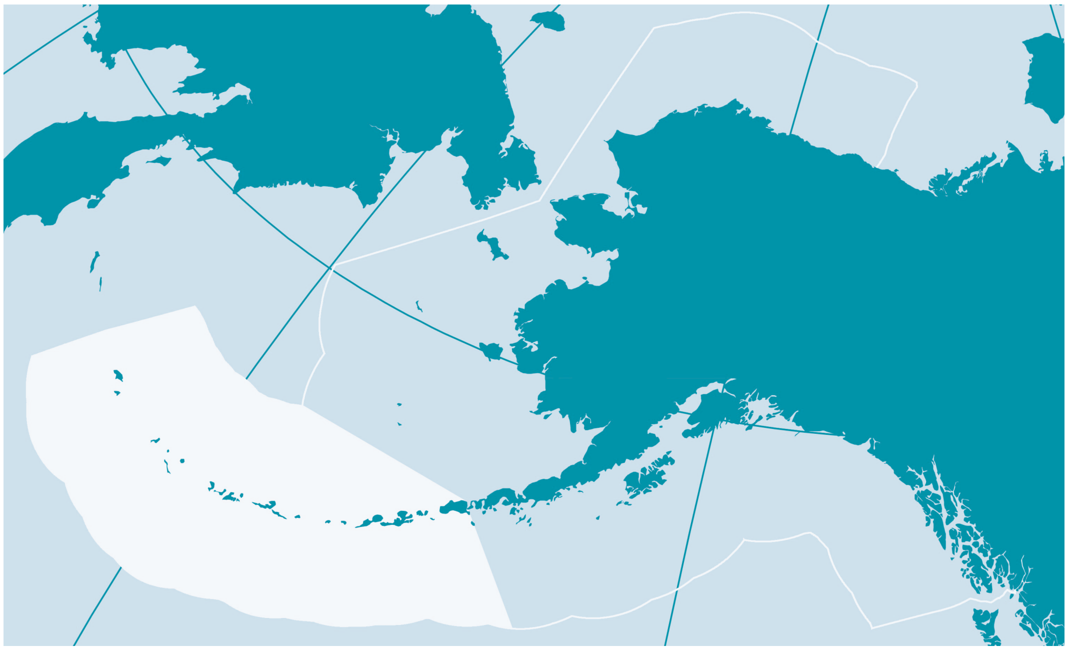
Ecosystem Status Report 2024

ALEUTIAN ISLANDS



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Time series from the report cards are available at `https://alaskaesr.psmfc.org/`

Contributing Partners

Purpose of the Ecosystem Status Reports

This document is intended to provide the North Pacific Fishery Management Council, including its Scientific and Statistical Committee (SSC) and Advisory Panel (AP), with information on ecosystem status and trends. This information provides context for the SSC's acceptable biological catch (ABC) and overfishing limit (OFL) recommendations, as well as the Council's final total allowable catch (TAC) determination for groundfish and crab. It follows the same annual schedule and review process as groundfish stock assessments, and is made available to the Council at the annual December meeting when Alaska's federal groundfish harvest recommendations are finalized.

Ecosystem Status Reports (ESRs) include assessments based on ecosystem indicators that reflect the current status and trends of ecosystem components, which range from physical oceanography to biology and human dimensions. Many indicators are based on data collected from NOAA's Alaska Fishery Science Center surveys. All are developed by, and include contributions from, scientists and fishery managers at NOAA, other U.S. federal and state agencies, academic institutions, tribes, nonprofits, and other sources. The ecosystem information in this report will be integrated into the annual harvest recommendations through inclusion in stock assessment-specific risk tables (Dorn and Zador, 2020), presentations to the Groundfish and Crab plan teams in annual September and November meetings, presentations to the Council in their annual October and December meetings, and submission of the final report to the Council in December.

The SSC is the primary audience for this report, as the final ABCs are determined by the SSC, based on biological and environmental scientific information through the stock assessment and Tier process[1],[2]. TACs may be set lower than the ABCs due to biological and socioeconomic information. Thus, the ESRs are also presented to the AP and Council to provide ecosystem context to inform TAC as well as other Council decisions. Additional background can be found in the Appendix (p. 109).

[1] https://www.npfmc.org/wp-content/PDFdocuments/fmp/GOA/GOAfmp.pdf
[2] https://www.npfmc.org/wp-content/PDFdocuments/fmp/BSAI/BSAIfmp.pdf

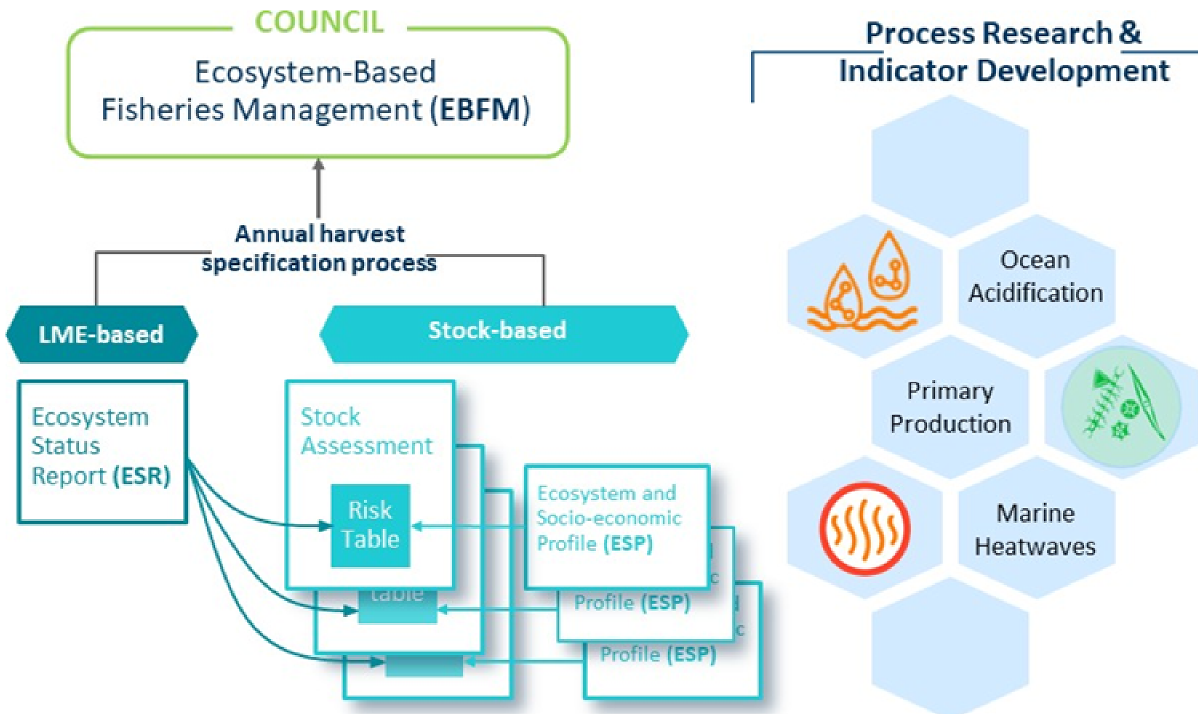

Figure 1: Ecosystem information mapping to support Ecosystem-Based Fisheries Management through Alaska's annual harvest specification process. The 'honeycomb' on the right shows examples of ecosystem indicators that are provided to Ecosystem Status Reports (ESRs) at the Large Marine Ecosystem (LME) scale and/or to Ecosystem and Socio-economic Profiles (ESPs) at the stock-based level.

Western Aleutian Islands 2024 Report Card

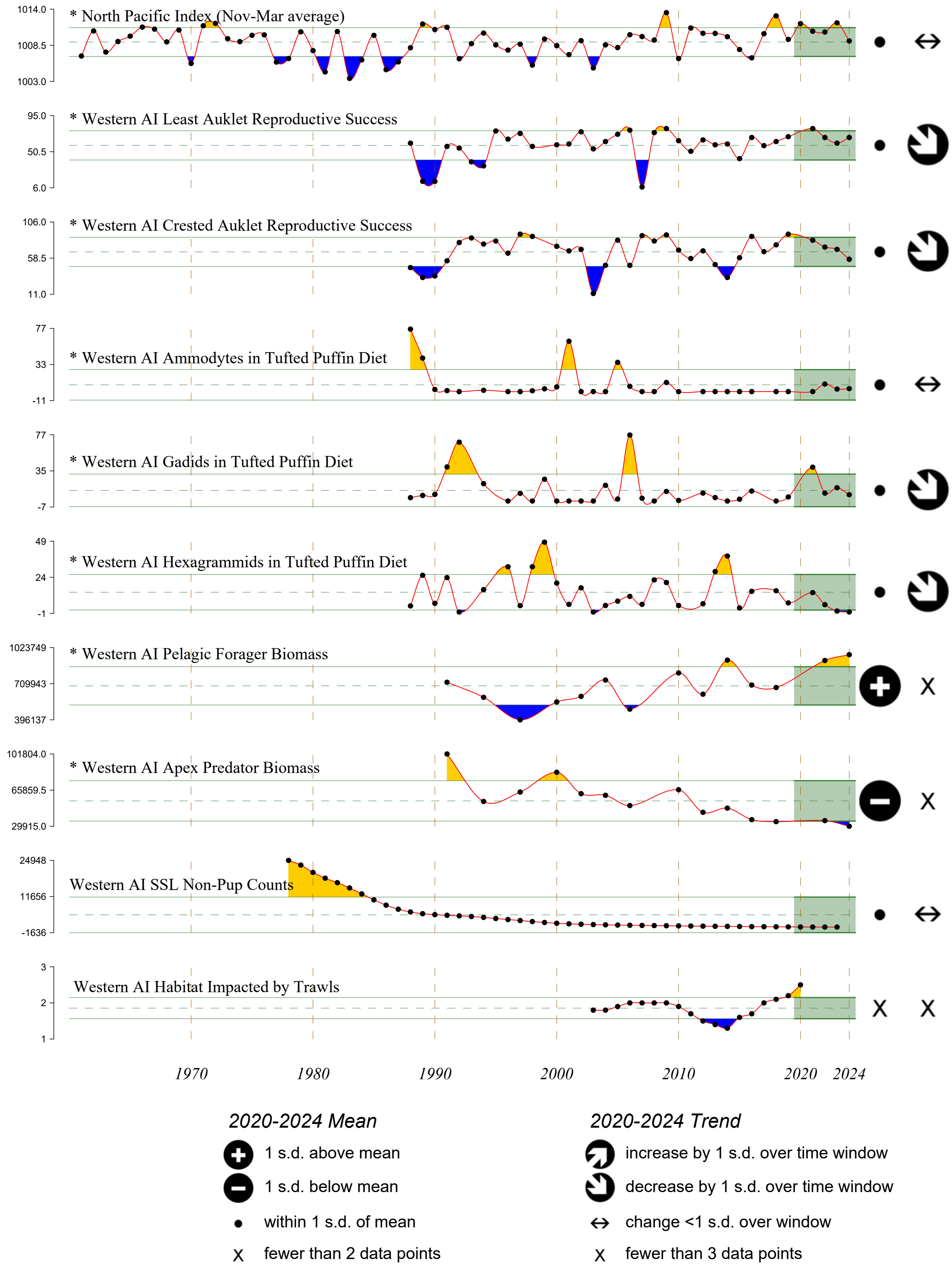

Figure 2: Region-wide and Western Aleutian Islands indicators. *indicates time series updated with 2024 data

Central Aleutian Islands 2024 Report Card

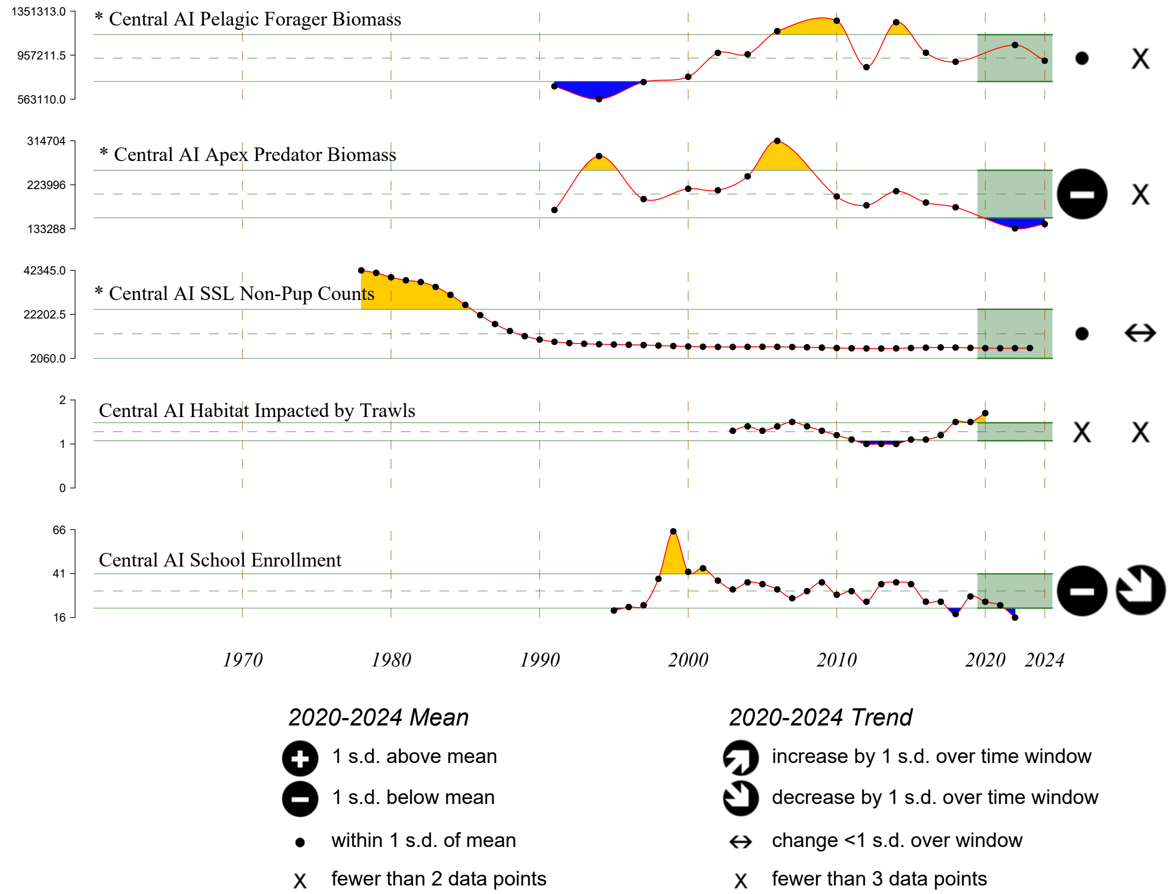

Figure 3: Central Aleutian Islands indicators. * indicates time series updated with 2024 data

Eastern Aleutian Islands 2024 Report Card

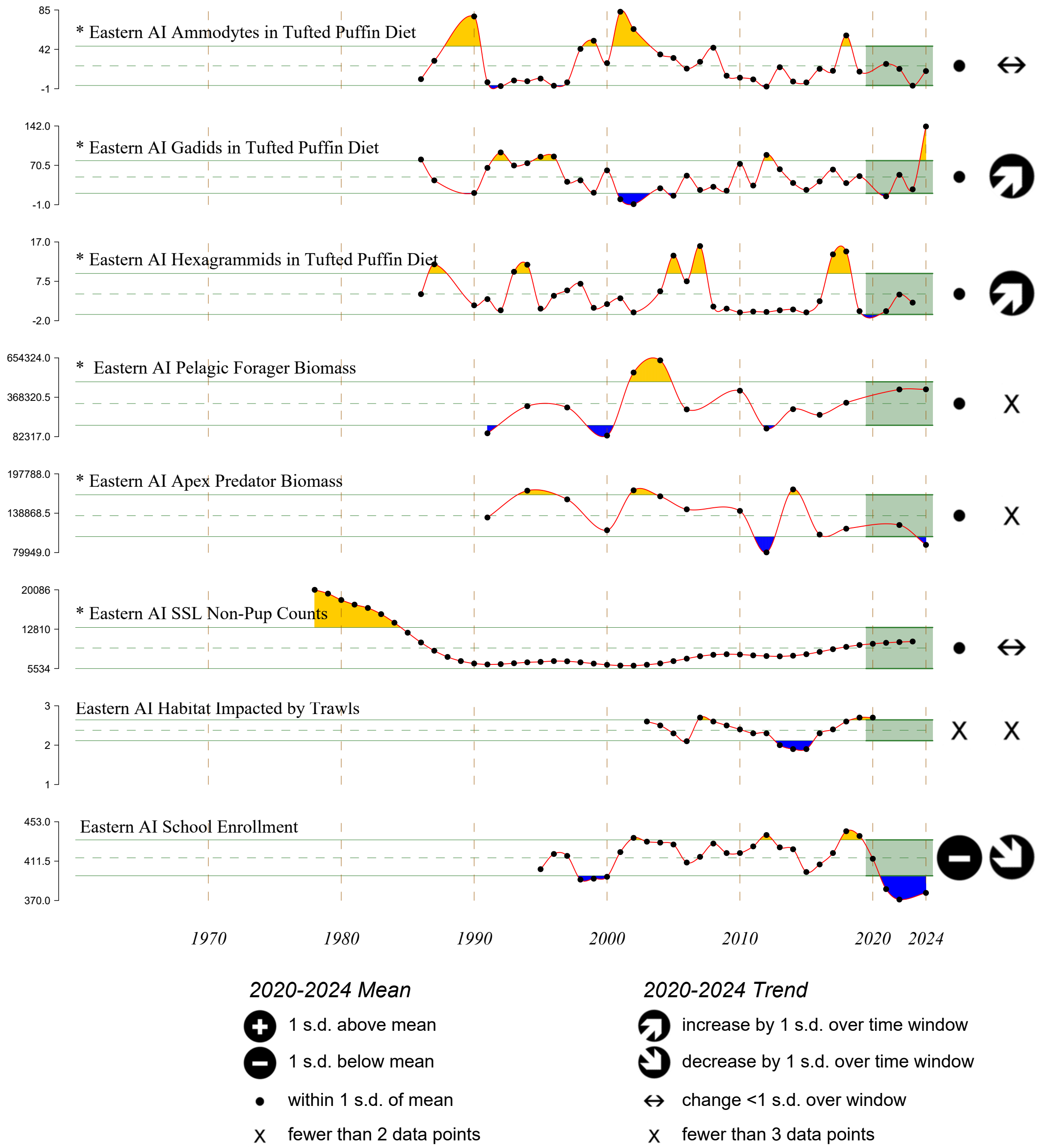

Figure 4: Eastern Aleutian Islands indicators. * indicates time series updated with 2024 data

For more information on individual Report Card Indicators, please see Description of Report Card indicators (p. 117). For more information on the methods for plotting the Report Card indicators, please see "Methods Description for Report Card Indicators" (p. 122).
* indicates Report Card information updated with 2024 data

To highlight the spatial dynamics and east to west gradients characterizing the Aleutian Islands, we divide the ecosystem into three ecoregions: the Western, Central and Eastern Aleutian Islands (p.10).

Western Aleutian Islands

- The North Pacific Index (NPI) effectively represents the state of the Aleutian Low Pressure System. Above average (below average) winter (Nov-Mar) NPI values imply a weak (strong) Aleutian Low and generally calmer (stormier) conditions. The NPI was average during winter 2023–2024 (Figure 12), while it had been positive during the last 4 years. The return to more neutral conditions this year may partially explain the **stormier conditions and strong winds**.
- Reproductive success was particularly poor this year for planktivorous auklets at Buldir Island. Three of the species (crested, parakeet and whiskered auklets) had both extremely late hatch dates and below-average breeding success, while only least auklets had above average reproductive success. The overall drop suggests that there was **below average availability of zooplankton** to support seabird reproductive success and potentially other plankton-eating commercial groundfish species.
- Forage fish trends, as indicated by their percent in the composition of tufted puffin chick meals, have varied over time, with episodic peaks lasting 1–2 years. In 2024, *Ammodytes* (sand lance) were close to the time series average, as were those of age-0 gadids (pollock mostly). Hexagrammids (primarily Atka mackerel) were absent from their diet, but appeared to be replaced by squid. However, puffin reproductive success was low, which suggests that they prey they brought back to their chicks was not optimal. While some seabird nests were lost after heavy rains, the decreased reproductive success across multiple species indicates **lower availability of forage fish** and potentially less available prey for groundfish feeding on fish.
- The **pelagic fish foraging guild biomass stayed above the time series mean and increased slightly** from 2022 to 2024. The increasing trend was driven mostly by northern rockfish, although pollock had a small increase as well. In contrast, the biomass of Atka mackerel and Pacific ocean perch decreased.
- The **overall biomass of the fish apex predator foraging guild continued declining** driven by Pacific cod and arrowtooth flounder. The decrease was somewhat offset mostly by increases in the biomass of rougheye/ blackspotted rockfish and other skates.
- Steller **sea lion numbers continue to decline**, with no signs of recovery. Non-pups declined 5.7% between 2008-2023.
- The amount of area trawled was not updated this year.

Central Aleutian Islands

- The **pelagic fish foraging guild biomass decreased** from 2022 to 2024, driven by Atka mackerel. The decrease was somewhat offset by increased biomass of pollock and Pacific ocean perch. Overall biomass is now close to the time series mean.
- The **fish apex predator foraging guild biomass had a modest increase** 2022 to 2024 but is still more than 1 SD below the long term average. Pacific halibut, arrowtooth flounder and skate biomass all declined, while Pacific cod, Kamchatka flounder and rougheye/ blackspotted rockfish biomass increased.

- Counts of non-pup **Steller sea lions were statistically stable but below the long term mean**. The trend is not the same in all rookeries: within the central Aleutians the two westernmost rookery complex areas are declining, while the two remained stable. Pup counts declined from 2008 to 2023 in the three westernmost rookery complex areas and were stable in the one furthest east.

- The amount of area trawled was not updated this year.

- **School enrollment continued a decreasing trend in the 2023-2022 school year**. The school at Adak was closed in 2023 after it opened with five enrolled students who subsequently left. Student enrollment started falling after the processing plant, one of the primary economic activities in the island, closed in 2020. Alaska schools need at least ten students to qualify for state funding. Amid rising operating costs and flat funding in general, small schools like those at Adak, Atka, and other small fishing communities, are at increasing risk of closure. Decreasing enrollment trends and/or school closures impact the stability of families living in those communities. This indicator is updated annually with data from the previous year.

Eastern Aleutian Islands

- Tufted puffin high reproductive success and the composition of the fish fed to chicks indicated that **forage fish were abundant, particularly capelin and age-0 pollock**, which may reflect good foraging conditions for fish-eating groundfish. *Ammodytes* (sand lance) and hexagrammids (Atka mackerel) were below the time-series mean in the puffin chick diets, although hexagrammids are uncommon in this region.

- The biomass of Atka mackerel increased substantially in the bottom trawl survey ($\sim$ 5x compared to 2022), offsetting decreases in Pacific ocean perch, pollock, and northern rockfish biomass and maintaining a **similar biomass level of pelagic forager groundfish compared to 2022**. Swings in Atka mackerel biomass are common in the area.

- **The fish apex predator foraging guild biomass decreased** 24%, driven by arrowtooth flounder, Pacific halibut the rougheye/ blackspotted rockfish complex. Offsetting the decrease, Pacific cod, large sculpins and other skates increased compared to 2022. The guild biomass had been consistently increasing from its lowest point in 2012 and in general has remained below average since 2016.

- In contrast to the other regions in the Aleutian Islands, **non-pup and pup counts of Steller sea lions continue to steadily increase**. The recent 2023 estimates show increases of 2.1% and 1.5% from 2008 to 2023. Increasing counts in this area offset declines observed in the other regions of the Aleutian Islands. In most regions, and population wide, stability in non-pup counts was preceded by stable pup counts.

- The amount of area trawled was not updated this year.

- **School enrollment had a slight improvement from 2022 to 2023**. Enrollment at the elementary school in Unalaska peaked in 2019-2020 at 238 students compared to the current 187 (note peak in 2018-2019 was due to the combined elementary and high school students). The small communities have either closed schools (Nikolski, in 2009) or are at risk of closure if they fall under the 10 student threshold (False Pass currently with 9 students and Akutan with 24). The generalized long-term decline in enrollment, except for Akutan, is a concern. As in the case of the central Aleutians, decreasing enrollment trends impact the stability of families living in those communities. This indicator is updated annually with data from the previous year.

Introduction

The Aleutian Islands ecoregions

The Aleutian Islands ecosystem assessment and Report Card are presented by three ecoregions. The ecoregions were defined based upon evidence of significant ecosystem distinction from the adjacent ecoregions by a team of ecosystem experts in 2011. The team also concluded that developing an assessment of the ecosystem at this regional level would emphasize the variability inherent in this large area, which stretches 1900 km from the Alaska Peninsula in the east to the Commander Islands in the west. For the purposes of this assessment, however, the western boundary is considered the U.S.–Russia maritime boundary at 170°E.

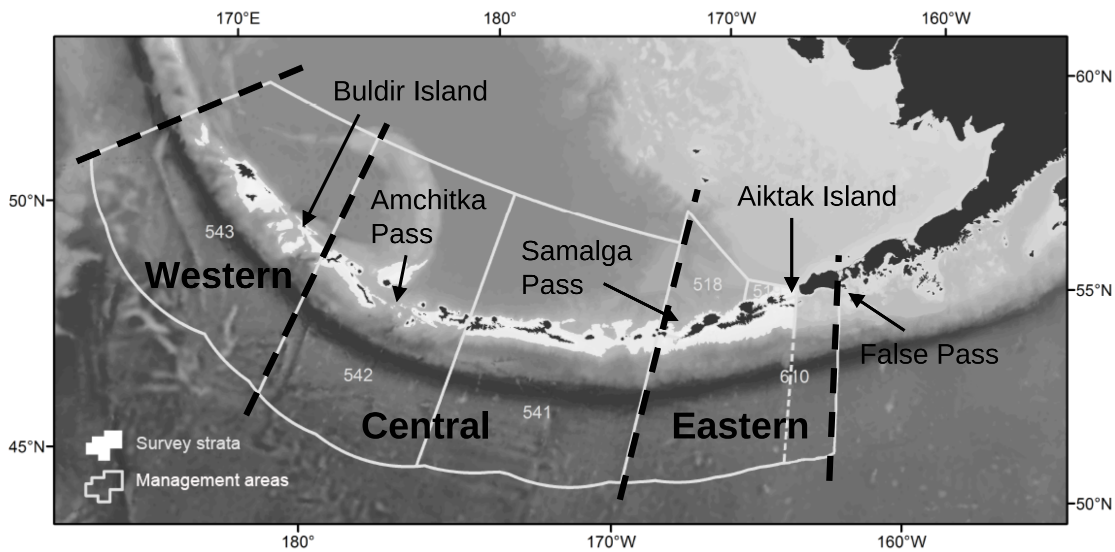

Figure 5: The three Aleutian Islands assessment ecoregions.

The three Aleutian Islands ecoregions are defined from west to east as follows (Figure 5). The western Aleutian Islands ecoregion spans $170°$ to $177°$E. These are the same boundaries as the National Marine Fisheries Service area 543. This ecoregion was considered to be distinct from the neighboring region to the east by primarily northward flow of the Alaska Stream through wide and deep passes (Ladd, pers. comm.), with fewer islands relative to the other ecoregions.

The central Aleutian Islands ecoregion spans $177°$E to $170°$W. This area encompasses the National Marine Fisheries Service areas 542 and 541. There was consensus among the team that the eastern boundary of this ecoregion occurs at Samalga Pass, which is at $169.5°$W, but for easier translation to fishery management areas, it was agreed that $170°$W was a close approximation. The geometry of the passes between islands differs to the east and west of Samalga Pass (at least until Amchitka Pass). In the central ecoregion the passes are wide, deep and short. The Alaska Stream, a shelf-break current, is the predominant source of water (Figure 6). There is more vertical mixing as well as bidirectional flow in the passes. This delineation also aligns with studies suggesting there is a biological boundary at this point based on differences in chlorophyll, zooplankton, fish, seabirds, and marine mammals (Hunt and Stabeno, 2005).

The eastern Aleutian Islands ecoregion spans $170°$W to False Pass at $164°$W. The passes in this ecoregion are characteristically narrow, shallow and long, with lateral mixing of water and northward flow. The prominent source is from the Alaska Coastal Current, with a strong freshwater component. This area encompasses the NMFS areas 518, 519 (EBS) and the western half of 610 (GOA).

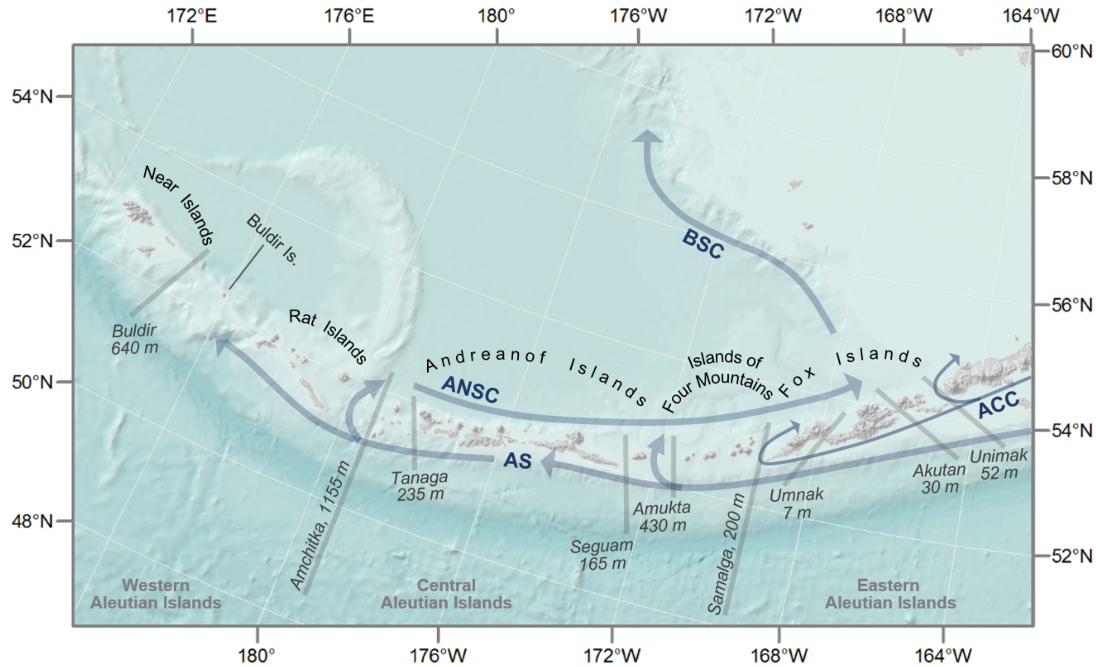

Figure 6: Ocean water circulation in the Aleutians. Currents are indicated with black lines. Currents are indicated by grey arrows. Selected passes are indicated by straight light grey lines

As the Aleutian Islands are situated between the Bering Sea and the Pacific Ocean, they are influenced by different ocean currents, eddies, and geographic constraints. Given these challenges, there are large gaps in knowledge about the local physical processes. The use of technology to address these challenges can be limited. For example, persistent cloudiness can preclude obtaining comprehensive satellite-derived data, and strong currents preclude the use of various unmanned underwater vehicles. The long distances involved in surveying the island chain make comparing west–east trends in indicators difficult due to time lags during oceanographic surveys across the region. The archipelago is also influenced by different processes in the eastern than in the western Aleutian Islands. Differences in survey timing and longitudinal gradients may also affect detection of biological patterns, as gradients are seldom monotonic in any direction. Integrative biological indicators such as fish or marine mammal abundances may be responding to physical indicators such as temperature, but are less sensitive to timing of when they are surveyed compared with direct measurements of temperature. Also, the extensive nearshore component of the ecosystem is a long, narrow shelf relative to the entire ecosystem, and strong oceanographic inputs mean that some metrics commonly used as ecosystem indicators in other systems may not be as informative in the Aleutian Islands. Therefore, our synthesis of ecosystem indicators by necessity includes speculation

Ecosystem Assessment

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Last updated: November 2024

Current Conditions 2024

The Aleutian Islands ecosystem in 2024 showed signs of a gradient of poor productivity in the west to high productivity in the east, largely based on counts of Steller sea lion pups and non-pups and seabird reproductive success. Despite the overall relaxation of the multi-year warm conditions across the ecosystem and a low abundance year in the biennial Kamchatka pink salmon cycle, groundfish condition remained poor across the ecosystem, which would not typically be expected in a year with relatively cooler conditions and fewer pink salmon. Rockfish continue to comprise the main biomass of pelagic foragers in the area, which means that overall pelagic forager biomass will respond more slowly to changes in the environment than when Atka mackerel and walleye pollock were dominant. Winter sea surface temperature was still among the ten warmest on record (Figure 16). Strong winds and storminess during the 2023-2024 winter through spring contributed to cooler conditions during late spring and summer and were accompanied by a deeper mixed layer in the water column, similar to the previous year. This may have impacted the vertical distribution and availability of prey throughout the water column.

Groundfish condition deteriorated across most species throughout the ecosystem, despite the cooler temperatures. In particular, the condition of Pacific cod, northern rockfish, and POP have been below the long-term mean since 2012 across all regions (Figure 33). The decline in fish condition may also be indicative of several interacting factors including poor prey quality, low availability of prey, competition, and increased metabolic rate (Holsman and Aydin, 2015).

The impacts of the biennial Eastern Kamchatka pink salmon were documented in the AI ESR 2023 (Ortiz and Zador, 2023). Their abundance in 2024 was very similar to that in 2022, around 60,000 mt, which is close to the current total biomass estimate for the Aleutian Islands Pacific cod stock (Spies et al., 2024). Notably, this "low" pink salmon abundance is similar to what was considered high abundance in the 1970s and 1980s (Figure 31). Counts of western DPS (distinct population segment) Steller sea lion non-pup and pups in 2023 continued to show an increasing trend since 2007 (p. 76).

Western Aleutians

Sustained high sea surface temperatures during winter resulted in a moderate marine heatwave in the western Aleutians (Figure 17). Sea surface temperatures cooled in later spring but increased again in summer and has remained above the long-term (1985-2014) average (Figure 17). Marine heatwave conditions returned in late summer and have prevailed through early November. At times during late summer, over 75% of the western Aleutians were in heatwave status and reached the highest surface temperatures across the island chain. Bottom temperatures cooled slightly to below the 1991-2012 mean for the region (Figure 21). Eddy kinetic energy was above the long term average early in the year but is now below average, suggesting that there were higher fluxes of nutrients, heat, and salt through the passes in the western Aleutians early in the year, but then those declined (Figure 24). Warm sea surface temperatures over the western Aleutians have been the dominant trend for the last decade, which may be due to weaker wind-driven mixing, warmer air temperature, or advection of warm water from the North Pacific Ocean.

Based on biomass estimates from the 2024 bottom trawl survey compared to 2022 estimates, apex predator abundance decreased 16% overall, driven by a decrease in Pacific cod and arrowtooth flounder. In contrast, the overall biomass estimate of pelagic foragers increased 6%, driven by northern rockfish and walleye pollock (Figure 61). Small walleye pollock were not only the sole groundfish group whose condition increased in the western Aleutians, their condition was the highest that has been recorded (Figure 34). The below average fish condition of all groundfish, other than small pollock, suggests that they continue to experience either poor prey quality and/or low availability of prey. In fact, the steady decline over the last decade of the biomass of eelpouts and shrimp lends support to this idea (Figures 36, 37). In the case of Pacific ocean perch and northern rockfish, which are both primarily planktivorous, their declining condition may also be due to instraspecific competition for prey, given their sustained high biomass.

The stormier conditions potentially had an impact on seabirds at Buldir. Reproductive success was lower in 2024 than in 2023, with most species across the prey and feeding strategy spectrum having below average reproductive success (8 out twelve, Figures 41, 42) and later than average hatch timing (8 out of eleven, Figure 39). This includes planktivorous auklets as well as fish-eating puffins and kittiwakes. This suggests that there was not enough available prey to support successful reproduction for the majority of seabird species in 2024. Tufted puffin chick diets by weight at Buldir were mainly composed of squids 64% and 22% pollock, while horned puffin chick diets there were primarily composed of Atka mackerel (42%) (Figure 43). The dominance of species in puffin chick diets concurs with stable or increasing biomass of these species based on bottom trawl survey data.

Numbers of Steller sea lions Steller sea lion non-pups and pups declined significantly from 2008 to 2023 (-5.69% y^{-1} and -3.98% y^{-1}, respectively; Figure 49). Their decline might be linked to the lower prey quality and availability, as observed in Pacific cod diets (Ortiz and Zador, 2023), decreased fish condition, and decreases in fish prey biomass.

Central Aleutians

Similar to the western Aleutians, the central Aleutians experienced a moderate but shorter marine heatwave in winter, with close to average temperatures during spring, and there was no heatwave in summer. While there were warm anomalies over 25% of the central Aleutians in summer, these were not sufficient to register in the spatial mean (Figure 17). Bottom temperatures were cooler than previous years, staying close to the 1991-2012 mean (Figure 21). Eddy kinetic energy in this region is usually lower in magnitude compared to those in the western and eastern Aleutians. Eddy events in this area are characterized either by multiyear or continuous eddies of low intensity. In 2024, eddy kinetic energy was generally below the 1993–2023 average, indicating potentially below-average flux of nutrients and heat across the passes (Figure 24).

Overall pelagic forager biopmass decreased 13% in the area, driven by Atka mackerel and northern rockfish. Apex predator biomass increased 7% (Figure 61). As in the western Aleutians, the condition of all groundfish remained below average; small pollock were not sampled in this area. Eelpouts, shrimp and poachers, which are prey to some of the apex predators, appear to have decreased in the region (Figure 61).

Steller sea lion non-pup counts were statistically stable from 2008-2023. However, there are four rookery complex areas which show a gradient of recovery from west to east. The RCAs located furthest west within the Central Aleutians declined significantly (RCA 2 and 3 with decreases of 2.56% and 3.2% per year, respectively). The RCAs on the eastern portion (RCAs 4 and 5) remained stable. In this region, pups declined significantly from 2008 to 2023 (almost 2% per year), with significant declines in RCAs 2-4 and stability in RCA 5.

We report on school enrollment as an indication of trends in coastal, rural community populations. There is currently only one active public school in the Central region. The state had no report for Adak School. School enrollment bottomed out at the state level in Alaska during 2020–2021 and decreased even further during the 2023–2024 school year (p. 8). Barring renewed activity by the now-closed fish processing plant in Adak and the lost potential to be a hub for clean energy (fuel) along the great circle route, the future stability of the Adak community and school is uncertain. It is unclear whether the school is permanently closed or not.

Eastern Aleutians

As in the central Aleutians, sea surface temperatures were not as high during winter as they were in the western Aleutians (Figure 17). The marine heatwave periods were also shorter, with no marine heatwave over the summer. While there were also warm anomalies over 25% of the region in summer, these were not sufficient to register in the spatial mean (Figure 17). Temperatures were sometimes above the 1985–2014 baseline but mostly close to the mean in the region. Bottom temperatures were cooler than previous years, staying close to the 1991-2012 mean (Figure 21). As in 2023, the predominant wind pattern in 2024 suppressed flows through Unimak Pass. Eddy kinetic energy, which is typically driven by a strong pulse eddy in this area, was significantly lower this year, similar to the generally low value that has largely been observed since 2012 (Figure 24). The exception was the high EKE from mid-2021 to early-2022 associated with a passing eddy. This indicates potentially decreased flows of nutrients, heat, and salt through the passes.

