2024 Alaskan forage report

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This forage species report is for both the Bering Sea and Aleutian Islands (BSAI) and the Gulf of Alaska (GOA) region. Starting in 2024, this joint report is prepared and presented to the Plan Teams and the North Pacific Fishery Management Council (NPFMC) in even years. This report is not a formal stock assessment; it is a presentation of the available data on trends in abundance and distribution of forage populations (primarily bottom trawl survey data) and a description of their interactions with federal fisheries through bycatch.

Forage species are a fundamental component of the GOA and BSAI ecosystems, so there is overlap between the information presented here and in the Ecosystem Status report (https://www.fisheries.noaa.gov/alaska/ecosystems/ecosystem-status-reports-gulf-alaska-bering-sea-and-aleutian-islands). This forage report primarily displays data from the GOA bottom trawl surveys. The Ecosystem Status report contains surface-trawl surveys, euphausiid abundances from acoustic surveys, and indirect indicators of forage species abundance such as seabird breeding success and groundfish predator diets.

A. Forage species and their management

Defining 'forage species' can be difficult. Small, energy-rich schooling fishes like sardines or herring are the classic 'forage fish', but most fish species experience predation in their life cycle. Forage species can be thought of as those whose primary ecosystem role is as prey and serve as a link between lower and upper trophic levels. Forage species tend to be short-lived, with highly dynamic population abundances. The following species or groups are defined as components of the forage base in Alaskan waters: members of the 'forage fish group' listed in the GOA and BSAI Fishery Management Plan (FMP), squids, shrimps, Pacific herring (*Clupea pallasii*), and juvenile groundfishes and salmon. Arctic cod (*Boreogadus saida*) is also included in the BSAI FMP.

Forage species groups

Forage species in federal waters of Alaska were either managed as part of the Other Species group (non-target species caught incidentally in commercial fisheries) or were classified as "non-specified" in the Fishery Management Plan, with no conservation measures prior to 1998. Amendment 36 to the BSAI FMP created a separate forage fish category in 1998, with conservation measures that included a ban on directed fishing. Members of this forage fish group (the "FMP forage group" in this report) are considered "Ecosystem Components" beginning in 2011. The group is large and diverse, containing over fifty species from many taxonomic groups.

The primary motivation for the creation of the FMP forage group was to prevent fishing-related impacts to the forage base in Alaska. This was an early example of ecosystem-based fisheries management (Livingston et al. 2011). Two key management measures for the group are specified in section 50 CFR 679b20.doc of the federal code: a closure to direct fishing and a prohibition of the sale, barter, trade or processing of forage species. Fishmeal production and sale from forage species is allowed provided it does not exceed the maximum retainable bycatch. Incidental catches of forage fish are limited to a maximum retention allowance (MRA) of 2% by weight of the retained target species.

It appears the figure of '2%' was chosen to accommodate existing levels of catch that were believed to be sustainable (Federal Register, 1998, vol. 63(51), pages 13009-13012), which suggests the intent of amendment 36 was 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, 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).

Taxonomic groups considered in the FMP forage group include (see Table 1 at the end of this report for a full list of species):

- Osmeridae (smelts; eulachon [*Thaleichthys pacificus*] and Pacific capelin [*Mallotus catevarius*] are the principal species)
- Ammodytidae (sand lances; Pacific sand lance [*Ammodytes personatus*])
- 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)

Pacific herring

Herring are abundant in Alaska marine waters. Commercial fisheries exist throughout State waters of Alaska in both the BSAI and GOA, primarily for herring roe with smaller fisheries for food and bait. 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 next largest stock is in Norton Sound (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 BSAI (Figure 1; Tojo et al. 2007). Herring fisheries also occur throughout the GOA, with many in Southeast Alaska (notably Sitka Sound) and around Kodiak Island. Prince William Sound once supported an important fishery, but has remained at low abundance since the early 1990s.

Herring fisheries are managed by the Alaska Department of Fish & Game (ADFG) which uses a combination of surveys and population modeling to set catch limits. In federal fisheries, herring are managed as Prohibited Species, which means 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 2) 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

Juvenile groundfish and salmon, particularly age-0 and age-1 walleye pollock, *Gadus chalcogrammus*, are key forage species in Alaska. Juveniles of all five species of Pacific salmon occur in the BSAI and GOA including Chinook salmon (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), and coho salmon (*O. kisutch*). ADFG is primarily responsible for salmon management in Alaska, with the exceptions in the exclusive economic zone. 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). These fishes are also included in the NFMS pelagic surveys to some extent, described below.

Shrimp

A variety of shrimps occur in Alaska. 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. 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

Several species of squid inhabit Alaska, mainly along shelf breaks. Squids were managed as part of the 'Other Species' complex before 2011; starting in 2011, they were managed as a target stock complex with annual harvest specifications. However, in June 2017, the NPFMC amended the FMP for the BSAI (Amendment 117) and GOA (Amendment 106) to move the squid stock complex into the Ecosystem Component category. The rationales for this decision included: the lack of a directed fishery for squid, low risk of overfishing given high productivity and no directed fishery, and small incidental fishing mortality.

The amendments were implemented in the Federal Register with an effective date of August 8, 2018 (Federal Register, Volume 83, Number 130, July 6 2018, pages 31460-31470). The amendments placed squid in the Ecosystem Component category, prohibited a directed fishery for squid, established a 20% maximum retention allowance, and established record keeping requirements. The new management regime was implemented in January 2019.

Arctic cod

Arctic cod is primarily a cold-water species with a northern distribution in the Bering Sea, 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/.

Bering Sea and Aleutian Islands

This forage species report for the Bering Sea and Aleutian Islands (BSAI) region is prepared and presented to the BSAI Plan Team and the North Pacific Fishery Management Council (NPFMC). The report was formerly reported in odd years but switched to an even year cycle in 2024. This report is not a formal stock assessment; it is a presentation of the available data on trends in abundance and distribution of forage populations and a description of their interactions with federal fisheries through bycatch.

Forage species are a fundamental component of the BSAI ecosystem, so there is overlap between the information presented here and in the Ecosystem Status report (https://www.fisheries.noaa.gov/alaska/ecosystems/ecosystem-status-reports-gulf-alaska-bering-sea-and-aleutian-islands). This forage report primarily displays data from the BSAI bottom trawl surveys and to a lesser extent, the pelagic surface trawl surveys. The Ecosystem Status report contains euphausiid abundances from acoustic surveys and indirect indicators of forage species abundance such as seabird breeding success and groundfish predator diets.

Estimated capelin density and prevalence from the NMFS bottom trawl surveys remained near all-time lows in 2024 with a slight uptick in prevalence since 2023. Pelagic trawl surveys in the EBS similarly showed very low densities of capelin, however in the NBS densities were the second highest of the time series (Yasumiishi et al. 2024). Since 2019/2020, eulachon prevalence and density have been low. Prevalence increased slightly since 2023, but densities were the lowest on record in 2024. Similarly, rainbow smelt metrics were near all-time lows after an all-time peak in 2020. Pacific herring density and prevalence from bottom trawl surveys have been above average for the last several years and remained slightly above the long term mean in 2024. This corroborates ADFG's biomass estimates of spawning herring in Togiak this year, which was the 5th highest since 1993 (ADFG, pers. comm). In contrast, pelagic trawl surveys found herring to be among the lowest of the time series since 2020 (Yasumiishi et al. 2024). Shrimp densities have been trending upward since the mid-1990s and remained high in 2024; prevalence peaked in 2010 and has since declined to approximately average in 2024. Magistrate armhook squid density in the Aleutian Islands was slightly below average in 2024 with average prevalence. The pelagic trawl forage index remained near all-time lows since 2021.

Total incidental catches of the FMP forage group were low in 2022 and 2023 compared to historical values, with a slight increase in 2024. Total shrimp catches decreased in 2022, but were near all time highs in 2023 with a slight decrease in 2024. Prohibited species catch of herring has been higher than average since 2020, with a steep decline in 2024 from the third highest catches ever observed in 2023.

B. Trends in density, prevalence, and distribution

Information content of data sources

The primary data source for this report is the bottom trawl survey, but this survey is not aimed at sampling the water column (where many forage species reside) and is not designed to capture small fish. Consequently, measures of density, prevalence, and distribution are uncertain. The goal of this report is to present the data from the bottom trawl survey for forage species while understanding the potential shortcomings of the survey for this task. The NMFS pelagic survey samples surface waters and presumably samples pelagic forage species better than the bottom trawl, but it has not been performed as long so does not provide the contrast the bottom trawl might.

Methods

NMFS bottom trawl surveys

For most of 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: https://www.fisheries.noaa.gov/alaska/population-assessments/alaska-stock-assessments). 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, so densities and prevalence before 1988 should be considered with this in mind. 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 will likely be increasingly important in ecosystem understanding.

NMFS pelagic trawl survey

The pelagic fishes of the eastern Bering Sea are assessed through two NMFS surveys which occur primarily in September with sampling during August and October in some years (Yasumiishi et al. 2024). The Northern Bering Sea (NBS) Ecosystem and Surface Trawl Survey has been conducted annually since 2003, although the extent and density of stations sampled has varied among years. The Southeast Bering Sea (SEBS) Survey begain in 2002 and utilizes surface and oblique trawls to sample the deeper water column, and, after 2012, has been conducted every other year in even years. Primary fish caught in these surveys include age-0 Pacific cod (*Gadus macrocephalus*), age-0 pollock (*Gadus chalcogrammus*), capelin (*Mallotus villosus*), Pacific herring (*Clupea pallasii*), juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile sockeye (*O. nerka*), juvenile chum salmon (*O. keta*), juvenile pink salmon (*O. gorbuscha*), juvenile coho salmon (*O. kisutch*), and saffron cod (*Eleginus gracilis*).

For both pelagic trawl surveys, annual CPUE was estimated using a single-species spatio-temporal model with the VAST package version 3.11.1, and R software version 4.3.1 (R Core Team 2023, Thorson 2015; Thorson and Kristensen 2016, Thorson 2019). We used the VAST package to reduce bias in density estimates due to spatially unbalanced sampling across years, while propagating uncertainty resulting from predicting density in unsampled areas. Spatial and spatio-temporal variation for both encounter probability and positive catch rate components were specified at a spatial resolution of 500 knots. We used a Poisson-link, or conventional, delta model and a gamma distribution to model positive catch rates and specified a bias-corrected estimate (Thorson 2019). Parameter estimates were within the upper and lower bounds and final gradients were less than 0.0005. Julian day was added as a normalized covariate with a spatially constant and linear response due to changes in the timing of the survey among years.

Pacific capelin

Capelin are distributed primarily in the inner domain of the EBS shelf (Figure 3). The pattern of CPUE varies substantially between the pelagic and bottom trawl surveys, with catches in the pelagic surveys occurring further north than in the EBS trawl survey (Yasumiishi et al. 2024). The reason for these differences is not clear. In the bottom trawl survey, biomass estimates are variable but there also appear to be decadal signals in density (Figure 4). Recent densities in the bottom trawl survey were at or near all-time lows, while prevalence increased slightly from the previous year in the EBS (Figure 4). This is in agreement with the very low density observed in the pelagic trawl survey in the EBS, but starkly contrasts the pelagic density in the NBS which was the 2nd highest of the 22-year time series (Yasumiishi et al. 2024).

Eulachon

Eulachon tend to occur deeper in the water column and are more likely to be associated with the bottom than other forage species. As a result the bottom trawl surveys sample eulachon more effectively than other forage species, and eulachon are essentially absent from the pelagic surveys. Eulachon are consistently distributed in the extreme southern portion of the outer EBS shelf (Figure 5). Decadal signals also appear in survey density estimates for eulachon (Figure 6). Recent densities and prevalence for eulachon in the bottom trawl survey were at or near all-time lows (Figure 6).

Rainbow smelt

Rainbow smelt are rare in the bottom trawl survey (Figure 7), with the highest abundance of rainbow smelt in the NBS and particularly Norton Sound (Figure 8 &Figure 7). 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).

Pacific sand lance

Sand lances are 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 limited. The bottom trawl survey suggests that they have a primarily inshore distribution in the EBS, particularly in areas with extensive sandy bottom substrates (Figure 9). They also occur in the AI, particularly in the islands west of Amchitka Pass (Figure 9). Densities and prevalence of sand lance have risen from all-time lows in 2016 to approximately the long-term average in 2024 (Figure 10).

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 11). The pelagic 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). Densities and prevalence of sandfish have been beneath long-term averages for the last decade, but prevalence has been trending upward over the last 4 years (Figure 12).

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 and along the shelf break and slope in the AI (Figure 13). Data are more sparse given their distribution on the slope and infrequent sampling.

Pricklebacks, gunnels, blacksmelts, bristlemouths, eelblennies

These species occur infrequently in the AFSC surveys, either due to their small size or their preference for unsurveyed habitats (e.g. nearshore areas or deep pelagic waters). This is particularly so for gunnels, blacksmelts, and bristlemouths, which are not presented below given their sparse data. Several species of pricklebacks and eelblennies are observed in the bottom trawl surveys and are combined here to present more complete picture of their distributions and abundance. Pricklebacks and eelblennies appear to be more prevalent in the northern Bering Sea (Figure 14 & Figure 16). Prevalence and density of both pricklebacks and eeblennies are low outside of the NBS (Figure 15 & Figure 17). Prevalence and density of pricklebacks declined since last year, while they have increased for eelblennies.

Pacific herring

The spatial distribution of herring in the BSAI described by the bottom trawl survey and the pelagic surveys differ and may result from seasonal herring movement. 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 18) are consistent with the movement patterns in (Figure 1). Herring density estimates and prevalence display high interannual variability with less of a decadal signal than other forage species and are both above the long-term mean in 2024 (Figure 19). This is corroborated by ADFG biomass estimates of spawning herring in Togiak this year, which was 5th highest since 1993 (ADFG, pers. comm.) In contrast, herring densities in pelagic trawl surveys remain among the lowest of the time series (Yasumiishi et al. 2024).

Squid

Magistrate armhook squid (*Berryteuthis magister*) are regularly encountered by the Aleutian Islands bottom trawl survey because of their relatively large size (Figure 20; maximum mantle length of ~28 cm, Sealifebase.com). Smaller species and juvenile squid are mainly found near surface waters. Density and prevalence are highest in the Aleutian Islands and on the slope (Figure 21). Recent densities are up slightly from values observed in 2000s, but prevalence has not markedly increased (Figure 21).

Shrimp

Observations of several shrimps are reported in the bottom trawl survey, including: unidentified pandalid shrimp, ocean shrimp, Alaska pink shrimp, sculptured shrimp, skeleton shrimp, coonstrip shrimp, humpy shrimp, opossum shrimp, Greenland shrimp, Aleutian coastal shrimp, sidestripe shrimp, and seven spine bay shrimp (among others). For this report, all shrimp were lumped together to represent the Bering Sea wide dynamics of shrimp. The highest densities of shrimp are consistently in the outer domain in deep waters (Figure 22). Average densities have trended upwards since the 1980s and prevalence peaked in the late-2000s (Figure 23). Prevalence in 2024 was near the long-term average.

Pelagic survey forage index

During 2024, the CPUE of pelagic forage fishes remained low in the NBS during late summer, with a slight decrease since 2023 (Figure 24). In the EBS, CPUE of forage fishes declined precipitously from 2022 by approximately 70%. Temporal trends in forage fish biomass indicated higher productivity during the recent warm years (2014-2018) and lower during the cold years (2007-2013), especially for the southern forage fish. In 2024, sea surface temperatures were average in the NBS, but remained warmer than average similar to 2022 in the EBS. In the EBS, trends in CPUE were dominated by age-0 pollock and juvenile sockeye salmon, while herring dominated CPUE trends in the NBS.

C. Bycatch and other conservation issues

FMP forage group

Osmerids regularly make up the vast majority of FMP forage fish group catches (Figure 25). Eulachon are the most abundant osmerid catch and it is likely that they make up the majority of the 'other osmerid' catch. Osmerid catches (and consequently total FMP forage group catches) have been low relative to historical levels (Figure 26). Other osmerids and shrimp accounted for almost all of the incidental catch in 2024. Squid catches since 2019 have been twice the historical maximums (Figure 27).

Pacific herring

The Prohibited Species Catch (PSC) of herring is generally low, with occasional larger catches (e.g. 1991, 2004, 2012, 2020, and 2023; Figure 28). Herring PSC in 2024 declined compared to 2023 and was slightly above the long-term mean. Most of the herring bycatch occurs in the midwater trawls for walleye pollock in the BSAI (Figure 28).

Table 1: A list of species designated as forage species in Alaska.

Scientific.name	Common.name
Mallotus villosus	capelin
Hypomesus pretiosus	surf smelt
Osmerus mordax	rainbow smelt
Thaleichthys pacificus	eulachon
Spirinchus thaleichthys	longfin smelt
Spirinchus starksi	night smelt
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
Leuroglossus schmidti	northern smoothtongue
Lipolagus ochotensis	popeye blacksmelt
Pseudobathylagus milleri	stout blacksmelt
Bathylagus pacificus	slender blacksmelt
Ammodytes hexapterus	Arctic sand lance
Ammodytes personatus	Pacific sand lance
Trichodon trichodon	Pacific sandfish
Arctoscopus japonicus	sailfin sandfish
Apodichthys flavidus	penpoint gunnel
Rhodymenichthys dolichogaster	stippled gunnel
Pholis fasciata	banded gunnel
Pholis clemensi	longfin gunnel
Pholis laeta	crescent gunnel
Pholis schultzi	red gunnel
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

Scientific.name	Common.name
Anoplarchus insignis	slender cockscomb
Phytichthys chirus	ribbon prickleback
Xiphister mucosus	rock prickleback
Xiphister atropurpureus	black prickleback
Sigmops gracilis	slender fangjaw
Cyclothone alba	white bristlemouth
Cyclothone signata	showy bristlemouth
Cyclothone atraria	black bristlemouth
Cyclothone pseudopallida	phantom bristlemouth
Cyclothone pallida	tan bristlemouth
Euphausia pacifica	krill

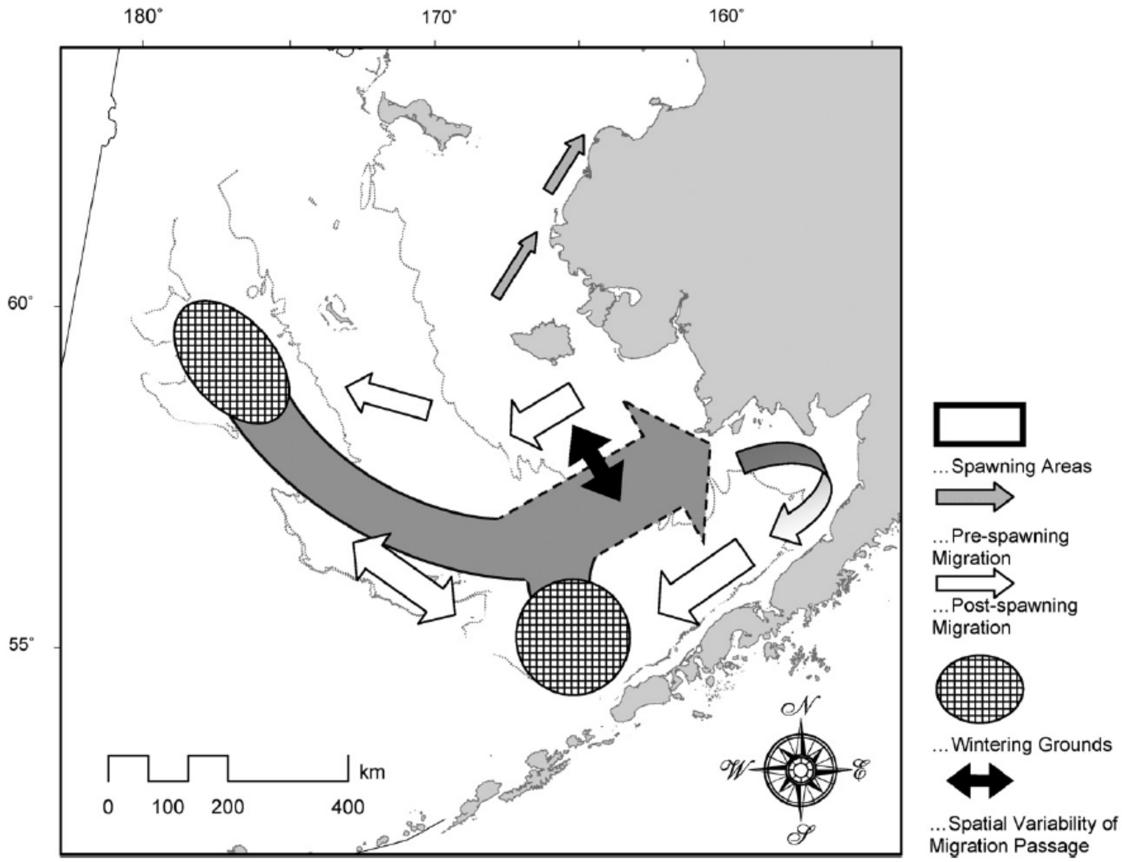

Figure 1: Hypothesized migration routes and seasonal distributions of Pacific herring in the eastern Bering Sea. Figure is from Tojo et al. 2007.

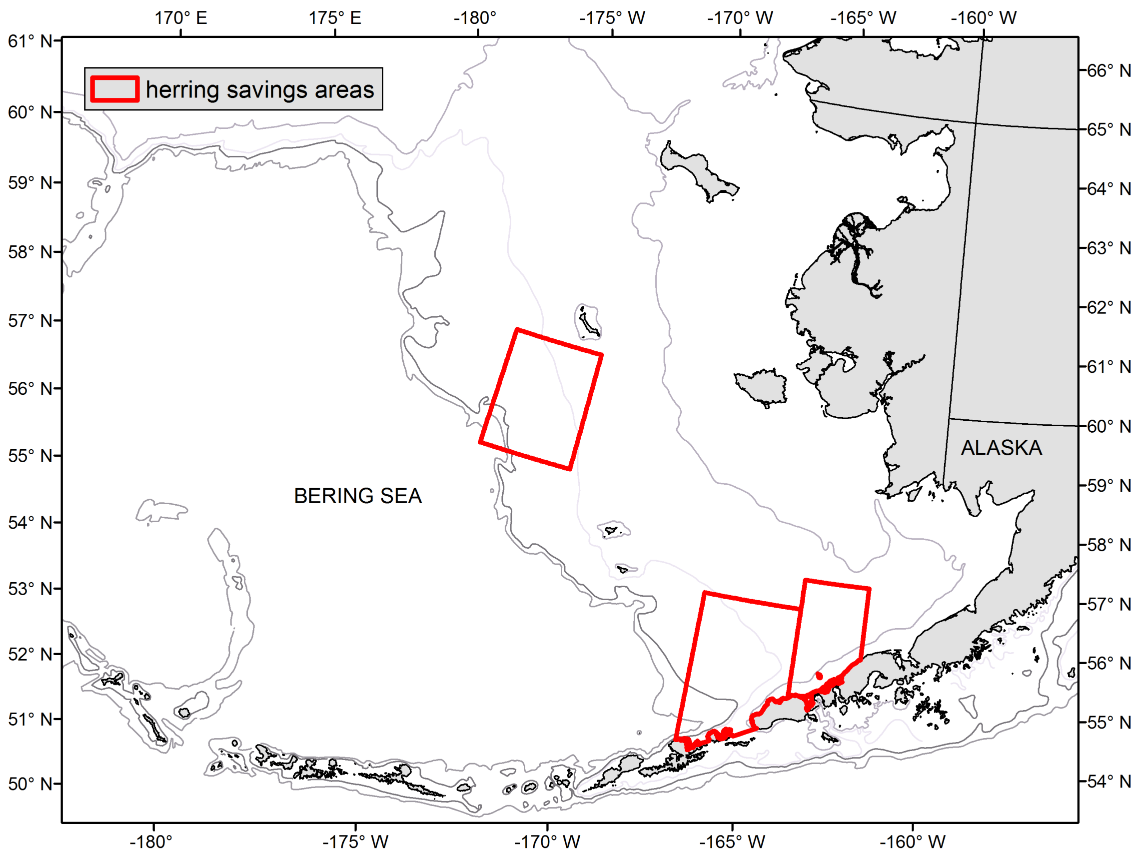

Figure 2: Locations of Herring Savings Areas (red-outlined polygons).

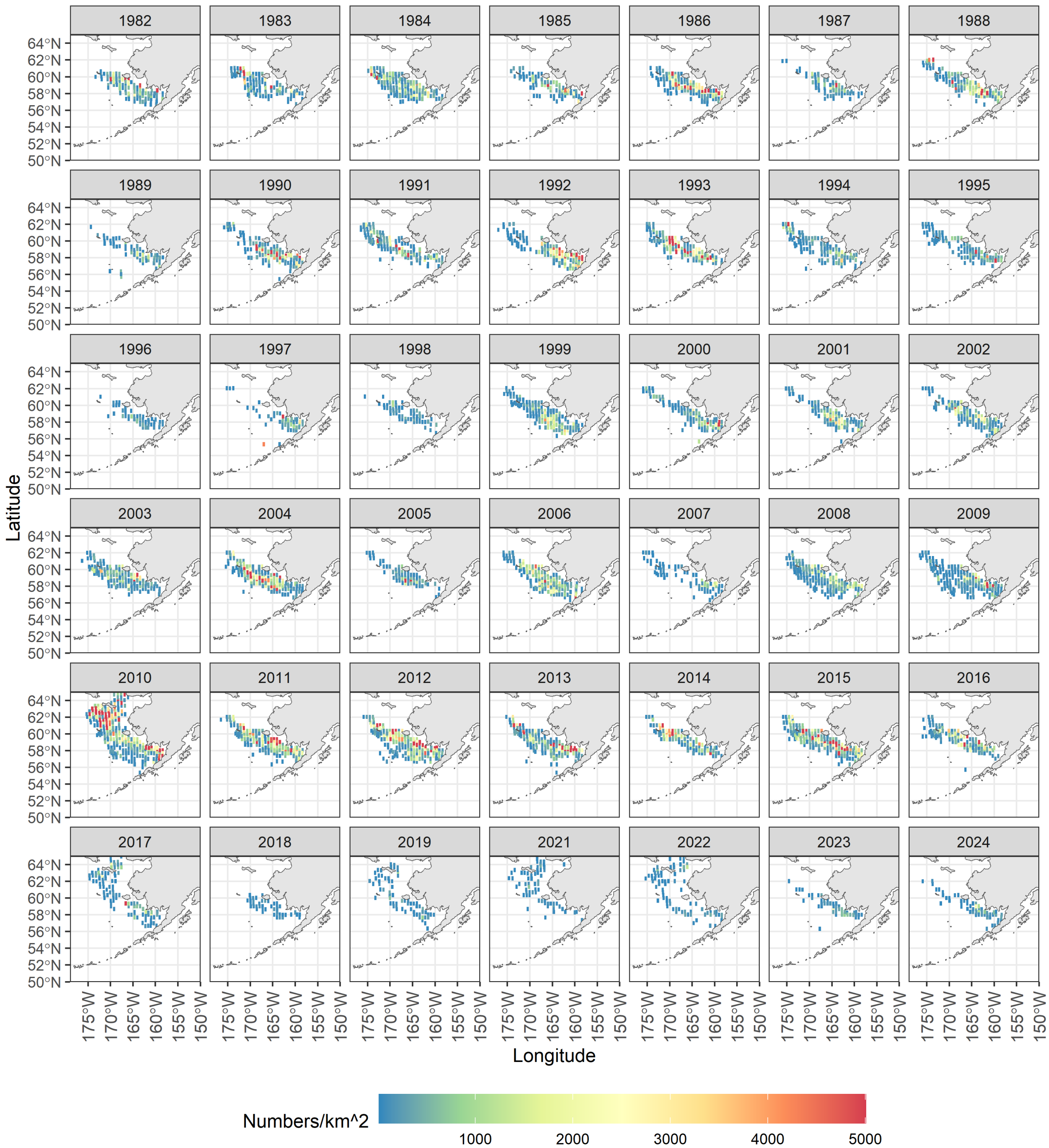

Figure 3: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for Pacific capelin (zoom for detail).

