Appendix 2. Preliminary assessment of forage species in the Gulf of Alaska

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Introduction to the new forage species reports and their relation to the ecosystem considerations chapter

Beginning in 2012, a new approach is being taken towards the reporting on Alaska marine forage species that occurs as part of the North Pacific Fishery Management Council's (NPFMC) annual stock assessment process. The primary changes are:

1) Historically, a forage fish report has been prepared for only the Gulf of Alaska (GOA). As of 2012 there will be reports for both the GOA and the Bering Sea and Aleutian Islands areas. A regular schedule of reporting will be established, most likely on a biennial basis that corresponds with the "off-survey" year in each area.
2) The forage report has historically focused only on those species included in the "forage fish" group included in the fishery management plan (FMP) for each area. However, the group excludes key forage species that are managed elsewhere in or independently of the NPFMC process. To provide a fuller assessment of the marine forage base in Alaska, the forage species reports will now consider a wider range of species.
3) Another historical characteristic of the forage fish reports is that they have been a catch-all repository for information on forage fishes. The reports will still include some descriptive information on forage species. However to make the document more useful and relevant, the focus will be narrowed to these main issues:
    a) Monitoring of the distribution, abundance, and availability to predators of forage species in Alaska. This is the most important content in the report, and the most challenging to address. Dedicated forage surveys do not exist in Alaska, and the existing surveys are inadequate for monitoring most forage species. As a result, this section will contain a variety of different types of data.
    b) Bycatch data and reporting on other conservation issues. This section will deal mainly with bycatch in federal fisheries, but other impacts to forage species may be included.
4) The forage reports will be tightly coordinated with the ecosystem considerations chapter. Some types of data (e.g. survey biomass timeseries) have been removed from the ecosystems chapter and will now reside exclusively in the forage fish reports. Other data types (e.g. predator diets) may exist in both reports but the forage fish report will include a broader description of these data. The rationale for this new coordination is that the ecosystem chapter should be limited to those data that are thought to be reliable ecosystem indicators, rather than just all of the survey time series. In contrast, the forage species report will be a repository for all relevant indices of abundance/population status/prey availability that are available, with greater exploration of each index than is possible in the ecosystem chapter.

NOTE: This report has been titled "preliminary assessment" because it is the first instance of this revised approach to the GOA forage fish report. This report will change substantially as a result of discussions among the author, the Plan Team, and the SSC.

Recent developments

- Forage fishes received considerable attention in 2012. In April, the Lenfest Ocean Program released a report analyzing forage fish management on a global scale (http://www.lenfestocean.org/foragefish). The analysis focuses on the role of forage fishes in ecosystems and the impacts of directed fishing for forage species. A symposium on the conservation of forage fishes on the US West Coast and in British Columbia and Alaska was held in Washington State in September. In November, the International Council for the Exploration of the Sea will hold a forage fish symposium in France. These events are likely to raise the public profile of forage fishes.
- The Midwater Assessment and Conservation Engineering group at the Alaska Fisheries Science Center has developed a method for distinguishing euphausiid biomass from acoustic backscatter in acoustic surveys for pollock. They have produced biomass estimates for the Bering Sea and have received funding from the North Pacific Research Board to duplicate these efforts in the GOA.

Responses to Plan Team and SSC comments

SSC comment December 2009: "The [forage fish] chapter reports that forage fish species in the GOA (with over 60 species) are similar to those in the Bering Sea, and thus this summary for GOA suffices for both regions. However, the SSC notes that species composition is not the same between regions, and requests that future reports and executive summaries provide results for both BS and GOA …. SSC requests that forage fish sections include distribution maps from trawl surveys and acoustical survey indices of abundance."

> *Response*: The author agrees that the forage base in the BSAI is substantially different, and reports will now be prepared for both regions. Key components of the new reports are distribution maps based on bottom trawl survey data, small-mesh trawl survey data, and acoustic surveys

SSC comment December 2011: "The SSC reiterates the need to integrate related studies and implementation of long-term survey capabilities to improve our knowledge of forage fish abundance, distribution, and ecology. The lack of useful data and the lack of substantive analyses of existing data remain hindrances to meaningful integration of forage fish into ecosystem management."

> *Response*: Beginning this year, the report now includes more comprehensive data regarding GOA forage fishes as well as analyses of these data and their relevance in monitoring forage fishes. These analyses are preliminary in the 2012 report but will be expanded in future years.

SSC comment December 2011: "…BEST/BSIERP program has demonstrated that the NOAA acoustic survey data could be used to examine indices of abundance and distribution for species such as capelin and euphausiids."

> *Response*: AFSC scientists have received an NPRB grant to develop euphausiid abundance and distribution estimates for the GOA. However, our discussions with the acousticians indicates that the straightforward frequency-differentiation technique use to analyze euphausiids is less effective for fishes in general and capelin in particular (i.e. the frequency response is very similar between pollock and capelin, so identification of capelin relies on sampling tows rather than just analysis of the acoustic backscatter).

SSC comment December 2011: "…the SSC suggests investigating the possibility of using eulachon as an indicator species for components of the forage fish complex. Additionally, high incidental catches of eulachon occurred in 2005 and 2008 and have been low since: Perhaps the authors can relate these fluctuations to oceanographic or zooplankton indices."

> *Response*: The 2012 report includes a detailed analysis of the eulachon time series. Correlations with environmental variables have not yet been included in the preliminary analysis presented here, but will be in the future. The author does not agree that eulachon might serve as an indicator species for forage species in general; there is simply too much variability in life history, ecology, and geographic distribution for any one species to be a sole representative of forage fish as a whole.

SSC comment December 2011: "Data on forage fish might be improved by comparing NOAA sampling to other indices, such as seabird diets, to determine how various methods might be used or combined to improve monitoring and integration of data on forage species into ecosystem management."

> *Response*: Inclusion of all relevant indices is the goal of this report. For 2012, the report integrates multiple abundance indices. In the future, identification of additional relevant datasets (e.g. predator diets) will be top priority for the report.

SSC comment December 2011: "The SSC notes that the biomass estimates for forage fish reported in Table 2 are orders of magnitude lower than those estimated from ecosystem models. The underlying causes of this discrepancy, as well as the high variation in biomass estimates, were not addressed in 2008 or any subsequent updates. The SSC requests that the differences be addressed in the upcoming full report."

> *Response*: The report now includes a discussion of the various abundance estimates.

SSC comment December 2011: "There seems to be disagreement between the ecosystem SAFE and the forage fish chapter about the underlying reliability and utility of CPUE and stock assessment for the various forage species. Clarification of CPUE data origin (trawl, acoustic, seabird) and the limitations of these sources should be included, and some effort made to coordinate data with the authors in charge of the forage fish chapter."

> *Response*: A large part of the change in forage fish reporting this year is to have much greater coordination between the ecosystem chapter and the forage fish report.

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 sardines and herring (e.g. Lenfest 2012), 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 Gulf of Alaska:

- members of the “forage fish group” listed in the GOA Fishery Management Plan (FMP)
- Pacific herring *Clupea pallasii*
- juvenile groundfishes and salmon
- shrimps
- squids

Forage fish group in the FMP

Prior to 1998, forage fishes in the GOA 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 39 to the GOA 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 group is large and diverse, containing over fifty species from these 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 villosus* are the principal species)
- Ammodytidae (sand lances; Pacific sand lance *Ammodytes hexapterus* is the only species commonly observed in the GOA and BSAI)
- 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 GOA; it was an early example of ecosystem-based fisheries management (Livingston et al. 2011). 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 to be sustainable (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, pers. comm., Alaska Groundfish Databank, Kodiak, Alaska).

Pacific herring

Herring are highly abundant and ubiquitous in Alaska marine waters. Commercial fisheries, mainly for herring roe, exist throughout the GOA. Sitka Sound in Southeast Alaska and Kodiak Island had the highest commercial catches during 2007-2011 (19,429 and 2,937 short tons, respectively, in 2011). Herring stocks in Prince William Sound crashed following the Exxon Valdez Oil Spill and have yet to recover sufficiently to permit a directed fishery. The herring fishery is 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 groundfish fisheries, herring are managed as Prohibited Species, where 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 to limit further impacts to the species.

Juvenile groundfishes and salmon

Members of this group, particularly age-0 and age-1 walleye pollock *Theragra chalcogramma*, are key forage species in some parts of the GOA. As they are early life stages of important commercially fished species, however, their status depends almost entirely on the assessment and management of the recruited portion of the population. Information regarding these species is available in NPFMC stock assessments and ADFG reports. In this report, they will be included mainly in the “monitoring” section.

Shrimps

A variety of shrimps occur in the GOA. Four species are targeted by commercial fisheries: northern (*Pandalus borealis*), coonstripe (*Pandalus hypsinotis*), spot (*Pandalus platyceros*), and sidestripe (*Pandalopsis dispar*). Large fisheries, mainly for northern shrimp, used to occur in the central and western GOA but populations declined and fishing for shrimp there has been closed since 1984. Currently almost all of the commercial catch occurs in Southeast Alaska. Detailed information on shrimps in waters off of Alaska is available from ADFG. This report includes data regarding incidental catch of shrimps in federal fisheries as well as an overview of the commercial catch.

Squids

The GOA may be inhabited by up to 15 species of squids, which are mainly distributed along the shelf break. Although no directed fisheries currently exist for squids, they are managed as "in the fishery" due to high levels of incidental catch, mainly in the fisheries for walleye pollock. This report contains limited information regarding squids; detailed information regarding GOA squids can be found in the relevant stock assessment report.

Distribution and abundance of forage species in the GOA

Overview of available surveys

Bottom trawl survey: Since 1984, the Alaska Fisheries Science Center (AFSC) has conducted a biennial (triennial prior to 1999) bottom trawl survey of the GOA for the purposes of groundfish stock assessment. The survey employs a bottom trawl with roller gear and a 5-inch mesh size, and covers areas of the continental shelf and upper slope from depths of 30m to approximately 500 m. Most forage fishes are small and occupy pelagic habitats. The large mesh size of the trawl survey gear and the limitation to sampling demersal habitats, likely results in high escapement and incomplete sampling of forage fish.. In addition, species with primarily nearshore habitats may be poorly represented and forage fishes are often characterized by patchy distribution.

Acoustic survey: The AFSC also performs echo integration-trawl (EIT) surveys directed towards assessment of walleye pollock. These surveys focus on the Shelikof Strait area west of Kodiak during the winter, but have occasionally covered a greater area. Summer EIT surveys in the GOA have also occurred in some years. Midwater echosign is sampled by trawling to identify species composition and provide biological information. Catches of capelin and eulachon in these tows can be used as a cruse measure of relative abundance.

Small-mesh survey: A third source of forage fish data in the GOA are small-mesh surveys (32 mm stretched mesh) conducted by NMFS and the Alaska Department of Fish & Game (ADF&G) at multiple nearshore locations in the central and western GOA. These surveys were designed to sample shrimp populations, but the small mesh net has proven to be effective at capturing smelt and other forage species when they are present. As is the case for the AFSC bottom trawl survey, the small-mesh survey samples only demersal habitats.

Cross-shelf distribution

Methods: The cross-shelf distribution of forage fishes in the GOA (i.e. nearshore vs. offshore) was investigated using data from the bottom trawl survey conducted in the region by the AFSC. Data were binned by the bottom depth at the location of survey hauls. Because the species examined normally have pelagic distributions, the bottom depth is not indicative of the depths inhabited by these species. Rather the bottom depth at the haul location reveals the cross-shelf location of the haul, from the most nearshore hauls (in about 20 m depth) to the outermost hauls on the continental slope (> 1000 m depth). Because the survey gears and fishing methods are not optimized for catching these species, data from any one year likely provide inaccurate depictions of distribution and relative abundance. Therefore, all trawl survey data from 2000-2012 were aggregated and a mean catch-per-unit-effort (CPUE; numbers/hectare) was calculated for each 1 m bottom depth bin. The data were normalized to 1 to enhance comparability.

Results and discussion: Interpretation of the results is made somewhat complicated due to the complex topography of the GOA (i.e. the presence of deep waters close to shore). However the analysis serves as a starting point for investigating differences in spatial distribution, and species and species groups appear to be fairly well segregated (Fig. 1). Pacific sandfish and Pacific sand lance are captured only in hauls where the bottom is <100 m, i.e. inshore areas of the GOA. Pacific herring and capelin are mainly distributed in areas with depths <100 m, but some herring are captured where the bottom is 100-200 m and capelin can occur out to approximately 300 m depth. This result for capelin may reflect their inhabitation of the deep canyons to the east of Kodiak Island (discussed in more detail below). The depths at eulachon locations range from approximately 100 m – 400 m. In the case of eulachon, they are primarily a shelf species but are abundant in deep troughs in the western GOA such as the Shelikof Sea Valley. The distribution of myctophids appears to be limited to the slope. The distributions of shrimps and squids (Fig. 2) also show some differences. While shrimp appear to be ubiquitous, squids are mostly distributed on the slope.

Geographic distribution – bottom trawl survey data

Methods: To further analyze the distribution of forage species in the GOA, maps of mean CPUE were generated for the six forage groups using the same data used in the cross-shelf analysis. Point data for each survey haul (latitude, longitude, CPUE by number) during the 2000-2012 time period was mapped in ArcGIS. Using the point-to-raster function within ArcGIS, individual haul data were aggregated into 20 km X 20 km cells and a mean CPUE was calculated for each cell using data from all years. The values were symbolized using a logarithmic distribution to visualize areas with high mean CPUEs. Shrimps and squids were not included in this part of the analysis.

Results and discussion: As suggested by the cross-shelf analysis, sandfish are limited to nearshore areas of the GOA (Fig. 3). They are distributed throughout the GOA except for Southeast Alaska. Sand lance are also primarily a nearshore species (Fig. 4). The analysis suggests that sand lance are concentrated in the western GOA, but unpublished data (Ormseth) indicates that they are also abundant in the eastern GOA. The survey is likely to be very poor at sampling sand lance, and it may be that they are found throughout the GOA but are sufficiently more abundant in the western GOA that the mean CPUE there is higher. Because the GOA trawl survey works from west to east over a 3-month period, the spatial pattern may also reflect seasonal differences in availability to the survey. As expected herring are distributed throughout the GOA (Fig. 5), except that they are rarely encountered west of Kodiak Island. “Hotspots” off Kodiak and Southeast Alaska correspond to the locations of the major commercial fisheries.

Capelin are ubiquitous in the GOA, although they appear less abundant in the eastern GOA (Fig. 6; Fig. 7 provides a more detailed view of the central and western GOA). The survey CPUEs appear highest to the east of Kodiak, where they have been demonstrated to occur in abundance in Barnabas & Chiniak troughs (Logerwell 2007; Guttormsen and Yasenak 2007). Thus the results of this analysis are consistent with other work. Eulachon are the most widespread and abundant species in the trawl survey (Fig. 8; detailed view in Fig. 9), which is likely due in part to attributes (including larger size and deeper distribution) that make them more likely to captured in the survey. High CPUEs in the Shumagin Islands and Shelikof Strait are consistent with patterns of eulachon catch in acoustic trawl surveys and commercial fisheries. Myctophids are distributed along the slope area sampled by the survey (Fig. 10) and show high CPUEs off Cross Sound in the eastern GOA.

Capelin distribution in acoustic surveys

In 2003 and 2005, acoustic surveys were conducted for pollock in the central and western GOA. Biomass estimates and distribution maps were generated for capelin using backscatter data and information from representative midwater tows. The results (Fig. 11) are a good match with the analysis described above: capelin were found in the troughs east of Kodiak Island and on Portlock Bank north of the island. The 2005 survey was limited due to equipment problems, but comparing the spatial extent of the 2003 acoustic survey with the distribution observed in the bottom trawl survey suggests that the full summer GOA acoustic survey may adequately sample the areas inhabited by capelin and that biomass estimates from a full acoustic survey may have some validity.

Abundance estimates

Abundance estimates for GOA forage fishes are highly uncertain. Biomass estimates can be made using the bottom trawl survey data, but are not considered to be reliable. In 2003 and 2005, biomass estimates of capelin were produced using data from the acoustic survey. A third source of biomass estimates comes from the mass-balanced ecosystem model created for the GOA (Aydin et al. 2007). Comparing the estimates from these three data sources for capelin, eulachon, and sand lance illustrates the level of uncertainty regarding abundance of GOA forage species:

	capelin	eulachon	sand lance
2011 bottom trawl biomass estimate (t)	491	71,507	3
ecosystem model biomass estimate (t)	2,050,112	335,636	712,880
2003 acoustic survey biomass estimate (t)	116,000		

The level of disagreement among these estimates stems from several sources. As discussed above, the bottom trawl survey estimates are poor samplers of forage fishes and the estimates are highly unreliable. The inadequacy of the bottom trawl survey also varies among species. Of the three species presented in the table, the bottom trawl survey is most effective at catching eulachon, as they are the largest and the species that is distributed closest to the bottom. In contrast the survey is especially bad at sampling sand lance, likely due to a combination of their small size, nearshore distribution, and the fact that they spend much of their time burrowed into sand. In general the bottom trawl survey likely underestimates the biomass of most forage species, but the degree by which it does so is highly uncertain.

The highest biomass estimates come from the ecosystem model. These estimates are derived by calculated the amount of forage required by upper trophic level predators; the abundance of predators is taken from independent populations assessments. The advantage of the model estimates is that they are based on predator diets, and predators are highly effective samplers of the forage base. However, the models employ a large number of assumptions regarding consumption rates and other variables, and the diet composition data come from many different sources and from different time periods. Therefore, while predator diets can be a good indicator of relative forage fish abundance they are not a reliable source of absolute abundance estimates.