Similar to the rest of the Aleutians, groundfish condition continued to be below average, with the exception of small pollock which had the highest condition recorded in the Aleutians and southern rock sole which had condition above the long term mean. This is a shift from mostly below-average condition throughout the chain since 2010 (Figures 33, 34). There were no significant changes in the overall biomass of pelagic foragers, although there was a notable increase in Atka mackerel, while the rest of the species in the complex decreased. Apex predator biomass decreased 24% in the eastern Aleutians, driven by a 55% decrease in arrowtooth flounder (Figure 61). Poachers and shrimp, common prey of apex predators, also seem to have declined in this area (Figures 36, 37).

This summer continues a successful trend for seabirds breeding at Aiktak Island, where reproductive success has been average or above average since 2019 (there were no surveys in 2020) for most seabird species. This indicates uniformly high prey availability for both nearshore and offshore foragers, including surface feeders and divers and across a broad spectrum of zooplankton to forage fish prey (Figure 41). Late hatch dates might have been impacted by the strong winds and storms (Figure 39). Tufted puffins chicks were fed primarily capelin again this year (50% by weight) followed by pollock (34%), indicating that high-quality forage fish were available to foraging seabirds (Figure 43). Together with the above-average condition of small pollock, this suggests a potentially good recruitment year for pollock.

Steller sea lions non-pup and pup counts in the eastern Aleutians increased significantly from 2008 to 2023 (2.14 and 1.48% decrease per year, respectively, Figure 49). In most regions, and population wide, stability in non-pup counts were preceded by stabilizing of pup counts.

Lab results published this year from a 2023 die-off (an opportunistic report of a die-off of over 150 shearwaters at Akutan Island in September 2023) showed samples tested negative for Highly Pathogenic Avian Influenza (HPAI) and below detectable levels for harmful algal bloom toxins (saxitoxin and its related congeners, STX). Paralytic shellfish toxins decreased significantly this year compared to 2023, but are still above the FDA regulatory limit, posing a continued seasonal concern for human health and food webs in the region. In 2024, maximum concentrations of 556 µg per 100 g were recorded in blue mussels (Figure 54). This is 7x (vs 47x in 2023, and 3.4x in 2022) above the regulatory limit (80 µg per 100 g, FDA). Concentrations above 1000 µg per 100 g are considered potentially fatal for humans. The level of toxins observed this year is still substantially lower than the toxins observed at 75x the limit in Unalaska during 2021.

Lastly, school enrollment in this region declined in 2020–21 and has not fully recovered, although both the elementary schools at Akutan and Unalaska had higher enrollment in 2023-24 (p. 9). Enrollment at Akutan has been steadily increasing and is currently at the same level as in late 1990. Unalaska had a similar enrollment to that in 2022, which is still below the average for the school. High school enrollment continues to slowly decrease, potentially signaling young adults or families with high school-aged children moving out of the area.

Contents

† indicates new contribution

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Ecosystem Indicators

Noteworthy Topics

We include information here that is deemed of relevance to ecosystem considerations of fisheries managers, but does not fit our typical indicator format. Information included here is often new, a one-time event, qualitative, some other type of non-standard ecosystem indicator, or a deeper discussion on a topic of interest.

School closure at Adak and school enrollment trends

The school at Adak closed last year after initial low enrollment (5 students). This follows the previous closure of the school at Nikolski in 2010[3]. Enrollment at small communities has a slow decreasing long term trend, with the exception of Akutan. Alaska requires public schools to have a minimum of 10 students enrolled to qualify for state funding. Communities in the Aleutians tend to have a significant portion of their economic activity dependant on fisheries. The SSC has highlighted the relevance of Adak as the only port for emergencies and supplies in the western Aleutians. The community of Adak lost one of its main economic activities and employers after the fish processing plant closed in 2020. Lack of schools pose a challenge for families to stay at or move to Adak (or other small communities), favoring temporary residents as opposed to year-round/ permanent residents that can further support the local economy.

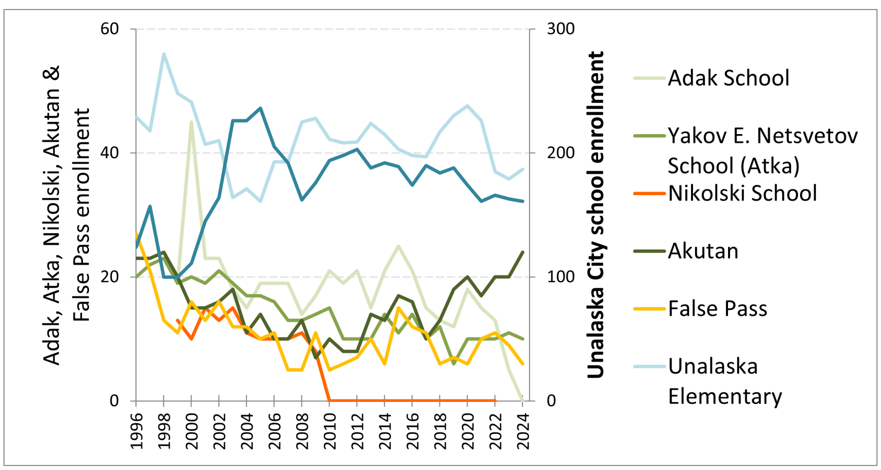

Figure 7: Total KG-12 enrollment at schools in the Aleutian Islands (west of False Pass).

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Gradients in diets and prey trends along the Aleutian Islands

Based on regional diets of Pacific cod presented last year, we take a closer look this year at survey data for prey items and current fish condition. Last year, as part of a preliminary analysis, we found the ratio of fish to invertebrate prey in diets has changed from a majority of fish in the early portion of the time series to a majority of invertebrates in the later portion. The trend however, appears to not be driven by an increase in invertebrate prey populations but rather a decrease in the availability of fish and lack of other fish prey substituting the decrease of Atka mackerel in Pacific cod diets (Ortiz and Zador, 2023).

Pacific cod diets can be further used as a case study of prey availability along a longitudinal gradient. We take a preliminary look at the combined biomass of Atka mackerel and pollock by region, as estimated from survey data, to look for correspondence between prey biomass, total prey weight consumed as a proportion of predator weight, fish condition, and bottom temperature (Figure 8). The combined biomass of pollock and Atka mackerel (prey biomass) follows similar trends to that of total prey weight as percent of predator weight, in the western and central Aleutians, but increasingly differs towards the east. This highlights the relevance of other prey such as shelf demersal fish (e.g. poachers and sculpins), squids, and shrimps. Survey estimates show an overall decreasing trend of miscellaneous benthic species: eelpouts, poachers, shrimp and sea stars, with eelpouts and shrimps decreasing particularly in the western Aleutian Islands. Fish condition appears to increase when fish eat at least 1% of their weight, but not always – which suggests the caloric value of the prey varies and can offset lower consumption rates or vice versa.

There might be a potential decrease of prey availability for predators feeding on fish or a combination of fish and invertebrates. The apparent decrease in prey highlights some of the challenges to apex foragers, not factoring increasing temperatures which also seem to coincide with lower fish condition. Food-webs in the Aleutian Islands tend to have an east-west gradient where food-webs in the east are more piscivorous and neritic while in the west they are more planktivorous and oceanic. The increase of rockfish abundance in the west, while bringing stability, reduces the amount/ quality of fish prey as well as the availability and timing of fish eggs and larvae to a variety of predators, as most rockfish are live bearers. In the Aleutians, Pacific ocean perch undergo parturition in April (TenBrink and Spencer, 2013) as opposed to gadids which hatch earlier in the year (e.g. cod spawns February to April, Neidetcher et al. 2014) and Atka mackerel spawn from July through mid-October with peak hatching in late November (McDermott et al., 2007; Lauth et al., 2007). A more holistic study is needed to evaluate the impacts on apex predators of a shift in the primary traits, phenology, and life history strategies within the pelagic foragers guild in the Aleutian Islands.

Contributed by: Ivonne Ortiz[1], Kerim Aydin[2], Rebecca Howard[3], Bianca Prohaska[3], Ned Laman[3], Sean Rohan[3], Christina Conrath[3], and Susanne McDermott[3]

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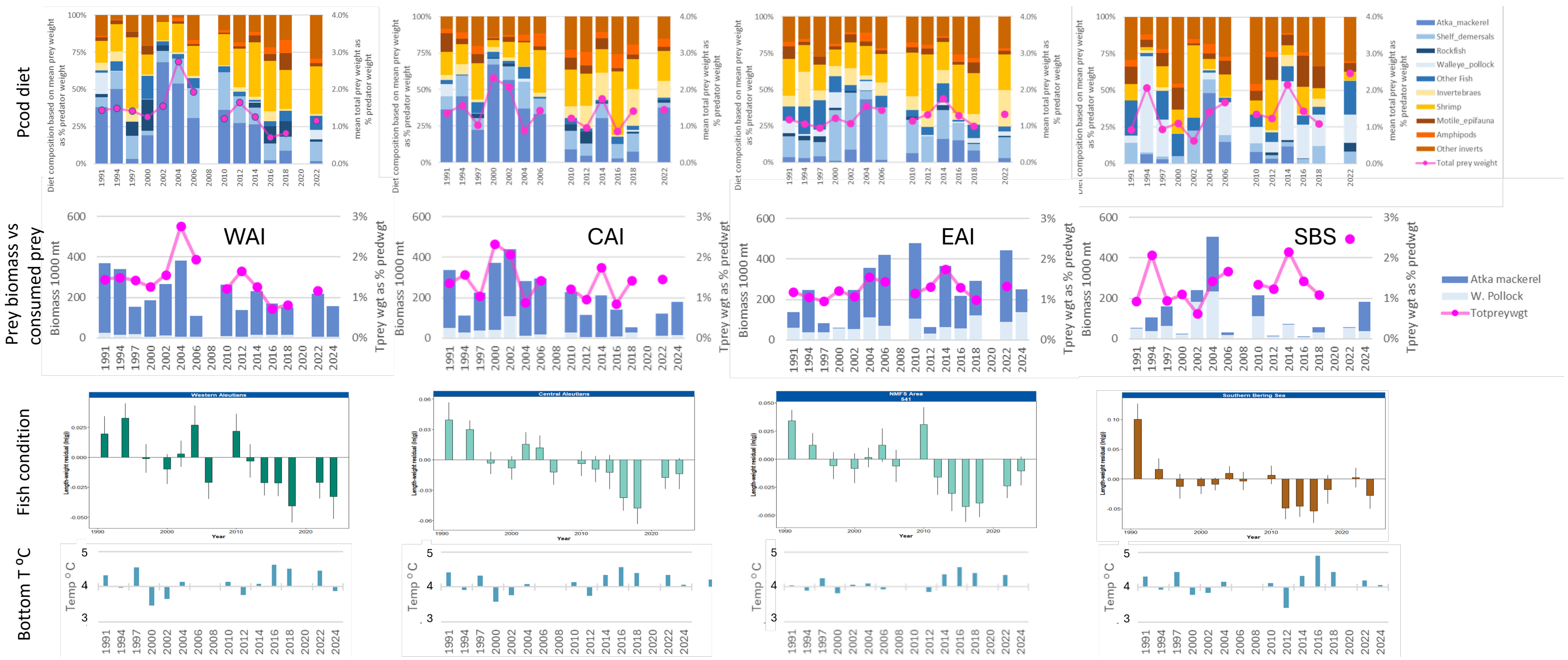

Figure 8: From left to right Western, Central, Eastern Aleutians, and Southern Bering (NMFS areas 543, 542, 541, and 518-519 respectively). From top to bottom: graphical summary for each region of (row 1) Pacific cod diet and total prey consumed as percent of predator (row 2) prey biomass (Atka mackerel and pollock) vs total prey consumed as percent of predator (Pacific cod) weight, (row 3) fish condition and (row 4) mean annual bottom temperature above or below timeseries mean.

Ecosystem Status Indicators

Indicators presented in this section are intended to provide detailed information and updates on the status and trends of ecosystem components. Older contributions that have not been updated are excluded from this edition of the report. Please see archived versions available online[4].

Biophysical Synthesis

This synthesis section provides an overview of physical oceanographic variables and contains contributions from (in alphabetical order):

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Last updated: October 2024

Synthesis: Along the Aleutian Islands, strong and eastward winds and storminess from last autumn through summer associated with the Aleutian low pressure system contributed to cooling the surface waters through early summer. This resulted in increased southward transport, which opposes the mean ocean currents over the eastern Aleutians that typically transport warmer water from the North Pacific onto the Bering Sea shelf. Strong winds also mixed the water column, deepening the mixed layer and entraining colder water from below the surface, which may have impacted the availability of zooplankton prey. This is the first time since 2012 that the summer temperature falls (slightly) below average. In contrast, winter (Nov–Apr) temperatures show a significant trend over the past 124 years, with this past winter remaining above average and within the ten warmest since 1900.

Over the western Aleutian Islands, spring surface temperatures were near normal conditions in spring, but warm anomalies returned in summer. At times during late summer over 75% of the western Aleutians were in MHW status. Warm SST anomalies over the western Aleutians have been the dominant trend for the last decade, which may be due to weaker wind-driven mixing, warmer air temperature, or advection of warm water from the North Pacific Ocean. In the eastern Aleutian Islands, there were few days of MHW status in 2024 relative to the mean

[4]`https://www.fisheries.noaa.gov/alaska/ecosystems/ecosystem-status-reports-gulf-alaska-bering-sea-and-aleutian-islands`

over the last decade, which was also the case in 2021 and 2022. While there were also warm anomalies and MHWs over 25% of the central and eastern Aleutians in summer, these were not sufficient to register in the spatial mean.

The bottom temperatures were close to the 20-year mean (1991–2012) for all subareas. This is in contrast with the four survey years prior, which were generally warmer than average for both surface and bottom temperatures. The addition of the 2024 AI bottom trawl survey temperature data to the time series extended an apparent cooling (but still above the mean) trend that began after the warmer temperatures observed in 2016. Currently, eddy kinetic energy (EKE) in all three regions is either near or below its respective long-term average, with values reaching their historical minima in the eastern Aleutian Islands near Unimak Pass. This concurs with winds suppressing transport to the north at Unimak Pass. The lower EKE suggests decreased heat and nutrient fluxes across all passes.

The National Multi-Model Ensemble (NMME) projections last year (October 2023) predicted a large region of relatively warm water in the central and western North Pacific between 30 and 50○N through Nov 2023-Jan 2024. Positive temperature anomalies were also predicted for the western Aleutian Islands with January through March 2024 Jan-Mar 2024 showing some moderation in tropical Pacific temperatures but still enough warmth to constitute El Niño. This was largely borne out by observations. This year La Niña is favored to emerge in September-November (60% chance) and is expected to persist through January-March 2025. With average condition thought the eastern and central Aleutians and warm anomalies of 0.25 to $0.5°C$ in the western Aleutians.

The meso-zooplankton biomass was positive (for the first time since 2017), while the diatom abundance presented a positive annual anomaly for the third year in a row. The copepod community size anomaly, which has been mostly negative in each season sampled since summer 2014 suggests a real increase in the relative abundance of smaller species, potentially because of warmer than normal conditions. This region appears to be subjected to top down influence by Pink Salmon as well as bottom up forcing by ocean climate, which is particularly challenging to interpret. Changes in abundance or biomass, together with size, influences availability and quality of prey to predators.

We provide an overview of the physical oceanographic conditions impacting the Aleutian Islands, describe conditions observed from fall 2023 through summer 2024, and place 2024 in the context of recent years. The physical environment impacts ecosystem dynamics and productivity important to fisheries within the system and their management. The information has been merged across sources, from broad-scale to local-scale, and is presented as follows:

Outline:

1. Regional Highlights
2. State of the North Pacific
3. Seasonal Projections of SST from the National Multi-Model Ensemble (NMME)
4. Long Term Sea Surface Temperatures
5. Regional Sea Surface Temperatures
6. Bottom and Surface Temperatures from Survey
7. Ocean Transport: Eddies in the Aleutian Islands
8. Zooplankton: Continuous Plankton Recorder data

1. Regional Highlights

Contributed by Emilie Lemagie and Shawn Bell

Summary: Southward winds associated with the near normal location of westward shifted Aleutian low (Figure 14) advected seasonal sea-ice southward in winter. Through spring, southward winds from the U.S. Arctic, along with low heat transport from the south, contributed to a maximum sea-ice extent over the Bering Sea shelf that reached near historical norms despite the warm fall conditions. Eastward wind anomalies around 45-50°N in winter through early spring, associated with southward Ekman transport, may have reduced northward heat transport through the Aleutian passes and along the eastern coastal Gulf of Alaska, leading to a cooling tendency across the shelf and coastal regions. The cooling tendency over the Gulf of Alaska basin in spring may have been associated with counterclockwise wind anomalies driving Ekman pumping of subsurface waters towards the surface. Storminess and strong winds also contributed to vertical mixing across the regions, which is associated with cooler surface temperatures.

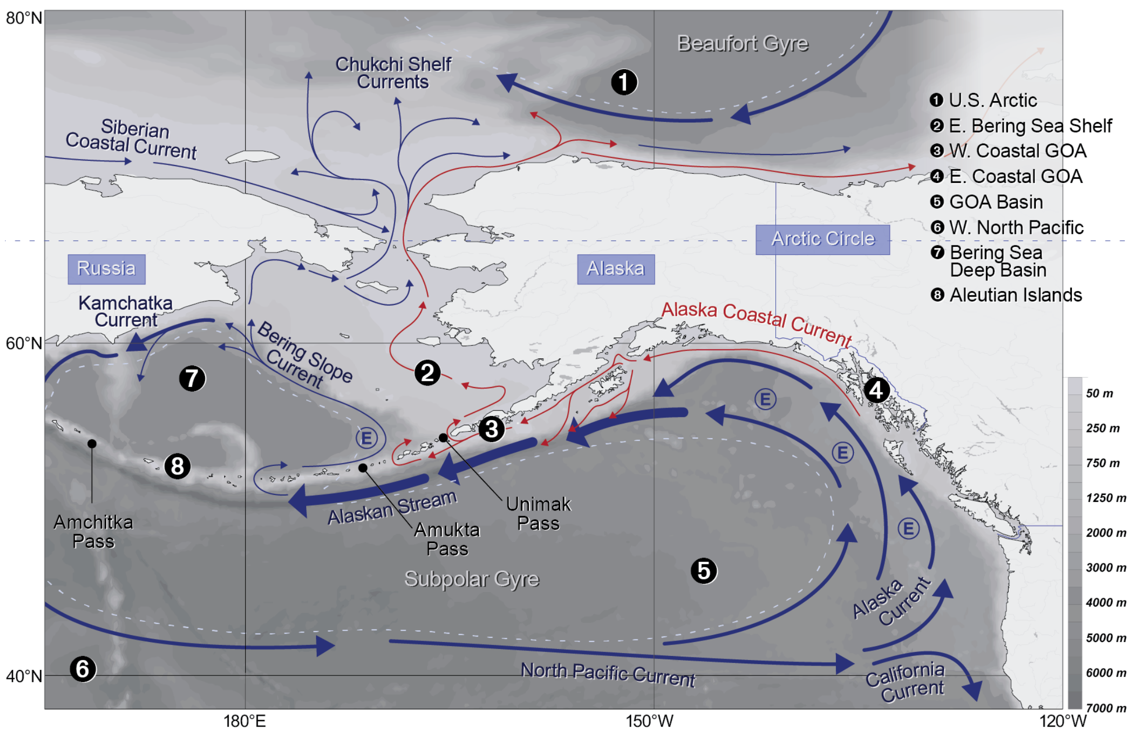

Figure 9: Geographic regions of interest, ocean bathymetry, and mean currents across the North Pacific and U.S. Arctic.

Aleutian Islands: Anomalously strong and eastward winds from autumn 2023 through spring and into summer 2024 corresponded with a negative tendency in the SST anomalies and a decline from warm SST anomalies in autumn to cool SST anomalies by summer (Figure 10). Along the Aleutian Islands, winds towards the east and northeast were stronger than the historic mean conditions throughout most of the last autumn through the summer. Winds in this sense increase southward Ekman transport, which opposes the mean ocean currents over the eastern Aleutians that typically transport warmer water from the North Pacific onto the Bering Sea shelf. Strong winds also mix the water column, deepening the mixed layer and entraining colder water from below the surface. Over the western Aleutian Islands, spring surface temperatures were near normal conditions in spring, but warm anomalies returned in summer. Warm SST anomalies over the western Aleutians have been the dominant trend for the last decade, which may be due to weaker wind-driven mixing, warmer air temperature, or advection of warm water from the North Pacific Ocean.

Western Coastal Gulf of Alaska: From the coastal waters off the Kenai Peninsula to the Alaska Peninsula, SST remained near historical mean temperatures from autumn 2023 through the spring of 2024 (Figure 10). Due to large topographic features along the shoreline and the channel formed between Kodiak Island and the mainland, this region is strongly influenced by local scale winds and ageostrophic dynamics. Over the winter, a combination of wind-driven mixing, coastal upwelling, and Ekman pumping contributed to decreasing the SST anomaly to near-normal temperatures. In spring, regional SST and winds remained near-normal, but in late summer 2024 wind anomalies were strongly upwelling-favorable, associated with cool SST anomalies along the coast.

Bering Sea Deep : Warm SST anomalies, up to 1oC were present over much of the Bering Sea deep basin in the autumn of 2023, but a decreasing tendency throughout the winter and spring culminated with cool or near-climatological mean SST by June 2024 (Figure 10). Stormy weather was prevalent in autumn through spring which can act to stir the water column, deepen the mixed layer, and decrease SST anomalies. Wind anomalies over the northern basin were towards the south, advecting cooler continental air masses over the basin, but the southern basin wind anomalies were towards the east much of the winter through summer. Eastward wind anomalies result in Equatorward Ekman transport anomalies and reduce northward advection of relatively warmer waters.

U.S. Arctic Autumn 2023 through spring 2024 was generally characterized by above average wind variability and late winter seasonal ice advance through the Bering Strait (Dec vs. Nov). Positive air temperature anomalies were present over the U.S. Arctic in autumn, coincident with high variability in the mean sea level pressure and anomalously weak and variable winds in the Chukchi, Bering Strait, and Northern Bering Sea regions (Figure 10). In November, SST was anomalously warm in the ice free regions of the Chukchi sea and northern Bering Sea shelf in November. An Aleutian low pressure system developed in January, located eastwards from its mean location (Figures 13, 14). This was associated with the anomalously strong and southward winds over the northern Bering Sea region (Figure 10). Winter seasonal mean winds were near the climatological average, but strong winds in early winter and late spring contributed to advecting sea ice southwards. The spring transition was also characterized by above-average wind variability, with southward winds through the Bering Strait region in the late spring stronger than the climatological mean. Cool surface temperature anomalies were present in summer over the open-water parts of the Chukchi Sea following the seasonal sea ice retreat.

Eastern Bering Sea Shelf: Despite warm SST anomalies over the Eastern Bering Sea in the autumn through winter and late winter sea-ice advance relative to historical norms, the maximum sea-ice extent was near historical norms and following sea-ice retreat, open-water SST was cooler than climatological mean temperatures. Strong off-shelf winds in October 2023, resulting in northward Ekman transport along the shelf, followed by weaker than mean westward winds from the Alaska mainland in November were accompanied by an increase in the SST anomaly over the Bering Sea shelf in the autumn (Figure 10). Historical mean winds along the southern Bering Sea shelf are westward in autumn and winter, with mean ocean currents flowing from the Gulf of Alaska northwards. Throughout the most recent winter and spring, wind anomalies over the southern Bering Sea shelf were strong and towards the east, such that the local wind-driven Ekman transport opposed the mean current and reduced heat transport of warmer waters from the south. Stormy weather also increases vertical ocean mixing that can entrain cooler water from depth into the surface layer. Spring 2024 observations from the ecosystem observatory M2 on the Eastern Bering Sea shelf reported a substantially deeper than historical mean mixed layer depth through the summer (not shown). From November through June, greater than usual seasonal cooling reduced the SST anomalies from up to $1.5°$C above monthly mean temperatures to as low as $1.5°$C below monthly mean temperatures over the Eastern Bering Sea shelf, a trend that continued through the summer resulting in even stronger cool anomalies by late summer.

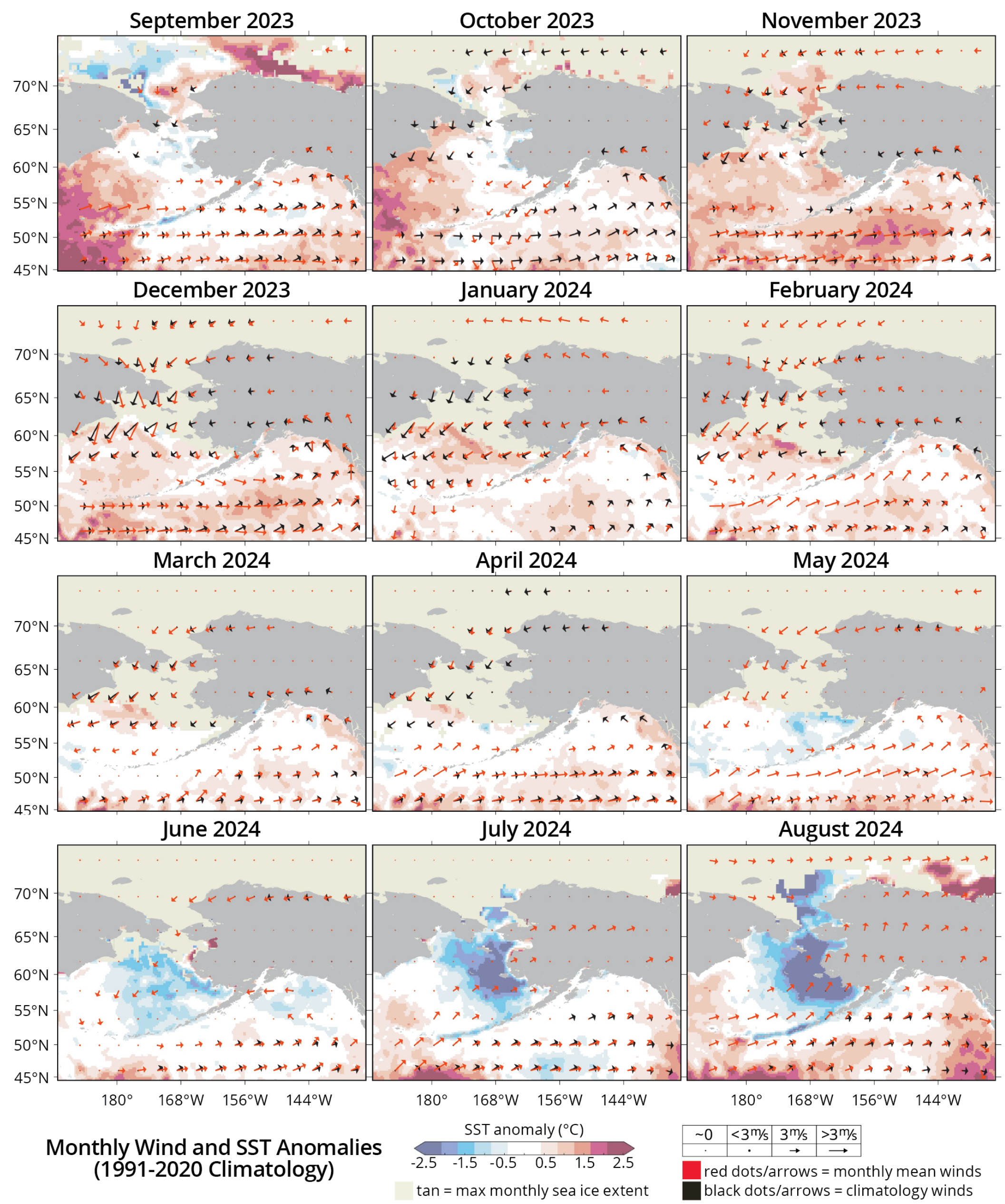

Figure 10: Monthly mean maps of sea surface temperature (SST) anomalies and surface winds. Monthly climatological winds (black) are compared to monthly mean winds (red). The climatological period is from 1991–2020. SST data are from the NOAA High-resolution Blended Analysis of Daily SST and Ice (OISST), and 10-m wind data are from the NCEP/NCAR Reanalysis II; both are available from NOAA's Physical Sciences Laboratory.

2. State of the North Pacific Ocean

Contributed by Emily Lemagie and Shawn Bell

The sea surface temperatures over the North Pacific were anomalously warm from the autumn 2023 through winter 2024 (Figure 11). The warmth was greatest between 30–$45°$N, where SST anomaly peaks over the western Pacific remained above $2.5°$C into spring 2024. Warm seasonal SST anomalies extending over most of the mid-latitude Western Pacific with peak magnitudes above $2°$C have persisted since the winter of 2019–2020, a pattern that is represented by the negative PDO index over the last 5 years (Figure 12). Over the most recent fall and winter, strong warm anomalies were also measured along the Equator (captured by the El Niño index, Figure 12). Warm autumn SST along the eastern Pacific coast are also consistent with El Niño conditions. Equatorial anomalies have weakened, but remained positive, in spring 2024. North of $45°$N, and throughout much of the Alaska marine waters, the warmth abated and SST were near historical mean temperatures in spring 2024. Seasonal average summer temperatures were near normal over most of the Alaska marine waters, except over the Bering Sea shelf where the mixed-layer depth was deeper than average.

The autumn (Sep–Nov 2023) SLP was near the climatological mean, a result of shifting atmospheric conditions, and was associated with autumn storms and variable wind speed and direction throughout the season. Jan–Feb 2024 winter mean sea level pressure was also similar to the mean winter pattern. The center of the Aleutian Low was shifted to the southwest from the historical mean (see Aleutian Low Index section), and with westward wind anomalies >2 m s^{-1} along the Aleutian Islands. The seasonal mean SLP in spring (Mar–May 2024) resulted in a clockwise wind anomaly of 2–3 m s^{-1} eastward between 45–$50°$N, westward focused between 20–$30°$N, and southward off the U.S. west coast, enhancing coastal upwelling (not shown). In summer, near-normal surface pressure and wind patterns were associated with near-normal surface temperatures over much of the region, except through the Aleutian Island passes and Eastern Bering Sea shelf where surface temperatures were below average due to the deep surface mixed layer.

WINTERTIME ALEUTIAN LOW INDEX

Contributed by James Overland and Muyin Wang

Winter atmospheric conditions over Alaska are heavily dominated by the Aleutian low pressure system, which develops and strengthens seasonally between the Beaufort high and North Pacific high pressure regions. The strength and location of the Aleutian low in January-February 2024 were similar to historical means (Figures 12-14).

Variability in strength and the position of the low is important to the Alaska marine ecosystem through its impact on circulation, surface heat fluxes, mixed layer depth, and the extent of sea ice cover over the Bering Sea, all of which influence the rich biological resources of the sea (Rodionov et al., 2005; Wooster and Hollowed, 1995). In general, the intensity and position of the Aleutian Low can significantly influence storm tracks, ocean circulation, and weather patterns across the North Pacific, impacting North America.

Motivated by work from Rodionov et al. (2005), we defined the Aleutian Low Index (ALI) as the areas where sea level pressure (SLP) is less than or equals to 1000hPa in the North Pacific region (40-$60°$N, and 160E-$160°$W). Aleutian Low is a statistical low, which exists in winter only. We computed the monthly Aleutian Low Index, and then averaged for the winter mean (January and February). A 30-yr climatology (1991-2020) mean is removed from the index. Figure 13 shows the anomalies of the ALI, from the 30-yr mean for each winter since 1980.

When there is a strong Aleutian low pressure system present, the ALI is positive, i.e. the low center occupies

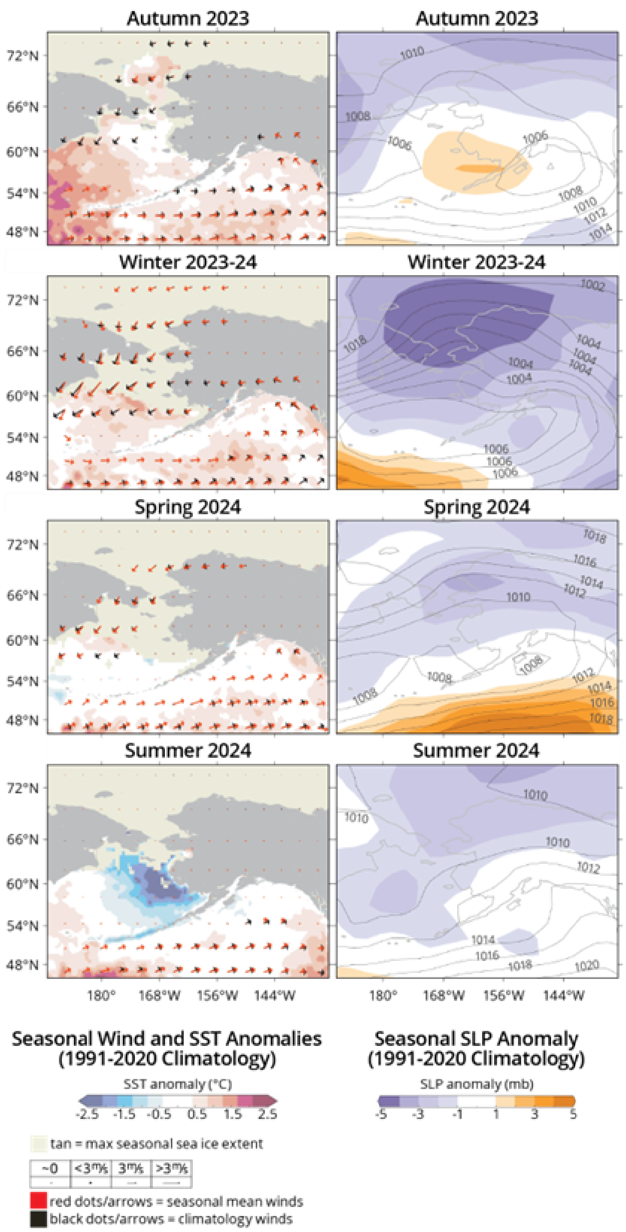

Figure 11: On the left, SST anomalies for autumn (Sep–Nov 2023), winter (Dec 2023–Feb 2024), spring (Mar–May 2024), and summer (Jun–Aug 2024), as well as seasonal climatological and mean winds. On the right, SLP anomalies and mean SLP contours for the same four time periods. Anomalies are relative to mean conditions from 1991–2020. Figure courtesy of Sarah Battle, PMEL

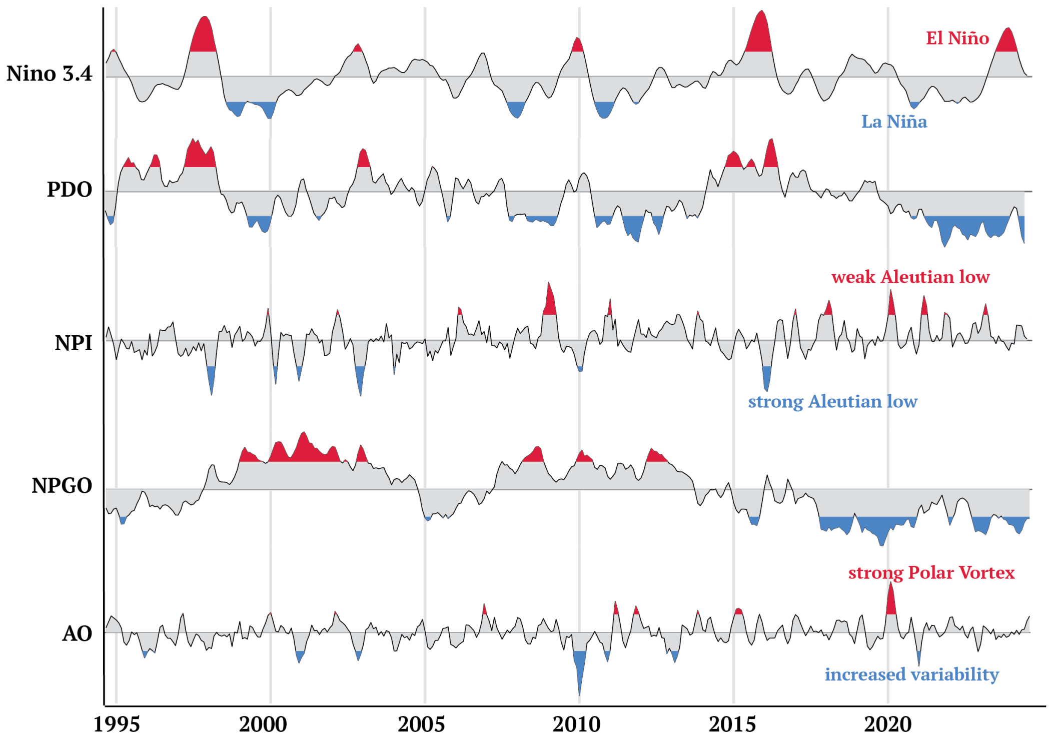

Figure 12: . Time series of five commonly used indices for relating patterns across the Alaska marine ecosystem, including the NINO3.4 index for the state of the El Nino/Southern Oscillation, the Pacific Decadal Oscillation (PDO), North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO), and the Arctic Oscillation (AO) indices for 2015–2024. Each monthly index is normalized using a 30-year climatology from 1991–2020 and smoothed using a 3-month running mean. Red and blue shading indicates positive and negative values, respectively. Lighter shaded areas are within one standard deviation of the 30-year climatology. Additional information on these indices can be found on the NOAA Physical Sciences Laboratory website

a larger area. However, the other factors that matter are how strong the Aleutian low center is and where the low center is located, with the latter playing a more important role. The east-west position of the Aleutian low center is captured relative to longitude 180: When the Aleutian low center is located to the west of 180, it is associated with warm ocean temperatures and low winter sea-ice extents over the Bering Sea shelf. Following Rodionov et al. (2005), cases with the Aleutian central pressure south of $51°$N are removed, and these years are left blank in Figure 14, as those tend to have a more zonal pattern. Based on Figures 13 and 14 together, we can see that the Aleutian low in 2024 is relatively weak (negative anomaly in Figure 13), and the center is more toward the eastern part of the Bering Sea (near $170°$W in Figure 14). Both the strength and location of the Aleutian Low resembles its climatological condition, i.e. it is a normal year. This may partially explain the near normal sea ice extent observed in winter 2024 in the Bering Sea as a weaker low allows for colder conditions and potentially greater sea ice coverage.

The Aleutian low is a key driver of the Pacific storm track and cyclones that form in the North Pacific tend to follow the path of the Aleutian low. The position and strength of the low determine whether these cyclones move northward into the Bering Sea or remain in the mid-latitudes. A strong Aleutian low brings more storms - stronger winds - to the Bering Sea, leading to increased precipitation. This is not the case for 2024. It can also be seen from Figure 11.