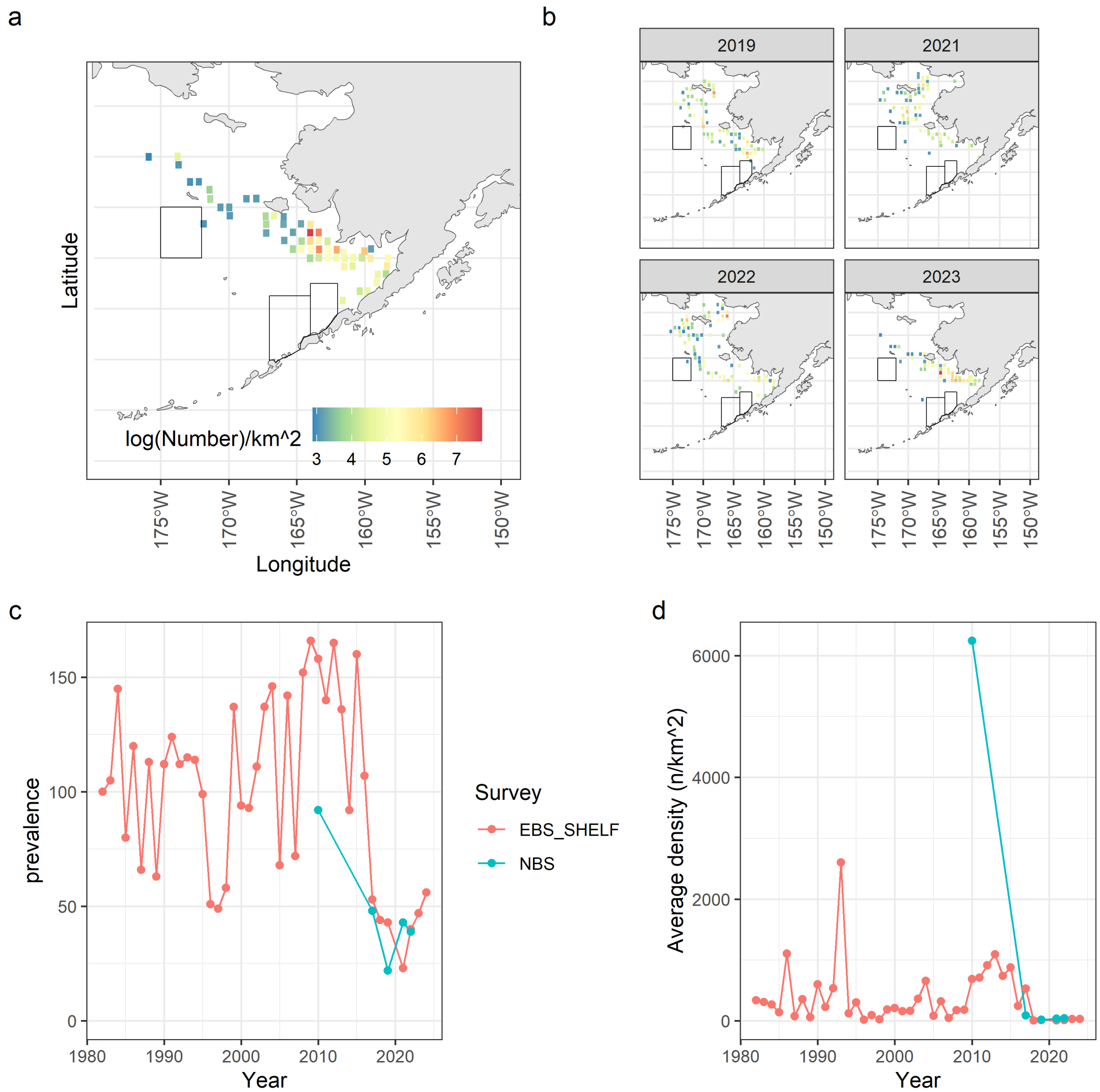

Figure 4: Pacific capelin survey data. Spatial density in BSAI bottom trawl surveys (a), spatial densities in the previous four years for which survey data was available (b), prevalence in terms of the number of survey stations that returned positive tows for this species (c), and average densities split by survey location in the BSAI (d).

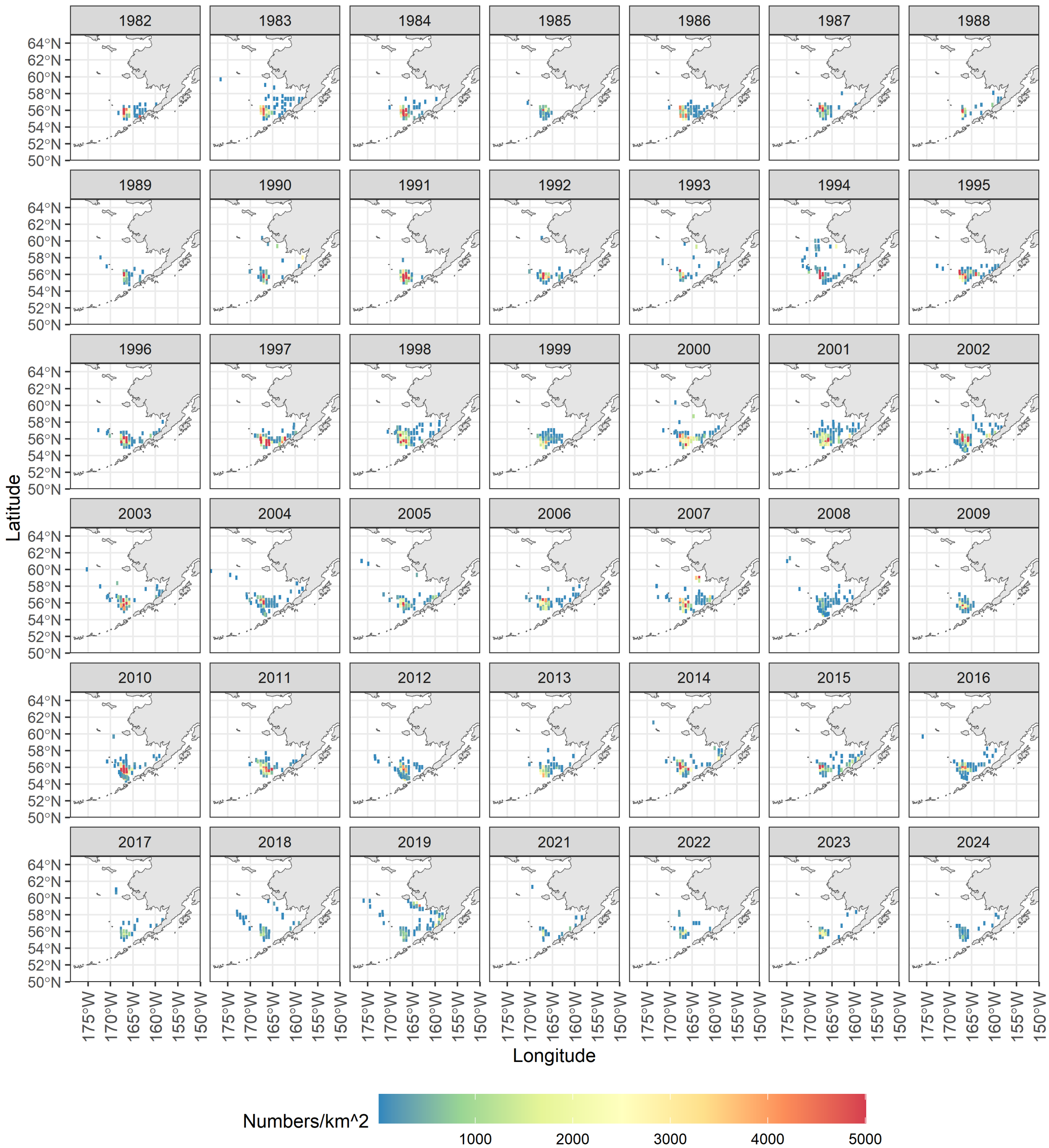

Figure 5: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for eulachon (zoom for detail).

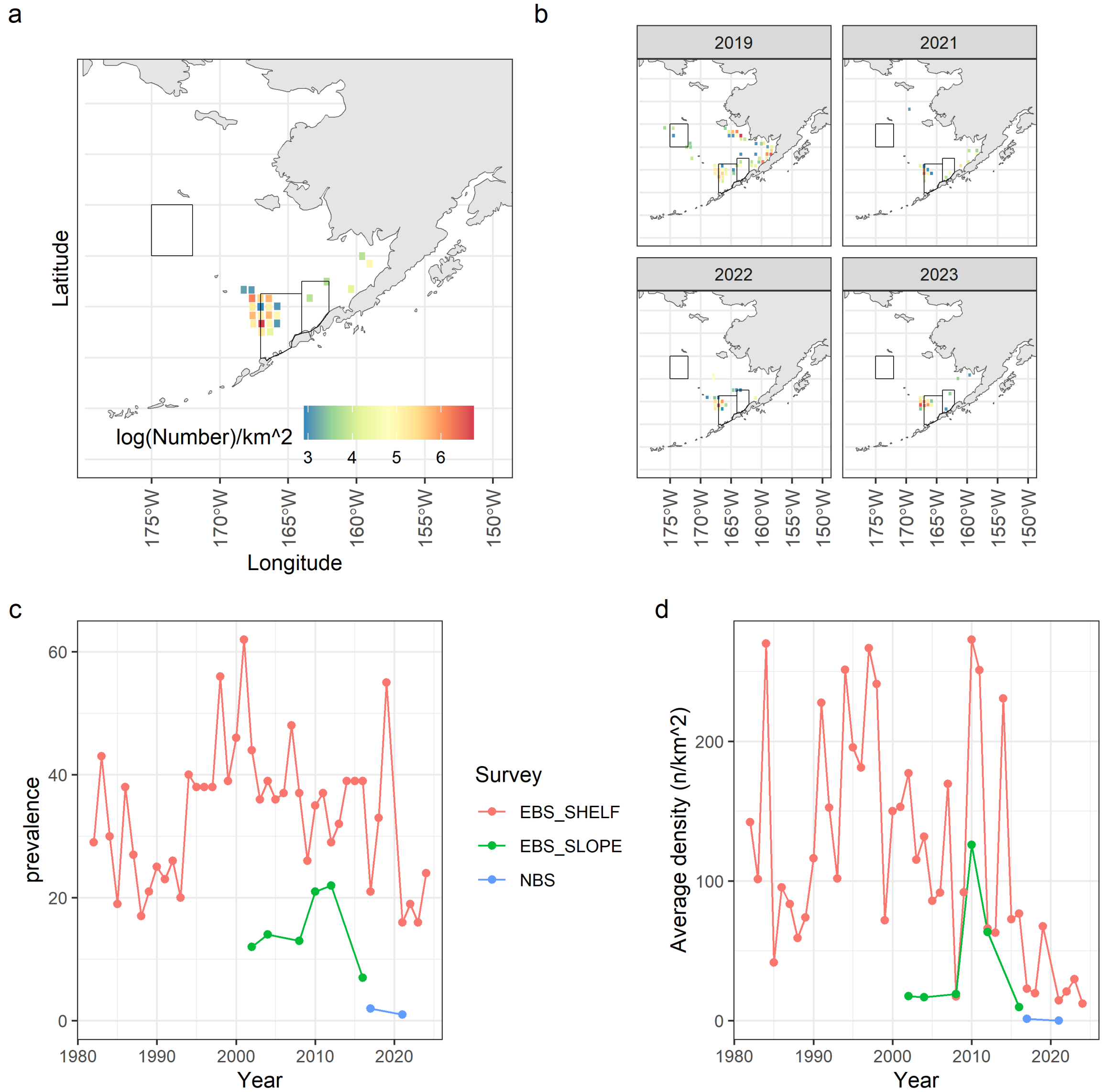

Figure 6: Eulachon survey data. Spatial density in BSAI bottom trawl surveys (a), spatial densities in the previous four years for which survey data was available (b), prevalence in terms of the number of survey stations that returned positive tows for this species (c), and average densities split by survey location in the BSAI (d).

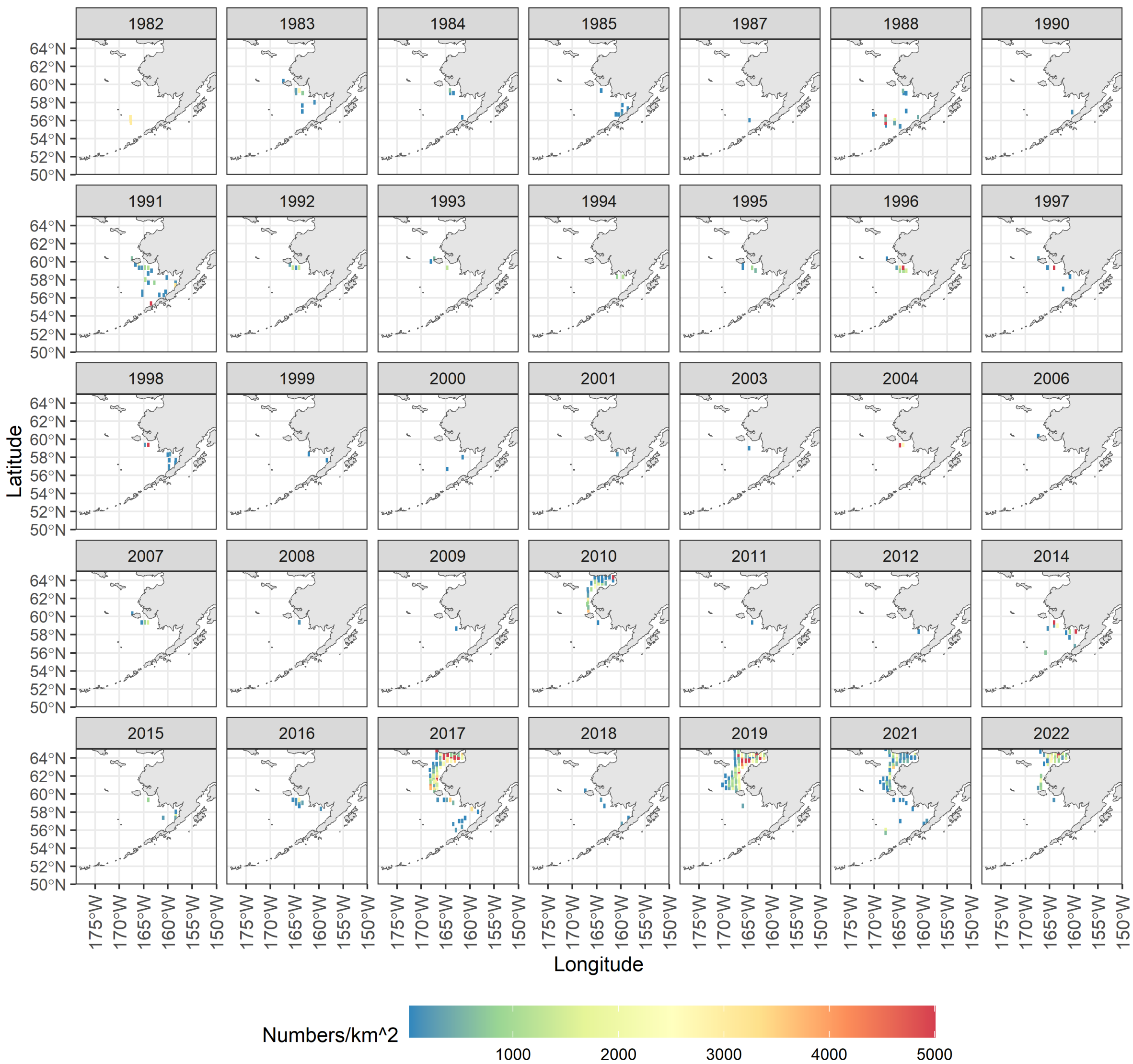

Figure 7: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for rainbow smelt(zoom for detail).

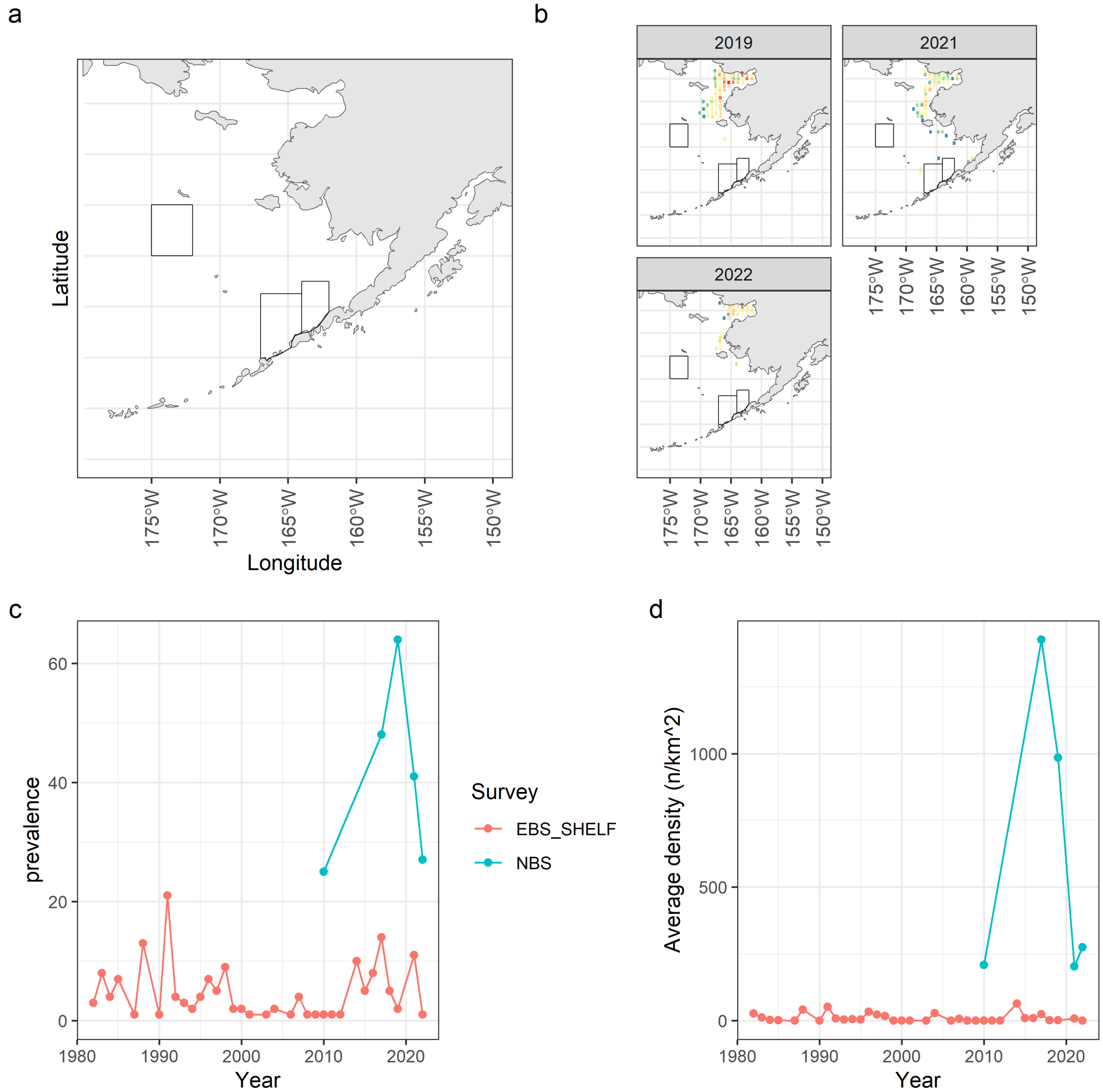

Figure 8: Rainbow smelt survey data. Spatial density in BSAI bottom trawl surveys (a), spatial densities in the previous four years for which survey data was available (b), prevalence in terms of the number of survey stations that returned positive tows for this species (c), and average densities split by survey location in the BSAI (d).

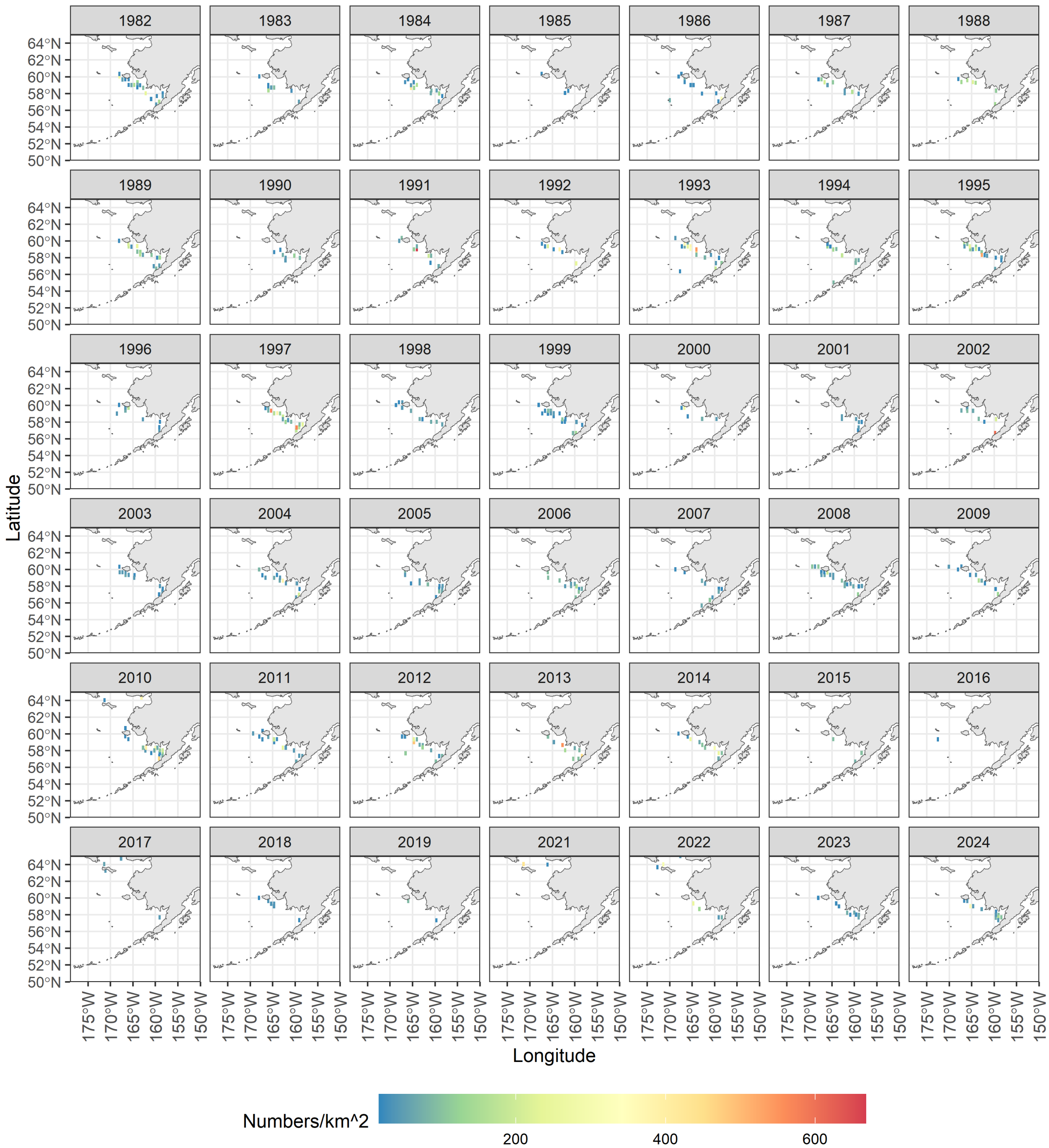

Figure 9: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for rainbow smelt(zoom for detail).

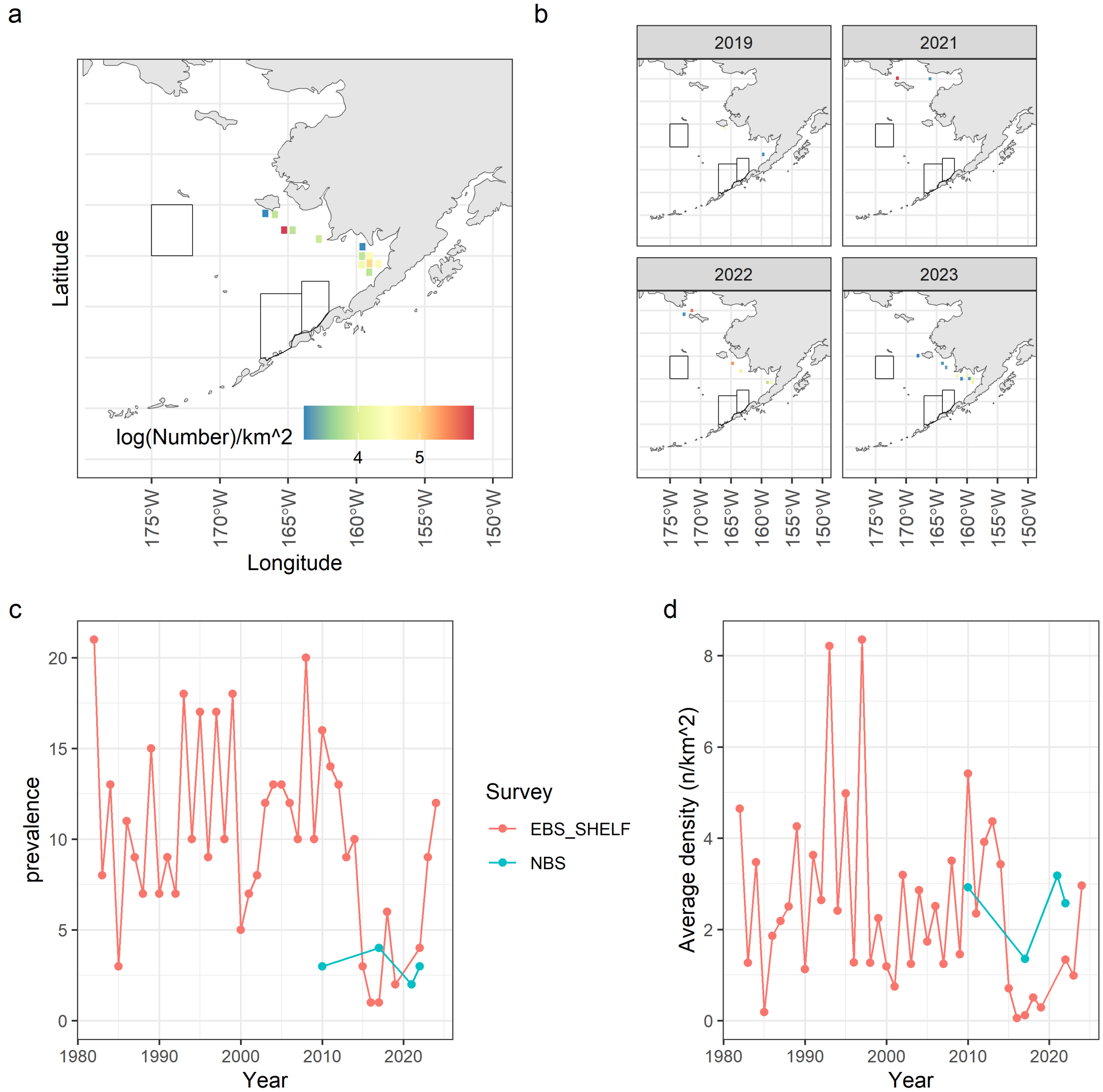

Figure 10: Pacific sand lance survey data. Spatial density in BSAI bottom trawl surveys (a), spatial densities in the previous four years for which survey data was available (b), prevalence in terms of the number of survey stations that returned positive tows for this species (c), and average densities split by survey location in the BSAI (d).