Acoustic surveys such as the one conducted in summer of 2003 probably have the greatest potential for producing reliable biomass estimates. The analysis of capelin distribution suggests that the 2003 survey covered much of the area inhabited by capelin in the central and western GOA. The pollock-centric nature of the survey does however limit the usefulness of the survey. It is unclear how much of the capelin population is not surveyed (e.g. how many capelin may be in unsurveyed nearshore regions), and how that effect varies with season. In addition, sampling tows are directed towards echosign typical of pollock and it is likely that capelin are undersampled. In sum the acoustic survey estimate- as long as the survey has the same spatial extent as in 2003- might be considered a reliable minimum biomass estimate. Unfortunately the survey has not been repeated to that extent since then. Vessel and gear problems resulted in truncated surveys in 2005 and 2011, and it is unclear how future budget difficulties will affect the summer survey. These uncertainties make the acoustic survey unreliable as a time series.

Bycatch and other conservation issues

FMP forage group

Data regarding incidental catches of this group exist from 2003 and are maintained by the Alaska Regional Office (Table 1). Prior to 2005, species identification by observers was unreliable and many smelt catches were recorded as “other osmerid”. While identification has improved since then, smelts 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 forage fish in catches, and it is likely that they make up the majority of the “other osmerid” catch.

Most of the osmerid bycatch occurs in the central GOA (Table 2 & Fig. 12) in the vicinity of Shelikof Strait. Almost all of the bycatch is in the pelagic trawl fishery for walleye pollock (Table 3) and is concentrated in the southeastern Bering Sea. Catches of eulachon & “other osmerids” were particularly high in 2005 & 2008.

Shrimps

The bycatch of pandalid shrimps in federal fisheries is generally low (Table 4 & Fig. 13) but is also highly variable. Catches occur mainly in the central GOA.

<u>Pacific herring</u>
Data regarding the Prohibited Species Catch (PSC) of herring exist from 1991 and are maintained by the Alaska Regional Office (Table 5 & Fig. 14). The PSC is generally low but was exceptionally high in 1994 and 2004. Recently, most catches occur in the central GOA (Fig. 14).

Monitoring

The monitoring section of this report is the most important section, but also the most difficult to address. Due to the complete lack of surveys dedicated to sampling forage fishes, monitoring of forage species relies on gleaning what data are available from existing surveys and the use of proxies (e.g. predator diets). As this report develops, this section aims to contain a full suite of indices relevant to forage abundance and availability. For this year this section includes data from the GOA bottom trawl surveys, the GOA acoustic survey, and the ADFG small-mesh survey. Prior to 2012, the bottom trawl surveys have been reported in the Ecosystem Considerations chapter. They have been removed from there and will now reside in this report. Data from these surveys should be treated with extreme caution, particularly for species such as sand lance. The time series include estimated confidence intervals (CIs), but the presence of a small CI does not necessarily mean that the data are valid indicators of population status. In general, analyses of these data should be limited to the existence of broad trends or to common patterns among time series from different surveys.

For 2012 the monitoring section focuses on two species, capelin and eulachon, and endeavors to synthesize different data sources to draw some broad conclusions regarding the status of these species.

<u>Patterns in capelin distribution and abundance</u>
The disappearance of capelin from catches in the ADFG small-mesh survey during the 1980s has been well-documented (Anderson & Piatt 1999), and their presence in the survey continues to be diminished (Fig. 15). This is in contrast to results from the bottom trawl survey (Fig. 16) and bycatch rates in the acoustic survey hauls (Fig. 17) that suggest an increase in capelin abundance since 2000. The increased availability of capelin is also supported by comparing maps of mean survey CPUE (using the methods described above) for three time periods: 1984-1989, 1990-1999, and 2000-2011 (Fig. 18). This comparison indicates that capelin catch rates in the survey have increased and that the distribution and density of capelin has increased over the central and western GOA. It is unclear why capelin continue to be missing from the small-mesh survey despite an apparent increase in their population. The spatial extent of capelin does not appear to have changed. This is also true in the small-mesh survey when capelin catch rates are compared between the two time periods 1970-1984 and 1985-2011 (Fig. 19; the breakpoint is when capelin largely disappeared from the survey). Although much bigger catches of capelin occurred in the 1970-1984 period, the spatial extent of catches is very similar between the periods. Further exploration of this preliminary analysis will be a priority for this assessment.

<u>Exploration of eulachon timeseries</u>
One of the goals of this report is to identify time series of data that can be used as indicators of forage fish abundance. As a first step in this direction, four types of data regarding eulachon abundance were compared: mean CPUE by sampling site in the small-mesh survey (Fig. 20), annual geometric mean CPUE in the small-mesh survey (Fig.21), biomass estimates from the GOA bottom trawl survey (Fig. 22),

and the rate of incidental catches is acoustic survey sampling tows (Fig. 23). The small-mesh data and the acoustic survey data show high CPUEs in two eras, although the timing of these eras is offset between the surveys. In the small-mesh data, eulachon abundance peaks around 1980 and 2004 (Fig. 21). In the acoustic survey, CPUE peaks around 1991 and 2008 (Fig. 23). The bottom trawl survey suggests an increase in biomass during the 2000s. Although the results for each survey differ somewhat, there seems to be strong evidence for an increase in eulachon biomass during the late 2000s. This is supported by the large incidental catches observed in 2005 and 2008.

To extend this analysis, length composition data from the acoustic survey (Fig. 24), small-mesh survey (Fig. 25), and bottom trawl survey (Fig. 26) were compared. The compositions from the acoustic survey are variable but suggest a decline in the size mode during the 2000s. A similar decline is present but less distinct in the bottom trawl data. Extracting the annual modes from these compositions and fitting a 3rd-order polynomial to the results (Fig. 27) suggests that mean size of eulachon declined during the 2000s but now may be increasing. Although very preliminary, these patterns would be consistent with a density-dependent reduction in growth as eulachon abundance increased.

Other indices

In contrast to capelin and eulachon, there seems to be little agreement among timeseries for sand lance, sandfish, and stichaeids (Figs. 28- 30). However, comparison of trends in small-mesh CPUE for sandfish, stichaeids, and herring (Figs. 29-31) seems to indicate a general decrease in those fish species in the survey area after a period of abundance in the 1970s and early 1980s.

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Table 1. Incidental catches (t) of fishes in the GOA "FMP forage" group, 2003-2012. * 2012 data are incomplete; retrieved September 28, 2012. Data are from the Alaska Regional Office.

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	***2012****
Eulachon	18	170	852	399	222	761	226	232	331	*200*
Other osmerids	353	66	186	182	50	402	177	7	79	*59*
Capelin	6	68	3	0	0	0	0	0	8	*0*
Stichaeidae	0	0	2	1	0	0	3	1	0	*0*
Pacific Sand lance	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	*0.0*
Gunnels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*1.6*
myctophidae)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*
Surf smelt	0.0	0.4	0.4	0.0	0.0	0.2	0.0	0.0	0.0	*0.0*

Table 2. Incidental catches (t) of eulachon and "other osmerids" in the GOA, by NMFS statistical area, 2003-2012. Data description as in Table 1.

	eulachon & "other osmerids"									
subarea	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	***2012****
WGOA Total	**46**	**11**	**49**	**34**	**63**	**273**	**28**	**34**	**68**	***28***
610	46	11	49	34	63	273	28	34	68	*28*
CGOA Total	**317**	**223**	**968**	**533**	**207**	**865**	**364**	**196**	**331**	***218***
620	260	158	862	441	141	675	291	186	302	*207*
630	58	65	105	92	65	190	73	9	28	*11*
EGOA Total	**9**	**2**	**21**	**14**	**3**	**25**	**12**	**9**	**12**	***14***
640	5	1	19	6	1	16	4	4	4	*2*
649	4	1	2	9	2	10	8	6	9	*11*
GOA total	**371**	**236**	**1,038**	**581**	**273**	**1,163**	**404**	**239**	**411**	***259***

Table 3. Incidental catches (t) of eulachon and "other osmerids" in the GOA, by target fishery, 2003-2012. Data description as in Table 1

	eulachon & "other osmerids"									
target_fishery	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	***2012****
walleye pollock	366	235	1,003	560	270	1,162	367	234	387	*257*
arrowtooth flounder	0	1	14	2	1	1	34	4	23	*2*
flathead sole	3	0	20	16	0	0	0	0	0	*0*
rex sole	0	0	0	0	1	0	1	0	0	*0*
rockfish	1	0	0	1	0	0	0	0	0	*0*
Pacific cod	0	0	0	2	0	0	0	1	0	*0*
sablefish	0	0	0	0	0	0	0	0	0	*0*
shallow flatfish	0	0	0	0	0	0	2	0	0	*0*
GOA total	**371**	**236**	**1,038**	**581**	**273**	**1,163**	**404**	**239**	**411**	***259***

Table 4. Incidental catches (t) of pandalid shrimps in the GOA, by NMFS statistical area, 2003-2012. *2012 data are incomplete; retrieved September 28, 2012. Data are from the Alaska Regional Office.

subregion	NMFS area	2003	2004	2005	2006	2007	2008	2009	2010	2011	*2012**
WGOA	610	0.10	0.08	0.73	1.54	1.04	0.31	0.02	0.30	0.05	*0.00*
CGOA	620	0.76	1.01	6.78	1.64	0.82	0.48	0.22	0.95	0.46	*0.19*
	630	2.55	1.68	3.07	1.02	0.45	0.52	1.01	2.17	4.69	*3.92*
EGOA	640	0.02	0.01	0.20	0.02	0.02	0.02	0.01	0.15	0.02	*0.00*
	649	0.00	0.00	0.01	0.00	0.00	0.01	0.05	0.02	0.00	*0.00*
GOA total		**3.42**	**2.79**	**10.80**	**4.21**	**2.34**	**1.34**	**1.31**	**3.59**	**5.23**	***4.12***

Table 5. Prohibited Species Catch (t) of herring in federal fisheries in the GOA, by NMFS statistical area, 1991- 2012. *2012 data are incomplete; retrieved October 23, 2012. Data are from the Alaska Regional Office.

		NMFs statistical area				
	total GOA	610	620	630	640	650
1991	1.3	0.6	0.0	0.6	0.0	0.0
1992	26.8	17.3	8.4	1.1	0.0	0.0
1993	6.3	0.7	0.6	5.0	0.0	0.0
1994	100.2	78.2	19.6	2.3	0.0	0.0
1995	47.4	2.1	43.5	1.5	0.1	0.2
1996	3.6	1.5	0.6	1.3	0.1	0.0
1997	9.2	1.4	5.8	2.0	0.0	0.0
1998	20.2	0.3	2.8	17.1	0.0	0.0
1999	10.8	0.7	8.5	1.6	0.0	0.0
2000	5.3	1.4	2.2	1.7	0.0	0.0
2001	6.9	0.5	4.9	1.5	0.0	0.0
2002	2.2	0.0	1.4	0.7	0.0	0.0
2003	11.8	0.0	0.1	11.7	0.0	0.0
2004	267.8	9.1	167.9	90.8	0.0	0.0
2005	12.2	1.0	10.5	0.1	0.6	0.0
2006	8.9	0.2	7.9	0.7	0.0	0.0
2007	19.7	1.4	5.3	12.9	0.0	0.0
2008	1.0	0.2	0.3	0.6	0.0	0.0
2009	8.7	0.1	7.9	0.6	0.1	0.0
2010	1.9	0.2	0.7	1.0	0.1	0.0
2011	10.4	0.8	9.4	0.0	0.1	0.0
2012*	*0.1*	*0.0*	*0.1*	*0.0*	*0.0*	*0.0*

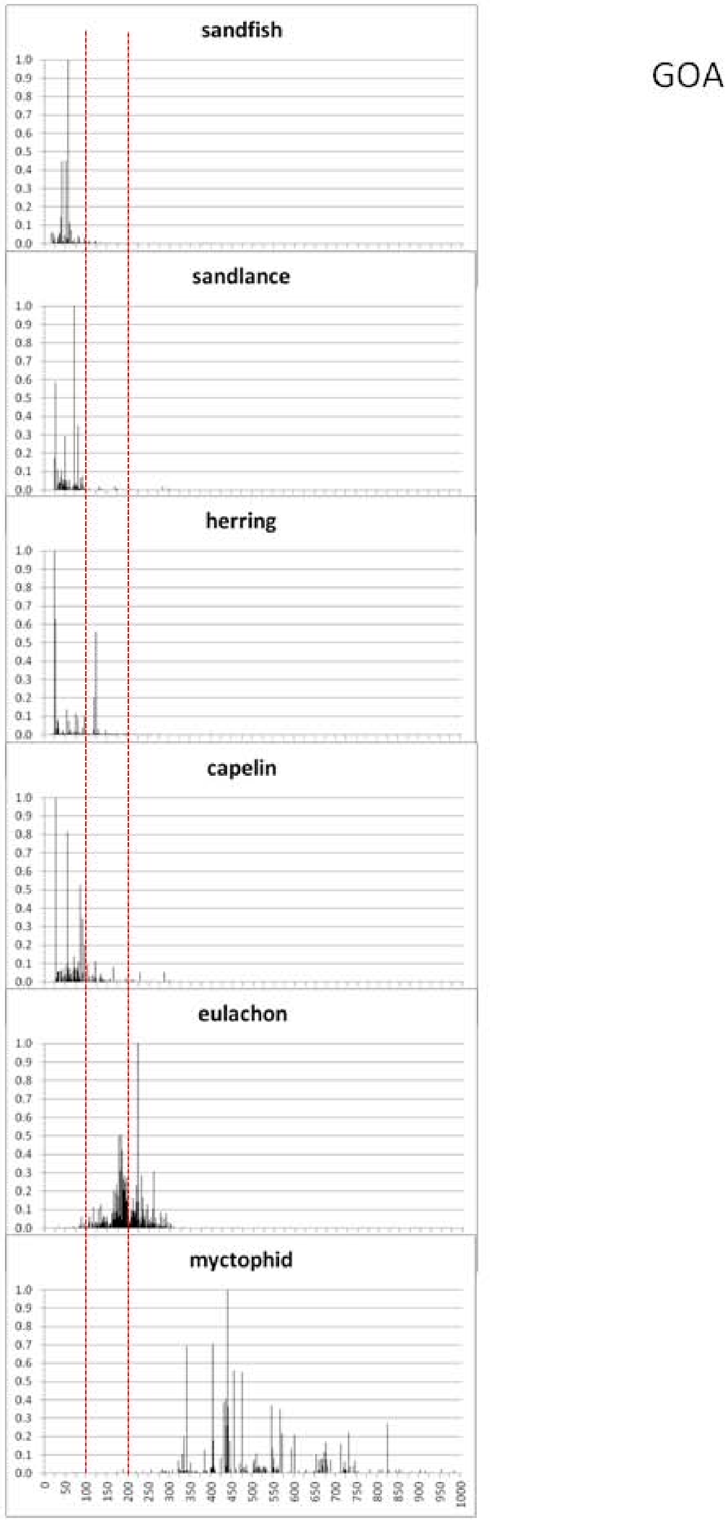

Figure 1. Normalized mean bottom trawl survey CPUE versus bottom depth (m) of haul for six forage fish groups in the Gulf of Alaska.

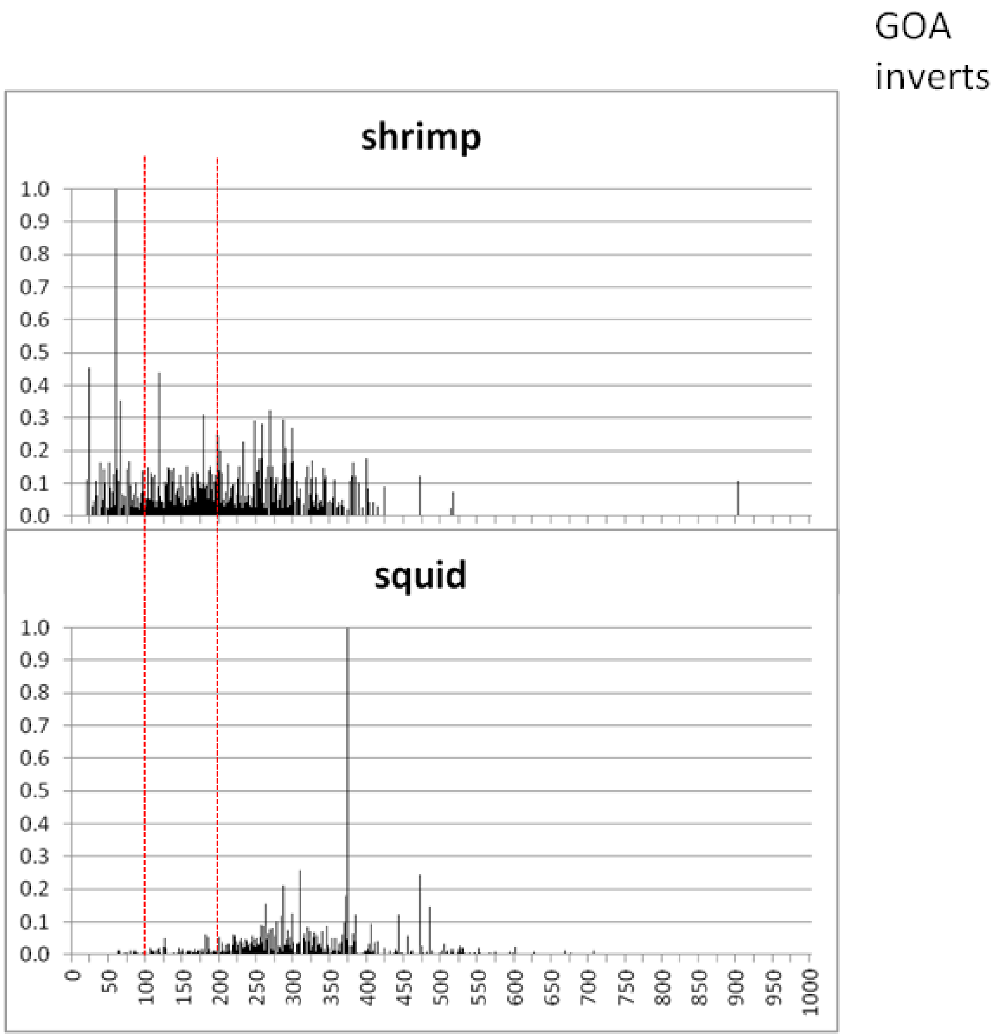

Figure 2. Normalized mean bottom trawl survey CPUE versus bottom depth (m) of haul for shrimps and squids in the Gulf of Alaska.

