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Factors Affecting Sablefish Recruitment in Alaska

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Executive Summary

Amendments to the EFH FMP text of Alaska sablefish included suggestions for future consideration of small, unobtrusive research closures in areas of intense fishing. This prompted a Council request to provide information regarding all factors influencing sablefish recruitment. This document responds to that request in the form of a review paper on a variety of aspects revolving around sablefish recruitment. The first two sections include a general overview of sablefish early life history and issues surrounding the estimation of recruitment in the stock assessment model. We follow this with a three stage rationale for defining sablefish recruitment, summaries of available data for each stage, and an evaluation of factors influencing the three stages. The document concludes with a discussion section that introduces three current research projects, identifies data gaps and research priorities, and considers implications for conservation efforts. We believe it is premature at this juncture to recommend habitat conservation measures specifically for sablefish. However, we continue to suggest that research closures are one effective tool for understanding effects of fishing, and we recommend that any new conservation measures be designed within a multi-species context as an effort by management to seek a better understanding of changes to the ecosystem and EFH.

Introduction

In 2009, stock assessment authors were requested to review current FMP text regarding Essential Fish Habitat (EFH) for each species or species complex and report any updates or changes since the 2005 EFH Environmental Impact Statement (EIS). The Plan Teams reviewed changes to the FMP text and any author recommendations for EFH conservation or Habitat Areas of Particular Concern (HAPC). The Alaska sablefish authors submitted changes to the Gulf of Alaska (GOA) FMP text on EFH description for early juveniles, known predators on adults, shifts in fishery gear type, information on food habits, and references or literature cited. Since sablefish are considered one stock for Alaska, the Bering Sea and Aleutian Islands (BSAI) text was changed substantially to be consistent with the GOA text. The authors stated that little is known about the early juvenile stage distribution, habitat requirements, and interaction with other components of the ecosystem, but that juveniles have been known to reside in habitat subject to potentially adverse fishing effects (NMFS 2005). An evaluation of the effects of fishing on habitat in these areas along with the role of these features in the ecosystem was suggested. The authors further clarified that an analysis of the recovery rates for sensitive habitat features in areas of intense fishing (NMFS 2005) and the role of those features on the growth and survival of juvenile sablefish and other species would be very useful. The EFH summary concluded that areas of persistent and intense bottom trawling could be a concern. The authors suggested a potential future step for NMFS is to consider implementing small, unobtrusive research closures to determine whether EFH for sablefish and other species in these areas were adversely affected.

Following review of the EFH updates, the Plan Teams submitted similar recommendations as that of the sablefish authors to the Council and recommended these statements as high priority for the Council to consider. In April 2010, the Council discussed this agenda item and issued a request that NMFS prepare a discussion paper on all factors that may affect sablefish recruitment. The request was issued to allow for the Council to determine what type of management tools or research efforts may be available for protecting juvenile sablefish and the resulting conservation measure required. This document is the response to the Council request. We first present known information on sablefish early life history (ELH) and a review of issues involving estimating recruitment for this species. We then put forward a three stage rationale for estimating sablefish recruitment and include a synopsis of available ELH data for each stage. Following this, we evaluate the main ecological factors influencing the three stages. We conclude the document with a discussion that introduces three current research projects, identifies data gaps and research priorities, and considers implications for conservation efforts.

Early Life History

Sablefish (*Anoplopoma fimbria*) are a fast growing, highly valuable commercial groundfish species distributed across the North Pacific from northern Mexico to the Bering Sea (Wolotira et al. 1993). Two populations exist within this range based on differences in growth rate, size at maturity, and tagging studies (McDevitt 1990, Saunders et al. 1996, Kimura et al. 1998). The northern or Alaska sablefish are assessed as a single population in Federal waters off Alaska due to their propensity for large scale movements (Heifetz and Fujioka 1991). Sablefish in northern BC and inside waters of Alaska (e.g., PWS, Chatham Strait, Clarence Strait) are generally considered part of the Alaska population but are assessed separately. Adults in Alaska are typically encountered between 200-1000 m along the continental slope, shelf gullies, and deep fjords. Spawning takes place in depths between 300-500 m and occurs between January and May, with later spawning at higher latitudes (Mason et al. 1983, McFarlane and Nagata 1988, Sigler et al. 2001). Average spawning date for Alaska is estimated to be March 30 from otolith analysis (Sigler et al. 2001) and peak spawning was observed in February for southeast Alaska (Hanselman et al. 2009). The eggs are pelagic and thought to incubate for several weeks, increasing in density and sinking to depths between 400-1000 m (Kendall and Matarese 1987). After hatch, larvae begin feeding at depth and immediately swim toward the surface, developing as far offshore as 160 km in southeast Alaska (Wing 1997) to 240 km in the Aleutians (Kendall and Matarese 1987). Sablefish larvae (<35 mm) grow very quickly, from 1.2 up to 2 mm per day (Kendall and Matarese 1987, Sigler et al. 2001). When larvae are small, diet consists mostly of copepod nauplii and eggs. As larvae grow, diet shifts to mainly copepods and euphausiids, but may also include amphipods, pelagic tunicates, and pteropods (Yang and Nelson 2000).

There is no clear transition from larvae to young-of-the-year (YOY) juveniles. However, large, pigmented pectoral fins are a diagnostic feature of larvae as they grow and both stages appear to be obligate surface dwellers as they drift inshore (Kendall and Matarese 1987). Juvenile sablefish may also exhibit some thermal intolerance to very cold water. Laboratory studies on early juveniles in Oregon indicate avoidance of cold water except when food was present and a potential lethal risk for extended dives below the thermocline (Sogard and Olla 1998). In Alaska, samples of YOY sablefish are primarily collected near the continental shelf break in the central and eastern Gulf of Alaska (GOA) and have been caught in some years on the Bering Sea shelf (Grover and Olla 1990, Sigler et al. 2001). YOY sablefish (35-200 mm) mainly consume euphausiids, but also ingest pelagic tunicates, pteropods, and polychaetes (Sigler et al. 2001). Typically by the end of the summer YOY less than 200 mm reach nearshore bays where they spend the winter and following summer reaching 300-400 mm. At this time juveniles begin offshore movement to deeper water with younger fish (ages 3-4) inhabiting the continental shelf and older fish migrating to the slope habitat (Rutecki and Varosi 1997a). Juvenile sablefish (400-600 mm) are opportunistic feeders with fish (e.g. pollock, eulachon, herring), squid, jellyfish, and euphausiids comprising the majority of their diet (Yang and Nelson 2000). As they age, sablefish tend to move counterclockwise through the GOA reaching adult habitat within 4 to 5 years (Maloney and Sigler 2008, Rutecki and Varosi 1997a, Heifetz and Fujioka 1991). Sablefish, therefore, do not recruit to the fishery until they are around four years old.

Issues Estimating Recruitment

Often considered the fundamental driver of fluctuations in stock size, recruitment is generally defined as the abundance of the youngest fish entering a population that can be estimated successfully (Myers 1998, Maunder and Watters 2003). Developing a reliable estimate of recruitment has been a long standing problem for fisheries management. Variability in recruitment results from fluctuations in spawning stock size (i.e. egg production) and variability in egg-to-recruit survival. Factors influencing the egg to recruit survival may include natural or anthropogenic changes in the physical environment, shifts in populations of prey, and changes in competition and/or predation. The difficulty in estimating recruitment is in understanding the underlying processes that influence recruitment and then estimating the most recent years of recruitment where there is a dearth of information.

The Alaska sablefish assessment model incorporates a variety of survey and fishery information (e.g. biomass indices, catch, age and length compositions) in a maximum likelihood framework to simultaneously estimate spawning biomass, recruitment, fishing mortality, and a projection of future harvests. Recruitment is not modeled with a stock-recruitment relationship; rather it is computed as mean recruitment and annual recruitment deviations. Recruits are estimated as 2-year-old fish because very little information is available in the age/length compositions for age-0 to age-1 fish. Annual estimated recruitment is extremely episodic and appears unrelated to spawning biomass over the range of observed abundances (Hanselman et al. 2009).

Recruitment estimates based on information from the 1960s are extremely uncertain as they are based only on limited fishery catch rate data. Additionally, estimates of the most recent years of recruitment are highly uncertain since there is no catch-at-age data available for the most recent years. Therefore, recent recruitment estimates are not used in projections. Average recruitment is reported as 18.0 million 2-year-old sablefish per year based on estimates from 1979-2007 (Hanselman et al. 2009). Estimates of annual recruitment vary widely but large year classes can be clearly tracked in the survey and fishery age composition data. The top 25% of recruitment values are considered strong year classes and occurred in the early 1960s, 1971, 1977-1978, early 1980s, 1989, 1991, 1997, and 2000 (Hanselman et al. 2009). Additionally, the extremely large 1977-78 and 1980-81 year classes occurred when sablefish biomass was near historic lows. More recently, the 1997 and 2000 larger than average year classes were also produced when the population was at a recent low. Conversely, weak or average year classes have been produced when the sablefish population was at historic highs. This information suggests that sablefish recruitment may be highly influenced by environmental conditions.

Several of these successful recruitment years for sablefish coincide with strong year classes for many northeast Pacific groundfish stocks (Hollowed and Wooster 1992). The high survival synchrony in 1977 has been attributed to a major regime shift in the north Pacific and associated with a phase change in the Pacific Decadal Oscillation (PDO) to warmer conditions (Hare and Mantua 2000). Other potential climate-recruit relationships have been suggested for the Alaska sablefish such as water mass movements and temperature changes. Above-average recruitment was somewhat more likely with northerly winter currents and much less likely for years when the drift was southerly (Sigler et al. 2001). One study on the west coast sablefish population showed significant relationships between Ekman transport and sea-level height with sablefish recruitment (Schirripa and Colbert 2006).

Stages of Recruitment

Typically, the two primary factors affecting recruitment are the level of adult spawning and the ecological processes influencing egg to recruit survival. As discussed previously, the level of adult spawners seems to be a secondary factor. Fishing on pre-recruits may also affect survival to the adult stage. Sablefish have been targeted since the 19^{th} century, but were not heavily exploited until the directed Japanese longline fishery began in the 1960s. Heavy fishing in the 1970s lead to a large decrease in the population and strict fishery regulations in Alaska were imposed to sharply reduce catches since this time (Hanselman et al.

2009). Large fluctuations in recruitment and stock size have occurred in spite of precautionary fishing levels since the 1980s. Given the highly variable recruitment during levels of high/low spawning biomass and fishing, it seems likely that sablefish recruitment is primarily driven by ecosystem process. We therefore rationalize that a critical window for sablefish survival is bound by the egg/larval development in the offshore pelagic zone through nearshore settlement and subsequent juvenile migration to the adult slope habitat approximately four years later.

We partition this early life history (ELH) into three distinct sequential steps or stages (Figure 1). Each successive stage mediates the output from the previous stage with the net output of all three stages resulting in recruitment to the adult population on the continental slope and deep gullies. We have provided a brief overview of sablefish ELH and draw upon this general information to define each stage. Egg, larval, and early juveniles in the pelagic oceanic offshore ecosystem define stage I. Juveniles from their first late summer to their second winter settling in nearshore waters define stage II. Early recruit two-year-olds to four-year-olds on the continental shelf and shallow gullies prior to migrating to the adult habitat define stage III. Stage I probably has the highest annual variability in survival due to highly complex interactions in the pelagic open ocean environment. Stages II and III likely have small annual variation within locale but may have long-term temporal or spatial trends due to changes in the benthic habitat or density dependent effects. In the following three sections, we list potential factors influencing survival in each stage and any available ELH data for sablefish.

Stage I: Pelagic Offshore to Nearshore

This first stage is spatially bound by egg and larval development in the offshore pelagic zone to early juvenile settlement in the nearshore zone. Timing of this stage occurs from late winter, early spring through late summer, early fall of the first year. Survival during this period is dependent on factors related to transport, productivity, and predation from the offshore to the nearshore. Larvae and early juvenile sablefish have protective coloration or countershading (dark on dorsal surface, light on ventral surface) which may aid in predator avoidance (Kendall and Matarese 1987). However, the rapid growth requirements and high consumption rates of larval and YOY sablefish result in a strong dependence on encounter of highly productive environments. Growth rate of young-of-the-year sablefish is higher in years when recruitment is above average (Sigler et al. 2001). Food shortage and adverse drift may be a significant source of mortality for this stage. (Kendall and Matarese1987).

Previous surveys have been successful in capturing egg, larvae, and YOY sablefish; however, sampling has been periodic and gear types differed between surveys. The Recruitment Processes Program at the Alaska Fisheries Science Center (AFSC) has successfully sampled eggs, larvae, and YOY sablefish from the Bering Sea through the central and western GOA since the early 1970s. Sampling primarily occurred during April and May and included bongo nets and Tucker trawls for vertical tows and neuston nets for surface tows (Matarese et al. 2003). The U.S. Global Ocean Ecosystem Dynamics (GLOBEC) program performed surface trawls along transects at various locations in the GOA from Yakutat to southwest Kodiak Island. YOY sablefish were captured during summer from 1999 through 2003 (J. Moss, pers. comm.). The Southeast Alaska Coastal Monitoring (SECM) program at the AFSC has conducted surface trawling at four coastal stations off Icy Point in southeast Alaska (7 to 65 km offshore) from spring to fall during 1997-1999. YOY sablefish were captured at various years, sometimes in large quantities such as in summer 1997 (Orsi et al. 2000). A survey was conducted by scientists at the AFSC in May 1990 to investigate sablefish and associated ichthyoplankton distribution in the eastern GOA. Neuston, bongo, and CTD (conductivity, temperature, depth) sampling occurred on stations along transects extending as far as 160 km offshore. Larval sablefish were caught at most stations (except nearshore) with a potential three-fold increase during night-time sampling (Wing 1995). As part of a voluntary logbook program in southeastern Alaska, commercial salmon trollers identified prey in stomachs of chinook and coho salmon from 1977-1991 along the outer coast of Alaska from Dixon Entrance to Yakutat. Sablefish YOY were common prey during September (Wing 1985). The Marine Ecology and Stock Assessment (MESA) program at the AFSC conducted nighttime sets using a variable-mesh gillnet during the annual AFSC sablefish longline survey from 1995-2004. Large numbers of YOY sablefish were captured from 1995 through 1998 generally in the eastern GOA. Numbers declined substantially from 1999 to 2004 when the gillnet survey ended.

Stage II: Nearshore Settlement

Timing and location of settlement is largely unknown for sablefish and likely includes a range of depths and benthic habitats. Generally, settlement is thought to be before the first overwinter period, although sablefish perform vertical migrations throughout their nearshore existence (Sogard and Olla 2001). Opportunistic surveys performed in nearshore bays and inlets throughout southeast Alaska suggests that YOY sablefish occur consistently in only a few locations. However, during years of high recruitment YOY sablefish were found throughout the area (Rutecki and Varosi 1997b). This suggests that YOY sablefish may utilize a variety of benthic habitats in the nearshore, but specific features of a few locations may be unique and critical to maintain a base level of recruitment. When they were encountered, YOY juveniles were collected using many different gear types at a variety of depths and times of year (Rutecki and Varosi 1997b). Therefore, ecological processes occurring in both the pelagic and benthic habitats of shallow nearshore coastal bays may influence survival for this stage. Upon arrival in the nearshore in late summer, early fall, YOY sablefish must acquire prey, compete with other species, avoid predation, and settle to suitable benthic habitat in order to recruit successfully to the next stage. Juveniles overwinter in the nearshore for one to three years before they begin offshore movement (Rutecki and Varosi 1997a). Accounts of widespread, abundant age-1 juveniles likely indicate a strong year class and have been reported for the 1960 (J. Fujioka & H. Zenger, pers. comm.), 1977 (Bracken 1983), 1980, 1984, and 1998 year classes in southeast Alaska, the 1997 and 1998 year classes in Prince William Sound (W. Bechtol, pers. comm.), and the 1998 year class near Kodiak Island (D. Jackson, ADFG, pers. comm.).

A few consistent surveys in central and eastern GOA have successfully sampled YOY to age-1+ juvenile sablefish during the nearshore settlement stage. Small mesh trawl surveys for shrimp and forage fish around Kodiak Island have been conducted by the AFSC and the Alaska Department of Fish and Game (ADFG) since 1953. Catch is dominated by shrimp, Pacific cod, pollock, and flatfish. A shorter time series of rockfishes and sablefish are available (Anderson and Piatt 1999). The SECM program at the AFSC has conducted surface trawling at nine stations sampling inshore, strait, and coastal habitats in the northern region of southeast Alaska from June to September 1997-present. Relatively large numbers of age-1+ sablefish were caught in the strait habitat in 1999 (between Chatham and Icy Strait) co-occurring with juvenile salmon which were the primary prey item for the juvenile sablefish. During years of high recruitment, sablefish in Stage II may be a significant predator of juvenile salmon during their offshore migration (Sturdevant et al. 2009). The MESA program at the AFSC performed opportunistic surveys in southeast Alaska from 1985 to present to sample and tag age-1+ sablefish in nearshore bays. One location, St. John Baptist Bay (SJBB) consistently produces large amounts of age-1+ sablefish. Limited oceanographic sampling and diet analysis on age-1+ sablefish was conducted in SJBB during various years. However, analysis of this data was not unique when compared to nearby bays (Rutecki and Varosi 1997b). Persistent oceanographic events offshore combined with bathymetric steering may contribute to the uniqueness of SJBB. Additionally, 726 electronic archival tags have been implanted and released in YOY sablefish since 2003. Five of these archival tags were recovered in the commercial fishery since 2008 (D. Hanselman pers. comm.).

Another potential source of information for this stage is data that may be used to define habitat suitability for stage II sablefish. Benthic habitat data exists at varying resolutions from detailed bottom mapping and actual bottom observations (e.g. Shotwell et al. 2008) to general low resolution bathymetry and regional sediment distribution paper maps (e.g. Carlson et al. 1977). Three main types of bathymetric data exist in the GOA and BSAI: low resolution remotely sensed data of broad regional extent, high-resolution multibeam bathymetry of limited areal extent, and National Ocean Service (NOS) point data of variable resolution. Scientists at the AFSC are currently constructing a highly detailed bathymetric map of the GOA seafloor so that seafloor measures (e.g. topographic roughness) can be analyzed (M. Zimmermann

AFSC pers. comm.). Since 2000, the US Geological Survey (USGS) and its collaborators have compiled seabed data from existing reports and datasets into usSEABED, which is a nation-wide integrated seafloor characterization database (Reid et al. 2006). Preliminary analysis of these data in central GOA shows muddy sediment in bathymetric lows such as Shelikof Strait with coarser sediment (to gravel) on bathymetric highs such as Albatross Bank. These data may be used to create continuous gridded surfaces of sediment and rock distributions. In combination, the highly detailed bathymetry with sediment distribution grids could provide regional contextual three-dimensional observations of sediment distributions in the GOA and BSAI. This information could provide an informative, scalable, basis for developing stage II juvenile sablefish habitat suitability models.

Stage III: Pre-recruit Migration to Adult Habitat

Juvenile sablefish begin offshore movement following their second summer and are found in varying concentrations on the continental shelf as sub-adults before recruiting to adult habitat on the slope and deep gullies. Length samples from the AFSC bottom trawl survey suggest that the spatial range of juvenile sablefish on the shelf varies dramatically from year to year. In particular, juveniles utilize the Bering Sea shelf extensively in some years, while not at all in others (S.K. Shotwell, unpublished report). On the continental shelf, juvenile sablefish share residence with a large variety of piscivorous groundfish in the GOA. Euphausiids are a common prey item for many juvenile groundfish species and density dependent effects on the continental shelf habitat may increase competition for this resource. Additionally, spatial overlap with adult groundfish may cause increased predation on juvenile sablefish (Yang et al. 2006). Survival through this final stage may largely depend on the density of other groundfish species throughout the continental shelf and their influence on the level of competition with and predation on pre-recruit sablefish.

A variety of surveys sample pre-recruit juveniles after settlement on their return to adult habitat. We define pre-recruits as individuals 45 cm or less because this is the average size of two-years-olds which are rarely seen in fisheries. The AFSC biennial trawl survey has captured pre-recruit juvenile sablefish in the GOA, Aleutian Islands and Bering Sea from 1984 through present. This survey has the most extensive coverage over the range of potential juvenile sablefish distribution. The domestic AFSC sablefish longline survey has conducted annual surveys in the GOA since 1987 and biennial surveys in the Aleutian Islands and Bering Sea since 1996 and 1997, respectively (Rutecki et al. 1987, Hanselman et al. 2009). This survey, which likely provides an accurate index of adult sablefish abundance, includes a set of 27 gully stations throughout the central and eastern GOA. Catches in the gully stations typically consist of smaller fish than nearby slope stations. Data from these stations are thought to be potential indicators of recruitment signals since the stations are typically at shallower depths and sample smaller fish. Results from a preliminary analysis of gully station catch rates suggests that gullies may show recruitment signals and strength earlier and better then slope stations (Hanselman et al. 2009). The International Pacific Halibut Commission (IPHC) performs a halibut longline survey each year utilizing a systematic grid to consistently sample the continental shelf from 1-500 m (Soderlund et al. 2009). The survey catches substantial amounts of sablefish which are likely smaller and younger than those caught on the AFSC sablefish longline survey which samples from 200 to 1000 m. However, only sablefish catch in numbers is available from this survey (Hanselman et al. 2009).

Potential Factors Affecting Recruitment

We have defined a critical window for sablefish survival bounded by the aforementioned three stages. Successful recruitment likely depends on several linked ecological processes influencing transport to the nearshore, prey availability, competition with other species, and predator avoidance. In addition to ecological effects, fishing activities represents another factor which may influence recruitment of sablefish throughout these stages. These processes control the quantity and condition of pre-recruit sablefish as they enter each stage. While the level of success at the end of stage I may determine the maximum potential for each year class, subsequent survival during stages II and III likely modulate that potential causing additional limits to survival. In the next four sections, we define the potential factors influencing sablefish recruitment at each stage through the main concepts of the environment, competition, predation, and fishing.

Environment

The physical structure, transport processes, and biology of the Northeast Pacific Ocean respond strongly to forcing at several time and space scales that can result in large interannual changes for both offshore and coastal regions (Batcheldor 2002). Cross-shelf and along-shore transport are influenced by several physical mechanisms including mesoscale eddies, episodic upwelling, freshwater runoff, tidal mixing, and complex bottom topography (Weingartner et al. 2002, 2005, Ladd et al. 2005, Bailey et al. 2008). Some of these mesoscale features (e.g. large fronts or anticyclonic eddies) persist for several years in the GOA and Aleutian Islands, traveling hundreds of kilometers and transporting heat and nutrients from the formation region (Belkin et al. 2002, Ladd et al. 2007).These physical properties additionally impact the stability of the water column influencing the timing and size of spring phytoplankton blooms. Secondary producers such as zooplankton and euphausiids respond to these seasonal and interannual fluctuations in prevailing oceanographic conditions and the primary producers (Coyle and Pinchuk 2005, Conners and Guttormsen 2005). Each of these factors may have compounding affects on the abundance, distribution, and condition of egg, larval, and YOY sablefish during the first recruitment stage. Since larval and YOY sablefish feed almost primarily on copepods and euphausiids (Grover and Olla 1990, Sigler et al. 2001), this stage may be particularly dependent on the fluctuations in the food web dynamics. Anomalous meanders and fluctuating intensities of mesoscale features directly impact the transport of YOY sablefish to the nearshore environment (Okkonen et al. 2003, Ladd et al. 2005).

Competition

Juvenile sablefish during stage I and II are typically less than 40 cm and have a relatively narrow diet consisting of copepods and euphausiids. As they grow and enter stage III they begin to feed more opportunistically (Yang and Nelson 2000) on fish, squid, jellyfish, and euphausiids. Diets in stage I and II overlap with several other species of juvenile groundfish and forage fish such as arrowtooth flounder (*Atheresthes stomias*), pollock (*Theragra chalcogramma*), Pacific ocean perch (*Sebastes alutus*), herring (*Clupea pallasii*), and capelin (*Mallotus villosus*). As sablefish juveniles approach the nearshore environment and space becomes limiting, the potential for interaction between sablefish and these other species increases. This can lead to increased competition for resources. During stage III, juvenile sablefish also share residence with many other groundfish species on the continental shelf. Diet of sablefish at this stage is known to overlap with arrowtooth flounder (Yang and Nelson 2000). Abundance of arrowtooth flounder has increased four-fold from 1976 to the present (Wilderbuer et al. 2009, Turnock and Wilderbuer 2009). Sharing a trophic level with such an abundant stock indicates potential for competitive effects on sablefish recruitment (Hanselman et al. 2009).

