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2009 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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Executive Summary

At the time of developing this draft 2009 SAFE report, only survey biomass data through 2008 and fishery data through the 2007/08 fishing season were available. In order to populate the model for the purpose of projecting the 2009/10 OFLs, we set the 2009 survey biomass estimates equal to those from the 2008 survey, and the 2008/09 fishery performance (retained catch, discard and bycatch losses) equal to those catch components projected in 2008/009 as specified in the 2008 Tanner crab SAFE report (Rugolo et al., 2008). Hereafter, and until the 2009 survey and 2008/09 fishery data are incorporated in the analysis, most of the following discussions are taken from the 2008 Tanner crab SAFE.

In 2008, Tanner crab male mature biomass (MMB) at the time of the survey was estimated at 143.1 million pounds. This represented a 22.7% decrease in mature male biomass relative to 2007. Legal males were sparsely distributed in 2008 with regions of highest abundance in southern Bristol Bay. The total abundance index for legal males was 13.1 million crabs which represented a 9% increase over 2007. Legal males were distributed 69.0% (9.1 million crabs) east and 31.0% (4.1 million crabs) west of 166^{o} West longitude (Western District) which compared to 44.5% and 55.5% respectively in 2007. The abundance index for pre-recruit male crabs (110-137 mm cw) declined 16.0%, and that for small males (<110 mm cw) declined 55.1% relative to 2007. Total male abundance declined 43.2% between 2007 and 2008. Comparison of the 2006-2008 male size frequency distributions revealed persistently declining abundance across all size ranges, a general failure for modes to persist inter-annually, and a relatively increasing percentage of old shell crabs in the mature male stock.

In 2008, a single station sampled in southern-most Bristol Bay was a high density station for male Tanner crab. Legal male (>=138 mm cw) abundance estimated at this station (6.1 million crabs) represented 67.8% of all legal male crab east of 166^{o} West longitude (Eastern District). It exceeded by 2.1 million the number of legal males in the Western District, and it comprised 46.7% of all legal males estimated throughout the eastern Bering Sea. Considerable uncertainty exists in the apparent strength (+9.0% increase) of the 2008 legal male estimate relative to 2007.

Large female (>=85 mm cw) Tanner crab showed a 21.4% decrease over 2007, and these were dominated (71.1%) by old shell females. Small female (<85 mm cw) Tanner crab declined 38.8% relative to 2007. Total 2008 female abundance declined 35.9%, and the total abundance of male and female combined declined 43.2% since 2007. The survey length frequency distributions of female Tanner crab from 2006-2008 revealed consistently declining abundance across the size modes and the general failure of modes of abundance to persist inter-annually.

Tanner crab is managed as a Tier-4 stock. The proxy B_{MSY} used in OFL-setting was the reference biomass (B_{REF}) = 189.76 million pounds male mature biomass (MMB) at the time of mating estimated as the average survey MMB_{mating} from 1969-80 inclusive. For Tier-4 stocks, the F_{OFL} is derived using and F_{OFL} Control Rule based on the relationship of current male mature biomass to B_{REF} as a proxy for B_{MSY}. Here, $F_{OFL} = \gamma M$. The Amendment 24 and its associated EA defines a default value of gamma=1.0. Gamma is allowed to be less than or greater than unity resulting in overfishing limits more or less biologically conservative than fishing at M. However, Amendment 24 states that γ should not be set to a value that would provide less biological conservation and more risk-prone overfishing definitions without defensible evidence that the stock could support fishing at levels in excess of M. The resultant overfishing limit (F_{OFL}) for Tier-4 stocks is specified in terms of a Total Catch OFL that includes all stock losses (retained catch, discard and bycatch) for male and female crab combined.

The value of M is 0.23 for EBS Tanner crab. For this analysis, gamma was set to 1.0. Relative to B_{REF} = 189.8 million pounds, the projected 2009 estimate of MMB at the time of mating (108.28 million pounds) represented B/B_{REF} = 0.571 resulting in and F_{OFL} = 0.120.

For the 2009/10 Tanner crab fishery, we estimated the Total Catch OFL = 15.52 million pounds. Directed and non-directed losses to MMB in 2009 are estimated to be 6.95 and 3.26 million pounds, respectively. After accounting for expected losses to MMB, the projected catch of legal-sized Tanner crab is 4.99 million pounds. The retained part of the catch of legal-sized crab (4.23 million pounds) accounts for expected directed and non-directed losses to LMB by all fisheries. In comparison to the overfishing limit, the retained legal catch would comprise 27.3% of the total male mature biomass losses. A significant component of the Total Catch OFL therefore is attributed to non-targeted losses under current EBS fisheries.

Expected discard losses of female Tanner crab from the 2009/10 ground fish fishery and the directed pot fishery combined was estimated at 1.06 million pounds. Therefore, total expected male plus female losses in 2009/10 comprising the Total Catch OFL = 15.511 million pounds. Estimated exploitation rates on LMB and MMB associated with these projected catches are 0.086 and 0.113 respectively.

Summary of Major Changes

There are no major changes in this draft 2009 Tanner crab SAFE relative to the 2008 report (Rugolo et al., 2008) in terms of input data, assessment methodology or assessment results, including projected biomass, the F_{OFL} or catch components comprising the Total Catch OFL.

Responses to SSC Comments

In their review of the 2008 Tanner crab SAFE report at their October 2008 meeting, the SSC commented concerning EBS Tanner crab SAFE and OFLs:

- *During the June 2008 meeting, the SSC was presented with an analysis for calculating gamma based on selectivities set equal to values given in the overfishing EA. The most recent three years of data suggest that selectivities in both the directed fishery and pot fisheries differ significantly from those used in the EA and therefore the June 2008 analysis may provide misleading results and should not be used. The SSC therefore concurs with the CPT and author to set gamma=1 for OFL and that B_{REF} be estimated as the average male mature biomass (MMB) at the time of mating for the period 1969-1980.*

The authors agree with the SSC comments and recommendations. Results of our feasibility analysis for estimating Tanner crab OFL using $F_{35\%}$ and estimated fishery selectivities are presented in Appendix A. The rationale presented in the 'Analytical Approach' and 'OFL Setting Results' sections of this document also support gamma=1.0 for this stock.

Responses to CPT Comments

In their review of the 2008 Tanner crab SAFE report at their September 2008 meeting, the Crab Plan Team commented concerning EBS Tanner crab SAFE and OFLs:

i. For consistency with Amendment 24, the term "total catch OFL" should consistently be applied only to the total catch of males and females in all fisheries.

The Total Catch OFL (TC_{OFL}) represents the total losses to male plus female stock biomass resulting from retained catch plus non-directed bycatch and discard losses from all fisheries. The projected male catch OFL is the sum of the retained component of the TC_{OFL} by the directed fisheries plus any directed and non-directed fishery discard losses to legal male biomass.

ii. Based on the assessment, much of the data and information needed to develop a stock assessment model for the entire EBS stock may exist. It is recommended that development of such a model should proceed; the stock assessment model developed for the eastern portion of the EBS Tanner crab stock should be reviewed for adaptation for a model to apply to the full EBS.

A length-based stock assessment model for the EBS Tanner crab stock is in initial stages of development; a progress report on the model will be presented to the CPT at the September 2009 meeting. The author's goal is to present a working model for review to the CPT in May 2010 and to the SSC in June 2010 if approved. While ambitious and dependent upon the successful completion of required antecedent data analyses on survey biomass and population dynamic input parameters and schedules, management of the EBS Tanner crab stock could be promoted to a Tier-3 status in 2010, and OFL-setting for the ensuing 2010/11 fisheries be based on the newly formulated assessment model-based OFLs.

The assessment model will be specified for the unit stock distributed over the EBS shelf. The existing snow crab stock assessment model (COSAM) (Turnock and Rugolo 2009) is being evaluated as a candidate to modify in developing the Tanner crab stock assessment model (TCSAM). Despite the precedent of establishing operational management controls for this stock east and west of 166° W longitude, the unit stock of Tanner crab in the EBS comprises crab throughout the geographic range surveyed by the NMFS trawl survey. No evidence exists to support the partitioning the unit stock into discrete, non-interbreeding and non-mixing sub-populations which can be assessed and managed as separate units. If clinal differences in biological metrics (e.g., growth and maturity) exist and are essential to the status of stock determination and OFL-setting, these may be accommodated within the formulation of the assessment model. Given requisite understanding of the geographic fidelity of the stock over its range, and its availability to the fisheries, partitioning of the Total Catch OFL may be possible to support operational decisions of setting TACs or issuing of IFQs for Eastern District and Western District fisheries.

iii. Future spring stock assessments should provide a full analysis on the choice of gamma and a full evaluation of alternatives relative to the default value, $\gamma=1$, and the appropriateness of the default value.

Following the recommendation of the SSC (October 2008 minutes quoted above) and consistent with that of the authors, a value of gamma=1.0 is adopted for OFL-setting. Use of a value of gamma greater than unity is unsupported by evidence that this stock can persist in the face of exploitation rates in excess of M. The rationale presented in the 'Analytical Approach' and 'OFL Setting Results' sections of this document also support the use of gamma=1.0 for this stock. Consistent with precautionary management principles embodied in the MSFCMA and national standards, the CPT may recommend the use of a gamma<1.0 to achieve stock rehabilitation goals considering the uncertainty in current stock status.

iv. The assessment should provide complete documentation on data sources and the calculations and assumptions used in the stock assessment for computing OFL. The total catch OFL should be clearly specified and provided in a table focused on deriving that OFL. Information on sub-dividing the OFL among catch components should be presented clearly.

More complete documentation of data sources has been made. The calculations used for deriving the OFL are shown. The table specifying the Total Catch OFL and the various catch components has been modified.

v. Research on handling mortality rates needs to be performed to better specify handling mortality rates used in the analysis.

The authors agree that more reliable estimates of post-release mortality rates on discards in the directed and non-directed pot fisheries and on bycatch in the groundfish trawl fisheries are required. Research on post-release mortality rates is needed on all king and Tanner crab stocks under the current NPFMC plan.

vi. The team will revise the terms of reference for assessments to include key management related stock status information consistently.

The authors agree.

vii. Responses to all comments by the SSC on the May draft of the stock assessment should be clearly addressed and responded to in the September draft.

This draft Tanner crab SAFE report addresses the SSC comments from their October 2008 meeting.

viii. The next assessment should include a full and reasonably detailed discussion on the pre-1980 data quality issues for both the survey and fishery data.

A retrospective re-analysis of the entire historical NMFS trawl survey database began in 2009. At the May 2009 meeting, an update on the progress of this work and the nature of data quality issues across the data record will be given to the CPT by the Stock Assessment Program. The length-based stock assessment model being developed for the EBS Tanner crab stock will use the newly derived time-series survey data. Authors will attempt to more fully describe the fishery data used in the OFL-setting where they may affect the results.

Introduction

Scientific name and general distribution

Originally described by Rathbun (1924), *Chionoecetes bairdi* is one of five species in the genus *Chionoecetes*. The taxonomic classification attributable to Garth (1958) has been revised (see McLaughlin et al. 2005) to include name changes for a number of hierarchical categories:

Class	Malacostraca
Order	Decapoda
Infraorder	Brachyura
Superfamily	Majoidea
Family	Oregoniidae
Genus	Chionoecetes

The common name for *C. bairdi* of "Tanner crab" (Williams et al. 1989), was recently been modified to "southern Tanner crab" (McLaughlin et al. 2005). Prior to this change, the term "Tanner crab" has also been variously used to refer to other members of the genus, or the genus as a whole. Hereafter, the common name "Tanner crab" will be used in reference to "southern Tanner crab".

Tanner crabs are found in continental shelf waters of the north Pacific. In the east, their range extends as far south as Oregon (Hosie and Gaumer 1974) and in the west as far south as Hokkaido, Japan (Kon 1996). The northern extent of their range is in the Bering Sea (Somerton

1981a) where they are found along the Kamchatka peninsula (Slizkin 1990) to the west and in Bristol Bay to the east.

In the eastern Bering Sea (EBS), the Tanner crab distribution may be limited by water temperature (Somerton 1981a). *C. bairdi* is common in the southern half of Bristol Bay, around the Pribilof Islands, and along the shelf break where water temperatures are generally warmer (Figures 1 and 2). The southern range of the cold water congener the snow crab, *C. opilio*, in the EBS is near the Pribilof Islands (Turnock et al. 2008). The distributions of snow and Tanner crab overlap on the shelf from approximately 56° to 58°N, and in this area, the two species hybridize (Karinen and Hoopes 1971).

Management units

Fisheries have historically taken place for Tanner crab throughout their range in Alaska, but currently only the fishery in the EBS is managed under a federal fisheries management plan (NPFMC 1998). The plan defers certain management controls for Tanner crab to the state of Alaska with federal oversight (Bowers et al. 2008). The state manages Tanner crab based on registration areas, divided into districts. Under the plan, the state can adjust or further subdivide these districts as needed to avoid overharvest in a particular area, change size limits from other stocks in the registration area, change fishing seasons, or encourage exploration (NPFMC 1998).

The Bering Sea District of Tanner crab Registration Area J (Figure 3) includes all waters of the Bering Sea north of Cape Sarichef at 54° 36' N lat. and east of the U.S.-Russia Maritime Boundary Line of 1991. This district is divided into the Eastern and Western Subdistricts at 173° W long. The Eastern Subdistrict is further divided at the Norton Sound Section north of the latitude of Cape Romanzof and east of 168° W long. and the General Section to the south and west of the Norton Sound Section (Bowers et al. 2008).

Stock structure

Tanner crabs in the EBS are considered to be a separate stock distinct stock from Tanner crabs in the eastern and western Aleutian Islands (NPFMC 1998). The unit stock is that defined across the geographic range of the EBS continental shelf, and managed as a single unit. Clinal differences in some biological characteristics may exist across the range of the unit stock (Somerton 1981a).

Life history

Reproduction

In most majid crabs, the molt to maturity is the final or terminal molt. For *Chionoecetes bairdi* specifically it is now generally accepted that both males (Tamone et al. 2007) and females (Donaldson and Adams 1989) undergo terminal molt at maturity. Females terminally molt from their last juvenile, or pubescent, instar usually while being grasped by a male (Donaldson and Adams 1989). Subsequent mating takes place annually in a hard shell state (Hilsinger 1976) and after extruding their clutch of eggs. While mating involving old-shell adult females has been documented (Donaldson and Hicks 1977), fertile egg clutches can be produced in the absence of males by using stored sperm from the spermathacae (Adams and Paul 1983, Paul and Paul 1992). Two or more consecutive egg fertilization events can follow a single copulation using stored sperm to self-fertilize the new clutch (Paul 1982, Adams and Paul 1983), however, egg viability decreases with time and age of the stored sperm (Paul 1984).

Maturity in males can be classified either physiologically or morphometrically. Physiological maturity refers to the presence or absence of spermataphores in the male gonads whereas morphometric maturity refers to the presence or absence of a large claw (Brown and Powell 1972). During the molt to morphometric maturity, there is a disproportionate increase in the size of the chelae in relation to the carapace (Somerton 1981a). While many earlier studies on Tanner crabs assumed that morphometrically mature male crabs continued to molt and grow, there is now substantial evidence supporting a terminal molt for males (Otto 1998, Tamone et al. 2007). A consequence of the terminal molt in male Tanner crab is that a substantial portion of the population may never reach the legal harvest size (NPFMC 2007).

Although observations are lacking for the eastern Bering Sea, seasonal differences have been observed between mating periods for pubescent and multiparous Tanner crab females in the Gulf of Alaska (GOA) and Prince William Sound. There, pubescent molting and mating takes place over a protracted period from winter through early summer, whereas multiparous mating occurs over a relatively short period during mid April to early June (Hilsinger 1976, Munk et al. 1996, and Stevens 2000). In the EBS egg condition for multiparous Tanner crabs assessed between April and July 1976 also suggested that hatching and extrusion of new clutches for this maturity status began in April and ended sometime in mid June (Somerton 1981a).

Fecundity

A variety of factors affect female Tanner crab fecundity including female size, maturity status (primiparous vs multiparous), age post terminal molt, and egg loss (NMFS 2004a). Of these factors, female size is the most important, with estimates of 89 to 424 thousand eggs for EBS females 75 to 124 mm carapace width (cw) respectively (Haynes et al. 1976). Maturity status is another significant factor affecting fecundity with primiparous females being only ~70% as fecund as equal size multiparous females (Somerton and Meyers 1983). The number of years post maturity molt, and whether or not, a female has had to use stored sperm from that first mating can also affect egg counts (Paul 1984, Paul and Paul 1992). Additionally, older senescent females often carry small clutches or no eggs (i.e., barren) suggesting that female Tanner crab reproductive output is a declining function of age (NMFS 2004a).

