Status of forage species in the Bering Sea and Aleutian Islands region

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A report on the status of forage species in the Bering Sea and Aleutian Islands (BSAI) region is prepared on a biennial basis and presented to the Plan Team and the North Pacific Fishery Management Council (NPFMC) in odd years. This report is not intended to be a formal stock assessment, although forage populations are analyzed if data are available. The two main objectives of the report are to 1) investigate trends in the abundance and distribution of forage populations and 2) describe interactions between federal fisheries and species that make up the forage base (i.e., to monitor potential impacts of bycatch). The report's structure is as follows:

1) Summary of findings and response to Plan Team & SSC comments
2) Overview of forage species and their management
3) Trends in abundance and spatial distribution
4) Bycatch and other impacts of federal fisheries on forage species
5) Data gaps and research priorities
6) Appendix

Because forage species are a fundamental component of the ecosystems in the BSAI, there is potential for overlap between the data presented here and forage-related information reported in the Ecosystem Considerations report published annually by the NPFMC (https://apps-afsc.fisheries.noaa.gov/refm/reem/ecoweb/index.php). To minimize duplication of efforts, this report relies mainly on data from the bottom trawl surveys in the BSAI as well as acoustic-survey results where applicable. The Ecosystem Considerations report contains results from the surface-trawl surveys conducted by the Ecosystem Monitoring and Assessment (EMA) program (Yasumiishi et al. 2017), as well as estimates of euphausiid abundance from acoustic surveys (Ressler 2016). Indirect indicators of forage species abundance and prey availability, such as seabird breeding success and groundfish predator diets, are also described in the Ecosystem Considerations report. A brief summary of relevant findings from that report are included in this document's "Summary of findings" section below, and in other relevant sections of the report.

Summary of findings

This report

1) Incidental catches of FMP forage species continue to be very low by historical standards. The preliminary 2019 catch is 24 t, and as is typical is dominated by osmerids, especially eulachon.
2) The 2019 squid catch is extremely high (5,173 t as of October 31, 2019). This is more than twice the previous high catch in the modern era (2,364 t in 2015) and the highest catch since 1981.
3) Prohibited Species catches (PSC) of Pacific herring were relatively low in 2018 (542 t) but the 2019 value is similar to recent years (1,179 t as of October 31, 2019). Since 2012 herring catches have been below the PSC limit.
4) According to the bottom trawl survey, capelin is at its lowest abundance on the eastern Bering Sea shelf since 1987.

5) Herring abundance is relatively high in the eastern Bering Sea shelf and northern Bering Sea bottom trawl survey.
6) Abundance data from the AFSC northern Bering Sea (NBS) survey are included for the first time. Capelin and Arctic cod abundance decreased sharply 2010-2019 while Pacific herring and rainbow smelt increased, but the results should be viewed with caution since so few data points are available for this survey.

Ecosystem Considerations report

1) In 2018, acoustic estimates of euphausiid density in the EBS remained relatively low.
2) Seabird breeding success was improved in 2019 relative to 2016-2018, suggesting greater availability of forage.
3) In contrast, poor condition of seabirds and marine mammals in the Bering Strait region during 2019 suggests that prey availability was limited in the northern Bering Sea.
4) The substantial decline in capelin encountered by the bottom trawl surveys is mirrored by very low catches in the 2019 surface trawl survey.

Responses to Plan Team and SSC comments

<u>From the November 2017 Plan Team minutes:</u>

The Team discussed the current results for the examination of temperature and trends. The Team recommends the assessment author plot mean annual CPUE as a function of annual temperature and until the warm /cold relationship is established, remove “warm” and “cold” from the block names.

> *Response*: The author has removed the use of time blocks from the report. For the selected species, the monitoring section now includes annual time series of biomass estimates, frequency of occurrence, and a comparison of biomass estimates to the long-term mean.

The Team discussed the herring savings area closures and potential mis-specificity of their application and locations The Team recommends that the assessment author examine catch inside and outside of the current herring areas in the next report. The Team also recommends evaluation of spatial population considerations to consider aspects such as herring migration and/or whether some core areas of abundance for herring and broader forage species locations have shifted over time. This could help to elucidate reasons for corollary issues such as broad scale seabird die-offs.

> *Response*: The section on herring catches has been expanded to include more detail regarding temporal and spatial patterns and their relation to management measures.

<u>From the December 2017 SSC minutes:</u>

The SSC supports the Team’s recommendation to remove the “warm” and “cold” stratification in the temperature analyses and instead plot mean annual CPUE as a function of annual temperature to explore the temperature – CPUE relationship.

> *Response*: See above response to Plan Team comments.

Further work could certainly be done on spatial analysis to better inform changes in forage fish distribution. This may provide useful information from the standpoint of where PSC is encountered relative to fishery activity. Along these lines, in our December 2016 report, the SSC noted that the 2015 BSAI Forage Fish Chapter presented a geographic distribution map of the 2010–2014 herring PSC that supports the change in herring distribution identified in Tojo et al. (2007), indicating that herring distributions continue to differ from those upon which Amendment 16A was based. The SSC concurs with the Plan Team recommendation that the assessment author should examine catch inside and outside of the current herring protection areas, and whether core areas of high forage fish (specifically herring) abundance and catch have changed over time.

Response: See above response to Plan Team comments.

Overview of forage species and their management

Defining "forage species" can be a difficult task, as most fish species experience predation at some point in their life cycle. A forage fish designation is sometimes applied only to small, energy-rich, schooling fishes like sardine and herring, but in most ecosystems this is too limiting a description. Generally, forage species are those whose primary ecosystem role is as prey and that serve a critical link between lower and upper trophic levels. For this report, the following species or groups of species are considered to be critical components of the forage base in the Bering Sea and Aleutian Islands (BSAI) area:

- members of the "forage fish group" listed in the BSAI Fishery Management Plan (FMP)
- Pacific herring *Clupea pallasii*
- juvenile groundfishes and salmon
- shrimps
- squids
- Arctic cod *Boreogadus saida*

Forage fish group in the FMP

Prior to 1998, forage fishes in the BSAI were either managed as part of the Other Species group (nontarget species caught incidentally in commercial fisheries) or were classified as "nonspecified" in the FMP, with no conservation measures. In 1998, Amendment 36 to the BSAI FMP created a separate forage fish category, with conservation measures that included a ban on directed fishing. Beginning in 2011, members of this forage fish group (the "FMP forage group" in this report) are considered "ecosystem components". The FMP forage fish group is large and diverse, containing over fifty species from the following taxonomic groups (see the appendix at the end of this report for a full list of species):

- Osmeridae (smelts; eulachon *Thaleichthys pacificus* and capelin *Mallotus catervarius* are the principal species, with rainbow smelt *Osmerus mordax* locally abundant in some areas)
- Ammodytidae (sand lances; Pacific sand lance *Ammodytes personatus* is the main representative)
- Trichodontidae (sandfishes; Pacific sandfish *Trichodon trichodon* is the main species)
- Stichaeidae (pricklebacks)
- Pholidae (gunnels)
- Myctophidae (lanternfishes)
- Bathylagidae (blacksmelts)
- Gonostomatidae (bristlemouths)
- Euphausiacea (krill; these are crustaceans, not fish, but are considered essential forage)

The primary motivation for the creation of the FMP forage group was to prevent fishing-related impacts to the forage base in the BSAI; it was an early example of ecosystem-based fisheries management. The management measures for the group are specified in section 50 CFR 679b20.doc of the federal code:

50 CFR 679b20.doc § 679.20 General limitations
(i) Forage fish
(1) Definition. See Table 2c to this part.
(2) Applicability.
The provisions of § 679.20 (i) apply to all vessels fishing for groundfish in the BSAI or GOA, and to all vessels processing groundfish harvested in the BSAI or GOA.
(3) Closure to directed fishing.
Directed fishing for forage fish is prohibited at all times in the BSAI and GOA.
(4) Limits on sale, barter, trade, and processing.
The sale, barter, trade, or processing of forage fish is prohibited, except as provided in paragraph (i)(5) of this section.
(5) Allowable fishmeal production.
Retained catch of forage fish not exceeding the maximum retainable bycatch amount may be processed into fishmeal for sale, barter, or trade.

In sum, directed fishing for species in the FMP forage fish group is prohibited, catches are limited by a maximum retention allowance (MRA) of 2% by weight of the retained target species (Table 10 to 50 CFR part 679), and processing of forage fishes is limited to fishmeal production. While the basis for a 2% MRA is not entirely clear, it appears this percentage was chosen to accommodate existing levels of catch that were believed not to significantly impact prey availability (Federal Register, 1998, vol. 63(51), pages 13009-13012). The intent of amendment 36 was thus to prevent an increase in forage fish removals, not to reduce existing levels of catch. In 1999, the state of Alaska adopted a statute with the same taxonomic groups and limitations (5 AAC 39.212 of the Alaska administrative code), except that no regulations were passed regarding the processing of forage fishes. This exception has caused some confusion regarding the onshore processing of forage fishes for human consumption (J. Bonney, Alaska Groundfish Data Bank, pers. comm.).

Pacific herring
Herring are highly abundant and ubiquitous in Alaska marine waters. Commercial fisheries in the BSAI, mainly for herring roe, exist along the western coast of Alaska from Port Moller north to Norton Sound (Figure 1). These fisheries target herring returning to nearshore waters for spawning, and herring in different areas are managed as separate stocks. The largest stock in the BSAI spawns in Togiak Bay in northern Bristol Bay: the spawning biomass was estimated at 163,480 short tons in 2015. The next largest stock, in Norton Sound, had a 2015 biomass estimate of 53,786 short tons (data can be retrieved at www.adfg.alaska.gov). Herring are hypothesized to migrate seasonally between their spawning grounds and two overwintering areas in the outer domain of the eastern Bering Sea (EBS) continental shelf (Figure 2; Tojo et al. 2007). The herring fisheries are managed by the Alaska Department of Fish & Game (ADFG) which uses a combination of various types of surveys and population modeling to set catch limits. In federal fisheries, herring are managed as Prohibited Species: directed fishing is banned and any bycatch must be returned to the sea immediately. The amount of herring bycatch allowed is also capped and if the cap is exceeded the responsible target fishery is closed in special Herring Savings Areas (Figure

1) to limit further impacts. In the BSAI, the Prohibited Species Catch Quota for herring is calculated as 1% of the estimated annual biomass of herring in the eastern Bering Sea.

Juvenile groundfishes and salmon

Members of this group, particularly age-0 and age-1 walleye pollock, *Gadus chalcogrammus*, are key forage species in the BSAI. As they are early life stages of important commercially fished species, however, their status is dependent on the assessment and management of the recruited portion of the population. Detailed information regarding these species is available in NPFMC stock assessments (http://www.afsc.noaa.gov/refm/stocks/assessments.htm) and ADFG reports (www.adfg.alaska.gov). Further information is not included in this report.

Shrimps

A variety of shrimps occur in the BSAI. Members of the family Pandalidae are generally found in offshore waters while shrimps of the family Crangonidae are distributed mainly in nearshore waters. Commercial fisheries for shrimps are managed by ADFG and are currently closed in the BSAI. Further information on shrimps in Alaska waters is available from ADFG (www.adfg.alaska.gov). This report includes data regarding catches of pandalid shrimps in federal groundfish fisheries.

Squids

Squids are abundant along the EBS slope and in the Aleutian Islands. Up to 15 species exist in the BSAI. Although no directed fisheries currently exist for squids, they have historically been managed as a target stock complex with annual harvest specifications due to high levels of incidental catch, mainly in the fisheries for walleye pollock. In June 2017, the North Pacific Fishery Management Council (NPFMC) took final action to amend the fishery management plans (FMPs) for the BSAI (Amendment 117) and Gulf of Alaska (GOA; Amendment 106) regions and move the squid stock complex into the Ecosystem Component category. The rationales for this decision included (1) the lack of a directed fishery for squids in the BSAI or GOA, (2) there is little risk of overfishing in the absence of a directed fishery because squids are highly productive, and (3) current incidental fishing mortality is considered insignificant at a population level.

The FMP amendments were implemented in the Federal Register on July 6, 2018 with an effective date of August 8, 2018 (Federal Register, Volume 83, Number 130, July 6 2018, pages 31460-31470. 50 CFR 679, docket # 170714670-8561-02. https://www.federalregister.gov/d/2018-14457). Briefly, the amendments accomplish the following:

- Place squids in the Ecosystem Component category of the FMP
- Prohibit directed fishing for squid
- Establish a 20% maximum retention allowance (MRA)
- Limit processing to fishmeal production
- Retain recordkeeping and recording requirements

The new management regime was implemented in January 2019. Beginning with this report, squid status and catch reporting will occur in this document.

Arctic cod

Arctic cod is not currently included in the FMP for the BSAI. It is primarily a cold-water species with a northern distribution in the EBS, generally captured in bottom trawl surveys north of 59°N latitude. In the

Alaskan Arctic it is likely the dominant prey species, and the Arctic FMP prohibits directed fishing for Arctic cod due to ecosystem concerns. As fish distributions and fishing locations shift, conservation measures for Arctic cod in the BSAI may become necessary. Further information is available at http://www.npfmc.org/arctic-fishery-management/.

Trends in abundance and spatial distribution

Data sources

There are a number of research surveys conducted on a regular basis in the BSAI, but none are optimized for sampling forage fishes. The main drawbacks are that the sampled areas do not correspond to forage fish distributions (e.g., bottom trawls do not effectively sample pelagic species) and that attributes of the sampling gears (e.g., net mesh size) are not suitable for small fishes. As a result, estimating abundance and analyzing trends and patterns in abundance and spatial distributions is difficult. Therefore results from individual surveys (i.e., years) are less important than longer-term trends.

For most of the species in this section, data are from bottom trawl surveys conducted by the AFSC on the EBS shelf (annual), the EBS slope (biennial) and in the AI (biennial; methods and data at: http://www.afsc.noaa.gov/RACE/groundfish/default.php). The standardized EBS shelf survey began in 1982 but some work using similar gear was conducted prior to 1982; the EBS slope and AI surveys have occurred biennially since the early 2000s. These surveys are conducted from May to August. The survey was expanded to the north in 1987 and this report includes only data from 1987 on. In 2010, the AFSC began to conduct an additional survey to the north of the 1987 survey area, comprising all waters south of Bering Strait including Norton Sound. Due to the loss of seasonal sea ice and corresponding changes in fish distribution this northern survey is conducted regularly as of 2017 and those data are included at the end of this section.

This section also references information from surface trawl surveys conducted by the AFSC Ecosystem Monitoring and Assessment (EMA) program (Yasumiishi et al. 2017). This survey has been conducted every year since 2003, although the extent and density of stations sampled has varied among years. This survey regularly visits the northeastern Bering Sea. The survey occurs primarily in September, with sampling during August and October in some years. There is also a biennial acoustic survey for walleye pollock that covers the middle and outer domains of the EBS shelf. An index of euphausiid abundance and distribution has been created using the results of this survey (Ressler et al. 2012) and is included in the Ecosystem Considerations report (Ressler 2016). Acoustic surveys are effective at sampling capelin, but the EBS survey does not extend to the inner domain of the EBS shelf where the capelin population is centered. Pacific herring are assessed by ADFG, primarily using aerial surveys and test fishing; these data are included here where appropriate.

Spatial analysis of survey data was conducted within ArcGIS. Point data for each survey haul were either symbolized directly or aggregated into 20 km X 20 km cells with a mean catch-per-unit-effort (CPUE) calculated for each cell using data from all years. To better understand variability in distributions, for some species standard deviational ellipses were created using geographic data weighted by CPUE (Lefever 1926; Gong 2002). Ellipses include all points within one standard deviation of the distribution's mean geographic center.

Spatial partitioning on the EBS shelf

The cross-shelf distribution of forage fishes in the BSAI (i.e., nearshore vs. offshore) was investigated for the 2013 report (Ormseth 2013), and the results for the EBS shelf are repeated here. There appears to be strong cross-shelf partitioning among the six species/species groups studied (Figure 3). The mean CPUE of sandfish and sand lance was highest at bottom depths below 50 m, indicating a nearshore distribution in the inner domain of the EBS shelf. Capelin CPUE was also highest at bottom depths of approximately 50 m, but their distribution extended out to beyond 100 m. The distribution of herring was more variable, existing at a range of depths from 0 to more than 100 m. Eulachon were concentrated in hauls with 100-200 m bottom depth, with some catch over the EBS slope, while myctophids were found only on the slope. This type of segregation is similar to segregation observed among capelin and juvenile pollock (Hollowed et al. 2012). Habitat preferences and competitive interactions are both likely to influence these distributions. For example, sandfish and sand lance both depend on sandy substrates for burrowing. Myctophids have a mesopelagic distribution, so are unlikely to be found on the shelf. Spatial partitioning among capelin and juvenile pollock in the Gulf of Alaska (GOA) is thought to be due to competition between the species (Logerwell et al. 2007).

<u>Capelin</u>

Capelin are distributed primarily in the inner domain of the EBS shelf (Figure 4). The pattern of CPUE varies substantially between the surface and bottom trawl surveys, with catches in the EMA survey occurring further north than in the trawl survey (Yasumiishi et al. 2017). The reason for these differences is not clear. Capelin occupy different parts of the water column depending on environmental factors such as light levels and prey availability. Surveys in the GOA using identical surface trawl gear have occasionally caught capelin, but simultaneous acoustic surveying on the same vessel indicates that capelin are often below the trawl’s footrope (Dave McGowan, UW, pers. comm.). The contrast between the surveys may also arise from differences in survey timing: the EMA survey occurs in late summer after the trawl surveys have been completed. In the bottom trawl survey, biomass estimates are variable for the reasons described above but there also appear to be decadal signals in abundance (Table 1; Figures 5 and 6). The greater abundance of capelin observed during 2010-2015 has now reversed itself; the 2018 and 2019 biomass estimates and frequency of occurrence (FO) are the lowest in the time series.

<u>Eulachon</u>

In contrast to capelin, eulachon dynamics in the BSAI appear to be fairly simple. Eulachon tend to occur deeper in the water column and are more likely to be associated with the bottom. As a result the bottom trawl surveys sample eulachon more effectively than other forage species, and eulachon are essentially absent from the EMA surface trawls. Eulachon are consistently distributed in the extreme southern portion of the outer EBS shelf (Figure 7).