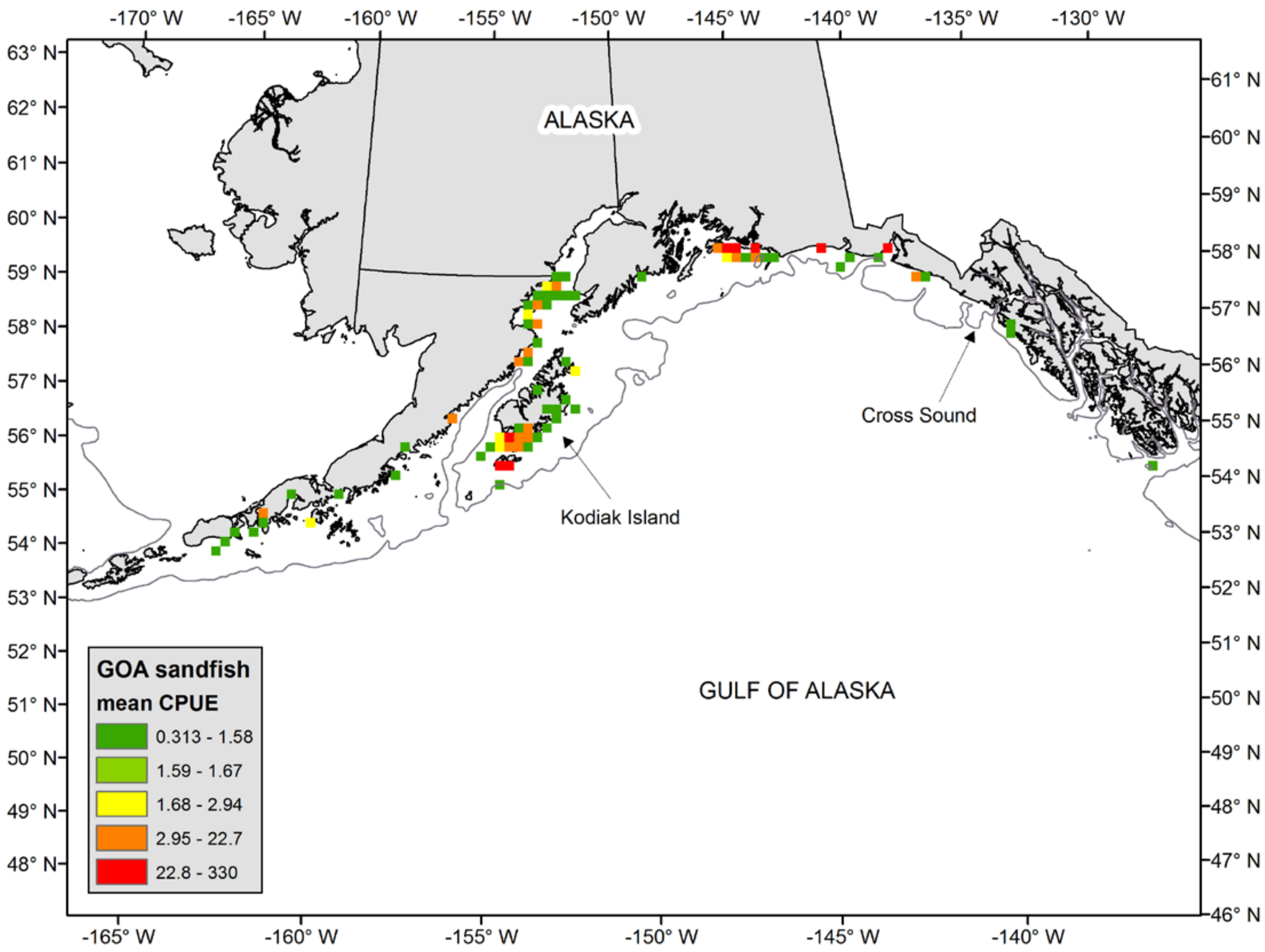

Figure 3. Mean bottom trawl survey CPUE (#/hectare) of Pacific sandfish in the Gulf of Alaska, 2000-2012. Grid cells are 20 km X 20 km.

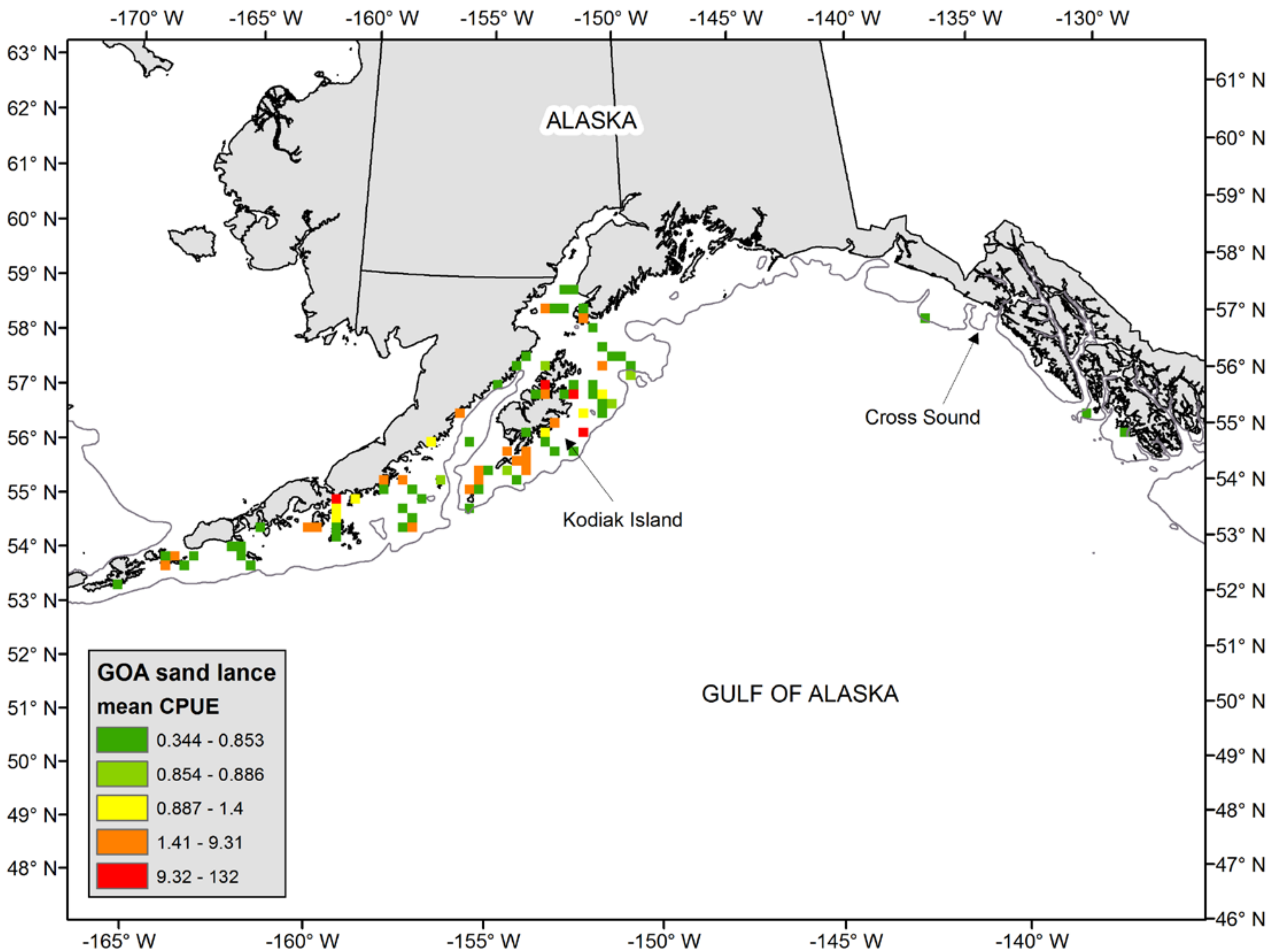

Figure 4. Mean bottom trawl survey CPUE (#/hectare) of Pacific sand lance in the Gulf of Alaska, 2000-2012. Grid cells are 20 km X 20 km.

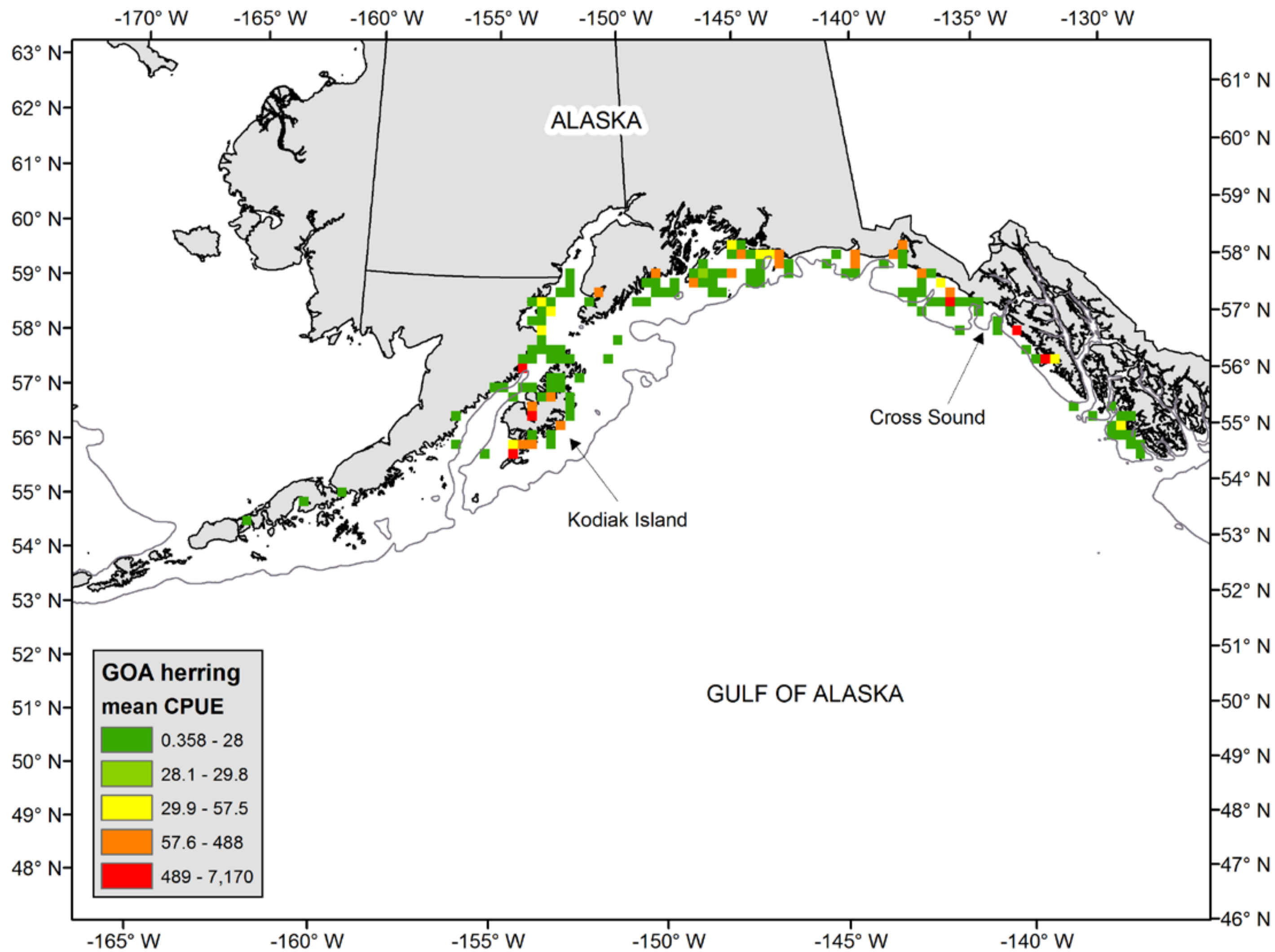

Figure 5. Mean bottom trawl survey CPUE (#/hectare) of Pacific herring in the Gulf of Alaska, 2000-2012. Grid cells are 20 km X 20 km.

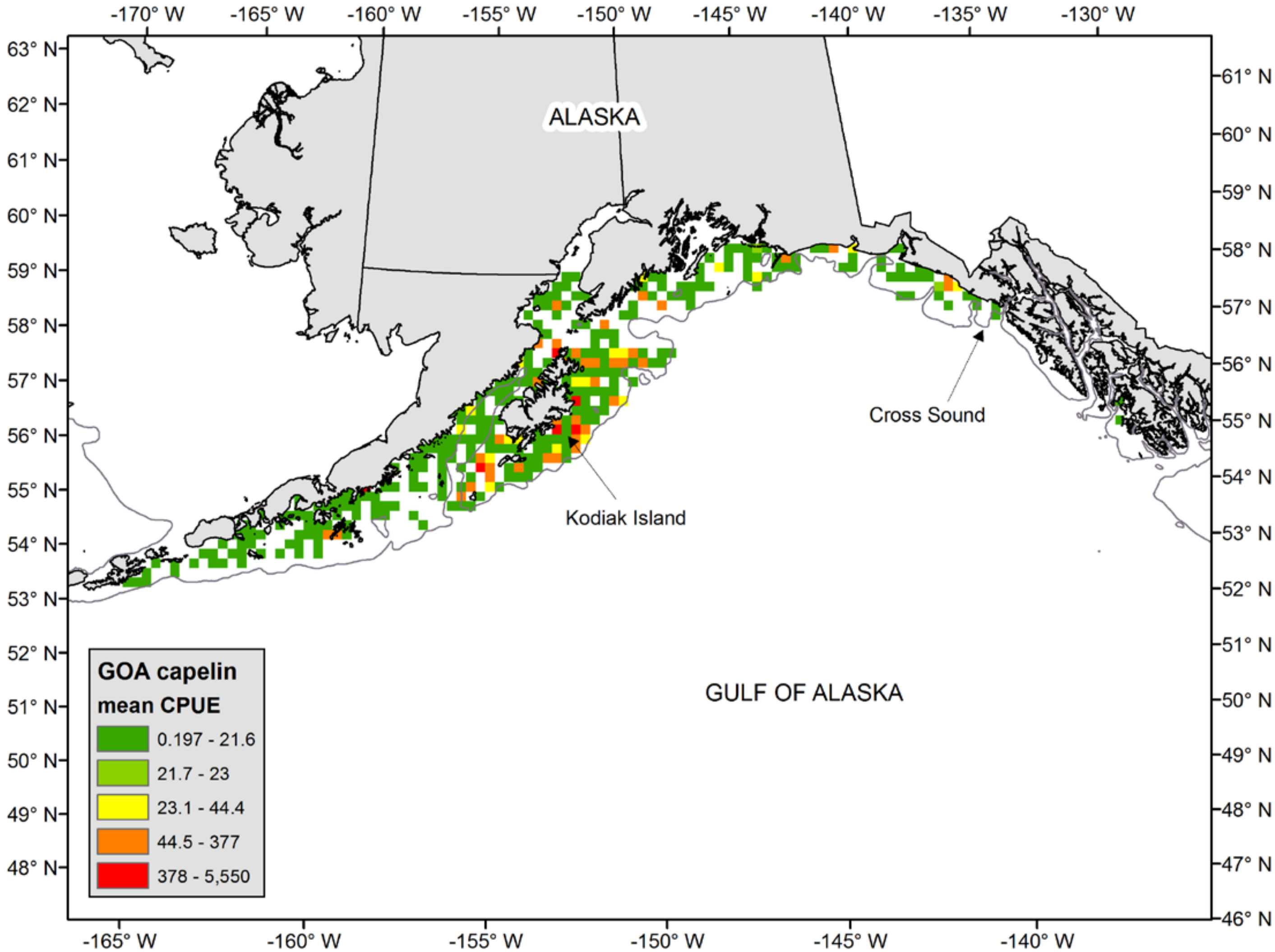

Figure 6. Mean bottom trawl survey CPUE (#/hectare) of capelin in the Gulf of Alaska, 2000-2012. Grid cells are 20 km X 20 km.