Size at Maturity

Somerton (1981b) noted differences in the size of Tanner crab female maturity across its EBS range. There is no more current information on EBS Tanner crab growth than that provided by Sommerton (1981b). For the 5 survey years from 1975 to 1979, east of 167° 15’ W longitude, the mean size of mature females ranged from 92.0 to 93.6 mm cw. West of that longitude, the size of 50% female maturity ranged from 78.0 to 82.0 mm cw. For harvest strategy purposes, mature females are defined as females >=80 mm cw (Bowers et al. 2008). For male Tanner crab during the same survey years, the estimated size at 50% maturity was 117.0 mm cw and 108.9 mm cw east and west of 167° 15’ W longitude, respectively (Somerton 1981b).

Mortality

Due to a lack of reliable age information, Somerton (1981a) estimated mortality separately for individual EBS cohorts of juveniles (pre-recruits) and adults. Somerton postulated that because of net selectivity of the survey sampling gear, age five Tanner crab (mean cw = 95 mm) were the first cohort to be fully recruited to the gear; he estimated an instantaneous natural mortality rate of 0.35 for this size class using catch curve analysis. Using a catch curve model with two different data sets, Somerton then estimated natural mortality rates of adults (fished population) from data from the EBS population survey of 0.20 to 0.28. When using CPUE data from the Japanese fishery the estimated rates were 0.13 to 0.18. Somerton concluded that estimates (0.22 to 0.28) from models that used both the survey and fishery data were the best. The natural mortality rate (M) of EBS Tanner crab is set at 0.23 for the purpose of assessing stock status and OFL-setting based on the current expectation of longevity of at least 15 y.

Data

Growth and Age

Somerton (1981a) studied growth of Tanner crab in the EBS and used size frequency data to estimate growth per molt. Because of a lack data on smaller instars and no estimates of molt frequency, he combined size at age estimates from Kodiak crab (Donaldson et al. 1981) to construct a growth and age schedule for EBS Tanner crabs (Table 1). Radiometric ageing has suggested that age after the terminal molt to maturity may be 6 to 7 years (Nevisi et al. 1996). If mean age at maturity is 7-8 y, these results suggest that maximum age of an exploited stock is 13-15 y.

Weight at length

Growth in weight data was collected during the 1975 EBS crab survey (Somerton 1981a). Carapace width and total weight were measured on 243 Tanner crab. Only clean shell 2 or 3 crab were selected with no missing or regenerating appendages. The fitted equation for male weight at carapace width is: $W=0.00019(CW)^{3.09894}$.

The Survey

The NMFS conducts an annual trawl survey in the EBS to determine the distribution and abundance of commercially-important crab and groundfish fishery resources. The survey has been conducted since 1968 by the Resource Conservation and Engineering (RACE) Division of the Alaska Fisheries Science Center. It's been conducted annually since 1975 when it was also expanded into Bristol Bay and the majority of the Bering Sea continental shelf. Since 1988, 376 standard stations have been included in the survey covering a 150,776 nm^2 area of the EBS with station depths ranging from 20 to 150 meters depth. The annual collection of data on the distribution and abundance of crab and groundfish resources provides fishery-independent estimates of population metrics and biological data used for the management of target fishery resources. Crustacean resources targeted by this survey and enumerated annually by NMFS are red king crab (*Paralithodes camtschaticus*), blue king crab (*P. platypus*), hair crab (*Erimacrus isenbeckii*), Tanner crab (*Chionoecetes bairdi*) and snow crab *(C. opilio*).

Only results of the 2008 NMFS trawl survey are available for inclusion in this draft 2009 Tanner crab SAFE report. The 2008 trawl survey consisted of 378 bottom trawls taken over an area of approximately 139,548 nm^2. The survey was conducted onboard the FV *Arcturus* and FV *Aldebaran*, between 4 June and 24 July. Sampling methodology was identical to that of previous surveys since 1982, and most tows were made at the centers of squares defined by a 20 x 20 nmi (37 x 37 km) grid (Figures 2 and 3). Near St. Matthew Island and the Pribilof Islands, additional tows were made at the corners of squares that define high density sampling strata for blue king crab and red king crab.

Both the FV *Arcturus* and FV *Aldebaran* fished an eastern otter trawl with an 83 ft (25.3 m) headrope and a 112 ft (34.1 m) footrope which has been the standard gear since 1982. Each tow was approximately 0.5 h in duration towed at 3 knot, and conducted in strict compliance with established NMFS groundfish bottom trawl protocols (Stauffer 2004). The average tow length of all tows taken in 2008 was 1.49 nmi (2.78 km). The mean bottom water temperature of all 378 trawls was 1.08^{o} C. Crabs were sorted by species and sex, and then a sample of the catch measured to the nearest millimeter to provide a size-frequency distribution. Population estimates are indices of relative population abundance and biomass and do not necessarily represent absolute abundance or biomass measures. They are most precise for large crabs, and are least precise for small crabs due to gear selectivity, and for females of some stocks due to differential crab behavior.

Stock Biomass

Tanner crab male mature biomass (MMB) and legal male biomass (LMB) exhibited periods of peak biomass in the early to mid-1970s and the early to mid-1990s (Table 5, Figures 4b and 6). LMB data are currently available only for 1980-2008. MMB estimates currently date to 1969; the variation in annual estimates between 1969-1975 reflect data source issues. Retrospective analysis of the historical NMFS trawl survey data is in progress which will complete the time series record and provide a consistent estimate of stock metrics across the time series record, 1968 to present. The components of MMB and LMB at the time the survey, at the time of the fishery and at the time of mating are shown in Table 5 and Figure 6. The historical bimodal distribution in male biomass (Figure 4) reflects that of the attendant directed fisheries with peak modes in the mid-1960s through mid-1970s and in the early-1990s (Table 5, Figure 5), and collapsed stock status following those modes. MMB at the survey revealed an all-time high of 623.9 million pounds in 1975, and a second peak of 255.7 million pounds in 1991. From late-1990s through 2008, MMB rose at a moderate rate from a low of 25.1 million pounds in 1997 to 185.2 million pounds in 2007 before falling to 143.1 million pounds in 2008 . Under the former BSAI King and Tanner Crab fishery management plan (NPFMC 1998) and overfishing definitions, the Tanner crab stock was above the B_{MSY} level indicative of a restored stock for the second consecutive year in 2007 and declared rebuilt.

The legal minimum size of 5.5 in cw (spine tip to spine tip) is equivalent to 138 mm cw measured between the spines. Legal males were sparsely distributed with regions of highest abundance in southern Bristol Bay and south of the Pribolof Islands (Figure 1). In 2005, the ADF&G stratified the management of the Bering Sea Tanner crab stock into two subareas, east and west of 166^{o} W longitude, hereafter Eastern and Western Districts respectively. The abundance index for legal male Tanner crab for both districts combined was 13.1 million crabs, a

9% increase over 2007. This abundance was distributed between management districts according to 69.0% Eastern and 31.0% Western compared to 44.5% and 55.5%, respectively in 2007. The abundance index (77.7 million crabs) for pre-recruit male crabs (110-137 mm cw) showed a 16.0% decrease, and the index of 186.8 million for small males (< 110 mm cw) showed a 55.1% decrease relative to 2007 for all areas combined (Figure 9).. The 2006 male size-frequency revealed a prominent mode in the 70-75 mm cw range, which persisted to 2007 at 90 mm cw (Figure 10). However, this mode is absent from the 2008 male length frequency and total male abundance was observed to decline 46.7% between 2007 and 2008 (Figures 9 and 10). Legal-sized males represent only a small portion (8.9%) of total male abundance in 2008. Among legal males, 91.3% were new-hardshells, and 8.7% were oldshell and older. Pre-recruit Tanner crab in 2008 were widely distributed across the range of the survey from southern Bristol Bay northwest to St. Matthew Island (Figure 1).

In 2008, a single station sampled in southern-most central Bristol Bay revealed a high density of male Tanner crab. The legal male abundance estimated at this station (6.1 million crabs) represented 67.8% of all legal male crab in the Eastern District. It exceeded by 2.1 million crab the estimate of all legal males in the Western District, or 150.9% of Western District, and it comprised 46.7% of all legal males estimated throughout the EBS. Considerable uncertainty exists, therefore, in the apparent strength (+9.0%) of the 2008 estimate of legal male abundance relative to 2007.

The combined Eastern and Western Districts abundance index (32.1 million crabs) of large females (≥ 85 mm cw) showed a 21.4% decrease over 2007 (Figure 9). Among sampled mature females, 1.8% were softshells; 27.0% were new-hardshell, of which 98.4% carried new eggs; and 71.1% were oldshell and older, of which 81.8% carried new eggs. The vast majority of mature females sampled had completed hatching by the time of the survey. The small (<85 mm cw) female Tanner crab abundance estimate in 2008 (125.6 million crab) showed a 38.8% decline relative to 2007. Total 2008 female abundance (157.7 million crab) declined 35.9% in from 2007, and the total abundance of male and female combined declined 43.2% since 2007 (Figure 9). Ovigerous females were sparsely distributed from southern Bristol Bay westward to south of St. Matthew Island (Figure 2). Immature female Tanner crab displayed a similar distribution to mature females with the exception of an area of relatively high concentration west of Bristol Bay and north of the Pribiolof Islands (Figure 2). Barren mature females were intermittently distributed (Figure 2). The survey length frequency distributions of female Tanner crab from 2006-2008 are shown in Figure 11. The prominent length mode between 65-75 mm cw seen in 2006 is not shown to persist through 2007 or 2008. Rather, it is shown in consistently declining abundance through 2008. A significant portion (71.1%) of mature female Tanner crab are in old or older shell class condition (Figure 11).

The Fishery

The domestic Tanner crab (*C. bairdi*) pot fishery rapidly developed in the mid-1970s (Table 2, Figures 5). For stock biomass and fishery data tabled in this document, we adopted the convention that 'year' refers to the survey year, and fishery data are those subsequent to the survey, through prior to the survey in the following year. United States landings were first reported for Tanner crab in 1968 at 1.01 million pounds taken incidentally to the EBS red king crab fishery (Table 2). Tanner crab was targeted thereafter by the domestic fleet and landings rose sharply in the early-1970s, reaching a high of 66.6 million pounds in 1977 (Table 2, Figure 5). Landings fell precipitously after the peak in 1977 through the early 1980s, and domestic fishing was closed in 1985 and 1986 as a result of depressed stock status. In 1987, the fishery reopened and landings rose again in the late-1980s to a second peak in 1990 at 40.1 million pounds, and then fell sharply through the mid-1990s (Figure 5). The domestic Tanner crab fishery closed between 1997 and 2004 as a result of severely depressed stock condition. The domestic Tanner crab fishery re-opened in 2005 and has averaged 1.7 million pounds retained catch between 2005-2007 (Table 2). Landings of Tanner crab in the foreign Japanese pot and tangle net fisheries were reported between 1965-1978, peaking at 44.0 million pounds in 1969 (Table 2, Figure 5). The Russian tangle net fishery was prosecuted between 1965-1971 with peak landings in 1969 at 15.6 million pounds. Both the Japanese and Russian Tanner crab fisheries were displaced by the domestic fishery by the late-1970s.

Discard and bycatch losses of Tanner crab originate from the directed pot fishery, non-directed pot fisheries (notably, for snow crab and red king crab), and the groundfish trawl fisheries (Table 3). Discard/bycatch mortalities were estimated using post-release handling mortality rates (HM) of 50% for pot fishery discards and 80% for trawl fishery bycatch (NPFMC 2008). Total Tanner crab discard and bycatch losses by sex are shown in Table 3 for 1965-2007. The pattern of total discard/bycatch losses is similar to that of the retained catch (Table 2). These losses were persistently high during the late-1960s through the late-1970s; male losses peaked in 1970 at 44.5 million pounds (Table 3). A subsequent peak mode of discard/bycatch losses occurred in the late-1980s through the early-1990s which, although briefer in duration, revealed higher losses for males than the earlier mode; peak=49.2 million pounds in 1990. From 1965-1975, the groundfish trawl fisheries contributed significantly to total bycatch losses, although the combined pot fisheries are the principal source of contemporaneous non-retained losses to the stock (Table 3). Total Tanner crab retained catch plus non-directed losses of males and females (Table 4, Figure 4a) reflect the performance patterns in the directed and non-directed fisheries. Total male catch rose sharply with fishery development in the early 1960s and reveals a bimodal distribution between 1965 and 1980 with peaks of 104.7 million pounds in 1969 and 115.5 million pounds in 1977 (Table 4, Figure 4a). Total male catch rose sharply after the directed domestic fishery reopened in 1987 and reached a peak of 89.3 million pounds in 1990. Total male and female catch fell sharply thereafter with the collapse of the stock and the fishery closure in 1997.

Since re-opening of the domestic fishery in 2005, the relationship of total male discard/bycatch losses by all pot and trawl fisheries combined to retained catch has shifted significantly relative to that between 1980-1996 (Tables 2 and 3). For 2005-2007, the ratio of total male discard losses to retained catch was 2.6, 3.6 and 2.9, respectively, and averaged 3.0 (se=0.3). The majority of these male losses are sub-legal sized crab, and a principal contributor to these non-retained losses is the directed Tanner crab fishery (see Table 7a). This contrasts the pre-closure performance of the domestic fishery between 1980-1996 which averaged 1.1 (se=0.1) pounds of non-retained male mortalities to each 1.0 pound of retained catch. These ratios in terms of numbers of male non-retained losses to retained legal crab are more striking due to the contribution of sub-legal sized crab to total male discards. Discard and bycatch losses of male and female Tanner crab (Table 3) during the closures of the directed domestic fishery (1985-

1986 and 1997-2004) reflect losses due to non-directed EBS pot fisheries and the domestic groundfish trawl fishery.

Exploitation Rates
The historical patterns of fishery exploitation on LMB and MMB were derived (Table 6, Figures 7a and 7b). The exploitation rate on LMB was estimated as the proportion of retained catch to LMB at the time of the fishery, while that on MMB as the proportion of total male catch to MMB at the time of the fishery. Estimates of LMB are currently available only for 1980-2008. When the re-analysis of the NMFS trawl survey database is complete in 2009, MMB estimates will be available for the entire record (1968 to present). During that period, exploitation rate (μ) on LMB was highest in 1980 at 0.19 and fell with stock condition through the mid-1980s. LMB exploitation rate revealed a second prominent mode during 1989-1993, peaking at 0.18 in 1991 and averaging 0.17 (Table 6, Figure 7b). These rates of exploitation on LMB are less than the equivalent value of M=0.23 for this stock; the EBS Tanner crab stock did not persist at sustainable or healthy stock levels under these rates. The pattern of μ on MMB from 1969-2007 reveals two high periods: one associated with the high total catches between 1969-1980; the other coincident with the mode of high catches in the late-1980s through early-1990s. The variability in μ on MMB during the early period (1969-1980) is attributed to uncertainty in early biomass estimates which will be replaced by a new biomass time-series biomass in 2010. Exploitation rate on MMB during the 1990s peaked at 0.42 in 1990, averaged 0.21 between 1986-1997, and closely followed the build up in stock biomass during that period.

The Analytic Approach

Tier-4 OFL Control Rule and OFL-Determination
In the Environmental Assessment proposed as Amendment 24 to the BSAI King and Tanner Crab fishery management plan (NPFMC 2008), Tier-4 stocks are characterized as those where essential life-history information and understanding are incomplete. Although a full assessment model cannot be specified for Tier-4 stocks or stock-recruitment relationship defined, sufficient information may be available for simulation modeling that captures essential population dynamics of the stock as well as the performance of the fisheries. Such modeling approaches can serve the basis for estimating the annual status determination criteria to assess stock status and to establish harvest control rules.

In Tier-4, a default value of M and a scaler Gamma (γ) are used in OFL setting. The proxy B_{MSY} represents the level of equilibrium stock biomass indicative of maximum sustainable yield (MSY) to fisheries whose mean performance exploits the stock at $F_{MSY.}$ For Tier-4 stocks, the proxy B_{MSY}, or B_{REF}, is commonly estimated as the average biomass over a specified period that satisfies the expectation of equilibrium biomass yielding MSY at F_{MSY}. It can also be estimated as a percentage of pristine biomass (B_0) of the unfished or lightly exploited stock where data exist. In Tier-4, the F_{OFL} is calculated as the product of γ and M, where M is the instantaneous rate of natural mortality. The Amendment 24 and its associated EA defines a default value of gamma = 1.0. Gamma is allowed to be less than or greater than unity resulting in overfishing limits more or less biologically conservative than fishing at M. The specification of the scaler γ in the EA was intended to allow adjustments in the overfishing definitions to account for differences in the biomass measures used in EA simulation analyses. However, since Tier-4 stocks are information-poor by definition, the EA associated with Amendment 24 states that **γ** should not be set to a value that would provide less biological conservation and more risk-prone overfishing definitions without defensible evidence that the stock could support fishing at levels in excess of M. The resultant overfishing limit for Tier-4 stocks is the total catch OFL that includes expected retained plus discard/bycatch losses. For Tier-4 stocks, a minimum stock size threshold (MSST) is specified; if current MMB drops below MSST, the stock is considered to be overfished.

