UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
P.O. Box 21668
Juneau, Alaska 99802-1668

AGENDA C-4(d)(1)
APRIL 2011

October 1, 2010

Mr. Eric Olson, Chair
North Pacific Fishery Management Council
605 West 4th Avenue, Suite 306
Anchorage, Alaska 99601

Dear Chairman Olson:

This letter serves as the North Pacific Fishery Management Council's (Council's) notification under section 304(e) of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) that Bering Sea Tanner crab (*Chionoecetes bairdi*) is overfished, according to the criteria in the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP).

The Alaska Fisheries Science Center (AFSC) has determined that the Tanner stock has declined below its minimum stock size threshold (MSST) based on the final 2010 stock assessment. The 2010 estimate of mature male biomass (MMB) at the time of mating is 62.70 million pounds, which is below the MSST of 92.37 million pounds. A copy of the memorandum from the AFSC on the 2010 status of the stocks, rebuilding progress, and overfishing levels for Bering Sea and Aleutian Islands crab stocks is enclosed. The status for the other stocks did not change.

To comply with section 304(e)(3) of the Magnuson-Stevens Act, the Council and NMFS have two years from this notification to develop and implement a plan to rebuild the overfished Tanner crab stock. Under section 304(e)(4) of the Magnuson-Stevens Act, the rebuilding plan for Tanner crab must specify a time period for rebuilding the fishery that is as short as possible, taking into account the status and biology of the stock, the needs of fishing communities, and the interactions of the stock within the marine ecosystem. The rebuilding period shall not exceed 10 years, except if the biology of the stock or other environmental conditions dictate otherwise. We look forward to working with the Council and the Alaska Department of Fish and Game to develop, analyze, and implement a rebuilding plan for the Tanner crab stock.

Sincerely,

James W. Balsiger, Ph.D.
Administrator, Alaska Region

Enclosure: Memorandum from Douglas P. DeMaster, Science and Research Director, Alaska Region, regarding the 2010 status of the stocks, rebuilding progress, and overfishing levels for Bering Sea and Aleutian Islands crab stocks

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September 27, 2010

MEMORANDUM FOR: James W. Balsiger
Regional Administrator, Alaska Region

FROM: Douglas P. DeMaster
Science and Research Director, Alaska Region

SUBJECT: 2010 status of stocks, rebuilding progress, and overfishing levels for Bering Sea and Aleutian Island Crab Stocks

This memorandum provides the current status of stocks, progress towards rebuilding, and the Alaska Fisheries Science Center's recommendations for the 2010/2011 overfishing levels for ten eastern Bering Sea crab stocks.

2010 Status of Stocks Determinations

At the May and September 2010 meetings of the North Pacific Fishery Management Council's Bering Sea/Aleutian Islands Crab Plan Team, the status of the ten Fishery Management Plan (FMP) crab stocks were reviewed and their status relative to overfished and overfishing determined (Table 1). A stock is determined to be overfished if the 2009/2010 estimate of mature male biomass on February 15, 2010 (MMB_{mating}) was below the minimum stock size threshold (MSST) or 0.5 B_{MSY}. In September 2010, stock projections of MMB at mating on February 15, 2011 are used to determine if a stock is approaching an overfished condition. ***Note that Tanner crab stock is now in an overfished condition. The Pribilof Islands blue king crab stock remains overfished. No crab stocks are approaching an overfished condition.***

The Tanner crab stock was determined to be overfished in 2009/10. The eastern Bering Sea Tanner crab stock biomass declined in 2009/10 below the minimum stock size threshold (MSST). In September 2009, the Tanner crab stock was determined to be approaching an overfished condition based on projections of MMB at mating (February 15, 2010). During the September 2010 Crab Plan Team meeting, 2009/2010 total catches were assessed and the MMB at the time of mating (62.70 million lbs.) was found to be below MSST (92.37 million lbs.). The projected 2010/2011 MMB at mating (57.48 million lbs.) is estimated to be lower than the 2009/10 MMB at mating estimate.

Overfishing is occurring if the total catch in 2009/2010 exceeds the 2009/2010 overfishing level (OFL) for the stock. The 2009/2010 overfishing determinations for the ten FMP crab stocks were reviewed by the Crab Plan Team in May and September 2010. The OFL is based on total catches including retained and discard mortalities except where noted. ***As shown in Table 1, there were no stocks where overfishing occurred in 2009/2010.***

Table 1. 2010 Status of stocks relative to the 2009/2010 overfishing determination and the current overfished status for ten Being Sea/Aleutian Islands crab stocks. Additional information on status and catch specifications can be found in the 2009 and 2010 Stock Assessment and Fishery Evaluation Reports for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands.

Stock	**Tier**	**MSST (10^6 lbs)**	**2009/2010* MMB_{mating} (10^6 lbs)**	**Overfished status**	**2009/2010 OFL (10^6 lbs)**	**2009/2010 Total catch (10^6 lbs)**	**2009/2010 Overfishing status**
Bristol Bay red king crab	3	34.3	89.0	No	22.6	18.3	No
Eastern Bering Sea snow crab	3	146.83	281.55	No	72.97	52.69	No
Eastern Bering Sea Tanner crab	4	92.37	62.70	Yes	5.00	3.72	No
Pribilof Islands red king crab	4	4.22	4.46	No	0.50	0.006	No
Pribilof Islands blue king crab	4	4.64	1.13	Yes	0.004	0.001	No
St Matthew Island blue king crab	4	3.48	12.76	No	1.72 [retained]	0.53	No
Pribilof Island golden king crab	5	NA	NA	NA**	0.17 [retained]	0 [retained]	No
Adak red king crab	5	NA	NA	NA**	0.50 [retained]	0 [retained]	No
Norton Sound red king crab	4	1.54	5.83	No	0.71 [retained]	0.43	No
Aleutian Island golden king crab	5	NA	NA	NA**	9.18 [retained]	5.91 [retained]	No

*MMB as estimated during the 2010 assessment.

**For Tier 5 stocks, it is not possible to set an MSST to determine overfished status because there are no reliable estimates of biomass.

2010 Progress Towards Stock Rebuilding

In 2009/2010 there were two Bering Sea/Aleutian Islands King and Tanner crab stocks still under rebuilding plans: Eastern Bering Sea snow crab and Pribilof Islands blue king crab. A review of the status of these stocks relative to rebuilding found that:

1. The eastern Bering Sea snow crab stock did not make adequate progress towards the 2009/2010 target rebuilding period. In order to be considered rebuilt by the established 10 year time period, MMB_{mating} would have needed to be greater than B_{MSY} in 2008/2009 and again in 2009/2010 in order to meet the two year standard above B_{MSY} required for rebuilding. The MMB_{mating} in 2008/2009 (241.1 million lbs) and in 2009/2010 (281.55 million lbs) were determined to be below $B35\%_{2008/2009}$ (326.7 million lbs) and $B35\%_{2009/2010}$ (293.7 million lbs). A revised rebuilding plan was called for by the North Pacific Fisheries Management Council (NPFMC) in collaboration with the National Marine Fisheries Service Alaska Region and the Alaska Department of Fish and Game (ADF&G) in 2009/2010. The initial review of the rebuilding plan occurred in June 2010 and final Council review is expected in October 2010.

   In the interim, an OFL based on the F35% control rule was recommended by the Crab Plan Team in September 2010. The AFSC recommends that F be below the maximum permissible (75% F35%) under National Standard Guidelines of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) to best meet the MSFCMA (Section 304(e)(4)) requirements for rebuilding time periods that are as short as possible, taking into account the needs of fishing communities. In addition, a reduced F during the interim period provides additional protection to Tanner crab, which is caught in the directed snow crab fishery and which is now in an overfished condition.

2. The Pribilof Islands blue king crab stock is not making adequate progress towards the 2012/2013 target rebuilding date. As a result, a revised rebuilding plan was initiated in 2009/2010 with preliminary review in April 2010. The initial Council review of the rebuilding plan is expected to occur in October 2010. In the interim, a low total catch OFL was recommended by the Crab Plan Team in September 2010 to account for low bycatch levels expected to occur in 2010/2011.

Recommended 2010/2011 Overfishing Level Definitions
Overfishing level (OFL) definitions for the ten Bering Sea and Aleutian Island crab stocks were discussed and reviewed at the May and September Crab Plan Team meetings and recommendations were made for OFLs (Table 2). Total allowable catch and guideline harvest levels are set by the ADF&G consistent with the FMP for the Bering Sea/Aleutian Islands King and Tanner crab and the State/Federal Action Plan for Management of Commercial King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands. For all ten stocks, SAFE reports which present the stock data, model estimates, and biological reference points have been prepared for review by the SSC and NPFMC in October.

Table 2. 2010/2011 Overfishing Levels for ten Being Sea/Aleutian Islands crab stocks. Additional information on status and catch specifications can be found in the 2010 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands.

Stock	Tier	2010/2011 MMB_{mating} (10^6 lbs)	F_{OFL}	2010/2011 OFL (10^6 lbs)
Bristol Bay red king crab	3a	83.1	0.32	23.5
Eastern Bering Sea snow crab	3b	224.6	0.91	97.9
Eastern Bering Sea Tanner crab	4b	57.48	0.05	3.55
Pribilof Islands red king crab	4b	5.44	0.11	0.77
Pribilof Islands blue king crab	4c	0.63	0	0.004
St Matthew Island blue king crab	4a	15.29	0.18	2.29*
Pribilof Island golden king crab	5	NA	NA	0.18
Adak red king crab	5	NA	NA	0.12
Norton Sound red king crab	4a	5.44	0.18	0.73
Aleutian Island golden king crab	5	NA	NA	11.0

NA = not applicable
*total male catch

EBS Tanner crab rebuilding plan overview

Prepared by Council staff

Overview

On October 1, 2010, the Council was informed by NMFS that the Bering Sea Tanner crab (*Chionoecetes bairdi*) stock is overfished according to criteria in the Fishery Management Plan for the Bering Sea/Aleutian Islands King and Tanner crab. This notification was based on the most recent stock assessment for Tanner crabs indicating that the stock biomass had declined below its minimum stock size threshold (MSST). The 2010 estimate of mature male biomass (MMB) at mating was 62.70 million pounds, below the MSST of 92.37 million pounds.

In order to comply with section 304(e)(3) of the Magnuson-Steven Act (MSA), the Council and NMFS thus have two years from that notification to develop and implement a plan to rebuild the overfished Tanner crab stock. Under section 304(e)(4) of the MSA, the rebuilding plan for Tanner crab must specify a time period for rebuilding the fishery that is as short as possible, taking into account the status and biology of the stock, the needs of fishing communities, and the interactions of the stock within the marine ecosystem. The rebuilding plan shall not exceed 10 years, except if the biology of the stock of other environmental conditions dictate otherwise.

At this meeting the Council will begin consideration of alternative management measures for rebuilding the Tanner crab stock. These measures may include a combination of directed fishery constraints, bycatch constraints in other fisheries and other considerations. Once alternative management measures have been finalized by the Council, analysts will provide an analysis of these measures in an appropriate NEPA document for initial review by the Council. This discussion paper provides an overview of the Tanner crab stock status, development of an assessment model and recent catch estimates in both directed Tanner crab fishery as well as non-directed catch in other crab fisheries, groundfish fisheries and scallop fisheries.

Aspects to developing a rebuilding plan for Council consideration:

1. Constraint on fishing mortality
    a. Either specifying a Fixed F rate over a time frame for rebuilding or an adjustable F rate to achieve a target probability of rebuilding
2. What fisheries to constrain to achieve the specified rebuilding
    a. Directed fishery harvest of Tanner crab
    b. Bycatch of Tanner crab in directed Tanner crab, snow crab fishery, Bristol Bay red king crab fisheries , groundfish and scallop fisheries
3. What benchmark for defining rebuilt status
    a. Currently second year above B_{MSY}.

Tanner crab stock status overview

For purposes of management, the fisheries is managed as two fisheries, one east and one west of 166° W. longitude, harvest eastern Bering Sea (EBS) Tanner crab (Figure 1). Under the Crab Rationalization

Program, ADF&G sets separate TACs and NMFS issues separate individual fishing quota (IFQ) for these two fisheries. However, one OFL is set for the EBS Tanner crab because there is no evidence that the EBS Tanner crab is not one stock. Both fisheries were closed from 1997 to 2005 due to low abundance. NMFS declared this stock overfished in 1999 and the Council developed a rebuilding plan. In 2005, abundance increased to a level to support a fishery in the area west of 166^0 W. ADF&G opened both fisheries for the 2006/07 to 2008/09 crab fishing years and to the area east of 166° W. longitude only in 2009/10. In 2007, NMFS determined the stock was rebuilt because the survey estimate of spawning biomass was above B_{MSY} for two consecutive years.

Tanner crabs are caught as bycatch in the groundfish fisheries, scallop fisheries, in the directed Tanner crab fishery (principally as non-retained females and sublegal males), and in other crab fisheries (notably, eastern Bering Sea snow crab and to a lesser extent in the Bristol Bay red king crab).

The Tanner crab stock is surveyed annually by the NMFS EBS trawl survey. Area-swept estimates of biomass from the EBS trawl survey are used to estimate biomass of stock components: mature male biomass (MMB), legal male biomass (LMB), and females. Fish ticket data are used for computing retained catch and observer data from the crab, and groundfish fisheries are used to estimate the non-retained catch; assumed handling mortality rates for fishery components are used to estimate the discard mortality.

MMB and LMB showed peaks in the mid-1970s and early 1990s (Figure 2). 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 2007, MMB has risen at a moderate rate from a low of 25.1 million pounds in 1997. Post-1997, MMB at the time of survey increased to 185.2 million pounds in 2007, but has subsequently declined. The survey data continue to show a general overall decline in stock abundance. The MMB projected for February 2011 (57.47 million lbs, or 26.07 thousand t) is 8% less than MMB in February 2010 (62.70 million lbs or 28.44 thousand t). Some moderate sign of recruits in the male and female size frequency at about 25-35 mm CW were shown in the 2010 survey data, but a general decline in abundance of males > 70 mm CW in the 2010 survey raises concerns for near-term future reproductive potential of the stock. From the 2010 survey data, Pre-recruit crab in 2010 were widely distributed across the range of the survey from southern Bristol Bay northwest to St. Matthew Island (Figure 3). Regions of highest abundance of pre-recruit males in 2010 were seen in southwestern Bristol Bay and the surrounding area of the Pribilof Islands (Figure 3). Total male abundance increased 8.5% between 2009 and 2010 which was largely driven by the increase in small males. Ovigerous females were distributed from southern Bristol Bay at relatively highest abundance northwestward to south of St. Matthew Island with an area of moderate density near the Pribilof Islands (Figure 4). Immature female Tanner crab displayed a similar distribution to mature females although they were slightly more densely distributed relative to matures along the southeast-northwest cline from southwestern Bristol Bay, north of the Pribilof Islands to west and south of St. Matthew Island (Figure 4).

The current OFL for this stock is based on the Tier 4 control rule because no stock assessment model has been developed for the entire EBS stock. Based on the estimated biomass, the stock is at stock status level b. B_{MSY} is currently based on the average MMB for the years 1969-1980, discounted by fishery removals (retained and non-retained mortalities) and natural mortality between the time of survey and the time of mating. This time period is thought to represent the reproductive potential of the stock because it encompasses periods of both high and low stock status equivalently. This equates to a BREF of 83.8 thousand t MMB. The 2009/10 estimate of MMB is 28.44 thousand tons or 34% of BREF. Hence the stock is estimated to have been in overfished condition. The projected 2010/11 estimate of MMB at the time of mating is 26.07 thousand t, or 31% of BREF.

In 2009/10, Tanner crab MMB was below the MSST at the time of the 2009 survey, below MSST at the time of the 2009/10 fishery, and below MSST at the time of mating in mid-February 2010. Overfishing did not occur during the 2009/10 fishing year because total catch losses (1.69 thousand t) did not exceed the total catch OFL (2.27 thousand t). The 2009/10 MMB at the time of mating was 38% of BREF. The 2009/10 Tanner crab MMB was estimated to be below MSST. In 2010 at the time of the survey, Tanner crab MMB declined further relative to 2009 and once again was estimated to be below MSST. The stock is projected to remain below MSST in 2011, even if there is zero retained catch in 2010/11

Update on Tanner crab assessment model development

A stock assessment model for the Tanner crab stock is under development by stock assessment scientists at the Alaska Fishery Science Center in Seattle. The developing model was reviewed in conjunction with the NPFMC crab modeling workshop held February 16-18, 2011.

Recommendations from the workshop are contained in the model report (available at: http://fakr.noaa.gov/npfmc/membership/plan_teams/CPT/211CrabWorkshop.pdf

At the April Council meeting, the SSC will receive an updated presentation on the Tanner crab model development. Comments from the SSC will be contained in their minutes. A revised assessment considering workshop and SSC comments will be presented for CPT review at the May 2011 meeting for consideration in the 2011/12 assessment cycle. It is anticipated that this model will be employed in the rebuilding analysis regardless of whether or not it is accepted for assessment purposes in the forthcoming year.

EBS Tanner crab catch (retained and discarded)

Tanner crab are caught in the directed Tanner crab fishery (when open) both as retained and discarded catch, as well as bycatch in the EBS snow crab fishery, the Bristol Bay red king crab fishery, groundfish fisheries and the Scallop fishery. Table 2 shows the relative contribution of catch by year of the directed Tanner fishery, the EBS snow crab fishery, Bristol Bay red king crab fishery and the groundfish fishery. Data are presented in both millions of pounds and thousands of tons. For comparison against trends in snow crab fishery bycatch of Tanner crab, the retained catch of snow crab in the snow crab directed fishery is also presented.

EBS Tanner crab groundfish management measures

Management measures exist for groundfish trawl fishery bycatch of Tanner crabs within specified areas of the Bering Sea (Figure 5). These areas are triggered by PSC limits specified for the groundfish trawl fisheries. Bycatch accrues within designated zones and when a specific allocation is reached by a fishery, the fishery is closed form that region for the remainder of the season. Trawl bycatch outside of Zones 1 and 2 is not limited by management measures. No fixed gear management measures exist for Tanner crab. All bycatch accrues towards the OFL for Tanner crab.

PSC limits for *C. bairdi* in Zones 1 and 2 are based on a percentage of the total abundance minus an additional reduction implemented in 1999 of *C. bairdi* crab as indicated by the NMFS trawl survey (Table 3). Based on the 2010 abundance (379 million crab), the PSC limit in 2011 for *C. bairdi* will be 830,000 *C. bairdi* crab in Zone 1 and 2,520,000 crab in Zone 2 (Table 3). Zones 1 and 2 are closed to directed fishing when the crab bycatch cap is attained in specified fisheries (Figure 5). Catch towards the Zone 1 and Zone 2 Tanner crab limits in the Bering Sea are listed in Table 4.

The process by which these caps were initially established was a combination of proposals for limits put forward by the State of Alaska, recommendations from the Crab Plan Team, and by committee discussions amongst interested stakeholders. For Tanner crab, proposed lower threshold limits were based upon the average observed bycatch for the stock at that level of abundance (NPFMC 1996). The upper range of the limit was based on negotiated amounts when the stock was at a high abundance in 1988 (NPFMC 1996). The middle "step" level was established at an intermediary level between steps 1 and 3 (Figure 6).