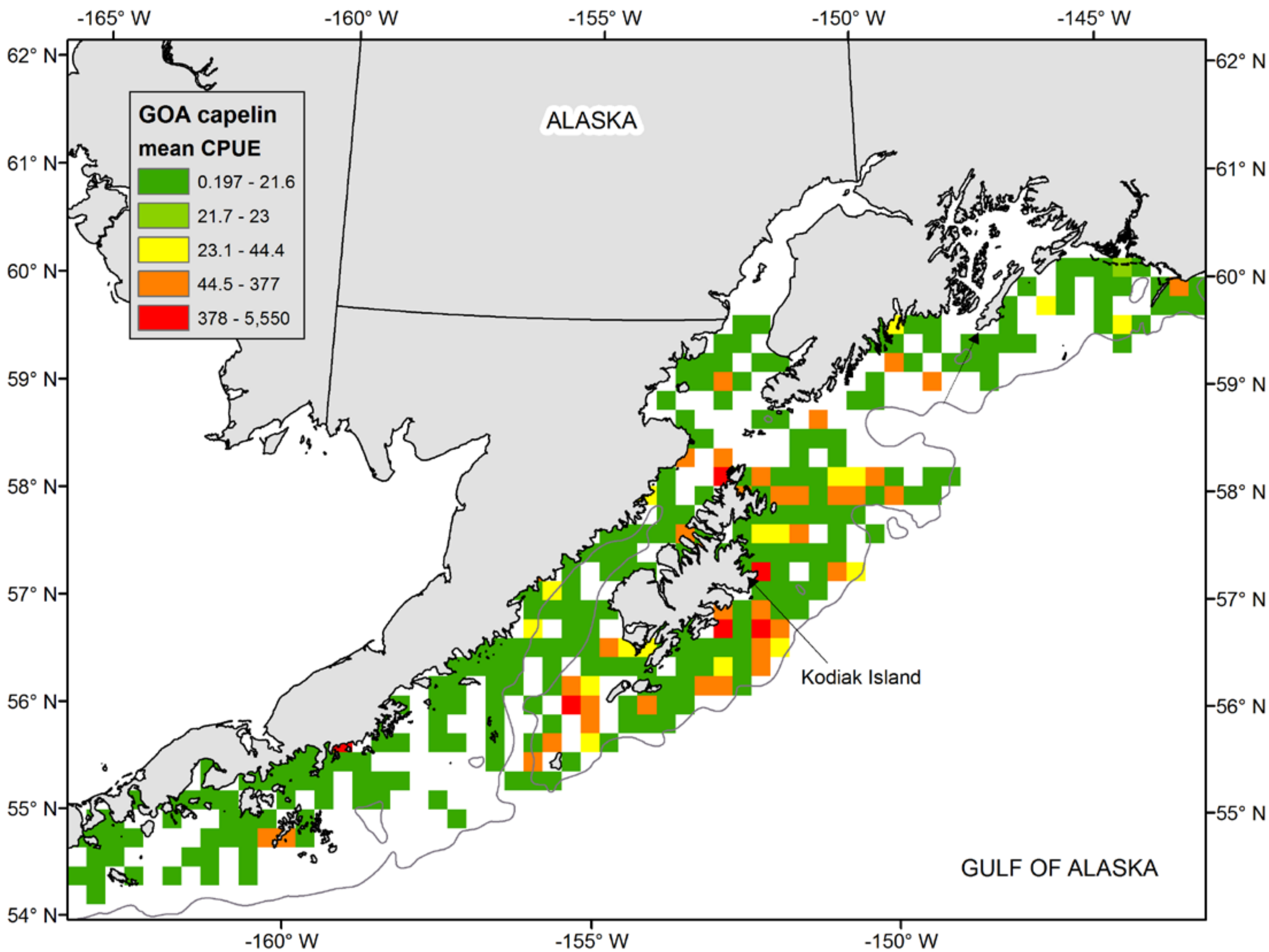

Figure 7. Detail view of mean bottom trawl survey CPUE (#/hectare) of capelin in the Gulf of Alaska, 2000-2012. Grid cells are 20 km X 20 km.

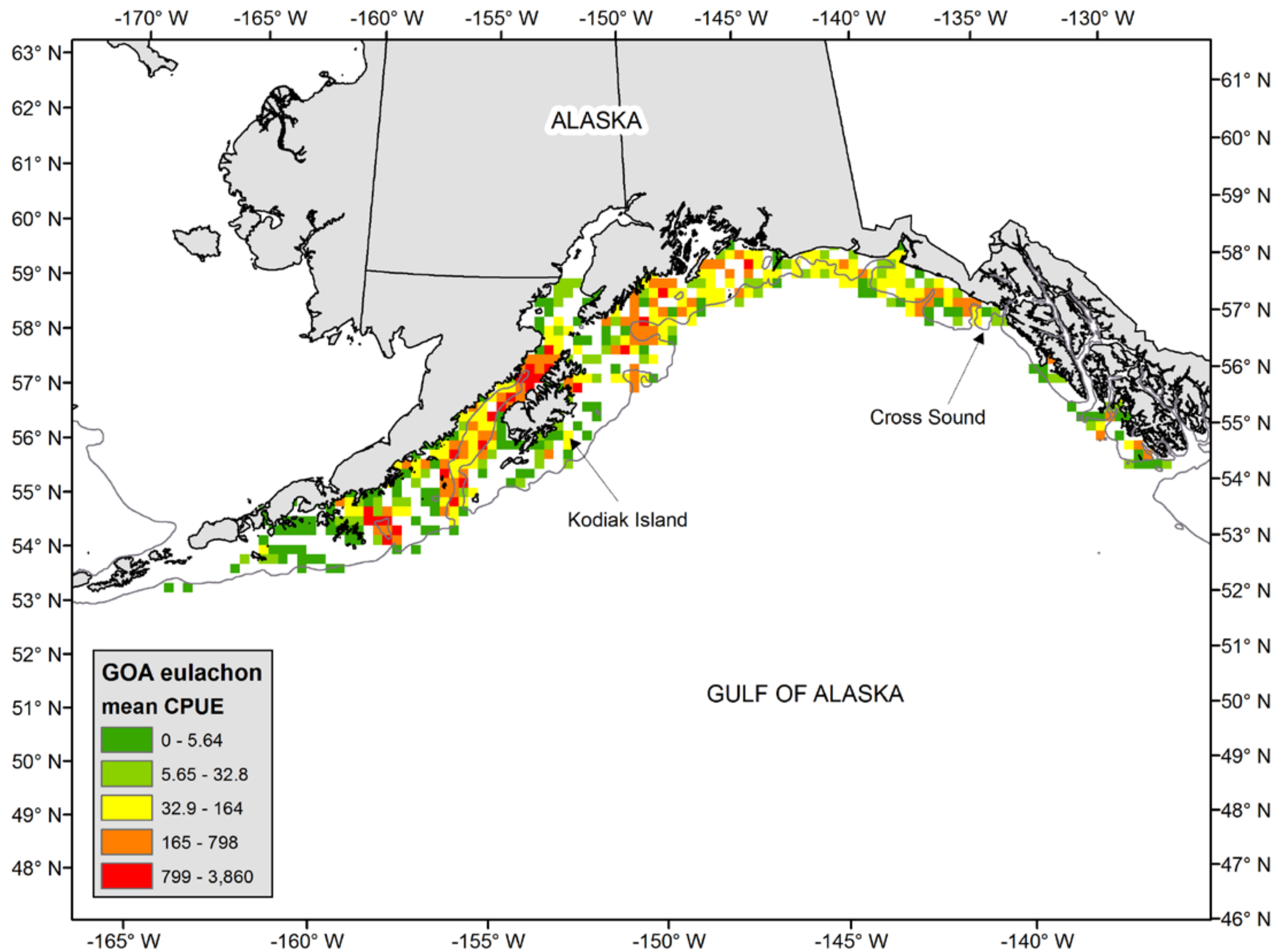

Figure 8. Mean bottom trawl survey CPUE (#/hectare) of eulachon in the Gulf of Alaska, 2000-2012. Grid cells are 20 km X 20 km.

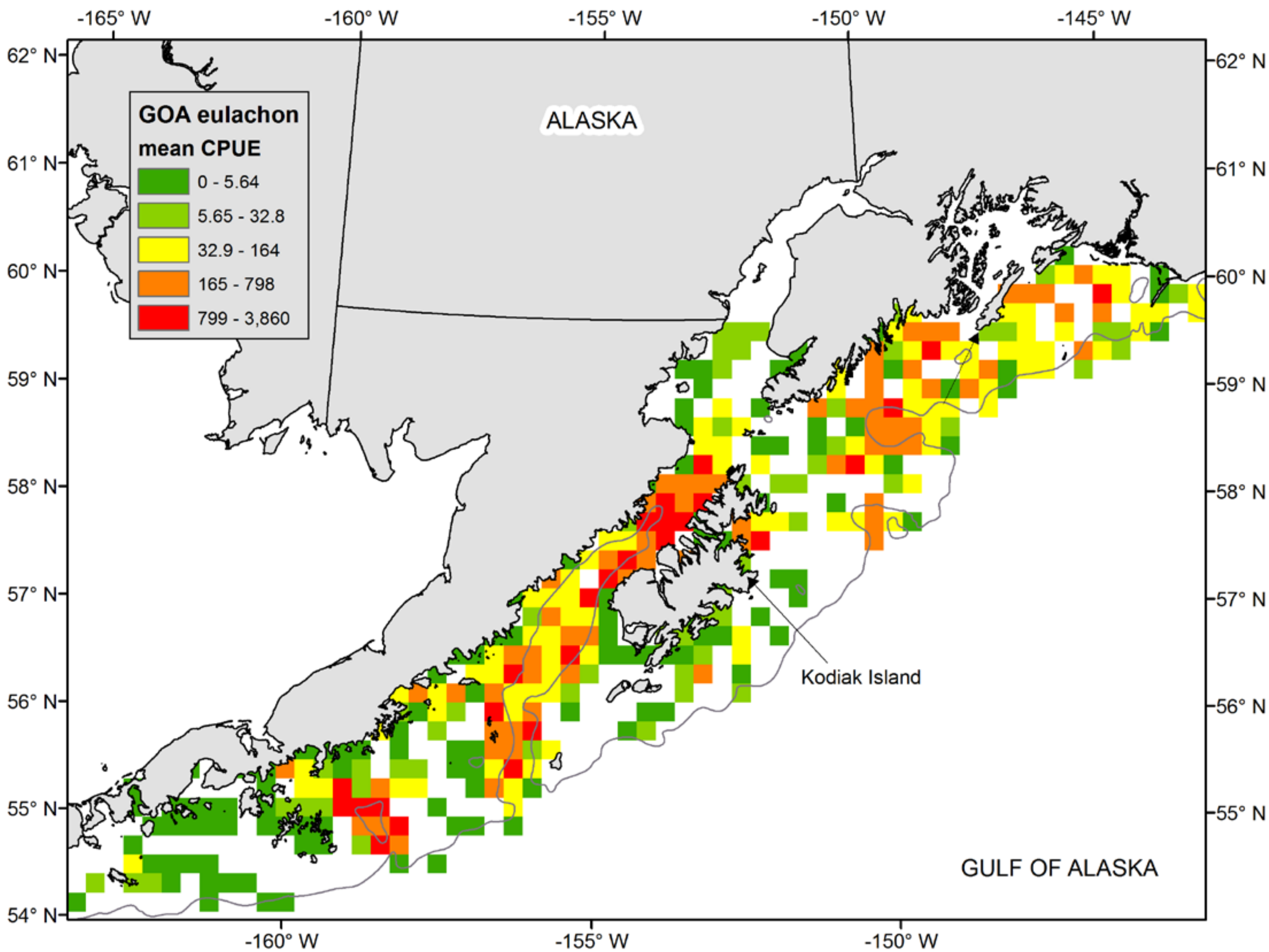

Figure 9. Detail view of mean bottom trawl survey CPUE (#/hectare) of eulachon in the Gulf of Alaska, 2000-2012. Grid cells are 20 km X 20 km.

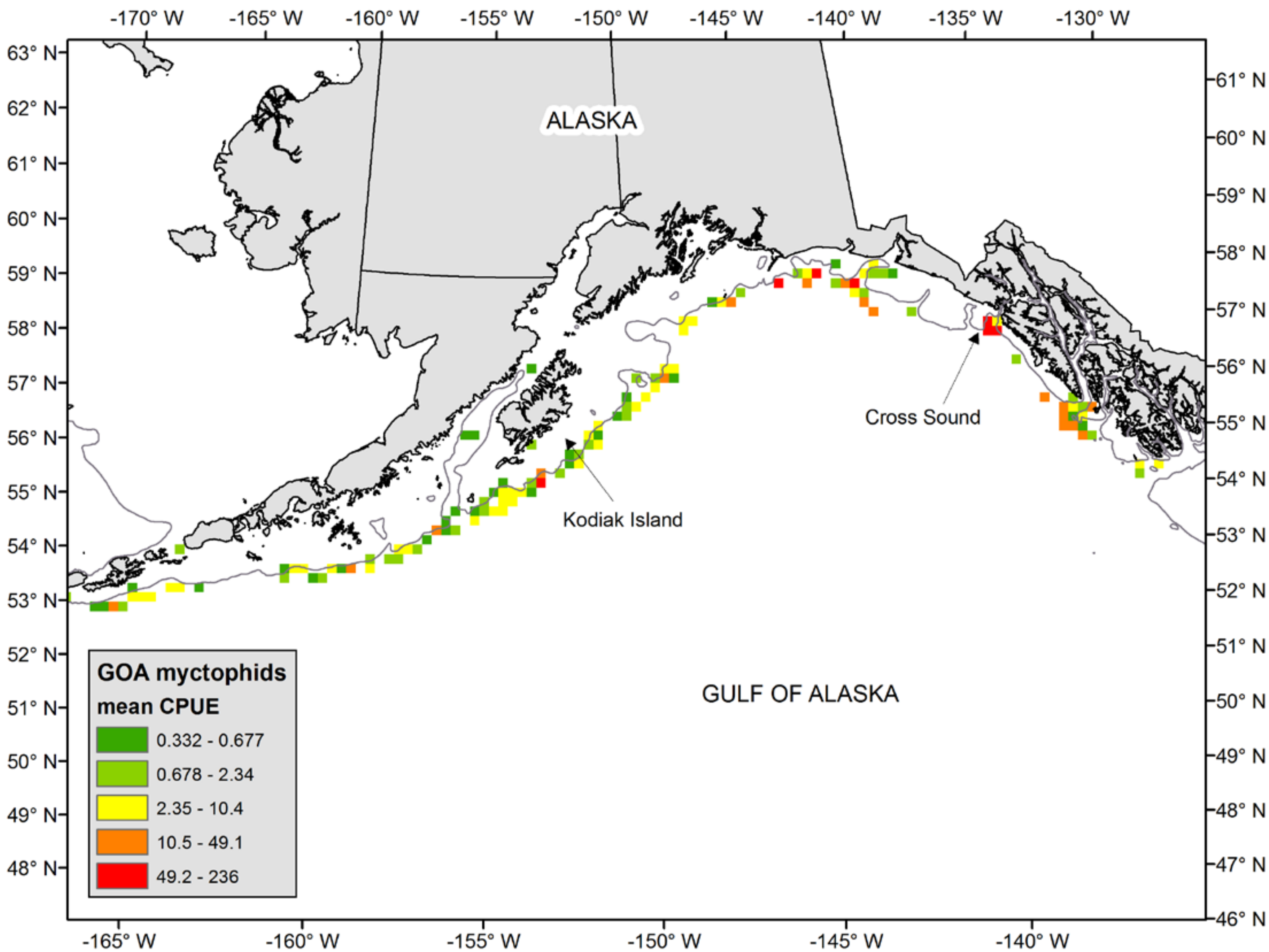

Figure 10. Mean bottom trawl survey CPUE (#/hectare) of myctophids in the Gulf of Alaska, 2000-2012. Grid cells are 20 km X 20 km.

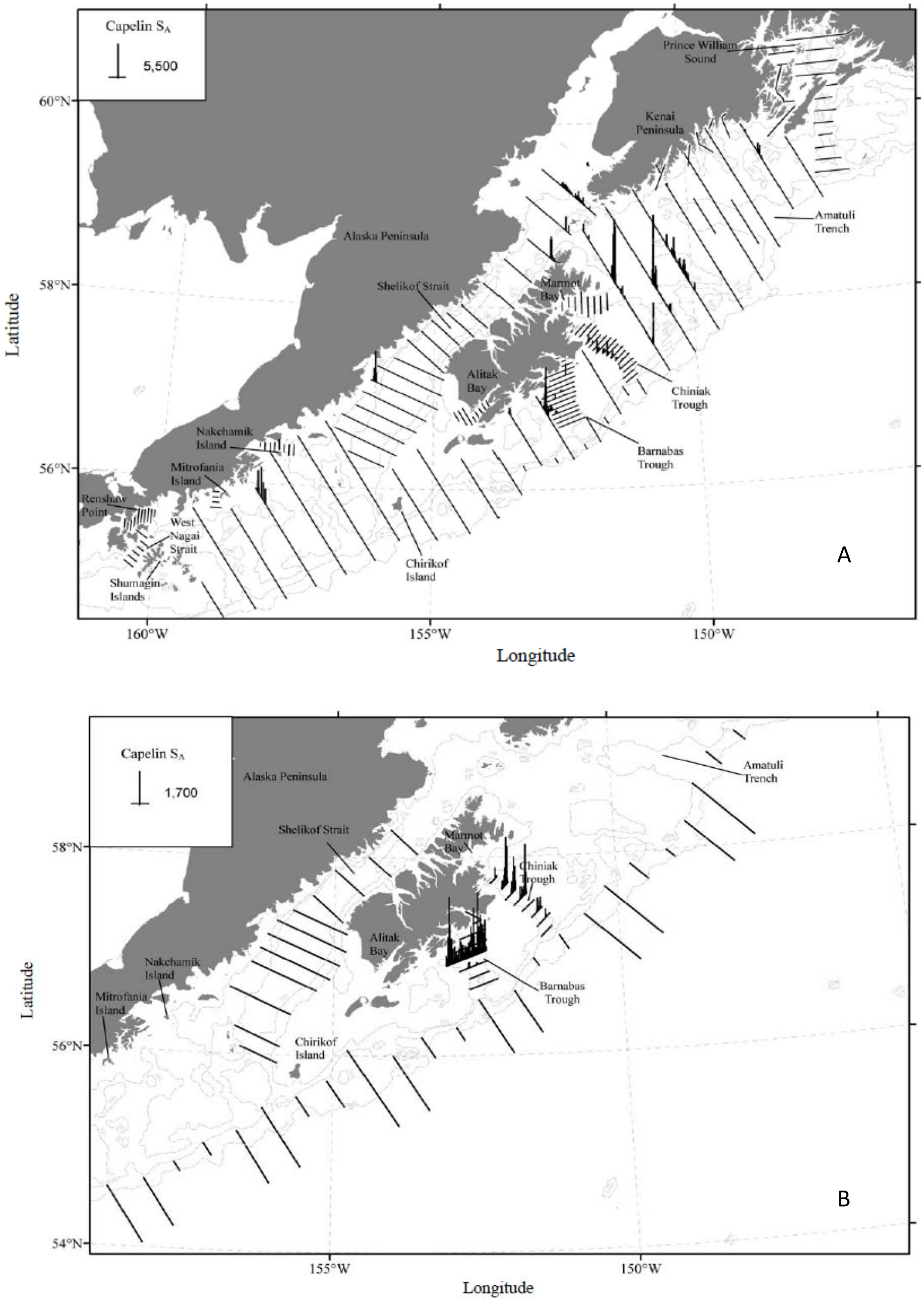

Figure 11. Acoustic backscatter attributed to capelin during acoustic surveys conducted in the GOA in 2003 (A) and 2005 (B). Figures are from Guttormsen and Yasenak 2007.