Predation

There are few reports of sablefish egg and larval predation. Generally samples of sablefish YOY are rare and few are captured at one time suggesting that predators are not keying in on stage I as a primary source of food (Kendall and Matarese 1987). However, YOY juveniles entering the nearshore environment are commonly reported in adult coho (*Oncorhynchus kisutch*) and chinook (*O. tshawytscha*) salmon stomachs in southeast Alaska. Juvenile sablefish were the fourth most commonly reported prey species in the salmon troll logbook program from 1977 to 1984 (Wing 1985). However the effect of salmon predation on sablefish survival during stage II is unknown. Although juvenile sablefish may not be a prominent prey item because of their relatively low and sporadic abundance compared to other prey items, during stage III they share residence with the main piscivorous groundfishes in the Gulf of Alaska (Yang et al. 2006). An additional source of predation may be piscivorous seabirds with an estimated 7.2 million breeding pairs in the GOA (Stephensen and Irons 2003). A recent paper from Thayer et al. 2008 discusses the diets of piscivorous seabirds at two major colonies in the GOA. Sablefish and rockfish are included in the top species of prey for juvenile predatory fishes in the GOA. Predation from piscivorous fish and seabirds during stage II and III may be an important influence on sablefish recruitment.

Fishing

Direct effects such as removals and indirect effects such as habitat degradation are the most likely influence of fishing activities on juvenile sablefish. These activities should only impact sablefish in stages II and III. Little is known about the distribution or the habitat requirements of stage II sablefish in the nearshore. Only a few surveys (such as SJBB) consistently sample sablefish during this stage and other reports are sparse and generally anecdotal. Preliminary analysis of AFSC bottom trawl survey data suggests the range of distribution of Stage III sablefish varies dramatically from year to year across the continental shelf. Furthermore, juveniles utilize specific areas such as the Bering Sea extensively in some years while not at all in others (Hanselman et al. 2009).

It is difficult to discern the direct or indirect effects that fishing activities may have on these stages due to the sparse and inconsistent nature of available data. However, direct effects by fisheries are likely limited in Stage II as nearshore areas are not heavily impacted by fishing activities. Stage III sablefish discards in other fisheries are relatively low and have decreased in recent years (Hanselman et al. 2009). These low discard rates correspond to years of poor recruitment which suggests that incidental bycatch mortality is unlikely to be a direct contributor to sablefish recruitment failure. Furthermore, the majority of sablefish discards are adults and not the pre-recruit stages discussed here. Since little is known about juvenile sablefish habitat requirements, indirect effects from fishing on benthic substrates are unknown and probably confounded by influences of competition and predation. Yet, the widespread occurrence of juvenile sablefish on the continental shelf suggests that these fish interact or are indirectly impacted by multiple gear types and fisheries occurring in these waters. Unfortunately, given the available data, any hypothesis of a substantial effect of these impacts can be neither proven nor disproven.

Discussion

Throughout this document we present the known information on sablefish early life history (ELH) and put forth a rationale for a three stage approach to describing sablefish recruitment. Included in this review are the available sources of sablefish ELH data. We discuss potential factors affecting recruitment during these three stages that manifest in the ecological processes of the biophysical environment, competition, and predation along with anthropogenic effects caused by fishing. A logical next step is to combine the sources of sablefish ELH data with hypotheses on mechanisms for influencing sablefish recruitment. Scientists at the AFSC Auke Bay Laboratories (ABL) have recently initiated three new research projects investigating the utility of ecological information for reducing recruitment uncertainty in the sablefish stock assessment. A complete description of these projects is presented in the **Ongoing and Future Sablefish Recruitment Research** section at the end of the document. Two of these studies focus specifically on sablefish recruitment in stage I. Mechanisms of offshore transport and prey availability represented by satellite-derived environmental variables (Project 1) and large-scale polar front dynamics (Project 2) are examined. Project 3 is a larger GOA integrated ecosystem research program (GOA-IERP) with sablefish as one of five focal groundfish species. Oceanographic and ichthyoplankton surveys will be conducted in an attempt to learn more about stage I sablefish distribution and condition. Ecosystem modeling will combine information from these surveys to gain understanding about potential mechanisms influencing recruitment through stage II.

These three current research projects are a first step toward understanding the ecological factors influencing sablefish recruitment. Data from these projects will supplement the current information on sablefish early life history and will develop environmental time series for potential integration into the sablefish stock assessment. Model evaluations within these projects may identify forcing mechanisms that cause the highly variable recruitment and potentially allow for reduction of uncertainty in the most recent recruitment estimates. However, there remain significant gaps in our current knowledge and future research projects should strive to improve our understanding in these areas. One specific item is the general lack of data on spawning locations. While there appears to be no clear relationship between spawning biomass and recruitment at the observed abundances, the spatial distribution of spawning females may provide insight on the highly specific nearshore settlement areas. Females may perform spawning migrations that situate them at the entrances of gullies throughout the GOA which may influence the pelagic dispersal pathway to the nearshore environment. Bailey et al. (2008) suggest this mechanism for some species of juvenile flatfish in the central GOA. The complex bathymetry of submarine canyons potentially amplifies the strong tidal signals in this region creating vertical instabilities which subsequently increase the upward movement of nutrients and larvae (Ladd et al. 2005, Bailey et al. 2008). Another significant data gap is information on juvenile sablefish benthic habitat preferences. Several studies have considered preferences and growth potential under different temperature regimes and food availability (e.g. Sogard and Olla 2001). However, habitat requirements are relatively unexplored. Controlled laboratory experiments could be conducted to test juvenile sablefish preference on a variety of benthic habitats. The influence of predator introduction on habitat selection could also be tested in this environment. Similar experiments on quillback rockfish (*Sebastes maliger*) and Pacific ocean perch have been successfully performed by the MESA program at ABL (Malecha pers. comm.). Information on benthic habitat preferences may be combined with bathymetric and substrate maps to develop habitat suitability models. High priority should be placed for projects that strive to enhance these specific data gaps in the sablefish early life history.

Conservation Concerns

Historically, periods of relatively intense fishing may have limited the sablefish population, but poor recruitment has also occurred during periods of precautionary fishing measures and relatively high spawning biomass. This suggests that ecological factors that manifest in the forms of transport, food availability, competition, predation, and habitat suitability are the main influences on sablefish recruitment. It is generally difficult to implement conservation measures that successfully mediate these ecological conditions. The previously mentioned research projects are designed to provide insight on the dominant mechanisms governing sablefish recruitment. Results from these studies may highlight critical seasons or areas that could respond well to protection.

We believe it is premature at this time to recommend any specific habitat conservation measures for sablefish. As results of current research projects become available, management will have an opportunity to utilize this information to make informed decisions for conservation measures. If research results identify, for example, a specific canyon entrance as a main pathway for transport to the nearshore (Stage I) or migration to adult habitat (Stage III), then these specific areas could be designated as HAPC for sablefish. Fishing in part of this corridor could be restricted during certain times of the year. If habitat suitability models for juvenile sablefish (Stage II) provide maps of preferred habitat, then research closures could be imposed on sections of this habitat. This progressive approach to implementing conservation allows management to utilize scientific research to base decisions and choose the most appropriate tool for protection. In a multispecies context, we continue to suggest that small, unobtrusive research closures in heavily fished areas are one effective tool for understanding the effects of fishing, especially on benthic habitat. We recommend that any new conservation measures be designed within a multi-species context as an effort by the management agency to seek a better understanding of changes to the ecosystem and EFH.

Ongoing and Future Sablefish Research

We conclude this document with a brief synopsis of the previously mentioned three new research projects initiated by the MESA program of the AFSC. These projects have potential to elucidate some of the data gaps in understanding sablefish recruitment mechanisms.

Project 1: Utilizing environmental information to reduce recruitment uncertainty in the Alaska sablefish stock assessment

Project Investigators: S. Kalei Shotwell, Dana H. Hanselman, David G. Foley, Anthony J. Booth

This research project uses Alaska sablefish and the associated stock assessment as a case study for investigating underlying mechanisms influencing recruitment. Objectives are to evaluate the various sources of early life history data for stage I sablefish and explore integration of NASA Earth Science satellite time series within the sablefish stock assessment model to understand recruitment variability. We collected all available early life history survey data to describe the spatial distribution of larval and YOY sablefish. A qualitative comparison with model recruitment estimates reveals potential critical spatial pathways during high recruitment years. Following this we considered potential mechanisms influencing recruitment and selected environmental indices representing these mechanisms. We considered several high resolution satellite measures and generated subset regions based on sablefish life history and management areas. Twenty-three indices of sea surface temperature, eddy kinetic energy, and chlorophyll *a* passed our model selection criteria and explain some of the recruitment variability in sablefish. Comparisons of satellite series time lapse visualizations suggest that the position of large scale eddies as they translate through the Gulf of Alaska and into the Aleutian Islands influence the survivability of young-of-the-year sablefish through offshore food availability and nearshore transport. Development of a modeling framework for sablefish that successfully incorporates NASA Earth Science data establishes a foundation for future ecosystem based management. Reducing uncertainty in recruitment estimates may increase efficiency in harvest decisions, improve geographic catch apportionment, and allow for more reliable future harvest projections.

Project 2: In the Path of the Polar Front: Reducing recruitment uncertainty through integration of large scale climate indices within the Alaska sablefish stock assessment

Project Investigators: S. Kalei Shotwell, Igor M. Belkin, Dana H. Hanselman, Lisa B. Eisner, Mark Zimmermann

The North Pacific Polar Front (NPPF) is associated with the North Pacific (or Subarctic) Current and therefore is a convenient proxy for the Subarctic Current and its extension, the Alaska Current. We propose that advection along the NPPF plays a key role in shaping the oceanographic climate of Alaskan waters. This would directly influence the cross-shelf transport of larval fish to their essential nearshore habitat and the productivity of the ocean environment. We use the Alaska sablefish and the associated stock assessment as a case study for investigating the influence of the NPPF. Analysis of temporal changes in the NPPF mechanism will allow for development of environmental time series for use in the sablefish stock assessment to reduce recruitment uncertainty. The primary objective of our research project is to estimate the NPPF and its variability and integrate this information into the sablefish stock assessment. We will first collect, process, and analyze both historic and recent satellite oceanographic and *in situ* hydrographic data to estimate the parameters of the NPPF (e.g. front location and cross-frontal ranges of temperature, salinity, density, nutrients, and chlorophyll *a*). We use two front detection algorithms (Cayula-Cornillon and Belkin-O'Reilly, Belkin and O'Reilly 2009) on satellite images of sea surface temperature and chlorophyll *a* to properly characterize the NPPF. Following the satellite mapping, oceanographic *in situ* data are analyzed across and along the front's path to generate time series representing properties of the NPPF. We will then analyze the propagation of temperature-salinity-nutrient anomalies along the NPPF path to estimate variability. The proximity of these anomalies to the shelf break provides a relative measure of the pelagic environment in which YOY sablefish must survive. Relevant time series are then incorporated into the sablefish stock assessment through the recruitment dynamics equations. Estimates using the NPPF are then compared to random simulations to determine if there is a reduction in recruitment uncertainty. We will also run a cross-validation exercise to calculate estimates of prediction error for recruitment estimates over time. This will determine if information from the Polar Front would have allowed for early detection of recruitment trends.

Project 3: Surviving the Gauntlet: A comparative study of the pelagic, demersal, and spatial linkages that determine groundfish recruitment and diversity in the Gulf of Alaska ecosystem (GOA-IERP)

Project Investigators: Jamal Moss, S. Kalei Shotwell, Franz Mueter, Shannon Atkinson

The overall goal of the proposed research focuses on identifying and quantifying the major ecosystem processes that regulate recruitment strength of key groundfish species in the Gulf of Alaska (GOA). We concentrate on a functional grouping of five top predatory groundfish species that are commercially or ecologically valuable and account for most of the predatory fish biomass in the GOA: arrowtooth flounder (*Atheresthes stomias*), Pacific cod (*Gadus macrocephalus*), Pacific ocean perch (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), and walleye pollock (*Theragra chalcogramma*). Taken together these species encompass a range of life history strategies and geographic distributions that provide contrast to explore regional ecosystem processes. Early life of these key species begins with an offshore pelagic phase (Stage I) followed by a nearshore settlement phase (Stage II). Spatial distribution, food preference, and habitat suitability of these two life history stages are poorly known. Four main components that are part of this integrated ecosystem research program (IERP) funded by the North Pacific Research Board (NPRB) will examine different aspects of the processes influencing recruitment of these five species. Research activities include retrospective analysis, offshore and nearshore field sampling, diet and health analysis, habitat suitability characterization, top predator tagging, and ecosystem modeling.

The retrospective analysis is a four component effort to provide a synopsis of available spatial and temporal datasets for understanding climatic, oceanographic, and biological drivers of the GOA ecosystem. Fieldwork conducted by the lower, middle, and upper trophic level components will include offshore pelagic to nearshore benthic sampling utilizing a variety of gear types to quantify the abundance, distribution, and condition of the key groundfish species. This information combined with concurrent sampling of the biophysical environment (i.e. oceanography, prey, competitors, and predators) will define a critical environmental window for these five focal species as they cross the gauntlet from offshore spawning to nearshore settlement areas. The upper trophic level will use samples from the field to develop growth curves and consumption rates as a measure of health during the two life history stages. High resolution bathymetry and substrate data will be combined with species specific habitat preferences to create benthic habitat suitability maps. The modeling component will develop a hydrographic model linked to a nutrient-phytoplankton-zooplankton (NPZ) model that will utilize data generated in the afore-mentioned research activities for calibration. Results from this model will be integrated into individual based models for each of the key groundfish species to predict recruitment. Forecasts will be compared with recruitment estimates from current single-species assessment models as a diagnostic check. Regional and seasonal recruitment estimates for each species will be evaluated to infer the relative influence of ecological processes. Finally, regional differences will be linked to dietary preference and movements of top level predators to infer causal mechanisms for population trends and influence of climate change on ecosystem structure and diversity.

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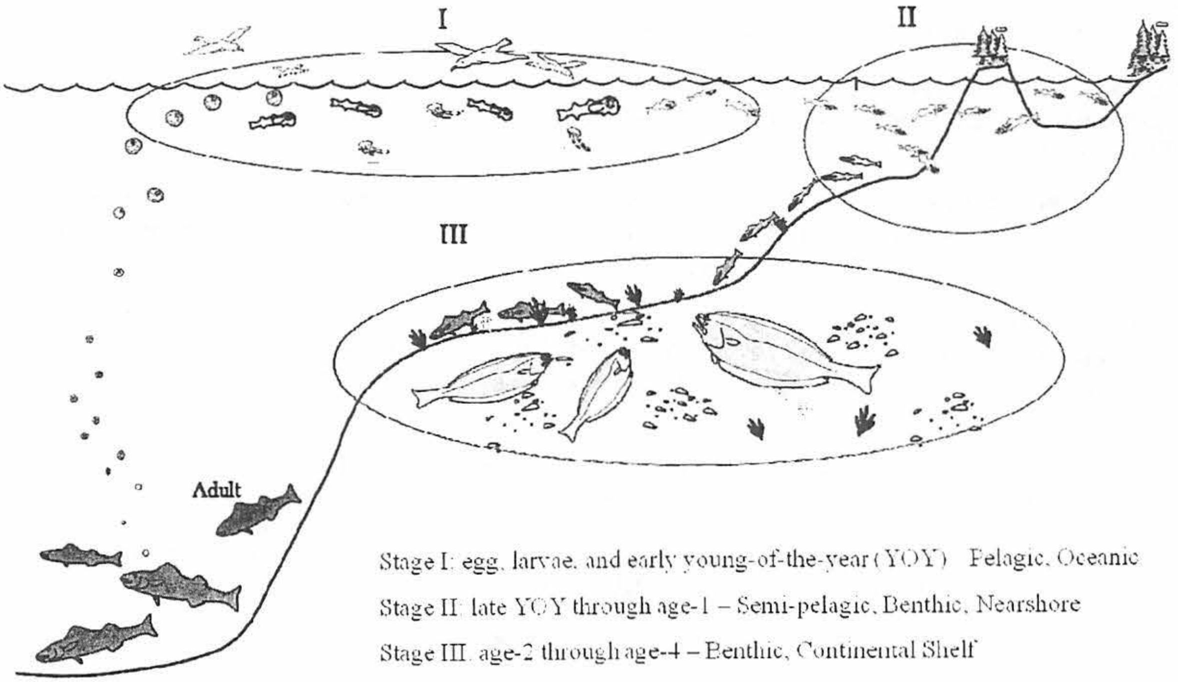
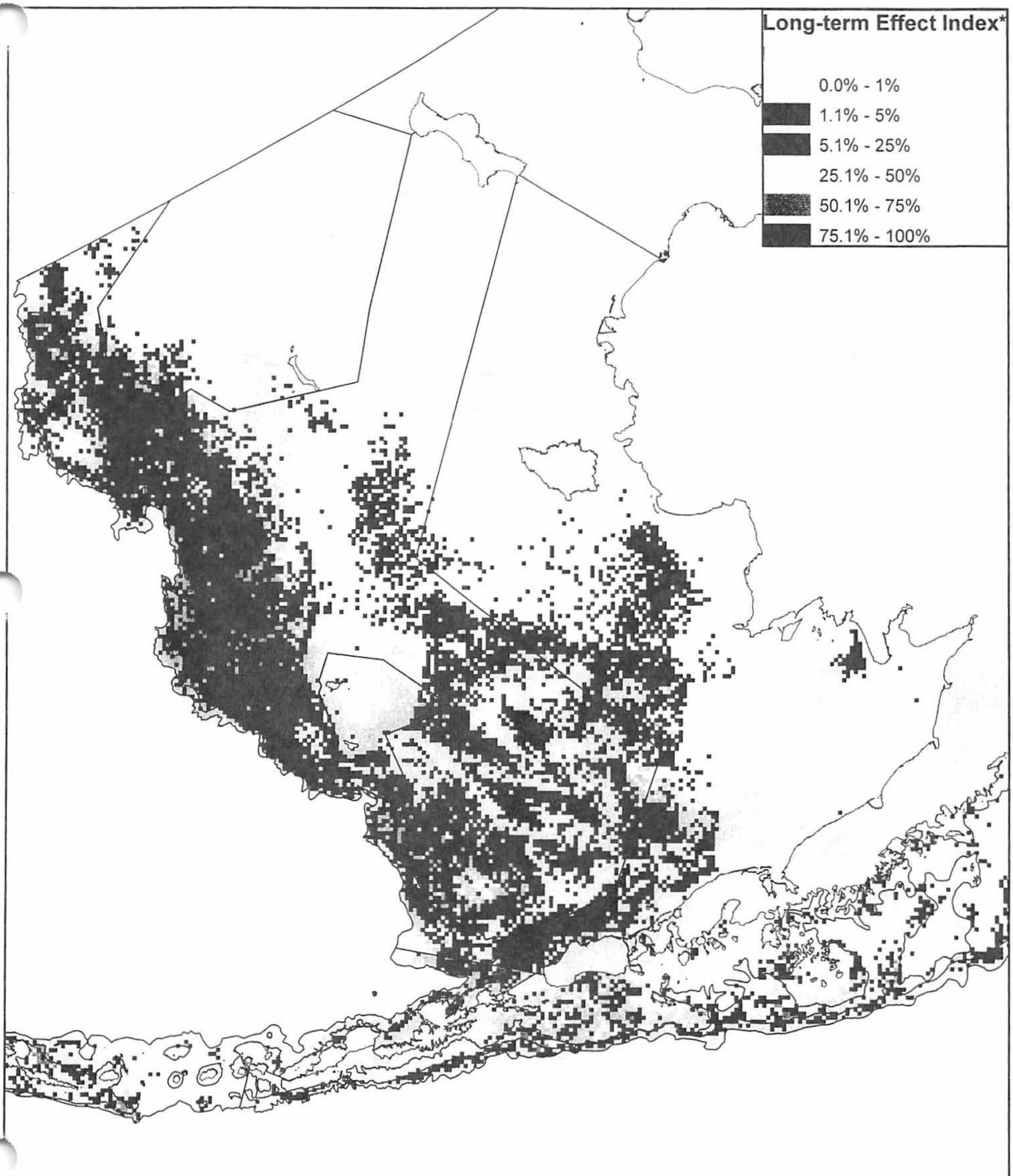


Figure 1: Sablefish pre-recruit life history depicting three critical stages.

Figure B.2-3a. Distribution of LEI of Fishing Effects on Living Structure - Bering Sea



Source: NMFS Data

* LEI - Estimated eventual reduction of the habitat feature if recent fishery intensity and distribution were continued until fishing effect rates and habitat recovery rates equalized (equilibrium)

Figure B.2-3b. Distribution of LEI of Fishing Effects on Living Structure - Gulf of Alaska

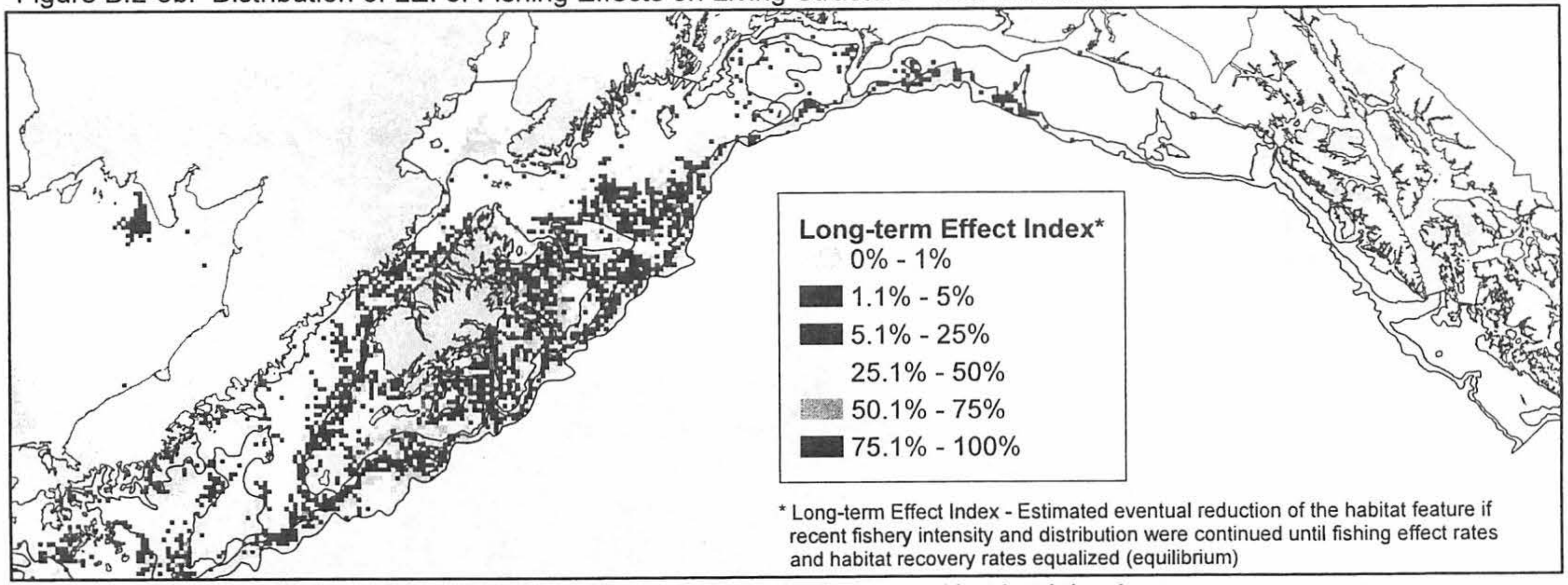
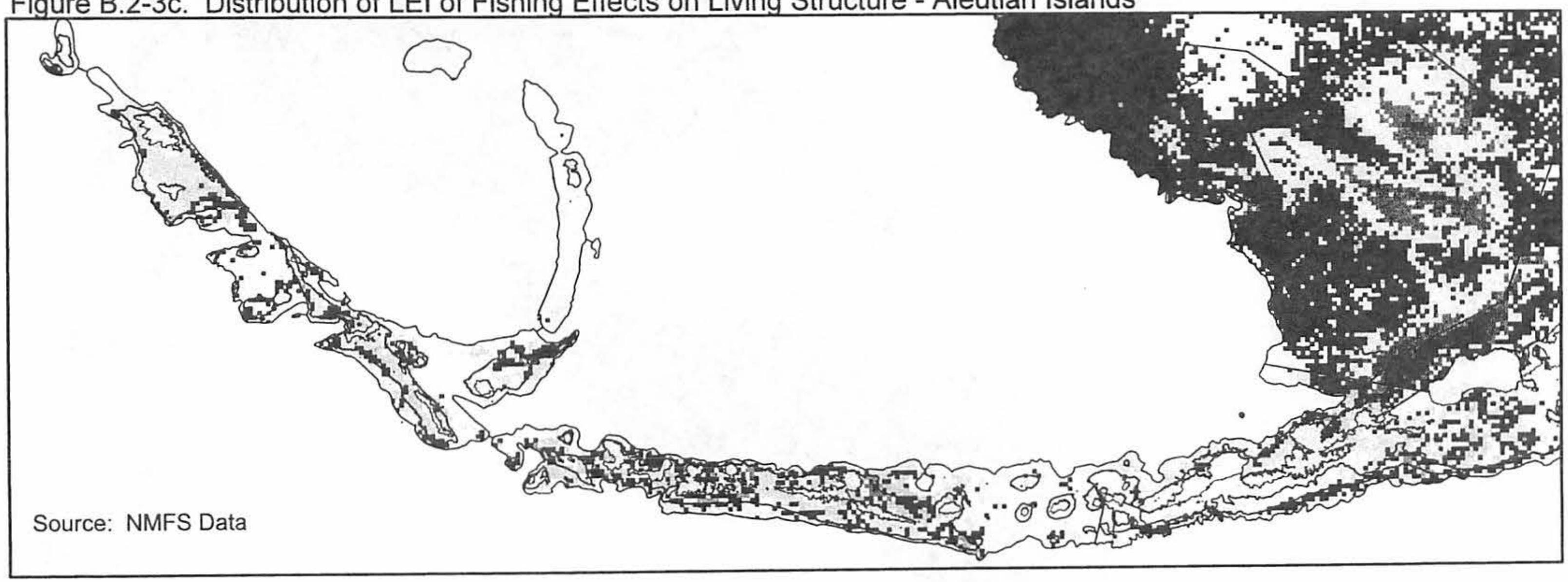