Amendment 41 further modified these limits whereby the current stair-step levels were approved as negotiated by industry representatives (NPFMC 1997). This negotiation process was the following: In June, 1996, the Council formed an industry workgroup to review proposed PSC limits for Tanner and snow crab as detailed in the analysis for Amendment 37 (the red king crab PSC amendment). This Council work group consisted of three crab fishery representatives, three trawl fishery representatives, and one shoreside processing representative. The group met over two days in August 1996 and came to consensus on bycatch limits for Tanner crab. The stair-step PSC limits, as shown (Figure 6 and Table 3) were agreed upon by the workgroup and were primarily developed from historical bycatch data.

Allocation of PSC limit across groundfish fleets

Crab PSC limits are allocated annually to vessels in the CDQ, Amendment 80, and the BSAI trawl limited access sectors (Table 7). To allocate the total groundfish harvest under the annually established PSC limits, PSC is apportioned among trawl fisheries during the annual specification process. When a target fishery attains a PSC apportionment or seasonal allocation specified in regulations, the bycatch zone to which the allocation applies closes to the target fishery for the remainder of the season.

The BSAI sector includes trawl catcher vessels and trawl catcher/processors not in the Amendment 80 program. During the harvest specifications process, the Advisory Panel (AP) makes recommendations to the Council on the amounts of the PSC limits allocated to each fishery category. The public has opportunity to comment on allocations during the AP and Council meetings. The Council votes on the final PSC limits which, if approved by the Secretary of Commerce, are published in the Federal Register. The fishery categories are: greenland turbot/Arrowtooth, flounder/sablefish, Pacific cod, Pollock/Atka mackerel/other species, rockfish, rock sole/flathead sole/other flatfish, and yellowfin sole.

10.7% of each PSC limit specified for crab is taken off the top and allocated for use by the groundfish CDQ program. The remaining available PSC allocations are split between the BSAI trawl limited access sectors and the Amendment 80 sector. The BSAI trawl limited access sectors and the Amendment 80 sector are allocated PSC limits according to percentage multipliers in Tables 35 and 36, CFR part 679. The Amendment 80 allocation is further apportioned between Amendment 80 cooperatives and Amendment 80 limited access fishery (those Amendment 80 vessels that do not join a cooperative) based on their relative proportion of Amendment 80 species quotq shares. The Amendment 80 cooperatives are allocated PSC limits proportional to the amount of Amendment 80 quota shares held by its members. PSC allocations for the BSAI trawl limited access sectors and Amendment 80 limited access sectors are further allocated between trawl fisheries categories.

Each Amendment 80 cooperative receives an exclusive allocation of the crab PSC, whereas the Amendment 80 limited access fishery must share crab PSC allocations with all other Amendment 80 limited access fishery participants. The Amendment 80 sector is the only sector that may receive a reallocation of unused PSC limits. There is no specific provision for reallocations to or from the cooperatives or from the BSAI trawl limited access sectors. The cooperatives can freely trade their allocations, subject to use cap limits, including post-delivery transfers from another cooperative. If NMFS projects that some of the PSC limits in the BSAI trawl limited sector will not be used, it has the discretion to reallocate those PSC limits to the Amendment 80 cooperatives. A reallocation from the BSAI trawl limited access sector is based on projected harvest rates in the trawl sector and on other criteria. Each cooperative would receive a reallocation based on the proportion of the quota share held by that cooperative as compared with all other Amendment 80 cooperatives. The Amendment 80 limited access sector, however, would not receive reallocated PSC limits.

A little more detail shows that percentages apportioned to the Amendment 80 sector for each crab PSC were selected based on the historic usage in all groundfish fisheries from 2000-2002 for red king crab, and from 1995-2002 for all other crab PSC species. The percentages selected at the time of implementation of Amendment 80 were 62.48% for red king crab, 61.44% for snow crab, 52.64% for Zone 1 Tanner crab, and 29.59% for Zone 2 Tanner crab. In order to reduce the overall crab PSC removals from the BSAI, each PSC limit is reduced 5% per year until the apportionment for the Amendment 80 sector is at 80% of the initial allocation (Table 5). The apportionment of PSC limits to the trawl limited access fisheries, as shown in (Table 5, were calculated using the sum of the AFA CP and CV sideboards. In addition, apportionment percentages presented in (Table 5 do not equal 100%. Because the sum of the Amendment 80 and BSAI trawl PSC apportionments do not equal 100%, any unallocated crabs remain in the water. In summary, both the Amendment 80 and the BSAI trawl limited access sectors receive a fixed percentage of the total trawl crab PSC limit, so the Amendment 80 crab PSC allocations do not affect the availability of crab PSC to the BSAI trawl limited access sectors.

Total bycatch of Tanner crab in all groundfish fisheries

Bycatch mortality from groundfish fisheries by gear type from 2003/04 to 2008/09 is shown in Figure 7. Spatial observations of bycatch by gear type over this time frame are shown in Figure 10. Mortality by fishery from 2003/04 to 2008/09 is shown in Table 6.

The 2008/09 OFL for EBS Tanner crab was 15.52 million pounds. Total groundfish fishery bycatch over this time period was approximately 559,440 lbs or 3.6% of the OFL. Bycatch mortality was primarily in the yellowfin sole trawl fishery, the Pacific cod pot fishery, and the rocksole trawl fishery. Here the mortality assumption of 20% for the Pacific cod pot fishery may be an underestimate of the actual mortality accruing against the OFL (the 2009/10 crab assessments use 50% for all pot gear). Thus mortality as represented in this paper for fixed gear may be an underestimate of the actual mortality accruing against the OFL for crab stocks.

Bycatch by month in the yellowfin sole fishery from July 2008-June 2009 shows that the highest bycatch was taken in the spring from March to May in 2009 (Figure 8). Bycatch was also taken in this fishery in the fall between September and November in 2008. This is the first year of rationalized flatfish fisheries (under Amendment 80), thus for these fisheries the snapshot of bycatch (timing and amounts) may be representative of future conditions given the transition from open-access to rationalization in these fisheries. Observer coverage is also increased as a result of implementation of Amendment 80. Bycatch in the Pacific cod pot fishery was highest in January 2009, with bycatch also taken in high numbers in September and October of 2008 (Figure 9). Observer coverage in the Pacific cod pot fishery is variable (http://www.fakr.noaa.gov/npfmc/current_issues/observer/percent_observed.pdf), but much of the catch is taken in the shoreside sector with lower observer coverage. The observed catch percentages from 2004-2007 in the shoreside sector for Pacific cod pot fishery ranged from 0-41% of the catch observed depending upon vessel size (0% in the <60' and a high of 41% observed catch in 2007 in the >125' class in 2007).

Crab Bycatch Limits in the Scallop Fishery

Bycatch of crabs in the scallop fishery is controlled through the use of Crab Bycatch Limits (CBLs) that are based on the condition of individual crab stocks. CBLs were first instituted by the state in July 1993. Methods used to determine CBLs in 1993 and 1994 were approved by the BOF and the NPFMC and, with few exceptions, remain unchanged. Annual CBLs are established preseason by ADF&G for areas with current crab resource abundance information (surveys). For areas without crab abundance estimates, CBLs may be set as a fixed number of crabs that is not adjusted seasonally.

In the Kodiak, Alaska Peninsula, and Dutch Harbor Registration Areas, the CBLs are set at 0.5% or 1.0% of the total crab stock abundance estimate based on the most recent survey data (Table 7). In registration areas or districts where red king crab or Tanner crab abundance is sufficient to support a commercial crab fishery, the cap is set at 1.0% of the most recent red king crab or Tanner crab abundance estimate. In registration areas or districts where the red king crab or Tanner crab abundance is insufficient to support a commercial fishery, the CBL is set at 0.5% of the most recent red king crab or Tanner crab abundance estimate. Bycatch caps are expressed in numbers of crabs and include all sizes of crabs caught in the scallop fishery.

In the Kamishak District of the Cook Inlet Registration Area, the Tanner crab bycatch limit is set at 0.5% of the total crab stock abundance from the most recent dredge survey and the red king crab limit is fixed at 60 crabs. In 2001, ADF&G set Tanner crab bycatch caps in the Prince William Sound Registration Area at 0.5% of the Tanner crab population estimate from the 2000 scallop survey. This resulted in bycatch limits of 2,700 and 8,700 crabs for the east and west harvest areas. These levels have remained in place for all subsequent years.

CBLs in the Bering Sea (registration Area Q) have evolved from fixed numbers in 1993 to a three tier approach used in the current fishery. In 1993, Bering Sea CBLs were set by ADF&G to allow the fleet adequate opportunity to explore and harvest scallop stocks while protecting the crab resource. CBLs were established at 260,000 *Chionoecetes* spp. and 17,000 red king crabs. In 1995, ADF&G recommended that CBLs be established at 0.003176% of the best available estimate of *C. opilio* (snow crab) and 0.13542% of the best available estimate of Tanner crab abundance in Registration Area Q. That equated to about

300,000 snow and 260,000 Tanner crabs based on 1994 crab abundance estimates in Registration area Q. In Amendment 1 of the federal scallop FMP, the NPFMC approved the CBLs established by ADF&G. The NPFMC also recommended that king crab bycatch limits be set within a range of 500 to 3,000 crabs annually. Beginning with the 1996/97 fishing season, ADF&G took a conservative approach and set the red king crab limit in Registration Area Q at 500 red king crabs annually.

From the 1996/97 through 1998/99 fishing seasons, the CBL for *Chionoecetes* spp. in the Bering Sea was established annually by applying the percentages established for snow and Tanner crab limits in Amendment 1 of the FMP. In 1998, consistent with the Tanner crab rebuilding plan in the Bering Sea, crab bycatch limits were modified.

The current three tier approach was established utilizing the bycatch limits established in Amendment 1 of the FMP: 300,000 snow and 260,000 Tanner crabs. The three tiers include: (1) Tanner crab spawning biomass above minimum stock size threshold (MSST); bycatch limit is set at 260,000 crabs; (2) Tanner crab spawning biomass below MSST; bycatch limit is set at 130,000 crabs; and (3) Tanner crab spawning biomass is below MSST and the commercial fishing season is closed; Tanner crab limit is set at 65,000 crabs. A similar three tier approach was taken with the snow crab bycatch caps. The three tiers include: (1) snow crab spawning biomass above the MSST; bycatch limit is set at 300,000 crabs; (2) snow crab spawning biomass below MSST; bycatch limit is set at 150,000 crabs; and (3) snow crab spawning biomass below MSST and the commercial fishing season is closed; the snow crab limit is set at 75,000 crabs.

Bycatch of Tanner crabs in the Bering Sea registration area for the scallop fishery in numbers of crabs as well as estimated total weight of crabs are shown in Table 8.

Comparison of bycatch by fishery

A comparison of bycatch amounts (in millions of lbs) by fishery is shown in Table 9. For consistency across sources of bycatch data, 2008/09 was used for comparative purposes. In order of magnitude the snow crab fishery contributes the highest overall bycatch of Tanners, followed by discards in the groundfish fisheries, the Tanner crab directed fishery, Bristol Bay red king crab fishery and scallops. Note that here the bycatch in the scallop fishery is an order of magnitude less than those from other sources. As the biomass of the Tanner crab stock declines the contribution to catch by bycatch in these fisheries becomes more important particularly in relation to the overall size of the stock.

Development of rebuilding plan alternatives

In considering aspects of the rebuilding alternative, the Council may wish to consider the structure of the snow crab alternatives from the amendment 39 (NPFMC/NMFS 2010) analysis. The alternatives that were considered for snow crab used a fixed time period and associated probabilities of rebuilding to establish a range of alternatives. For example, the following alternatives were considered for snow crab (excerpted from NPFMC 2010):

Alternative 1: No Action

> *This is the no action alternative. This alternative would be future management under which ever alternative is selected under Action 1.*

Alternative 2: Set target rebuilding time frame (T_{TARGET}) based on the minimum number of years necessary to rebuild the stock.

This alternative would set T_{target} based on minimum number of years necessary to rebuild the stock, under the current assessment of the snow crab stock, if all sources of fishing-related mortality are set to zero[1].

For example, the current estimate of the minimum number of years to recover to $B_{35\%}$ for one year (i.e. under assumption of a catch corresponding to 75% of F_{OFL} through 2010/11 and implementing F=0 beginning in the 2011/12 fishing year) is 2012/13. The minimum number of years is the same with very low levels of catch (equivalent to estimated incidental catch in other fisheries).

Alternative 3 to Alternative 4: Set T_{TARGET} above the minimum number of years (between 1 above the minimum and T_{END}).

Under these alternatives, the annual fishing mortality rate would be calculated so that the probability of rebuilding by T_{TARGET} is fixed at the selected value. Note that closures in groundfish fisheries and crab fisheries would need to occur in a given year if F=0 is necessary to achieve the agreed probability in that year. Under the default scenario (i.e., if none of the options below is selected), T_{TARGET} would be the year in which the probability of rebuilding is 50%. Additional options under would increase this time frame to 8 years (under option 1)

The timeframes associated with the alternatives are the following:
Alternative 3: 3 years to rebuild (T_{TARGET} = time of mating 2013/14)
Alternative 4: 4 years to rebuild (T_{TARGET} = time of mating 2014/15)

In addition to these alternatives, options are considered that would increase the probability of rebuilding by the agreed T_{TARGET}. Increasing probability of rebuilding for a given T_{TARGET} is achieved through either extending the time frame for rebuilding (option 1) or through directed fishery harvest constraints (options 2 and 3).

Under these options, the annual fishing mortality rate would be calculated so that the probability of rebuilding by T_{target} is fixed at the selected value. Note that closures in groundfish fisheries and crab fisheries would need to occur in a given year if F=0 is necessary to achieve the agreed probability in that year. Under the default scenario (i.e., if none of the options below is selected), T_{target} would be the year in which the probability of rebuilding is 50%.

Options to increase probability of rebuilding:
option 1: increase probability of rebuilding to 70% by increasing time frame to T_{end} to 8 years
option 2: increase probability of rebuilding to 75% by T_{target}.
option 3: increase probability of rebuilding to 90% by T_{target}.

Under option 1 the probability of rebuilding would be increased to 70% by extending the time frame for T_{end} while retaining the maximum fishing mortality constraint of 75% of F_{OFL} for 3 additional years from the Alternative 4. Under options 2 and 3, the time frame to rebuild cannot be extended to increase the probability of rebuilding higher than under option 1 thus these

[1] Recovery by the minimum T_{target} could occur with low levels of catch although this would decrease the probability of rebuilding by T_{end}.

options would require a more constraining maximum fishing mortality rate than the 75% of F_{OFL} assumed under the other alternatives and option 1.

The time frames and the relative probability of rebuilding for each alternative and option are summarized below for the current stock assessment model (Table ES-6). The probability of rebuilding assumes the definition of rebuilt in which calculated biomass must be above the B_{MSY} estimate for one year before the stock is considered 'rebuilt'. Additional results for the current definition of rebuilt (second consecutive year above the B_{MSY} estimate) are shown in Chapter 4 of this analysis.

For all options, the values for the probability of rebuilding for each year of the rebuilding period and the associated rebuild fishing mortality rate would be calculated annually using the best assessment of the EBS snow crab stock, as recommended by the SSC. The CPT, SSC, and Council will annually review progress towards rebuilding and recommend annual adjustments to the fishing mortality rates on which management decisions are based consistent with the intent of the chosen alternative and progress towards rebuilding. If rebuilding to the proxy for B_{MSY} does not occur by T_{end}, then the maximum F will be the rebuilding F^2, the F of the final year, or 75% of F_{OFL}, whichever is lower, until a new rebuilding plan is developed.

A similar structure could be considered for the Tanner crab alternatives. Alternatively a fixed F rate could be considered over the time frame of the rebuilding plan. Rebuilding time frames and associated probabilities of rebuilding will be calculated from an accepted assessment model projection. A model is anticipated to be accepted during the May Crab Plan Team meeting.

Unlike the snow crab alternatives however where all fishery constraints under consideration were in the directed snow crab fishery, for Tanner crab a much higher proportion of the catch in any year comes from non-directed catch in crab and groundfish fisheries. The Council will likely need to consider management measures on fisheries in addition to the directed Tanner crab fishery in developing alternatives to rebuild this stock.

Currently the Tanner crab stock is considered 'rebuilt' the second year the reference biomass (currently in MMB) is above the B_{MSY} for this stock. The Council could also consider options for redefining this according to Tier structure should the Tanner crab assessment move to a model-based assessment (and thus to Tier 3 status) in the future. The Council could also consider options which would increase this time frame (i.e. more than two consecutive years above B_{MSY}).

Tables

Table 1 Historical status and catch specifications in (a) millions lbs and (b) thousands of tons for eastern Bering Sea Tanner crab

a) Millions of lbs:

Year	MSST	Biomass (MMB)	TAC (east + west)	Retained Catch	Total Catch	OFL
2006/07 [c]		130.47	2.98	2.12	6.94	
2007/08 [c]		151.59	5.62	2.12	8.00	
2008/09 [c]	94.89	118.23	4.30	1.94	4.96	15.52
2009/10	92.37	62.70	1.34 [a/]	1.32	3.73	5.00
2010/11		57.47 [b/]				3.55

b) Thousands of tons:

Year	MSST	Biomass (MMB)	TAC (east + west)	Retained Catch	Total Catch	OFL
2006/07 [c]		59.18	1.35	0.96	3.15	
2007/08 [c]		68.76	2.55	0.96	3.63	
2008/09 [c]	43.04	53.63	1.95	0.88	2.25	7.04
2009/10	41.90	28.44	0.61 [a/]	0.60	1.69	2.27
2010/11		26.07 [b/]				1.61

a/ Only the area east of 166 deg. W opened in 2009/10; TAC was 1.85 million lbs.
b/ Projected 2009/10 MMB at time of mating after extraction of the estimated total catch OFL.
c/ biomass and threshold values based on fixed net width

Table 2 Retained catch of snow crab and Tanner crab in directed fisheries and discarded catch of Tanner crab in the directed Tanner fishery, Snow crab fishery, BBRKC fishery and groundfish fisheries 1965 – 2008/09 crab fishing years in millions of lbs and thousands of tons.