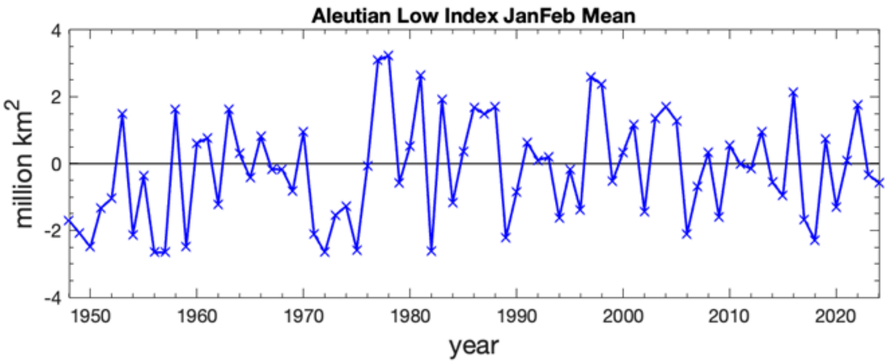

Figure 13: Winter (Jan and Feb) Aleutian Low Index which is defined as the area occupied by sea level pressure less than or equal to 1000hPa in the North Pacific region (40-60°N, and 160E-160°W). Time series shows the anomalies relative to 1991-2020 period mean

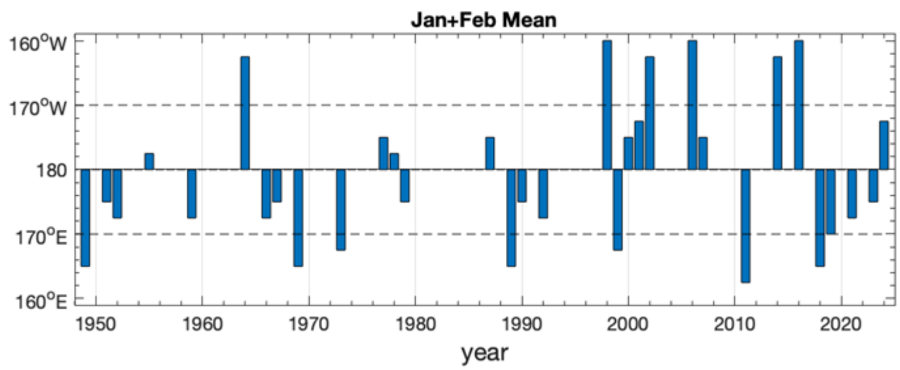

Figure 14: Longitude of the January-February Aleutian low central pressure location when the center is located north of 51°N for 1948-2024. Dashed line indicates 170°W/E. For center locations south of 51°N, or the low center above 1000hPa the plot has a blank year. SLP data are based on NCEP/NCAR Reanalysis.

3. Seasonal Projections of SST from the National Multi-Model Ensemble (NMME)

Contributed by Emily Lemagie

Seasonal projections of SST from the National Multi-Model Ensemble (NMME) are shown in Figure 15a–c. An ensemble approach incorporating different models is appropriate for seasonal and longer-term simulations; the NMME represents the average of eight climate models. The uncertainties and errors in the predictions from any single climate model can be substantial. More detail on the NMME, and projections of other variables, are available at the National Weather Service Climate Prediction Center[5].

These NMME forecasts of three-month average SST anomalies indicate a continuation of El Niño in the tropical Pacific and a large region of relatively warm water in the central and western North Pacific between 30 and 50°N through the end of the calendar year (Nov 2023-Jan 2024; Figure 15). Positive temperature anomalies are also predicted for the western Aleutian Islands, and coastal Alaskan waters extending from the southeast Bering Sea shelf to the Beaufort Sea. The models also indicate an atmospheric circulation pattern that would bring reduced storminess to the GOA (not shown). The ensemble of model predictions for January through March 2024 (Jan-Mar

[5] http://www.cpc.ncep.noaa.gov/products/NMME/

2024; Figure 15) shows some moderation in tropical Pacific temperatures but still enough warmth to constitute El Niño. As is typical with these events; the projections show warming in the coastal zone of the eastern GOA. Moderation is indicated in the warm anomalies elsewhere in the coastal regions of Alaska. The projections for March through May of 2024 (March-May 2024; Figure 15) indicate continued decreases in tropical Pacific SST anomalies. On the other hand, substantial warming is forecast for the GOA and northern Bering Sea. It bears mentioning that the individual model predictions yield rather consistent outcomes for the GOA but range from near-normal to moderately above normal temperatures for the southeast Bering Sea shelf. Nevertheless, these solutions also indicate conditions should not be extreme relative to the past 20-30 years with the result that sea ice should extend south of $60°$N perhaps all the way to M2, and as far south as Bristol Bay along the coast. The retreat of the sea ice on the southeast Bering Sea shelf in the spring of 2024 is apt to occur earlier than usual.

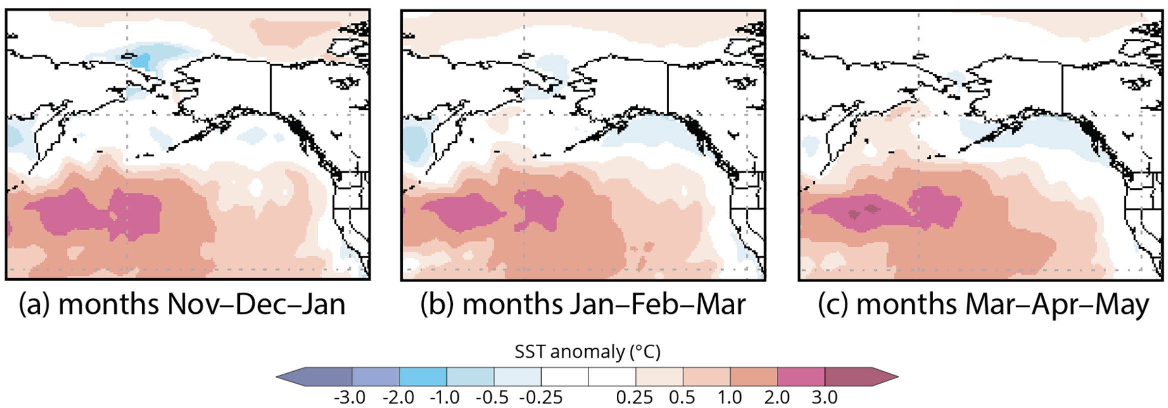

Figure 15: Predicted SST anomalies from the NMME model for Nov–Dec–Jan (1-month lead) for the 2024–2025 season, Jan–Feb–Mar (3-month lead), and Mar–Apr–May (5-month lead) 2025

4. Regional Long-term Sea Surface Temperature

Contributed by Rick Thoman

Sea surface temperatures in the Aleutian Islands can be calculated using NOAA's Extended Reconstructed SST V5 data[6]. ERSST is a global monthly sea surface temperature dataset produced at 2 x 2 resolution starting in 1854. Statistical processes are used to infill data sparse/missing areas and standardize the many ways that ocean surface temperatures have been collected and reported over the decades. However, known problems remain, especially pre-1900 and in the WW2 era and in general in Arctic and Southern Oceans. Constrained B-Spline regression used here is a form of nonparametric quantile regression using quadratic splines. This approach allows for conditional estimates of any quantile of interest. Initial analyses examined eastern, central and western AI separately, but regions were combined due to reduced subregional sample sizes and similar trends across the three ecoregions.

[6] `https://psl.noaa.gov/data/gridded/data.noaa.ersst.v5.html`

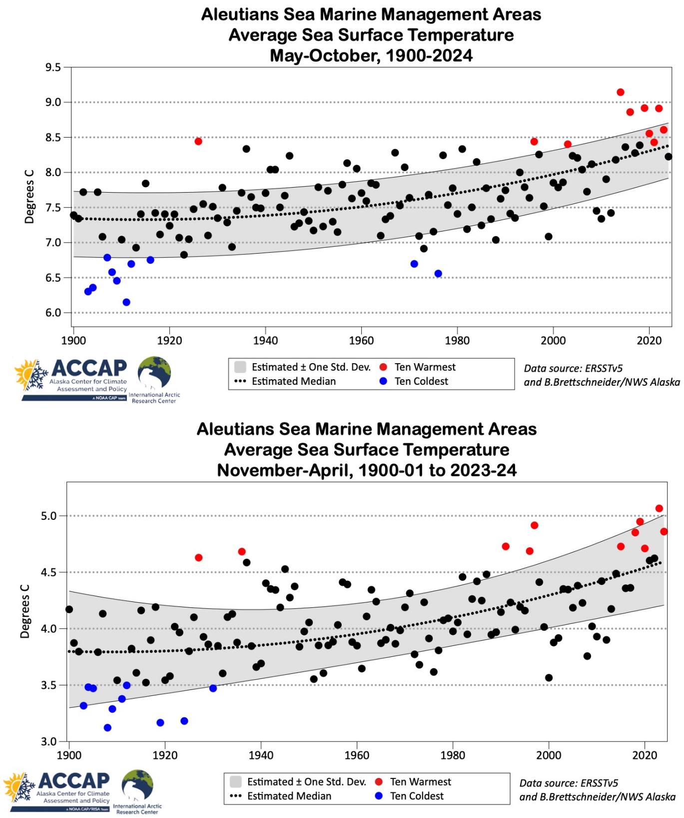

Figure 16: Sea surface temperatures for the Aleutian Islands from 1900–2024 for (a) summer (May–Oct) and (b) winter (Nov–Apr). Presented here are the quantiles representing ± 1 standard deviation of a Gaussian distribution and for completeness the median calculated using constrained B-Spline regression.

Status and Trends: Summer (May–Oct) sea surface temperatures (Figure 16 over the Aleutian Islands show a warming during the first decades of the 20th century followed by an extended period of little long-term trend, with substantial warming resuming in the late 1990s. Likewise, winter (Nov–Apr) temperatures show a significant trend over the past 123 years, with this past winter being the warmest on record.

The surface waters in the Aleutian Islands have been warming since 1900. This analysis provides context for the short-term sea surface temperature time series presented elsewhere in this report (see Sea Surface Temperature, p.35). The seasonal difference in warming trends is not determined but could be due to changes in stratification, precipitation and freshwater runoff, cloud cover, circulation or other oceanographic and atmospheric drivers.

'Above' or 'below' average surface temperatures, as reported in shorter-term time series in this report, may have different meaning if considered relative to the longer-term time series presented here. The thermal responses of species in the Aleutian Islands marine ecosystem must be considered in terms of these longer-term shifts in temperature, to understand better their response to changing temperatures. Research on species-specific thermal ranges can also help interpret potential implications of continued warming of this marine system.

5. Regional Sea Surface Temperature and Marine Heatwaves

Contributed by Emily Lemagie and Matt Callahan

Sea surface temperature is a foundational characteristic of the marine environment and temperature dynamics can impact many biological processes. Changes in temperatures can influence physiological processes of fish (e.g., metabolic rates and growth rates), fish distribution (e.g., (Yang et al., 2019), trophic interactions, availability of spawning habitat (e.g., Laurel and Rogers, 2020), and energetic value of prey (von Biela V. R. et al., 2019). At shorter timescales of days-to-weeks, changes in water temperature can also influence predator-prey interactions (Sydeman et al., 2006), feeding rates (Sanford, 2002; Clements et al., 2020), and food web composition (Barth et al., 2007). Extended periods of elevated SST for greater than 5 consecutive days are defined as marine heat waves (MHWs), which can drastically influence ecosystem dynamics (Bond et al., 2015; Hobday et al., 2016). Here, trends in SST and MHWs throughout the Aleutian Islands ecosystem regions are presented (Figures 17-20). Note that high SST can be indicative of a shallow surface layer (high surface temperature, even if a relatively moderate or low overall heat content integrated over the full water depth), and/or high temperatures throughout the water column.

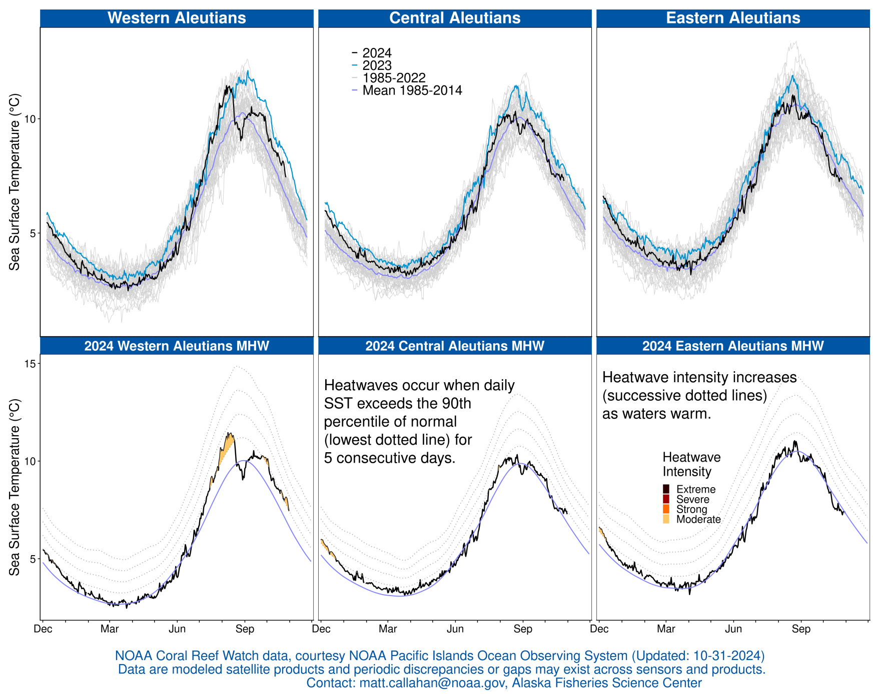

Figure 17: Annual sea surface temperatures and 2023 marine heatwave status for Aleutian Islands ecosystem regions. Data extends through November 2, 2024.

Satellite SST data and MHW status[7] were accessed via Alaska Fisheries Information Network (AKFIN) database for January 1, 1985 - November 2, 2024. Daily SST data were averaged within the western (west of 177°W), central (170–177°W), and eastern (165–170°W) Aleutian Islands.

A MHW is defined as when SST exceeds the 90th percentile of temperatures for a particular day of the year based on a 30-year baseline for five or more days (Hobday et al., 2016). The intensity of a MHW can be further characterized by examining the difference between the 90th percentile threshold for a given day and the base- line ("normal") temperature for that day. When the threshold is exceeded, the event is considered moderate, strong

[7] NOAA Coral Reef Watch Program, `https://coralreefwatch.noaa.gov,5kmresolution`

(2 times the difference between the threshold and normal), severe (3 times the difference), or extreme (4 times the difference; Hobday et al. 2018. The earliest complete 30-year time series (January 1, 1985 – December 31, 2014) was used as the baseline period for mean and standard deviation comparisons[8] (Figure 17). Annual SST time series are apportioned from December of the previous year through November so that the winter season (Dec–Feb) for each year can be consistently aggregated. A time series decomposition (i.e., seasonality and noise removed; Edullantes 2019) is also provided to better illustrate the long-term trends in SST data (Figure 18). We also use spatially explicit MHW status (to examine the extent of heatwaves within each region throughout the year (Figure 20).

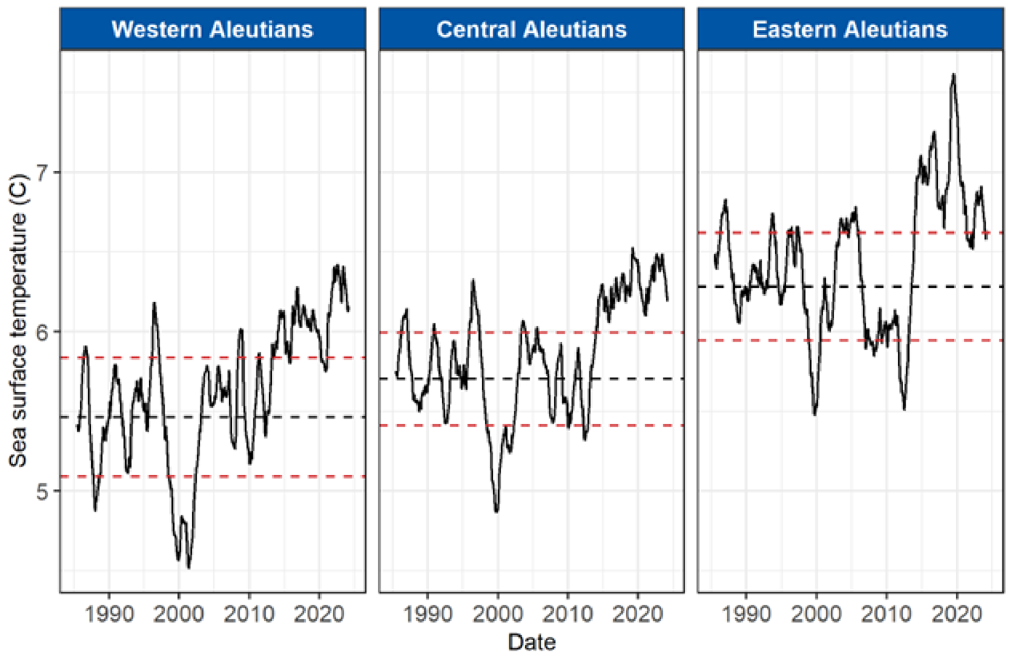

Figure 18: Time series trend (i.e., seasonality and noise removed) of sea surface temperatures. Horizontal dashed lines represent the mean (black) and standard deviation from the mean (red) during the earliest complete 30-yr baseline period (1985-2014).

Trends: Generally, all three regions have trended towards anomalously warm (>1 standard deviation from the long term mean) conditions over the last 10 years (Figure 18). MHWs have occurred periodically throughout the SST time series but with greater frequency during the last decade (Figure 19). The number of days in MHW status over the western and central Aleutians has been low relative to conditions over the last decade, excepting 2020. Over the eastern Aleutian Islands, there were few days of MHW status in 2024 relative to the mean over the last decade, which was also the case in 2021 and 2022. At times during late summer over 75% of the western Aleutians were in MHW status (Figure 20). While there were also warm anomalies and MHWs over ≤25% of the central and eastern Aleutians in summer, these were not sufficient to register in the spatial mean.

Implications: Barbeaux et al. (2020) demonstrated that marine heatwaves impact Pacific cod populations and during recent warm years, the Gulf of Alaska has seen record low returns for several salmon stocks. Meanwhile, growing evidence supports the notion of temperature driven northward range shifts. While we do not connect SST to fish production here, continued warm periods are concerning for the predictability of fish populations and recruitment.

[8]see Hobday et al. 2018; Schlegel et al. 2019 for discussions of baseline choices. MHW indices were developed using the heatwaveR package (Schlegel and Smit, 2018).

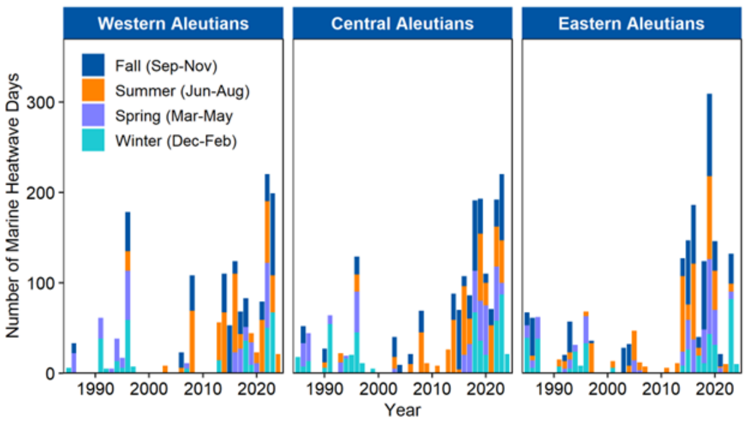

Figure 19: Number of days during which marine heatwave conditions persisted in a given year. Seasons are summer (Jun–Aug), fall (Sept – Nov), winter (Dec – Feb), spring (Mar – Jun). Years are shifted to include complete seasons so December of a calendar year is grouped with the following year to aggregate winter data (e.g., Dec 2020 occurs with winter of 2021). Data extends through summer 2024.

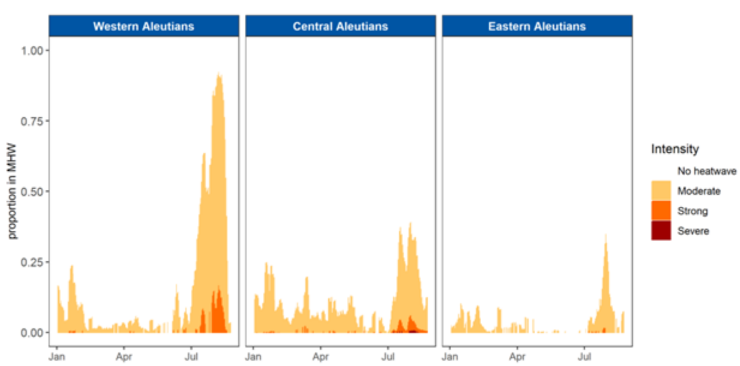

Figure 20: Proportion of region in heatwave status. Heatwave status calculations were performed on each 5 x 5 km grid cell within the Aleutian Islands. This figure shows a five day rolling average of the proportion of cells within each region that are in MHW status.

6. Bottom and Surface Temperatures from Survey

Contributed by Rebecca Howard and Ned Laman

Water temperatures are among the most influential environmental factors affecting the distribution of species collected in our fishery-independent bottom trawl surveys in the Aleutian Islands (Harris et al., 2022). Evidence is mounting that baseline temperatures have been changing in this region of the North Pacific over the last decade and more (e.g., Stevenson and Lauth 2012; Cooper et al. 2023). Since 1991, water temperature data have routinely been collected during the Aleutian Islands (AI) Bottom Trawl Survey conducted by the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering Division Groundfish Assessment Program (RACE-GAP; von Szalay et al. 2023). There were four triennial AI bottom trawl surveys between 1991 and 2000; since 2000 the surveys have been conducted biennially (except in 2008 and 2020 when the AI bottom trawl surveys did not take place). Microbathythermographs (MBTs) attached to the headrope of the net measure and record water temperature and depth during each trawl haul. In 2004, the SeaBird (SBE-39) MBT (Sea-Bird Electronics, Inc., Bellevue, WA) replaced the Brancker XL200 data logger (Richard Brancker Research, Ltd., Kanata, Ontario, Canada) which had been in use since 1993. Surface temperatures have been measured since 1991 in the Aleutians with a combination of the Brancker XL200, other unspecified time-depth-recorders (TDRs), the Seabird SBE-39, and thermometer-in-bucket measurements (as recently as 2006). The analyses presented here utilize bathythermic data collected on the standardized AI bottom trawl surveys since 1991.

The RACE-GAP AI bottom trawl survey has historically begun in late spring (late May to early June), proceeding west from around Unimak Pass to Stalemate Bank over the course of the summer, sampling in the Bering Sea and Pacific Ocean north and south of the archipelago (von Szalay et al., 2023). In 2002, 2006, and 2024, our typical sampling progression from east to west was altered with some western stations being sampled sooner than during a more typical summer survey. We anticipate that water temperatures will increase with advancing collection date and increasing day length as the survey progresses westward over the summer which could lead to spatially and temporally confounded data and complicating inter-annual comparisons.

Trends: Across the AI in 2024, surface temperatures were cooler than in 2022 with all areas except the Western Aleutian subarea cooler than average. The bottom temperatures were close to the 20-year mean (1991–2012) for all subareas (Figure 21). This is in contrast with the four survey years prior, which were generally warmer than average for both surface and bottom temperatures. Mean surface temperature anomalies in 2024 were also typically cool while bottom temperature anomalies were near zero. Temperature anomalies for the previous four years were warm in almost all cases for both surface and bottom temperature. Patterns by region illustrate spatial trends in temperature across the Aleutian archipelago. The 20-year mean surface temperature is markedly warmer for the western Aleutians when compared to the other three regions, while the bottom temperature means are similar across all four regions (Figure 21). Surface temperatures in the previous four years were also warmer than average for all except the eastern Aleutians. The eastern Aleutians also exhibited the lowest average surface temperature in 2024; an apparent departure from the 20-year mean. In all other cases, the surface and bottom temperatures averages for 2024 were similar to the 20-year mean. These regional patterns from the past and current survey years are also evident in the surface temperature anomalies. Overall, temperatures in the AI appear to have been cooler or close to the long term average in 2024. The marked differences amongst survey years, between regions, and the warm and cold year patterns illustrate the highly variable and dynamic oceanographic environment found in the Aleutian archipelago.

The temperatures and thermal anomalies observed during the RACE-GAP bottom trawl surveys of the AI are spatial and temporal snapshots of the water temperatures at each trawling station. The conditions at each of these locations are subject to short term events such as storms, tidal exchange, or freshwater runoff and may also be influenced by the timing of data collection. Thus, fine scale interpretation of temperature patterns should be viewed with some caution, but aggregations of temperature over broader areas and longer time scales can be expected to mirror real trends in the region.

The addition of the 2024 AI bottom trawl survey temperature data to the time series extended an apparent cooling trend that began after the warmer temperatures observed in 2016. Surface temperatures in the western Aleutians remained above the long term mean though they were below the long term mean elsewhere in the Aleutians. The surface temperature anomaly in western Aleutians was positive, as it has been since 2010, but was closer to the long term average anomaly than it has been for more than a decade. Mean bottom temperatures and bottom temperature anomalies across all of the Aleutians subareas were cooler and closer to their long term averages than they have been for several consecutive surveys.

The strength and persistence of various oceanographic features in the AI are anticipated to influence ecological processes in the area. For example, the depth and horizontal dispersion of the mixed layer affect primary production in this region (Mordy et al., 2005) while water temperatures influence ontogenesis of Atka mackerel eggs and larvae (Lauth et al., 2007) and have been shown to impact pollock abundance in the eastern Bering Sea (Stevenson and Lauth, 2012). Water temperatures have also been shown to be important determinants of occupied habitat in the Aleutian Islands marine environment (Harris et al., 2022).

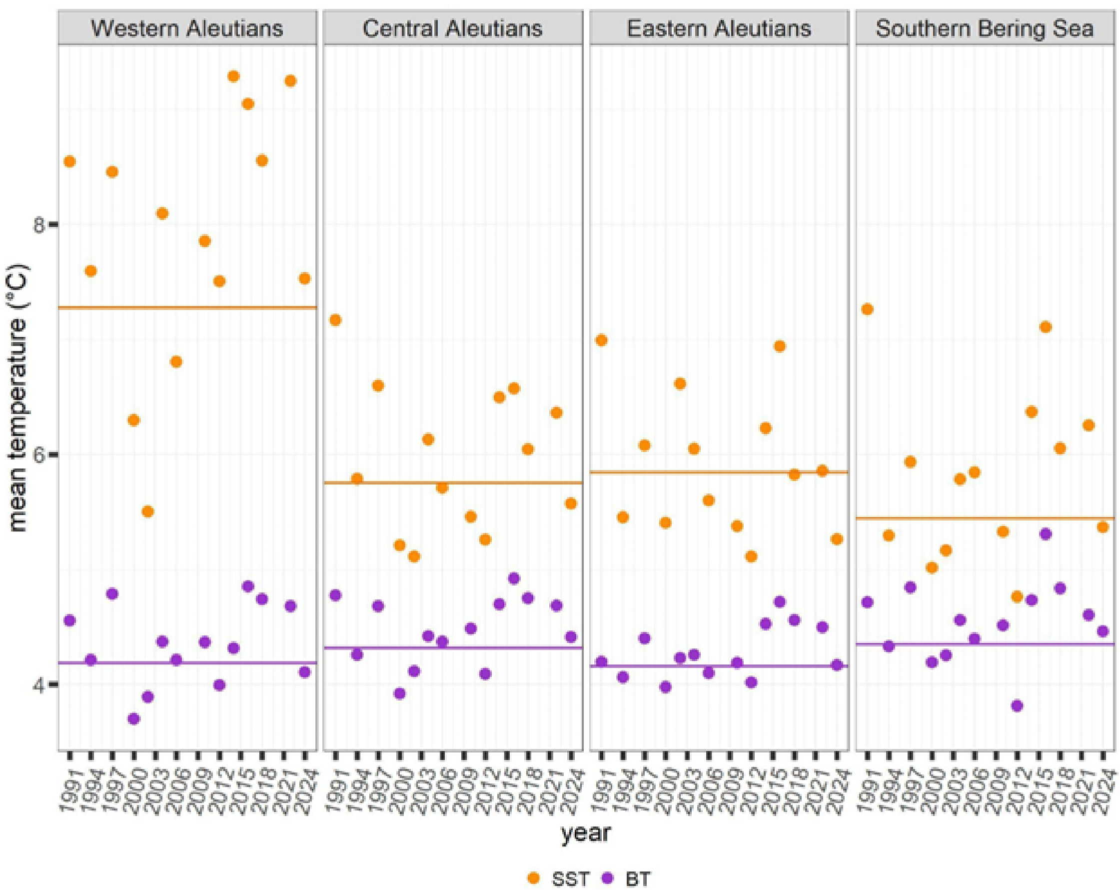

Figure 21: Regional mean annual sea surface (orange points) and bottom temperature (purple points; °C) from 1991 – 2024 from the Aleutian Islands bottom trawl surveys relative to the regional twenty-year average sea surface or bottom temperature (orange and purple horizontal lines; 1991 – 2012)

7. Ocean Transport: Eddies in the Aleutian Islands

Contributed by Wei Cheng

Description of indicator: Eddy kinetic energy can be used as an index of strength and frequency of eddies. Three regions of high eddy kinetic energy are highlighted in Figure 22. Eddies in the Alaskan Stream south of the Aleutian Islands and east of $\sim 180°$ (easternmost box in map figure) have been shown to influence flow into the Bering Sea through the Aleutian Passes (Okkonen, 1996; Stabeno and Hristova, 2014). Numerical models have suggested that eddies passing near Amukta Pass may result in increased flow from the Pacific to the Bering Sea (Maslowski et al., 2008). By influencing flow through the passes, eddies can impact flow in the Aleutian North Slope Current (Stabeno et al., 2009) and Bering Slope Current (Ladd, 2014) as well as influence the transports of heat, salt and nutrients (Mordy et al., 2005; Stabeno et al., 2005) into the Bering Sea. Eddies north of the Aleutian Islands (middle box in map, Figure 22) typically form in the Bering Slope Current near Pribilof Canyon and propagate southwestward toward Amchitka Pass (Ladd et al., 2012). They are typically weaker than those in the Alaskan Stream but may play a role in modulating flow through Amchitka Pass. Eddies formed west of 180° are called Aleutian Eddies (westernmost box in Figure 22). They typically form near the Aleutian Islands and then move southwestward away from the Aleutians (Saito et al., 2016) potentially influencing the distribution of phytoplankton and zooplankton (Saito et al., 2013) during their propagation.

Since 1992, a suite of satellite altimetry system has been monitoring sea surface height. Eddy kinetic energy (EKE) can be calculated from gridded altimetry data (Ducet et al., 2000). Average EKE in the three regions WAI, CAI, and EAI provides indices of eddy energy likely to influence flow through the passes as well as phytoplankton and zooplankton distributions. The Ssalto/Duacs altimeter products were produced and distributed by the Copernicus Marine and Environment Monitoring Service (CMEMS)[9].

The most recent data were downloaded on September 7, 2023 so we have daily time series from 1/1/1993 to 9/07/2024 on a $0.25°$ longitude x $0.25°$ latitude grid. Original data is global but we subset it to $150°$E-$125°$W and $40°$N-$72°$N during download. Data from 1993 to 2020 is from the delayed/re-processed product whereas data from 2021 onward is from the "NRT" (near real time) products. Horizontal map (Figure 22) and monthly climatology (Figure 24) shown below are averaged over 1993-2023 (period with full year coverage).

Status and trends: In the western Aleutian Islands, (Figure 24, top panel), EKE since 2020 (2023 included) is near its long-term mean; earlier (later) months of 2023 have EKEs slightly above (below) its long-term average. Over the decadal time period (from 1993 to the present day), EKE was low from 1993 to 2006 when it abruptly increased and remained relatively high until 2012. This region experienced another period of high EKE in 2015–2016 but has been low since 2020.

Trends: In the western Aleutian Islands (Figure 24, time series, top panel), EKE since 2020 (2023 included) is near its long-term mean; earlier (later) months of 2024 have EKEs above (below) its long-term average. Over the decadal time period (from 1993 to the present day), EKE was low from 1993 to 2006 when it abruptly increased and remained relatively high until 2012. This region experienced another period of high EKE in 2015–2016 but has fluctuated around the mean been low since 2018.

EKE north of the Aleutian Islands near Amchitka Pass (Figure 24, middle panel) has generally been above its long-term average since 2016. Starting from early 2023, EKE in this region dropped and moved toward its long-term mean and has been fluctuating around its mean state. Presently, it is below its long-term mean. Note this area is north of the A.I. chain and generally has lower EKE than the eastern and western boxes.

Particularly strong eddies were observed south of Amukta Pass (Figure 24, bottom panel) in 1997, 1999, 2004, 2006/2007, 2009/2010, and 2021/2022. The High EKE in this box from mid-2021 to early-2022 is associated with a passing eddy. Presently, EKE in this region is below its climatological seasonal cycle and long-term average.

[9] http://www.marine.copernicus.eu

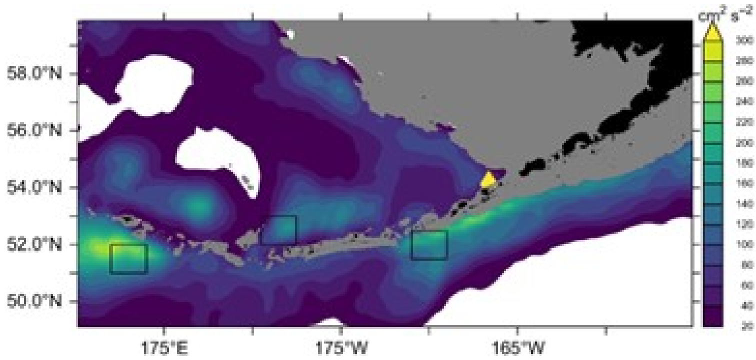

Figure 22: Eddy Kinetic Energy computed from satellite sea surface height (SSH) averaged over January 1st, 1993 – December 31st, 2023. Squares denote regions over which EKE was averaged for Figure 24.

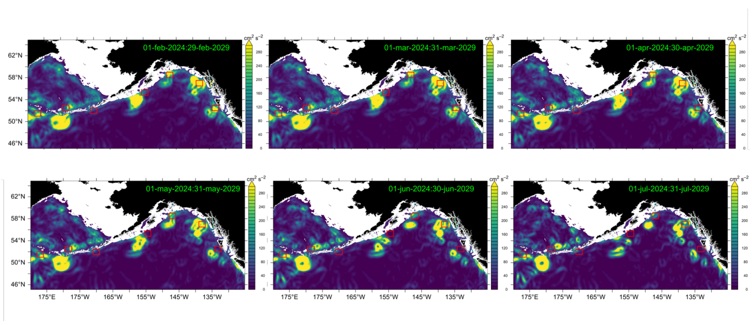

Figure 23: Monthly Eddy Kinetic Energy computed from daily satellite sea surface height (SSH) by month for February through July 2024. Squares denote regions over which EKE was averaged for Figure 24

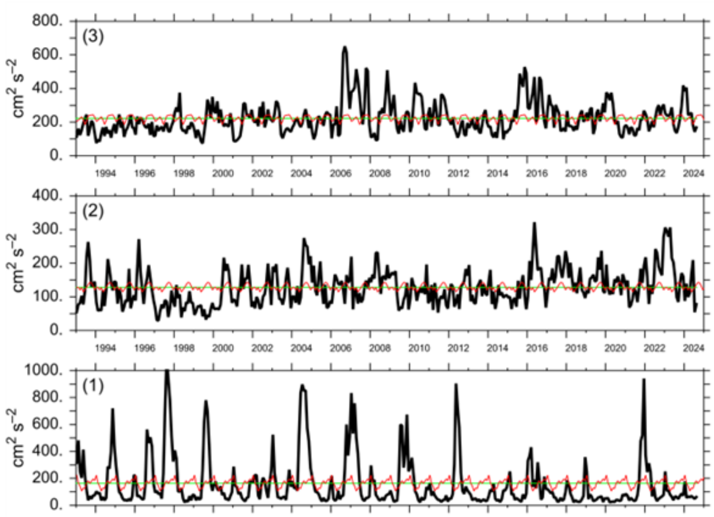

Figure 24: Eddy kinetic energy (cm^2 s^{-2}) averaged over boxes shown in Figure 22 (panels from the top to the bottom correspond to west to east boxes).). Plotted are monthly EKE time series (black), monthly climatology of EKE (red) and the long-term (1993-2023) average of EKE (green straight line).

Eddies in the eastern AI are related to the strength of the Alaska Stream (AS) which in turn is forced by large scale atmospheric forcing and the North Pacific gyre. Local wind can push the AS against or away from the coast and change transport in Unimak Pass. Transport and eddies in the western AI passes are less studied/measured. Presumably transport in the western region is highly correlated with the AS. Causes of variability in EKE in this region are currently unclear and a subject of ongoing research. For example, it is unclear whether changes in the time series reflect a long-term trend in the large scale forcing (e.g., wind, NPGO, the latter shows a declining trend since 2011), and it is unknown whether the relationship between mean flow and eddy strength reinforce or counteract each other.

Implications: These trends indicate that higher than average volume, heat, salt, and nutrient fluxes to the Bering Sea through Amukta Pass may have occurred in 1997/1998, 1999, 2004, 2006/2007, 2009, and summer 2012, and 2021/2022. Currently, EKEs in all three boxes are below their respective long-term averages, with values being close to their historical minima. While EKE within the boxes is low, a strong eddy is situated near 180°E and 50°N (Figure 23).

8. Zooplankton: Continuous Plankton Recorder Data from the Aleutian Islands and southern Bering Sea

Contributed by Clare Ostle and Sonia Batten

Description of indicator: Continuous Plankton Recorders (CPRs) have been deployed in the North Pacific routinely since 2000. Two transects are sampled seasonally, both originating in the Strait of Juan de Fuca, one sampled monthly (∼Apr–Sept) which terminates in Cook Inlet, the second sampled 3 times per year (in spring, summer and autumn) which follows a great circle route across the Pacific terminating in Asia. Several indicators are now routinely derived from the CPR data and updated annually. In this report we update three indices for the region around the Aleutian islands, including deep waters of the southern Bering Sea (Figure 25): large diatoms (the CPR only retains large, hard-shelled phytoplankton so while a large proportion of the community is not sampled, the data are internally consistent and may reveal trends), mesozooplankton biomass (estimated from taxon-specific weights and abundance data), and mean Copepod Community Size (see Richardson et al. 2006 for details but essentially the length of an adult female of each species is used to represent that species and an average length of all copepods sampled calculated) as an indicator of community composition. Anomaly time series of each index have been calculated as follows: A monthly mean value for each region is first calculated. Each sampled month's mean is then compared to the long-term mean of that month (calculated using the geometric mean) and an anomaly calculated (Log10). The mean anomaly of all sampled months in each year is calculated to give an annual anomaly. The Aleutian Island region, including the southern Bering Sea is sampled at most 4 times per year by the east-west transect. Note that in 2001, 2015, 2017 the region was only sampled in June, October and May respectively, owing to variability in the ship's transect.

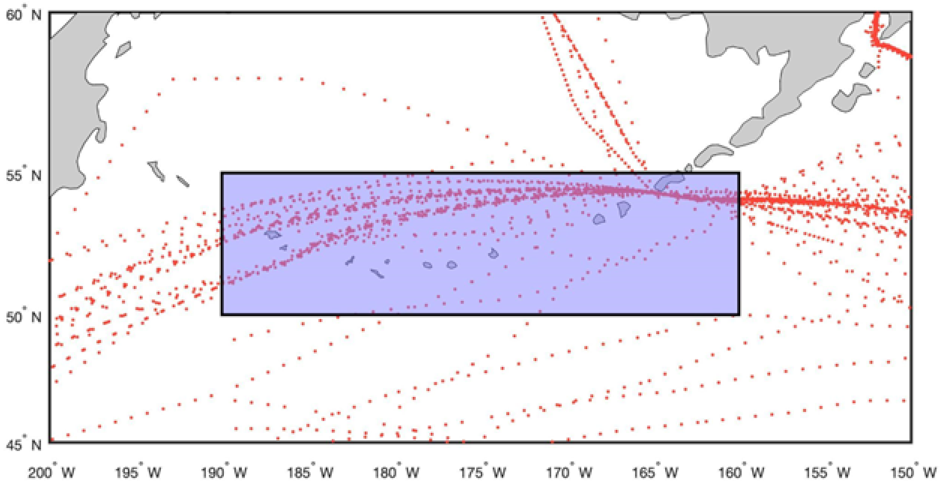

Figure 25: Location of the samples collected for the CPR analysis. Dots indicate actual sample positions and may overlay each other.