Decadal signals also appear in survey biomass estimates for eulachon (Figures 8 and 9). Biomass estimates were mainly above the mean until the mid-2000s, fluctuated around the mean for a decade, and since 2014 have been consistently below the mean. Decadal variation in eulachon abundance also occurs in the GOA (Ormseth 2014).

<u>Rainbow smelt</u>

Rainbow smelt are rare in the bottom trawl survey (Table 1), so the EMA survey is the primary source of information for this osmerid. These data are included here because no rainbow smelt information is presented in the Ecosystem Considerations report. Data from EMA surveys were only available through

2011, and indicate that the highest abundance of rainbow smelt is in the northeastern Bering Sea and particularly Norton Sound (Figure 10). Rainbow smelt are often found in shallow nearshore waters, so this apparent distribution may not be fully representative. For example, nearshore studies in northern Bristol Bay (Nushagak and Togiak bays) captured large number of rainbow smelt in multiple size classes (Ormseth, unpublished data).

Ammodytidae: Pacific sand lance

Sand lances are extremely difficult to sample due to their patchiness and behavior, which entails spending much of their time burrowed into sand. As a result, information for Pacific sand lance in the BSAI is extremely limited. The bottom trawl survey suggests that they have a primarily inshore distribution in the EBS, particularly in areas such as Bristol Bay with extensive sandy bottom substrates (Figure 11). They also occur in the AI, particularly in the islands west of Amchitka Pass (Figure 12). Despite the difficulty of sampling them, after myctophids, they are the most commonly observed member of the FMP forage group in the AI bottom trawl survey.

Trichodontidae: Pacific sandfish

Similar to sand lance, sandfishes burrow into sandy substrates. This is reflected in their distribution which is centered in the shallow inshore waters of the EBS, in Bristol Bay and along the northern shore of the Alaska Peninsula (Figure 13). The EMA surveys suggest a similar distribution (Yasumiishi et al. 2017). Unlike most of the other forage species, neither survey has found them north of Cape Romanzof (61°47' N), so this is likely the northern extent of their range. This is confirmed by historical reports (Mecklenburg et al. 2002).

Myctophidae (lanternfishes)

Myctophids are generally deep-water fishes (> 200 m depth), although diel migrations can bring them into surface waters. This is consistent with their distribution observed in BSAI survey data, where they occur on the EBS slope (Figure 14) and along the shelf break and slope in the AI (Figure 15).

Euphausiacea

The AFSC's Midwater Assessment and Conservation Engineering (MACE) program has recently developed the ability to discriminate between acoustic backscatter associated with fish versus backscatter from euphausiids. They have applied this methodology to acoustic data from acoustic trawl surveys conducted on the outer EBS shelf and have produced information regarding distribution and abundance of euphausiids since 2004 (Ressler et al. 2012). These results suggest that the distribution of euphausiids is variable but that the largest biomass is consistently found in the southeastern Bering Sea. The index suggests that euphausiid abundance has declined during the last decade (Ressler 2016).

Stichaeidae (pricklebacks), Pholidae (gunnels), Bathylagidae (blacksmelts), Gonostomatidae (bristlemouths)

These species occur rarely in the AFSC surveys, either due to their small size or their preference for unsurveyed habitats (e.g. nearshore areas or deep pelagic waters). No information exists regarding their abundance, and information regarding distribution is not presented in this report.

Pacific herring

The spatial distribution of herring in the BSAI described by the bottom trawl survey and the EMA survey vary substantially and may result from seasonal herring movement. Herring spawn in nearshore areas in the spring, then migrate to overwintering areas on the outer EBS shelf (Figure 3; Tojo et al. 2007). Older studies suggest that this is primarily a clockwise migration along the southern edge of the EBS ending at a single overwintering area north of the Pribilof Islands (Barton and Wespestad 1980). A more recent analysis suggests a more complex series of movements, with an additional overwintering ground in the southern EBS and multiple migration routes (Figure 2; Tojo et al. 2007). The routes used in any one year may depend on environmental factors, particularly temperature. The bottom trawl survey occurs primarily in June and July and is likely capturing herring that are out-migrating from nearshore spawning areas; the areas of high CPUEs on the southern edge of the EBS and around Nunivak Island (Figure 16) are consistent with the movement patterns in Figure 2. The EMA survey is conducted primarily during September, and by this time herring may have moved out of the sampling area in the southeastern Bering Sea and are no longer available to the survey. The high CPUEs observed in the EMA survey in the northeastern Bering Sea, particularly in Norton Sound (Yasumiishi et al. 2017), are harder to explain. It is possible that those herring belong to the Norton Sound stock, which is the second-largest in the BSAI, but it is unclear whether they are migrating or have a different overwintering strategy.

Herring biomass estimates and FO display high interannual variability with less of a decadal signal than other forage species (Figures 17 and 18). Biomass estimates were above the mean during 2017-2019.

Forage species in the northern Bering Sea

Four major forage species are encountered in the northern Bering Sea bottom trawl survey: capelin, rainbow smelt, Pacific herring, and Arctic cod (Figure 19). These species display very different abundance trends over the short time series (biomass estimates exist only for 2010, 2017, and 2019). Estimates for capelin and Arctic cod (Figure 20) dropped precipitously from 2010 while Pacific herring and rainbow smelt (Figure 21) estimates showed substantial increases. These conclusions should be treated with caution as they are highly influenced by the 2010 data and the data do not exist to indicate what an average level of abundance might be for these species.

Bycatch and other conservation issues

FMP forage group

Data regarding incidental catches of this group are available since 2003 and are maintained by the Alaska Regional Office (AKRO; Table 2). Osmerids is the only species group that is caught incidentally in appreciable numbers, with the exception of substantial myctophid catches in 2006 & 2007. The years 2006 & 2007 were also years of exceptionally high osmerid catches. Eulachon and myctophids are both abundant in the Bering Canyon area, so the high catches in those areas may have resulted from a change in fishing activity by the pollock fishery.

Prior to 2005, osmerid species identification by observers was unreliable and many catches were recorded as “other osmerid”. While identification has improved since then, osmerids in catches are often too damaged for accurate identification and much of the catch is still reported as “other osmerid”. Eulachon are the most abundant osmerid in catches and it is likely that they make up the majority of the “other osmerid” catch. For this analysis, all osmerid categories in the AKRO database (eulachon, capelin, surf smelt, “other osmerid”) were combined into a single “osmerids” group.

The osmerid bycatch primarily occurs in two trawl fisheries: walleye pollock and yellowfin sole (Table 3). Catches are generally greater in the pollock fishery, but in some years (e.g., 2008, 2012, 2016) the yellowfin sole fishery catches are higher. During 2008-2018, total osmerid catch varied between 2.3 t and 34.6 t. In 2006 and 2007, however, catches were an order of magnitude higher (103.4 and 181.3 t, respectively) with most of the additional catch occurring in the pollock fishery. A similar pattern is observed in the Gulf of Alaska, where a background level of eulachon bycatch is periodically interrupted by very high bycatch levels in midwater fisheries (Ormseth 2014). The 2019 BSAI catch of osmerids as of October 31 was 22.0 t (Table 2). In 2006 & 2007 most of the osmerid catches occurred in February (Figure 22), with some additional catches in October, so it is unclear how much the total catch will increase during the rest of 2019.

The spatial concentration of eulachon bycatch corresponds to their distribution in the bottom trawl survey and the location of the fisheries in which they are caught. Most catches occur in areas 517 and 519 in the southeastern EBS (Table 4; Figures 23 & 24). Additional catch occurs in some years in area 514 in the northern part of the inner shelf, an area of intensive fishing for yellowfin sole.

Squids

In many ways the 2019 incidental catch of squids in 2019 was similar to last years: the majority of catches occur in the vicinity of Bering Canyon (Table 5) and in the fisheries for walleye pollock (Table 6). However the 2019 catch was extremely high relative to catches in the modern era: 5,173 t as of October 31, 2019 (Tables 5 and 6; Figures 25 and 26). This is more than twice the previous record catch of 2,364 t in 2015 and the highest catch since 1981. Squid catches in the BSAI typically follow a seasonal pattern with catches increasing in July at the start of the pollock "B" season, and then leveling off after 1-2 months either as a result of reduced overall fishing effort or active avoidance of squids by the pollock fleet. Because there is no longer a catch limit for squids, fishers have less incentive to avoid them and this likely contributed to the large 2019 catch. In addition, there was confusion regarding the new Ecosystem Component classification and squids were retained for sale as bait despite the Council's limitation of processing to fishmeal (Mary Furuness, NMFS, personal communication). Finally, the pollock fleet was under pressure to avoid salmon and sablefish in 2019 and may have been less able to avoid areas of squid abundance.

In response to the situation in 2019, the Council has proposed an amendment that would allow for processing of squids beyond fishmeal. The author has concerns regarding this proposal: The management approach for the FMP forage group and squids is effective as a conservation measure because, while it lacks the catch limits that otherwise prevent overfishing, the limits on retention and processing provide strong disincentives to avoid large incidental catches. The proposed changes remove one of these incentives and would contribute to increased catches of squids in future years.

Pacific herring

Data regarding the Prohibited Species Catch (PSC) of herring are available since 1991 and are maintained by the AKRO (Table 7 & Figure 27). During the 1990s herring bycatch was consistently high, but from 2000-2011 catches were relatively low. In 2012 the herring PSC was 2,376 t, an order of magnitude higher than catches in preceding years, and the PSC quota was exceeded. After smaller catches in 2013 & 2014, catches during the last three years have been more substantial, on the order of 1,000 t but still below the limit.

The spatial pattern of herring catches is consistent with the migration patterns discussed earlier and the presence of an overwintering area north of the Pribilof Islands. During periods of relatively low catch (e.g. 2014-2017) catches were highest at the southern end of the bycatch distribution (Figures 28 & 29). In contrast, in the one year that catches exceeded the PSC limit the highest catches were on the northern edge. There is also a spatiotemporal interaction in herring catch: catches occurring later in the year occur further to the north (Figure 30). The area of high catch in 2012 is north of the winter Herring Savings Area (Figure 28), so closure of the Savings Area in that year may not have achieved much in reducing herring bycatch.

Data regarding the size of herring captured in federal fisheries are sparse and could only be located for the years 2000-2007. There is substantial annual variability, but most captured herring were between 24 cm and 32 cm. In 2010, the average size for Togiak herring aged 5, 7, and 9 was 25, 29, and 31 cm, respectively (Buck 2012). In 2010, herring between the ages of 5 and made up most of the Togiak harvest (72.3%), while age 6 herring was the most abundant age class harvested (Buck 2012). The harvest in other years is comprised of similar age ranges (Elison et al 2015), so herring bycatch in the federal fishery appears to consist mainly of potential spawners.

Pandalid shrimps

Bycatch of pandalid shrimps has ranged between 0.98 t and 4.12 t since 2003 (Table 7). Shrimps in observed hauls are not identified to species, and shrimp populations are poorly understood. The federal bycatch is much smaller than the commercial shrimp harvest in combined Alaska waters, which was approximately 230 t in 2016 (ADF&G Commercial Operator's Annual Reports; http://www.adfg.alaska.gov/index.cfm?adfg=fishlicense.coar_shrimpproduction)

Data gaps and research priorities

Information regarding BSAI forage fishes is very limited, so any increase in research activity would be beneficial. Areas of particular interest are:

1) Absolute abundance of capelin, eulachon, and rainbow smelt: In the GOA, the summer acoustic survey provides a reasonable estimate of capelin abundance. Unfortunately the corresponding survey in the EBS occurs outside of the main capelin distribution. Acoustic data collected during the EMA survey may provide useful information. Estimates exist from the ecosystem models but these are highly uncertain.
2) Spawning areas of BSAI eulachon: Eulachon spawning runs have been researched in the GOA but are not well known in the BSAI. Information on where eulachon spawn would be very useful for understanding the relationship of EBS eulachon to eulachon in other areas.
3) Stock structure of federally captured herring: Genetic studies to determine population structure, similar to those conducted for BSAI chinook and chum salmon, could be conducted and should include a comparison of the genetic composition of herring on overwintering grounds versus those on the spawning grounds.
4) Enhanced knowledge regarding seasonal migrations of herring: What is the reason for the high EMA survey CPUE in Norton Sound during September? A possible approach would be to use recent observer estimates of herring catches in the groundfish trawl fishery to continue the analysis of Tojo et al. (2007) and explore the seasonal migration of herring in relation to variability in climate and oceanographic conditions.

5) Enhanced knowledge of survey selectivity and catchability for capelin, eulachon, etc.; Knowledge of the effectiveness of the surveys at sampling forage species would allow us to make the most accurate calculations using the existing survey data.
6) Continued studies of how climate variability influences the abundance, distribution, and energy content of forage species in the BSAI.

Acknowledgments

A very big thank you to all the survey personnel for gathering the various data.

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Tables

Table 1. Biomass estimates (t) and frequency of occurrence (FO) for selected forage species in the eastern Bering Sea shelf bottom trawl survey, 1987-2019. CV= coefficient of variation.

	Pacific herring			eulachon			capelin			rainbow smelt		
	biomass	CV	FO	biomass	CV	FO	biomass	CV	FO	biomass	CV	FO
1987	9,565	0.35	12%	1,816	0.28	8%	961	0.24	18%	8	1.00	0%
1988	150,345	0.87	27%	1,717	0.44	5%	3,094	0.14	31%	1,196	0.52	3%
1989	7,832	0.44	17%	1,208	0.44	6%	595	0.17	17%	0	0.00	0%
1990	4,290	0.22	18%	2,137	0.34	7%	4,476	0.32	30%	7	1.00	0%
1991	33,263	0.49	17%	6,289	0.30	6%	1,851	0.17	33%	1,757	0.61	6%
1992	9,190	0.43	12%	2,975	0.40	8%	5,450	0.20	31%	282	0.63	1%
1993	143,913	0.57	23%	2,302	0.53	5%	23,631	0.64	31%	138	0.70	1%
1994	35,049	0.45	32%	5,025	0.46	11%	1,753	0.13	31%	94	0.73	1%
1995	54,421	0.52	35%	4,641	0.30	10%	2,891	0.61	26%	108	0.67	1%
1996	24,246	0.28	14%	3,652	0.47	10%	366	0.14	14%	564	0.48	2%
1997	36,014	0.41	18%	6,987	0.32	10%	1,527	0.45	13%	471	0.87	1%
1998	15,670	0.33	21%	4,415	0.29	15%	413	0.14	15%	447	0.83	2%
1999	22,979	0.33	43%	1,795	0.22	10%	1,747	0.14	37%	4	0.89	1%
2000	31,792	0.56	23%	4,159	0.19	12%	2,220	0.31	26%	6	0.71	1%
2001	49,189	0.72	24%	3,978	0.21	17%	1,427	0.13	25%	6	1.00	0%
2002	12,308	0.30	15%	4,502	0.31	12%	1,245	0.14	30%	0	0.00	0%
2003	49,624	0.40	26%	2,368	0.28	10%	2,790	0.49	36%	3	1.00	0%
2004	90,313	0.20	45%	2,933	0.56	10%	5,814	0.21	39%	686	0.77	1%
2005	120,633	0.20	44%	1,626	0.27	10%	590	0.31	18%	0	0.00	0%
2006	28,276	0.20	43%	1,967	0.32	10%	2,604	0.12	38%	0	0.99	0%
2007	27,846	0.30	31%	3,867	0.24	13%	456	0.26	19%	188	0.64	1%
2008	81,816	0.63	36%	392	0.21	10%	1,717	0.10	41%	11	1.00	0%
2009	2,440	0.24	20%	1,043	0.28	7%	1,927	0.21	44%	1	1.00	0%
2010	34,197	0.76	13%	4,624	0.28	9%	5,316	0.26	42%	1	1.00	0%
2011	16,458	0.43	19%	4,856	0.44	10%	6,608	0.25	37%	3	1.00	0%
2012	168,947	0.34	35%	900	0.36	8%	8,376	0.20	44%	2	1.00	0%
2013	107,083	0.23	24%	1,116	0.23	9%	9,522	0.56	36%	0	0.00	0%
2014	8,743	0.49	10%	4,831	0.37	10%	5,062	0.61	24%	1,089	0.52	3%
2015	21,526	0.23	31%	1,548	0.23	10%	7,922	0.29	43%	228	0.69	1%
2016	12,573	0.25	23%	1,618	0.30	10%	2,147	0.34	28%	198	0.73	2%
2017	58,710	0.28	39%	531	0.26	6%	837	0.68	14%	596	0.46	4%
2018	101,314	0.24	25%	592	0.26	9%	74	0.17	12%	62	0.62	1%
2019	76,743	0.33	19%	1,757	0.24	15%	122	0.24	11%	77	0.73	1%

Table 2. Bycatch (t) of FMP forage fish groups in BSAI federal fisheries, 2003-2019. *2019 data are incomplete; retrieved on October 31, 2019.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
eulachon	2.5	20.2	9.4	94.0	106.0	2.5	5.4	0.4	1.8	1.3
capelin	0.01	5.4	0.4	2.6	1.2	0.2	0.6	0.8	4.1	2.4
surf smelt	-	-	-	-	0.563	0.001	-	-	-	-
other osmerids	16.2	7.0	4.7	6.8	73.5	12.4	1.1	2.9	2.6	4.9
total osmerids	18.8	32.6	14.5	103.4	181.3	15.1	7.0	4.2	8.6	8.5
Pacific sand lance	0.1	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.6	0.2
myctophids	0.3	0.1	0.6	9.6	5.8	1.5	0.5	0.2	0.2	0.05
Pacific sandfish	-	-	-	-	-	-	-	0.03	0.05	0.01
pricklebacks	0.2	0.1	0.1	0.2	0.8	0.3	0.1	0.2	0.4	0.3
gunnels	-	0.003	0.012	-	0.002	0.000	-	-	0.031	0.000
deep sea smelts	0.000	0.000	-	0.001	0.004	-	-	-	-	-
bristlemouths	-	-	-	-	-	-	-	-	-	-
total FMP forage fish	**19.4**	**33.1**	**15.6**	**113.3**	**188.0**	**17.0**	**7.7**	**4.7**	**9.8**	**9.2**

