Alaska FISHERIES SCIENCE CENTER

Quarterly Report

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Alaska Sablefish Tag Program 1972 – 2012

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NOAA FISHERIES

Alaska Sablefish Tag Program, 1972 – 2012

By K. B. Echave, D. H. Hanselman, and N. E. Maloney

The National Marine Fisheries Service (NMFS) Alaska Sablefish Tag Program has released over 360,000 tagged sablefish in Alaska waters since 1972 and over 33,500 of those fish have been recovered by members of the fishing industry. Data from the releases and recoveries are maintained in the Sablefish Tag Database. These data have been used to examine movement patterns, evaluate areal apportionment strategies of annual catch quota, validate ageing methods, and examine growth. The following article summarizes release and recovery data within the tag database and describes the results of studies utilizing these tag data by NMFS and others on sablefish age, growth, and migration.

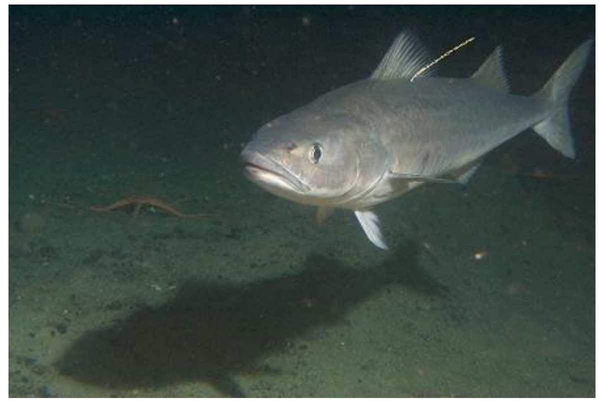
INTRODUCTION

Several marine species have been extensively tagged using a variety of methods over the years in order to determine or estimate spatial distribution within a geographic range, migratory patterns, abundance, and growth. One such species with a lengthy history of tagging data is sablefish, *Anoplopoma fimbria*, in the northeast Pacific Ocean. Sablefish is a long-lived, highly mobile demersal species which inhabits the northeastern Pacific Ocean from Baja Mexico to the Gulf of Alaska (GOA), westward to the Aleutian Islands (AI), and into the eastern Bering Sea (BS). Sablefish is one of the deepest dwelling commercially valuable species, with an ex-vessel value of over $100 million in 2010. Adult sablefish are generally found along the continental slope, shelf gullies, and in deep fjords. In contrast, juvenile sablefish (< 40 cm) spend their first 2-3 years on the continental shelf and in interior bays, moving into deeper waters along the slope as they age. Based on evidence from tagging studies and differences in growth rate and size at maturity, it is thought that there are two populations of sablefish: the Alaska population, found in Alaska and northern British Columbia waters, and the West Coast population, found in southern British Columbia, Washington, Oregon, and California waters.

Because sablefish have a long-term time series of tag-recovery data, they may be a candidate for a spatially explicit stock assessment. Few stocks have the necessary quality of data to reasonably estimate a spatially explicit stock assessment because estimates of movement between areas and good estimates of areal abundance are preferred. Spatially explicit stock assessment has been identified as a goal and a step toward realizing ecosystem-based management. In order to estimate movement and examine appropriate scales of spatial management, the Alaska Fisheries Science Center's (AFSC) Auke Bay Laboratories (ABL) has been tagging sablefish since 1972 using a variety of methods including traditional anchor tags (Fig. 1), electronic archival tags (Fig. 2), and most recently, pop-off satellite tags (Fig. 3).

As a major contributor to the history of sablefish tagging in the North Pacific, ABL has deployed traditional anchor tags on over 360,000 sablefish, recovering more than 33,500. Beginning in 2003, electronic archival tags were deployed inside approximately 1,460 juvenile and adult sablefish; 141 of those have been recovered. Upon release and recapture of the archival tagged fish, geo-position, depth, and biological data may be collected. Beginning in 2011, exploratory work using pop-off satellite tags on sablefish was initiated. These tags are similar to archival tags in that they collect depth and temperature data

REWARD



FOR TAGGED SABLEFISH

The U.S. National Marine Fisheries Service Auke Bay Laboratory in Juneau, AK tags sablefish (blackcod) in the Gulf of Alaska, Bering Sea and Aleutian Islands in order to study distribution and migration.

Tags may be yellow, red, or orange and are usually located below the first dorsal fin on the left side of the fish. Postage-paid envelopes are available in most areas. Please send tags with as much of the following information as possible:

Name of vessel	**Date of recovery**
Location of recovery	**Sex of the fish**
Fork length (from tip of snout to fork in tail)	**Round weight**
Depth fished	**Type of gear**

A reward and information on the history of the fish will be sent for each tag returned to:

Sablefish Tag Program
NOAA/NMFS Auke Bay Laboratories
17109 Pt. Lena Loop Rd.
Juneau, AK 99801

at pre-determined sampling intervals, but they also record an estimated location. Satellite tags release from the fish at a preprogrammed date and float to the surface where they upload recorded data to passing satellites.

Although sablefish are assessed as one population in federal waters off Alaska (seaward of the 3-mile state line), harvest is allocated to discrete geographic regions (management areas) to distribute exploitation throughout their wide geographic range. Harvest is managed by NMFS under regulations recommended by the North Pacific Fishery Management Council. A total harvest quota, called the acceptable biological catch (ABC) is calculated for the entire GOA, BS, and AI region, and then this ABC is apportioned among six management areas (Fig. 4). These annual quotas for each area are based on the distribution of biomass among the areas, estimated from annual longline surveys and commercial catches. Because of the high movement rates determined by the tag data, it has been shown that apportionments can be flexible to achieve other objectives, while still maintaining spawning biomass. The total ABC is derived from a population model that incorporates age composition, growth rates, and survey and commercial catches. Much of the biological information for estimates of these factors comes from annual sablefish longline surveys, observer samples of the fishery, and fishery logbooks, but tagging results can be used as an independent check on these results.

TAG RELEASES

The AFSC has been tagging and releasing sablefish in Alaska waters since 1972. Tagging effort in Alaska has been centered in three main areas: 1) adult sablefish in offshore waters of the GOA, BS, and AI; 2) adult sablefish in the inside waters of Chatham and Clarence Straits; and 3) juvenile sablefish in interior bays of Southeast Alaska. As stated previously, to date, approximately 360,000 sablefish have been tagged and released (Table 1).

Adult Tag Releases in Offshore Waters

Most of the GOA, BS, and AI tagged sablefish have been released during the annual Japan-U.S. cooperative or the NMFS domestic longline surveys conducted from 1978 to the present. Figure 5 shows the major release and recovery areas discussed in this document, as well as the location of the annual longline survey stations. Approximately 5% of the longline survey catch of sablefish are tagged and released each year, which generally equals about 3,000 – 3,500 fish per year. Offshore tagging utilizes conventional anchor tags, internally implanted electronic archival tags, and externally attached pop-off satellite tags. To date, 322,263 adult fish have been tagged with conventional anchor tags in offshore waters, 619 electronic archival tags have been implanted in adult sablefish, and 43 sablefish have been tagged with pop-off satellite tags on the NMFS annual longline surveys in offshore waters.

Figure 1. A traditional anchor tag inserted below the dorsal fin of an adult sablefish.

Figure 2. Picture of an electronic archival tag. The pencil is pointing to the location on the sablefish in which an incision will be made to insert the tag.

Adult Tag Releases in Inshore Waters

Most of the nearly 70,000 tags released by NMFS in Chatham and Clarence Straits have been released from various NOAA research vessels. Chatham and Clarence Straits are considered Eastern GOA Inside waters (Fig. 5). The State of Alaska has jurisdiction over fisheries in these waters, and many of the tag releases were made in cooperation with the Alaska Department of Fish and Game (ADF&G).

Tag Releases of Juvenile Sablefish

Juvenile sablefish in Southeast Alaska make up a third group of NMFS tag releases. Beginning in 1985, juvenile sablefish were tagged and released in a number of bays and inlets in Southeast Alaska, ranging from Ketchikan to Juneau. Most of these fish were tagged from NOAA ships or from docks in Sitka, Ketchikan, and Juneau. Approximately 37,100 juvenile sablefish have been tagged and released to date (Table 1). The majority of juvenile tagging efforts have centered in St. John Baptist Bay outside of Sitka on Baranof Island (Fig. 6).

To date, 852 electronic archival tags (Fig.2) have been implanted and released in juvenile sablefish from the 2003-2012 year classes in St. John Baptist Bay. These tags should be available for recovery as the fish recruit to the commercial fishery. The first three of these archival tags were recovered in 2008, and five more have been recovered since 2009. These tags store depth and temperature data recorded at preset time intervals throughout each day. Data from these tags provide information about inshore-offshore migration, daily depth movements, and habitat temperature.

Figure 3. Picture of experimentally tagged sablefish with pop-off satellite tags in the laboratory at Ted Stevens Marine Research Institute, Auke Bay Laboratories, in Juneau, Alaska.

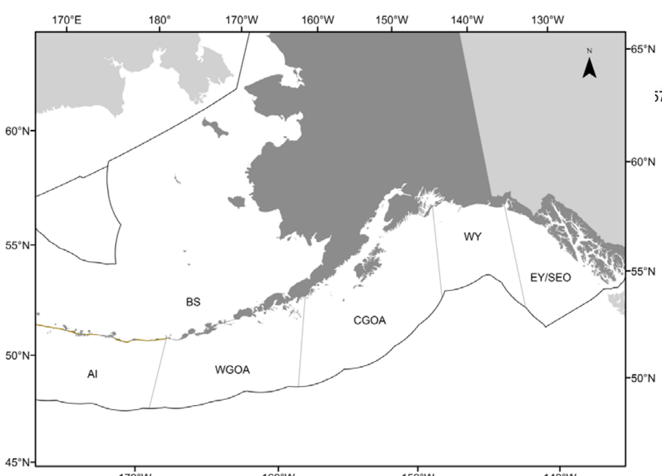


Figure 4. Map of the six management areas sablefish harvest is geographically apportioned: Bering Sea (BS); Aleutian Islands (AI); Western Gulf of Alaska (GOA) (WGOA); Central GOA (CGOA); West Yakutat (WY) ; and East Yakutat/Southeast Outside (EY/SEO).

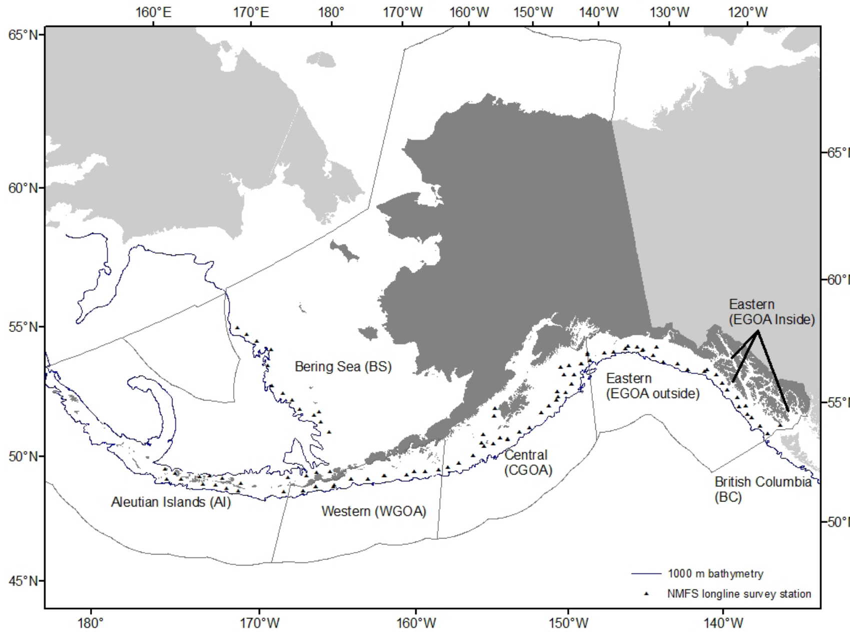


Figure 5. Map of the NMFS annual longline survey stations (triangles) and Fishery Management Plan areas: the Bering Sea (BS), Aleutian Islands (AI), and the subareas of the Gulf of Alaska (GOA). Tags are deployed at all stations in the GOA each year, and in alternating years in the BS and AI. Eastern GOA Inside consists of Chatham and Clarence Straits.

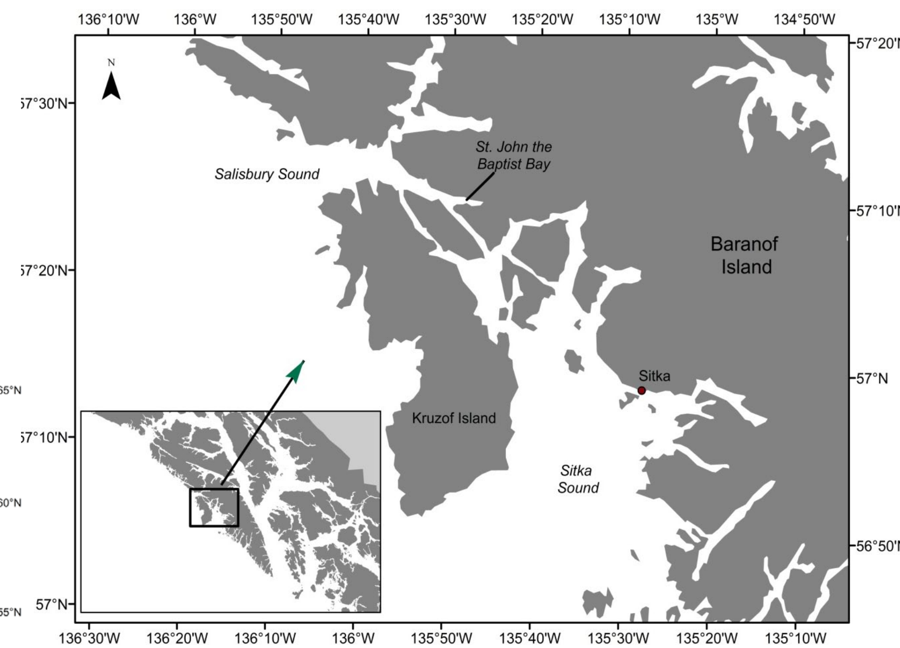


Figure 6. Map of location of juvenile sablefish tagging in St. John Baptist Bay on Baranof Island in Southeast Alaska.

TAG RECOVERIES AND MIGRATION

Accurate tag recovery position information helps identify major migration routes. If recovery dates are available, it is possible also to calculate movement rates as well as routes. Analysis of tag data is the primary method used at the AFSC to study sablefish movement. Several tagging studies have shown sablefish to be highly migratory for at least part of their life cycle, with the pattern of movement related to fish size and progression of maturity. It had previously been reported that sablefish traveled primarily in a counter clockwise direction around the GOA (Fig. 7); small, immature fish tagged in shallow inshore waters of the eastern GOA travel north and westward from their release sites out on the continental shelf and eventually end up as adults in the deeper waters of the continental slope throughout the distribution where spawning takes place. Large fish tagged in the western areas of the GOA would move eastward, and large fish tagged in the eastern areas of the GOA had a tendency to remain there (Fig. 7). Young sablefish would routinely undertake migrations of a thousand miles or more, and older fish would commonly travel the same distance on a return journey. However, recent updated work has reported that sablefish mobility has increased over time, that the directionality of movement has changed since previously reported, and that annual movement probabilities differ greatly between areas. Annual movement rates have been re-estimated for tagged sablefish among regulatory areas using tag recovery data (over 300,000 tag releases in Alaska and 27,000 recoveries) from 1979 to 2009, as well as tag release data from the inside waters of Southeast Alaska from the ADF&G. Direction of movement changed the most for small sablefish. Small sablefish (41-56 cm) are more likely than previously shown to move out of their current area in all areas except the EGOA, and to move predominately eastward; whereas previous studies showed that they moved westward. Medium (57-66 cm) and large (>66 cm) fish are moving more than in previous years, and large sablefish still display a tendency to move east rather than west. So overall, if the CGOA is considered the center of distribution of Alaska sablefish, it is more likely for all size groups to move east than west.

Tag data for sablefish from the NMFS Alaska Sablefish Tag Database are summarized in the following sections by region, with reference to migration patterns. Release size categories are based on length frequency data: small (41-56 cm); medium (57-66 cm); and large (>66 cm). In general, these size ranges correspond to ages 3-4 (small), ages 5-7 (medium), and age 8 and over (large), although males grow more slowly than females. For example, a 5-year-old female would probably have reached “medium” size while a 5-year-old male might still be of “small” size. The size categories “small,” “medium,” and “large” refer to the size of the fish at release and not the actual size at recovery unless otherwise stated.

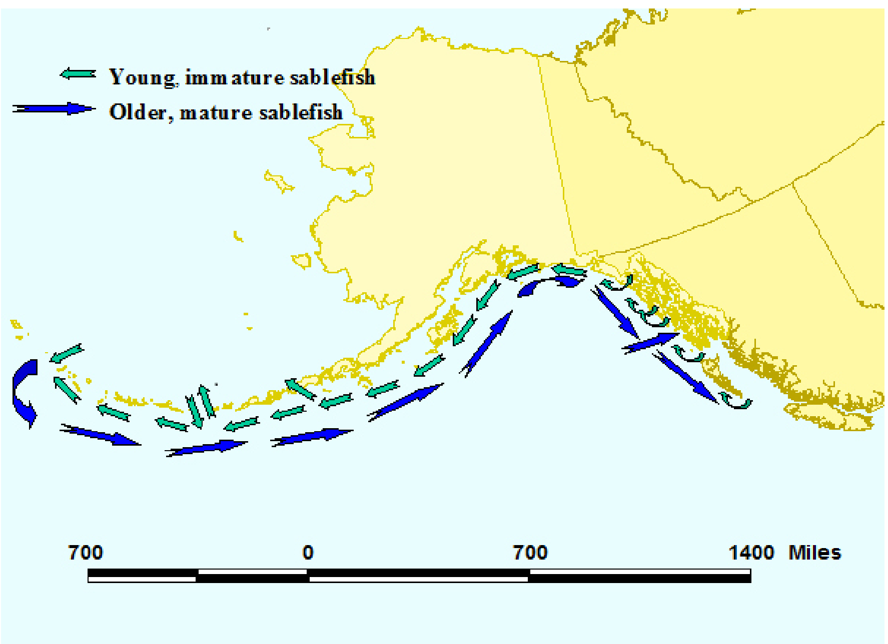


Figure 7. The traditional concept of the migration pattern of sablefish in the northeast Pacific Ocean. Young, immature fish travel north and west from inshore nursery areas in Canada and the Eastern Gulf of Alaska (GOA) to the Western GOA, Bering Sea, and Aleutian Islands. Older, mature fish move offshore and return eastward. New analyses of more recent data have shown that this pattern may have changed.

Eastern Gulf of Alaska Tag Releases

The majority of tag releases by NMFS have been in the EGOA (approximately 217, 050; Fig. 8, Table 2). This number includes releases in inside waters (Chatham Strait, Clarence Strait, and juveniles tagged in Southeast Alaska), as well as outside or offshore waters (during the annual longline survey).

Analysis of released tags from the EGOA verifies the reported movement pattern of sablefish: all size groups of both male and female tagged sablefish from the EGOA have a tendency to remain in the EGOA (Figs. 9, 10, Tables 3, 4). Fish released in outside EGOA waters moved less than fish released in other areas: 55% of fish released in the EGOA were recovered in outside EGOA waters, 15% recovered in the CGOA, and 14% recovered in BC (Fig. 9, Table 3). The same holds true for fish released in Chatham Strait. Over half of the recovered fish that were released in Chatham Strait were later recovered Chatham Strait (Table 3). Close to half (47%) of the recovered fish from Clarence Strait releases were recovered in Clarence Strait; however, a high percentage (26%) were also recovered in BC (Table 3). In summary, the EGOA is the largest recipient of moving fish moving out of inside waters.