For Tier-4 stocks, the F_{OFL} is derived using and F_{OFL} Control Rule (Figure 8) according to whether current mature stock biomass metric (B_t) belongs to stock status levels a, b or c in the algorithm below. The stock biomass level beta (β) represents a minimum threshold below which directed fishing mortality is set to zero. The F_{OFL} Control Rule sets β=0.25. The parameter alpha moderates the slope of the non-constant portion of the control rule. For biomass levels where $\beta < B_t \leq B_{MSY}$, the F_{OFL} is estimated as a function of the ratio B_t/B_{MSY}. The value of M is 0.23 for eastern Bering Sea Tanner crab. In the analysis of Tier-3 for snow crab, *Chionoecetes opilio,* and red king crab, *Paralithodes camtschaticus*, a B_{MSY} proxy reference value (B_{REF}) equal to 35% of the maximum spawning potential of the unfished stock was specified (Annon 2008, EA associated with Amendment 24). For Tier-4 stocks, a reference biomass value (B_{REF}) must is specified consistent with the expectation of a measure of equilibrium stock biomass (B_{MSY}) capable of yielding MSY to the fisheries operating at F_{MSY}.

Stock Status Level:	F_{OFL}:
a. $B_t/B_{REF} > 1.0$	$F_{OFL} = \gamma \cdot M$
b. $\beta < B_t/B_{REF} \leq 1.0$	$F_{OFL} = \gamma \cdot M\,[(B_t/B_{REF} - \alpha)/(1 - \alpha)]$
c. $B_t/B_{REF} \leq \beta$	Directed Fishery F=0
	$F_{OFL} \leq F_{MSY}$

The OFL Model Structure

In the Tier-4 OFL-setting approach EBS Tanner crab, various measures of stock biomass and catch components are integrated in the overfishing level determination. Here, we define each component and illustrate the approach used for OFL-setting based on these metrics.

Male Mature and Legal Biomass:

Annual estimates of male biomass are derived from the NMFS Eastern Bering Sea summer trawl survey. Two measures are specified: male mature biomass (MMB) and legal male biomass (LMB). From these measures derived at the time of the survey, we estimate MMB and LMB at the time of mating by depreciating survey biomass by the partial natural mortality rate (M) over 8 months from the survey to mating and extracting total catch components (C_{MMB} or C_{LMB}).

$$MMB_{mating} = MMB_{survey}e^{-2M/3} - C_{MMB} \quad (1)$$

$$LMB_{mating} = LMB_{survey}e^{-2M/3} - C_{LMB} \quad (2)$$

Estimating F_{OFL}:
Given MMB_{mating} (or B_t) and the specification of a biomass reference (B_{REF}) proxy for B_{MSY}, the overfishing limit F_{OFL} is found using the OFL algorithm. In the case where, for example, $\beta < B_t/B_{REF} \leq 1.0$, the overfishing limit is estimated, where α=0.1:

$$F_{OFL} = \gamma M \left((B_t/B_{REF} - 0.1)/(1 - 0.1)\right) \quad (3)$$

Total Catch OFL and Catch Components:
A total catch overfishing limit (Total Catch OFL) corresponding to the F_{OFL} can be estimated as the product of the annual fishing mortality rate ($1\text{-}e^{-Fofl}$) and the male mature biomass at the time of the fishery ($MMB_{survey}e^{-M/2}$). Here, the time lag from the survey to the fishery is 6 months.

$$\text{Total Catch OFL} = (1-e^{-Fofl})\,(MMB_{survey}e^{-M/2}) \quad (4)$$

This total catch overfishing limit includes all retained, plus discard and bycatch losses from the directed fishery and all non-directed fisheries (pot and groundfish trawl). These catch components are defined as:

i. $C_{ret,LMB}$ = retained legal male biomass by the directed fishery
ii. $C_{dir\text{-}dsc,MMB}$ = discard losses to MMB by the directed fishery
iii. $C_{non\text{-}dsc\text{-}pot,MMB}$ = discard losses to MMB by the non-directed pot fisheries
iv. $C_{non\text{-}dsc\text{-}gf,MMB}$ = discard losses to MMB by the non-directed trawl fisheries

Therefore, using these catch components,

$$\text{Total Catch OFL} = C_{ret,LMB} + C_{dir\text{-}dsc,MMB} + C_{non\text{-}dsc\text{-}pot,MMB} + C_{non\text{-}dsc\text{-}gf,MMB} \quad (5)$$

In practice, the catch components i-iv are estimated from past performance in the respective fisheries considered to be most representative of current conditions. Catch components i and iv are co-related, and the magnitude of the discard losses to MMB by the directed fishery is a function of the retained legal male biomass. In this case, $C_{ret,LMB}$ is found by iteration such that the Total Catch OFL (5) equated to that estimated in equation (4).

Discard Catches:
Discard losses of mature male biomass by the directed fishery ($C_{dir\text{-}dsc,MMB}$) was estimated using data from the most recent 2007 Tanner crab fishery supplied by D. Barnard (ADF&G, 08/11/08) (Table 7a). The ratios of legal and sublegal male and female discards to the retained catch are used to project discard losses in the terminal 2008 OFL fishery. Here, DSC,MMB_{07} is the discarded mature male biomass by the directed 2007 Tanner crab fishery. For all pot discards, a post-release handling mortality rate of 50% was used (HM_{pot}=0.50). Directed fishery discard losses to MMB is given by:

$$C_{dir\text{-}dsc,MMB} = C_{ret,LMB}\,(DSC,MMB_{07} / C_{ret,LMB\ 07})\,HM_{pot} \quad (6)$$

Non-directed pot fishery discard losses to male mature biomass ($C_{non\text{-}dsc\text{-}pot,MMB}$) are principally attributed to the EBS snow crab fishery and to the Bristol Bay red king crab fishery to al lesser extent. In this analysis, we used data from the previous two fishing seasons (2006 and 2007) to estimate of the average ratio of combined Tanner crab mature male discards to snow crab retained catch (Table 7b). $C_{ret,opilio\ 2008}$ is the projected 2008 retained catch OFL (Turnock, pers. Comm.). Using this ratio, projected non-directed pot fishery discard losses to MMB in the terminal OFL fishery is given by:

$$C_{non\text{-}dsc\text{-}pot,MMB} = C_{ret,Opilio\ 2008}\,(C_{non\text{-}dsc\text{-}pot,MMB} / C_{ret,opilio})_{mean,07}\, HM_{pot} \qquad (7)$$

Discard losses to MMB resulting from bycatch in the groundfish trawl fisheries ($C_{non\text{-}dsc\text{-}gf,MMB}$) was estimated using the average groundfish bycatch of Tanner crab over 2003-07 (Table 7c). We assumed that this average (5 y) bycatch of Tanner crab would occur in the 2008 OFL fishery. Reported bycatch are for males and females combined. The sex distribution and length frequency of this bycatch is unavailable for this analysis. The proportion of males in the bycatch was estimated assuming a sex ratio of 1:1 in the bycatch and apportioning the catch based on the ratio of mean weights of 120 mm cw male crab to 87.5 mm cw female crab resulting in a 60.2% v. 39.8% male to female split. For all trawl discards, a post-release handling mortality rate of 80% was used (HM_{gf}=0.80). Ground fish trawl fishery discard losses to MMB is given by:

$$C_{non\text{-}dsc\text{-}gf,MMB} = Mean_{03\text{-}07,dsc,gf}\ Porportion_{male}\ HM_{gf} \qquad (8)$$

Exploitation rates on legal male biomass (μ_{LMB}) and mature male biomass (μ_{MMB}) at the time of the fishery are calculated as the ratio of total directed plus non-directed losses to LMB and MMB to respective legal and mature male biomass at the time of the fishery:

$$\mu_{LMB} = \text{Total LMB Losses} / LMB_{fishery} \qquad (9)$$

$$\mu_{MMB} = \text{Total MMB Losses} / MMB_{fishery} \qquad (10)$$

Using the F_{OFL} Control Rule (Figure 8), F_{OFL} is determined based on MMB at time of mating after extraction of the Total Catch OFL. Since the ratio of B/B_{REF} is dependent on the extracted catch and the catch OFL upon the estimated F_{OFL}, the solution for the F_{OFL} and catch OFL is found iteratively based on the relationship of MMB at mating to B_{REF}. The Total Catch OFL includes all sources of fishery-induced removals from the stock (directed retained catch, directed discards, and non-directed pot and trawl bycatch mortalities). Given specification of all component losses, the retained portion of the legal catch is a fishery control which should be set so not to exceed the OFL if the expected non-retained losses are realized.

The OFL-Setting Results

For the purpose of OFL-setting for the terminal 2009/10 fishery, the proxy B_{MSY} is B_{REF} = 189.76 million pounds of male mature biomass estimated as the average MMB at mating from 1969-1980 inclusive. The SSC (October 2008) recommended using these 12 y of MMB estimates to specify B_{REF} despite both the author's and CPT's concerns about the quality and availability of survey biomass data prior to 1975. We note that the use of the average 1969-1980 MMB at mating estimates as a proxy for B_{MSY} is confounded by contemporaneous and antecedent high exploitation rates (Table 6, Figure 7a). This B_{REF} benchmark may underestimate the capacity of this stock to persist at B_{MSY} and provide maximum sustainable yield to the fisheries. We will revisit the choice of a proxy B_{MSY} once the retrospective analysis of the historical trawl survey is completed and consistent estimates of stock metrics are available.

From 1980-2007, the EBS Tanner crab stock collapsed twice resulting in two periods of fishery closures and the imposition of a rebuilding plan by the NPFMC. During this period, the stock experienced exploitation rates in excess of current F_{MSY} estimates. Specifically, at approximately three times that rate in the late-1970s, and twice that in the late-1980s, both preceded by stock collapses. Over 1980-2007, the stock has not maintained itself at a level that could be reasonably construed as in dynamic equilibrium, or at a level indicative of B_{MSY} thereby capable of providing MSY to the fisheries.

In May 2008, the CPT requested that the authors examine the feasibility of estimating $F_{35\%}$ for the Tanner crab stock using fishery selectivity. The SSC had recommended using fishery selectivity and maturity to estimate $F_{35\%}$ as the proxy F_{OFL}, and to estimate gamma as the ratio of $F_{35\%}$ to M. Results of that study are presented in Appendix A, which the SSC reviewed in October 2008. Fishery selectivity for Tanner crab used in the EA analysis were estimated based on historical fishery performance prior to the 1997 closure. We estimated selectivity for the contemporary Tanner crab fishery following its reopening in 2005 and found that the current selectivity patterns for both the directed and non-directed pot fisheries differed profoundly from those used in the EA analysis. While it's desirable for Tier-4 stocks to employ the $F_{35\%}$ proxy for F_{MSY} where reliable data and understanding on fishery performance exist, we considered it premature to employ this approach for Tanner crab given the changes in the directed and non-directed pot fisheries performance observed from 2005-2007 relative to those of the pre-1997 closure. Since the EA selectivity patterns no longer applied, their use in estimating $F_{35\%}$ and a factor in estimating gamma, may provide misleading and incorrect results in terms of management controls. The SSC concurred with this assessment and recommended the $F_{35\%}$ not be used in OFL-setting and to set gamma=1.0. An EBS Tanner crab stock assessment model is being developed in which fishery selectivity will be estimated across the time-series record.

For this analysis, we set gamma=1.0. We accounted for discard mortalities from the directed and non-directed pot fisheries and the groundfish trawl fisheries. Even if pot fishery selectivities were equivalent pre-1997 and post-reopening in 2005, the EA simulations which suggest that $F_{35\%}$ may be a suitable F_{MSY} proxy for snow crab and Bristol Bay red king crab did not equivalently account for non-retained losses. Thus, it's uncertain what scaler of M is appropriate to relate M to full-selection $F_{35\%}$ rates in EA simulations. Further confounding specification of gamma for EBS Tanner crab is the fact that the MMB measure derived in this analysis employs a maturity schedule, whereas the EA simulations employed knife-edge sex-specific maturity at size. The EA guidance prescribes that gamma should not be set to a level that would provide for more risk-prone overfishing definitions without defensible evidence that the stock could support levels in excess of M. Examination of the historical performance of the fishery (Figure 4a) and stock biomass (Figure 6) reveals that the Tanner crab stock has not maintained itself in dynamic equilibrium over any sustained period, nor persisted in the face of exploitation rates (Table 6, Figures 7and 7b) in excess of M. The difference between fishery selectivity and maturity in EBS crab stocks has been suggested as a reason to allow gamma to exceed unity. Notwithstanding the technical challenges noted in estimating current fishery selectivity, this relies on theoretical population dynamic considerations in mature male biomass which are violated given the unique reproductive dynamic features of this stock (e.g., male-female size dependencies for successful copulation, male guarding and competition). Since a fundamental precept of precautionary fishery management is that the stock should not be exploited at a rate in excess of the F_{OFL}, we find no evidence that would justify a gamma in excess of 1.0 or fishing at an F_{OFL} rate greater than M on this stock.

The 2009/10 Overfishing Limits

For the 2009/10 Tanner crab fishery, we estimated the total male catch OFL = 14.45 million pounds (Table 8). Relative to B_{REF} = 189.76 million pounds, the 2009 estimate of MMB at mating (108.28 million pounds) represents B/B_{REF} = 0.571 resulting in and F_{OFL} = 0.120.

Directed and non-directed losses to MMB in 2009/10 are estimated to be 6.95 and 3.27 million pounds, respectively. The retained part of the total male catch OFL is 4.23 million pounds. Relative to the overfishing limit, the retained legal catch would comprise 29.3% of the total male mature biomass losses. A significant component of the total male catch OFL therefore results from non-targeted losses under current EBS fisheries.

Expected total discard losses of female Tanner crab from the 2009/10 pot and ground fish fisheries is estimated at 1.06 million pounds. Therefore, total expected male plus female losses in 2009/10 comprising the Total Catch OFL = 15.51 million pounds. The estimated exploitation rate on MMB associated with these projected catches is 0.113.

Ecosystem Considerations

Ecosystem Effects on Stock

Prey availability or abundance trends

Tanner crab food habits in the EBS are largely unstudied. Jewett and Feder (1983) examined stomach contents from 1,025 Gulf of Alaska Tanner crab near Kodiak Island > 40 mm cw. Their principal findings were that arthropods (mainly juvenile Tanner crab) dominated stomach contents by weight; fishes and mollusks (mainly *Macoma* spp. and *Yoldia* spp.) were the second and third-most important food groups. In the western Bering Sea, the ascidian *Halocynthia autantium* is preyed upon by snow and Tanner crabs (Ivanov 1993). While the target prey of EBS Tanner crab and their associated trends in abundance are largely unknown, it is thought that recent warmer temperatures may have oriented the Bering Sea food web into a top-down control regime (Hunt et al. 2002, Aydin and Mueter 2007); prey availability may not be limiting adult Tanner abundance. The relative importance of climate effects on prey availability is uncertain (Aydin and Mueter 2007).

Predator population trends

Pacific cod (*Gadus macrocepahalus*) are documented as predators of Tanner crab in the eastern Bering Sea as well as Pacific halibut (*Hippoglossus stenolepis*) and skates (*Raja* sp.) (Livingston 1989, Livingston et al. 1993, Lang et al. 2005). Pacific cod biomass increased steadily from 1978 through 1983, remained relatively constant thereafter through 1988, fluctuated slightly from 1988 through 1994 (peak observed) and has steadily declined since then with 2007 estimates being the lowest on record (Thompson et al. 2007). Halibut biomass was lowest in 1982, fluctuated from 1983 through 1988 (peak), and increased from 1990 through 1996 (peak observed) (pers comm. Steven Hare, IPHC). Biomass estimates of all skate species in the EBS are not reported with the exception of that for Alaska skate (*Bathyraja parmifera*) which has been estimated since 1982. Alaska skate biomass fluctuated from 1982 through 1986, increased from 1986 through 1990 (peak), decreased from 1991 through 1999, and demonstrated an increasing trend from 1999 to present (Ormseth and Matta 2007).

Disease effects on the stock
Bitter crab syndrome (BCS) is caused by a non-motile single celled protistan blood parasite *Hematodinium* sp. (Meyers et al. 1990). BCS has been detected in EBS Tanner crab for 20 years with no clear trends in prevalence. The long-term effect of this syndrome on crab populations is not well understood (Workshop on "Hematodinum Associated Diseases: Research Status and Future Directions", Prince Edward Island, Canada, 2007). Another disease detected in EBS Tanner crab is black mat syndrome (BMS); a systemic fungal infection caused by *Trichomaris invadens.* BMS is thought lethal to crab by preventing (Sparks 1982). However, BMS is not considered to be an issue of concern in the EBS (pers comm. F. Morado, NOAA Fisheries).