	2013	2014	2015	2016	2017	2018	*2019**
eulachon	0.6	1.7	19.4	4.4	1.7	0.1	*0.1*
capelin	0.2	1.3	6.8	0.4	0.1	0.03	*0.3*
surf smelt	-	-	-	0.015	0.000	-	*0.000*
other osmerids	1.2	9.6	7.6	6.1	4.2	1.5	*21.5*
total osmerids	2.0	12.6	33.8	10.9	6.1	1.6	*22.0*
Pacific sand lance	0.1	0.2	1.1	0.7	0.5	0.6	*1.7*
myctophids	0.5	0.6	0.5	0.3	0.1	0.2	*0.1*
Pacific sandfish	0.03	0.17	0.12	0.08	0.01	0.20	*0.12*
pricklebacks	0.2	0.7	0.6	0.5	0.1	0.6	*0.1*
gunnels	0.005	0.000	0.049	0.218	0.096	-	*0.002*
deep sea smelts	0.015	-	0.027	0.015	0.001	0.005	*0.001*
bristlemouths	-	-	-	-	-	0.001	-
total FMP forage fish	**2.8**	**14.2**	**36.2**	**12.7**	**6.8**	**3.2**	***24.0***

Table 3. Total bycatch (t) of osmerids (eulachon, capelin, surf smelt, and "other osmerids") in the BSAI by target fishery, 2003-2019. Fisheries with less than 0.1 t of catch in any year are combined into the "miscellaneous fisheries" group. *2019 data are incomplete; retrieved on October 31, 2019.

	pollock	yellowfin sole	rock sole	Pacific cod	flathead sole	arrow-tooth flounder	misc fisheries	total
2003	10.0	4.3	3.7	0.17	0.25	0.34	0.02	18.8
2004	21.6	9.0	0.5	0.65	0.26	0.57	0.01	32.6
2005	12.9	0.6	0.7	0.04	0.18	0.05	0.03	14.5
2006	102.0	0.9	0.3	0.22	0.07	0.01	0.00	103.4
2007	139.9	41.2	0.2	0.00	0.01	-	0.00	181.3
2008	4.4	10.0	0.7	0.00	0.02	-	0.00	15.1
2009	5.6	1.2	0.1	0.00	0.02	0.00	0.00	7.0
2010	0.3	3.7	0.2	0.00	0.01	0.00	0.00	4.2
2011	1.5	6.5	0.5	0.01	0.08	0.01	0.01	8.6
2012	1.3	7.1	0.1	0.01	0.00	0.00	0.00	8.5
2013	0.6	1.2	0.1	0.03	0.14	0.01	0.01	2.0
2014	1.3	11.1	0.1	0.03	0.04	0.01	0.00	12.6
2015	21.2	6.8	5.7	0.03	0.00	0.03	0.03	33.8
2016	1.9	8.2	0.7	-	0.03	0.04	0.00	10.9
2017	1.7	2.9	1.4	0.00	0.00	0.01	0.00	6.1
2018	0.1	0.5	0.9	-	0.01	-	0.00	1.6
*2019**	*0.1*	*13.2*	*8.6*	-	*0.02*	-	*0.01*	*22.0*

Table 4. Total bycatch (t) of osmerids (eulachon, capelin, surf smelt, and “other osmerids) in the BSAI by NMFS statistical area, 2003-2019. Areas with less than 0.1 t of catch in any year are combined into the “all others” group. *2019 data are incomplete; retrieved on October 31, 2019.

	517	514	519	513	509	521	516	all others	total
2003	7.4	7.4	0.2	3.67	0.07	0.089	0.004	0.01	18.8
2004	22.1	8.9	0.2	0.92	0.17	0.167	0.003	0.12	32.6
2005	12.3	1.2	0.1	0.26	0.31	0.132	0.001	0.21	14.5
2006	65.9	1.0	35.5	0.48	0.30	0.099	0.002	0.17	103.4
2007	96.2	41.2	41.4	1.43	0.78	0.123	0.004	0.21	181.3
2008	2.0	10.5	1.3	0.06	0.48	0.681	0.000	0.03	15.1
2009	1.4	1.1	4.2	0.04	0.22	0.037	0.001	0.00	7.0
2010	0.2	3.4	0.1	0.24	0.21	0.002	-	0.00	4.2
2011	0.9	5.6	0.02	1.10	0.98	0.003	0.001	0.00	8.6
2012	1.2	6.6	0.04	0.09	0.52	0.013	0.005	0.00	8.5
2013	0.6	1.1	0.001	0.04	0.21	0.053	0.003	0.02	2.0
2014	1.1	10.9	0.02	0.18	0.31	0.028	0.106	0.00	12.6
2015	11.5	12.6	9.1	0.59	0.05	0.013	0.002	0.00	33.8
2016	0.6	8.8	1.3	0.20	0.05	0.005	0.000	0.00	10.9
2017	1.0	4.1	0.8	0.02	0.15	0.001	0.002	0.00	6.1
2018	0.1	1.4	0.05	0.02	0.01	0.002	0.001	0.00	1.6
*2019**	*0.1*	*17.7*	*0.01*	*0.02*	*3.64*	*0.023*	*0.493*	*0.00*	*22.0*

Table 5. Incidental catches (t) of squids in the Bering Sea and Aleutian Islands region by NMFS statistical area, 2003-2019. The "all others" category includes areas with < 1 t of annual catch. Data are from the Alaska Regional Office Catch Accounting System. *2019 data are incomplete; retrieved on October 31, 2019.

	517	519	521	541	523	509	518	543	542	524	all others	total
2003	746	484	12	9	0	2	0	17	10	0	2	1,282
2004	587	398	5	4	0	7		3	7	0	2	1,014
2005	539	527	95	3	3	5		12	2	0	0	1,186
2006	965	261	15	2	0	162	0	7	6	0	1	1,418
2007	690	419	26	2		13		8	3	15	12	1,188
2008	1,066	344	25	25	1	25	23	18	6	0	9	1,542
2009	143	74	9	66	0	1	40	20	5	0	2	360
2010	133	145	5	90	1	5	17	11	4	0	0	410
2011	119	52	17	75	3	3	30	16	8	12	1	336
2012	308	187	20	114	0	16	17	8	6	9	2	688
2013	63	41	33	107	1	5	2	30	5	11	1	299
2014	938	548	13	76	3	19	43	21	13	5	0	1,678
2015	1,495	580	59	32	94	9	42	40	12	2	1	2,364
2016	891	180	49	25	83	3	25	16	9	3	1	1,286
2017	1,331	265	170	24	149	8	18	14	5	11	1	1,996
2018	893	577	185	21	26	12	1	8	6	5	1	1,736
*2019**	*3,323*	*946*	*510*	*33*	*165*	*27*	*6*	*3*	*6*	*153*	*1*	*5,173*

Table 6. Incidental catches (t) of squids in the Bering Sea and Aleutian Islands region by target fishery, 2003-2019. Data are from the Alaska Regional Office Catch Accounting System. Fisheries with less than 0.1 t of catch in any year are combined into the “miscellaneous fisheries” group.*2019 data are incomplete; retrieved on October 31, 2019.

	pollock	arrowtooth	rockfish	Kamchatka	Atka	misc fisheries	total
2003	1,226	6.5	12.5		20.6	16.5	1,282
2004	977	6.3	6.4		7.2	17.6	1,014
2005	1,150	10.1	7.1		9.0	10.3	1,186
2006	1,399	4.1	5.9		8.6	1.2	1,418
2007	1,169	2.5	8.4		5.2	3.5	1,188
2008	1,452	46.3	24.7		12.2	7.0	1,542
2009	209	96.0	17.5		13.6	23.4	360
2010	277	103.7	12.0		15.9	1.5	410
2011	178	67.0	36.9	48.5	5.1	0.6	336
2012	495	59.8	32.5	76.3	22.8	0.7	688
2013	118	68.5	59.8	35.9	14.7	2.8	299
2014	1,478	69.0	55.6	41.9	30.8	2.2	1,678
2015	2,206	23.7	66.2	51.7	13.0	3.3	2,364
2016	1,164	29.7	25.7	21.9	16.3	28.0	1,286
2017	1,887	10.1	30.6	24.0	12.4	32.0	1,996
2018	1,645	3.1	49.6	6.0	6.0	26.6	1,736
*2019**	*5,003*	*16.1*	*21.0*	*37.2*	*8.5*	*88.1*	*5,173*

Table 7. Bycatch (t) of Pacific herring and pandalid shrimps in BSAI groundfish fisheries, 1991-2019. Data are from the Prohibited Species Catch (PSC) and nontarget catch databases, respectively, maintained by the NMFS Alaska Regional Office. *2019 data are incomplete; retrieved on October 31, 2019.

	Pacific herring		pandalid shrimp
	groundfish fishery catch	PSC limit	
1991	3,761	834	-
1992	1,059	956	-
1993	784	2,122	-
1994	1,728	1,962	-
1995	970	1,861	-
1996	1,513	1,697	-
1997	1,298	1,579	-
1998	963	1,585	-
1999	895	1,685	-
2000	512	1,853	-
2001	270	1,526	-
2002	134	1,526	-
2003	962	1,525	0.98
2004	1,200	1,876	2.22
2005	676	2,013	1.74
2006	484	1,770	3.24
2007	417	1,787	2.08
2008	215	1,726	2.48
2009	88	1,697	2.63
2010	356	1,973	2.14
2011	397	2,273	4.12
2012	2,376	2,094	2.45
2013	988	2,648	4.01
2014	186	2,179	3.05
2015	1,531	2,742	2.22
2016	1,493	2,630	1.89
2017	1,023	2,013	1.68
2018	542	1,830	1.88
2019*	*1,179*	*2,547*	*2.67*

Figures

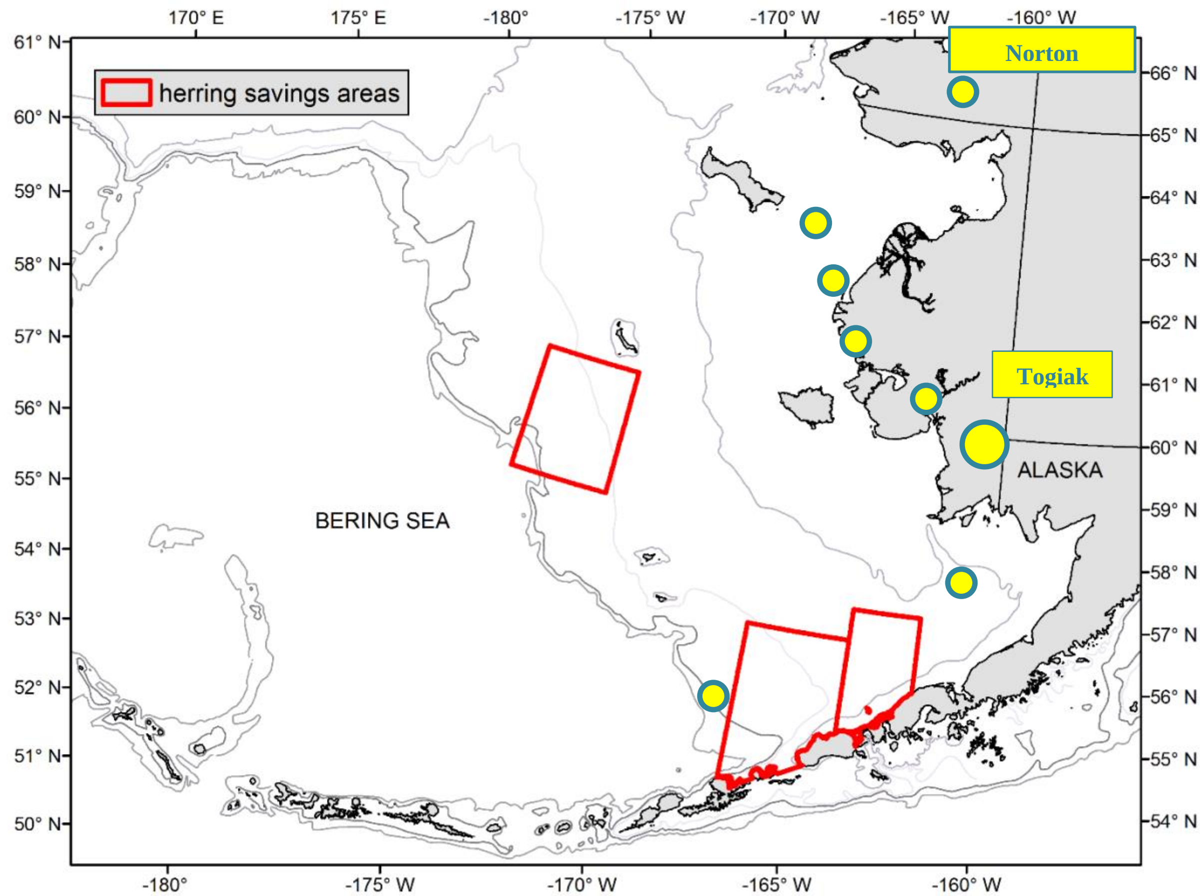


Figure 1. Locations of Pacific herring fisheries in the Bering Sea/Aleutian Islands region (yellow dots) and Herring Savings Areas (red-outlined polygons). The two largest herring fisheries are labeled by name; the larger dot at Togiak indicates that this is by far the biggest fishery.

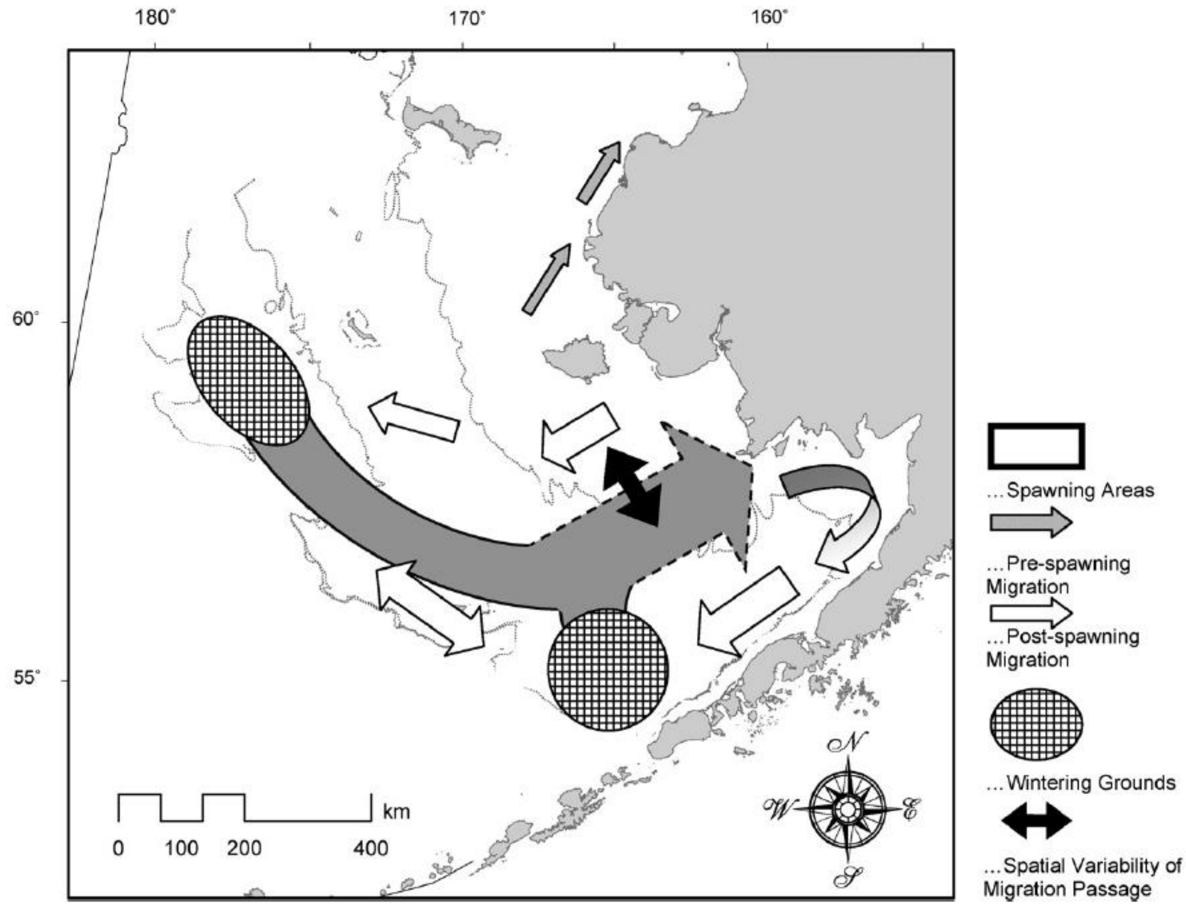


Figure 2. Hypothesized migration routes and seasonal distributions of Pacific herring in the eastern Bering Sea. Figure is from Tojo et al. 2007.