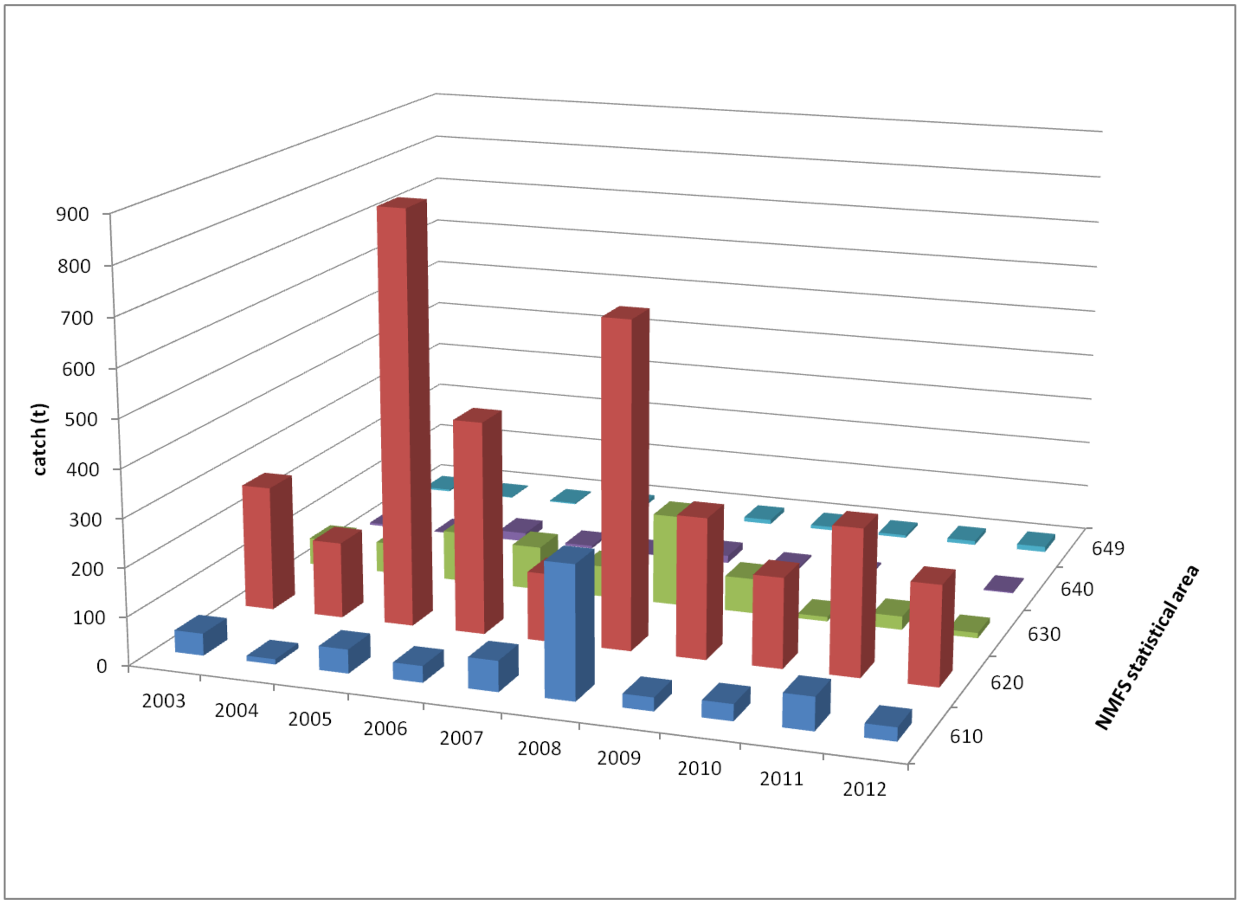

Figure 12. Incidental catches (t) of eulachon & “other osmerids” in the GOA, by NMFS statistical area, 2003-2012. 2012 data are incomplete; retrieved September 28, 2012. Data are from the Alaska Regional Office.

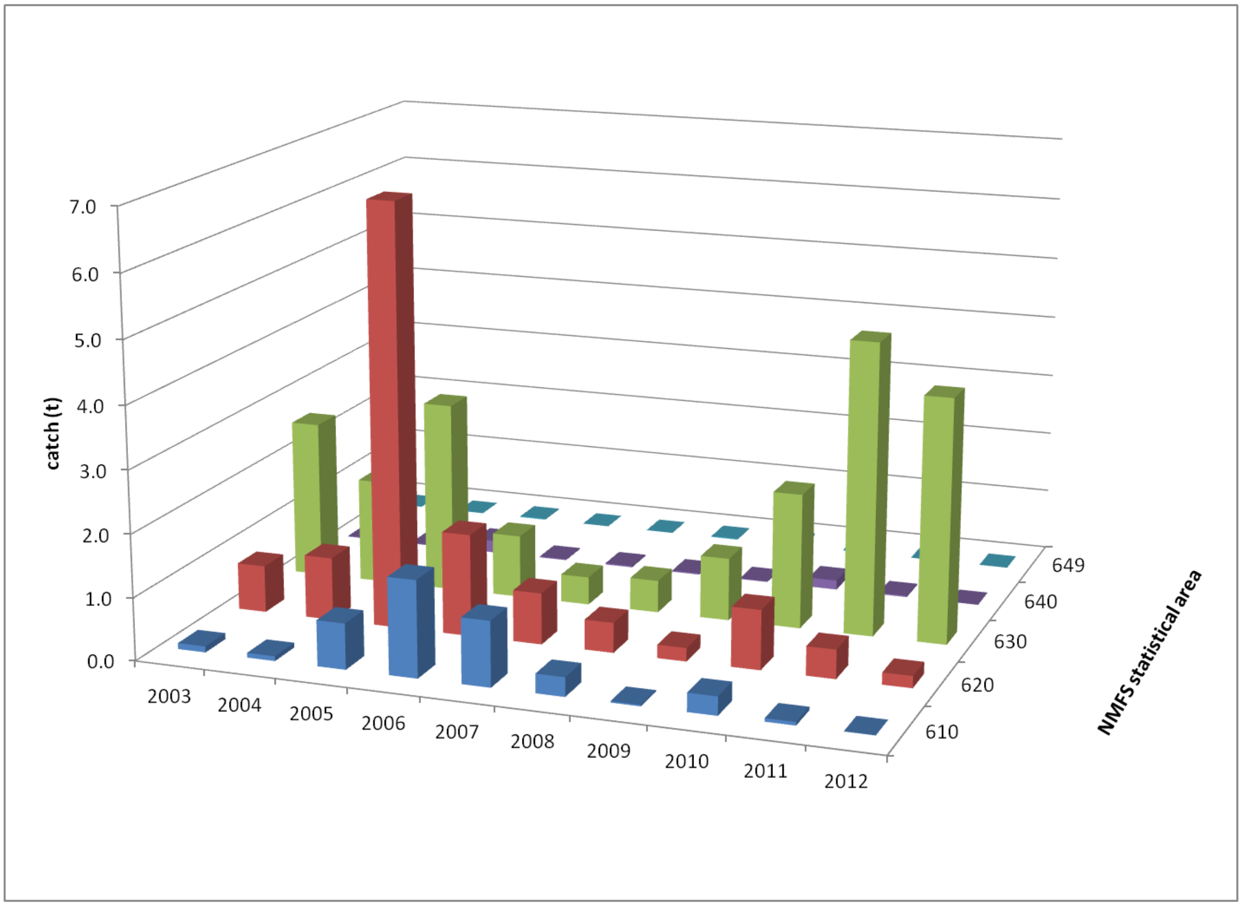

Figure 13. Incidental catches (t) of pandalid shrimps in the GOA, by NMFS statistical area, 2003-2012. 2012 data are incomplete; retrieved September 28, 2012. Data are from the Alaska Regional Office.

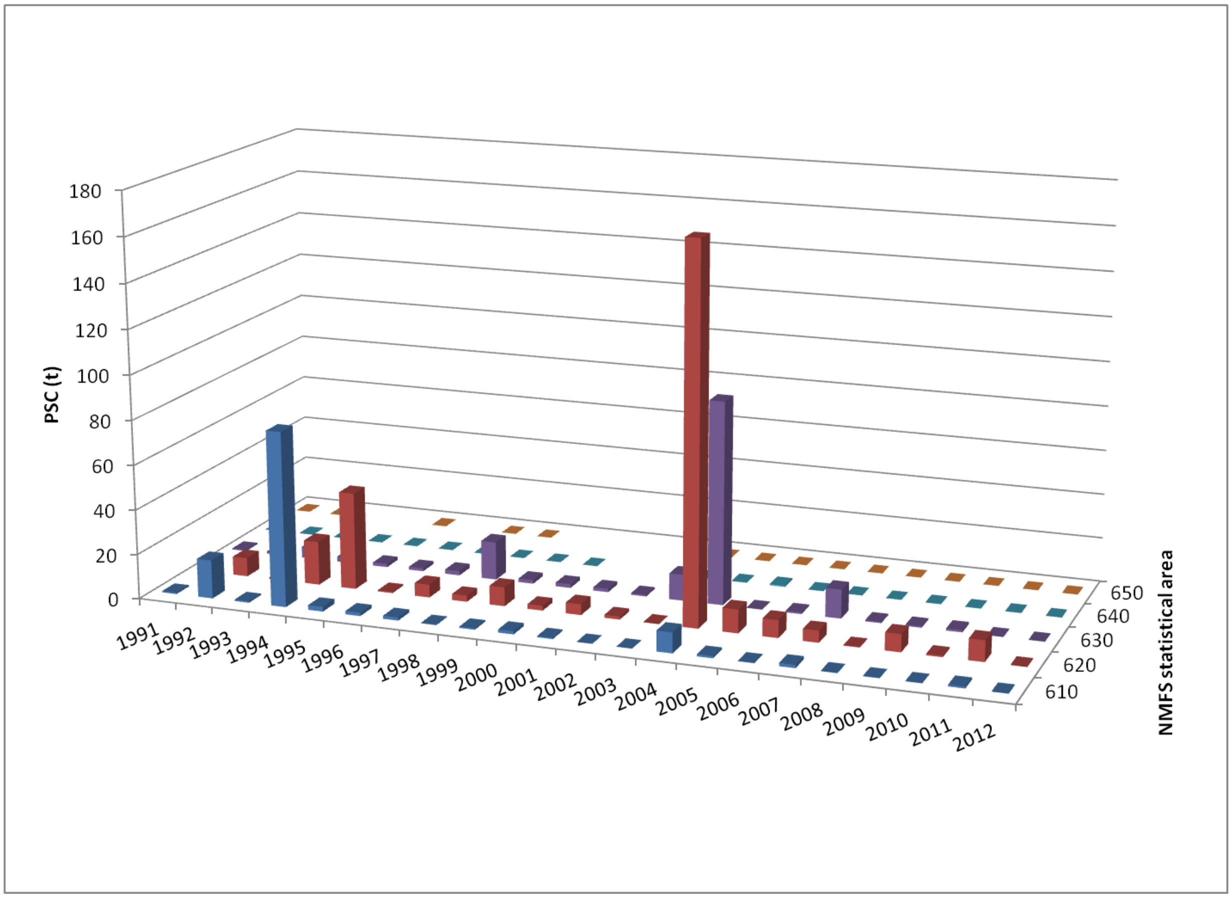

Figure 14. Prohibited Species Catch (t) of herring in federal fisheries in the GOA, by NMFS statistical area, 1991- 2012. 2012 data are incomplete; retrieved October 23, 2012. Data are from the Alaska Regional Office.

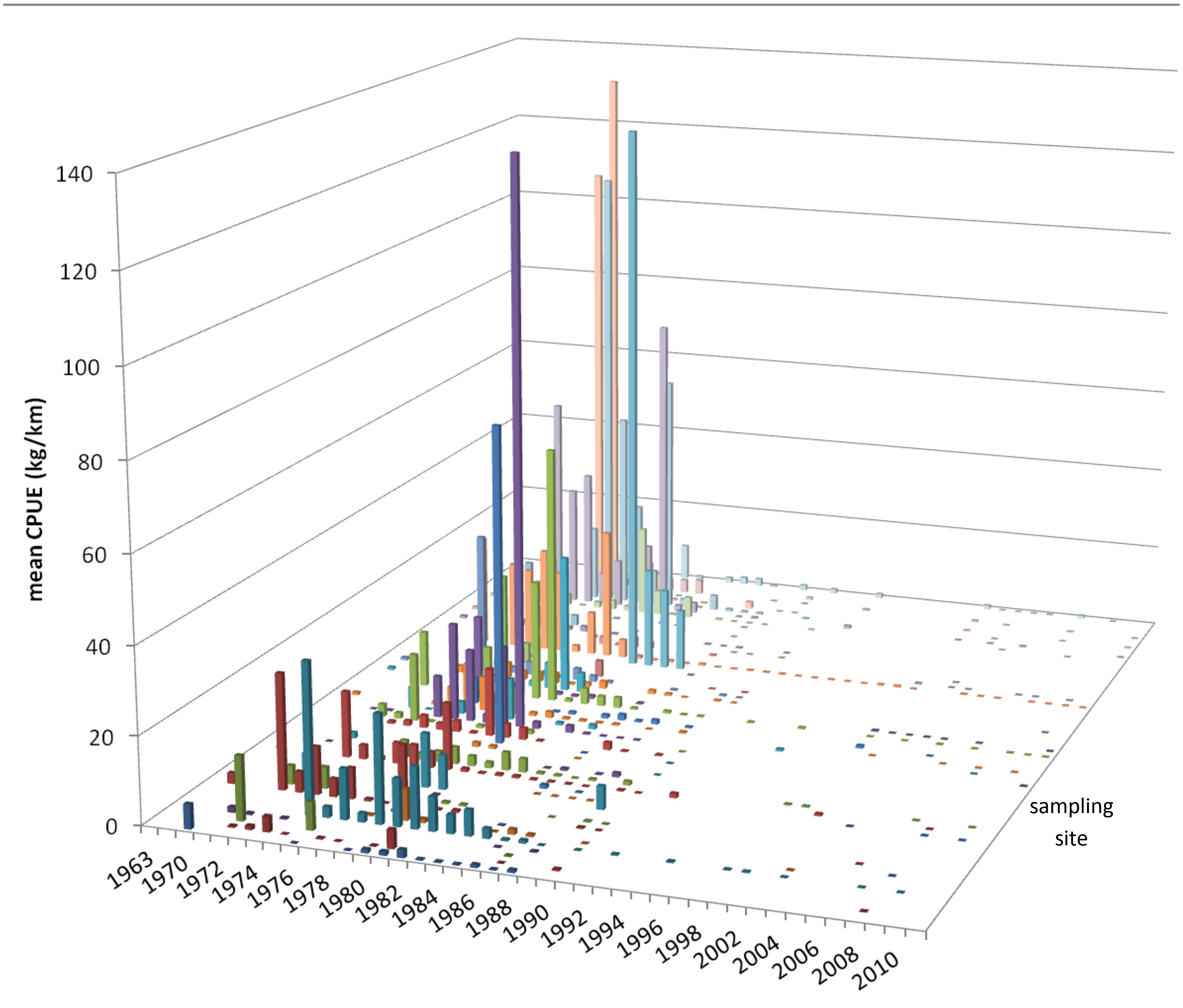

Figure 15. Mean CPUE (kg/km trawled) of capelin in the ADFG small-mesh survey, by year and bay, 1963-2011. The z-axis (corresponding to chart depth and labeled "sampling site") represents the numerous nearshore sites (bays) sampled during the surveys. For clarity, bay names are not included on the chart and the sites are not located on the axis in any meaningful way (i.e. the data are arranged alphabetically by bay name and are not related to any geographic quantity).