Changes in habitat quality
The EBS ecosystem reorganization following the 1976/77 regime shift and, to a lesser degree, the 1998/1999 shift (Connors et al. 2002, Litzow 2006) are believed not to favor decapod stocks, however, mechanisms of action impacting EBS crabs are conjectural and the exact nature of the biological response to such changes is poorly understood (Litzow 2006). It's hypothesized that future temperature increases and ocean acidification, if any, may affect the growth and survival of larval EBS crab (unpublished data, M. Litzow, NOAA Fisheries), or result in changes to the phytoplankton community in the EBS (Hare et al. 2007) upon which larval Tanner crab depend (Incze et al. 1987, Incze and Paul 1983). The current effects of temperature change and ocean acidification on Tanner crab population dynamics or stock status, and/or on phytoplankton community structure are unknown.

Tanner Crab Fishery Effects on the Bering Sea Ecosystem
Fishery contribution to bycatch
Bycatch data from the directed Tanner crab fishery in the EBS were examined for the 2005/06 and the 2006/07 fisheries (Table 9). Non-targeted sublegal male and female Tanner crab comprised the largest component of bycatch followed by snow crab. Fish species are also a component of Tanner crab fishery bycatc and include a number of crab predators, notably, Pacific cod, Pacific halibut, yellowfin sole, and sculpin (*Myoxocephalus* spp.) (Barnard and Burt 2007, Barnard and Burt 2008). The invertebrate component of bycatch included sea stars, snails, hermit crabs and lyre crab.

Handling mortality
It's generally accepted that a certain amount of mortality is inflicted on the non-target species captured and released during fishing operations. MacIntosh et al. (1996) examined handling-induced injuries on survival on EBS Tanner crab and found that subsequent mortality was low and not significantly greater than controls. Stress due to windchill causes mortality to EBS

Tanner crab (Carls 1989), and can result in leg loss or immediate mortality. Stevens and MacIntosh (1992) observed an mortality of 11% for Tanner crab caught on one commercial crab vessel. Tracy and Byersdorfer (2000) and Byersdorfer and Barnard (2002) observed a relatively high incidence of pre-discard injuries in snow crab and Tanner crab during their respective directed fisheries, however, there is poor understanding of the magnitude of post-release mortality in EBS crabs (NMFS 2004).

Mortality to fish and non-target invertebrates from ghost pot fishing in the EBS is not well studied. The ADFG requires the use of a biodegradeable twine panel in each crab pot intended to disable ghost fishing in lost pots approximately 30 days. Recent work indicates that even biodegradeable twine may remain intact for up to 89 days in lost pots (Barnard 2008), or 3 times the length of time (30 d) found to cause irreversible starvation in crabs (Paul et al. 1994).

Benthic species and habitat impacted by pot gear

In the final Environmental Impact Statement (EIS) for the BSAI crab fisheries, the impact of pot gear on benthic EBS species is discussed (NMFS 2004). Benthic species examined included fish, gastropods, coral, echinoderms (sea stars and sea urchins), non-target crab, and invertebrates (sponges, octopuses, anemones, tunicates, bryozoans, hydroids, and jellyfish). Physical damage to the habitat by pot gear depends on habitat type. Sand and soft sediments where the Tanner crab pot fishing occurs are less likely to be impacted, whereas coral, sponge, and gorgonian habitats are more likely to be damaged by commercial crab pot fishing (Quandt 1999, NMFS 2004). The total portion of the EBS impacted by commercial pot fishing may be less than 1% of the shelf area (NMFS 2004). The report concludes that BSAI crab fisheries have an insignificant effect on benthic habitat. Considering that bycatch species impacted by the Tanner crab pot fishery are widespread across the EBS shelf, the impacts of pot gear on benthic populations should be minimal.

ESA and non-ESA marine mammals and seabirds

As noted in the Endangered Species Act EIS report, crab fisheries do not adversely affect ESA listed species, destroy or modify their habitat, or comprise a measurable portion of the diet (NMFS 2004), including listed marine mammals or seabirds although the possibility of strikes of listed seabirds with crab fishing vessels does exist (NMFS 2000).

Of non-listed marine mammals, bearded seals (*Erignathus barbatus*) are the only marine mammal potentially impacted by crab fisheries insofar as crab are a measurable portion of their diet (Lowry et al. 1980, NMFS 2004). For non-listed seabirds, the Alaska Groundfish Fisheries Final Programmatic SEIS (NMFS 2004b) provides life history, population biology and foraging ecology for marine birds. The SEIS concluded that crab stocks under the NPFMC fishery management plan (NPFMC 1998), including Tanner crab, have very limited interaction with non-listed seabirds.

Fishery Contribution to Discards and Offal Production

The EIS for the BSAI Crab Fisheries summarizes some of the effects of discards and offal production (NMFS 2004). Returning discards, process waste, and the contents of used bait containers to the sea provides energy to scavenging birds and animals that may not otherwise have access to those energy resources. The total offal and discard production as a percentage of the unused detritus already going to the bottom has not been estimated.

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Table 1. Age (months), mean size (mm cw) and instar number for male Tanner crab in Kodiak and the eastern Bering Sea.

	Kodiak		EBS
Instar Number	Mean Size (mm cw)	Mean Age (months)	Mean Size (mm cw)
1	3.4	1.8	-
2	4.5	4.5	-
3	6.0	3.5	-
4	7.9	4.9	-
5	10.4	6.6	-
6	13.7	8.9	-
7	18.1	11.9	17.2
8	23.9	15.9	24.4
9	31.6	21.1	33.5
10	41.7	28.1	45.9
11	53.6	37.3	60.7
12	67.8	47.2	79.3
13	84.6	59.0	98.5
14	106.3	73.1	112.5
15	129.5	85.3	126.8
16	154.3	106.2	141.8
17	180.8	124.5	157.2

Table 2. Eastern Bering Sea *Chionoecetes bairdi* retained catch in the United States pot, the Japanese tangle net and pot, and the Russian tangle net fisheries, 1965-2008.

Eastern Bering Sea Chionoecetes bairdi Retained Catch (106 lb)					
	US Pot Fishery		Japan	Russia	Total
Year		[Crabs/Pot]			
1965			2.58	1.66	4.24
1966			3.73	1.66	5.39
1967			21.50	8.48	29.98
1968	1.01	12.0	29.95	8.73	39.69
1969	1.02	29.0	43.98	15.61	60.60
1970	0.17	8.0	41.73	14.31	56.20
1971	0.11	10.0	35.04	10.51	45.66
1972	0.23	6.0	37.04		37.27
1973	5.04	115.0	23.67		28.72
1974	7.03	72.0	26.58		33.60
1975	22.30	63.0	16.62		38.92
1976	51.50	68.0	14.67		66.17
1977	66.60	51.0	11.72		78.32
1978	42.50	42.0	4.00		46.50
1979	36.60	30.0	5.30		41.90
1980	29.60	21.0			29.60
1981	11.00	10.0			11.00
1982	5.27	8.0			5.27
1983	1.21	8.0			1.21
1984	3.15	12.0			3.15
1985	0	0			0
1986	0	0			0
1987	2.20	8.0			2.20
1988	7.01	16.0			7.01
1989	24.50	15.0			24.50
1990	40.10	19.0			40.10
1991	31.80	10.0			31.80
1992	35.10	13.0			35.10
1993	16.90	13.0			16.90
1994	7.80	13.0			7.80
1995	4.23	8.0			4.23
1996	1.81	5.0			1.81
1997	0	0			0
1998	0	0			0
1999	0	0			0
2000	0	0			0
2001	0	0			0
2002	0	0			0
2003	0	0			0
2004	0	0			0
2005	0.95	0			0.95
2006	2.12	13.8			2.12
2007	2.11	17.0			2.11
2008	*4.36*	*17.0*			*4.36*

Table 3. Eastern Bering Sea *Chionoecetes bairdi* total discard and bycatch losses by sex in the directed plus non-directed pot and the groundfish trawl fisheries, 1965-2008.

Eastern Bering Sea *Chionoecetes bairdi* Discard and Bycatch Losses (10^6 lb)
[HM_{Pot}=0.50; HM_{GF}=0.80]

	All Pot		Groundfish		Total	
Year	Male	Female	Male	Female	Male	Female
1965	1.73	0.48	6.15	4.07	7.88	4.56
1966	2.20	0.62	11.16	7.38	13.36	8.00
1967	12.23	3.42	17.37	11.50	29.60	14.92
1968	16.20	4.53	13.18	8.72	29.37	13.25
1969	24.73	6.92	19.35	12.81	44.08	19.73
1970	22.94	6.42	21.52	14.24	44.46	20.66
1971	18.63	5.21	24.15	15.98	42.78	21.19
1972	15.21	4.25	13.86	9.18	29.07	13.43
1973	12.28	3.33	18.97	12.55	31.25	15.89
1974	14.52	3.91	26.25	17.37	40.77	21.29
1975	17.95	4.64	10.16	6.73	28.12	11.37
1976	28.29	7.68	4.40	2.91	32.70	10.59
1977	34.22	9.15	2.98	1.97	37.20	11.13
1978	22.76	5.67	3.42	2.27	26.18	7.93
1979	20.77	5.13	2.73	1.81	23.50	6.94
1980	17.62	3.91	2.24	1.48	19.86	5.39
1981	6.36	1.43	1.56	1.03	7.92	2.47
1982	3.34	0.72	0.48	0.32	3.82	1.03
1983	1.20	0.21	0.71	0.47	1.92	0.68
1984	2.49	0.47	0.69	0.45	3.18	0.93
1985	1.03	0.10	0.42	0.28	1.45	0.38
1986	1.46	0.14	0.69	0.46	2.15	0.60
1987	4.38	0.58	0.68	0.45	5.06	1.03
1988	11.26	1.60	0.49	0.33	11.75	1.93
1989	25.08	4.23	0.71	0.47	25.80	4.70
1990	48.17	7.60	1.00	0.66	49.17	8.27
1991	45.45	6.72	1.54	1.02	46.98	7.73
1992	27.25	2.41	2.07	1.37	29.32	3.78
1993	14.86	2.72	1.65	1.09	16.51	3.81
1994	7.74	2.34	1.23	0.81	8.97	3.15
1995	5.33	2.61	1.11	0.73	6.44	3.34
1996	1.21	0.36	1.02	0.68	2.23	1.03
1997	2.11	0.25	0.95	0.63	3.06	0.88
1998	2.32	0.20	0.73	0.48	3.06	0.68
1999	0.85	0.16	0.30	0.20	1.15	0.36
2000	0.23	0.03	0.38	0.25	0.62	0.28
2001	0.40	0.01	0.59	0.39	0.99	0.40
2002	0.68	0.04	0.72	0.47	1.40	0.52
2003	0.27	0.03	1.31	0.87	1.58	0.90
2004	0.14	0.02	0.95	0.63	1.09	0.65
2005	1.43	0.11	1.02	0.68	2.45	0.79
2006	6.61	0.20	1.64	1.09	8.25	1.29
2007	5.41	0.28	0.61	0.40	6.01	0.68
2008	*6.01*	*0.28*	*0.61*	*0.40*	*6.61*	*0.69*

Table 4. Eastern Bering Sea *Chionoecetes bairdi* total catch in the directed (retained) and non-directed (discard + bycatch) fisheries, 1965-2008.

Eastern Bering Sea *Chionoecetes bairdi* Total Catch in the Directed + Non-Directed Fisheries (10^6 lb)			
Year	Male	Female	Total
1965	12.12	4.56	16.68
1966	18.74	8.00	26.74
1967	59.58	14.92	74.50
1968	69.06	13.25	82.31
1969	104.68	19.73	124.41
1970	100.66	20.66	121.32
1971	88.44	21.19	109.63
1972	66.34	13.43	79.77
1973	59.97	15.89	75.85
1974	74.38	21.29	95.66
1975	67.03	11.37	78.40
1976	98.87	10.59	109.46
1977	115.52	11.13	126.64
1978	72.68	7.93	80.61
1979	65.40	6.94	72.34
1980	49.46	5.39	54.85
1981	18.92	2.47	21.39
1982	9.10	1.03	10.13
1983	3.12	0.68	3.80
1984	6.33	0.93	7.26
1985	1.45	0.38	1.82
1986	2.15	0.60	2.74
1987	7.26	1.03	8.29
1988	18.77	1.93	20.69
1989	50.30	4.70	55.00
1990	89.27	8.27	97.54
1991	78.78	7.73	86.52
1992	64.42	3.78	68.20
1993	33.41	3.81	37.22
1994	16.77	3.15	19.92
1995	10.68	3.34	14.02
1996	4.03	1.03	5.07
1997	3.06	0.88	3.94
1998	3.06	0.68	3.74
1999	1.15	0.36	1.52
2000	0.62	0.28	0.90
2001	0.99	0.40	1.39
2002	1.40	0.52	1.91
2003	1.58	0.90	2.48
2004	1.09	0.65	1.74
2005	3.41	0.79	4.19
2006	9.77	2.17	11.95
2007	8.12	0.68	8.80
2008	*10.97*	*0.69*	*11.66*

Table 5. Eastern Bering Sea *Chionoecetes bairdi* male mature biomass and legal male (≥ 138mm cw) biomass at time of the survey, fishery and mating, 1965-2008. (2008 MMB and LMB at mating are estimates based on extraction of respective 2008/09 catch OFLs under Scenario-2).

Eastern Bering Sea Chionoecetes bairdi Survey Biomass (10^6 lb)						
	Male Mature Biomass (10^6 lb)			Legal Male Biomass (10^6 lb)		
Year	Survey	Fishery	Mating	Survey	Fishery	Mating
1965						
1966						
1967						
1968						
1969	604.93	539.22	414.26			
1970	151.81	135.32	29.57			
1971						
1972						
1973	208.44	185.80	118.84			
1974	396.83	353.72	266.04			
1975	623.89	556.11	468.16			
1976	318.43	283.83	174.29			
1977	344.02	306.65	179.60			
1978	179.55	160.05	81.35			
1979	121.38	108.20	38.73			
1980	205.47	183.15	126.80	170.86	152.30	116.97
1981	158.07	140.90	116.68	77.16	68.78	55.19
1982	113.32	101.01	88.11	55.67	49.62	42.48
1983	65.70	58.56	53.23	36.93	32.92	30.47
1984	45.41	40.48	32.63	31.97	28.49	24.27
1985	26.01	23.19	20.87	24.25	21.62	20.80
1986	35.49	31.64	28.30	17.09	15.23	14.66
1987	63.93	56.99	47.59	32.52	28.99	25.70
1988	139.55	124.39	100.95	78.81	70.25	60.60
1989	231.48	206.34	148.28	185.19	165.07	134.36
1990	240.30	214.20	116.87	248.57	221.57	173.13
1991	255.73	227.95	140.59	193.45	172.44	134.15
1992	246.92	220.09	147.39	230.38	205.35	162.53
1993	144.40	128.71	90.47	113.54	101.20	80.50
1994	95.02	84.70	64.74	84.88	75.66	65.01
1995	71.65	63.87	50.79	55.12	49.13	43.05
1996	58.64	52.27	46.27	50.71	45.20	41.69
1997	25.13	22.40	18.50	18.74	16.70	16.08
1998	25.35	22.60	18.69	12.13	10.81	10.40
1999	43.87	39.11	36.48	11.57	10.32	9.93
2000	39.24	34.98	33.05	27.56	24.56	23.64
2001	43.65	38.91	36.45	35.82	31.93	30.73
2002	44.53	39.70	36.80	38.58	34.39	33.10
2003	61.29	54.63	50.99	40.79	36.35	34.99
2004	65.48	58.36	55.08	29.76	26.53	25.53
2005	104.50	93.15	86.24	62.83	56.01	52.95
2006	158.95	141.68	126.58	80.19	71.48	66.67
2007	185.19	165.07	150.74	58.49	52.13	48.07
2008	143.06	127.52	108.28	64.80	57.76	50.53

Table 6. Eastern Bering Sea *Chionoecetes bairdi* fishery rate of exploitation on male mature biomass (MMB) and legal mature biomass (LMB) at the time of the fishery, 1965-2007. Exploitation rates are based on biomass; μ on MMB uses total catch losses while μ on LMB uses total retained legal catch.