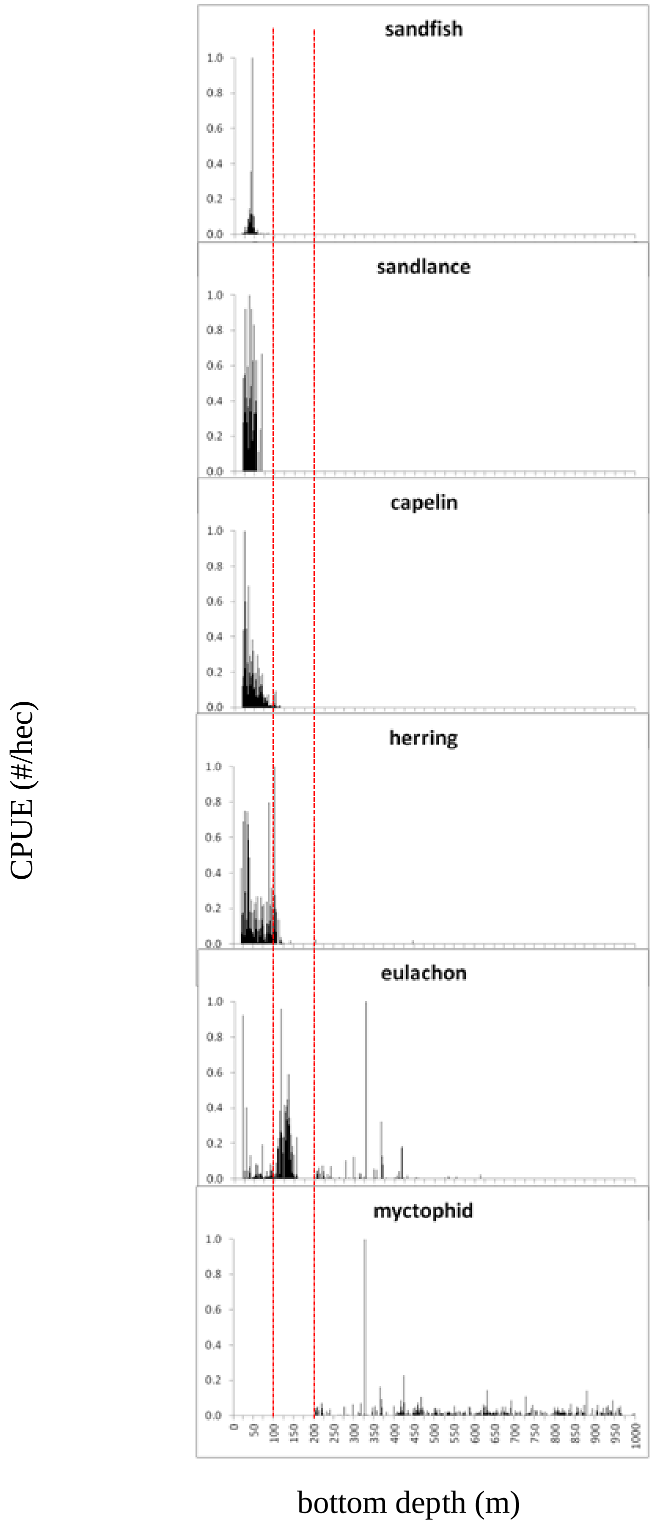
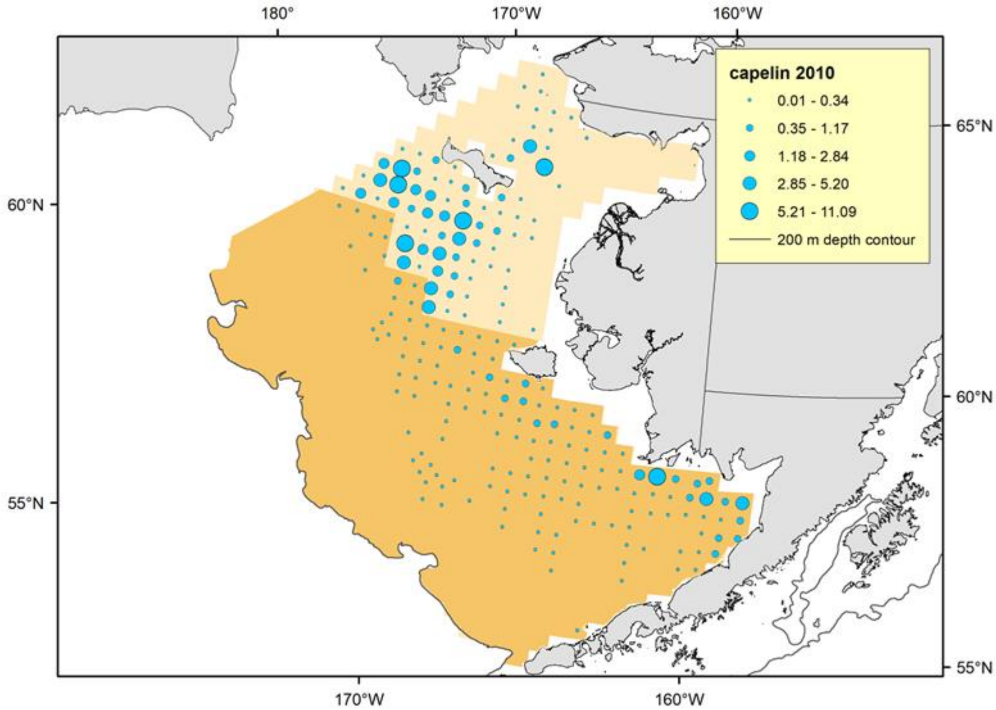


Figure 3. Mean bottom trawl survey catch-per-unit-effort (CPUE; number/hec) versus bottom depth (m) of haul for six forage groups in the eastern Bering Sea. Red reference lines represent the 100 m and 200 m depth contours.



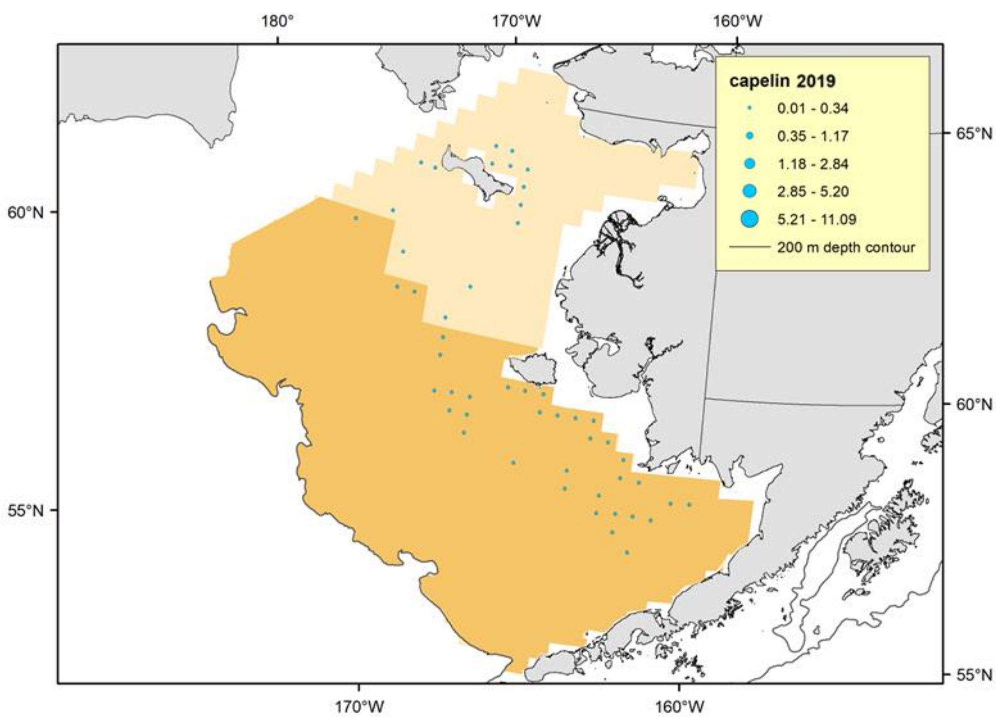


Figure 4. Mean catch-per-unit-effort (CPUE; kg/hec) of **capelin** in AFSC bottom trawl surveys in 2010 (top panel) and 2019 (bottom panel).

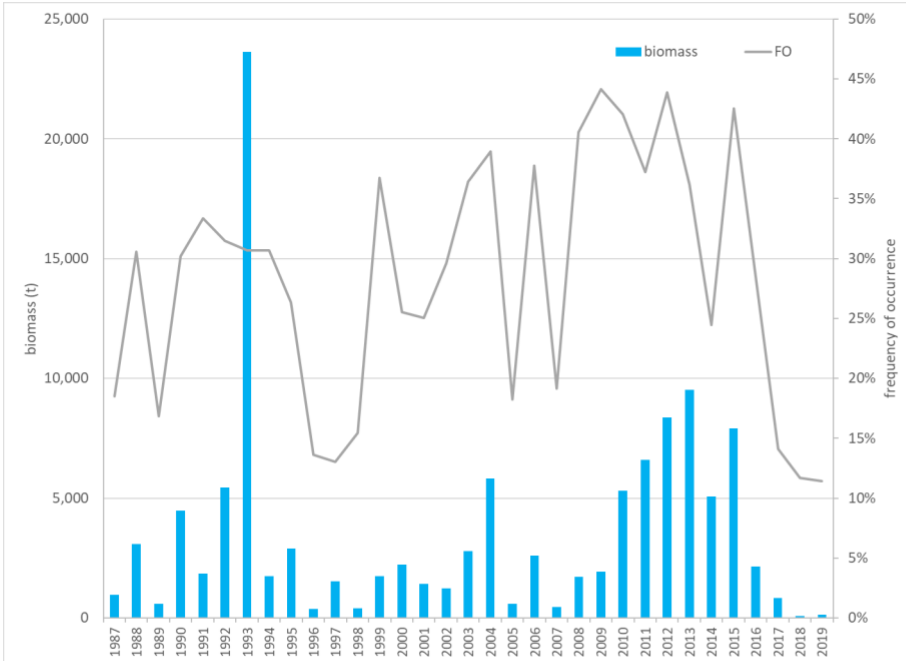


Figure 5. Biomass estimates (t) and frequency of occurrence for **capelin** in the eastern Bering Sea shelf bottom trawl survey, 1987-2019. The confidence intervals are omitted for clarity; please see Table 1 for information regarding uncertainty.

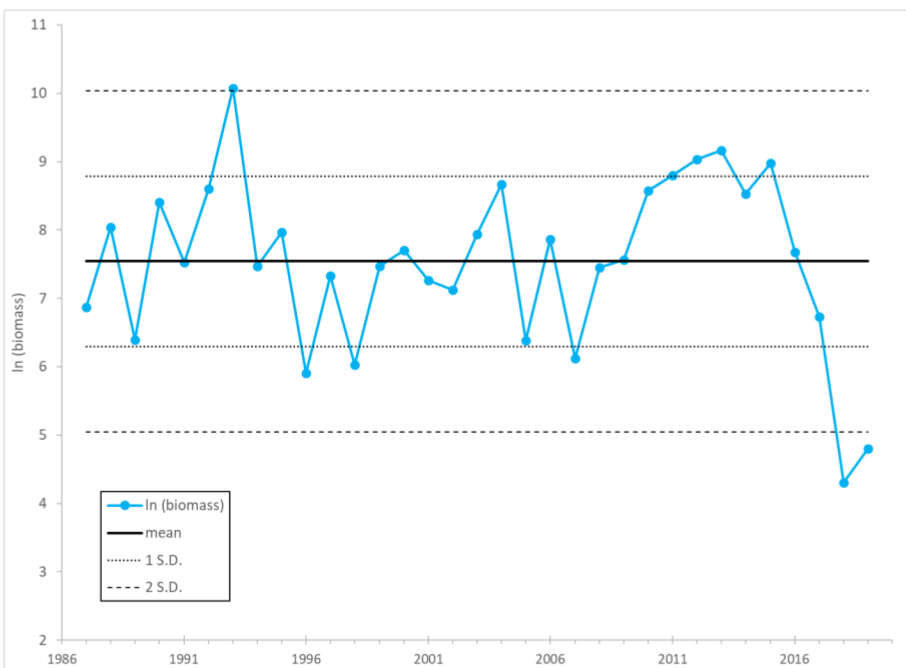


Figure 6. Natural log (ln) of **capelin** biomass estimates from the eastern Bering Sea shelf bottom trawl survey, 1987-2019. Plot includes the mean ln (biomass) over the entire time series; dashed lines indicate 1 and 2 standard deviations (S.D.) from the mean. Horizontal axis does not cross at 0.

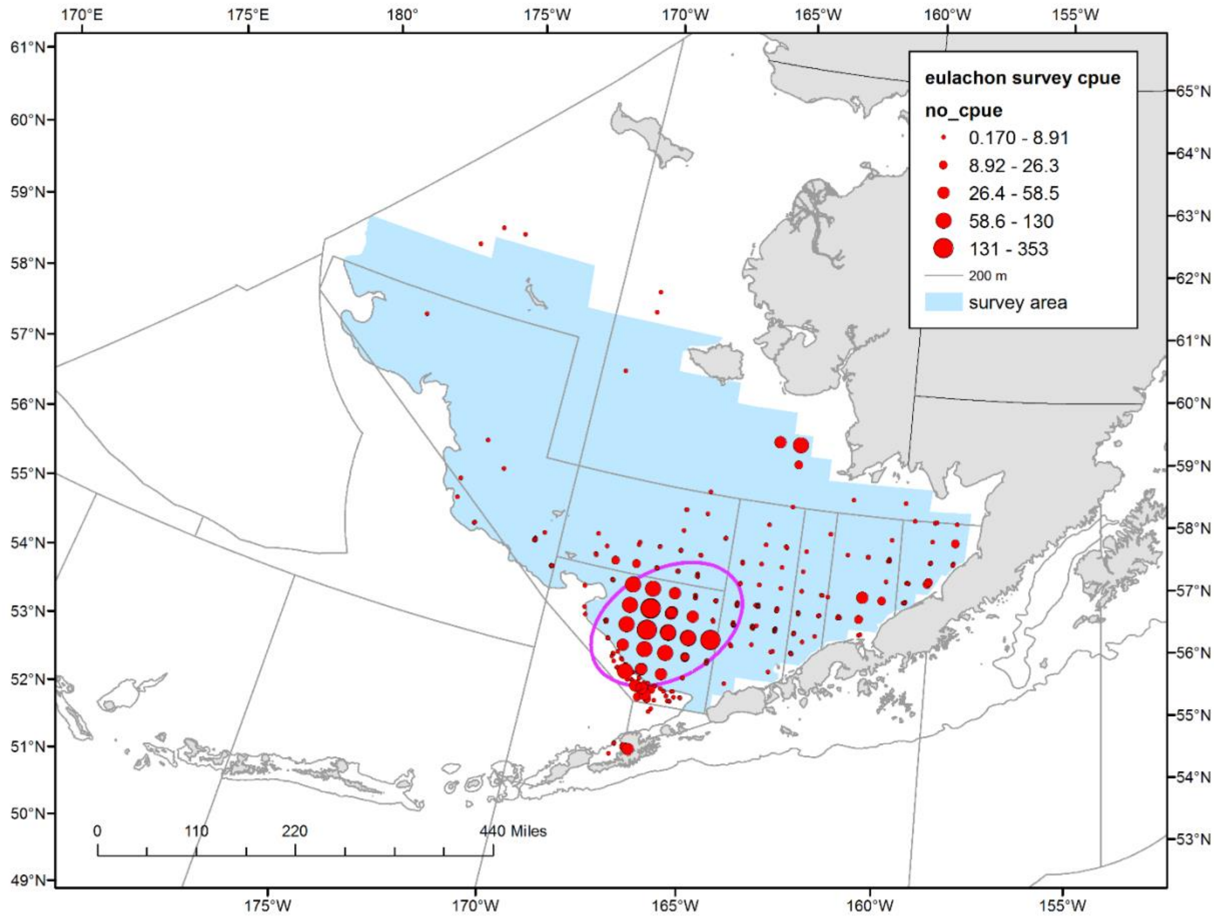


Figure 7. Mean catch-per-unit-effort (CPUE; number/km2) of **eulachon** in NMFS Bering Sea/Aleutian Islands (BSAI) bottom trawl surveys, 2006-2017. Oval indicates weighted standard deviational ellipse, which includes all points within one standard deviation of the distribution's mean geographic center.

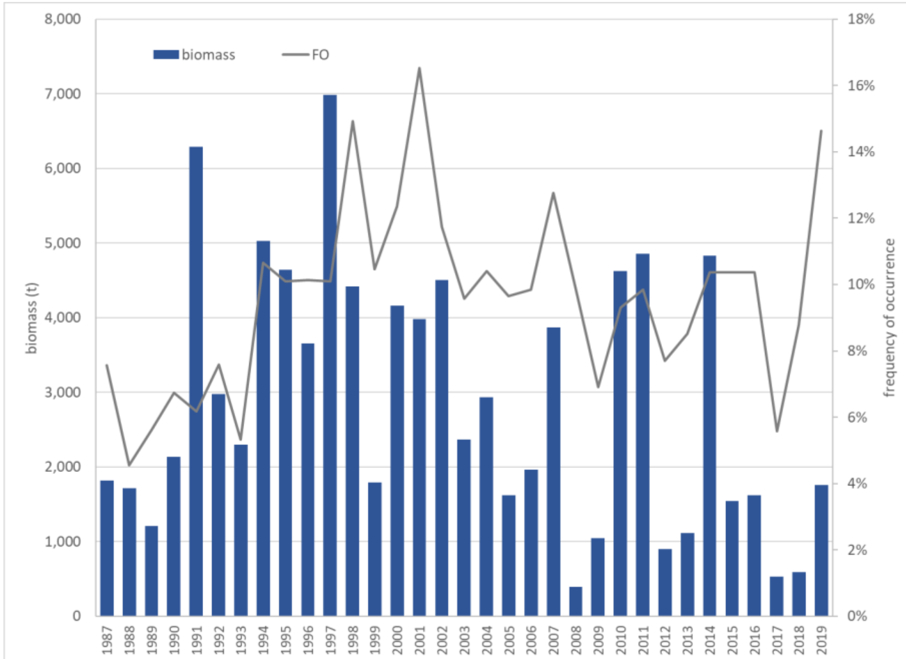


Figure 8. Biomass estimates (t) and frequency of occurrence for **eulachon** in the eastern Bering Sea shelf bottom trawl survey, 1987-2019. The confidence intervals are omitted for clarity; please see Table 1 for information regarding uncertainty.

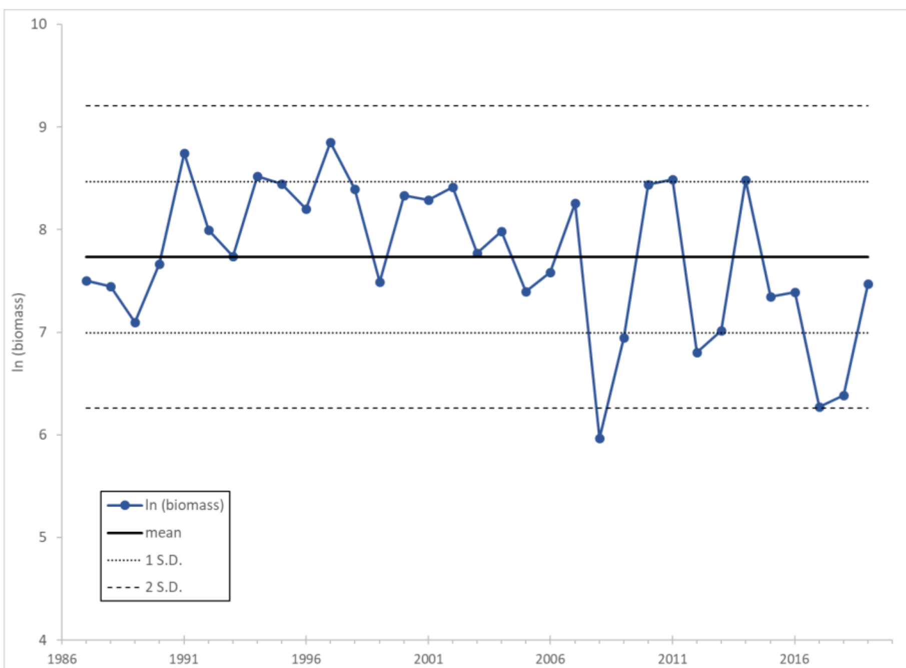


Figure 9. Natural log (ln) of **eulachon** biomass estimates from the eastern Bering Sea shelf bottom trawl survey, 1987-2019. Plot includes the mean ln (biomass) over the entire time series; dashed lines indicate 1 and 2 standard deviations (S.D.) from the mean. Horizontal axis does not cross at 0.

