions. The model did not fit the mature crab abundance directly and caught the trends of the mature abundance well. The worst fit to the mature abundance was during 1991-1996 for females with the predicted abundance being higher than the area-swept estimate each year. Model A(2) with a constant natural mortality during this period also predicted higher abundances than the area-swept estimates, whereas Model A(1) with two levels of natural mortality fit the data very well (Figures 9 and 10). Estimated mature crab abundance has increased during the last 20 years with mature females being about 6 times as many in 2006 as in 1985 and mature males being about 2.5 times as many in 2006 as in 1985 (Figure 18).

Model B also fit the length and shell composition data well (Figures 19-22). The model fit the length compositions of newshell males and females of the trawl survey data much better than those of the oldshell males. The model predicted much lower proportions of oldshell males in 1993, 1994 and 2002 and much higher proportions of oldshell males in 1988, 1997, 2001, 2003, 2004 and 2006 than those of the area-swept estimates (Figure 19b). In addition to size, molting probability may also be affected by age and environmental conditions. Tagging data show that molting probability changed over time

(Basilger 1974). Therefore, a constant molting probability function in Model B did not fit the data as well as two molting probability functions used in Model A. It is surprising that the model fit the length proportions of the pot male bycatch very well with two simple linear selectivity functions (Figure 21a). I also tried to use a logistic selectivity function, but due to long left tail of the pot male bycatch selectivity, the logistic selectivity function did not fit the data well.

Modal progressions are tracked well in the trawl survey data (Figure 19). Cohorts first seen in the trawl survey data in 1986, 1990, 1995, 1999, 2002, 2004 and 2005 can be tracked over time. Some cohorts can be tracked over time in the pot bycatch as well (Figure 21), but the bycatch data did not track the cohorts as well as the survey data. Groundfish trawl bycatch data provide little information to track modal progression (Figure 22). About one-third of the model parameters (64 out of 212) deal with groundfish trawl bycatch. Since the trawl bycatch mortality biomass is a very small proportion of total crab catch biomass and the length compositions do not provide much information about the population length structure, a future modification of Model B may be to assume that the observed trawl bycatch data are accurate and to not estimate them in the model.

Parameter estimates for Model B are summarized in Tables 9 and 10. Length-specific fishing mortality is equal to selectivity times full fishing mortality. Although estimated retained fishing mortalities in 1993 and 1996 were very high, relatively low selectivities for the whole legal population resulted in much lower fishing mortalities on the legal abundance than these estimated values. Likewise, extremely low selectivity for pot male bycatch resulted in high estimated bycatch fishing mortalities. Lengths at 50% selectivity for groundfish trawl bycatch appear to have increased since 1994; this may be due to more restrictions after 1993. Mean length-specific selectivities over time were identical for both male and female bycatch in the groundfish trawl fisheries although their annual selectivities differed (Figure 23). In the directed pot fishery, mean length-specific selectivities were basically constant for mature females, and annual selectivities for the first length group (137.5 mm CL) of the legal population could vary greatly (Figure 23).

The most important results for Model B are estimated trawl survey selectivities/catchability (Figure 23). Survey selectivity affects not only the fitting of the data but also the absolute abundance estimates. Because the estimated selectivity is smaller for mature females than mature males, the differences between absolute and relative abundance are larger for mature females than mature males (Figure 24). Estimated survey selectivities in Figure 23 are generally smaller than the capture probabilities in Figure 7 because survey selectivities include capture probabilities and crab availability. The reliability of estimated survey selectivities for Model B will greatly affect the application of Model B to fisheries management. The estimated selectivities for Model B should be examined in the future before the abundance estimates from Model B can be used to set a TAC.

Model B can be extended to the data before 1985. However, due to sharp decrease in population abundance in the early 1980s, it is difficult to fit the data with a constant natural mortality. Model B can be used to investigate changes in natural mortality and impacts of observed and unobserved bycatch on the population in the late 1970s and early 1980s. These were the original objectives to develop Model B as a research model.

S–R RELATIONSHIPS

I estimated S-R relationships for Bristol Bay RKC from the results of the LBA base scenario (Model A(1)) (Figure 25). Generally, strong recruitment occurred with intermediate levels of effective spawning biomass, and very weak recruitment was associated with extremely low levels of effective spawning biomass. These features suggest a density-dependent S–R relationship. On the other hand, strong year classes occurred in the late 1960s and early 1970s, and weak year classes occurred in the 1980s and 1990s. Therefore recruitment is highly autocorrelated, so environmental factors may play an important role in recruitment success. I used the general Ricker curve to describe the density-dependent relationship and the autocorrelated Ricker curve to depict the autocorrelation effects. Because the autocorrelated curve regards the strong recruitment during the late 1960s and early 1970s as a result of autocorrelation, the recruitment associated with intermediate effective spawning biomass is much lower for the autocorrelated curve than for the general curve (Figure 25). Likewise, because the autocorrelated curve is less density-dependent, it has much higher recruitment than the general curve when effective spawning biomass is very high. Overall, the general Ricker curve (R^2=0.51, df=28) fit the data better than the autocorrelated curve (R^2=0.44, df=28), in contrast to the earlier results when S–R data were fitted up to the 1987 brood year (Zheng et al., 1995a, 1995b). The autocorrelation parameter fit the residuals well only before the 1982 year class and then fit the residuals poorly. As expected, recruitment levels as a function of the spawning stock are lower from the S–R curve estimated with the data after 1976 than those estimated with all data (Figure 25).

The S–R curves estimated with mature male biomass on February 15 have overall lower recruitment levels than those estimated with effective spawning biomass (Figure 25). The S–R curves fit the data better with effective spawning biomass than with mature male biomass (R^2=0.39, df=28 for the general curve and R^2=0.38, df=28 for the autocorrelated curve).

Egg clutch data collected during summer surveys may provide information about mature female reproductive conditions. Egg clutch data are subject to subjective rating errors as well as sampling errors, but their trends over time may be useful. Proportions of empty clutches for newshell mature females >89 mm CL were high during some years before 1990 and have been very low since 1990 (Figure 26). The highest proportion of empty clutches was in 1986 with 0.20, and they were found with primarily soft shell females (shell condition 1). Clutch fullness fluctuated annually around their average levels during two periods: before 1991 and after 1990 (Figure 26). The average clutch fullness was almost identical for these two periods (Figure 26).

The recruitment strength and the Aleutian Low Pressure index were examined by Zheng and Kruse (2000, 2006) and are compared in Figure 27. The average seasonal index of December-March with a 3-point running average was used. The recruitment trends of Bristol Bay RKC may partly relate to decadal shifts in physical oceanography: all strong year classes occurred before 1977 when the Aleutian Low was weak. The largest year class during the last 20 years, the 1990 year class, was also coincidental with the weak Aleutian Low index during 1989-1991.

Many Alaskan RKC stocks, like Bristol Bay, tend to have periods of weak recruitment that coincide with decades of strong winter Aleutian Lows, the opposite of trends for many fish stocks (Hollowed and Wooster 1992; Beamish and Bouillon 1993).

The mechanisms are uncertain, but food availability is hypothesized to be important to RKC (Zheng and Kruse 2000) because their larvae suffer reduced survival and feeding capability if they do not feed within the first 2-6 days after hatching (Paul and Paul 1980). Diatoms such as *Thalassiosira* are important food for first-feeding RKC larvae (Paul et al. 1989) and they predominate the spring bloom in years of light winds when the water column is stable (Ziemann et al. 1991; Bienfang and Ziemann 1995). One hypothesis is that years of strong wind mixing associated with intensified Aleutian Lows may depress RKC larval survival and subsequent recruitment (Zheng and Kruse 2000).

Spatial distributions of Bristol Bay RKC changed profoundly during the last three decades (Hsu 1987; Loher 2001; Zheng and Kruse 2006). Generally speaking, RKC abundance in southern Bristol Bay was high during the 1970s, declined, and was extremely low after 1979 (Zheng and Kruse 2006). Female RKC were found primarily in central Bristol Bay during 1980-1987 and 1992-2006 (Zheng and Kruse 2006). The distribution centers of mature females moved south slightly during 1988-1991 but did not reach the southern locations previously occupied in the 1970s. Loher (2001) hypothesized that changes in near bottom temperatures associated with the 1976/77 regime shift are causes for spatial shifts of RKC female distributions. Because small juvenile RKC are generally located downstream of the mature females (Zheng and Kruse 2006), larval advection appears to be an important process for RKC. The shifts of spatial distributions of mature females make it difficult to supply larvae to the southern range of their spatial distributions. This reduces the number of suitable habitats to which larvae are delivered (Armstrong et al. 1983; Loher 2001) and may affect recruitment strength.

PROJECTIONS AND FUTURE OUTLOOK

Future population projections primarily depend on future recruitment predictions. Crab recruitment is extremely difficult to predict. Therefore, unless the projections are required for regulatory purposes, no projections are made in the stock assessment report.

The near future outlook for the Bristol Bay RKC stock is stable. Recent three above-average year classes (hatching years 1990, 1994, and 1997) have almost all entered the legal population in 2006 (Figure 28). So the recruitment to the legal population during the next two years may be low. However, year class 1997 entered the legal population primarily in 2006, and these crabs will continue to gain weight to offset the legal biomass loss due to fishing and natural mortalities. The cohort (with lengths centered around 87.5 mm CL for both males and females in 2006) also appears to be above average in abundance (Figure 28). These crabs will enter the mature female population next year and mature male population in 2 or 3 years. The negative side is that there are no strong cohorts observed in the survey data after this cohort (Figure 28). Due to these above average year classes, mature and legal crabs should maintain relatively high levels compared to those during the last 20 years if natural mortality does not increase greatly, as in the early 1980s for this stock and in 1999 for St. Matthew Island blue king crabs (Zheng and Kruse 2002b). Current crab abundance is still very low relative to those in the late 1970s, and without favorable environmental conditions, recovery to the high levels of the late 1970s may be difficult.

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Table 1. Bristol Bay red king crab annual catch and bycatch mortality biomass (million pounds) from June 1 to May 31. A handling mortality rate of 20% for pot and 80% for trawl was assumed to estimated bycatch mortality biomass.

	Retained Catch				Pot Bycatch		Trawl
Year	U.S.	Cost-recovery	Foreign	Total	Males	Females	Bycatch
1960	0.600		26.898	27.498			
1961	0.427		44.592	45.019			
1962	0.068		54.275	54.343			
1963	0.653		54.963	55.616			
1964	0.823		58.170	58.993			
1965	1.429		41.294	42.723			
1966	0.997		42.356	43.353			
1967	3.102		33.636	36.738			
1968	8.686		27.469	36.155			
1969	10.403		14.383	24.786			
1970	8.559		12.984	21.543			
1971	12.946		6.134	19.080			
1972	21.745		4.720	26.465			
1973	26.914		0.228	27.142			
1974	42.266		0.476	42.742			
1975	51.326		0.000	51.326			
1976	63.920		0.000	63.920			1.426
1977	69.968		0.000	69.968			2.685
1978	87.618		0.000	87.618			2.757
1979	107.828		0.000	107.828			2.783
1980	129.948		0.000	129.948			2.135
1981	33.591		0.000	33.591			0.448
1982	3.001		0.000	3.001			1.201
1983	0.000		0.000	0.000			0.885
1984	4.182		0.000	4.182			2.316
1985	4.175		0.000	4.175			0.829
1986	11.394		0.000	11.394			0.432
1987	12.289		0.000	12.289			0.311
1988	7.388		0.000	7.388			1.174
1989	10.265		0.000	10.265			0.374
1990	20.362	0.081	0.000	20.443	1.139	1.154	0.501
1991	17.178	0.206	0.000	17.384	0.881	0.142	0.576
1992	8.043	0.074	0.000	8.117	1.191	0.780	0.571
1993	14.629	0.053	0.000	14.682	1.649	1.133	0.836
1994	0.000	0.093	0.000	0.093	0.000	0.000	0.180
1995	0.000	0.080	0.000	0.080	0.000	0.000	0.213
1996	8.406	0.108	0.000	8.514	0.356	0.002	0.238
1997	8.756	0.155	0.000	8.911	0.528	0.034	0.168
1998	14.757	0.188	0.000	14.946	2.074	1.547	0.355
1999	11.670	0.186	0.000	11.856	0.679	0.015	0.408
2000	8.154	0.086	0.000	8.241	0.779	0.078	0.230
2001	8.403	0.120	0.000	8.523	0.902	0.309	0.330
2002	9.570	0.096	0.000	9.666	0.956	0.013	0.245
2003	15.697	0.034	0.000	15.731	1.945	0.709	0.298
2004	15.245	0.202	0.000	15.447	0.746	0.338	0.277
2005	18.309	0.209	0.000	18.518	2.923	0.879	0.403

Table 2. Comparison of GHL/TAC and actual catch (million pounds) of Bristol Bay red king crabs.

Year	GHL Range	GHL Mid-point	Actual Catch	Rel.Error	%Rel.Error
1980	70-120	95.00	129.95	34.95	36.79
1981	70-100	85.00	33.59	-51.41	-60.48
1982	10-20	15.00	3.00	-12.00	-79.99
1983	0	0.00	0.00	NA	NA
1984	2.5-6	4.25	4.18	-0.07	-1.59
1985	3-5	4.00	4.18	0.18	4.38
1986	6-13	9.50	11.39	1.89	19.94
1987	8.5-17.7	13.10	12.29	-0.81	-6.19
1988		7.50	7.39	-0.11	-1.50
1989		16.50	10.26	-6.24	-37.79
1990		17.10	20.36	3.26	19.08
1991		18.00	17.18	-0.82	-4.57
1992		10.30	8.04	-2.26	-21.91
1993		16.80	14.63	-2.17	-12.93
1994		0.00	0.00	0.00	
1995		0.00	0.00	0.00	
1996		5.00	8.41	3.41	68.11
1997		7.00	8.76	1.76	25.09
1998		16.40	14.76	-1.64	-10.02
1999		10.66	11.67	1.01	9.48
2000		8.35	8.15	-0.20	-2.34
2001		7.15	8.40	1.25	17.52
2002		9.27	9.57	0.30	3.24
2003		15.71	15.70	-0.01	-0.08
2004		15.40	15.25	-0.15	-1.00
2005		18.33	18.31	-0.02	-0.11
Total		425.32	395.57	-29.75	-6.99

Table 3. Annual sample sizes for catch by length and shell condition for retained catch and bycatch of Bristol Bay red king crabs.

	Trawl Survey		Retained	Pot Bycatch		Trawl Bycatch	
Year	Males	Females	Catch	Males	Females	Males	Females
1960			3960				
1961			3116				
1962			9120				
1963			9600				
1964			13080				
1965			10559				
1966			11772				
1967			21834				
1968	3684	2165	18044				
1969	6144	4992	22812				
1970	1546	1216	3394				
1971			10340				
1972	1106	767	15046				
1973	1783	1888	11848				
1974	2505	1800	27067				
1975	2943	2139	29570				
1976	4724	2956	26450			2327	676
1977	3636	4178	32596			14014	689
1978	4132	3948	27529			8983	1456
1979	5807	4663	27900			7228	2821
1980	2412	1387	34747			47463	39689
1981	3478	4097	18029			42172	49634
1982	2063	2051	11466			84240	47229
1983	1524	944	0			204464	104910
1984	2679	1942	4404			357981	147134
1985	792	415	4582			169767	30693
1986	1962	367	5773			62023	20800
1987	1168	1018	4230			60606	32734
1988	1834	546	9833			102037	57564
1989	1257	550	32858			47905	17355
1990	858	603	7218	873	699	5876	2665
1991	1378	491	36820	1801	375	2964	962
1992	513	360	23552	3248	2389	1157	2678
1993	1009	534	32777	5803	5942		
1994	443	266	0	0	0	4953	3341
1995	2154	1718	0	0	0	1729	6006
1996	835	816	8896	230	11	24583	9373
1997	1282	707	15747	4102	906	9035	5759
1998	1097	1150	16131	11079	9130	25051	9594
1999	820	540	17666	1048	36	16653	5187
2000	1278	1225	14091	8970	1486	36972	10673
2001	611	743	12854	9102	4567	56070	32745
2002	1032	896	15932	9943	302	27705	25425
2003	1669	1311	16212	17998	10327	281	307
2004	2871	1599	20038	8258	4112	137	120
2005	1283	1682	21938	55019	26775	186	124
2006	2321	2672					

Table 4. Annual catch (millions of crabs) and catch per unit effort of the Bristol Bay red king crab fishery.

	Japanese Tanglenet		Russian Tanglenet		U.S. Pot/trawl		Standardized
Year	Catch	Crabs/tan	Catch	Crabs/tan	Catch	Crabs/potlift	Crabs/tan
1960	1.949	15.2	1.995	10.4	0.088		15.8
1961	3.031	11.8	3.441	8.9	0.062		12.9
1962	4.951	11.3	3.019	7.2	0.010		11.3
1963	5.476	8.5	3.019	5.6	0.101		8.6
1964	5.895	9.2	2.800	4.6	0.123		8.5
1965	4.216	9.3	2.226	3.6	0.223		7.7
1966	4.206	9.4	2.560	4.1	0.140	52	8.1
1967	3.764	8.3	1.592	2.4	0.397	37	6.3
1968	3.853	7.5	0.549	2.3	1.278	27	7.8
1969	2.073	7.2	0.369	1.5	1.749	18	5.6
1970	2.080	7.3	0.320	1.4	1.683	17	5.6
1971	0.886	6.7	0.265	1.3	2.405	20	5.8
1972	0.874	6.7			3.994	19	
1973	0.228				4.826	25	
1974	0.476				7.710	36	
1975					8.745	43	
1976					10.603	33	
1977					11.733	26	
1978					14.746	36	
1979					16.809	53	
1980					20.845	37	
1981					5.308	10	
1982					0.541	4	
1983					0.000		
1984					0.794	7	
1985					0.796	9	
1986					2.100	12	
1987					2.122	10	
1988					1.236	8	
1989					1.685	8	
1990					3.130	12	
1991					2.661	12	
1992					1.208	6	
1993					2.270	9	
1994					0.015		
1995					0.014		
1996					1.264	16	
1997					1.338	15	
1998					2.238	15	
1999					1.923	12	
2000					1.272	12	
2001					1.287	19	
2002					1.484	20	
2003					2.510	18	
2004					2.272	23	
2005					2.763	30	

Table 5. Area-swept estimates of 30 stations for Bristol Bay red king crabs in 2006. Haul numbers <191 are standard survey, and haul numbers >190 are resurvey.

N. Lat.	W. Long.	Station	Haul #	Legal males	Mature males	Males>89mm	Mature females
56.01	-162.27	D10	25	184917	246556	493112	1910808
56.34	-162.80	E09	27	30028	120112	390363	150140
56.34	-162.18	E10	24	94995	94995	1108276	1868237
56.33	-161.62	E11	12	241270	271428	603174	1447618
56.34	-160.97	E12	11	315209	409772	535855	1134753
56.66	-162.78	F09	26	279288	310320	434447	124128
56.66	-162.17	F10	23	64395	96592	643947	1062512
56.67	-161.58	F11	13	315762	378914	473643	189457
56.66	-160.98	F12	11	158548	253677	475645	285387
56.66	-160.38	F13	10	0	0	61957	309786
57.00	-162.78	G09	24	333984	485794	1153761	425070
57.00	-162.18	G10	22	284086	473477	852259	378782
56.99	-161.56	G11	14	154256	154256	401065	401065
57.00	-160.95	G12	13	224498	224498	481067	994206
57.00	-160.33	G13	10	245296	306620	429268	1349129
57.31	-163.42	H08	34	247318	432806	618295	741954
57.33	-162.77	H09	23	462926	740682	1049299	277756
57.33	-162.15	H10	21	159900	287820	607620	1375141
57.33	-161.53	H11	15	1046419	1648903	2568483	2822160
57.32	-160.90	H12	14	32014	96042	960424	1536679
57.34	-160.30	H13	9	0	88548	118064	118064
57.67	-163.33	I08	35	215736	246556	246556	277375
57.66	-162.75	I09	22	414856	733976	765888	351032
57.66	-162.13	I10	20	219264	407205	563823	375882
57.67	-161.49	I11	16	251287	282698	691041	691041
57.67	-160.85	I12	15	98387	360751	1115048	491933
57.67	-160.27	I13	8	94167	125556	156945	345279
57.99	-161.48	J11	17	31258	31258	93775	218808
58.00	-160.83	J12	16	127062	254125	381187	254125
58.00	-160.22	J13	7	62473	62473	124946	218656
55.99	-162.27	D10	215	186000	278999	464999	526999
56.33	-162.80	E09	216	153206	214488	337053	0
56.34	-162.19	E10	214	153206	306412	1440134	1685263
56.32	-161.63	E11	207	503102	848984	1100535	2012406
56.34	-160.99	E12	206	127332	445662	509328	445662
56.68	-162.80	F09	217	272066	362755	876658	272066
56.66	-162.16	F10	213	188400	753600	2637599	2700399
56.67	-161.61	F11	208	277661	401065	1326601	2498945
56.66	-160.97	F12	205	94895	158158	316317	506106
56.66	-160.38	F13	204	60786	91179	91179	182357
57.00	-162.78	G09	218	91550	152583	732396	2166672
57.00	-162.17	G10	212	154256	185107	493619	1881922
57.00	-161.57	G11	209	96008	192016	992085	2432208
57.00	-160.94	G12	202	93128	124171	465640	2545499
57.00	-160.34	G13	203	91612	213761	274835	702356
57.33	-163.39	H08	220	382266	668966	796388	286700
57.33	-162.78	H09	219	397929	550978	857077	489758
57.34	-162.16	H10	211	127558	223226	733456	1690137
57.33	-161.53	H11	210	31021	62043	124085	2357616
57.33	-160.92	H12	201	93580	155966	561478	1372503
57.34	-160.29	H13	200	189457	189457	315762	757829
57.67	-163.33	I08	191	192496	224578	224578	224578
57.67	-162.74	I09	192	182913	304855	335341	365826
57.67	-162.12	I10	193	89309	148849	267928	327467
57.67	-161.47	I11	194	90325	150541	662382	1565630
57.67	-160.88	I12	196	91457	243884	518254	1158449
57.67	-160.27	I13	199	31455	31455	31455	314548
57.99	-161.50	J11	195	126261	189391	789128	347216
58.00	-160.84	J12	197	92364	215515	461818	492606
58.00	-160.23	J13	198	31323	62647	62647	62647

Table 6. Average weight and assumed maximum number of female mates for male red king crabs in Bristol Bay by length-class.