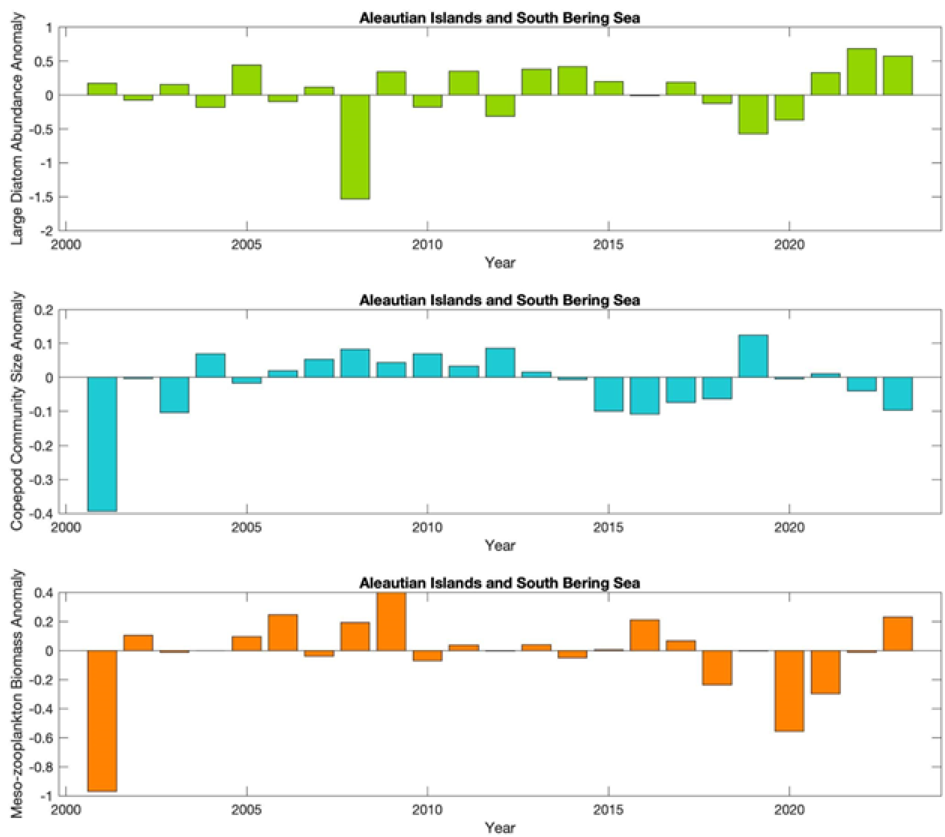

Figure 26: Annual anomalies of three indices of lower trophic levels (see text for description and derivation) for region shown in Figure 25.

Status and trends: Figure 26 shows that the annual meso-zooplankton biomass remained negative in 2023 but that the meso-zooplankton biomass was positive (for the first time since 2017), while the diatom abundance presented a positive annual anomaly for the third year in succession.

Analysis of summer CPR data in this region has revealed a general alternating (and opposing) pattern of high and low abundance of diatoms and large copepods between 2000 and 2012, believed to be the result of a trophic cascade caused by maturing Pink Salmon present in the region (Batten et al., 2018). Although the upper panel (diatoms) in Figure 26 contains data from spring and autumn, as well as summer, the alternating pattern is clear up until 2014. The zooplankton data in Figure 26 consist of more taxa than just large copepods but it is likely that there is some top-down influence of the Pink Salmon also present in these data. In 2013 the east Kamchatka Pink Salmon run was much lower than expected and in 2014 it was much higher. CPR data were not collected in this region in the summers of 2015 to 2017 so we are not certain if their influence on the plankton continues, nor how to tease out the simultaneous influence of ocean climate. However, the copepod community size anomaly has been negative in each season sampled since summer 2014 (apart from 2019 and in 2021) which suggests a real increase in the relative abundance of smaller species, potentially because of warmer than normal conditions.

Implications: This region appears to be subjected to top down influence by Pink Salmon as well as bottom up forcing by ocean climate, which is particularly challenging to interpret. Changes in community composition (e.g. abundance and composition of large diatoms, prey size as indexed by mean copepod community size) may reflect changes in the nutritional quality of the organism to their predators. Changes in abundance or biomass, together with size, influences the availability of prey to predators.

Acknowledgments: The North Pacific CPR survey is supported by a consortium comprising the North Pacific Research Board, the Exxon Valdez Oil Spill Trustee Council through Gulf Watch Alaska, Fisheries and Oceans Canada, the North Pacific Marine Science Organisation and the Marine Biological Association, UK.

Habitat

Structural Epifauna in the Aleutian Islands Ecosystem

Contributed by Christina Conrath, Ned Laman, and Sean Rohan
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Last updated: September 2024

Description of indicator: Biota considered to be Habitat Areas of Particular Concern (HAPC) are structural epifauna that include groups of sea pens, corals, anemones, and sponges. Since 1991, the RACE Groundfish Assessment Program fishery-independent summer bottom trawl survey in the Aleutian Islands (AI) has deployed the same standardized trawl gear (footrope and trawl net) across the survey region. Therefore, biomass index trends are likely to reflect changes in the abundance of species and life history stages that are available to the survey, especially if trends are sustained over time. However, bottom trawl survey gear is inefficient at sampling HAPC fauna and the survey does not sample in rough or rocky areas where these groups are likely to be more abundant (Rooper et al., 2016, 2017). Sponges include calcareous sponges, hexactinellid sponges, and demosponges, which are the most common and abundant sponges within this larger grouping. Gorgonians include families of upright branching coral (Primnoidae, Plexauridae, Isididae, etc.). Hydrocorals include stylasterid corals and stony corals. Soft corals are uncommon in the AI bottom trawl survey catches, but are represented by genera like Gersemia. Sea anemones include all sea anemones captured in the bottom trawl surveys and sea pens comprise all pennatulaceans including sea whips.

Regional and subarea indices of abundance (biomass in kilotons) and confidence intervals were estimated for each taxonomic group by fitting a multivariate random effects model (REM) to subarea design-based index of abundance time series that were calculated from AFSC summer bottom trawl survey catch and effort data. Indices were calculated for the entire standardized survey time series (1991 to 2024). Design-based indices of abundance were calculated using the *gapindex* R package (Oyafuso, 2024) and REM were fitted to the time series using the *rema* R package (Sullivan and Balstad, 2022) Code and data used to produce these indicators are provided in the *esrindex* R package and repository (Rohan, 2024).

Methodological Changes: Methods for producing this indicator have been updated this year to account for process error in survey abundance estimates, facilitate interpretation of indicator trends, utilize consistent statistical methods across ESR regions, and ensure consistent species group composition across regions. Previously, two time series were presented for each species group: (1) average bottom trawl survey catch-per-unit effort for within INPFC subareas (CPUE, kg ha^{-1}) that were scaled proportionally to the maximum CPUE in the bottom trawl survey time series, and (2) frequency of occurrence of each species group among bottom trawl survey hauls within INPFC subareas.

This year, subarea biomass estimates were calculated using the *gapindex* R package (Oyafuso, 2024), which uses the Wakabayashi et al. (1985) method to estimate design-based abundance index means and coefficients of variation (CVs) from catch (kg) and effort data (area swept; ha) collected during Aleutian Islands summer bottom trawl surveys. Then, abundance index time series means and confidence intervals were estimated by fitting a multivariate random effects model (REM) to INPFC subarea biomass estimates and CVs using the R package *rema* (Sullivan et al., 2022; Sullivan and Balstad, 2022) to account for process error in indicator time series. The code and methods to calculate abundance indices and fit REM to time series are implemented in the R package *esrindex* (Rohan, 2024).

Switching to REM addresses an issue raised during the November 2023 BSAI Groundfish Plan Team meeting pertaining to statistical methods to estimate Structural Epifauna abundance in the EBS:

"The Team had a conversation about utilizing random effects models to deal with process error in the indicator and standardizing the index for variables such as bottom contact time."

We note that bottom contact time is already accounted for in bottom trawl survey effort data because effort is only calculated for the time the net is on bottom based on bottom contact sensor data.

Status and trends: A few general patterns are clearly discernible (Figure 27). Sponges are caught in most tows (>80%) in the AI west of the southern Bering Sea. Sponge abundance began declining in the Aleutians west of the southern Bering Sea in 2010, but appears to have begun stabilizing in recent years (2016–2022). Gorgonian corals occur in about 20–40% of AI bottom trawl survey tows. Abundance of coral in all areas has declined since about 1991–1993 and is at generally low levels in all areas, but the frequency of occurrence has remained steady. Hydrocorals are fairly commonly captured, except in the southern Bering Sea. They typically occur in about 20–40% of tows in other areas in the AI. Similar to sponges, hydrocoral frequency of occurrence and abundance has decreased in the western and central AI over recent surveys (from a peak in the 2000 survey). Soft corals occur in relatively few tows, except in the eastern AI where they occur in about 20% of tows. A high abundance year is documented in 1991 with less abundance found in subsequent surveys. Sea anemones are also relatively common in survey catches (∼20–40% of tows) but abundance trends are not clear for most areas. Sea pens are much more likely to be encountered in the southern Bering Sea and eastern AI than in areas farther west. Abundance estimates are low across the survey area. Any large apparent increases in abundance, such as that seen in the eastern AI in 1997 are typically based on a single large catch. One large catch in the eastern AI may also explain the increase in the abundance index in 2024. The 2024 results suggest relatively little change in the abundance trends of corals, sea anemones, and sponges from 2022.

Factors influencing the observed trends: The two major threats to populations of benthic invertebrates in the AI have been identified as fishing impacts and impacts of climate change (Rooper et al., 2017). Both of these processes are occurring in the Aleutian archipelago. Much of the benthic habitat in the Aleutians (∼50% of the shelf and slope to depths of 500 m) has been protected from mobile fishing gear since 2006; these closures effectively 'froze the footprint' of fisheries within this area. Fishing effects are therefore limited to a proportion of the benthic habitat in the Aleutians, though it is documented to occur in locations that have been identified as coral and sponge gardens (Stone and Lehnert, 2011). Climate factors that may impact the abundance of these groups include changes in temperature, water chemistry, and changes in the movement and speed of ocean currents. The 2024 bottom trawl survey temperature data were cooler than the previous 3 biennial surveys, though in several of the Aleutian subareas temperature anomalies remained positive with actual temperatures above or near the long term means (Howard and Laman, p. 39). In addition, some of these species have carbonate skeletons that require the absorption of carbonate ions from the surrounding water and are likely to be negatively impacted by changing water chemistry. In addition, there is some evidence of changes to the strength and variability of the Alaska Stream in recent years, which could result in changes to the strength of currents and transport of biological material through the oceanic passes of the Aleutian Islands Stabeno and Hristova (2014). These changes in currents will impact the food that is available to filter feeding organisms. Non-motile HAPC organisms are particularly sensitive to these changes in the benthic environment.

Implications: The association of many commercially important groundfish species with high relief habitat containing structure-forming invertebrates like coral and sponge is documented. Structurally complex habitat provides a refuge from strong currents, protection from predators, spawning habitat, and may act to increase prey resources (Carlson and Haight 1976; Carlson and Straty 1981; Lauth et al. 2008). In Alaska, the three most commercially important rockfishes, Pacific ocean perch (*Sebastes alutus*), northern rockfish (*S. polyspinis*), and dusky rockfish (S. variabilis) have all been documented to have strong associations with this habitat type (Carlson and Straty 1981; Rooper and Zimmerman 2007; Rooper and Martin 2011; Conrath et al. 2019). Atka mackerel nesting sites have also been documented to occur in rocky substrata in the Aleutian Islands (Lauth et al., 2008). The decline in biomass indices for sponges, anemones, and corals is concerning given these associations with commercially important fish species. Although, the unknown catchability and the grouping of many species into large taxonomic groups limit the amount of interpretation that is possible from these results, these surveys are conducted in a standardized manner and the trends in these large taxa groups are an indication of a decline in the habitat available to rockfishes and other species. It should be noted that another factor could impact these trends. Due to the difficulty in finding towable grounds in the high relief bottom habitat of the Aleutians Islands about 50% of the survey stations tend to be re-towed using the same towpath. This re-towing of the same area could potentially contribute to a decline in benthic invertebrates for the re-towed area that is not representative of the general trend in neighboring untowed areas. The amount of new ground surveyed compared to the total ground surveyed generally continues to decline since the 1990s; this decline was reversed after 2022 when a fixed percentage of tows over new ground were added to the sampling allocation program. In light of these caveats, research aimed at achieving a more comprehensive understanding of these changes in the abundance of structure forming invertebrates in the annual bottom trawl surveys would be valuable.

Research priorities: The bottom trawl survey uses standardized survey protocols aimed at ensuring consistent sampling efficiency. However, additional research is needed to better characterize the catchability and selectivity of structural epifauna groups by the bottom trawl survey. Additional research is also needed to better understand how potential losses in habitat formed by structural epifauna will impact commercially important species.

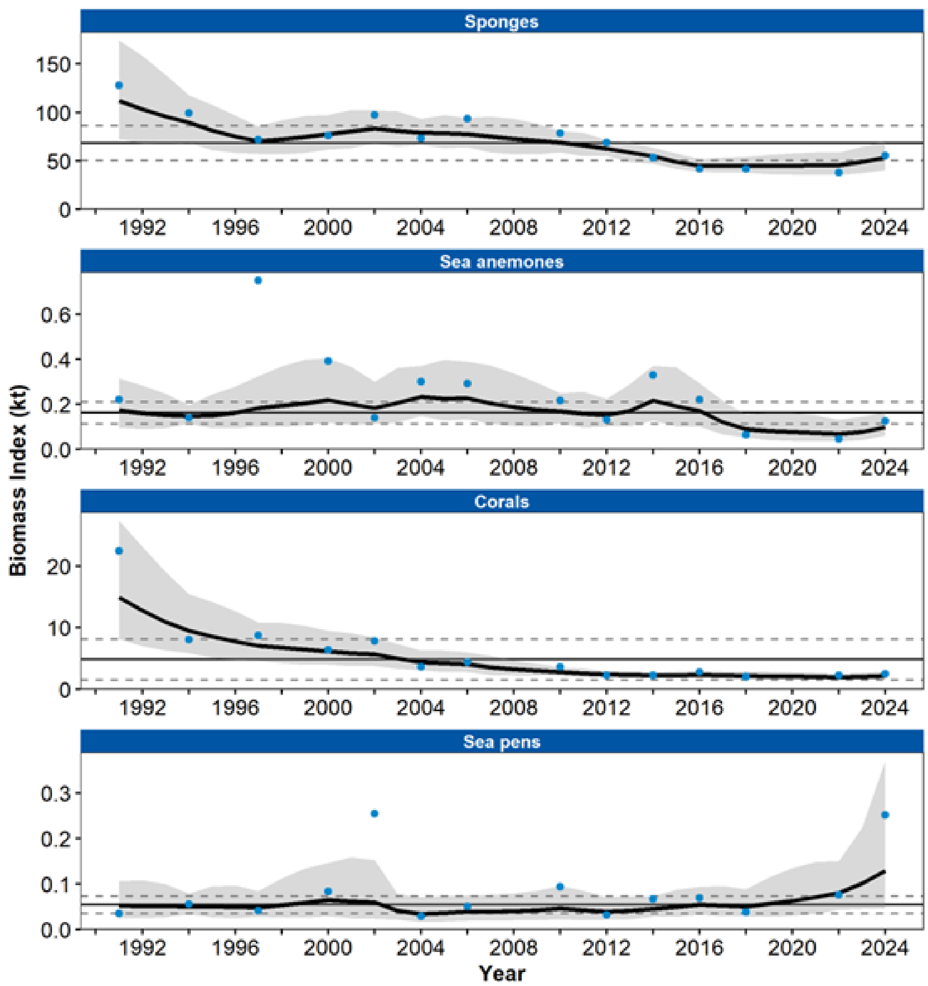

Figure 27: Figure STEP1. Biomass index (kilotons) of Structural Epifauna (sponges, sea anemones, corals, and sea pens) from RACE Groundfish Assessment Program summer bottom trawl surveys of the Aleutian Islands from 1991 to 2024. Panels show the observed survey biomass index mean (blue points), random effects model fitted mean (solid black line), 95% confidence interval (gray shading), overall time series mean (solid gray line), and horizontal dashed gray lines representing one standard deviation from the mean.

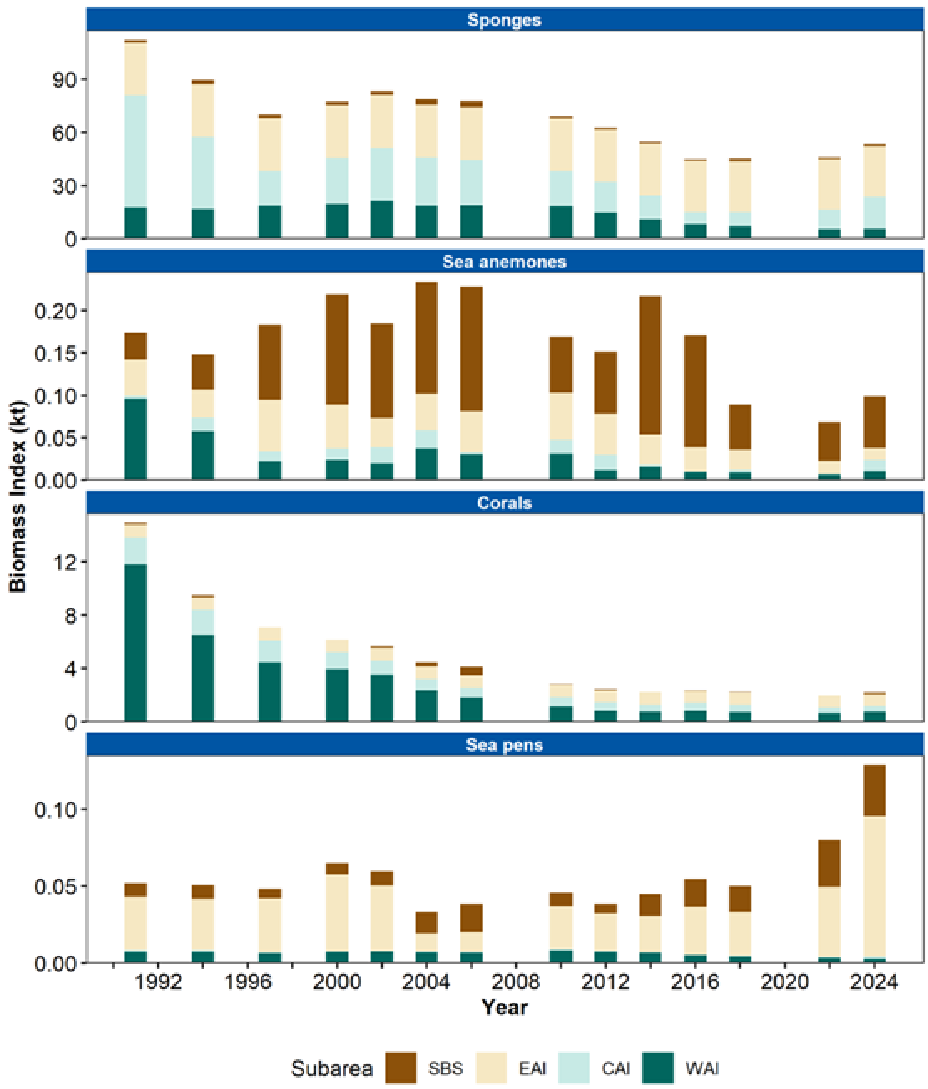

Figure 28: Figure STEP2. Biomass index (kilotons) of Structural Epifauna (sponges, sea anemones, corals, and sea pens) in Aleutian Islands subareas (Southern Bering Sea [SBS], Eastern Aleutian Islands [EAI], Central Aleutian Islands [CAI], and Western Aleutian Islands [WAI]) estimated from RACE Groundfish Assessment Program summer bottom trawl survey data from 1991 to 2024.

Jellyfish

Jellyfish in the Aleutian Islands

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Last updated: September 2024

Description of indicator: Jellyfish are an important component of plankton communities and an active area of research at the Alaska Fisheries Science Center (AFSC)[10]. Jellyfish act as both predators and competitors of fish, especially early life history stages (Purcell and Arai, 2001). Thus, fluctuations in jellyfish abundance may affect ecosystem dynamics and fish abundance through indirect (e.g., competition for prey) and direct (e.g., predation) competition with forage fishes and other commercially and ecologically important species.

Since 1991, the Resource Assessment and Conservation Engineering Division's Groundfish Assessment Program (RACE-GAP) at AFSC has employed standardized operating procedures in the Aleutian Islands (AI) to deploy the same gear (footrope and bottom trawl net) on triennial (1991-2000) and then biennial (2002-present) bottom trawl surveys. Therefore, biomass index trends are likely to reflect changes in the abundance of species and life history stages that are available to the survey, especially if trends are sustained over time and the relative abundance of jellies from these surveys may be informative of their population trends within the ecosystem (e.g.Decker et al. 2023).

Regional and subarea indices of abundance (biomass in kilotons) and confidence intervals were estimated for jellyfish by fitting a multivariate random effects model (REM) to stratum-level design-based abundance index time series calculated from AFSC summer bottom trawl survey catch and effort data. The index was calculated for the entire standardized bottom trawl survey time series (1991 to 2024). The design-based index of abundance was calculated using the *gapindex* R package (Oyafuso, 2024) and REM was fitted to the time series using the *rema* R package (Sullivan and Balstad, 2022). Code and data used to produce this indicator are provided in the *esrindex* R package and repository (Rohan, 2024).

Methodological changes: Methods for producing this indicator have been updated this year to account for process error in survey abundance estimates, facilitate interpretation of indicator trends, utilize consistent statistical methods across ESR regions, and ensure consistent species group composition across regions. Previously, two time series were presented for each species group: (1) average bottom trawl survey catch-per-unit effort for within INPFC subareas (CPUE, kg ha^{-1}) that were scaled proportionally to the maximum CPUE in the bottom trawl survey time series, and (2) frequency of occurrence of each species group among bottom trawl survey hauls within INPFC subareas.

This year, subarea biomass estimates were calculated using the *gapindex* R package (Oyafuso, 2024), which uses the Wakabayashi et al. (1985) method to estimate design-based abundance index means and coefficients of variation (CVs) from catch (kg) and effort data (area swept; ha) collected during Aleutian Islands summer bottom trawl surveys. Abundance index time series means and confidence intervals were estimated by fitting a multivariate random effects model (REM) to INPFC subarea biomass estimates and CVs using the R package *rema* (Sullivan et al. 2022; Sullivan and Balstad 2022) to account for process error in indicator time series. The code and methods to calculate abundance indices and fit REM to time series are implemented in the R package *esrindex* (Rohan, 2024).

Switching to REM addresses an issue raised during the November 2023 BSAI Groundfish Plan Team meeting pertaining to statistical methods to estimate Structural Epifauna abundance in the EBS:

[10] https://www.fisheries.noaa.gov/alaska/ecosystems/jellyfish-monitoring-program-auke-bay-laboratories

"The Team had a conversation about utilizing random effects models to deal with process error in the indicator and standardizing the index for variables such as bottom contact time."

We note that bottom contact time is already accounted for in bottom trawl survey effort data because effort is only calculated for the time the net is on bottom based on bottom contact sensor data.

Status and trends: Jellyfish biomass was above average in the relatively warm year of 2016 and, after declining from that peak, has fluctuated around the long term average since then and remains near and slightly above the long term average in 2024 (Figure 29). High biomass estimated in 1991 was primarily attributable to their abundance in the WAI (Figure 30) while the peaks in 2004 and 2006 indicate that jellyfish were abundant throughout the Aleutians Islands except in the SBS area east of EAI and north of the archipelago. In 2024, jellyfish were more abundant in the EAI and WAI than they were in the CAI or SBS.

Factors influencing the observed trends: Jellyfish populations in Alaska can vary widely in response to changing climate and prey availability (Decker et al., 2023). Brodeur et al. (2008) linked changes in jellyfish abundance to increasing sea surface temperature. However, the high jellyfish biomass estimates recorded in 2004 and 2006 did not coincide with particularly higher surface temperatures recorded in those years (Howard and Laman, p. 39). Though RACE-GAP standardized bottom trawl surveys are a platform that can be used to assess relative abundance trends of jellyfishes in the Aleutian Islands, they do not provide the data necessary to address mechanisms responsible for their fluctuating biomass in this region of Alaska.

Implications: Jellyfish abundance can fluctuate widely over space and time as evidenced by their wide ranging biomass estimates across the RACE-GAP Aleutian Islands bottom trawl survey time series (Figure 29). Posited relationships between surface temperature and jellyfish abundance have not been consistently supported in our time series thus far. Jellyfish biomass has remained near the long term average for the last four biennial RACE-GAP bottom trawl surveys of the Aleutians, but we lack data to speculate on the implications of past increases or present trends.

Research priorities: The bottom trawl survey uses standardized survey protocols aimed at ensuring consistent sampling efficiency. However, additional research is needed to better characterize the catchability and selectivity of jellyfish by the bottom trawl survey.

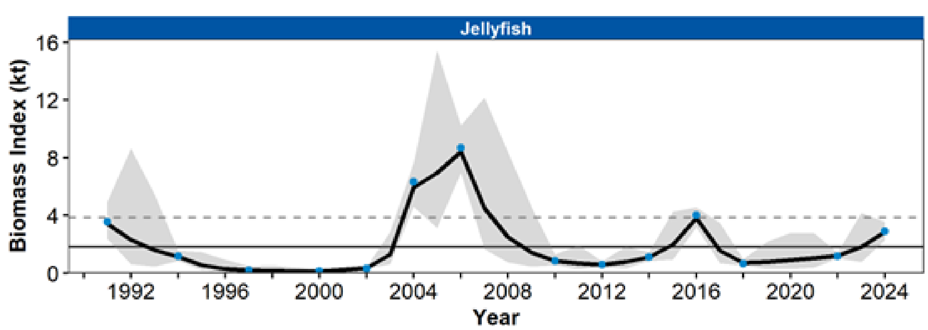

Figure 29: Biomass index (kilotons) of jellyfish from RACE Groundfish Assessment Program summer bottom trawl surveys of the Aleutian Islands from 1991 to 2024 showing the observed survey biomass index mean (blue points), random effects model fitted mean (solid black line), 95% confidence interval (gray shading), overall time series mean (solid gray line), and horizontal dashed gray lines representing one standard deviation from the mean.

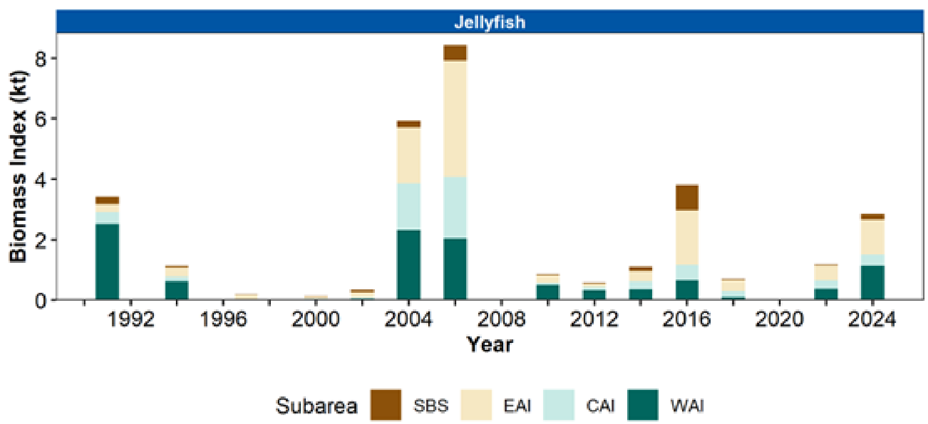

Figure 30: Figure JELLY2. Biomass index (kilotons) of jellyfish in Aleutian Islands subareas (Southern Bering Sea [SBS], Eastern Aleutian Islands [EAI], Central Aleutian Islands [CAI], and Western Aleutian Islands [WAI]) estimated from RACE Groundfish Assessment Program summer bottom trawl survey data from 1991 to 2024.

Salmon

The Increasing Abundance and Expanding Role of Eastern Kamchatka Pink Salmon in the Aleutian Islands Ecosystem

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Description of indicator: Eastern Kamchatka pink salmon (Russia) are the primary pink salmon population occupying the Aleutian Islands Ecosystem and adjacent areas, based on historical tag and recovery studies (Takagi et al., 1981). Other pink salmon populations from Russia, Japan, and Alaska may occur here to a lesser extent. However, stock-specific analyses of pink salmon in this region have not been conducted in several decades and it is unknown whether the increasing abundances of all pink salmon populations has led to a broader distribution at sea. Eastern Kamchatka pink salmon emerge from spawning grounds in coastal rivers during early spring, migrate to sea with little rearing in freshwater, then migrate southward in epipelagic waters of the East Kamchatka Current and eastward with the Subarctic Current along the southern side of the Aleutian Islands up to about 150°W. Little sampling of age-0 pink salmon has occurred in the Aleutian Islands Ecosystem owing to their small size, but some have been captured in this region during August and September. Pink salmon spend only one winter at sea and are typically distributed farther south below the Aleutian Islands during winter compared with sockeye salmon (Ruggerone et al., 2005). During spring (primarily June and July), maturing pink salmon migrate north and west through the Aleutian Island passages (including the eastern area) and into the Bering Sea where they are exceptionally abundant in spring and summer of odd-numbered years prior to migrating back to their natal rivers in summer. Sampling at sea indicates abundance of pink salmon in odd years is approximately 40 times greater than that in even years (Batten et al., 2018), owing to their fixed two-year life history.

Status and trends: The eastern Kamchatka pink salmon is an exceptionally abundant population of wild pink salmon, especially in odd-numbered years (Figure 31). No hatchery production of pink salmon occurs in this region. Pink salmon abundance was relatively stable over time from 1952 through the mid-1970s, then odd year runs began to increase over time. Even year abundances began to increase in 2014, corresponding with the unexpected decline in the 2013 return (only ∼33 million adults). From 2011 to 2023, abundance averaged 210 million salmon in odd-numbered years and 64 million salmon in even-numbered years. The largest run on record occurred in 2019 (∼315 million adults), followed by the small run in 2020 (∼28 million adult fish), a very large run in 2021 (273 million), and a small run in 2022 (53 million adult fish).In 2023, approximately 273 million pink salmon returned to Eastern Kamchatka, i.e., the second largest run on record along with that in 2021. Fish size was exceptionally small in 2023 (1.03 kg). During odd years (2015, 2017, 2019, 2021, 2023), Eastern Kamchatka pink salmon represented ∼ 37% of total pink salmon returning from the North Pacific compared with 18% during even years (2016, 2018, 2020, 2022).

The 2024 commercial catch of pink salmon in Eastern Kamchatka was nearly identical to that in 2022. Russian salmon runs in 2024 were typically below the preseason forecast, leading to an inquiry to determine the cause. Tradex, a seafood marketing group, reported on September 23 that the global harvest of Pacific salmon could be the lowest on record since 1944. If correct, this decline could be partially related to the record-high abundance of North Pacific pink salmon in 2023 as suggested by the tipping point hypothesis presented in response to the 2020 decline of all species of salmon following the exceptional back-to-back pink salmon abundances throughout the North Pacific in 2018 and 2019 (Ruggerone et al. 2021).

As a species, pink salmon represent nearly 70% of all Pacific salmon (Ruggerone and Irvine, 2018). In 2018 and 2019, record numbers of Pacific salmon returned from the North Pacific (950 and 854 million, respectively, excluding Chinook and coho salmon that represent less than 4% of the total), of which approximately 75% were pink salmon (Ruggerone et al., 2021). In 2021 and 2023, record high total abundances of Pacific salmon continued

(∼1 billion adults) with pink salmon representing approximately 81% of the total in both years (∼798 and 864 million fish, respectively; Ruggerone et al. 2023; Connors et al. 2024). Exceptionally small salmon body size has been reported throughout Alaska in 2024 (and other recent years), and evidence indicates the high abundances of pink salmon was a major factor. Abundance of non-native pink salmon in the Atlantic Ocean continues to increase every odd-numbered year, raising concerns for native species Lennox et al. (2023).

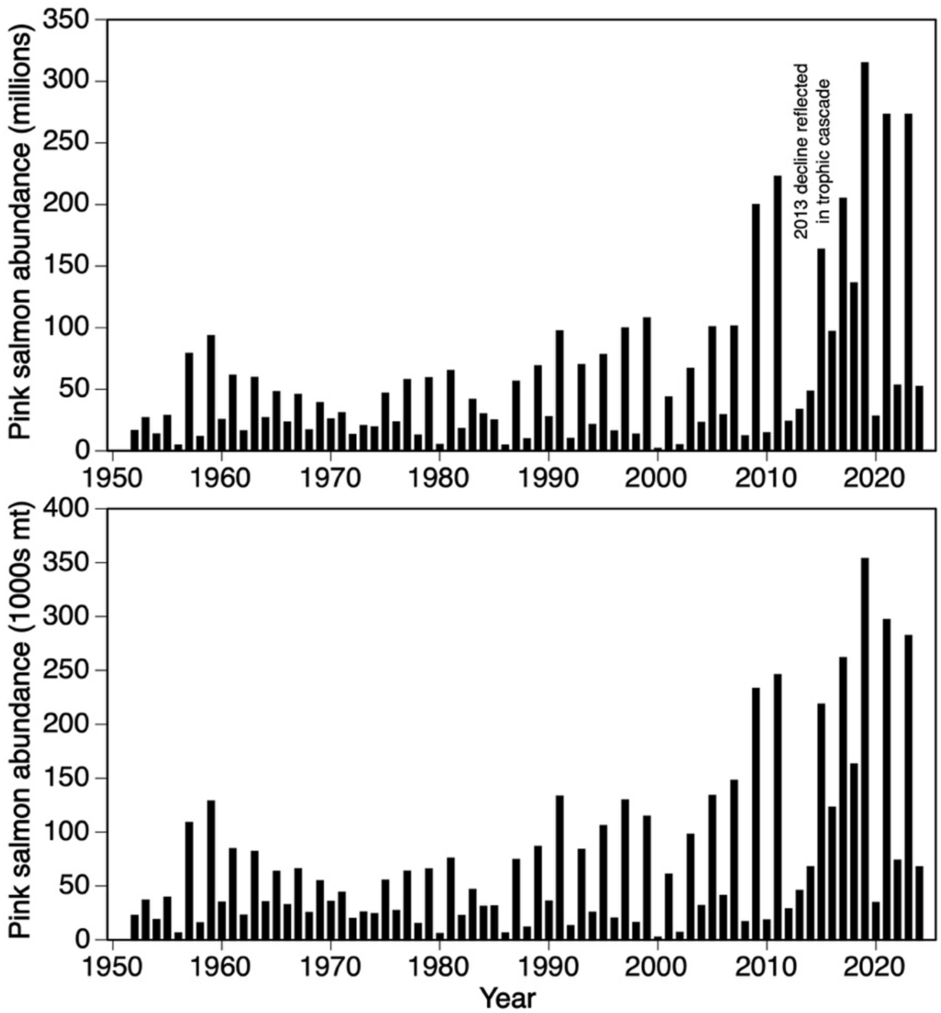

Figure 31: Time series of Eastern Kamchatka pink salmon abundance (numbers of fish and biomass), 1952-2024. Values include catch and spawner abundances. Recent values are preliminary. Sources: (Ruggerone and Irvine, 2018; Ruggerone et al., 2023). The 2024 value is based on preliminary harvest data.

Factors influencing observed trends: Abundances of pink salmon in Eastern Kamchatka and other regions increased after the 1977 ocean regime shift that was generally associated with warmer sea surface temperatures and greater zooplankton production (e.g., Brodeur and Ware 1992). Ocean heat content of the North Pacific Ocean explained 51% of the annual variability in pink salmon numbers returning from the North Pacific Ocean, 1952-2021, suggesting that climate change is benefiting pink salmon abundance and thus indirectly contributing to increased competition at sea for prey. In 2013 the abundance of Eastern Kamchatka pink salmon declined sharply for unknown reasons, potentially supporting an increase in even-year abundances of pink salmon in 2014, 2016 and 2018, exceptionally low abundance in 2020, then high abundance for an even-year in 2022 (Figure 31). Odd-year abundances quickly recovered after 2013 to record numbers in 2019 and near record numbers in 2021 and 2023.

Implications: Pink salmon is the smallest (and youngest) species of Pacific salmon (as mature adults), but they grow exceptionally fast, consume a large amount of various prey, and potentially affect growth and survival of other species in the North Pacific Ocean and Bering Sea, including all species of Pacific salmon and steelhead trout, 11 seabird species, four forage fish species, and southern resident killer whales (Ruggerone et al., 2023). The unique biennial pattern of pink salmon in this region facilitates detection and evaluation of pink salmon competition with other species because physical oceanography studies have not been able to explain the biennial patterns. In the Aleutian Islands region, pink salmon give rise to a trophic cascade in which zooplankton declines and phytoplankton increases as pink salmon abundance increases (Batten et al., 2018). In 2013, when pink salmon abundance abruptly declined, the abundance of zooplankton rebounded to a high level, providing additional support for the trophic cascade hypothesis. Effects of this trophic cascade in the Aleutian Island region have been documented in the growth, survival, and abundance of Bristol Bay sockeye salmon (Ruggerone et al., 2003; Connors et al., 2020), seven sockeye populations originating from the Gulf of Alaska region (Rand and Ruggerone, 2024), Yukon/Kuskokwim/Nushagak Chinook salmon (Ruggerone et al., 2023), otolith growth of Atka mackerel (Matta et al., 2020), and reproduction of seabirds (Springer and van Vliet, 2014) that occupy the Aleutian Islands Ecosystem.

In 2020, the commercial harvest of all five salmon species, including salmon populations from most regions of the North Pacific, declined more than ever since comprehensive record keeping began in 1925 (Ruggerone et al., 2021). Chinook salmon experienced the greatest decline relative to the previous 10 years (54% decline). Investigators hypothesized that frequent marine heatwaves and unprecedented abundances of pink salmon in 2018 and 2019 contributed to the harvest decline. The high abundance of pink salmon in 2023 may have contributed to the unexpected decline of pink salmon in 2024, especially in Alaska.

Bristol Bay sockeye salmon, which inhabit the Aleutian Islands Ecosystem, was a primary exception to the unprecedented decline of all salmon species in 2020. Abundances of Bristol Bay sockeye salmon set record highs in 2021 (66 million adults) and 2022 (78 million; www.adfg.alaska.gov). The exceptional abundance of both Eastern Kamchatka pink salmon and Bristol Bay sockeye salmon in recent years might seem counterintuitive because evidence indicates Kamchatka pink salmon adversely affect the growth, survival and abundance of Bristol Bay sockeye salmon (e.g., (Ruggerone et al., 2003, 2016). However, competition for prey between these salmon populations does not begin until the second growing season at sea, based on scale growth analysis. Furthermore, studies of seasonal and annual growth of Bristol Bay sockeye salmon reported that the large increase in survival and abundance of Bristol Bay sockeye salmon after the 1976/1977 ocean regime shift was associated with greater growth during early marine life (Ruggerone et al., 2005, 2007). The recent consistently high abundance of Bristol Bay sockeye salmon is likely associated with favorable conditions in freshwater and greater early marine growth and survival in the warming Bering Sea, a benefit that overwhelms the adverse effect of pink salmon on sockeye growth and survival during later marine life (Ruggerone et al., 2023).