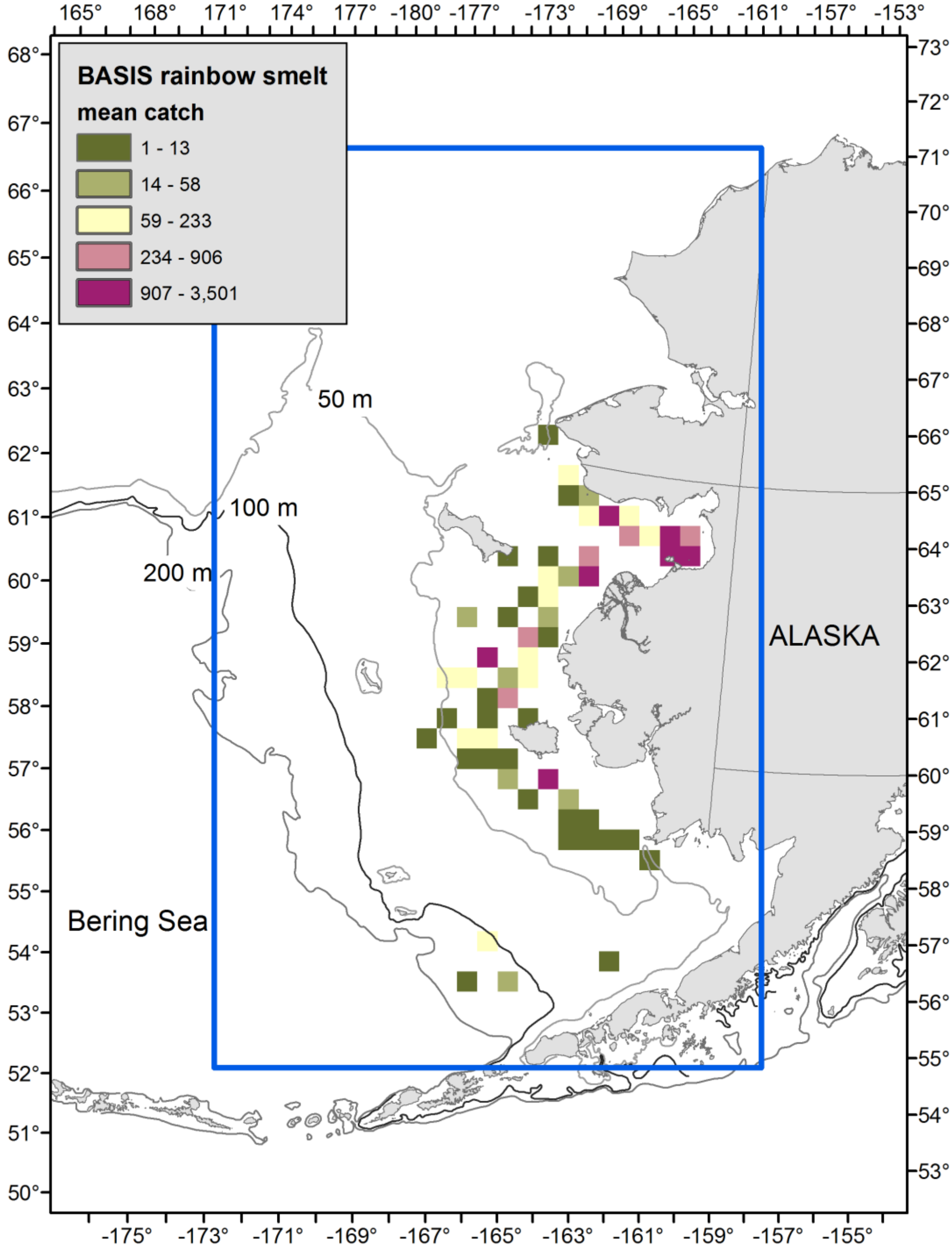


Figure 10. Mean catch (in numbers) of rainbow smelt in surface-trawl surveys conducted by the Ecosystem Monitoring and Assessment program in the eastern Bering Sea, 2002-2011. Grid cells are 20 km X 20 km. Blue box indicates approximate extent of survey hauls over the entire time period.

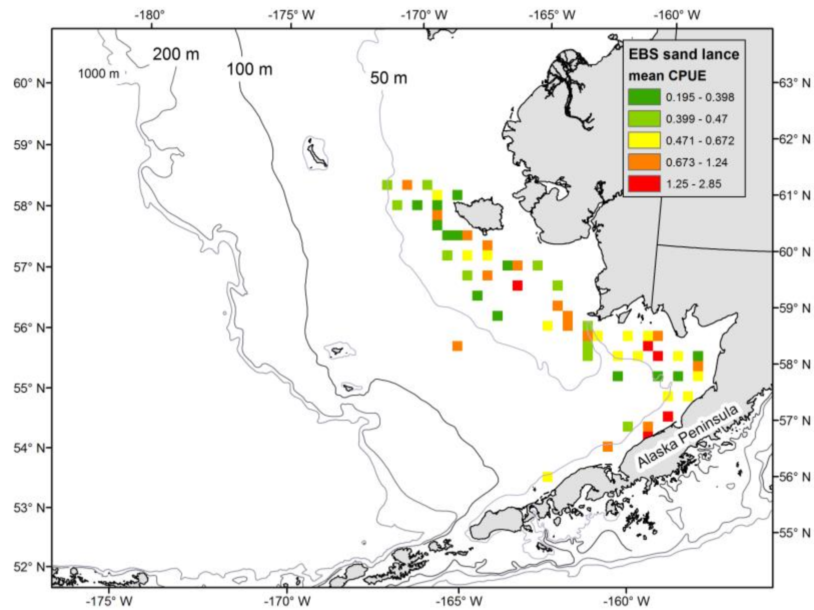


Figure 11. Mean catch-per-unit-effort (CPUE; kg/km2) of Pacific sand lance in the NMFS eastern Bering Sea shelf survey, 2000-2017. Grid cells are 20 km X 20 km.

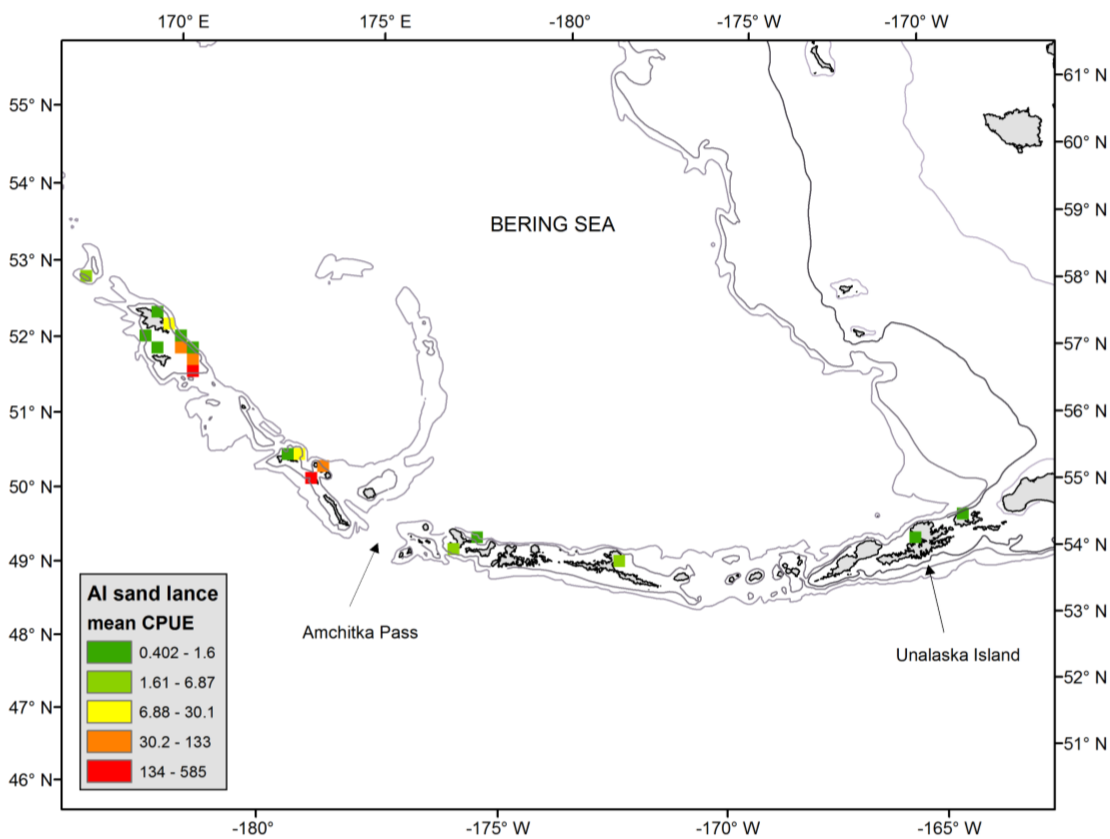


Figure 12. Mean catch-per-unit-effort (CPUE; kg/km2) of Pacific sand lance in the NMFS Aleutian Islands bottom trawl survey, 2000-2016. Grid cells are 20 km X 20 km.

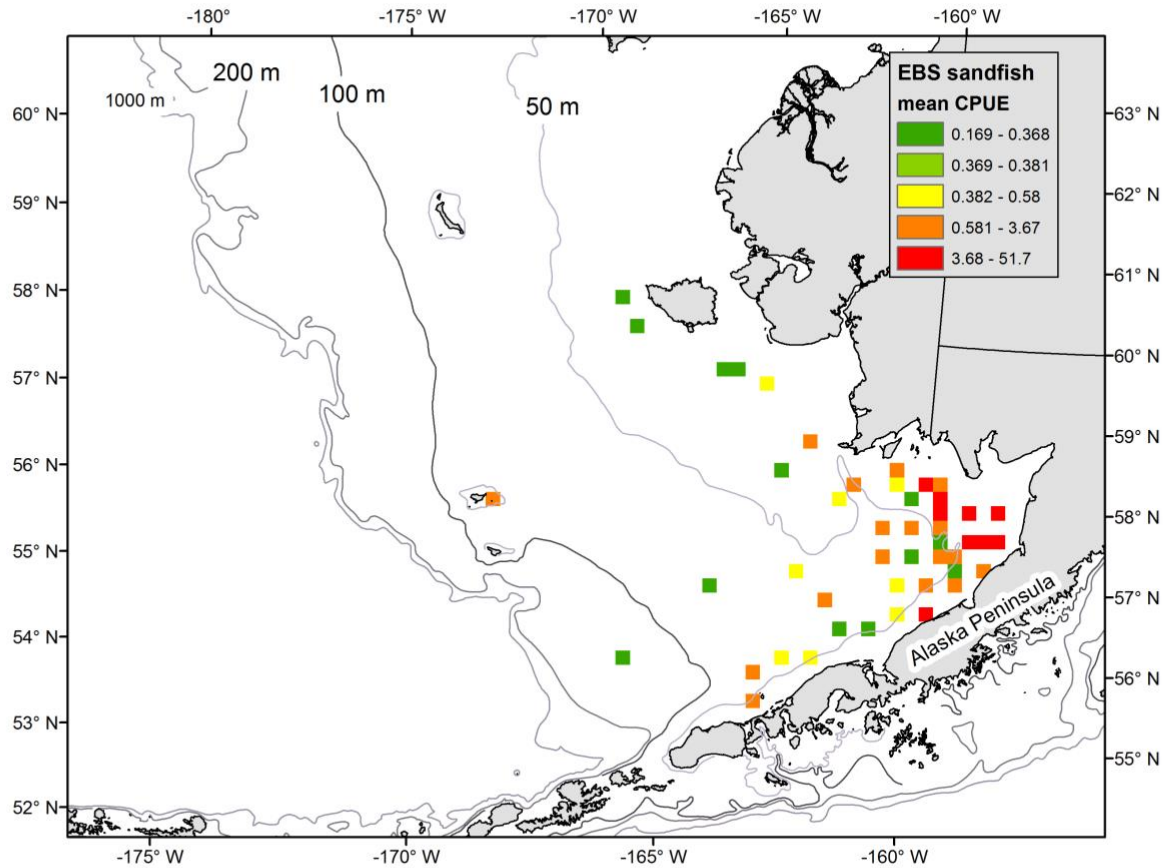


Figure 13. Mean catch-per-unit-effort (CPUE; kg/km2) of Pacific sandfish in the NMFS eastern Bering Sea bottom trawl survey, 2000-2017. Grid cells are 20 km X 20 km.

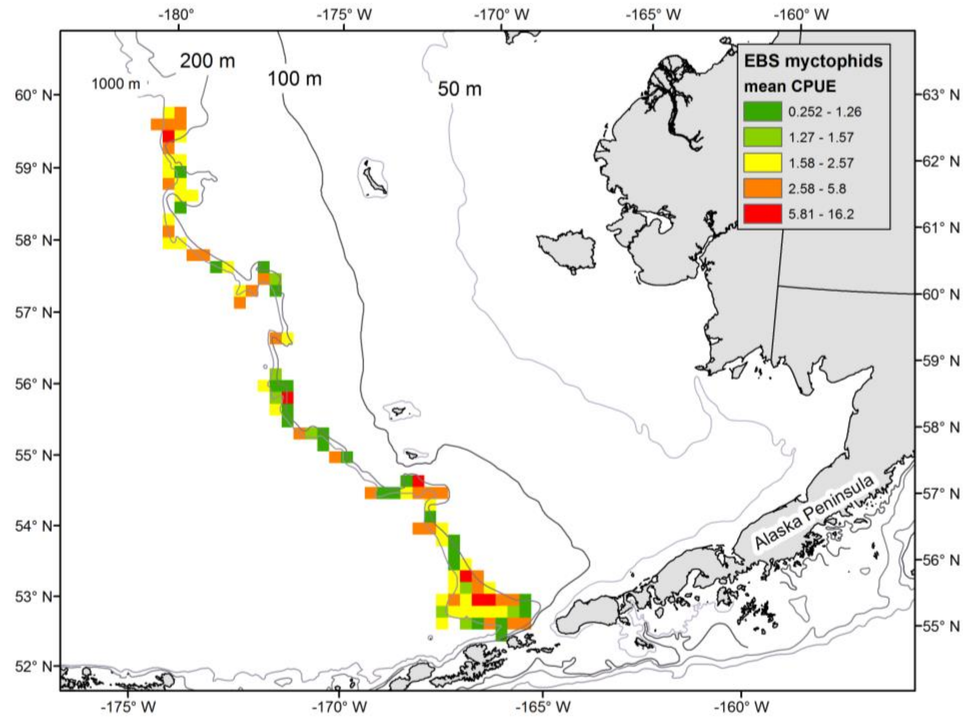


Figure 14. Mean catch-per-unit-effort (CPUE; kg/km2) of myctophids in the NMFS eastern Bering Sea shelf and slope bottom trawl surveys, 2000-2017. Grid cells are 20 km X 20 km.

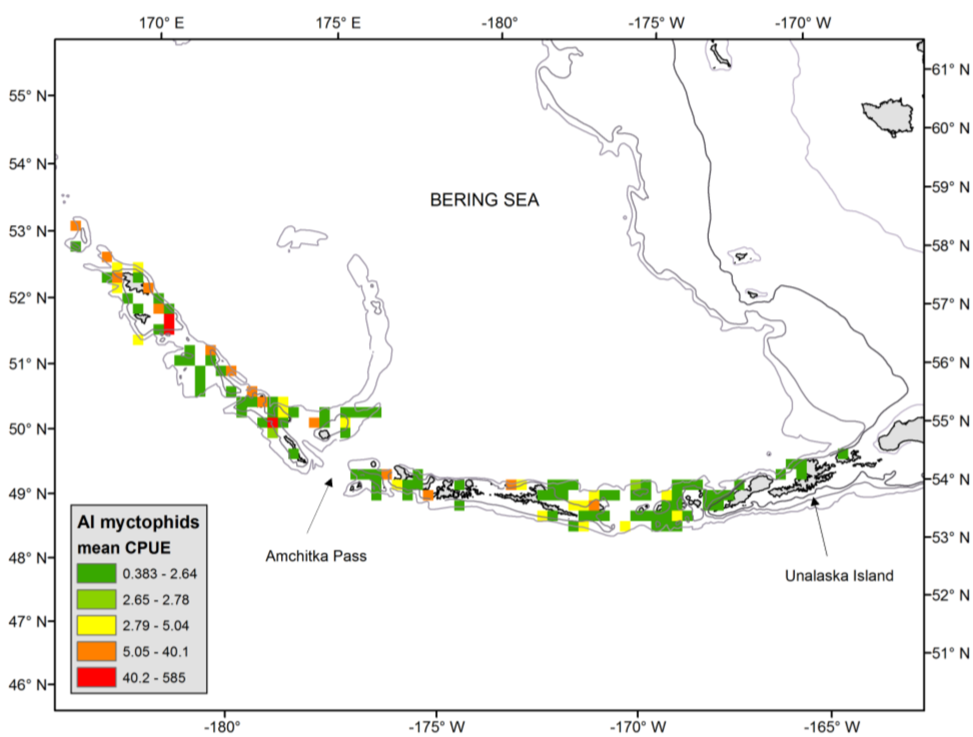


Figure 15. Mean bottom trawl survey catch-per-unit-effort (CPUE; kg/km2) of myctophids in the NMFS Aleutian Islands bottom trawl survey, 2000-2016. Grid cells are 20 km X 20 km.