Eastern Bering Sea *Chionoecetes bairdi* Fishery Exploitation Rate @ Time Fishery		
Year	MMB	LMB
1965		
1966		
1967		
1968		
1969	0.19	
1970	0.74	
1971		
1972		
1973	0.32	
1974	0.21	
1975	0.12	
1976	0.35	
1977	0.38	
1978	0.45	
1979	0.60	
1980	0.27	0.49
1981	0.13	0.40
1982	0.09	0.27
1983	0.05	0.10
1984	0.16	0.30
1985	0.06	0
1986	0.07	0
1987	0.13	0.15
1988	0.15	0.21
1989	0.24	0.33
1990	0.42	0.39
1991	0.35	0.38
1992	0.29	0.38
1993	0.26	0.34
1994	0.20	0.21
1995	0.17	0.18
1996	0.08	0.08
1997	0.14	0
1998	0.14	0
1999	0.03	0
2000	0.02	0
2001	0.03	0
2002	0.04	0
2003	0.03	0
2004	0.02	0
2005	0.04	0.04
2006	0.07	0.06
2007	0.05	0.04
2008	*0.11*	*0.08*

Table 7. Data used to estimate discard and bycatch losses projected in the terminal 2009/10 Bairdi OFL fishery: (a) 2007/08 Tanner crab fishery performance, (b) 2006/07 and 2007/08 Tanner crab discards in the EBS pot fisheries and snow crab retained catch, and (c) 2003-07 EBS groundfish trawl fishery Tanner crab bycatch.

(a)

2007/08 Observer Fishery Data
EBS Tanner Crab Directed Fishery

		LB	Ratio
Discard”			
	S.Legal ♂:	6,842,396	3.24799
	Legal ♂:	82,896	0.03935
	All ♀:	328,283	0.15583
Retained:		2,106,655	1.0
	Total:	9,360,230	

(b)

Tanner Crab Non-Directed Pot Fishery Bycatch
(Combined Opilio + RKC Pot Fisheries)

Year	Opilio Retained (10^6 LB)	Bairdi Discard (10^6 LB)	Ratio
2006/07	37.00	3.19	0.086103
2007/08	63.03	3.89	0.061657
2008/09	58.55 *		
		Average:	0.073880
Projected 2009/10 Bairdi Discard (10^6 LB):			4.325669

* 2008/09 Opilio TAC = retained catch OFL

(c)

Trawl Fishery Tanner Crab Bycatch
(Male + Female Combined)

Year		Bycatch (10^6 LB)
2003		2.7151
2004		1.9751
2005		2.1226
2006		3.4113
2007		1.2594
	Average:	2.2967

Table 8. Catch overfishing limits, stock and fishery metrics for the 2008 Eastern Bering Sea *Chionoecetes bairdi* fishery under Scenario-2, where B_{REF}=mean 1969-1980 MMB at the time of mating.. (µ on LMB is total legal retained catch/LMB at the time of the fishery, µ on MMB is Total Catch OFL/MMB at the time of the fishery).

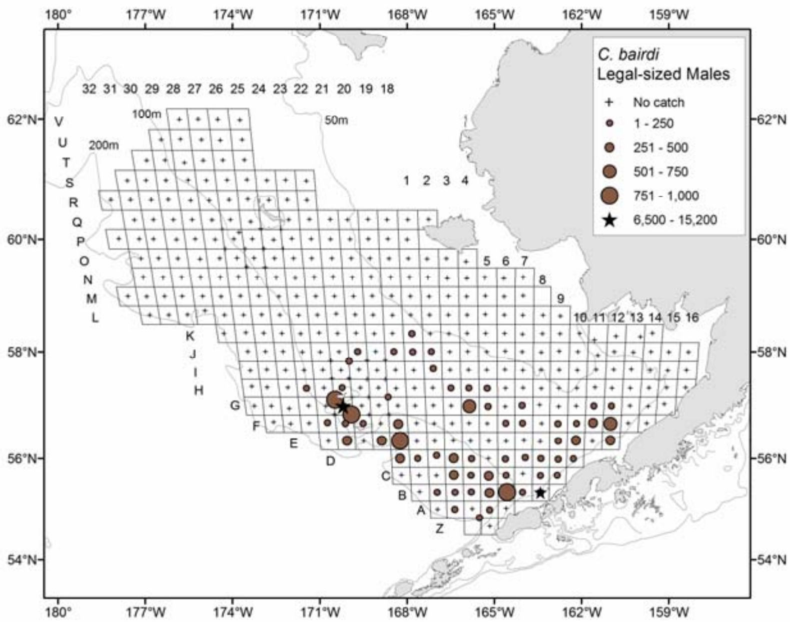
2009/10 Eastern Bering Sea *Chionoecetes baridi*
Catch OFL, Stock and Fishery Metrics

Metrics (10^6lb):	
B_{REF}:	189.764
MMB @ Mating:	108.277
B/B_{REF}:	0.571
F_{OFL}:	0.120
Catch Components (10^6lb):	
Total ♂ Catch OFL:	14.450
Directed Discard Losses MMB:	6.952
Non-Directed Discard Losses MMB:	3.268
Retained Part of Total ♂ Catch OFL:	4.229
Discard + Bycatch Losses ♀:	1.061
Total ♂ Catch OFL + ♀ Losses:	15.511
Rates:	
µ on MMB @ Fishery:	0.113

B_{REF}=mean 1969-80 MMB @ mating as proxy for B_{MSY}.

Table 9. Total observed bycatch (#) in pot lifts of the directed EBS Tanner crab fishery sampled during the 2005/06 (n=160) and the 2006/07 (n=141) fisheries (Barnard and Burt 2007; Barnard and Burt 2008). A total of 29,693 and 49,192 pots were lifted during the 2005/06 and 2006/07 fisheries respectively (Bowers et al. 2008).

Species	Total Catch		Species	Total Catch	
	2005/06	2006/07		2005/06	2006/07
Tanner crab			Yellowfin sole	270	123
Legal male	6,612	12,130	Sea star (unidentified)	156	317
Sublegal male	18,578	20,222	Sculpin (inidentified)	132	60
Female	2,838	10,768	Snail (unidentified)	129	23
			Pribilof Neptune	62	0
Snow crab			Pacific cod	55	31
Legal male	2,726	889	Hermit crab (unidentified)	27	3
Sublegal male	258	13	Lyre crab	18	23
Female	16	0	Yellow Irish lord	16	96
			Jellyfish (unidentified)	10	0
Red King crab			Sea urchin (unidentified)	8	0
Legal male	0	3	Brittle star (unidentified)	7	5
Sublegal male	29	1	Pacific Halibut	5	1
Female	137	9	Arrowtooth flounder	2	0
			Bryozoan (unidentified)	1	0
Snow crab			Flatfish (unidentified)	1	0
Legal male	107	2	Prowfish	1	0
Sublegal male	50	94	Rock sole (unidentified)	1	2
Female	2	3	Sea cucumber	1	2
			Flathead sole	0	2
Blue King crab			Hydroid (unidentified)	0	2
Legal male	8	0	Decorator crab	0	1
Sublegal male	112	0	Snailfish (unidentified)	0	1
Female	0	1			



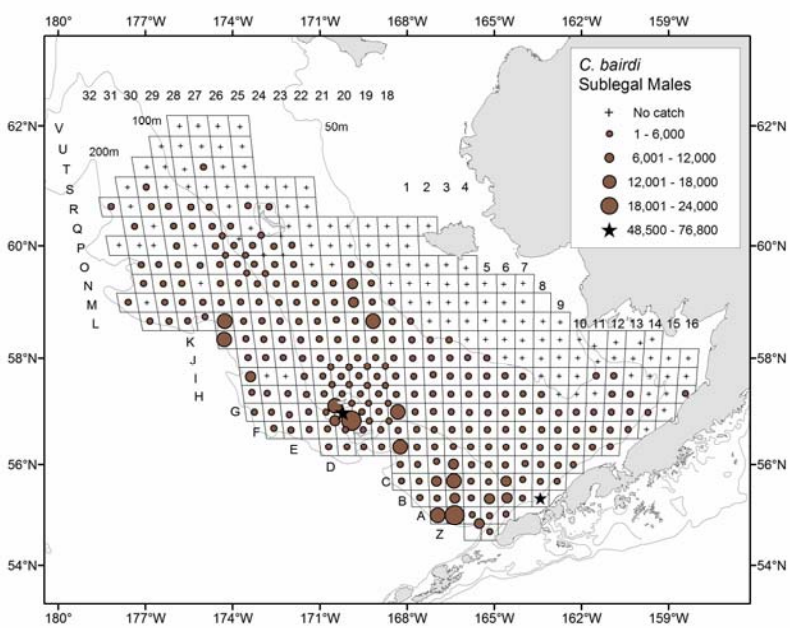


Figure 1. Distribution and abundance of legal (>= 138 mm cw) and sublegal (< 138 mm cw) male Tanner crab in the summer 2008 NMFS EBS trawl survey.

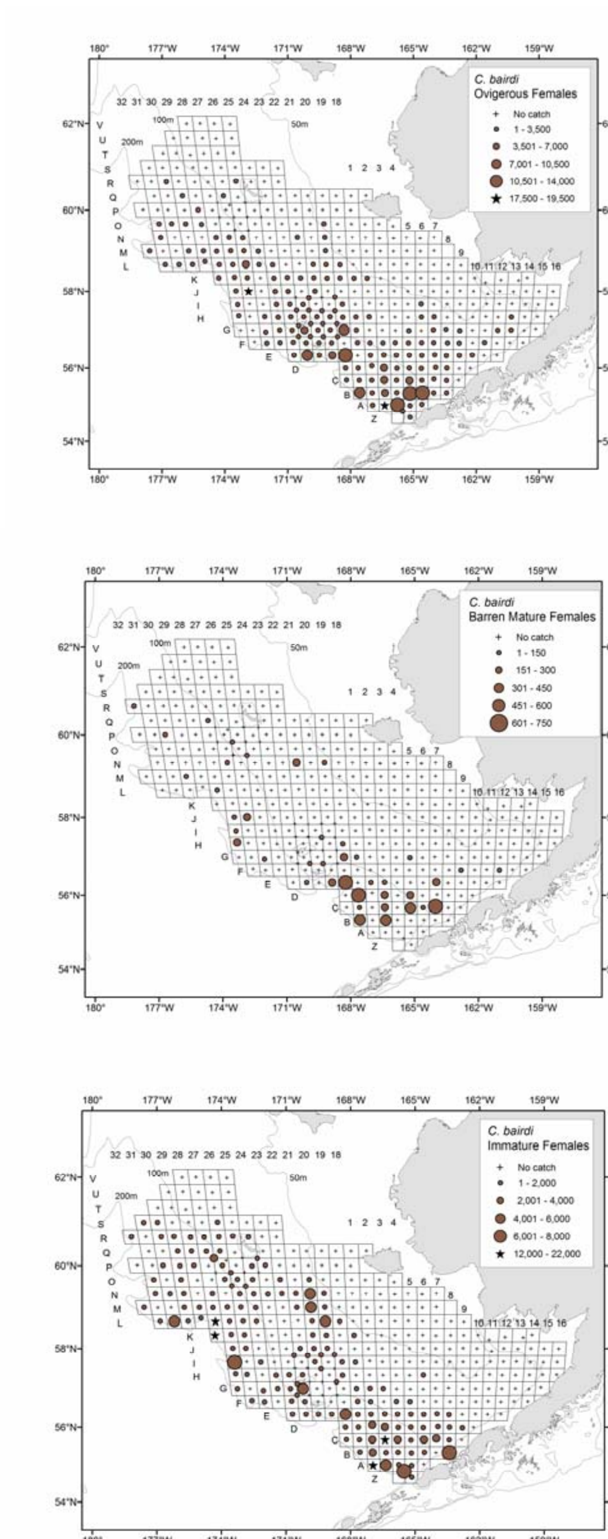


Figure 2. Distribution and abundance of ovigerous, barren mature, and immature female Tanner crab in the summer 2008 NMFS EBS trawl survey.

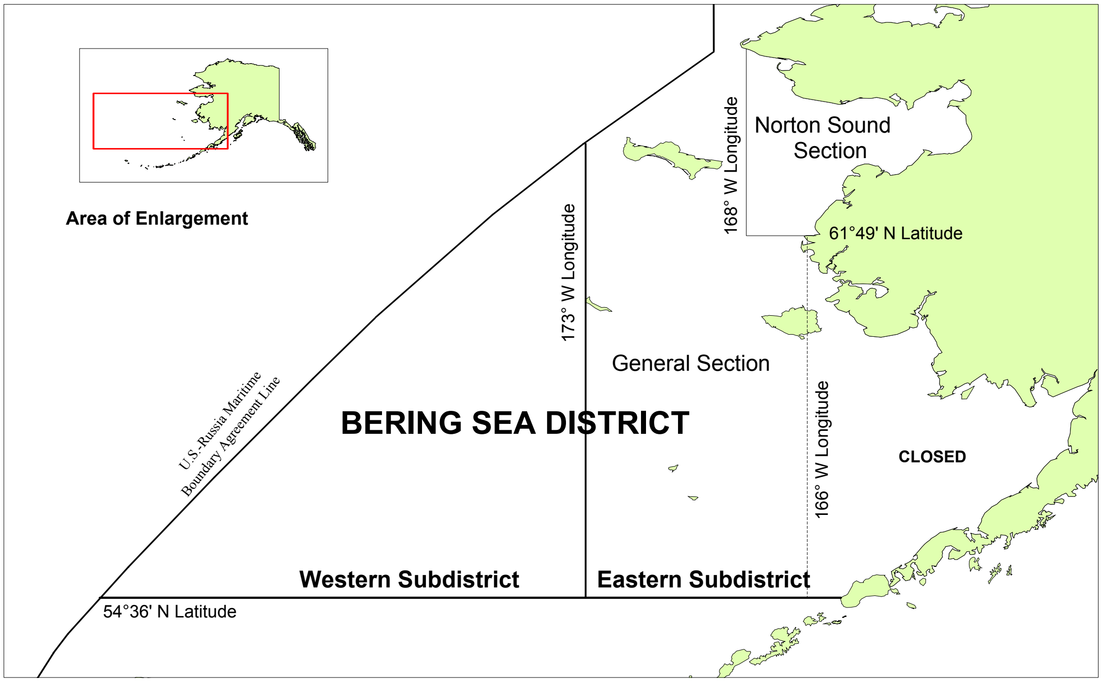
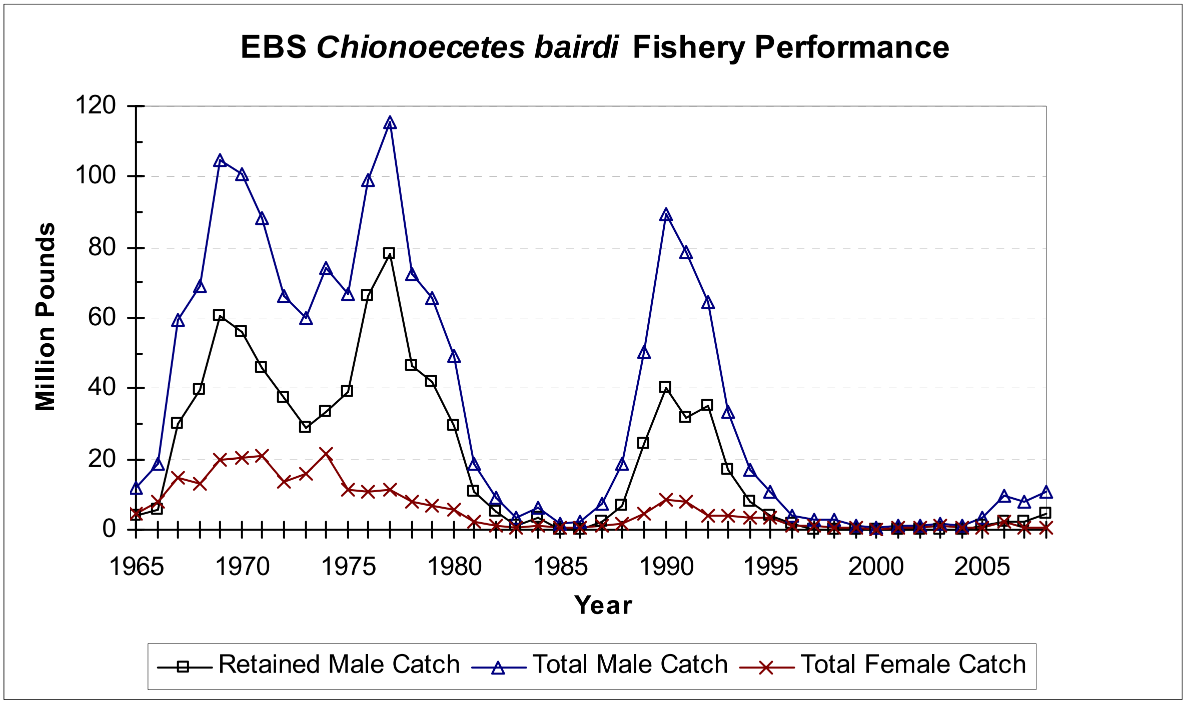


Figure 3. Eastern Bering Sea District of Tanner crab Registration Area J including subdistricts and sections (From Bowers et al. 2008).