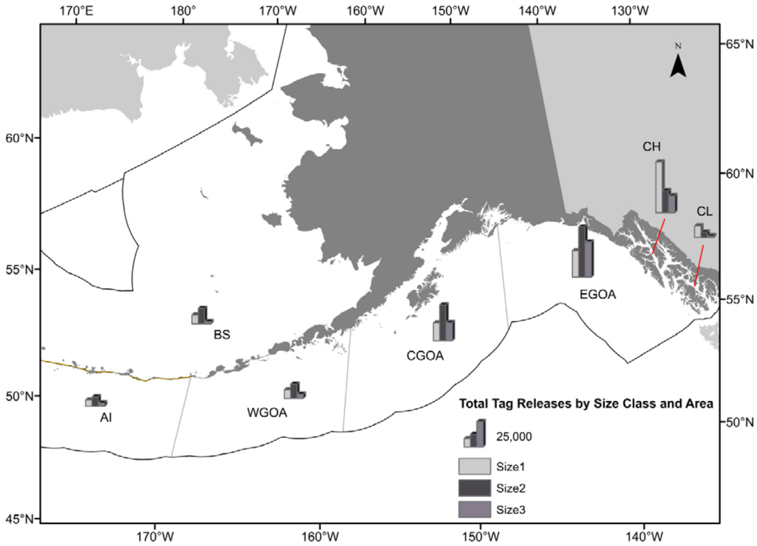


Figure 8. Total number of tag releases by NMFS by size and area during years 1972–2012; Bering Sea (BS); Aleutian Islands (AI); Western Gulf of Alaska (GOA)(WGOA); Central GOA (CGOA); Eastern GOA (EGOA); Chatham Strait (CH); and Clarence Strait (CL). Small = 41-56 cm; medium = 57-66 cm; and large >66 cm.

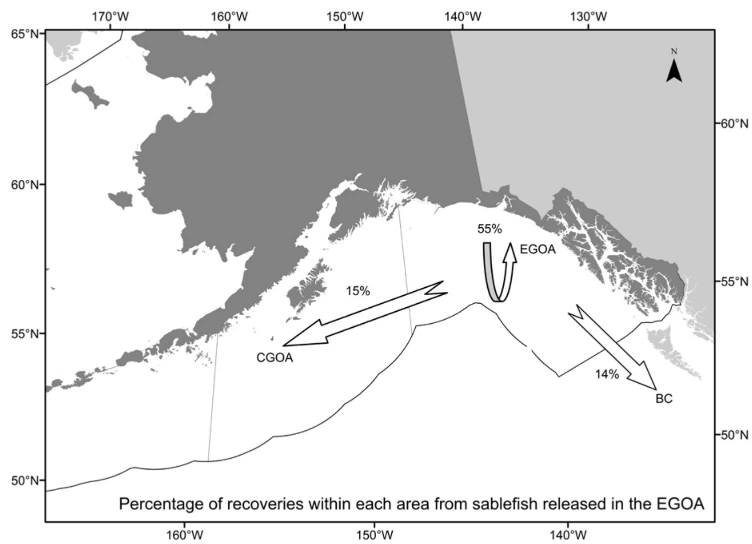


Figure 9. The percentage of tagged sablefish recovered within each area from fish released in outside Eastern Gulf of Alaska (EGOA) waters; 55% of fish were recovered in outside EGOA waters; 15% were recovered in the Central GOA (CGOA); and 14% were recovered in British Columbia (BC).

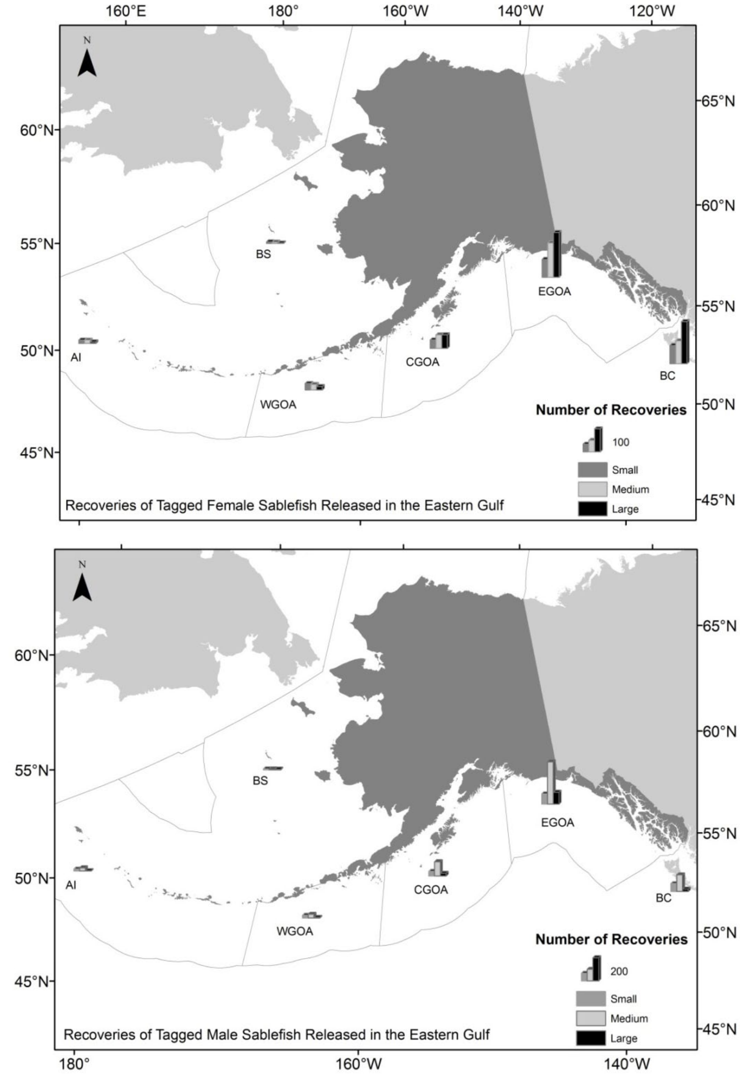


Figure 10. Number of recoveries of tagged female (top panel) and male (bottom panel) sablefish released in the Eastern Gulf of Alaska (GOA), by release size and recovery area. Please note the different scale between the two panels. British Columbia (BC); Eastern GOA (EGOA); Central GOA (CGOA): Western GOA (WGOA); Aleutian Islands (AI); and Bering Sea (BS). Small = 41-56 cm; medium = 57-66 cm; and large >66 cm.

Central Gulf of Alaska Tag Releases

The CGOA is considered a mixing zone of small and large sablefish and is the location of the second highest number of tag releases in federal waters (Fig. 8, Table 2). In the CGOA, it is more likely for all size groups to move east than west; however, the probability of fish moving west is higher from this area than others. This coincides with the original movement conceptual model describing a counterclockwise movement by sablefish around the GOA (Fig. 7). The probability of fish moving west or east from the CGOA is 29% and 39% for small sablefish, respectively, and 22% and 47% for large sablefish, respectively. Fish recovered in the CGOA may have originated in the EGOA and were still traveling westward, or they may have already been west and were returning east when captured. Fish tagged (all sizes combined) in the CGOA were most likely to be recovered in the CGOA (44%) and EGOA (26%; Fig. 11, 12, Table 3).

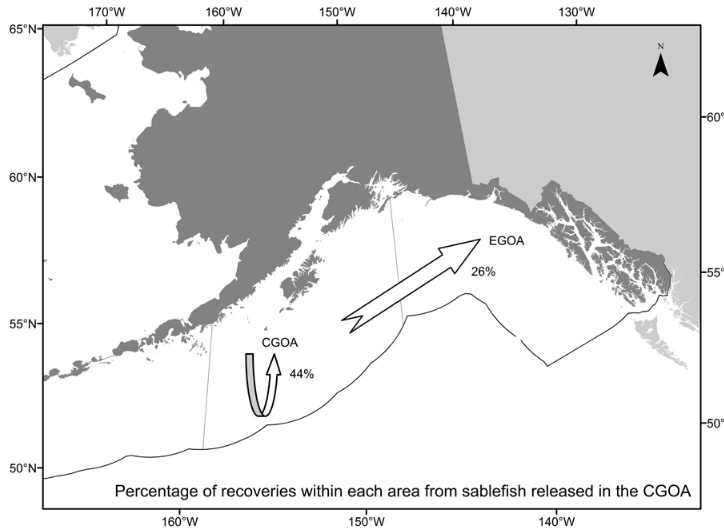


Figure 11. The percentage of tagged sablefish recovered within each area from fish released in the Central Gulf of Alaska (CGOA); 44% of fish were recovered in the CGOA; and 26% recovered in the Eastern GOA (EGOA).

Western Gulf of Alaska Tag Releases

Fish of all sizes that are tagged in the western GOA are more likel to immediately move from this area than remain. It appears that th WGOA is a transition zone for all-sized sablefish, as there is betwee an 80%–90% probability that a sablefish will leave the WGOA 1 yea after arriving. However, fish tagged at a small size in the WGOA ten to remain in the western areas (WGOA, AI, BS) longer than large fisl before heading east. The majority of small-sized sablefish released i the WGOA were caught in the WGOA, AI, and BS 0–3 years follow ing tagging. However, the majority of small fish recovered 5+ yeaı following tagging were caught primarily in the CGOA, EGOA, an BC, reinforcing the movement model of their eventual eastwar movement. Large-sized sablefish have a tendency to move from th WGOA immediately and appear to move eastward. The majorit of large tagged sablefish from the WGOA were immediately (1- years following tagging) recovered in the CGOA, EGOA, and BC Since sablefish tagging was initiated, only eight large tagged fish i the WGOA have been recovered in the BS and only nine in the AI.

Similar percentages of recoveries from WGOA-released fish (all size groups and years at liberty combined) were found in the WGOA (25%); EGOA (24%); and CGOA (21%; Fig. 13, 14, Table 3). The pattern of movement from this area is strikingly different from other areas in the GOA, where the majority of fish remained in their release area. It should be noted, as is evident in Figure 8, that there are not as many large-sized sablefish tagged in the WGOA. Length frequency data from the longline survey show that there are an increased number of smaller-sized sablefish caught in the WGOA than in other areas. For example, 59 cm is the most frequent caught length of sablefish within the Shumagin geographic area (within the WGOA) on the longline survey compared to 67 cm within the Kodiak geographic area (within the CGOA).

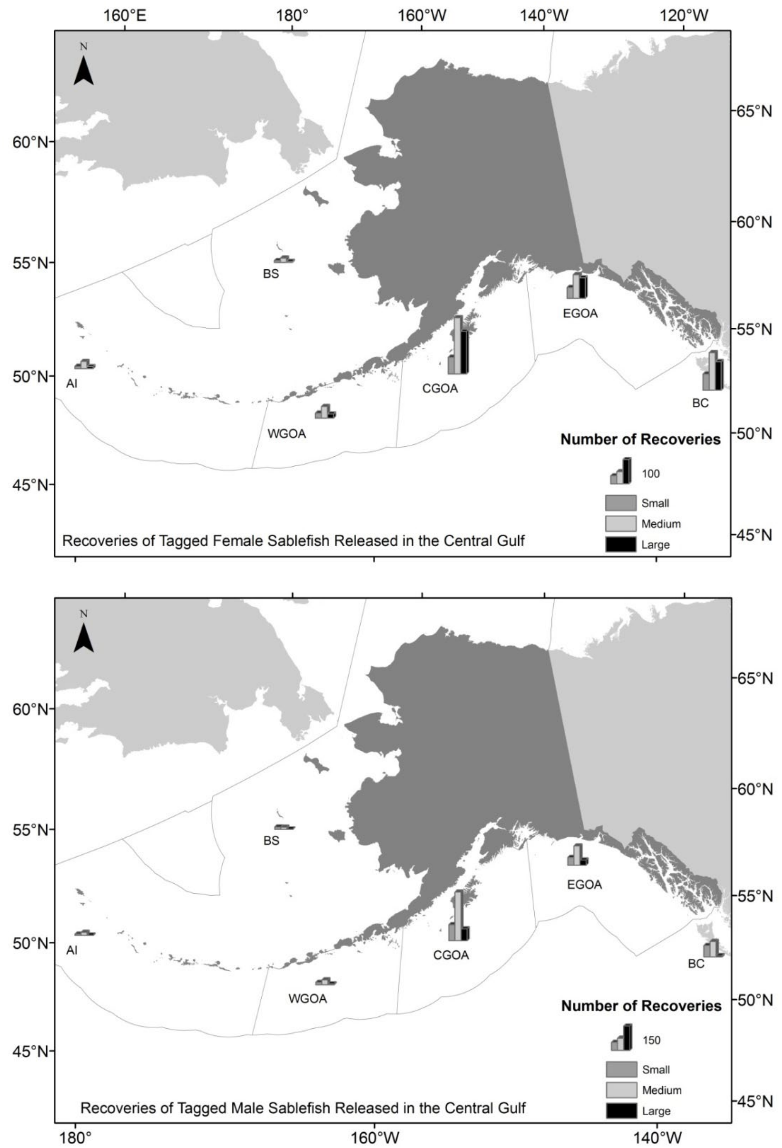


Figure 12. Number of recoveries of tagged female (top panel) and male (bottom panel) sablefish released in the Central Gulf of Alaska (GOA), by release size and recovery area. Please note the different scale between the two panels. British Columbia (BC); Eastern GOA (EGOA); Central GOA (CGOA); Western GOA (WGOA); Aleutian Islands (AI); and Bering Sea (BS). Small = 41-56 cm; medium = 57-66 cm; and large >66 cm.

Aleutian Islands and Eastern Bering Sea Tag Releases

Fish that are tagged further west in the BS and AI are more likely to move out of the area in which they were tagged and into areas further east (Figs. 15, 16, 17, 18, Tables 3, 4). Equally high percentages of recoveries from AI-released fish were found in the EGOA (27%), AI (26%), and BC (18%; Fig. 15, Table 3); and a high percentage of recoveries from BS-released fish were found in the EGOA (29%), CGOA (20%), and BS (19%, Fig. 16, Table 3). Small fish appear to remain in the BS the first 3 years following tagging and then move east from the area. Five to ten years following tagging in the BS, an increasing proportion of small fish appear in the CGOA and EGOA. Large fish tagged in the BS are more likely to stay there, but a large proportion of fish are still recovered in the EGOA and BC within 10 years of tagging. Small fish in the AI show a high probability of remaining in the area for the first 5 years following tagging. Five to ten years following tagging, there are increasing numbers of tagged small sablefish recovered in the EGOA. Unlike large sablefish tagged in the BS, the majority of large sablefish tagged in the AI move immediately. Tag data indicates that most fish (small- and large-sized) leaving the AI do not move eastward by way of the BS. Only 3.5% of all recoveries of AI releases were made in the BS (Table 3). Tagged sablefish released in the AI traveled the furthest, on average, before being recaptured (Table 5).

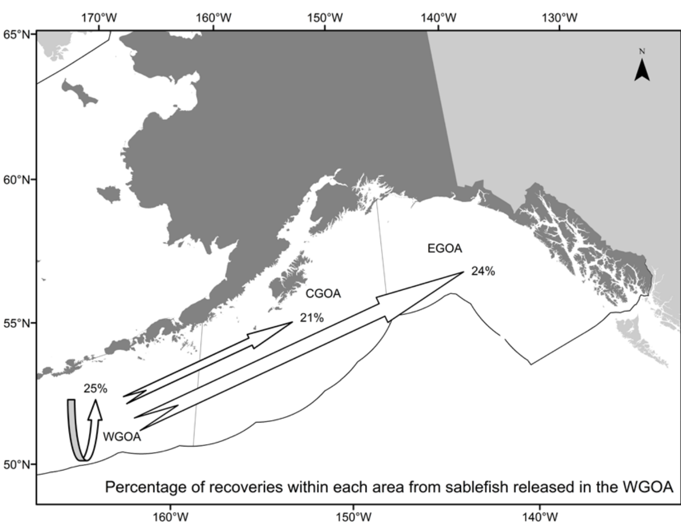


Figure 13. The percentage of tagged sablefish recovered within each area from fish released in the Western Gulf of Alaska (WGOA): 25% of fish were recovered in the WGOA; 24% were recovered in the Eastern GOA (EGOA); and 21% were recovered in the Central GOA (CGOA).

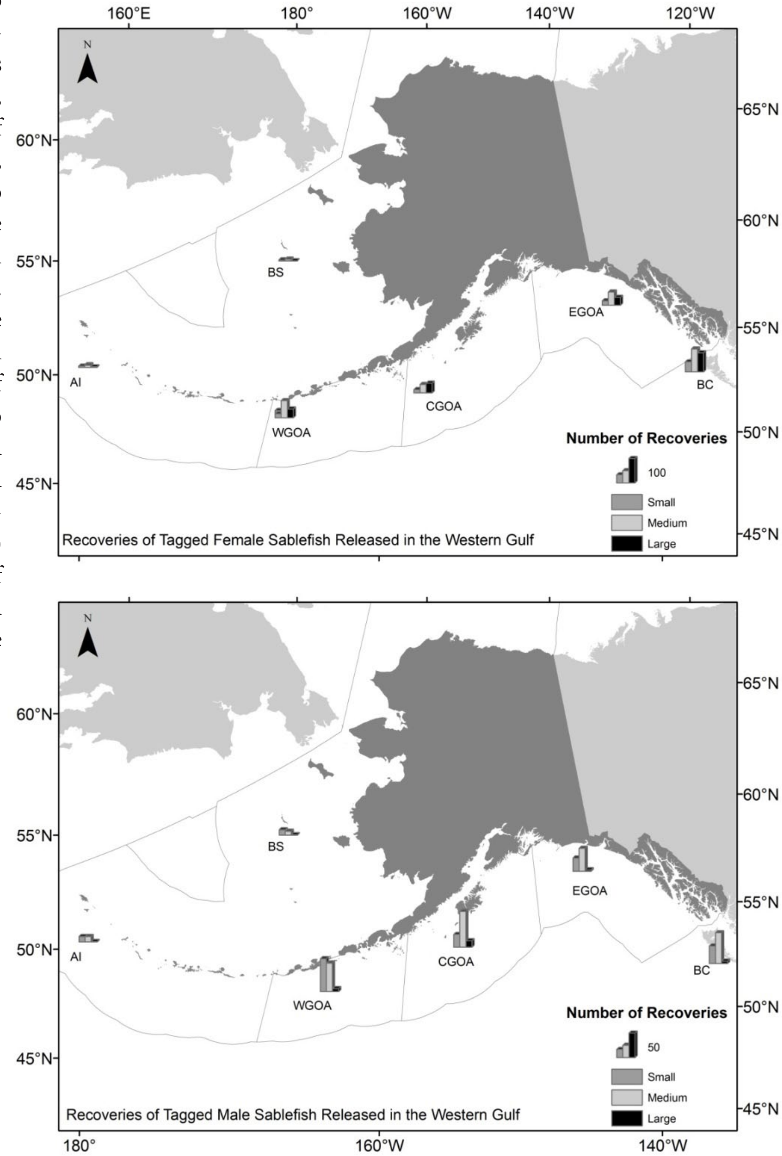


Figure 14. Number of recoveries of tagged female (top panel) and male (bottom panel) sablefish released in the Western Gulf of Alaska (GOA), by release size and recovery area. Please note the different scale between the two panels. British Columbia (BC); Eastern GOA (EGOA); Central GOA (CGOA); Western GOA (WGOA); Aleutian Islands (AI); and Bering Sea (BS). Small = 41-56 cm; medium = 57-66 cm; and large >66 cm.

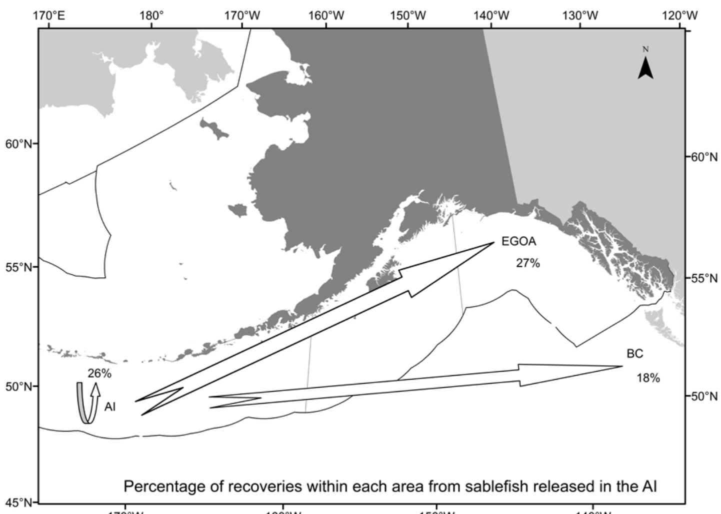


Figure 15. The percentage of tagged sablefish recovered within each area from fish released in Aleutian Islands (AI): 27% of fish were recovered in the Eastern GOA (EGOA); 26% were recovered in the AI; and 18% were recovered in British Columbia (BC).