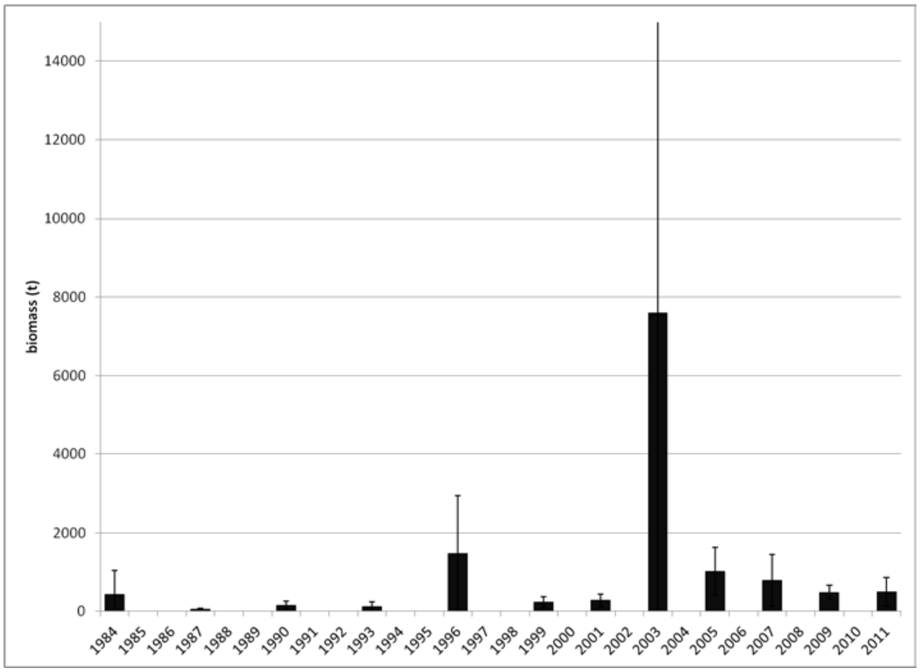

Figure 16. Biomass estimates (t) of capelin from the GOA bottom trawl survey, 1984-2011. Error bars represent 95% confidence interval.

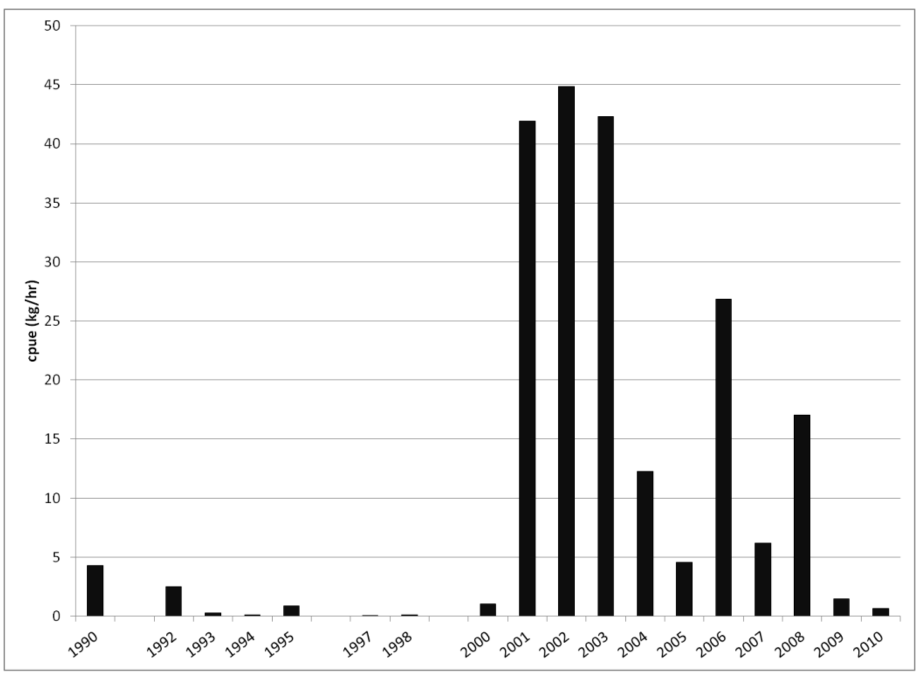

Figure 17. Capelin CPUE (kg/hr.) in sampling tows conducted during AFSC acoustic trawl surveys in the GOA, 1990-2010.

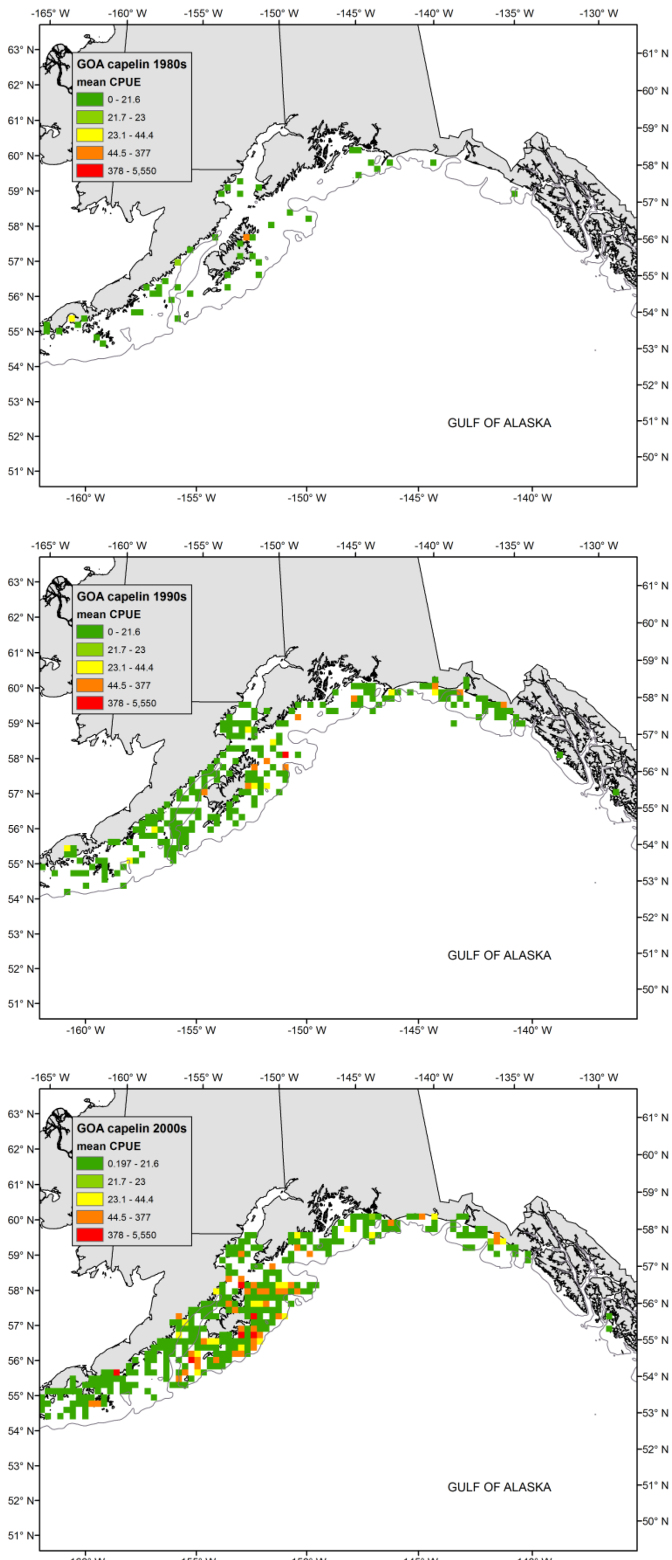

Figure 18. Mean bottom trawl survey CPUE (kg/hectare) of capelin in the Gulf of Alaska for three time periods: 1984-1989 (top panel), 1990-1999 (middle panel), and 2000-2011 (bottom panel). Grid cells are 20 km X 20 km and color levels are identical for all figures.

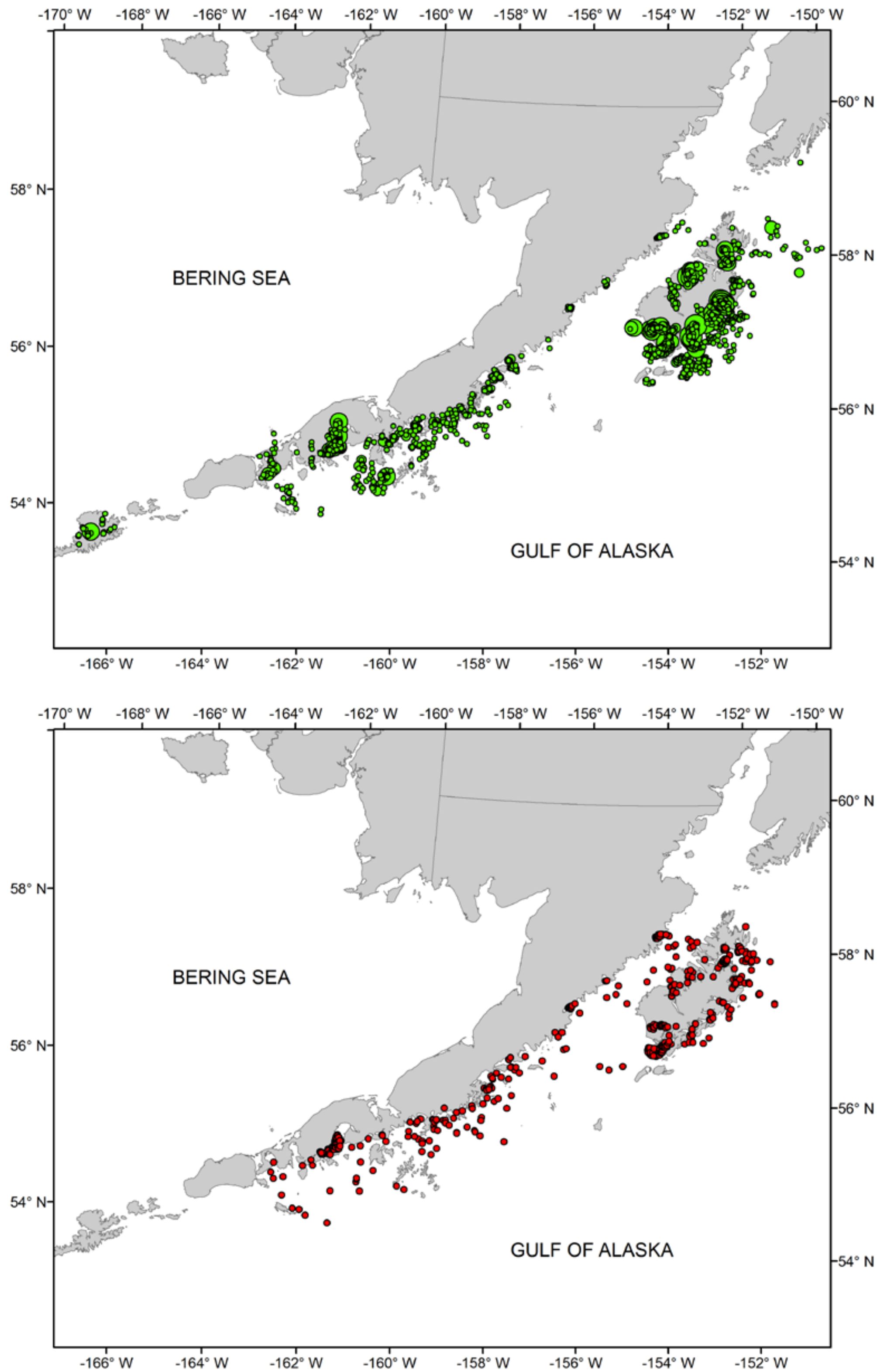

Figure 19. Mean CPUE (kg/km trawled) of capelin in the ADFG small-mesh trawl survey for two time periods, 1970-1984 (top panel) and 1985-2011 (bottom panel) Symbol size represents CPUE and the scale is identical between the plots.

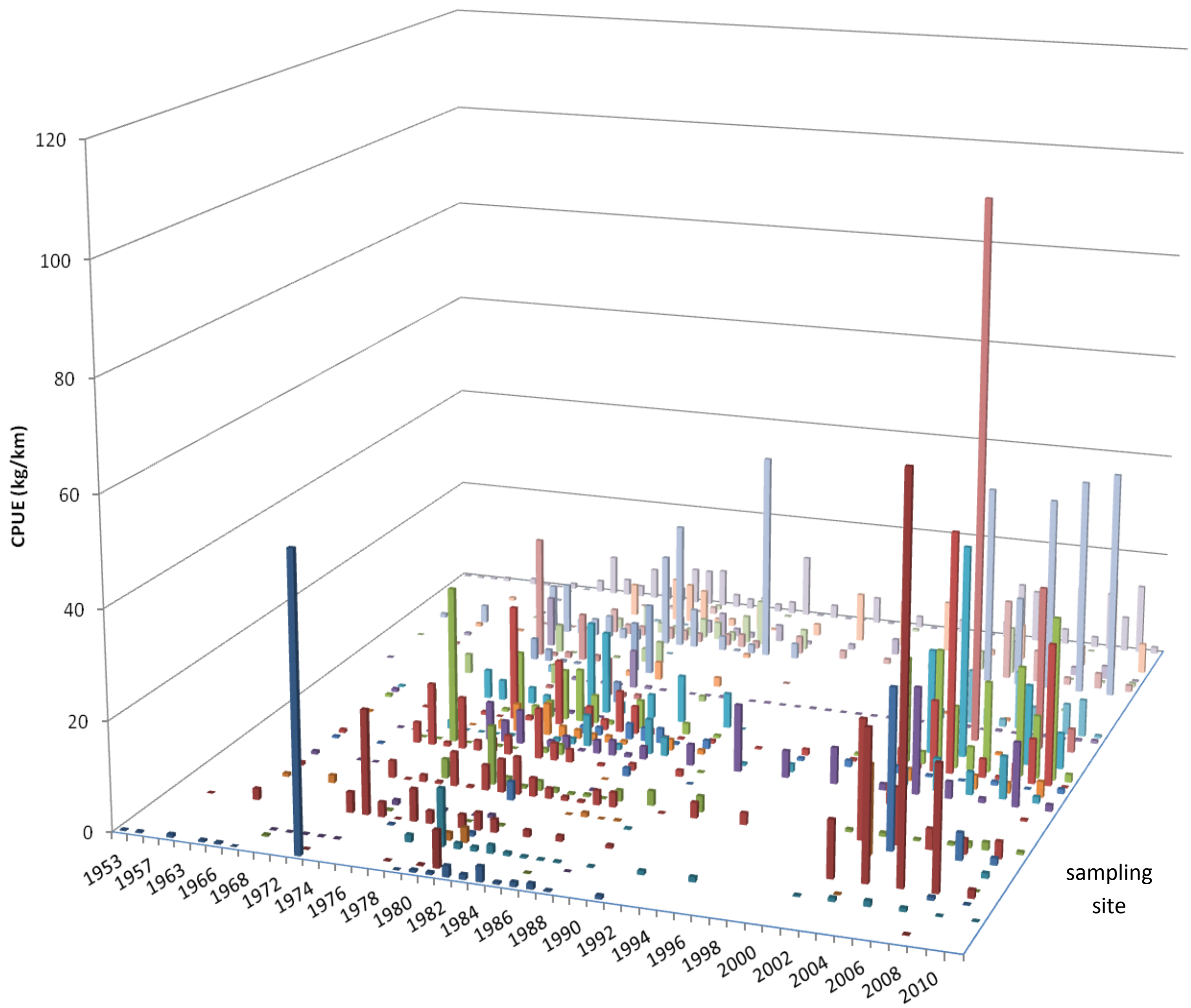

Figure 20. Mean CPUE (kg/km trawled) of eulachon in the ADFG small-mesh survey, by year and bay, 1953-2011. The z-axis (corresponding to chart depth and labeled “sampling site”) represents the numerous nearshore sites (bays) sampled during the surveys. For clarity, bay names are not included on the chart and the sites are not located on the axis in any meaningful way (i.e. the data are arranged alphabetically by bay name and are not related to any geographic quantity).

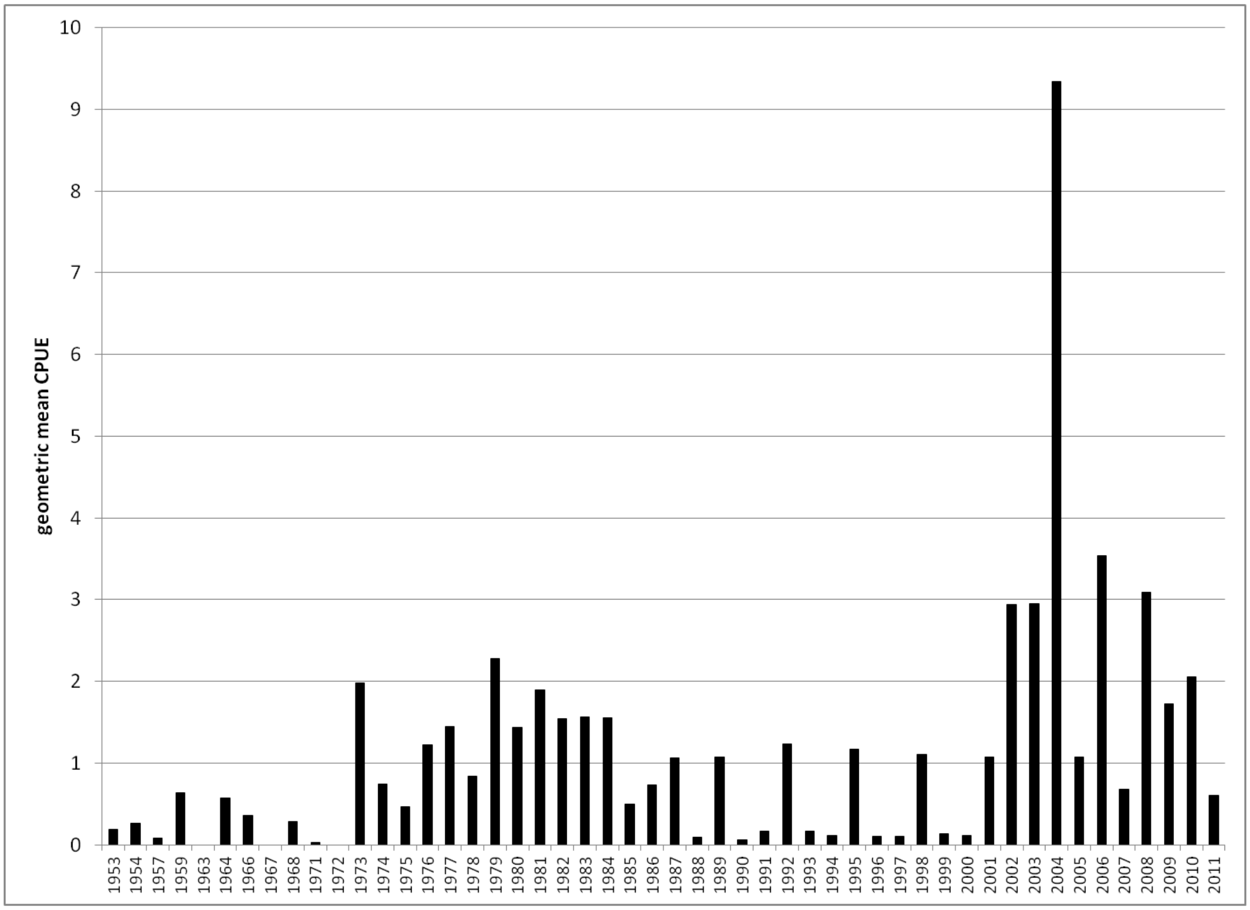

Figure 21. Annual geometric mean CPUE (kg/km trawled) of eulachon in the ADFG small-mesh survey, 1953-2011.