(a)



(b)

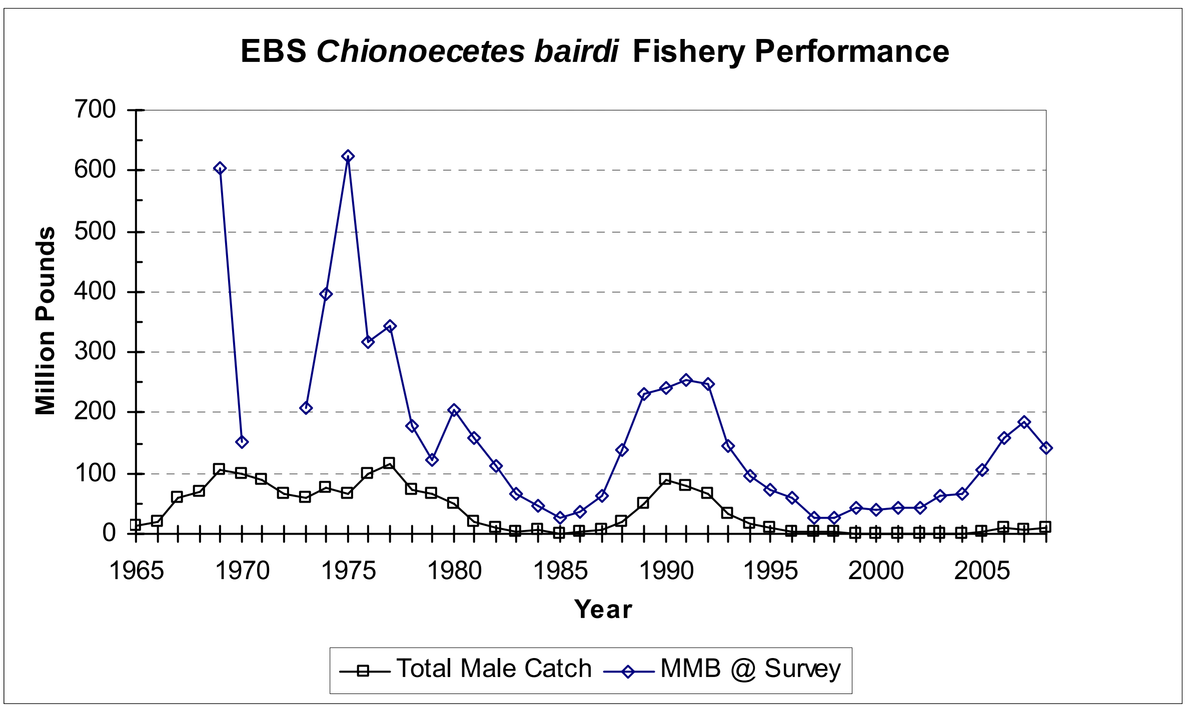


Figure 4. Eastern Bering Sea *Chionoecetes bairdi* retained male catch, total (retained + discard/bycatch) male catch and total female catch (a), and total male catch vs male mature biomass at the time of the survey (b), 1965-2008.

(a)

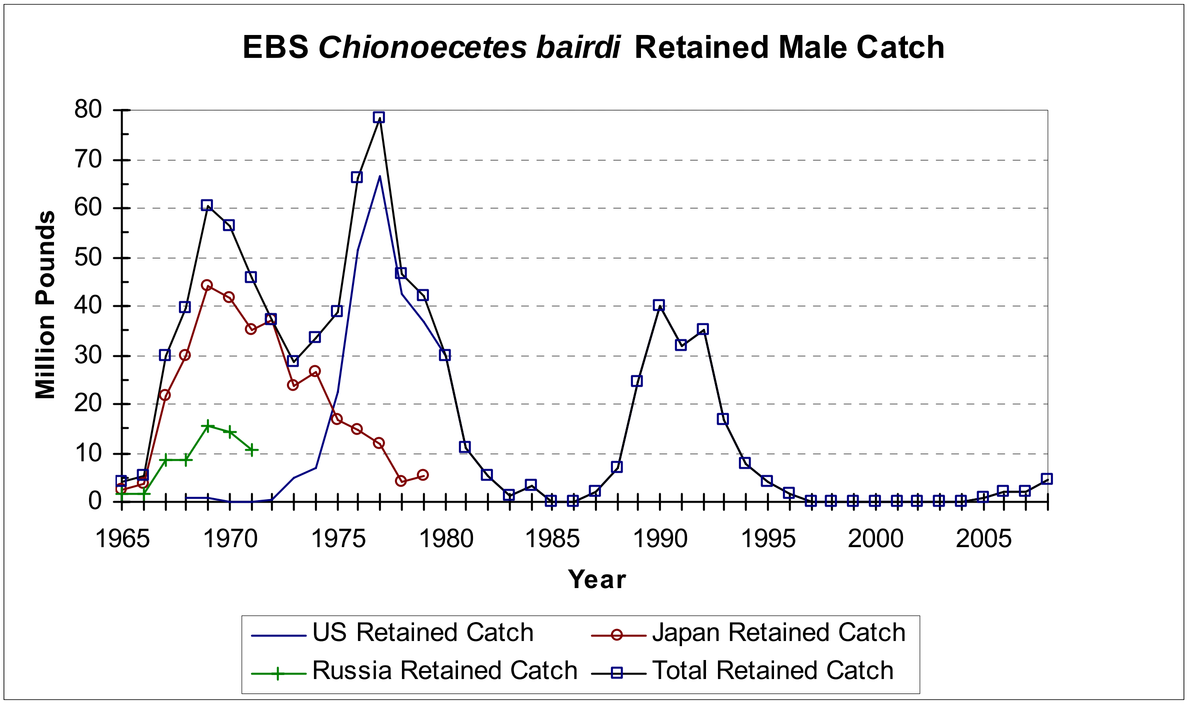


Figure 5. Eastern Bering Sea *Chionoecetes bairdi* retained male catch in the directed United States, Russian and Japanese fisheries, 1965-2008.

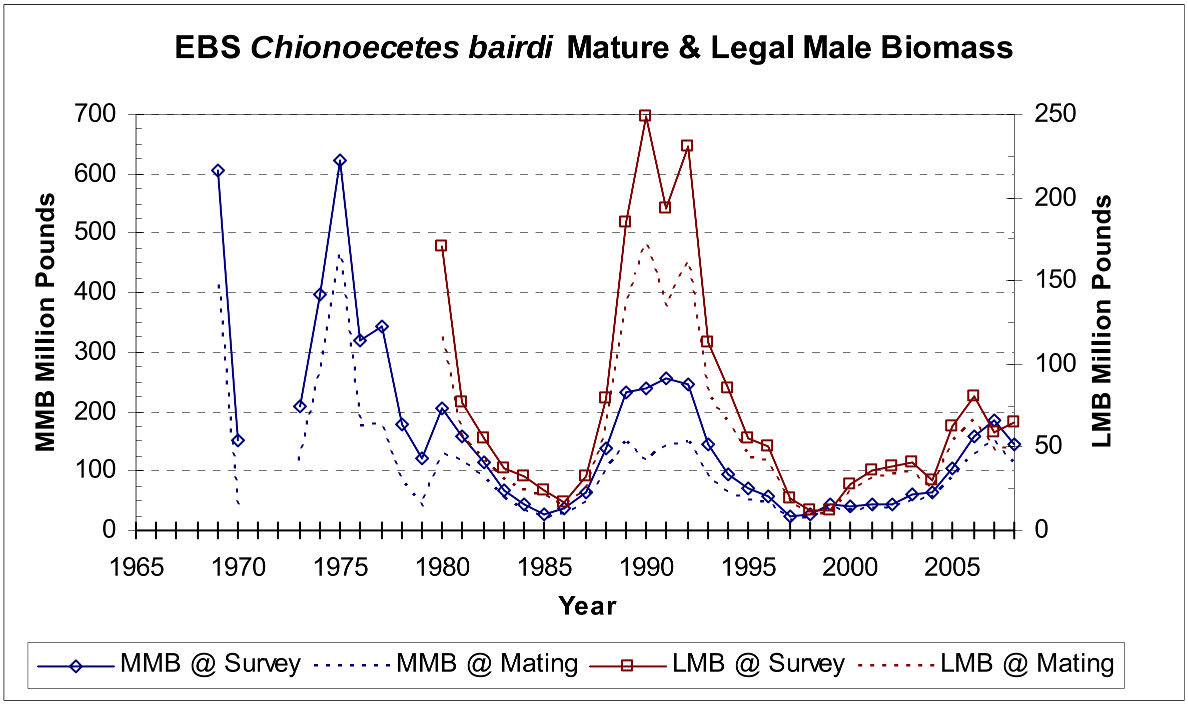
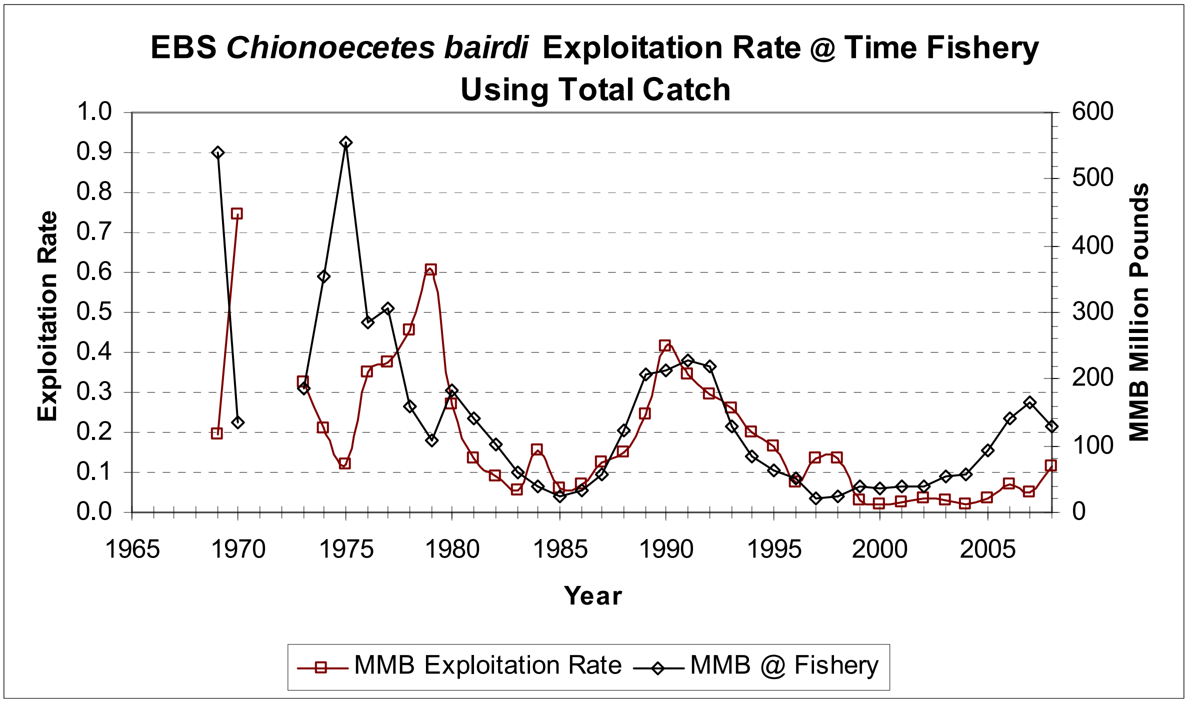


Figure 6. Eastern Bering Sea *Chionoecetes bairdi* mature and legal male biomass at time of the survey and subsequent mating, 1965-2008. (Note: 2008 MMB and LMB at time of mating are estimates based on extraction of respective 2008 catch OFLs).

(a)



(b)

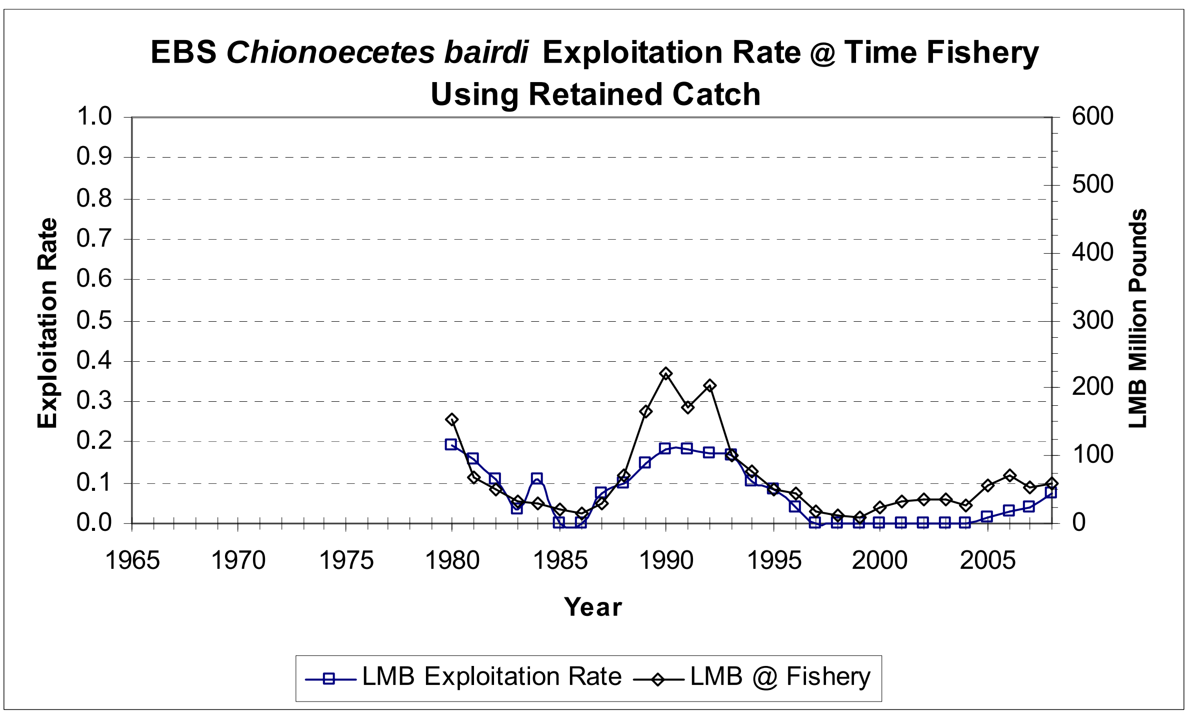


Figure 7. Eastern Bering Sea *Chionoecetes bairdi* exploitation rate on mature (a) and legal (b) male biomass at the time of the fishery with associated male biomass metric, 1965-2008.

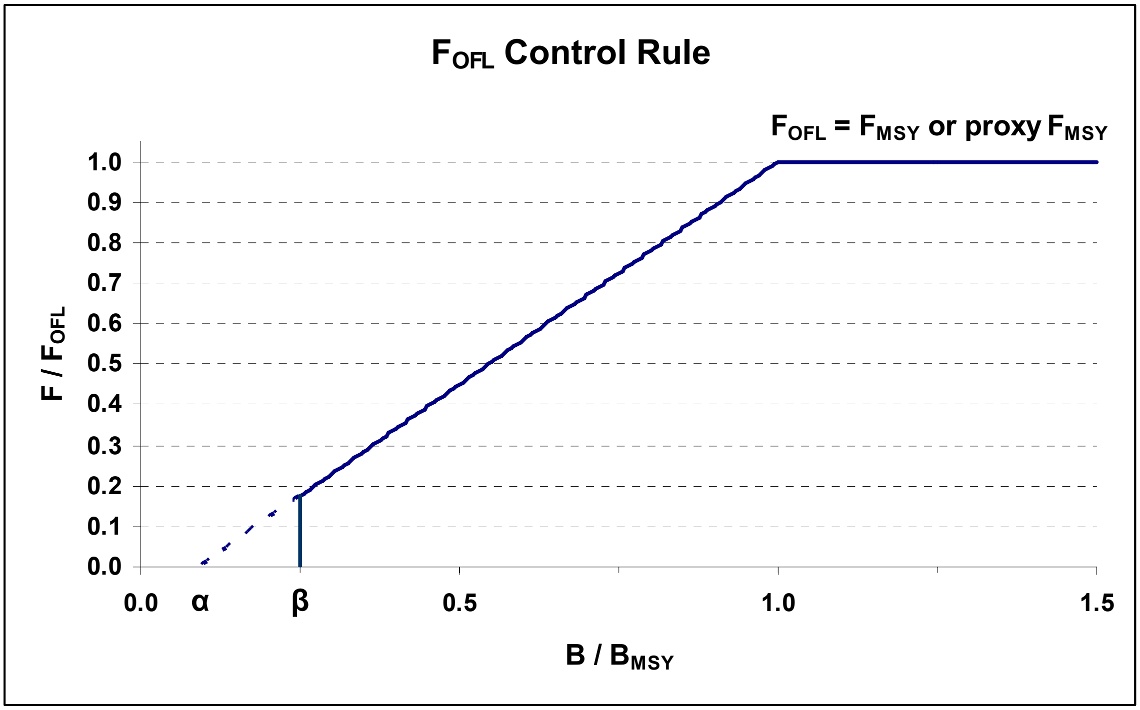


Figure 8. F_{OFL} Control Rule for Tier-4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set 0 below β.