Figure B.2-3c. Distribution of LEI of Fishing Effects on Living Structure - Aleutian Islands



EXCERPT - Minutes of the Joint Plan Teams for the Groundfish Fisheries of the Gulf of Alaska and Bering Sea Aleutian Islands

November 15-16, 2010
North Pacific Fishery Management Council
605 W 4th Avenue, Suite 306
Anchorage, AK 99501

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Sablefish recruitment processes

Dana Hanselman presented a document on sablefish recruitment processes which stemmed from the Sablefish EFH update. In the EFH update, it was noted that little was known about juvenile EFH, and that NMFS should consider research closures to try to learn more about effects of intense fishing in a multi-species context. The Council requested a document relating to all factors of sablefish recruitment, so this document reviews early life history and issues with estimating recruitment. Three critical stages were identified: 1) pelagic to nearshore, 2) young of year juveniles settling nearshore, and 3) then moving off to slope habitat. In stage one, eggs hatch at depth and larvae swim to the surface emerging sometimes as far offshore as 200 km. These young-of-the-year grow rapidly and move inshore as pelagics. In stage two, they overwinter and settle in nearshore bays, although it is not known what is special about certain bays. In stage three, 2 year old and older fish move to the shelf break. It is unknown whether there are particular spawning locations. Most data are from summer, and summer habitat is not the same as spawning habitat. It is unknown if there is a type of structure they want for spawning. It is hypothesized that the environment may be most important in stage 1, larval transport. Larvae are transported by currents, and there are persistent GOA offshore eddies that could influence the encounter of preferred habitat. Water column stability and plankton blooms would also affect this stage. In stage 2, competition is more important, and perhaps diet overlap of other predators or euphausiids. In stage 3, predation may be most important. Fishing could directly affect stage 3 by removals, and perhaps habitat degradation. However, there is low discard mortality of juvenile sablefish, so direct fishing effects may not be large. Several research projects are already underway which may address some of these processes, including a NASA funded project, a polar front FATE project, and the GOA-IERP which has sablefish among its 5 key species. The conclusion was that this research could guide next steps, and that we are not yet ready to suggest conservation measures. The authors do suggest that establishing unobtrusive closures in heavily fished areas are one way to learn about fishing effects on benthic habitats and potential affects on multiple fish species.

The EFH Sablefish recruitment update report will be appended to minutes for presentation to Council in December. The Team discussed how effects of fishing on habitat are considered for both sablefish and in the context of broader efforts at marine spatial planning, etc. The Teams commented on the need for small scale research through specific closures to look at effects of benthic habitat on recruitment and production in intensively fished areas. The Plan Team supports making better use of our current closed areas (perhaps by initiating monitoring there) and more coordinated efforts towards assessing the effects of fishing on habitat for multiple species.

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GOA Trawl Sweeps modification
Discussion Paper
February 2011

In October 2010, the Council initiated a trailing amendment to require trawl sweep modifications on non-pelagic trawl vessels fishing in the Central Gulf of Alaska (GOA). The action was initiated in conjunction with final action on the GOA Tanner crab bycatch measures. A similar gear modification, which requires elevating devices to be placed on the trawl sweeps to lift the sweep off the seafloor, was implemented beginning in 2011 for flatfish vessels in the Bering Sea. Bering Sea research has demonstrated that elevated sweeps can reduce unobserved mortality of crab from interacting with the trawl sweeps.

Unlike the modification required to the Bering Sea (BS) trawl sweeps, however, which is required only in the directed flatfish fisheries, the proposed trawl sweep modification for the Central GOA would apply to all non-pelagic trawl fisheries (e.g., flatfish, Pacific cod, pollock, and rockfish). These other target fisheries were not included in the BS trawl sweep modification amendment, and the BS analysis did not address whether sweep modifications would work effectively for other target fisheries. The Council spent time during the October Council meeting debating the merits of whether the trawl sweep modification should apply to all trawl target fisheries, and whether it should be required GOA wide, or be limited to only the Central GOA. By including the western GOA trawl fleet in this proposed amendment, the Council was concerned that they could be requiring a gear modification for a fleet of largely small vessels, on which the trawl sweep modification has, to date, not been tested.

During the October 2010 discussions, the Council recognized that there are some outstanding questions with respect to the extent research is necessary to ensure that the modifications are practicable in the fleet, and meet the Council's intent to reduce crab mortality. Given these outstanding issues, the Council requested staff prepare a brief discussion paper. The paper includes a discussion on the practicality of trawl sweep modification for different non-pelagic GOA fisheries, a discussion of the effectiveness of the modification at reducing crab bycatch in the non-pelagic GOA fisheries, and a brief outline of the proposed steps for verification of lift achievement and a testing plan. Much of the information in the discussion paper is based on a letter presented at the December 2010 Council meeting that was written by John Gauvin, Alaska Seafood Cooperative, and Julie Bonney, Alaska Groundfish Databank, in consultation with Dr. Craig Rose, NMFS.

Is the trawl sweep modification practicable for GOA trawl fleets?

What type of vessels are required to use sweep modifications now in the Bering Sea?
In the BS, vessels directed fishing for flatfish are required to install elevating devices on the sweeps at regular intervals, to raise the sweep off the seafloor. Figure 1 illustrates where the sweeps are on the trawl gear, and Figure 2 provides an example of elevating devices. In order to provide a standard that is enforceable, the regulations define minimum and maximum distances for the spacing between elevating devices, as well as a minimum clearance height for the sweep measured adjacent to the elevating device[1]. There are two different configurations which were planned for in the regulations: vessels using elevating devices that are spaced 60 ft apart would have a minimum clearance height of 3 inches (e.g., 8 inch disks or bobbins attached to 2 inch wire), and vessels using elevating devices that are spaced 90 ft apart would have a minimum clearance height of 4 inches (e.g., 10 inch bobbins or disks on 2 inch combination wire). The regulations were purposefully written to allow a degree of flexibility around these parameters, to

[1] The clearance of the sweep at the elevating device is used because it can easily be measured by vessel operators and enforcement agents. Field testing in the Bering Sea identified the relationship between clearance height at the elevating device, and the clearance of the sweep from the seafloor at its lowest point between elevating devices.

allow for wear and tear that might occur during a tow. Field testing in the Bering Sea showed that these parameters would result in a seafloor clearance across the entire length of the sweep which reduced unobserved mortality of crab.

Figure 1. Relative positions of doors, sweeps, and trawl

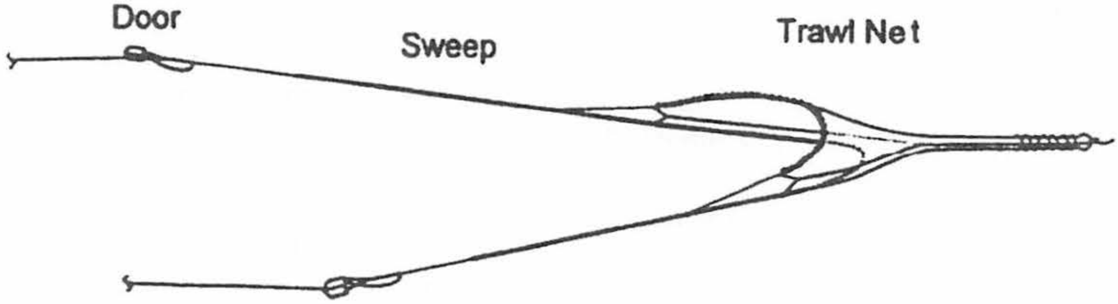
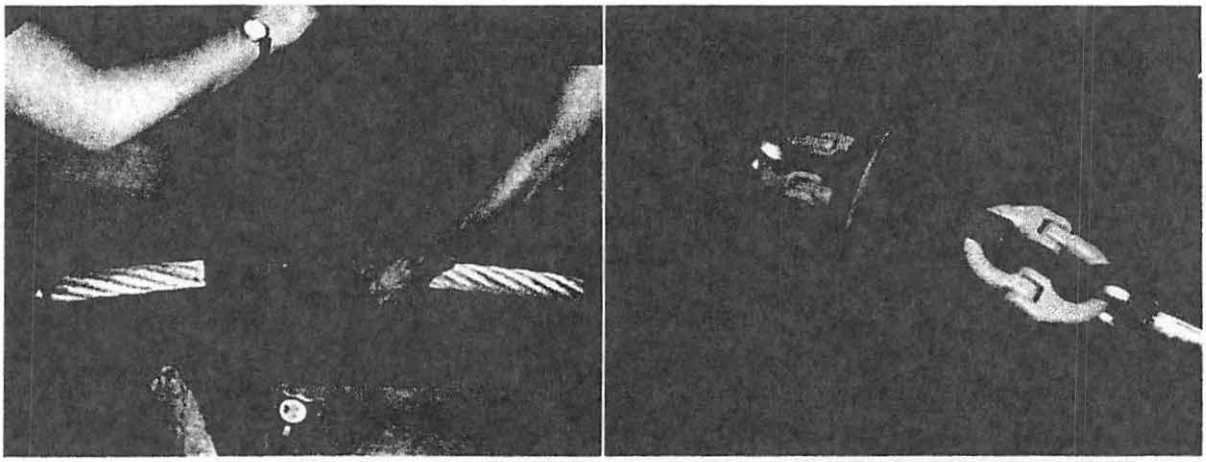


Figure 2. Example of elevating devices



In the Bering Sea, the flatfish fisheries are almost exclusively prosecuted by catcher processors using non-pelagic trawl gear. The majority of catch is harvested by vessels that are now in the Amendment 80 sector. The remainder of the catch of flatfish is primarily taken by other trawl catcher vessels. The 28 qualified Amendment 80 vessels consist of a relatively wide variety of vessels that range from 103 feet to 295 feet in length. As would be expected, the smaller vessels are relatively less productive than the larger vessels.

Most of the vessels targeting flatfish in the Bering Sea have net reels. For most dedicated flatfish Amendment 80 vessels, the total length of sweep used varies between 50 and 200 fathoms, depending on their door size and spread, and their horsepower and catch needs (see Figure 2). Bigger flatfish boats may use approximately 150 to 200 fathoms of sweep, and smaller boats use approximately 50 to 90 fathoms. Many vessels use combination rope in 90 foot segments, and the bobbins are attached between segments with coupling links.

For vessels without net reels, the trawl sweeps are wound onto the main deck winches. Vessels that put their sweeps on the main winches typically use much shorter, bare wire sweeps. Vessels using main line winches will likely use disks that are clamped on to cable to comply with the modified trawl sweep requirement. Most of the vessels without net reels are likely to use the regulatory option that allows the use of 8-inch disks at 60-ft spacing.

What does the GOA fleet look like?

GOA non-pelagic groundfish vessels participate in various non-pelagic targets including flatfish, Pacific cod, pollock[2], and rockfish in both Central and Western GOA. Table 1 shows the number of vessels that have participated in the flatfish fishery in the GOA from 2003 through 2010. As shown in the table, including Central GOA non-pelagic fisheries other than the flatfish fishery will likely increase the number of additional vessels requiring trawl sweep modifications. For example, 10 catcher vessels participated in the Pacific cod fishery and 6 catcher vessels participated in the pollock fishery during the 2003 through 2010 period that did not participate in the flatfish fishery. The addition of other non-pelagic fisheries, as is currently define in the motion, will likely result in vessels having to meet the modification requirement that historically do not target flatfish.

In addition, requiring trawl sweep modifications for Western GOA non-pelagic fisheries would likely increase significantly the number of vessels requiring trawl sweep modifications. One of the more potentially significant expansions of the trawl sweep modification requirement would likely occur if the Western GOA Pacific cod fishery were included in the proposed action. As shown in Table 1, 41 catcher vessels targeted Western GOA Pacific cod from 2003 through 2010 that did not target flatfish in the Western GOA or the Central GOA.

As for catcher processors, since nearly all those that target flatfish in the Central GOA also target flatfish in the Western GOA, requiring modified trawl sweeps beyond Central GOA flatfish fishery would not significantly affect additional vessels. Additionally, all of the GOA trawl catcher processors targeting non-pelagic fisheries in the GOA are also Amendment 80 vessels and as such, they are likely already using the modified sweeps in the BS.

Table 1. Number of vessels in the flatfish fishery by subarea from 2003 through 2010, and number of additional vessels in other non-pelagic target fisheries that did not also fish flatfish

Area	Flatfish		Pacific cod		Rockfish		Non-pelagic pollock
	Catcher processors	Catcher vessels	Catcher processors*	Catcher vessels*	Catcher processors*	Catcher vessels*	Catcher vessels*
Central GOA	12	48	1	10	2	2	6
Western GOA	14	3	0	41	1	4	12

Source: Catch Accounting for catcher processors and Fish Tickets for catcher vessels
*Number of vessels in target fishery that did not target flatfish

GOA flatfish catcher vessels are generally smaller, lower horsepower vessels, although some larger catcher processor vessels that have used the modified sweeps in the Bering Sea also participate in the GOA flatfish fisheries. With respect to gear type, specifically flatfish gear, Alaska Groundfish Data Bank surveyed their members to describe the most relevant characteristics of the trawl gear used in the GOA bottom trawl fisheries. Alaska Fishery Science Center (AFSC) scientists compiled and summarized the data from the returned survey forms. Fourteen vessels responded to the survey, describing 22 nets used to target flatfish. The survey indicated that GOA bottom trawl gear used to target flatfish in the GOA is similar to that used in the Bering Sea. It consists of bottom trawls with footropes equipped with large diameter bobbins or disks. Most of the area affected by these trawls is covered by sweeps, long cables between the trawl doors and the net that heard flatfish into the path of the capture net. The differences in the gear used in the GOA include:

[2] Note, while the majority of vessels participating in the GOA pollock fishery use pelagic gear, there a small number of vessels that use non-pelagic gear (generally due to size or horsepower constraints of the vessel).

1. Most of the GOA trawlers reported diameters of footrope bobbins from 16 to 18 inches diameter in the center and 14-16 inches in the wings (sides of the trawl footrope) while Bering Sea trawlers use footrope bobbins and disks from 18-23 inches in diameter.
2. Most GOA sweeps used 3 inch diameter rubber disks strung over a steal cable instead of the 2 inch diameter combination rope (polyethylene-wrapped steel) used in the Bering Sea fisheries. Some GOA vessels reported using combination rope. Some also reported using widely spaced (90-120 ft) devices that raised the sweeps above the seafloor.
3. Finally, GOA vessels used shorter sweeps than those used by the larger Bering Sea trawlers. While Bering Sea sweeps cover approximately 90% of the area affected by the trawls, similar calculations for GOA gear yield 75%.

The general similarity of GOA flatfish trawl gear to that used in the Bering Sea tests indicates that the results of those tests should approximate crab mortality rates in GOA fisheries. The smaller area swept by the sweeps in the GOA indicates that the benefits of sweep modifications would be somewhat smaller than those for Bering Sea fisheries, but still substantial

Since the research on modified gear has been limited to flatfish vessels only, little is known about whether modified sweeps would work in the other non-pelagic GOA fisheries. Sweep lengths for other non-pelagic fisheries may be less than is used in the flatfish target fisheries. Vessels also tend to use shorter sweeps in rough bottom areas where some of these other non-pelagic trawl target fisheries occur. In the rockfish fishery, in recent years many of the vessels are employing pelagic gear. For those rockfish vessel that still use bottom gear, many of these nets are equipped with so-called "tire gear," in which automobile tires are attached to the footrope to facilitate towing over rough substrates (NMFS, 2010). It is likely that elevated disks in fisheries with a rough bottom habitat would be less effective and require a high level of maintenance to replace continually eroded/destroyed disks. In addition, the smaller sweeps employed in other non-pelagic fisheries results in less area swept and therefore the benefit of modified sweeps in reducing crab morality would be less in these fisheries.

Is the trawl sweep modification effective at reducing crab mortality in the GOA?

The trawl sweep modification has been tested to be effective in the Bering Sea flatfish trawl fishery in reducing trawl sweep impact effects on C. bairdi, C. opilio, and red king crabs by reducing the unobserved mortality of these species. Additionally, the trawl sweep modification has proven effective on the Bering Sea shelf at reducing effects on sea whips (a long-lived species of primary concern), and did not substantially reduce catches of target flatfish. Test for reduced impacts on basketstars, sponges, and polychaete siphons were positive in direction, but non-significant.

The relevance of that study to crabs in the GOA depends largely on the similarities in sediment type in the Bering Sea and GOA, and between the bottom trawl gear tested in the Bering Sea and those used in the GOA. The sediment in the Bering Sea where the flatfish fishery occurs consists mainly of sand, muddy sand, or gravelly muddy sand (NMFS 2009), and such was the sediment in the areas of the research study. Sediment in the GOA flatfish fisheries is variable, with similar sand and gravelly sand substrates, but also gravelly mud and silty clay areas. GOA Pacific cod preferred substrate is soft sediment, from mud and clay to sand, while rockfish preferred substrate is relatively rough, variously defined as hard, steep, rocky or uneven bottom on the banks of the outer continental shelf (NPFMC, 2010).

Given that crab bycatch by non-pelagic vessels differs across target fisheries and areas, a trawl sweep modification requirement for non-pelagic gear will likely have varying degrees of success at reducing crab mortality. As shown in Table 2, the flatfish fisheries account for the largest portion of the non-pelagic Tanner crab bycatch, averaging 90 percent of the bycatch from 2003 through 2010. By comparison, other non-pelagic fisheries, which include Pacific cod, rockfish, and bottom pollock account for only 6 percent of the Tanner crab bycatch. Bycatch at the area level shows that the Central GOA (area 620 and 630 combined) accounts for the largest share of Tanner crab bycatch, averaging 92 percent from 2003 through 2010, while in the Western GOA bycatch is significantly lower with an average of 8 percent from 2003 through 2010. Overall, the flatfish fisheries in the Central GOA appears to the primary contributor of Tanner crab bycatch, while other non-pelagic fisheries in the Central GOA and Western GOA account for only a modest amount of Tanner crab bycatch. In addition, the bycatch data suggest that the flatfish targets tend to occur on bottom types which are preferred crab habitat.

Table 2. Bycatch of C. bairdi Tanner crabs in Federal non-pelagic groundfish fisheries, in reporting areas 610, 620, and 630, by target fishery, 2003-2010

Subarea	Target Fishery		2003	2004	2005	2006	2007	2008	2009	2010
610	Flatfish	Arrowtooth Flounder	970	247	1,985	1,566	1,417	685	1,004	0
		Flathead Sole	152	5,199	31,416	2,414	279	0	35	993
		Shallow Water Flatfish	535	117	58	340	221		0	
		Rex Sole	4,465	3,142	63	2,615	477	26	54	32
	Other non-pelagic	Pacific Cod	695	267	1,045	209	3,967	5,130	917	1,750
		Pollock*	2	17	0	11	32	945	50	25
		Rockfish	7	0	0	129	81	0	34	0
610 Total			6,826	8,989	34,567	7,285	6,474	6,786	2,094	2,799
620	Flatfish	Arrowtooth Flounder	7,255	252	20	2,752	2,575	582	1,839	2,025
		Flathead Sole	883	65	0			112	0	757
		Shallow Water Flatfish	2,838	1,077	854	2,017	13,010	2,242	9,079	2,339
		Rex Sole	12,226	1,773	3,211	33,503	19,817	26,619	35,254	10,905
	Other non-pelagic	Pacific Cod	34	48	0	6	286	4,264	22	174
		Pollock*	0	670	0	26,816	2,874	19	3,485	31
		Rockfish	0	0	0	0	21	1	0	100
620 Total			23,237	3,886	4,085	65,094	38,582	33,840	49,678	16,332
630	Flatfish	Arrowtooth Flounder	20,934	33,012	66,925	84,108	40,523	33,716	37,884	45,160
		Deep Water Flatfish	0	0			0			0
		Flathead Sole	16,601	2,249	12,540	23,470	24	6,397	7,647	4,747
		Shallow Water Flatfish	55,780	7,506	5,091	31,098	65,687	20,456	21,177	19,393
		Rex Sole	17,241	4,115	1,187	37,410	24,979	21,373	105,058	3,330
	Other non-pelagic	Pacific Cod	1,498	846	270	526	11,878	9,282	1,434	0
		Pollock*	3	536	5	57,178	16,552	255	3,097	51
		Rockfish	171	1,517	1,750	830	57	64	195	0
630 Total			112,228	49,782	87,767	234,620	159,700	91,544	176,492	72,681
Grand Total			142,291	62,656	126,419	307,000	204,756	132,169	228,263	91,812

Source: Catch Accounting
*Caught with non-pelagic gear

One explanation for the variability of crab bycatch across the different areas and target fisheries could be the geographic overlap between the different target fisheries and areas of Tanner crab abundance. As shown in Figures 3 and 4, most of the Tanner crab abundance is located in the near shore portion of South East Kodiak Island (Central GOA) and in the near shore portion of the Alaska Peninsula (Western GOA). As shown in Figure 5, the primary fisheries occurring in close proximity to Kodiak Island are the arrowtooth flounder, shallow-water flatfish, and the Pacific cod fisheries. The rockfish fishery tends to be located in deeper waters of the GOA along the shelf edge. As such, the arrowtooth and shallow-water flatfish have higher Tanner crab bycatch which is supported in Table 2, while the rockfish fishery has lower Tanner crab bycatch. As for Pacific cod, data in Table 2 suggests a lower bycatch of Tanner crab despite being in close proximity to the Tanner crab grounds. One explanation for the lower bycatch numbers could be because the Pacific cod fishery tends to be limited to a few very specific locations that have low Tanner crab abundance.