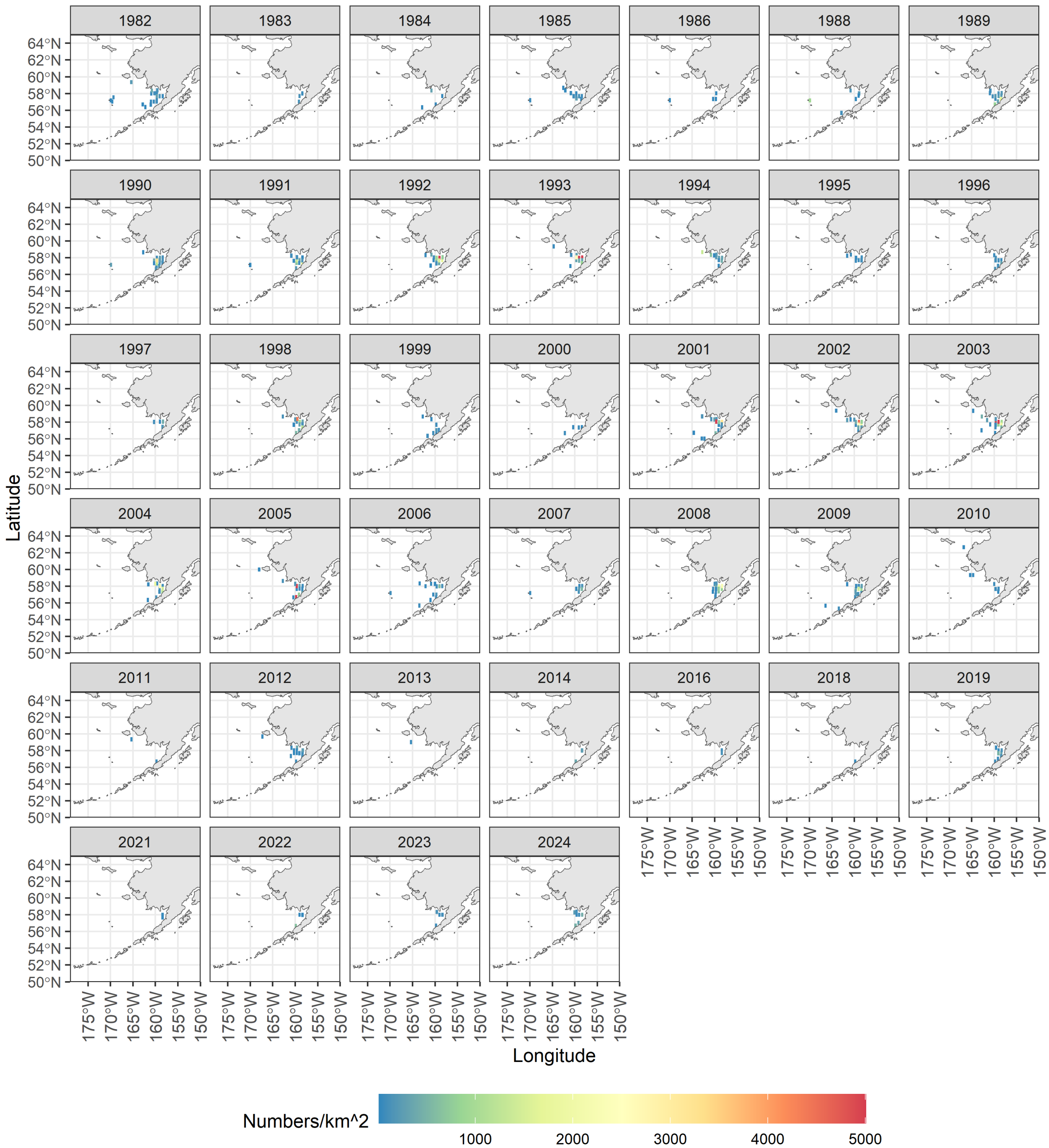

Figure 11: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for Pacific sandfish(zoom for detail).

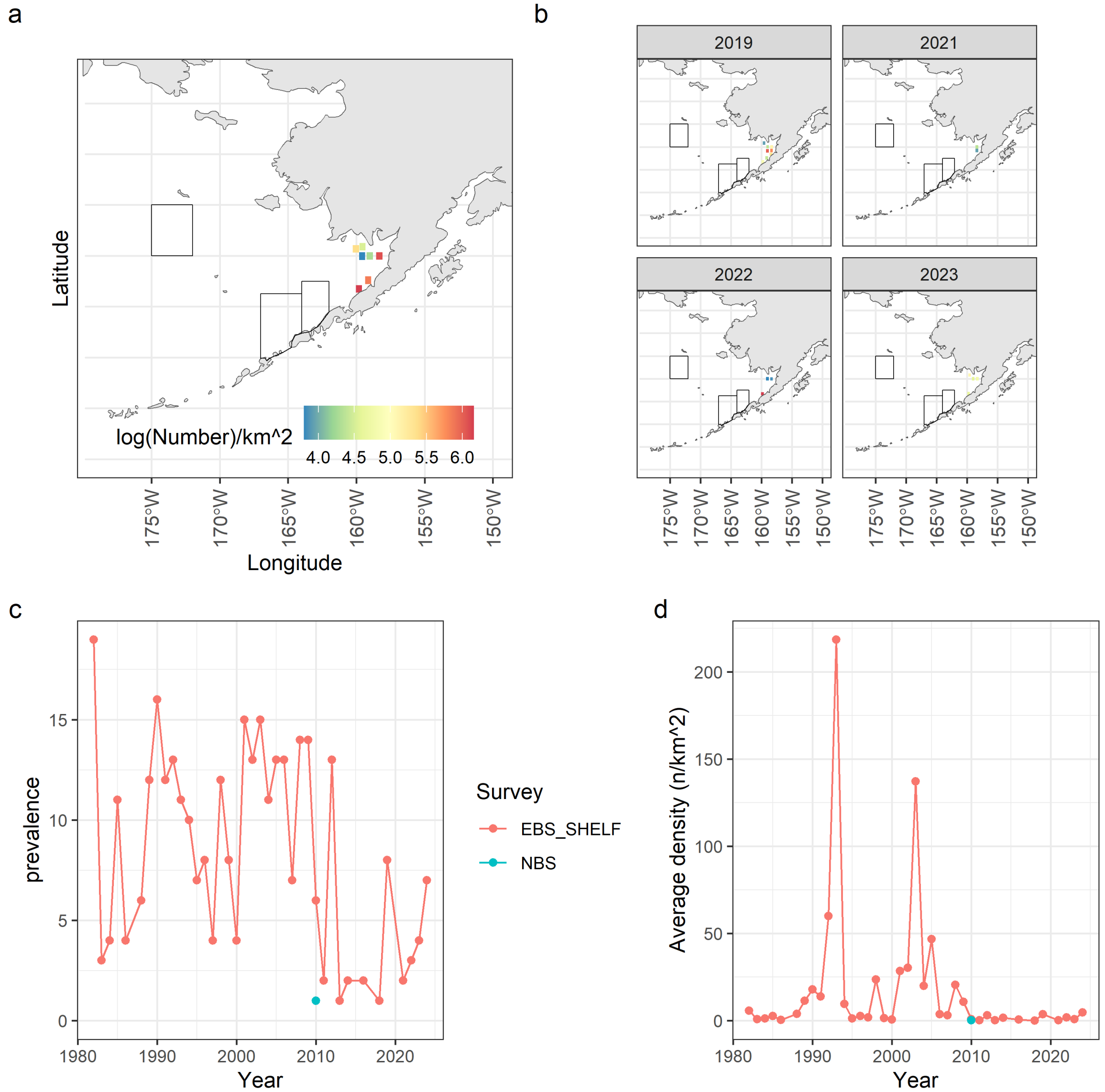

Figure 12: Pacific sandfish survey data. Spatial density in BSAI bottom trawl surveys (a), spatial densities in the previous four years for which survey data was available (b), prevalence in terms of the number of survey stations that returned positive tows for this species (c), and average densities split by survey location in the BSAI (d).

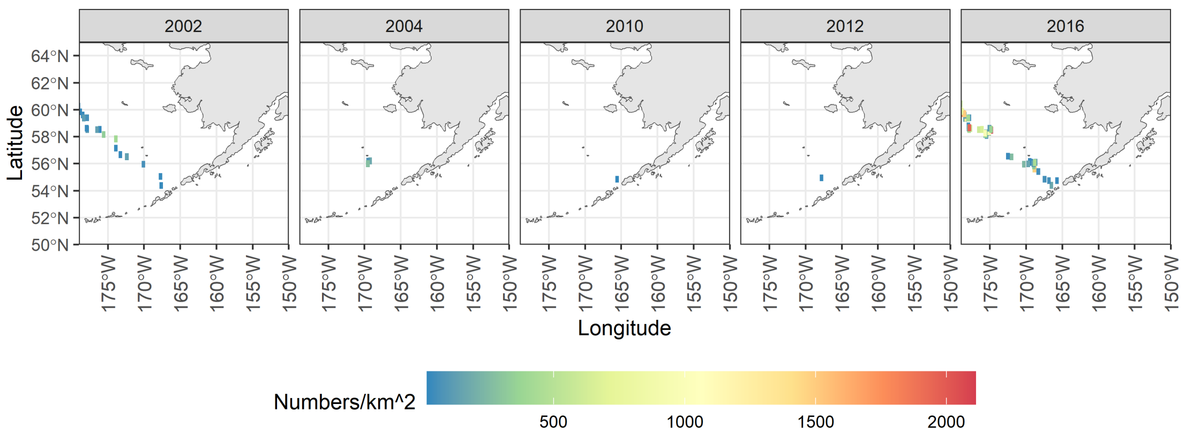

Figure 13: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for Pacific mytophids (zoom for detail).

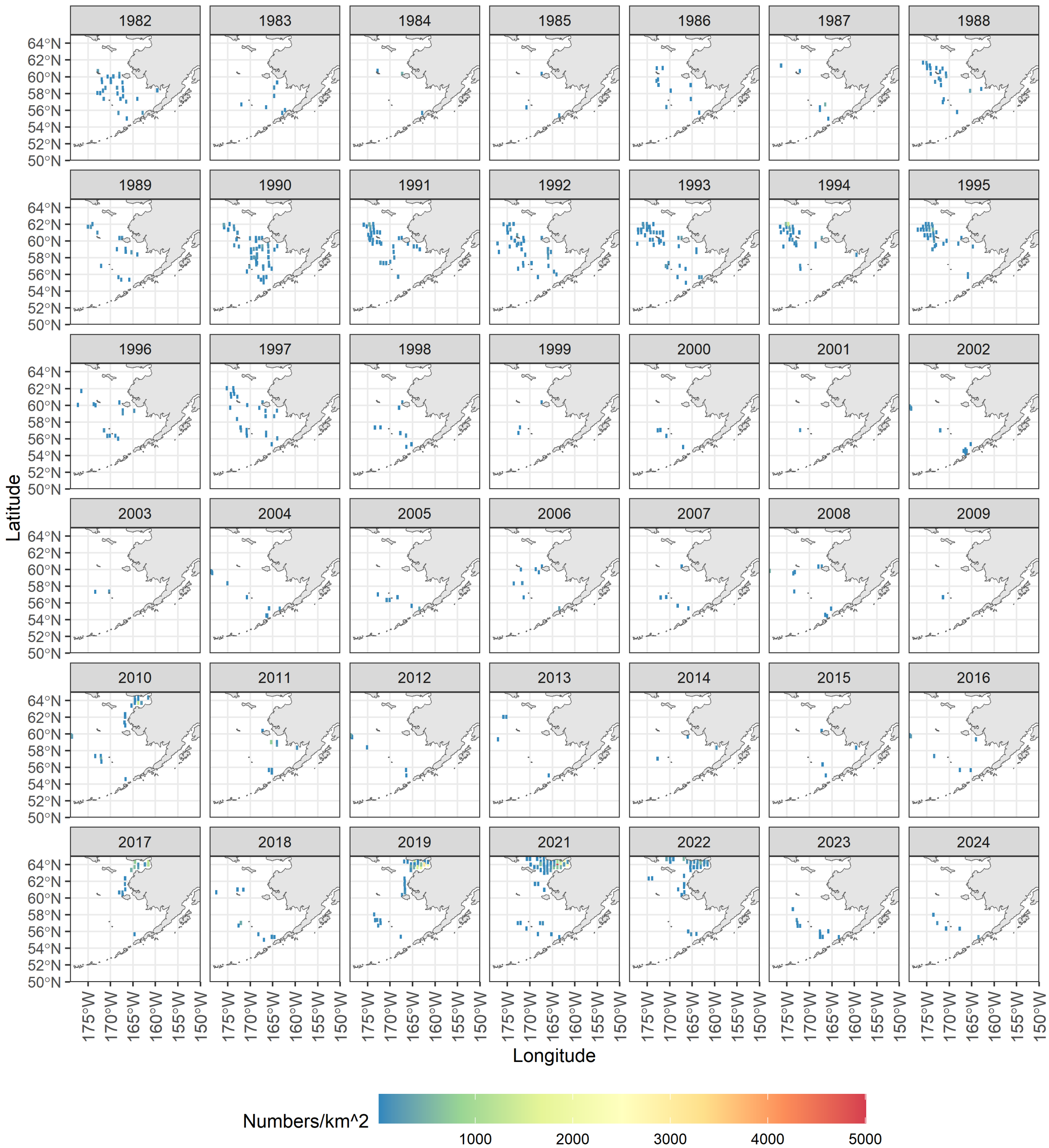

Figure 14: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for pricklebacks (zoom for detail).

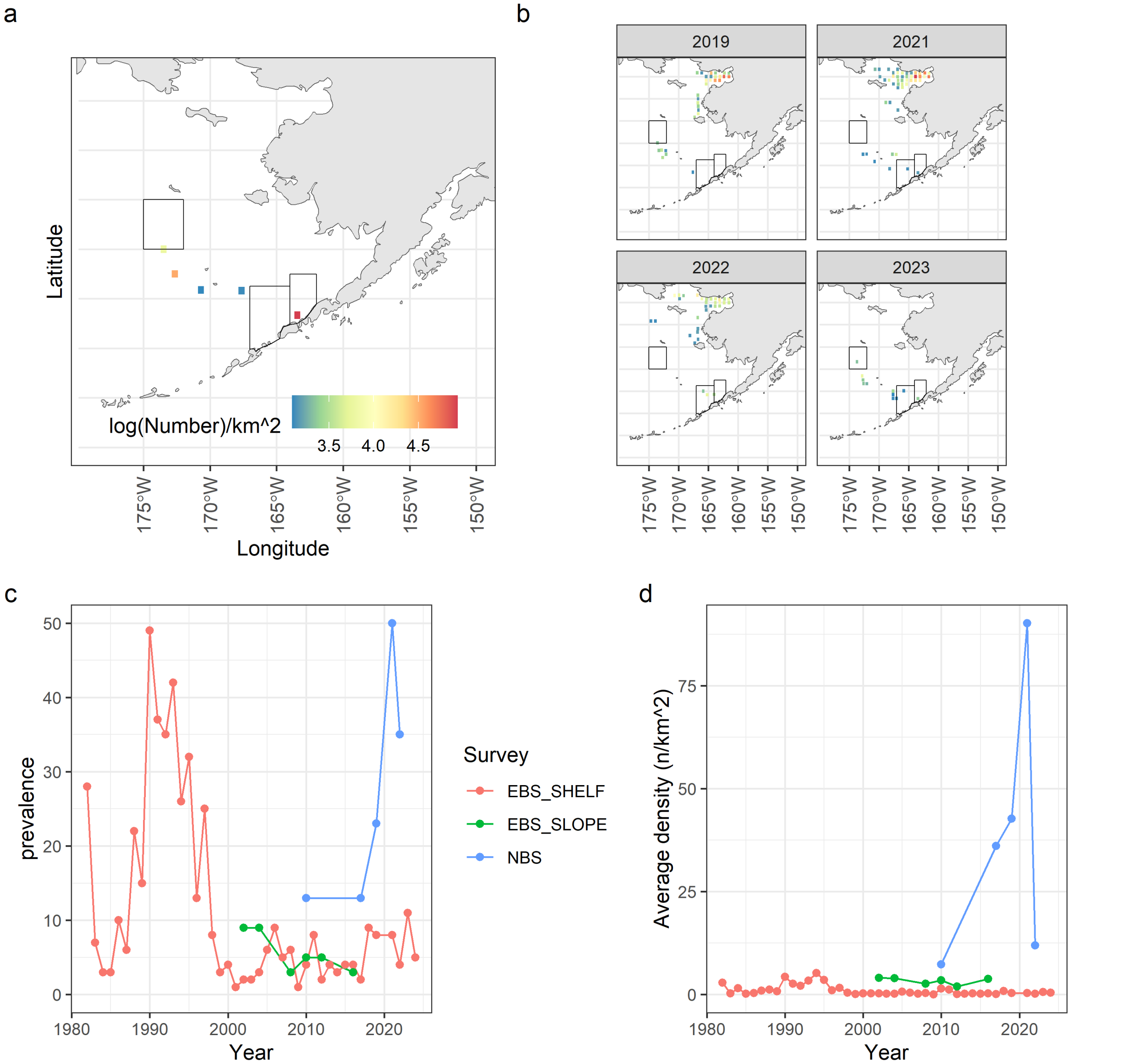

Figure 15: Prickleback survey data. Spatial density in BSAI bottom trawl surveys (a), spatial densities in the previous four years for which survey data was available (b), prevalence in terms of the number of survey stations that returned positive tows for this species (c), and average densities split by survey location in the BSAI (d).

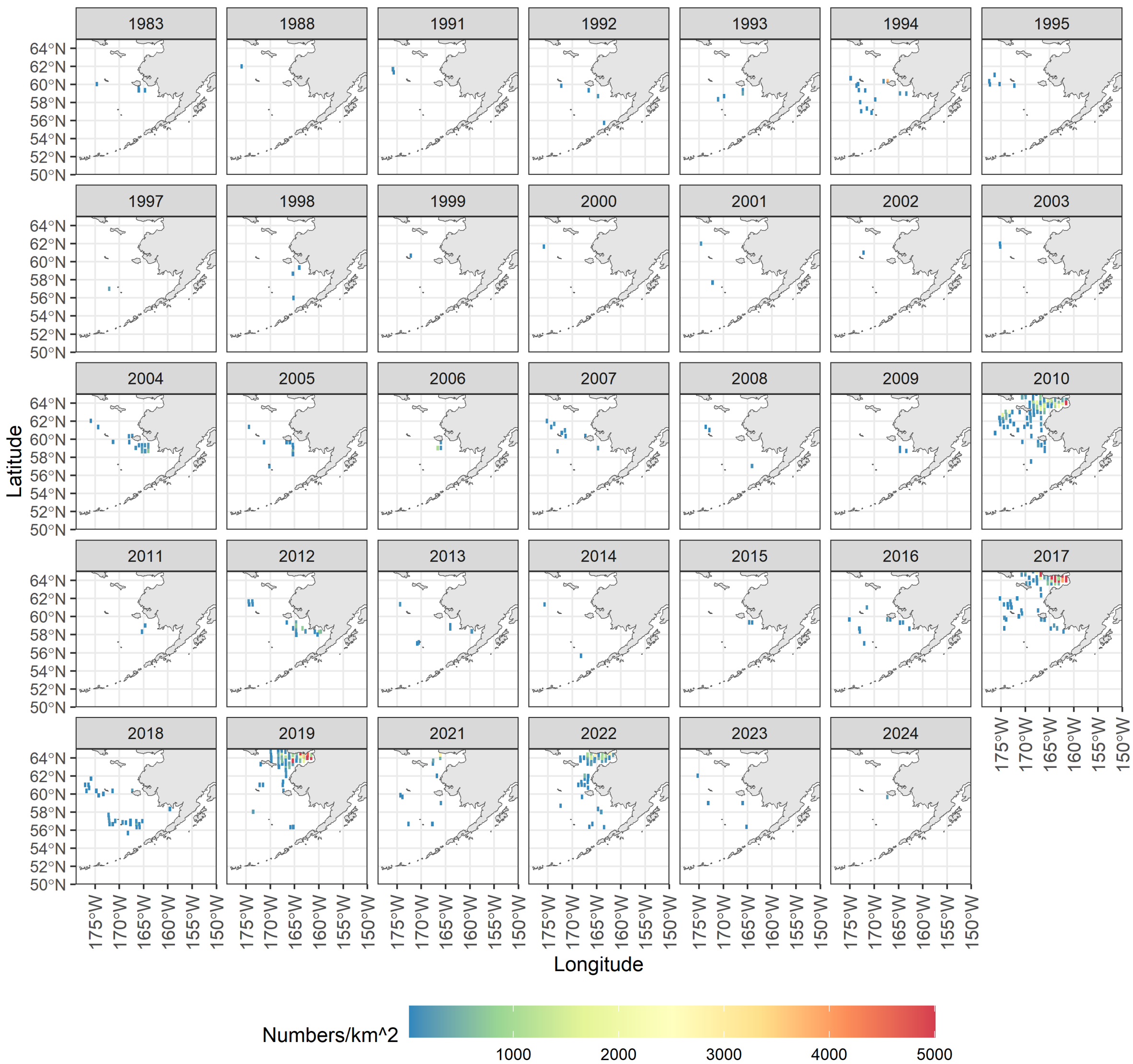

Figure 16: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for eelblennies (zoom for detail).

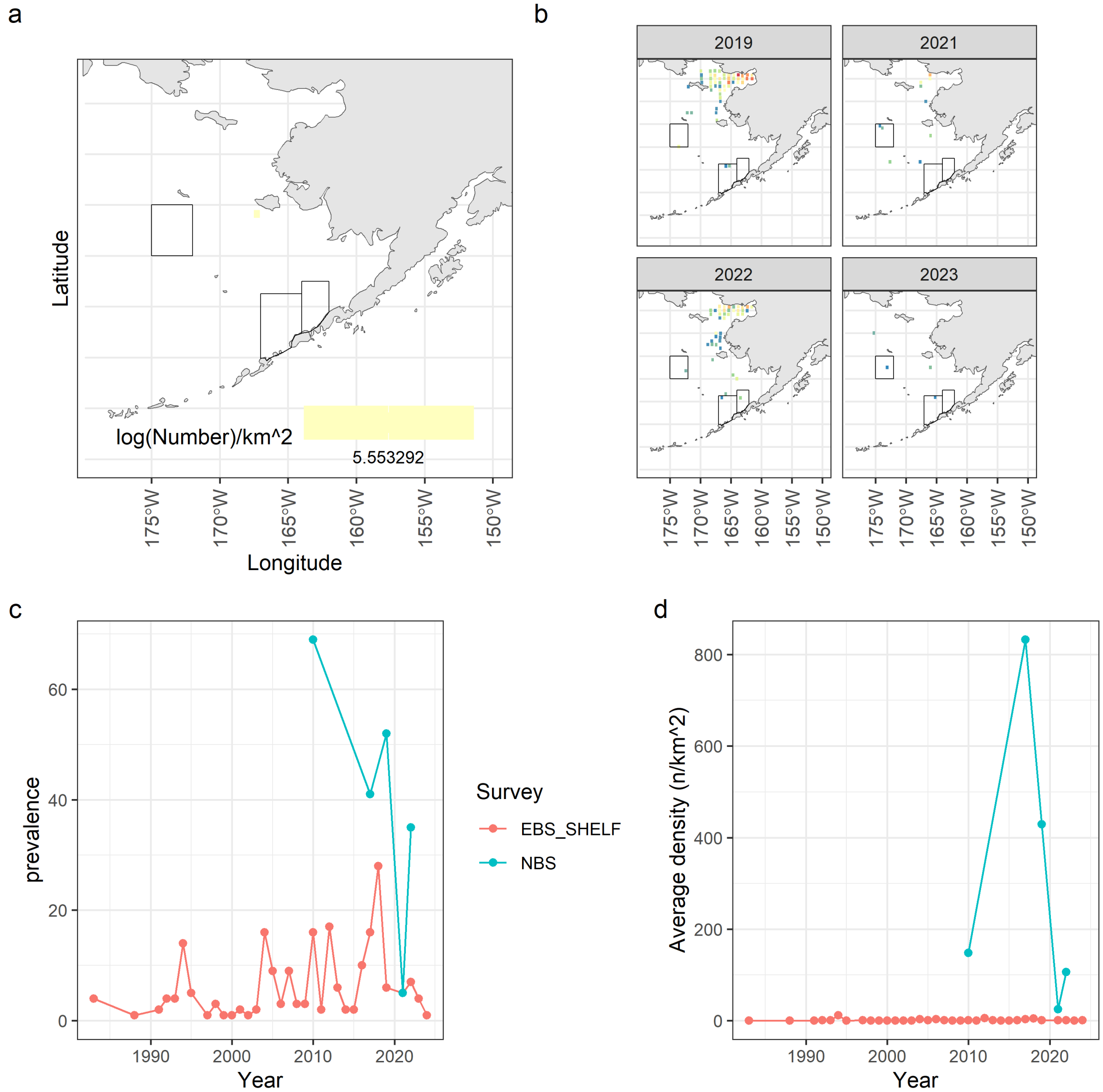

Figure 17: Eelblenny survey data. Spatial density in BSAI bottom trawl surveys (a), spatial densities in the previous four years for which survey data was available (b), prevalence in terms of the number of survey stations that returned positive tows for this species (c), and average densities split by survey location in the BSAI (d).

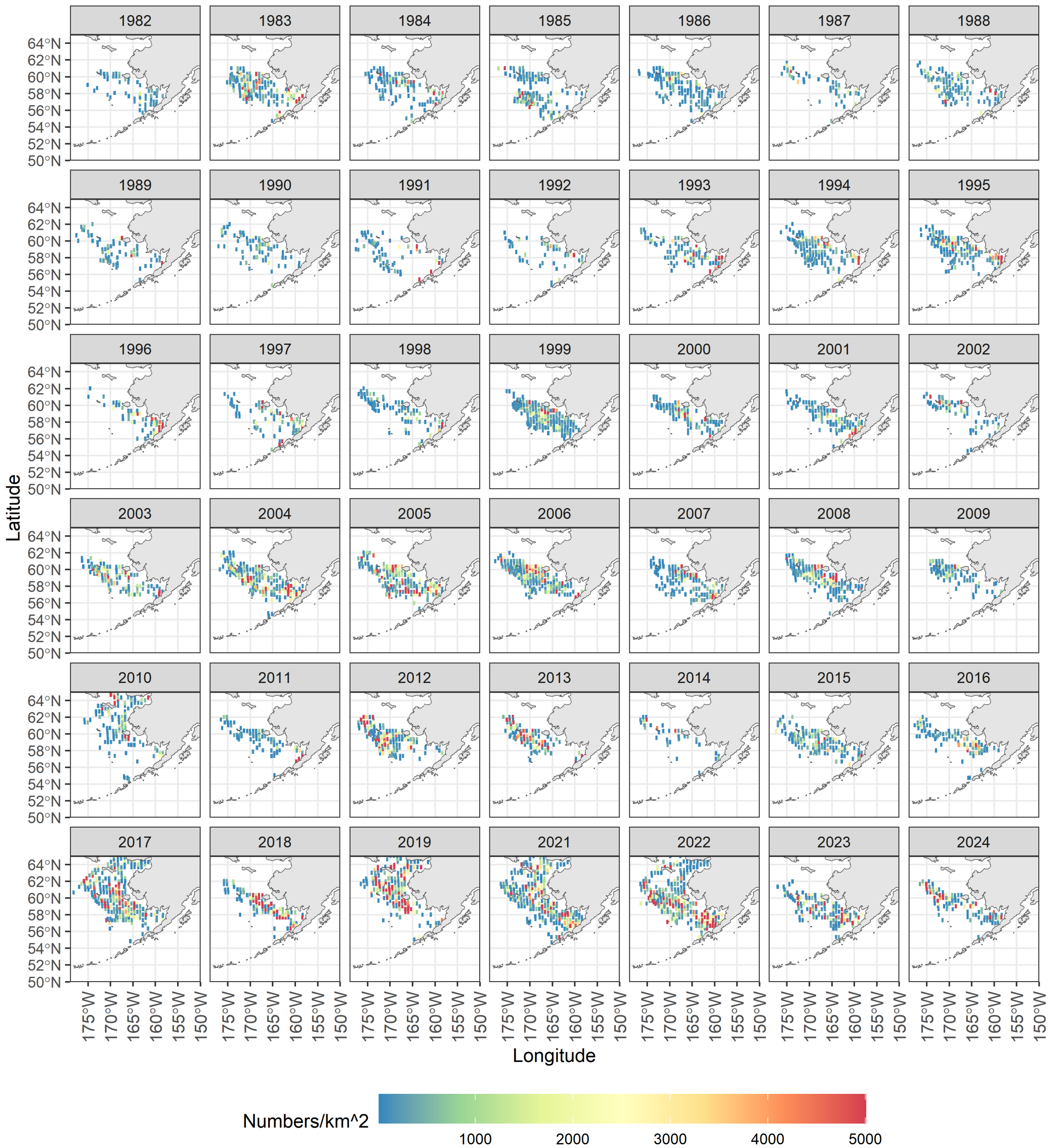

Figure 18: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for Pacific herring (zoom for detail).