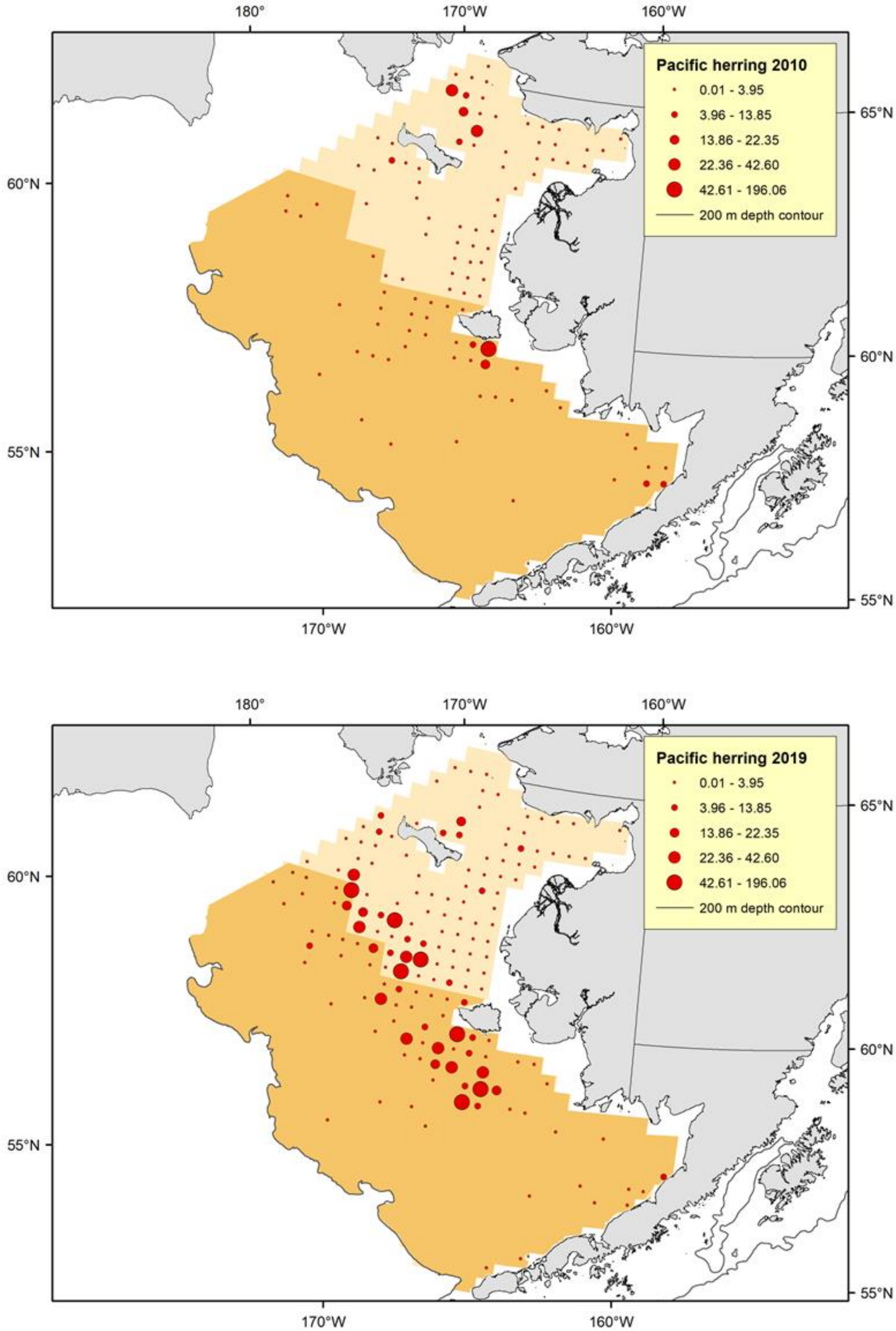


Figure 16. Mean catch-per-unit-effort (CPUE; kg/hec) of **Pacific herring** in AFSC bottom trawl surveys in 2010 (top panel) and 2019 (bottom panel).

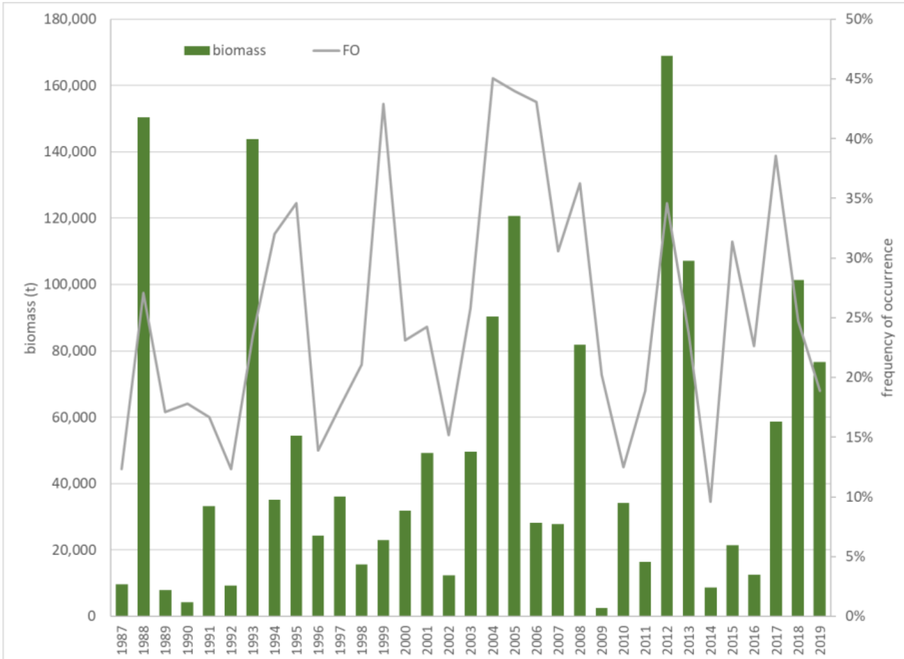


Figure 17. Biomass estimates (t) and frequency of occurrence for **Pacific herring** in the eastern Bering Sea shelf bottom trawl survey, 1987-2019. The confidence intervals are omitted for clarity; please see Table 1 for information regarding uncertainty.

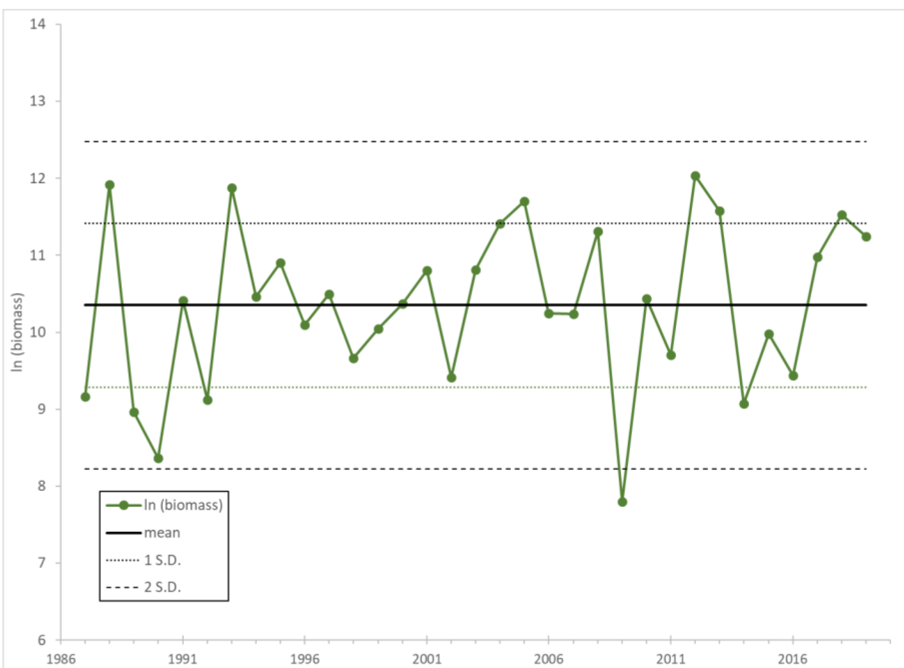


Figure 18. Natural log (ln) of **Pacific herring** biomass estimates from the eastern Bering Sea shelf bottom trawl survey, 1987-2019. Plot includes the mean ln (biomass) over the entire time series; dashed lines indicate 1 and 2 standard deviations (S.D.) from the mean. Horizontal axis does not cross at 0.

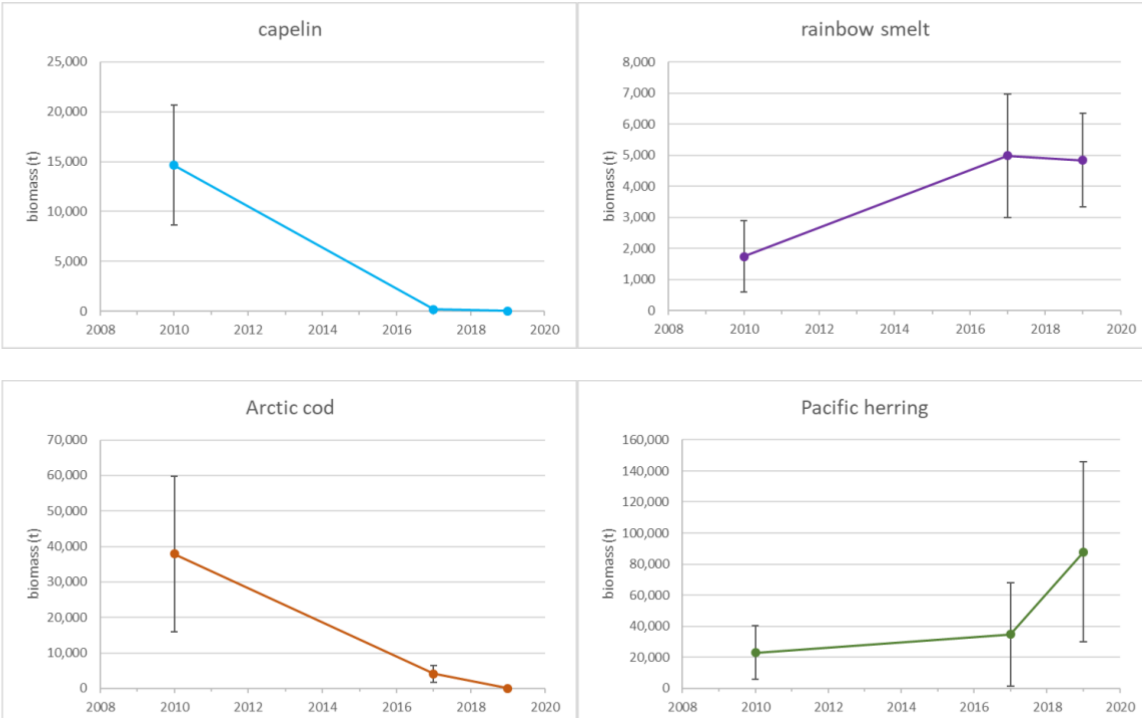


Figure 19. Biomass estimates (t) for the four most abundant forage fishes in the northern Bering Sea bottom trawl survey, 2010-2019. Error bars indicate 95% confidence interval.

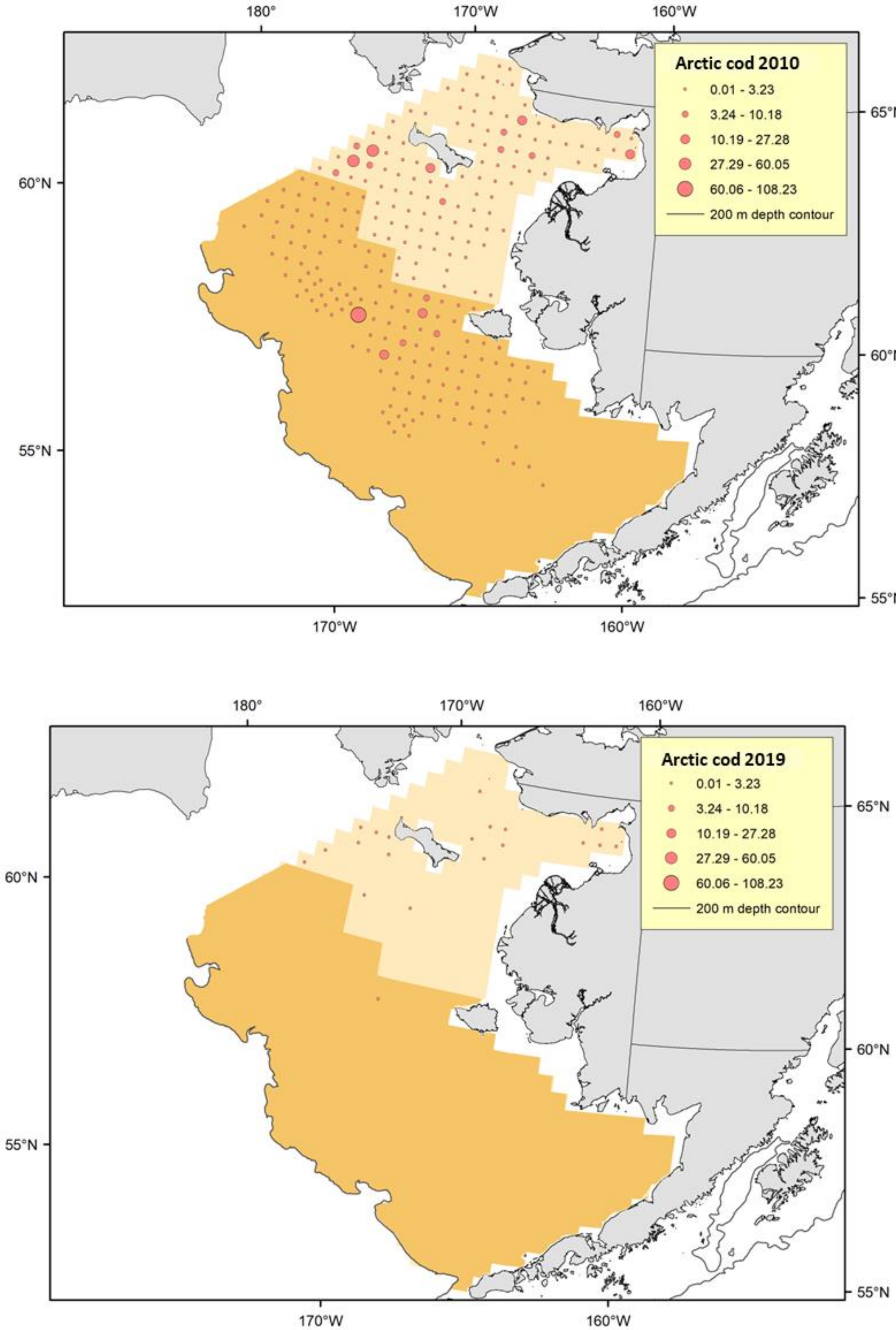
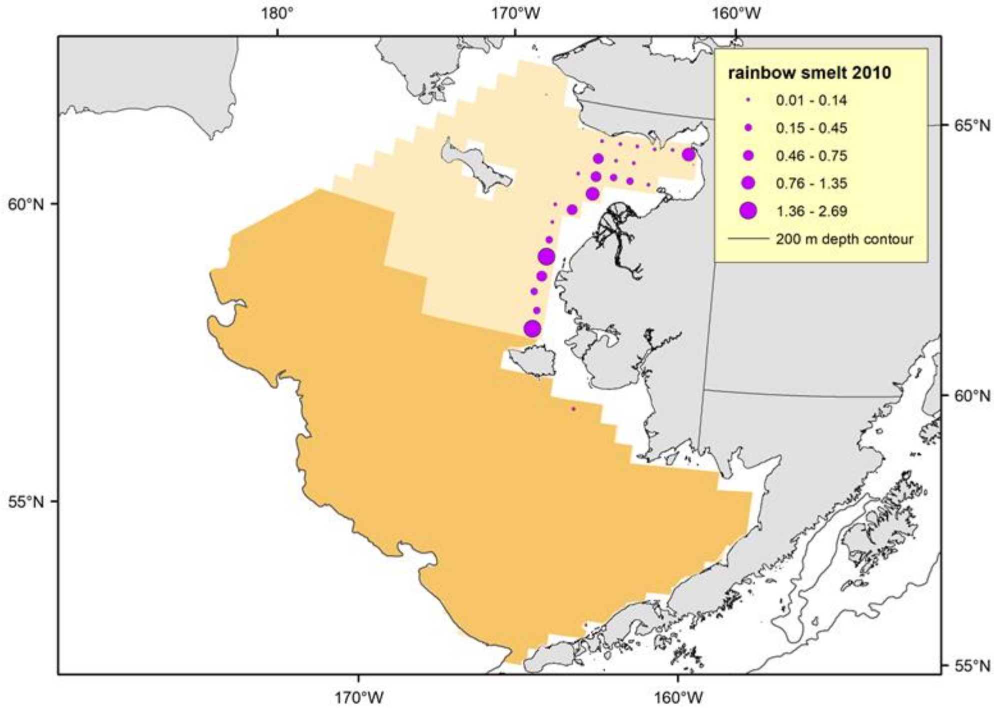


Figure 20. Mean catch-per-unit-effort (CPUE; kg/hec) of **Arctic cod** in AFSC bottom trawl surveys in 2010 (top panel) and 2019 (bottom panel).