Groundfish

Aleutian Islands Groundfish Condition

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Last updated: September 2024

Description of indicator: Morphometric condition indicators for Alaska groundfish species based on length-weight relationships characterize variation in somatic growth and can be considered indicators of prey availability, growth, general health, and habitat condition for these animals (Blackwell et al. 2000; Froese 2006). This contribution presents two morphometric condition indicators based on length-weight relationships: a new relative condition indicator that is estimated using a spatiotemporal model and the historical indicator based on residuals of the length-weight relationship.

To calculate indicators, length-weight relationships were estimated from linear regression models based on a log-transformation of the exponential growth relationship, W = aLb, where W is weight (g) and L is fork length (mm) for all areas surveyed by the AFSC trawl survey in the Aleutian Islands for the period 1991–2024 (Figure 32). For each species, unique intercepts (a) and slopes (b) were estimated for each survey stratum, sex, and interaction between stratum and sex to account for sexual dimorphism, spatial-temporal variation in growth, and bottom trawl survey sampling. In addition, for walleye pollock, length-weight relationships for 100–250 mm fork length (corresponding with ages 1–2 years) were calculated separately from adult walleye pollock (> 250 mm) in order to evaluate these life stages separately. Length-weight residuals for individual fish were obtained by subtracting observed weights from bias-corrected weights-at-length that were estimated from regression models. Individual length-weight residuals were aggregated and averaged for each stratum. These averages were then weighted based on the proportion of fish biomass present in each stratum compared to the total biomass for the entire survey area. The AFSC survey design-based stratum biomass estimates (CPUE; i.e., area-swept expansion of bottom trawl survey catch-per-unit-effort) were used in this calculation. Variation in fish condition was then evaluated by comparing average length-weight residuals among years. To minimize the influence of unrepresentative samples on indicator calculations, combinations of species, stratum, and year with a sample size < 10 were used to fit length-weight regressions but were excluded from calculating length-weight residuals. Morphometric condition indicator time series, code for calculating the indicators, and figures showing results for individual species are available through the *akfishcondition* R package and GitHub repository[11].

Methodologial changes:: In 2022, historical stratum-biomass weighted residuals condition indicators were presented alongside condition indicators that were calculated using the R package VAST following methods that were presented for select GOA species during the Spring Preview of Ecological and Economic Conditions in May 2020. The authors noted there were strong correlations between VAST and stratum biomass weighted condition indicators for most species (r = 0.79–0.98). The authors received the following feedback about the change from the BSAI Groundfish Plan Team meeting during their November 2022 meeting: "The Team discussed the revised condition indices that now use a different, VAST-based condition index, but felt additional methodology regarding this transition was needed. The Team recommended a short presentation next September to the Team to review the methods and tradeoffs in approaches. The Team encouraged collaboration with the NMFS longline survey team to develop analogous VAST indices." Based on feedback from the Plan Team, staff limitations, and the lack of a clear path to transition condition indicators for longline species to VAST, the 2024 condition indicator was calculated from stratum-biomass weighted residuals of length-weight regressions.

Status and trends: Body condition varied amongst survey years for all species considered (Figure 33). Overall,

[11] `https://github.com/afsc-gap-products/akfishcondition`

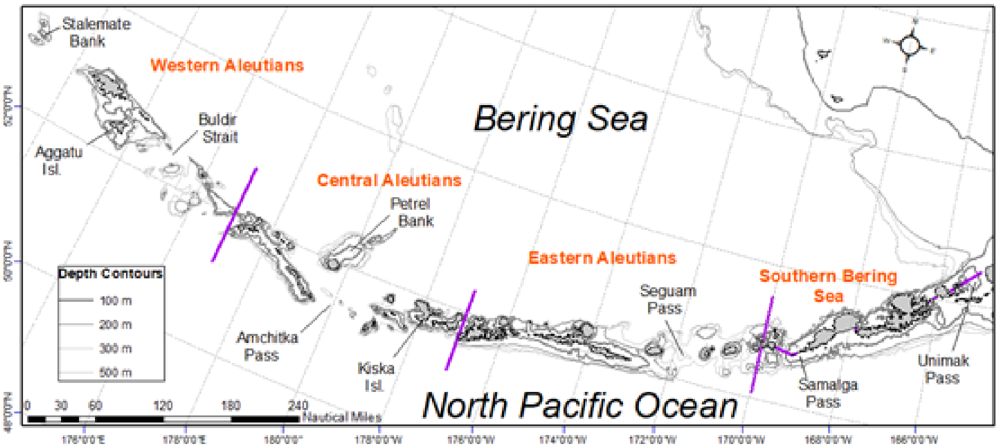

Figure 32: National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering Groundfish Assessment Program (RACE-GAP) Aleutian Islands summer bottom trawl survey area with International North Pacific Fisheries Commission (INPFC) statistical fishing strata delineated by the purple lines.

residual body condition of all species except southern rock sole and small walleye pollock (100-250 mm) were below their time series means in 2024. Prior to 2010, the Aleutian Islands bottom trawl survey was characterized by condition cycling between positive and negative values through the years. The conditions of most species since 2012 have primarily been below the time series average (> 1 standard deviation below average) or neutral (within 1 standard deviation), though there are some exceptions. Notably, in 2024 small walleye pollock (100-250 mm) had the highest residual body condition in the survey time series, falling two standard deviations above the mean. In contrast, large walleye pollock (>250 mm) were below the historical mean in 2024. Southern rock sole residual body condition has generally been trending positive in the Aleutians since 2012 and fell above the time series mean, but remained within one standard deviation in 2024. Atka mackerel body condition was negative in 2024 and has generally been declining since 2010. Similarly, northern rockfish body condition has been declining since 2010 and 2024 was the worst body condition of the time series. Pacific ocean perch followed a similar pattern to Atka mackerel and northern rockfish, but with a decline beginning in 2012. Pacific cod and arrowtooth flounder body condition was above or near average condition in 2010, but subsequently declined through 2018. These two species were in better condition in 2022 and 2024 but still below the historical mean.

In the Aleutian Islands in 2024, condition was negative in all strata for all species except small walleye pollock (100-250 mm) and southern rock sole (Figure 3). Condition was positive for small walleye pollock (100-250 mm), with only two strata represented: the Western Aleutian Islands and Eastern Aleutian Islands. There was a divergence in condition for southern rock sole, with more negative condition in the Central Aleutian Islands and more positive condition in the Southern Bering Sea and Eastern Aleutian Islands.

Factors influencing observed trends: Several factors could affect morphological condition, including water temperature. From 2014-2022, there was a general trend of warming ocean temperatures in the survey area that could affect fish growth conditions, though cooler temperatures were recorded in the Aleutian Islands in 2024. The influence of temperature on growth rates depends on the physiology of predator species, prey availability, and the adaptive capacity of predators to respond to environmental change through migration, changes in behavior, and acclimatization. Thus, the factors underpinning the negative or neutral condition remain unclear.

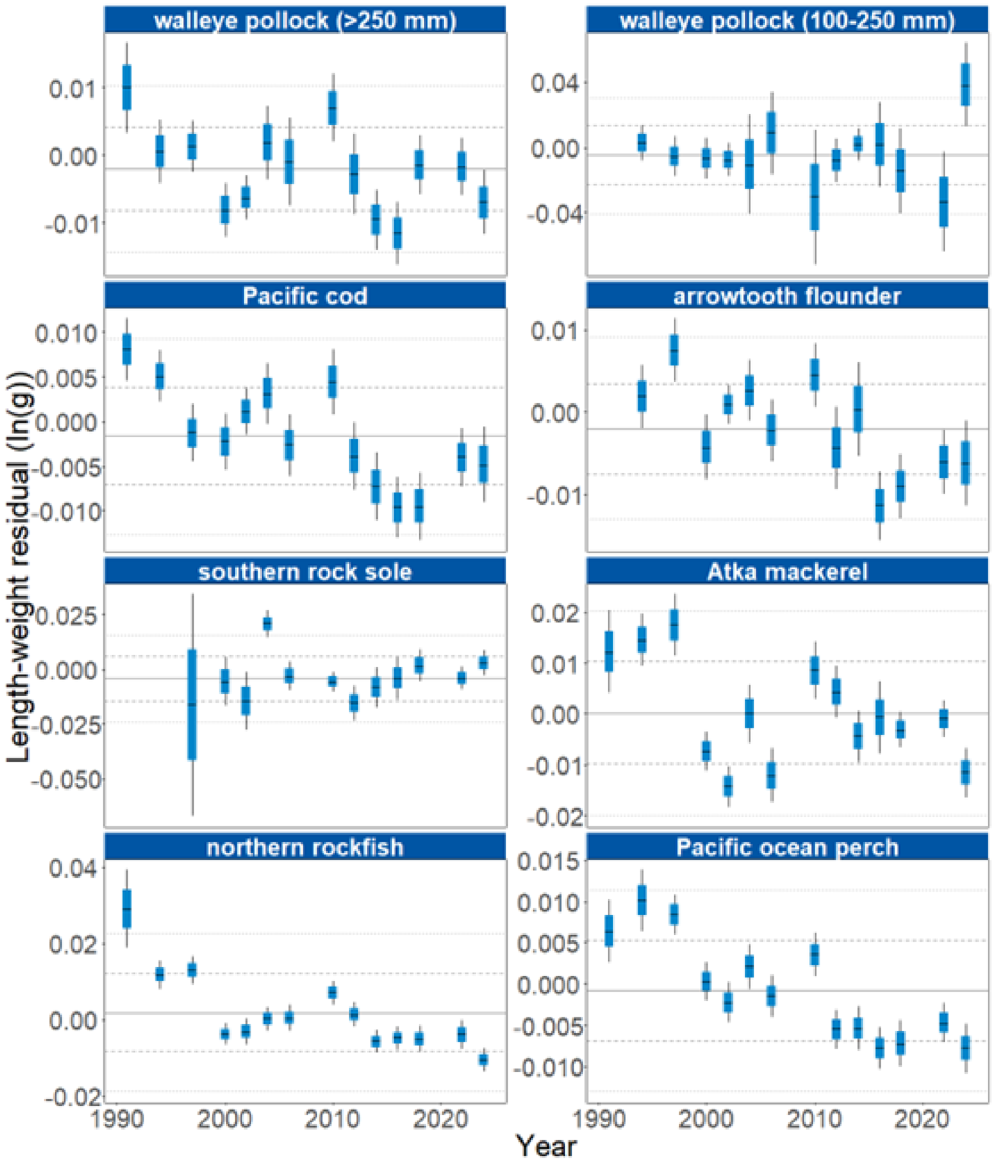

Figure 33: Weighted length-weight residuals for seven groundfish species collected during AFSC/RACE GAP standard summer bottom trawl surveys of the Aleutian Islands, 1991-2024. Filled bars denote weighted length-weight residuals using this year's indicator calculation. Error bars denote standard errors, thin black lines are 2 standard errors and thick blue boxes are 1 standard error.

Other factors that could affect morphological condition include survey timing, stomach fullness, fish movement patterns, sex, and environmental conditions (Froese, 2006). Changing ocean conditions along with normal patterns of movement can cause the proportion of the population resident in the sampling area during the annual bottom trawl survey to vary. The date that the first length-weight data are collected is generally in the beginning of June and the bottom trawl survey is conducted throughout the summer months moving from east to west so that spatial and temporal trends in fish growth over the season become confounded with survey progress. Although we account for some of this variation by using spatially-varying coefficients in the length-weight relationship, variation in condition could relate to variation in the timing of sample collection within survey strata. We can expect some fish to exhibit seasonal or ontogenetic movement patterns during the survey months. Effects of survey timing on

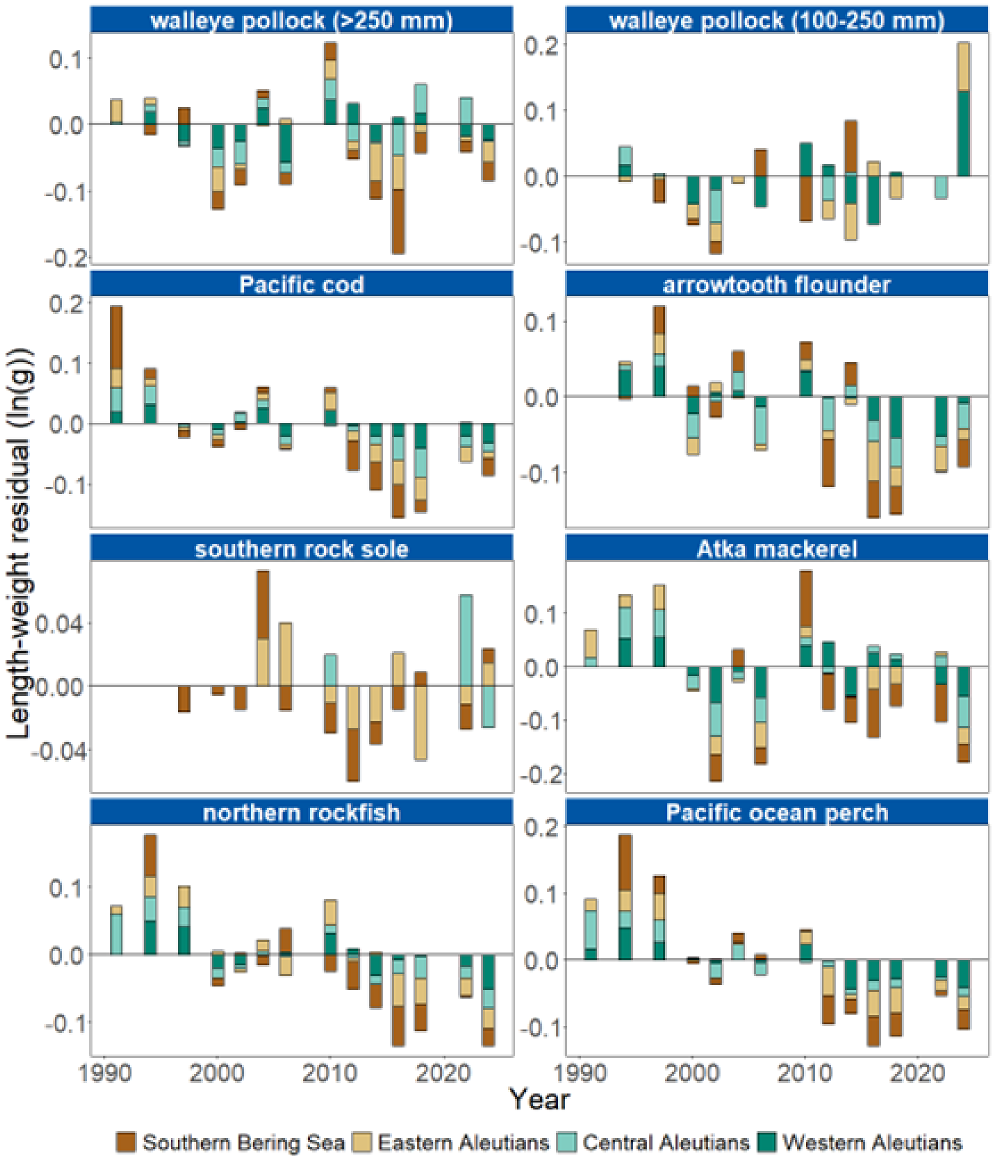

Figure 34: Residual body condition index for Aleutian Islands groundfish species collected on the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center Resource Assessment and Conservation Engineering (AFSC/RACE) Groundfish Assessment Program (GAP) standard summer bottom trawl survey (1991–2024) grouped by International North Pacific Fisheries Commission (INPFC) statistical sampling strata.

body condition can be further compounded by seasonal fluctuations in reproductive condition with the buildup and depletion of energy stores (Wuenschel et al., 2019). Another consideration is that fish weights sampled at sea include gut content weights so variation in gut fullness may influence weight measurements. Since feeding conditions vary over space and time, prey consumption rates and the proportion of total body weight attributable to gut contents may also be an important factor influencing length-at-weight.

Finally, although condition indicators characterizes spatial and temporal variation in morphometric condition of groundfish species in the Aleutian Islands, it does not inform the mechanisms or processes behind the observed patterns.

Implications: Fish morphometric condition can be considered an indicator of ecosystem productivity with implications for fish survival, maturity, and reproduction. For example, in Prince William Sound, the pre-winter condition of herring may determine their overwinter survival (Paul and Paul, 1999), differences in feeding conditions have been linked to differences in morphometric condition of pink salmon in Prince William Sound (Boldt and Haldorson, 2004), variation in morphometric condition has been linked to variation in maturity of sablefish (Rodgveller, 2019), and lower morphometric condition of Pacific cod was associated with higher mortality and lower growth rates during the 2014–2016 marine heat wave in the Gulf of Alaska (Barbeaux et al., 2020). The condition of Aleutian Islands groundfish may similarly contribute to variability of survival, reproductive success and recruitment and provide insight into ecosystem productivity, fish survival, demographic status, and population health.

Survivorship is likely affected by many factors not examined here. As future years are added to the time series, the relationship between length-weight residuals and subsequent survival will be examined further. It is important to consider that residual body condition for most species in these analyses was computed for all sizes and sexes combined. Requirements for growth and survivorship differ for different fish life stages and some species have sexually dimorphic growth patterns. It may be more informative to examine life-stage (e.g., early juvenile, subadult, and adult phases) and sex specific body condition in the future for more insight into individual health and survivorship (Froese, 2006).

The trend of decreasing body condition for many Aleutian Islands species from 2010 to 2024 is a potential cause for concern. Recent downward trends in body condition could indicate poor overwinter survival or spawning success and may reflect the influence of locally changing environmental conditions depressing fish growth, local production, or survivorship. Indications are that the 2014 Warm Blob (Bond et al., 2015; Stabeno and Bell, 2019) has been followed by subsequent years with elevated water temperatures (e.g., Barbeaux et al. 2020) which may be related to changes in fish condition in the species examined. Body condition can also be lower in food-limited populations when population density is high (Haberle et al., 2023). However, Pacific ocean perch were the only species examined in 2024 with high population density and negative condition relative to the time series average. As we continue to add years of fish condition to the record and expand on our knowledge of the relationships between condition, growth, production, and survival, we hope to gain more insight into the overall health of fish populations in the Aleutian Islands.

Research priorities: Research is underway to explore variation in condition indices between life history stages alongside density dependence and climate change impacts(Bolin et al., 2021; Oke et al., 2022).

Distribution of rockfish species along environmental gradients in Aleutian Islands bottom trawl surveys

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Last updated: September 2024

Description of indicator: In a previous analysis of rockfish from 14 bottom trawl surveys in the Gulf of Alaska and Aleutian Islands (Rooper, 2008), five species assemblages were defined based on similarities in their distributions along geographical position, depth, and temperature gradients. The 180 m and 275 m depth contours were major divisions between assemblages inhabiting the shelf, shelf break, and lower continental slope. Another noticeable division was between species centered in southeastern Alaska and those found in the northern Gulf of Alaska and Aleutian Islands.

In this time-series, the mean-weighted distributions of six rockfish (four *Sebastes* species, rougheye-blackspotted rockfish complex, and *Sebastolobus alascanus*) along the three environmental gradients (position, depth and temperature) were calculated for the Gulf of Alaska and Aleutian Islands. A weighted mean value for each environmental variable was computed for each survey as:

$$Mean = \frac{\sum (f_i x_i)}{\sum f_i},$$

where f_i is the CPUE of each rockfish species group in tow i and x_i is the value of the environmental variable at tow i. The weighted standard error (SE) was then computed as:

$$SE = \frac{\sqrt{\frac{(\sum (f_i x_i^2)) - ((\sum f_i) * mean^2)}{(\sum f_i) - 1}}}{\sqrt{n}},$$

where n is the number of tows with positive catches. Details of the calculations and analyses can be found in Rooper (2008). These indices monitor the distributions of major components of the rockfish fisheries along these environmental gradients to detect changes or trends in rockfish distribution. Changes in geographic position are referenced to Hinchinbrook Island in the Gulf of Alaska.

Status and trends: There were no significant trends in rockfish distance from Hinchinbrook Island, Alaska or in mean-weighted temperature distributions for any of the species, all of which were found within a a 1°C temperature envelope. There are four statistically significant depth-related trends over the survey time series that have continued over the last several surveys: the distribution of adult rougheye-blackspotted rockfish complex, adult Pacific ocean perch, shortraker rockfish, and northern rockfish are trending shallower (Figure 35). The more shallow-water dusky rockfishes and deeper-water shortspine thornyhead are maintaining their same depth interval over time. This trend appears to be more pronounced for the rougheye-blackspotted rockfish complex and shortraker rockfish.

Factors influencing the observed trends: The observed changes in depth and spatial distributions for adults of the rougheye-blackspotted rockfish complex, shortraker rockfish, northern rockfish and adult Pacific ocean perch are noteworthy.There appears to be an expansion in the shortraker and rougheye-blackspotted rockfish complex distributions into shallower habitats in the Aleutian Islands over time. These results may also be impacted by the contraction of survey operations into shallower waters over the past several surveys with fewer deep water stations available for catching deep-water rockfishes and therefore more of the observed fish distribution located in shallower stations. For the rockfish with more static population trends, such as northern rockfish and Pacific ocean perch, other explanations are needed to interpret depth and spatial distributions. It is also worth noting that, in the cases of all four of the rockfishes considered in this analysis, the occupied depth range is shallower but the occupied temperature range remains near the long-term average in 2024.

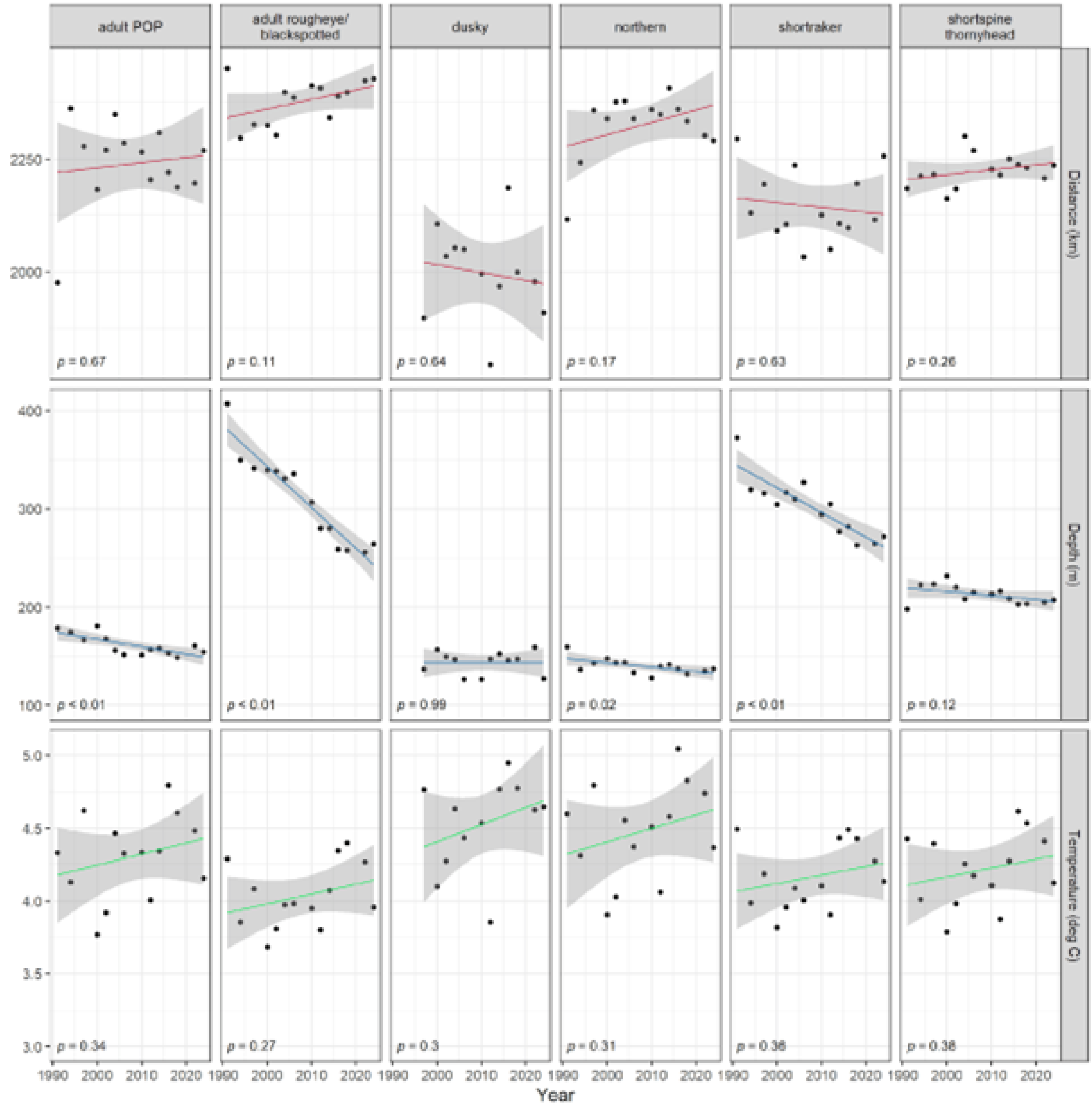

Figure 35: Plots of mean weighted (by catch per unit effort) distributions of six rockfish species-groups along three environmental gradients in the Aleutian Islands. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance from Hinchinbrook Island, Alaska, with positive values west of this point and negative values are southeastward. P-values are located on each plot. P-values close to zero are defined as statistically significant.

Implications: The trends in the mean-weighted distributions of rockfishes should be monitored, with special attention to potential causes of the shift in depth to shallower waters. In particular, how these depth changes relate to changing temperatures is crucial. During surveys in 2016 and 2018, all five rockfish groups were found at the highest mean-weighted temperature in the time series. However, in 2022 and 2024, the occupied mean-weighted temperature for each rockfish group was lower than the previous two surveys. For each rockfish group, except dusky rockfish, the trend with temperature was lower again in 2024. The overall trend for all of these rockfish complexes over this time series is toward occupying warmer temperatures.

Benthic Communities and Non-target Fish Species

Miscellaneous benthic fauna—Aleutian Islands

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Last updated: September 2024

Description of indicator: Benthic species are often reliable ecosystem indicators due to their sensitivity to environmental fluctuations (Tampo et al., 2021) and their integral role in marine food webs (Griffiths et al., 2017). Thus, changes in their abundance are widely used as sentinels for shifts in environmental conditions and ecosystem functioning (Salas et al., 2006; Jayachandran et al., 2022). The benthic fauna presented here are categorized into four taxonomic groups: eelpouts (family Zoarcidae), poachers (family Agonidae), shrimps (infraorder Caridea), and sea stars (class Asteroidea). The three species comprising the bulk of the eelpout group are the ebony eelpout (*Lycodes concolor*), bicolor eelpout (*L. beringi*) and, to a lesser extent, the shortfin eelpout (*L. brevipes*). The biomass of poachers is dominated by sturgeon poachers (*Podothecus accipenserinus*) and sawback poachers (*Sarritor frenatus*). The biomass of shrimps is largely composed of Alaskan pink shrimp (*Pandalus eous*) and yellowleg pandalids (*P. tridens*), whereas the biomass of sea stars are primarily comprised of *Henricia* stars and the fragile sea star (*Cheiraster dawsoni*). These benthic fauna, when considered alongside formally assessed and commercially targeted species, can provide valuable context for the overall status of the Aleutian ecosystem. Since 1991, the biennial RACE Groundfish Assessment Program fishery-independent summer bottom trawl survey in the Aleutian Islands (AI) has deployed the same standardized trawl gear (footrope and trawl net) across the survey region. Therefore, biomass index trends are likely to reflect changes in the abundance of species and life history stages that are available to the survey, especially if trends are sustained over time.

Methodological changes: Methods for producing this indicator have been updated this year to account for process error in survey abundance estimates, facilitate interpretation of indicator trends, utilize consistent statistical methods across ESR regions, and ensure consistent species group composition across regions. Previously, two time series were presented for each species group: (1) average bottom trawl survey catch-per-unit effort within INPFC subareas (CPUE, kg ha^{-1}) that were scaled proportionally to the maximum CPUE in the bottom trawl survey time series, and (2) frequency of occurrence of each species group among bottom trawl survey hauls within INPFC subareas.

This year, subarea biomass estimates were calculated using the *gapindex* R package (Oyafuso, 2024), which uses the Wakabayashi et al. (1985) method to estimate design-based abundance index means and coefficients of variation (CVs) from catch (kg) and effort data (area swept; ha) collected during Aleutian Islands summer bottom trawl surveys. Abundance index time series means and confidence intervals were estimated by fitting a multivariate random effects model (REM) to INPFC subarea biomass estimates and CVs using the R package *rema* (Sullivan et al., 2022; Sullivan and Balstad, 2022) to account for process error in indicator time series. The code and methods to calculate abundance indices and fit REM to time series are implemented in the R package *esrindex* (Rohan, 2024).

Status and trends: Over the first decade of the survey (1991-2000), estimates of sea stars and shrimps indicated relatively stable biomass, with some degree of fluctuation across years (Figure 36). Biomass was largely centered in the Eastern Aleutian Islands (EAI) for sea stars, and in the Western Aleutian Islands (WAI) for shrimps. However, we find steady declines in biomass over the last decade in both invertebrate taxonomic groups, predominantly from the WAI. Since the 2022 survey, shrimps and sea stars remain relatively stable with comparatively low biomass. The subarea pattern of sea star abundance largely mirrors 2022, with the majority of the biomass concentrated in the EAI (Figure 37). In contrast, we find a significant reduction of shrimp biomass in the Southern Bering Sea relative to the previous Aleutian Islands bottom trawl survey.

Historically, the biomass of eelpouts and poachers has been relatively stable, with the majority of eelpouts found in the Central Aleutian Islands (CAI) and EAI, and poachers dominating the EAI and WAI. Reflecting similar patterns in the invertebrate taxa, we also find substantial declines in eelpouts since 2010 and poachers since 2006. Despite the regional trend, poachers have become more abundant in the WAI and eelpouts in the EAI. While the biomass of both poachers and eelpouts have increased from the 2022 estimates, this appears to largely be due to biomass increases in the EAI for eelpouts and in the WAI for poachers, consistent with the longer term subarea trends for these two groups.

Factors influencing observed trends: We hypothesize that persistent warm conditions and decreased ecosystem productivity documented since 2013 in the Aleutian Islands (Xiao and Ren, 2023) may be contributing to the steady biomass declines found in all four taxonomic groups. Many of these taxa are known to be sensitive to thermal stress (Anderson, 2000; Brodte et al., 2006), and sea stars in particular have been subjected to an outbreak of wasting disease, presumably triggered by such temperature shifts. Likewise, the recent biomass increases in both poachers and eelpouts could be attributed to cooler conditions in the Aleutians this year. However, other factors, such as changes in prey or predator dynamics, disturbance, or a combination of effects may also be contributing to these patterns. Further investigation of these non-target benthic taxa is needed to provide a more robust understanding of the mechanisms responsible for the biomass trends documented here.

Implications: These taxa are an important dietary component of many commercially important species, like Atka mackerel, Pacific cod, and king crab. Therefore, changes in biomass could substantially alter trophic dynamics and have ecosystem-wide ramifications.

Research priorities: The bottom trawl survey uses standardized survey protocols aimed at ensuring consistent sampling efficiency. However, additional research is needed to better characterize the catchability and selectivity of miscellaneous benthic fauna groups by the bottom trawl survey.

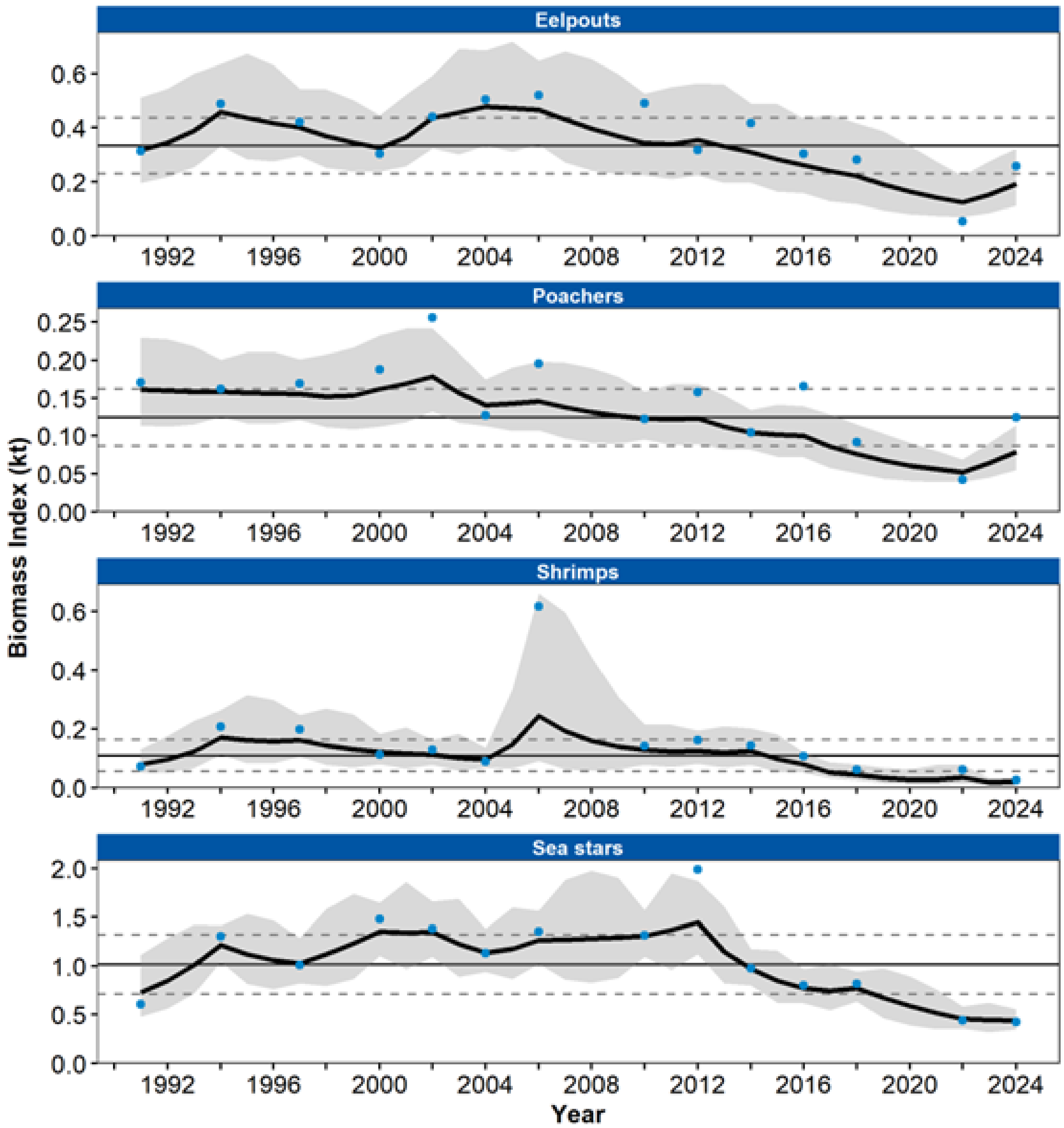

Figure 36: Biomass index (kilotons) of miscellaneous benthic fauna (eelpouts, poachers, shrimps, sea stars) from RACE Groundfish Assessment Program summer bottom trawl surveys of the Aleutian Islands from 1991 to 2024. Panels show the observed survey biomass index mean (blue points), random effects model fitted mean (solid black line), 95% confidence interval (gray shading), overall time series mean (solid gray line), and horizontal dashed gray lines representing one standard deviation from the time series mean.

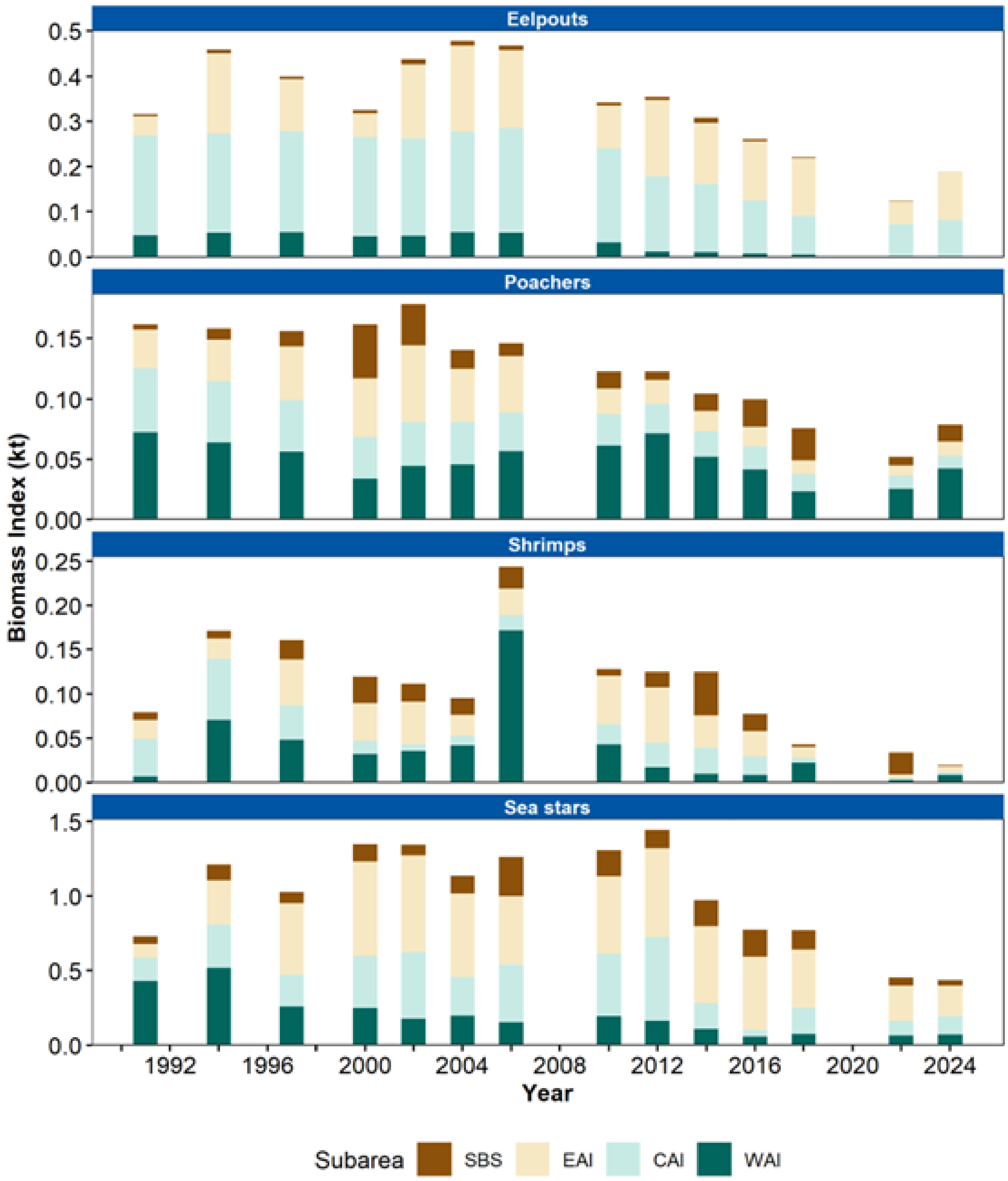

Figure 37: Biomass index (kilotons) of miscellaneous benthic fauna (eelpouts, poachers, shrimps, sea stars) in the Aleutian Islands subareas (Southern Bering Sea [SBS], Eastern Aleutian Islands [EAI], Central Aleutian Islands [CAI], and Western Aleutian Islands [WAI]) estimated from RACE Groundfish Assessment Program summer bottom trawl survey data from 1991 to 2024.