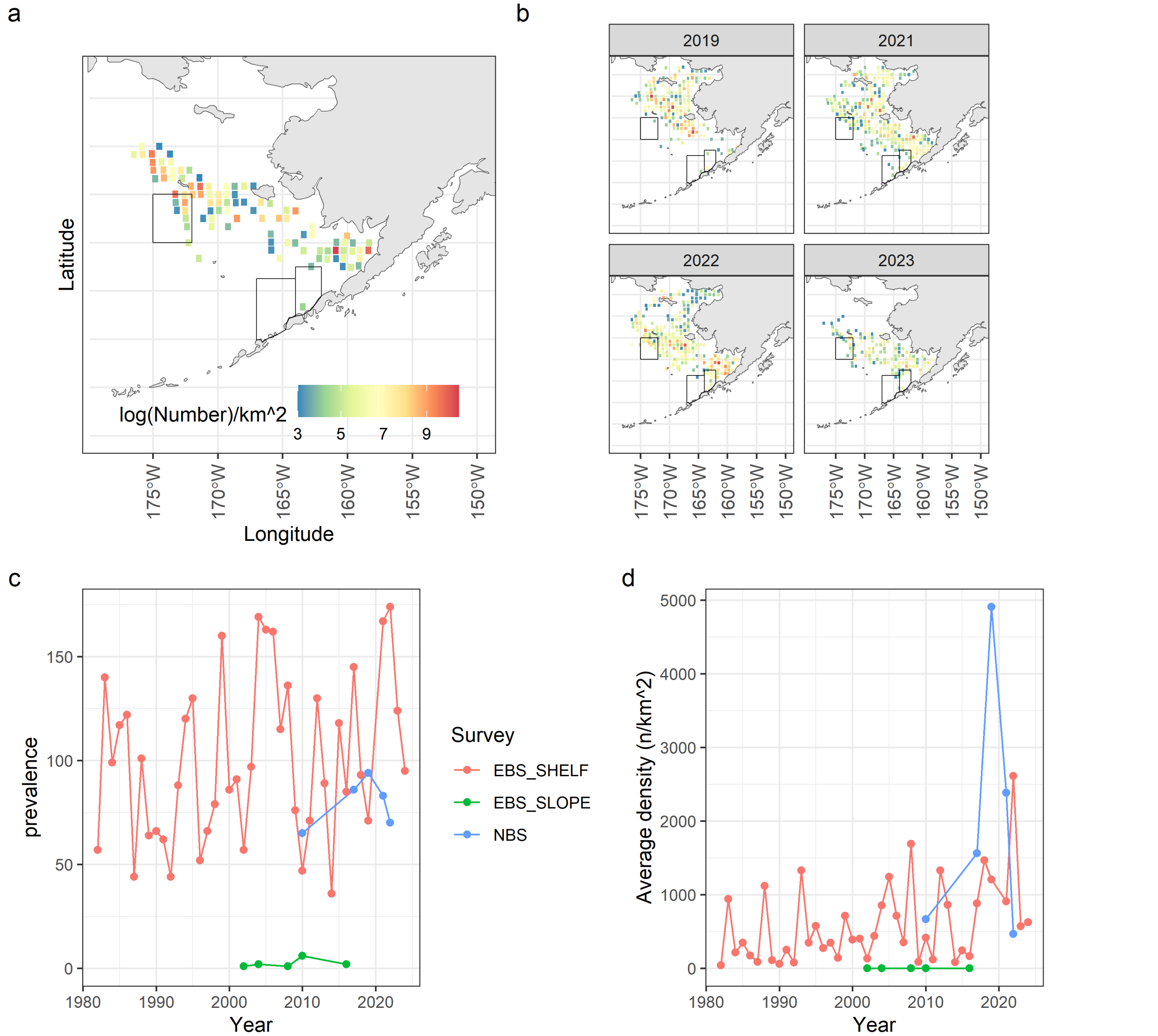

Figure 19: Pacific herring survey data. Spatial density in BSAI bottom trawl surveys (a), spatial densities in the previous four years for which survey data was available (b), prevalence in terms of the number of survey stations that returned positive tows for this species (c), and average densities split by survey location in the BSAI (d).

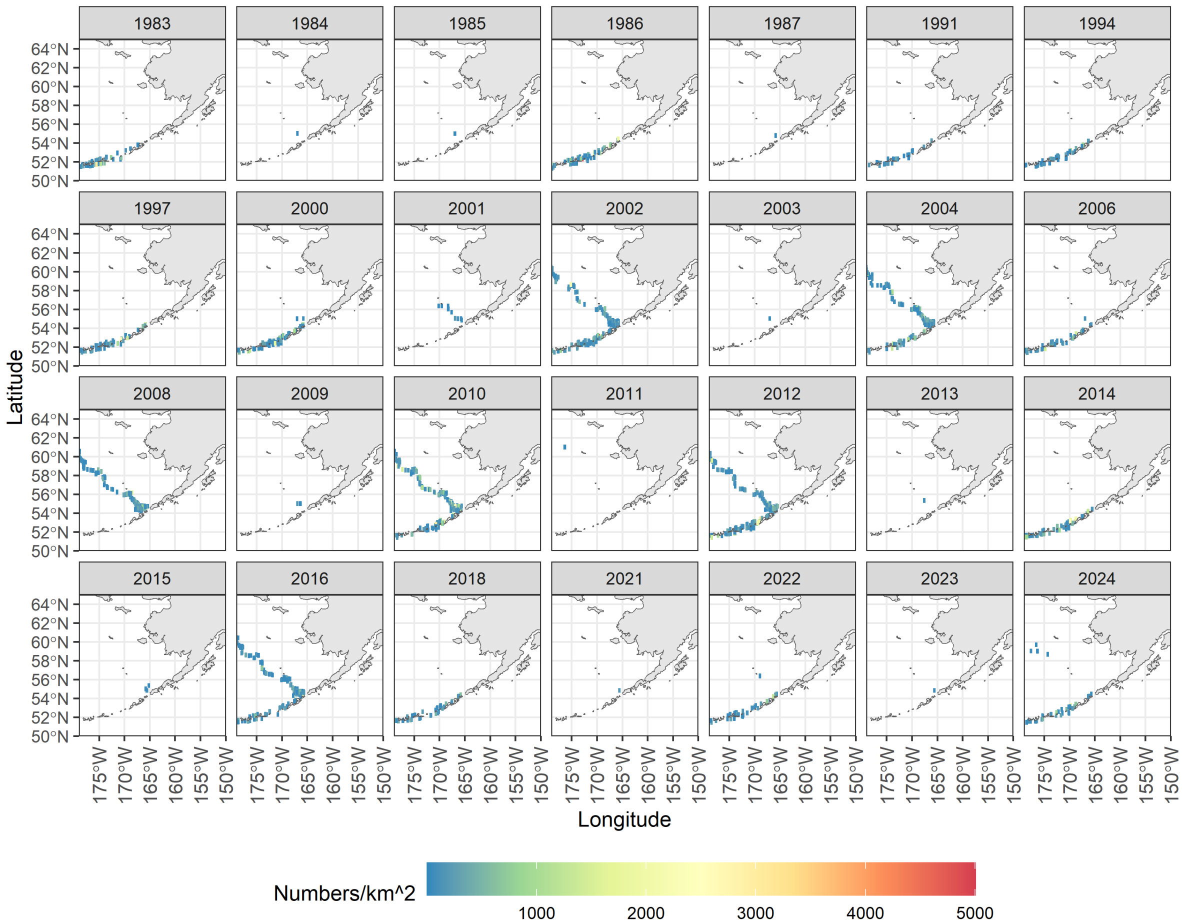

Figure 20: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for squid (zoom for detail).

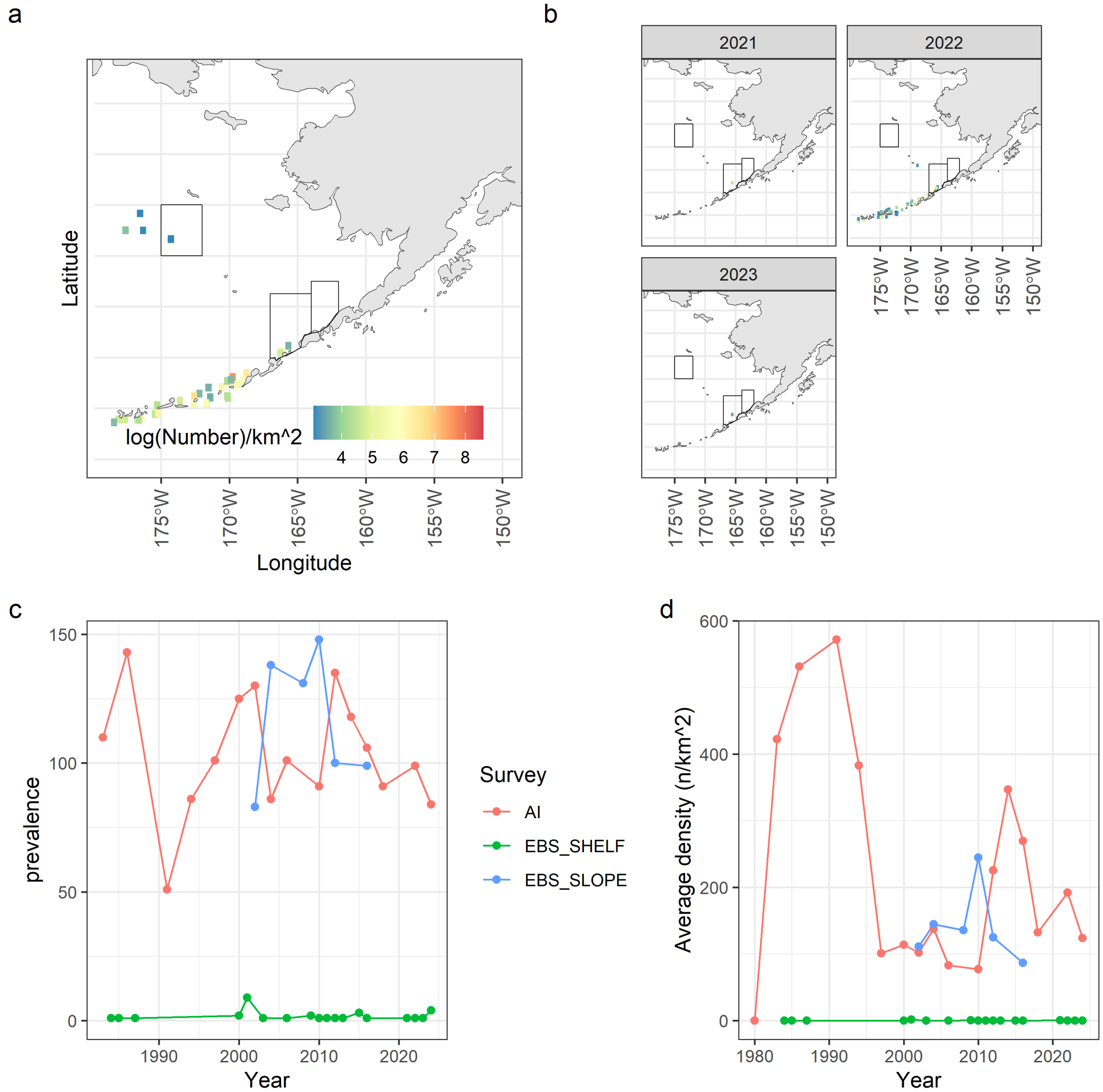

Figure 21: Squid survey data. Spatial density in BSAI bottom trawl surveys (a), spatial densities in the previous four years for which survey data was available (b), prevalence in terms of the number of survey stations that returned positive tows for this species (c), and average densities split by survey location in the BSAI (d).

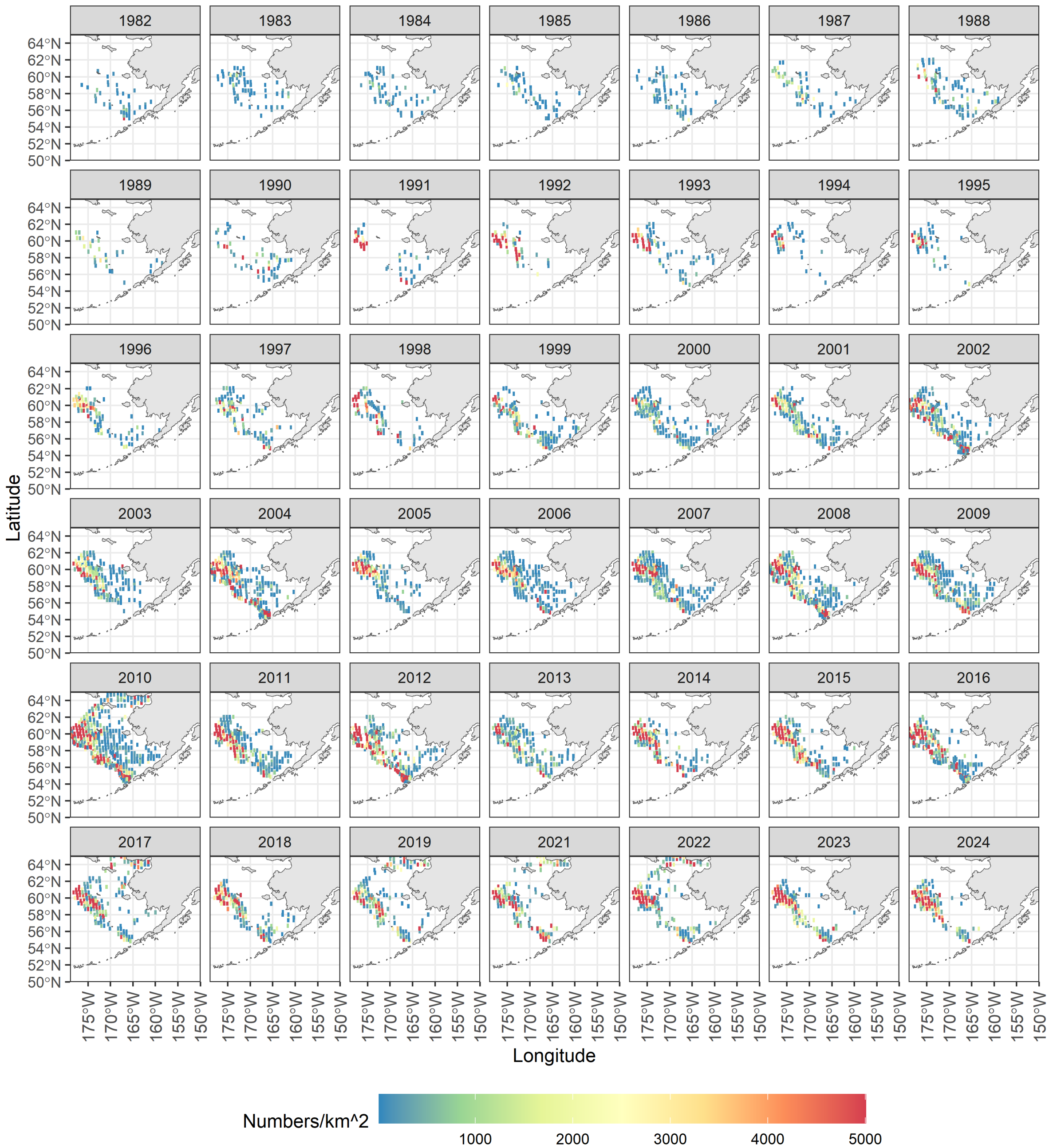

Figure 22: Map of distribution of prevalence and density from the BSAI bottom trawl surveys for shrimp (zoom for detail).

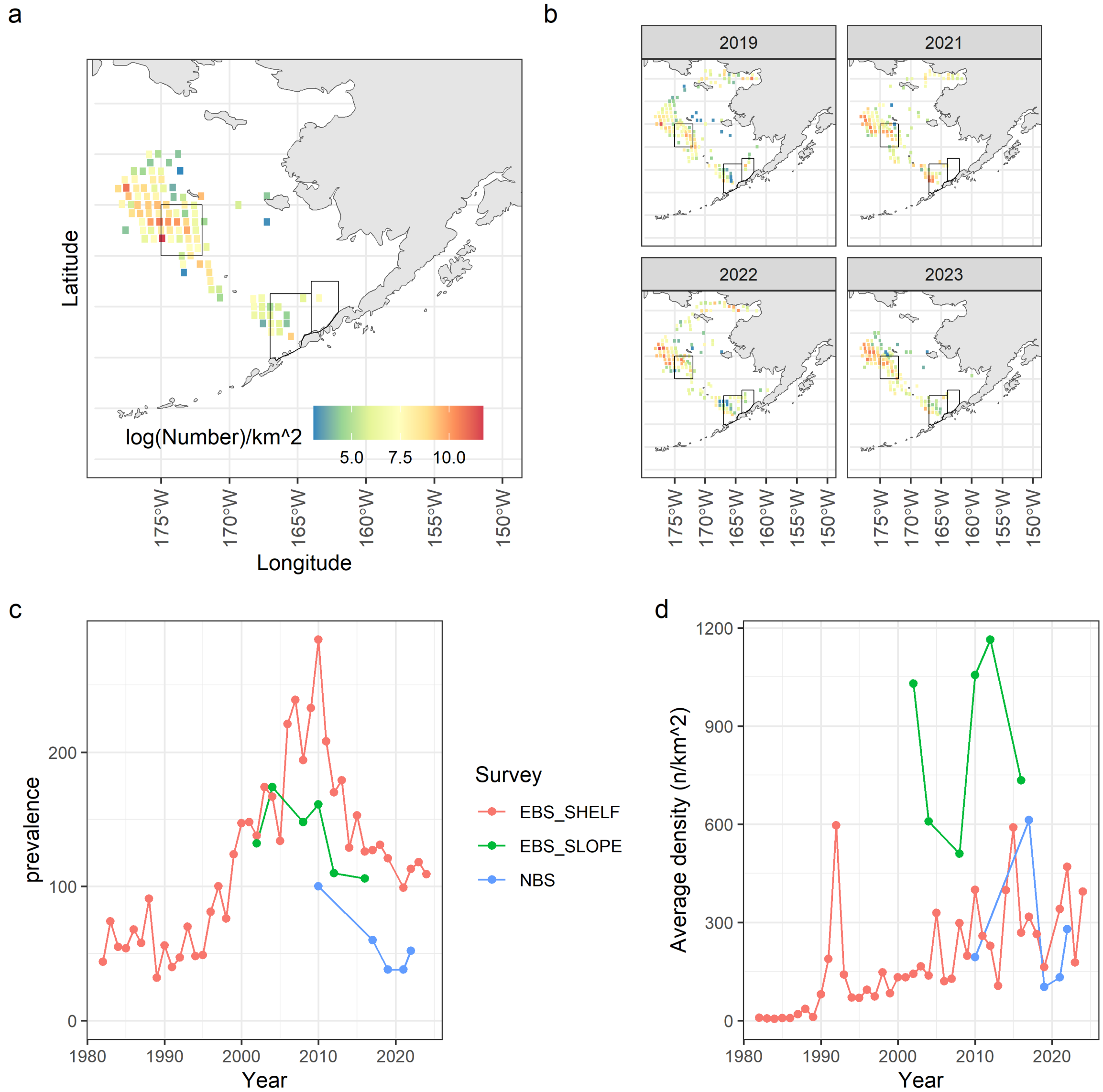

Figure 23: Shrimp survey data. Spatial density in BSAI bottom trawl surveys (a), spatial densities in the previous four years for which survey data was available (b), prevalence in terms of the number of survey stations that returned positive tows for this species (c), and average densities split by survey location in the BSAI (d).

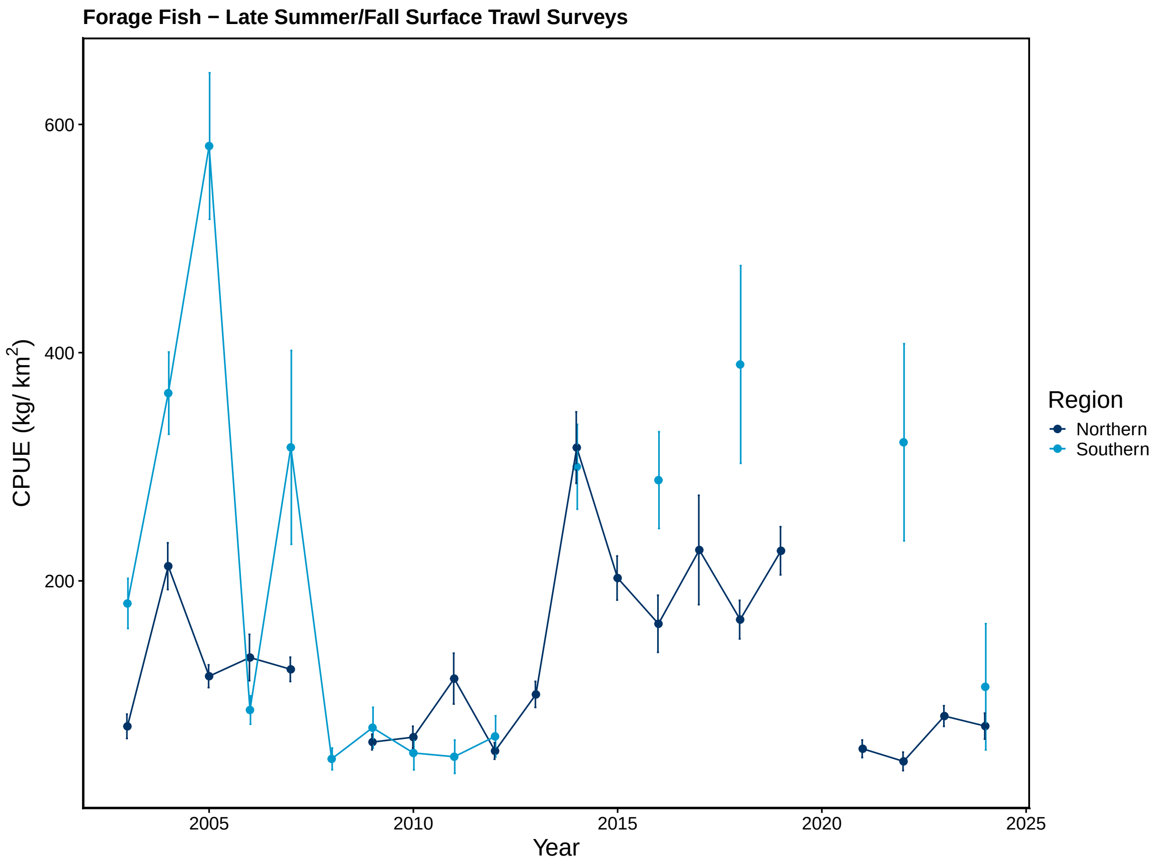

Figure 24: Index of forage abundance developed based on the BASIS pelagic trawls. Error bars represent 95% confidence intervals.

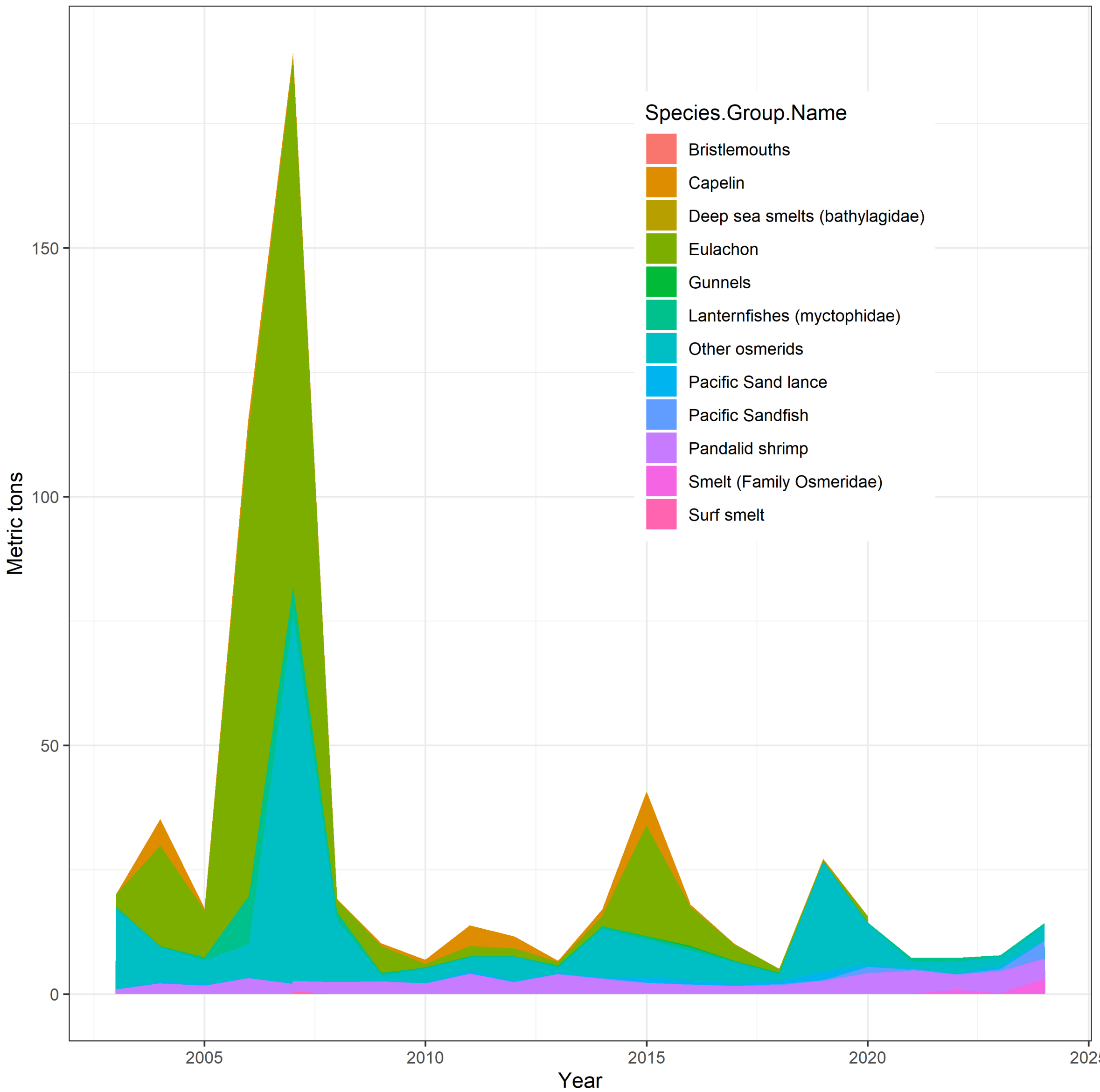

Figure 25: Incidental catches of fishes in federal fisheries in the BSAI FMP forage group (2003-2024).

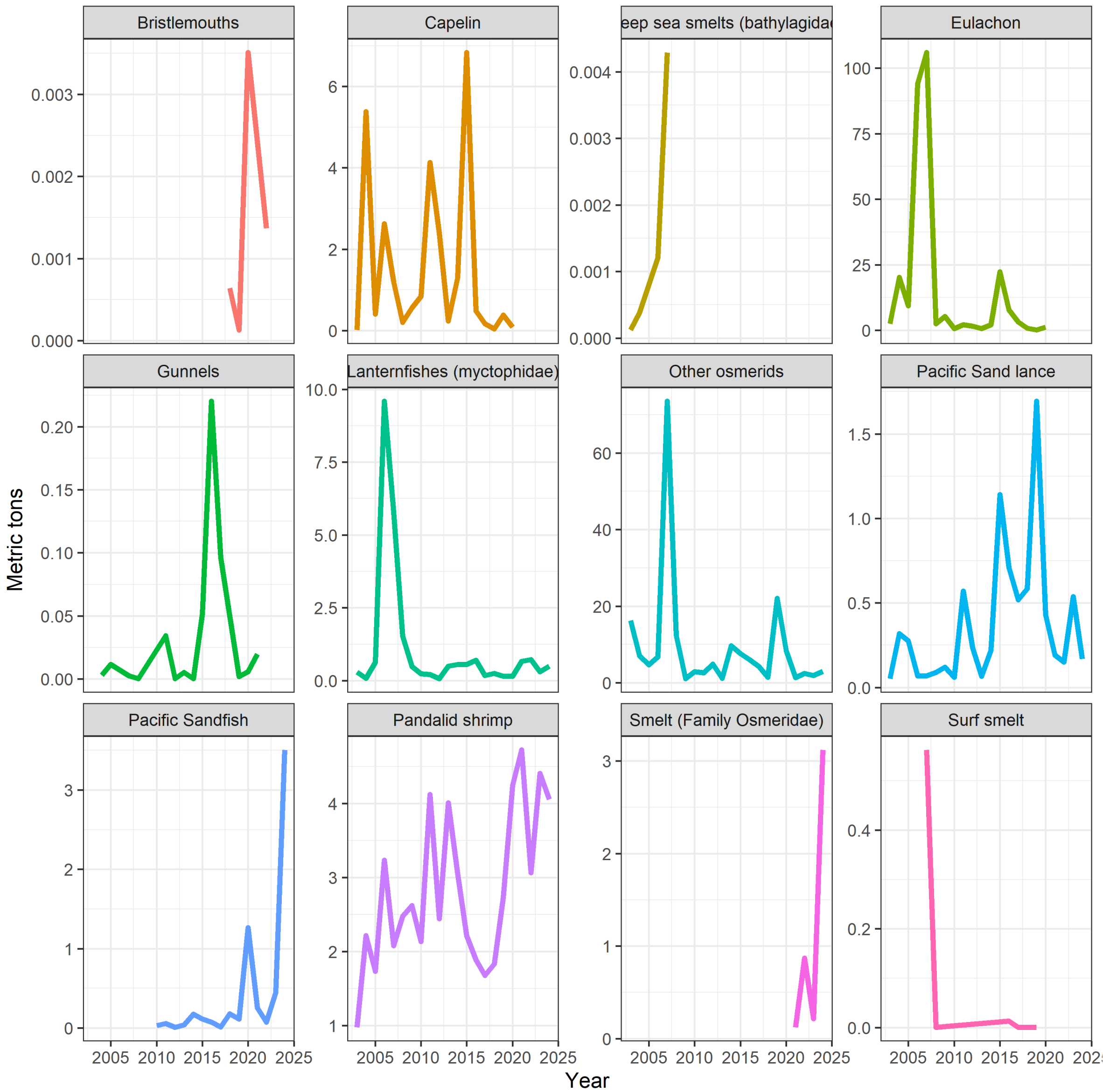

Figure 26: Incidental catches of fishes in federal fisheries in the BSAI FMP forage group (2003-2024).