Male Carapace Length (mm)	Average Male Weight (kg)	Number of Female Mates
0-119		0.0
120-124	1.43	1.0
125-129	1.63	1.2
130-134	1.84	1.4
135-139	2.06	1.6
140-144	2.31	1.8
145-149	2.58	2.1
150-154	2.86	2.4
155-159	3.17	2.7
160+	3.50	3.0

Table 7. Summary of parameter estimates for Model A(1) and A(2) for Bristol Bay red king crabs. The abundance in 1972, N_{72}, and recruits, R_t, are in millions of crabs.

	Model			
Parameter	A(1): males	A(2): males	A(1): females	A(2): females
N_{72}	39.205	38.290	59.556	38.601
$ß$	0.626	0.635	0.991	1.241
$ß_r$	1.344	1.300	0.447	0.445
L_{501}	155.976	155.656	NA	NA
L_{502}	129.954	130.029	NA	NA
L_{503}	143.639	143.562	NA	NA
$ß_1$	0.0817	0.0821	NA	NA
$ß_2$	0.0812	0.0825	NA	NA
$ß_3$	0.0883	0.0880	NA	NA
M_1	0.192	0.174	0.478	0.288
M_2	1.010	1.017	1.745	1.918
M_3	0.140	NA	0.334	NA
M_4	NA	NA	0.093	NA
R_{73}	32.284	30.225	34.804	17.143
R_{74}	22.523	21.718	28.982	17.338
R_{75}	35.140	33.550	22.403	15.429
R_{76}	46.510	44.259	34.173	23.864
R_{77}	57.828	55.152	73.870	48.318
R_{78}	24.883	24.244	50.895	38.948
R_{79}	14.170	14.035	21.876	19.231
R_{80}	26.209	26.648	36.861	32.810
R_{81}	18.240	18.389	14.224	14.261
R_{82}	21.757	21.894	17.897	20.577
R_{83}	12.165	12.095	4.600	4.879
R_{84}	18.861	18.661	7.932	8.404
R_{85}	9.900	9.038	5.540	5.214
R_{86}	6.678	6.303	4.034	3.604
R_{87}	6.665	6.247	9.935	8.962
R_{88}	6.691	6.295	6.122	5.894
R_{89}	5.684	5.379	5.896	5.888
R_{90}	1.572	1.571	0.965	0.904
R_{91}	4.527	4.466	3.883	4.303
R_{92}	6.413	6.560	3.677	4.787
R_{93}	2.646	2.787	2.441	3.022
R_{94}	1.206	1.280	0.430	0.449
R_{95}	3.139	3.424	1.674	2.100
R_{96}	3.392	3.622	4.414	5.556
R_{97}	13.980	14.602	16.261	24.701
R_{98}	3.031	3.039	1.809	1.641
R_{99}	1.428	1.429	0.680	0.652
R_{00}	3.858	3.967	4.776	5.093
R_{01}	8.309	9.255	8.234	13.716
R_{02}	2.154	2.253	2.724	3.197
R_{03}	5.349	5.695	7.986	10.294
R_{04}	9.823	10.239	9.095	11.417
R_{05}	6.962	7.076	6.707	7.502
R_{06}	6.288	6.301	6.404	6.482
Ln(L)	-1946.143	-1954.010	-582.815	-902.803
df	907	908	334	336

Table 8. Annual abundance estimates (millions of crabs), effective spawning biomass (ESB, million pounds), and 95% confidence intervals for 2006 for red king crabs in Bristol Bay estimated by length-based analysis from 1972-2006 for the base scenario (Model A(1)). Size measurements are mm CL.

	Males					Females		
Year mm→	Recruits (to model)	Small (95-109)	Prerec. (110-134)	Mature (>119)	Legal (>134)	Recruits (to model)	Mature (>89)	ESB (M lbs)
1972	NA	13.741	15.299	18.812	10.166	NA	59.556	56.381
1973	32.284	21.960	26.597	23.021	10.787	34.804	70.824	64.467
1974	22.523	15.889	35.211	34.749	15.095	28.982	71.916	95.267
1975	35.140	23.879	36.075	40.880	20.681	22.403	66.098	117.011
1976	46.510	31.768	46.399	48.957	24.896	34.173	74.322	128.360
1977	57.828	39.591	60.861	62.108	29.926	73.870	118.843	164.926
1978	24.883	18.275	60.580	75.754	39.209	50.895	122.854	205.217
1979	14.170	10.169	38.200	73.464	47.036	21.876	96.575	172.893
1980	26.209	17.729	27.027	59.274	43.363	36.861	95.319	169.834
1981	18.240	12.906	17.320	17.974	9.159	14.224	71.360	57.726
1982	21.757	14.968	15.048	9.483	2.711	17.897	29.842	22.150
1983	12.165	8.785	12.420	8.370	2.333	4.600	9.737	16.370
1984	18.861	12.880	12.256	7.743	2.295	7.932	9.626	14.457
1985	9.900	7.178	10.219	6.645	1.719	5.540	7.168	10.673
1986	6.678	4.814	11.970	11.204	4.232	4.034	9.049	14.381
1987	6.665	4.665	10.325	12.678	6.295	9.935	16.247	25.568
1988	6.691	4.679	9.574	13.282	7.589	6.122	17.546	29.342
1989	5.684	4.021	9.223	14.691	9.136	5.896	18.318	31.981
1990	1.572	1.273	7.133	14.705	9.910	0.965	13.956	27.000
1991	4.527	3.052	4.955	11.753	8.573	3.883	13.451	25.979
1992	6.413	4.406	6.302	10.077	6.814	3.677	13.238	25.753
1993	2.646	2.253	7.236	10.450	6.181	2.441	11.557	23.227
1994	1.206	1.051	5.524	8.934	5.101	0.430	8.255	17.958
1995	3.139	2.198	4.746	9.523	6.330	1.674	9.193	20.194
1996	3.392	2.510	5.333	10.296	7.072	4.414	12.779	26.218
1997	13.980	9.360	8.982	11.587	7.355	16.261	27.871	38.689
1998	3.031	3.170	13.282	15.033	7.532	1.809	27.068	49.814
1999	1.428	1.114	8.154	15.630	9.430	0.680	19.443	41.262
2000	3.858	2.672	5.925	13.009	8.849	4.776	18.697	38.998
2001	8.309	5.784	7.575	12.132	8.034	8.234	21.579	42.129
2002	2.154	2.137	9.226	13.456	7.930	2.724	22.194	45.886
2003	5.349	3.646	7.269	14.383	9.576	7.986	28.186	55.124
2004	9.823	6.691	8.850	13.915	9.289	9.095	34.408	54.168
2005	6.962	5.007	11.699	16.161	9.544	6.707	37.848	61.421
2006	6.288	4.449	11.033	17.364	10.452	6.404	40.469	67.158

95% Confidence Limits in 2006

Lower	5.225	NA	9.600	14.373	8.247	5.347	33.591	NA
Upper	8.186	NA	12.606	19.714	12.100	8.555	50.218	NA

Table 9. Summary of parameter estimates (except recruits, which are in Table 10) for Model B for Bristol Bay red king crabs.

Year	Retained L_{50}	Pot disc female L_{50}	Trawl disc male L_{50}	Trawl disc female L_{50}	Retained F	Pot disc male F	Pot disc female F	Trawl disc F
1985	136.43		123.07	126.25	0.385			0.014
1986	136.42		123.11	127.47	0.574			0.009
1987	137.48		123.28	126.97	0.483			0.005
1988	138.52		123.59	126.10	0.224			0.015
1989	137.84		124.39	126.78	0.253			0.004
1990	138.63	85.24	125.18	128.73	0.571	1.065	0.033	0.008
1991	138.97	79.77	126.07	129.32	0.624	1.005	0.003	0.008
1992	139.86	82.54	128.29	129.05	0.343	1.222	0.018	0.014
1993	146.36	84.78	132.07	126.97	1.740	1.328	0.030	0.018
1994			134.42	127.32	0.000	0.000	0.000	0.002
1995			135.55	129.23	0.000	0.000	0.000	0.006
1996	148.77	84.89	135.48	134.18	0.425	0.371	0.000	0.002
1997	138.23	90.36	137.88	138.00	0.242	0.371	0.001	0.002
1998	137.30	90.91	139.35	142.06	0.433	0.993	0.025	0.004
1999	138.71	87.78	140.36	145.23	0.298	0.353	0.000	0.006
2000	138.76	81.33	142.31	146.35	0.157	0.584	0.001	0.003
2001	137.54	78.46	145.52	146.18	0.143	0.685	0.004	0.005
2002	136.61	74.66	148.57	146.16	0.165	0.630	0.000	0.004
2003	136.08	79.20	150.77	146.48	0.268	1.405	0.008	0.004
2004	139.24	83.00	152.59	148.06	0.326	0.457	0.004	0.003
2005	138.25	90.11	154.57	149.52	0.447	1.323	0.009	0.004

Growth β: males: 0.965, females: 1.432;
Recruits β: males: 0.769, females: 0.686;
Molting: $L50$: 133.975, β: 0.133;
Total abundance in 1985: 62.208 millions of crabs;
Retained selectivity β: 0.593;
Pot disc. female selectivity β: 0.328;
Pot disc. male selectivity parameters: φ: -0.0875, κ: 0.000997, γ: 0.0052;
Groundfish trawl disc. selectivity β: 0.0666;
Highgrading parameter in 2005: *hg*: 0.118;
Trawl survey selectivity: females: β: 0.0539, L_{50}: 78.447, males: L_{50}: 83.835;

Table 10. Annual abundance estimates (millions of crabs) for red king crabs in Bristol Bay estimated by length-based analysis from 1985-2006 for Model B. Size measurements are mm CL.

	Males			Females	
Year mm→	Recruits (to model)	Mature (>119)	Legal (>134)	Recruits (to model)	Mature (>89)
1985	0.492	8.881	2.803	0.524	10.782
1986	12.734	13.041	5.357	15.970	16.485
1987	6.582	15.098	7.067	6.390	20.961
1988	2.076	15.522	8.552	1.572	25.465
1989	4.502	16.453	9.861	5.719	25.336
1990	11.424	16.376	10.468	9.109	23.680
1991	8.913	12.438	8.676	4.795	23.636
1992	0.922	9.639	6.422	0.887	24.799
1993	6.972	10.910	5.967	4.421	23.075
1994	0.577	11.120	5.564	0.790	20.460
1995	31.236	11.763	7.859	31.110	19.069
1996	9.086	12.181	8.735	7.478	24.191
1997	0.576	11.837	8.193	0.550	34.142
1998	6.206	17.833	8.012	6.818	34.129
1999	15.849	20.658	10.526	18.506	30.432
2000	6.213	18.173	12.593	4.815	32.631
2001	2.188	16.540	12.215	5.595	36.120
2002	30.645	18.221	11.555	36.240	34.815
2003	6.205	18.540	12.219	5.502	40.573
2004	21.938	16.161	11.253	19.446	49.333
2005	37.536	20.449	10.302	43.134	50.956
2006	13.227	22.101	11.889	13.935	60.828

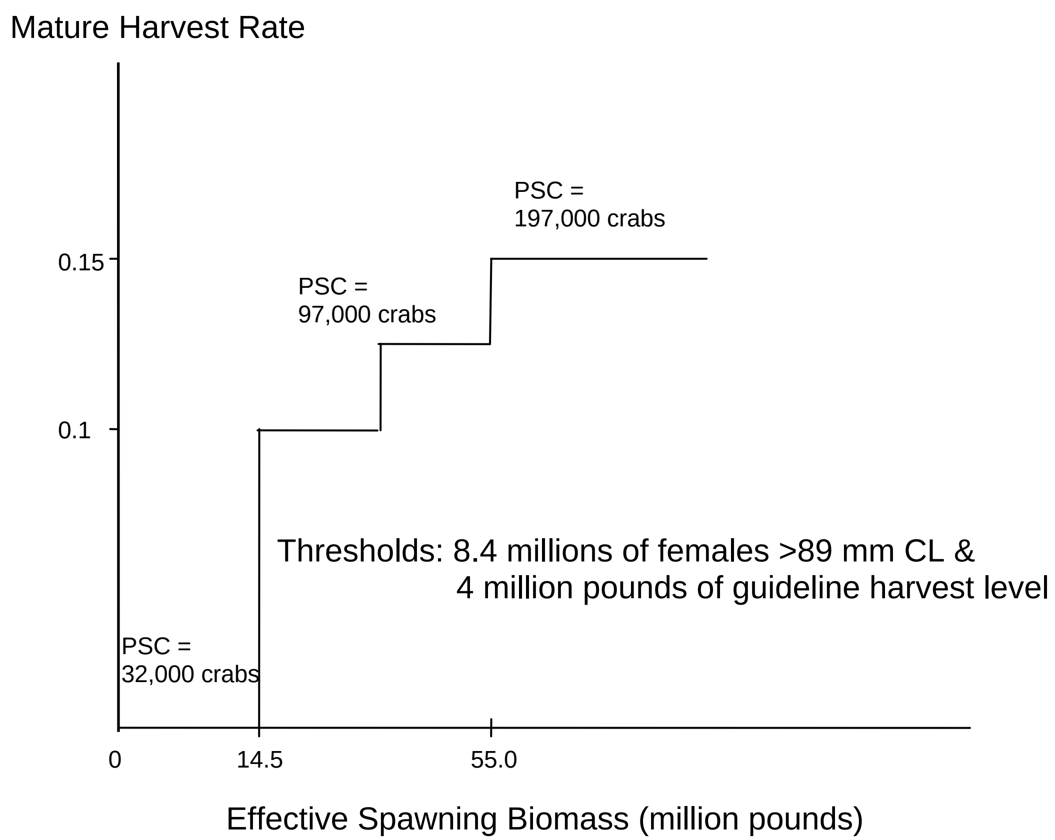


Figure 1. Current harvest rate strategy (line) for the Bristol Bay red king crab fishery and annual prohibited species catch (PSC) limits (numbers of crabs) of Bristol Bay red king crabs in the groundfish fisheries in zone 1 in the eastern Bering Sea. Harvest rates are based on current-year estimates of effective spawning biomass (ESB), whereas PSC limits apply to previous-year ESB.

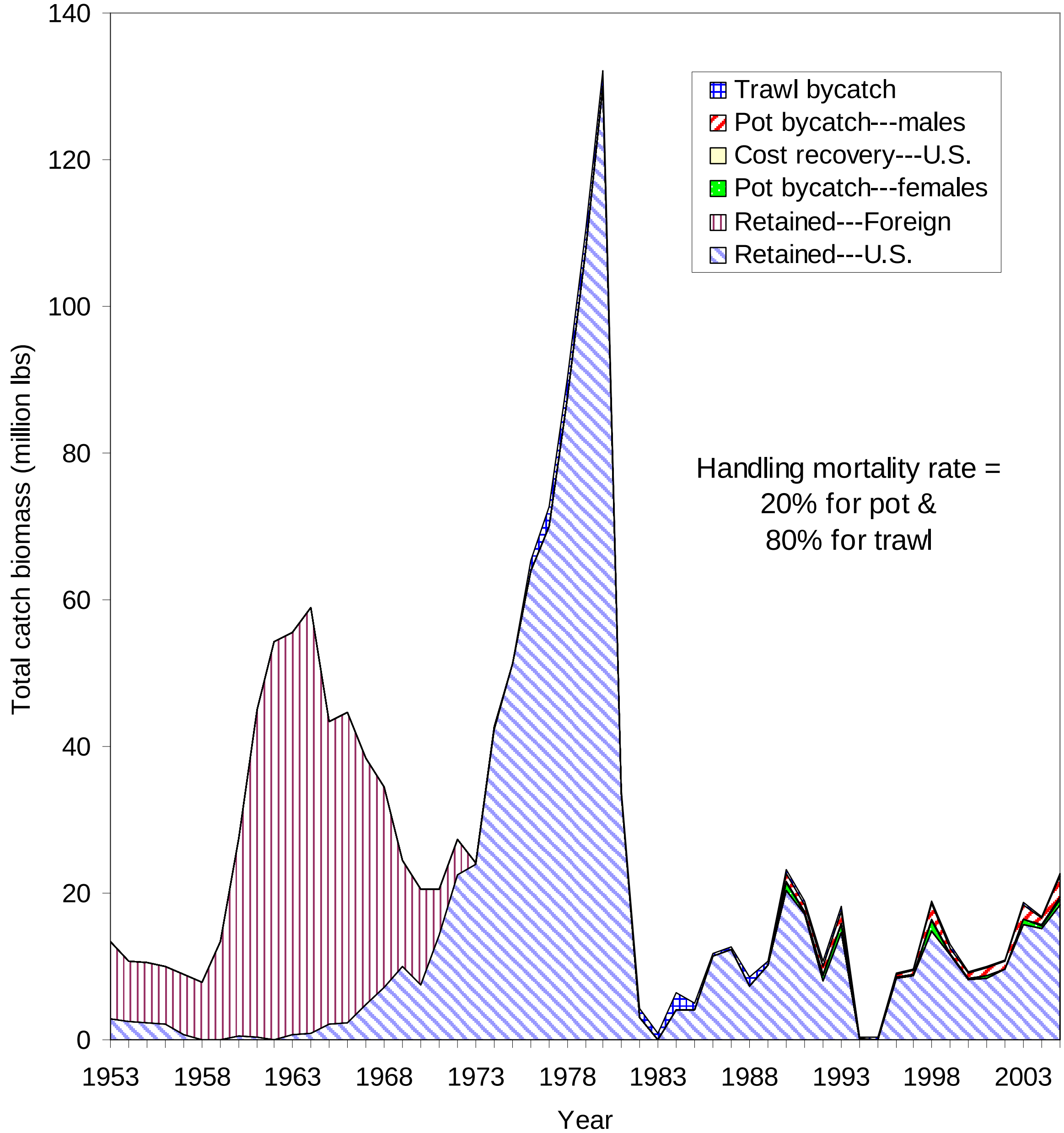


Figure 2. Retained catch biomass and bycatch mortality biomass (million pounds) for Bristol Bay red king crabs from 1960 to 2005. Handling mortality rates were assumed to be 0.2 for the directed pot fishery and 0.8 for the trawl fisheries.

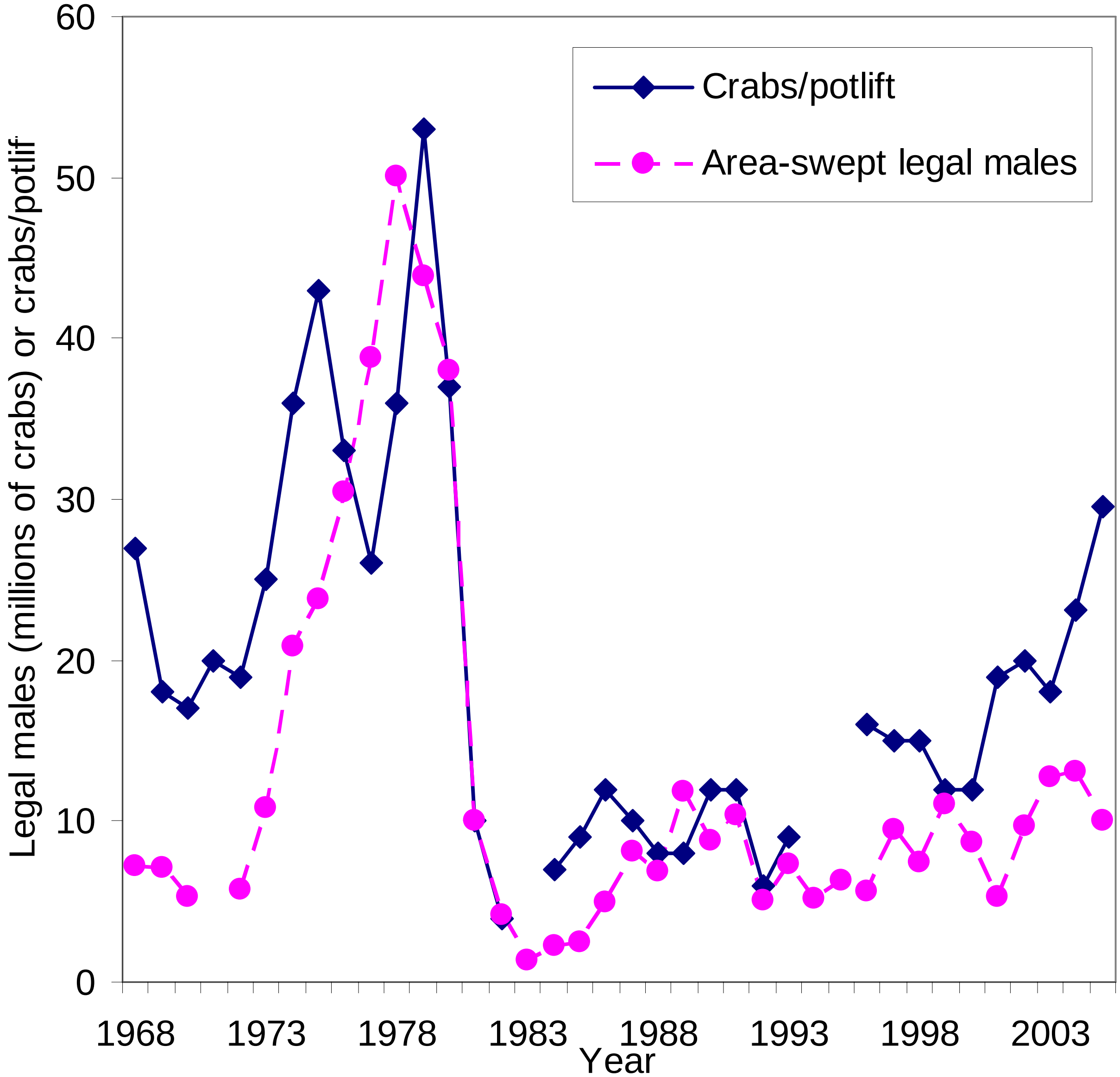


Figure 3. Comparison of survey legal male abundances and catches per unit effort for Bristol Bay red king crabs from 1968 to 2005.