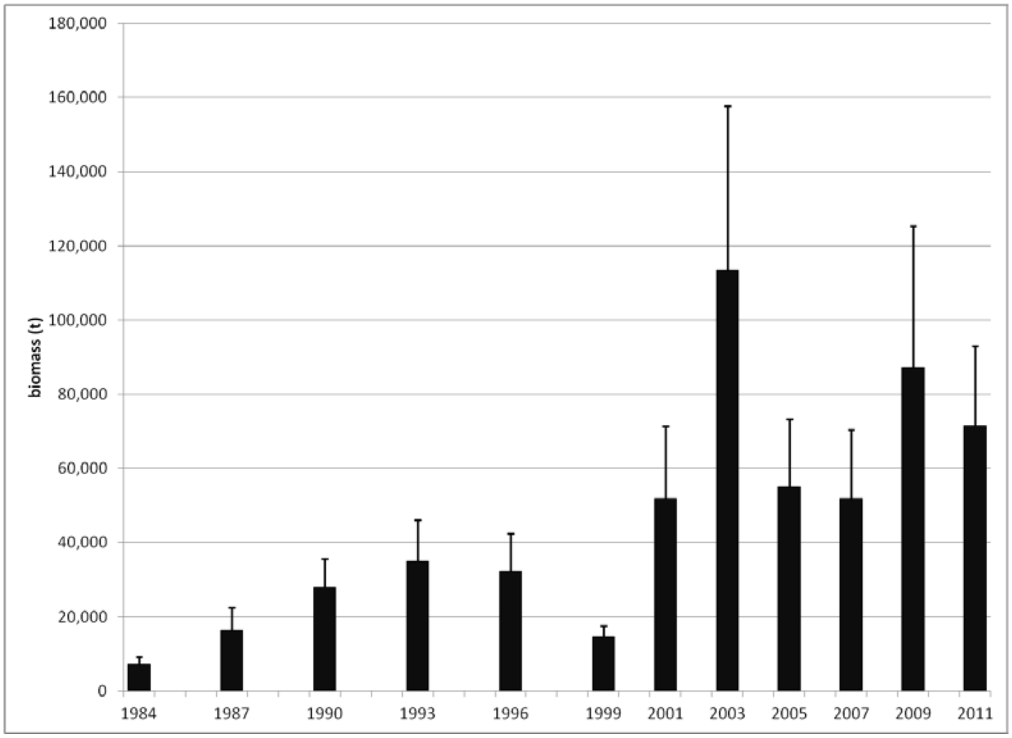

Figure 22. Biomass estimates (t) of eulachon from the GOA bottom trawl survey, 1984-2011. Error bars represent 95% confidence interval.

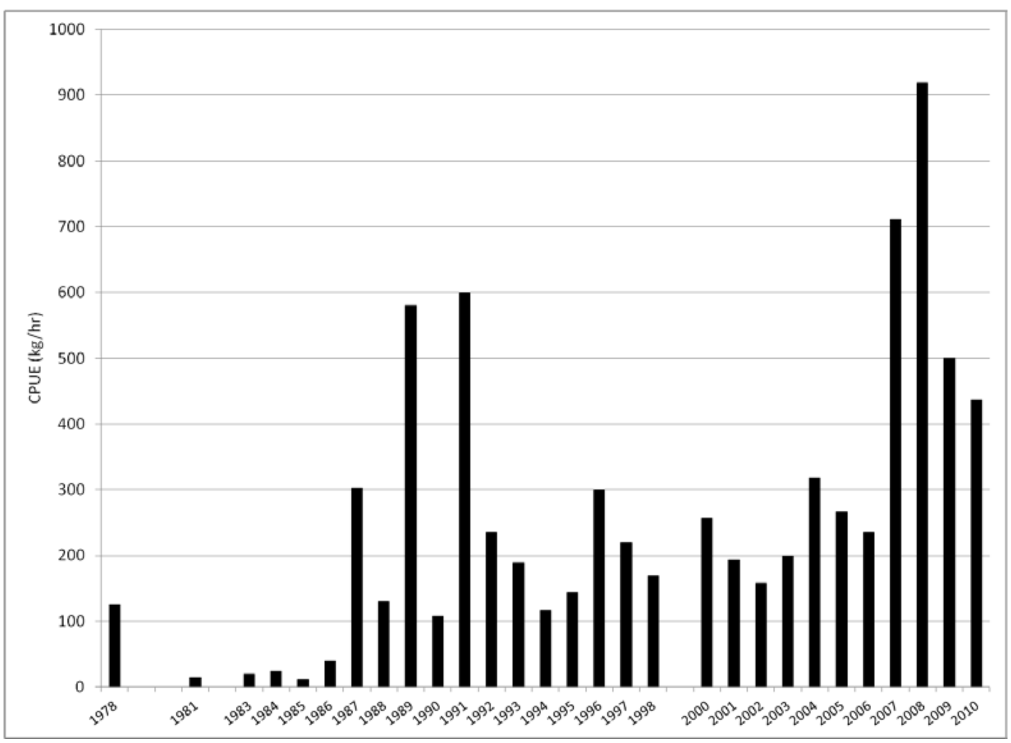

Figure 23. Eulachon CPUE (kg/hr.) in sampling tows conducted during AFSC acoustic trawl surveys in the GOA, 1978-2010.

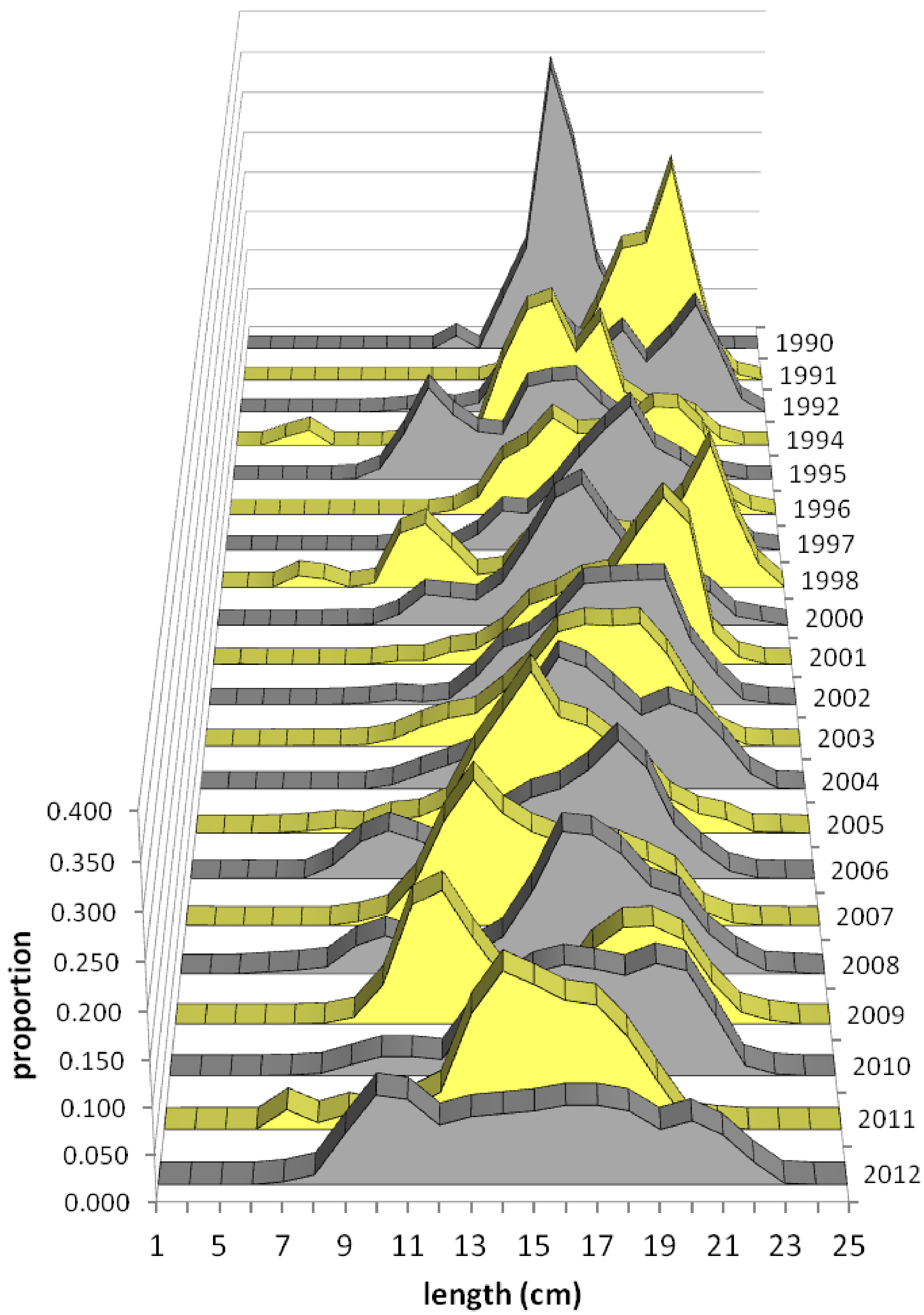

Figure 24. Length compositions for eulachon captured in sampling tows conducted during AFSC acoustic trawl surveys in the GOA, 1990-2012.

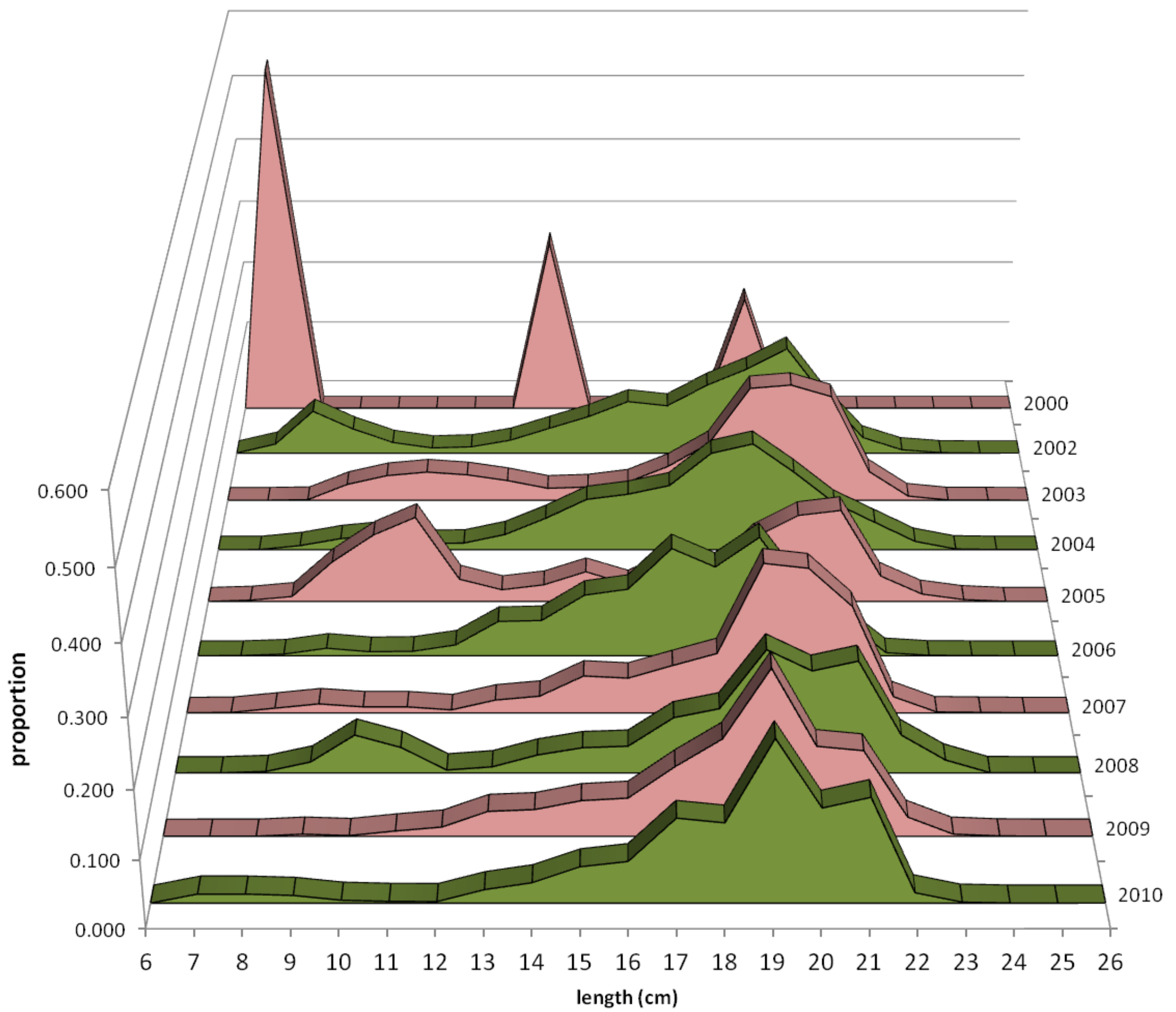

Figure 25. Length compositions for eulachon captured in the ADFG small-mesh trawl survey, 2000-2010.

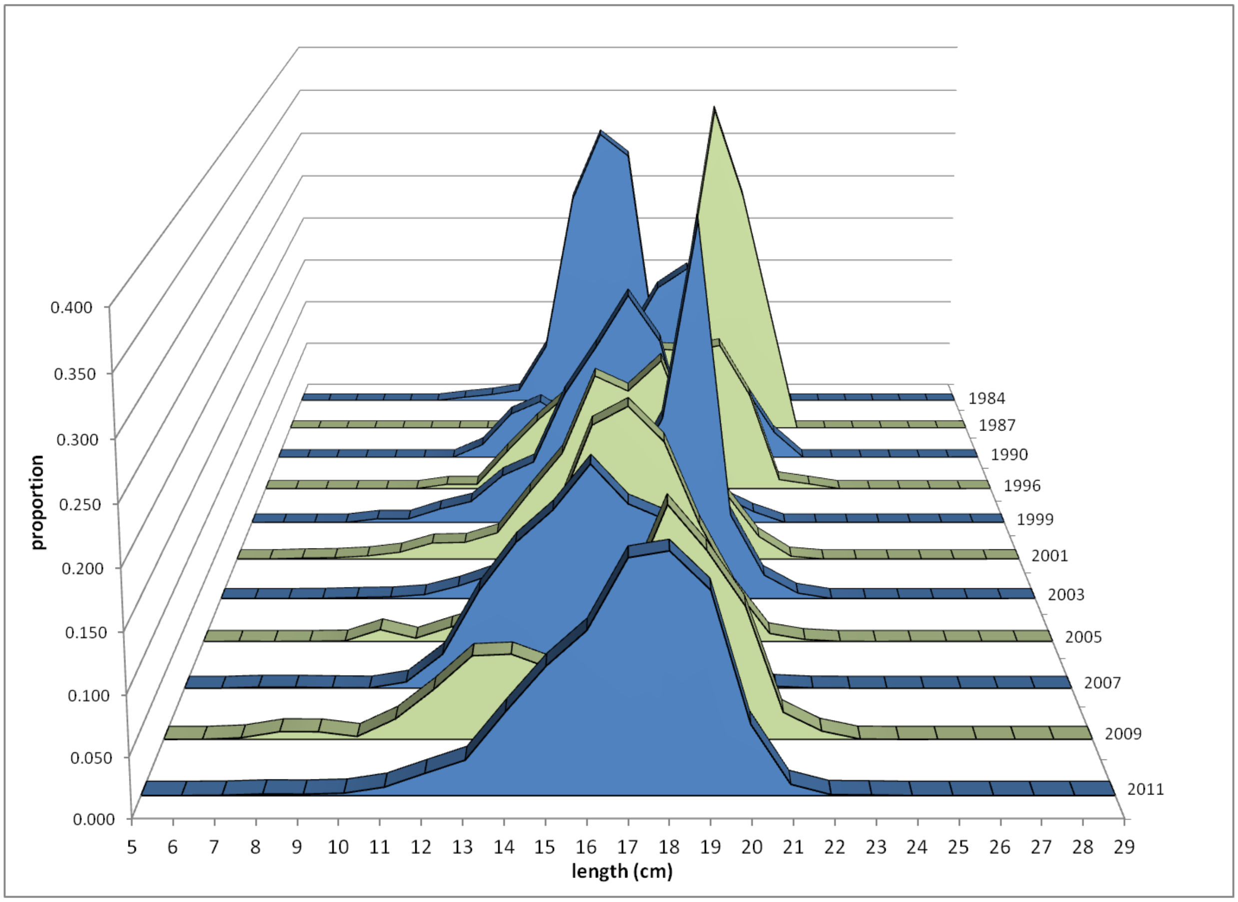

Figure 26. Length compositions for eulachon captured during the GOA bottom trawl survey, 1984-2011.