Figure 3. Tanner crab distribution of Kodiak from the 2009 trawl surveys

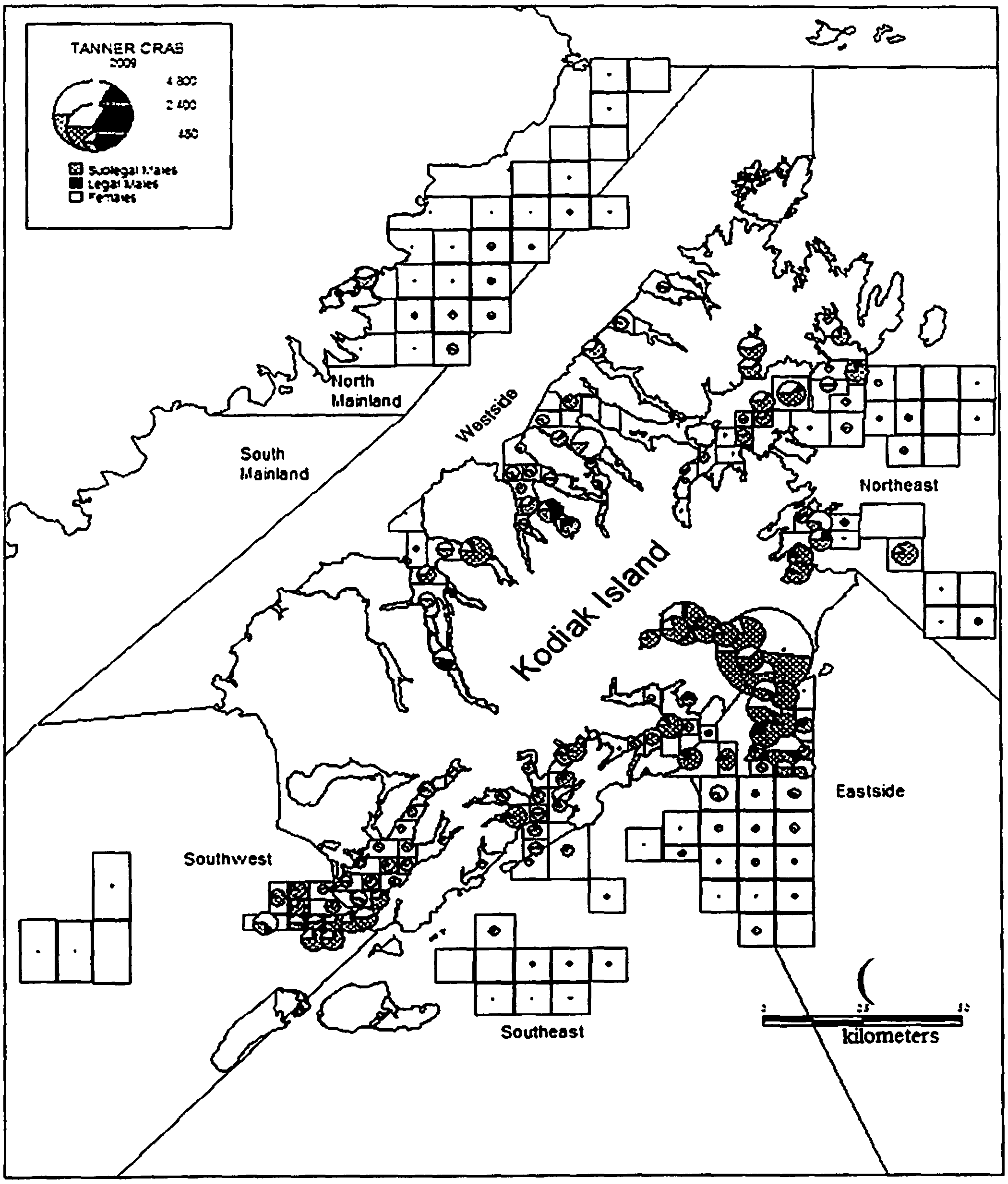


Figure 4. Tanner crab distribution of Alaska Peninsula from the 2009 trawl surveys

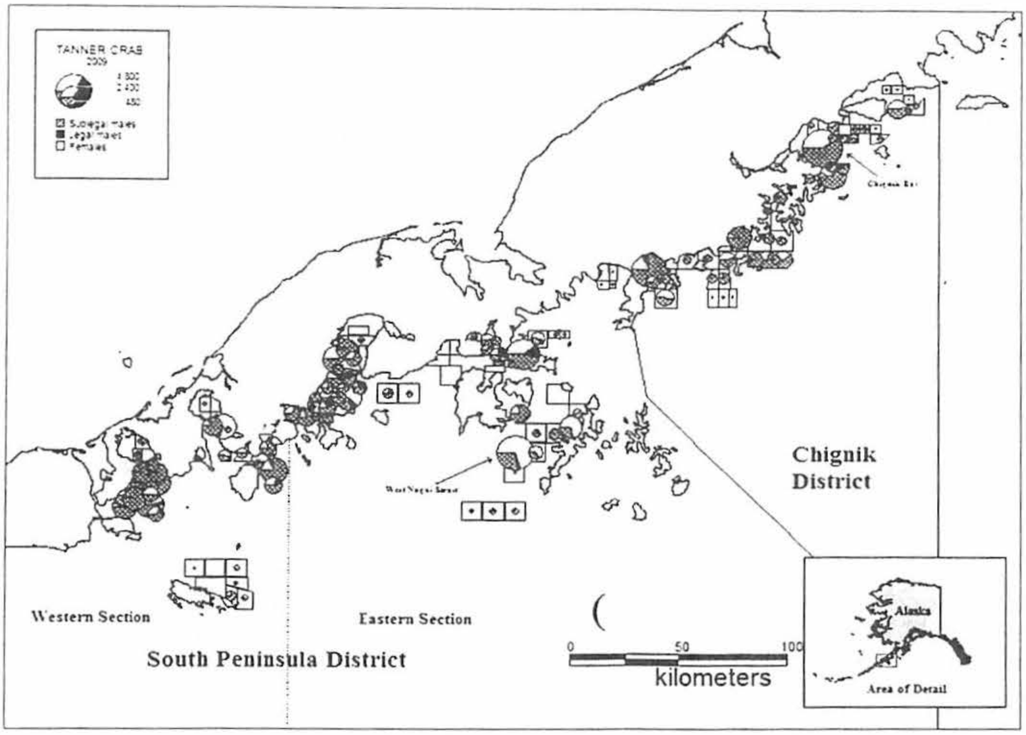
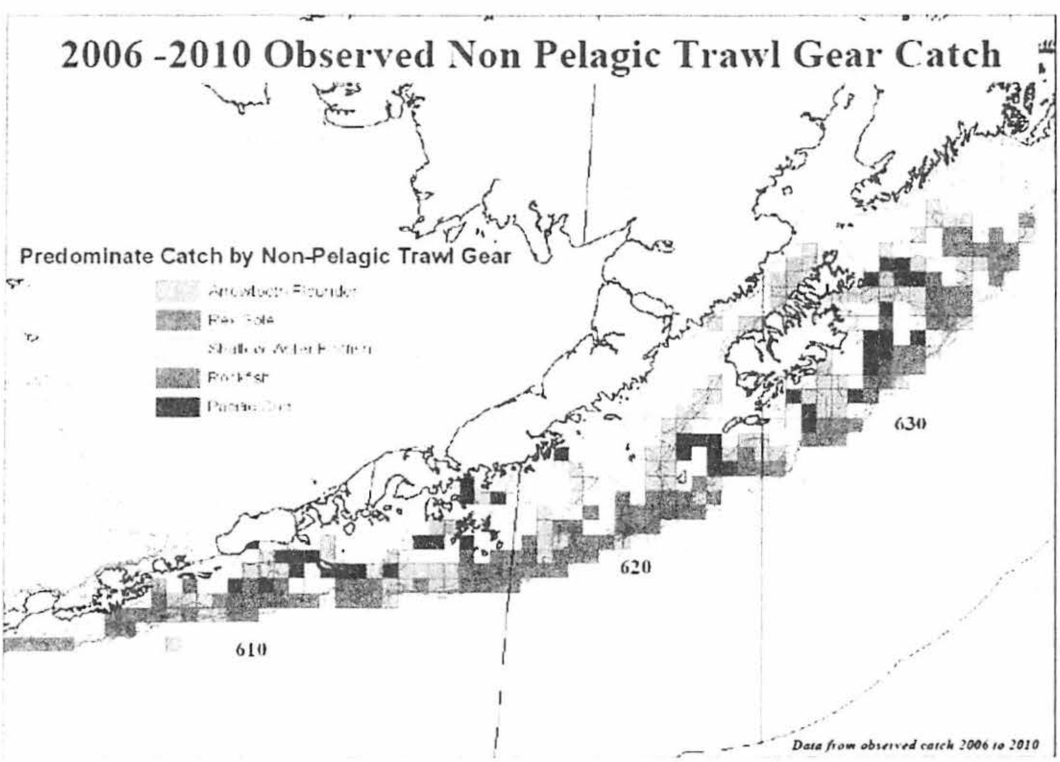


Figure 5. Observed non-pelagic trawl gear catch from 2006 through 2010 shows observed non-pelagic trawl fishery catch from 2006 through 2010 for the Western and Central GOA



Proposed Research

Research and field testing is needed to ensure that the BS tests and regulation requirements are applicable in the GOA. Verification and comparative work in the GOA will focus on disc or bobbin (sweep elevation device) height and spacing (between elevating devices) so that the same degree of elevation from the seafloor (approximately 3 inches) is achieved given the specifics of the GOA flatfish fisheries. Factors affecting whether sufficient lift can be attained in the GOA flatfish fisheries as compared to the BS include: towing power and/or speed of GOA vessels, styles and/or sizes of trawl doors, rigging of trawl nets, bridle and sweep materials (e.g. cookie sweeps rather than combination rope), and sediments and bathymetry of the GOA flatfish fishing grounds as compared to the Bering Sea grounds. The starting point for this research should be the BS spacing and disc height requirements as described in the sweep modification regulations (e.g., the equivalent of 10 inch elevating devices for 2 inch combination rope sweeps and 90 foot spacing. This will help show if the GOA physical environment and/or vessel and gear differences affect sweep lift, compared to the Bering Sea.

From a practical perspective, using the BS spacing and elevation requirements would also help to avoid potentially unnecessary costs for vessels that have already made investments in meeting the sweep modifications regulations that are in place for the Bering Sea flatfish industry. The spacing that was implemented in the BS reflects what was feasible given the net reel capacity of the larger Bering Sea flatfish vessels. If the testing in the GOA shows that significantly closer spacing is required for the GOA flatfish fisheries, knowing this from the outset will be important in terms of consideration of costs and benefits of implementing a sweep modification requirement in the GOA for the different GOA flatfish dependent fishermen.

In January 2011, captains of both the GOA catcher vessel fleet and the head and gut catcher processor fleet met to discuss the modified trawl sweep implementation in the GOA. During the meetings, there was discussion concerning the measuring of the modified trawl sweeps for enforcement purposes. Height measurements of GOA cookie gear would be the same as combination wire, but from the high point of the cookie adjacent to elevating device. The use of a specific length of rope to measure spacing lengths could be used in the GOA much like what will employed in the BS. In addition, measuring from the aft reel will be more problematic at sea, thus it was thought that verifying height and spacing at the dockside would be easier. Like the BS, 30 foot minimum spacing would likely work in the GOA. Summer testing would require 1 to 2 vessels of various horsepower and size to test elevated devices using 90 foot sections. It was also noted that it would be best to test the modified trawl sweeps in less intense fisheries, like shallow water flatfish and arrowtooth. For Pacific cod, testing can be performed in the Central GOA rockfish program using Pacific cod catch quota. One concern was that elevated disks are likely to be less effective as well as eroded/destroyed in rough bottom fisheries (rockfish, Pacific cod, and rex sole), so testing of elevated devices will be needed to determine the viability of these devices.

Proposed steps for verification of lift achievement and testing plan

As noted above, the testing plan builds on work done in the BS flatfish fishery. Many scientific questions would need to be answered first before applying the modified sweeps to other target fisheries. Some examples include the impact on catch per unit effort if the elevation devices are required on sweeps, sweep characteristics for the different targets to measure benefit to crabs, and wear and tear on the gear in rougher bottom types. Utility or practicality of the gear for other fisheries has not been studied.

January 2011: Meeting with fishermen to gather testing parameters for different vessel classes and sweep modification designs. Vessel owners / operators will give their perspective of the practicability of different sweep modification designs for their individual vessel platform and net reels.

Spring/summer 2011: When flatfish fishing commences in 2011, a field technician with experience in tilt sensor placements on sweeps will go out on three GOA flatfish vessels of different sizes. The goal of this "ride along" cruise under regular commercial fishing conditions will be to place tilt sensors between the elevating devices installed on a section of modified sweeps that is added to each vessel for each cruise. The initial configuration of modified sweep gear will comply with the current Bering Sea regulations. The vessel size classes of interest for this work should be smaller GOA flatfish catcher vessels (range of horsepower < 800), larger GOA flatfish catcher vessels (horsepower > 800), and a Bering Sea flatfish catcher processor that fishes GOA flatfish (range of horsepower : 1,200 to 3,000). This work will establish whether the current Bering Sea standards for modified sweeps achieve the same lift at the midpoints of the sweeps as was seen in the Bering Sea.

Follow-up cruise if adjustments are needed: Once analysis of the tilt sensor data from the first fieldwork is complete, adjustments to spacing or height of elevating devices, if deemed necessary, can be made on the section of modified sweeps used in the first stage of verification work. This may include reducing the spacing to 60 feet or increasing the height of elevating devices to 11 inches. The second stage of testing would confirm whether the adjustments were sufficient to achieve the desired elevation. Another round of tilt sensor testing would be done to verify that the new parameters achieve the desired amount of lift between elevating devices.

Fleet implementation evaluation: Once the field testing has come up with a set of parameters that the testing shows will achieve the necessary lift, fishermen will need to do some practicability evaluation. For this, a full set of sweeps that meet the GOA height and spacing parameters would be needed. This will allow fishermen to evaluate the differences in setting and retrieving the trawl gear with the modified sweeps as well as seeing if their current net reel capacity is sufficient for loading a full set of modified sweeps meeting the GOA parameters. Conducting a field demonstration for enforcement practicality issues with NMFS enforcement and NOAA GC would also be worthwhile at that point so that enforcement concerns can be addressed early on in the pre-implementation process.

The Central GOA trawl industry in partnership with AFSC scientists would share in the costs of the research for implementing sweeps in flatfish fisheries. The trawl industry would provide fishing platforms and gear as available at no cost to scientific staff from RACE. RACE will analyze the tilt sensor data and provide project staff for the collection of data and analyses the data for achieving the desired crab mortality reduction benefits. **Funding and the timeline for research for implementing sweeps in other non-pelagic fisheries have not been addressed.**

Council action

- None required (Council motion stands): implement sweep modification for non-pelagic trawl fisheries in the Central GOA
- Options (may be combined):
  - a) limit amendment to just flatfish fisheries;
  - b) limit amendment to flatfish, Pacific cod, and pollock (remove rockfish)
  - c) limit geographic scope of amendment to areas of Tanner crab abundance around Kodiak included in Council's October 2010 Tanner crab analysis (Marmot, Chiniak, and statistical area 525702 (see Figure 6 and Table 3).
  - d) expand to WGOA;
  - e) bifurcate amendment (e.g., do flatfish first and follow with other non-pelagic trawl targets)

Figure 6. Areas of Tanner crab bycatch measures from October 2010 Council action

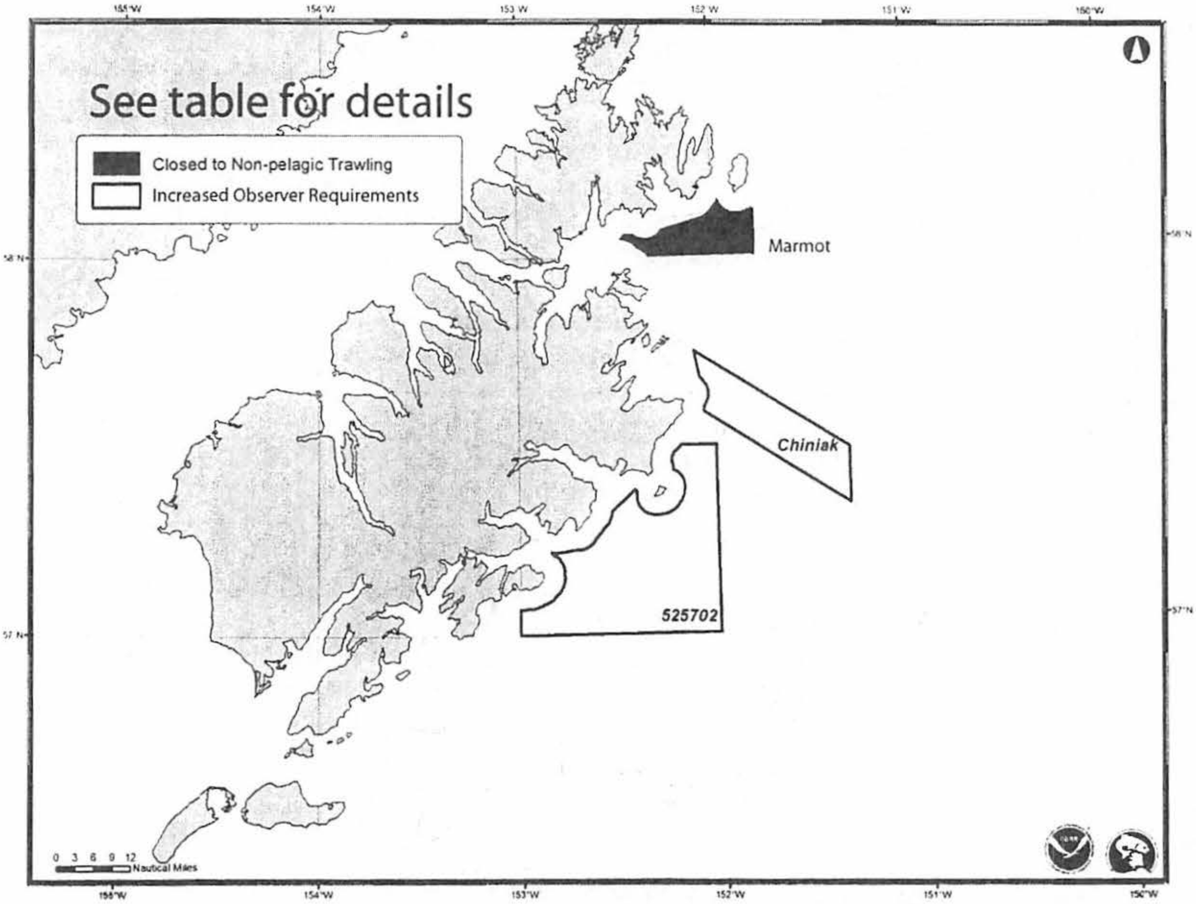


Table 3. Tanner crab bycatch measures from October 2010 Council action

<table>
<tr><th>Area</th><th>Trawl</th><th>Pot</th></tr>
<tr><td>Marmot Bay</td><td>Closed
(vessels using pelagic trawl gear to fish for pollock are exempt)</td><td rowspan="3">Closed to pot gear unless 30% observer coverage</td></tr>
<tr><td>Chiniak Gully</td><td rowspan="2">Closed to non-pelagic trawl gear unless 100% observer coverage</td></tr>
<tr><td>ADFG statistical area 525702</td></tr>
</table>

References

National Marine Fisheries Service. 2009. Proposed Amendment 94 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area to Require Trawl Sweep Modification in the Bering Sea Flatfish Fishery, Establish a Modified Gear Trawl Zone, and Revise Boundaries of the Northern Bering Sea Research Area and Saint Matthew Island Habitat Conservation Area: Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility Analysis. National Marine Fisheries Service, Juneau, AK. October 2009.

North Pacific Fishery Management Council. 2010. Stock Assessment and Fishery Evaluation (SAFE) Report for the Groundfish Resources of the Gulf of Alaska. Compiled by the Plan Team for the Groundfish Fisheries of the Gulf of Alaska. NPFMC, 605 West 4th Avenue, Anchorage, AK. 99501.

SSC Document

Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet

Working Group Participants:
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1.0 Introduction

The discarded catch of groundfish species (bycatch) in the halibut IFQ fishery is largely unobserved, undocumented, and is not incorporated into most of the Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA) stock assessments. Bycatch of some groundfish species in the halibut IFQ fishery has been estimated using the International Pacific Halibut Commission's (IPHC) annual longline survey as a proxy for observer data (Gaichas et al. 2005, Courtney et al. 2006, Brylinsky et al. 2009, Ormseth et al. 2009, Tribuzio et al. 2009). However, there has been no consensus among authors as to the best method to estimate removals of groundfish species.

At its December 2009 meeting, the SSC requested improvements to estimation methods of discard and continued monitoring of estimated bycatch in the halibut IFQ fishery (NPFMC 2009). Specifically, the SSC recommended monitoring at-sea discard of rockfish species, skates and sharks:

Rougheye Rockfish: "In particular, the authors should monitor the bycatch trends in the sablefish, halibut longline fisheries, and look for evidence of "topping off" in the POP fishery."

Skate complex: "The new method of bycatch estimation used the IPHC halibut survey bycatch data to estimate skate bycatch in the commercial fishery and used only those survey stations with the highest one-third of halibut catch rates. The rationale for this approach is the expectation that most of the commercial effort in the halibut fishery is likely to be in the high CPUE areas. The plan team was uncomfortable with this new approach, noting that the impact on the estimate of skate bycatch, which is primarily taken in the halibut fishery, is to reduce that estimate by an order of magnitude. The SSC concurs with the plan team's request for an investigation of alternative methods of estimating skate bycatch in the commercial halibut fishery, to include stratification based on the geographic distribution of the commercial fishery, as well as depth and area stratification."

Shark complex: "The SSC supports further development of both proposed methods to estimate shark bycatch in halibut fisheries reported in the Appendix. When completed, reconstructed historical estimates of shark catch should be added to the historical catch time series for sharks."

To address these recommendations, a working group composed of scientists from the Alaska Fishery Science Center (AFSC), Alaska Regional Office (AKRO), Alaska Department of Fish and Game (ADF&G), IPHC, and North Pacific Fishery Management Council (NPFMC) was formed in January of 2010. The goal of this group is to investigate quantitative methods to estimate incidental catches in the unobserved halibut IFQ fishery and report its findings to the Plan Teams and NPFMC. The purpose of this document is to provide Plan Team and SSC members with an overview of the analytical methods and associated estimates for several example species: Pacific cod, spiny dogfish, Pacific sleeper shark and salmon shark within the GOA. The working group has focused on three areas: 1) estimation of variance for extrapolated survey catch and CPUE; 2) investigate methods to better represent commercial fishing behavior by using annual IPHC survey data; and 3) extrapolate survey catch to commercial effort using ratio estimators.

1.1 Timeline

- January-August 2010: Working group meetings and method developments
- September 2010: Presentation of methods to joint Plan Teams, discussion and feedback, selection of best method
- November 2010: Presentation of best method with catch estimates of example species to joint Plan Teams
- February 2011: Presentation of best method to SSC for approval
- March 2011: Make necessary changes requested by SSC
- August 2011: Estimation of catches for non-target species prepared and provided to stock assessment authors

2.0 Methods

The IPHC provided data sets from their annual survey as well as effort data (total IFQ halibut landings and effective skates fished) from the commercial halibut IFQ fishery.. To preserve confidentiality, commercial effort data (effective skates and total landings) were grouped by year into NMFS reporting areas (541, 542, 543, 610, 620, 630, 640+649, 650, 659 and Bering Sea, Figure 1, top panel) and binned into three depth categories (0-99 fathoms (f), 100-199 f, and 200+ f). The commercial landing data was assumed to be known without error and thus no error is calculated. This is a reasonable assumption given halibut is debited from IFQ accounts upon landing and reporting of all landed halibut is mandatory. Further, because some areas had a low number of vessels fishing halibut IFQ, depth categories were combined within an area to avoid very small sample sizes (e.g., areas 542 and 543 had all depths combined). Survey stations were similarly grouped by year, NMFS area, and depth stratum for estimating variances for survey CPUE. The "proportional to catch" weighting uses catch (landings) of halibut at the smallest spatial resolution available (ADF&G statistical area, Figure 1, bottom panel) to proportion landings within each larger NMFS area (Figure 1, top panel).