Seabirds

Integrated Seabird Information

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Last updated: November 2024

Synthesis: Most seabirds in the Aleutians feed offshore, so population and reproductive trends at breeding colonies can reflect conditions in the pelagic ocean environment. At Buldir Island in the western Aleutians in 2024, hatch dates were later than average for the majority of seabird species, including both fish and planktivorous feeders. Reproductive success at Buldir was below average for the majority of seabird species, including both fish and planktivorous feeders. This was a particularly poor year for most of the planktivorous auklets; three of the species had both extremely late hatch dates and below-average breeding success. Also, fish-eating thick-billed murres had the lowest breeding success reported for this species at Buldir. The late hatch dates and below-average reproductive success for puffins (diving fish- and squid-eaters) and other seabird species at Buldir suggests possibly unfavorable foraging conditions for them, or other factors, such as stormy weather during July and August, that may have affected their ability to successfully breed this year. Puffin diet sampling showed tufted puffins predominately fed chicks squids and age-0 pollock, and horned puffins fed chicks Atka mackerel and sand lance. Given their poor reproductive success, we can assume that the number and/or quality of these prey items were not sufficient to fledge chicks.

At Aiktak Island in the eastern Aleutians, hatch timing was mixed for fish-eating seabird species and late for storm-petrels, which have mixed fish and invertebrate diets. Both mixed diet and fish-eating species had an average to above-average reproductive season at Aiktak in 2024, presumably indicating high prey availability for both nearshore and offshore foragers, including surface feeders and divers. Capelin was particularly abundant in tufted puffin chick diets at Aiktak, followed by age-0 pollock in much smaller quantities. Reproductive success has been average or above-average since 2019 (no data for 2020) for most seabirds breeding at Aiktak

No large or unusual seabird die-offs were documented via standardized beach-based surveys. Opportunistic reports of beached birds included low numbers of seabirds that have nesting colonies in the Aleutians. Lab results published this year from a 2023 die-off (an opportunistic report of a die-off of over 150 shearwaters at Akutan Island in September 2023) showed samples tested negative for Highly Pathogenic Avian Influenza (HPAI) and below detectable levels for harmful algal bloom toxins (saxitoxin and its related congeners,STX

The influence of pink salmon abundance on seabirds that breed in Alaska can be observed in the reproductive timing of some species and possibly bycatch trends, but they do not seem to drive die-offs. This contrasts with seasonally resident shearwaters that breed in Australia during the austral summer/northern winter. High pink salmon abundance has been found to correlate to occasional mortality events and low abundance of short-tailed *shearwaters. This was a low abundance year of East Kamchatka pink salmon and earlier hatch dates were observed for tufted puffin along with increased seabird bycatch last year, a high pink salmon abundance year.*

Description of indicator: : Seabirds are considered to be useful ecosystem indicators, as their breeding performance and diet composition reflect conditions in the marine environment. Here we provide an overview of environmental impacts to seabirds and what those may indicate for ecosystem productivity as it pertains to fisheries management. We synthesize data and field observations collected by government, university, and non-profit partners to assess the status of seabirds in the Aleutian Islands during 2024.

We present information in four main sections as indicators of processes at different spatio-temporal scales:

1. Timing of breeding, which reflects ecosystem conditions prior to breeding,
2. Reproductive success, which reflects feeding conditions during the breeding season,
3. Puffin chick diet composition, which reflects preferred available prey, and
4. Population information, including mortality, which encompasses environmental and ecosystem effects during spring/summer.

Each type of information is presented for seabirds based on their feeding strategy and main prey: surface or diving seabirds feeding on fish or plankton (see Figure 38). Seabirds discussed here feed offshore, as well as nearshore (∼3 km from land, Byrd et al. 2005), regardless of their feeding strategy or prey. However, because nearshore feeders generally forage in shallow water, their prey is less likely to be affected by currents and fronts (Byrd et al., 2005). The western Aleutians are dominated numerically by planktivorous seabirds, while the eastern Aleutians are dominated by piscivorous seabirds.

strategy		prey	habitat	common name
surface		plankton	offshore	fork-tailed and Leach's storm-petrels
		fish	nearshore	glaucous-winged gull
		fish	offshore	red/black-legged kittiwakes and northern fulmars
diving		plankton	nearshore	parakeet auklets, whiskered auklet
		plankton	offshore	ancient murrelets, least auklets, crested auklet
		fish	nearshore	red-faced cormorant, horned puffin
		fish	offshore	common murre, thick-billed murre, tufted puffin

Figure 38: Feeding strategy, prey and habitat of the main seabird species monitored annually by AMNWR in the Aleutian Islands, based on Byrd et al. (2005)

TIMING OF BREEDING (BULDIR AND AIKTAK)

Seabirds at Buldir Island, in the western Aleutians, and Aiktak Island, in the eastern Aleutians, were monitored by the Alaska Maritime National Wildlife Refuge (AMNWR). The long-term average hatch dates for seabirds at Buldir fall between mid-June to early August (Dragoo et al., 2019), along with average hatching periods of 30 to 42 days.

At Buldir, many of the species were later than average in 2024, including some of the fish-eaters (murres and horned puffins) and all the planktivorous auklets. Other fish-eaters (tufted puffin, kittiwakes) and glaucous-winged gulls had average hatch timing. None of the monitored species were early this year. Most notably, mean hatch timing in 2024 was the latest ever recorded for parakeet (15 days later than average), whiskered (11 days later than average), and crested auklets (15 days later than average) (Figure 39).

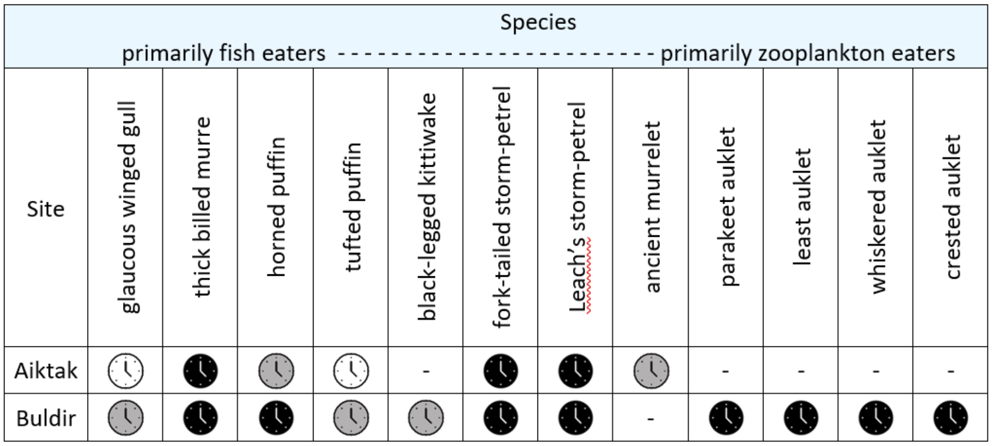

Figure 39: Seabird relative breeding chronology in 2024 compared to long-term averages for past years at Aiktak and Buldir islands. White clock indicates hatching chronology was >3 days earlier than average. Gray clock within 3 days of average. Black clock <3 days later than average. Dashes indicate species not monitored at a site or for which sample size too small for comparison.

The hatch timing of tufted puffins nesting at Buldir has been shown to vary between odd and even years, matching the pattern of high/low biennial runs of Eastern Kamchatka pink salmon (Springer and van Vliet, 2014) where high pink salmon numbers (odd years) correlated with later tufted puffin hatch dates. The pattern could not be discerned in some of the recent years: in 2017-2018, which were two consecutive years of poor reproductive success with little or no hatch data, and in 2020, when no data were collected. The biennial pattern that correlates with pink salmon was observed again in 2021-2024, although the correlation was weak in 2024, when tufted puffin mean hatch date was one day earlier than the long-term mean (Figure 40). The abundance of Eastern Kamchatka pink salmon this year was similar to that in 2022 (Figure 31)), but abundance has been increasing in both odd and even years. The current abundance in even years is similar to that of odd years in the 1970s and 1980s, with 2011-2023 odd years averaging 4.5 times higher abundances.

Hatch dates were mixed at Aiktak in 2024, with earlier than average hatch for glaucous-winged gulls and tufted puffins, average hatch for horned puffins and ancient murrelets, and late hatch for murres and storm-petrels.

REPRODUCTIVE SUCCESS (BULDIR AND AIKTAK)

Reproductive success at Buldir in 2024 was below average for the majority of species, including thick-billed murres, puffins, kittiwakes, and most of the auklets. However, least auklets had above average reproductive success. Storm-petrels had average (fork-tailed) or above average (Leach's) reproductive success. Thick-billed murres had the lowest ever reported reproductive success at Buldir. Some of the nest failures (14% of nest sites) were due to a large cliff erosion event after heavy rains that resulted in rockslides that eliminated murre nesting sites and eggs during the incubation period. Overall success was still low excluding these sites. Black-legged kittiwakes had poor reproductive success, which is not unusual for this species that tends to cycle between very poor and better years. Twenty percent of this year's black-legged kittiwake monitored nest sites were also lost to the same cliff erosion/rockslide event that affected the murres. Whiskered auklets had the second lowest recorded

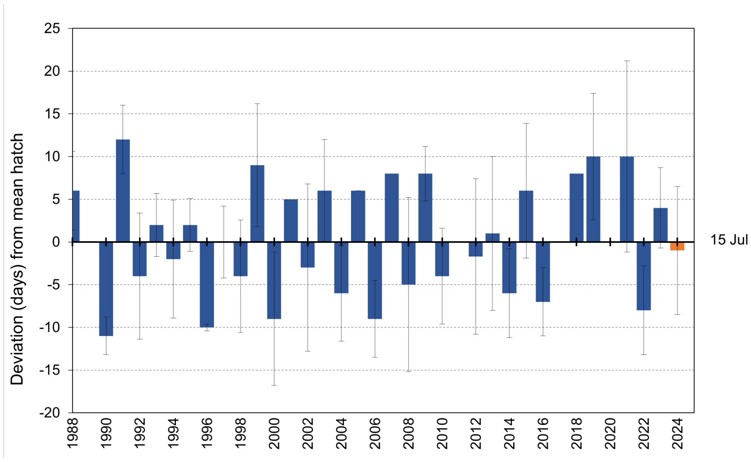

Figure 40: Yearly hatch date deviation (from the 1988–2024 average of 15 July) for tufted puffins at Buldir Island, Alaska. Negative values indicate earlier than mean hatch date, positive values indicate later than mean hatch date. Error bars represent standard deviation around each year's mean hatch date (years without error bars have sample size of one); red highlights the current year. No data were collected in 2020; no hatch dates were recorded with the appropriate egg to chick interval ($\leq$7 days) in 1989 or 2017 and no eggs hatched in plots in 2011.

reproductive success (along with the latest mean hatch date for this species). June was particularly dry on Buldir in 2024, followed by numerous heavy rainfall events in July and stormy weather extending into August that likely impacted nesting success for several species (Figures 41 and 42).

In contrast, seabird reproductive success at Aiktak in 2024 was average to above average of the long-term mean for all species monitored. This is the fifth year since 2019 (not including 2020 when no data were collected) that breeding by most seabirds at Aiktak was average or above average. This includes diving, fish-eating seabirds (common and thick-billed murres, tufted and horned puffins), mixed foragers (storm-petrels, which consume mix of fish and invertebrate), and predominately planktivores (ancient murrelets). Fork-tailed storm-petrels had the highest ever recorded reproductive success and tufted puffins the second highest recorded reproductive success at Aiktak.

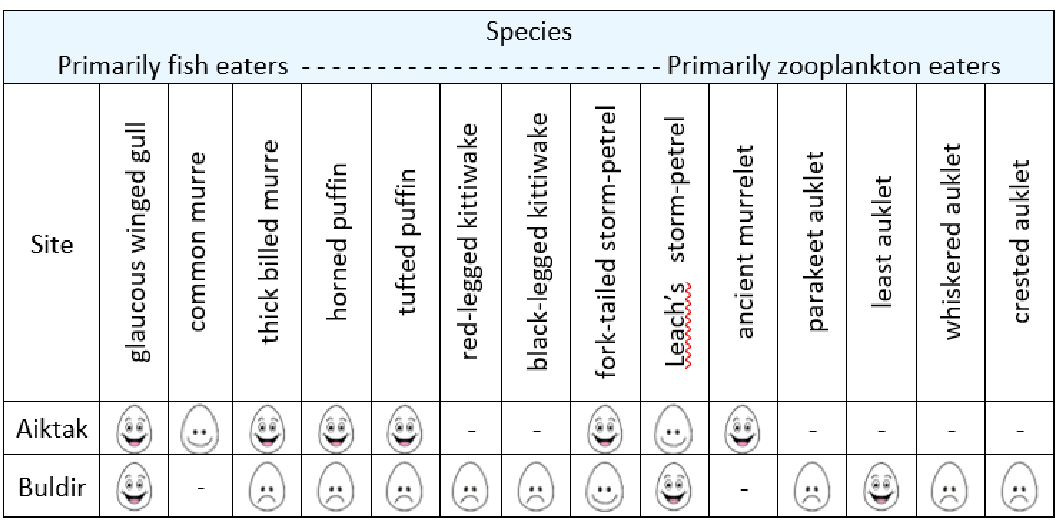

Figure 41: Seabird reproductive success in 2024 compared to long-term means for past years at Aiktak and Buldir islands. Big smiley face indicates reproductive success >1 SD above the long term mean, smiley indicates within 1 SD of long term mean, frowny face indicates >1 SD below long term mean. Dashes indicate species not present or monitored at a site or for which sample size is too small for comparison.

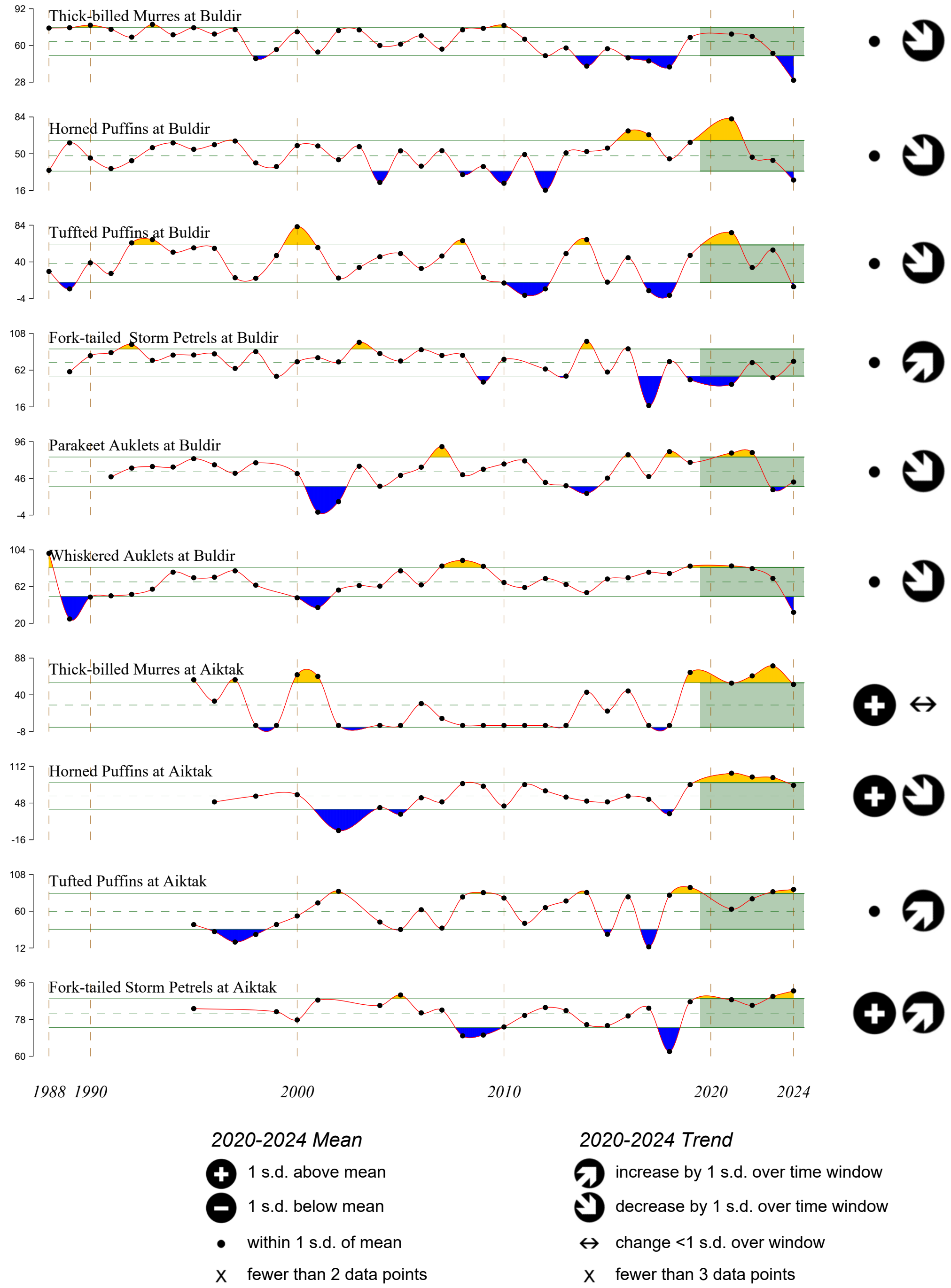

Figure 42: Time series of seabird reproductive success through 2024 at Buldir and Aiktak Islands

SEABIRD PUFFIN CHICK DIET AT BULDIR AND AIKTAK

Seabird diet data span 48 years in the Aleutian Islands. Puffins (tufted puffins and horned puffins, hereafter "puffins") are medium-sized seabirds that nest in varying densities throughout the Aleutians. AMNWR samples puffin chick diets annually at Buldir and Aiktak Islands, and less frequently at puffin colonies on other Aleutian Islands. Puffins feed their chicks primarily small pelagic schooling fish, juvenile groundfish, and mesopelagic species (Sydeman et al., 2017; Piatt et al., 2018) by carrying multiple prey items in their bills when they return to their colonies to feed their chicks. Energy-rich and densely schooling small pelagic species, especially Pacific sand lance (*Ammodytes personatus*), Pacific capelin (*Mallotus catervarius*) (in the eastern Aleutians only), greenlings (Hexagrammidae) including juvenile Atka mackerel (*Pleurogrammus monopterygius*), juvenile gadids (Gadidae) including walleye pollock (*Gadus chalcogrammus*), and squid are preferred prey for puffins provisioning chicks in the Aleutians. Collectively, puffin chick diets provide information on prey communities across large marine ecosystems and context for multidecadal changes in upper trophic-level biology and ecology in Alaska. In the absence of direct measures of forage fish abundance, the diet composition in puffin chick meals may be used as indicators of forage fish abundance and system-wide productivity.

In 2024, tufted puffin chick diets by percent biomass at Buldir were largely composed of squids (64%), followed by gadids (22% pollock) and sand lance (11%). The squid identified to species were shortarm gonate squid (Gonatus kamtschaticus). Horned puffins also fed chicks squid (19%), but their primary prey was Atka mackerel (42%) and sand lance (29%). In contrast, diets of tufted puffin chicks on Aiktak were primarily composed of capelin (50%), followed by age-0 pollock (34%) (Figure **??**).

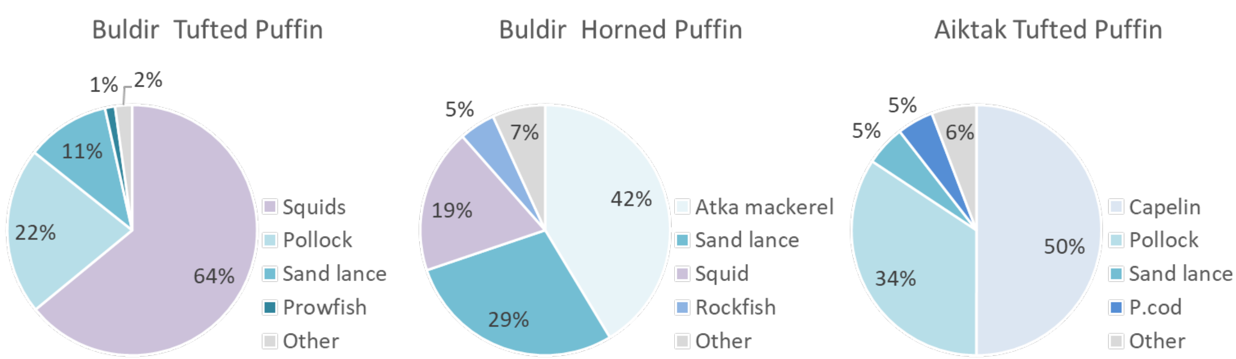

Figure 43: Diet composition by percent weight, based on samples collected in 2024 for tufted puffin and horned puffin at Buldir (wester Aleutians) and tufted puffin at Aiktak, (eastern Aleutians)

To provide indices of forage fish availability over time, we updated time series plots of frequency of occurrence (FO, proportion of samples with at least one fish per species per year) (Figure 44). Samples were pooled across horned puffin and tufted puffins. Diet compositions were plotted as relative frequencies, FO/sum(FO).

Since 2019, puffin chick diets show increasing trends of sand lance indices at Buldir, and declining trends at Aiktak. Capelin indices peaked at Aiktak in 2023 but declined again in 2024. Age-0 walleye pollock are generally less important in puffin chick diets west of Unimak Pass; however, more than 50% of samples at Aiktak (in Unimak Pass) contained one or more walleye pollock in 2024. Juvenile greenling, which were identified mainly as Atka mackerel in 2024, and squid are generally more frequent in diets at Buldir than Aiktak (Figures 44 and 45).

Trends in forage fish in puffin chick diets may reflect abundance for some species. Recent peaks in gadids (ie., age-0 pollock) in puffin chick diets from Aiktak correspond to large year classes in Gulf of Alaska pollock in 2012, 2018, and 2019. The high frequency of age-0 pollock observed this year suggests that the 2024-year class may be abundant.

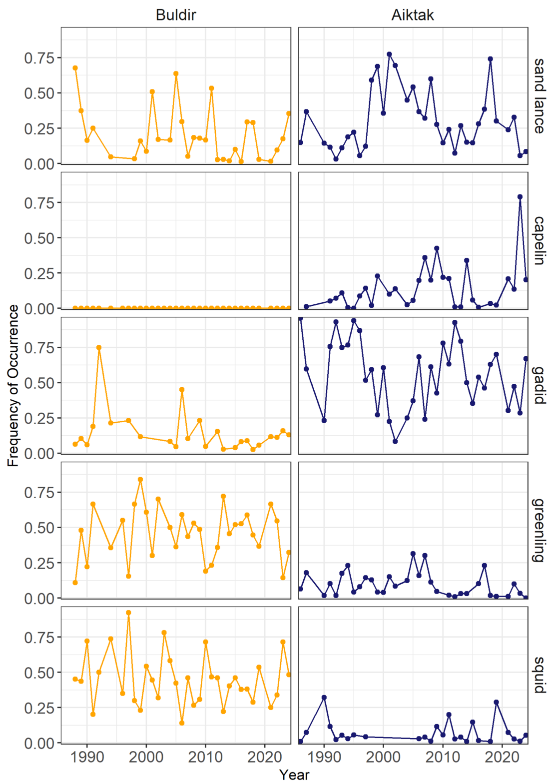

Figure 44: Diet composition by percent weight, based on samples collected in 2024 for tufted puffin and horned puffin at Buldir (wester Aleutians) and tufted puffin at Aiktak, (eastern Aleutians)

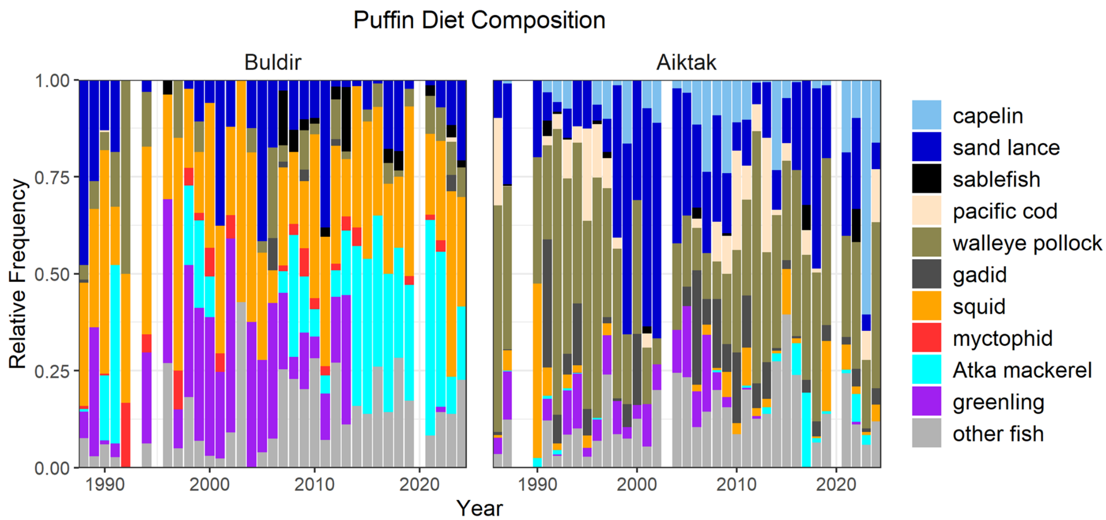

Figure 45: Diet composition by percent weight, based on samples collected in 2024 for tufted puffin and horned puffin at Buldir (wester Aleutians) and tufted puffin at Aiktak, (eastern Aleutians)

POPULATION INFORMATION—MORTALITY

Historically, seabird die-offs are not uncommon in Alaska (Bailey and Davenport 1972), but are seldom reported from the Aleutian Islands, likely due to its remoteness, where die-offs may go unobserved (Alaska Report 2006). Opportunistic reports of beached birds were submitted to the Coastal Observation and Seabird Survey Team (COASST) and regional partners during the summer of 2024. These reports combine contributions by community members in remote coastal locations with reports by citizen scientists. Documentation of species (if known), count, and location is required for each report, but standardized survey effort (outside of COASST and NPS surveys) is rarely available. Monitoring by COASST and regional partners provides a standardized measure of relative beached bird abundance. Surveys began in the Aleutian Islands in 2006, and since that time over 715 surveys have taken place across 18 beaches. In 2024, 29 surveys took place across 5 beaches located mainly in the Eastern Aleutians. Detailed methods for beached bird surveys can be found in Jones et al. (2019).

Between May and September 2024, most reports of carcasses in the Aleutian Islands were from AMNWR seasonal surveys (using COASST protocols) at Buldir, Adak, and Aiktak Islands. In 2024, encounter rates were not indicative of a die-off event, which is generally defined as 5x the baseline encounter rate for mass mortality events. Beach-cast seabird species composition was primarily glaucous-winged gulls and puffins (Figure 46). The observed composition of species is not unusual given the abundance of these species that breed on the islands where monitoring primarily took place. There were relatively few opportunistic reports of additional beached bird carcasses in the Aleutian Islands. The relatively few opportunistic reports received, in conjunction with low encounter rate on regular beached bird surveys performed by COASST suggests that there was no major die-off event in this region in 2024.

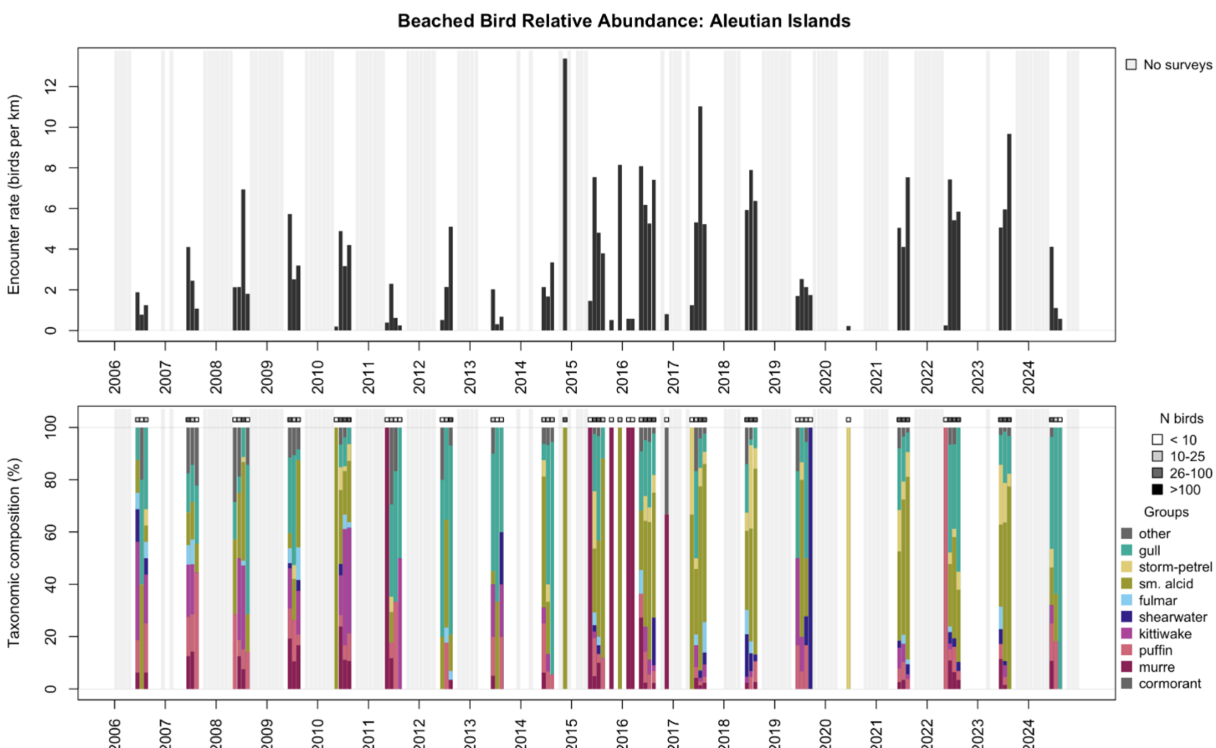

Figure 46: Encounter rate (top panel) and month-averaged beached bird abundance (bottom), standardized per km of survey effort, for the Aleutian Islands. Species groups (gull, storm-petrel, small alcid, fulmar, shearwater, kittiwake, puffin, murre) are depicted with different colors within each bar, with gray bars indicating months where no survey was conducted. Credit: COASST

Seabird bycatch rates have been shown to be related to environmental conditions and bird abundance (Bi et al., 2020). 2020). In the Aleutians, the total estimated seabird bycatch in groundfish and halibut fisheries for all gear types appears to follow a biennial pattern starting in 2014 and continuing through 2023 (see Figure 56) with higher bycatch coinciding with years of high Eastern Kamchatka pink salmon (see Figure 31). The estimated seabird bycatch increased from 496 in 2022 to 885 in 2023, but it is below the 1,673 and 2,244 observed in 2019 and 2021 when EK pink salmon reached its top and second highest abundances, respectively. Shearwaters and northern fulmar account for most of the bycatch, with shearwater bycatch region been higher in odd years since 2016, although this pattern is not as apparent in 2015 and earlier. This biennial pattern is not evident in the relative abundance of beached birds which are primarily gulls and small alcids. The species composition of seabird bycatch estimates differs from that of beached birds. One possible explanation could be that the competitive effects of pink salmon abundance on seabird prey might increase how aggressively seabirds go after bait, but not enough to drive mortality or beached bird numbers. Pink salmon abundance has been linked to kittiwake reproductive success on the Pribilof Islands, with lower reproductive success in odd-numbered years (Zador et al., 2013) Similarly, short-tailed shearwater reproductive success at breeding colonies in Southeastern Australia is negatively correlated with high runs (odd years) of Eastern Kamchatka pink salmon in the preceding austral winter (Springer et al., 2018).

In mid-September 2023, an opportunistic report of a die-off of over 150 shearwaters was reported at Akutan Island. Of the 115 carcasses recovered, six were sent to the Alaska Department of Environmental Conservation (ADEC) where samples tested negative for Highly Pathogenic Avian Influenza (HPAI). The Office of the State Veterinarian, ADEC sent six carcasses to the USGS Alaska Science Center Harmful Algal Blooms (HAB) Laboratory. The seabirds were identified as sooty shearwaters and six samples each of gastrointestinal tract and liver were screened for saxitoxin and its related congeners (STX). All samples resulted in below detectable levels (Smith et al. 2022, ver 4.0, August 2024), no additional information has been received and the cause of death remains unidentified.

Factors influencing observed trends: As in 2023, the deeper mixed layer may have adversely impacted the availability of prey for both surface feeders and diving seabirds. Bond et al., 2011 suggested a correlation exists between a strong Aleutian Low and decreased seabird productivity in the Aleutian Islands, which may be due to decreased prey (zooplankton) availability; additionally, they found a higher NPGO index corresponded with lower seabird reproductive success. The NPGO index has remained negative since late 2013 (Figure 12), and the Aleutian low was weak six out of the last eight winters (except winter 2018-2019). Jointly, these indices suggest increased zooplankton availability and favorable conditions for seabird productivity. However, this year the Aleutian Low was close to its climatological mean (Figures 13 and 14). Strong winds and storminess from last autumn through the summer of 2024 cooled surface waters, deepened the mixed layer, and decreased flows through the passes (Figure 10. This may have impacted the vertical distribution and availability of prey throughout the water column, particularly in the western Aleutians where winds seem to have been stronger. The decrease in the copepod community size since summer of 2014 suggests a real increase in the relative abundance of smaller species, which may impact the composition, size, and nutritional quality of prey available to planktivorous seabirds (see Figure 26).

Implications: Reproductive activity of central-place foraging seabirds can reflect ecosystem conditions at multiple spatial and temporal scales. This year all monitored species in Aiktak had average to above average breeding success compared to the long-term means. This suggests that foraging conditions for both plankton and fish-eating commercial groundfish may have been favorable in the eastern Aleutians. The presence of capelin, considered a high-quality forage fish, supports this assessment. In the western Aleutians at Buldir, the fact that many seabirds had below average reproductive success across feeding strategies and prey types suggest limited availability or lower quality prey, or other factors, such as stormy weather and a resulting deeper mixed layer, contributed to poor breeding conditions.

Acknowledgements: We thank Danielle Gerik from the USGS Alaska Science Center Harmful Algal Blooms (HAB) Laboratory for completing the STX ELISA quantification and releasing the data in time for its inclusion in this report.

Methods

1. AMNWR: The Alaska Maritime National Wildlife Refuge (AMNWR) has monitored seabirds at colonies around Alaska in most years since the early- to mid-1970's. Monitored colonies in the Aleutians include Buldir Island in the western Aleutians and Aiktak Island in the eastern Aleutians. The Refuge monitors breeding chronology, productivity and/or population parameters for indicator species representing four major feeding guilds: 1) diving fish-feeders (e.g., common and thick-billed murres, horned and tufted puffins), 2) surface fish- feeders (e.g., black and red-legged kittiwakes), 3) diving plankton feeders (e.g., parakeet and least auklets), and 4) surface plankton feeders (e.g., Leach's and fork-tailed storm-petrels).

   The timing of breeding is based on mean hatch date at a site. The deviation of the current year mean hatch dates from the mean of all prior years is used to determine whether the timing in the current season is earlier, average, or later than the long-term mean. For this summary, early hatch is defined as >3 days earlier than mean hatch, average as within 3 days of the mean, and late as >3 days later than the mean. Reproductive success is defined as the proportion of nest sites with eggs (or just eggs for murres, which do not build nests) that fledged a chick. For the summary presented in Figure 41 of seabird productivity at these sites, success categories (depicted with egg icons) were determined using parametric SD estimates for most species, and nonparametric bootstrap SD estimates (based on 1000 resamples) for those species with the possibility of more than one egg/chick. For each species and location, using all previous years' data, success was delineated as follows:

   (a) Way above average: current year's values above the quantity (mean + 1 SD) received big smiley faces;
   (b) current year's values between (mean - 1 SD) and (mean + 1 SD) received smiley faces; III.
   (c) Below average: current year's values below (mean - 1 SD) received frowny faces;
   (d) Complete failure: current year's values at or near zero received cracked frowny faces.

2. Seabird Reproductive time series: Based on data from AMNWR above, shown with respect to the average of the entire time series. (AMNWR uses the mean of previous years only; the current year is not included).

3. Puffin chick diet time series: Based on seabird diet data from AMNWR; samples consist of bill loads from adult puffins returning to the colony to feed chicks. Time series were based on frequency of occurrence (percentage of food samples in which each prey item was present), whereas the year specific diet composition is based on relative biomass of major prey items (numbers represent the percentage of the mass of combined food samples comprised by each prey item). Prey are identified to the lowest taxon possible.

4. COASST: The Coastal Observation and Seabird Survey Team (COASST) provided a standardized measure of relative beached bird abundance collected by citizen scientists for the Aleutian Islands from 2006 to present. Time-series of month-averaged beached bird abundance show several of the recent mortality events that have affected the Bering Sea. Time- series of month-averaged beached bird abundance for the Aleutian Islands show several of the recent mortality events that have affected this area.

Marine Mammals

Steller Sea Lions in the Aleutian Islands

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Description of indicator: As a large apex, piscivorous predator that ranges across a broad geographic range, Steller sea lions serve as an indicator species. Depending on the area, a large portion of the Steller sea lion diet is typically comprised of one or more of these three commercial groundfish species: Atka mackerel, Pacific cod, and walleye pollock (Sinclair et al., 2013).

In Alaska, Steller sea lions range throughout the southern coastline from southeast Alaska to the western Aleutian Island chain. The species is divided into two populations at the 144ºW longitudinal line (near Cape Suckling): the eastern and the western Distinct Population Segments (DPSs). The Aleutian Islands geographic area is comprised of three regions: the eastern, central, and western Aleutian Islands (western DPS; Figure 47). Rookery cluster area (RCA) 1 is equivalent to the western Aleutian Islands (hereafter referred to as ALEU) region, and generally, the central ALEU is comprised of RCAs 2-5, and the eastern ALEU (including Bering Sea) is comprised by RCA 6.

During the non-breeding season, sea lions disperse and can move widely throughout the North Pacific Ocean, especially juveniles and males. During the summer breeding season, sea lions aggregate on land, usually at their natal rookery site, to breed and birth pups. The Marine Mammal lab (MML) conducts annual population surveys during the peak of the breeding season to collect counts throughout the range in Alaska (Fritz et al., 2016, 2015). Generally, survey effort across the population range in Alaska alternates between the Gulf of Alaska and Aleutian Islands. Challenging survey weather and logistical factors can result in sites being missed. MML uses the R package, agTrend (Johnson and Fritz, 2014; Gaos et al., 2021) to interpolate counts for the missed sites and model estimated counts (an index of population abundance) and trends for defined geographic areas.

A note about agTrend model outputs— MML does not report abundance estimates but rather agTrend derived modeled counts (an index of population abundance) and trends. The model outputs do not account for non-pups (juveniles and adults) at-sea during the survey. The Steller sea lion agTrend model was updated (Gaos et al. 2021) to increase precision and results are shared in this report. Modeled counts represent a minimum population estimate (Nmin; Muto et al. 2020). As pups do not take to the water until they are older (>1 month), pup counts are considered a census but do not account for pups that are born or died after the survey. Two types of count estimates are generated with agTrend:

1. Realized counts—Uses the standardized variance of raw counts at each site throughout the time series to estimate survey counts we could expect to collect if we had completely surveyed all sites. Therefore, the more complete the survey, the more similar raw counts are to realized counts. When available, MML uses realized counts that have not been "smoothed" (i.e., predicted counts) to report on changes over time.