Figure 27. Length composition modes of eulachon sampled in three different surveys, by year. Blue and green lines show the 3rd-order polynomial fit to the bottom trawl and EIT (acoustic) surveys, respectively.

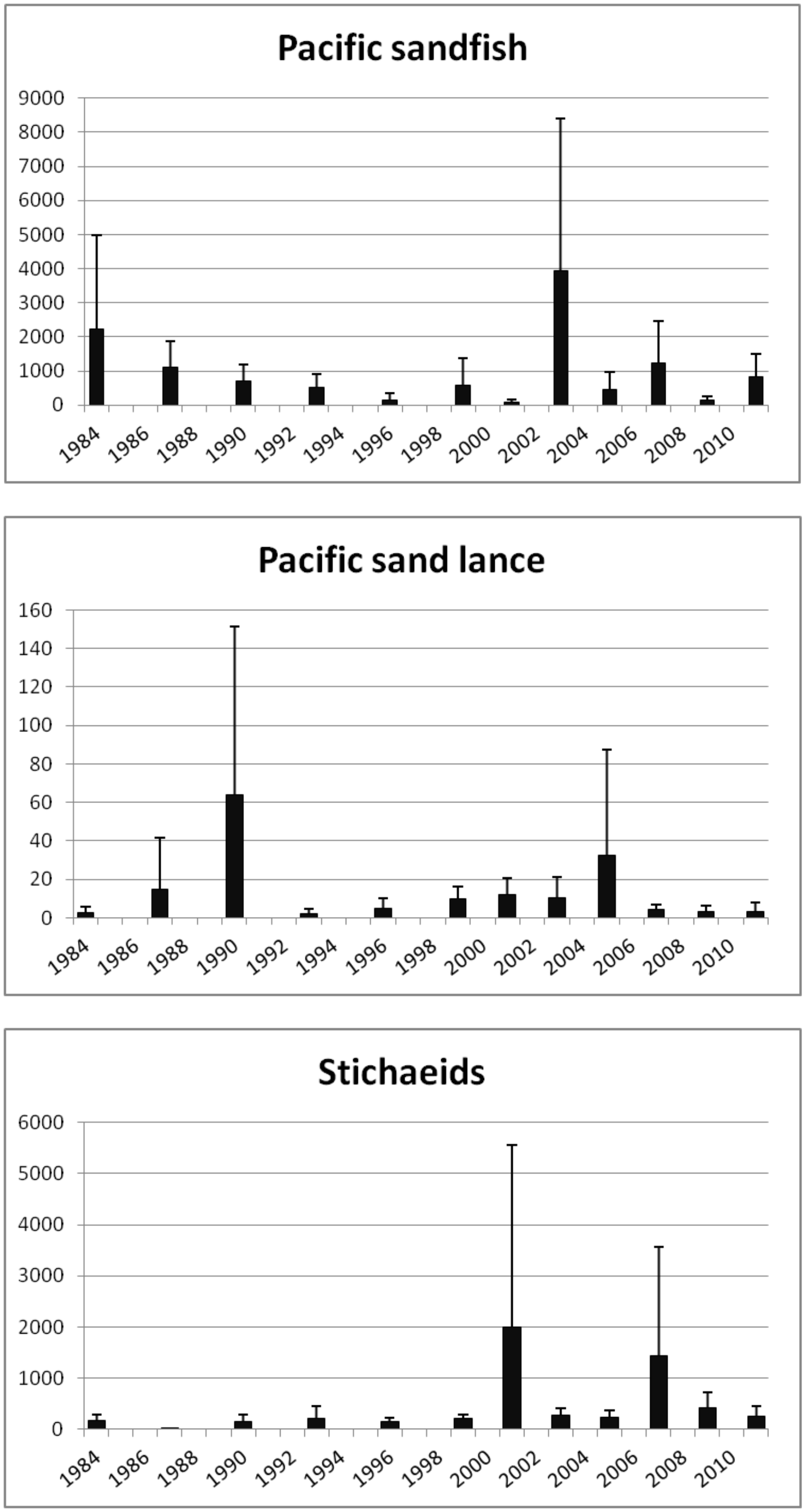

Figure 28. Biomass estimates (t) from the GOA bottom trawl survey for Pacific sandfish, Pacific sand lance, and stichaeids. Error bars show 95% confidence intervals.

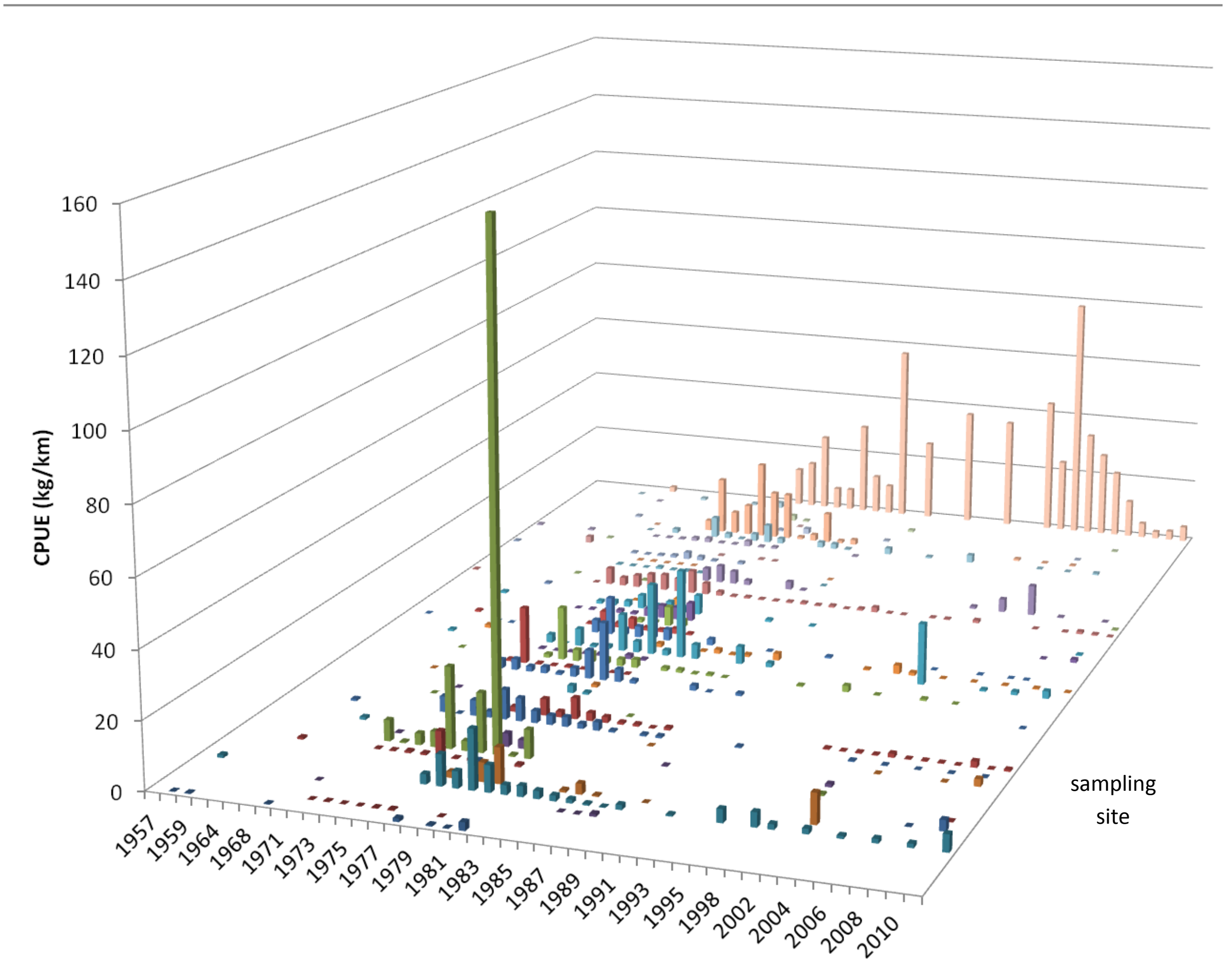

Figure 29. Mean CPUE (kg/km trawled) of Pacific sandfish in the ADFG small-mesh survey, by year and bay, 1957-2011. The z-axis (corresponding to chart depth and labeled "sampling site") represents the numerous nearshore sites (bays) sampled during the surveys. For clarity, bay names are not included on the chart and the sites are not located on the axis in any meaningful way (i.e. the data are arranged alphabetically by bay name and are not related to any geographic quantity).

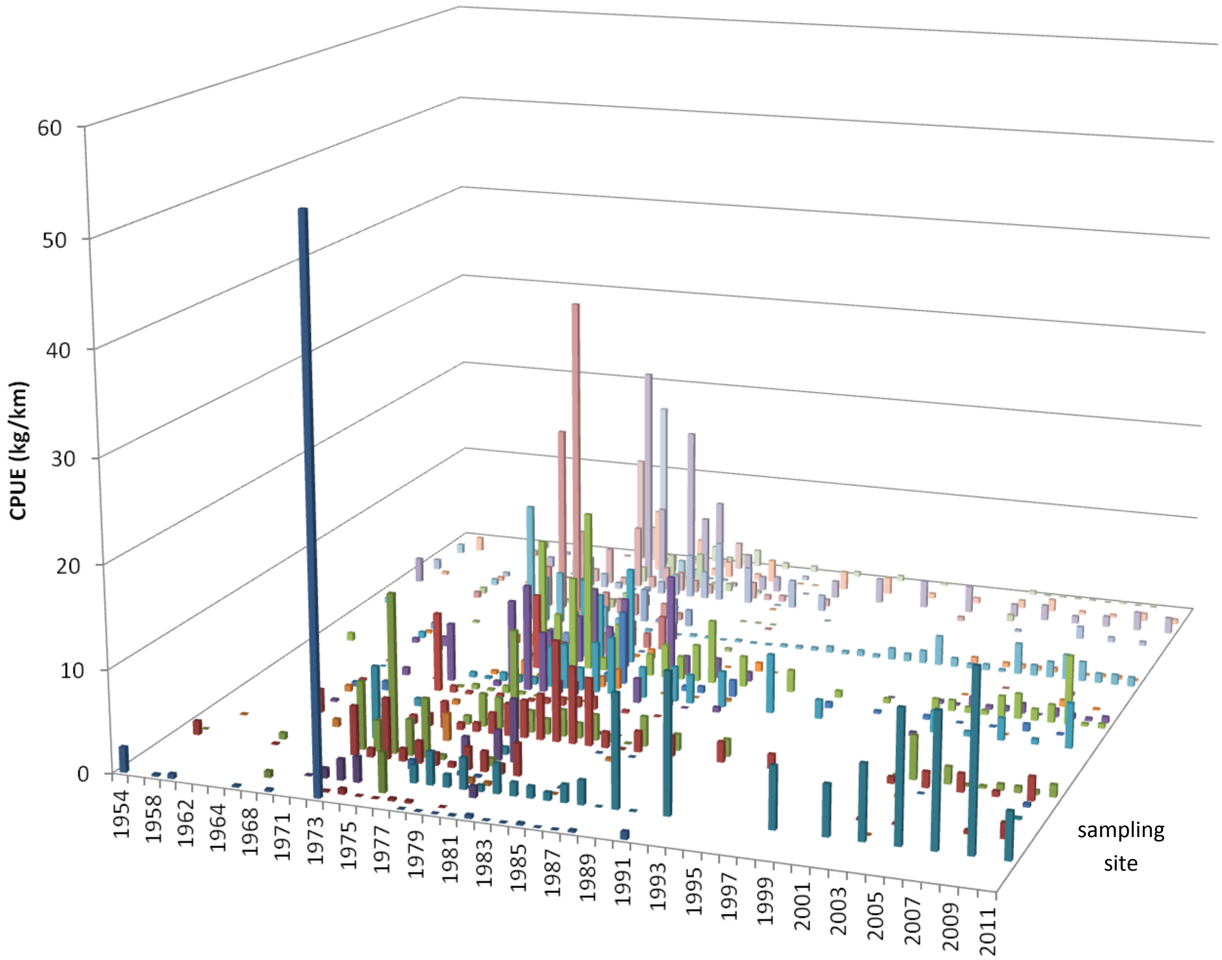

Figure 30. Mean CPUE (kg/km trawled) of stichaeids (all species combined) in the ADFG small-mesh survey, by year and bay, 1954-2011. The z-axis (corresponding to chart depth and labeled "sampling site") represents the numerous nearshore sites (bays) sampled during the surveys. For clarity, bay names are not included on the chart and the sites are not located on the axis in any meaningful way (i.e. the data are arranged alphabetically by bay name and are not related to any geographic quantity).

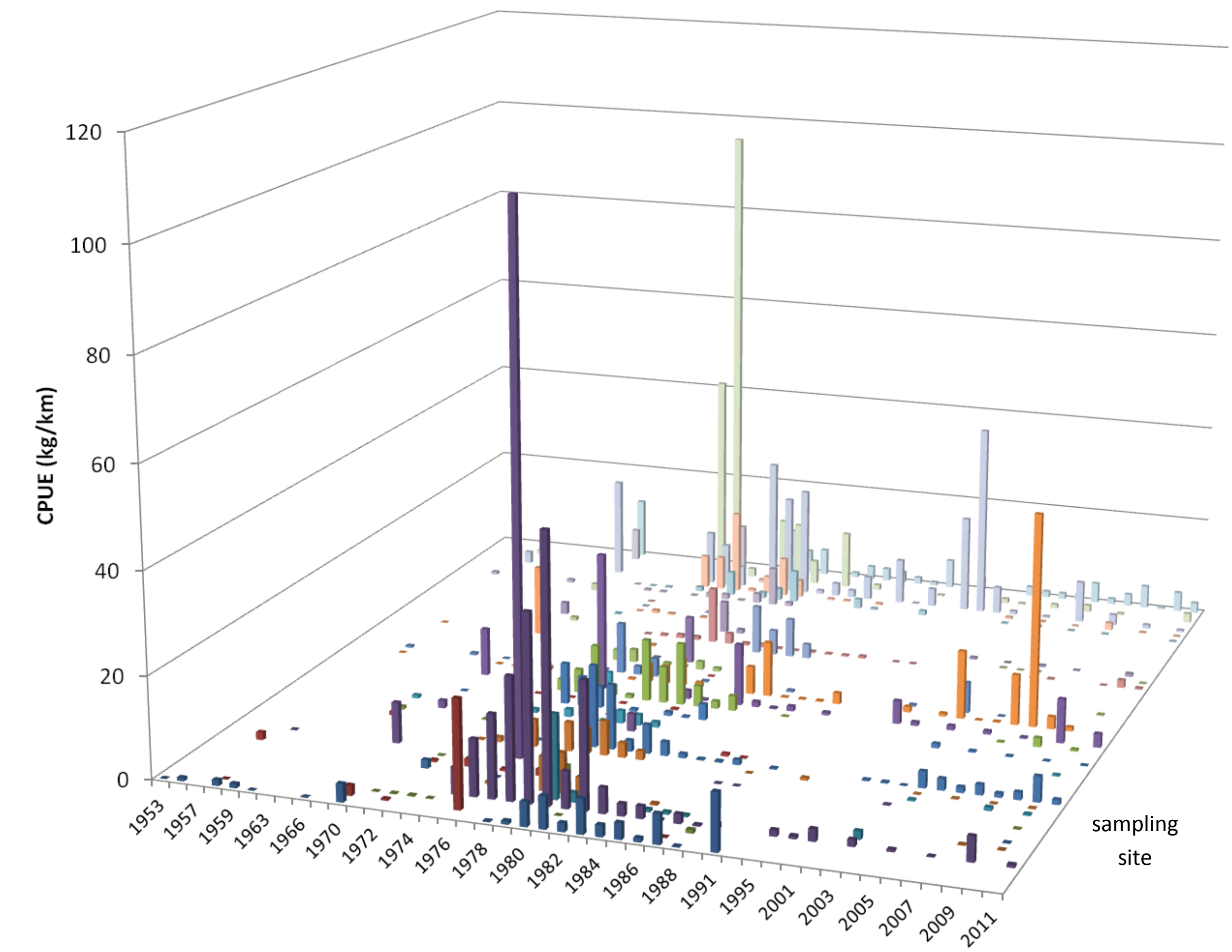

Figure 31. Mean CPUE (kg/km trawled) of Pacific herring in the ADFG small-mesh survey, by year and bay, 1953-2011. The z-axis (corresponding to chart depth and labeled "sampling site") represents the numerous nearshore sites (bays) sampled during the surveys. For clarity, bay names are not included on the chart and the sites are not located on the axis in any meaningful way (i.e. the data are arranged alphabetically by bay name and are not related to any geographic quantity).

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	Pacific sand lance
Family Trichodontidae	sandfish
Trichodon trichodon	Pacific sandfish
Arctoscopus japonicus	sailfin sandfish
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

Scientific Name	**Common Name**
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

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