2.1 Survey Catch and CPUE Variance

The annual IPHC survey provides catch data for all species caught on the survey; however, catch data is based on a stratified systematic sampling plan. For each station, the catch on the first 20 hooks of each skate is recorded, with generally 5 skates fished. Each skate consists of 100 hooks, resulting in 100 hooks per station that are generally observed. A species-specific strata catch rate (catch per unit effort, CPUE, here defined at #'s per hook) and resultant catch estimate (in numbers of fish caught) can be made by summing the relevant data over the strata and calculating the CPUE or by averaging the CPUEs for each station. While averaging the CPUE over the stations is simple and provides convenient confidence intervals using a theoretical variance, it assumes normality of the data. Based on the central limit theorem, this assumption is generally not violated if the sample size is large enough; however, many of the strata had low sample sizes.

A bootstrap procedure was used to estimate confidence intervals around the CPUE to avoid having to make assumptions about the distribution of the data. The goal was to estimate approximate 95% confidence intervals for the CPUE (numbers of fish/hooks) and the extrapolated catch (numbers). Following the IPHC assumptions that the 20% stratified subsample of hooks is an adequate representation of the total hooks fished at each station for bycatch of common species, we assumed that the subsample of observed hooks was representative of the station and was in essence a complete census of the hooks. Stations within a stratum were re-sampled by drawing 10,000 samples with replacement and the mean CPUE for each species within a stratum calculated. Bias-corrected 95% confidence intervals were calculated to account for any impacts of skewed data. These intervals were similar to the 2.5th and 97.5th

percentile of the bootstrap replicates, suggesting that bootstrapping produced unbiased estimates of mean CPUE and 95% confidence intervals.

The survey CPUE was then multiplied by the total number of effective hooks retrieved within each year, NMFS area, and depth strata of the survey to estimate the total estimated survey catch (in numbers) of each species (and 95% confidence intervals). Estimating CPUE and catch for rare species presents a problem due to low detection probabilities and a preponderance of zero values that cause over dispersion and potential bias in estimates. In other words, species that are estimated, but do not occur in the subsample result in an estimate of zero catch and CPUE despite likely occurrence in the area. Conversely, if catch and/or effort are clustered, the catch and CPUE may be over estimated. In both situations, estimates of variance, confidence intervals, and mean values are likely not accurate relative to the population.

2.2 Treatment of Survey Data

During the September 2010 Joint Plan Team meeting, the teams and working group participants discussed three options for treating the survey data to more accurately represent commercial behavior: no treatment, filtering the top 1/3rd of survey stations (based on halibut CPUE within a strata) and a proportional weighting scheme where stations are weighted based on the proportion of commercial effort that occurs in that area (described below). The joint Plan Teams recommended the working group "use the proportional to catch method, which was considered most likely to reflect spatial differences in species composition while sacrificing little survey data compared with the top-third method." (Groundfish Plan Team minutes, September 2010). This proportional method retains more survey stations, broader spatial coverage than the top 1/3rd filter (Figure 2), and may more accurately represent commercial effort.

The main difference between the three treatments is the spatial coverage. Figure 3 shows a hypothetical "area" with survey stations undergoing each of the three treatments. The large square represents a NMFS area, the dots are individual stations within the area. For the "No Filter" treatment all stations are weighted equally (left panel). For the "Top 1/3rd Filter" only 1/3rd of the stations (blue dots) are included in the analysis and these stations tend to be clustered, so that a small set of stations in one part of the NMFS area is used to represent the entire area (center panel). The remaining stations are dropped from the analysis (black dots). For the "Proportional Weight" treatment (right panel), the smaller squares represent ADF&G areas within a NMFS area and the darkest grey boxes are those with the most commercial IFQ landings (lighter grey represents less commercial landings and white is an area with no commercial landings). The stations within each ADF&G area are weighted by the proportion of catch in that area (here the numbers in each square). The station that fell within the ADF&G area with no landings (white box) was dropped from the analysis. This example also highlights a hypothetical area with high landings, but there are no survey stations in that area.

Here we are presenting catch estimates based on the recommended proportional weighting as well as catch estimations made with the full survey data set for comparison. For the "no treatment" method, all of the survey stations are included in the estimation of catch procedures. The "proportional to catch" weighting uses catch (landings) of halibut at the smallest spatial resolution available (ADF&G statistical area, Figure 1, bottom panel) to proportion landings within each larger NMFS area (Figure 1, top panel). Depth was not available at this spatial resolution; therefore, the proportional weights are only stratified by year and area. Because the ADF&G areas are geographically small relative to the larger NMFS area, and the depth bins used in the analysis are large (at least 100 fathoms), there is likely little impact of not stratifying the weights by depth within the ADF&G area. Each survey station within an ADF&G area is assigned the same proportion as the area. All proportions are renormalized by setting all stations within an area with no landings to zero, which results in the weighted proportion for each station. The last step accounts for ADF&G areas that contain survey stations, but have not commercial landings. Note however that this proportional to catch weighting does not account for ADF&G areas where commercial fishing occurs but are not covered by the IPHC survey. Roughly 14% of the commercial catch reported in the ADF&G areas occurred in areas not covered by the IPHC survey (Figure 4). One option to deal with this may be to use a "nearest neighbor" approach to assign survey CPUEs to areas without surveys.

2.3 *Average Weight*

An issue that is enveloped in the catch estimation procedure is the data quality of species-specific average weights that are used for converting numbers to biomass. For the purposes of this report we are not proposing a universal method for calculating species specific average weight; instead, we have attempted to find the best available data for the four example species. Observer data from longline vessels was used to calculated mean weights for three shark species and Pacific cod and were compared between reporting areas, depth strata, and by year to look for significant differences between strata. Strata (year, NMFS area, and depth combinations) were the same as those used on the catch estimation analysis, further comparisons of mean weight between "shallow" (< = 99 fathoms) and "deep" (> 99 fathoms), FMP (BSAI vs. GOA) and regions (BSAI, WGOA, CGOA and EGOA) were also conducted.

The extrapolated weights and numbers used to derive the mean weights are calculated by FMA (North Pacific Observer Program) and take into account sampling fractions for each haul. Mean weights were derived from the extrapolated weights divided by the extrapolated numbers. Data was pulled from the Alaska Region Catch Accounting System, which contains the necessary data fields from the observer database (NORPAC). These weights were taken from all observer hauls and thus do not consider potential observer effects (e.g. the effect of 100% or 30% observer coverage vessels). Further, the majority of this data resulted from observed hauls in the sablefish and Pacific cod fisheries, which may not necessarily reflect fishing attributes associated in the halibut hook-and-line fishery.

For spiny dogfish and Pacific cod, a non-parametric bootstrap was used to compare means, 95 percentile intervals between post strata, and bias. Results from this analysis showed that the year, area, and depth strata resulted in certain stratum having small sample sizes (e.g., 3 sets or less) and are thus not robust to the population caught on hook-an- line gear. Further investigation of alternative data groupings (deep vs. shallow, Western GOA, Central GOA,. Eastern GOA) found fairly robust sample sizes with strata specified by year, FMP, and deep (>99.1 fathoms) vs. shallow (<99.1 fathoms). For both cod and dogfish, weight differences were observed for the depths (Table 1). Thus, this analysis uses mean weights for spiny dogfish and Pacific cod that are stratified by year, FMP, and depth (deep or shallow).

Observer data was not used to estimate weights for salmon sharks and sleeper sharks. The number of samples was very low for both species and the weights collected by observers may not represent the true population of shark bycatch. Further, the larger specimens of these shark species are generally not brought aboard a vessel due to safety and logistical reasons, resulting in smaller sharks in the weighed samples. For both species, mean weights were calculated based on targeted research surveys.

Salmon shark are rarely encountered in federal surveys, especially on longline gear. However, weight data is available from targeted research surveys in Prince William Sound (seine and hook and line gear, Goldman and Musik 2006) and from sport fishery data (S. Meyer pers. comm.). Sport fish data were not used in this case because it is possible that it is biased towards larger animals. Salmon shark are highly migratory and data collected in Prince William Sound may be an appropriate proxy for GOA caught salmon shark.

Weight data on Pacific sleeper shark is difficult to obtain due to the large size of the animal and generally larger individuals are not brought on board to be sampled for safety and logistical reason. In addition, the weight of some specimens may be estimated by the observer or by using proxy weights (for trawl data) are used from RACEBASE. For this analysis weight data collected during a targeted longline survey near Kodiak, in which all sharks were weighed, is assumed to be the best available data for this species and gear type (M. Sigler, unpublished data).

2.4 *Ratio Estimators*

Catch Per Unit Effort Method

Commercial fishery data were used to estimate the number of effective hooks fished. Commercial logbook data were reported by weight (landings), effective skates hauled (skate is defined as 1,800 feet of groundline with 100 hooks), and number of vessels within each year, NMFS area, and depth strata. Fish ticket data were reported by weight and number of vessels by year and NMFS area strata. Logbook coverage provides a view of how effort is proportioned by depth and was used to proportion the fish ticket landings into depth categories. We assumed that fishing gear was universal in that all skates consisted of 100 hooks (Gaichas et al. 2005, Courtney et al. 2006), consistent with the survey, and estimated the number of effective hooks fished from the number of effective skates hauled in each grouped statistical area and depth category. The species specific survey CPUE in each stratum was multiplied by the number of effective hooks in the fishery to estimate the total number of the species of interest caught. Biomass for a species was estimated as the product of the estimated number and the average weight.

Weight Ratio Method

The IPHC stock assessment survey data are used to determine the ratio of the weight of the species of interest to the weight of legal sized halibut by year, NMFS area, and depth strata. The catch (in numbers) of the species of interest observed in 20% of subsampled hooks was extrapolated to the entire set, and a total weight of species of interest is estimated by multiplying the average weight of the species of interest by the number caught on each survey set that occurred in a particular area. The ratio estimator is then the weight of the species of interest to the total weight of legal sized halibut for each stratum. Note that we are using the round weight of the species of interest to the net weight (dressed, head-off) of halibut. However, since these weight ratios are consistent through the calculations, this is not a problem. This weight ratio is then applied to the commercial halibut landings in the same stratum, resulting in bycatch pounds of the species of interest.

3.0 Results and Discussion

Species specific survey average CPUEs were calculated for each year/NMFS area/depth stratum based on the full survey dataset and the proportionally weighted dataset. The CPUE results based on the full survey dataset were used to calculate total estimated survey catch of each species, in numbers, with approximate confidence intervals. The extrapolated total estimated survey catch will be used by all assessment authors in the future as part of accounting for research catch (Table 2).

The survey CPUE results from both datasets and the average weights were used in the procedures described above to estimate total catch of the species of interest by the unobserved halibut fleet (Figure 5). Estimates of catch for Pacific sleeper shark were the greatest of the four species examined (ranging from 3,640 mt to 15,191 mt, depending on method/treatment and year, Table 3). Pacific cod and spiny dogfish catch estimates were similar in range (from 1,858 mt up to 6,464 mt, and 1,746 mt to 5,653 mt, respectively, depending on method/treatment and year, Table 3). Catch estimates for salmon shark were much lower, ranging from 0 mt to 184 mt, and in most catch estimation scenarios the lower confidence bound for the catch estimate included zero, reflecting uncertainty due to rare occurrences (Table 3). For all species catch estimates made using the weight ratio method, regardless of the data treatment, were greater than those made using the CPUE method, although the approximate confidence intervals were overlapping. Likewise, catch estimates based on non-treated survey data were generally greater than those estimates based on treated survey data, but again, the 95% confidence intervals were overlapping, indicating statistical similarity.

The purpose of this analysis was to determine the best method for estimating incidental catch of non-target species. Because no statistical tests were conducted, and data do not exist to ground truth these estimates, the "best" method is to be determined by qualitative means.

1. Should the full survey dataset be used or should the survey data be treated to better represent the commercial fishery?
    a. IPHC annual survey is designed to survey halibut habitat, not fishery areas, thus the survey effort may not reflect commercial effort.
    b. The proportional weighting proposed here attempts to account for commercial effort by spatially weighting each survey station based on the effort that occurs in that area.

   c. It is likely a better spatial representation of commercial effort than both the full survey data set and the top 1/3rd filter used in the IPHC stock assessments.
2. Which catch estimation method is most appropriate?
   a. Each catch estimation procedure has caveats.
      i. CPUE method bases the extrapolation on estimated effective hooks, calculated from fish ticket and log book data for effective skates and landings.
      ii. CPUE method assumes that all effective skates consist of 100 hooks, similar to the IPHC survey design, which may or may not be similar to commercial gear configuration.
      iii. Weight ratio method is based on the actual fish ticket landings, and hence requires no assumptions about gear
      iv. Weight ratio method assumes a biological relationship between the species of interest and halibut. Because the linkages between species are elastic and species specific habitat needs are different, this assumption may be easily violated.
      v. Uncertainty in average weight estimates for rare or difficult to sample species (e.g. salmon and Pacific sleeper sharks) is not taken into account in either method, but the average weight estimates are integral to the weight ratio method, it likely has a greater impact in that method. The CPUE method is not reliant on average weights, except to convert estimated catch to weight if desired.

While the analysis presented in this report provides an estimate for unobserved catch of non-target species in the halibut IFQ fishery, it does not provide information for managers. For species which are reliant on catch history for ABC and OFL specifications (Tier 6), the question still remains of what to do with these catch estimates. The commercial halibut fish ticket and logbook data are not available from IPHC for at least a year after the annual fishing year is over, therefore catch estimates are not available for the current stock assessments or for in-season management. Secondly, the catch estimates produced by these methods do not account for any groundfish that are landed and subsequently subsampled by port samplers. While the Catch Accounting System does calculate estimates of catch for fishing trips deemed a "halibut target", a fishing trip where halibut was the primary species caught, these catch estimates can not be simply subtracted from the total catch estimates produced in this report. These are not questions investigated in this report, but issues that need to be considered by managers.

At the November 2010 Plan Team meeting, Plan Team members requested catch estimates divided by state and federal (or "inside" vs. "outside") waters. The simplest means of approaching this is to separate NMFS areas 659 and 649 from the other NMFS areas. Area 659 was separated in this analysis, however, NFMS area 649 was combined with 640 due to confidentiality. NMFS area 649 could be separated from 640, but no estimates of catch would be available. A more complicated approach would be to create separate catch estimates for all waters within 3 nm, however, this may not be meaningful for all species (e.g. sablefish, where all catch in all areas except for 649 and 659 is managed federally). Also, subdividing out 3nm waters may create more issues with confidentiality and create more areas where catch estimates are not possible.

In summary, the working group recommends moving forward with the CPUE catch estimation procedure and using the proportionally weighted survey data. If this method is approved, catch estimates in numbers should be available for stock assessment authors for the next assessment cycle. The working group prefers to present stock assessment authors with estimated catch in numbers because of the uncertainty in the average weight. This will allow authors to interpret the numbers as best for the individual assessments until a universal method is determined. As additional data sources appropriate to this estimation problem become available, the estimation methods proposed here will be reevaluated, for example, observer data on the IFQ vessels will allow ground truthing of this method for historical catch estimates.

4.0 Sources

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5.0 Tables and Figures

Table 1. Average weight parameters, with upper and lower confidence bounds used in this analysis. For Pacific cod and spiny dogfish n represents the number of sets with observer data and for Pacific sleeper shark and salmon shark n represents the number of animals examined.

		Depth	Avg wt (kg)	LL	UL	n
Pacific cod	2006	<= 99 fa	3.56	3.49	3.64	755
	2006	> 99 fa	2.43	2.05	2.76	8
	2007	<= 99 fa	3.65	3.55	3.73	534
	2007	> 99 fa	2.92	2.72	3.17	23
	2008	<= 99 fa	3.56	3.47	3.66	470
	2008	> 99 fa	2.21	1.95	2.52	12
Spiny dogfish	2006	<= 99 fa	2.67	2.60	2.73	560
	2006	> 99 fa	1.91	1.80	2.04	232
	2007	<= 99 fa	2.59	2.52	2.67	382
	2007	> 99 fa	2.06	1.94	2.20	198
	2008	<= 99 fa	2.52	2.37	2.67	95
	2008	> 99 fa	2.05	1.94	2.16	179
Pacific sleeper shark			79.63	74.32	84.94	186
Salmon shark			146.90			146

Table 2. Summary of extrapolated survey catches (in numbers) in the Gulf of Alaska with the bootstrapped estimate, approximate confidence intervals.

	No Data Treatment		
	Extrapolated Numbers Caught by the IPHC Survey		
		Survey Est	Boot Est
Pacific Cod	1997	23,315	23,458(18,443-30,420)
	1998	27,286	27,407(21,976-34,299)
	1999	19,845	19,753(15,628-24,830)
	2000	24,412	24,457(19,469-31,438)
	2001	14,178	14,199(11,086-18,824)
	2002	19,370	19,573(15,073-25,087)
	2003	28,278	28,453(21,559-38,384)
	2004	24,305	24,312(19,326-31,061)
	2005	25,958	25,937(20,307-33,856)
	2006	21,858	21,847(17,152-28,341)
	2007	21,538	21,682(17,163-27,595)
	2008	25,163	25,265(20,886-31,098)
	2009	46,746	46,770(39,705-55,647)
Spiny Dogfish	1997	13,015	12,806(8,950-18,382)
	1998	39,035	38,505(29,878-50,956)
	1999	17,962	17,578(11,841-27,468)
	2000	24,334	24,441(17,617-34,957)
	2001	30,254	30,208(23,672-38,530)
	2002	18,016	17,971(12,806-25,344)
	2003	62,583	63,191(50,075-80,846)
	2004	41,805	42,842(32,323-56,988)
	2005	40,266	40,351(30,891-54,119)
	2006	38,189	38,416(29,199-50,287)
	2007	31,677	31,749(25,043-39,864)
	2008	22,332	22,633(17,385-30,623)
	2009	27,140	27,406(20,519-37,320)
Salmon Shark	1997	27	28(0-78)
	1998	19	19(0-59)
	1999	5	5(0-15)
	2000	25	29(0-91)
	2001	5	5(0-20)
	2002	5	5(0-15)
	2003	8	8(0-25)
	2004	0	0(0-0)
	2005	0	0(0-0)
	2006	20	20(0-54)
	2007	5	5(0-15)
	2008	1	1(0-3)
	2009	10	10(0-30)
Pacific Sleeper Shark	1997	1,084	1,118(548-2,052)
	1998	3,691	3,757(2,256-6,273)
	1999	3,842	3,947(2,483-6,243)
	2000	4,202	4,296(2,676-6,914)
	2001	3,731	3,815(2,387-5,856)
	2002	3,604	3,666(2,297-5,747)
	2003	5,801	5,880(3,705-9,433)
	2004	4,204	4,318(2,659-7,247)
	2005	3,398	3,477(1,748-6,230)
	2006	2,703	2,780(1524-5159)
	2007	2,034	2,062(1,028-3,802)
	2008	1,595	1,662(836-3,047)
	2009	1,873	1,932(956-4,005)

Table 3. Estimates of catch for each method (CPUE or Weight Ratio) and both data sets (not treated, i.e. full dataset, or proportionally weighted). 95% confidence intervals are in parentheses.

		CPUE		Weight Ratio	
	Year	No Treatment	Proportional	No Treatment	Proportional
Pacific Cod	2006	2,089	1,858	3,434	3,019
		(1,645-2,708)	(1,288-2,703)	(2,700-4,480)	(2,095-4,109)
	2007	2,563	2,114	3,734	3,110
		(2,027-3,308)	(1,293-3,486)	(2,924-4,912)	(1,841-4,782)
	2008	3,540	3,020	6,464	5,441
		(2,995-4,269)	(2,173-4,330)	(5,5448-7,818)	(3,722-7,402)
Spiny Dogfish	2006	3,223	2,888	5,186	4,653
		(2,380-4,491)	(2,044-4,375)	(3,823-7,183)	(3,249-6,471)
	2007	2,991	2,489	5,653	4,794
		(2,281-3,926)	(1,780-3,454)	(4,320-7,302)	(3,503-6,382)
	2008	1,954	1,746	3,480	3,091
		(1,464-2,789)	(1,115-2,875)	(2,615-4,931)	(1,830-4,728)
Salmon Shark	2006	92	61	184	117
		(0-252)	(7-315)	(0-508)	(15-601)
	2007	22	3	34	5
		(0-64)	(0-26)	(0-100)	(0-41)
	2008	8	0	14	0
		(0-24)	(0-0)	(0-42)	(0-0)
Pacific Sleeper Shark	2006	6,238	5,603	10,895	10,257
		(3,027-13,082)	(1,697-13,922)	(4,876-22,799)	(2,660-24,601)
	2007	6,616	4,102	15,191	6,767
		(3,093-12,605)	(1,170-11,897)	(4,672-24,822)	(1,666-19,608)
	2008	4,686	3,640	8,682	6,639
		(2,423-9,050)	(1,263-7,689)	(4,242-16,800)	(1,882-15,154)

Table 4. Estimated catch for each stratum in the Gulf of Alaska using the recommended CPUE method and recommended proportional weighting treatment. 95% confidence intervals are in parentheses and n represents the number of stations within each strata.