	Tanner Discards in Snow Crab				Tanner Discards in BBRKC				Tanner Discards in Directed Fishery				Tanner Discards in Groundfish		Tanner Retained Catch		Snow Retained Catch	
	Million lbs			1000 t	Million lbs			1000 t	Million lbs			1000 t	Million lbs	1000 t	Million lbs	1000 t	Million lbs	1000 t
	Female	Male	Total	Total	Female	Male	Total	Total	Female	Male	Total	Total						
1965															4.2	1.9		
1966															5.4	2.4		
1967															30.0	13.6		
1968															39.7	18.0		
1969															60.6	27.5		
1970															56.2	25.5		
1971															45.7	20.7		
1972															37.3	16.9		
1973													39.4	17.9	28.7	13.0		
1974													54.5	24.7	33.6	15.2	6.7	3.0
1975													21.1	9.6	38.9	17.7	5.0	2.3
1976													9.2	4.2	66.2	30.0	8.3	3.7
1977													6.2	2.8	78.3	35.5	10.1	4.6
1978													7.1	3.2	46.5	21.1	16.3	7.4
1979													5.7	2.6	41.9	19.0	52.3	23.7
1980													4.7	2.1	29.6	13.4	75.0	34.0
1981													3.3	1.5	11.0	5.0	66.9	30.4
1982													1.0	0.4	5.3	2.4	29.4	13.3
1983													1.5	0.7	1.2	0.5	26.1	11.9
1984													1.4	0.6	3.2	1.4	26.8	12.2
1985													0.9	0.4	0.0	0.0	66.0	29.9
1986													1.4	0.6	0.0	0.0	98.0	44.4
1987													1.4	0.6	2.2	1.0	101.9	46.2
1988													1.0	0.5	7.0	3.2	135.4	61.4
1989													1.5	0.7	24.5	11.1	149.5	67.8
1990													2.1	0.9	40.1	18.2	161.8	73.4
1991													5.6	2.5	31.8	14.4	328.6	149.1
1992	3.9	56.8	60.7	27.5	0.1	2.6	2.7	1.2	3.9	24.2	28.2	12.8	6.1	2.8	35.1	15.9	315.3	143.0
1993	4.0	32.0	36.0	16.3	0.4	6.5	7.0	3.2	4.0	15.1	19.1	8.6	3.9	1.8	16.9	7.7	230.8	104.7
1994	2.8	15.7	18.5	8.4	0.0	0.0	0.0	0.0	2.8	6.9	9.7	4.4	4.6	2.1	7.8	3.5	149.8	67.9
1995	3.9	10.6	14.5	6.6	0.0	0.0	0.0	0.0	3.9	6.1	10.0	4.5	3.4	1.5	4.2	1.9	75.3	34.1
1996	0.5	1.8	2.3	1.1	0.0	0.1	0.1	0.0	0.2	0.5	0.7	0.3	3.5	1.6	1.8	0.8	65.7	29.8
1997	0.5	3.9	4.4	2.0	0.0	0.4	0.4	0.2	0.0	0.0	0.0	0.0	2.6	1.2	0.0	0.0	119.5	54.2
1998	0.4	4.4	4.8	2.2	0.0	0.3	0.3	0.1	0.0	0.0	0.0	0.0	2.1	0.9	0.0	0.0	252.2	114.4
1999	0.3	1.5	1.9	0.8	0.0	0.2	0.2	0.1	0.0	0.0	0.0	0.0	1.4	0.6	0.0	0.0	194.2	88.1
2000	0.0	0.3	0.4	0.2	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	1.6	0.7	0.0	0.0	33.3	15.1
2001	0.0	0.7	0.7	0.3	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	2.6	1.2	0.0	0.0	25.3	11.5
2002	0.1	1.2	1.3	0.6	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	1.6	0.7	0.0	0.0	32.6	14.8
2003	0.1	0.4	0.5	0.2	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.9	0.4	0.0	0.0	28.3	12.8
2004	0.0	0.2	0.2	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	1.5	0.7	0.0	0.0	23.9	10.9
2005	0.1	2.1	2.2	1.0	0.0	0.1	0.1	0.0	0.1	0.6	0.7	0.3	1.4	0.6	1.0	0.4	24.9	11.3
2006	0.4	3.2	3.6	1.6	0.0	0.1	0.1	0.0	0.7	2.7	3.5	1.6	1.6	0.7	2.1	1.0	37.0	16.8
2007	0.2	4.1	4.4	2.0	0.0	0.1	0.1	0.1	0.2	4.6	4.9	2.2	1.5	0.7	2.1	1.0	36.4	16.5
2008	0.1	2.5	2.6	1.2	0.0	0.6	0.6	0.3	0.0	1.0	1.0	0.4	1.2	0.5	1.9	0.9	63.0	28.6
2009	0.0	2.9	2.9	1.3	0.0	0.3	0.3	0.2	0.0	0.2	0.2	0.1	0.4	0.2	1.3	0.6	58.5	26.6

Table 3. PSC limits for EBS Tanner crab in numbers of crabs

PSC limits for *bairdi* Tanner crab: Zone 1 and 2		
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

Table 4 Catch of EBS Tanner crabs in numbers of crabs by groundfish fisheries 2009-2011(through 3/12/2011) by groundfish trawl fisheries.

Year	Zone	Total Catch	Limit	Remaining	% Taken
2009	1	191,392	980,000	788,602	20%
	2	287,116	2,970,000	2,682,884	10%
2010	1	178,730	830,000	651,270	22%
	2	326,933	2,520,000	2,193,067	13%
2011*	1	52,481	830,000	777,519	6%
	2	104,990	2,520,000	2,415,010	4%

*2011 catch through 3/12/2011

Table 5 Apportionment of crab PSC between the Amendment 80 and BSAI trawl limited access sectors.

Fishery	Year	Zone 1 PSC red king crab limit in the BSAI	C. *opilio* (snow) crab PSC limit (COBLZ)	Zone 1 Tanner crab (*C. bairdi)* PSC limit	Zone 2 Tanner crab (*C. bairdi)* PSC limit
		*As a percentage of the total BSAI trawl PSC limit after allocation as PSQ			
Amendment 80 Sector	2008	62.48	61.44	52.64	29.59
	2009	59.36	58.37	50.01	28.11
	2010	56.23	55.3	47.38	26.63
	2011	53.11	52.22	44.74	25.15
	2012, and all future years	49.98	49.15	42.11	23.67
BSAI trawl limit access Sector		30.58	32.14	46.99	46.81

Table 6. Bycatch mortality by fishery and gear type (lbs) for EBS Tanner crab 2003/042008/09.

	Target fishery	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	Average 03/04 to 08/09
Nonpelagic trawl	Pollock, bottom	7	2	466	525	1,284	4,762	1,174
	Pacific cod	86,048	200,165	142,498	153,343	28,181	10,041	103,379
	Yellowfin sole	240,869	487,846	294,700	274,736	177,198	269,327	290,779
	Rock sole	119,531	240,985	130,217	88,603	62,740	64,831	117,818
	Arrowtooth flounder	4,150	7,150	7,295	37,350	1,363	23,862	13,528
	Flathead sole	247,616	130,322	281,921	95,416	114,601	57,851	154,621
	Other flatfish	3,344	5,962	2,094	3,229	1,933	413	2,829
	Greenland turbot	1,977	0	72			0	341
	Atka mackerel	526	1,151	42	253	65	0	340
	Other species	221	1,485	46	112	689	28	430
Pelagic trawl	Pollock	324	778	554	1,054	681	763	692
Hook and line	Pacific cod	3,843	5,441	8,130	9,769	6,797	16,461	8,407
Pot	Pacific cod	18,727	54,624	154,684	378,143	508,508	297,445	235,355
Grand Total		727,441	1,136,080	1,023,787	1,042,687	904,545	746,121	930,110

Table 7 Statewide crab bycatch limits in percentage of crab abundance estimates (where available) or number of crabs.

Area/District	Red King Crab	*C. bairdi*	*C. opilio*
Yakutat District 16	NE[a]	NE	NA[b]
Yakutat Area D	NE	NE	NA
Prince William Sound	NE	0.5%	NA
Cook Inlet Kamishak District	60 crab	0.5%	NA
Kodiak Northeast District	0.5% or 1.0%	0.5% or 1.0%	NA
Kodiak Shelikof District	0.5% or 1.0%	0.5% or 1.0%	NA
Kodiak Semidi District	NE	NE	NA
Alaska Peninsula	0.5% or 1.0%	0.5% or 1.0%	NA
Bering Sea	500 crab[c]	3 tier approach	3 tier approach
Dutch Harbor	0.5% or 1.0%	0.5% or 1.0%	NA
Adak[d]	50	10,000 crab	NA

[a] Not established.

[b] Not applicable.

[c] Fixed CBL.

[d] Bycatch limit established to provide scallop fleet opportunity for exploratory fishing while protecting crab resources.

Table 8 Estimates total weights associated with Tanner crab bycatch in the Bering Sea scallop fishery 2006/07-2009/10. Source: G. Rosenkrantz (ADF&G), pers. comm.

Year	Number of Tanner crabs	Estimated total weight (lbs) of Tanner crabs
2006/07	45,204	23,780
2007/08	35,288	16,892
2008/09	60,373	31,263
2009/10	27,430	16,288

Table 9 Comparison of bycatch of Tanner crabs in millions of lbs across fisheries with comparison to retained catch in the 2008/09 directed fishery.

Year	Directed Tanner fishery (retained) catch	Tanner fishery bycatch	Snow crab fishery bycatch	BBRKC fishery bycatch	Groundfish trawl fishery bycatch	Scallop fishery bycatch
2008/09	1.3	0.2	2.9	0.3	0.4	0.03

Figures

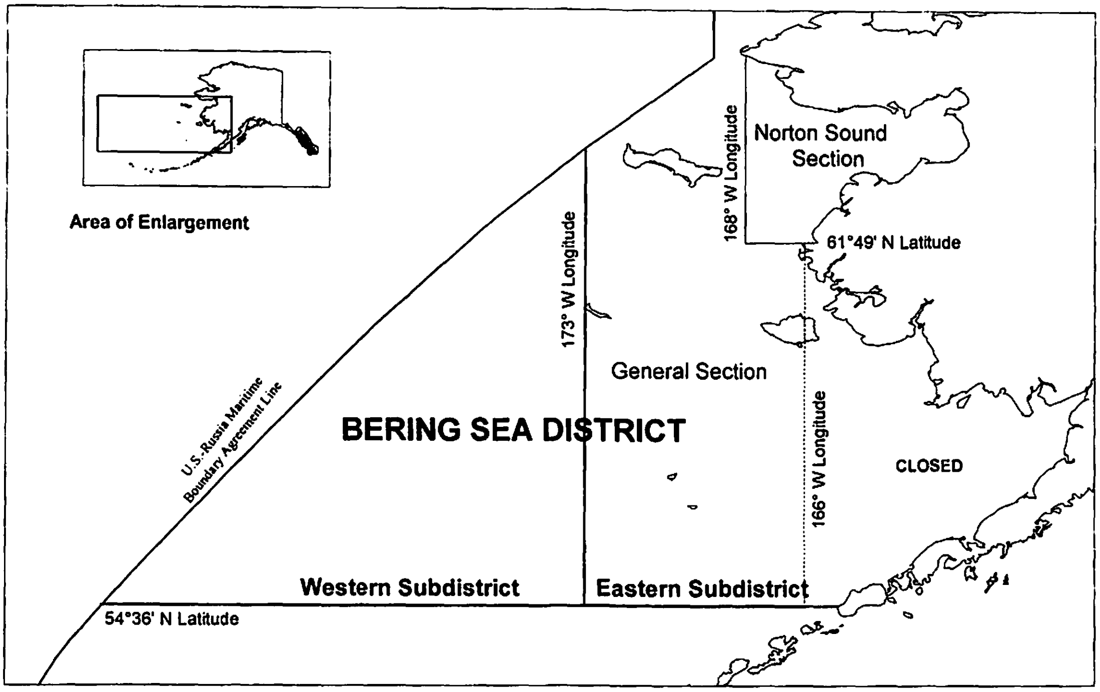


Figure 1 Eastern Bering Sea District of Tanner crab Registration Area J including subdistricts and sections (From Bowers et al. 2008).

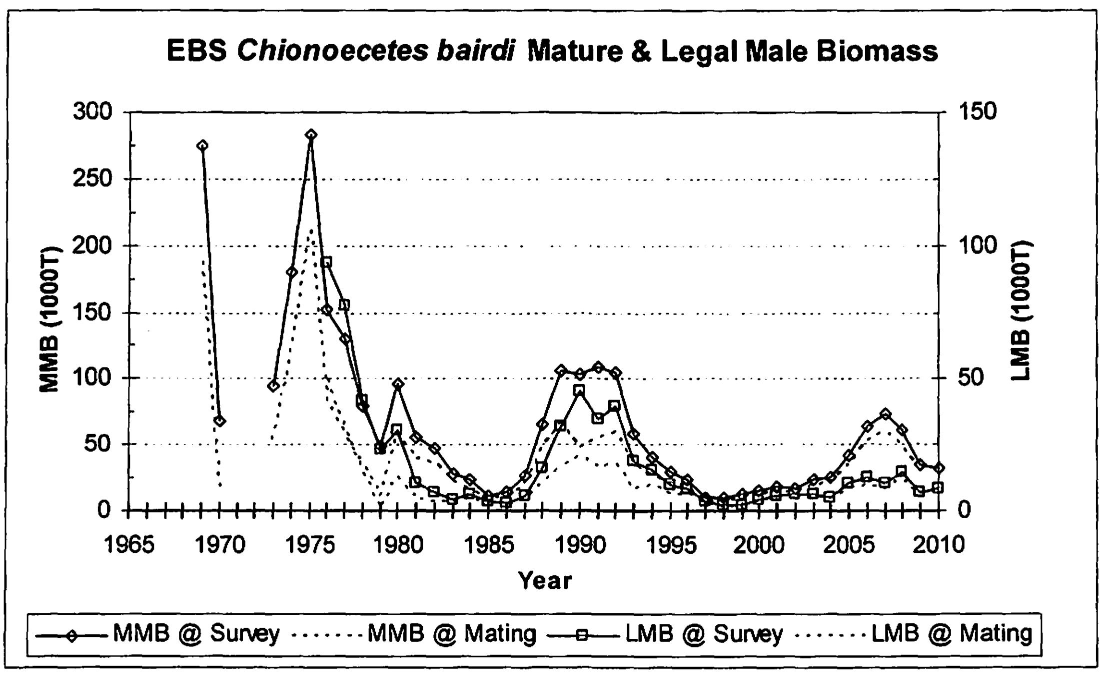
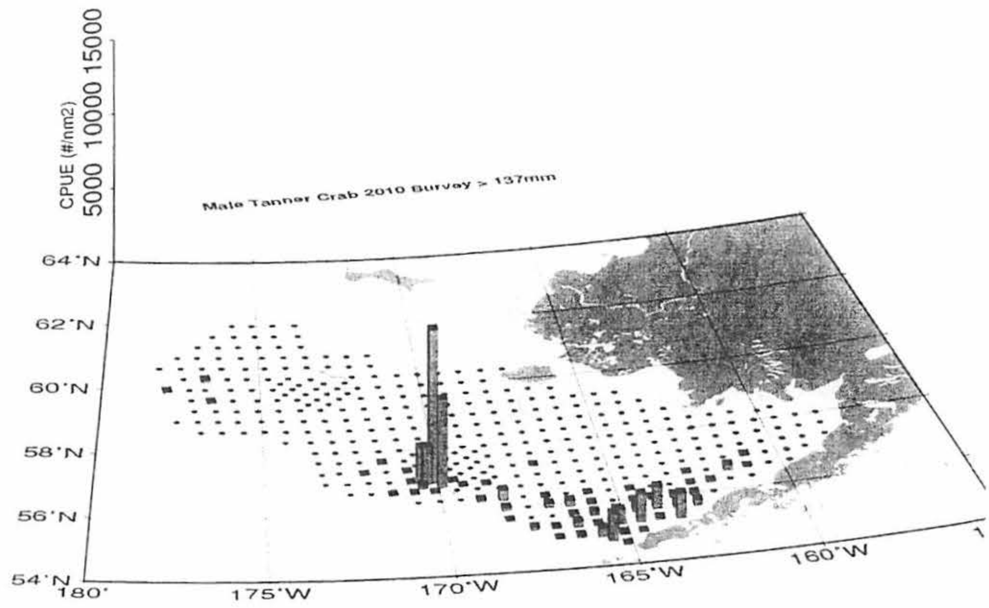


Figure 2 Eastern Bering Sea C. bairdi mature and legal male biomass at time of the survey and mating, 1965-2010. (2010/11 MMB and LMB at time of mating not estimable absent 2010/11 catch data). From Rugolo and Turnock, 2010.



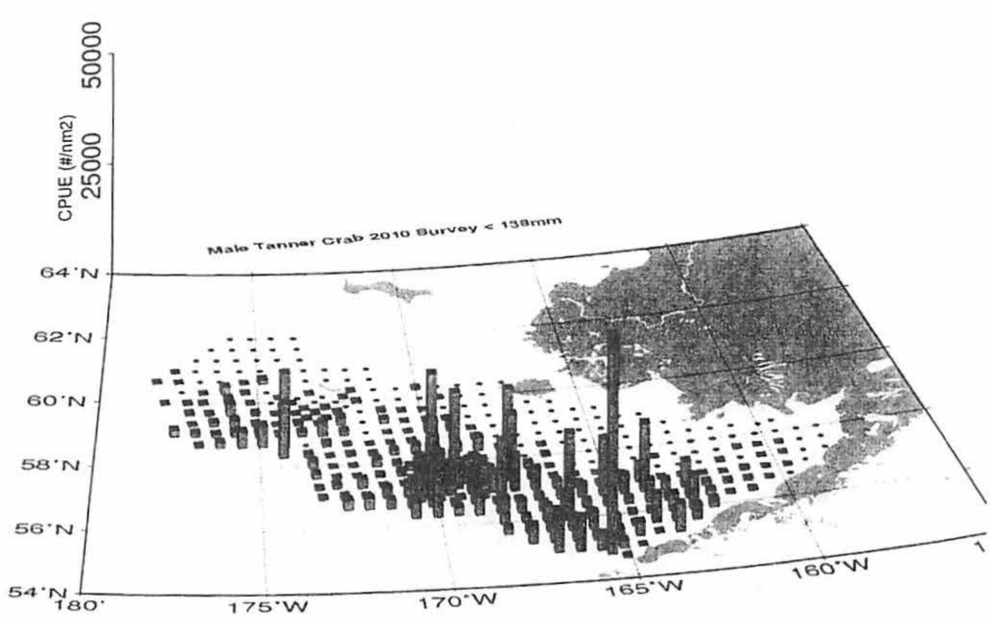


Figure 3 Distribution and abundance of legal (>= 138 mm cw) (top) and sublegal (< 138 mm cw) (bottom) male Tanner crab in the summer 2010 NMFS bottom trawl survey. From Rugolo and Turnock, 2010.

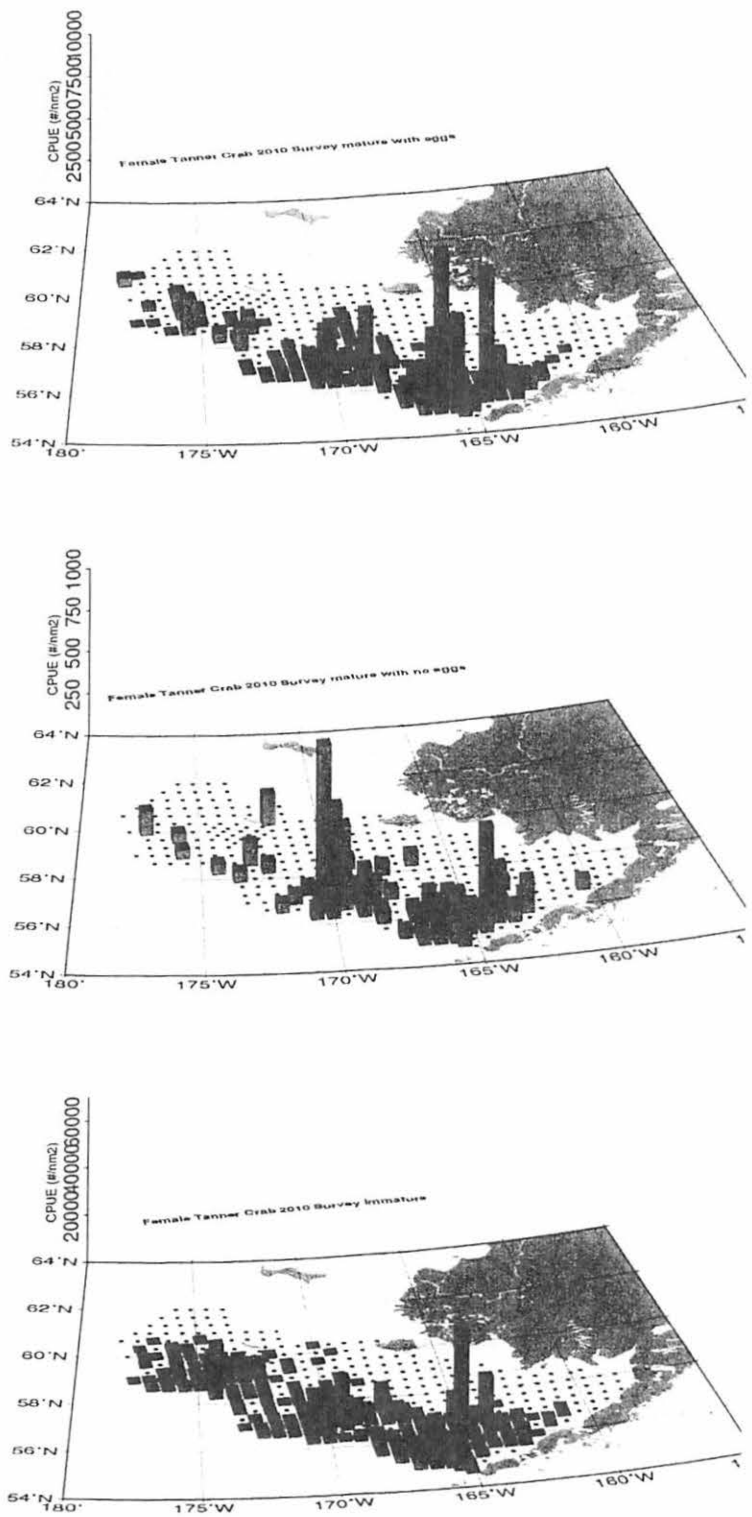


Figure 4 Distribution and abundance of ovigerous (top), barren mature (middle), and immature (bottom) female Tanner crab in the summer 2010 NMFS bottom trawl survey. From Rugolo and Turnock, 2010.