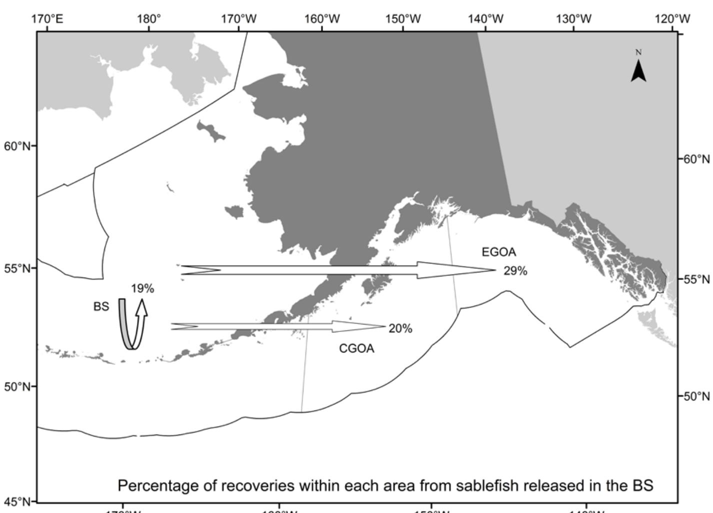
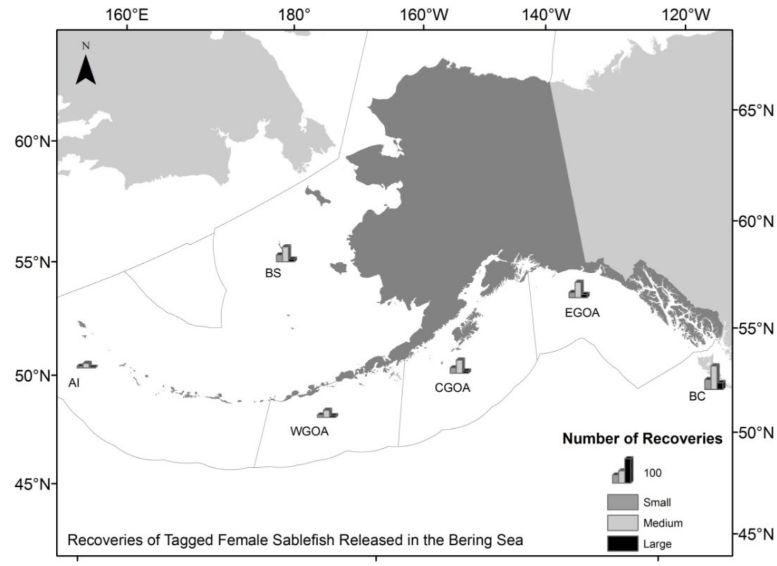


Figure 16. The percentage of tagged sablefish recovered within each area from fish released in outside the Bering Sea (BS): 29% of fish were recovered in the Eastern Gulf of Alaska (EGOA); 20% were recovered in the Central GOA (CGOA); and 19% were recovered in the BS.



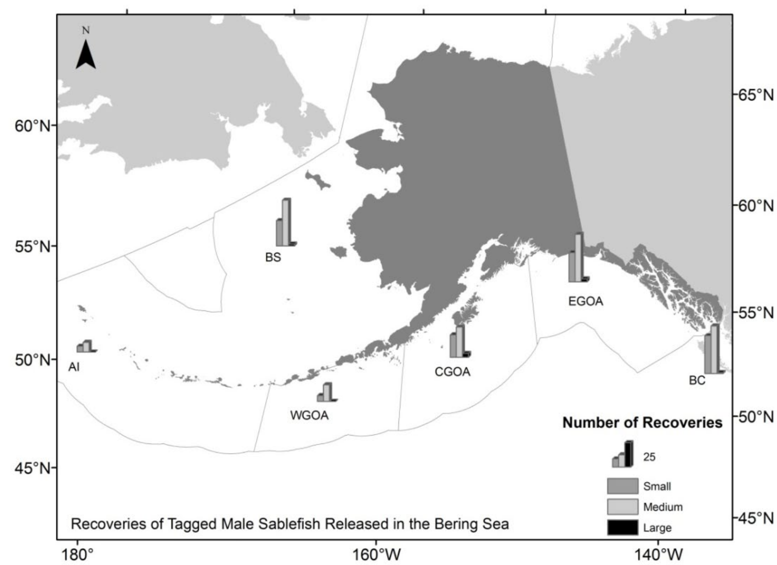


Figure 17. Number of recoveries of tagged female (top panel) and male (bottom panel) sablefish released in the Bering Sea, by release size and recovery area. Please note the different scales between the two panels. British Columbia (BC); Eastern Gulf of Alaska (GOA) (EGOA); Central GOA (CGOA); Western GOA (WGOA); Aleutian Islands (AI), and Bering Sea (BS). Small = 41-56 cm, medium = 57-66 cm, and large >66 cm.

MOVEMENT RATES

Estimated movement rates are essential in the management of a species in which quotas are geographically apportioned, especially for a species such as sablefish, in which movement rates are great enough to affect the amount of fish available for harvest in an area. Rates of movement from one area to another are affected by a wide range of environmental and biological factors and may vary greatly between years, areas, and individual fish. In addition, the use of traditional anchor tag release/recapture data is not without problems. The length of time a fish was in an area before being captured and tagged, and the length of time a fish was in an area before being recovered are both unknown. The longer a fish is at liberty and the further it has traveled, the more uncertain the estimates of between-area movement rates become. For example, if a fish is recovered more than one area distant from the release area (e.g., released in the EGOA and recovered in the AI), it is impossible to know how much time was spent in each of the areas between release and recovery. In addition, if a fish is released and recaptured in the same area, it is impossible to know if the fish left the tagging area and returned after some time, or in fact remained in the tagging area without ever leaving. Regardless, analysis of all available conventional tag data is useful for providing overall patterns of movement and for estimating migration rates.

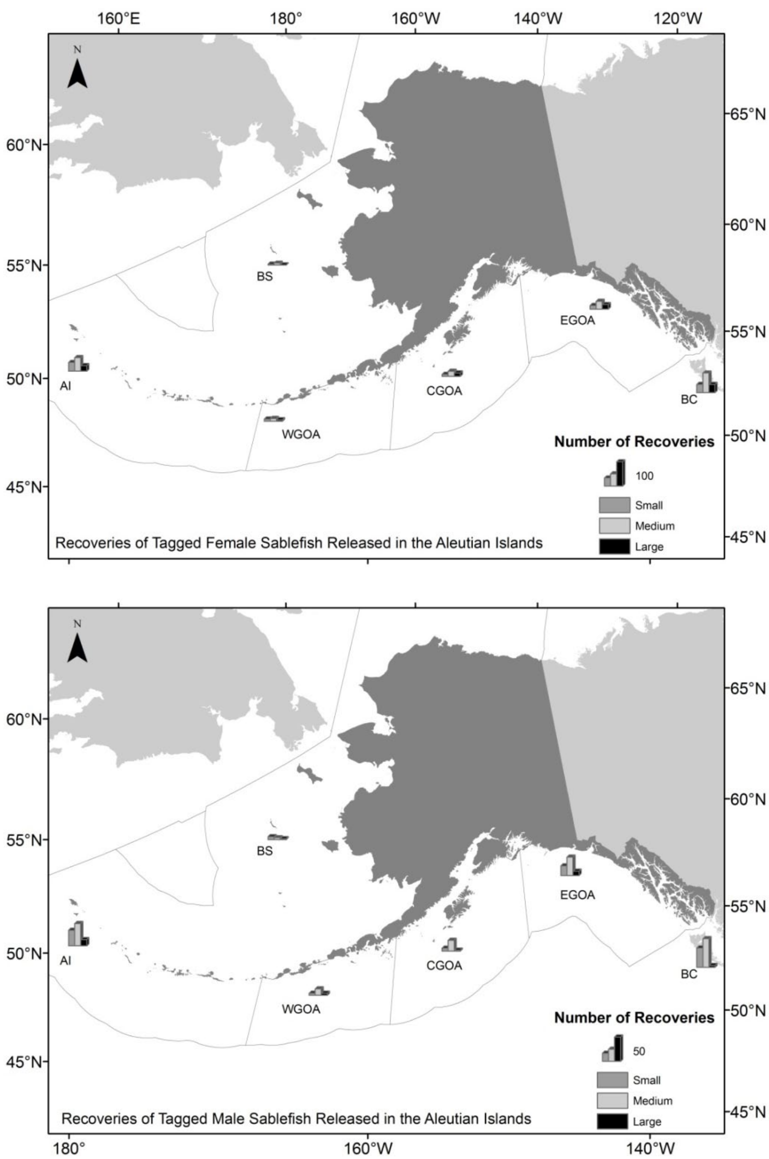


Figure 18. Recoveries of tagged female (top panel) and male (bottom panel) sablefish released in the Aleutian Islands, by release size and recovery area. Please note the different scales between the two panels. British Columbia (BC); Eastern Gulf of Alaska (GOA) (EGOA); Central GOA (CGOA); Western GOA (WGOA); Aleutian Islands (AI), and Bering Sea (BS). Small = 41-56 cm, medium = 57-66 cm, and large >66 cm.

Annual movement rates of tagged sablefish among regulatory areas using tag recovery data from 1979 to 1987 were estimated in 1991. These results were presented in the "2001 Report to Industry on the Alaska Sablefish Tag Program, 1972-2001." As previously mentioned, annual movement rates have since been re-estimated for all three size groups of tagged sablefish among regulatory areas using tag recovery data from 1979 to 2009, as well as tag data from the ADF&G. The ADF&G tag releases are all from the inside waters of Southeast Alaska and are in addition to the EGOA Inside releases by NMFS that were previously discussed. This updated analysis was done with hopes of incorporating these tag recovery and movement data into a fully age-structured spatial stock assessment model in the future. Calculated movement rates were high (annual movement rates ranged from 10% to 80% depending on area and size group), and estimated movement rates in all areas were higher than previously calculated in 1991. Table 4 shows the annual percentage of small, medium, and large sablefish from each regulatory area that moved into another area or remained in the same regulatory area. The increase in annual probability of movement in the majority of areas and size groups from the 1991 estimates was substantial. The largest differences in annual movement rates were related to the area they occupied and not because of fish size, meaning that sablefish movement appears to be more directly influenced by the geographic location of the fish and not the size (or age) of the fish.

Overall, fish of all size groups are more likely to move than stay. This behavior change was most evident in fish that are further west: annual movement rates for fish in the BS and AI were estimated to be almost 80% higher than previously estimated. The directionality of movement in comparison to earlier studies has changed as well. New results show that it is more likely for a fish from all size groups to move east than west. Regarding movement with relation to size, small fish are more likely to move out of their current area and eastward, in all areas except the EGOA, while medium and large fish move more than previously thought in all areas except the BS. Large fish did show a large increase in annual probability of movement out of the EGOA and WGOA.

Sablefish moved large distances throughout the 39 years of tagging studies. Mean great-circle distance moved in 1 year over all size groups was 148 km and 626 km over all time at liberty. These distances are calculated as point-to-point, so they surely are minimum distances. Female sablefish moved slightly farther on average than male fish. The longest a recaptured tagged fish has been at liberty is slightly over 37 years—a fish tagged in 1973 and recovered in 2010. More than half of all recovered tagged fish have been recovered within 10 years of being tagged: 33% of tagged fish were recovered within 2 years of their release; 28% were recovered 3–5 years following release; and 24% were recovered 6– 10 years following release (Table 6).

JUVENILE SABLEFISH

Juvenile sablefish (mostly age-1) have been tagged in varying numbers since 1985 with traditional anchor tags and internal electronic archival tags in bays and inlets in Southeast Alaska, from Ketchikan to Juneau. Since 1987, the majority of the tagging has occurred in St. John Baptist Bay near Sitka, Alaska, on Baranof Island because juvenile sablefish have consistently been found there (Fig. 6). Through 2012, more than 36,200 juveniles have been tagged with traditional anchor tags and 852 tagged with internal electronic archival tags.

Researchers generally have thought that most young of the year (YOY; 0-age) sablefish occur east of Kodiak Island and that most sablefish recruitment takes places in the northeastern Pacific in the coastal waters of BC and the EGOA. However, there has been recent documentation by ABL researchers of YOY sablefish in the BS. Adult sablefish spawn offshore in deep-water below 300 m in late winter/early spring. Eggs and larvae are subject to drift as they rise to the surface after hatching and drift inshore. By late summer, juveniles are found in coastal bays and inlets. These 0-age fish usually remain in the bays and inlets until early fall of the following year (about a year), although some remain for 2 years. The average length of an age-1 juvenile sablefish tagged in Southeast Alaska is 31- 35 cm.

Because of the known-age (age-1) of juvenile sablefish tagged in St. John Baptist Bay, these tagging studies are especially unique and provide valuable information that differs from information derived from the tagging of adults on the longline survey. Tagging of known-age juveniles before they leave coastal areas offers an opportunity to document age-specific movement; that is, recoveries of known-age fish provide information on the age at which fish become available to the fishery. Recoveries of electronic archival tags from known-age juveniles are especially useful for this purpose. These tags store depth and temperature data at preset time intervals, providing information about inshore-offshore migration at known ages, daily depth movements, and habitat temperature. Recoveries of known-age tagged fish have aided in evaluation of ageing methods, such as otolith reading.

Results of studies on known-age tagged fish confirm that sablefish move to deeper water with age. Sablefish availability to the commercial fishery increases rapidly for fish of younger ages, peaking at age 5 to 6, and then gradually declines as sablefish move deeper with age. The average time at liberty of a tagged juvenile sablefish recovered in the commercial fishery is 4 years, which equates to a 5-year-old fish. This number is slightly low because of the inclusion of Chatham and Clarence Strait recoveries, which are generally much sooner following release than in outside watersl; approximately 1.3 and 1.8 years, respectively. If we remove Chatham and Clarence Strait juvenile tag recoveries from this analysis, the average time at liberty of tagged juvenile sablefish recovered in the commercial fishery (in offshore waters) becomes 6.3 years (approximately 7 years old).

Figure 19 displays movement by age and size of 862 juvenile sablefish tagged in Southeast Alaska, for which recovery size was available. In the panel displaying recoveries 0–2 years following release (2 – 3 year olds), the majority of fish are still in the small size group, and very few fish have been recaptured in outside waters. Most fish captured within 2 years following tagging are sport-caught in inside Southeast Alaska waters. Over half of the tagged juvenile sablefish recaptured 3–4 years following tagging (4 – 5 year olds) have become medium-sized fish, and 33% remain small-sized fish (Fig. 19). These small fish are likely males, as they grow slower than females. By this age/size, most of the sablefish have moved out of the shallow inshore bays into offshore waters, where they have become vulnerable to commercial fishing gear. The majority of recoveries are in the EGOA and CGOA. By the time fish are recovered 5–6 years following tagging (6–7-year-old fish; Fig. 19), the majority are in the medium to large size class. As of this writing, the number of recoveries in the WGOA, AI, and BS are increasing, but the EGOA and CGOA still have the highest recoveries of these fish. This could also be a result of higher fishing concentration in these areas. At age 8 and older, the majority of recoveries were large fish (Fig. 19). In addition, there were far more recoveries of tagged juveniles 7+ years following tagging than in the earlier years, re-emphasizing size and age when the majority of sablefish are vulnerable to the commercial fishery.

RELATED STUDIES

Tag-Reporting Rate

An essential part of estimating migration rates from tagging data is the tag-reporting rate, or the estimate of the percentage of recovered tags that are returned. The tag-reporting rate for the sablefish fishery during 1980-98 was estimated by comparing tag returns from the commercial fishery with tag returns from the annual longline survey. The primary assumption of this method is that all tagged fish caught on the longline survey are reported. Reporting rates were highest in the CGOA (38.5%) and EGOA (31.5%); intermediate in the WGOA (26.9%); and lowest in the AI (17.4%) and BS (16.9%). The overall reporting rate had reportedly increased over time. This increased rate was coincidental with the implementation of the IFQ system and may have been a result of the number of tags available for recovery, the length of the commercial fishing season, increased observer coverage, the implementation of the tag reward program, and an increased interest of fishermen in the management of sablefish. Tag-reporting rates were recalculated in 2012 for an updated look at sablefish movement by pooling data in 3-year increments. Figure 20 shows how these rates have fluctuated over time. The 90% BC value is the Fisheries and Oceans Canada assumed tag reporting rate.

Age and Growth

Length measurements and otoliths (ear bones) of sablefish have been collected during longline surveys since 1981. The annular growth zones found on sablefish otoliths (similar to reading rings on a tree) and the size of the fish at the time of sampling provide a means to age the fish and estimate growth rates. These data are used in the assessment of the stock. Tagging data, consisting of release and recovery sizes and the length of time fish were at liberty, provide an independent estimate of growth rates and a means to validate otolith ages. Fork length measurements are made on all tagged fish when they are released. A fork length measurement taken at recovery, together with the recovery date, provides a direct growth observation for the period that the fish was free. If the sex of the fish is also provided together with date, position, depth, and size, then comparisons between migration and growth rates of males and females can be made.

Data from tagged fish show that sablefish grow rapidly for the first 3-4 years of their life, after which growth rates slow and remain low for the remainder of their lives. Females grow faster, larger, and mature at a larger size than males. An updated growth analysis of Alaska sablefish revealed that sablefish are growing to a larger maximum size at a faster rate in more recent years (1996–2004 compared to 1981–93). In addition, it has been determined that significant differences in growth patterns exist among management regions; the GOA regions consistently display the largest and fastest

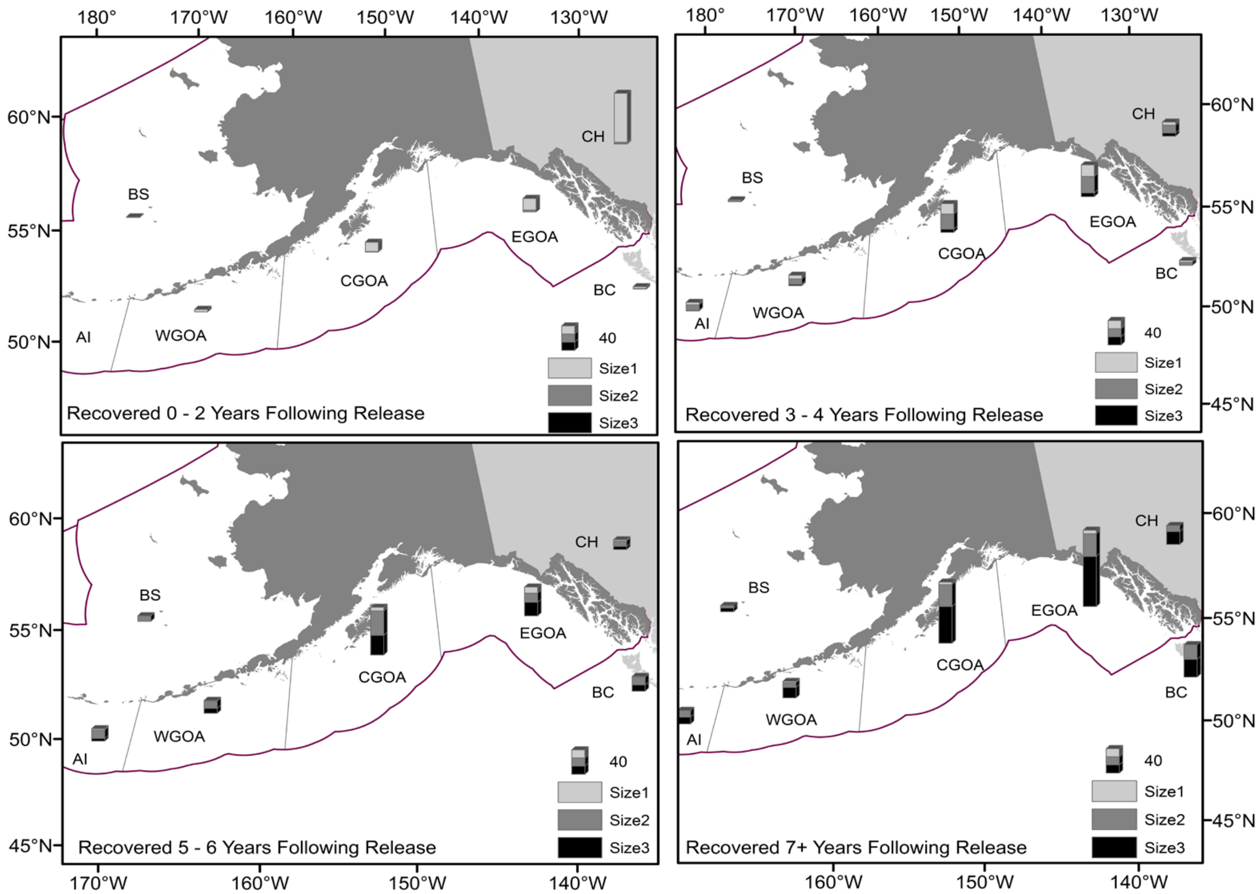


Figure 19. Number of recoveries of known-age tagged juvenile sablefish by recovery size and recovery area, recovered 0–2 years following release (top left panel), recovered 3–4 years following release (top right panel), recovered 5–6 years following release (bottom left panel), and recovered 7+ years following release (bottom right panel). British Columbia (BC); Eastern Gulf of Alaska (GOA) (EGOA); Central GOA (CGOA); Western GOA (WGOA); Aleutian Islands (AI), and Bering Sea (BS). Size 1 (small) = 41-56 cm; Size 2 (medium) = 57-66 cm; and Size 3 (large) >66 cm.

growing sablefish for both sexes. As more studies continue to point towards the development of a spatially explicit age-structured stock assessment model, these different growth patterns among management regions will become particularly important for the management of the stock.