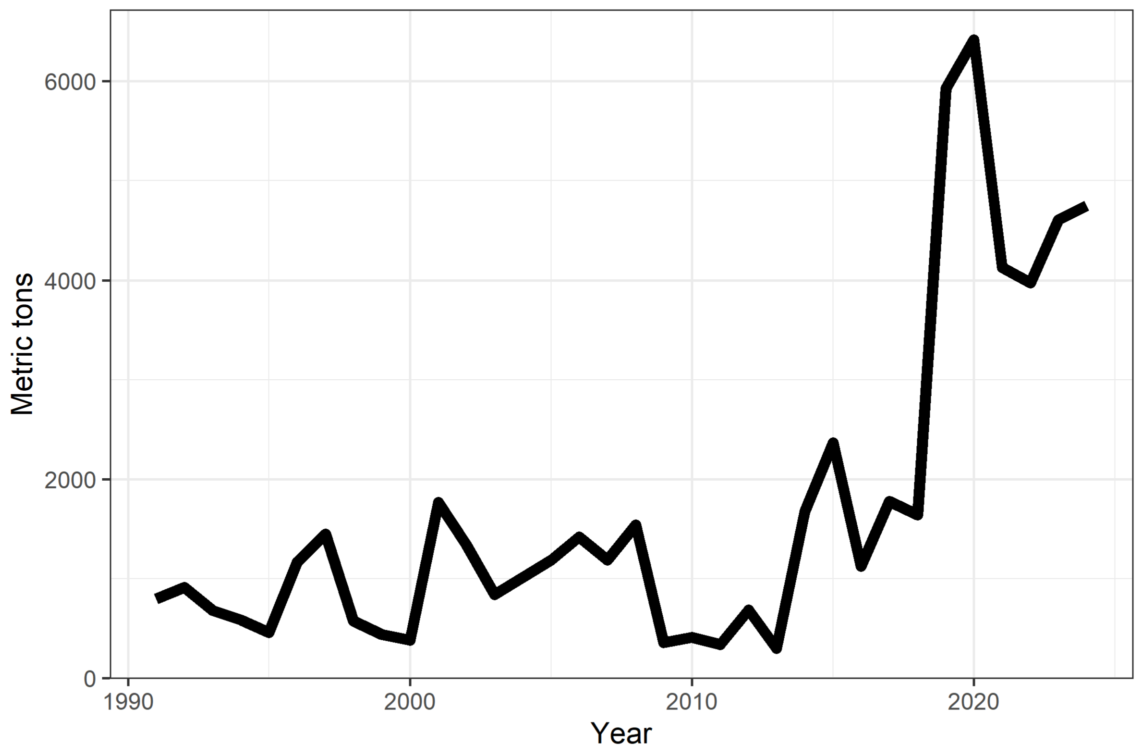

Figure 27: Incidental catches of squid in federal fisheries in the BSAI.

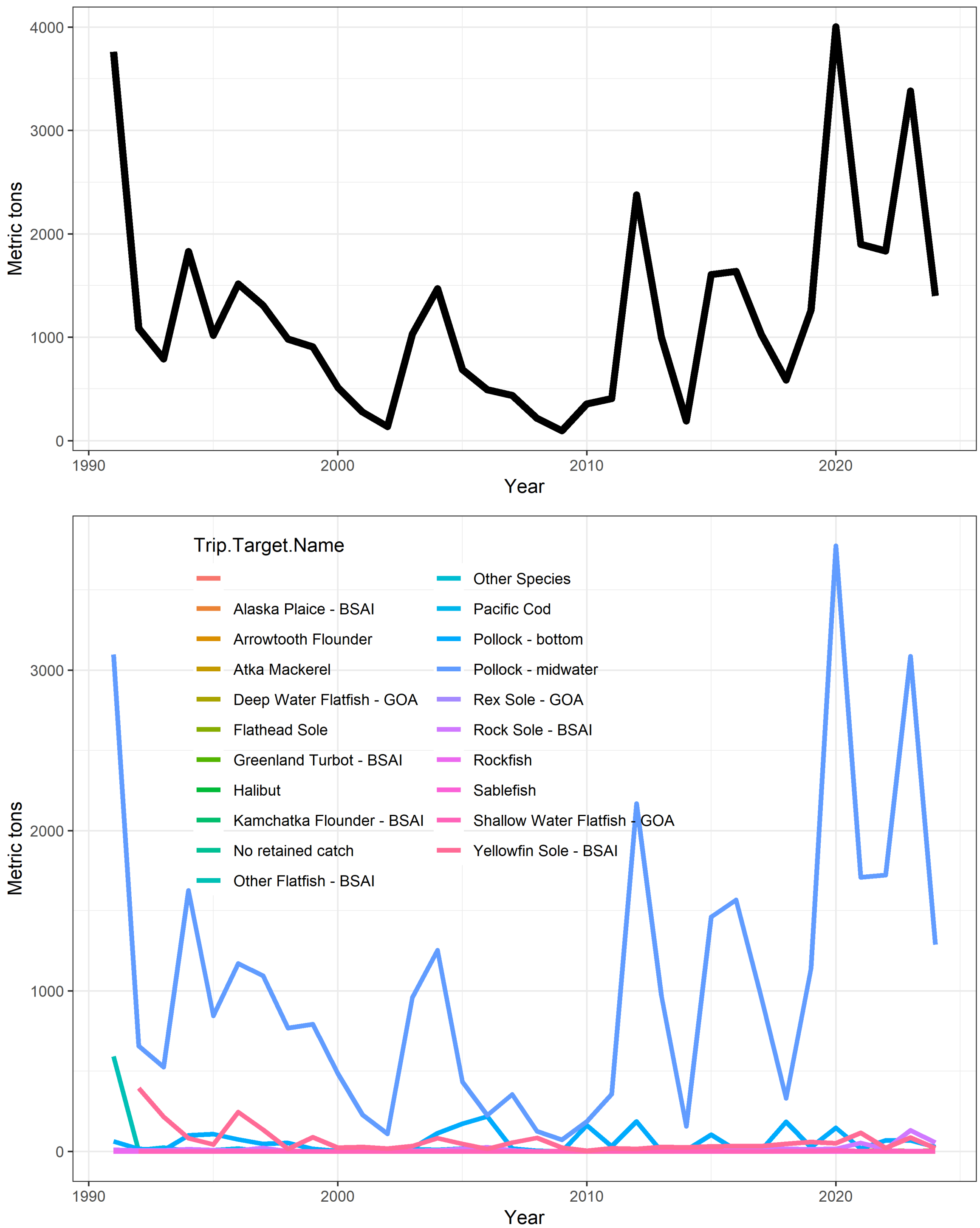

Figure 28: Incidental catches of Pacific herring in federal fisheries in the BSAI, delineated by target fishery.

Gulf of Alaska

In the past, this forage species report for the Gulf of Alaska (GOA) region was prepared and presented to the GOA Plan Team and the North Pacific Fishery Management Council (NPFMC) in even years. Going forward, it will be combined with the BSAI and continue on an even year cycle. This report is not a formal stock assessment; it is a presentation of the available data on trends in abundance and distribution of forage populations and a description of their interactions with federal fisheries through bycatch.

Forage species are a fundamental component of the GOA ecosystem, so there is overlap between the information presented here and in the Ecosystem Considerations report (https://www.fisheries.noaa.gov/alaska/ecosystems/ecosystem-status-reports-gulf-alaska-bering-sea-and-aleutian-islands). This forage report primarily displays data from the GOA bottom trawl surveys. The Ecosystem Status report contains surface-trawl surveys, euphausiid abundances from acoustic surveys, and indirect indicators of forage species abundance such as seabird breeding success and groundfish predator diets.

Estimated capelin abundance and biomass from the NMFS bottom trawl surveys had declined from near all-time highs in 2021 to historical averages in 2023, with greatest abundance in the Kodiak International North Pacific Fisheries Commission (INPFC) area. Eulachon increased slightly in 2023 compared to 2021 but remain relatively low compared compared to high abundances in 2001-2015. Eulachon were most abundant in the central Gulf. Magistrate armhook squid, most abundant in the western GOA, continued to increase and were near all-time high estimated abundance, biomass, and prevalence during 2023, up from all-time lows in 2017. Similarly, unidentified squid abundance was near all-time high and prevalence has shown a continual increase to 2023, the highest on record. After a positive trend in abundance and biomass of sidestripe shrimp since the mid-1980's, 2023 saw continued declines from all-time highs in 2019. Similarly, estimated abundance of unidentified shrimp declined since all-time highs in 2021 and estimated biomass fell to near-average values.

With the exception of squid, total incidental catches of the FMP forage group in 2024 remained low since 2022 compared to historical observations. Incidental catch of squid fell to a third of a large peak in 2023. Incidental catch of squid is greatest in the central GOA, and most consistently in the walleye pollock bottom trawl surveys. Incidental catch of pandalid shrimp has remained among the lowest since 2021. Prohibited species catch of herring mostly occurs in midwater trawl fisheries for pollock in the central GOA. Herring catch is generally low with some occasional larger catches, and has continued to declined since a large catch in 2022.

D. Trends in biomass, abundance, prevalence, and distribution

Information content of data sources

The primary data source for this report is the bottom trawl survey conducted by AFSC biennially in odd years since 1990 (methods and data at: http://www.afsc.noaa.gov/RACE/groundfish/default.php). However, this survey is not aimed at sampling the water column (where many forage species reside) and is not designed to capture small fish. Furthermore, the sampling does not include very shallow or very deep waters in the GOA. Consequently, measures of abundance, prevalence, and distribution are uncertain. The goal of this report is to present the data from the bottom trawl survey for forage species as a time series of a relative index to monitor changes while understanding the potential shortcomings of the survey for this task.

Methods

Data for many of the species listed above as 'forage species' are available in the bottom trawl survey data (Figure 29). However, for many of these species, a large fraction of the available observations are associated with life stages that are not 'forage' sized. Filtering out tows in which the average weight of an individual was greater than 0.5 kilograms focuses on the fraction of tows in which only forage sized animals were present (Figure 30). This is an overly restrictive filter because tows with average weights higher than 0.5 kilograms could have forage sized fish in them. However, it is also clear that not filtering the data would lead to distributions and abundances that include primarily adult fish. The actual distribution of forage sized individuals of given species is likely somewhere between the filtered and unfiltered data set. After the application of this filter, eulachon, capelin, squid, and shrimp are the primary species that appear to prevalent enough to provide meaningful time series, so they will be the primary focus of this report. Juvenile walleye pollock and salmon are not evaluated further as they are reported elsewhere (Ecosystems Status, NPFMC stock assessments, ADF&G reports). All forage fish groups are considered for incidental bycatch analyses.

Pacific capelin

Pacific capelin are an important forage species in the GOA for which information from both the bottom trawl and acoustic surveys exist. Acoustic survey data are not presented here. Previous forage reports have noted the similarity in the trends of abundance between the acoustic and trawl survey. Estimates of both biomass and abundance of capelin during 2023 in the GOA were near the historical averages (Figure 31). Capelin were observed in ~21% of the 2021 bottom trawl samples, which was the third highest frequency of occurrence (the previous high occurring in 2013 at 25%; Figure 32). Historically, capelin are observed widely throughout the GOA (Figure 33), but the largest survey estimates have been observed in the Kodiak area in shallow water (Figure 34).

Eulachon

Eulachon are larger than capelin and distributed closer to the seafloor, which allows them to be more efficiently sampled by the bottom trawl survey. Eulachon lack swim bladders, so they are not detected in NMFS acoustic surveys. Abundance and biomass estimates of eulachon during 2023 were similar to 2021, but lower than those observed from 2001-2015 (Figure 31). Eulachon were observed in ~27% of the 2023 bottom trawl samples, which was a decline from high values seen in 2021 (Figure 32). Trawl indices of oceanic eulachon in 2023 were corroborated by spawning run strengths the following spring in 2024. Commercial harvests of eulachon in the Sustina River (Kodiak INFPC area) were 67% of the 10-year average (ADFG pers. comm.) while runs in northern southeast Alaska were below average with the exception of the Chilkat River (Takshanuk Watershed Council pers. comm.). Like capelin, eulachon are observed widely throughout the GOA (Figure 35), but the largest survey estimates have been observed in the Kodiak area in water 100-300 meters deep (Figure 36).

Pacific herring

The frequency of occurrence of herring in the GOA bottom trawl has never exceeded 15%, but the last three years are the highest on record (Figure 37). Estimated abundance and biomass are variable with 2023 observations at approximately average levels (Figure 38). The highest densities of herring have historically occurred in the Yakutat area in shallow waters (Figure 39 & Figure 40).

Squid

Observations of two groups of squid are reported from the bottom trawl survey: magistrate armhook squid (*Berryteuthis magister*) and unidentified squid. Adult *B. magister* are regularly encountered by the bottom trawl survey because of their relatively large size (maximum mantle length of ~28 cm; Sealifebase.com). Smaller species and juvenile squid are mainly found near surface waters. Estimated abundance and biomass for magistrate armhook squid during 2023 were higher than 2021 estimates, and abundance estimates for unidentified squids were near all-time highs (Figure 41). The historical trends of the prevalence of occurrence for both *B. magister* and unidentified squid are increasing, and the 2023 prevalence for each species was at or near all-time highs (Figure 42). *B. magister* is distributed throughout the GOA (Figure 43), but the largest biomasses have been observed in Kodiak, Chirikof, and Shumagin at depths of 200-300 meters (Figure 44).

Shrimp

Observations of two groups of shrimp are reported from the bottom trawl survey: sidestripe shrimp (*Pandalopsis dispar*) and unidentified shrimp. *P. dispar* can reach 8 inches in length and were seen in ~23% of survey samples in 2023; unidentified shrimp were observed in ~30% of samples (Figure 45). The 2023 estimated abundance of unidentified shrimp declined from all-time highs in 2021 but the estimated biomass was closer to average (Figure 46). The trend in sidestripe shrimp abundance and biomass has been positive since the GOA survey began in the 1980s, but 2023 estimates declined further from the all-time highs seen in 2019 (Figure 46). Sidestripe shrimp are observed in shallower waters the farther east into the GOA the survey progresses (Figure 47).

E. Bycatch and other conservation issues

FMP forage group

Incidental catch data in federal fisheries for the FMP forage group are available starting in 2003 (Figure 48 & Figure 49). Prior to 2005, species identification by observers was unreliable and many smelt catches were recorded as 'other osmerid'. Identification has improved since then, but smelts are often too damaged for accurate identification and much of the catch is still reported as other osmerid. Osmerids regularly make up the vast majority of FMP forage fish group catches . Eulachon are the most abundant osmerid catch and it is likely that they make up the majority of the 'other osmerid' catch. Osmerid catches (and consequently total FMP forage group catches, excluding squid) have been low relative to historical levels since 2015, save 2021 (Figure 50). Osmerids accounted for almost all of the incidental catch in 2024.

Squid

Squid catches are generally relatively low compared to biomass estimates from trawl surveys. Recent squid incidental catches are high compared to catches observed before 2020 (save 2006; Figure 51). Catches from midwater trawls for pollock have been consistently higher than the bottom trawls and almost all of the squid catch occurs in the central GOA.

Shrimp

Bycatch of pandalid shrimp in federal fisheries is generally low and all is discarded (Figure 52). Catches in 2019 and 2020 were the highest in the time series, but 2021 and 2023 catches were the lowest (Figure 52). Recently, the arrowtooth flounder fishery accounts for nearly all of the bycaught shrimp in the GOA and those catches primarily occur in the Central GOA.

Pacific herring

Pacific herring are a prohibited species and data on catches in federal fisheries are available beginning in 1991. The Prohibited Species Catch (PSC) of herring is generally low, with occasional larger catches (e.g. 1994, 2004, 2016, 2019, and 2022; Figure 53). Herring PSC in 2024 was near the long-term mean. Most of the herring bycatch occurs in the midwater trawls for walleye pollock in the Central GOA (Figure 53).

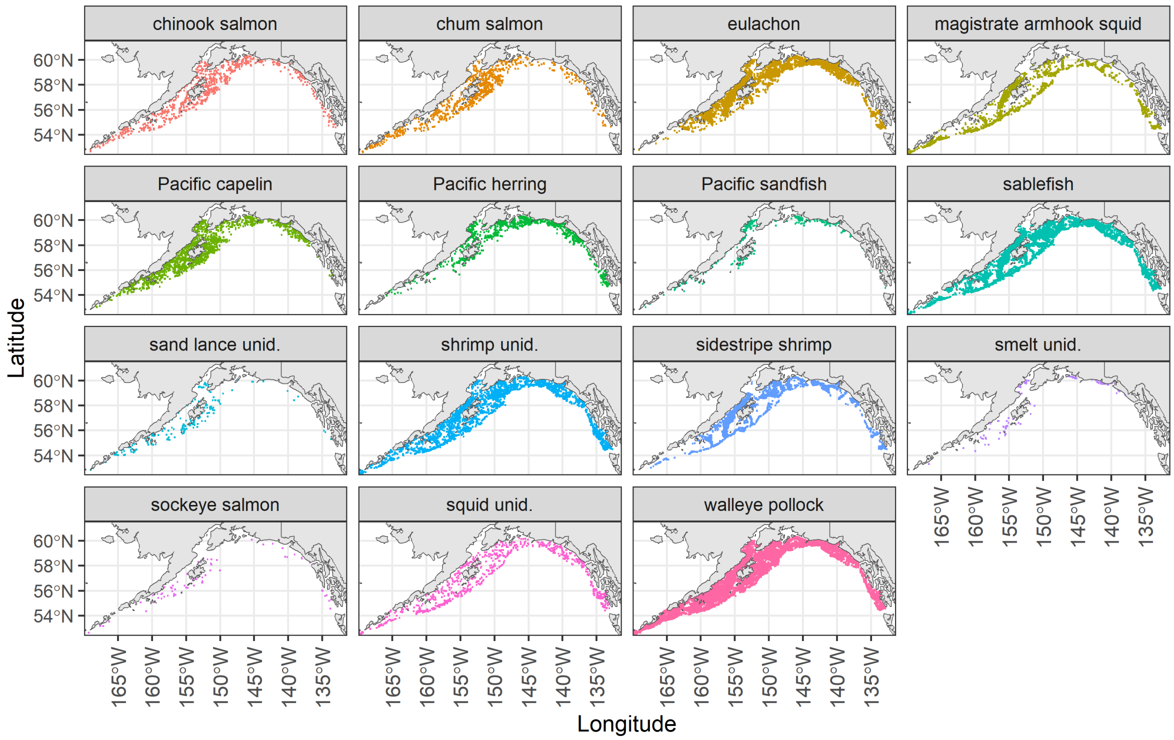

Figure 29: All non-zero tows for select forage species.

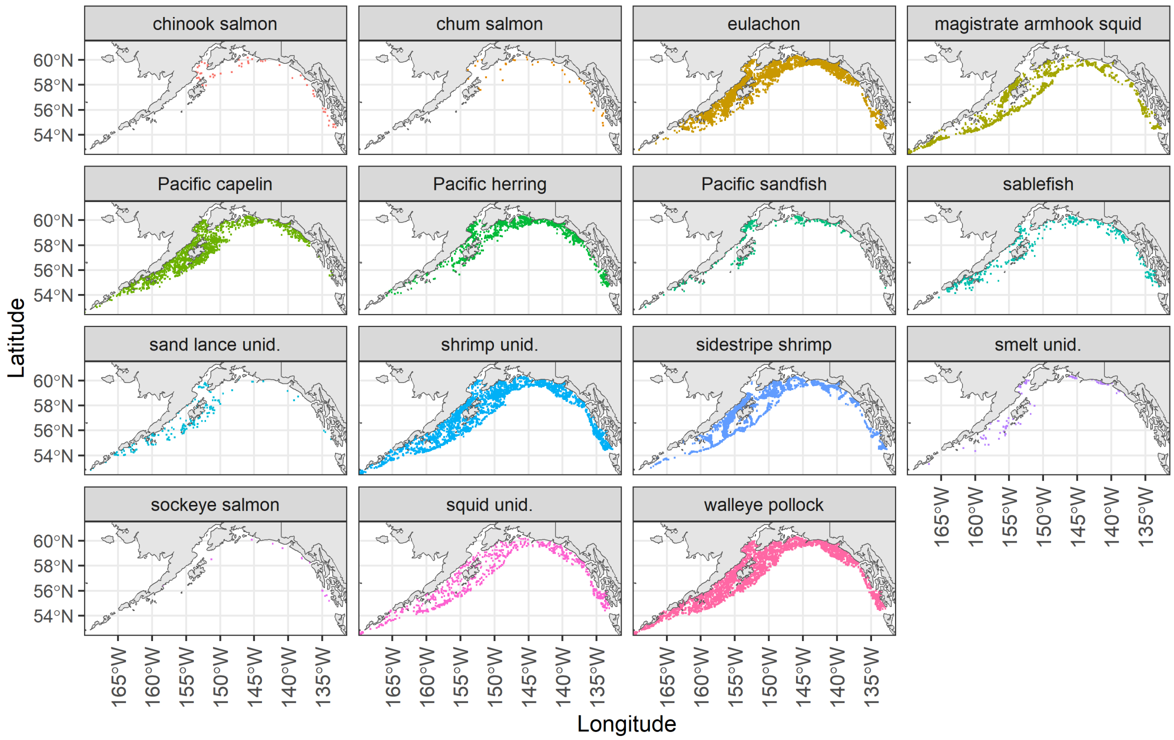

Figure 30: All non-zero tows for select forage species filtered for tows that have an average weight of an individual less than 0.5 kilograms.

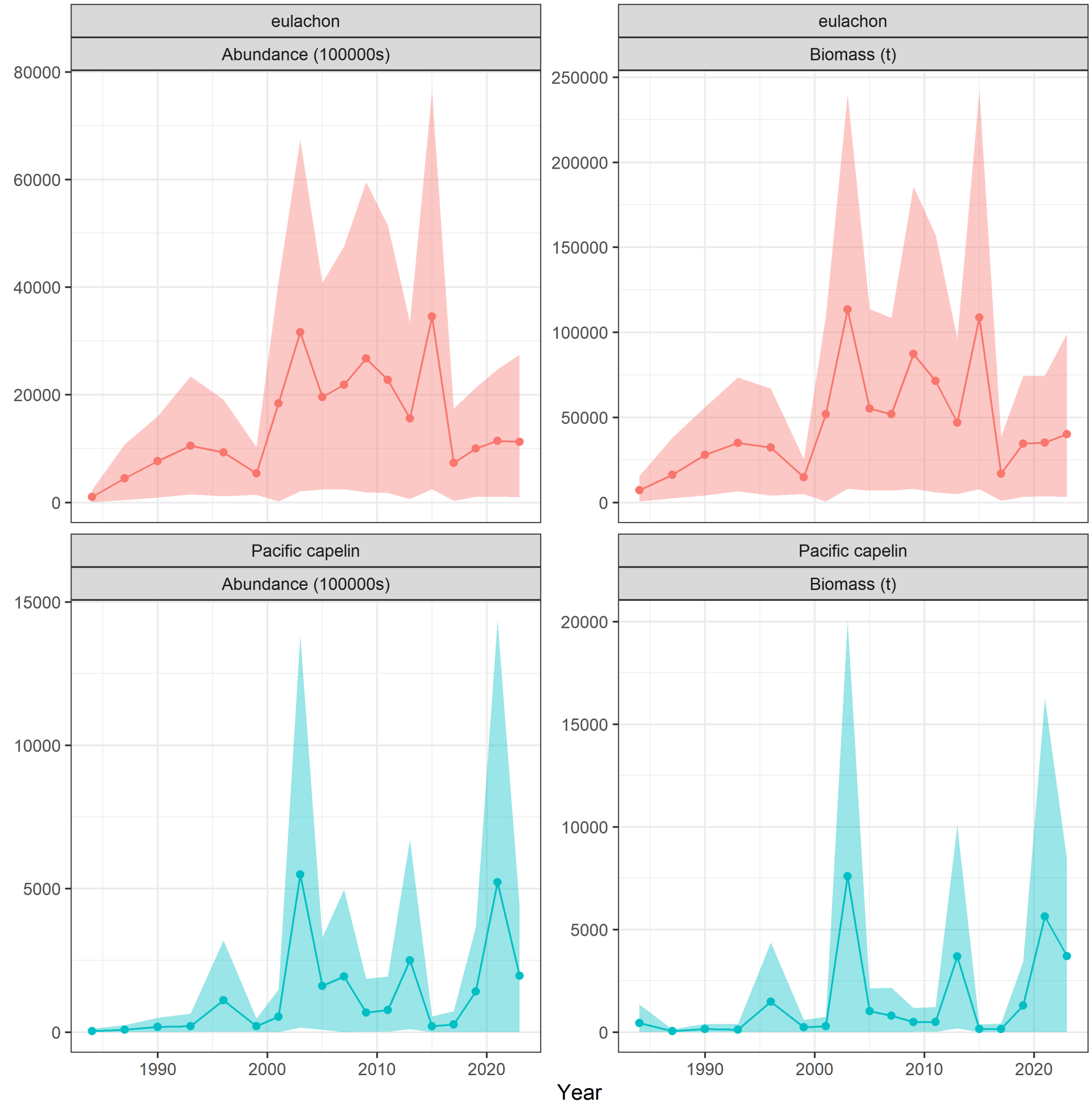

Figure 31: Estimated biomass and abundance of eulachon and Pacific capelin in the Gulf of Alaska with 95% confidence intervals.

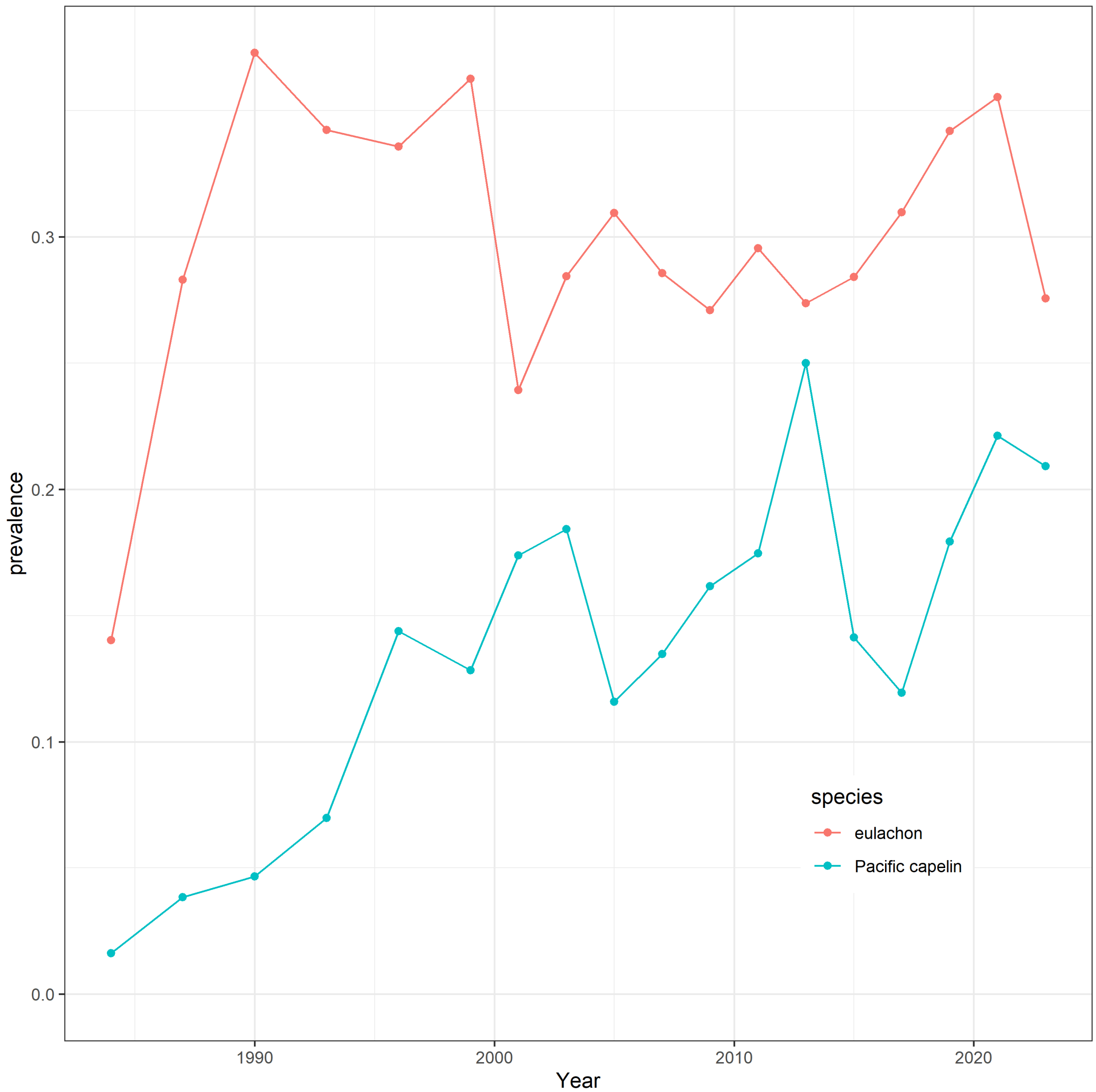

Figure 32: Frequency of occurrence of eulachon and Pacific capelin in the Gulf of Alaska bottom trawl survey.