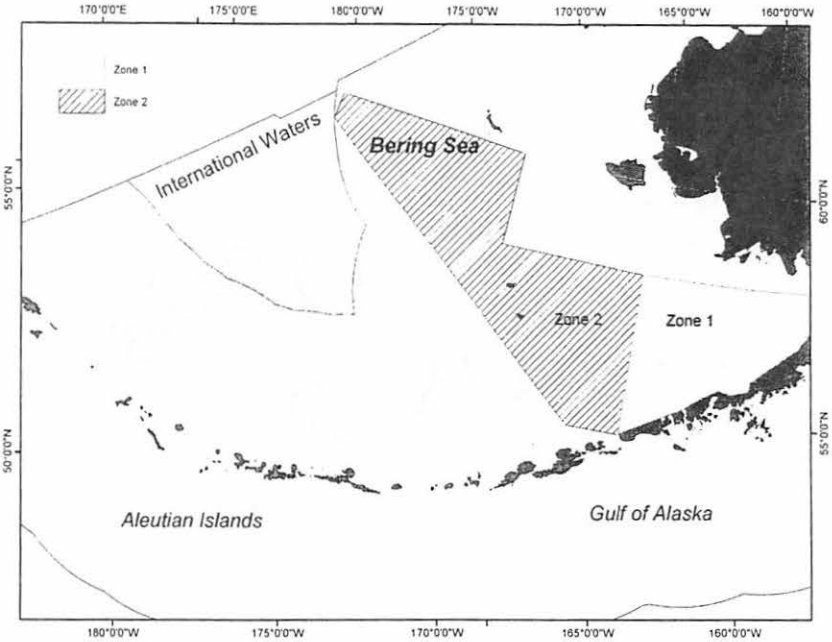


Figure 5. Zones 1 and 2 area for closures (Bristol Bay red king crab and EBS Tanner crab).

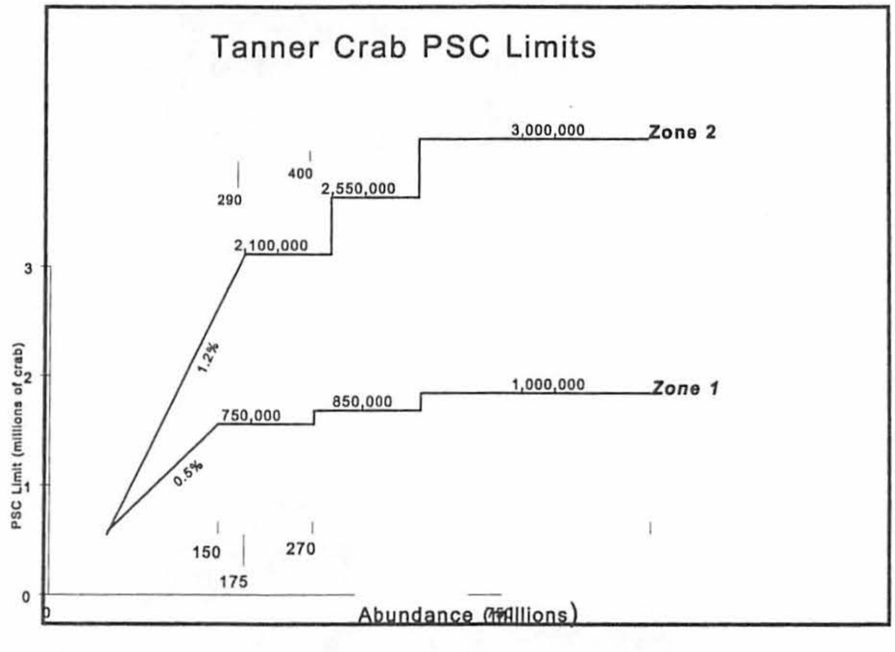


Figure 6 Tanner Crab PSC Limits.

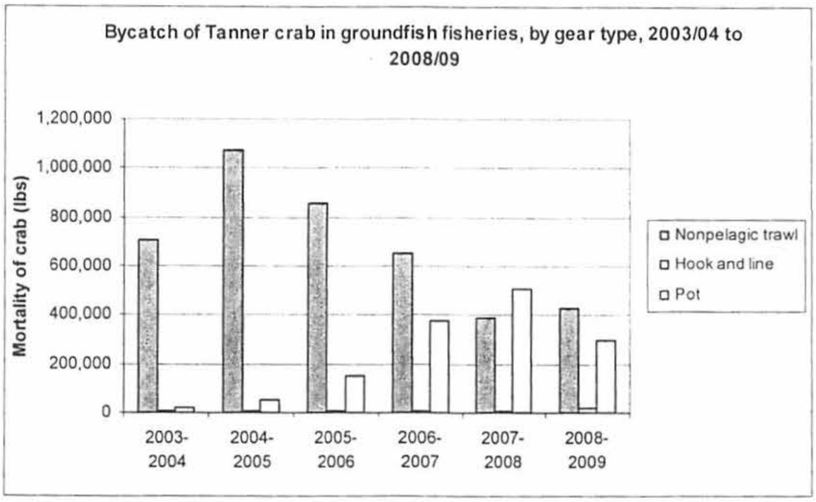


Figure 7 Bycatch mortality (lbs) by gear type for EBS Tanner crab.

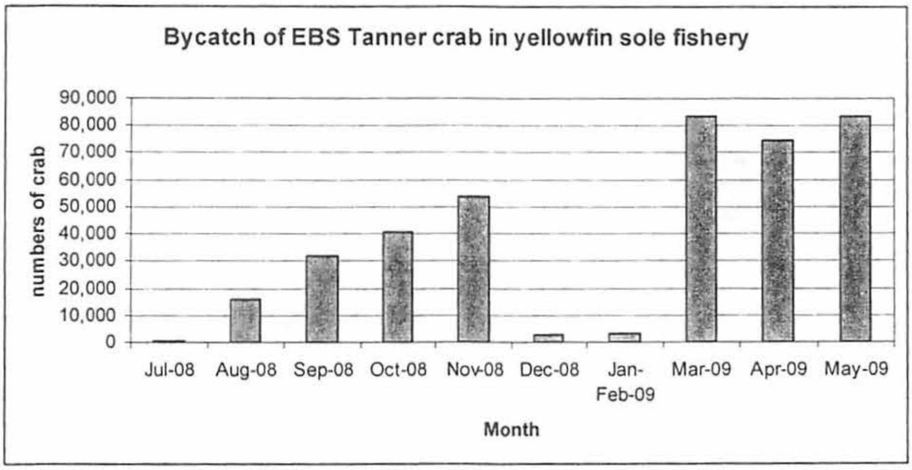


Figure 8 Bycatch of EBS Tanner crab in the Yellowfin sole fishery from July 2008-June 2009 (crab fishing year). Numbers of crab, not discounted for mortality

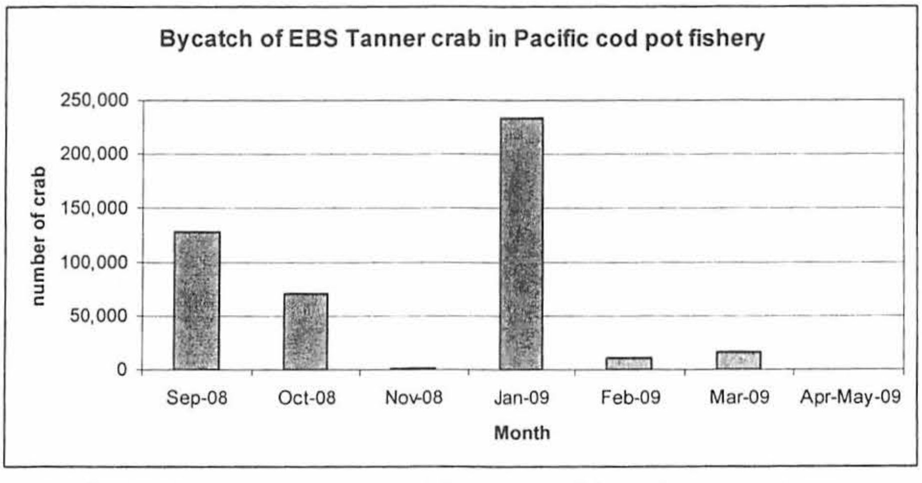


Figure 9 Bycatch of EBS Tanner crab in the Pacific cod pot fishery from July 2008-June 2009 (crab fishing year). Numbers of crab, not discounted for mortality.

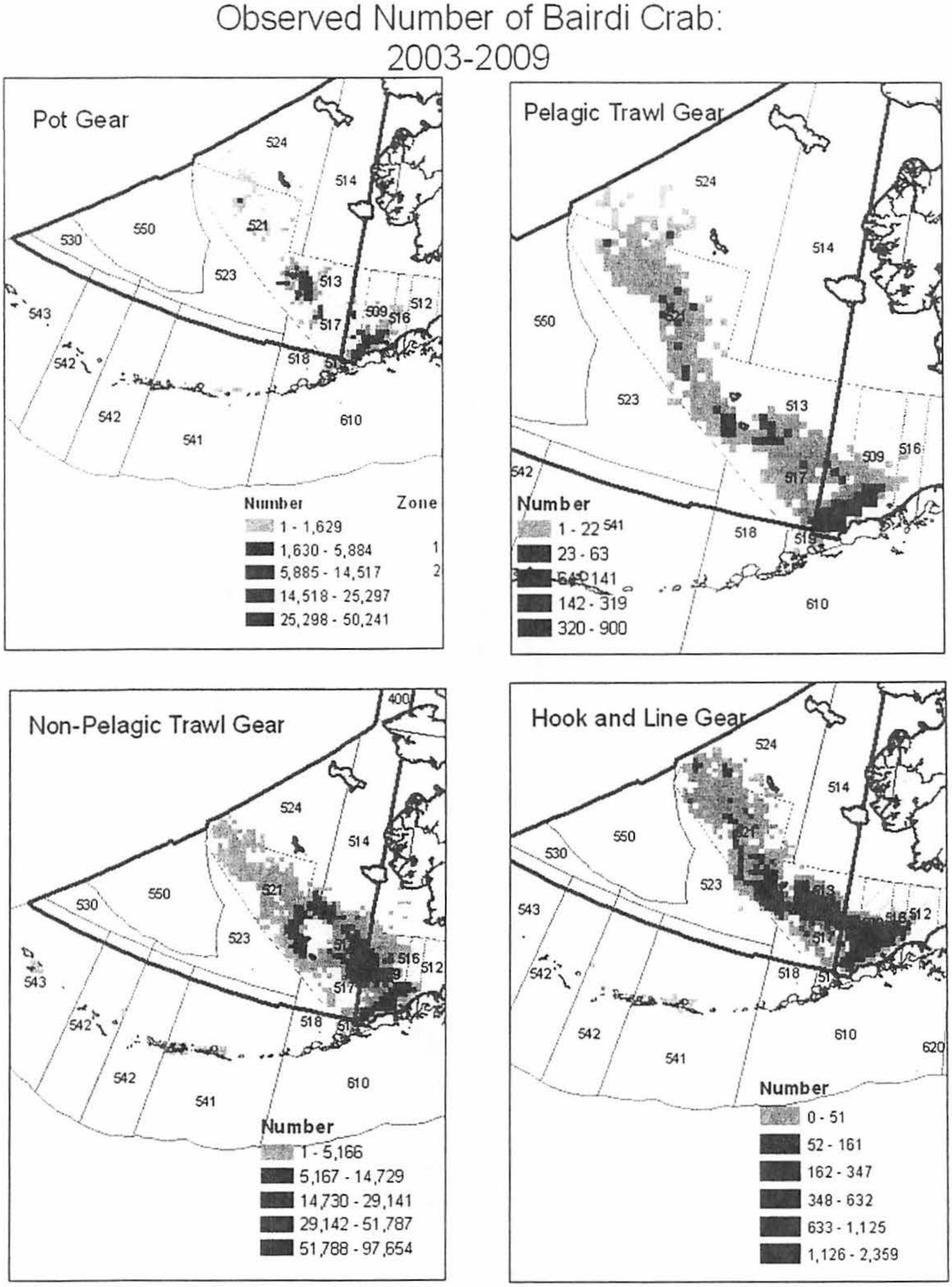


Figure 10 Observed number of Tanner crab in groundfish fisheries 2003-2009 by gear type. Note Zone 1 and Zone 2 closures shown in gray.

Report on the North Pacific Fishery Management Council's

Crab Modeling Workshop

February 16-18, 2011
AFSC, SEATTLE, WA

Prepared By Steven Martell & Diana Stram

EXECUTIVE SUMMARY

- A crab modeling workshop took place from February 16-18, at the Alaska Fisheries Science Center in Seattle WA. The meeting was chaired by Steven Martell, from the University of British Columbia, and was attended by members of the Crab Plan Team (CPT), the authors of the stock assessment models (absent Jie Zheng), and the general public. [see Appx. 1 for list of participants]
- The over-arching objective of the workshop was to give the assessment authors feedback and recommendations on the assessment models that are currently in use for estimating stock status and reference points.
- Assessment models for Bering Sea Tanner crabs, blue and red king crabs from the Pribilof Islands, red king crabs from Bristol Bay, and selectivity experiments from the Eastern Bering Sea snow crab were presented at the workshop. Discussions about the data, assessment models, and interpretation of the results took place.
- A series of consensus recommendations were identified for each of the above named assessments and are categorized as short-term and long-term.
- The majority of the workshop focused on the Tanner crab assessment, the Tanner crab model is not yet adequate for providing management advice or to be used for a rebuilding analysis. Early recruitment estimates are unrealistic, the 1969-1973 survey data are questionable, and the early catch needs to be verified. All of these points have implications for the estimates of reference points.
- The Catch-Survey Assessments (CSA) that are proposed for use for the Pribilof Island king crab stocks and currently in use for the St Matthew stock need to be fully documented including the large number of undocumented constants in the code. The code should either be re-written so that the assessment authors are comfortable with internal workings, or the existing code should be cleaned up and peer reviewed by an expert who is familiar with the AD Model Builder language.
- The selectivity experiments based on a side-by-side trawl survey conducted jointly by NMFS and the BSFRF clearly show that previous assumptions that q=1 in the NMFS trawl survey are unfounded. Additional work needs to be conducted to integrate the information from the 2009 and 2010 experiments into the stock assessment models. A mistake or misinterpretation in the snow crab assessment was identified: the predicted catch at length in the NMFS trawl within the experimental survey areas should be the product of

the numbers-at-length times the availability-at-length times the catchability in the survey area, times the selectivity of the NMFS trawl survey times the catchability of the NMFS trawl survey.

TANNER CRAB MODEL

Documents available for review during workshop:

Appx 2.	Draft assessment model/preliminary results
Appx. 3.	Model presentation
Appx 4.	Maturity presentation
Appx 5.	Additional model runs and fits to data

Background & Objectives:

Lou Rugolo presented the progress to date on the development of a Tanner crab assessment model. The proposed Tanner crab model is an adaptation of the current snow crab model developed by J. Turnock, and is being modified by L. Rugolo and J. Turnock.

The objectives of this review are two fold:

1) Is the model suitable for an assessment and determining and OFL and moving the stock from Tier 4 to Tier 3?
2) Is the model suitable enough for a rebuilding analysis?

Technical Issues

Four major technical issues were identified going into this workshop: 1) treatment of the early recruitment series, 2) size limit proposal and potentially splitting selectivity, 3) biomass estimates from the early survey period (1969-1973), and 4) survey selectivity issues. In addition additional issues were also identified during the course of the workshop that pertained to the input data, especially the early catch and discard data.

Edward Poulson also commented that the closure of the Tanner crab fishery in 1997, rationalization of the fleets in 2005, and reopening the Tanner crab fishery in 2007 resulted in a marked change in fleet behavior that could impact bycatch rates. Also , prior to the 1980s the ratio of Tanner crabs in the snow crab fishery may have changed, and this change may be linked to just a few vessels.

The early survey data between 1969 and 1973 is unlikely to have a similar catchability (survey q) due to the spatial expansion of the survey over this time period. Furthermore, due to the spatial ontogeny of tanner crabs, the expansion of the survey in the early 1970s likely increased the catchability of small crabs as the survey moved out towards the shelf break.

Short-term Recommendations

1. Verify historical catch and discard data that go into the assessment model. Verify species id and aggregate *Chionoecetes* species that goes into calculating the catch/discard series. Closer inspection of the bycatch in the yellowfin sole fishery or other directed groundfish fisheries.
2. Remove the 1969-1973 survey data in the assessment model as the spatial coverage during this period changed each and every year.
3. A prospective analysis (run the model successively with the first year(s) of the data removed) should be conducted to better understand the influence of the early catch and survey data on estimates of reference points, and recruitment.
4. The assessment document must include a table comparing estimated catch versus catch based on actual data. It is not clear what is derived catch information and what is based on actual reported landings.
5. It was noted on several occasions that the catch data are the most important information going into the assessment model, yet there are concerns with respect to the reliability of these data in the early years of the time series. Sensitivity of the estimated bycatch should be explored by running a model scenario without the estimated bycatch included in the input data and examine sensitivity of model outputs and reference points.
6. Currently, natural mortality rates (M) are estimated externally to the assessment model and there are some concerns that the estimates of M are biased. If the same data that are used to estimate M externally are also used in the assessment model, the M should be internally estimated within the assessment model.
7. Verify the growth parameters in the text versus those listed in Table 5.
8. Follow the terms of reference; for example in Table 5, please specify the bounds of each parameter, MLE estimate and the SE based on the inverse hessian. Provide the assumed survey CVs in tabular format.
9. Clear documentation of the model is required; the equations presented in the text should be consistent with the equations used inside the ADMB template code.
10. Bubble plots for residuals in catch-at-length should demarcate changes in management (i.e., a line break showing when escape rings went into place, fleet rationalization, fishery closures etc.) to determine if residual patterns are influence by potential changes in fleet behavior.
11. Consider feasibility of a spatial model between areas, a split model between areas or simply evaluating the survey data east and west of 168° to better inform relative abundance in each region.
12. As currently formulated, the model is not sufficient for use in a rebuilding analysis. Should modifications be made to the model to address the major issues as addressed above, scenarios should then be run under various

rebuilding and bycatch reduction scenarios to evaluate rebuilding trajectories for use in a forthcoming rebuilding analysis.