Pop-off Satellite Tagging

Sablefish spawn in the winter between January and March when the fishery is closed. For this reason, there is little knowledge of sablefish distribution during the winter spawning season. To overcome the shortcomings of fishery-dependent recovery of tagged fish, sablefish were tagged with geomagnetic pop-off satellite tags (Desert Star Co.) off of Kodiak Island in December 2011 and during the AFSC summer longline survey in 2012. Tagging will also continue on the AFSC longline survey in 2013, 2014, and 2015. These tags measure the strength of the earth's magnetic field along three axes in order to provide an estimated location of the fish. The tag is programmed to release on a predetermined date, and once surfaced, archived data is uploaded by a passing satellite. We targeted mature females by tagging fish with a fork length > 85 cm and

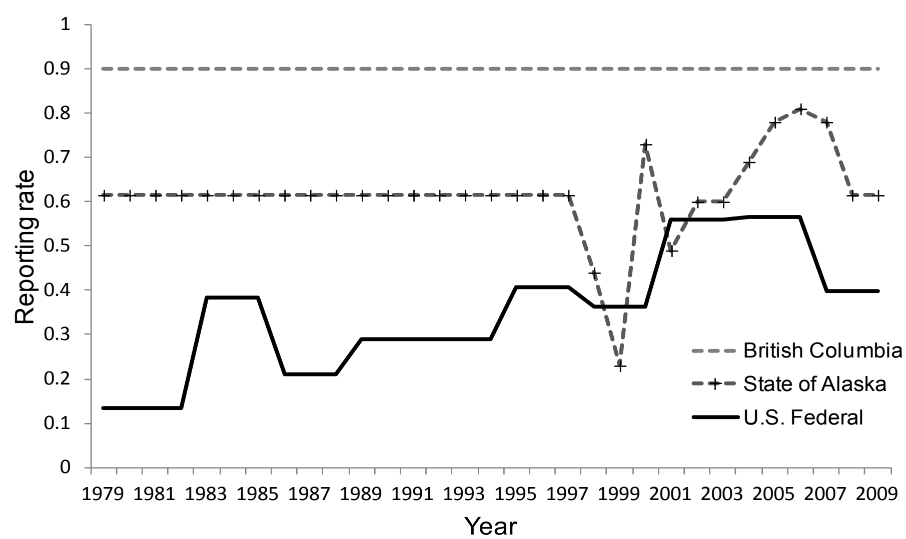


Figure 20. Values for tag reporting rates in Alaska federal waters, State of Alaska waters, and British Columbia waters used in the sablefish movement model.

programmed tags to release during spawning times in hopes of determining spawning locations.

Pop-off satellite tags were placed on five large sablefish off of Kodiak Island to monitor their movements during the spawning season in December 2011. Four of the five tags successfully released on their respective programmed dates in mid-January and early February with known pop-off locations. The two fish that were initially captured, tagged, and released nearshore on the edge of Amatuli Trough northeast of Kodiak Island (Fig. 21) remained within 1 km of their tagging location on the shelf. The two fish that were initially captured offshore but released nearshore traveled approximately 75 km (great circle distance) back to the slope within 10 km of their initial capture location. Future work will examine the daily tracking calculated by magnetic field measurements once the raw data are fully acquired.

Pop-off satellite tags were also deployed on 43 sablefish throughout the geographic range of the summer 2012 AFSC longline survey to study daily and large-scale movements. These tags were programmed to release from the fish on 1 January 2013 and 1 February 2013, in hopes of determining spawning locations and ultimately areas which may be used to help assess recruitment. Data from these tags will also provide an improved picture of the daily movements and behavior patterns of sablefish. Approximately half of the tags successfully released from the fish on their respective dates and have been transmitting data successfully via satellite. With just 1 year of data acquired and still in the early stages of analysis of the data received, it is too early to determine if there is a directed movement by sablefish for spawning purposes. However, having the release location of the tag and the pop-off location (location of the fish when the tag released) has provided great insight into (relatively) short-term and winter behavior of sablefish. In the approximate 6-month period, movement has ranged from less than 5 km to a Gulf crossing from the WGOA to the EGOA.

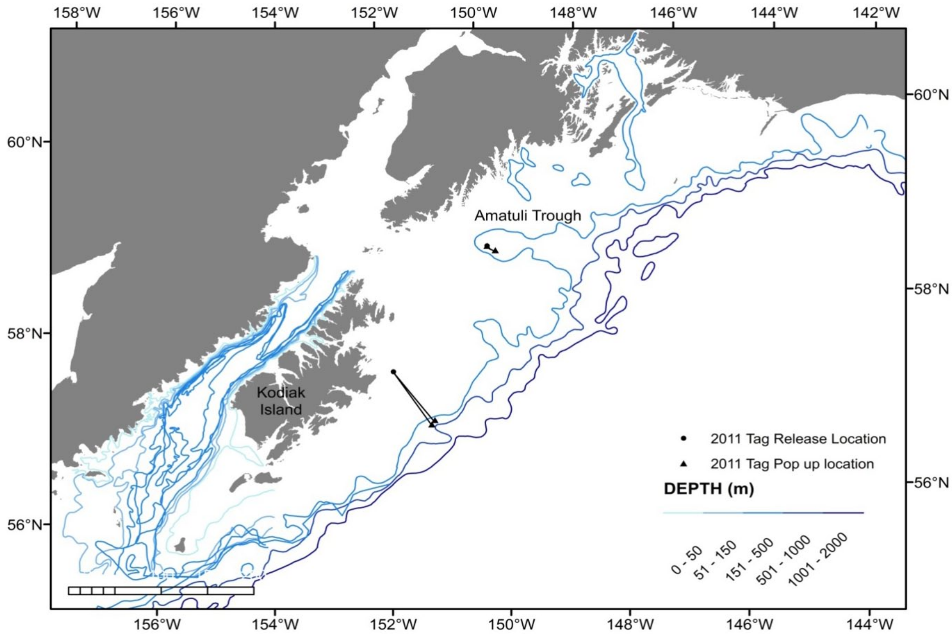


Figure 21. Release and pop-off locations of four satellite tagged sablefish released off of Kodiak Island in December 2011.

FUTURE STUDIES

The use of pop-off satellite tags remains relatively new, and all the applications and benefits from the data acquired from these tags are still unknown. We hope that the information they provide will give us insight into the behavior and movement of fish during the times of year when the fishery is closed. For instance, there is hope that patterns of spawning behavior will be identified in addition to the location of possible spawning aggregations. This information would help with future studies of recruitment. In addition, the reason for sablefish movement is still unknown. It could be the result of density overcrowding, spawning migration, physiology, or just random movement. The use of archival and satellite tag data will hopefully shed some light onto these questions.

Although we did find trends in movement direction, based on anchor and archival tag data, not all tagged fish followed the general movement trends, and it is not completely understood what factors influence the variability in migration rates from year to year and between individuals. Several pairs of sablefish, tagged and released at the same time and place, have been recovered together at a new location several years later, indicating that their respective movement patterns were very similar. On the other hand, some fish starting from the same area at the same time have been recovered at approximately the same time hundreds of miles apart, indicating vastly different movement patterns. Our tag database, in addition to increasing the amount of archival data and satellite data soon to be acquired, will continue to be used to help answer questions about sablefish movement patterns.

ACKNOWLEDGMENTS

Many individuals have contributed to the success of the Sablefish Tag Program, from the biologists and crews of chartered vessels who have spent endless hours tagging sablefish, to the many fishermen, observers, and processors who have taken the time to take measurements and return recovered tags. We gratefully thank all those who have been involved and continue to help this project succeed! In addition, we would like to thank the Alaska Department of Fish and Game for providing sablefish tag data for the updated movement analyses reported in this article, in addition to their cooperation throughout the years with the exchange of tag recoveries and recovery information.

Reviews by Cara Rodgeveller, Jon Heifetz, and Phil Rigby are much appreciated and contributed greatly to the improvement of this document.

TABLES

Table 1. Total number of adult and juvenile sablefish tag releases by NMFS each year.

Year	Adults	Juveniles	Total
1972	2,402		2,402
1973	6,999		6,999
1975	476		476
1976	162		162
1978	7,705		7,705
1979	24,397		24,397
1980	16,904		16,904
1981	27,526		27,526
1982	26,342		26,342
1983	26,449		26,449
1984	14,160	1	14,161
1985	17,285	6,179	23,464
1986	17,164	1,178	18,342
1987	16,546	7,918	24,464
1988	12,892	3,904	16,796
1989	15,115	531	15,646
1990	5,984		5,984
1991	10,052	3,370	13,422
1992	4,231	1,659	5,735
1993	4,016	613	4,629
1994	3,489	1,199	4,688
1995	2	987	989
1996	1	1,737	1,738
1997	3,857	58	3,915
1998	3,491	1,174	4,665
1999	4,650	869	5,519
2000	4,191	737	4,927
2001	5,362	106	5,468
2002	4,504	477	4,981
2003	4,079	760	4,839
2004	4,184	291	4,474
2005	3,539	697	4,236
2006	3,931	84	4,013
2007	3,825	164	3,988
2008	3,295	459	3,754
2009	3,388	312	3,700
2010	3,739	227	3,966
2011	4,323	948	5,264
2012	3,041	497	3,538

Table 2. Number of sablefish releases by NMFS by release area and size, and the total number of recoveries from those releases: AI (Aleutian Islands); BS (Bering Sea); WGOA (Western Gulf of Alaska (GOA)); CGOA (Central GOA); and EGOA (the outside waters of the Eastern GOA; and EGOA inside (the inside waters of Southeast Alaska in the Eastern GOA). Small = 41-56 cm; medium = 57-66 cm; and large >66 cm. The sum of releases of each of the three sizes for each area won't match the total release number due to missing size data.

		Release Size					
		Small		Medium		Large	
Release Area	Total Releases	Release	Recovery	Release	Recovery	Release	Recovery
AI	18,906	6,325	516	9,229	984	3,352	362
BS	26,404	8,815	755	15,283	1,566	2,278	257
WGOA	26,796	8,631	809	14,014	1,630	4,142	523
CGOA	70,851	17,211	1,346	35,397	3,129	18,031	1,501
EGOA	110,472	25,678	1,696	49,435	4,225	34,916	2,908
EGOA inside	106,578	61,460	1,785	26,812	1,470	18,187	986

Table 3. Percentage of sablefish recovered in each area from each tagging area. AI (Aleutian Islands); BS (Bering Sea); WGOA (Western Gulf of Alaska(GOA)); CGOA (Central GOA); EGOA (Eastern GOA outside); CH (Chatham Strait (inside Southeast Alaska waters in the EGOA); CL (Clarence Strait inside Southeast Alaska waters in the EGOA); Outside reporting waters (water beyond the Alaska Exclusive Economic Zone); BC (British Columbia); and WC (West Coast). Totals for each release area don't equal 100% due to rounding.

		Recovery Area									
Release Area	Total Recoveries	AI	BS	WGOA	CGOA	EGOA	CH	CL	Outside reporting waters	BC	WC
AI	1,865	26%	4%	6%	13%	27%	2%	<1%	3%	18%	2%
BS	2,582	4%	19%	7%	20%	29%	3%	<1%	3%	13%	<1%
WGOA	2,961	4%	4%	24%	21%	24%	3%	<1%	3%	16%	1%
CGOA	5,994	3%	2%	5%	44%	26%	2%	0	3%	13%	<1%
EGOA	8,849	3%	2%	4%	15%	55%	4%	1%	3%	14%	1%
CH	7,287	1%	1%	2%	7%	15%	62%	<1%	2%	11%	1%
CL	1,545	1%	1%	1%	3%	16%	4%	47%	1%	26%	<1%

Table 4. Annual movement probability estimates by area; a≠k is the total probability of moving to any other area: BC (British Columbia); CL (Clarence Strait); CH (Chatham Strait); EGOA (Eastern Gulf of Alaska (GOA)); CGOA (Central GOA): WGOA (Western GOA); BS (Bering Sea); and AI (Aleutian Islands). The analysis to calculate these movement probabilities for the CH and CL were from the ADF&G tagged sablefish data and not NMFS.

Area	BC	CL	CH	EGOA	CGOA	WGOA	BS	AI	$a \neq k$
					Small (<57 cm)				
CL	20%	69.7%	1.4%	18.6%	6.1%	1.8%	0.2%	0.2%	30.3%
CH	1.2%	0.2%	89.6%	6.3%	2%	0.6%	0.1%	0%	10.4%
EGOA	2.5%	0.1%	1%	50.3%	29.4%	12.7%	2.1%	1.9%	49.7%
CGOA	1%	0%	0.4%	37.2%	32.5%	18%	5.7%	5.3%	67.5%
WGOA	0.55	0%	0.2%	27.1%	30.4%	19.6%	11.2%	11%	80.4%
BS	0.1%	0%	0%	7%	14.8%	17.2%	56.7%	4.2%	43.3%
AI	0%	0%	0%	3.8%	8.5%	10.5%	4.9%	72.2%	27.8%
					Medium (57-66 cm)				
CL	5.8%	72.3%	1.8%	15.4%	3.6%	0.8%	0.1%	0.1%	27.7%
CH	2.3%	0.1%	85.7%	9.2%	2..1%	0.5%	0%	0.1%	14.3%
EGOA	2.5%	0.1%	1.5%	58.4%	26.1%	7.9%	1.4%	2.1%	41.6%
CGOA	0.8%	0%	0.5%	36.9%	35.6%	13.9%	4.9%	7.5%	61.4%
WGOA	0.4%	0%	0.3%	27.1%	33.9%	15.1%	9.1%	14%	84.9%
BS	0.1%	0%	0%	8.1%	20%	15.1%	50.2%	6.5%	49.8%
AI	0.1%	0%	0%	7.3%	18.3%	14.1%	5.4%	54.8%	45.2%
					Large (>66 cm)				
CL	10.8%	67.8%	3.6%	12.7%	3.6%	1.1%	0.2%	0.2%	32.2%
CH	1.6%	0.2%	90.3%	5.7%	1.6%	0.5%	0.1%	0.1%	9.7%
EGOA	2.3%	0%	1.4%	55%	27.2%	9.4%	2.3%	2.4%	45%
CGOA	1%	0%	0.6%	45.8%	30.6%	11.4%	5%	5.5%	69.4%
WGOA	0.8%	0%	0.5%	42.3%	30.4%	11.7%	6.7%	7.6%	88.3%
BS	0.2%	0%	0.1%	17.2%	22.7%	11.5%	39.5%	8.7%	60.5%
AI	0.2%	0%	0.1%	15.3%	20.7%	10.6%	3%	50.1%	49.9%

Table 5. Average distance traveled (km) for sablefish of each size type from each release area of both females (Sex 2) and males (Sex 1): EGOA (Eastern Gulf of Alaska (GOA); CH (Chatham Strait); CL (Clarence Strait); CGOA (Central GOA); WGOA (Western GOA); BS (Bering Sea); and AI (Aleutian Islands). Small = 41-56 cm; medium = 57-66 cm; and large >66 cm.

		Release Area						
Release Size	Sex	EGOA	CH	CL	CGOA	WGOA	BS	AI
All	2	231	121	120	355	586	722	972
Small	2	267	257	177	328	626	738	1,009
Medium	2	324	281	191	433	557	766	1,001
Large	2	199	92	102	334	586	702	946
All	1	359	229	180	369	533	673	869
Small	1	396	454	246	415	514	771	980
Medium	1	453	486	308	443	574	730	845
Large	1	319	158	158	324	521	624	825

Table 6. The percentage of sablefish tag recoveries after so many years at liberty.

Number of years at liberty	Percentage of recoveries
0 – 2	33 %
3 – 5	28 %
6 – 10	24 %
11 – 15	9 %
16 – 20	4 %
21 – 25	2 %
26 – 30	<1 %
30+	<1 %

EMA: Southeast Alaska Coastal Monitoring

Using Ecosystem Indicators from the Southeast Alaska Coastal Monitoring Project to Forecast Pink Salmon Harvest in Southeast Alaska

An objective of the Alaska Fisheries Science Center (AFSC), Auke Bay Laboratories (ABL) Southeast Alaska Coastal Monitoring (SECM) project is to understand the effects of climate and ocean on year class strength of salmon and ecologically-related species in Southeast Alaska (SEAK). Since 1997, the SECM project has collected a time series of data using surface trawls and oceanographic instruments in coastal SEAK which has allowed an annual index of ecosystem metrics to be constructed and used for pre-season pink salmon (Oncorhynchus gorbuscha) forecast models. Pink salmon are an ecologically and economically important species in SEAK ($92.5 M in 2011) that do not lend themselves to traditional sibling or stock assessment models because of their brief ocean life history. However, adult returns are notoriously difficult to forecast because their brief 2-year life history includes only one ocean winter and therefore precludes the use of younger returning ocean age classes to predict cohort abundance. Thus, an SECM pink salmon pre-season forecast model was developed beginning in 2004 to 1) help fishery managers maintain sustainable fisheries, 2) meet the pre-season planning needs of the resource stakeholders in the commercial fishing industry, and 3) gain a better understand of mechanisms related to salmon production in the Gulf of Alaska (GOA) large marine ecosystem.

Status and Trends

Since 1960 pink salmon year-class success has varied widely, with harvests ranging from 3 to 78 million fish annually in SEAK. This variability may result from dynamic ocean conditions or ecological interactions that affect juvenile salmon. Additionally, pink salmon production in SEAK is predominately derived from mostly (>95%) wild stocks of varied run timings that originate from more than 2,000 anadromous streams throughout the region. Therefore, the SECM approach has been to sample 4-65 km offshore along coastal localities in the vicinity of Icy Strait on monthly research surveys. This sampling locality integrates an amalgam of SEAK stocks since it is the principal northward migration corridor in SEAK. Oceanographic sampling is conducted in May, June, July, and August, while surface trawling for epipelagic fish species is conducted in the latter 3 months as juvenile salmon are actively migrating. The SECM data has also been used to describe epipelagic fish assemblages in the Alaska Coastal Current compared to the California Current, to define Essential Fish Habitat for Pacific salmon in the U.S. Exclusive Economic Zone of Alaska, and to document life history patterns of threatened and endangered salmon stocks off SEAK. For the pink salmon forecasting, SECM data is used with other regional and basin-scale data sources to construct an ecosystem matrix of input and response variables.

Researchers from the SECM project have provided forecasting information to stakeholders of the pink salmon resource of SEAK since 2004. These forecasts have allowed stakeholders to anticipate the harvest with more certainty than previous forecasting methods. For example, in 8 of the past 9 years, SECM forecast estimates have only deviated from the actual harvests by an average of 7%) (Fig. 1). Catch per unit effort (CPUE) data from juvenile pink salmon catches are also shared with the Alaska Department of Fish and Game (ADF&G) to help refine their SEAK pink salmon harvest forecast that is developed by a different method.

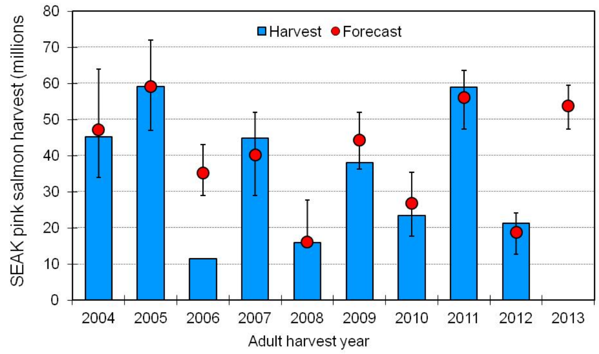


Figure 1. Previous SECM pink salmon forecast model predictions (with 80% confidence intervals) and actual SEAK harvests.