2. Predicted counts—Uses the model fit to estimate count values that would be predicted at a site in a given year if it were resurveyed. For trend analyses, predicted counts are more appropriate because they account for both measurement and process error.

Status and trends: Declines in Steller sea lion populations were first observed in the 1970s, with the steepest declines occurring in the mid-1980s (Fritz et al., 2016). The western DPS as a whole began to rebound in 2002

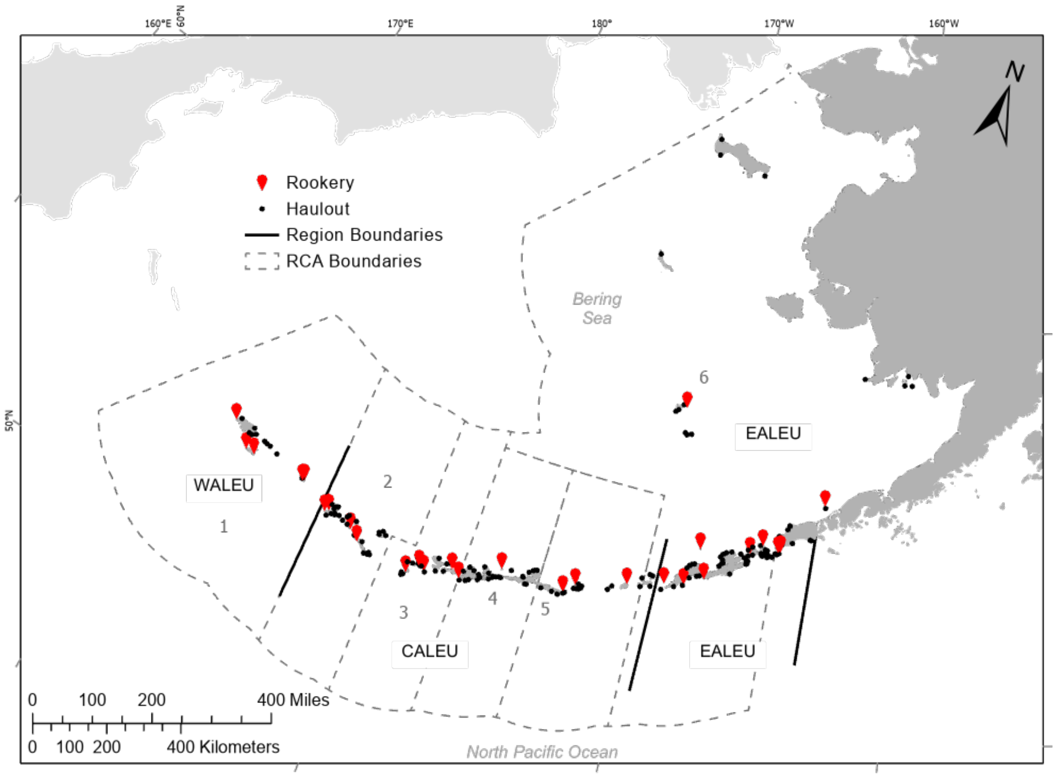

Figure 47: Map of Steller sea lion known rookery and haulout sites in the western (W-), central (C-), and eastern (E-) Aleutian Island (-ALEU) regions and rookery cluster areas (RCA) 1–6 (Fritz et al. 2015).

however, contrasting regional trends have been observed. West of Samalga Pass, sea lions showed no signs of recovery and continue to decline (Sweeney et al., 2023).

In 2022 and 2023, MML surveyed the eastern, central, and western ALEU regions. MML conducted a redundant survey in this area because the 2022 survey was largely incomplete (because of inclement weather and survey logistics) and anomalous declines were observed (Sweeney et al., 2023). Among all regions, the non-pup (realized) counts were all lower in 2022 than in 2023. This was the first survey of the Aleutian Islands sites which had not been surveyed since 2018 or earlier (because of the COVID-19 pandemic), while the Gulf of Alaska regions had been surveyed on schedule and with near-complete coverage in and prior to 2021.

In the total western DPS in Alaska between 2008 and 2023, non-pup and pup counts increased 1.09% y^{-1} (95% confidence interval [CI] 0.46–1.74) and 0.64% y^{-1} (95% CI 0.20–1.08), respectively (Table 1, Sweeney et al. 2023). Growth of this population in Alaska has been approaching stable since 2010. Non-pups in the combined Aleutian Islands regions significantly increased 0.91% y^{-1} between 2008 and 2023 (Figure 48), though this area appears to be moving towards stability (95% CI 0.03–1.98% y^{-1}). Pups in the combined ALEU regions were stable from 2008-2023 (-0.23% y^{-1}, 95% CI -0.78– 0.30).

In the western ALEU, Steller sea lion non-pups and pups significantly declined from 2008 to 2023 (-5.69% y^{-1} and -3.98% y^{-1}, respectively; Figure 49). Pups in this region have declined 95% since their peak in 1984 (38 years). The peak non-pup count was observed in 1971 (the earliest count for this region) and has declined 99% since. In this region, Buldir rookery has entirely disappeared: a historical count reported for all sites on Buldir in 1979 was just over 5,000 non-pups; more recent counts have ranged from 0–28 since 2010 (Fritz et al., 2013).

Table 1: Annual rates of change (% y^{-1} with ±95% credible intervals [CI]; estimated from predicted counts) of counts of Steller sea lion non-pups and pups modeled with agTrend. We modeled the total western DPS in Alaska and spatial areas therein for the 15-year period, 2008–2023: Aleutian Islands (ALEU) regions combined; western (W), central (C), and eastern (E) ALEU regions; and rookery cluster areas (RCA) 2–5 within the C ALEU region.

	NON-PUP			PUP		
AREA/ REGION	Rate	-95%CI	+95%CI	Rate	-95%CI	+95%CI
Aleutian Islands	0.91	0.03	1.98	-0.23	-0.78	0.30
W ALEU	-5.69	-7.98	-3.47	-3.98	-4.94	-3.00
C ALEU	-0.11	-1.75	1.81	-1.97	-2.88	-1.04
RCA 2	-2.56	-4.78	0.08	-4.44	-6.24	-2.77
RCA 3	-3.20	-4.71	-1.65	-5.31	-5.97	-4.64
RCA 4	-0.21	-2.44	2.26	-2.21	-3.94	-0.49
RCA 5	2.44	-0.96	6.70	1.29	-0.73	3.30
E ALEU	2.14	1.00	3.28	1.48	0.78	2.17
Western DPS (Alaska)	1.09	0.46	1.74	0.64	0.20	1.08

In the central ALEU, non-pups were statistically stable from 2008-2023, however, they declined significantly in RCAs 2 and 3 (-2.56 and -3.20% y-1, respectively) while RCAs 4 and 5 remained stable (-0.21 and 2.44% y^{-1}, respectively). In this region, pups declined significantly from 2008 to 2023 (-1.97y^{-1}), with significant declines in RCAs 2-4 and stability in RCA 5. RCAs 4 and 5 continue to be a challenge to survey resulting in wider credible intervals, and therefore, relative higher uncertainty in model estimates.

Non-pups and pups in the eastern ALEU significantly increased from 2008 to 2023 (2.14 and 1.48%$^{-1}$, respectively). In most regions, and population wide, stability in non-pups were preceded by stabling of pup counts.

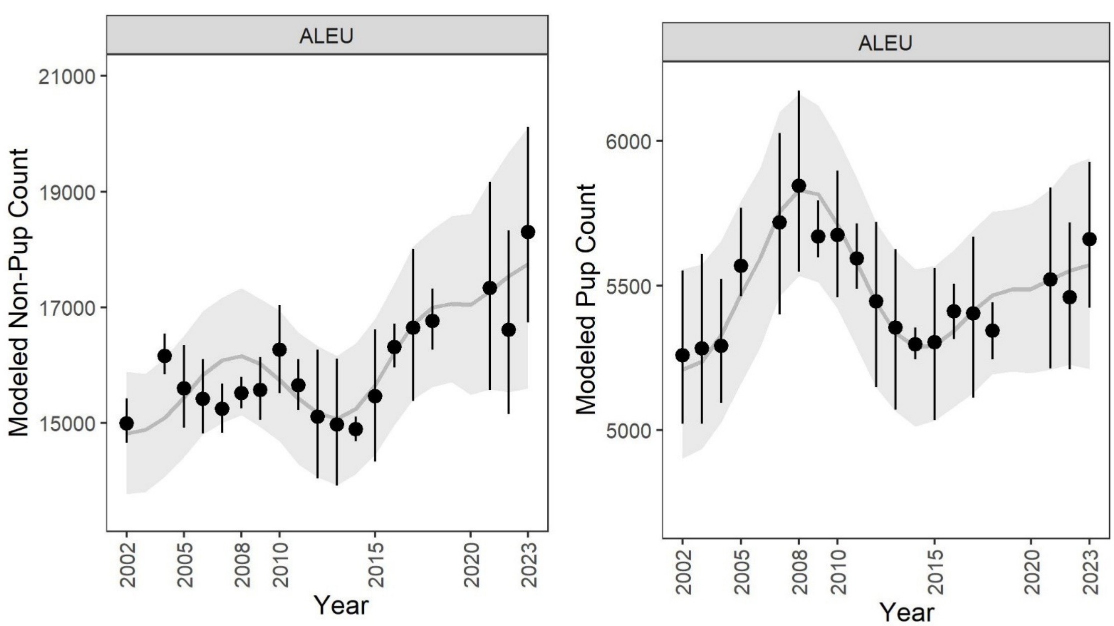

Figure 48: Steller sea lion modeled non-pup and pup counts of the combined regions within the Aleutian Islands (ALEU), 2002–2023. Realized counts are represented by points and vertical lines (±95% credible intervals). Predicted counts are represented by the gray line and shaded area (±95% confidence intervals; Sweeney et al. 2023).

Factors influencing observed trends: Atka mackerel and Pacific cod have been the two dominant prey species

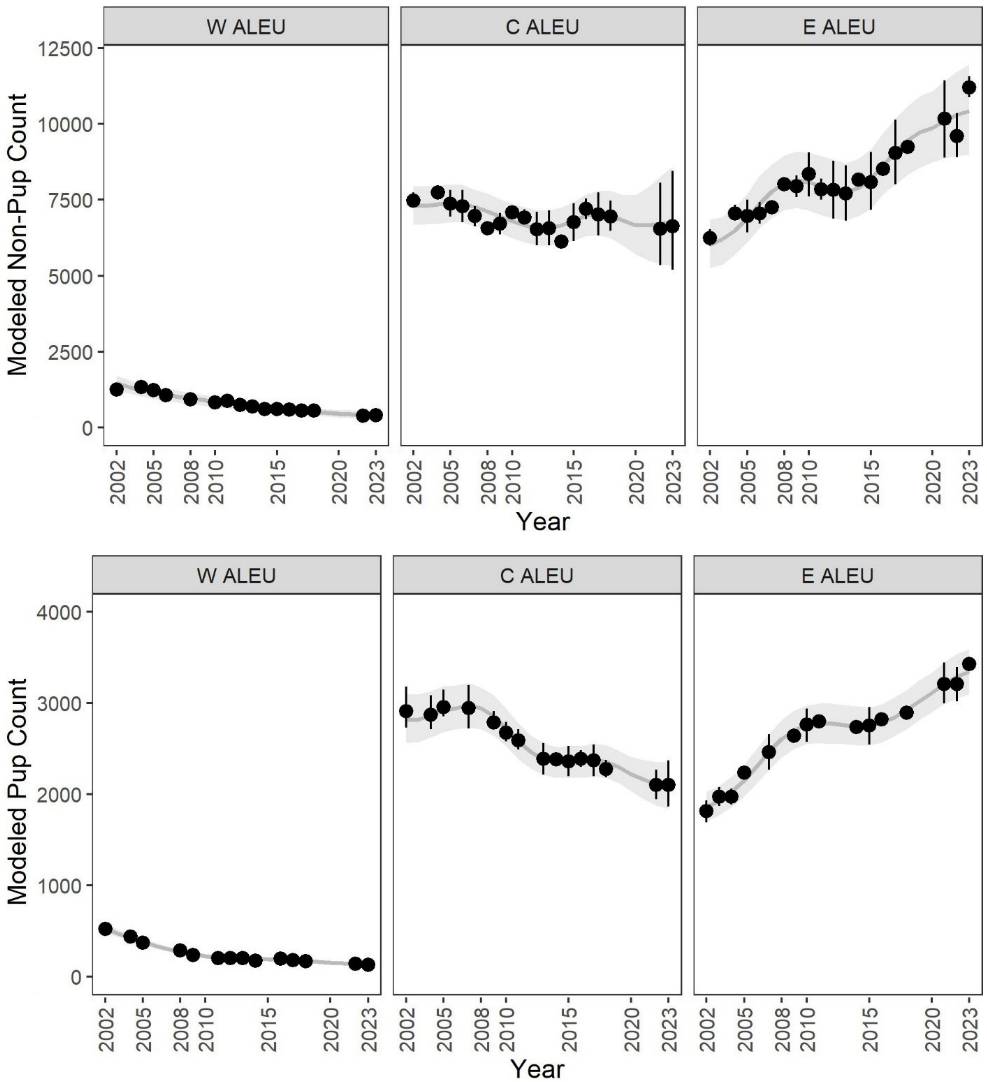

Figure 49: Steller sea lion modeled non-pup and pup counts of the western (W-), central (C-), and eastern (E-) Aleutian Island (-ALEU) regions, 2002–2023. Realized counts are represented by points and vertical lines (±95% credible intervals). Predicted counts are represented by the gray line and shaded area (±95% credible intervals; Sweeney et al. 2023).

of Steller sea lions in the central and western ALEU (Sinclair et al., 2013; Tollit et al., 2017). Summer (i.e., breeding season) diets in these areas were largely dominated by Atka mackerel (during the breeding/brooding season when Atka mackerel enter shallow waters), whereas winter (i.e., non-breeding) diets had greater diversity (with more temporal and spatial variability): Atka mackerel made up less than 15% of energy consumed while about 50% of energy consumed was composed of a suite of prey (octopus, smooth lumpsucker, and Pacific cod; Fritz et al. 2019).

Fritz et al. (2019) found no evidence to support correlations between population trend and certain diet metrics—diet diversity, species mix, and energy density—suggesting other factors were at play if nutrition was a factor in sea lion declines. There were more dense and consistent aggregations of Atka mackerel in the central ALEU, where Steller sea lions had largely stabilized (Rand et al., 2019). Ecosystem Status Reports have reported persistent warming conditions since around 2013/2014, suggesting lower productivity. Additionally, the dominant groundfish species has changed from Atka mackerel and walleye pollock (in the 1990s) to rockfish species. Steller sea lion prey species (e.g., Atka mackerel, Pacific cod, and walleye pollock) are likely to have lower overall abundance, less predictable spatial distributions, and altered demographics in fished versus unfished habitats (Hsieh et al., 2006; Barbeaux et al., 2013; Fritz et al., 2019).

In the stable and/or increasing central ALEU region, Rand et al. (2019) reported dense and consistent aggregations of Atka mackerel; however, in the western ALEU region, this important prey species was more spread out over a larger area. Rand et al (2019) reported that Steller sea lions foraging for Atka mackerel likely expended more energy in the western ALEU region than in the central ALEU because of the larger density aggregations of Atka mackerel in this region. This could result in increases in energy expenditures by Steller sea lions associated with finding and capturing prey, as evident by increased frequency and duration of foraging trips observed in juvenile Steller sea lions in the western Aleutians (Lander et al., 2010) than in the central ALEU (Rand et al., 2019).

Prey availability in winter is thought to be a key factor in energy budgets of sea lions, especially for pregnant females and especially those supporting a pup and/or juvenile (NMFS 2013). Females have smaller blubber stores (than males) and require more accessible availability of prey to sustain themselves and their fetus and/or nurse their pup or juvenile (Boyd, 2000; Malavaer, 2002; Winship et al., 2002; Williams, 2005).

Overall, Lander et al. (2020) reported spatial foraging variability among individual adult females (i.e., on-shore, shelf and slope environmental features; Lander et al. 2020). Adult females foraging on the shelf were likely targeting predictable prey fields, though, they were observed to also utilize off shelf prey fields (more often than juveniles) during the non-breeding season (Lander et al. 2020) targeting pelagic species (e.g., rockfishes, walleye pollock, salmonids, etc.; Lander et al. 2020).

Implications: As an indicator species, the lack of recovery in Steller sea lions in the western population, especially in the Aleutian Islands, is indicative of impacts from nutritional or environmental stress, or other conditions in the ecosystem. The NOAA Fisheries Steller sea lion 5-year review (of the endangered listing under the Endangered Species Act) sustained the endangered listing status, largely driven by declines in the ALEU, incomplete information of the Russian subpopulation, and the uncertainty of the cause. As an endangered species, the status of Steller sea lions has potential to impact and influence fishery management decisions. Overall, the continued declines in the ALEU indicates this protected endangered species is still at-risk and susceptible to threats.

Marine Mammal Strandings

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Last updated: September 2024

Description of indicator:: : Since 1985, members of the NMFS Alaska Marine Mammal Stranding Network (AMMSN) have collected and compiled reports on marine mammal strandings throughout the state. These reports are indices of events witnessed by members of the stranding network, the scientific community, and the general public, with varying degrees of knowledge regarding marine mammal biology and ecology. A marine mammal is considered "stranded" if it meets one of the following criteria: 1) dead, whether found on the beach, ice, or floating in the water; 2) alive on a beach (or ice) but unable to return to the water; 3) alive on a beach (or ice) and in need of apparent medical attention; or 4) alive in the water and unable to return to its natural habitat without assistance. The causes of marine mammal strandings are often unknown but some causes include disease, exposure to contaminants or harmful algal blooms, vessel strikes, and entanglement in or ingestion of human-made gear or debris.

When a stranded marine mammal is reported, information is collected including species, location, age class or size. In some cases, the initial photos and observations reported to AMMSN may be the only opportunity to collect information on the event. When possible trained and authorized AMMSN members respond and collect life history data and samples as part of a postmortem examination. Photos and carcasses are evaluated for potential human interactions such as entanglements or vessel strikes. These responses are conducted under the Marine Mammal Protection Act authorization either under a 112 (c) agreement issued by NMFS to AMMSN members through a Stranding Agreement or under 109 (h) authority exercised by local, state, federal or tribal entities. All responses involving ESA-listed species and some enhanced responses (e.g. remote sedation) are authorized under the NOAA Permit No. 24359.

Status and trends: The number of reported strandings in Alaska has increased over time. As of September 18, 2024, 189 confirmed stranded marine mammals have been reported for the year in Alaska; five occurred in the Aleutian Islands region (Table 2). These numbers do not include entangled pinnipeds with no response or live, entangled baleen whales. Reported strandings in the Aleutian Islands since 2020 varied between years without an overall pattern or consistent increase in reports (Table 2). The 2024 stranding data includes strandings reported between January 1, 2024 and September 18, 2024. These data are preliminary and the details may change as we receive additional information.

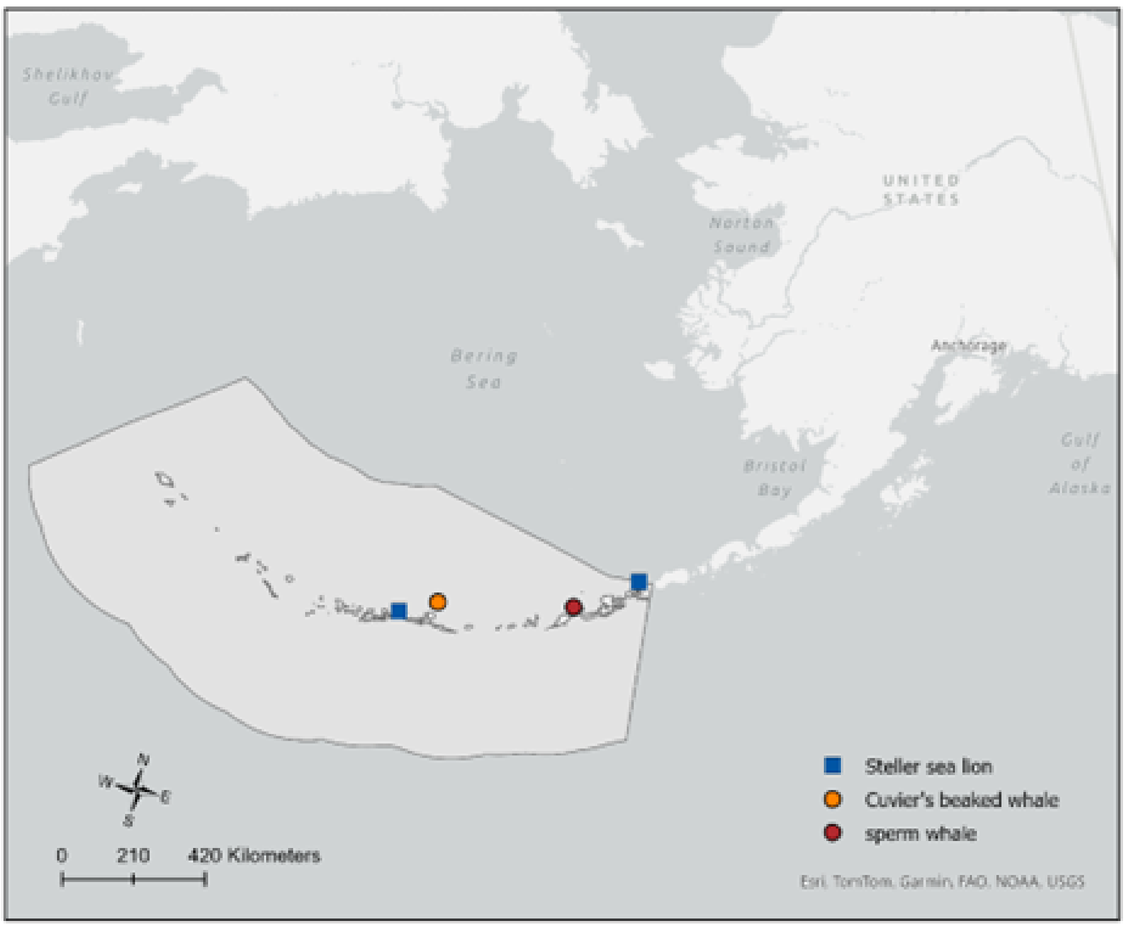

Figure 50: Reported stranded marine mammals in the Aleutian Islands Region reported between January 1, 2024 and September 18, 2024

Factors influencing observed trends:: It is important to recognize that stranding reports represent effort that has varied substantially over time and location and overall has increased over time and within areas with higher human population densities. There have been relatively few reported stranded marine mammals in the Aleutian

Table 2: Reported stranded NMFS marine mammal species for 2024* and the previous five years in the Aleutian Islands by species and year. The number of live stranded animals is reported in parenthesis by species and year.

	2020	2021	2022	2021	2023	2024
fin whale	1					
humpback whale	1	1			2	
unidentified baleen whale				1		
Baird's beaked whale			1			
Cuvier's beaked whale						1
killer whale		1	1			
sperm whale					1	1
unidentified dolphin		1				
total cetaceans	2	3	2	1	3	
ringed seal		1(1)				
Steller sea lion	3(1)	4(1)		4	3	3
total pinnipeds	3	5		4	3	3
total	5	8	2	5	6	5

* 2024 stranding data includes confirmed strandings reported between January 1, 2024 and September 18, 2024.

Islands (Table 2) likely due to the remoteness of the area and the low and sporadic population throughout the Aleutian Islands (Figure 50). The number of stranded marine mammals are likely grossly underestimated as observations are opportunistic and without consistent effort.

Implications: Across Alaska, reported marine mammal strandings have been increasing in more recent years which may signal changes in the environment or human interactions (e.g. vessel strike). It is important to track and have a sense of the regular number of strandings in an area to provide a context to mass strandings or Unusual Mortality Events. Marine mammal stranding data can be paired with other datasets and may give clues to ecosystem-wide changes or other stressors.

Ecosystem or Community Indicators

Stability of Groundfish Biomass

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Last updated: October 2024

Description of indicator: The stability of the groundfish community total biomass is measured with the inverse biomass coefficient of variation (1 divided by the coefficient of variation of total groundfish biomass (1/CV[B]). This indicator provides a measure of the stability of the ecosystem and its resistance to perturbations. The variability of total community biomass is thought to be sensitive to fishing and is expected to increase with increasing fishing pressure (Blanchard and Boucher, 2001). This metric is calculated following the methods in Shin et al. (2010). The CV is the standard deviation of the groundfish biomass index over the previous 10 years divided by the mean over the same time period. This metric is presented as an inverse, so as the CV increases the value of this indicator decreases, and if the CV decreases the value of this indicator increases.

The biomass index for groundfish species was calculated from the catch of the NMFS/AFSC biennial summer bottom-trawl survey of the Aleutian Islands. The Aleutian Islands survey time series began in 1980 and was conducted on a triennial basis until 2000 when it switched to a biennial schedule. The surveys prior to 1991 were conducted jointly with Japan and preceded the establishment of standardized survey methodology for the Aleutian Islands (von Szalay et al., 2023) Thus, this indicator begins with the 1991 survey. The 2008 and 2020 surveys did not occur leaving 4 year gaps. Since 10 years of data are required to calculate this metric, the indicator values start in 2014, the tenth time the Aleutian Islands were surveyed over the time series examined (1991-2024). Previous year's contributions included the 1983 and 1986 surveys.

Since 2022, rockfish are included in this indicator, including dusky rockfish, northern rockfish, Pacific Ocean perch, rougheye rockfish, shortraker rockfish, shortspine thornyhead, and other Sebastes. Rockfishes are abundant in the Aleutian Islands and variations in their population could drive the value of this indicator. Therefore, the mean lifespan of groundfish is presented as two series, one with rockfish included and one without.

Status and trends: : The stability of groundfish biomass with rockfish included is 8.0 in 2024 and has been increasing since 2014. Without rockfish, the stability of groundfish biomass has gradually decreased from a high of 4.0 in 2014 to 3.5 in 2024.

Factors influencing observed trends: Fishing is expected to influence this metric as fisheries can selectively target and remove larger, long-lived species effecting population age structure (Berkeley et al., 2004; Hsieh et al., 2006). Larger, longer-lived species can become less abundant and be replaced by smaller shorter-lived species (Pauly et al., 1998). Larger, longer-lived individuals help populations to endure prolonged periods of unfavorable environmental conditions and can take advantage of favorable conditions when they return (Berkeley et al., 2004). A truncated age-structure could lead to higher population variability (CV) due to increased sensitivity to environmental dynamics (Hsieh et al., 2006). Interannual variation in this metric could also be influenced by interannual variation in species abundance in the trawl survey catch, and patchy spatial distribution for some species. This metric, as calculated here with trawl-survey data, reflects the stability of the groundfish community that is represented in the catch of the Aleutian Islands summer bottom-trawl survey. In general, as total biomass decreases species spatial distribution may contract or have increasingly isolated patches, both of which may lead to increased CV (Shin et al., 2010).

The biomass of Pacific ocean perch increased over the time series to a peak in 2014 and has remained high in the years since. The relatively high biomass of Pacific ocean perch over the most recent survey years has imparted additional stability on the total groundfish biomass, dampening the destabilizing effect of oscillations in species

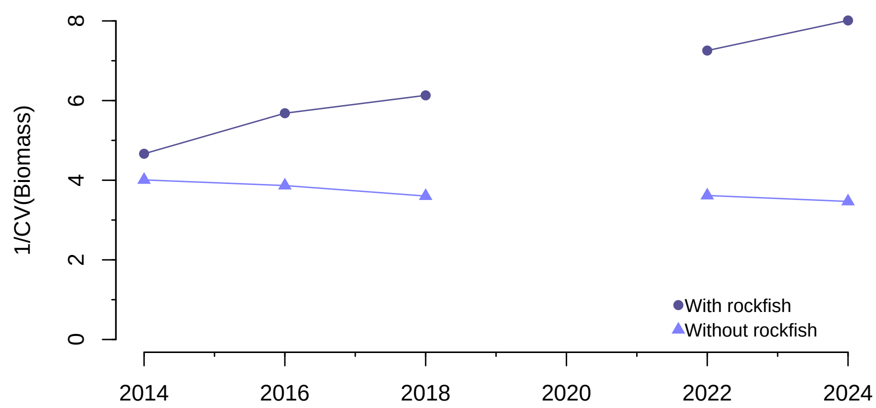

Figure 51: The stability of groundfish in the Aleutian Islands, represented by the inverse biomass coefficient of variation (1 divided by the coefficient of variation of total groundfish biomass (1/CV[B]). Ten years of data are required to calculate this metric, so the indicator begins in 2014 after the tenth occurrence of the NMFS/AFSC summer bottom-trawl survey over the time period examined (1991-2024).

with higher levels of interannual biomass variation, such as Atka mackerel.

In the series with rockfish excluded, walleye pollock and Atka mackerel are two of the biomass dominant species in the catch of the Aleutian Islands bottom trawl survey. Atka mackerel has had the highest biomass index in all years of the survey examined here and exhibits considerable variability between survey years. The biomass index for walleye pollock has similarly exhibited high variability between survey years. Collectively, this heightened variability has led to lower groundfish stability for the series without rockfish.

Implications: : The biomass of the groundfish community in the Aleutian Islands has trended upward over the time period examined. Elevated biomass in recent survey years for long-lived species, such as Pacific Ocean perch and northern rockfish, has been a stabilizing force for the total groundfish community biomass. The current status and trends indicate the overall groundfish biomass is stable.

Mean Length of the Fish Community

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Last updated: October 2024

Description of indicator:: The mean length of the groundfish community tracks fluctuations in the size of groundfish over time. This size-based indicator is sensitive to the effects of commercial fisheries because larger predatory fish are often targeted by fisheries and their selective removal would reduce mean size (Shin et al., 2005). This indicator is also sensitive to shifting community composition of species with different mean sizes. Fish lengths are routinely recorded during the biennial NMFS bottom trawl survey of the Aleutians Islands. The survey time series began in 1980 and was conducted on a triennial basis until 2000 when it switched to a biennial schedule.

The surveys prior to 1991 were conducted jointly with Japan and preceded the establishment of standardized survey methodology for the Aleutian Islands (von Szalay et al., 2023). Thus, this indicator begins with the 1991 survey. The 2008 and 2020 surveys did not occur leaving 4 year gaps. Previous year's contributions included the 1983 and 1986 surveys.

Species-specific mean lengths are calculated for groundfish species from the length measurements collected during the trawl survey. The mean length for the groundfish community is calculated with the species-specific mean lengths, weighted by biomass indices (Shin et al., 2010) calculated from the bottom-trawl survey catch data. The survey biomass index is weighted by strata area (km2). This indicator specifically applies to the portion of the demersal groundfish community efficiently sampled with the trawling gear used by NMFS during the summer bottom-trawl survey of the Aleutian Islands and have their lengths regularly sampled (for complete survey details see von Szalay et al. 2023). This includes species of skates, flatfishes, and roundfishes (e.g., cods, sculpins, eelpouts). Species that are predominately found in the pelagic environment (e.g., capelin, pelagic smelts), are infrequently encountered (e.g., sharks, grenadiers, myctophids), or not efficiently caught by the bottom-trawling gear are excluded from this indicator.

Since 2022, rockfish are included in this indicator, including dusky rockfish, northern rockfish, Pacific Ocean perch, rougheye rockfish, shortraker rockfish, shortspine thornyhead, and other *Sebastes*. Rockfishes are abundant in the Aleutian Islands and variations in their population could drive the value of this indicator. Therefore, groundfish mean length is presented as two series, one with rockfish included and one without.

Status and Trends: *With rockfish*—The mean length of the Aleutian Islands groundfish community in 2024 is 37.2 cm. This is equal to the long term mean of 37.2 cm and is nearly equal to the mean length of 37.7 cm in 2024 (Figure 52). This indicator has shown a small amount of year to year variation and has generally stayed close to the long term mean

Without rockfish—The mean length of the groundfish community in 2024, excluding rockfish, is 39.9 cm. This is down from 40.1 cm in 2022 and is above the long-term mean of 39.5 cm. The trends in this indicator without rockfish approximately mirrors that of the indicator with rockfish, however it is shifted up about 1–3 cm.

Factors influencing observed trends: : This indicator is specific to the fishes that are routinely caught and sampled during the NMFS summer bottom-trawl survey. The estimated mean length can be biased if specific species-size classes are sampled more or less than others, and is sensitive to spatial variation in the size distribution of species. Changes in fisheries management or fishing effort could also affect the mean length of the groundfish community. Modifications to fishing gear, fishing effort, and targeted species could affect the mean length of the groundfish community if different size classes and species are subject to changing levels of fishing mortality. The mean length of groundfish could also be influenced by fluctuations in recruitment, where a large cohort of small forage species could reduce the mean length of the community. Environmental factors could also influence fish growth and mean length by affecting the availability and quality of food, or by direct temperature effects on growth rate.

Pacific Ocean perch and northern rockfish are the biomass dominant species of rockfish included in this indicator. Their mean lengths are generally less than the mean length for Atka mackerel and are less than the mean lengths for walleye pollock and Pacific cod, which are the biomass dominant species among non-rockfish species. This leads to the groundfish community mean length being greater when rockfish are excluded.

Implications: The mean length of the groundfish community in the Aleutian Islands has been stable over the bottom-trawl time series (1991-2024) with some interannual variation. There is no evidence at this time of an obvious trend in mean size or other indication that an external pressure such as climate or fishing is affecting the mean length of groundfish.

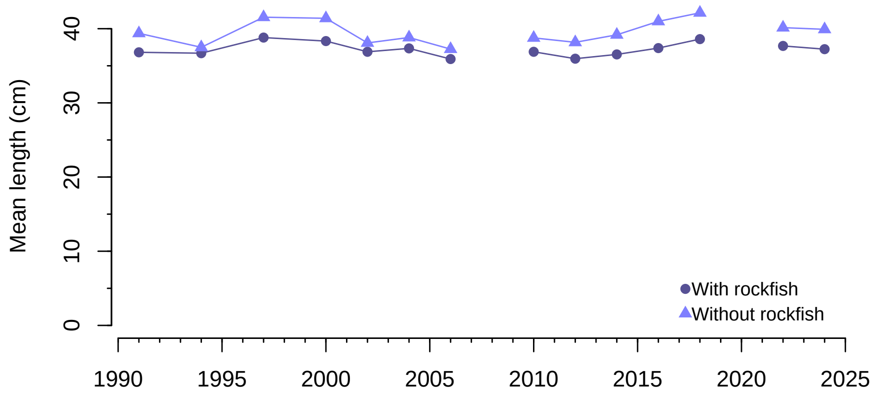

Figure 52: . Mean length of the groundfish community sampled during the NMFS/AFSC summer bottom-trawl survey of the Aleutian Islands (1991-2024). The groundfish community mean length is weighted by the relative biomass of the sampled species.

Mean Lifespan of the Fish Community

Contributed by George A. Whitehouse [1] and Geoffrey M. Lang[2]
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Last updated: October 2024

Description of indicator: The mean lifespan of the community is a proxy for the turnover rate of species and communities and reflects the resistance of the community to perturbations(Shin et al., 2010). The indicator for mean lifespan of the groundfish community is modeled after the method for mean lifespan presented in Shin et al. (2010). Lifespan estimates of groundfish species regularly encountered during the NMFS/AFSC biennial summer bottom-trawl survey of the Aleutian Islands were retrieved from the AFSC Age and Growth Program Database[12] . The groundfish community mean lifespan is weighted by biomass indices calculated from the bottom-trawl survey catch data.

This indicator specifically applies to the portion of the demersal groundfish community that is efficiently sampled by the trawling gear used by NMFS during this survey (for complete survey details see von Szalay et al. 2023). This includes species of skates, flatfishes, and roundfishes (e.g., cods, sculpins, eelpouts). Species that are predominately found in the pelagic environment (e.g., capelin, pelagic smelts), are infrequently encountered (e.g., sharks, grenadiers, myctophids), or not efficiently caught by the bottom-trawling gear are excluded from this indicator. The Aleutian Islands survey time series began in 1980 and was conducted on a triennial basis until 2000 when it switched to a biennial schedule. The surveys prior to 1991 were conducted jointly with Japan and preceded the establishment of standardized survey methodology for the Aleutian Islands (von Szalay et al., 2023). The 2008 and 2020 surveys did not occur leaving 4 year gaps. Previous year's contributions included the 1983 and 1986 surveys.

Since 2022, rockfish are included in this indicator, including dusky rockfish, northern rockfish, Pacific Ocean perch, rougheye rockfish, shortraker rockfish, shortspine thornyhead, and other Sebastes. Rockfishes are abundant in the Aleutian Islands and variations in their population could drive the value of this indicator. Therefore, the mean

[12]Short, J.A., and D. M. Anderl. 2012. The Age and Growth Program Database. Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way NE, Seattle WA 98115

lifespan of groundfish is presented as two series, one with rockfish included and one without.

Status and Trends: *With rockfish*—The mean lifespan of the Aleutian Islands demersal fish community in 2024 is 63.8 which is up from 62.1 in 2022 and above the long term mean of 53.9 over the years 1991–2024. This indicator has generally trended upward from a low of 33.1 in 1994 to a peak of 68.5 in 2012 and has been relatively stable since 2014 (Figure 52).

Without rockfish—The mean lifespan of the groundfish community, excluding rockfish, is 21.2 in 2024, which is nearly unchanged from 21.4 in 2022 and remains above the long-term mean of 20.5. This indicator with rockfish excluded has shown little year-to-year variation and no apparent trend.

Factors Causing Trends: Fishing can affect the mean lifespan of the groundfish community by preferentially targeting larger, older fishes, leading to decreased abundance of longer-lived species and increased abundance of shorter-lived species (Pauly et al., 1998). Interannual variation in mean lifespan can be influenced by the spatial distribution of species and the differential selectivity of species and age classes to the trawling gear used in the survey. Strong recruitment events or periods of weak recruitment could also influence the mean community lifespan by altering the relative abundance of age classes and species.

Lower values of this indicator in the early part of the time series (e.g., 1994) when rockfish are included, reflect relatively lower abundances of biomass dominant long-lived rockfish species, such as Pacific Ocean perch and northern rockfish, and relatively higher abundances of shorter-lived species, in particular Atka mackerel and walleye pollock. Higher values of this indicator since 2012 reflect greater abundances of Pacific Ocean perch and northern rockfish.

Implications: The groundfish mean lifespan with rockfish included has generally trended upward over the time series indicating an increasing prevalence of longer-lived species. The mean lifespan when rockfish are excluded has been stable over the time series, showing no signs of an increasing or decreasing trend. Species that are short-lived are generally smaller and more sensitive to environmental variation than larger, longer-lived species (Winemiller, 2005). Longer-lived species help to dampen the effects of environmental variability, allowing populations to persist through periods of unfavorable conditions and to take advantage when favorable conditions return (Berkeley et al., 2004; Hsieh et al., 2006).