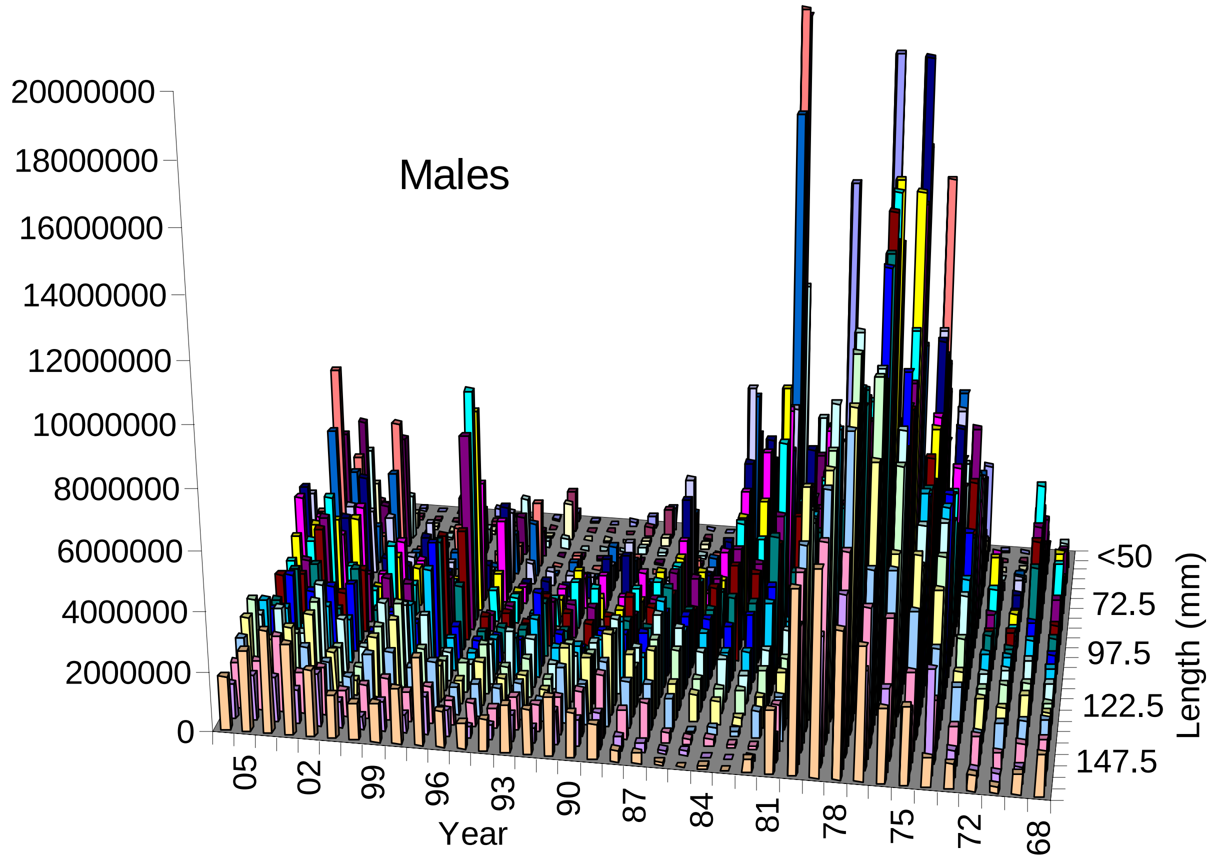


Figure 4a. Survey abundances by length for male Bristol Bay red king crabs from 1968 to 2006.

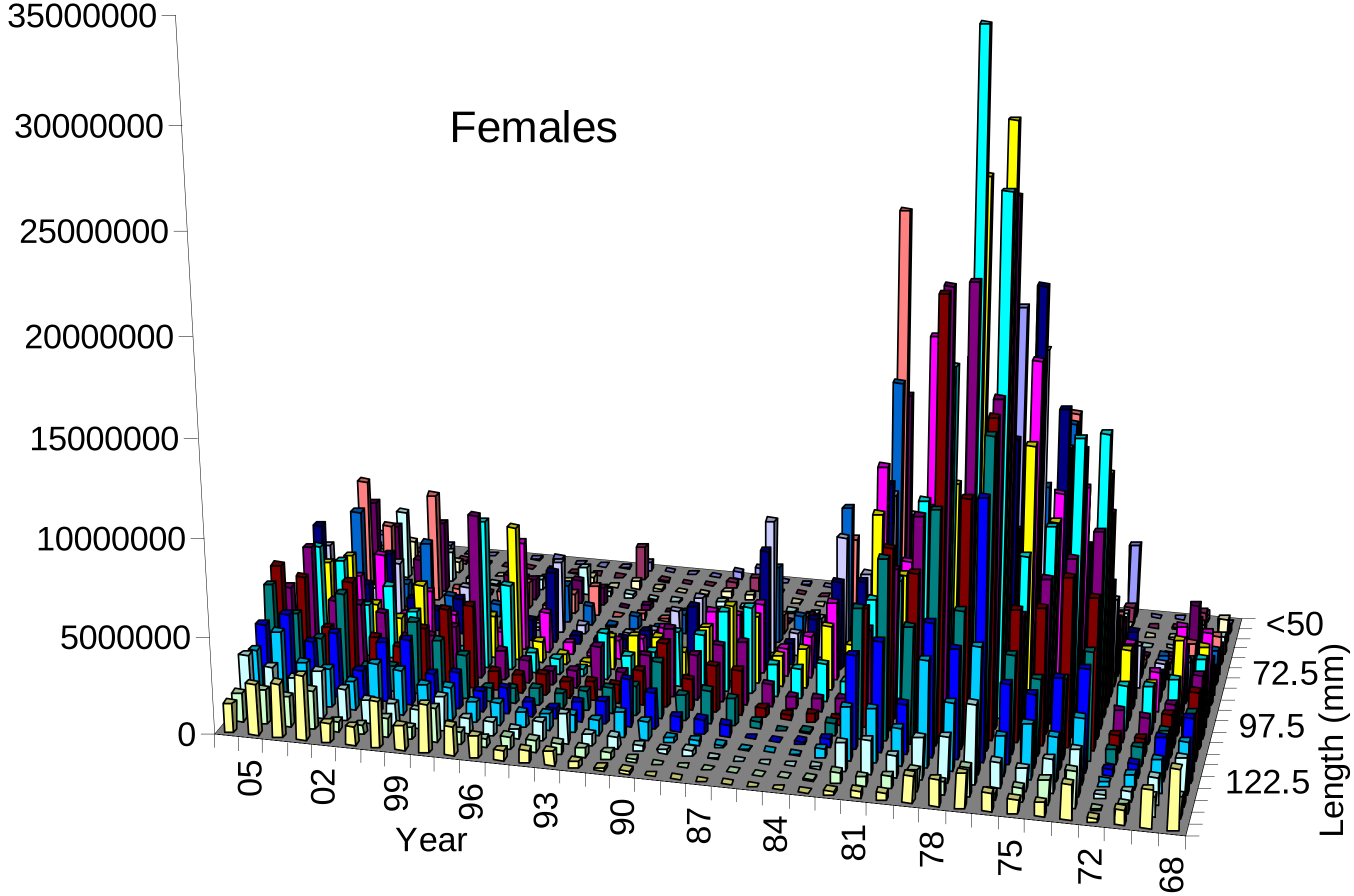
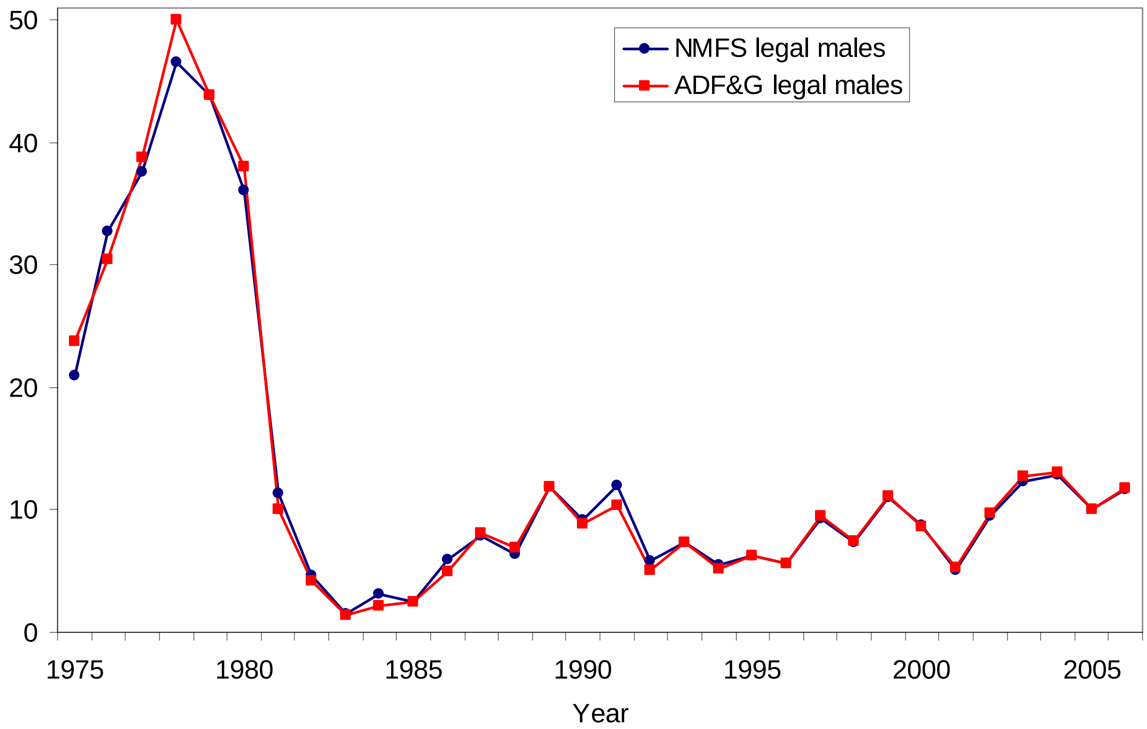


Figure 4b. Survey abundances by length for female Bristol Bay red king crabs from 1968 to 2006.



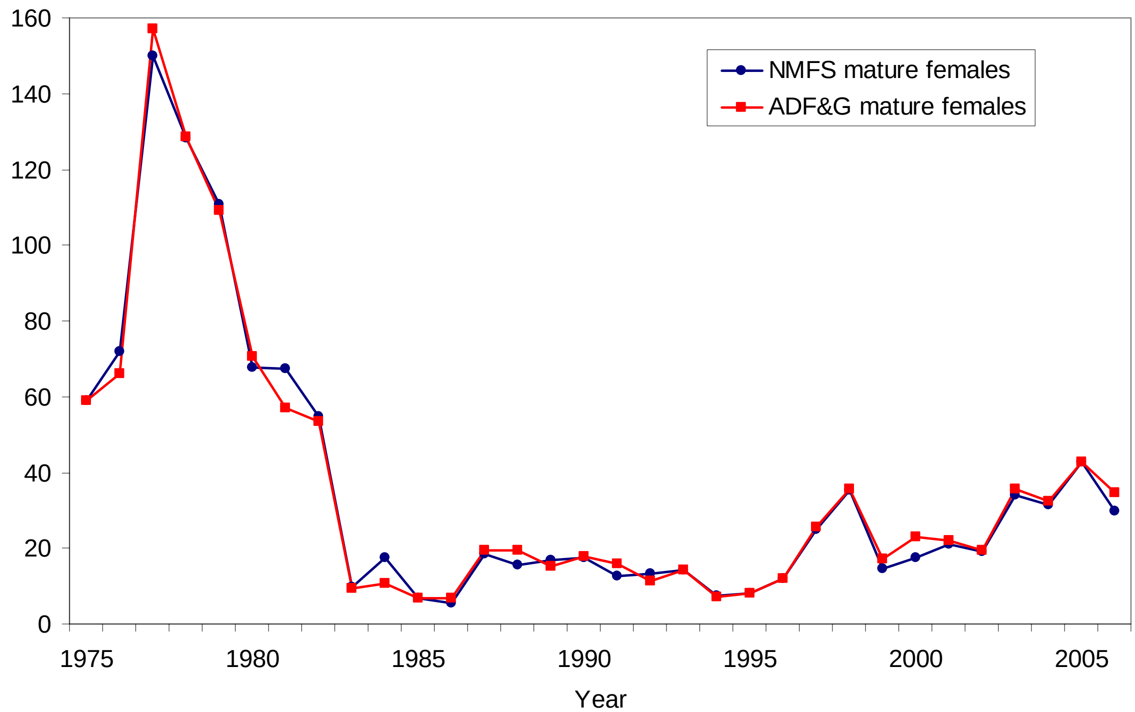


Figure 5. Comparison of survey abundance estimates (millions of crabs) by NMFS and ADF&G for Bristol Bay red king crabs from 1975 to 2006.

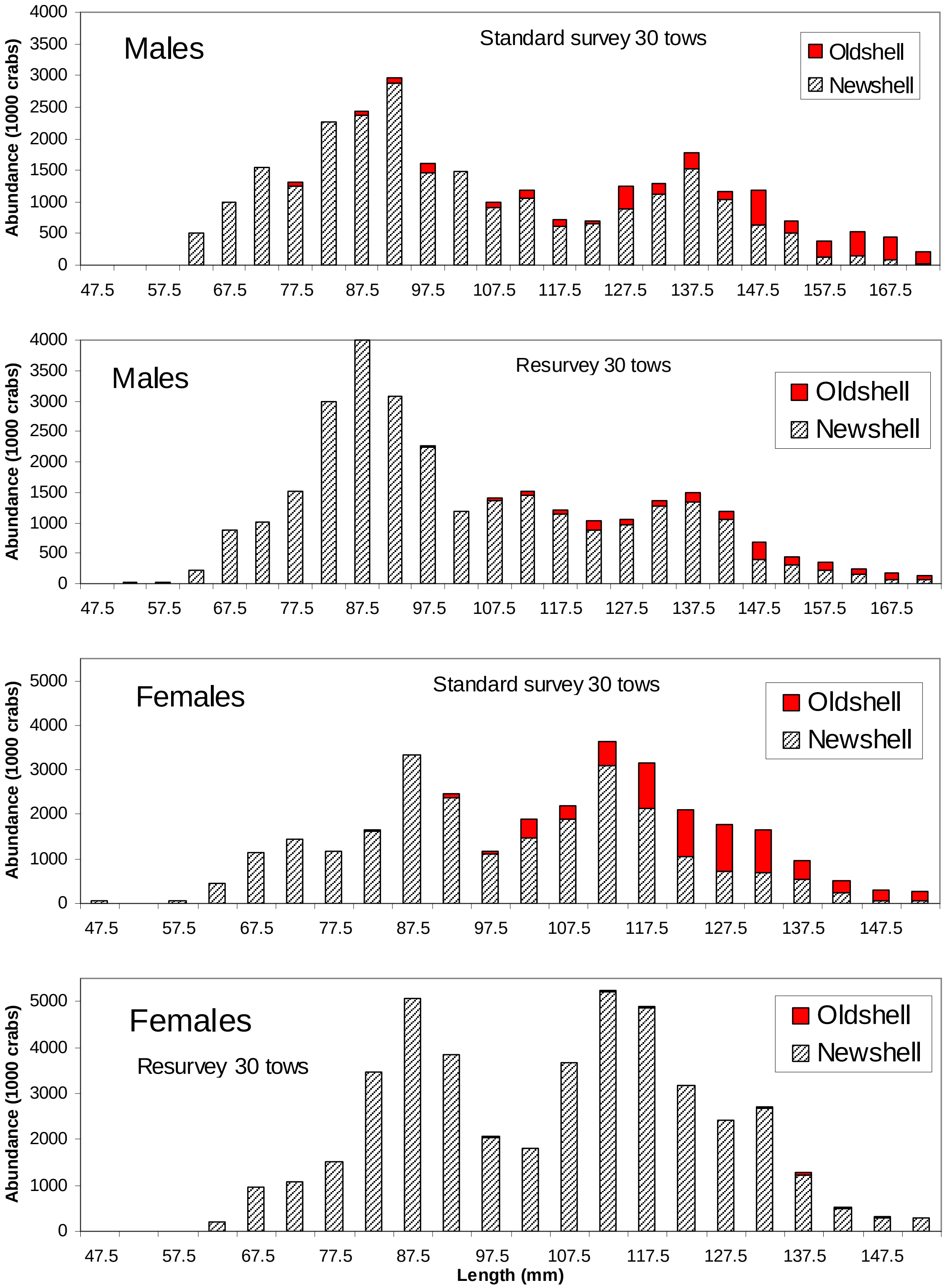


Figure 6. Comparison of area-swept estimates of abundance in 30 stations from the standard trawl survey and resurvey in 2006.

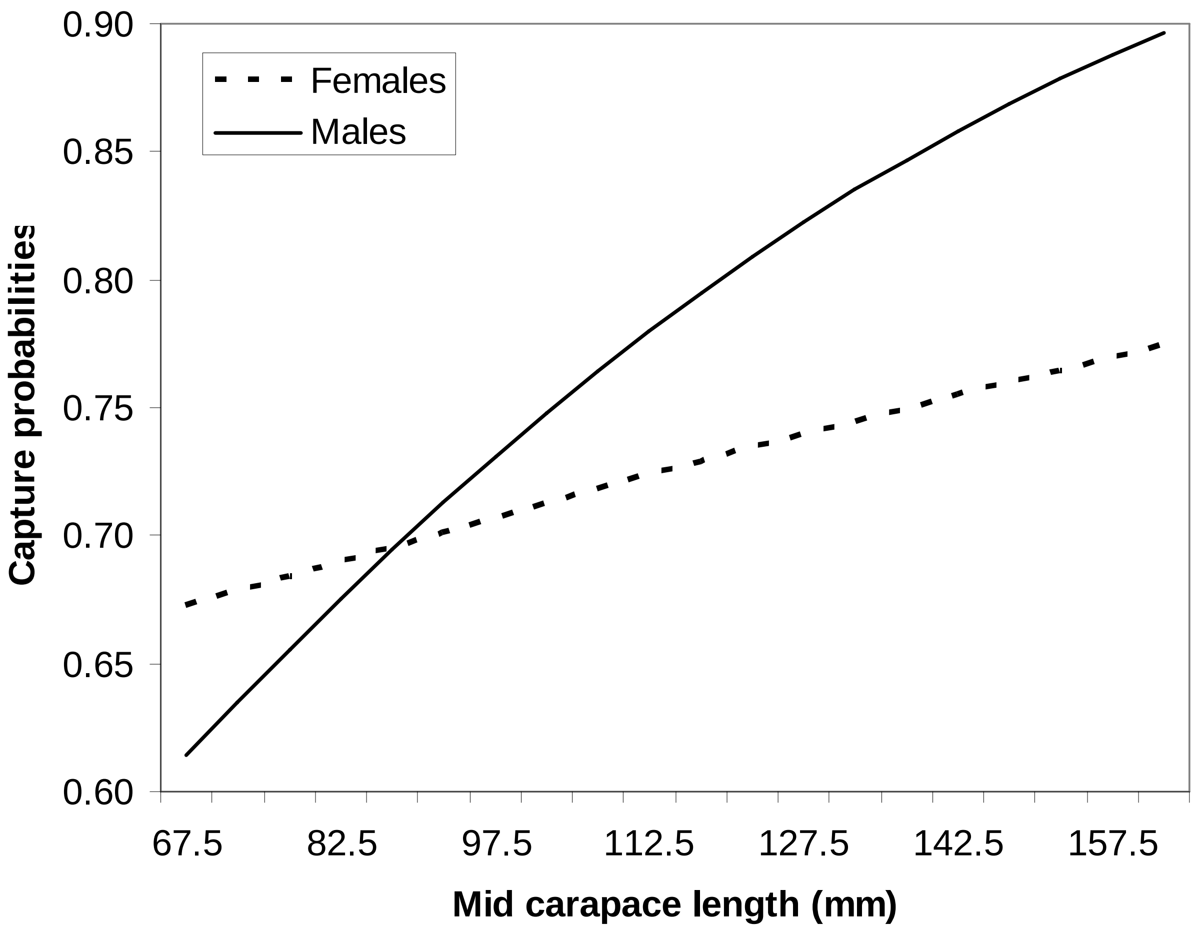
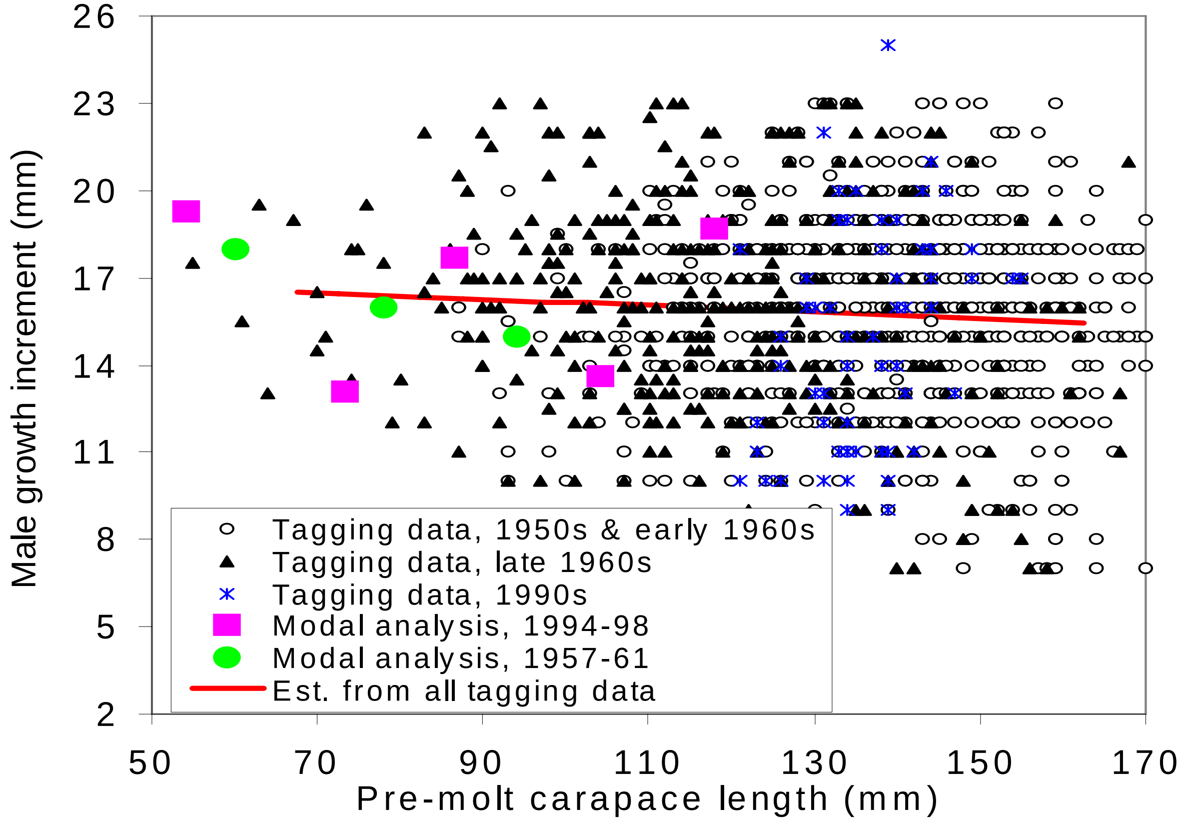


Figure 7. Estimated capture probabilities for Bristol Bay red king crab trawl survey by Weinberg et al. (2004).