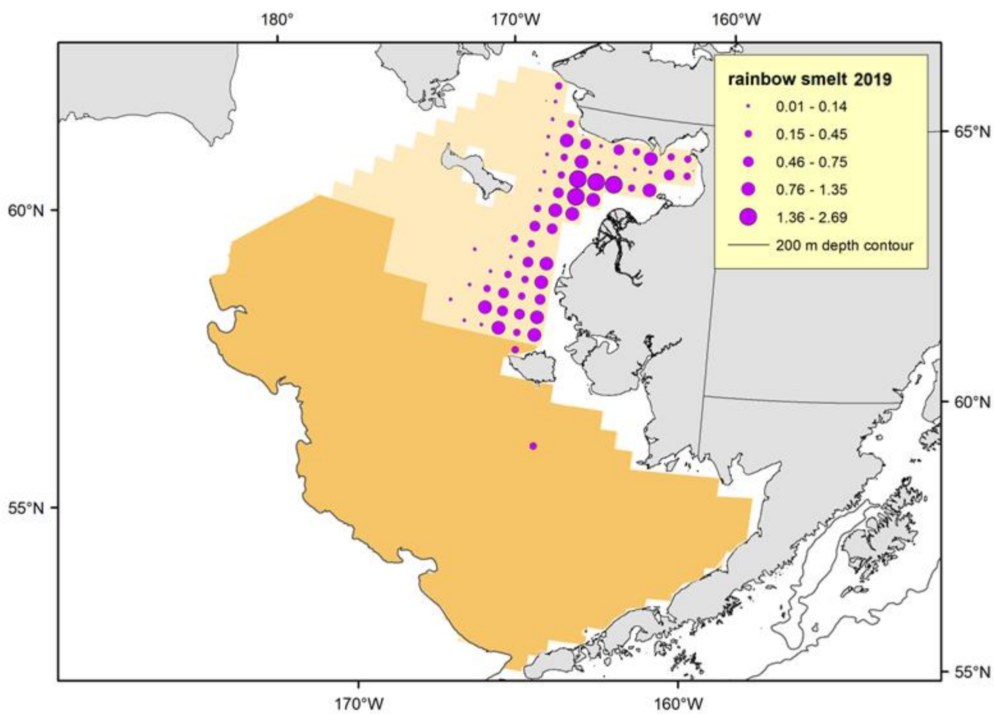


Figure 21. Mean catch-per-unit-effort (CPUE; kg/hec) of **rainbow smelt** in AFSC bottom trawl surveys in 2010 (top panel) and 2019 (bottom panel).

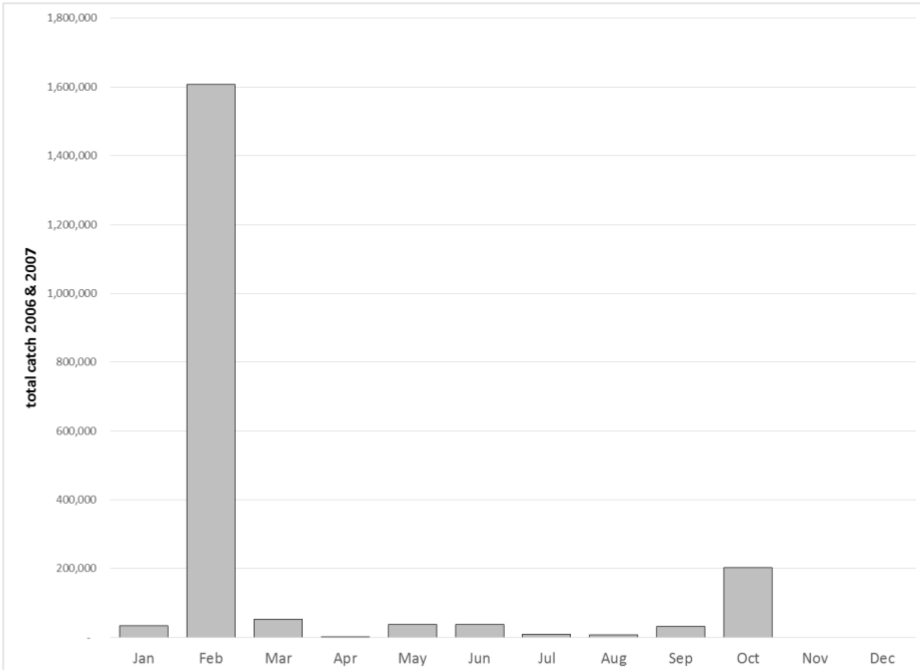


Figure 22. Seasonal pattern of observed eulachon catches (numbers) in the Bering Sea/Aleutian Islands region during 2006 & 2007.

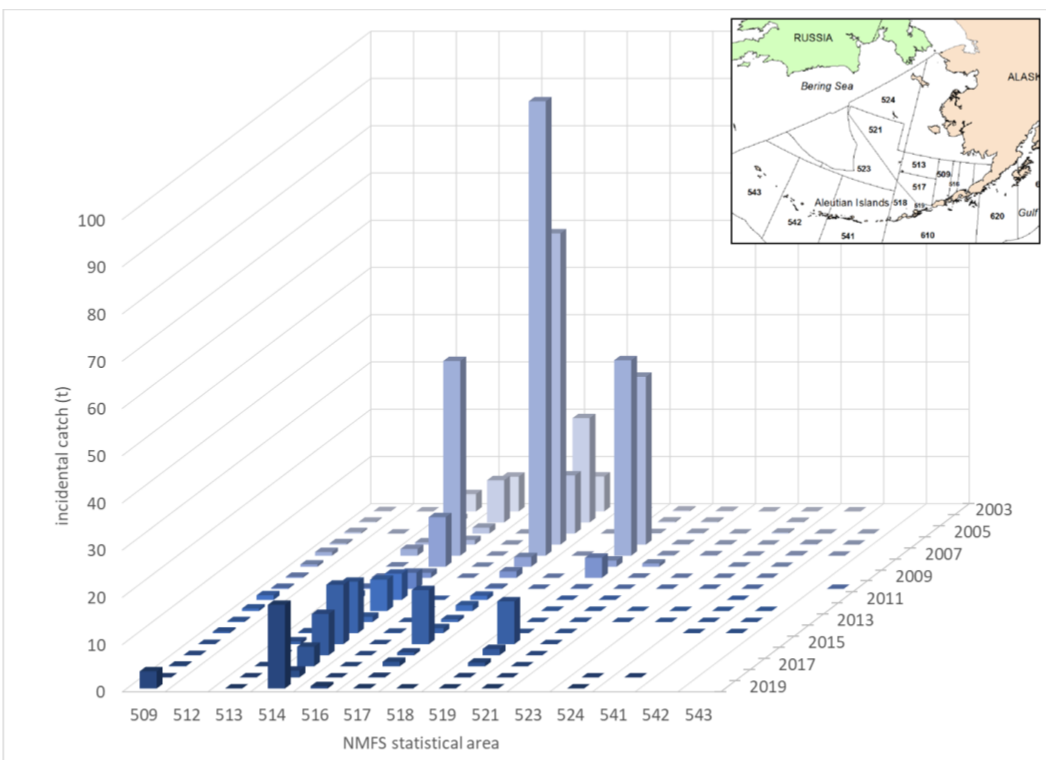


Figure 23. Incidental catches (t) of all osmerids (eulachon, capelin, surf smelt, “other osmerids”) in the Bering Sea/Aleutian Islands by NMFS statistical area, 2003-2019. The 2019 data are incomplete; retrieved on October 31, 2019. Inset map shows the boundaries of the statistical areas.

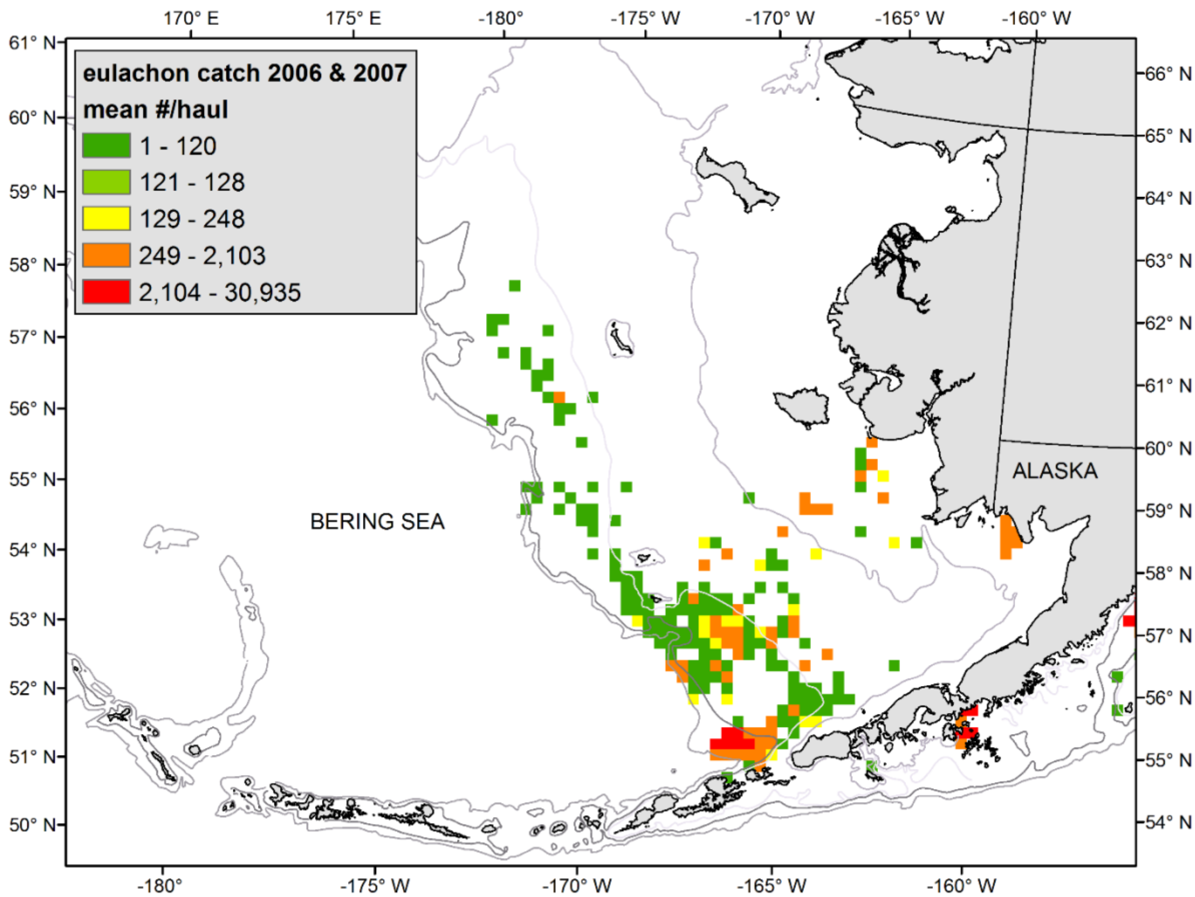


Figure 24. Mean catches of eulachon in observed fishery hauls (number/haul) in the Bering Sea and Aleutian Islands (BSAI) during 2006 & 2007.

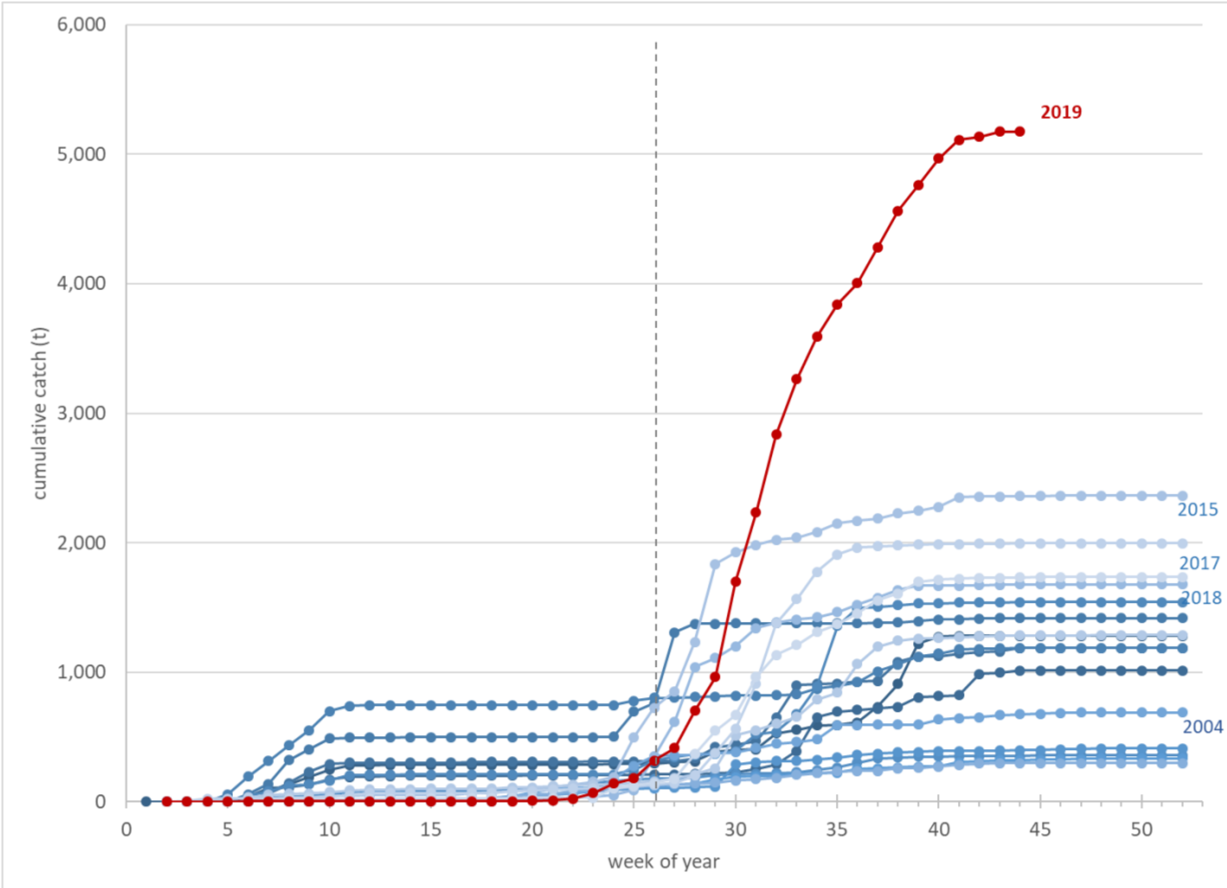


Figure 25. Cumulative weekly catches of squids in the Bering Sea and Aleutian Islands region, 2003-2019. Each line indicates a separate year. The 2019 catch data are incomplete (retrieved October 31, 2019) and marked in red; selected additional years indicated by lettering. Week 26 (year midpoint) marked with vertical dashed line. Data are from the Alaska Regional Office Catch Accounting System.

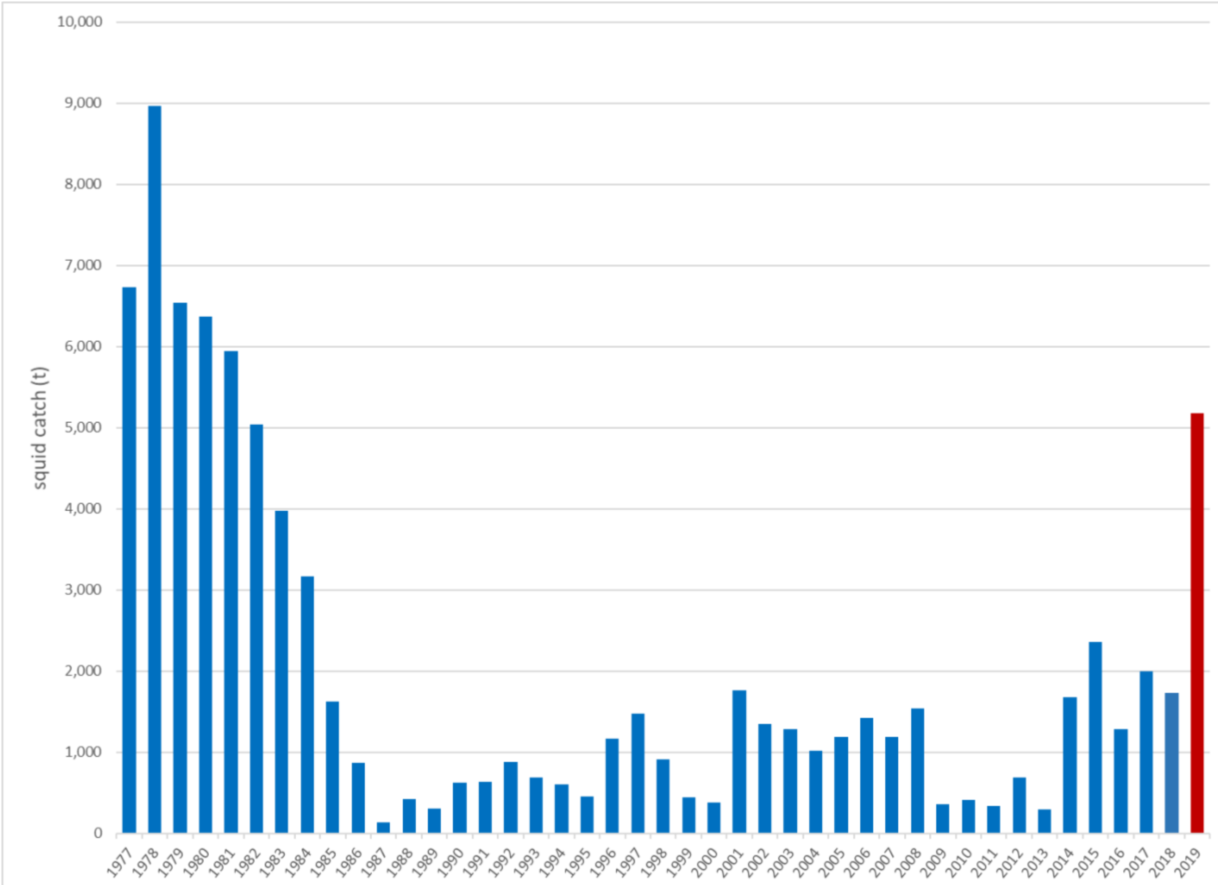


Figure 26. Catches of squids in the Bering Sea and Aleutian Islands region, 1977-2019. The 2019 catch data are incomplete (retrieved October 31, 2019) and marked in red. Data from before 2003 are from the Alaska Regional Office (AKRO) foreign blend and blend databases; data from 2003-present are from the AKRO Catch Accounting System.