Year	Area	Depth (fm)	Pacific Cod		Spiny Dogfish		Salmon Shark		Pacific Sleeper Shark		n
2006	610	0	763	(642-914)	2	(0-5)	56	(8-285)	263	(139-484)	110
		100	24	(3-54)	0	(0-0)	0	(0-0)	258	(0-639)	14
		200	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	1
	620	0	311	(201-431)	78	(22-232)	0	(0-0)	1,770	(705-3997)	98
		100	36	(14-87)	1	(0-3)	0	(0-0)	1,013	(485-2239)	62
	630	0	438	(316-619)	282	(192-455)	0	(0-0)	175	(42-631)	180
		100	71	(31-158)	93	(39-243)	5	(0-30)	353	(87-1337)	50
		200	13	(0-29)	0	(0-0)	0	(0-0)	0	(0-0)	3
	640.649	0	7	(2-20)	295	(220-395)	0	(0-0)	17	(1-71)	56
		100	7	(3-16)	149	(66-286)	0	(0-0)	338	(100-934)	27
		200	0	(0-0)	1	(0-2)	0	(0-0)	601	(2-940)	4
	650	0	23	(3-87)	1,452	(1170-1777)	0	(0-0)	0	(0-0)	72
		100	7	(3-17)	407	(285-598)	0	(0-0)	36	(0-195)	41
		200	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-0)	3
	659	0	90	(27-176)	110	(41-346)	0	(0-0)	11	(0-88)	21
		100	63	(43-90)	16	(6-32)	0	(0-0)	649	(137-1789)	30
		200	4	(0-6)	0	(0-0)	0	(0-0)	120	(0-578)	5
2007	610	0	706	(450-1180)	0	(0-1)	3	(0-26)	472	(188-1320)	112
		100	13	(0-28)	0	(0-1)	0	(0-0)	126	(0-271)	13
	620	0	364	(232-526)	35	(16-65)	0	(0-0)	1,034	(432-2569)	100
		100	81	(35-185)	0	(0-1)	0	(0-0)	415	(105-1070)	60
	630	0	634	(475-866)	476	(339-679)	0	(0-0)	461	(248-959)	178
		100	109	(50-224)	108	(48-238)	0	(0-0)	446	(28-2336)	53
		200	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	4
	640.649	0	3	(1-7)	238	(183-286)	0	(0-0)	16	(0-63)	54
		100	15	(5-40)	148	(87-236)	0	(0-0)	220	(92-520)	29
		200	0	(0-0)	1	(0-1)	0	(0-0)	19	(0-19)	2
	650	0	12	(3-36)	1,056	(839-1242)	0	(0-0)	48	(0-165)	72
		100	19	(6-42)	329	(237-491)	0	(0-0)	74	(0-419)	44
		200	0	(0-0)	6	(0-6)	0	(0-0)	0	(0-0)	3
	659	0	67	(27-172)	70	(25-156)	0	(0-0)	0	(0-0)	21
		100	36	(9-89)	18	(6-43)	0	(0-0)	242	(77-638)	31
		200	56	(0-90)	4	(0-6)	0	(0-0)	529	(0-1549)	4
2008	610	0	1,234	(977-1541)	8	(3-19)	0	(0-0)	43	(0-265)	110
		100	10	(2-20)	1	(0-2)	0	(0-0)	210	(0-522)	14
		200	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	1
	620	0	813	(542-1265)	24	(9-53)	0	(0-0)	706	(182-1617)	97
		100	35	(17-67)	3	(0-11)	0	(0-0)	703	(310-1242)	61
	630	0	719	(539-930)	403	(269-666)	0	(0-0)	154	(61-316)	179
		100	98	(46-248)	56	(21-126)	0	(0-0)	107	(11-453)	50
		200	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	4
	640.649	0	15	(5-42)	153	(109-210)	0	(0-0)	1	(0-8)	54
		100	17	(7-35)	61	(29-148)	0	(0-0)	390	(111-1026)	28
		200	0	(0-2)	1	(0-2)	0	(0-0)	192	(0-483)	5
	650	0	14	(5-54)	609	(449-787)	0	(0-0)	24	(0-97)	69
		100	4	(2-10)	301	(182-467)	0	(0-0)	13	(0-69)	42
		200	0	(0-0)	3	(1-4)	0	(0-0)	0	(0-0)	5
	659	0	36	(17-76)	72	(20-253)	0	(0-0)	14	(0-76)	19
		100	23	(13-41)	46	(21-109)	0	(0-0)	1,075	(588-1661)	32
		200	0	(0-0)	5	(1-18)	0	(0-0)	7	(0-32)	5

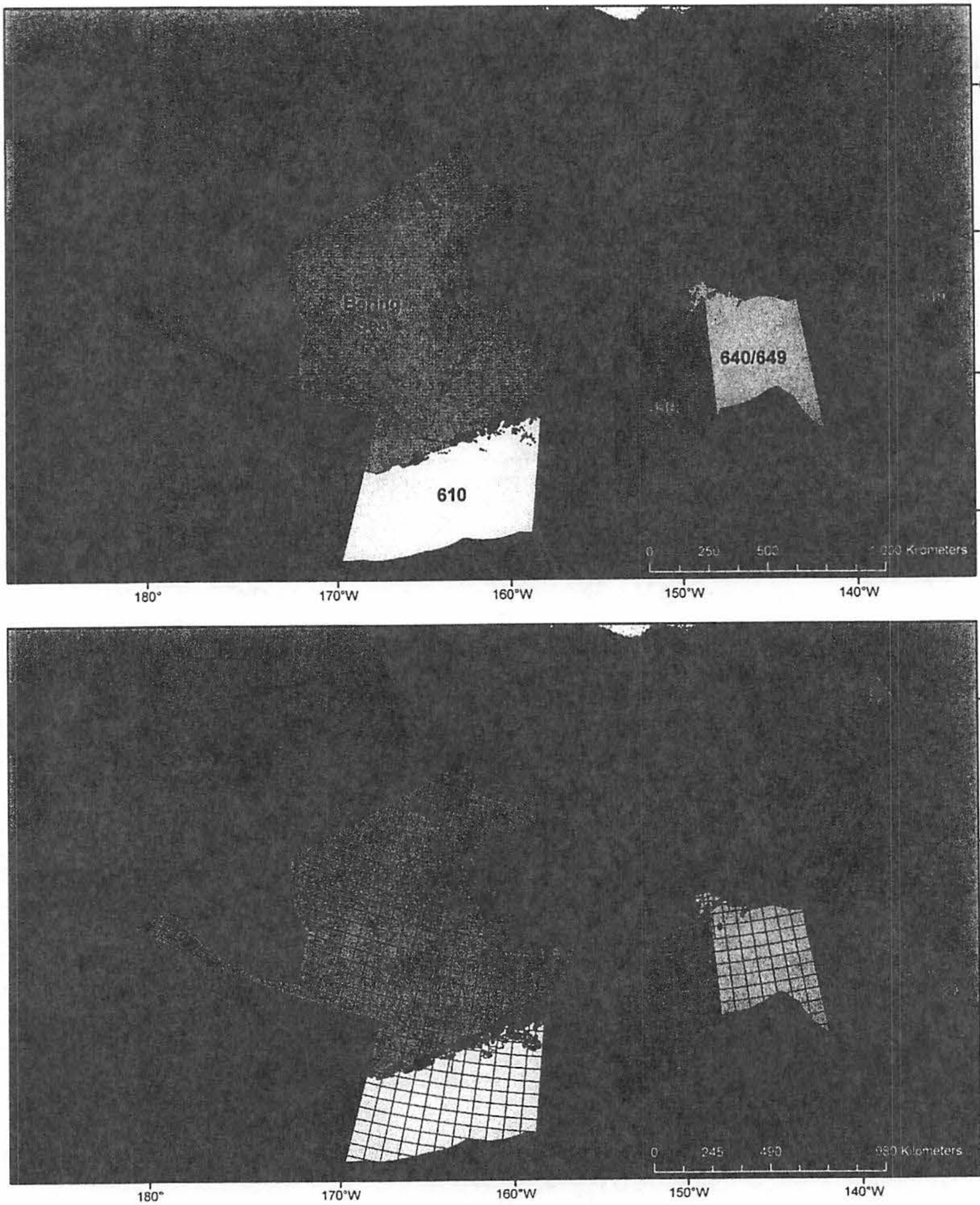


Figure 1. Top: Map of the NMFS area strata used for the estimation of catch. Bottom: Map of the ADF&G statistical areas used for calculating the relative weighting of each survey station. More detailed maps of the ADF&G statistical areas are available at: http://www.cf.adfg.state.ak.us/geninfo/statmaps/charts.php

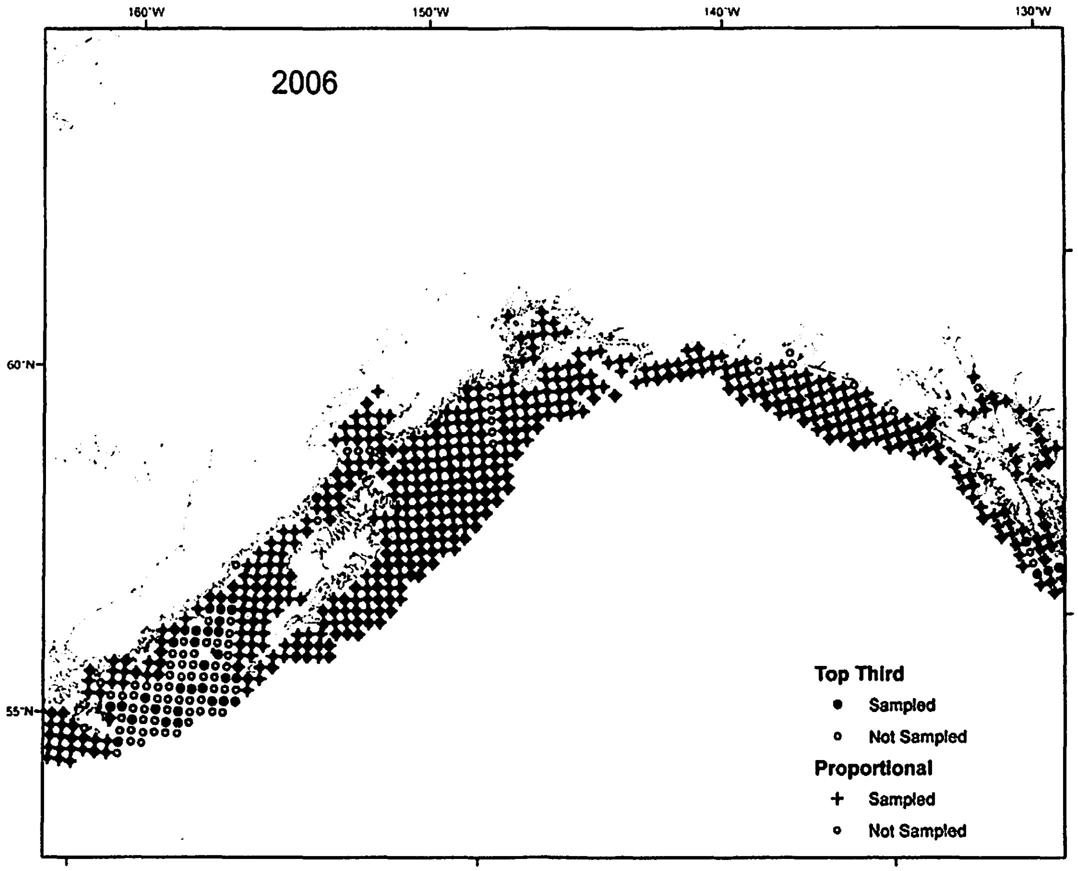
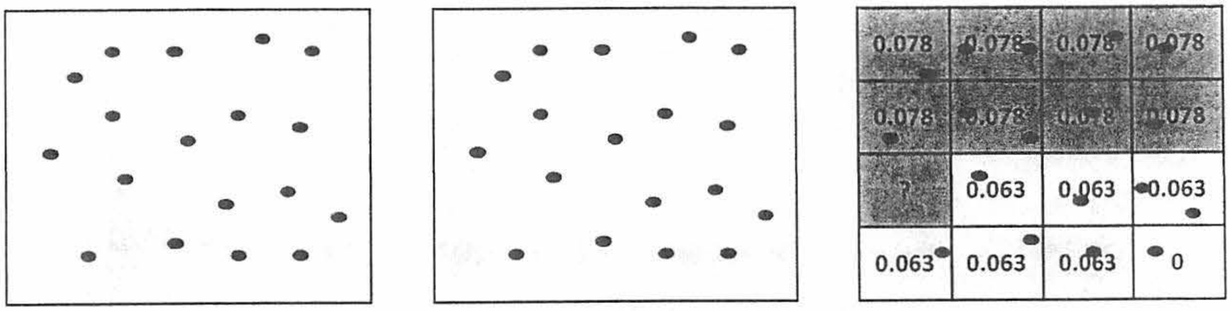


Figure 2. Map of IPHC survey stations (2006 shown here as an example) showing stations that were in the top 1/3rd of stations based on halibut CPUE (red circles) and stations that were given a proportional weight based on commercial effort (black crosses). Stations that were excluded from analysis based on both data treatments are in the open circles.



No Filter — Top 1/3rd Filter — Proportional Weight

Figure 3. Hypothetical representation of each of the data treatments. The large squares represent a NMFS area, the dots are individual stations within the area. Blue dots represent stations in the analysis, black dots are station not included. The smaller squares in the "Proportional Weight" panel represent ADF&G areas and the numbers are the proportional weight applied to the stations within that area.

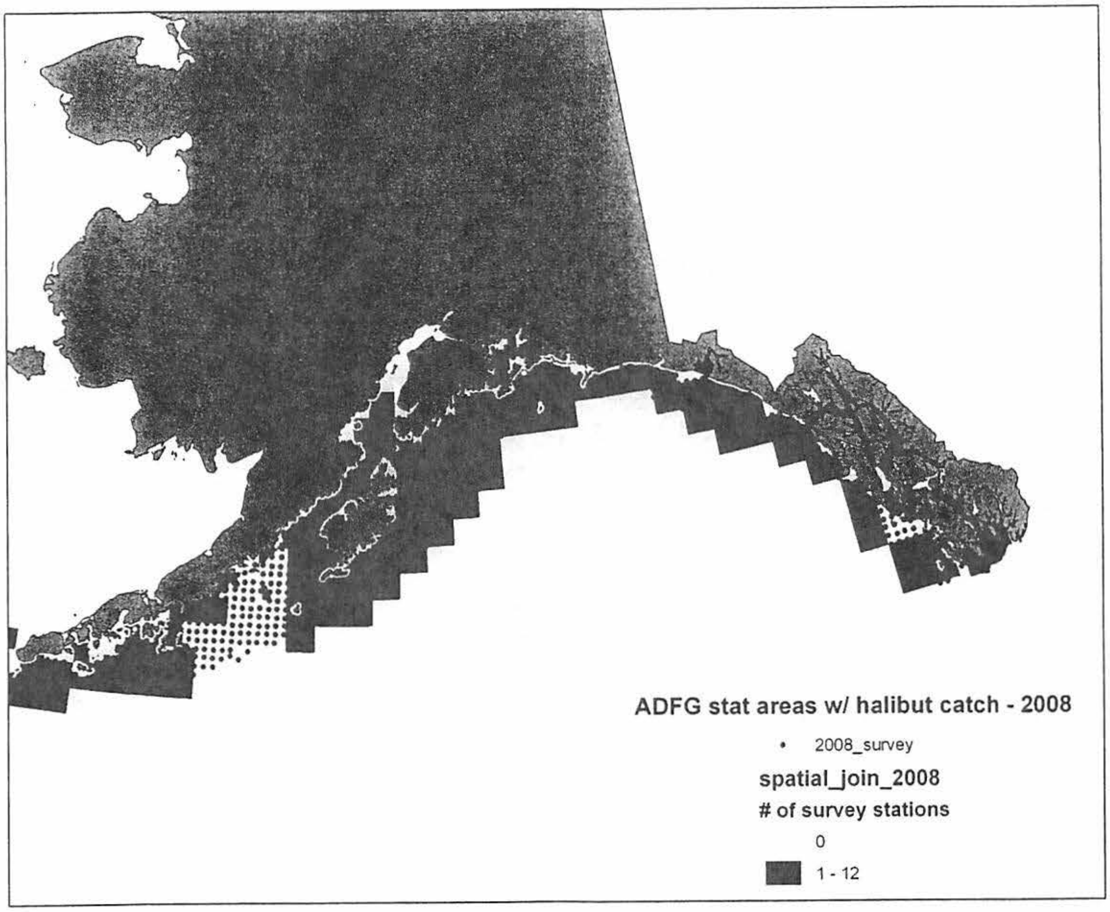


Figure 4. Map of IPHC survey stations and ADF&G areas with commercial catch. Light blue areas are ADF&G areas where commercial halibut landings were reported but that do not overlap the IPHC survey. Dark blue areas are ADF&G areas where commercial landings were reported and do overlap with the IPHC survey.

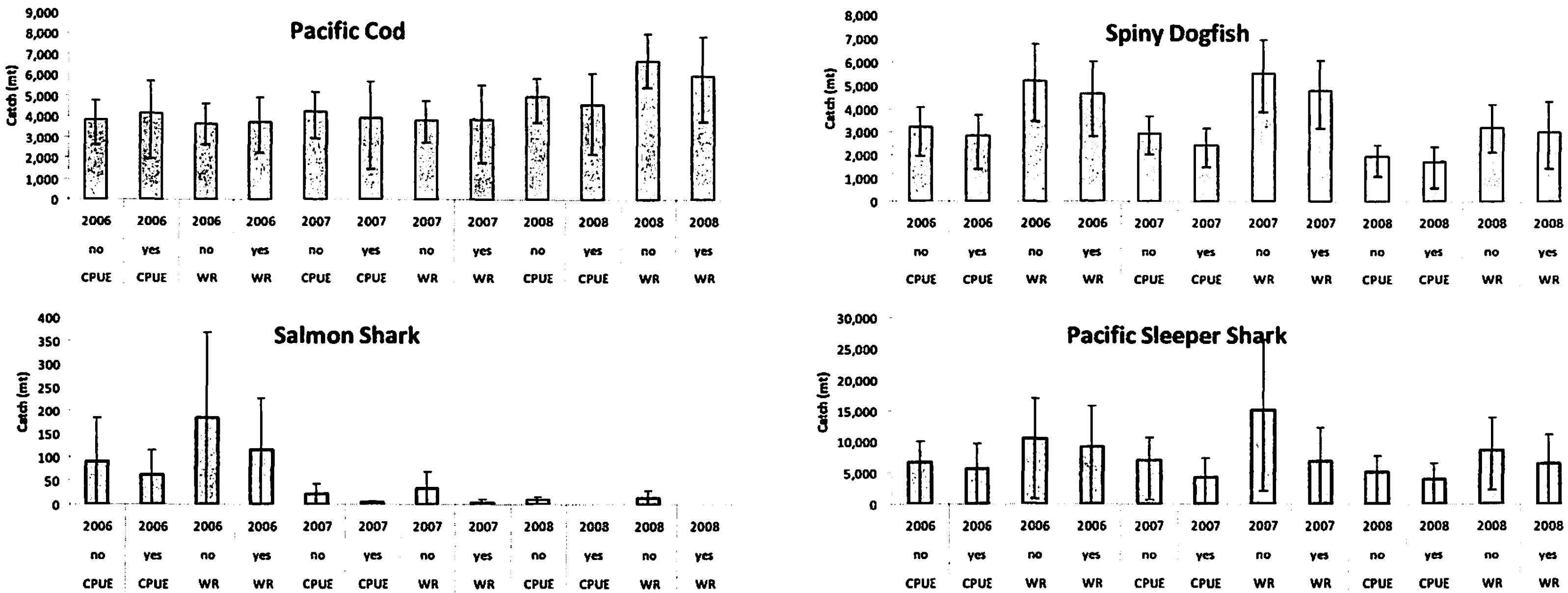


Figure 5. Estimates of catch in metric tons for each of the four example species. Each bar represents a different method/dataset scenario with 95th percentile confidence intervals (based on the CPUE estimates). The x-axis is composed of year, data treatment (no=no treatment, yes=proportionally weighted), and method (CPUE or weight ratio).

Snow crab selectivity by the NMFS trawl survey

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Size or age structured fishery management models typically include functions and parameters describing the processes of growth, natural mortality and survey selectivity. When the time series of catch and survey data used by the model is relatively long and the estimates of growth and natural mortality are well determined, as is true for the most of the major Bering Sea fish stocks, then the estimates of survey selectivity may be confidently estimated as part of the model fitting process. However, for species such as snow crab, that cannot be directly aged, growth and natural mortality are relatively ill determined and, as a consequence, estimates of survey selectivity produced in the model fitting process are potentially biased due to the inherent parametric correlations in the model. In such situations, model outputs could be improved if survey selectivity were set at, or constrained by, selectivity estimates derived from experimental data (Somerton et al. 1999). Here we examine the research leading to and culminating in the 2010 NMFS-BSFRF cooperative study, which focused on the problem of estimating snow crab survey selectivity from experimental data.

To better understand the research approaches that have been taken, it is important to clearly understand the goal. Survey selectivity is considered in the snow crab management model as a size-dependent proportionality between the true population abundance and that estimated by the annual EBS bottom trawl survey using swept area methodology. It is typically described mathematically using a logistic function, with the asymptote or maximum value of this function referred to as "q". In contrast to this, trawl selectivity is the proportion by size of the crabs in the path of the trawl that is actually caught, and, equivalent to survey selectivity, the asymptote of this function can be referred to as "Q". In all of the approaches described here, survey selectivity is estimated from estimates of trawl selectivity, which, in turn, are estimated from data collected using trawl selectivity experiments.

Trawl selectivity experiments can be generally grouped into two categories: 1) bagging experiments, where auxiliary mesh bags are attached to the outside of the trawl to capture animals that have escaped and 2) side by side trawling experiments, where the test trawl is fished simultaneously next to another trawl that is assumed to capture everything in its path (Wileman et al. 1996). Both approaches have been previously applied to the bottom trawl used on the NMFS EBS survey to estimate its selectivity for snow crab.

The first experiment, which was conducted in 1998 using the bagging methodology, obtained an estimate of the crab density in the trawl path by attaching a heavily weighted auxiliary bag under the trawl to capture crab escaping beneath the footrope (Somerton and Otto, 1999). The estimated trawl selectivity function, based on the ratio of the trawl catch to the combined catch of the trawl and the auxiliary bag, was logistic in shape and rose to a maximum of about 0.85. Although this study demonstrated that the NMFS trawl did not capture all snow crab in its path, the estimated trawl selectivity is likely a poor proxy for survey selectivity for two reasons. First, to compensate for the increased catch and drag of the auxiliary bag, tow length was shortened from the standard 30 min to 15 min, and previous research (Somerton et. al 2002) indicated that snow crab CPUE increases when tow length is reduced. Second, the experimental area was moved into shallower, sandier areas where invertebrate bycatch was less and net performance was better. Thus the experimental tows were not conducted exactly like the standard survey tows and the experimental area was not representative of the snow crab survey area but instead was restricted to the shallowest and most southerly part (Fig.1).

The second experiment, which was conducted in 2009 jointly by NMFS and BSFRF using the side-by-side methodology, paired the NMFS survey trawl with a *nephrops* trawl used by BSFRF to conduct experimental crab surveys. However, similar to the bagging experiment, there were also compelling reasons to question the validity of these trawl selectivity estimates as a good proxy for survey selectivity. Again, to compensate for the high bycatch of other invertebrates and debris, NMFS tow duration had to be reduced from the standard 30 minutes to only 5 minutes and the experiment was conducted in a restricted area that was not representative of the entire snow crab distribution (Fig. 1)

The third experiment, which was a synthetic side-by-side experiment, joined together data from the independently conducted 2009 BSFRF and NMFS bottom trawl surveys. The analysis focused on 27 NMFS statistical blocks (Fig. 1) where NMFS conducted a single 30 min tow at the center and BSFRF conducted 4, 5 min tows randomly located within the block perimeter. Although the BSFRF tows differed in both time and location from the NMFS tow, the 4 tows were averaged and used as a proxy for a single side-by-side tow. In addition, because the 27 statistical blocks encompassed a much larger geographic area than the previous two experiments, spatially varying covariates known to influence trawl performance, including depth, sediment size and net spread (Weinberg and Kotwicki 2008; von Szalay and Somerton, 2005), were included as part of the selectivity estimation model. The best model fitted to this data was logistic in form, with a Q of about 0.70, and contained a single covariate, net spread. Although the results from the third experiment, presented at the January 2010 Science and Statistical Committee (SSC) meeting of the North Pacific Fisheries Management Council, were based on standard NMFS survey tows, the non-synchronous nature of the sampling again brought into question the representativeness of the results as a proxy for survey selectivity. Despite this shortcoming, this modeling effort clearly demonstrated that trawl selectivity for snow crab varies spatially and that, to obtain an unbiased estimate, sampling must be conducted at stations covering a broad geographic range that representatively samples the variety of conditions occurring in the survey area.

Based on this knowledge, during the 2010 NMFS bottom trawl survey, NMFS and BSFRF again jointly conducted side-by-side towing, but unlike all previous experiments, sampling occurred over a broad geographic area in order to capture the biological and environmental variability of the snow crab population. The results of this experiment are the focus of this report.

Methods

Side-by-side trawling was conducted at 92 standard NMFS stations (Fig. 2) chosen to best represent the size distribution of male snow crab (Fig. 3) as well as to capture the variability of depth and sediment type within the area occupied by the snow crab population (Fig. 4).

At each of the 92 locations, the NMFS and BSFRF vessels started towing simultaneously on parallel courses that were roughly 0.1-0.2 nm apart. The NMFS vessel towed the standard survey trawl at 3 knots for 30 min while the BSFRF vessel towed the *nephrops* trawl at 2 knots for 5 min. On both vessels the snow crab catch was separated by sex then sub-sampled, if the catches were larger than 300 individuals in the aggregate, before measurement of carapace width in mm. Since the NMFS trawl sampled almost 7 times more area than the BSFRF trawl, the catches were much larger and therefore the sub-sampling proportion was typically lower. In addition, at all NMFS survey stations where snow crab were caught, depth and net width were measured at the time of sampling and the sediment type, expressed in units of phi (-log of grain diameter), was later interpolated from the AFSC EBS sediment database.

A statistical model relating the paired catches from the two trawls as a function of sex, carapace width and the spatial covariates was determined as follows (a detailed mathematical development is provided in the appendix). Unlike the 2009 study (an unpublished manuscript presented at the January 2010 SSC meeting), where the catches were expressed as the catch ratio (i.e., $\frac{C_{nmfs}}{C_{bsfrf}}$), this study expressed the catches as the catch proportion (i.e. $\frac{C_{nmfs}}{C_{bsfrf} + C_{nmfs}}$), which is consistent with the standard approach used by the International Council for the Exploration of the Sea (ICES) working groups (Wileman et al 1996). One particularly important advantage of doing this is that the data from size intervals in which $C_{bsfrf} = 0$ are unusable for calculating catch ratios but are acceptable for catch proportions. To minimize the number of size intervals where this was an issue, interval size was increased (10 mm for males and 5 mm for females) and size intervals larger than a cutoff size (125 mm for males and 70 mm for females) were pooled together. In addition, since extremely small crabs may not have been completely separated from the catch, data from sizes < 25 mm were ignored. Also consistent with the ICES methodology, the error structure was modeled as a binomial rather than a normal random variable, as in the 2009 report, using the number of crabs measured by each vessel. However, departing from the ICES methodology, the underlying model structure was not a logistic function of size, but instead was a nonparametric smooth function estimated using Generalized Additive Modeling (GAM). Methodology for inclusion of the spatial covariates into the model was similar to the 2009 study, where the variables depth, sediment size, and net width were added individually until the model with the lowest value of the Akaike Information Criterion (AIC; Burnam and Anderson 1998) was determined. This procedure was repeated for the addition of other covariates, either singly or jointly, until the overall minimum AIC was achieved. As described in the Appendix, once an acceptable model of the catch proportion was achieved, the catch proportion was then transformed back to trawl selectivity.