Long-term Recommendations

1. Profiling of M, Q and Growth parameters should be done to better understand the information the data and the level of parameter confounding in the model.
2. Treat the male catch-at-length and chela height to carapace width ratio data as two separate data sources with separate likelihood functions, as these data are not independent (i.e., better to use the data as they are). Currently the chela-height to carapace width ratio data are used to apportion male catch-at-length into immature and mature length frequency datasets.

Non-consensus recommendations

1. There was a suggestion to start the model in 1983 when the survey became standardized, and ignore all data prior to 1983 in the assessment. This would address concerns about the early data and changes in survey protocol/gear prior to 1982. There was also a concern about the sudden decrease in female biomass between 1982 and 1983 that is inconsistent with the M=0.23 hypothesis. The assessment authors did not agree with this recommendation because the survey was also consistent between 1974 and 1981, but would just have a separate q.

PRIBILOF ISLANDS RED AND BLUE KING CRAB

Documents available for review during workshop:

Appx. 6. Draft assessment model/preliminary results (PI blue king crab)

Appx. 7. Draft assessment model/preliminary results (PI red king crab)

Appx. 8. Presentation

Background and Objectives:

Bob Foy presented an overview of the development of assessment models for PI blue and red king crabs. The assessment model that is currently proposed for use for Pribilof Islands Blue and Red King Crab is a four-stage variant of a catch-survey assessment model (CSA) that predicts the size-specific abundances of male crabs. The code was adapted from a previous model implemented by Zheng. This model is not yet being used for annual assessments for these stocks. In the current model implementation, M and survey Q are fixed, and there is a separate M in 1999 for the red king crab to explain the large changes in survey abundance between 1999 and 2000. The growth transition matrix needs verification as growth and molting probabilities are key in this model. The pot survey data is only 3 years long and if included in the model causes convergence problems.

A major objective of the review of these models at this stage of development was to provide guidance as to whether a four-stage model is appropriate compared to a three-stage approach or if more simplified modeling approach would be warranted.

Andre Punt also provided a brief overview of a grossly simplified growth increment model and compared the results with the much more complicated snow crab assessment; results between the two models were remarkably similar.

Technical Issues:

The model is initialized based on the survey data and assumes no observation errors in the initial abundances. Ideally these should be estimated within the model to allow for the inclusion of observation errors.

The existing code is not well documented and there are a large number of undocumented fixed constants throughout the code.

There are a number of recommendations that involve either developing a simplified model (i.e., similar to the model Andre Punt showed during the workshop), to reducing the current model structure from four stages to three stages, to completely re-writing the code such that the investigators are much more intimate with the assessment model. The time commitment for each of these could be considerable and the SSC should advise priorities for modeling work. In any case, the existing model should not be used until it is fully documented and the code itself is peer reviewed by an independent expert who is familiar with ADMB and non-linear parameter estimation. Note that during the workshop, a few participants examined the code and it was questionable if the actual objective function was continuous and differentiable (e.g., inappropriate use of if statements in the calculations).

Short-term Recommendations

1) Collapse the post-recruits and recruits into one category (i.e., develop a three-stage model).
2) Develop a simplified assessment model based on single estimated growth increment matix G:

    $N_{y+1}=G\,S_y\,N_y + R_{y+1}$ where N is a vector of numbers at length, S is a vector of survival rates (incl. effects of fishing), and R is a vector of new recruits

3) Completely re-write the current assessment model such that the assessment authors are more intimate with the data inputs, model equations, and various undocumented constants can then be addressed.
4) Pribilof Islands and St. Matthew stock assessments share similar issues, and model development for both of these areas should be consistent. There was

a strong consensus that the development of the assessment model should be done in concert for both of these areas.

BRISTOL BAY RED KING CRAB CIE REVIEW RESPONSE

Documents available for review during workshop:

Appx. 9. CIE report 1

Appx. 10. CIE report 2

Appx. 11. Response to CIE reviews

Background:

Sideek provided an overview of the authors' response to the CIE review comments of the Bristol Bay RKC assessment on a point-by-point basis. A total of seven alternative model scenarios were developed and compared to the base scenario to examine the various points made by the CIE review team. One specific recommendation by the CIE reviewers was to modify the variance formula in the robust normal approximation to the multinomial distribution to use the observed proportions-at-length rather than the estimated proportions. This adjustment was held constant for all seven alternative scenarios and is consistent with the literature on this subject.

Recommendations & Suggestions:

1) Justify why the choice of switching the variance terms in the robust multinomial likelihood to the observed proportions-at-length for all scenarios, rather than switching back to the base scenario that used the predicted proportions-at-length. Bubble plots of the residual patterns using either formulation should be shown side-by-side for comparative purposes. There is some concern that very small sample sizes may create large residuals.
2) Provide a table of model parameters and describe which parameters are fixed and which are estimated (as per terms of reference) as well as the corresponding parameter bounds assumed. If fixed then please justify the fixed value.
3) A suggestion to run a sensitivity analysis with and without retow data. The retow data should be treated consistently in both the survey abundance estimate and the population assessment model.
4) The model is initialized with the 1968 size distribution data; the model should be run with estimated initial conditions and evaluate the effects on management quantities.

EASTERN BERING SEA SNOW CRAB SELECTIVITY EXPERIMENTS

Documents available for review during workshop:

Appx. 12. NMFS/BSFRF snow crab selectivity study

Appx. 13. Snow crab assessment results with 2009 and 2010 cooperative survey data

Background:

Dave Somerton provided an overview of the cooperative study for snow crab selectivity. There have been a total of four experiments to estimate selectivity and the most recent experiments were conducted in 2009 and 2010. The 2009 experiment was limited in area compared to the 2010 survey. The basic assumption in the selection experiment is that the net used by the Bering Sea Fisheries Research Foundation (BSFRF) catches all crabs of all sizes that are available (present in the trawl path). The ratio of size specific catch rates in the NMFS trawl and the BSFRF trawl in the side-by-side tows is then an empirical estimate of selectivity for the NFMS trawl survey.

In the 2009 experiment, the data were analyzed by fitting a simple logistic model to the ratios of NMFS catch-at-size to the BSFRF catch-at-size. In 2010, the analyses of the paired tow data were based on a Generalized Additive Model (GAM) similar to the methods used by ICES. This method allows for the incorporation of two environmental indices, sediment type and depth (which are also weakly positively correlated). Due to differences in the two gears and tow duration, the BSFRF trawl sweeps roughly 1/7 the area of the NMFS trawl. As a consequence, there were a large number of zero captures in the BSFRF net of certain size classes due to the restricted tow duration. To compensate some, the crab-size bin width interval was increased from 5mm to 10mm to avoid this issue. The choice of bin interval widths may affect estimation.

There was some discussion surrounding the performance of the BSFRF net and if the bycatch or contents of the net could affect performance with respect to catching snow crab. It was generally thought that selectivity of the net was determined by the belly of the net; none of the analyses performed considered the bycatch or total catch as a covariate.

There was a great deal of discussion regarding the differences between the empirical selectivity curves estimated in 2009 and 2010, and Dave Somerton suggested that the two curves be averaged for the assessment model. There was also a discussion initiated by Mark Maunder to try an alternative model using a simultaneous negative binomial mixed effects regression. This may resolve the issue of zeros and avoid problems associated with changing bin widths.

Jack Turnock also provided a summary of the snow crab assessment results with the experimental data included in the assessment model. In this case, a 6 parameter selectivity curve comprised of the addition of two logistic functions was used to estimate the selectivity of the NMFS trawl survey. This parametric function accommodated a wide variety of shapes for the size-specific selectivity including shapes that appeared to be similar to the empirical data obtained from the ratio of the NMFS trawl to the BSFRF trawl.

Nearing the end of the presentation of the snow crab assessment model, it became apparent there was some confusion on how selectivity was being modeled in the snow crab assessment. It appeared that the method that was being used to integrate the BSFRF data was incorrect; Jack Turnock was in the process of correcting the code to properly implement the BSFRF data but time was insufficient to preview the results of this correction.

Andre Punt provided a quantitative description of how the BSFRF data should be integrated into the snow crab assessment model:

$$C_l^F = N_l Q^s A_l$$

$$\tilde{C}_l^N = N_l Q^s A_l S_l Q^n$$

$$C_l^N = N_l Q^n S_l, \quad \text{where}$$

C_l^F = vector of catches by the BSFRF survey

$\tilde{C}_l^N$ = vector of catches by NMFS in the survey area

C_l^B = vector of cathes by NMFS in total area

N_l = vector of numbers at length

Q^s = catchability in survey area

Q^n = catchability in the EBS area

A_l = Availability at length

S_l = Selectivity of the NMFS survey

In the 2009 snow crab assessment, estimated values of q would go to 1 (its upper bound). If the 2009 BSFRF data were added the estimate of q would drop to 0.9, and if M and q were both estimated, q dropped to 0.77, and if M growth and q were estimated q dropped to 0.73. Clearly q is confounded with natural mortality rates and growth and the selectivity experiments are very important in providing independent information on population scale via the NMFS trawl survey.

Short-term Recommendations:

1) Fit the snow crab model to the 2010 BSFRF data only; ignore the data from the 2009 survey (these data may be biased because the bottom type was not considered, limited spatial coverage, and not all paired trawls were conducted on the same day).
2) Explore other options for combining the 2009 and 2010 selectivity experiment results including:

a. Separating the survey data by sediment types for the studies and overall survey area and by length frequency and have a different selectivity for each sediment type.

3) Provide clarification on the BSFRF survey area q calculation Q (availability) should be a vector in the 2009 BSFRF survey selectivity.
4) Examine the profile likelihood for M, and evaluate M based on the empirical selectivity based on the trawl experiments. Is there any biological sense to the M profile if in fact the empirical data are correct?

Long-term Recommendations:

1) Develop an integrated analyses for the trawl experimental data based on Mark Maunders suggestion of a negative binomial mixed effects model.
2) Integrate a non-parametric selectivity function within the snow crab assessment model. This could involve the estimation of length-specific selectivity coefficients directly, a GAM type model, or estimate the nodes of a cubic spline interpolation.

Appendices: Documents presented at the workshop for each discussion topic

Note that these documents and additional supplemental materials are available at http://www.tinyurl.com/crab2011

Appx. 1. List of participants

Appx 2. Tanner crab draft assessment model/preliminary results

Appx. 3. Tanner crab model presentation

Appx 4. Tanner crab maturity presentation

Appx 5. Tanner crab: Additional model runs and fits to data

Appx. 6. Draft assessment model/preliminary results (PI blue king crab)

Appx. 7. Draft assessment model/preliminary results (PI red king crab)

Appx. 8. PIBKC/PIRKC Presentation

Appx. 9. BBRKC CIE report 1

Appx. 10. BBRKC CIE report 2

Appx. 11. BBRKC Response to CIE reviews

Appx. 12. NMFS/BSFRF snow crab selectivity study

Appx. 13. Snow crab assessment results with 2009 and 2010 cooperative survey data

Appendix 1. List of Participants

Invited participants:

Steve Martell (UBC)	Chair	Jack Turnock (AFSC-Seattle)	presenter
Lou Rugolo (AFSC-Seattle)	presenter	Bob Foy (AFSC-Kodiak)	presenter
Shareef Siddeek (ADF&G –Juneau)	presenter	Jim Ianelli (AFSC-Seattle)	
Dave Sommerton (AFSC-Seattle) presenter		Doug Pengilly (ADF&G –Kodiak)	
Karla Bush (ADF&G-Juneau)		Buck Stockhausen (AFSC-Seattle)	
Anne Hollowed (AFSC-Seattle)		Terry Quinn (UAF-Juneau)	
Gordon Kruse (UAF-Juneau)		Doug Woodby (ADF&G-Juneau)	
Bill Gaeman (ADF&G-Kodiak)		Ginny Eckert (UAF-Juneau)	
Diana Stram (NPFMC)		André Punt (Univ. Washington)	
Teresa A'mar (AFSC-Seattle)			

Additional participants:

Mark Maunder (QRA)	Jack Tagart (Tagart Consulting, BSFRF)
Scott Goodman (NRC, BSFRF)	Edward Poulson (Alaska Bering Sea Crab Assoc)
Brett Reasor (Unisea, Inc)	Steve Hughes (NRC, BSFRF)
Gary Stauffer (BSFRF)	Doug Wells (Baranof)
Bob Lauth (AFSC)	Russ Nelson (AFSC)
Ed Richardson (At Sea Processors)	
Craig Rose (AFSC)	

Bering Sea Snow Crab Survey Selectivity
Supplemental Information
March 23, 2011

Benjamin Turnock
AFSC

This document presents revisions to the snow crab assessment model following the February 2011 modeling workshop to accompany presentation to at the March 28, 2011 SSC meeting.

All Bering Sea male survey selectivity was estimated using three different parameterizations:

1. 3 parameter logistic (ascending only),

$$\text{Selectivity}_l = \frac{Q}{1+e^{\left\{\frac{-\ln(19)(l-l_{50\%})}{(l_{95\%}-l_{50\%})}\right\}}}$$

2. 6 parameter combined logistic (various shapes),

$$\text{Selectivity}_l = \frac{q}{1+e^{-a_1(l-b_1)}} + \frac{q-c}{1+e^{-a_2(l-b_2)}}$$

3. Smooth function (23 parameters, 1 parameter for each length bin(22) and Q.

$$Sel_l = Q\exp(p_l)$$

A second difference constraint was added to the likelihood with a weight of 5.0,

$$5.0\sum_{l=1}^{L}(\textit{first differences}(\textit{first differences}(p_l)))^2 \ .$$

Availability of crab in the study area for the BSFRF was estimated as a 3 parameter logistic function. The formulation of survey selectivity for the NMFS study area data was revised following the February 2011 workshop recommendations, Survey selectivity in study area NMFS = All Bering Sea NMFS selectivity * Study area BSFRF availability.

All Bering sea NMFS is a vector which is the same over all years. Study area BSFRF availability is a 3 parameter logistic vector with separate parameters for 2009 and 2010. The formulation of survey selectivity used in the September 2010 snow crab stock assessment used information mainly on larger crab (Q) to inform the Q for the whole Bering Sea selectivity. The formulation in this document uses fewer parameters and is a more complete use of the study area data.

Female survey selectivity was formulated the same as male selectivity with separate parameters estimated, except all selectivity curves were 3 parameter logistic.

Survey selectivity of all Bering sea male crab was estimated using the September 2010 assessment model (mature male M estimated at 0.30)(Figure 1). The smooth function survey selectivity is maximum (0.84) at about 50-60mm carapace width then declines to about 0.5 above 105mm. The 3 parameter exponential curve reaches a maximum of 0.63 at sizes above 50mm. The 6 parameter combined logistic curve has the same shape as the 3 parameter, but with a maximum of 0.60.

The selectivity of smaller crab declines with increasing immature natural mortality (Figure 2). When immature M is estimated (mature M fixed at 0.23) the best fit is at 0.31, however, an immature M of 0.4 is needed for the selectivity to be estimated similar to a 3 parameter exponential (Figure 2). The maximum selectivity for the 3 parameter curve with immature M fixed at 0.4 was 0.58.

Figures 3 through 15 show fits to various data and survey selectivity curves for the model run using the 3 parameter exponential curve for all Bering sea male crab and immature M fixed at 0.4.

Figures 16 through 22 show data fits and survey selectivity using a smooth function for all Bering sea male crab with immature M = 0.40.

The best fit to the biomass data in the 2009 and 2010 study areas is achieved at immature M = 0.4 (Table 1). However, the best overall likelihood is at a lower immature M (Table 2)

Table 1. Observed and predicted male and female mature biomass in the 2009 and 2010 study areas for BSFRF and NMFS tows for four values of immature crab natural mortality using a smooth function for all Bering sea male survey selectivity.

				Immature M			
				0.23	0.3	0.35	0.4
Females	2009	BSFRF	Obs	12.2	12.2	12.2	12.2
		BSFRF	Pred	13.8	15.0	16.1	17.5
		NMFS	Obs	11.9	11.9	11.9	11.9
		NMFS	Pred	11.1	10.4	9.8	9.1
	2010	BSFRF	Obs	279.0	279.0	279.0	279.0
		BSFRF	Pred	206.1	226.4	244.0	264.0
		NMFS	Obs	91.5	91.5	91.5	91.5
		NMFS	Pred	162.9	154.2	145.0	133.1
Males	2009	BSFRF	Obs	68.4	68.4	68.4	68.4
		BSFRF	Pred	62.4	61.9	62.5	64.3
		NMFS	Obs	32.3	32.3	32.3	32.3
		NMFS	Pred	35.3	35.5	35.1	34.1
	2010	BSFRF	Obs	193.3	193.3	193.3	193.3
		BSFRF	Pred	183.5	180.8	180.0	180.6
		NMFS	Obs	77.7	77.7	77.7	77.7
		NMFS	Pred	107.1	106.2	102.7	96.3

Table 2. Likelihood values for model runs with smooth male survey selectivity and four values of immature crab natural mortality (0.23, 0.3, 0.35 and 0.40).