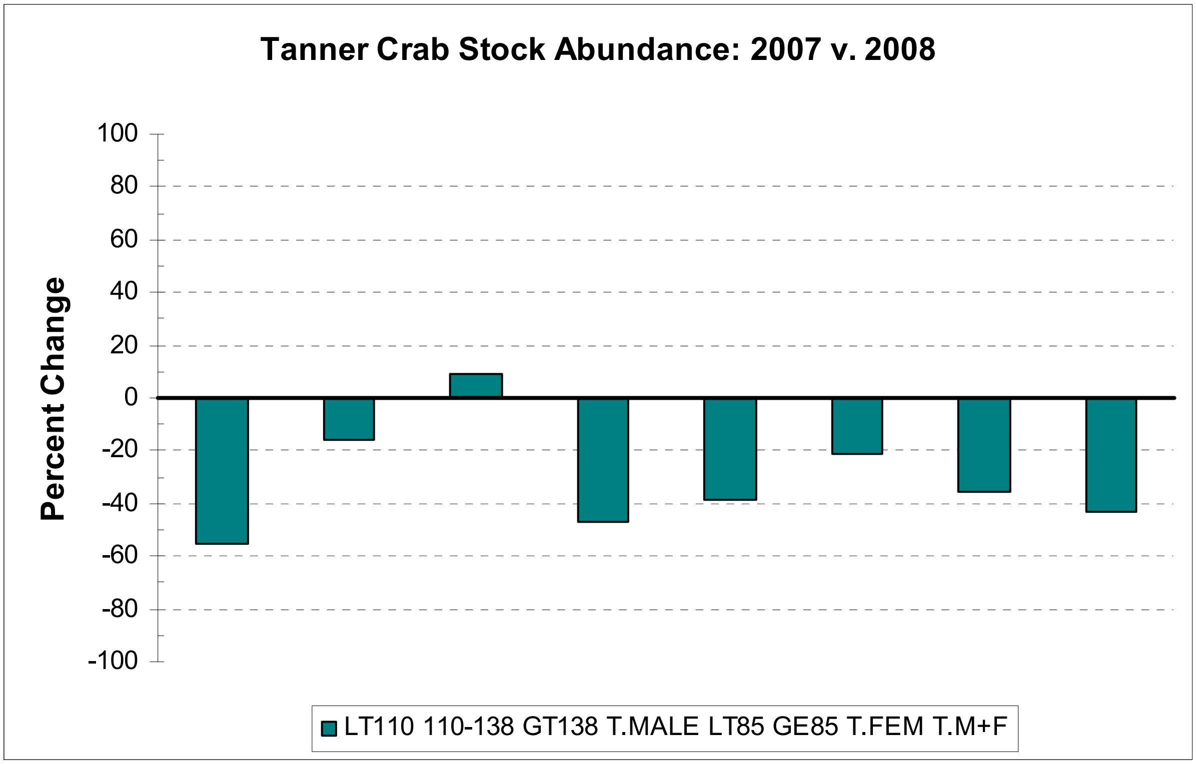


Figure 9. Percent change in Tanner crab stock abundance between 2007 and 2008 for males (< 110 mm cw, 110-137 mm cw, >= 138 mm cw and total males), females (<85 mm cw, >=85 mm cw and total females), and for total males + females combined.

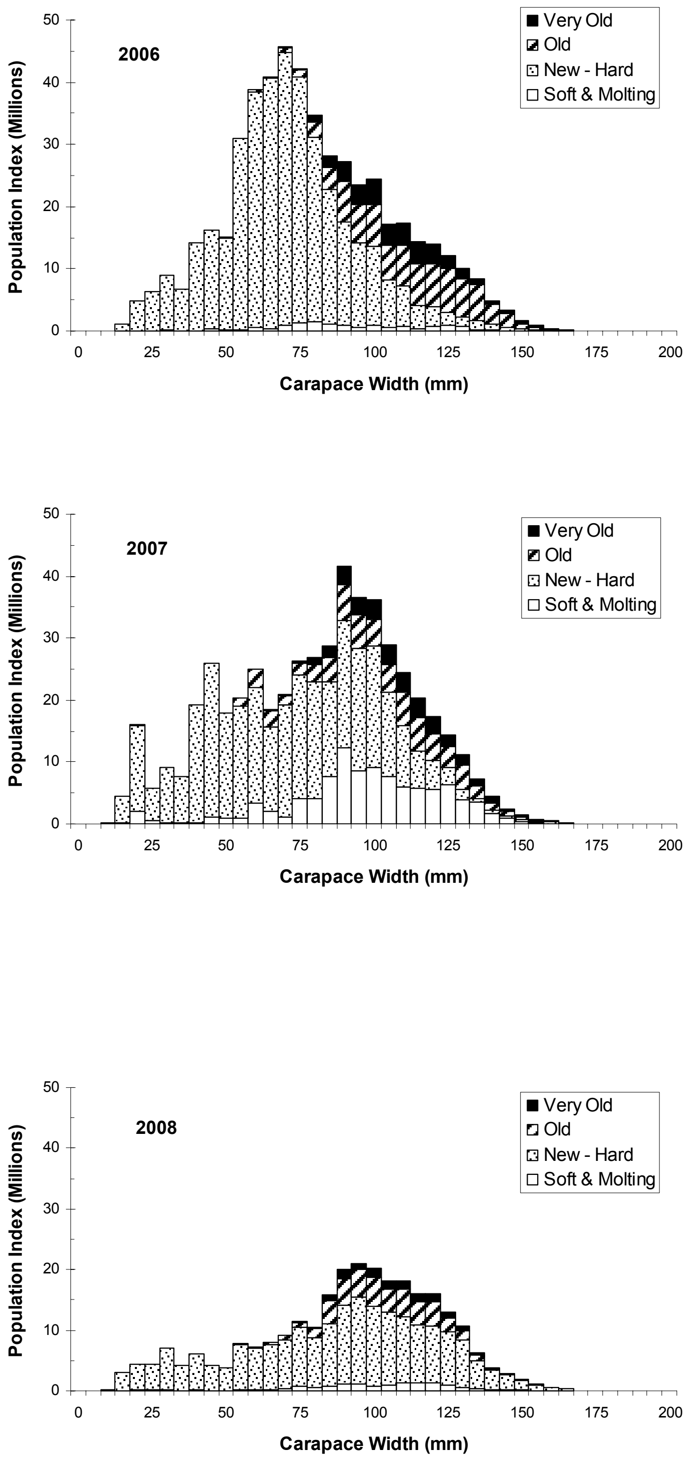


Figure 10. Male Tanner crab length frequency by shell class condition sampled by the EBS trawl survey, 2006-2008.

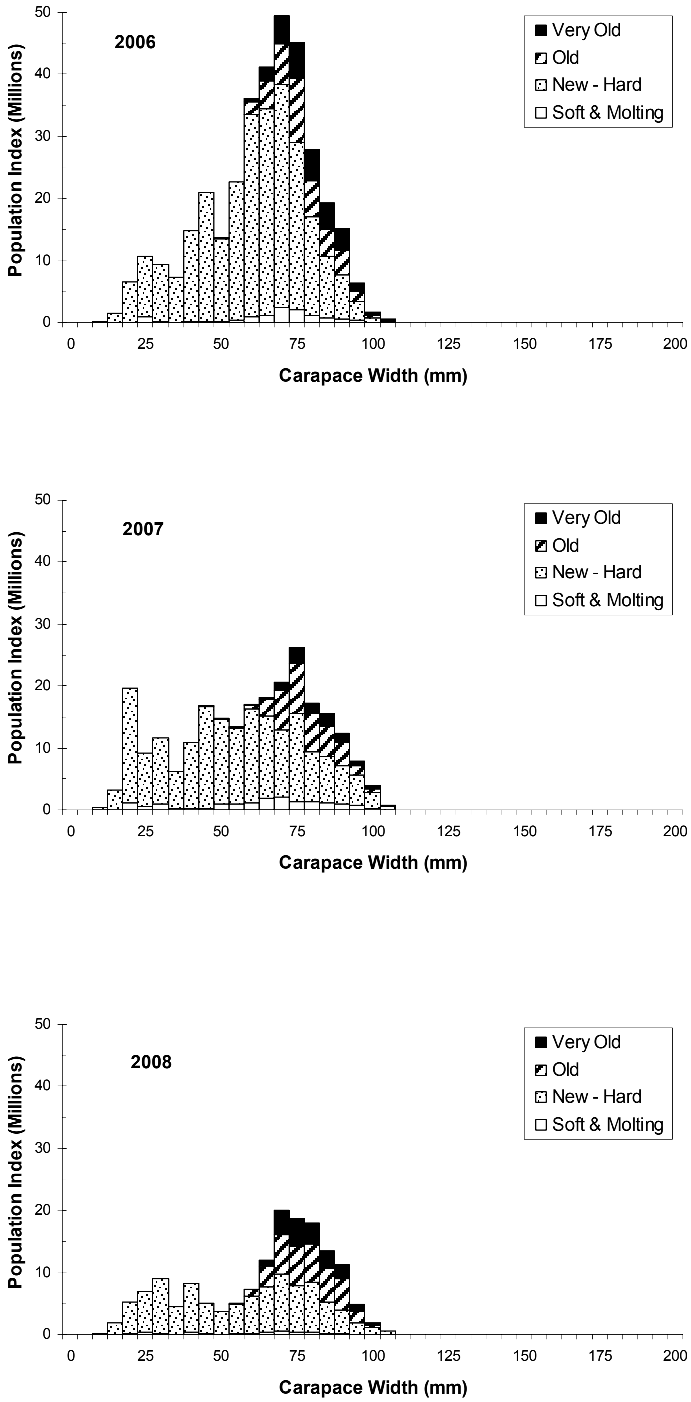


Figure 11. Female Tanner crab length frequency by shell class condition sampled by the EBS trawl survey, 2006-2008.

Appendix A. Feasibility study: estimation of eastern Bering Sea Tanner crab OFL using $F_{35\%}$ and estimated fishery selectivities

The calculation of the OFL in this study follows the method proposed by the SSC at their June 2008 meeting. The SSC recommended using fishery selectivities taken from the Environmental Assessment (EA) on new OFL definitions for EBS crab stocks to derive an $F_{35\%}$ proxy for F_{MSY} (Figure A-5) due to the lack of recent data on selectivities. The F_{MSY} proxy was recommended as a scaler multiple of the instantaneous mortality rate (M) derived as $F_{35\%}$ / M and estimated as 2.1 x M from the analysis presented in June 2008. The same method is used here, except that new fishery selectivity curves are estimated from the most recent year of fishery data and $F_{35\%}$ is calculated using these newly estimated fishery selectivities. The F_{MSY} proxy for the control rule would be:

$$\text{Proxy } F_{MSY} = \gamma M \quad (1)$$

The SSC proposed that gamma might be estimated as $F_{35\%}$ / M, therefore,

$$\text{Proxy } F_{MSY} = (F_{35\%} / M) \cdot M = F_{35\%} \quad (2)$$

Under this formulation, the use of $F_{35\%}$ as the F_{MSY} proxy in the control rule is equivalent to using γ, where γ is estimated as $F_{35\%}$ / M. As recommended by the SSC, this value of $F_{35\%}$ is used with the estimated fishery selectivities estimate the OFL. Thus, γ is specific to the $F_{35\%}$ used in the ratio $F_{35\%}$ / M, and it cannot be used without those fishery selectivities, for example in a simple multiplication on M and mature male biomass to estimate the total catch OFL.

The observer data from the 2006/7 and the 2007/8 fishery seasons were not available for analysis in June 2008 so the fishery selectivities used in the EA analysis for new OFL definitions were used in the June 2008 SSC presentation. However, the last two years of fishery data indicate a change in selectivity and an increase in the discarding in the directed Tanner crab fishery. Discard and retained selectivities were estimated using the length frequency of the observed catch from the 2007/8 season as well as the ratio of discarded to retained numbers of crab (Figure A-1 and Table A-2) and the predicted catch length frequency and numbers (discard and retained) using the 2007 survey abundance by length projected forward to the time of the fishery. The discard fishery selectivities were used along with trawl selectivities to estimate bycatch in the snow crab and trawl fisheries (Figure A-2). $F_{35\%}$ was then determined base on the estimated fishery selectivities and the OFL calculated. Two fishery selectivity scenarios were estimated, one with retained selectivity at 1.0 for the 140-145 mm cw length bin and then dropping to 0.5 for larger sizes (Figure A-1 and Table A-2), and scenario 2 were retained selectivity was 1.0 for all crab > 140mm cw (Figure A-4 and Table A-2). The scenario with retained selectivity at 1.0 for all crab larger than 140 mm cw did not fit the length frequency of the catch as well and also did not fit the ratio of discard to retained numbers as well as the scenario with retained selectivity at 0.5 at > 145 mm cw (Figures A-3 and A-5).

The discard fishery selectivities were estimated differently for each scenario to fit the total length frequency and the ratio of retained and discarded numbers in the 2007/8 fishery using the 2007 survey length frequency projected forward. The current Tanner crab fishery may not be targeting specifically on Tanner crab, which results in the drop in selectivity at larger sizes fitting the fishery data better than selectivity of 1.0 at larger sizes.

The 2008 survey abundance by length was projected forward to estimate catch and MMB using $F_{35\%}$ and the estimated fishery selectivities (Table A-1). The total catch OFL for scenario 1 (0.5 selectivity size>145 mm cw) was 16.1 million pounds with a retained directed fishery catch of 5.27 million pounds. The total catch OFL for scenario 2 (1.0 selectivity size>140 mm cw) was 15.67 million pounds with a retained directed fishery catch of 5.21 million pounds. The total catch OFL with F=M was 15.37 million pounds with a retained directed fishery catch of 4.71 million pounds.

Table A-1. Total male catch OFL (million pounds) using $F_{35\%}$ and 2008 survey numbers by length and mature biomass at mating. Ratio of numbers of discard to retained was 4.09 in the 2007/8 fishery. Scenario 1 ratio in the fitting was 4.37, for the selectivity = 1.0 ratio was 5.05.

Metric:	Scenario 1	Scenario 2
	Retained sel >145mm = 0.5	Retained sel >140 mm = 1.0
Directed Legal Catch	5.62	5.57
Retained Directed Legal Catch	5.27	5.21
Directed Discard	7.13	6.75
Non-Directed Discard (snow crab + groundfish trawl)	3.35	3.36
Total Male Catch OFL	16.10	15.67
MMB	106.03	106.47
B_{REF}	178.2	178.2
MMB/ B_{REF} (%)	59.49	59.75
Directed $F_{35\%}$	0.585	0.411
Directed Control Rule F 2008/09	0.322	0.227
F Snow Crab Fishery	0.105	0.09

Table A-2. Estimated retained and discard selectivity. Discard selectivity estimated as a logistic function with slope 0.17 and size at 50% selected 120 mm cw from 95 mm cw to 135 mm cw. Value at 135-140 mm fixed at 0.5, and discard selectivity 0 after 140 mm cw. Values of retained selectivity set at 1 and 140-145 mm cw other values (0.5) estimated to fit the length frequency of the catch and the split in catch between retained and discarded.

	Scenario 1		Scenario 2	
CW (mm)	Retained	Discard	Retained	Discard
97.5	0	0.014064	0	0.032295
102.5	0	0.032295	0	0.072426
107.5	0	0.072426	0	0.154465
112.5	0	0.154465	0	0.299433
117.5	0	0.299433	0	0.5
122.5	0	0.5	0	0.700567
127.5	0	0.700567	0	0.845535
132.5	0	0.845535	0	1
137.5	0.5	0.5	0.5	0.5
142.5	1	0	1	0
147.5	0.5	0	1	0
152.5	0.5	0	1	0
157.5	0.5	0	1	0
162.5	0.5	0	1	0
167.5	0.5	0	1	0
172.5	0.5	0	1	0
177.5	0.5	0	1	0

Table A-3. Fishery selectivities for discard and retained males by shell condition used in the EA analysis.