Factors Causing Observed Trends

Selected ecosystem metrics associated with SEAK adult pink harvest over the 16-year SECM time series are shown in Figure 2 below. The ranges of values below each metric are color-coded, with the highest values in green, intermediate values in yellow, and the lowest values in red. Metrics to the right of the response variable column for SEAK pink harvest are ordered by declining correlation and significance (increasing "P-value" = declining significance); the corresponding correlation coefficient "r" and "P-value" are shown below each metric. Note that in addition to CPUE, four other variables are significantly correlated with harvest (Peak migration month, North Pacific Index (NPI), %pink in June-July trawl hauls, and the ADF&G Escapement Index) and suggest an intermediate pink harvest in 2013. Additionally, this matrix shows that anomalously low (red: 2000, 2006, 2008, 2012) or high (green: 1999, 2001, 2005, 2011) return years always flag 3-5 ecosystem indicators of the respective color signal in each row. For the 2013 forecast, however, no "red" ecosystem indicators were flagged. The Icy Strait temperature index (ISTI) shown in the last column is not significantly correlated with harvest, but is an important secondary parameter to explain the error in the CPUE and harvest regression model. Mmore details about the SECM pink salmon forecasts are available on the SECM pink salmon forecast web page.

Factors Causing Observed Trends

Selected ecosystem metrics associated with SEAK adult pink harvest over the 16-year SECM time series are shown in Figure 2 below. The ranges of values below each metric are color-coded, with the highest values in green, intermediate values in yellow, and the lowest values in red. Metrics to the right of the response variable column for SEAK pink harvest are ordered by declining correlation and significance (increasing "P-value" = declining significance); the corresponding correlation coefficient "r" and "P-value" are shown below each metric. Note that in addition to CPUE, four other variables are significantly correlated with harvest (Peak migration month, North Pacific Index (NPI), %pink in June-July trawl hauls, and the ADF&G

Brood year (BY)		BY +1					BY	BY +1	BY +1
Adult pink salmon return year	SE pink harvest (response variable)	Ocean entry year	Juvenile peak pink CPUE June or July	Peak seaward migration month	North Pacific Index (June, July, Aug)	% pink in trawl hauls average June-July	Adult pink escapement index for SEAK	Auke Creek fry outmigration (1,000s) Lat 58° N	Upper 1-20 m avg. Icy Strait temp. "ISTI" May-Aug
	ADFG	SECM$_{year}$	NOAA	NOAA	CGD	NOAA	ADFG	NOAA	NOAA
1998	42.5	1997	2.5	July	15.6	12%	18.1	31.1	9.5
1999	77.8	1998	5.6	June	18.1	57%	14.8	60.8	9.6
2000	20.2	1999	1.6	July	15.8	8%	14.3	53.5	9.0
2001	67.0	2000	3.7	July	16.9	18%	27.3	132.1	9.0
2002	45.3	2001	2.9	July	16.8	19%	10.8	61.5	9.4
2003	52.5	2002	2.8	July	15.6	14%	18.6	150.1	8.6
2004	45.3	2003	3.1	July	16.1	24%	16.6	95.1	9.8
2005	59.1	2004	3.9	June	15.1	29%	20.0	169.6	9.7
2006	11.6	2005	2.0	Aug	15.5	19%	15.7	87.9	10.3
2007	44.8	2006	2.6	June	17.0	30%	19.9	65.9	8.9
2008	15.9	2007	1.2	Aug	15.7	9%	10.2	81.9	9.3
2009	38.0	2008	2.5	Aug	16.1	14%	17.6	117.6	8.3
2010	23.4	2009	2.1	Aug	15.1	22%	9.5	34.8	9.6
2011	58.5	2010	3.7	June	17.6	66%	12.7	121.6	9.6
2012	20.7	2011	1.4	Aug	15.7	21%	11.2	30.9	8.9
2013	53.8?	2012	3.2	July	16.7	40%	14.3	61.8	8.7
Pearson correlation "*r*"			0.93	-0.78	0.65	0.59	0.52	0.46	-0.06
P-value (*= significant @ <0.05)			0.00*	0.00*	0.01*	0.02*	0.05*	0.09	0.84

Figure 2. Matrix of ecosystem metrics considered for pink salmon forecasting, data sources include: the Alaska Department of Fish and Game (A. Piston), NOAA (SECM/Auke Creek-J. Joyce), and Climate & Global Dynamics (J. Hurrell, http://www.cgd.ucar.edu/cas/jhurrell/indices.data.html).

However, adult returns are notoriously difficult to forecast because their brief 2-year life history includes only one ocean winter and therefore precludes the use of younger returning ocean age classes to predict cohort abundance.

Escapement Index) and suggest an intermediate pink harvest in 2013. Additionally, this matrix shows that anomalously low (red: 2000, 2006, 2008, 2012) or high (green: 1999, 2001, 2005, 2011) return years always flag 3-5 ecosystem indicators of the respective color signal in each row. For the 2013 forecast, however, no "red" ecosystem indicators were flagged. The Icy Strait temperature index (ISTI) shown in the last column is not significantly correlated with harvest, but is an important secondary parameter to explain the error in the CPUE and harvest regression model. More details about the SECM pink salmon forecasts are available on the SECM pink salmon forecast web page.

Implications

Additional evidence from SECM research and other biological or ecosystem indicators suggests a ***strong pink salmon harvest in SEAK of 53.8 M fish in 2013***. The strongest indicator for this favorable forecast is the 2012 peak juvenile pink salmon CPUE, which was the fourth highest on record. Other ecosystem indicators in 2012 that were significantly correlated (P < 0.05) with SEAK pink salmon harvest (1998-2012) were 1) a favorable July month of peak seaward migration; 2) a high North Pacific Index (NPI = 16.7); and 3) a high average percentage of pink salmon (40%) caught among juveniles in June-July trawl hauls. Less favorable ecosystem indicators were a below average ADF&G escapement index for the pink salmon parent year (2011) in SEAK and a below average wild fry production in Auke Creek (2012). An additional indicator favoring a good harvest in 2013 was the ocean catch rates of juvenile pink salmon from a research survey downstream from the SECM project, the Gulf of Alaska Integrated Research Project (GOAIRP) conducted offshore of Baranof and Chichagof Islands both west and south of Icy Strait. Compared to the SECM surveys, pink salmon catch data from this project may better represent southern and coastal SEAK pink salmon stocks, and higher juvenile pink catches in 2012 than in 2011 suggest a higher harvest of these stocks in 2013 than in 2012.

Given the ecosystem conditions and SECM metrics sampled in 2012, the two best SECM forecast models for the 2013 SEAK pink salmon harvest are shown below in Table 1. Each forecast model value has an 80% bootstrap confidence interval shown in parentheses. The 2-parameter model is the best fit predictor for the relationship of the 16-year time series of SECM data parameters with subsequent SEAK pink salmon harvests from 1998 to 2012, based on the R2 and AICc.

Table 1. The two best SECM pink salmon forecast models for the 2013 SEAK harvest.

2013 SECM Pink Salmon Forecast Models	Adj.R2	AICc	Regression P value	Prediction for 2013
(1-parameter) Peak CPUE	84.8%	98.1	< 0.001	47.8 M (41.5-51.8)
(2-parameter) Peak CPUE + ISTI20m temp	91.2%	92.0	< 0.001	**53.8 M (46.2-58.4)**

By Joe Orsi

Ecosystem Monitoring & Assessment

Trends in Jellyfish Bycatch from the BASIS Survey

Description of Index

Jellyfish sampling was incorporated aboard the BASIS (Bering Aleutian Salmon International Surveys) vessels beginning in 2004 and will continue through 2013. All jellyfish medusae caught in the surface trawl (top 18-20 m of the water column) are sorted by species and subsampled for bell diameter and wet weight. Six species are commonly caught with the surface trawl: Aequorea sp., *Chrysaora melanaster*, *Cyanea capillata*, *Aurelia labiata*, *Phacellocephora camtschatica*, and *Staurophora mertensi*. Biomass is calculated for each species and compared across species, and oceanographic domains on the Bering Sea shelf (Inner Domain <50m; Middle Domain 50m-100m; Outer Domain = >100m). Yearly distributions throughout the sample grid for all species have been patchy. Despite uneven distributions throughout oceanographic domains, highest concentrations of all species were found to occur in the Middle Shelf Domain. Of the six species sampled, Chrysaora melanaster had the highest weight per unit effort (kg) for all years.

Status and Trends

In 2012 total jellyfish biomass more than doubled compared to 2011 and was the highest recorded biomass year for our survey (Fig. 1). One station in the southern Bering Sea portion of our grid during 2012 was responsible for half the total catch for the entire survey. During 2010, combined jellyfish species biomass also nearly doubled compared to the previous highs of 2004 and 2005. Unlike in 2012, half the total catch did not come from a single station but was spread out over the sampling grid. Starting in 2006, notable declines in jellyfish species compostion were observed for all taxa except *C. melanaster* and continued through 2012 (Fig. 2). The dominant species, *C. melanaster* continued to increase in 2010, nearly tripling its biomass compared to 2009. In 2008 our station grid was significantly reduced. However, comparisions with past years using the same survey area as 2008 indicate similar trends in species composition and distribution patterns. During 2006-09, biomass of all other species remained low in comparison to 2004 and 2005, suggesting the trend for the region has shifted from multiple species to a single species dominant catch.

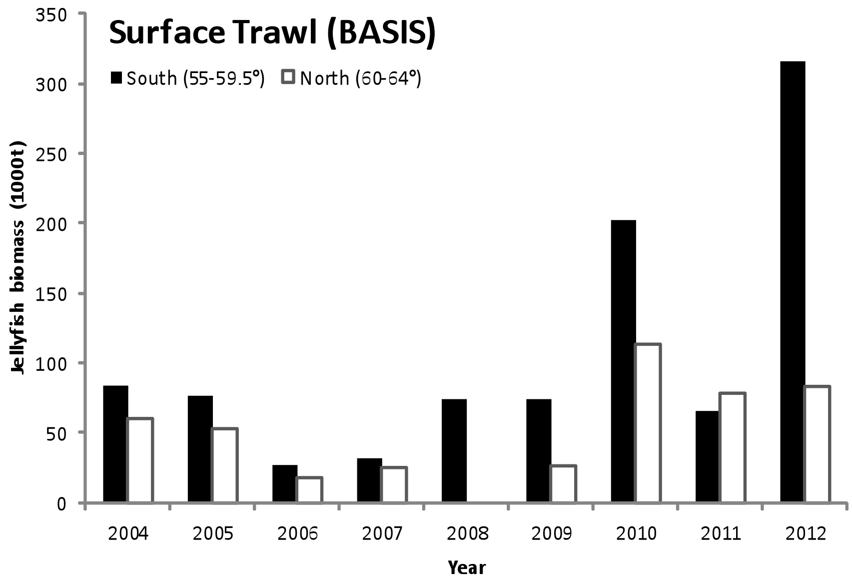


Figure 1. Total annual jellyfish biomass (1,000 metric tons (t)) split by region. Includes combined species caught in surface trawls in the eastern Bering Sea during August-October. Biomass was calculated using average effort per survey area in km2 by year.

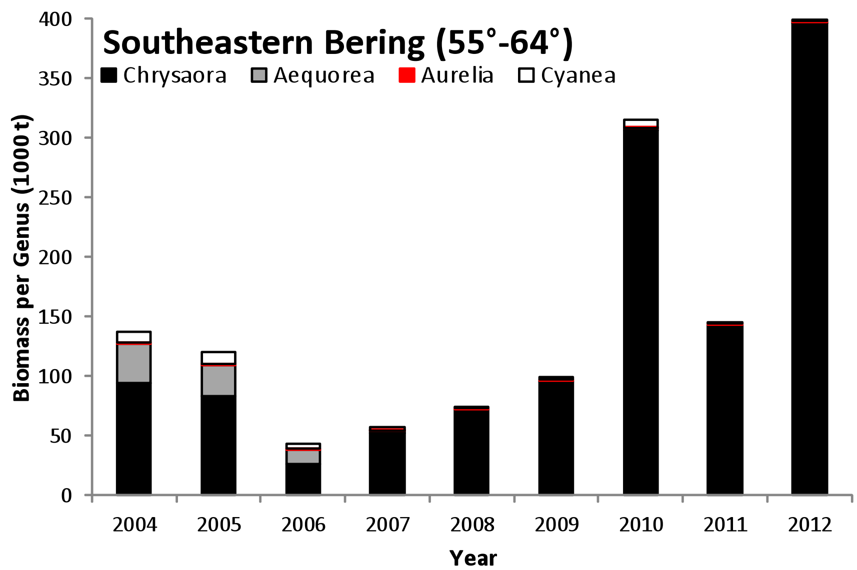


Figure 2. BASIS surface trawl Biomass (1,000 t) by genus for 2004-12 in the eastern Bering Sea during August -October. Biomass was calculated using average effort per survey area in km2 by year.

Factors Causing Trends

The cause for these shifts in biomass and distribution do not seem to rely solely on physical ocean factors (temperature and salinity). These shifts could also be a result of environmental forcing earlier in the growing season or during an earlier life history stage (polyp), which may influence large medusae biomasses and abundances.

Implications

Significant increases in jellyfish biomass may redirect energy pathways in the eastern Bering Sea food web through jellyfish predation on zooplankton and larval fish, and could result in limiting carbon transfer to higher trophic levels.

By Kristin Cieciel, Jeanette Gann, and Lisa Eisner

Regional Water Mass Characteristics in the Northern Bering Sea

Description of Index

The oceanography and shelf dynamics of the southern eastern Bering Sea (EBS) have been well-studied, while less attention has been given to the northern EBS, although commercially important fisheries are present in both the south and the north. Sea ice extent and duration, and freshwater inputs from the Yukon River are substantially higher in the north compared to the south, resulting in large variations in oceanography between the northern and southern EBS and between regions within the northern EBS. We describe spatial variations in oceanographic characteristics (salinity, temperature, and zooplankton abundance) for pre-defined regions (Fig. 1), and compare these characteristics to juvenile salmon biomass (all species combined) in the northern EBS. Sampling was conducted on a station grid using a conductivity-temperature-depth (CTD) cast (Seabird Electronics (SBE) 19, 25 or 9-11) equipped with a Wet Labs fluorometer, and beam transmissometer. The survey grid (60-km station spacing) encompassed areas between lat. 60° and 65°N over the EBS shelf. Zooplankton were collected over the water column: large taxa (>505um) with oblique bongo-net tows (505 µm) and small taxa (<505um) with a vertical Juday-net tow (168 µm). Samples were preserved in 5% formalin and enumerated at shore-based facilities. Juvenile salmon were caught with a surface rope trawl (Can trawl model 400-580 spread 60 m (width) by 15 m (depth)), towed 30 min at 3.5 to 5 knots. Salmon weights were measured for each species (chum, pink, chinook, coho, sockeye), and the multispecies biomass catch per unit effort (CPUE) was estimated for all species combined. Bering Sea Integrated Ecosystem Research Program (BSIERP) region delineations were drawn by consensus across researchers based on observed oceanography, bathymetry, benthic fauna, fish, seabird and marine mammal distribution. Data were broken out by BSIERP region for primary investigations.

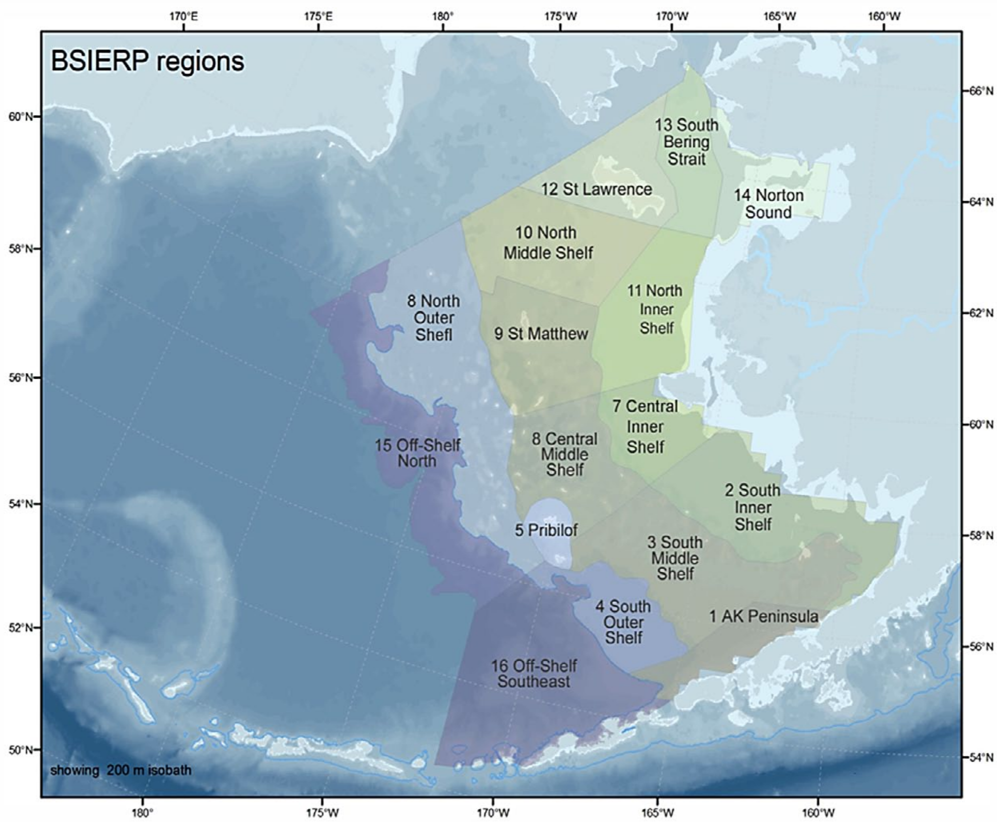


Figure 1. Bering Sea Integrated Ecosystem Research Program(BSIERP) marine regions in the Bering Sea.

Status and Trends

Norton Sound stands out as a distinct region within the northern EBS characterized by high surface and bottom temperatures, low surface and bottom salinities, and lower than average light transmission (Table 1). The South Bering Strait and North Inner Shelf regions are areas of high juvenile salmon biomass and of high numbers of large zooplankton (S. Bering Strait) and high numbers of small zooplankton (N. Inner Shelf). Highest light transmission values are seen with high bottom and surface salinity in the St. Lawrence region, while low transmission values are found with low bottom and surface salinity in Norton Sound.

Table 1. Oceanographic parameters, large and small zooplankton abundance and juvenile salmon biomass by BSIERP region. Red indicates high/maximum values and blue indicates minimum values.

BSIERP Region	Temp Top (° C)	Temp Bottom (° C)	Salinity Top	Salinity Bottom	Transmission (% light trans)	Large zoo abund. (# m-3)	Small zoo abund. (# m-3)	Juvenile salmon biomass (kg km-2)
North Inner	8.25	6.53	30.63	30.92	82	84	**104127**	**3706**
North Middle	7.83	**1.26**	31.15	31.57	83	90	54969	819
Norton Sound	**9.70**	**8.92**	27.00	28.29	65	**41**	13037	575
South Bering Strait	**7.51**	5.15	31.11	31.59	82	**2418**	10399	**2287**
St. Lawrence	7.65	2.97	31.80	32.20	89	183	13108	**194**
St. Matthews	7.61	1.33	31.32	31.74	84	67	**5941**	930

Initial findings reveal connections between juvenile salmon and bottom temperature, bottom salinity, and large and small zooplankton, depending on the region. Surface temperature and salinity changes over the northern EBS can change considerably from season to season and from near to offshore. Norton Sound has relatively low juvenile salmon biomass during late summer/early fall, while highest juvenile salmon biomass is found in South Bering Strait and North Inner Shelf regions. Future analysis will focus on individual salmon species while investigating their spatial and temporal relationships with oceanographic parameters.

Factors Causing Trends

Ice melt and high fresh water run-off contribute to Norton Sound's low salinities, while shallow depths contribute to higher temperatures in summer/early fall.

Implications

Because highest abundances of large and small zooplankton were seen in the South Bering Strait and North Inner regions, respectively (coinciding with the two highest regions of juvenile salmon CPUE), large zooplankton could be important prey for juvenile salmon in the South Bering Strait region, while small zooplankton could be important prey for juvenile salmon in the North Inner region. By Jeanette Gann and Lisa Eisner

By Jeanette Gann, and Lisa Eisner

FMA Staff Participate in 7th International Fisheries Observer & Monitoring Conference, Viña del Mar, Chile

The 7th International Fisheries Observer & Monitoring Conference (IFOMC), hosted by the Instituto de Fomento Pesquero, IFOP (Institute for Fisheries Development), was held 8-12 April 2013 in Viña del Mar, Chile. The goal of this 5-day conference was to a) improve fishery monitoring programs worldwide through sharing of practices and development of new methods for data collection and analysis, and b) provide a forum for dialog between those responsible for monitoring fisheries and those who rely upon the data they collect. The conference, which was attended by 150 attendees representing 27 countries, was guided by the motto: "Scientific Fisheries Observers are the first essential link in fisheries research for sustainable resources management."