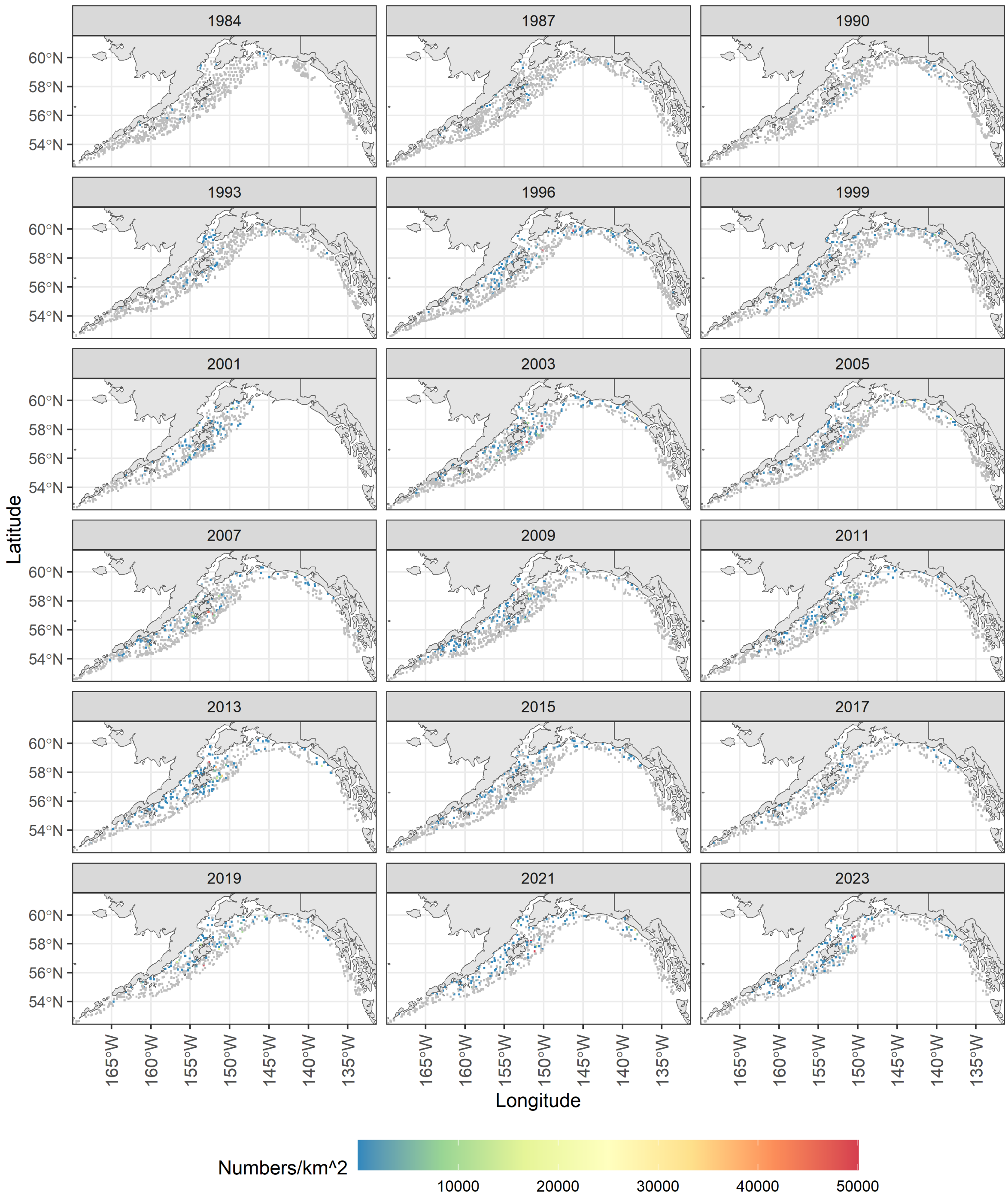

Figure 33: Map of distribution of prevalence and density from the all GOA surveys for Pacific capelin. Grey squares indicate surveyed stations at which no capelin were observed. (zoom for detail)

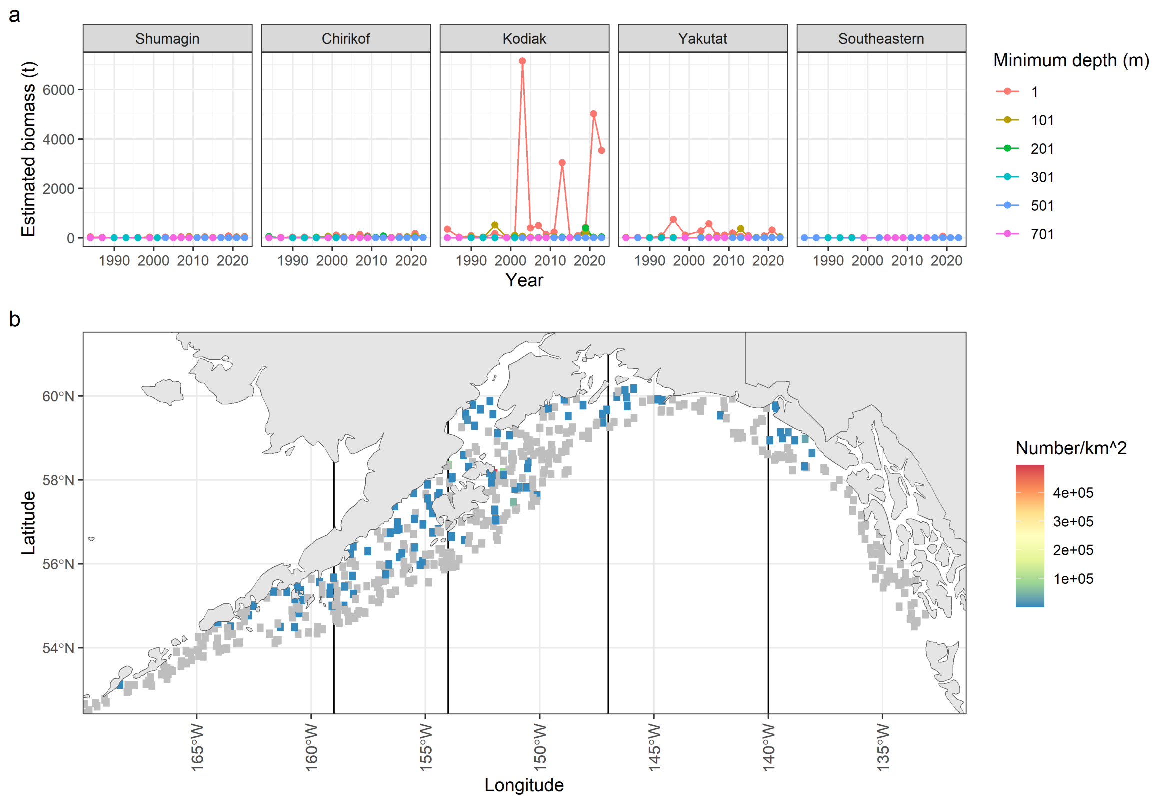

Figure 34: Estimated biomass of Pacific capelin by INFPC area and depth over time in the Gulf of Alaska (top) and map of distribution of prevalence and density from the most recent GOA survey (bottom). Grey squares indicate surveyed stations at which no capelin were observed. Vertical black lines delineate International North Pacific Fisheries Commission (INFPC) areas.

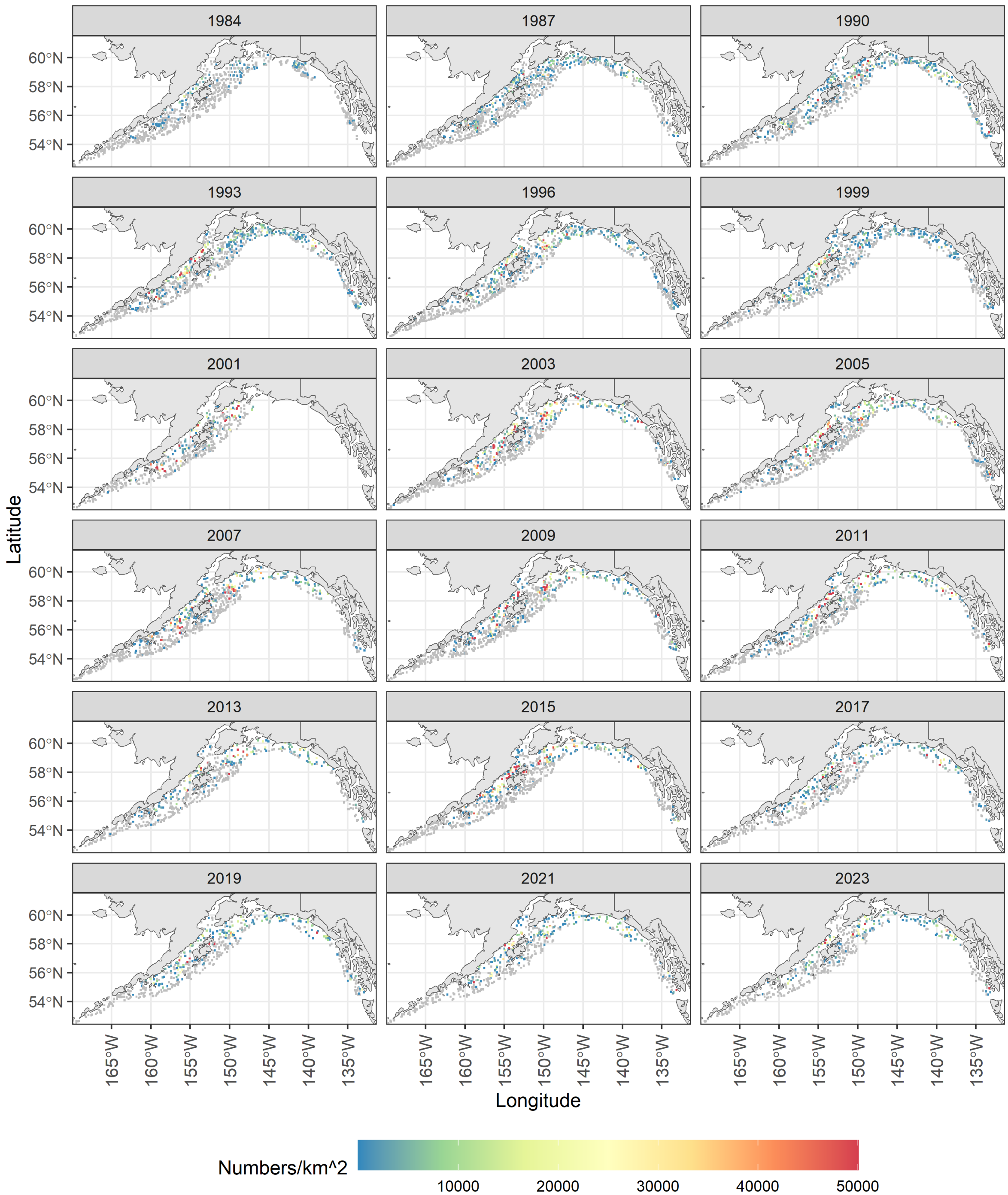

Figure 35: Map of distribution of prevalence and density from the all GOA surveys for eulachon. Grey squares indicate surveyed stations at which no eulachon were observed. Vertical black lines delineate INFPC areas. (zoom for detail)

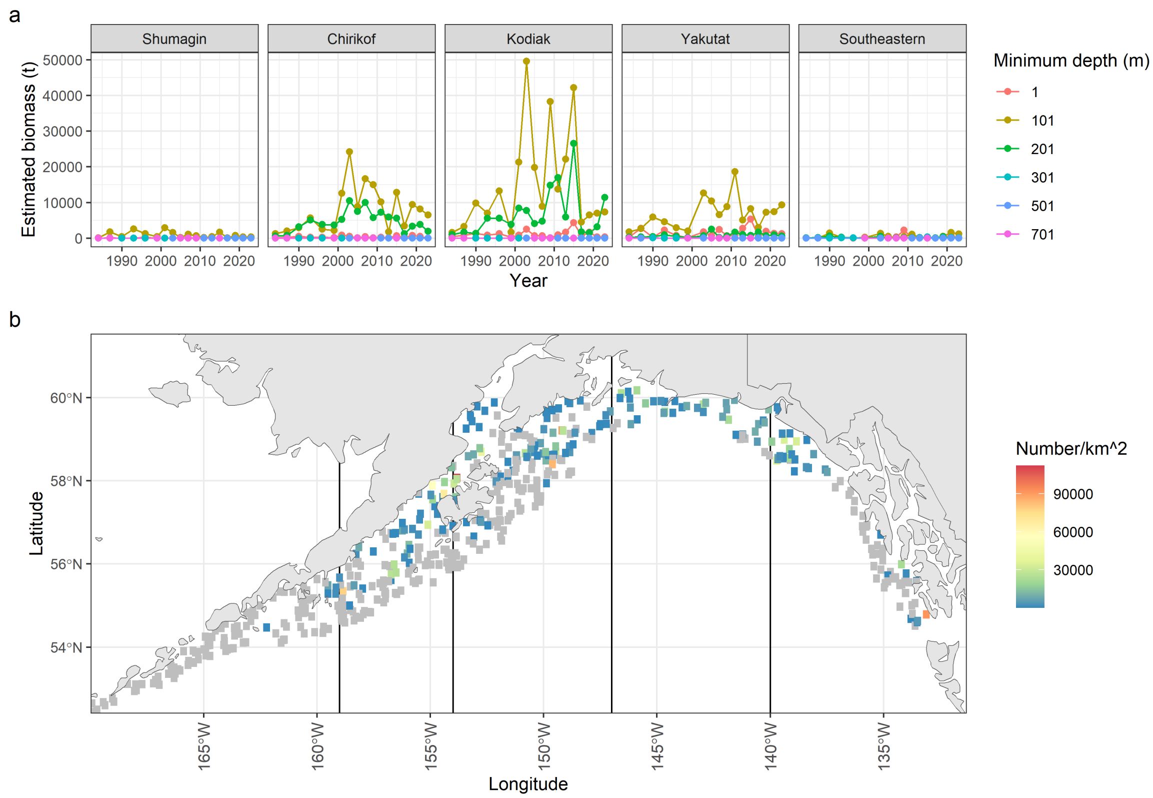

Figure 36: Estimated biomass of eulachon by INFPC area and depth over time in the Gulf of Alaska (top) and map of distribution of prevalence and density from the most recent GOA survey (bottom). Grey squares indicate surveyed stations at which no eulachon were observed.

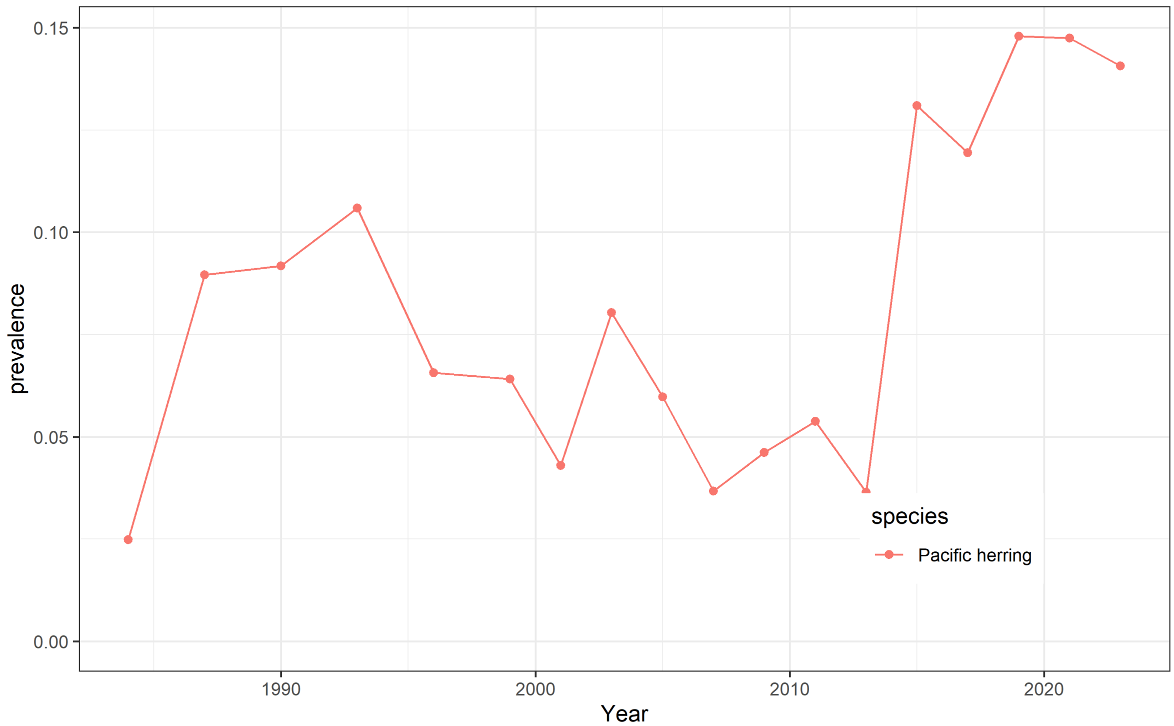

Figure 37: Frequency of occurrence of Pacific herring in the Gulf of Alaska bottom trawl survey.

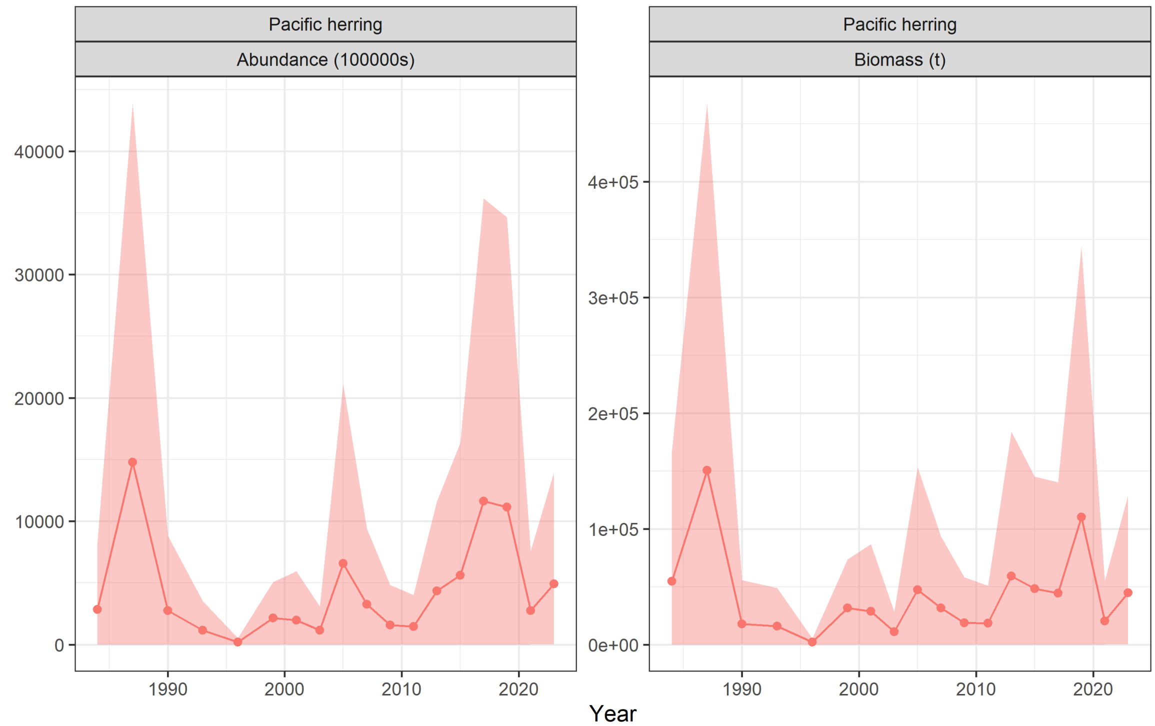

Figure 38: Estimated biomass and abundance of Pacific herring in the Gulf of Alaska with 95% confidence intervals.

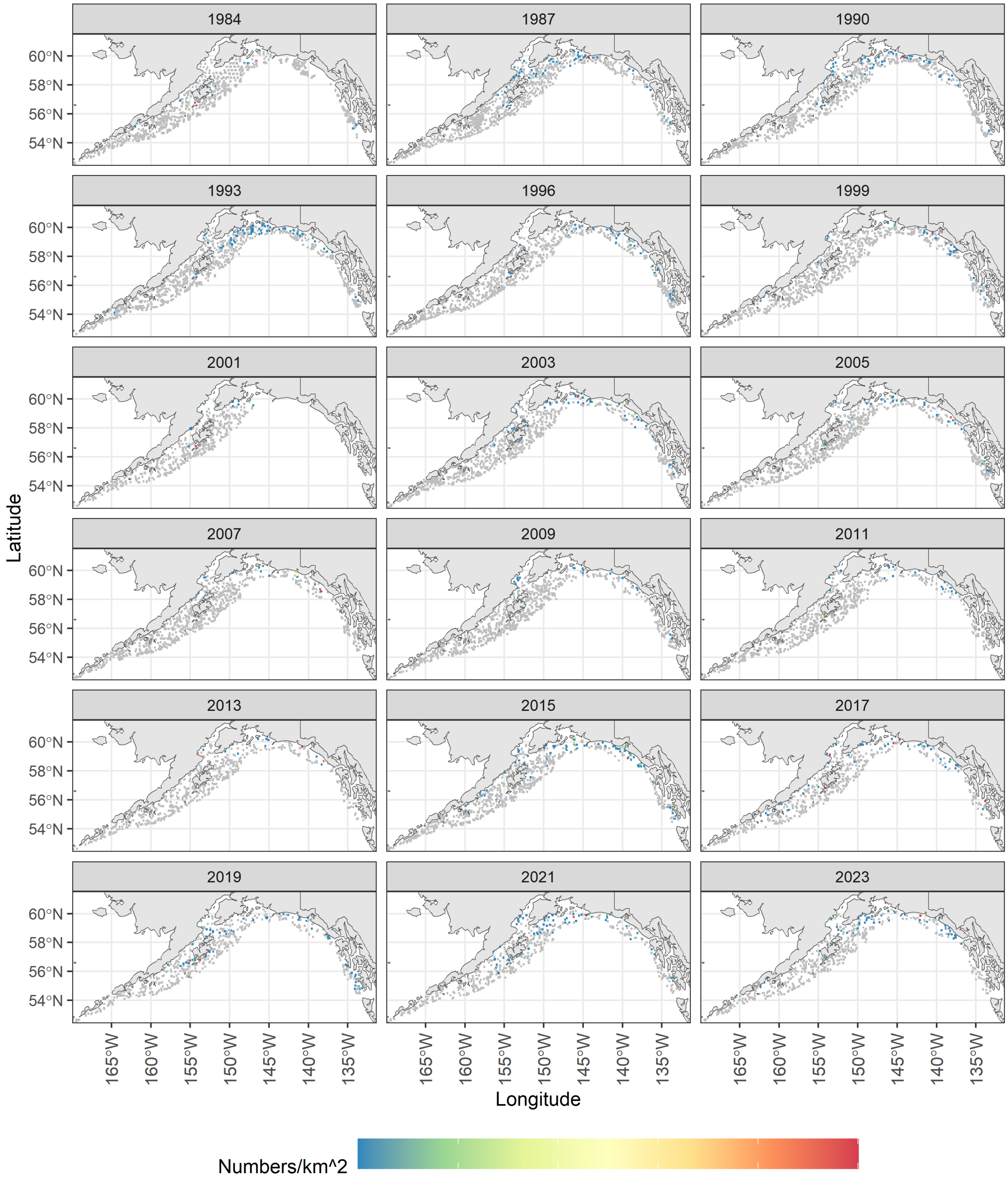

Figure 39: Map of distribution of prevalence and density from the all GOA surveys for Pacific herring. Grey squares indicate surveyed stations at which no herring were observed. Vertical black lines delineate INFPC areas. (zoom for detail)

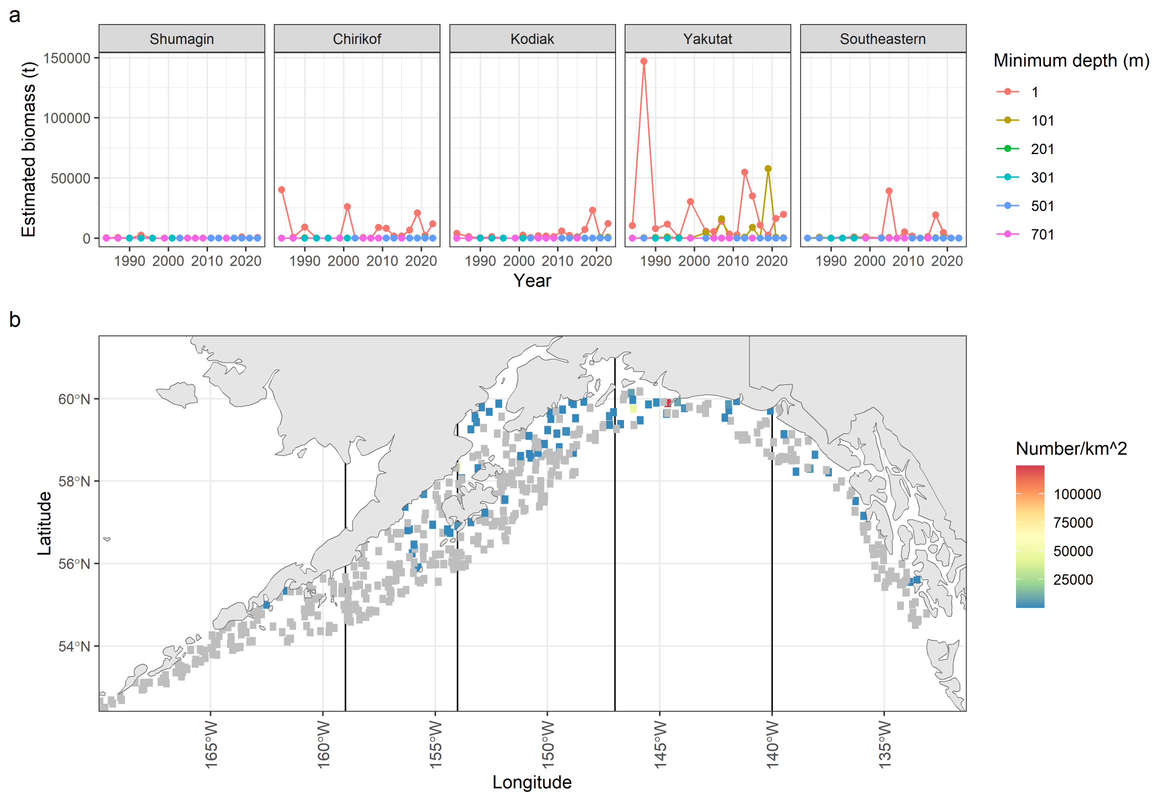

Figure 40: Estimated biomass of Pacific herring. by INFPC area and depth over time in the Gulf of Alaska (top) and map of distribution of prevalence and density from the most recent GOA survey (bottom). Grey squares indicate surveyed stations at which no herring were observed.