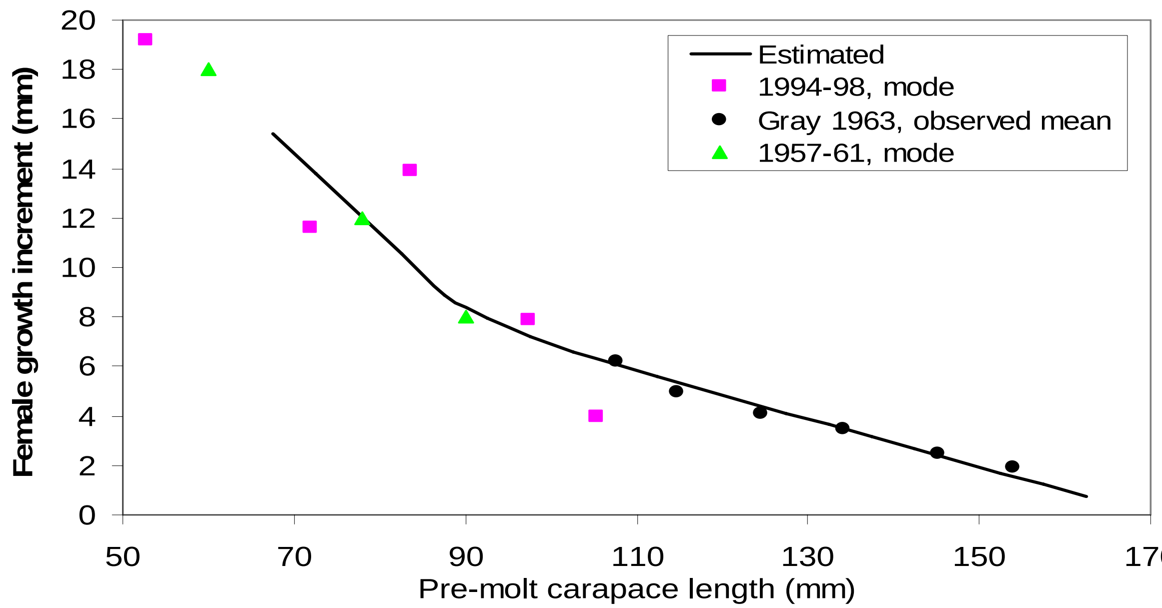


Figure 8. Mean growth increments per molt for Bristol Bay red king crabs. Note: "tagging"---based on tagging data; "mode"---based on modal analysis.

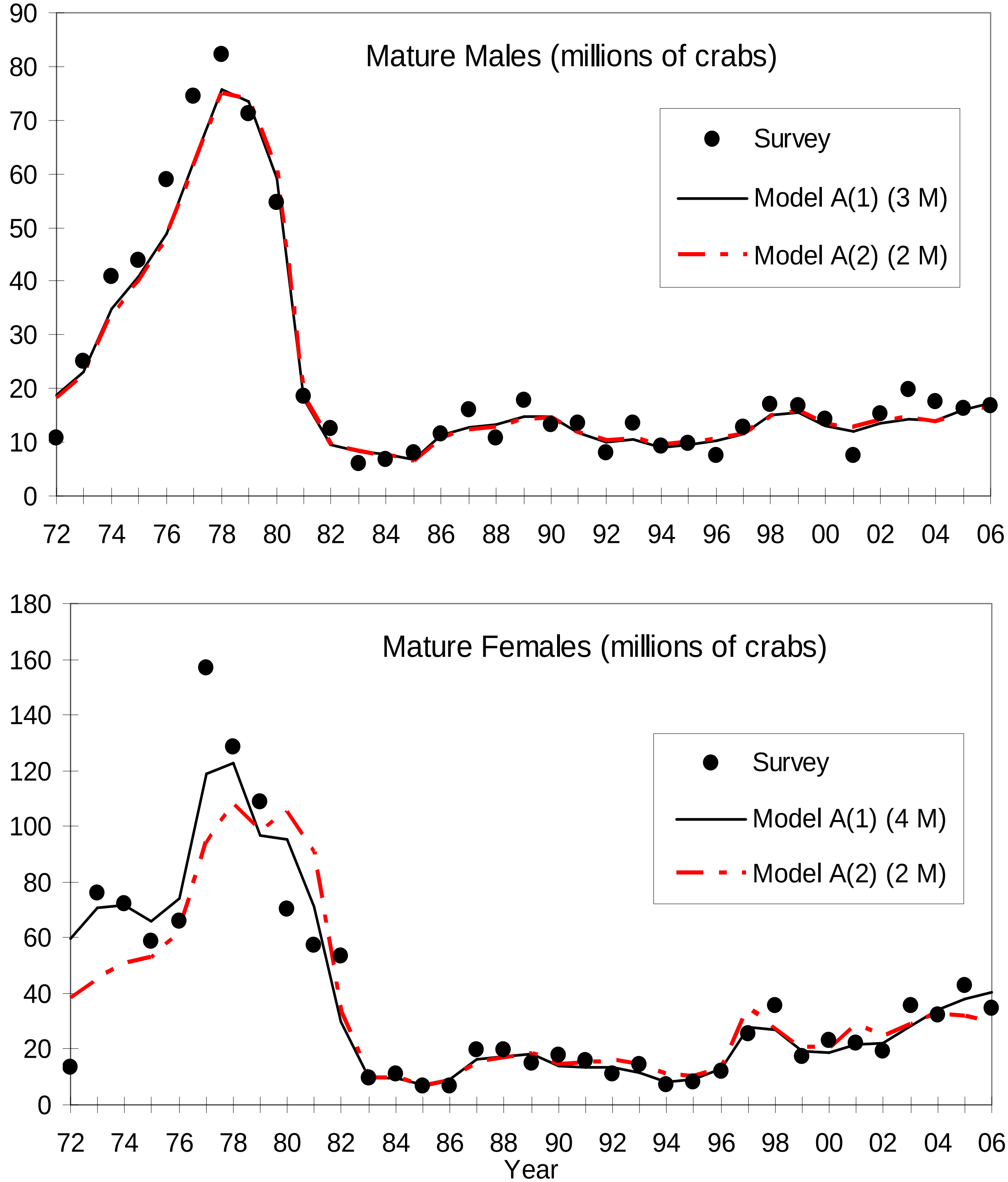


Figure 9. The length-based analysis fit (lines) to area-swept estimates (dots) of mature male (top panel) and mature female (bottom panel) Bristol Bay red king crab abundance (millions of crabs) for Model A(1) and A(2) with different levels of natural mortality.

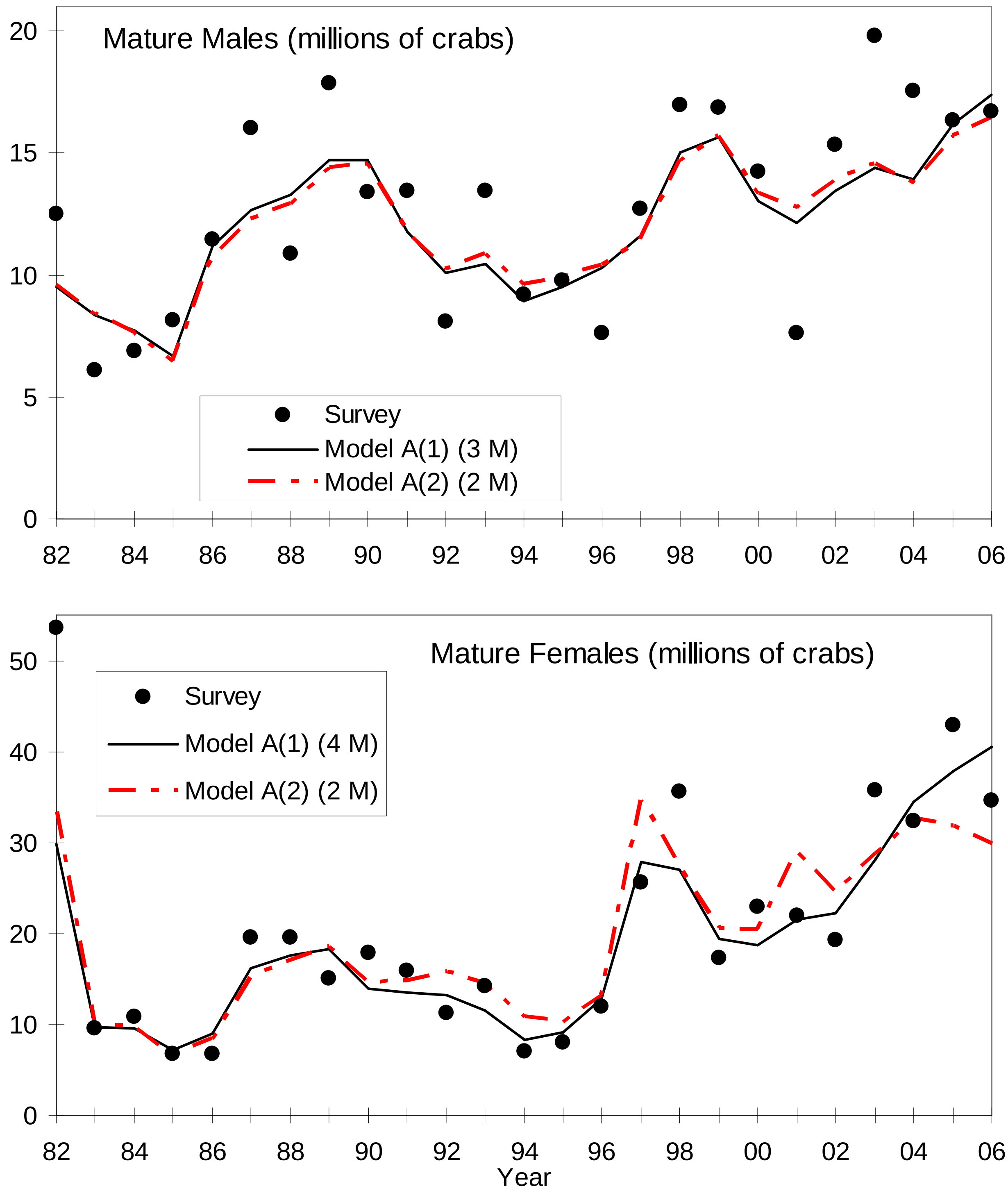


Figure 10. The length-based analysis fit (lines) to area-swept estimates (dots) of mature male (top panel) and mature female (bottom panel) Bristol Bay red king crab abundance (millions of crabs) for Model A(1) and A(2) with different levels of natural mortality. Results are illustrated from 1982 to 2006.

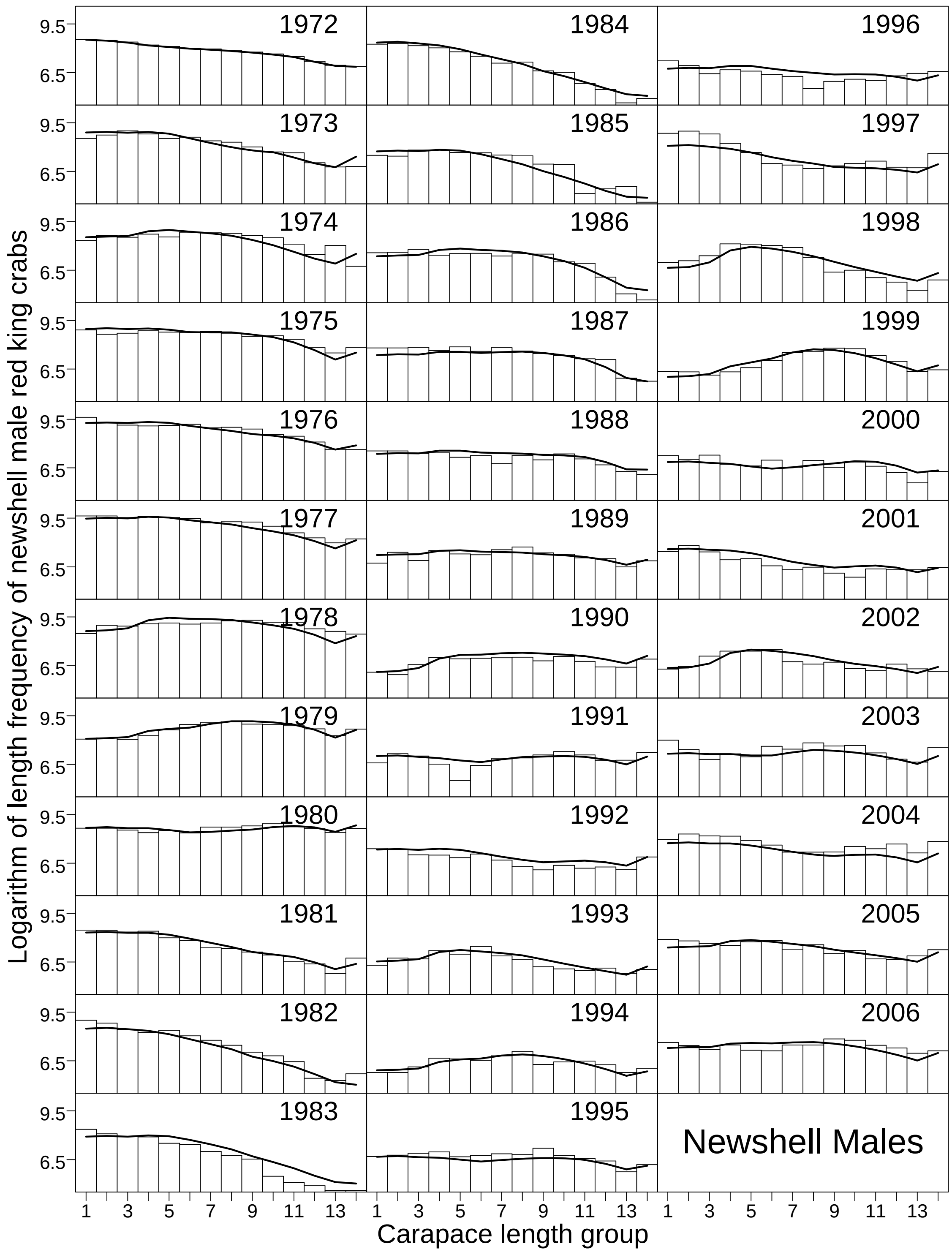


Figure 11a. Comparison of area-swept and model estimated length frequencies of Bristol Bay newshell male red king crabs by year for Model A(1). The first length group is 97.5 mm.

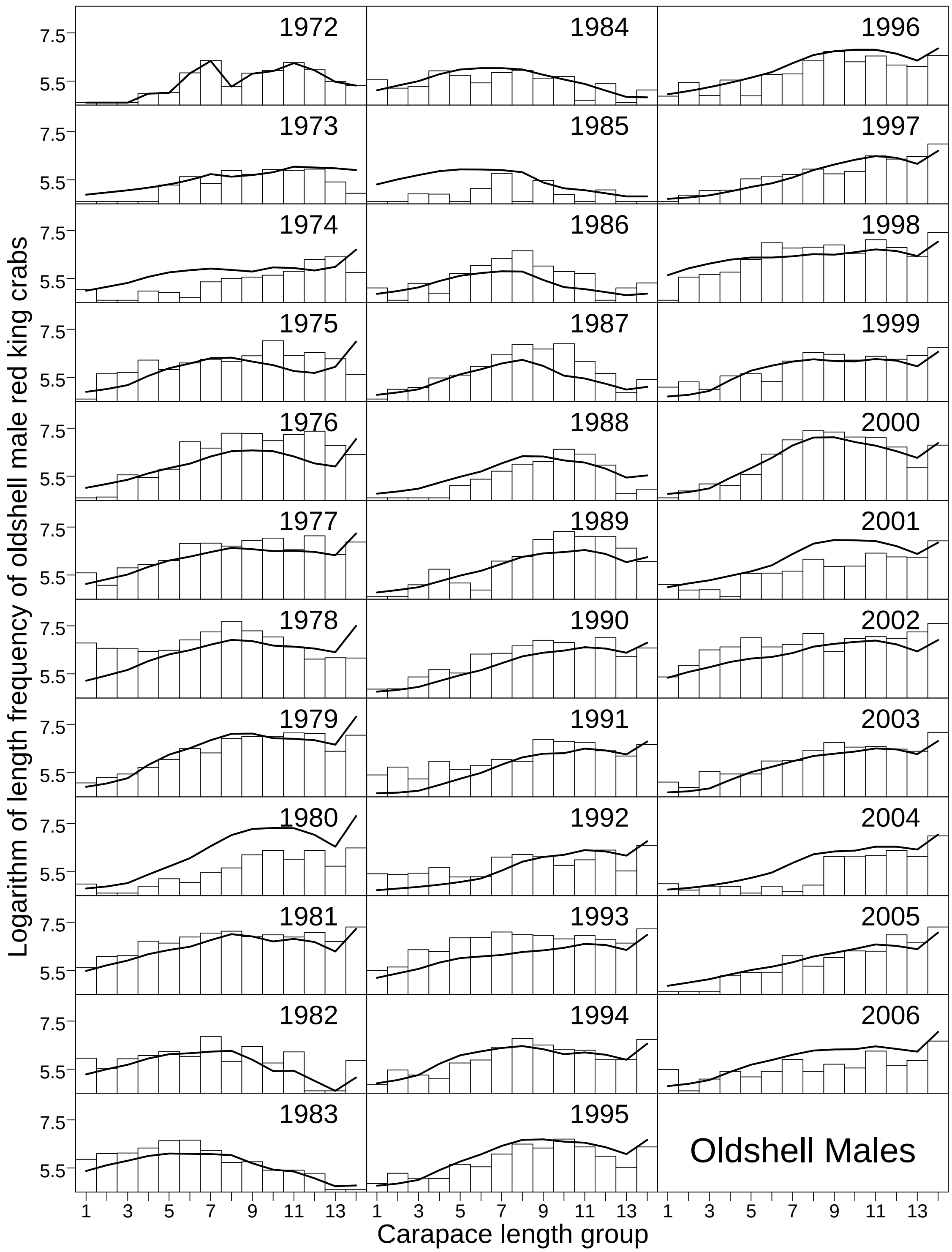


Figure 11b. Comparison of area-swept and model estimated length frequencies of Bristol Bay oldshell male red king crabs by year for Model A(1). The first length group is 97.5 mm.

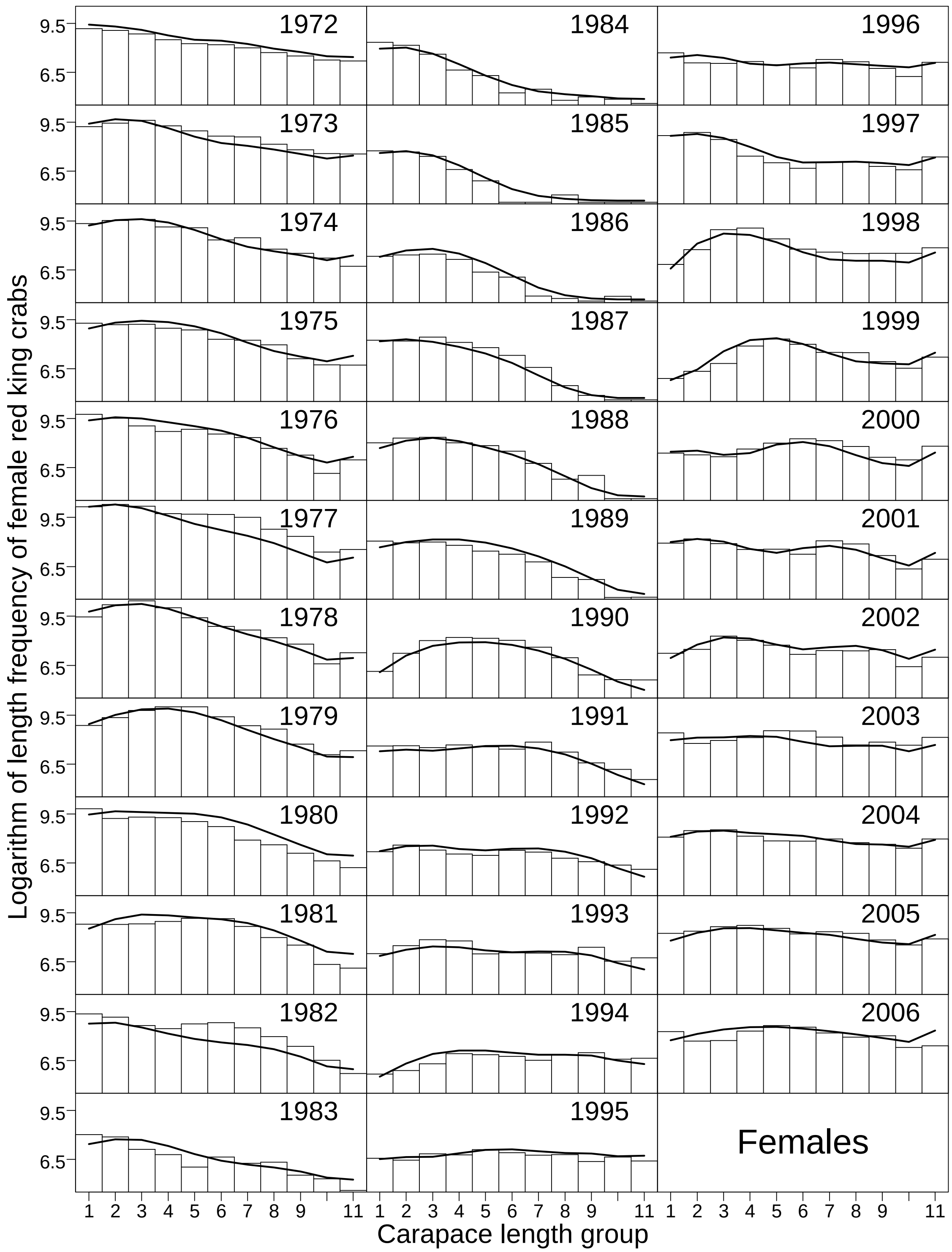


Figure 11c. Comparison of area-swept and model estimated length frequencies of Bristol Bay female red king crabs by year for Model A(1). The first length group is 92.5 mm.