Likelihood Component	Immature M			
	0.23	0.3	0.35	0.4
Recruitment	32.69	32.66	32.58	32.46
Initial numbers smooth constraint	23.50	55.75	55.53	23.38
initial numbers fit	517.05	515.16	515.60	520.06
survey biomass	191.65	165.58	165.15	185.57
survey length	3094.64	3085.99	3080.92	3079.55
M prior	0.00	0.00	0.00	0.00
maturity smooth	26.19	27.44	28.36	28.87
growth a	2.59	2.19	1.98	1.94
growth b	0.04	0.04	0.04	0.04
2009 BSFRF length	-92.85	-91.82	-91.31	-91.21
2009 NMFS study area length	-81.95	-80.98	-80.24	-79.63
2009 BSFRF biomass	0.05	0.07	0.07	0.07
2009 NMFS study area biomass	0.04	0.05	0.05	0.04
2010 BSFRF length	-66.42	-66.50	-66.44	-66.31
2010 NMFS study area length	-85.38	-85.70	-85.89	-86.11
2010 BSFRF Biomass	1.45	0.88	0.56	0.32
2010 NMFS study area Biomass	3.28	2.84	2.24	1.42
Bering sea NMFS male survey selectivity smooth constraint	0.88	0.82	0.81	0.77
Retained fishery length	-2017.61	-2052.61	-2052.41	-2019.90
total fish length	657.94	655.85	656.38	659.39
female fish length	152.44	152.95	153.30	153.77
trawl length	187.21	188.83	188.75	187.02
Retained catch	2.77	2.77	2.89	3.17
discard catch	109.74	111.62	116.39	125.41
Groundfish catch	11.77	12.57	12.64	12.22
female discard catch	3.52	3.46	3.46	3.52
F penalty	74.62	74.83	75.28	76.07
Total	2749.86	2714.74	2716.69	2751.89

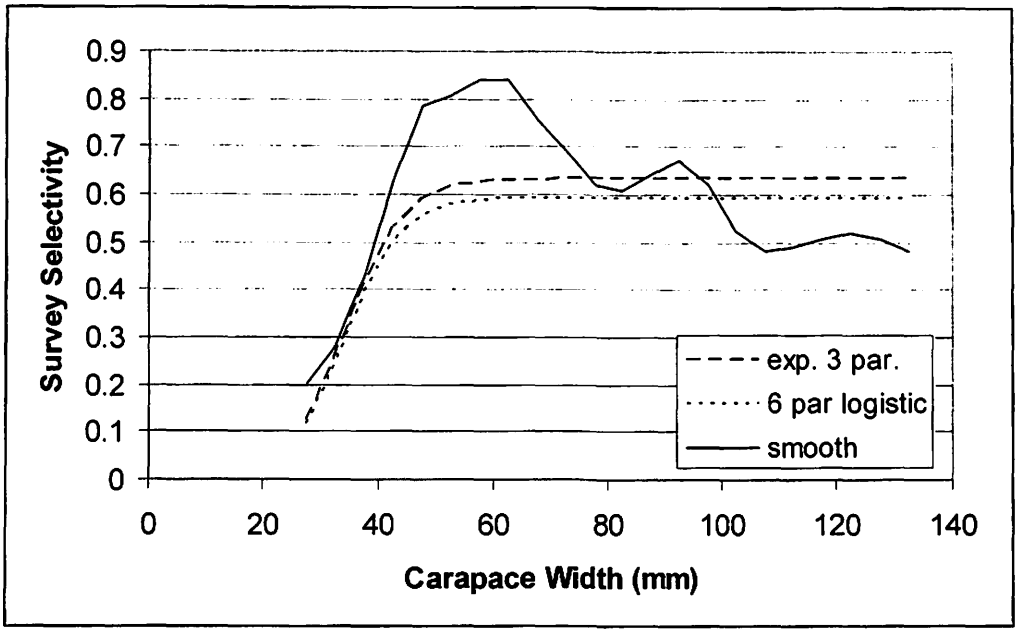


Figure 1. All Bering sea male survey selectivity for 1989-present using a 3 parameter logistic function, a 6 parameter combined logistic and a smooth function. Growth and mature male M were estimated (M=0.30). Immature M and mature M for females fixed at 0.23.

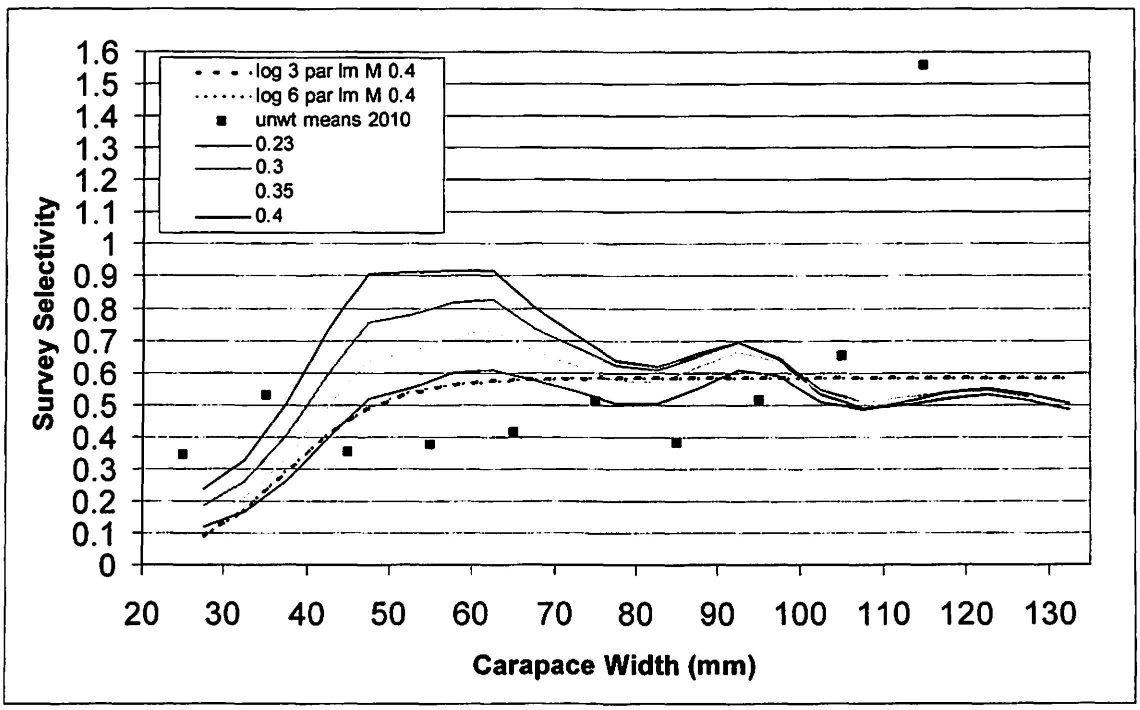


Figure 2. All Bering sea male survey selectivity 1989- present estimated using a smooth function with M on immature crab (male and female) fixed at 0.23, 0.30, 0.35 and 0.4. Mature M for males and females was fixed at 0.23. Dotted lines are a 3 parameter logistic curve and a 6 parameter combined logistic with immature M fixed at 0.4. Points are the unweighted mean values (binned by 10 mm) of the ratio of NMFS density to NMFS plus BSFRF density in the 2010 study area converted to selectivity.

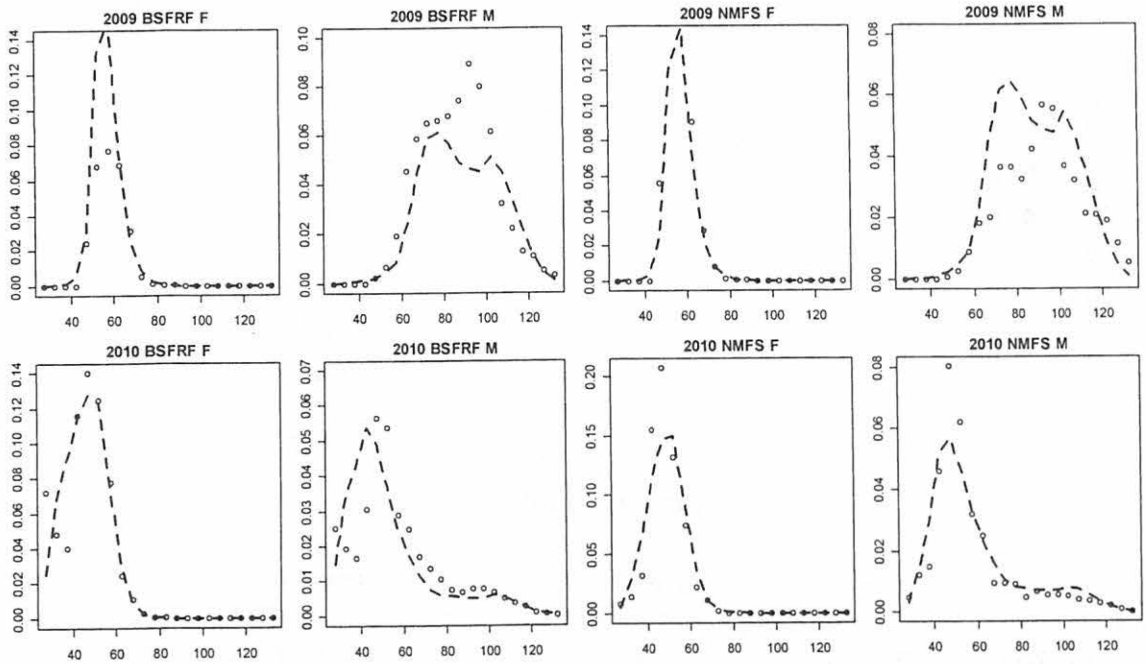


Figure 3. Fit to length frequency data in the study areas for 2009 and 2010. Model with 3 parameter exponential and immature M = 0.40.

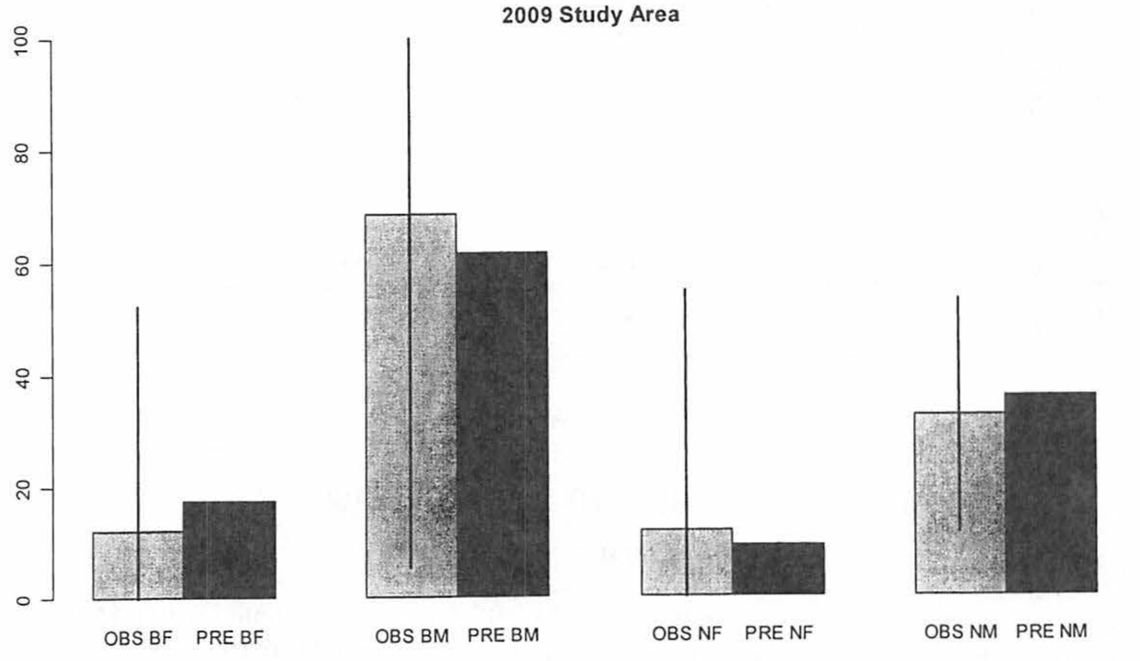


Figure 4. Fit to mature biomass data in the 2009 study area. Model with 3 parameter exponential and immature M = 0.40. BF = BSFRF, NF = NMFS, OBS = observed, PRE = predicted. Bars are +- 2 se.

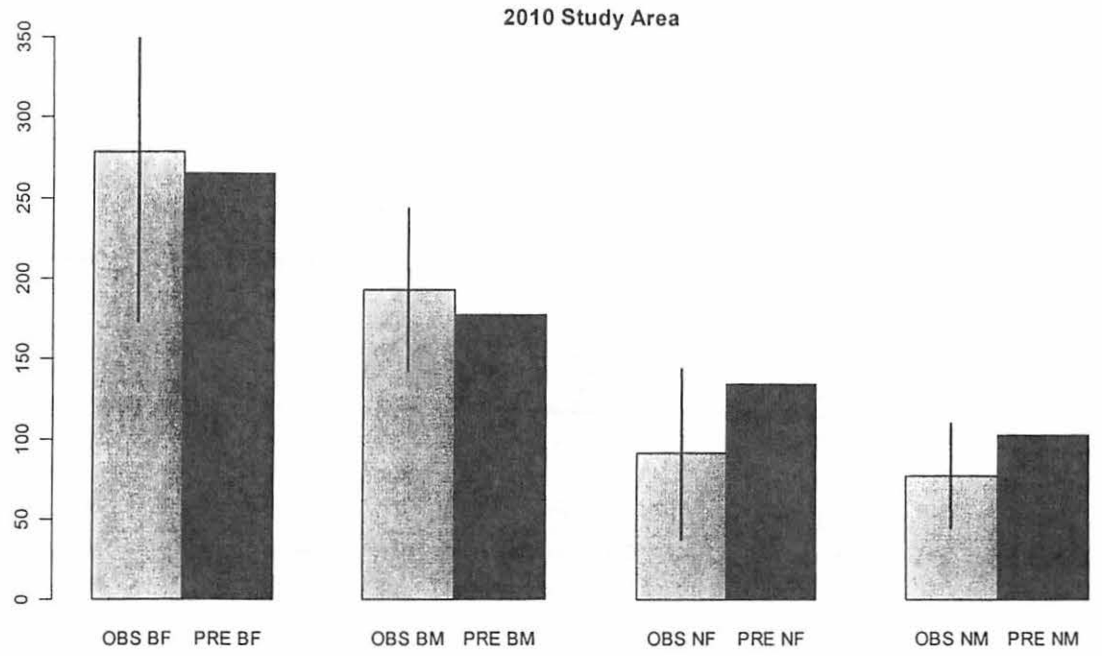


Figure 5. Fit to mature biomass data in the 2010 study area. Model with 3 parameter exponential and immature M = 0.40. BF = BSFRF female, NF = NMFS female, BM = BSFRF male, NM= NMFS male, OBS = observed, PRE = predicted. Bars are +- 2 se.

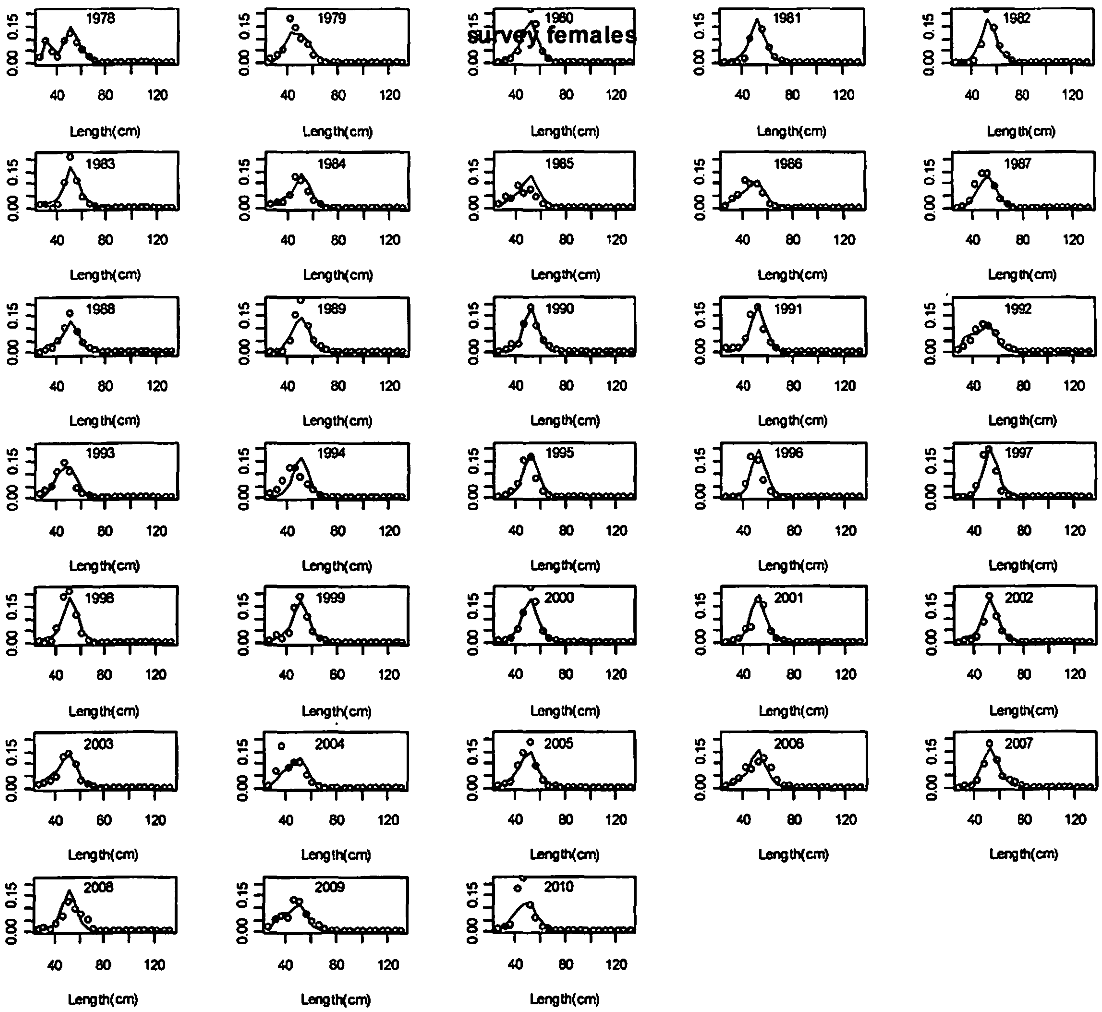


Figure 6. Fit to female survey length frequency. Model with 3 parameter exponential and immature M = 0.40.

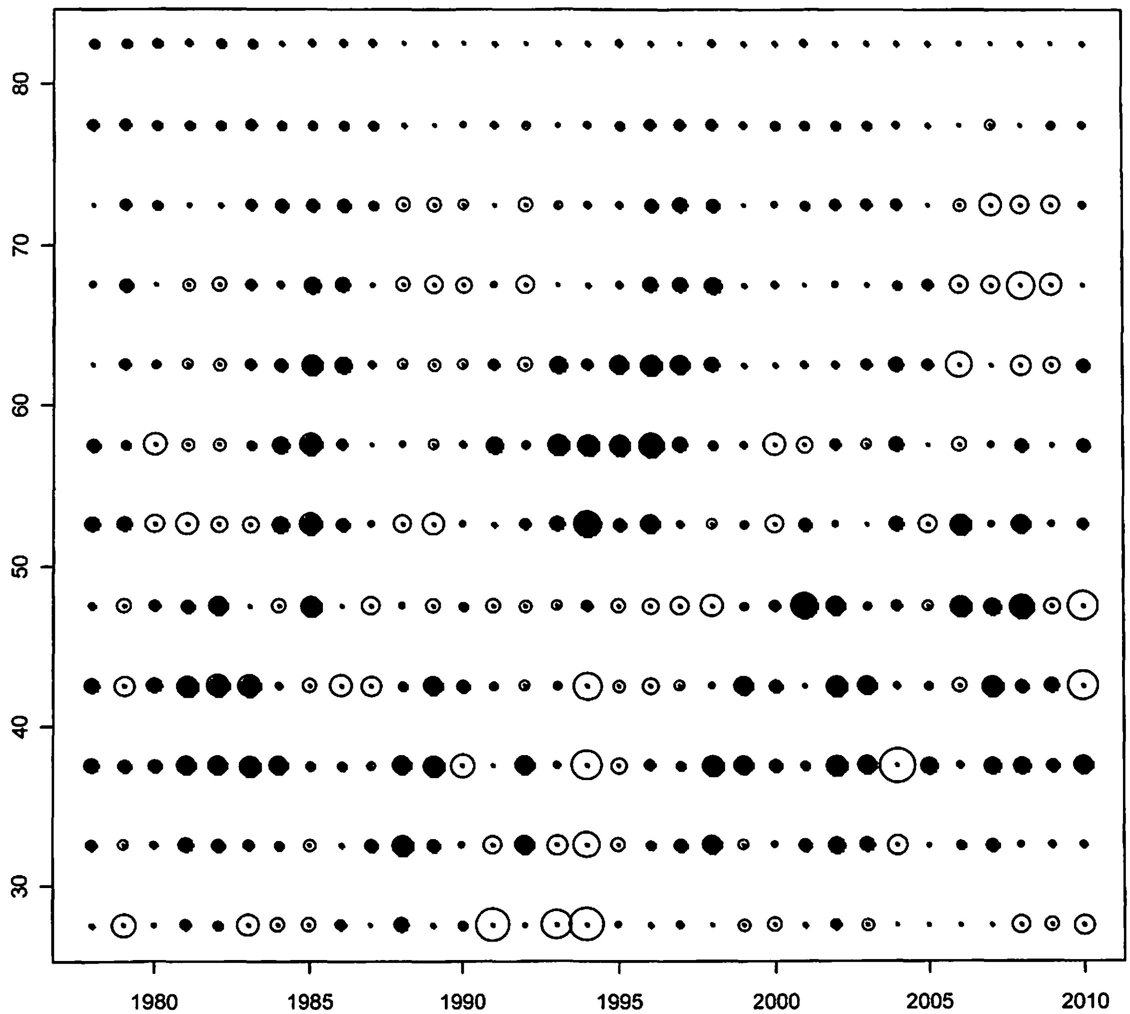


Figure 7. Residuals for fit to female survey length frequency. Model with 3 parameter exponential and immature M = 0.40.