The Fisheries Monitoring and Analysis Division (FMA) submitted six abstracts that were selected as presentations or posters, but due to travel restrictions only four were presented at the conference. Dr. Craig Faunce attended the conference representing our FMA efforts.

The conference included 11 topical panel sessions with a moderator and four to seven panelists. Each panelist gave an oral presentation followed by questions. Following each sessions' complete panel presentations was a dynamic question and answer period between the audience and panelists. In addition to the verbal presentations, many posters displayed additional information related to each session topic. Three sessions were of particular interest to FMA. These sessions focused on data quality, electronic monitoring, and potential sources of bias in the collection and analysis of scientific data.

The goal of this 5-day conference was to a) improve fishery monitoring programs worldwide through sharing of practices and development of new methods for data collection and analysis, and b) provide a forum for dialog between those responsible for monitoring fisheries and those who rely upon the data they collect.

Session 1 titled "How to balance cost effectiveness of data quality in fisheries monitoring programs?" explored how monitoring and sampling programs have balanced their budgets without slashing data quality. During this session, Dr. Faunce served as a panelist and presented "A field test of an observer-audit approach to improve catch reporting in Alaska: NPRB Project 1017 Alternative catch monitoring of Alaskan groundfish"- a cooperative research project designed to test whether species composition data collected by observers at shoreside processing plants could be used to gauge the quality of the catch information reported on fish tickets. The project is co-authored by Jennifer Cahalan from the Pacific States Marine Fisheries Commission (PSMFC) and Julie Bonney of the Alaska Groundfish Data Bank. Craig also presented a poster assigned to this session entitled: "The 2013 Alaskan Observer Program by the Numbers, describing the quantities of individual elements that together comprise the most recent effort to 'restructure' the North Pacific Groundfish and Pacific Halibut Observer Program. This restructure began in April 2010 and was successfully implemented in January 2013.

Although unable to attend the conference, AFSC scientists Mike Moon from FMA and co-author Duane Stevenson from the AFSC RACE Division provided a poster assigned to Session 1. In this poster, the authors illustrate a Geographical Information System model developed in 2009 providing FMA staff a low-cost and efficient method to automate the detection of species identification outliers.

Dr. Faunce also served on the panel for Session 7 entitled "How to determine and reduce bias in monitoring programs?" Because there can be many potential sources of bias in the collection and analysis of scientific data, this session discussed the main sources of sampling or analysis bias and considered procedures or methodologies that can be employed to minimize them. Craig, Farron Wallace (FMA), and Jennifer Cahalan co-authored this presentation, which explained how sampling strata, a deployment rate that could be afforded by the program budget, and a comparison of the amount of coverage that would be expected from the new deployment were derived for the 2013 (restructured) Observer Program.

The final book of abstracts and conference program can be found at: http://www.ifomc.com/. Full conference proceedings will be available soon.

By Patti Nelson

Research Funding for FY 2013

The AFSC received $376,450 for Ocean Acidification research in FY 2013. These new funds primarily will be used to conduct species-specific physiological research. The species-specific physiological response to ocean acidification is unknown for most marine species. Lacking basic knowledge, research will be directed toward several crab, fish and coral taxa. The research will be conducted at the Kodiak, Auke Bay, and Newport Laboratories. The king crab results also will be incorporate into a king crab bioeconomic model; this work will be completed by the Socioeconomics Assessment Program in Seattle.

Principal Investigators	Abbreviated Titles	Funding
Foy	Alaska crab growth and survival	$195,950
Dalton	Alaska crab abundance forecast	$46,200
Hurst	Growth and survival of finfish	$52,300
Foy and Hurst	Water chemistry	$71,500
Stone	Calcium carbonate mineralogy of Alaskan corals	$10,500
Total		**$376,450**

Essential Fish Habitat Funding Received

Proposals for FY 2013 Essential Fish Habitat (EFH) recently were funded. Project selection for EFH research is based on research priorities from the Alaska Essential Fish Habitat Research Plan. Research priorities are

1. Characterize habitat utilization and productivity; increase the level of information available to describe and identify EFH; apply information from EFH studies at regional scales.
2. Assess sensitivity, impact, and recovery of disturbed benthic habitat.
3. Validate and improve habitat impacts model; begin to develop geographic-based database for offshore habitat data.
4. Map the seafloor.
5. Assess coastal and marine habitats facing development.

The Habitat and Ecological Processes Research (HEPR) team completed a scientific rating of the 2013 proposals last fall. Alaska Regional Office Assistant Regional Administrator for Habitat Conservation Jeanne Hanson and HEPR Program Leader Mike Sigler agreed on rankings based on the scientific review and management priorities. The management prioritization generally followed the science ranking but a few changes were made to reflect the relevance of the proposals for fishery management decisions.

Principal Investigators	Titles	Funding
Helser, Matta, Ormseth, Miller	Otolith microchemical fingerprinting: Assessing juvenile Pacific cod habitat utilization in the Gulf of Alaska - Year 2	$38,235
Zimmermann	Bathymetry and substrate compilation from smooth sheet charts	$57,388
Rooper, Etnoyer, Stone	Simulation modeling of sustainable removals of Primnoa in the Gulf of Alaska based on field studies of size structure and recruitment rates	$52,500
Hurst, Cooper, Duffy-Anderson, Miller	Essential fish habitats of juvenile pacific cod, yellowfin sole, and northern rock sole along the Alaska Peninsula	$73,858
Conrath, Knoth, Rooper	The distribution and productivity of commercially important rockfish species in coral and sponge habitats of the Gulf of Alaska	$31,800
Total		$253,781

By Mike Sigler

Alaska Ecosystems Program

Estimating Steller Sea Lion Population Trends

Part of the NMFS' mission is to monitor populations of Steller sea lions (*Eumetopias jubatus*). Estimating trends in growth is a central tenet in managing ecological populations and there are many methods for estimating general population trends. The most common include simple linear regression of log-abundance, state-space modeling, and Bayesian hierarchical modeling.

While all of these methods have benefits, they have one downfall that is a major stumbling block for Steller sea lion monitoring: trend is estimated from a single parameter in the model. Thus, estimating regional trends in sea lion abundance can prove difficult if the many survey sites are not surveyed in a single year.

The National Marine Mammal Laboratory's Alaska Ecosystems Program (AEP) proposed a methodology and software to overcome this problem by treating a trend as a summary of abundance, rather than a model parameter. To make this method widely available for future sea lion monitoring, as well as to other ecologists in general, we created the add-on package agTrend for the R statistical environment (R Development Core Team 2013).

The package is freely available from the project website http://nmml.github.io/agTrend. Users can find links and directions for installation.

In the AEP's Steller sea lion monitoring studies, aggregating site-level abundance into regional abundance is problematic because sites may not be surveyed in the same years. So, site-level abundance cannot simply be "summed up" to form regional abundance observations. Moreover—because sea lion monitoring has been going on for more than 20 years—survey methods have changed, prohibiting direct comparison of abundance across years. For example, in the 1990s and early 2000s photographs of sea lion sites were taken with handheld cameras during aerial surveys. Beginning in 2004, photographs were taken with high-resolution, belly-mounted cameras on the survey plane.

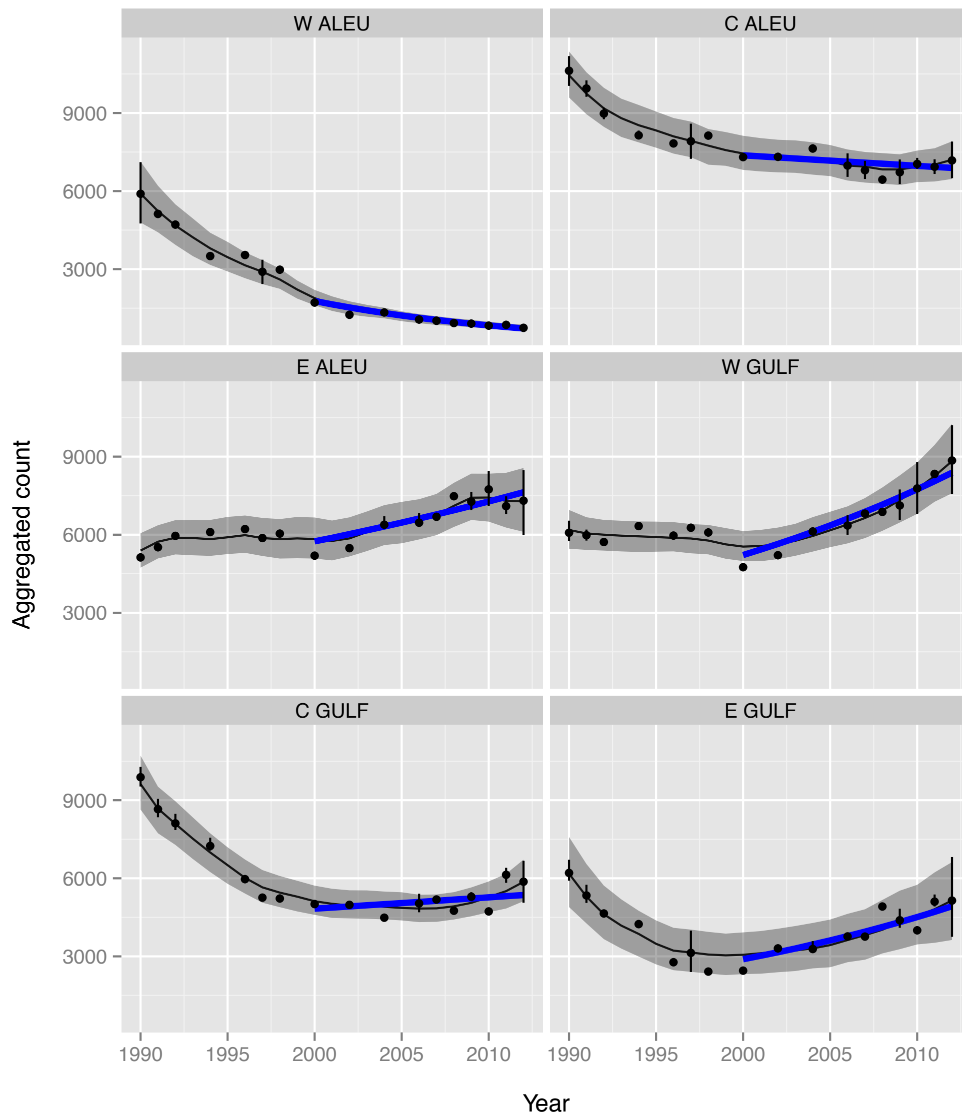


Figure 1. Estimated regional trends of Steller sea lion aerial survey counts in the wDPS. The blue line represents the fitted trend for each region from 2000 to 2012 and the gray envelope represents the total augmented counts over each site within the separate regions. The points are the regional total of each count plus the augmented data. The error bars represent the variation in the observed counts plus the augmented data. Plot titles correspond to regions of the Aleutian Islands and Gulf of Alaska, e.g., W ALEU=Western Aleutian Islands, C ALEU=Central Aleutian Islands, and E GULF=Eastern Gulf of Alaska.

Hierarchical models can be used to estimate regional-level trends and correct for changing methodology; however, the resulting inference is interpreted as the average trend, which is not the same as the trend of the regional total abundance. To circumvent this problem, we took an approach using Bayesian Markov Chain Monte Carlo (MCMC) methods and a hierarchical model to augment missing site data.

After the missing data is simulated, forming regional sums of abundance over many sites is straightforward. The augmentation procedure used by agTrend is based on two hierarchical processes, the observation process and the abundance process. The observation model accounts for changes in survey methodology or environmental conditions over the course of the monitoring program that affect the observed sea lion aerial survey observations. The abundance process models the normalized sea lion counts.

The normalized abundance refers to the count that would be observed had the surveys been conducted under what could be termed "ideal" conditions. The normalization allows for proper comparisons of sea lion counts across years. The basic procedure is to simulate realizations of the normalized sea lion counts at every site, then sum the values over regions of interest, and finally, the trend in abundance is calculated for each simulation. We then summarize the distribution of simulated trends to form estimates of regional Steller sea lion trends.

The agTrend package includes several demonstration scripts for analyzing Steller sea lion aerial survey data. Figure 1 illustrates estimated trend lines (2000-12) and augmented data for a regional aggregation of Steller sea lion aerial survey counts in the western Distinct Population Segment (wDPS; sites west of 144°W longitude). The estimates of trend in aerial survey counts from this analysis are provided in Table 1.

Data augmentation for individual sites is illustrated in Figure 2. Figure 2 also illustrates another technical challenge of trend estimation for Steller sea lions, observed counts of zero at some sites in some years. To model this phenomenon, a zero-inflated abundance model can be used for some sites. In Figure 2, (a) shows the augmented aerial counts for the Glacier Island haul-out site, (b) shows the estimated probability of observing zero animals in any given survey year, and (c) illustrates the data augmentation for the Marmot Island rookery, a large site with essentially zero probability of observing an empty beach.

Table 1. Regional trend estimates for 2000-12. The trend estimates are given in percent growth form. The columns are the simulated median and the lower and upper 95th percentiles.

Region	Estimate	Lower CI	Upper CI
Western Aleutian Islands	-7.23	-9.04	-5.56
Central Aleutian Islands	-0.56	-1.45	0.43
Eastern Aleutian Islands	2.39	0.92	3.94
Western Gulf of Alaska	4.01	2.49	5.42
Central Gulf of Alaska	0.87	-0.34	2.18
Eastern Gulf of Alaska	4.51	1.63	7.58

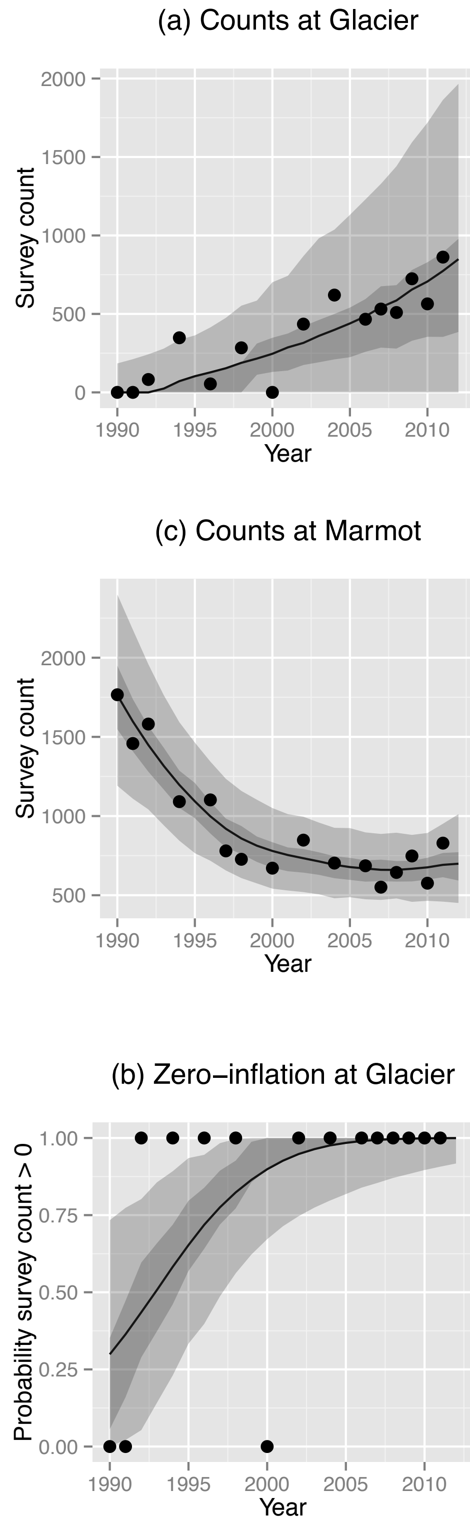


Figure 2. Predicted survey counts at the Glacier haul out and Marmot rookery. The dark and light grey envelopes are the 50th and 90th percentiles for the simulation distribution, respectively. For plots (a) and (c), the points are the observed counts; while for plot (b), the points are indicators of positive counts. The black line is the median augmented counts for (a) and (c); while in (b), it is the median probability of a positive count.

Cetacean Assessment and Ecology Program

National Marine Mammal Lab Participates in 10 Years of NOAA Science Camp

Scientists at the National Marine Mammal Laboratory (NMML) prepared for the 11th-annual NOAA Science Camp at the NOAA Western Regional Center (WRC), in Seattle, Washington, when middle-school students visit labs all over the WRC campus to learn first-hand how NOAA scientists chart oceans; study oceanography, watersheds, weather, fisheries, and marine mammals; conduct diving operations; restore habitat; and respond to hazardous spills. Campers visiting NMML labs participate in hands-on activities that demonstrate how NMML scientists study the abundance, movements, diet, individual identification, acoustics, and genetics of marine mammals.

As coordinators of NMML's Science Camp program, we have worked with NMML scientists to develop hands-on activities that illustrate the research methods and techniques they use to study populations of marine mammals. The activities have been revised and updated over the years, based on feedback from campers, Science Camp staff, and the NMML scientists who lead the activities each year. Since the first NOAA Science Camp in 2003, 49 scientists have participated in NMML's Science Camp sessions—some for one year and some for many years—and in the process have had the opportunity to share their enthusiasm and research experiences with many future scientists.

Jim Thomason explains how scientists identify bones in seal scat to determine what the seals ate.

A Junior Leadership Program for high-school students was added to NOAA Science Camp in 2011 to offer high-school students hands-on experience in leadership and communication skills and give them the opportunity to learn more about NOAA careers by interacting with NOAA scientists and working with them to teach marine science to the middle-school campers. As part of this program, NMML scientists have worked with Junior Leaders in NMML's telemetry, diet, acoustics, and genetics activities; participated in interview sessions and job shadows; and conducted tours of NMML's labs and osteological collection.

During NMML's sessions for the middle-school campers, small groups of campers rotate through approximately four activity stations to try their hand at different research techniques we use to answer some basic questions about marine mammal populations:

How many are there? Campers watch video from aerial surveys of Cook Inlet belugas, use a computer program to track and count the number of belugas in a video clip, measure the size and determine the color (white adults vs. dark juveniles) of individual animals, and discuss how video counts can be used to calculate correction factors (to account for animals that were missed or were below the surface during aerial counts) to determine the abundance of different populations of marine mammals.

Where do they go? To explore how radio telemetry can be used to monitor the presence or absence of pinnipeds at rookery sites, campers are given radio tags and corresponding numbered tags to wear while rotating through all of NMML's activity stations. At the telemetry station, they use a receiver to detect signals transmitted by the radio tags and visually check for numbered tags on other campers. Scientists also use a variety of time-depth recorders, radio tags, and satellite tags, as well as maps of marine mammal tracks, to discuss the development of telemetry and how NMML uses the information collected by the instruments to study the movements and behavior of marine mammals.

What do they eat? Campers study pinniped diet by examining and identifying the prey remains (fish bones, fish otoliths (ear stones), and squid beaks) found in pinniped scats. By identifying and measuring one of the otoliths and using a regression formula to determine the length and weight of the fish consumed, campers can compare the species and sizes of fish targeted by pinnipeds and fisheries.

Campers work with Heather Ziel to learn about radio frequencies and tracking marine mammals.

How do you identify individual animals? Campers examine photos of humpback whale tail flukes and aerial photos of bowhead whales, discover how natural marks (pigment patterns) and scars can be used to identify individual animals, practice matching different photos of individual whales, and discuss how identifying individual animals in different areas, seasons, and years enables scientists to study the life history and movements of whale populations.

What sounds do they make? Campers learn to identify several species of marine mammals by listening to recordings of their vocalizations, practice navigating to a vocalizing whale in real time by using information from two sonobuoys (floating underwater listening devices that transmit sounds via radio waves) to determine the whale's position, and learn how NMML uses bottom-moored passive acoustic recorders to determine the presence of marine mammals in different seasons and years in locations and environments that are difficult to monitor in real time.

Who is related to whom? Campers determine the paternity and maternity of northern fur seal pups by matching a pup's DNA to the DNA of a male and a female fur seal. DNA from several locations (loci) on the genome are considered during the matching process. Campers then discuss with scientists how genetic studies can provide information about pinniped rookery structure and the reproductive success of individual animals.

A culminating Science Camp activity that demonstrates how different NOAA offices work together to respond to environmental events presents campers with an environmental mystery (a fish kill in Puget Sound). Campers come up with questions to determine the cause and effects of the fish kill and return to the NOAA offices to carry out their investigations. At the NMML session, campers research which marine mammals are found in Puget Sound at the time of the fish kill, learn more about pinnipeds and cetaceans in the area, and discuss the possible effects of the fish kill event on marine mammals. After gathering information from each of the NOAA offices, the campers compile and analyze their data, draw conclusions, create posters to illustrate the scientific process they used in their investigations, and then present and explain their posters to their families, Science Camp staff, and NOAA scientists during a poster session on the last day of camp.