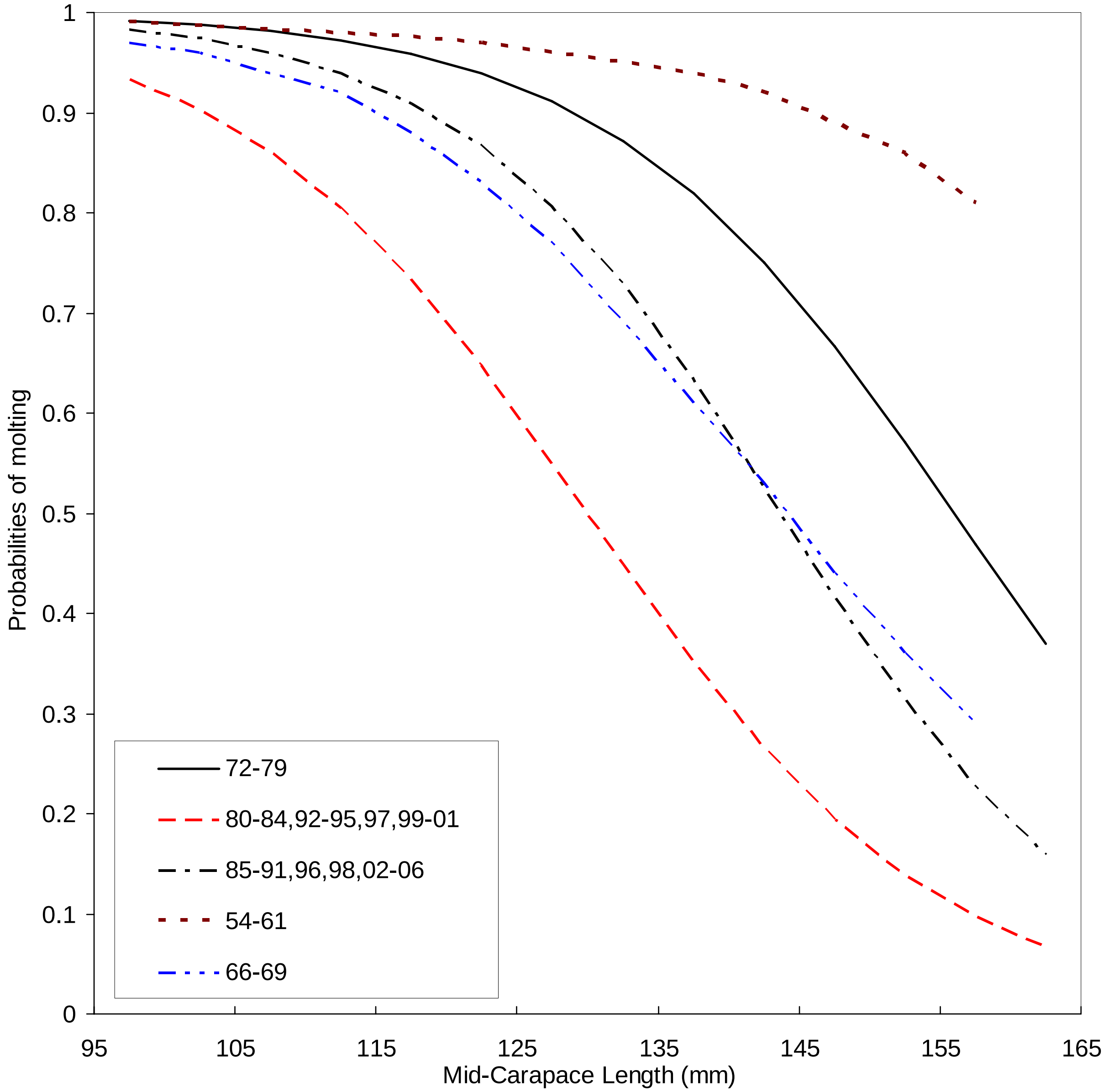


Figure 12. Comparison of estimated probabilities of molting of male red king crabs in Bristol Bay for different periods. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for the other periods were estimated under the base scenario (Model A(1)).

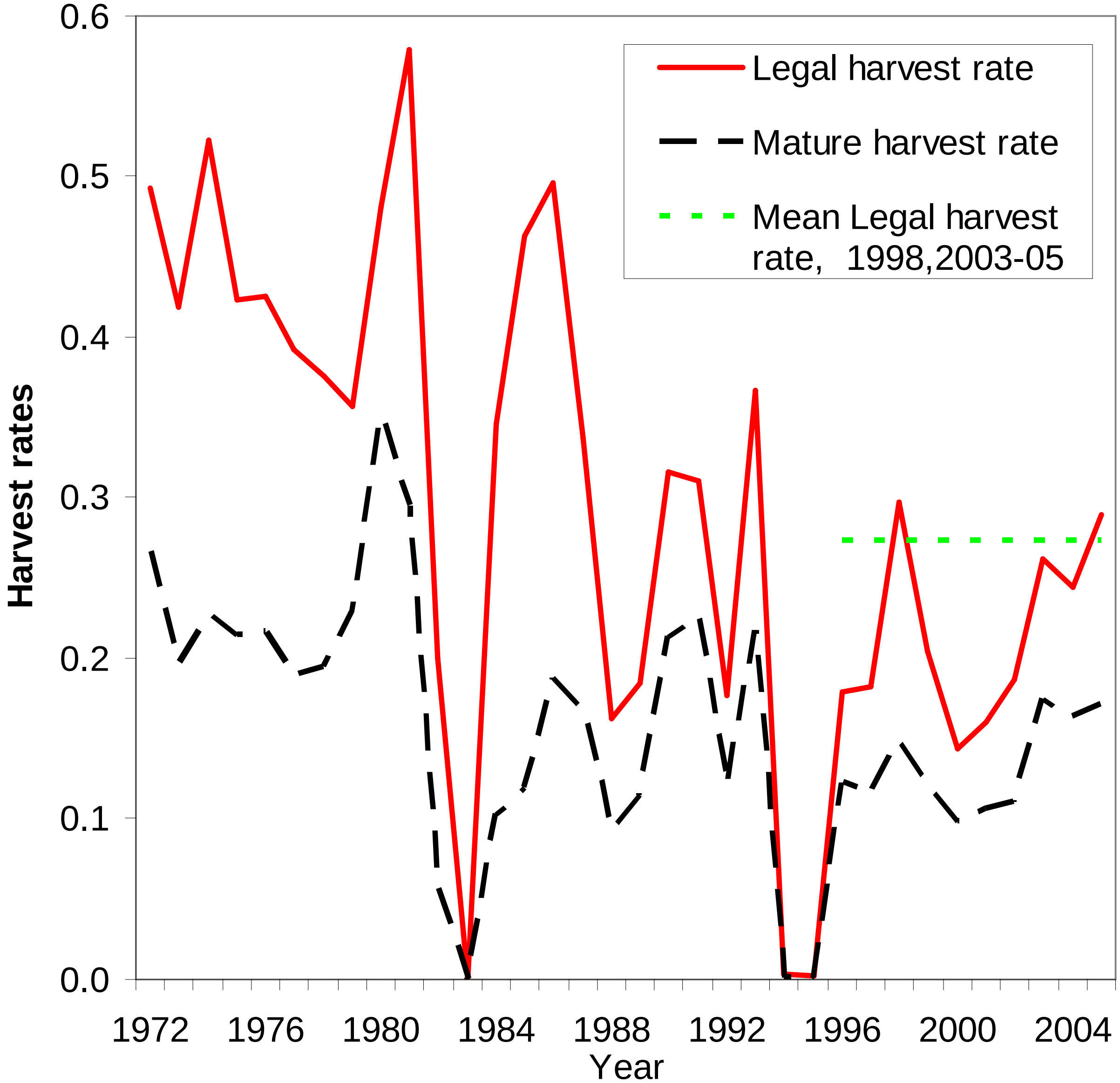


Figure 13. Mature male crab harvest rates and legal male crab harvest rates of red king crabs in Bristol Bay from 1972 to 2005 under the base scenario (Model A(1)).

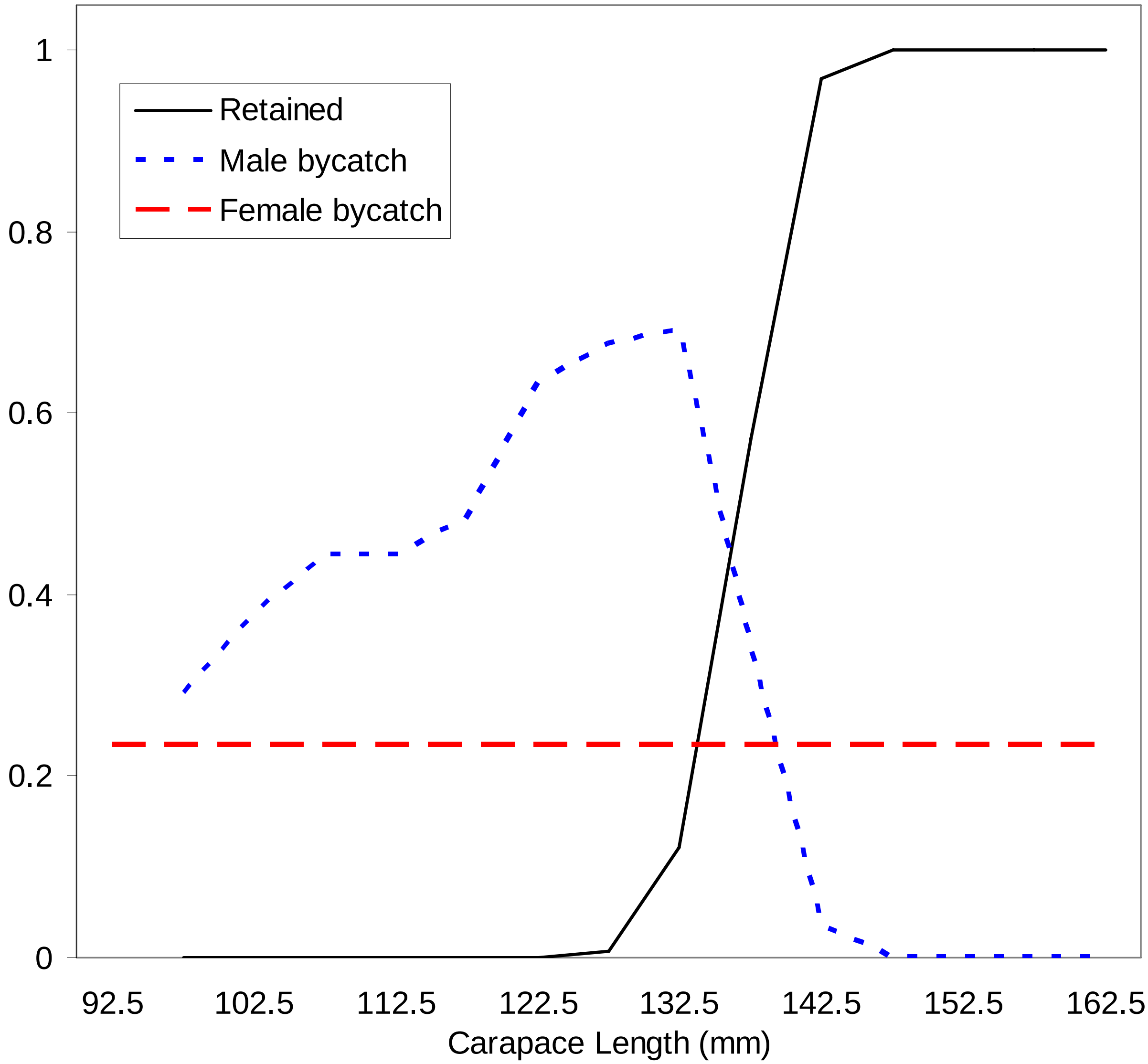
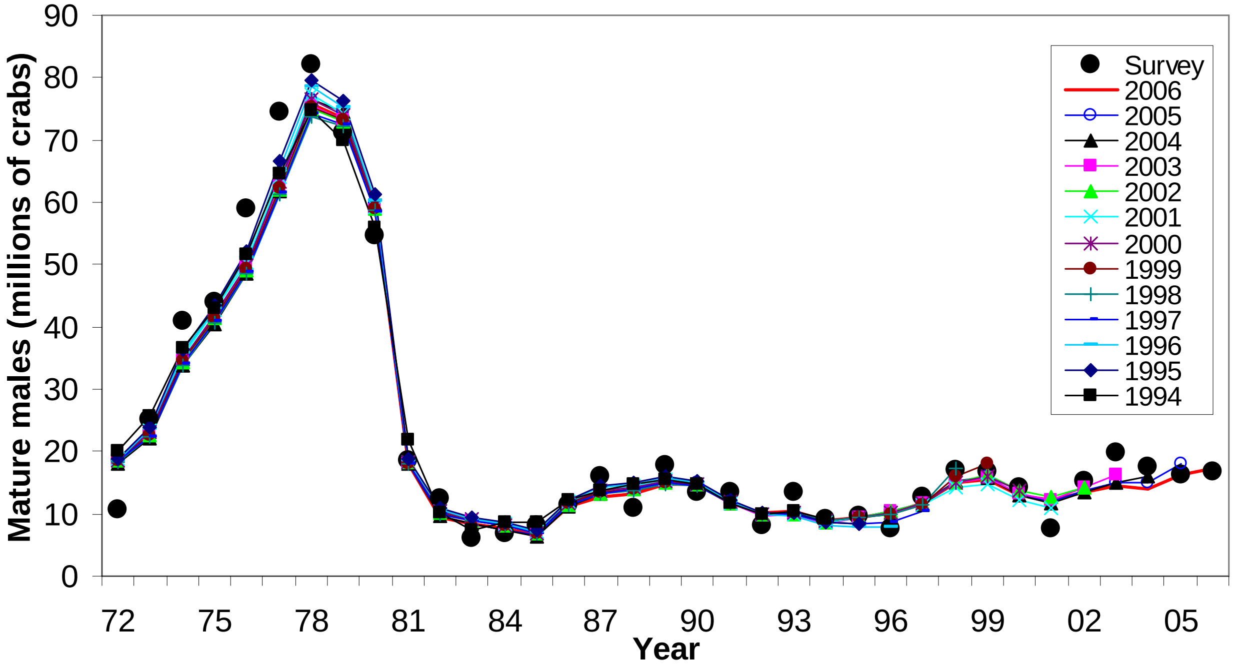


Figure 14. Estimated mean retained selectivity and bycatch selectivities in the directed pot fishery based on observed catch and bycatch data and model estimated population abundance (Model A(1)) from 1972 to 2005.



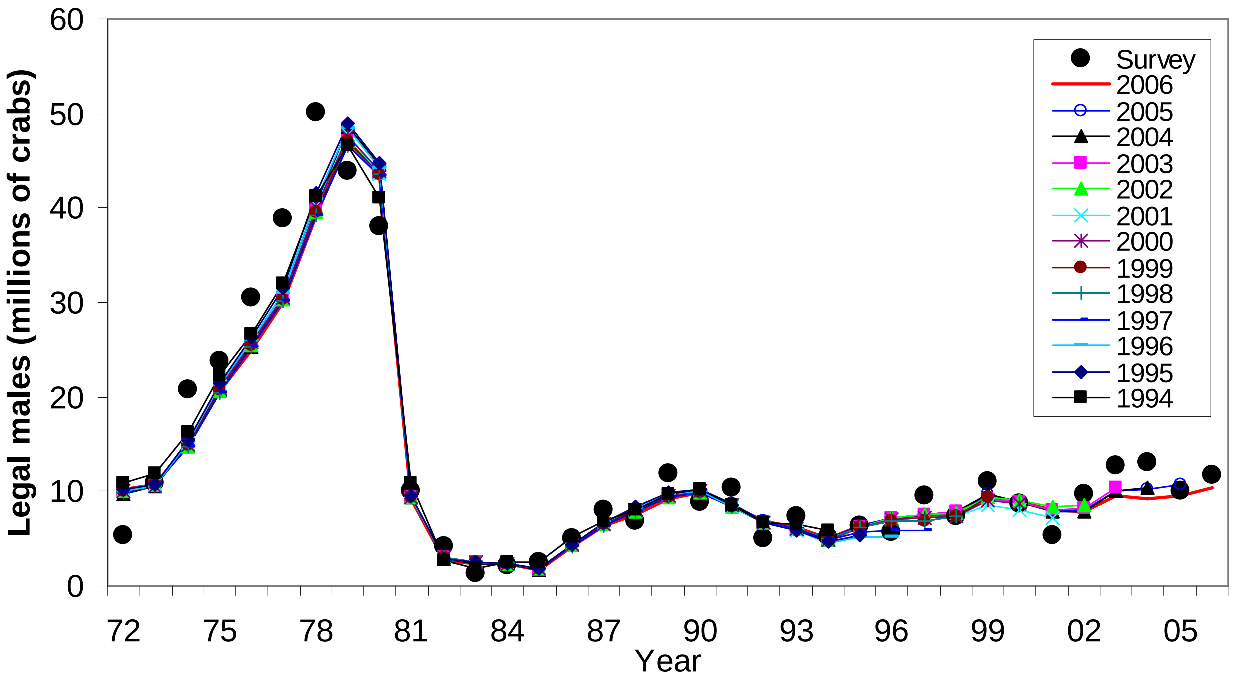


Figure 15. Comparison of mature (top) and legal (bottom) male abundance estimates of Bristol Bay red king crabs from 1972 to 2006 made by LBA assessments with terminal years 1994-2006 under the base scenario and by area-swept methods. Legend shows the year in which the assessment was conducted. For each assessment year, abundances were estimated from 1972 to the terminal year.

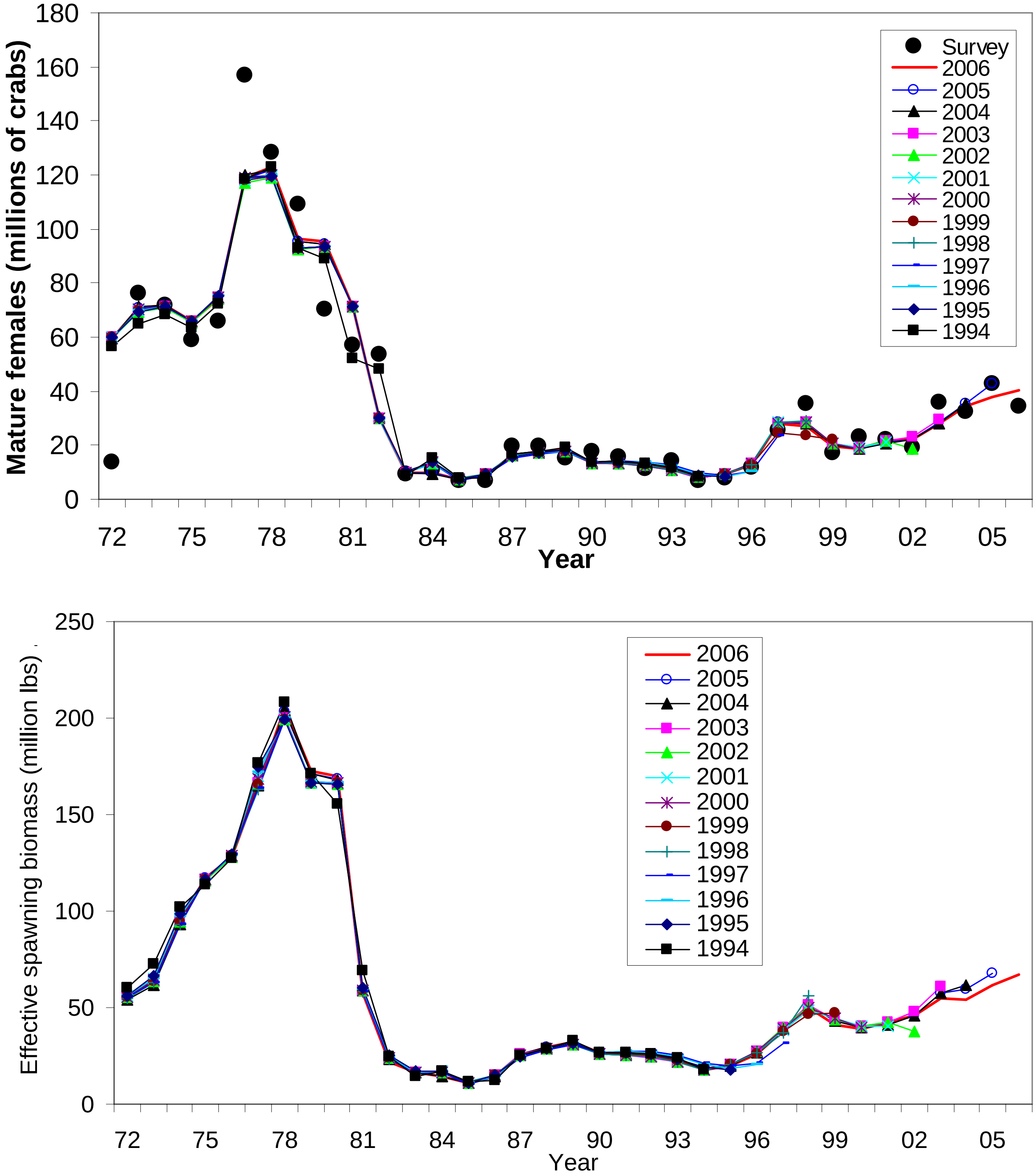


Figure 16. Comparison of mature female abundance estimates (top) and effective spawning biomass estimates (bottom) of Bristol Bay red king crabs from 1972 to 2006 made by LBA assessments with terminal years 1994-2006 under the base scenario and by area-swept methods. Legend shows the year in which the assessment was conducted. For each assessment year, abundances were estimated from 1972 to the terminal year.