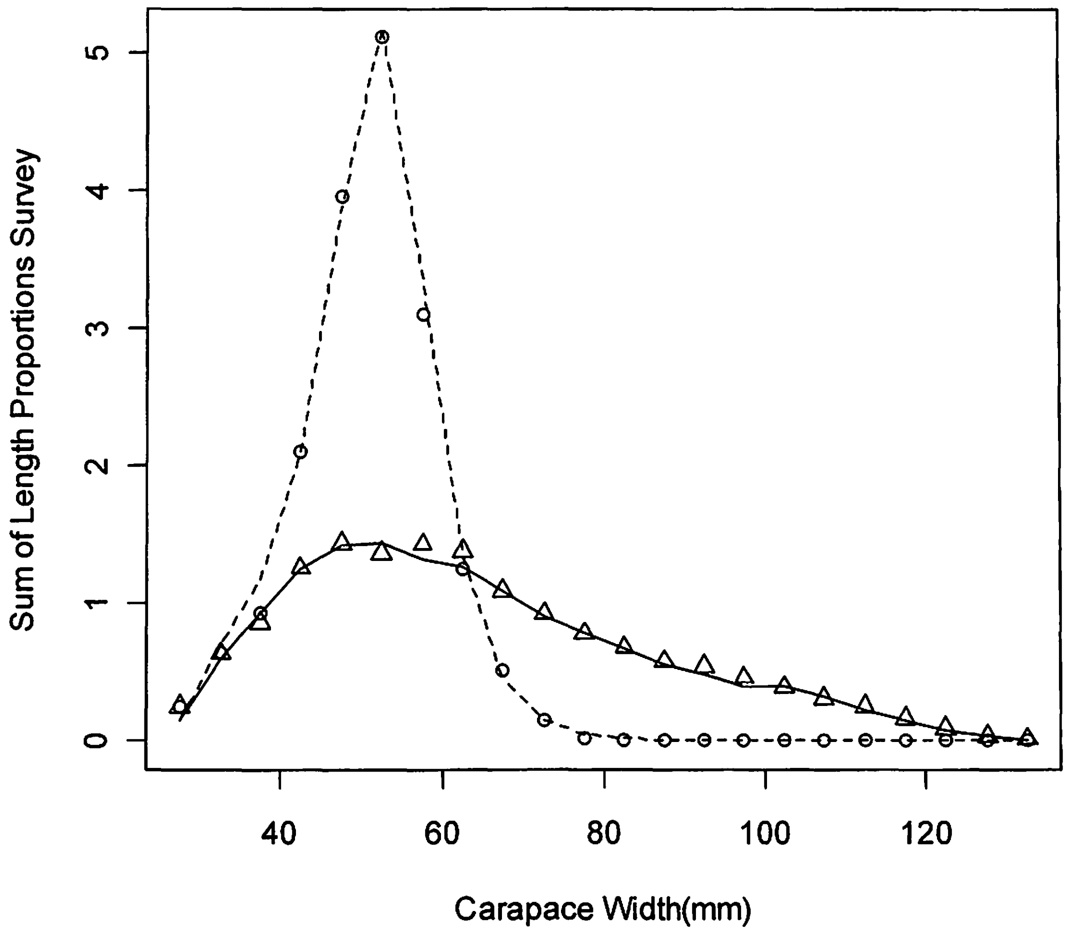


Figure 8. Summary of fit to female and male survey length frequency. Model with 3 parameter exponential and immature M = 0.40.

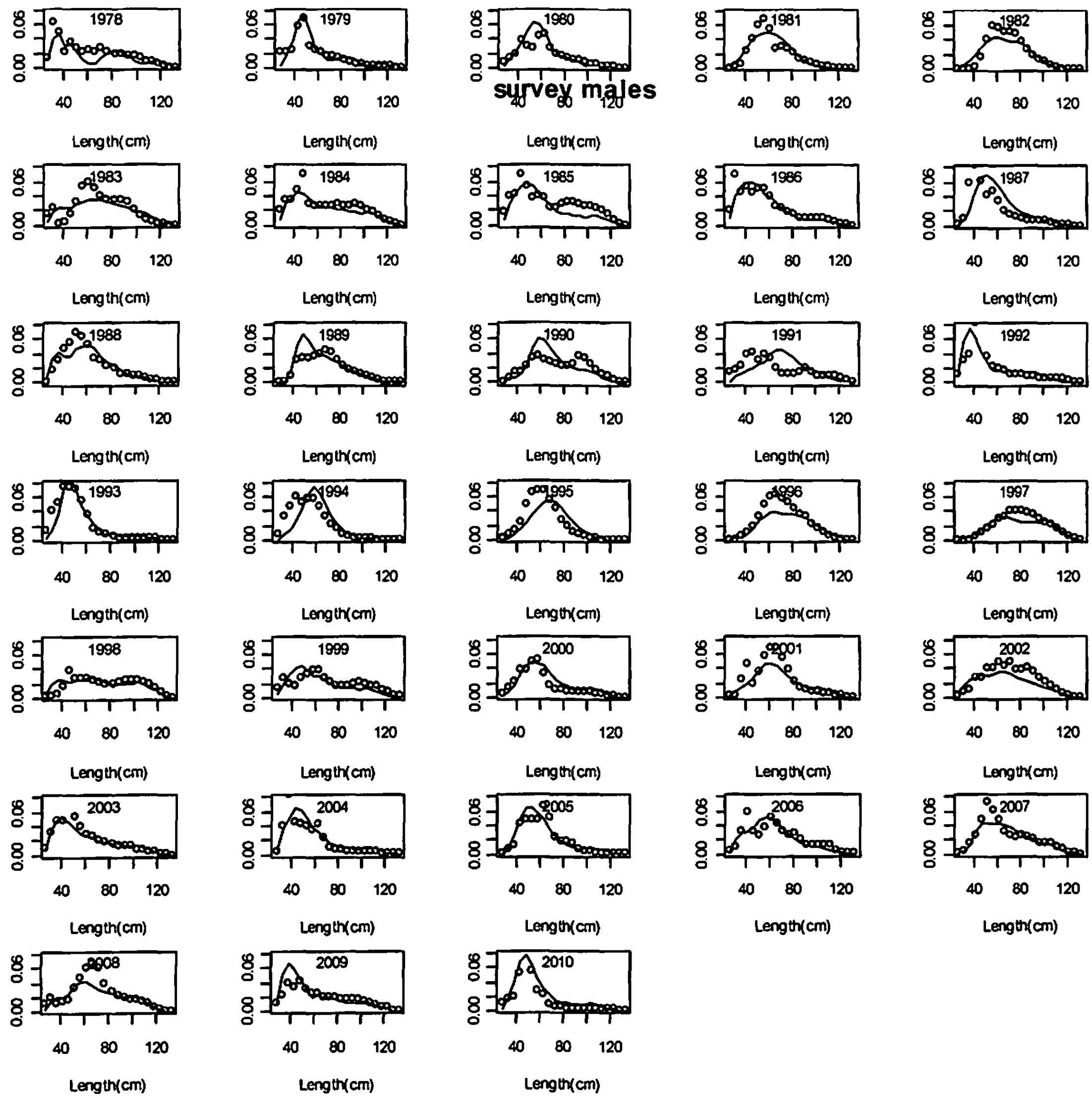


Figure 9. Fit to male survey length frequency. Model with 3 parameter exponential and immature M = 0.40.

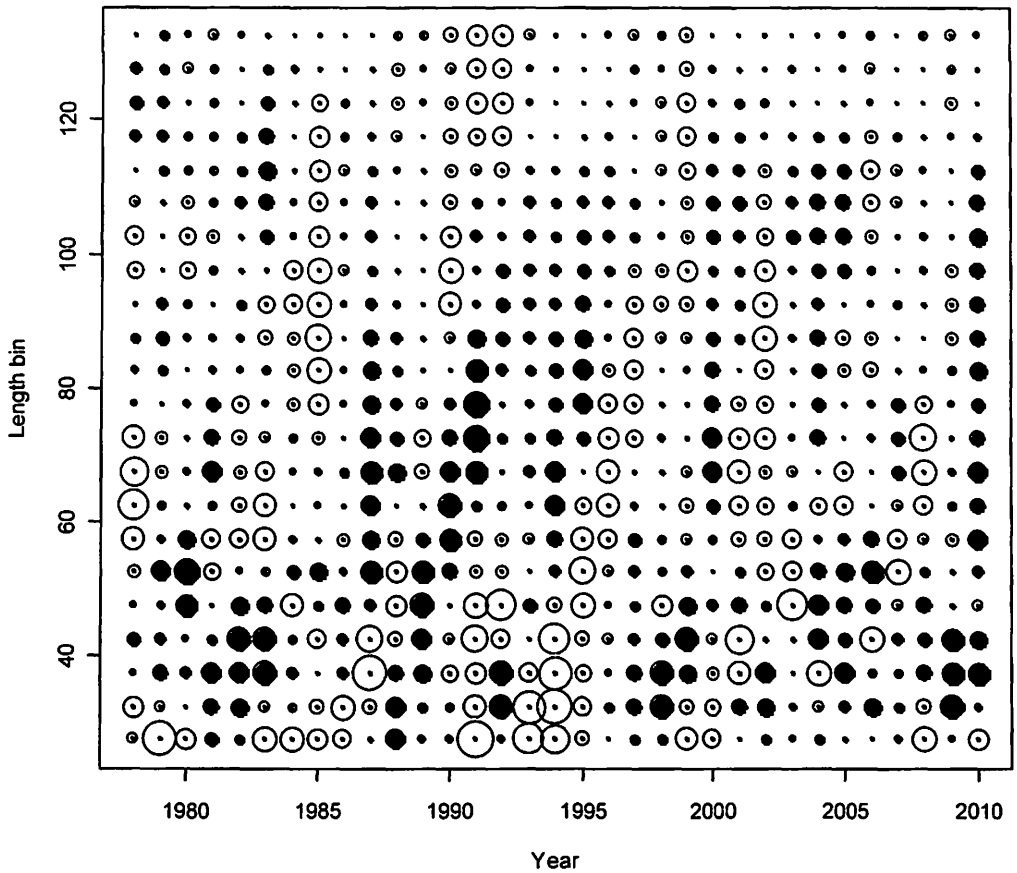


Figure 10. Residuals for fit to male length frequency. Model with 3 parameter exponential and immature M = 0.40.

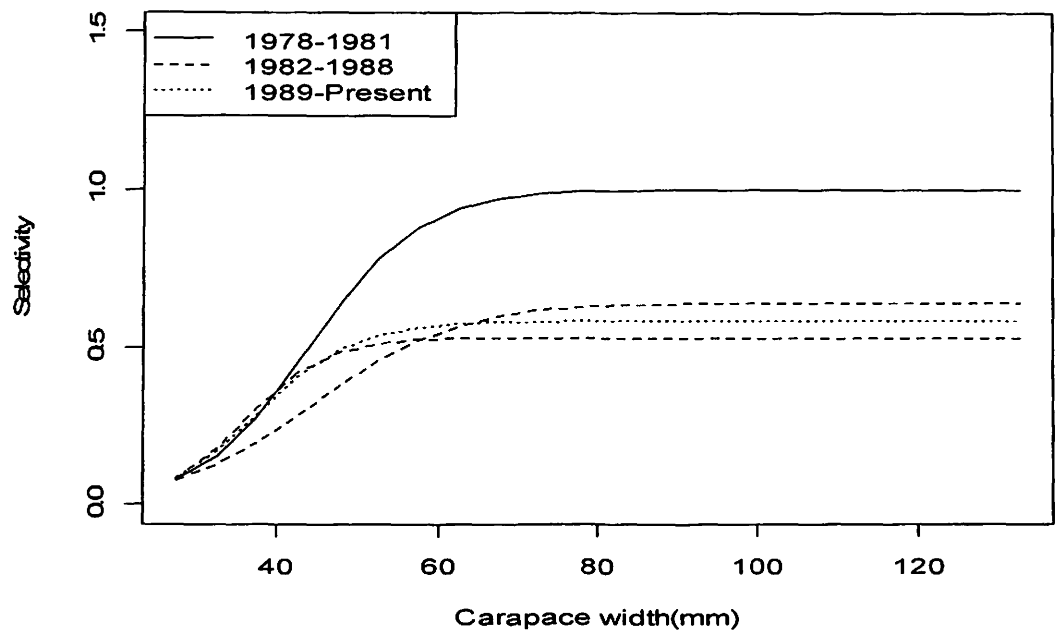


Figure 11. Survey male selectivity for three time periods. Lowest curve is female survey selectivity for 1989-present. Model with 3 parameter exponential and immature M = 0.40.

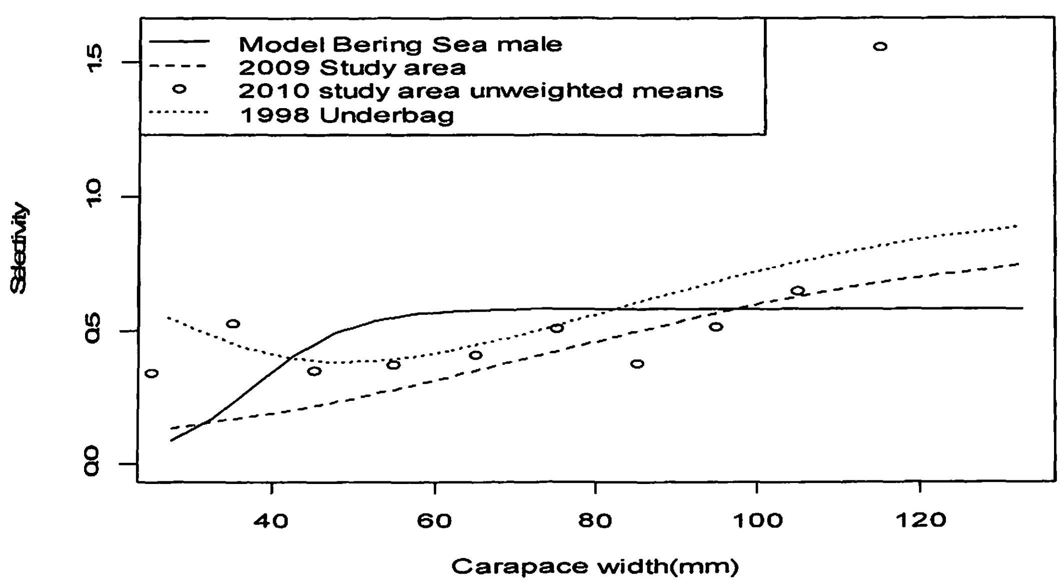


Figure12. Survey male selectivity for 1989-present (Model Bering Sea male), 2009 study area male selectivity estimated by Somerton, the 1998 underbag experiment selectivity and the unweighted mean values or male selectivity from the 2010 study area. Model with 3 parameter exponential and immature M = 0.40.

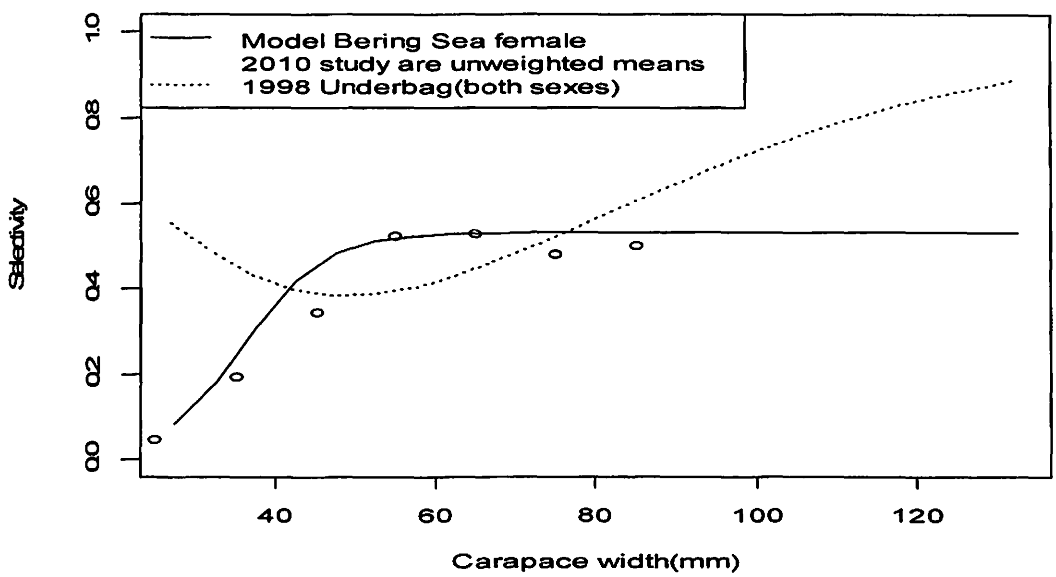


Figure13. Survey female selectivity for 1989-present (Model Bering Sea female), the 1998 underbag experiment selectivity and the unweighted mean values or female selectivity from the 2010 study area. Model with 3 parameter exponential and immature M = 0.40.

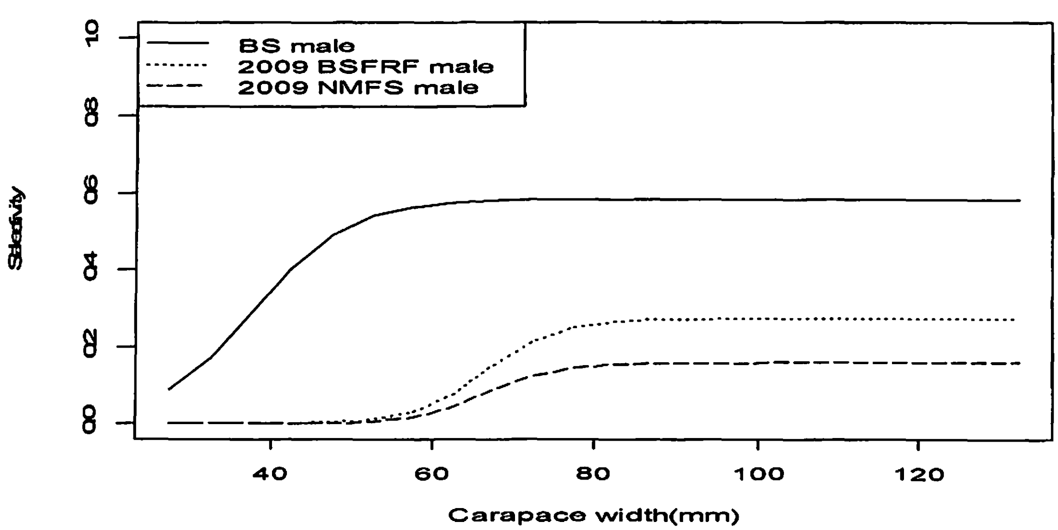


Figure14. Survey male selectivity for 1989-present (BS male), the availability curve for 2009 study area BSFRF male and the male selectivity curve for 2009 study area NMFS. Model with 3 parameter exponential and immature M = 0.40.