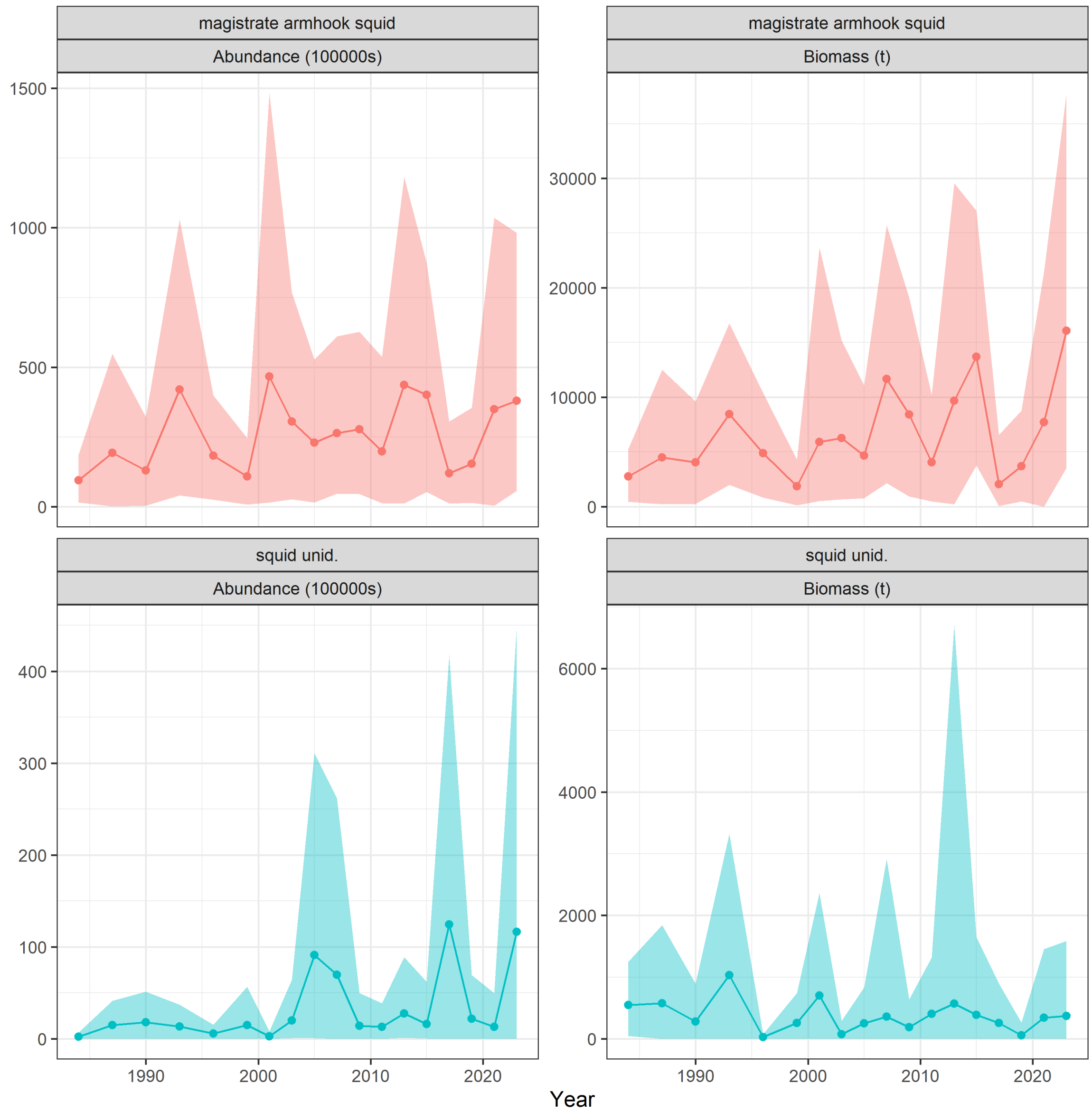

Figure 41: Estimated biomass and abundance of magistrate armhook squid and unidentified squid in the Gulf of Alaska with 95% confidence intervals.

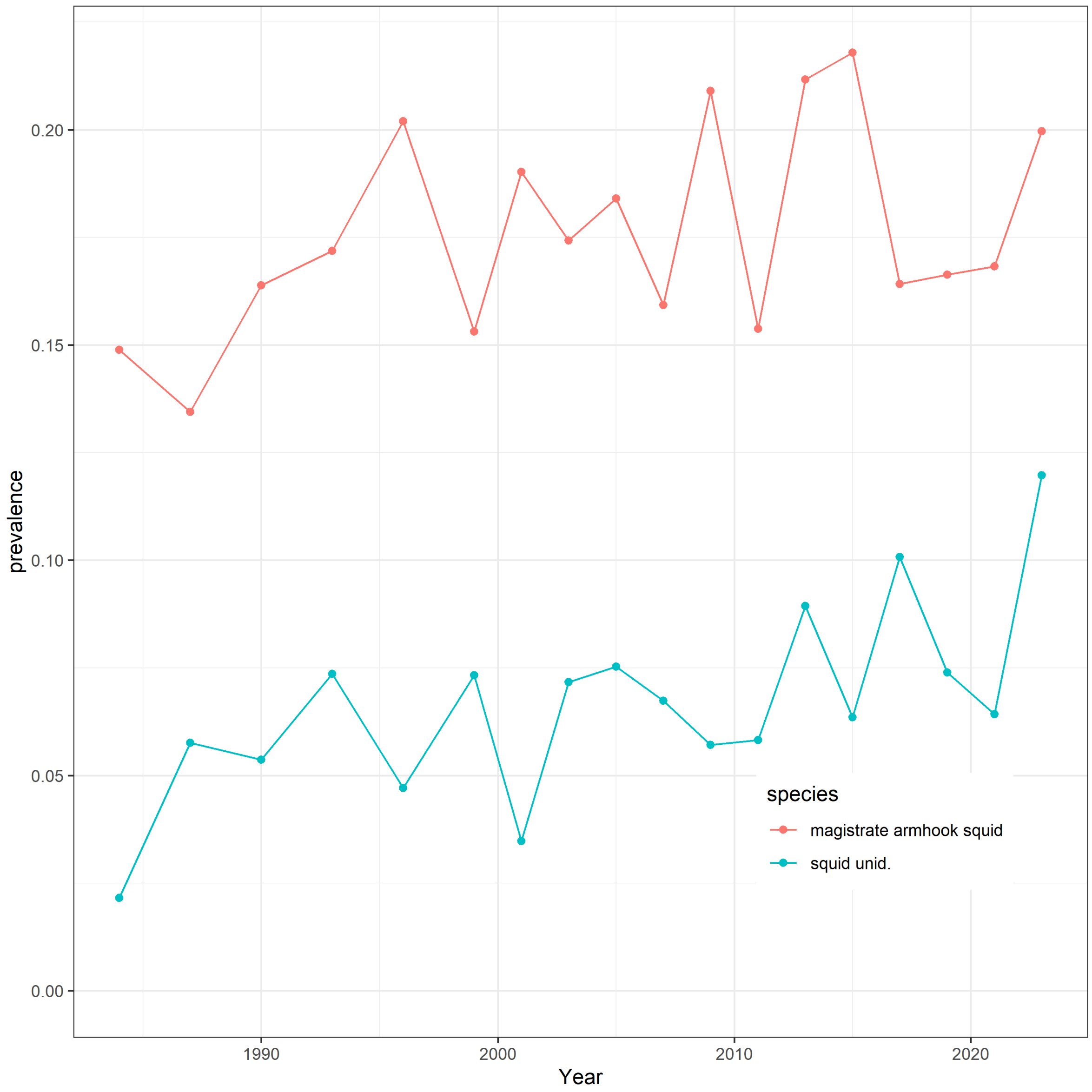

Figure 42: Frequency of occurrence of magistrate armhook squid and unidentified squid in the Gulf of Alaska bottom trawl survey.

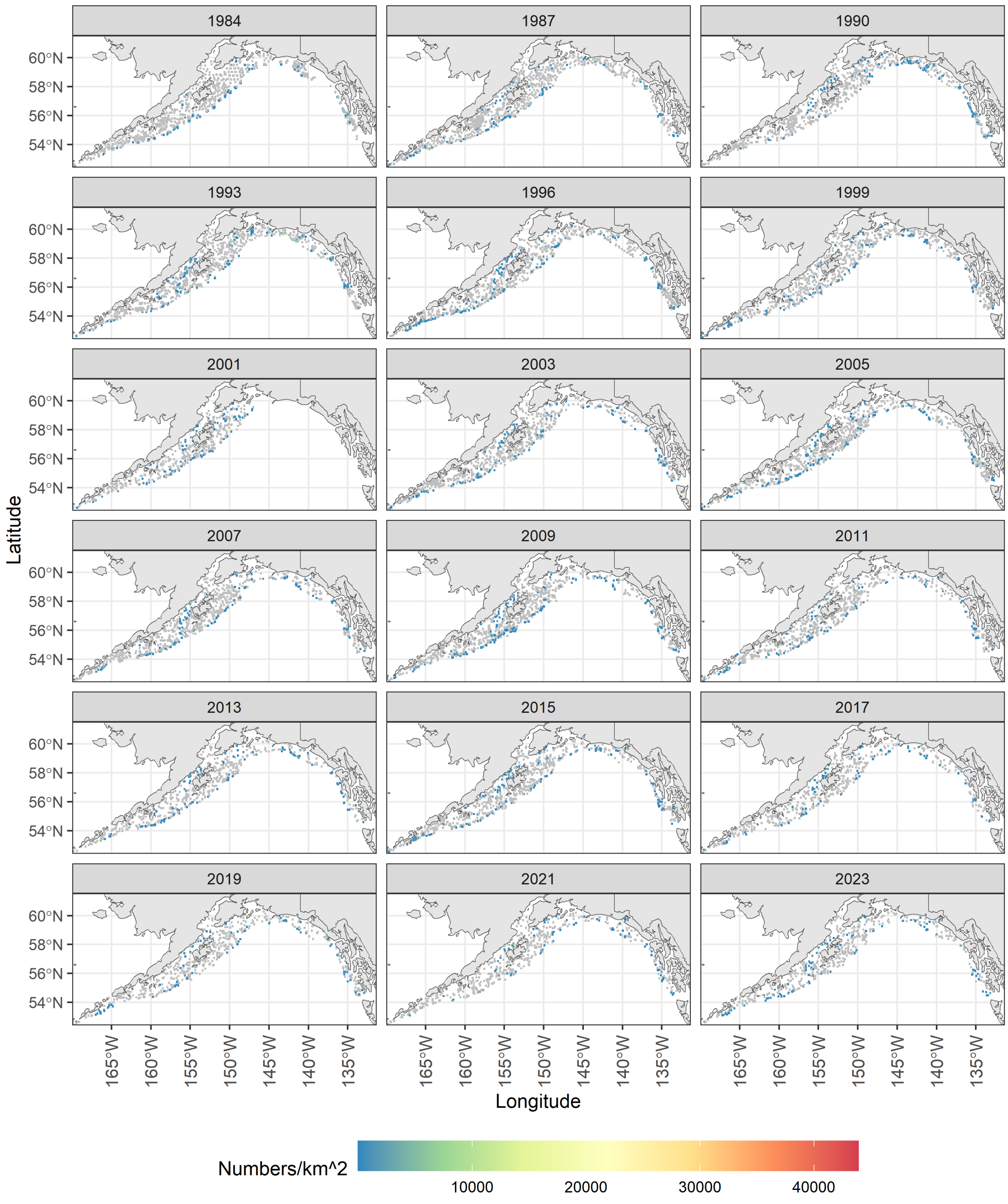

Figure 43: Map of distribution of prevalence and density from the all GOA surveys for magistrate armhook squid. Grey squares indicate surveyed stations at which no squid were observed. Vertical black lines delineate INFPC areas. (zoom for detail)

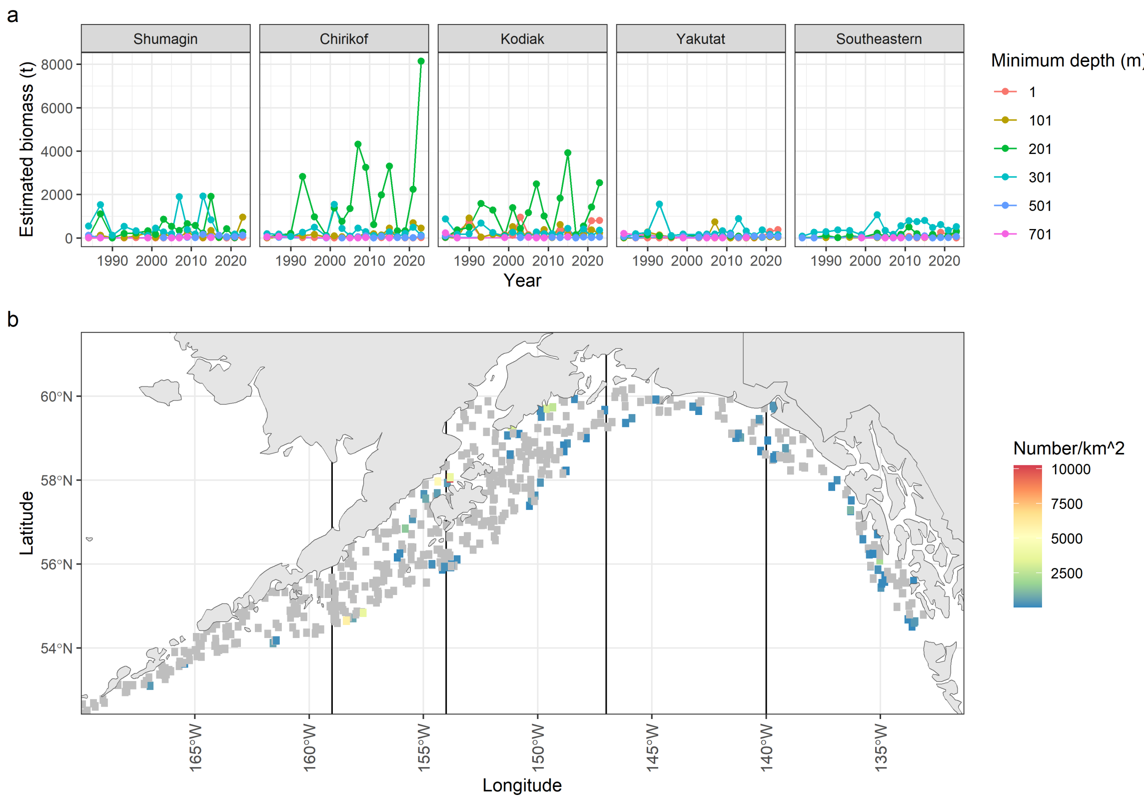

Figure 44: Estimated biomass of magistrate armhook squid by INFPC area and depth over time in the Gulf of Alaska (top) and map of distribution of prevalence and density from the most recent GOA survey (bottom). Grey squares indicate surveyed stations at which no squid were observed.

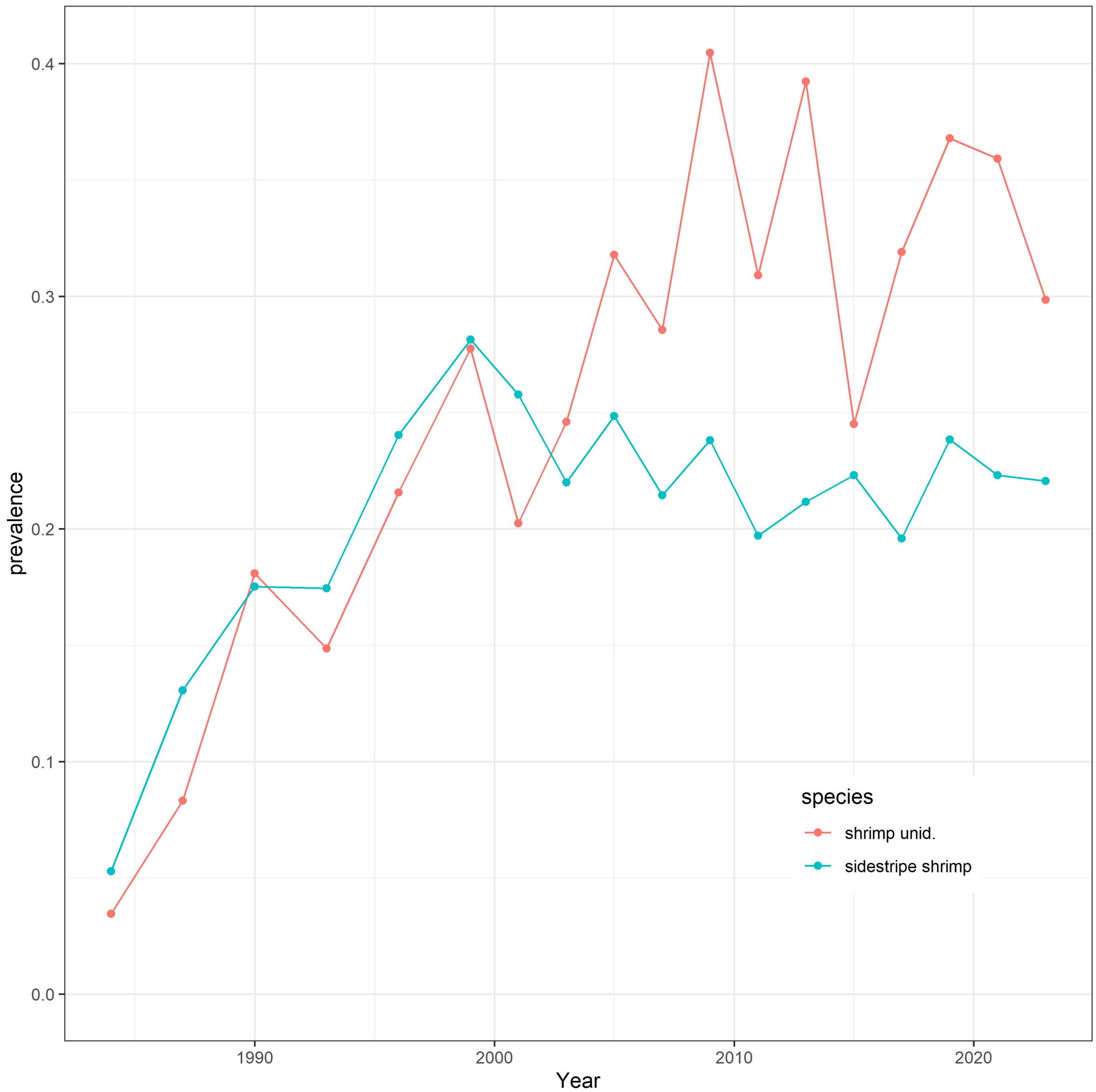

Figure 45: Frequency of occurrence of sidestrip shrimp and unidentified shrimp in the Gulf of Alaska bottom trawl survey.

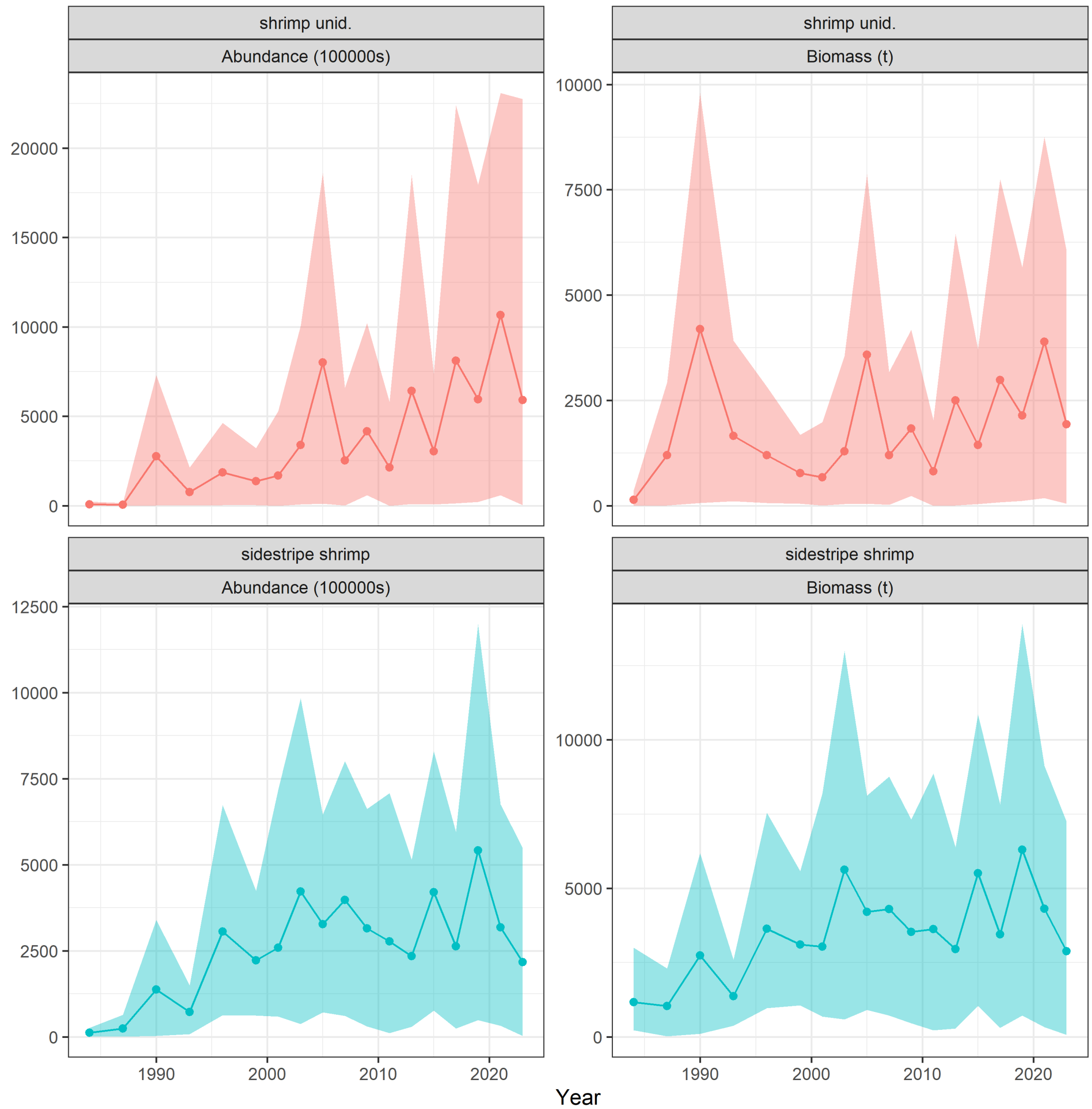

Figure 46: Estimated biomass and abundance of sidestrip shrimp and unidentified shrimp in the Gulf of Alaska with 95% confidence intervals.

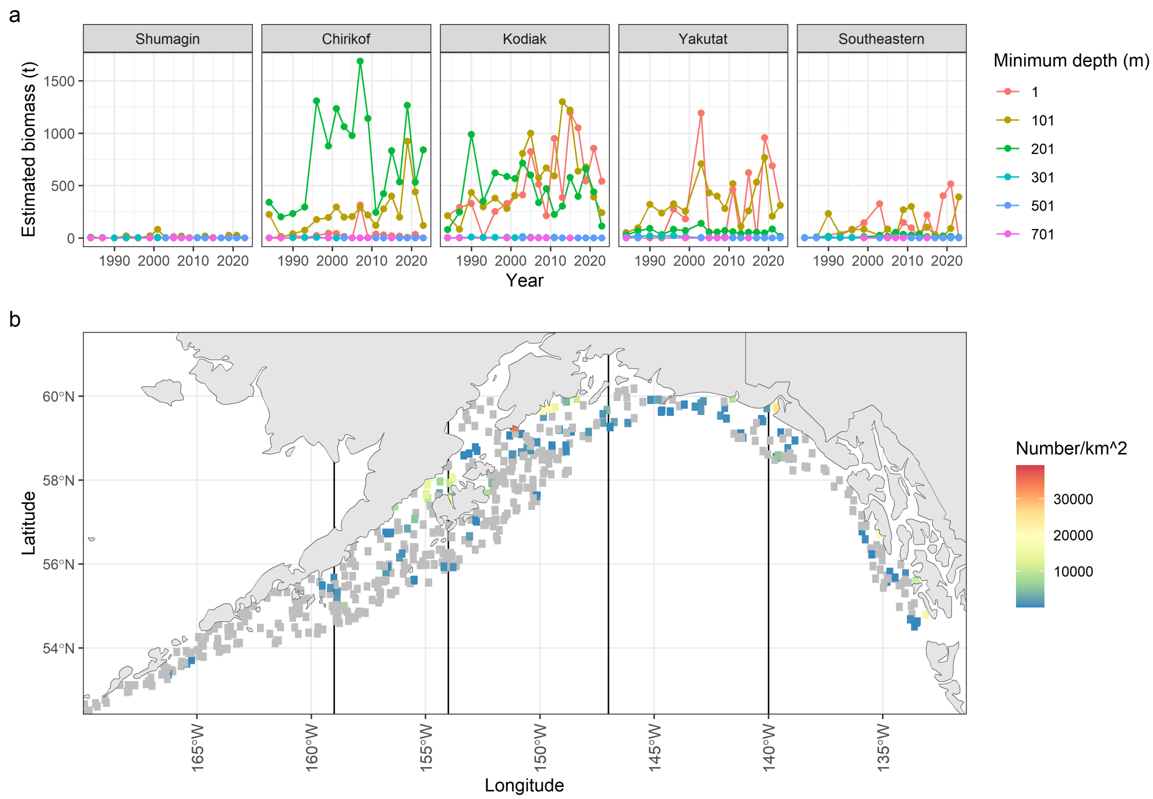

Figure 47: Estimated biomass of sidestrip shrimp by INFPC area and depth over time in the Gulf of Alaska (top) and map of distribution of prevalence and density from the most recent GOA survey (bottom). Grey squares indicate surveyed stations at which no shrimp were observed.

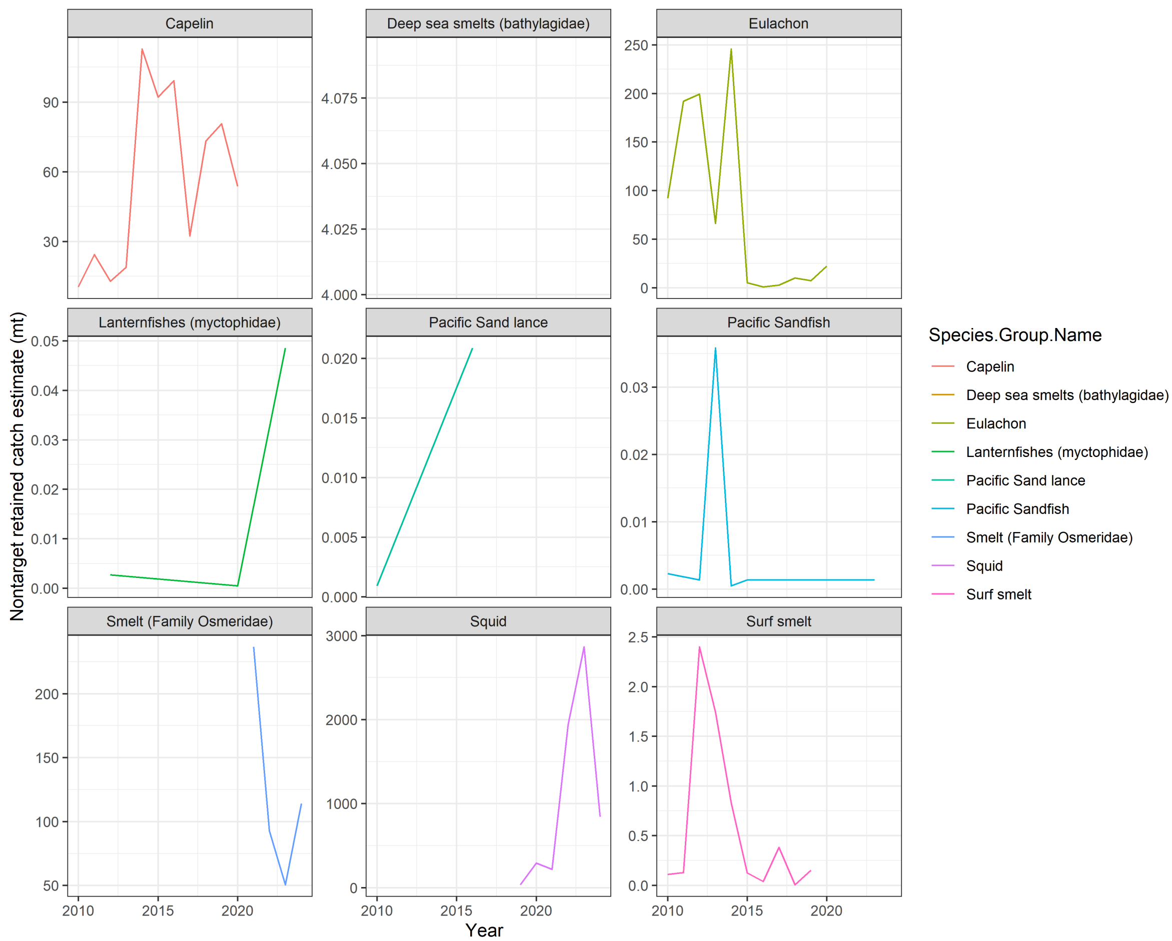

Figure 48: Retained incidental catches in federal fisheries of fishes in the GOA FMP forage group (2003-2024).