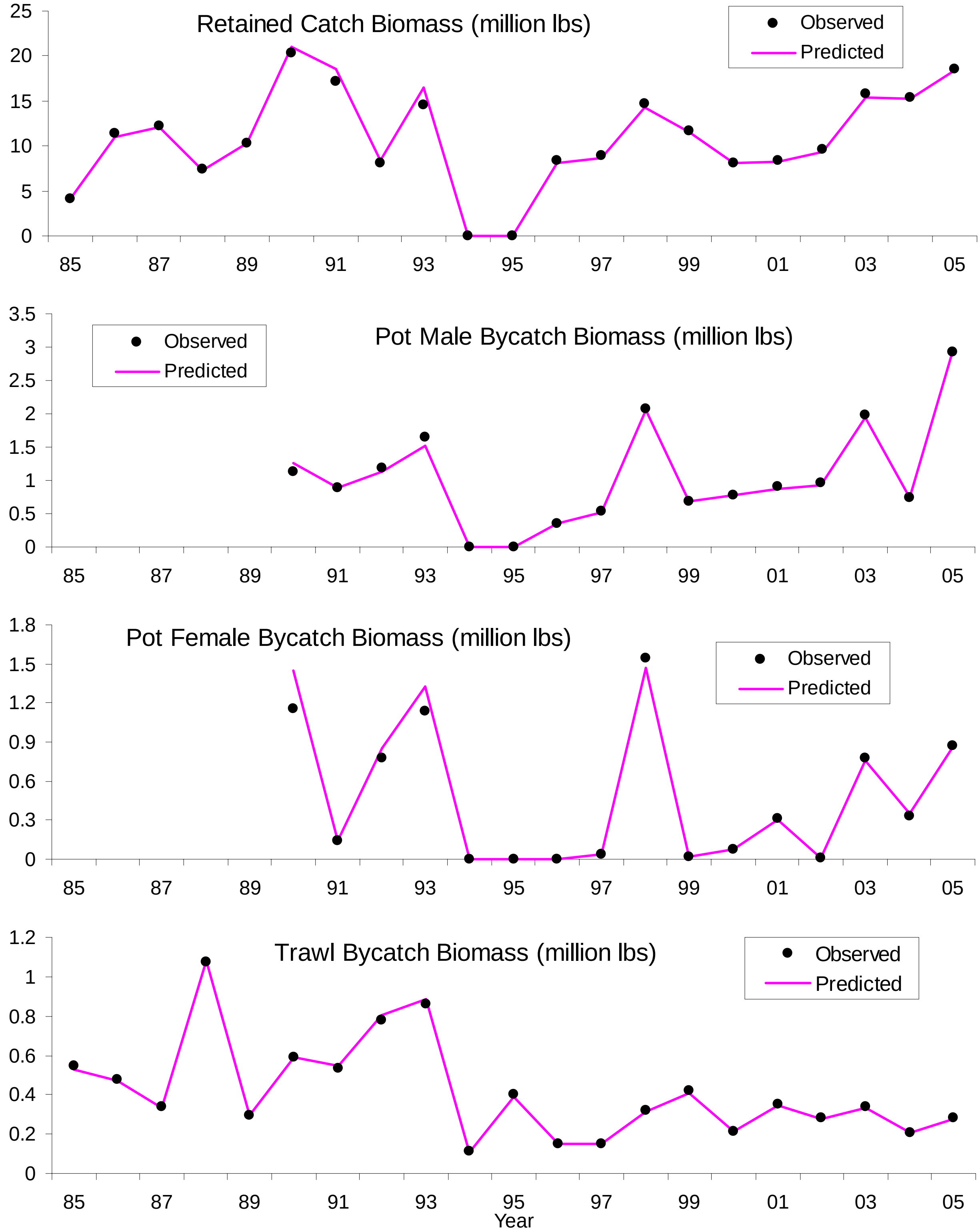


Figure 17. Observed and predicted catch mortality biomasses for Model B. Mortality biomass is equal to caught biomass times a handling mortality rate.

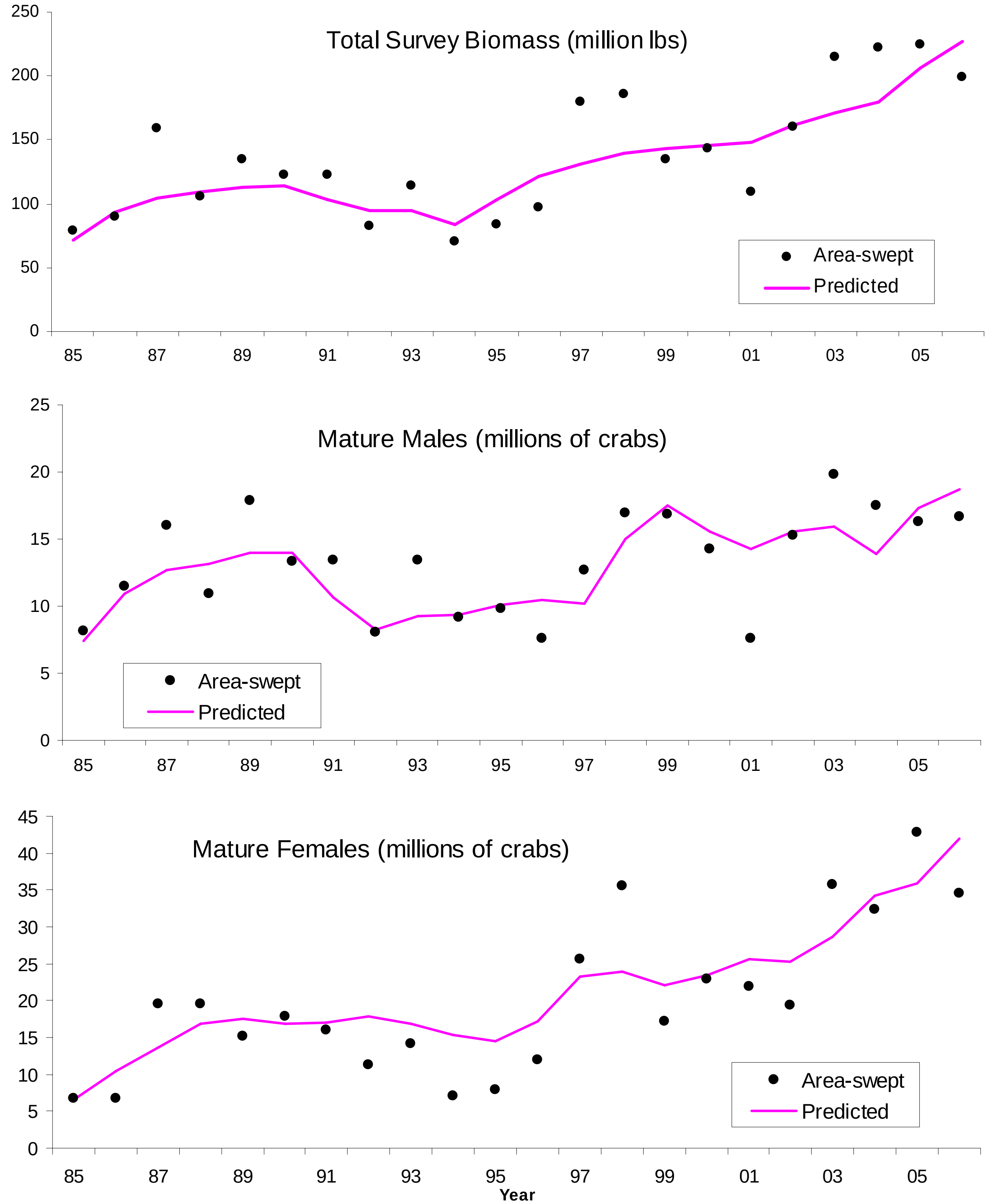


Figure 18. Comparisons of area-swept estimates of total survey biomass, mature male (>119 mm) and mature female (>89 mm) abundance and model prediction for Model B.

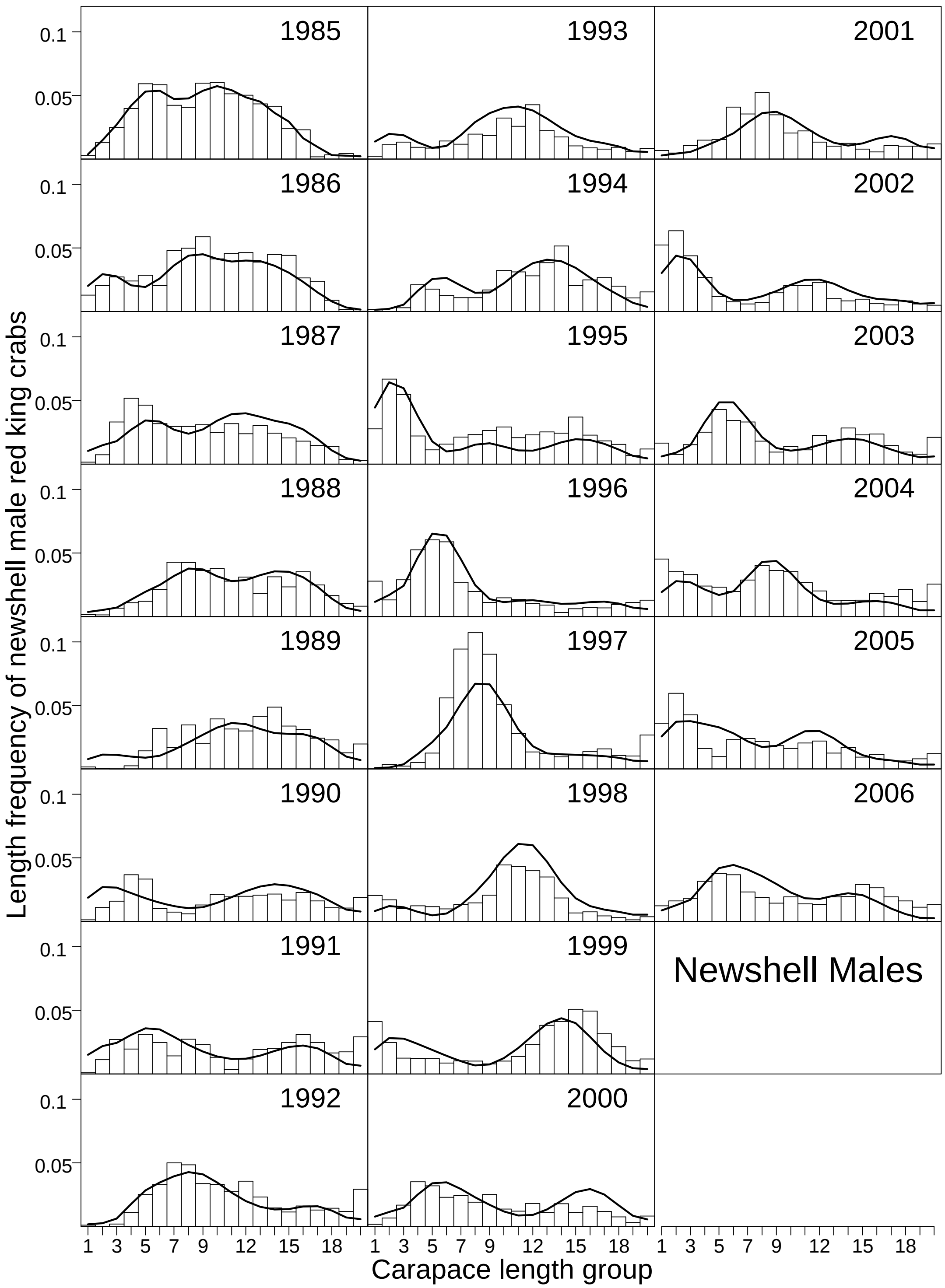


Figure 19a. Comparison of area-swept and model estimated survey length frequencies of Bristol Bay newshell male red king crabs by year for Model B. The first length group is 67.5 mm.

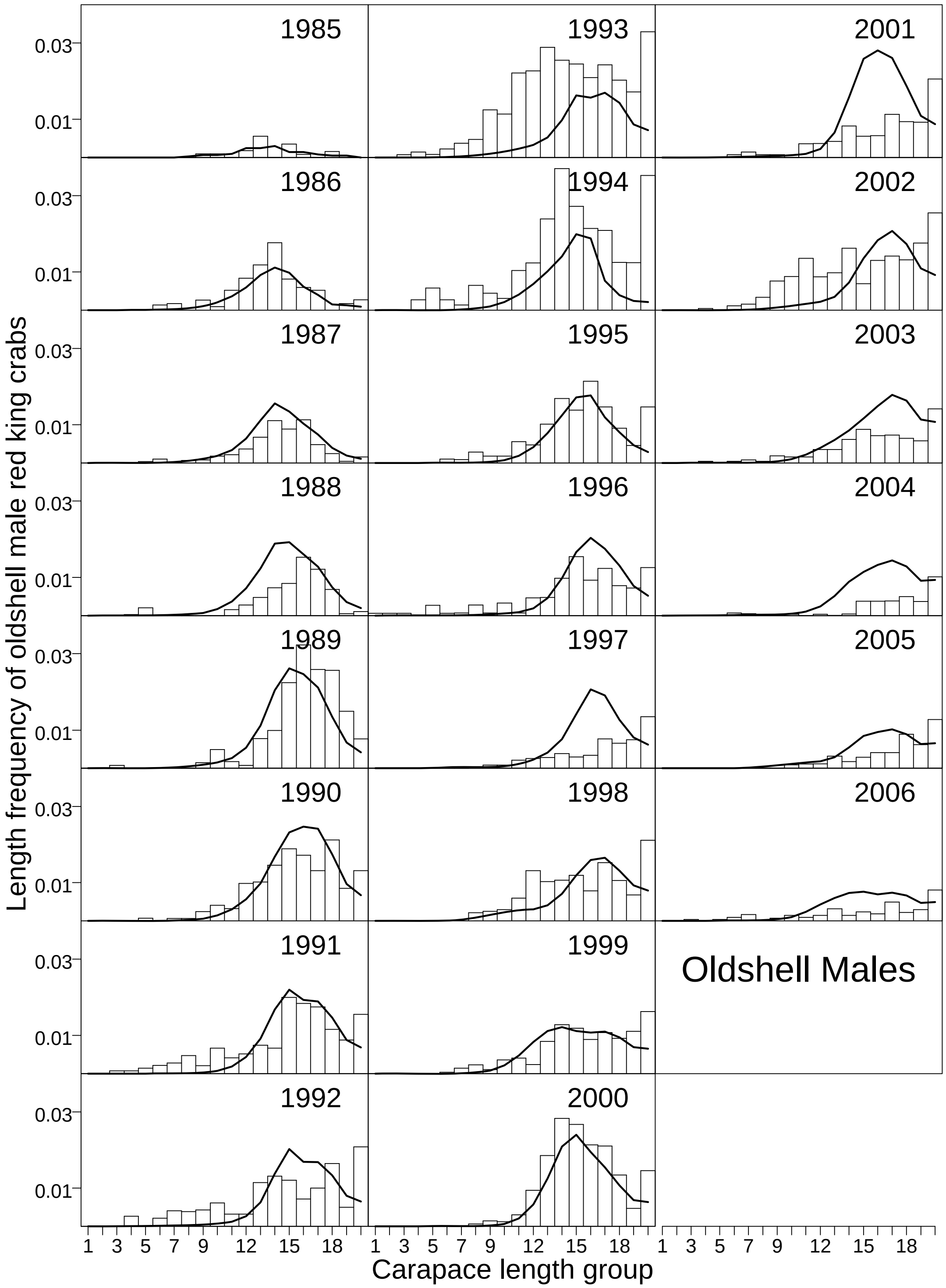


Figure 19b. Comparison of area-swept and model estimated survey length frequencies of Bristol Bay oldshell male red king crabs by year for Model B. The first length group is 67.5 mm.

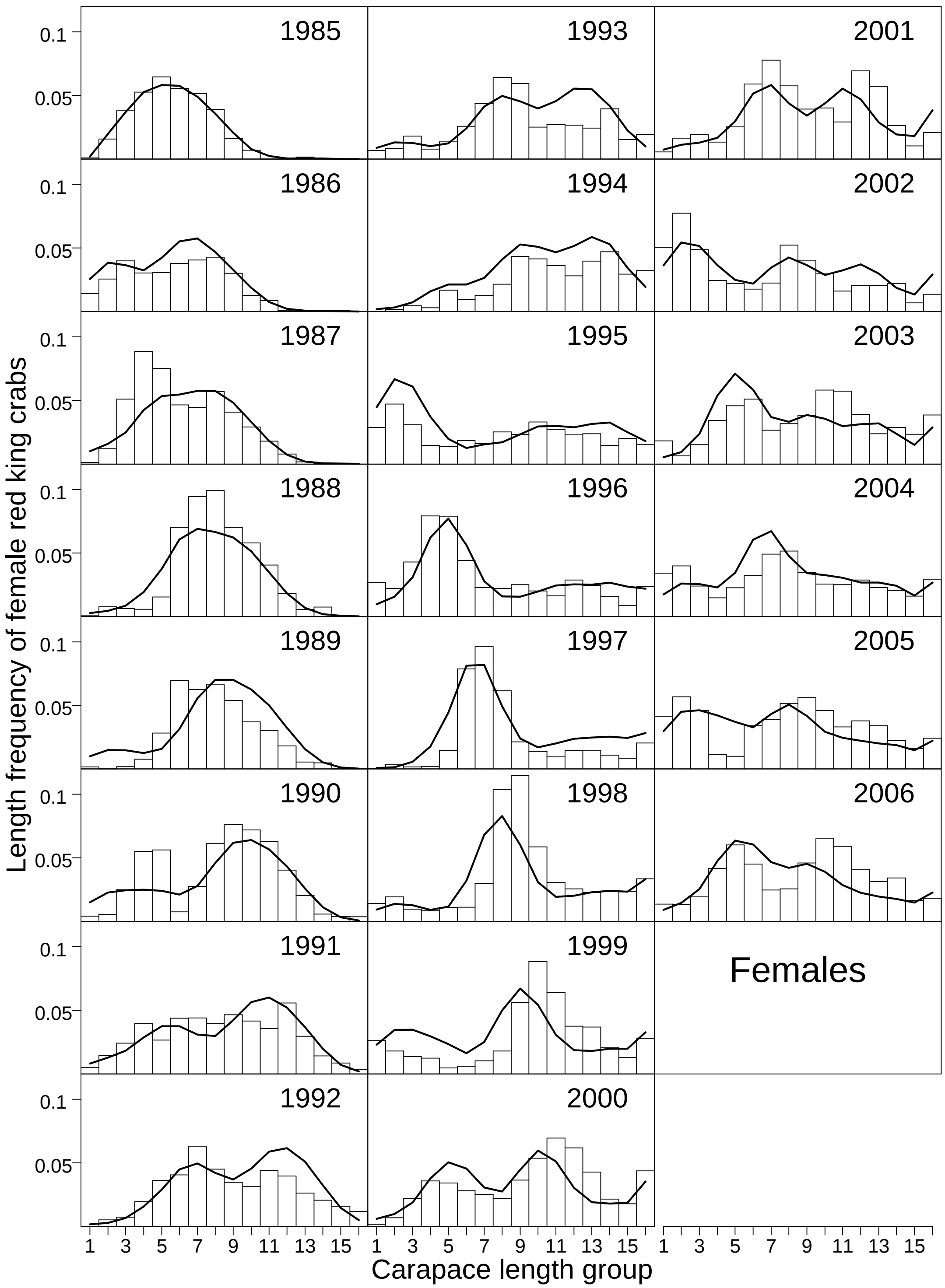


Figure 19c. Comparison of area-swept and model estimated survey length frequencies of Bristol Bay female red king crabs by year for Model B. The first length group is 67.5 mm.