A culminating Science Camp activity that demonstrates how different NOAA offices work together to respond to environmental events presents campers with an environmental mystery (a fish kill in Puget Sound).

Thanks to the efforts of all of the NMML scientists who have created and led Science Camp activities, NMML is consistently recognized—by campers and staff—for providing engaging, hands-on activities that illustrate marine mammal research methods and objectives, for giving campers and staff the opportunity to meet and interact with many different scientists, and for increasing the campers' knowledge of and interest in NOAA science.

Many scientists have been instrumental in creating NMML's Science Camp activities, including Christy Sims (abundance), Carolyn Gudmundson (diet), Sally Mizroch (humpback photo-ID), Julie Mocklin and Kim Shelden (bowhead photo-ID), Jessica Crance (acoustics), Bobette Dickerson (genetics), and Janice Waite and Kim Parsons (killer whale ecotypes).

By Marcia Muto and Lisa Hiruki-Raring

Habitat Research Group

International Committee Forms to Study Bottom-trawl Effects

There is considerable evidence that mobile bottom-contact gears (MBCG) such as trawls and dredges affect the integrity of benthic environments that support prey and provide habitat for managed populations of fish and crab. Widespread use of these gears could thus have substantial effects on the growth, survival, and productivity of these stocks. There is, however, considerable variability in the magnitude and characteristics of the effects. Hard-bottom areas with surface-dwelling invertebrate fauna are particularly sensitive, whereas soft-bottom areas with frequent natural disturbances are relatively insensitive. Given that approximately 25% of world fish catch comes from the use of these gears, a clear understanding of the overlap between trawling effort and different benthic habitats is of considerable global importance.

An international group of experts in ecology and fisheries management has formed to summarize the global use of mobile fishing gears, their impacts on marine habitats and the productivity of fish stocks, and related management practices. The committee is comprised of individuals from both academia and government and is being lead by Professors Ray Hilborn (University of Washington, Seattle), Simon Jennings (Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, U.K.), and Michel Kaiser (Bangor University, Bangor, U.K.). Other members of the committee are Drs. Adriaan Rijnsdorp (Wageningen University and Research Center, Ijmuiden, Netherlands), Roland Pitcher (Commonwealth Scientific and Industrial Research Organization, Brisbane, Australia) , Bob McConnaughey (NOAA Alaska Fisheries Science Center, Seattle), Jeremy Collie (University of Rhode Island, Narragansett), Jan Hiddink (Bangor University, Bangor, U.K.), and Ana Parma (Argentine Council for Science and Technology , Chubut, Argentina). Two post-doctoral research associates (Drs. Ricardo Amaroso and Kathryn Hughes) are also actively working on the project.

The full project will consist of five phases spread over the next 2 years. The first phase of this project will systematically map MBCG effort and its distribution with respect to benthic habitats. Phase 2 will compile and evaluate data about the impacts of MBCG on the abundance and diversity of biota. Phase 3 will use information from the first two phases to conduct a risk assessment of the effects of trawling and to illustrate trends in the risk of change to seabed habitats and communities. Phase 4 will look at the medium- and long-term impact of trawling on the productivity and sustainable yield of different target species and ecosystems. Phase 5 will identify and test a range of management options and industry practices that may improve the environmental performance of trawl fisheries, with a view to defining 'best practice.'

To date, a questionnaire has been widely distributed to stakeholders and the responses were compiled to identify priority issues. The committee's first meeting was held at the University of Washington School of Aquatic and Fishery Sciences on 17-19 June. The next meeting is tentatively scheduled for the Netherlands in November of this year. Additional details about the project and the study group are available at http://trawlingpractices.wordpress.com/.

By Bob McConnaughey

Commendations for the 2012 FISHPAC Project

The FISHPAC project is investigating whether quantitative information about seafloor characteristics can be used to improve existing habitat models for eastern Bering Sea groundfish and crab species. The project is a collaborative effort between the Center's Habitat Research Group (HRG), two other branches of NOAA, the U.S. Navy, and outside technical experts. Although primarily a scientific study, the project also provides hydrographic-quality bathymetry data for updating NOAA nautical charts in areas with outdated or nonexistent information. During 2012, five different sonar systems acquired acoustic backscatter over a large area in the Bristol Bay region of the eastern Bering Sea. These data will be combined with trawl-survey catches to determine the most cost-effective system for broad-scale characterization of seafloor habitats.

Several commendations have been issued to recognize outstanding contributions during the 2012 FISHPAC cruise. The officers, crew, and support engineers of Fairweather were awarded a Unit Citation from former Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator Dr. Jane Lubchenco. Captain Mark P. Ablondi, Executive Officer of NOAA Fisheries, and Dr. Bob McConnaughey, FISHPAC chief scientist and HRG leader, presented a plaque to the Commanding Officer James Crocker on 23 April, along with 46 certificates to members of Fairweather's complement. The award stated that "an ambitious cruise plan for the multi-mission FISHPAC project was accomplished due to uniformly high levels of personal commitment, technical proficiency and leadership" and that "all departments made significant contributions to prepare the vessel and to maintain fully productive and safe operations under extremely challenging and high-tempo conditions at sea."

Dr. Lloyd Huff, an underwater acoustics expert, was selected as 2012 NOAA Fisheries Team Member of the Year for the AFSC. The award recognized his extraordinary contributions to the agency mission over the period 2004-2012. In particular, Dr. Huff has served as the cornerstone of a technical team working to develop and transition a prototype acoustic instrument, the Klein 7180 long-range sidescan sonar system (LRSSS). The LRSSS is a complex underwater platform (towfish) consisting of multiple acoustic, environmental, and navigational sensors that is distinguished from all other sonar systems by its ability to collect fully corrected quantitative information about seafloor characteristics and to do so at high speed over a very broad swath of ocean. It is being developed to address the need for a more efficient survey system to simultaneously accomplish broad-scale characterization and mapping of essential fish habitat (EFH) and reconnaissance hydrographic surveying. Dr. Huff volunteered to join the scientific party for the 21-day cruise on *Fairweather* in 2012, during which time he worked tirelessly during multiple shifts each day to assure the proper operation of the LRSSS and the integrity of 3.7 terabytes of multi-purpose data collected during around-the-clock operations.

Steve Intelmann, a member of the HRG program, was recognized for his technical skills, creative use of internal and external resources, and an impressive commitment to success during a long and challenging period leading up to and including the 2012 FISHPAC cruise. His contributions yielded substantial improvements in the accuracy and precision of data from the LRSSS and the eventual biological and hydrographic products. The professionalism, competence, commitment, and resourcefulness of support personnel from the Naval Undersea Warfare Center, Division Keyport were also recognized in a letter from the AFSC to their Commanding Officer. Mark Moody (team leader), Edwin Draper, William Heather, James Hosford, and James Husted were recognized for very high levels of technical competence and commitment to the FISHPAC project. Finally, sincere thanks to all FISHPAC partners for their many significant contributions.

By Bob McConnaughey

Kodiak Laboratory

Juvenile Red and Blue King Crabs: Can They Coexist?

Red king crab (*Paralithodes camtschaticus*) (Fig. 1) and blue king crab (*P. platypus*) (Fig. 2) are two commercially important, federally managed species in Alaska, with many ecological similarities. For both species, larvae are released in the spring, are planktonic for about 2-3 months, feed on a diet of phytoplankton and zooplankton, and go through a series of four zoeal stages before molting to a non-feeding, post-larval glaucothoe stage. Glaucothoe seek out structurally complex habitats on the ocean bottom for settling (cobble, shell-hash, tubeworms, and hydroids) and protection from predators and foraging opportunities. After settling, glaucothoe molt to the first juvenile stage and remain on the ocean bottom for the rest of their lives. As juveniles and adults, both species are opportunistic omnivores and consume a range of food items including bivalves, gastropods, echinoderms (sea stars and brittle stars), and crustaceans.

Given their ecological similarities, it is unknown whether both species can coexist successfully. In many cases, competition between two ecologically similar species leads to the exclusion of one. The ranges of red and blue king crabs do not generally overlap much. In Alaskan waters, red king crabs occur throughout the Gulf of Alaska, in Bristol Bay, and Norton Sound, whereas the only currently healthy blue king crab population is around St. Mathew Island. Generally, blue king crabs live in cooler areas, but the relationship between the distribution of the two species and temperature is not clear-cut. The Pribilof Islands is an area where both species co-occur and where population abundances of both species have historically fluctuated. In the 1970s blue king crab dominated the area around the Pribilofs, but in the early 1980s the population crashed. Then in the early 1990s the populations of both species increased, but in the late 1990s the blue king crab population crashed again and has not recovered.

Figure 1. Photo of red king crabs in experimental setup on cobble habitat.

Although there is no evidence to suggest that adult red and blue king crabs compete for resources, no one has examined the potential for coexistence at the juvenile stage. One potential mechanism that would allow coexistence is habitat partitioning, where each species utilizes different structures for food or refuge from predators. Some field studies suggest that red king crabs prefer cobble habitat whereas blue king crabs prefer shell hash. Our study was designed to test the hypothesis that habitat type can influence the ability of both species to coexist. To test this hypothesis, year-0 crabs were reared in the laboratory in small tubs for 13 weeks with either cobble or shell hash as the habitat. Three species treatments were fully crossed with habitat: 10 red king crab alone, 10 blue king crab alone, and a mixture of 5 red and 5 blue king crabs. Four replicates of each combination of habitat and species were established. Crabs were reared at 5°C, which is well within the range of tolerance for both species, and were fed to excess three times a week. At the end of each week, all of the habitat was removed from each tub and all of the surviving crabs were counted. The mortality rates for each species was calculated in each tub and compared among treatments.

Figure 2. Photo of blue king crabs on shell hash habitat. Photo by Scott Van Sant.

Habitat type and species composition affected mortality rates for red and blue king crabs. Both species had better survival in shell hash than in cobble (Figs. 3 and 4). However, red king crabs survived better in the presence of blue king crabs, especially in shell hash, where the mortality rate was almost cut in half (Fig. 3). In contrast, blue king crab survival was much poorer when reared with red king crabs. Survival was especially poor in cobble where all of the blue king crab died within 9 weeks when red king crabs were present; however, the data suggest that all blue king crabs would have also died in shell hash within weeks if the experiment had not been ended (Fig. 4). Most of the mortality in the trials was probably due to cannibalism and inter-species predation as no dead crabs were removed from the tanks.

The data from this study suggest that habitat alone does not allow red and blue king crabs to coexist. Although shell hash habitat did reduce blue king crab mortality compared to cobble, adding red king crabs to the trials substantially increased mortality regardless of habitat type. Red king crab juveniles had a substantial advantage over blue king crabs in this study under all tested condition, warranting further investigations into the role of competition and predation between the species.

By William Christopher Long

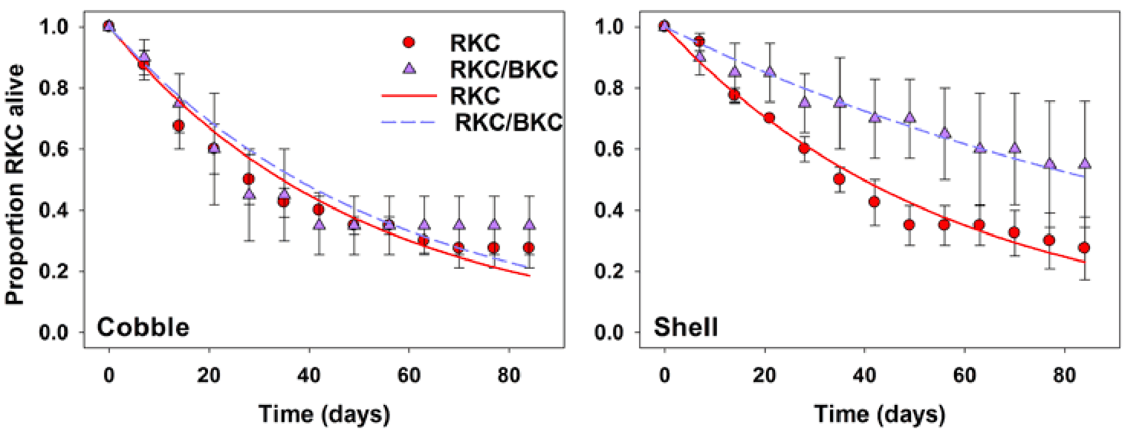


Figure 3. Proportional survival of year-0 red king crabs in cobble and shell hash habitats reared alone (RKC) and with blue king crabs (RKC/BKC). Points represent average ± 1 SE, and lines represent the best-fit trend lines assuming a constant rate of mortality.

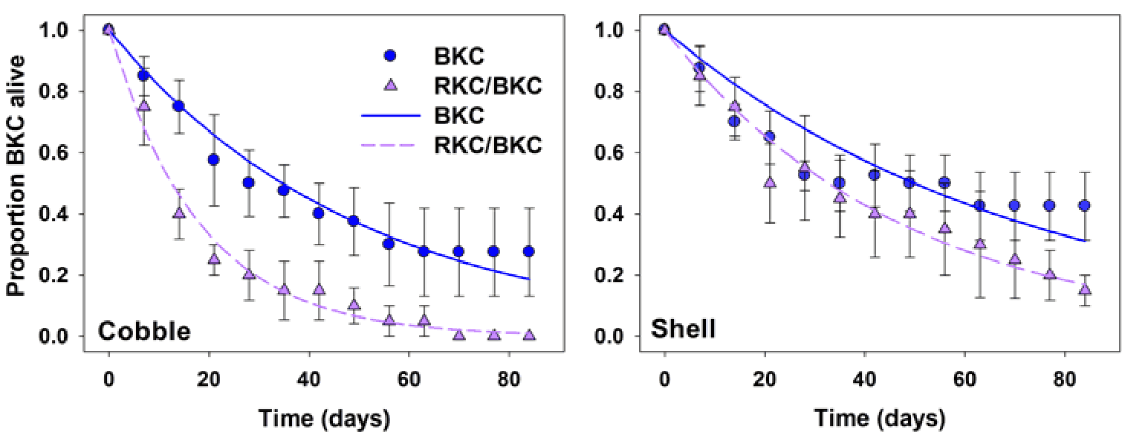


Figure 4. Proportional survival of year-0 blue king crabs in cobble and shell hash habitats reared alone (BKC) and with blue king crabs (RKC/BKC). Points represent average ± 1 SE, and lines represent the best-fit trend lines assuming a constant rate of mortality.

Fisheries Behavioral Ecology Program

New Cold Water Research Lab

This summer, the Center's Fisheries Behavioral Ecology Program will begin utilizing a newly renovated Cold Water Research Laboratory specifically designed to accommodate studies on arctic species. This new capability will support expanding efforts in studying basic growth and physiology of ecologically important species such as Arctic cod, Boreogadus saida, and snow crab, Chionoecetes opilio,as well as the effects of climate change upon fish and crab populations.

Figure 1. The seawater chilling plant consists of two 100-ton chilling units that continually cool and recirculate glycol through a 5,000-gallon reservoir. From the reservoir the glycol is pumped to exchangers throughout the facility in order to chill seawater.

The Fisheries Behavioral Ecology Program, based at the Hatfield Marine Science Center in Newport, Oregon, has been at the forefront of research focusing on the ecology, growth, physiology and by-catch of commercially important Alaskan species for 30 years. The program is supported by four critical attributes, unique to the Newport facility.

- The first is a high quality, sand filtered seawater system, operated collaboratively with the NOAA's Northwest Fisheries Science Center, the U.S. Environmental Protection Agency, and Oregon State University. Although the campus is on an estuary, the temperature and salinity of the water pumped through the labs is surprisingly constant, typically in the range of 9°– 12°C and 280/00 – 330/00, respectively. This is attributable to an 800,000-gallon pump storage facility, which allows cool high salinity water coming into the bay on the height of the flood tide to be stored and then filtered and distributed to the labs throughout the remainder of the tidal cycle

Figure 3. The current iteration of the Cold Water Research Lab incorporates 32 tanks for studying the effects of water temperature on fish and crab growth. Water can be chilled down to 0°C, to study Arctic species. The lab was designed with flexibility in mind, to allow for various sized tanks and precise control of ambient illumination and photo periods.

Figure 2. Ten titanium heat exchangers are located throughout the facility, allowing specific seawater temperatures to be maintained throughout the 18,000 square feet of wet-lab space.

Figure 4 (left). Arctic cod were captured in the Chukchi Sea last summer and returned to Newport to establish a broodstock. Amazingly, these fish started spawning when they were not yet a year old! Figure 5 (right). Juvenile Tanner crab are collected from Kodiak waters and utilized in growth and habitat preference studies.

- Second, a centralized 200-ton chilling plant (Fig. 1) pumps -6°C glycol to exchangers (Fig. 2) throughout the facility and allows flow-through seawater to be chilled to as low as 2°C in the various labs.
- Third, a 2,300 square foot quarantine wet-lab allows for species from anywhere in the North Pacific and Arctic to be studied under conditions that prevent possible transmission of species or pathogens to the local ecosystem.
- Finally, with over 18,000 square feet of combined wet lab space, the program is able to develop and continually redesign laboratories for specialized studies.

The new Cold Water Research Laboratory takes advantage of each of these attributes to provide a dedicated facility were the growth and ecology of arctic species can be studied. In its present configuration (Fig. 3), the lab hosts 32 rectangular tanks (64 x 46 x 30cm) allowing for highly replicated studies on juvenile fish and crustacean growth. In addition, while 2°C is about as low as water can be chilled in other laboratories, a secondary chilling system in this laboratory is capable of chilling water down to 0°C or lower. Also, the program has received NOAA facility funds to initiate a new quarantine system which will utilize UV treatment of effluent water, reducing the hazards and costs associated with the use of chlorine.

The first experiments to be conducted this summer will examine the interactive effects of temperature and food availability on Arctic cod growth, condition, and lipid storage. These experiments will provide model parameterization to forecast future effects of warming and food web change in the Arctic (NPRB project #1228). Following the experiment, juveniles will be transferred to larger temperature-controlled tanks to investigate age-structure in the program's Arctic cod broodstock (Fig. 4). Temperature effects on egg and larval Arctic cod will be examined in FY14 and FY15. A second study in FY13 will examine interactive effects of dietary lipid, ration size and temperature upon rates of growth and body condition of juvenile Tanner crab (Fig. 5). This experiment is related to the Center's Habitat and Ecological Processes Research program-funded field studies which have demonstrated differing growth rates of newly settled Tanner crabs, C. bairdi, in various embayments around Kodiak. The goal is to develop a 'nursery quality' index relative to age-0 Tanner crabs that can be applied throughout the species range. These experiments will also serve to develop techniques that will be incorporated in future snow crab research.

This laboratory represents a unique resource at the Center which will be available for collaborative projects involving other AFSC, state, and academic partners.

By Clifford Ryer

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Resource Ecology and Ecosystem Modeling Program

Fish Stomach Collection and Lab Analysis

During the second quarter of 2013, Resource Ecology and Ecosystem Modeling (REEM) program staff analyzed the contents of 1,989 groundfish stomachs. The majority of these samples were from 35 species sampled from the Chukchi Sea and 6 species were from the northern Bering Sea. Most of the small crustacean prey (e.g., euphausiids, hyperiid amphipods, gammarid amphipods, mysids, and calanoid copepods) were identified to species whenever their condition allowed.

Stomach contents from four species of groundfish sampled in Marmot Bay, Alaska (Gulf of Alaska region) were also analyzed. In total, these stomach content analyses resulted in 1,703 records being added to the AFSC Groundfish Food Habits database.

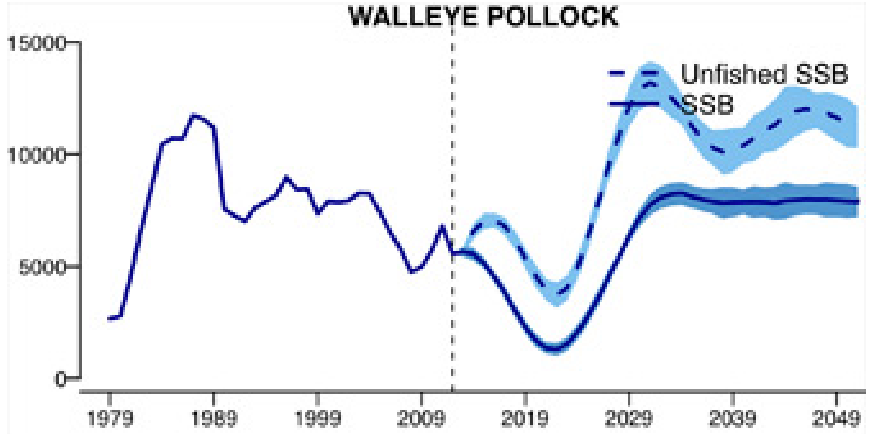
In preparation for stable isotope analysis, 90 muscle and liver tissue samples from Alaskan groundfish were ground, and 35 tissue samples were tinned in preparation for gas isotope-ratio mass spectroscopy. This ongoing project provides additional information on long-term integration of energy transfer in Alaska's marine food webs. Analysis of flatfish stomach contents and benthic grab samples for REEM's Flatfish Essential Fish Habitat project are also ongoing.