This analysis produced a trawl selection function. To obtain a survey selection function appropriate for the snow crab population, this trawl selection function was evaluated at and averaged over the 275 NMFS trawl stations having a catch of at least one individual snow crab. For each of these stations, trawl selectivity was predicted for each size interval utilizing the measured depth and predicted sediment size. The selectivity in each size interval was then averaged over all stations using weights equal to the product of the catch and the size of the sampling block (standard station blocks have an area of 400 sq nm, but stations within the two high density sampling strata (Fig. 2) have a smaller area).

Precision of these estimates of survey selectivity as a function of size were estimated using bootstrapping, which is a method intended to mimic replication of the side-by-side experiment. This was done as follows: 1) the experimental data was re-sampled by choosing 92 stations, with replacement (a single station can be chosen more than once or not at all). Since this might result in samples that are geographically concentrated and unrepresentative of a true replication of the experiment, the 92 stations were grouped into 4 geographic quadrants, and the re-sampling was restricted to the stations in each quadrant (this technique is called block bootstrapping); 2) analysis of each bootstrap sample proceeded as describe above, however the model form and the specific covariates included were maintained as in the original model; 3) bootstrap re-sampling and data analysis were repeated 100 times and the approximate empirical 95% confidence intervals were determined for each 1 cm size interval as the 3rd and the 97th elements of the sorted array. The upper and lower bounds of all intervals were then smoothed as a function of size.

Results

Based on the catches of the NMFS survey vessel at the 92 experimental stations, the carapace width frequency distribution in the experimental area was dominated by an extremely high abundance of both sexes near 45 mm (Fig. 5). For both sexes, few large individuals were encountered and males >125 mm and females >70 mm were extremely rare and patchily distributed.

The best fitting model describing trawl selectivity (proportion captured) included a smooth function of width and a smooth bivariate function of sediment size and depth (for males; R^2=0.94, n=824). For males, proportion captured, when averaged by width, rapidly rises to a relative peak near 45 mm, slowly rises from this size to about 100 mm, and thereafter rises sharply (Fig. 6). For females, proportion captured again rapidly rises to a maximum near 55 mm, then decreases slightly at larger sizes. Over the size range 45-70 mm, the estimated proportion captured was greater for females than for males, which was consistent with the 2009 study. These patterns of change with increasing size were clearly not a logistic function in shape and therefore required the use of a non-parametric smooth function. When evaluated at the range extremes of sediment size, the capture proportion for males is higher in sand and lower in mud (Fig.7); when evaluated similarly for depth, the capture proportion is higher in shallow water and lower in deeper water.

Survey selectivity for both sexes varies with size in a pattern similar to trawl selectivity. The uncertainty of the survey selectivity estimates (Fig. 8) increased with size as the abundance of each sex declined. For males, this resulted in an increasing spread of the 95% confidence intervals starting at about 100 mm, while for females, the increase started at about 50 mm. For both sexes the uncertainty at the largest modeled size (males, 125 mm; females, 70 mm) was quite high due to the high incidence of catch proportions based on the combined catch of only a single crab.

Discussion

The survey selectivity function was calculated as a weighted average of a spatially varying trawl selectivity function over the entire portion of the survey inhabited by snow crab. One question is whether this spatial extrapolation and averaging made a difference or could the trawl selection function itself be used as a reasonable proxy for the survey selection function? Both of these functions are plotted together in Fig. 9. For males, the two functions are very similar because one of the criteria for choosing the experimental stations was that the male size distribution at these stations was a good representation of the population size distribution. However, for females, the two functions are quite different because of the decision to optimize the choice of stations for males. From this perspective, it is clear that the results of the 1998 bagging experiment and the 2009 NMFS-BSFRF side-by-side experiments, which both occurred in limited geographic areas, likely represent poor proxies for survey selection (Fig. 1).

The spatial variability in the trawl selection function is related to the spatial variability in the geometry of the trawl. We believe that the most important dimension is the distance between the footrope and the sea floor (Weinberg and Kotwicki, 2008), because video observations have indicated that most snow crab escape capture by passing under the footrope. Several studies have been conducted on how this distance varies under a variety of environmental conditions, but for the two covariates shown to be significant in this study (depth and sediment size) it has been found that footrope distance off bottom increases with depth (vonSzalay and Somerton 2005) and with decreasing sediment particle size (increasing phi; Weinberg and Kotwicki 2008). Since these attributes have distinct spatial patterns over the snow crab distribution (Fig. 4), such variation leads to variation in trawl selectivity.

This variability in trawl selectivity interacts with the spatial variability in snow crab distribution to produce the survey selectivity. Both sexes of snow crab undergo an ontogenetic migration which is generally southward in direction (Fig. 3). For males (except for the largest sizes which likely perform a seasonal migration), this migration takes them into progressively deeper water with a sandier bottom type (Fig. 10). Thus, for snow crab, trawl selectivity not only varies with size because small animals escape more readily under the footrope but also because selectivity varies with habitat type and the preferred habitat of snow crab changes with time over their lifespan.

The survey selectivity function proposed here is not logistic, but instead is a non-parametric smooth function of carapace width. Use of a smooth function is not new, because other studies on trawl selectivity (Lauth et al. 2004; Skalski and Perez-Comas, 1993) have also found that non-parametric functions described the selection data better than a logistic function. Furthermore, the use of a logistic function to describe survey selection rests on a very weak theoretical foundation. An early and still common use of the logistic function in fisheries is to describe the retention of fish of varying sizes trying to pass through a panel of webbing (Wileman et al 1996), where the smallest individuals may all pass through while the largest may all be retained. The logistic function can still be useful for describing selection by an entire trawl, where size selective processes such as herding and avoidance may be even more important than mesh selection in determining the size distribution of the retained catch. However, it was such "whole trawl" selectivity studies that departures from logistic form were recognized (Lauth et al. 2004; Skalski and Perez-Comas, 1993). Survey selectivity is still more complicated because, as in the case of snow crab, trawl selectivity varies spatially as well as by size. With each stage of increasing complexity from mesh selectivity to survey selectivity the theoretical foundation for the use of the logistic function diminishes. It is true that, if scaled correctly, survey selectivity is a proportion, however it does not necessarily follow that its dependency on animal size is strictly logistic in shape.

Although a smooth function describes the selectivity data better than a logistic function, there are two distinct drawbacks to its use. First, few large crabs were sampled during the 2010 side-by-side experiment, consequently there were few data to define the selection at large sizes. When a more rigid function (i.e. less parameters) like the logistic is used to describe the data, the estimated selection values at large sizes are influenced by the values at smaller sizes. However, when a smooth function is used the estimated selection values are determined only by the available data at large sizes. This aspect, along with the low number of large crabs and their patchy distribution, jointly contribute to the high uncertainty of the selectivity estimates at large size.

The second drawback is that nearly every fishery management model used at the AFSC, including the snow crab model, uses one of the various forms of the logistic function, perhaps because of its mathematical and computational convenience compared to a smooth function. A smooth function does not have a parameter equivalent to "q" of the logistic, which has received so much attention by both assessment modelers and the fishing community. In addition, moving from a parametric to a non-parametric representation of the selection process may require considerable work on model re-development, especially on how the uncertainty associated with the proposed survey selection function could be used in a Bayesian framework to constrain model estimates of survey selectivity.

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Figure 1. Location of the 2009 joint NMFS-BSFRF side-by-side trawling experiment (shown with pink shading); locations the 3 BSFRF survey areas encompassing the 27 NMFS survey blocks (shown with a red line); and locations of the 1998 auxiliary bag experiment sampling areas (blue circles).

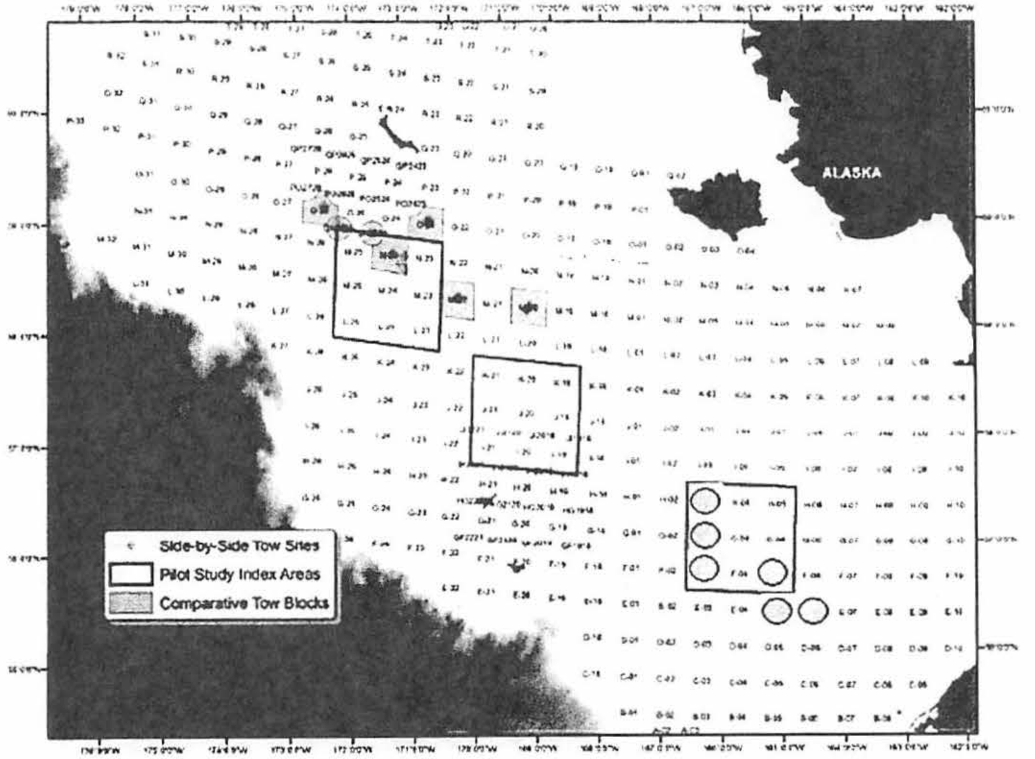


Figure 2. Locations of the sampling sites where NMFS and BSFRF jointly conducted side-by-side towing during the 2010 EBS bottom trawl survey.

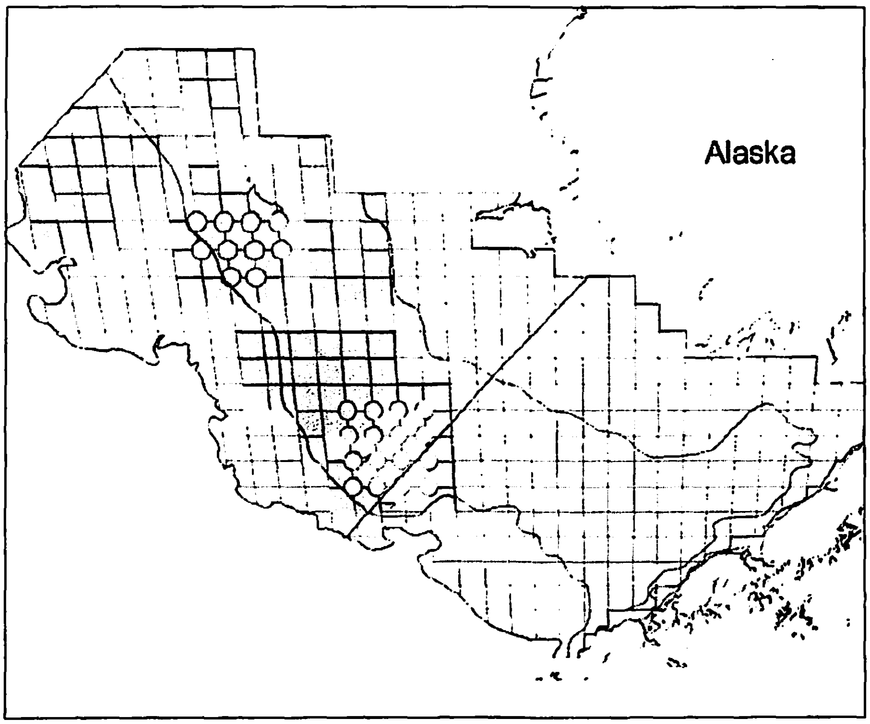


Figure 3. Distribution of large and small size classes of both sexes of snow crab and the sampling grid used on the 2010 side-by-side experiment. Note that for both sexes, there is southward movement into deeper water over their life spans.

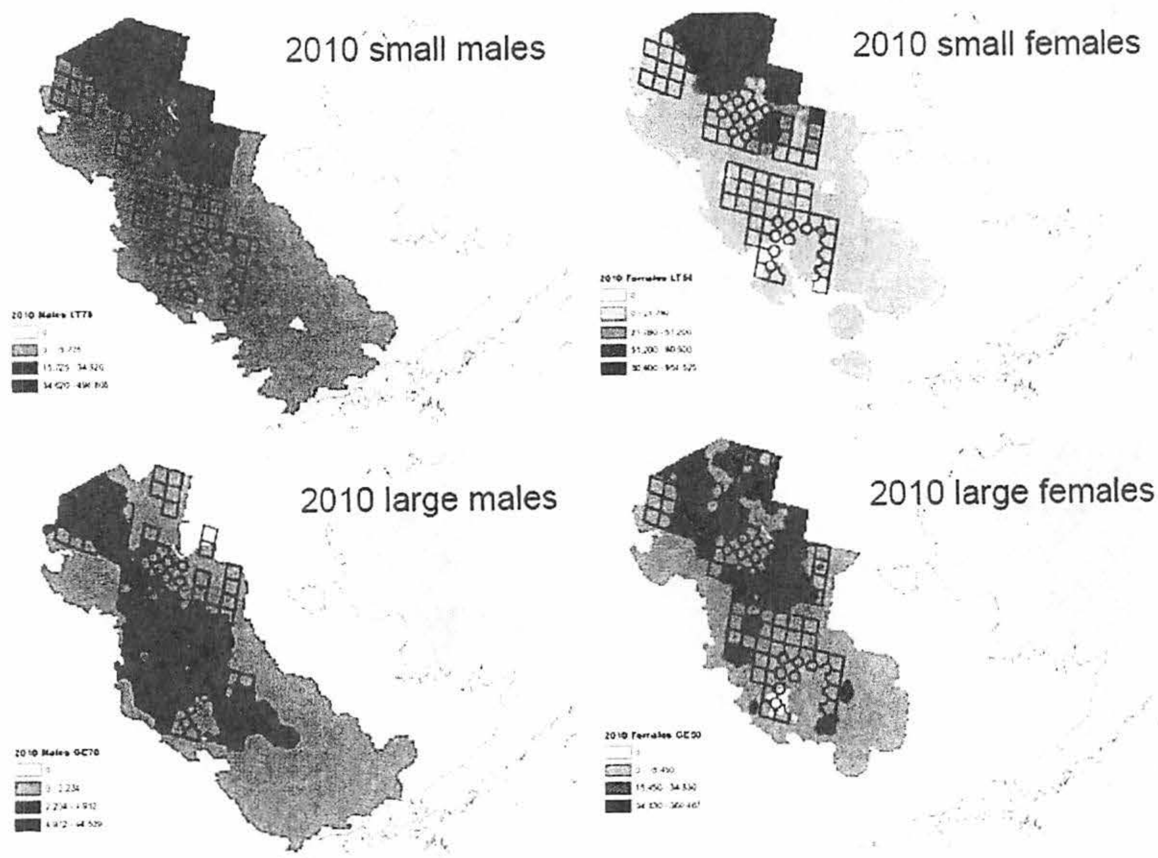


Figure 4. Depth and sediment size distributions in the EBS are shown along with the 2010 NMFS-BSFRF side-by-side sampling stations.

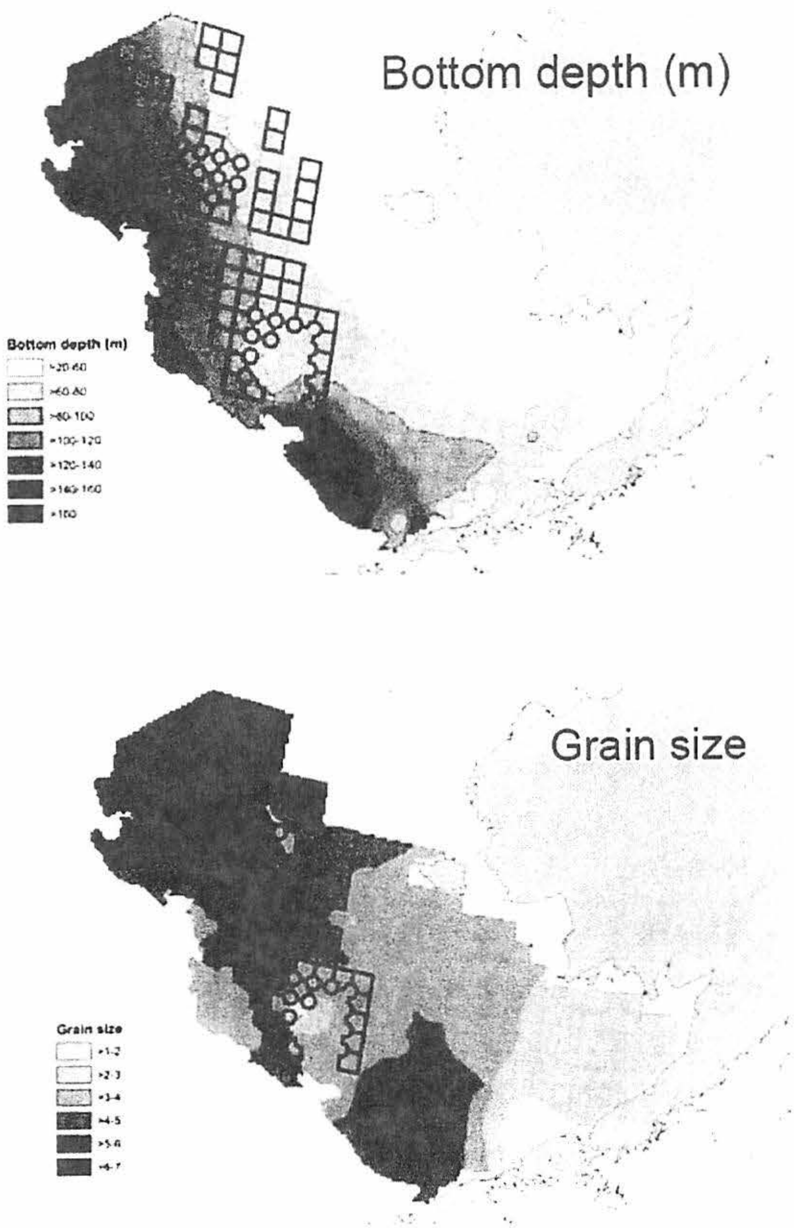
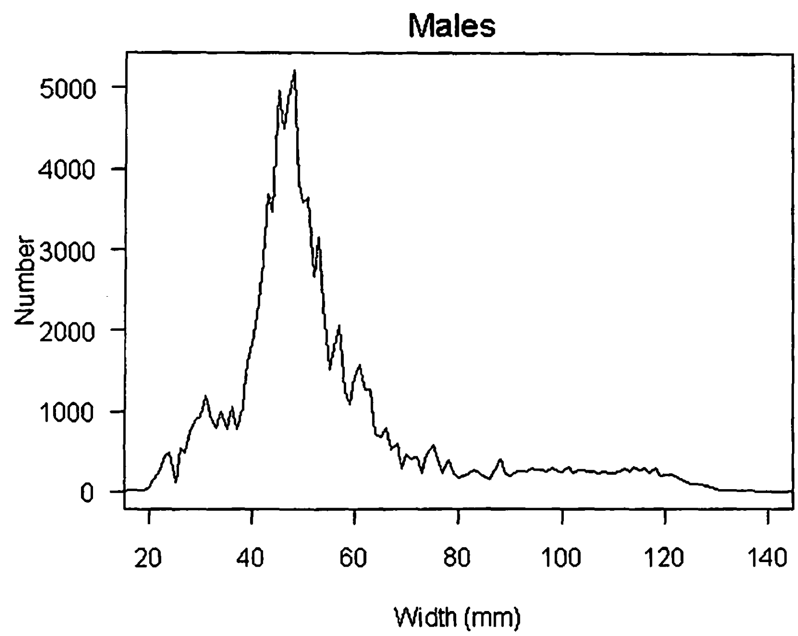


Figure 5. The carapace width frequency distribution of the crabs sampled aboard the NMFS vessel during the NMFS-BSFRF experiment.



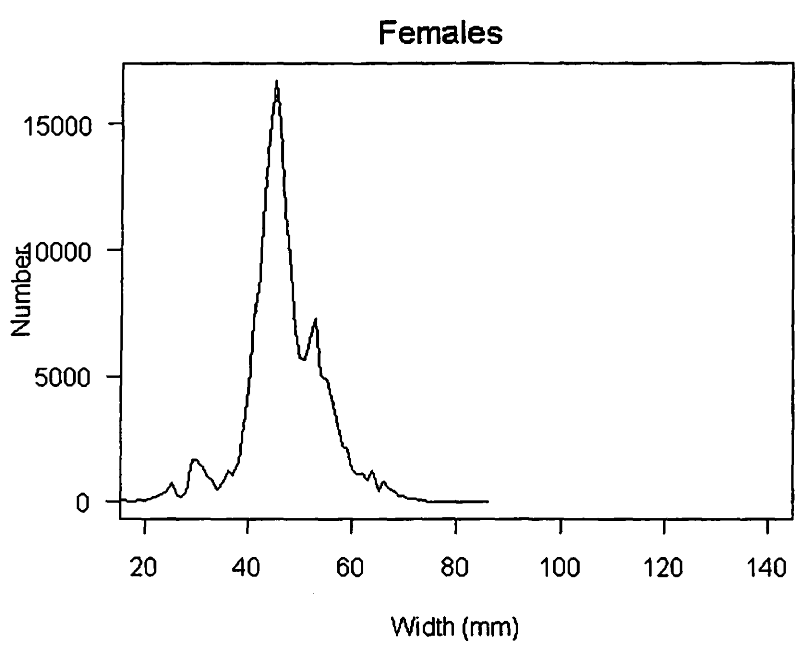


Figure 6. Trawl selectivity functions for males (black line) and female (blue line) snow crab.

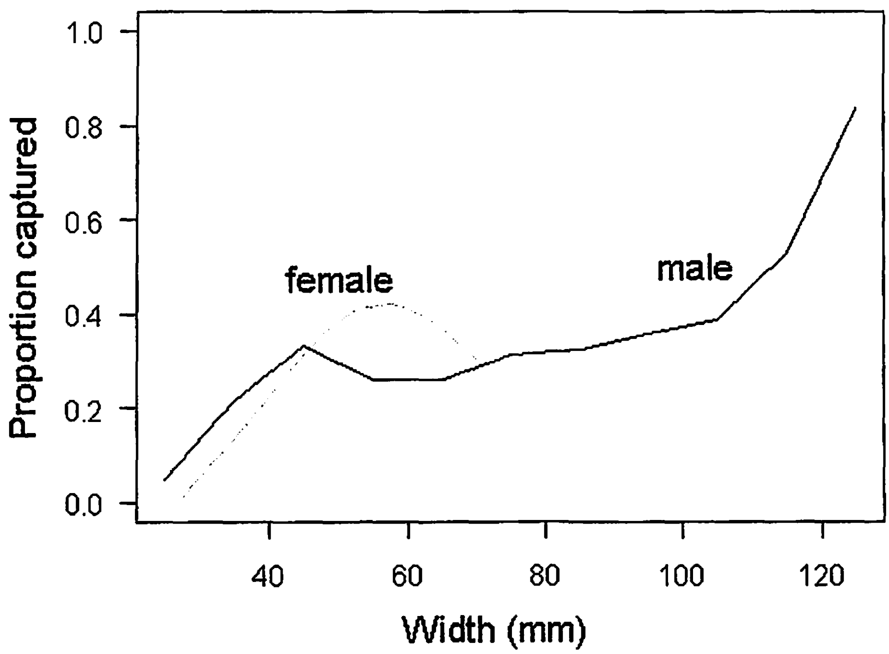


Figure 7. Trawl selection function evaluated at the extremes of sediment size and depth.