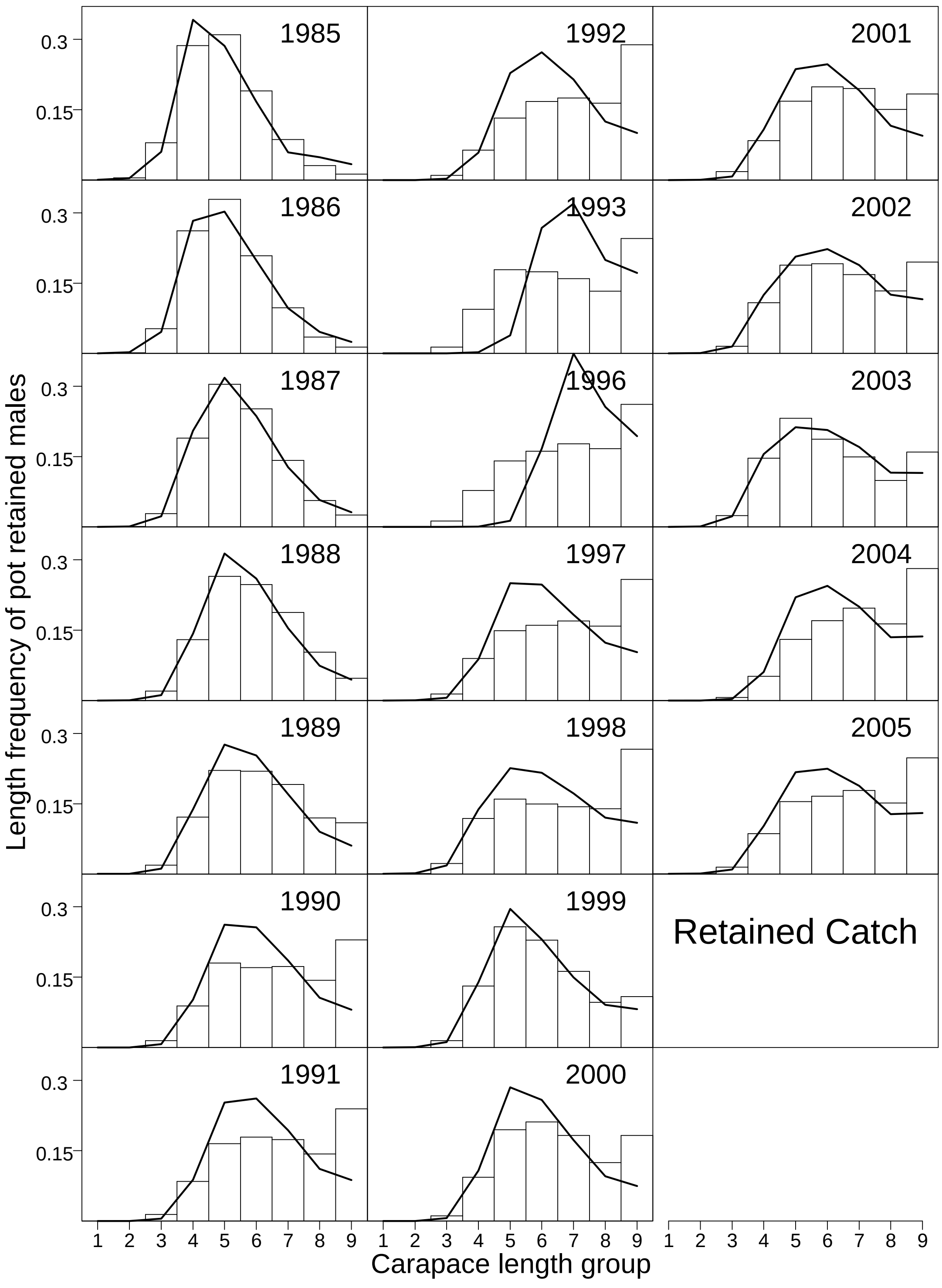


Figure 20. Comparison of observed and model estimated retained length frequencies of Bristol Bay male red king crabs by year in the directed pot fishery for Model B. The first length group is 122.5 mm.

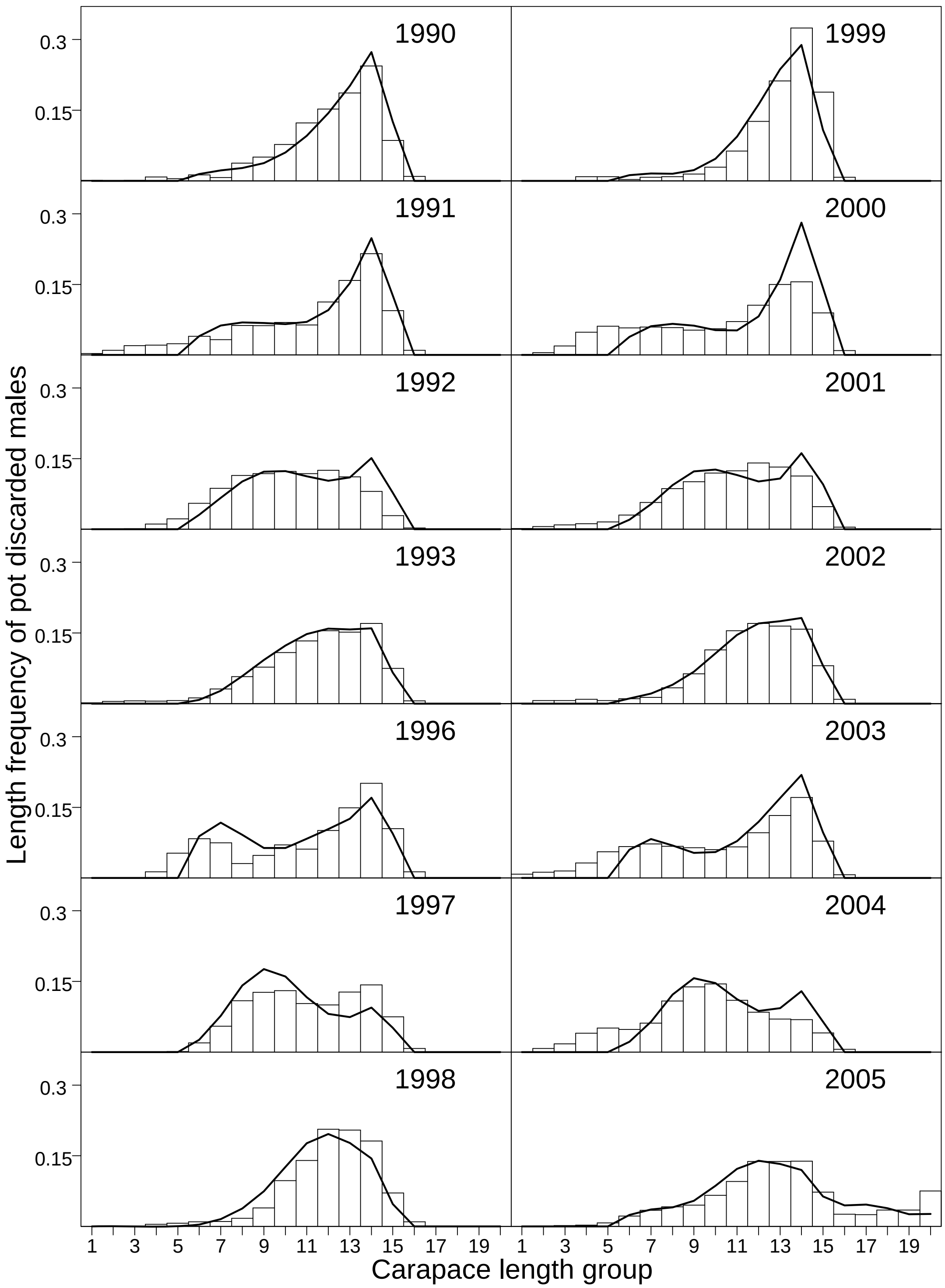


Figure 21a. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crabs by year in the directed pot fishery for Model B. The first length group is 67.5 mm.

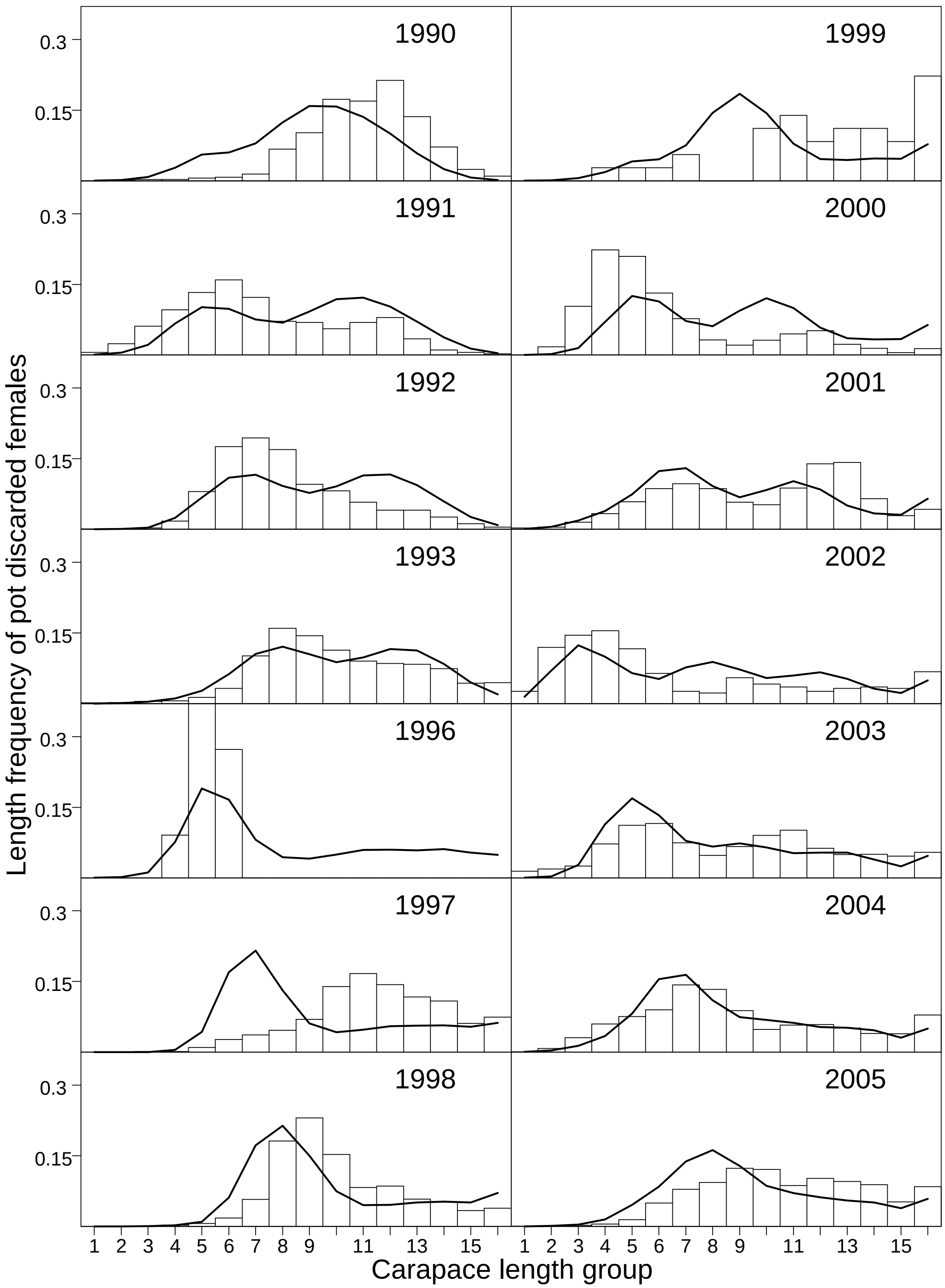


Figure 21b. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crabs by year in the directed pot fishery for Model B. The first length group is 67.5 mm.

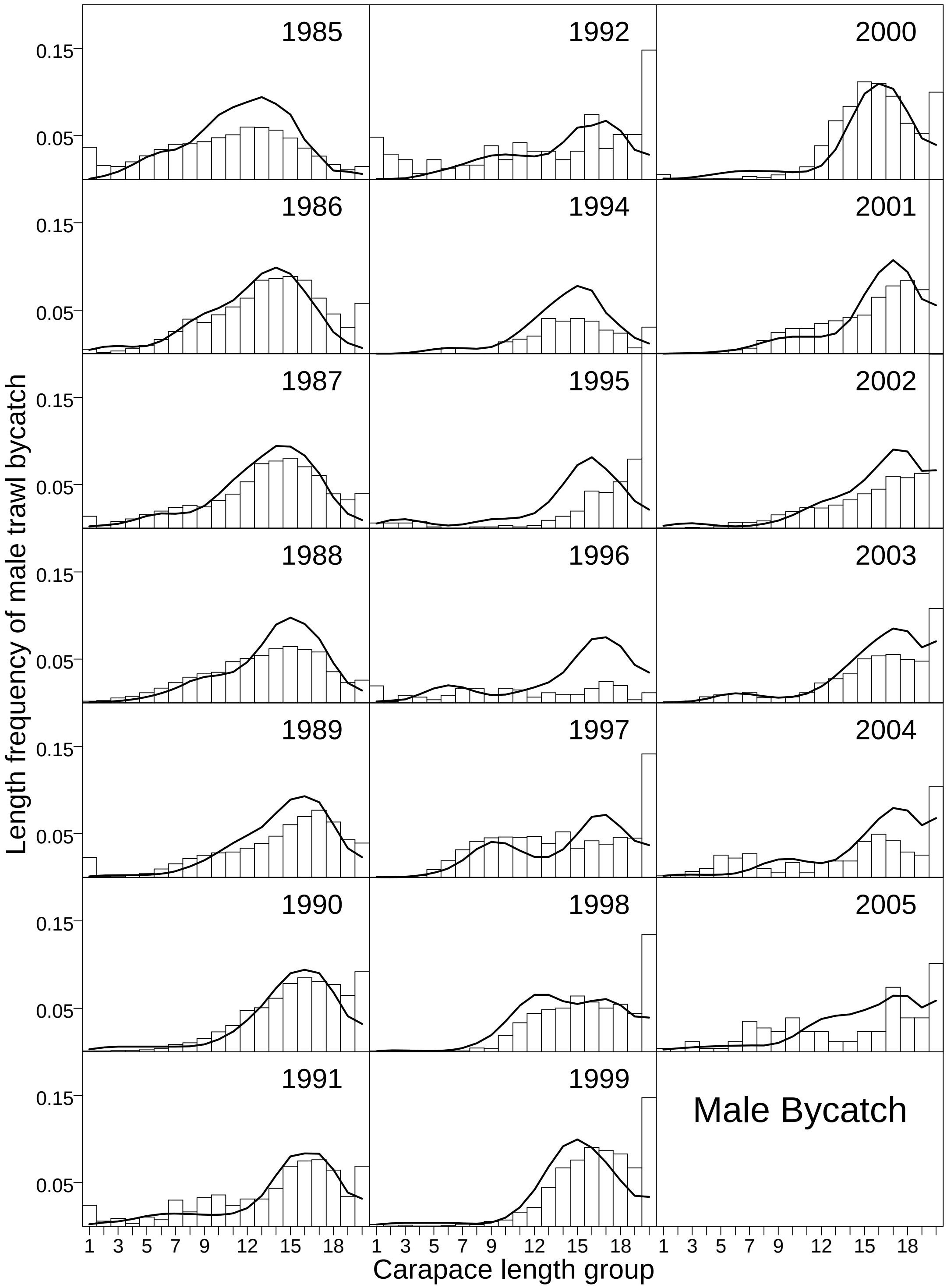


Figure 22a. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crabs by year in the groundfish trawl fisheries for Model B. The first length group is 67.5 mm.

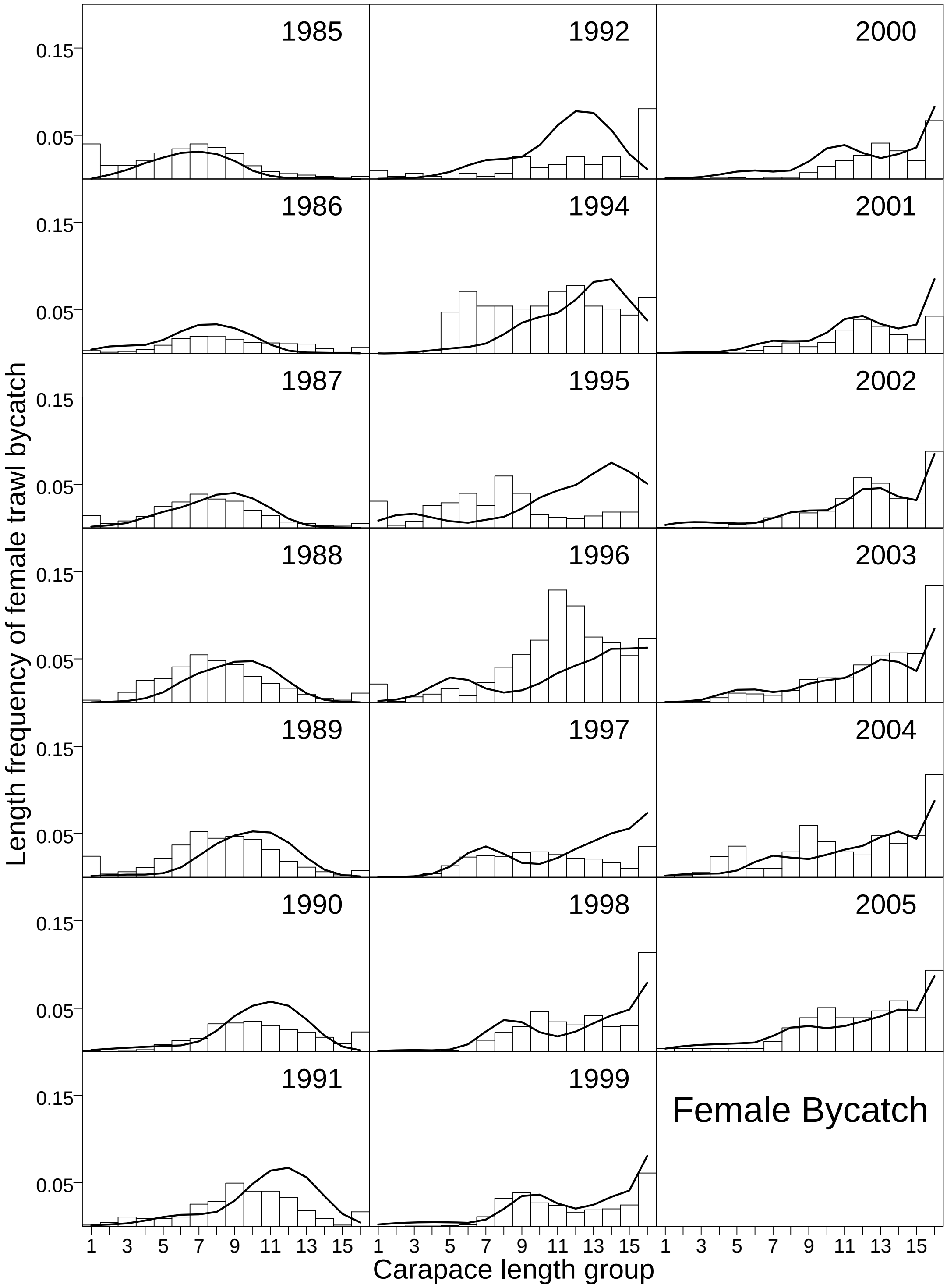


Figure 22b. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crabs by year in the groundfish trawl fisheries for Model B. The first length group is 67.5 mm.

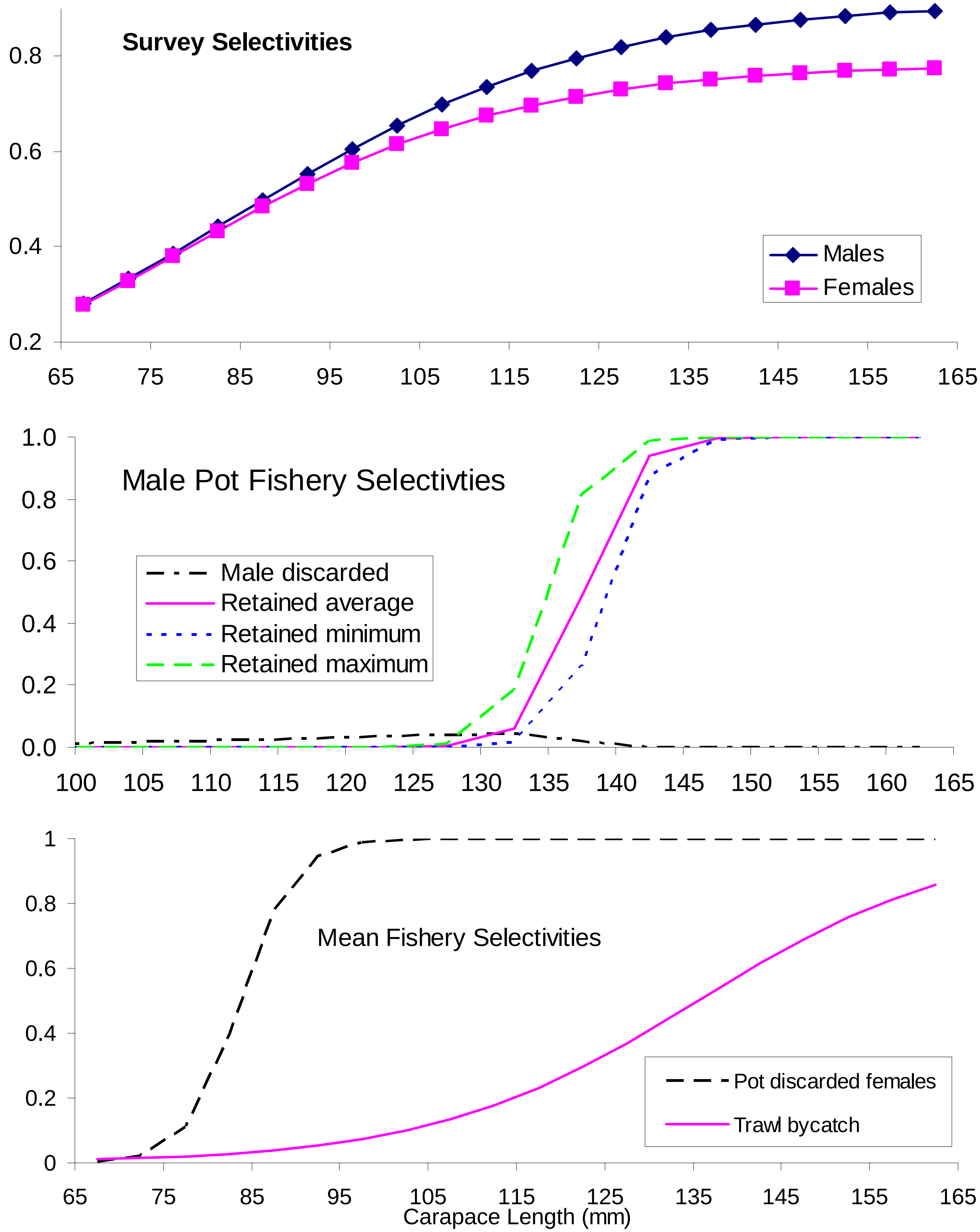


Figure 23. Estimated trawl survey selectivities, mean pot fishery selectivities, and mean groundfish trawl bycatch selectivities for Model B.