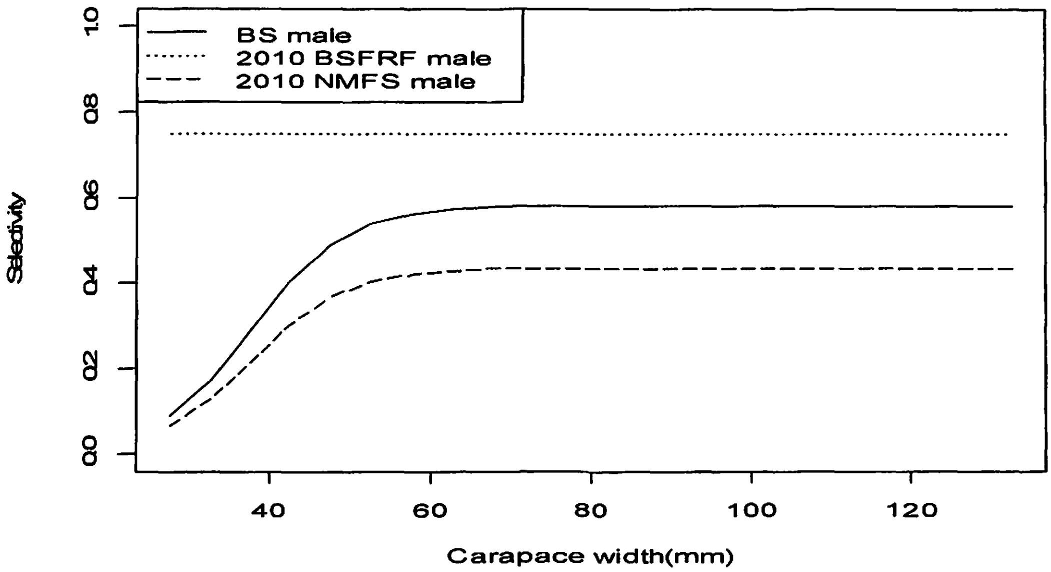


Figure15. Survey male selectivity for 1989-present (BS male), the availability curve for 2010 study area BSFRF male and the male selectivity curve for 2010 study area NMFS. Model with 3 parameter exponential and immature M = 0.40.

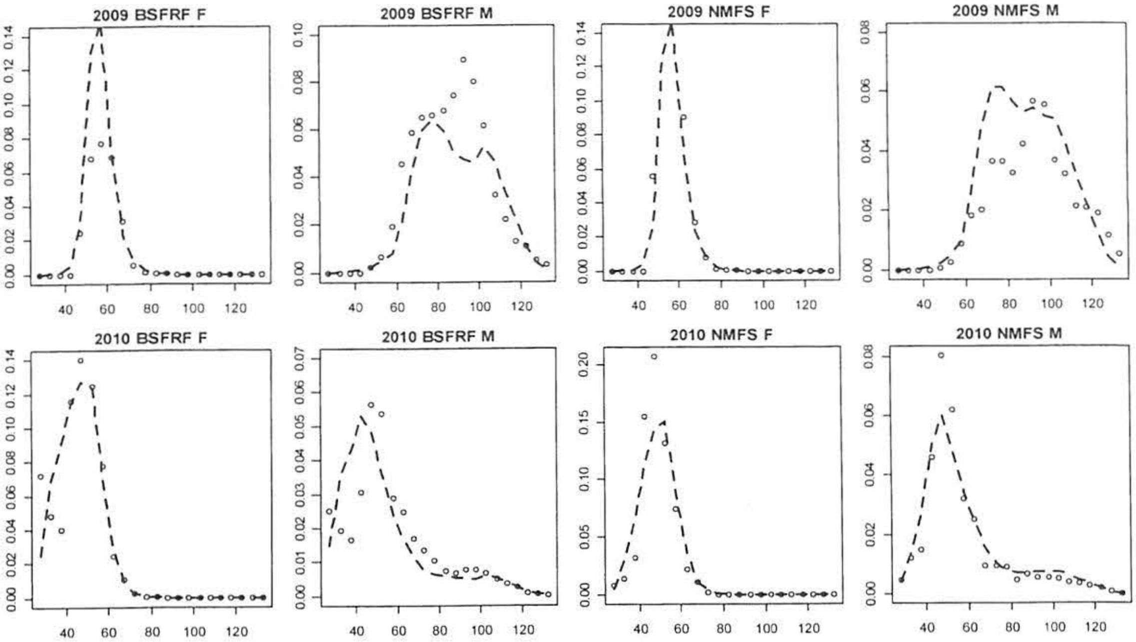


Figure16. Fit to length frequency data in the study areas for 2009 and 2010. Model with smooth survey selectivity function and immature M = 0.40.

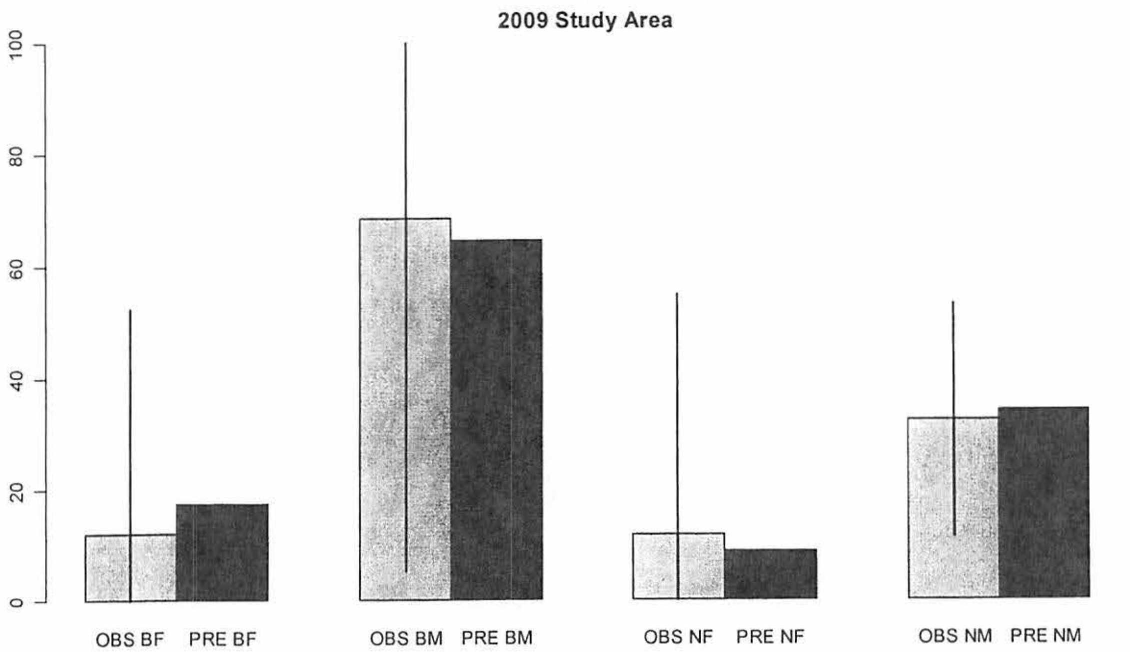


Figure17. Fit to mature biomass data in the 2009 study area. Model with smooth survey selectivity function and immature M = 0.40. BF = BSFRF, NF = NMFS, OBS = observed, PRE = predicted. Bars are +- 2 se.

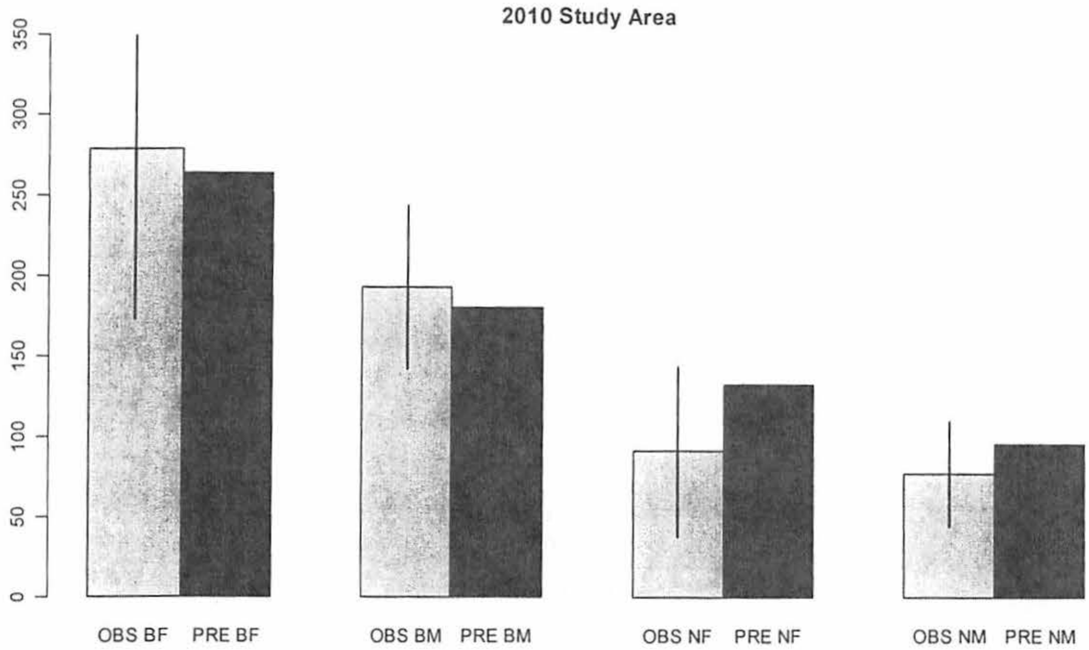


Figure18. Fit to mature biomass data in the 2010 study area. Model with smooth survey selectivity function and immature M = 0.40. BF = BSFRF, NF = NMFS, OBS = observed, PRE = predicted. Bars are +- 2 se.

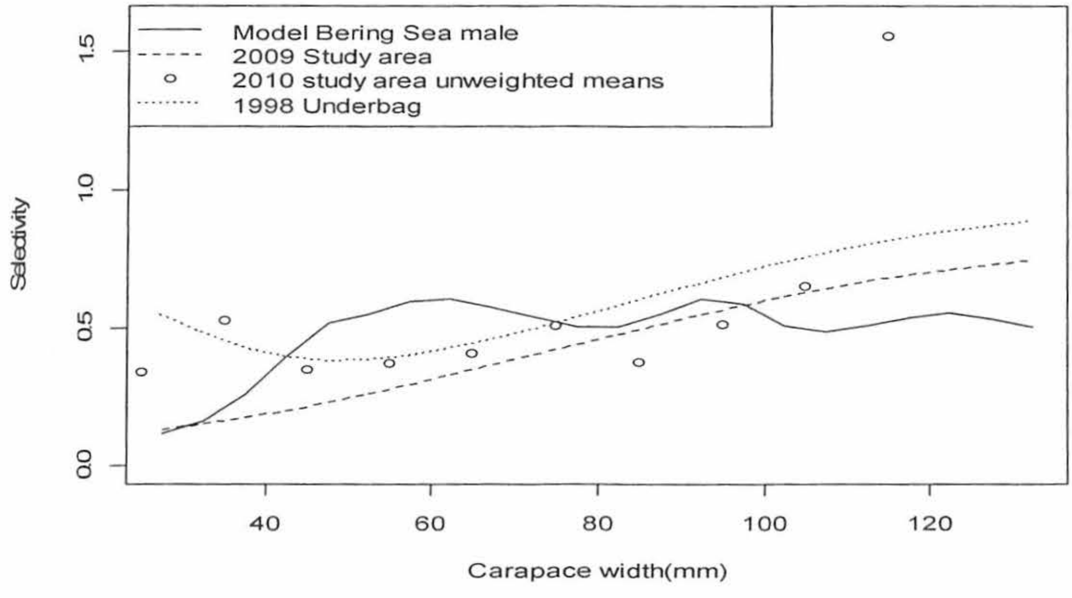


Figure19. . Survey male selectivity for 1989-present (Model Bering Sea male), 2009 study area male selectivity estimated by Somerton, the 1998 underbag experiment selectivity and the unweighted mean values or male selectivity from the 2010 study area. Model with smooth selectivity function immature M = 0.40.

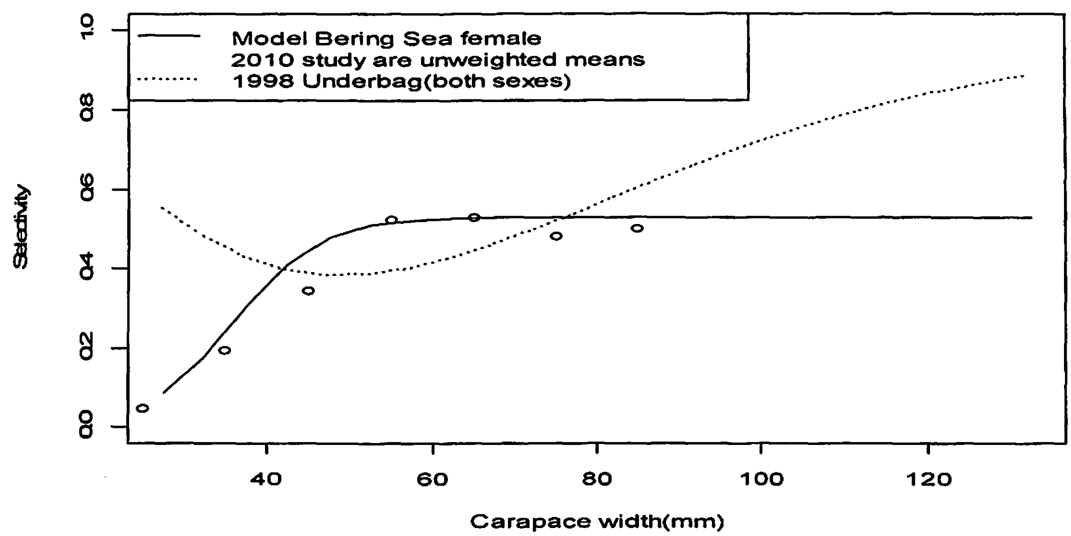


Figure 20. . Survey female selectivity for 1989-present (Model Bering Sea female), the 1998 underbag experiment selectivity and the unweighted mean values or female selectivity from the 2010 study area. Model with smooth selectivity function and immature M = 0.40.

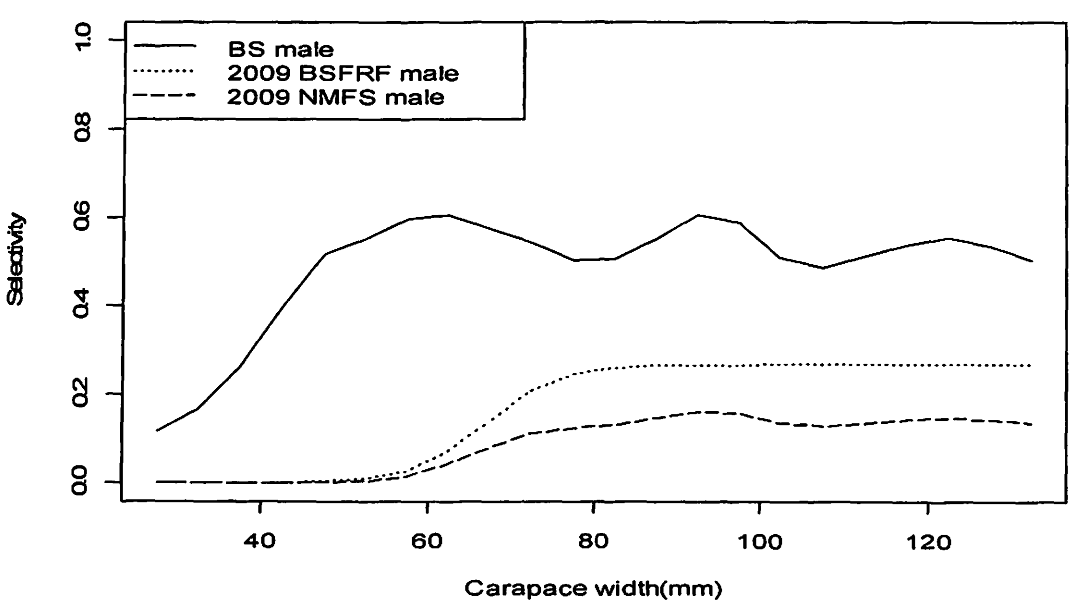


Figure 21. Survey male selectivity for 1989-present (BS male), the availability curve for 2009 study area BSFRF male and the male selectivity curve for 2009 study area NMFS. Model with smooth selectivity function and immature M = 0.40.

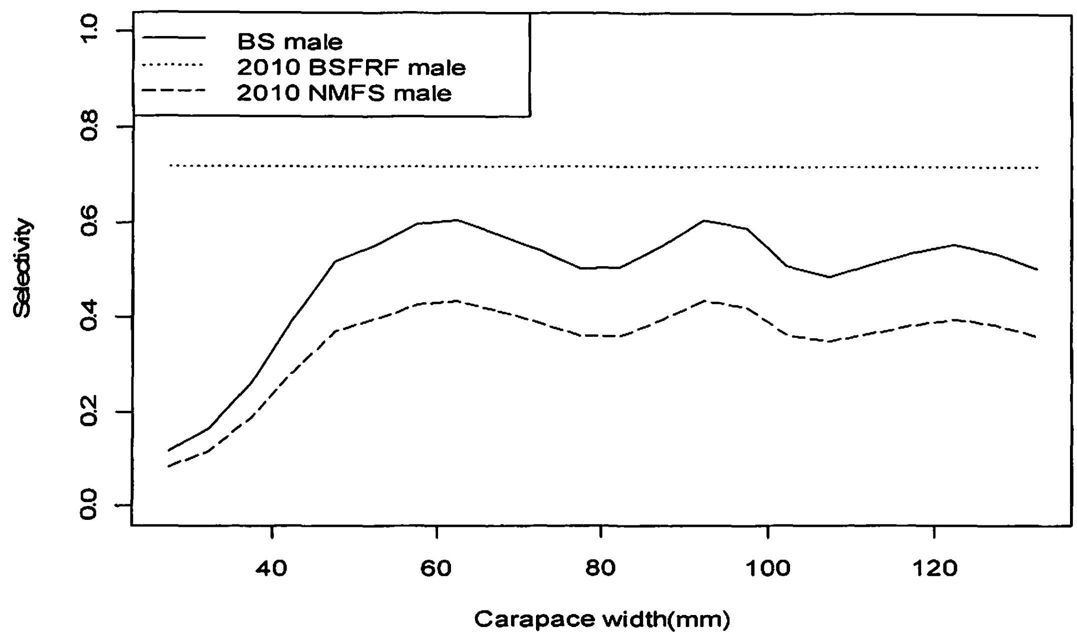


Figure 22. Survey male selectivity for 1989-present (BS male), the availability curve for 2010 study area BSFRF male and the male selectivity curve for 2010 study area NMFS. Model with smooth selectivity function and immature M = 0.40.