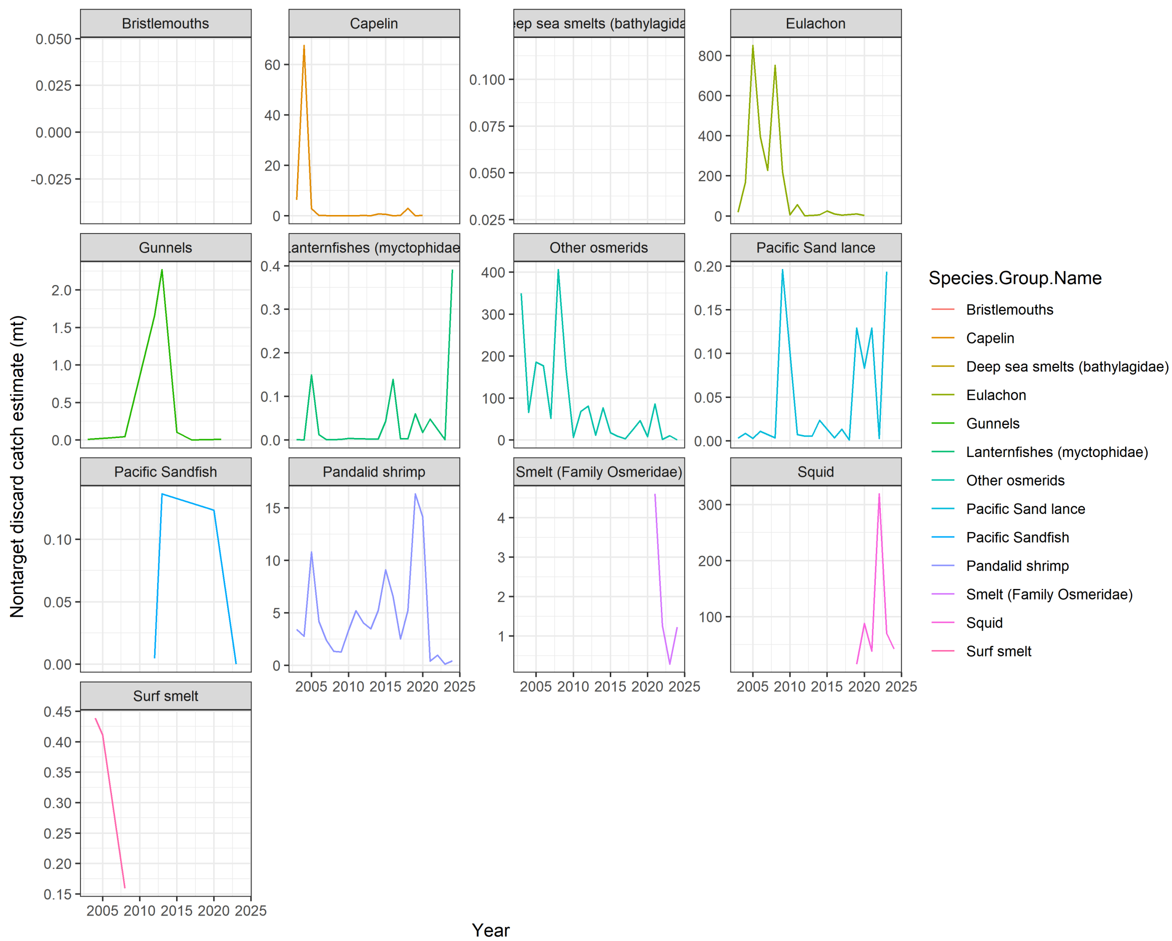

Figure 49: Discarded incidental catches in federal fisheries of fishes in the GOA FMP forage group (2003-2024).

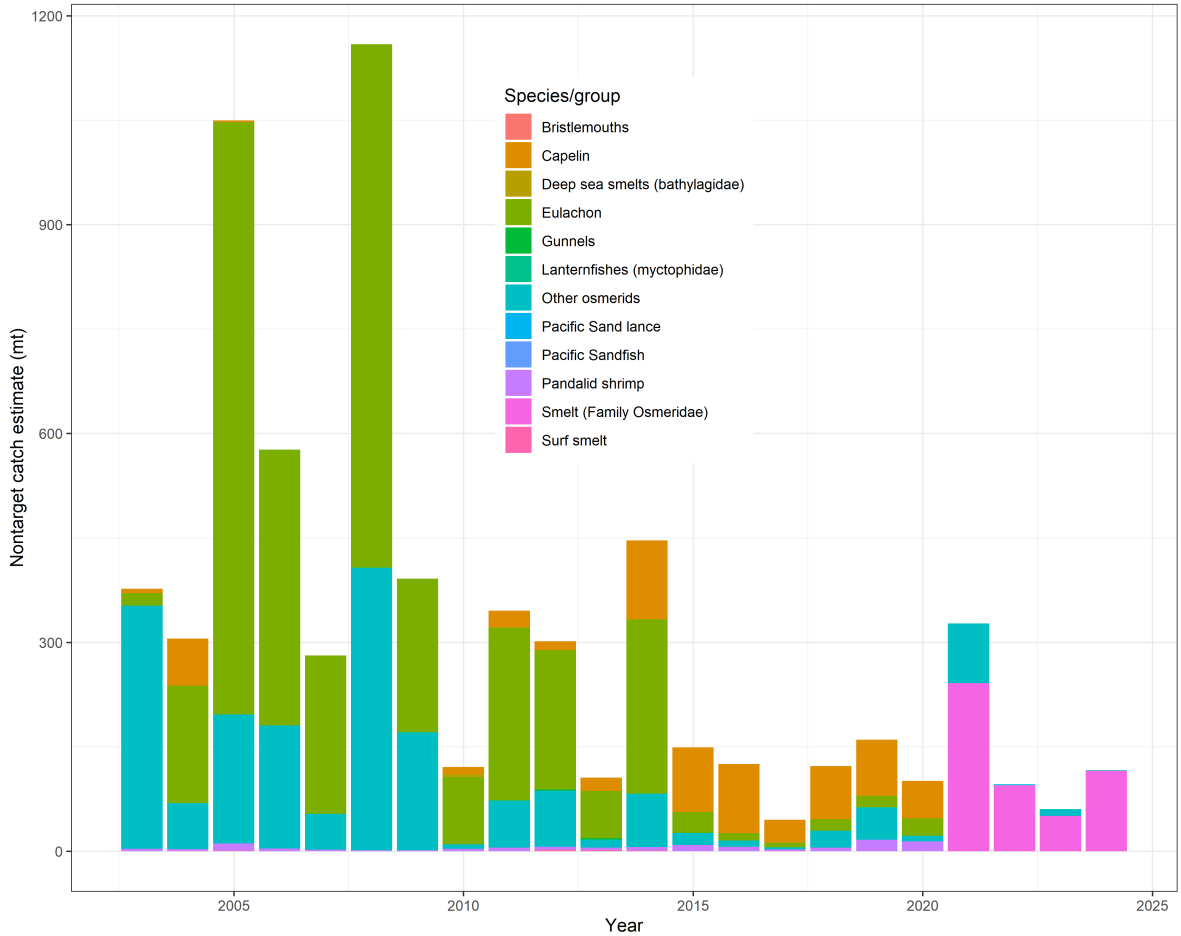

Figure 50: Total incidental catches of fishes in federal fisheries in the GOA FMP forage group (2003-2024).

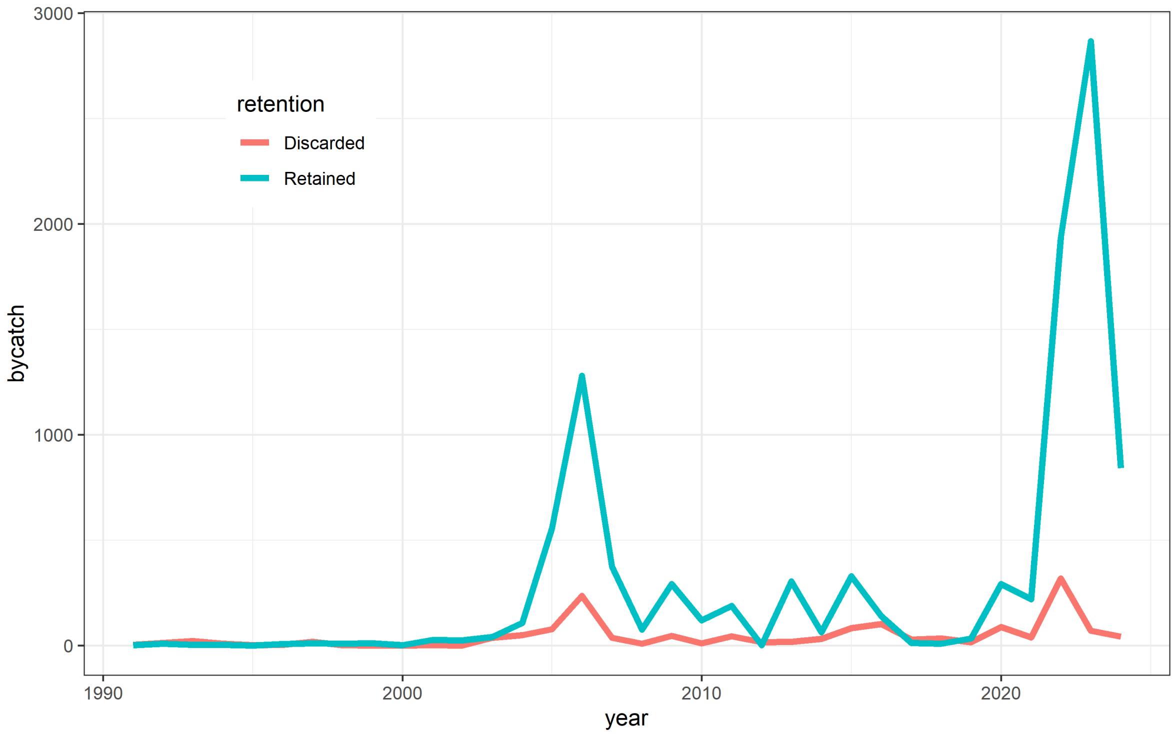

Figure 51: Catches of squid incidentally caught in federal fisheries in the GOA that were discarded vs. retained (top). Biomass of squid caught by target fishery (middle). Location of squid caught in the GOA (bottom).

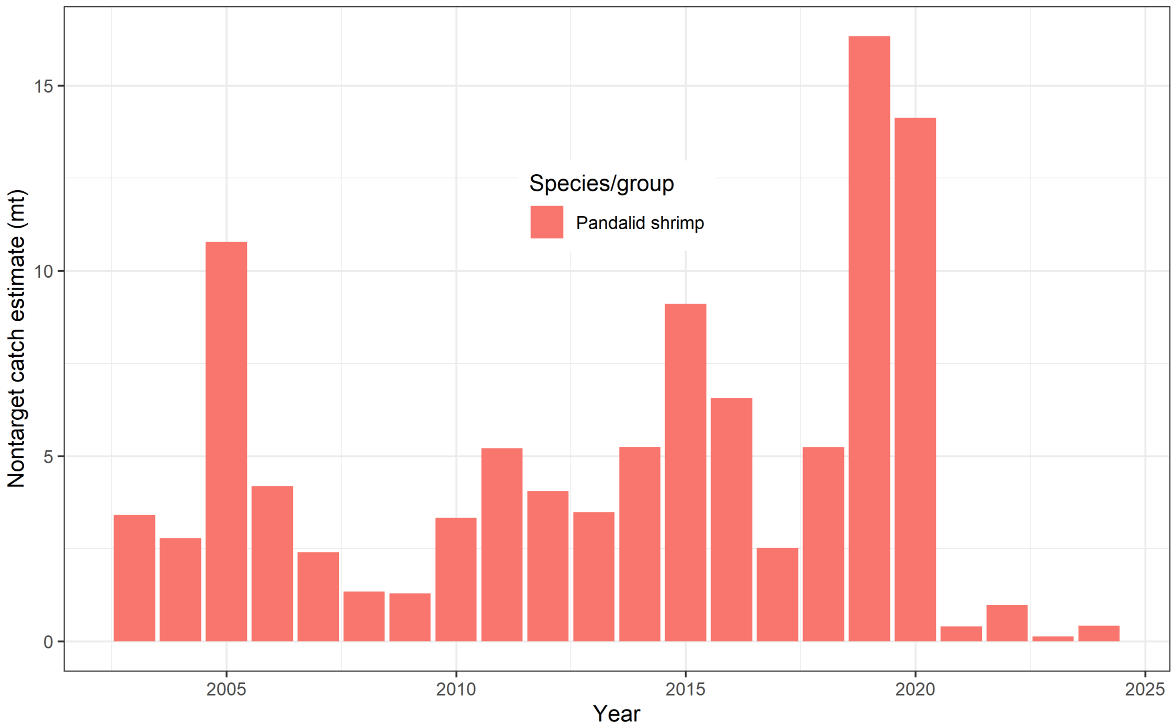

Figure 52: Discarded catches of shrimp in federal fisheries in the GOA.

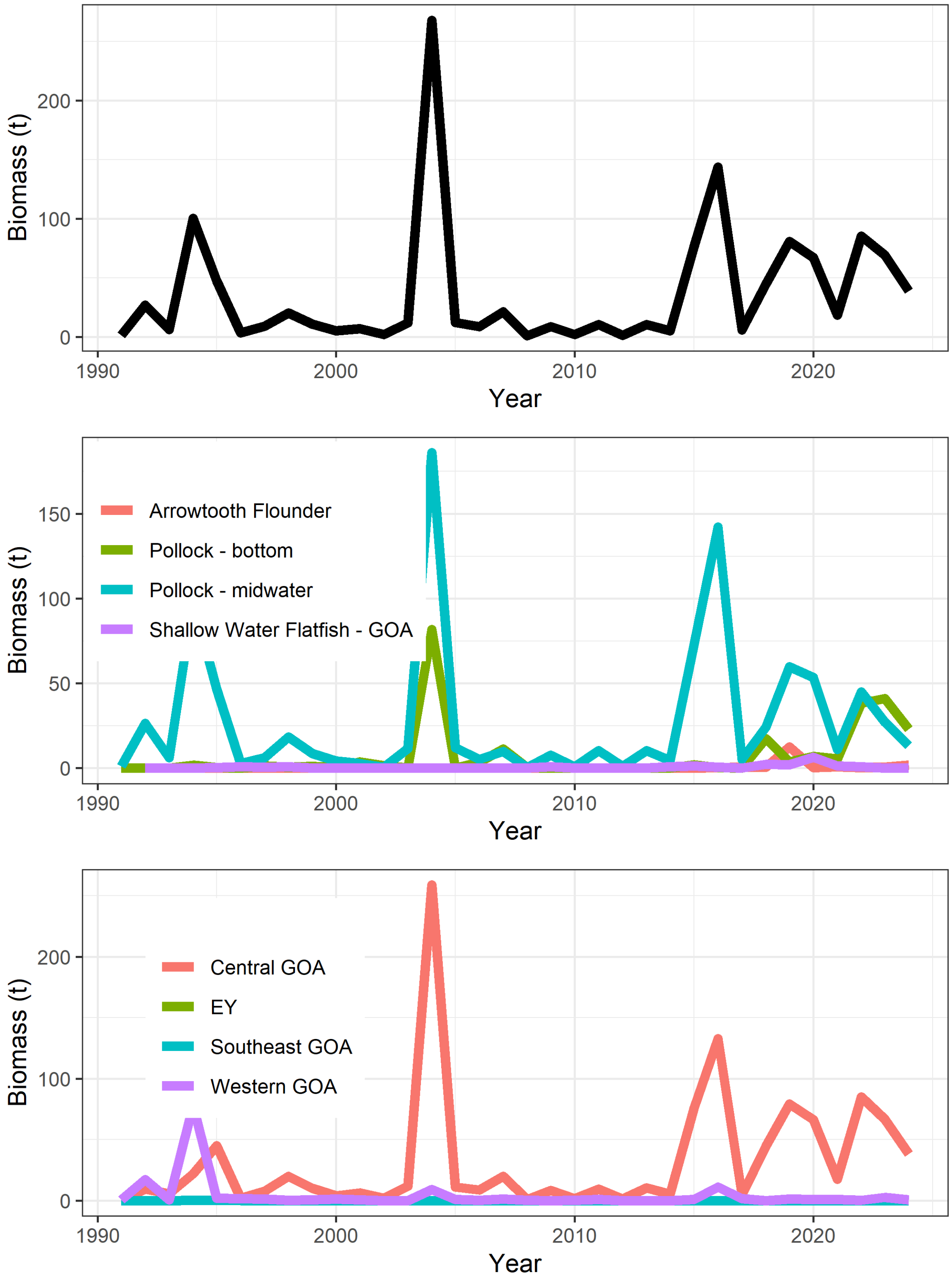

Figure 53: Catches of herring in the GOA (top). Prohibited species catch of herring caught by target fishery (middle). Location of herring caught in the GOA (bottom).

F. Environmental linkages

The physical environments of Alaskan waters are variable and experiencing rapid change. Identifying environmental niches occupied by species could be useful to understanding potential climate change impacts on forage species in Alaska. As an initial step towards this goal, presence/absence data for select species in the GOA and BSAI were fit using Generalized Additive Models (GAMs) with a binomial error structure and a logit link. Bottom temperature, sea surface temperature (SST), and depth were used to predict the probability of occurrence in each data set. The deviance explained by these GAMs was 32% and 40% for the BSAI and GOA, respectively. Hierarchical clustering was applied to the resulting ogives of estimated probability of occurrence for SST and depth in the GOA and BSAI, respectively. This allowed for grouping of species based on the shape of the probability of occurrence curves and the identification of different environmental niches.

Species and species groups were clustered into 4 niches based on depth on the BSAI shelf (Figure 54; NBS data are not included in this model). The clusters roughly correspond to species/groups that have a peak in occurrence in the middle domain (Arctic cod, eelblenny, eulachon, prickleback, shrimp), species/groups that are found primarily in deep water (magistrate armhook squid, myctophids, squid unid.), species/groups found primarily in water shallower than 150 m (Pacific capelin, Pacific herring), and species/groups that are found in either deep or shallow water, but not in between (Pacific sandfish, rainbow smelt, sand lance unid., smelt unid.).

Species and species groups were clustered into 4 niches based on SST in the GOA (Figure 55). The clusters roughly correspond to warmer water species/groups (chinook salmon, eulachon, pacific herring, shrimp unid., and squid unid.), species/groups that have a thermal niche in the middle of the observed SST (chum salmon, Pacific capelin, and sidestrip shrimp), colder water species/groups (magistrate armhook squid, sand lance unid., and sockeye salmon), and species/groups observed in cold and warm water, but not in intermediate temperatures (Pacific sandfish and smelt unid.).

A potential next step in this analysis is to feed projections of SST and bottom temperature into the GAMs developed for each region to produce maps of potential distributions of occurrence in the bottom trawl survey of forage species under climate change.

G. Future research directions

Given the change in authorship for the forage report, the goal for this year's report was only to replicate the previous report with updated data with some small additions. Discussions have been underway with current co-authors and potential new co-authors regarding future changes to the report. Future efforts may include developing synthetic (i.e. incorporating multiple data sources) indices of forage base and linking spatio-temporal changes in these indices to environmental variables. An exploration of more quantitative, model-based assessments of forage species that include indices derived from the biomass of their predators as seen through diet data may also be useful for quantifying changes in forage in Alaskan ecosystems.

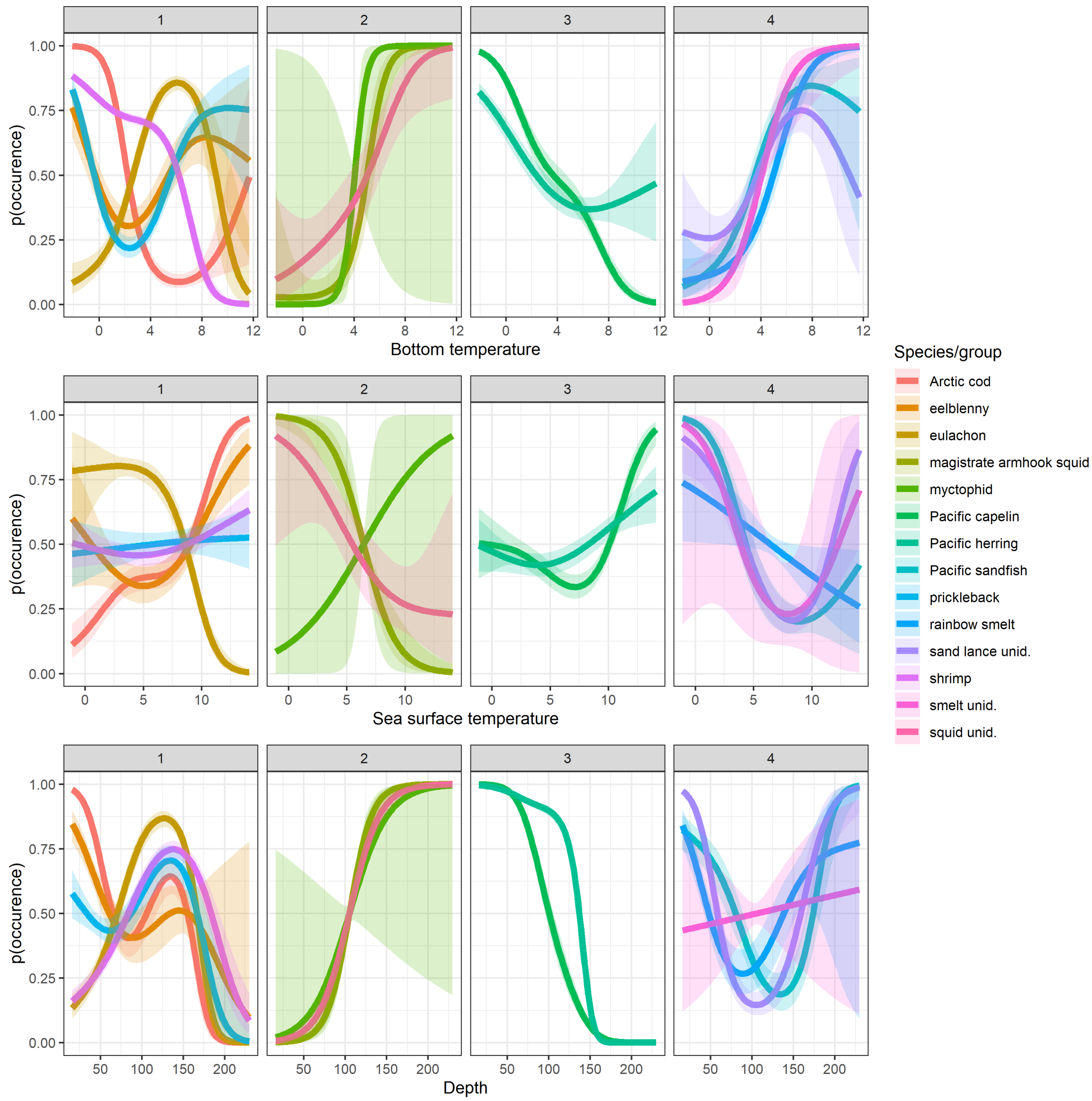

Figure 54: Probability of occurrence for selected forage species/groups in the BSAI based on GAMs incorporating depth, SST, and bottom temperature. Species/groups were sorted to one of the four columns based on hierarchical clustering on the relationship to depth.

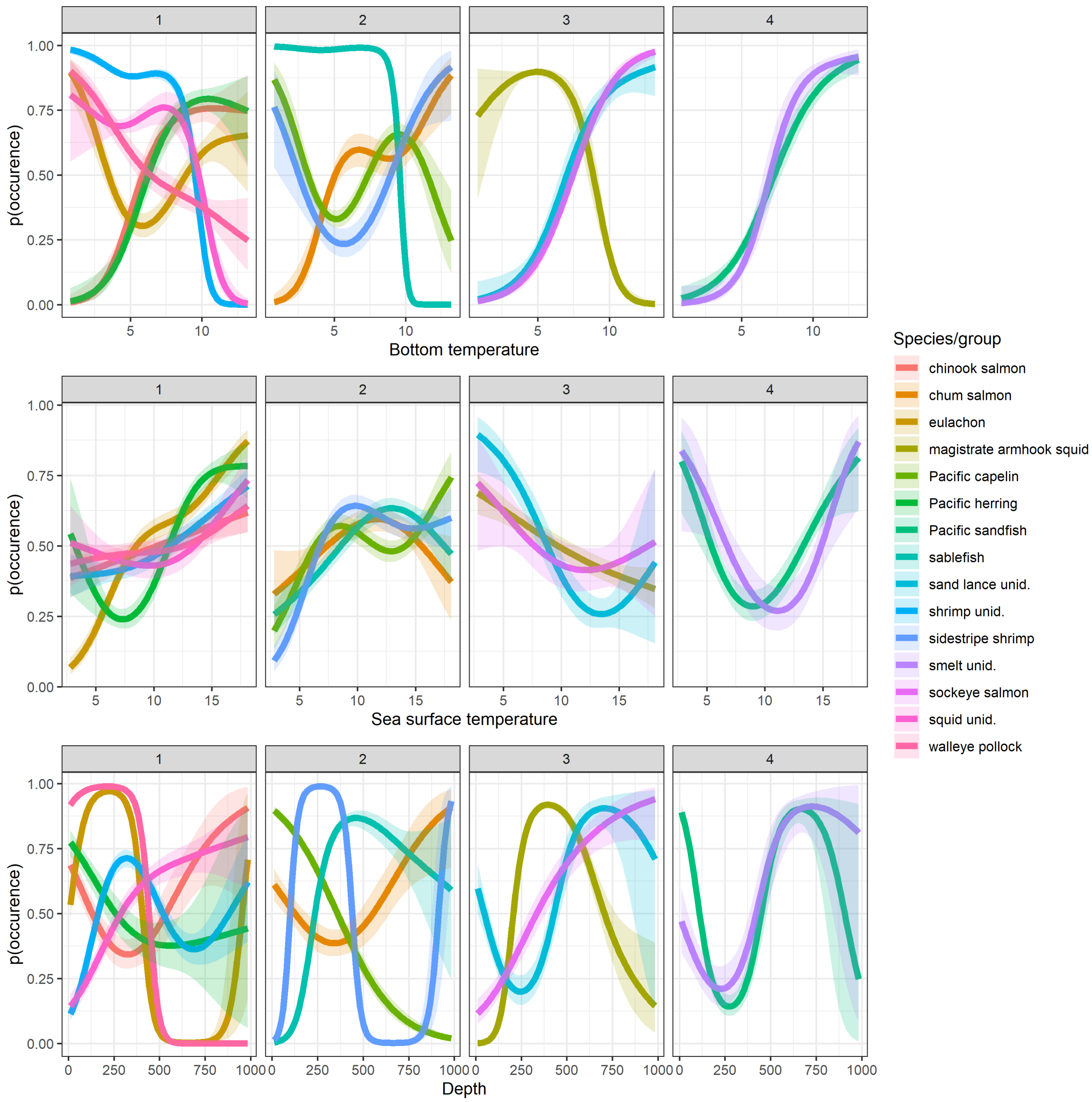

Figure 55: Probability of occurrence for selected forage species/groups in the GOA based on GAMs incorporating depth, SST, and bottom temperature. Species/groups were sorted to one of the four columns based on hierarchical clustering on the relationship to SST.

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