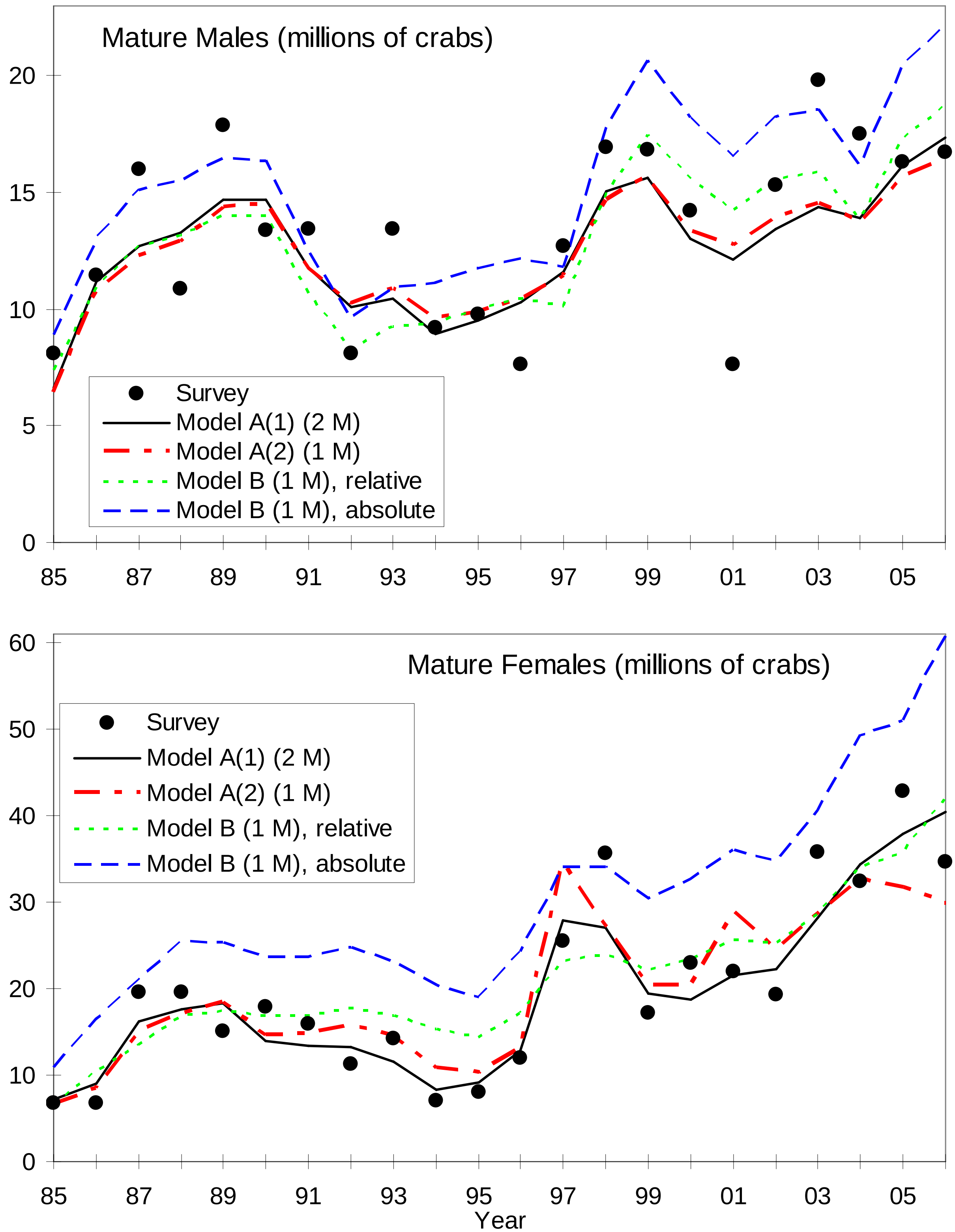


Figure 24. Comparison of mature abundance estimates for Model A and Model B and relative and absolute abundance estimates for Model B from 1985 to 2006.

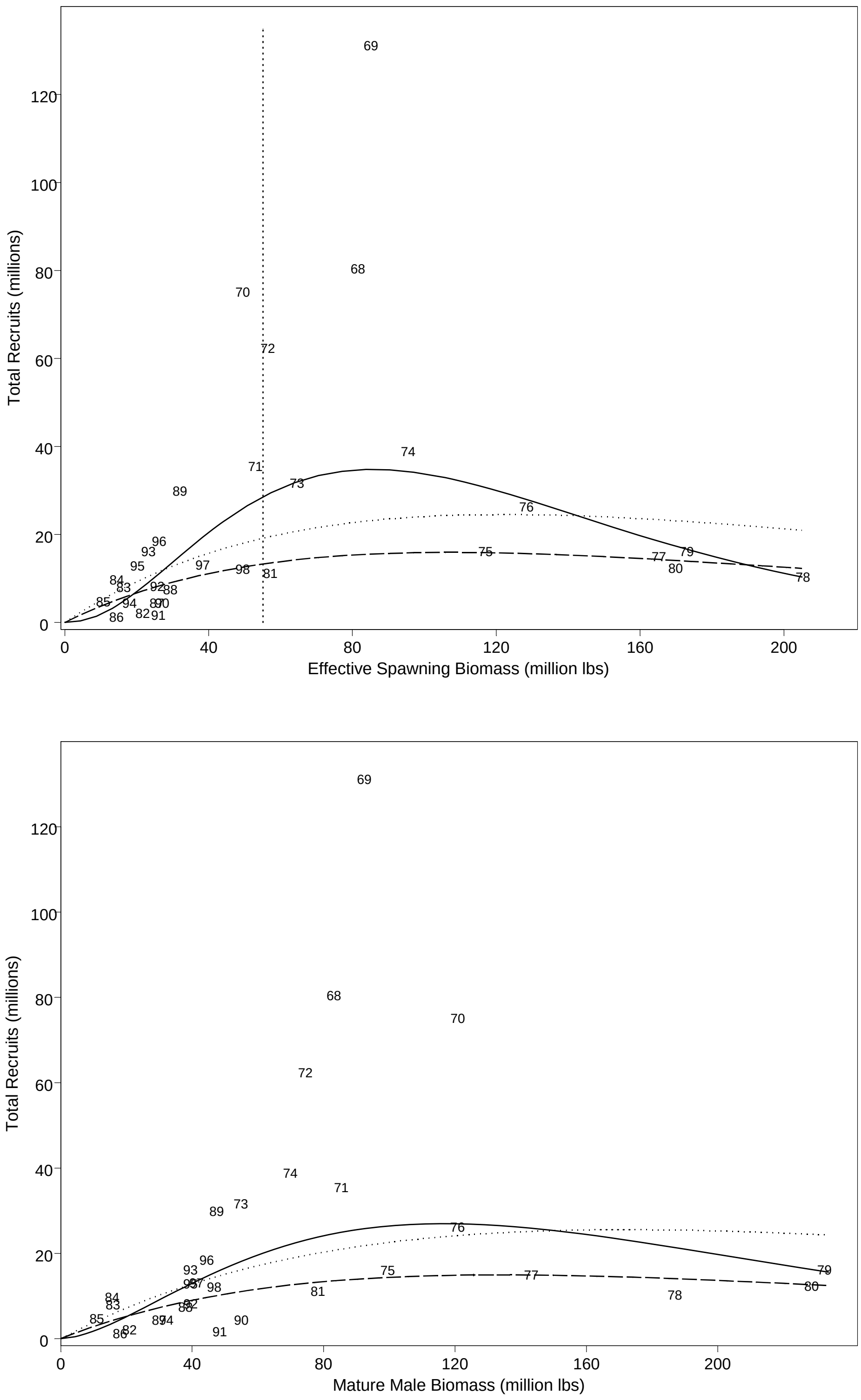


Figure 25. Relationships between effective spawning biomass and total recruits and between mature male biomass on Feb. 15 and total recruits at age 7 (i.e., 8-year time lag) for Bristol Bay red king crabs under the base scenario. Numerical labels are years of mating, the solid line is a general Ricker curve, the dotted line is an autocorrelated Ricker curve without υ_t values (equation 16), and the dashed line is a Ricker curve fit to recruitment data after 1976 brood year. The vertical dotted line is the targeted rebuilding level of 55 million lbs effective spawning biomass.

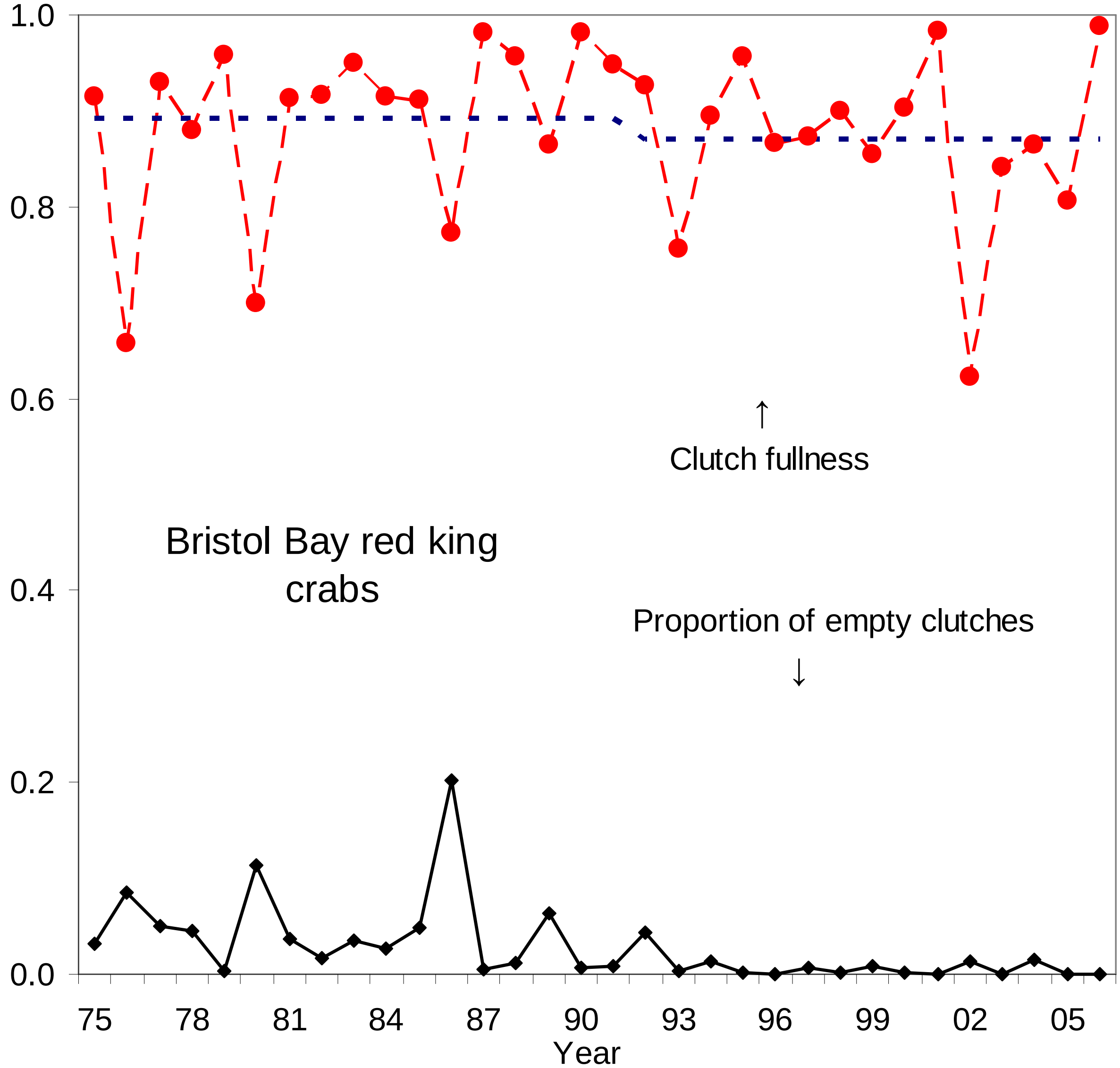


Figure 26. Average clutch fullness and proportions of empty clutches of newshell (shell conditions 1 and 2) mature female crabs >89 mm CL from 1975 to 2006 from survey data. Oldshell females were excluded.

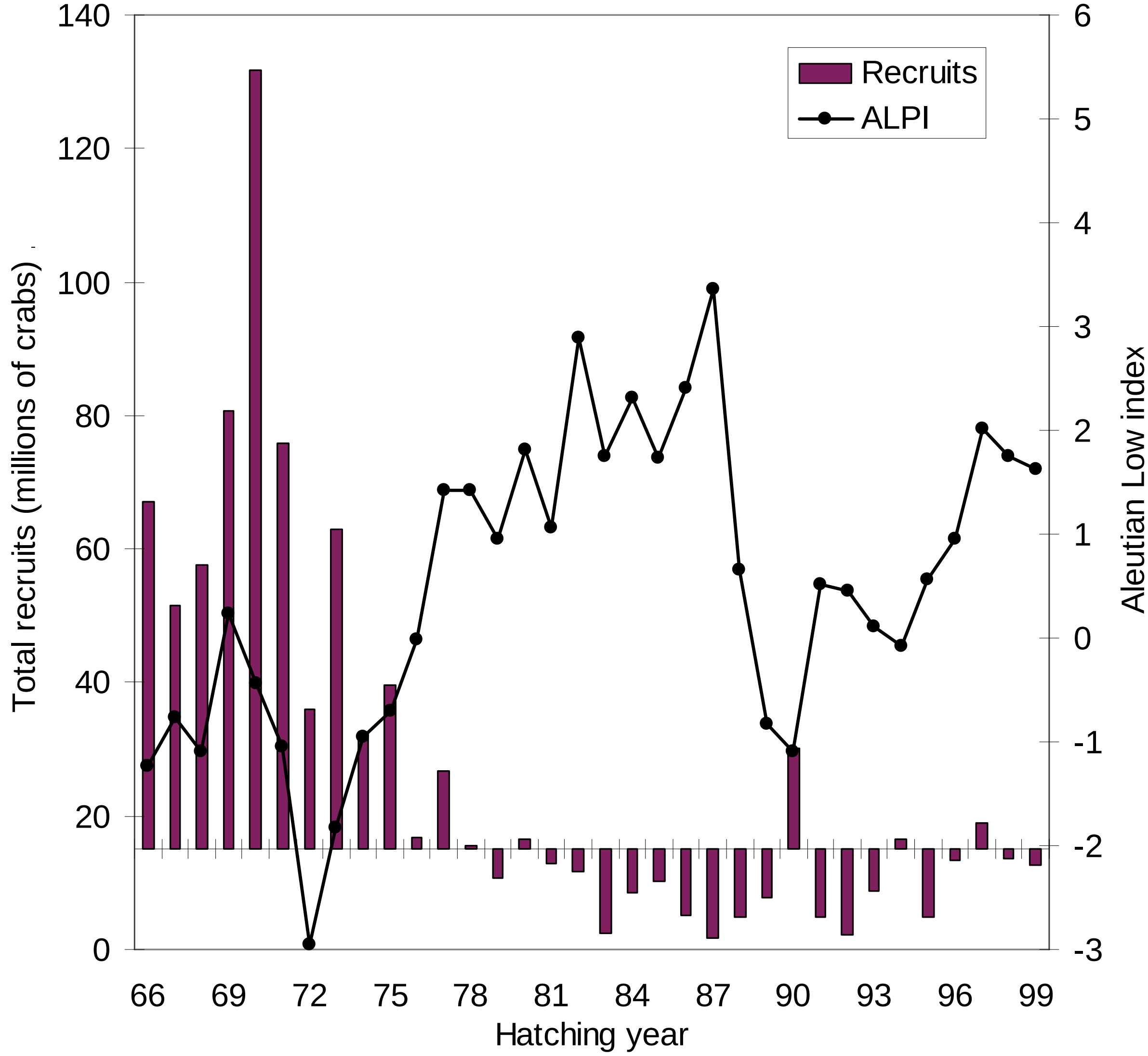
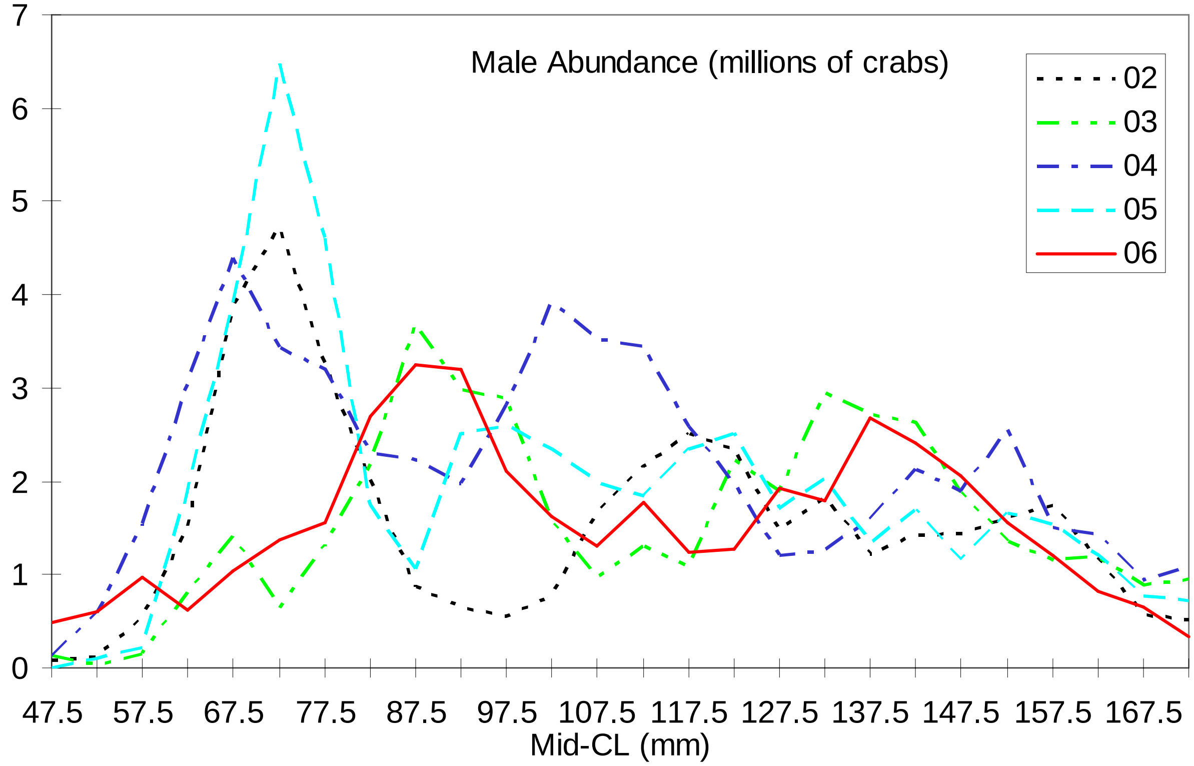


Figure 27. Recruits of Bristol Bay red king crabs and anomalies of the Aleutian Low index (December-March, 3-year moving average). A 7-year lag from hatching to recruitment was used.



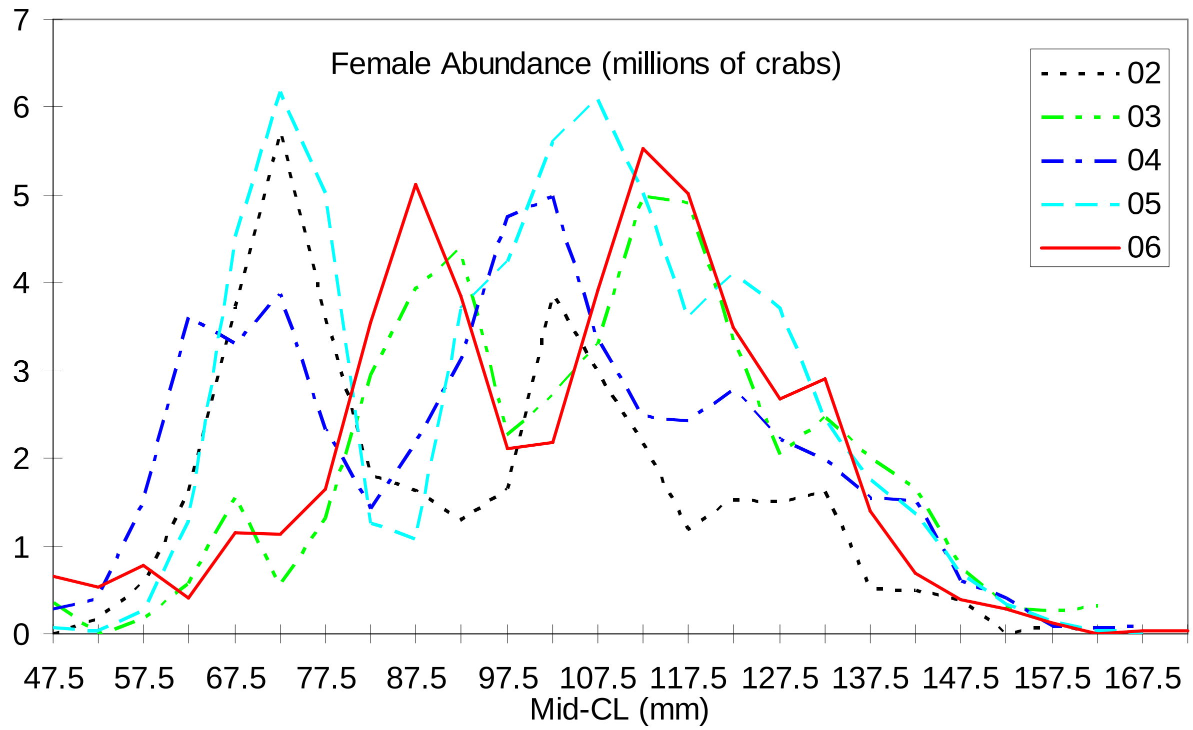


Figure 28. Length frequency distributions of male (top panel) and female (bottom panel) red king crabs in Bristol Bay from NMFS trawl surveys during 2002-2006. For purposes of these graphs, abundance estimates are based on area-swept methods.