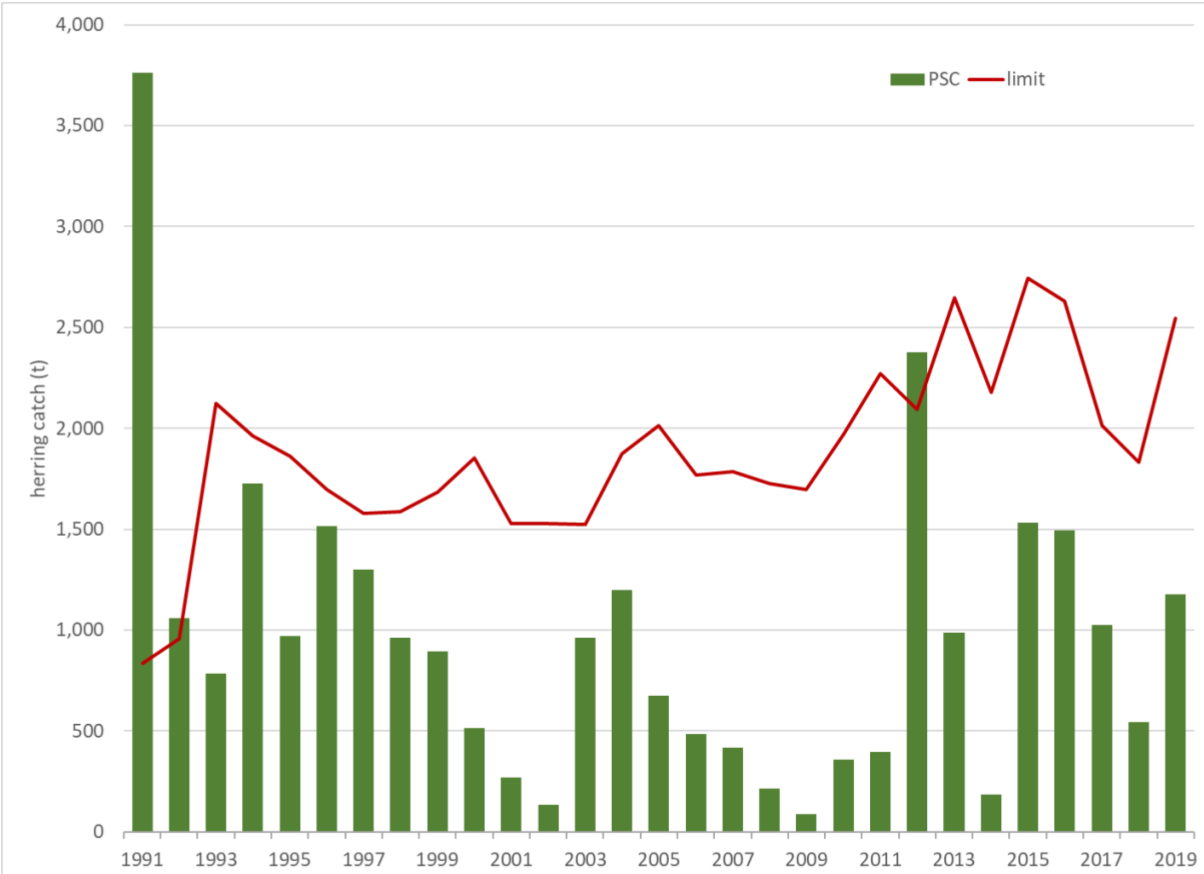


Figure 27. Catch (t) of Pacific herring in federally-managed groundfish fisheries in the Bering Sea and Aleutian Islands, 1991-2019 (green columns). The annual limit on Prohibited Species Catch (PSC) of herring is indicated by a red line. Data are from the NMFS Alaska Regional Office. 2019 data are incomplete; retrieved on October 31, 2019.

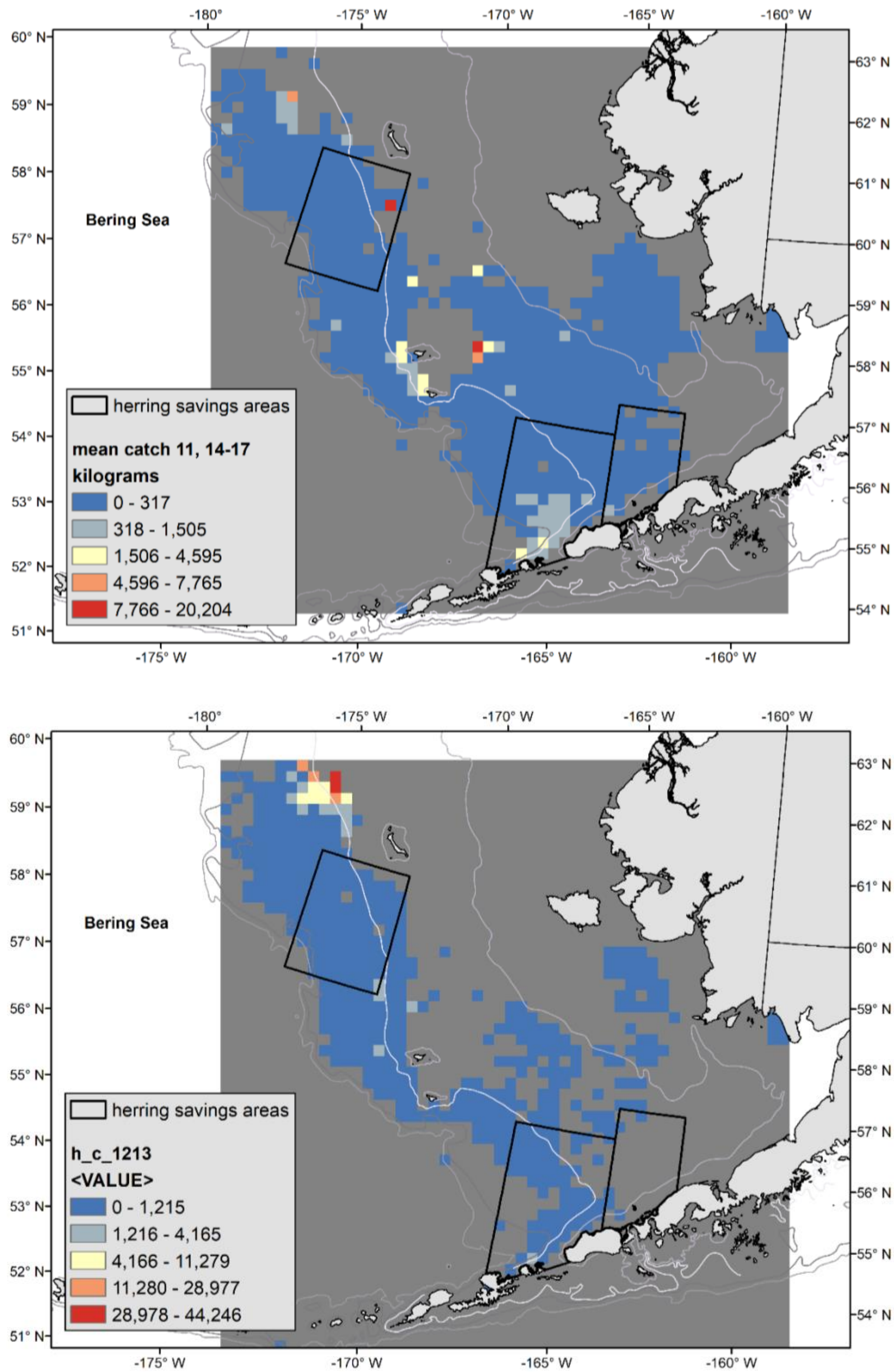


Figure 28. Mean observed catch (kg/haul) of Pacific herring in commercial groundfish hauls in the Bering Sea/Aleutian Islands region during years of low catches (top panel; 2011, 2014-2017) and high catches (bottom panel; 2012-2013). Grid cells are 20 km X 20 km. The NMFS Herring Savings Area are indicated.

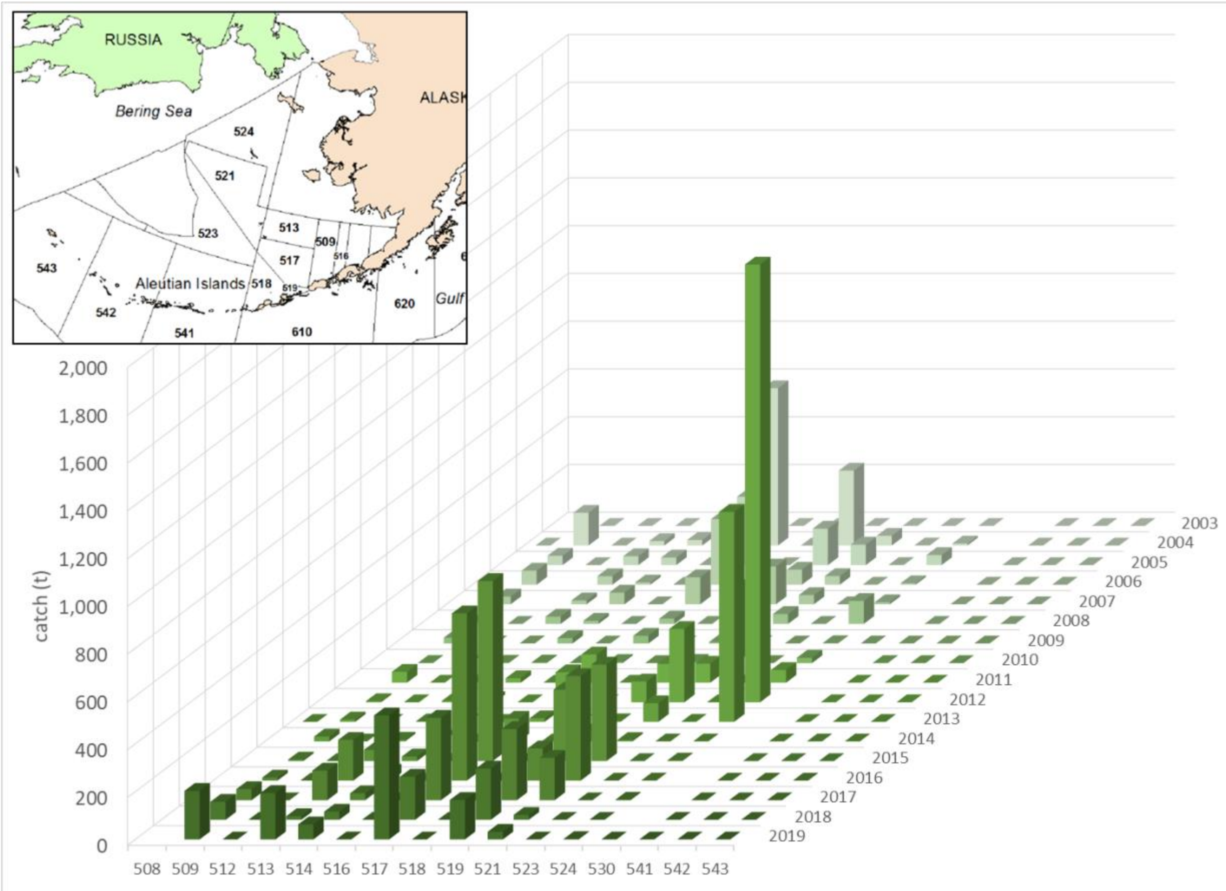


Figure 29. Annual spatial patterns of observed Pacific herring catches (t) in federally-managed groundfish fisheries in the Bering Sea and Aleutian Islands, 2003-2019. Numbers on the depth axis refer to the NMFS statistical areas outlined in the inset map. Data are from the NMFS Alaska Regional Office. 2019 data are incomplete; retrieved on October 31, 2019.

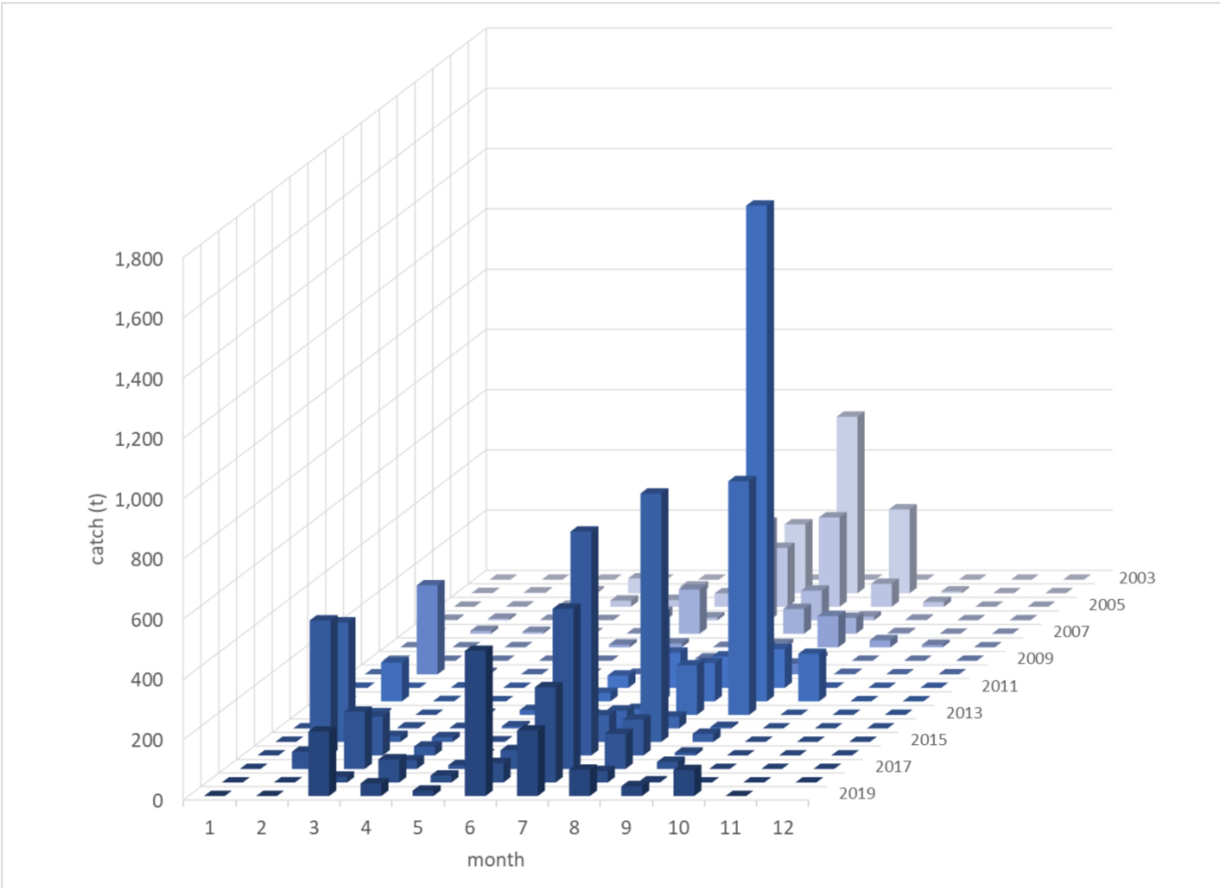


Figure 30. Seasonal and annual patterns of observed Pacific herring catches (t) in federally-managed groundfish fisheries in the Bering Sea and Aleutian Islands, 2003-2019. Data are from the NMFS Alaska Regional Office. 2019 data are incomplete; retrieved on October 31, 2019.

Appendix: List of scientific and common names of species contained within the "FMP forage fish" category. Data sources: BSAI FMP, "Fishes of Alaska" (Mecklenburg et al. 2002).

Scientific Name	Common Name
Family Osmeridae	smelts
Mallotus villosus	capelin
Hypomesus pretiosus	surf smelt
Osmerus mordax	rainbow smelt
Thaleichthys pacificus	eulachon
Spirinchus thaleichthys	longfin smelt
Spirinchus starksi	night smelt
Family Myctophidae	lanternfish
Protomyctophum thompsoni	bigeye lanternfish
Benthosema glaciale	glacier lanternfish
Tarletonbeania taylori	taillight lanternfish
Tarletonbeania crenularis	blue lanternfish
Diaphus theta	California headlightfish
Stenobrachius leucopsarus	northern lampfish
Stenobrachius nannochir	garnet lampfish
Lampanyctus jordani	brokenline lanternfish
Nannobrachium regale	pinpoint lampfish
Nannobrachium ritteri	broadfin lanternfish
Family Bathylagidae	blacksmelts
Leuroglossus schmidti	northern smoothtongue
Lipolagus ochotensis	popeye blacksmelt
Pseudobathylagus milleri	stout blacksmelt
Bathylagus pacificus	slender blacksmelt
Family Ammodytidae	sand lances
Ammodytes hexapterus	Arctic sand lance
Ammodytes personatus	Pacific sand lance
Family Trichodontidae	sandfish
Trichodon trichodon	Pacific sandfish
Arctoscopus japonicus	sailfin sandfish

Scientific Name	**Common Name**
Family Pholidae	gunnels
Apodichthys flavidus	penpoint gunnel
Rhodymenichthys dolichogaster	stippled gunnel
Pholis fasciata	banded gunnel
Pholis clemensi	longfin gunnel
Pholis laeta	crescent gunnel
Pholis schultzi	red gunnel
Family Stichaeidae	pricklebacks
Eumesogrammus praecisus	fourline snakeblenny
Stichaeus punctatus	arctic shanny
Gymnoclinus cristulatus	trident prickleback
Chirolophis tarsodes	matcheek warbonnet
Chirolophis nugatory	mosshead warbonnet
Chirolophis decoratus	decorated warbonnet
Chirolophis snyderi	bearded warbonnet
Bryozoichthys lysimus	nutcracker prickleback
Bryozoichthys majorius	pearly prickleback
Lumpenella longirostris	longsnout prickleback
Leptoclinus maculates	daubed shanny
Poroclinus rothrocki	whitebarred prickleback
Anisarchus medius	stout eelblenny
Lumpenus fabricii	slender eelblenny
Lumpenus sagitta	snake prickleback
Acantholumpenus mackayi	blackline prickleback
Opisthocentrus ocellatus	ocellated blenny
Alectridium aurantiacum	lesser prickleback
Alectrias alectrolophus	stone cockscomb
Anoplarchus purpurescens	high cockscomb
Anoplarchus insignis	slender cockscomb
Phytichthys chirus	ribbon prickleback
Xiphister mucosus	rock prickleback
Xiphister atropurpureus	black prickleback
Family Gonostomatidae	bristlemouths
Sigmops gracilis	slender fangjaw
Cyclothone alba	white bristlemouth
Cyclothone signata	showy bristlemouth
Cyclothone atraria	black bristlemouth
Cyclothone pseudopallida	phantom bristlemouth
Cyclothone pallida	tan bristlemouth
Order Euphausiacea	krill