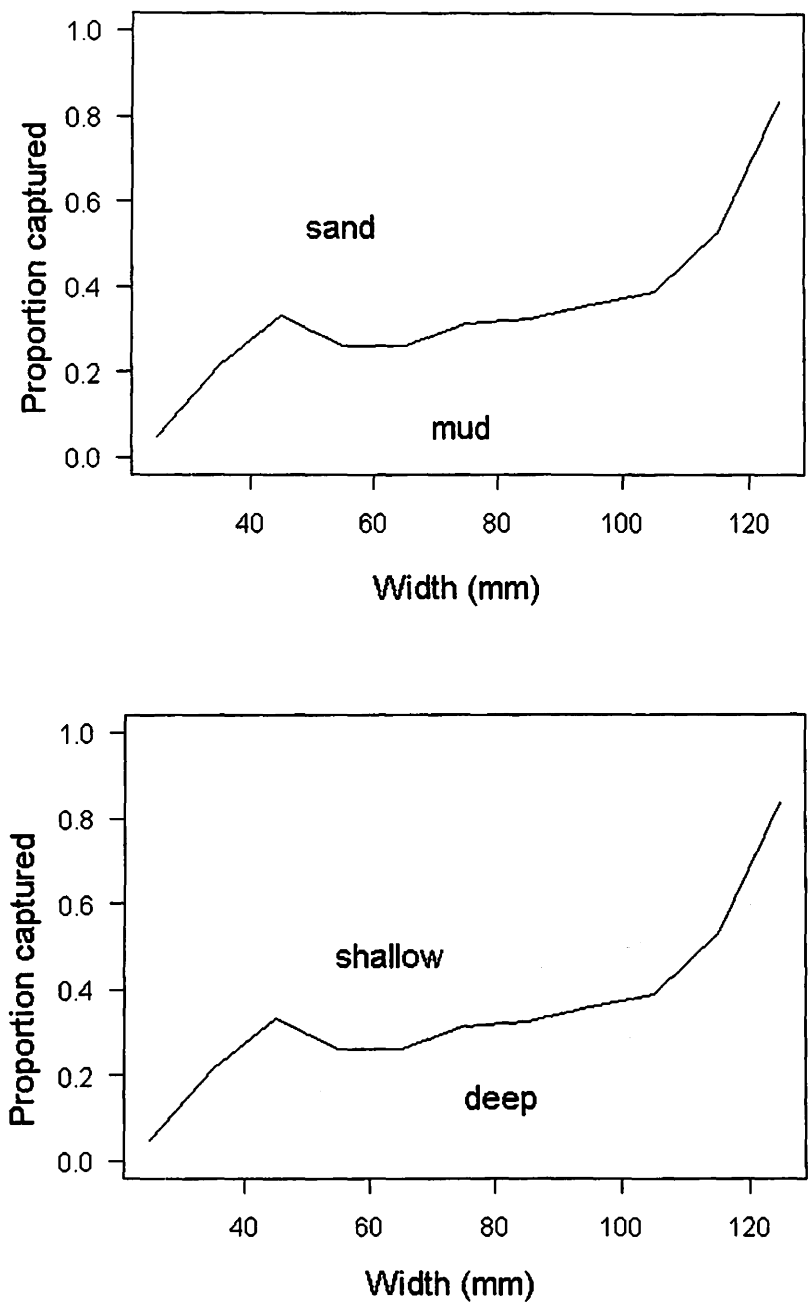


Figure 8. Survey selection function, including approximate 95% empirical confidence limits.

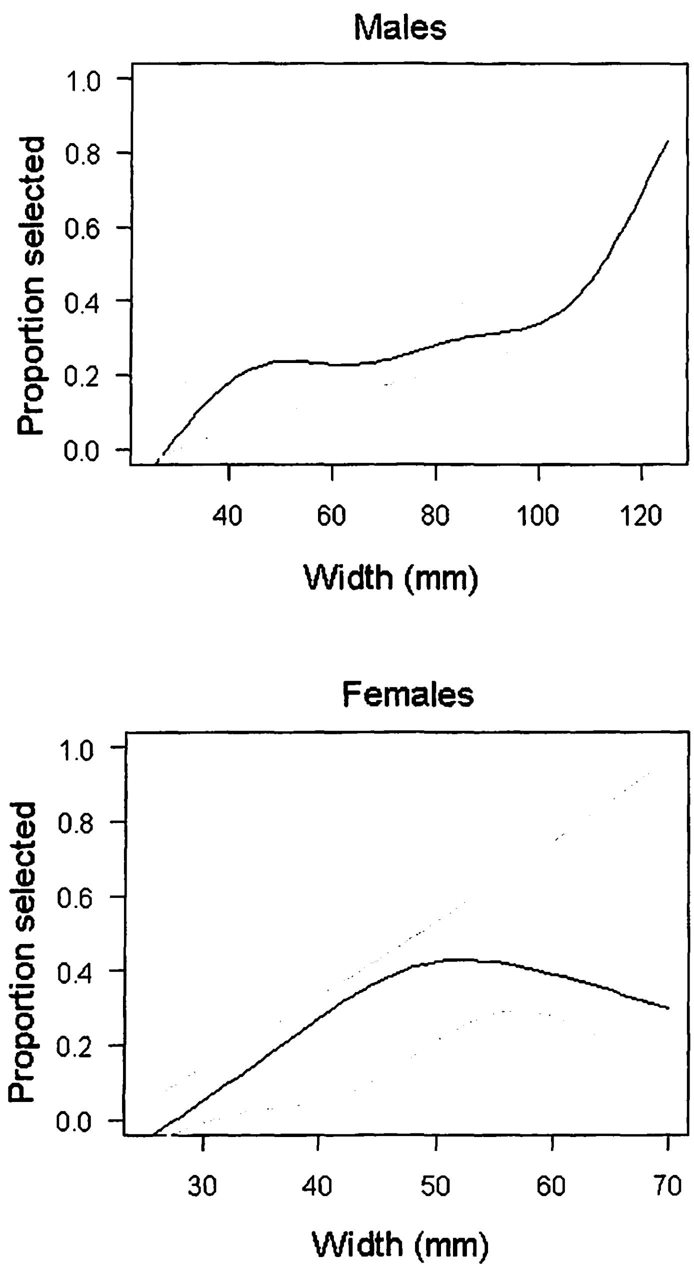


Figure 9. The survey selectivity (black line and circles) evaluated over the 275 positive snow crab stations and the trawl selectivity (blue line) evaluated over the 92 stations where the NMFS-BSFRF side by size trawling was conducted.

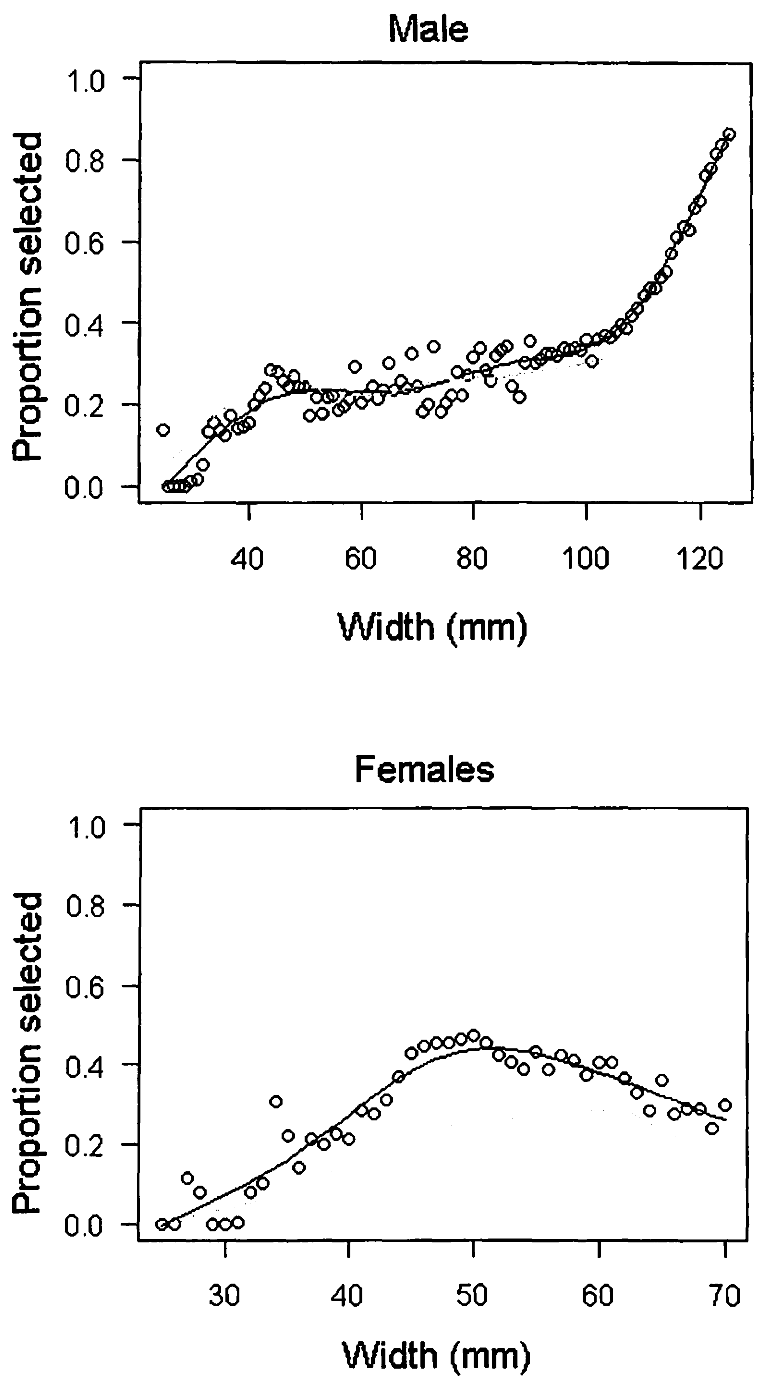
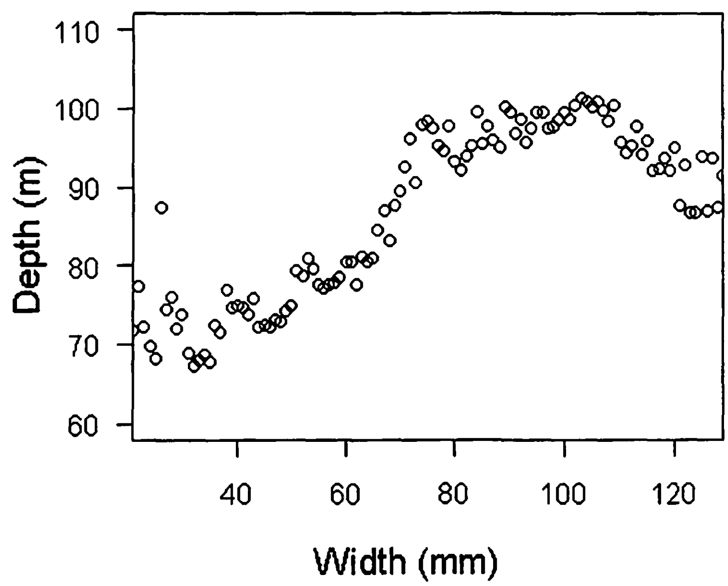
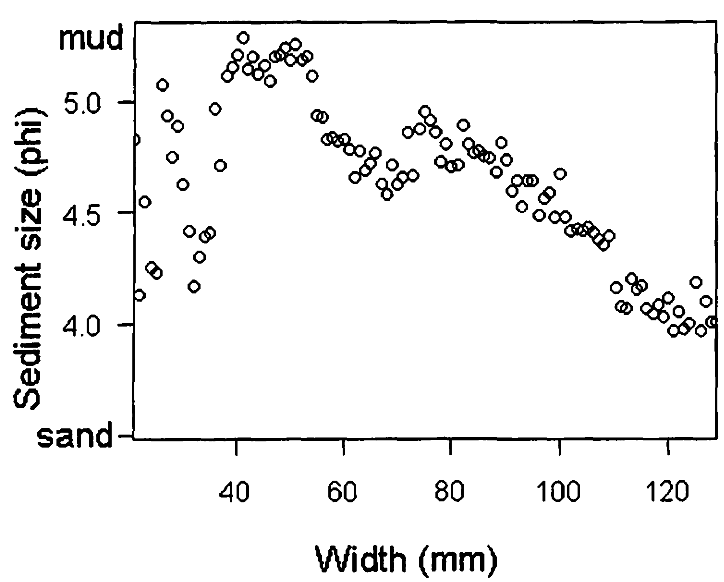


Figure 10. Mean depth and sediment size (in phi units) for male snow crab as a function of carapace width from the 2010 EBS survey.





Appendix 1. Development of the trawl selectivity model.

Assuming the that BSFRF *nephrops* trawl catches all crabs in the tow path, then the interpretation of the catch ratio (i.e., $\frac{C_{nmfs}}{C_{bsfrf}}$) as an estimator of the selectivity of the NMFS trawl is perfectly clear. However the weakness of this estimator, is that it is undefined when $C_{bsfrf}=0$, and simply discarding all cases where this is true will lead to biased estimates. In response to this frequent problem, ICES working groups (Wileman et al., 1996; Millar 1992) developed an alternate estimator which is statistically conditioned on the combined catch in a size interval, that is, the catch proportion (i.e. $\frac{C_{nmfs}}{C_{nmfs}+C_{bsfrf}}$). Since this is not as intuitive as the catch ratio, we will develop the concepts behind its use here. Consider first a situation where the NMFS and BSFRF trawls have identical swept areas and that all crabs were measured without sub-sampling. Also consider all of the crabs in the combined swept area as pooled together, and let the proportion of these that were in the path of the NMFS trawl be equal to P. In the case of equal swept area, then P is on average = 0.5. Further, let the selectivity of the BSFRF trawl =1 and that of the NMFS trawl = r. Combining all of this together leads to the relationship:

$$\frac{C_{nmfs}}{C_{nmfs}+C_{bsfrf}}=\frac{P\,r}{P\,r+(1-P)}=\frac{r}{r+1}$$

When the swept areas (A) are not identical, then:

$$P=\frac{A_{nmfs}}{A_{nmfs}+A_{bsfrf}}\quad ,$$

In addition, when the sub-sampling proportion (S) also differs between vessels (Millar, 1994), then:

$$R=\frac{S_{bsfrf}}{S_{nmfs}}\text{, and}$$

$$\frac{C_{nmfs}}{C_{nmfs} + C_{bsfrf}} = \frac{r}{r + R\frac{A_{bsfrf}}{A_{nmfs}}} .$$

Letting $\Phi = \frac{C_{nmfs}}{C_{nmfs} + C_{bsfrf}}$, then the estimation function is:

$$\Phi = S(width) + S(X)$$

Where S represents some nonparametric smooth function and X includes one or more of the covariates depth, sediment and net width. This equation is fit to the catch proportions for each width interval for each paired tow using GAM, with binomial error. Binomial, rather than Normal, error was used because Φ is a proportion and often has the value of 1 or 0 (this invalidates the use of the Normal approximation to the Binomial distribution). The trawl selection function is then obtained by back transformation:

$$r = \frac{\Phi R \frac{A_{bsfrf}}{A_{nmfs}}}{1 - \Phi} .$$

April 2010 NPFMC motion on ACL II Discussion Paper

1. Request the SSC to discuss potential of developing new methods for determining ACLs for Tier 6 stocks on June 2010 agenda. This may result in a Summer 2010 Work Shop with Groundfish Plan Team members and Tier 6 assessment authors.
2. Task staff with development of a discussion paper on the following topics:
   - For stocks in the fishery:
     - Discuss how species could be apportioned to particular targets/gears as is done with PSC (a 'skeleton' framework for apportionments with actual numbers determined in the annual specification process)
     - Update Smoker and Miller (cite) that includes spatial and seasonal analysis, along with potential impacts on directed fisheries, and including tables of the data along with graphical interpretations;
     - Effects of moving grenadiers in the fishery by FMP area;
     - General discussion of discard mortality rates (DMR), with focus on sharks and octopus examples. Include discussion of effect of retention requirements (GRS) on mortality.
     - Description of Agency authority to control catch to prevent large closures (e.g., area-specific closures, careful release programs)
     - Discussion of effect of unobserved/poorly observed fisheries on determination of total catch accounting and the effects of extrapolation of observed fisheries
     - Brief discussion of data needs to move stocks from Tier 6 to Tier 5
   - For stocks in the EC category:
     - Effects of managing squids and/or octopus (compared to status quo);
     - Effects of managing grenadiers (compared to status quo or in the fishery) by FMP area;
     - General discussion of current NMFS management authority for EC species (specific issues include 1) processing limits, 2) how to define EC criteria of "not generally retained," 3) MRAs, 4) DMRs, 5) mandatory review of species, and 6) frequency of vulnerability analyses;
     - General discussion of management implications for total catch accounting (e.g., observer program) for stocks moved into the EC category

The following is a brief overview of octopus management in state waters and our understanding of octopus management in federal waters. Contributions from Alaska Department of Fish & Game (ADF&G) staff in Southeast, Prince William Sound, Cook Inlet, Kodiak, Chignik, South Alaska Peninsula and BSAI management areas, May 2008.

National Marine Fisheries Service (NMFS) classifies octopus as a groundfish in federal waters, whereas the state of Alaska classifies octopus as a miscellaneous shellfish in state waters. Different classification by state and federal management systems results in fishery management that is not coordinated for this transboundary species.

State Waters

Directed fishing for octopus in state waters may occur only by commissioner's permit (5 AAC 38.062) and requires a Commercial Fisheries Entry Commission (CFEC) interim use permit card for octopus. The commissioner's permit allows ADF&G to stipulate harvest location and duration, limit gear and other harvest procedures, and require periodic or annual reporting. Commissioner's-permit terms are crafted to structure fishing so that ADF&G may gather CPUE, distribution and other biological data with gear restrictions designed to reduce crab and fish bycatch. Harvests are closely monitored through catch reporting and biological catch sampling. In Westward Region, during recent years only several vessel operators have requested this permit and harvests have been very limited. In Prince William Sound no permits have been issued in recent years. Cook Inlet is closed to directed fishing; octopus may only be retained as bycatch. In Southeast Alaska, in the 1980s, permits were issued for exploratory fisheries using lair pots but catch was insignificant. Since 2000, two permit requests in Southeast Alaska for a directed octopus fishery were denied since ADF&G has no funding or program in place to sustainably manage a directed octopus fishery. In all management areas there are no preseason harvest levels established for octopus, or survey or biomass information.

Retention of octopus bycatch in other directed fisheries within state waters is allowed (this would include parallel groundfish fisheries). In most management areas bycatch is allowed at 20%, however in the Southeast Alaska pot shrimp fishery octopus bycatch is limited by permit to 5% of the total converted whole weight of shrimp on board the fishing vessel. In Southeast Alaska a commissioner's permit is required for retaining octopus bycatch, however the bycatch is landed on the directed fishery CFEC permit card. In Southeast Alaska, since 2001 an average of 22 permits have landed an average of 2,806 pounds of octopus per year, 0.3% of total shrimp landings.

Bycatch is landed on the harvester's directed species CFEC permit, not an octopus CFEC permit. This practice allows ADF&G to calculate the octopus bycatch harvest as a percentage of the target species harvest. Bycatch retention does not require a registration, except in Southeast Alaska. Octopus are regularly landed as bycatch, constituting the bulk of octopus landed from state waters.

Federal Waters

In federal waters octopus is open to directed fishing with any legal gear for groundfish. Octopus are part of the federal "other species" groundfish assemblage. The TAC for this assemblage is set at an arbitrary percentage of all other TACs. These levels are generally set to provide for traditional bycatch retention without restricting the major directed fisheries and to provide limited opportunity for the development of new fisheries. Substantial bycatch landings of octopus occur during the Pacific cod fishery. At times these incidental harvests are landed on a CFEC octopus permit card indicating a directed fishery, whereas they were actually taken in conjunction with fishing for another species. Landing octopus on a separate octopus permit card does not provide a true picture in the state's fish ticket database of harvesting practices.

If a directed octopus fishery were to develop in federal waters there are few protection measures in place. Skates are a good example of a species that was in the other species assemblage and quickly developed into a targeted fishery simultaneous to the Pacific cod fishery, particularly for the longline fleet. In 2003, markets for skates developed creating rapid increases in effort and harvest. The 2002 skate harvest in the Central and Western Gulf was 15.9 million pounds and the 2003 harvest was 74.1 million pounds.

Concerns

The management differences for octopus between state and federal waters may lead to misreporting of octopus bycatch harvests when vessel operators are participating in a directed fishery that is open in state and federal waters (e.g. parallel/federal Pacific cod). A vessel participating in both state and federal waters could not land more than 20% octopus bycatch from state waters but could land an amount above 20% from federal waters.

The generic life history of octopus is conducive for a viable directed fishery because they are short-lived, fast growing, and are fecund. However, little is known about the species assemblage. Cephalopod identification is difficult and it is likely that there are several species that are harvested in Alaska. The majority of harvested octopus are assumed to be the Giant Pacific octopus. Biomass, migrations, and discard mortality by gear type and the level of nonreporting of octopus retained for personal use as bait, are unknown. Biomass estimates of octopus from the NMFS trawl survey have been produced but are considered highly unreliable.

The following is a synopsis of octopus fishing in BSAI:

* Directed fishing in state waters is by commissioner's permit only. Within the last several years only a small number of people have requested this permit annually. The individuals that have obtained the permit have either landed very little or no octopus. The most recent permits were issued in 2006. Permits terms are crafted to structure fishing in way that allows for the collection of relative abundance and biological data.

* Bycatch of octopus is allowed in other directed fisheries within state waters (this would include parallel fisheries) up to 20%. Bycatch does not require any special registration and is landed on the card for the directed fishery, not an octopus card. This type of fishing does occur.

* Octopus are part of the federal "other species" assemblage. The TAC for this assemblage is set at an arbitrary percentage of all other TACs. These levels are generally set to allow bycatch without restricting fisheries.

* In federal waters octopus are considered "open". While no one targets octopus, substantial landings do occur simultaneous to the Pacific cod fishery. Typically this harvest is on the order of 300,000 pounds or less per year, but over 700,000 pounds were taken in 2004. 2004 was the peak year for industry interest in octopus harvest in the BSAI. Since 2004 interest has waned. Anecdotal evidence suggests that BSAI octopus abundance was at a peak in 2004.

Concerns

* One basic concern is the difference in management between state and federal waters. Inconsistencies lead to misreporting and unintentional-violations.

* The generic life history of octopus is conducive for a viable directed fishery because they are short-lived, have fast growth, and fecund. However, little is known about the species assemblage in the BSAI.

* Cephalopods identification is difficult and it is likely that there are several species that are harvested. Biomass is unknown, migrations are unknown, and discard mortality is unknown.

* Biomass estimates of octopus from the NMFS trawl survey have been produced but considered highly unreliable.
* The amount of octopus retained as unreported bait in Pacific cod fisheries is unknown.
* The majority of harvested octopus are assumed to be the Giant Pacific octopus.

In retrospect, there is not a lot to discuss in regard to octopus management in RII. As described below, directed fishing is closed by area regulation and all octopus currently harvested comes as bycatch to the Pacific cod pot fisheries. The CI state waters GHL of 35,000 lb has been achieved several years, resulting in closure to retention of octopus. We have sampled octopus bycatch and and can provide information on size/sex composition of the harvest. Thus far, all sampled CI harvest has been Octopus dolfleini.

In PWS, the very low levels of Pacific cod pot fishing have resulted in very little octopus bycatch. An individual could obtain a commissioner's permit to target octopus in PWS. Permit stipulations would include "no bait in pot" as this unnecessarily results in bycatch. Typically, directed octopus fishing involves use of an "alternative lair" type of pot.

I don't see the benefit to the state in taking over octopus mgmt in the EEZ. Regardless, the disconnect between state and federal regulations in their respective considerations of octopus as shellfish or groundfish is the first problem that we would need to address. Let me know if you need additional information.

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