	Discard		Retained	
CW (mm)	New	Old	New	Old
97.5	0.097	0.053	0	0
102.5	0.098	0.053	0	0
107.5	0.158	0.055	0	0
112.5	0.302	0.096	0	0
117.5	0.327	0.121	0	0
122.5	0.482	0.124	0	0
127.5	0.701	0.138	0	0
132.5	0.955	0.2	0	0
137.5	0.5	0.16	0.5	0.16
142.5	0	0	1	0.317
147.5	0	0	1	0.317
152.5	0	0	1	0.317
157.5	0	0	1	0.317
162.5	0	0	1	0.317
167.5	0	0	1	0.317

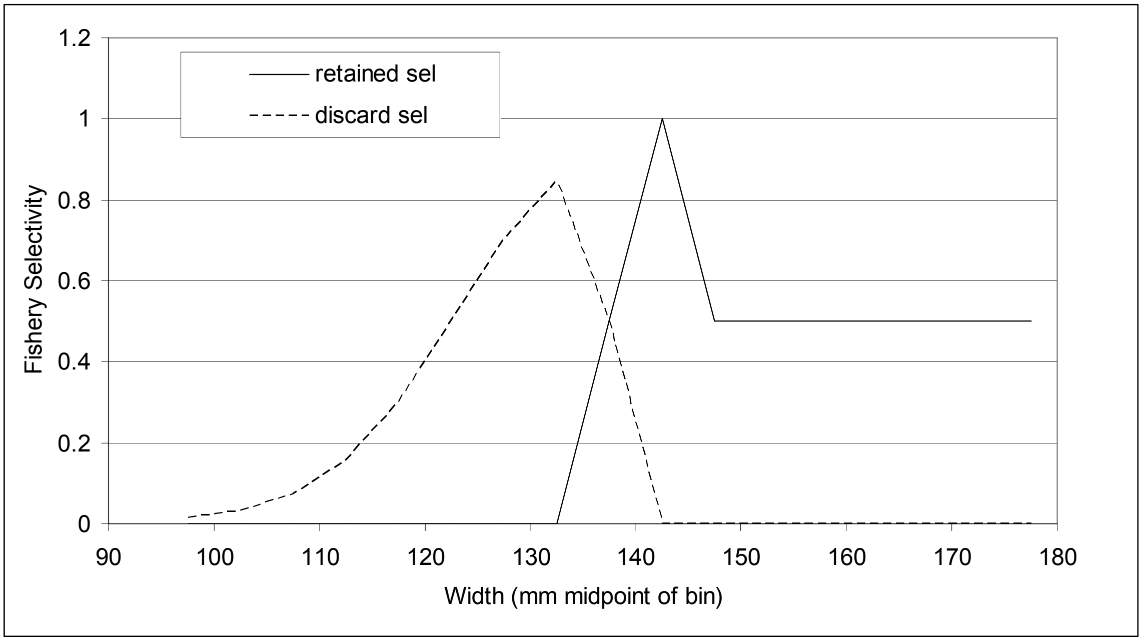


Figure A-1. Retained and discard directed Tanner fishery selectivities estimated for the 2007/8 fishery before discard mortality is applied.

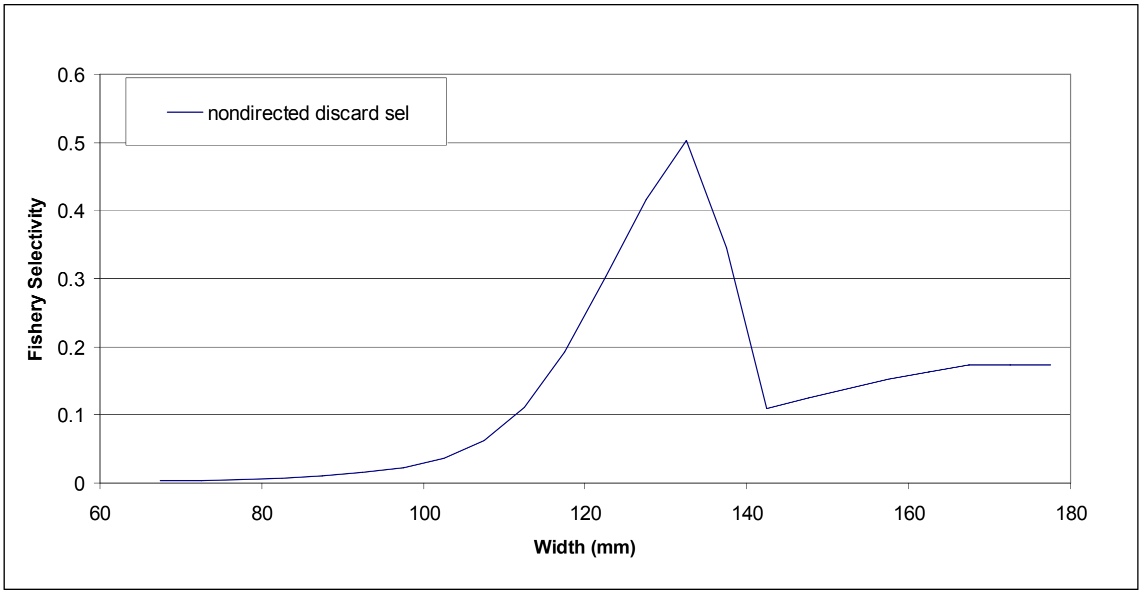


Figure A-2. Non-directed discard fishery selectivities with 50% mortality in the snow crab fishery and 80% mortality from trawl fisheries. The directed Tanner crab discard selectivity was used for snow crab fishery discards. Selectivity for the trawl discard is from the EA on overfishing analysis.

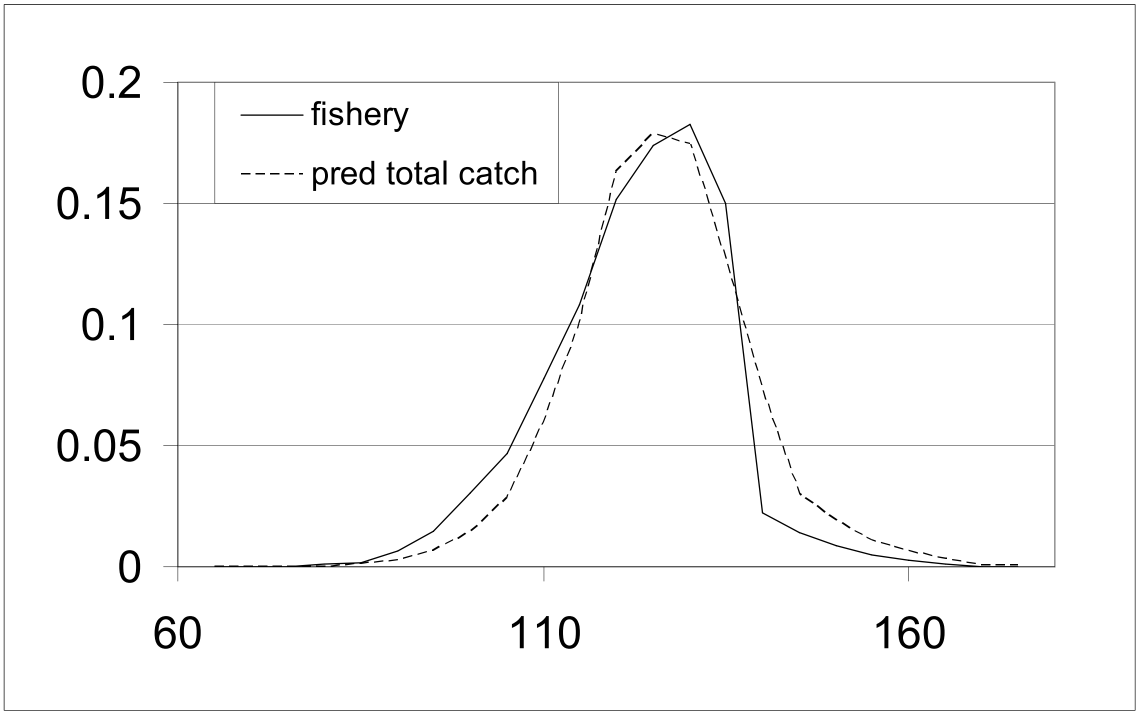


Figure A-3. Length frequency of total directed Tanner fishery catch (fishery) and predicted total directed Tanner fishery catch with estimated discard and retained fishery selectivities (Figure A-1) using the 2007 survey data and 2007/8 fishery observer data.

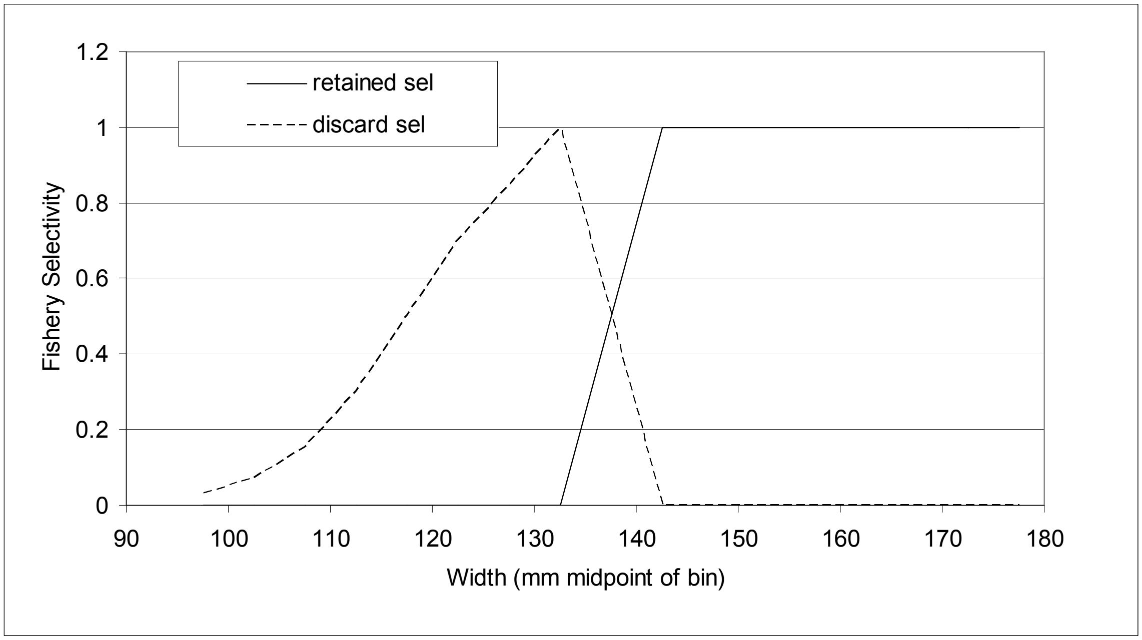


Figure A-4. Retained and discard directed Tanner fishery selectivities estimated for the 2007/8 fishery (before discard mortality is applied), with retained selectivity of crab >140 mm cw fixed at 1.0.

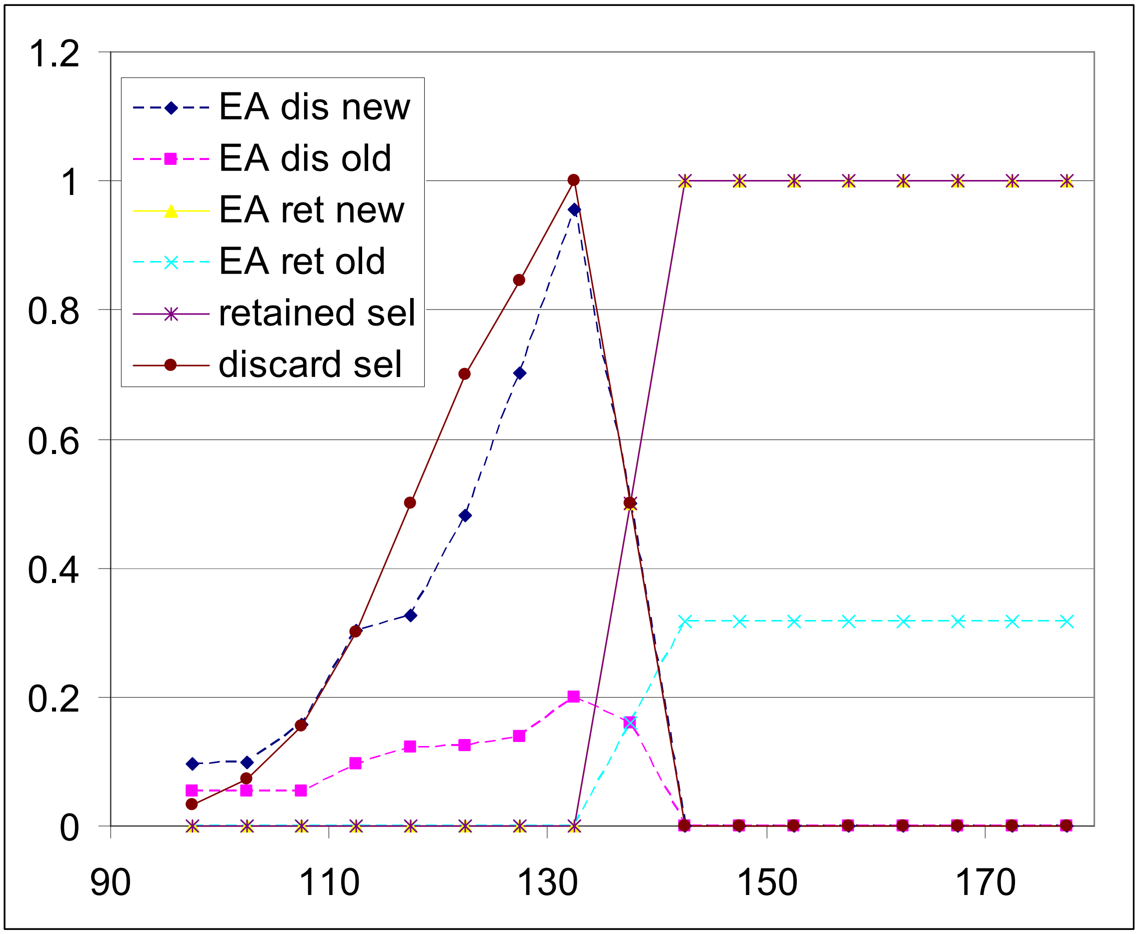


Figure A-5. Retained and discard directed Tanner fishery selectivities estimated for the 2007/8 fishery shell condition combined, before discard mortality is applied. Selectivities on discard and retained split by new and old shell from the EA analysis.

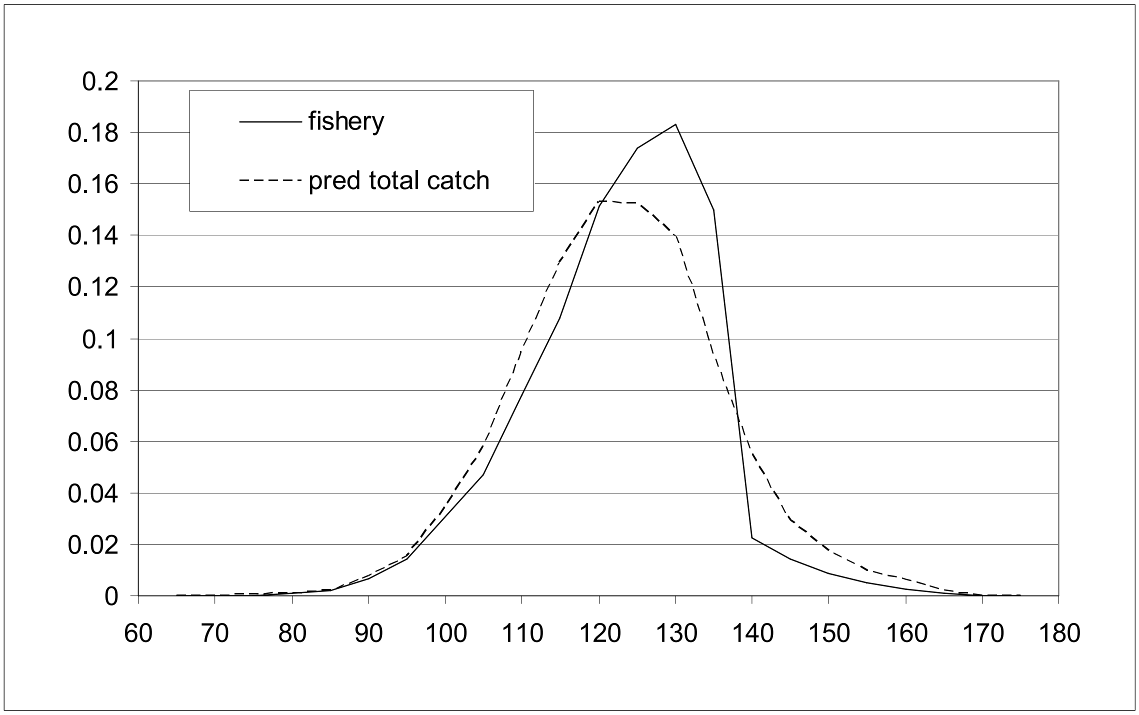


Figure A-6. Fit to total catch length frequency using retained selectivity at 1.0.