Fisheries observers collected stomach samples from arrowtooth flounder and walleye pollock in the eastern Bering Sea and Aleutian Islands region. In preparation for future stomach sampling by fisheries observers, REEM staff assembled stomach collection kits and delivered them to commercial fishing vessels in the Seattle-Tacoma area.

REEM personnel trained new fisheries observers on stomach sampling procedures and instructed them on how the samples are analyzed and the data are used. REEM personnel also trained AFSC personnel in the proper collection of stomach contents on board AFSC groundfish trawl surveys.

REEM staff participated in several outreach activities this quarter, including the NOAA Open House on June 13 and 14. The Food Habits Laboratory display and hands-on activity were very popular with children, teens, and adults. Finally, presentations and tours of the Food Habits Laboratory were conducted for a class of new fisheries observers.

By Troy Buckley, Geoff Lang, Mei-Sun Yang, Richard Hibpshman, Kimberly Sawyer, Caroline Robinson and Sean Rohan



An example output from a multi-species stock assessment model that accounts for climate effects on future fished and unfished biomass estimates.

Multispecies Management Strategy Evaluations

The North Pacific Fisheries Management Council (NPFMC) has stated that one of its four priority objectives is to incorporate and monitor effects of climate change on Bering Sea and Aleutian Islands marine ecosystems and their dependent fisheries.

Thus, REEM program scientists (K. Aydin, K. Holsman, I. Ortiz, and E. Moffitt) and Status of Stocks and Multispecies Assessment (SSMA) program scientist J. Ianelli are working to address this council objective using a multi-species stock-assessment model (MSM).

Climate change is expected to impact marine ecosystems globally, with the largest changes anticipated for arctic and sub-arctic ecosystems. The 2°C projected increase in mean summer sea surface temperature for Alaskan marine ecosystems may alter trophic demand, predator and prey distributions, and overall system productivity.

REEM program scientists are collaborating with other AFSC and Pacific Marine Environmental Laboratory (PMEL) scientists to use multi-species food-web and assessment models to link changes in the physical environment and food-web to recruitment and survival and help distinguish fishery impacts from large-scale climate pressures.

Recently, model runs have been completed for the Bering Sea using a 10km2 Regional Ocean Modeling System (ROMS) model coupled to a Nutrient-Phytoplankton-Zooplankton (NPZ) model to produce detailed hindcasts for the period 1970-2012 and forecasts using Intergovernmental Panel on Climate Change (IPCC) scenarios through 2040. These results drive a climate-driven Multispecies Statistical Model (MSM) for use in a management strategy evaluation of three groundfish species from the Bering Sea (walleye pollock, Pacific cod, arrowtooth flounder).

First, ROMS model results modulate bioenergetics, food supply, growth, recruitment, and species overlap (i.e., functional responses and predation mortality) as fit in the MSM using hindcast-extracted time series. Then the MSM model is applied to downscaled IPCC climate projections via a ROMS and NPZ model projection of temperature, circulation, and zooplankton abundance.

Results of model simulations have helped REEM scientists understand and predict how future climate driven changes to the system may impact predation and fishery harvest limits.

By Kirstin Holsman

Alaska Integrated Ecosystem Assessments

The national Integrated Ecosystem Assessment (IEA) Program website team has recently completed an IEA website (Fig. 1) which is now live at www.noaa.gov/iea. The website serves as a portal for IEA research and highlights a number of recent advancements in regional IEAs. In addition, IEA scientists have recently completed a manuscript detailing the process for developing IEAs in a given region and it will be published soon in ICES Journal of Marine Science (Levin et al. in press).

Lastly, an integral component of the IEA process is to synthesize the response of ecosystem indicators to changes in natural and anthropogenic drivers (e.g., fishing and climate change) and develop ecosystem indicators and targets for conducting risk analyses. Ecosystem components identified as at risk are then targeted for intervention and evaluated for management actions through subsequent management strategy evaluations.

AFSC and IEA scientists have recently leveraged efforts of an ongoing North Pacific Marine Science Organization (PICES) working group (WG-28) and FATE (Fisheries And The Environment) funded project to derive a composite index of ecosystem condition from combined risk scores for Alaskan marine habitats. The approach provides information on the relative risk of each habitat to combined climate and anthropogenic pressures (Fig. 2) as well as an overall index of the present condition of the ecosystem that can be compared to a target ecosystem reference point (ERP).

The ERP and Riskh values can also be used to evaluate the probability of dropping below a specified ERP (and/or individual Riskh) threshold under status quo or future climate conditions and management actions.

Ecosystem reference points (ERP) and included risk scores will be applied directly to the Alaska IEA and reported annually in the Ecosystem Assessment section of the regional stock assessment and fishery evaluation (SAFE) report. This report is reviewed annually by regional members of the North Pacific Fisheries Management Council.

Some promising groundwork towards an ecosystem risk assessment has recently been completed and new IEA and FATE support will help move this work towards a comprehensive synthesis for GOA and EBS marine ecosystems. Final Riskh and ERP values calculated and evaluated through this project will directly inform the Risk Assessment step of the Alaska IEA and will serve as a framework for ecosystem risk analysis in regional IEAs that are in development elsewhere.

Further, since the Riskh and ERP values can be improved through management actions as well as increased research and data quality (i.e., increase the certainty score), then this project can help identify both future management and research priorities.

By Kirstin Holsman

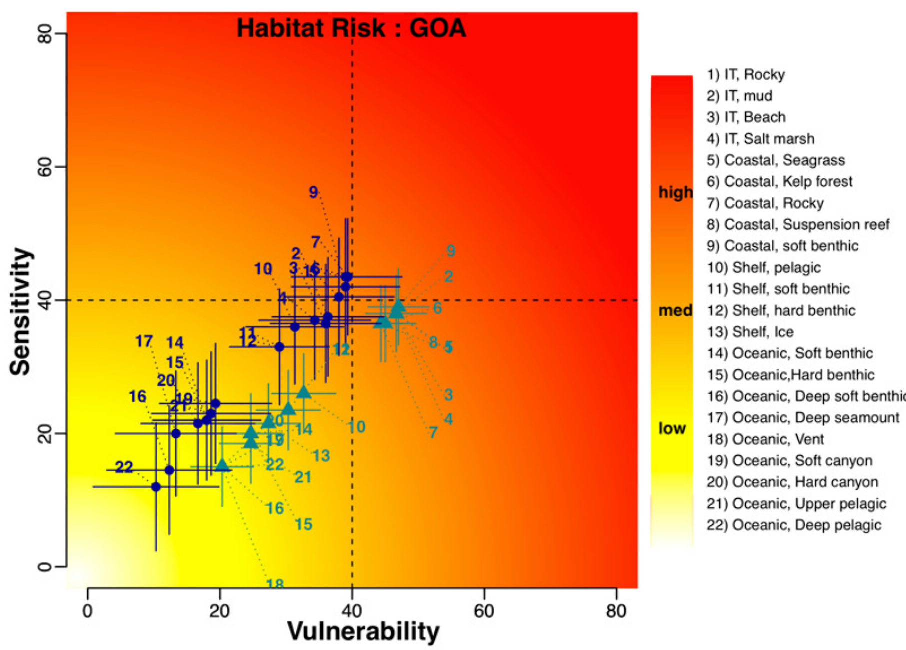


Figure 2. Habitat specific risk (cumulative for all pressures) for EBS and GOA ecosystems based on results of surveys from reviewers 1 and 2 (circles and triangles, respectively). Adapted from Samhouri and Levin (2012). Error bars represent uncertainty indices for each habitat (scored from 1 to 4; low to high).

Economics & Social Sciences Research Program

Productivity Growth and Product Choice in Fisheries: the Case of the Alaskan Pollock Fishery Revisited

Many fisheries worldwide have exhibited marked decreases in profitability and fish stocks during the last few decades as a result of overfishing. However, more conservative, science- and incentive-based management approaches have been practiced in the U.S. federally managed fisheries off Alaska since the mid 1990s.

The Bering Sea pollock fishery is one such fishery and remains one of the world's largest in both value and volume of landings. In 1998, with the implementation of the American Fisheries Act (AFA) this fishery was converted from a limited access fishery to a rationalized fishery in which fishing quota were allocated to cooperatives which could transfer quotas, facilitate fleet consolidation, and maximize efficiency. The changes in efficiency and productivity growth arising from the change in management regime have been the subject of several studies, with a few focusing on the large vessels that both catch and process fish onboard (catcher-processors).

In this study we modify existing approaches to account for the unique decision-making process characterizing catcher-processor's production technologies. In particular, we focus on sequential decisions regarding what products to produce and the factors that influence productivity once those decisions are made using a multiproduct revenue function.

The estimation procedure is based on a latent variable econometric model and departs from and advances previous studies since it deals with the mixed distribution nature of the data. Our productivity growth estimates are consistent with increasing productivity growth since rationalization of the fishery took place, even in light of large decreases in the pollock stock.

These findings suggest that rationalizing fishery incentives can help foster improvements in economic productivity even during periods of diminished biological productivity. A manuscript is currently under internal review and will be sent out to a scientific journal soon.

By Ron Felthoven and Marcelo Torres

Using Indicators to Assess the Vulnerability and Resiliency of Alaskan Communities to Climate Change

Communities in Alaska are experiencing impacts of unexpected climate-related changes and unprecedented environmental conditions in the harvests of marine and terrestrial resources. Residents of rural Alaska are already reporting heretofore unseen changes in the geographic distribution and abundance of fish and marine mammals, increases in the frequency and ferocity of storm surges in the Bering Sea, changes in the distribution and thickness of sea ice, and increases in river and coastal erosion. When combined with ongoing social and economic change, climate, weather, and changes in the biophysical system interact in a complex web of feedbacks and interactions that make life in rural Alaska extremely challenging.

We develop a framework of indicators to assess three basic forms of community vulnerability to climate change: exposure to the bio-physical effects of climate change, dependence on resources that will be affected by climate change, and a community's adaptive capacity to offset negative impacts of climate change. We conduct a principal components analysis on each of the three forms of vulnerability, and then combine all three components together to determine each community's overall vulnerability to climate change for 315 communities throughout Alaska.

The top five communities that rank the highest in overall vulnerability to climate change do so for different reasons. Three of the five communities are among the most vulnerable communities due to their high exposure to the bio-physical effects of climate change, one community has the lowest level of adaptive capacity, and the other community is highly dependent on marine resources that will be affected by climate change.

This research can be used to inform communities as to the ways in which their communities are vulnerable to climate change and help develop adaptation strategies.

By Amber Himes and Steve Kasperski

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By Amber Himes and Steve Kasperski

Participants at the BOBLME stock assessment workshop held in Bangkok, Thailand.

Management Institutions, Incentives, and the Margins of Selectivity in Fishing: Evidence from the Amendment 80 Trawl Fishery

The ecological and economic ramifications of imperfect selectivity in fisheries are well-known and significant – particularly with respect to bycatch. In both fisheries science and a sizable portion of the fisheries economics literature, it is commonplace to see the selectivity of gear across species assumed as static, with the particularities of gear modifications and the spatial and temporal decisions associated with gear use implicitly ignored. However, if variations in the spatial and temporal deployment of gear have important implications for catch composition at the individual gear-deployment level, this implies there may be a significant aspect of catch composition that is behavioral in nature rather than purely technical.

The extent to which the realized catch composition in a fishery is behaviorally rather than technologically determined is critical to resolving an important debate in multispecies management policy – the applicability of catch shares to multispecies fisheries.

A number of critics, often relying upon inferences from pre-catch-share data, have asserted that fishermen may find it difficult or impossible to accommodate their catch composition to their portfolio of quota holdings with potential consequences including high prices for binding species' quota, a collapse in markets for "slack" species, rampant illegal discarding, data fouling and subverted quota markets. In stark contrast to these predictions, ex post evidence from multispecies catch share systems have often shown far greater malleability of catch composition than anticipated.

We address this disagreement in the literature in several ways. First, we utilize detailed data at the individual haul level on the Amendment 80 trawl fishery before and after the implementation of catch shares in 2008. In the initial phase, the catch of all species, including bycatch species, was regulated by the assignment of multiple total allowable catches (TACs) for each species to the entire fleet.

Under this common pool incentive system, bycatch species often closed the entire fishery prematurely. Under Amendment 80, individual vessels essentially operate under a multispecies catch share system, with individual accountability for their catch of target and bycatch species.

We find dramatic evidence of a shift in overall catch composition away from formerly binding bycatch species and toward valuable target species. We also note far less variability in the target/bycatch ratio than in the pre-catch share era.

Second, we conduct a detailed analysis of behaviors that fishermen employed to affect their catch composition. This analysis shows that fishermen were able to alter their catch composition substantially through their choices of when and where to fish on fine and coarse scales. We find evidence that large scale and durable shifts in fishing grounds, spatial avoidance behavior in response to high bycatch signals, and strategic shifts in the incidence of night-fishing have all contributed significantly to the observed changes.

Importantly, these margins of change were all available to fishermen before the institutional change, and yet were not adopted. This suggests that management systems which provide few incentives for selective fishing may obscure significant hidden short-run flexibilities of fishermen to alter their catch composition.

By Joshua K. Abbott, Alan C. Haynie, and Matthew N. Reimer

Status of Stocks & Multispecies Assessment Program

AFSC Staff Contribute to Stock Assessment Workshop

Through multi-agency collaboration and a long NOAA commitment to the Large Marine Ecosystem program (http://www.lme.noaa.gov/), AFSC scientist, Dr. James Ianelli was invited to help conduct a week-long stock assessment course for the Bay of Bengal Large Marine Ecosystem (BOBLME) program with support from the United Nations' Food and Agricultural Organization (FAO).

Over 30 participants from many countries including Sri Lanka, India, Bangladesh, Myanmar, Indonesia, the Maldives, Malaysia, and Thailand took part, and each analyst brought with them datasets to help with hands-on fisheries issues.

The workshop was organized to be about one third lectures, one third hands-on practice assignments based from the lectures, and one third focusing on current data and issues faced by participants. One of the objectives of this course was to understand basic concepts of population dynamics models and how they can relate to management practices.

A major part of the course was designed to introduce computational tools to evaluate and understand how to collect and analyze data for ecological and environmental studies. The activities focused on developing advanced data-processing and modeling skills using spreadsheets and some rudimentary scripting within the R programming environment.

A wide variety of species and settings were brought forward by participants—from industrial tuna longline data to spiny lobster to small scale (but in aggregate large volume) coastal fisheries. Other instructors included an expert from the Indian Ocean Tuna Commission (Mahé, Seychelles) and one from Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO).

Participants benefitted from having access to all presentations and examples electronically in real time and the web site developed for the short-course remains available for their reference.

By James Ianelli

AD-Model Builder (ADMB) Developers Workshop

During the week of 3 June 2013, Dr. James Ianelli convened an AD-Model Buidling (ADMB) developer's workshop at the University of Washington, Seattle, Washington. This annual workshop serves to focus advancement of the ADMB software in a number of ways—one by bringing together expert developers but also by introducing new scientists to this type of activity.

ADMB presently is at the core of arguably a very large fraction of fisheries stock assessment modeling activities both nationally and worldwide (see map inset). The software has also gained application into non-fisheries areas. Proudly, NOAA is one of the strongest supporters of the software developments, and several scientists from different Science Centers remain actively involved in improving and continuing to advance the software.

The workshop kicked off with a review of the infrastructure support which includes: maintaining the Web Server (http://www.admb-project.org), a version control system which has tracked over 1,000 refinements from 18 different developers (http://www.admb-project.org/svn/), maintaining an Issue Tracking system (http://www.admb-project.org/redmine/projects/issues/), an automated build server (http://www.admb-project.org/buildbot/waterfall) and a searchable mailing list with nearly 200 subscribers.

Discussions and activities during the week focused on the technical side of ADMB development with goals to continue to make the software easier to use (and contribute to as developers) and to enhance capabilities. These capabilities include developing protocols where models can be written more easily to take advantage of many processors simultaneously (multi-threading) to increase the speed of estimation (both of the point estimates but also the uncertainty).

Drs. Teresa A'mar (AFSC) along with Carey McGilliard and Athol Whitten (AFSC/UW post-docs) contributed to the workshop. Scientists from three other NMFS Science Centers, Canada, the University of Hawaii, the University of Washington, and the International Halibut Commission contributed to the activity.

By James Ianelli

…NOAA is one of the strongest supporters of the software developments, and several scientists from different Science Centers remain actively involved in improving and continuing to advance the software.

Inset of map where ADMB is presently applied for fisheries issues. For updates and details of fisheries applications see: http://www.admb-project.org/users/user-base/.


Figure 1. Group photo of participants of the ICES-PICES SICCME-Spatial workshop.

ICES-PICES Workshop on Global Assessment of the Implications of Climate Change on the Spatial Distribution of Fish and Fisheries

The International Council for the Exploration of the Sea (ICES) and the North Pacific Marine Science Organization (PICES) Strategic Initiative (Section) on Climate Change Impacts on Marine Ecosystems (SICCME) held a workshop on changes in spatial distribution (WKSICCME-Spatial) on the island district of Vasileostrovskiy, in St. Petersburg, Russia, 22-24 May 2013.

The workshop was attended by 67 scientists from 13 nations as well as representatives from ICES, PICES and the United Nations Food and Agriculture Organization (FAO) (Fig. 1). The workshop, chaired by Anne Hollowed (USA, PICES), Suam Kim (Korea, PICES) and Myron Peck (Germany, ICES), was convened to foster the development and testing of analytical methods for detecting changes in distribution, assessing the skill of different modeling approaches, and quantifying uncertainty in projected climate-driven changes. Other important questions addressed were: how do we best to design a global database of marine observations and what strategies should we use to assess vulnerability (of resources and those that depend upon them) to shifts in distribution?

The workshop was organized around six theme sessions: 1) Analytical methods for detecting changes in spatial distribution, 2) Skill assessment and model inter-comparison, 3) Quantifying uncertainty, 4) Design specification for database of observations of distribution of living marine resources, 5) Vulnerability assessment, and 6) Communicating outcomes to inform decisions regarding management of living marine resources under changing climate.

Each session had one or two keynote speakers and three breakout group leaders; the latter guided participants through a set of pre-defined discussion questions. The key points from each session were discussed in plenary, and consensus recommendations were made for future PICES-ICES activities on climate-driven changes in spatial distribution of living marine resources.

The format of the workshop allowed ample time for discussion and debate and a considerable amount of information was exchanged within the 3 days. The workshop participants and other PICES and ICES scientists will continue to work together in the coming year towards a synthesis of climate-driven changes in distribution and recommendations on how to improve methods to assess regional and/or latitudinal differences in the vulnerability of species to climate change-induced shifts in ocean conditions.

A first step towards these goals will be summarizing the outcomes of this workshop in a set of manuscripts stemming from the discussions in each session. The manuscripts will continue to strengthen the close ties between ICES and PICES scientists within the SICCME and will create a lasting legacy for the workshop.

By Anne Hollowed

Age and Growth Program

Age and Growth Program Production Numbers

Estimated production figures for 1 January – 30 June 2013. Total production figures were 12,621 with 2,638 test ages and 63 examined and determined to be unageable.

Species	Specimens Aged
Alaska plaice	269
Arrowtooth flounder	955
Atka mackerel	910
Blackspotted rockfish	360
Dusky rockfish	427
Greenland turbot	360
Northern rock sole	864
Northern rockfish	122
Pacific cod	2,502
Pacific ocean perch	795
Rex sole	516
Rougheye rockfish	290
Sablefish (blackcod)	396
Walleye pollock	3,732
Yellowfin sole	123

By Jon Short

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[1] The NOAA Technical Memorandum series NMFS AFSC (formerly F/NWC) is a Center publication which has a high level of peer review and editing. The Technical Memorandum series reflects sound professional work and may be cited as publications. Copies may be ordered from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161 or at *www.ntis.gov*.

[2] The AFSC Processed Report series is not formally reviewed and individual reports do not constitute publications. The reports are for information only and a limited number of copies are available from the author.

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The mission of the NOAA Fisheries Service is to provide stewardship of the nation's living marine resources through science-based conservation and management and promotion of healthy ecosystems

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