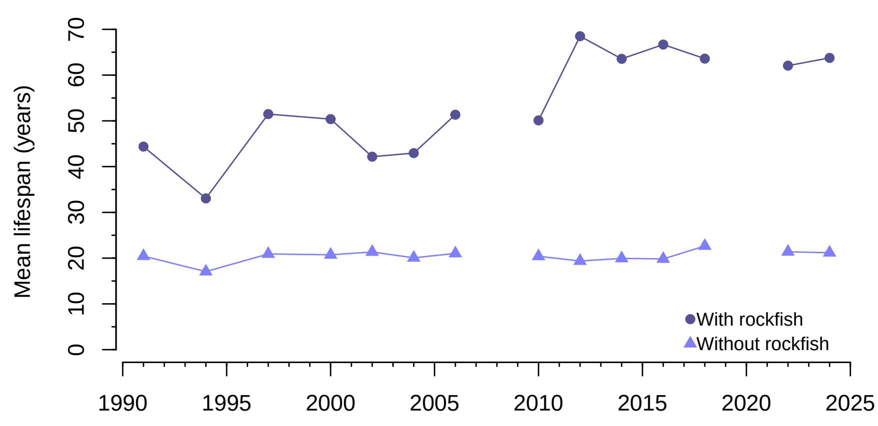

Figure 53: The mean lifespan of the Aleutian Islands groundfish community, weighted by biomass indices calculated from the NMFS/AFSC summer bottom-trawl survey (1991-2024).

Disease Ecology Indicators

Harmful Algal Blooms in the Aleutian Islands

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Last updated: October 2024

HABs Sampling Partners:

Alaska Ocean Observing System	Central Council of Tlingit and Haida*
Chilkoot Indian Association*	Craig Tribal Association*
Hoonah Indian Association*	Hydaburg Cooperative Association*
Kachemak Bay NERR	Ketchikan Indian Association*
Klawock Cooperative Association*	Knik Tribe of Alaska
Kodiak Area Native Association	Metlakatla Indian Community*
Organized Village of Kake*	Organized Village of Kasaan*
Petersburg Indian Association*	Sitka Tribe of Alaska*
Skagway Traditional Council*	Southeast Alaska Tribal Ocean Research
Sunaq Tribe of Kodiak*	Wrangell Cooperative Association*
Yakutat Tlingit Tribe*	

**Partners of Southeast Alaska Tribal Ocean Research (SEATOR)*

Description of indicator: Alaska's most well-known and toxic harmful algal blooms (HABs) are caused by *Alexandrium spp.* and *Pseudo-nitzschia spp. Alexandrium* produces saxitoxin which can cause paralytic shellfish poisoning (PSP) and has been responsible for five deaths and over 100 cases of PSP in Alaska [13] since (Ostasz, 2001). Analyses of paralytic shellfish toxins are commonly reported as μg of toxin/100 g of tissue, where the US Food and Drug Administration (FDA) limit for paralytic shellfish poinsoning is 80μg/100g. Toxin levels between 80μg–1000μg/100 g are considered to potentially cause non-fatal symptoms in humans, whereas levels above 1000μg/100g ($\sim$ 12x) are considered potentially fatal.

Testing for PSTs is done for all commercial species, and for many marine subsistence food items, primarily shellfish. Different species tend to accumulate and depurate these toxins at different rates. Blue mussels (*Mytilus trossulus*) have been found to accumulate and depurate PSTs relatively quickly (on the order of days to weeks). This makes blue mussels a good sentinel species to use as an indicator of when a HAB may have happened. Therefore, this report focuses on the toxin levels of blue mussels from around the state, in addition to the presence of harmful algal species.

Another harmful algal species, *Pseudo-nitzschia* produces domoic acid which can cause amnesic shellfish poisoning and inflict permanent brain damage. *Pseudo-nitzschia* has been detected in 13 marine mammal species and has the potential to impact the health of marine mammals and birds in Alaska. No human health impacts of domoic acid have been reported in Alaska, although both acute and chronic amnesic shellfish poisoning has been reported in several states, including Washington and Oregon.

Another organism, *Dinophysis* spp., produces okadaic acid which can lead to diarrhetic shellfish poisoning. This primarily impacts the gastrointestinal system and is not usually life-threatening but can lead to nausea, vomiting, abdominal cramping, and diarrhea. Although there have not been recorded cases of diarrhetic shellfish poisoning

[13]see DHSS fatality report: `https://aoos.org/wp-content/uploads/2019/06/DHSS_PressRelease_PSPFatality_20200715.pdf`)

in Alaska, Dinophysis has been detected throughout Alaska, and okadaic acid is at times detected in shellfish.

The Alaska Department of Environmental Conservation (ADEC) tests bivalve shellfish harvested from classified shellfish growing areas meant for commercial market for marine biotoxins including paralytic shellfish toxin (PST) in all bivalve shellfish and domoic acid (DA) specifically in razor clams. The Environmental Health Laboratory (EHL) is the sole laboratory in the state of Alaska certified by the FDA to conduct regulatory tests for commercial bivalve shellfish. The EHL also does testing for research, tribal, and subsistence use.

The State of Alaska tests all commercial shellfish harvest, however there is no state-run shellfish testing program for recreational and subsistence shellfish harvest. Regional programs, run by Tribal, agency, and university entities, have expanded over the past five years to provide test results to inform harvesters and researchers and reduce human health risk. All of these entities are partners in the Alaska Harmful Algal Bloom Network which was formed in 2017 to provide a statewide approach to HAB awareness, research, monitoring, and response in Alaska. More information can be found on the Alaska HAB Network website[14] or through the sampling partners listed above.

Status and trends: Alaska Region:: Results from shellfish and phytoplankton monitoring showed a slight downtick in the presence of harmful algal blooms (HABs) and toxins throughout all regions of Alaska in 2024 compared to 2023, and the overall levels were lower than in 2019-2021. Bivalve shellfish from areas that are well known for having PSP levels above the regulatory limit, including Southeast Alaska and the Aleutians, continued to have samples that tested above the regulatory limit, albeit less frequently than since 2019 and 2020. Overall, 2024 seems to have been slightly less active for blooms and toxin levels than 2021, 2020 and 2019, but areas continue to have HAB organisms in the water, and shellfish testing well above the regulatory limit, primarily between May and September in 2024. Over the last few years, the dinoflagellate *Dinophysis* has become more common and abundant in water samples, and 2024 continued that trend. We are also seeing a geographic expansion of areas that are sampling for phytoplankton species. In the Bering Sea, HABs were being monitored through the opportunistic placement of Imaging FlowCytobots (IFCB) on the USCGC Healy as it transited the Bering, Chukchi and Beaufort Seas on research cruises.

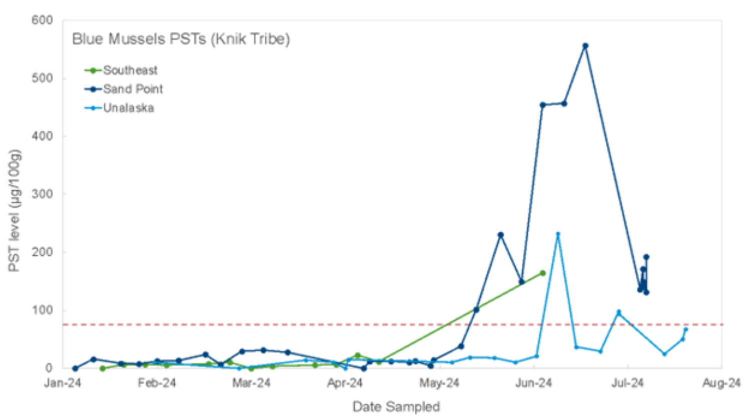

Figure 54: Paralytic shellfish toxin levels in blue mussels tested by the Knik Tribe in three regions. The red horizontal dashed line represents the FDA regulatory limit is 80µg/100g. Testing for these data was done using the mouse bioassay or high-performance liquid chromatography testing method

Aleutian Islands: The Knik Tribe has been sampling for PSTs in the Aleutian Islands region since 2006, and 51 blue mussel samples have been tested from Sand Point and Unalaska so far in 2024. The Knik Tribe's harmful algal blooms (HABs) project, Paralytic Shellfish Poisoning Risk Management, is a 4-year project working closely with the Alaska Department of Environmental Conservation's Environmental Health Laboratory, testing shellfish, fish, and invertebrate samples sent to us from across Alaska. Paralytic shellfish toxin levels are analyzed using

[14] https://aoos.org/alaska-hab-network/

mouse bioassay or high-performance liquid chromatography analysis. In 2024, Sand Point showed persistent PST levels above the regulatory level in blue mussels between May and July, with a maximum of 556 µg/100g on June 21st (Figure 2). Unalaska showed overall lower toxin levels, with only three samples above the regulatory, in June and July (Figure 54).

Factors influencing observed trends: HABs are likely to increase in intensity and geographic distribution in Alaska waters with warming water temperatures. Observations in Southeast and Southcentral Alaska suggest *Alexandrium* blooms occur at temperatures above 10°C and salinities above 20 (Vandersea et al., 2018; Tobin et al., 2019; Harley et al., 2020). As waters warm throughout Alaska, blooms may increase in frequency and geographic extent.

Implications: HABs pose a risk to human health when present in wildlife species that people consume, including shellfish, birds and marine mammals. Research across the state is attempting to better understand the presence and circulation of HABs in the food web. HAB toxins have been detected in stranded and harvested marine mammals from all regions of Alaska in past years (Lefebvre et al., 2016). A multi-disciplinary statewide study funded by NOAA's ECOHAB program is underway and encompasses ship-based sediment samples, water samples, zooplankton samples which include krill and copepods, multiple species of fish, bivalves, and the continuation of sampling subsistence-harvested and dead stranded marine mammals.

The Alaska Department of Health, Section of Epidemiology (SOE) continues to partner with the AHAB network. Nurse consultants join in on the monthly meetings and collaborate with stakeholders so they can be made aware of reportable illness such as Paralytic shellfish Poisoning (PSP). SOE published an Epidemiology Bulletin describing cases of PSP from 1993-2021[15]. More information about PSP and other shellfish poisoning can be found on the SOE website[16].

[15] https://epi.alaska.gov/bulletins/docs/b2022_05.pdf
[16] https://health.alaska.gov/dph/Epi/id/Pages/dod/psp/default.aspx

Fishing and Human Dimensions Indicators

Time Trends in Non-Target Species Catch

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Last updated: August 2024

Description of indicator: This indicator reports the catch of non-target species in groundfish fisheries in the Aleutian Islands (AI). Catch since 2003 has been estimated using the Alaska Region's Catch Accounting System (Cahalan et al., 2014). This sampling and estimation process does result in uncertainty in catches, which is greater when observer coverage is lower and for species encountered rarely in the catch. Since 2013, the three categories of non-target species tracked here are::

1. Scyphozoan jellyfish
2. Structural epifauna (seapens/whips, sponges, anemones, corals, tunicates)
3. Assorted invertebrates (bivalves, brittle stars, hermit crabs, miscellaneous crabs, sea stars, marine worms, snails, sea urchins, sand dollars, sea cucumbers, and other miscellaneous invertebrates).

The catch of non-target species/groups from the AI includes the reporting areas 518, 519, 541, 542, 543, and 610 [17]. Within reporting area 610, the GOA and Aleutian Islands (AI) Large Marine Ecosystems (LMEs) are divided at 164°W. Non-target species caught east of 164°W are within the GOA LME and the catch west of 164°W is within the AI LME.

Status and trends: : The catch of Scyphozoan jellies in the AI increased from 2015 to 2020, with peaks in 2017 and 2020, then declined to its second lowest value over this time series in 2022 (Figure 55). The catch of scyphozoan jellies in 2023 is more than double the catch in 2022. Scyphozoan jellies are primarily caught in the pollock fishery. The catch of structural epifauna in the AI has been variable from 2011-2023, with a peak catch in 2015 and a low catch in 2022. Sponge comprise the majority of the structural epifauna catch, followed by corals and bryozoans. These species are primarily caught in the Atka mackerel and rockfish fisheries. The catch of assorted invertebrates in the AI has been variable from 2011 to 2023, with a peak in 2013 and lows in 2011, 2014, and 2020. Sea stars dominate the catch of assorted invertebrates and are primarily caught in the Pacific cod and halibut fisheries.

Factors causing trends: The catch of non-target species may change if fisheries change, if ecosystems change, or both. Because non-target species catch is unregulated and unintended, if there have been no large-scale changes in fishery management in a particular ecosystem, then large-scale signals in the non-target catch may indicate ecosystem changes. Alternatively, changes in allowable catch for target species, external market forces, fishing effort, or fishing gear restrictions can affect the catch of non-target species. Catch trends may be driven by changes in biomass or changes in distribution (overlap with the fishery) or both. Fluctuations in the abundance of jellyfish are influenced by a suite of biophysical factors affecting the survival, reproduction, and growth of jellies including temperature, wind-mixing, ocean currents, and prey abundance ((Purcell, 2005; Brodeur et al., 2008; Decker et al., 2023).

[17]https://www.fisheries.noaa.gov/alaska/sustainable-fisheries/alaska-fisheries-figures-maps-boundaries-regulatory-areas-and-zones

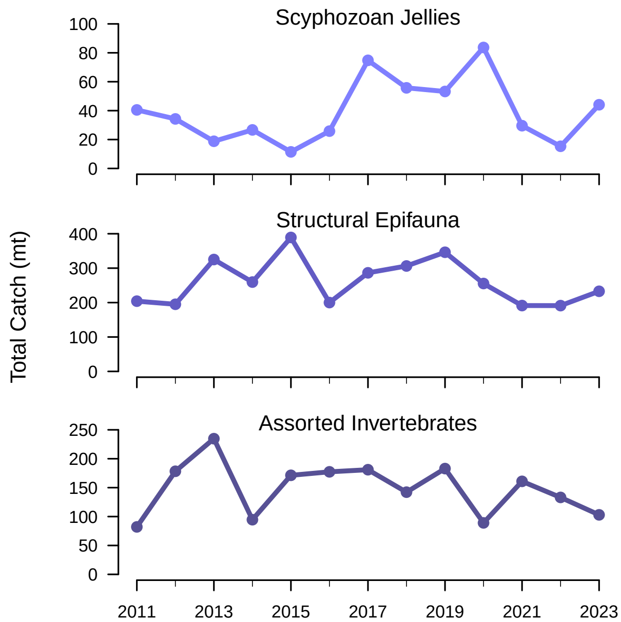

Figure 55: Total catch of non-target species (tons) in AI groundfish fisheries (2011–2023). Please note the different y-axis scales.

Implications: The catches of structural epifauna species and assorted invertebrates are very low compared with the catches of target species. The higher catches of scyphozoan jellies in 2017–2020 may reflect interannual variation in jellyfish biomass or changes in the overlap with fisheries. Abundant jellyfish may have a negative impact on fishes as they compete with planktivorous fishes for prey resources (Purcell and Sturdevant, 2001), and additionally, jellyfish may prey upon the early life history stages (eggs and larvae) of fishes (Purcell and Arai, 2001; Robinson et al., 2014).Additionally, jellyfish may be an important prey resource for predators, including commercially important groundfishes (Brodeur et al. 2021)

Maintaining and Restoring Fish Habitats

There are no updates in this year's report. See the contribution archive for previous indicators at: `https://www.fisheries.noaa.gov/alaska/ecosystems/ecosystem-status-reports-gulf-alaska-bering-sea-and-aleutian-islands`.

Seabird Bycatch Estimates for Groundfish and Halibut Fisheries in the Aleutian Islands, 2013–2023

Contributed by Adam Zaleski[1], Jessica Beck[2], and Cathy Tide[1]
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[2]2Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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Last updated: September 2024

Description of indicator: This report provides estimates of the numbers of seabirds caught as bycatch in commercial groundfish and halibut fisheries operating in waters off Alaska in the Aleutian Islands for the years 2013 through 2023. Data collection on the Pacific halibut longline fishery began in 2013 with the restructured North Pacific Observer Program. Estimates of seabird bycatch from earlier years using different methods are not included here (see previous Ecosystem Status Reports). Fishing gear types included are demersal longline, pot, pelagic trawl, and non-pelagic trawl. These numbers do not apply to jig, gillnet, seine, or troll fisheries[18].

The NMFS Alaska Regional Office Catch Accounting System (CAS) produces the estimates (Cahalan et al. 2014, Calahan 2010).) and provides near real-time delivery of accurate groundfish and prohibited species catch and bycatch information for inseason management decisions. These estimates are based on three sources of information: (1) data provided by NMFS-certified fishery observers deployed to vessels and floating or shoreside processing plants, (2) video review of electronically monitored (EM) fixed gear vessels, and (3) industry reports of catch and production. CAS also estimates non-target species (such as invertebrates) and seabird bycatch in the groundfish fisheries. The three data sets used by CAS are subject to change over time. Observer deployment plans are reviewed and updated annually in the Annual Deployment Plan (the 2023 plan is available online[19]).

Estimates of seabird bycatch from the AI include the reporting areas 610 west of 164 split, 518, 519, 541, 542, and 543[20].

Status and trends: The numbers of seabirds estimated to be caught incidentally in the Aleutian Islands fisheries in 2023 (885 birds) was 78% more than estimates from 2022 (496 birds), and were 9% more than the 2013–2022 average of 969 birds (Table 3; Figure 56). This dramatic increase in the estimated seabird takes between 2022 and 2023 is primarily due to the low number of shearwaters taken in 2022. Excluding shearwater bycatch, seabird takes in the Aleutian Islands fisheries in 2023 were relatively similar to takes in 2022 (339 and 341 respectively). In this region, there were an estimated total of 7 albatrosses taken: 2 short-tailed (*Phoebastria albatrus*), 2 black-footed (*Phoebastria nigripes*), and 3 Laysan albatrosses (*Phoebastria immutabilis* (Figure 57).

In previous years, the Aleutian Islands Atka mackerel trawl fisheries and rockfish trawl fisheries have been responsible for the majority of seabird bycatch in the Aleutian Islands. In 2021, the estimated seabird bycatch in the Atka mackerel fisheries was 230% higher than the 2012-2020 average (1,000 birds; NMFS unpublished data). Estimated seabird bycatch in 2021 in the rockfish fisheries was below the 2012-2020 average by 52% (304 birds; NMFS unpublished data).

In the Aleutian Islands, an estimated average of 56 albatross (unidentified, short-tailed, Laysan, and black-footed combined) were taken per year from 2013 through 2023 (Table A). The number of estimated albatross takes in this region has remained low since 2018 (Table 3). Three albatross were estimated to be taken as bycatch in 2021. The number of estimated albatross takes in this region has remained low since 2018.

[18]This report does not include estimates of seabird bycatch in fisheries using gillnet, seine, troll, or jig gear because NOAA Fisheries does not have independent observer data from these fisheries. These estimates also do not apply to State of Alaska-managed salmon, herring, shellfish (including crab), or dive fisheries

[19]https://www.fisheries.noaa.gov/resource/document/2023-annual-deployment-plan-observers-and-electronic-monitoring-groundfish-and)

[20]https://www.fisheries.noaa.gov/alaska/commercial-fishing/alaska-fisheries-figures-maps-boundaries-regulatory-areas-and-zones

Table 3: : Estimated seabird bycatch in Aleutian Islands groundfish and halibut fisheries for all gear types, 2012 through 2023. Note that these numbers represent extrapolations from observed bycatch, not direct observations. See text for estimation methods

Species Group	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Unidentified Albatrosses	0	<1	25	0	0	0	0	0	0	0	0	0
Short-tailed Albatross	0	0	<1	0	0	0	0	0	0	0	0	2
Laysan Albatross	86	116	51	143	58	18	75	0	<0	0	0	3
Black-footed Albatross	3	17	12	20	25	38	1	3	<1	3	3	2
Northern Fulmar	25	60	71	1,091	185	572	293	163	350	21	231	207
Shearwaters	60	6	61	24	192	1,076	141	2,069	7	1,516	156	546
Storm Petrels	0	0	0	0	0	0	177	0	0	29	48	23
Gulls	23	31	11	56	20	8	9	7	6	58	20	64
Kittiwakes	0	0	0	0	0	0	0	0	0	0	0	0
Murres	0	0	0	0	5	0	0	0		0	0	0
Puffin	0	0	0	0	0	0	0	0	0	0	0	0
Auklets	0	0	0	5	28	11	102	0	0	0	0	0
Other Alcid	0	0	0	0	0	0	0	0	0	0	0	0
Cormorants	0	0	0	1	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	<1	0	34	0
Unidentified	6	16	1	1	1	14	5	2	3	46	5	38
Grand Total	204	246	272	1,340	514	1,737	804	2,244	367	1,673	496	885

Factors influencing observed trends: There are many factors that may influence annual variation in bycatch rates, including seabird distribution, population trends, prey supply, and fisheries activities.

In 2023, there was an increase in seabird bycatch in the Aleutian Islands groundfish and halibut fisheries compared to 2022. This difference was primarily driven by an increase in shearwater (*Ardenna* spp.) bycatch in the region. When shearwater take is excluded, the seabird bycatch levels in the region were virtually the same for 2022 and 2023. Shearwater bycatch can fluctuate dramatically based on the annual abundance of primarily short-tailed shearwaters (*Ardenna tenuirostris*) in the region. Other oceanographic and ecological factors can affect the amount of shearwater bycatch. For example, Ortiz and Zador (2023) noted a report of a die-off of >150 shearwaters at Akutan Island. Samples from this die-off tested negative for highly-pathogenic avian influenza and similar die-offs in the past have been linked to prey shortages. If there was a prey shortage in the region for short-tailed shearwaters, they may be more attracted to fishery bait and discards than in years where natural prey was more plentiful. Additionally, Rojek et al. (2023) noted that high pink salmon abundance has been correlated with mortality events and reduction in natural prey for short-tailed shearwaters. This may also have implications for increases in bycatch interactions. East Kamchatka pink salmon abundances are typically greater in odd years, and 2023 was a very productive year for pink salmon (Ortiz and Zador, 2023). Shearwater bycatch in the region has been higher in odd years since 2016, although this pattern is not as apparent in 2015 and earlier.

It is also worth noting that standard observer sampling methods on trawl vessels do not account for additional mortalities from net entanglements, cable strikes, and other sources. Thus, the trawl estimates may be downward biased.

ESA species: On December 8, 2023 there was a lethal take of an endangered short-tailed albatross in the Gulf of Alaska, Pacific cod hook-and-line fishery. The take occurred approximately 33 nautical miles southeast of Unalaska Islands, in NMFS reporting area 610. The bird was a juvenile which was banded at the Hatsunezaki colony on Torishima Island in Japan in March 2023. This is the first recorded take of a short-tailed albatross by any fisheries operating in the Bering Sea and Aleutian Islands (BSAI) or GOA Management Areas since October 16, 2020. Since 1995 this is only the second take of a short-tailed albatross south of the Aleutian Islands. The vessel used dual streamer lines as deterrents during the setting, which were in good condition. While this observed take occurred in a Gulf of Alaska region, it is extrapolated to a total of 3 estimated birds, 2 of which are accounted for in this Aleutian Islands Ecosystem Status Report due to fishing area estimation methodology.

Implications: Estimated seabird bycatch in the Aleutian Islands groundfish and halibut fisheries in 2023 increased compared to 2022, but was below average of 969 birds per year for the 2013-2022 time series.

It is difficult to determine how seabird bycatch estimates and trends are linked to changes in ecosystem components. Many seabird species caught in groundfish and halibut fisheries in Alaska are wide-ranging and can fly hundreds of miles per day, resulting in less restricted foraging areas. Of the species caught as bycatch in the Aleutian Islands in 2023, only gulls, northern fulmars, and some storm petrel species breed in the region. The level of short-tailed shearwater bycatch may reflect top-down ecosystem effects from pink salmon abundances in odd-years, but these relationships need more thorough analysis. Changes in fleet dynamics and use of seabird bycatch mitigation tools in hook-and-line fisheries also affect seabird bycatch estimates, further complicating direct links with ecosystem components.

Fisheries bycatch can also affect seabird populations directly. In Alaska, bycatch of federally listed species is tightly regulated, and NOAA works in conjunction with outside agencies and partners to assess and manage the risk of bycatch to unlisted seabird species, including requiring seabird bycatch mitigation tools in hook-and-line groundfish and halibut fisheries.

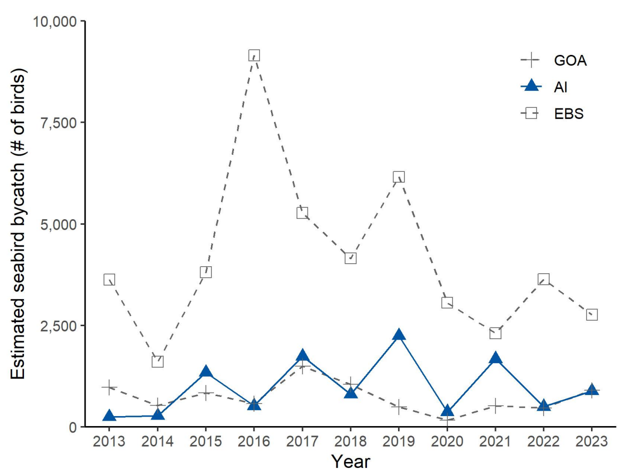

Figure 56: Total estimated seabird bycatch in eastern Bering Sea (EBS), Eastern Gulf of Alaska (EGOA), Western Gulf of Alaska (WGOA), and Aleutian Islands (AI), groundfish fisheries, all gear types combined, 2011 through 2020.

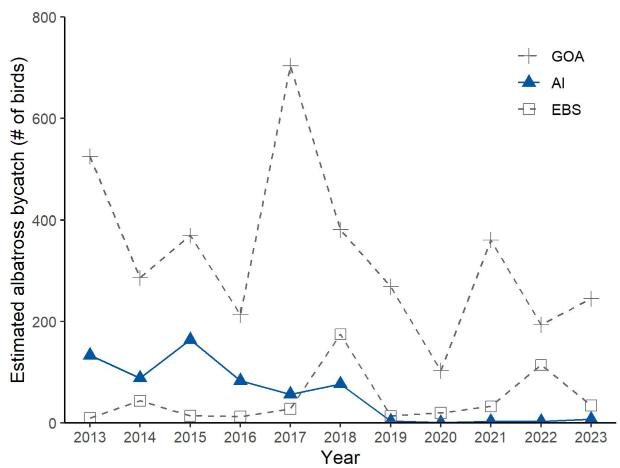

Figure 57: Total estimated albatross bycatch in eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) groundfish fisheries, all gear types combined, 2011 through 2020.

Sustainability (for consumptive and non-consumptive uses)

Fish Stock Sustainability Index – Bering Sea/ Aleutian Islands

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Description of indicator: The Fish Stock Sustainability Index (FSSI) is a performance measure for the sustainability of fish stocks selected for their importance to commercial and recreational fisheries[21]. The FSSI will increase as overfishing is ended and stocks rebuild to the level that provides maximum sustainable yield. The FSSI is calculated by awarding points for each fish stock based on the following rules:

1. Stock has known status determinations:
   (a) overfishing level is defined = 0.5
   (b) overfished biomass level is defined = 0.5
2. Fishing mortality rate is below the "overfishing" level defined for the stock = 1.0
3. Biomass is above the "overfished" level defined for the stock = 1.0
4. Biomass is at or above 80% of the biomass that produces maximum sustainable yield (B_{MSY}) = 1.0 (this point is in addition to the point awarded for being above the "overfished" level)

The maximum score for each stock is 4.

In the Alaska Region, there are 35 FSSI stocks and an overall FSSI of 140 would be achieved if every stock scored the maximum value, 4. Over time, the number of stocks included in the FSSI has changed as stocks have been added and removed from Fishery Management Plans (FMPs). To keep FSSI scores for Alaska comparable across years we report the FSSI as a percentage of the maximum possible score (i.e., 100%).

Additionally, there are 26 non-FSSI stocks in Alaska, three ecosystem component species complexes, and Pacific halibut which are managed under an international agreement. Two of the non-FSSI crab stocks are overfished but are not subject to overfishing. The Pribilof Islands blue king crab stock is in year nine of a rebuilding plan, and the Saint Matthews Island blue king crab stock is in year three of a 26-year rebuilding plan. None of the other non-FSSI stocks are known to be subject to overfishing, are overfished, or known to be approaching an overfished condition. For more information on non-FSSI stocks see the Status of U.S. Fisheries webpage [22].

Status and trends: The overall Alaska FSSI generally trended upwards from 80% in 2006 to a high of 94% in 2018, then trended downward from 2018 to 88.2% in 2022 (Figure 58). It has increased incrementally to 89% in 2023 and 90

As of June 30, 2024, no BSAI groundfish stock or stock complex was subject to overfishing, or known to be approaching an overfished condition (Table 4). One was known to be overfished. The BSAI groundfish FSSI score is 59 out of a maximum possible 64. The AI Pacific cod stock and the walleye pollock Bogoslof stock both have FSSI scores of 1.5 due to not having known overfished status or known biomass relative to their overfished levels or to B_{MSY}. All other BSAI groundfish FSSI stocks received the maximum possible score of four points

[21] https://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates
[22] https://www.fisheries.noaa.gov/national/population-assessments/status-us-fisheries

Table 4: BSAI FSSI stocks under NPFMC jurisdiction updated through June 2024 adapted from the NOAA Fishery Stock Status Updates webpage [23]. *See FSSI and Non-FSSI Stock Status Table on the Fishery Stock Status Updates webpage for definition of stocks, stock complexes, and notes on rebuilding.

BSAI FSSI (21 stocks)	Yes	No	*Unknown*	*Undefined*	N/A
Overfishing	0	21	0	0	0
Overfished	1	18	2	0	0
Approaching Overfished Condition	0	18	2	0	1

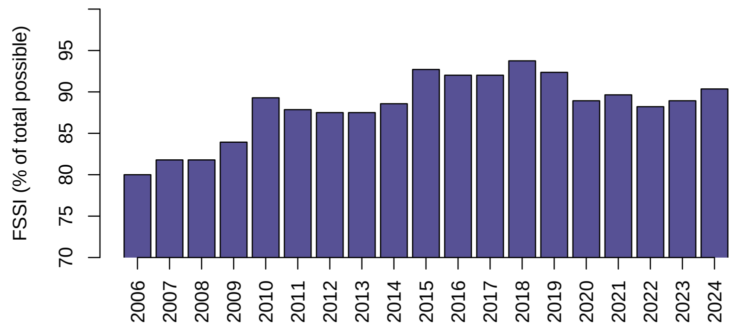

Figure 58: The trend in overall Alaska FSSI from 2006 to 2023 as a percentage of the maximum possible FSSI. The maximum possible FSSI was 140 from 2006 to 2014, 144 from 2015 to 2019, and 140 since 2020. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website[a]

[a]https://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates.

The BSAI king and tanner crab FSSI is 19 out of a possible 20. One point was deducted for the Bering Sea snow crab biomass being below the B/BMSY threshold.

The overall BSAI FSSI score is 78 out of a maximum possible score of 84 (Table 5).). The BSAI FSSI trended upward from 74% in 2006 to a peak of 95.5% in 2019. It dropped to 92.9% in 2020 and has generally been stable since (Figure 59).

Factors causing trends: The overall trend in Alaska FSSI has been positive over much of the duration examined here (2006-2024). The recent improvement Bristol Bay red king crab and Bering Sea snow crab contributed a two point increase to this year's FSSI.

Implications: The majority of Alaska groundfish and crab fisheries appear to be sustainably managed. None of the FSSI groundfish or crab stocks in the BSAI are subject to overfishing or known to be overfished. Only snow crab is currently overfished.

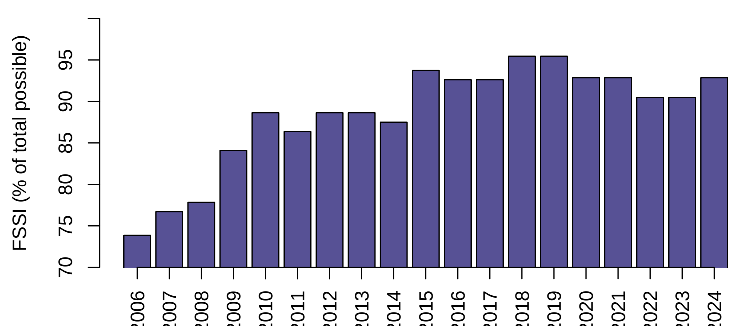

Figure 59: The trend in BSAI FSSI from 2006 to 2024 as a percentage of the maximum possible FSSI. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website.

Table 5: BSAI FSSI stocks under NPFMC jurisdiction updated through June 2024 adapted from the NOAA Fishery Stock Status Updates webpage: for definition of stocks, stock complexes, and notes on rebuilding. www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates. *See FSSI and Non-FSSI Stock Status Table on the Fishery Stock Status Updates webpage for definition of stocks and stock complexes.

Stock	Overfishing	Overfished	Approaching	Progress	B/Bmsy	FSSI Score
Golden king crab - Aleutian Islands*	No	No	No	NA	1.121, 0.918	4
Red king crab - Bristol Bay	No	No	No	NA	0.947	4
Red king crab - Norton Sound	No	No	No	NA	1.240	4
Snow crab - Bering Sea*	No	No - rebuilding	No	Year 1 of 6 year plan	0.593	3
Southern Tanner crab - Bering Sea	No	No	No	NA	2.039	4
BSAI Alaska plaice	No	No	No	NA	1.578	4
BSAI Atka mackerel	No	No	No	NA	1.164	4
BSAI Arrowtooth Flounder	No	No	No	NA	2.583	4
BSAI Kamchatka flounder	No	No	No	NA	1.504	4
BSAI Flathead Sole Complex*	No	No	No	NA	2.077	4
BSAI Rock Sole Complex*	No	No	No	NA	1.612	4
BSAI Skate Complex*	No	No	No	NA	2.065	4
BSAI Greenland halibut	No	No	No	NA	1.489	4
BSAI Northern rockfish	No	No	No	NA	2.095	4
BS Pacific cod	No	No	No	NA	1.075	4
AI Pacific cod	No	Unknown	Unknown	NA	not estimated	1.5
BSAI Pacific Ocean perch	No	No	No	NA	1.600	4
Walleye pollock - Aleutian Islands	No	No	No	NA	1.309	4
Walleye pollock - Bogoslof	No	Unknown	Unknown	NA	not estimated	1.5
Walleye pollock - Eastern Bering Sea	No	No	No	NA	1.373	4
BSAI Yellowfin sole	No	No	No	NA	1.699	4

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Appendices

Appendix I. History of the ESRs

Since 1995, staff at the Alaska Fisheries Science Center have prepared a separate Ecosystem Status (formerly Considerations) Report within the annual Stock Assessment and Fishery Evaluation (SAFE) report. Each new Ecosystem Status Report provides updates and new information to supplement the original report. The original 1995 report presented a compendium of general information on the Gulf of Alaska, Bering Sea, and Aleutian Island ecosystems as well as a general discussion of ecosystem-based management. The 1996 edition provided additional information on biological features of the North Pacific, and highlighted the effects of bycatch and discards on the ecosystem. The 1997 edition provided a review of ecosystem-based management literature and ongoing ecosystem research, and provided supplemental information on seabirds and marine mammals. The 1998 edition provided information on the precautionary approach, essential fish habitat, effects of fishing gear on habitat, El Niño, local knowledge, and other ecosystem information. The 1999 edition again gave updates on new trends in ecosystem-based management, essential fish habitat, research on effects of fishing gear on seafloor habitat, marine protected areas, seabirds and marine mammals, oceanographic changes in 1997/98, and local knowledge.

In 1999, a proposal came forward to enhance the Ecosystem Status Report by including more information on indicators of ecosystem status and trends and more ecosystem-based management performance measures. The purpose of this enhancement was to accomplish several goals:

1. Track ecosystem-based management efforts and their efficacy
2. Track changes in the ecosystem that are not easily incorporated into single-species assessments
3. Bring results from ecosystem research efforts to the attention of stock assessment scientists and fishery managers
4. Provide a stronger link between ecosystem research and fishery management
5. Provide an assessment of the past, present, and future role of climate and humans in influencing ecosystem status and trends

Each year since 1999, the Ecosystem Status Reports have included new contributions and will continue to evolve as new information becomes available. Evaluation of the meaning of observed changes should be in the context of how each indicator relates to a particular ecosystem component. For example, particular oceanographic conditions, such as bottom temperature increases, might be favorable to some species but not for others. Evaluations should follow an analysis framework such as that provided in the draft Programmatic Groundfish Fishery Environmental Impact Statement that links indicators to particular effects on ecosystem components.

In 2002, stock assessment scientists began using indicators contained in this report to systematically assess ecosystem factors such as climate, predators, prey, and habitat that might affect a particular stock. Information regarding a particular fishery's catch, bycatch, and temporal/spatial distribution can be used to assess possible impacts of that fishery on the ecosystem. Indicators of concern can be highlighted within each assessment and can be used by the Groundfish Plan Teams and the Council to justify modification of allowable biological catch (ABC) recommendations or time/space allocations of catch.

We initiated a regional approach to the ESR in 2010 and presented a new ecosystem assessment for the eastern Bering Sea. In 2011, we followed the same approach and presented a new assessment for the Aleutian Islands based on a similar format to that of the eastern Bering Sea but with regional report cards for the western, central, and eastern Aleutian Islands. In 2012, we provided a preliminary ecosystem assessment on the Arctic. Our intent was to provide an overview of general Arctic ecosystem information that may form the basis for more comprehensive future Arctic ecosystem assessments. In 2015, we presented a new Gulf of Alaska report card and assessment, which was further divided into Western and Eastern Gulf of Alaska report cards beginning in 2016. This was also the year that the previous Alaska-wide ESR was split into four separate report, one for the Gulf of Alaska, Aleutian Islands, eastern Bering Sea, and the Arctic[24]. In 2024, a new report card for the Northern Bering Sea was added to the eastern Bering Sea ESR.

The eastern Bering Sea and Aleutian Islands ecosystem assessments were based on additional refinements contributed by Ecosystem Synthesis Teams. For these assessments, the teams focused on a subset of broad, community-level indicators to determine the current state and likely future trends of ecosystem productivity in the EBS and ecosystem variability in the Aleutian Islands. The teams also selected indicators that reflect trends in non-fishery apex predators and maintaining a sustainable species mix in the harvest, as well as changes to catch diversity and variability. Indicators for the Gulf of Alaska report card and assessment were also selected by a team of experts, via an online survey first, then refined in an in-person workshop.

Originally, contributors to the Ecosystem Status Reports were asked to provide a description of their contributed indicator, summarize the historical trends and current status of the indicator, and identify potential factors causing those trends. Beginning in 2009, contributors were also asked to describe why the indicator is important to groundfish fishery management and implications of indicator trends. In particular, contributors were asked to briefly address implications or impacts of the observed trends on the ecosystem or ecosystem components, what the trends mean and why they are important, and how the information can be used to inform groundfish management decisions. Answers to these types of questions will help provide a "heads-up" for developing management responses and research priorities.

In 2018, a risk table framework was developed for individual stock assessments as a means of documenting concerns external to the stock assessment model, but relevant to setting the Acceptable Biological Catch (ABC) value for the current year. These concerns could be categorized as those reflecting the assessment model, the population dynamics of the stock, and environmental and ecosystem concerns—including those based on information from Ecosystem Status Reports. In the past, concerns used to justify an ABC below the maximum estimated by the assessment model were documented in an ad-hoc manner in the stock assessment report or in the minutes of the Groundfish Plan Teams or Scientific and Statistical Committee (SSC) reviews. With the risk table, formal consideration of concerns—including ecosystem—are documented and ranked, and the stock assessment author presents a recommendation for the maximum ABC as specified by the stock assessment model or a lower value. The recommended ABC (whether at maximum or lower) from the lead stock assessment author is subsequently reviewed and adjusted or accepted by the Groundfish Plan Team and the Scientific and Statistical Committee. Five risk tables were completed in 2018 as a test case. After review, the Council requested risk tables to be included in all full stock assessments in 2019. The SSC also requested a fourth category of concern to be added to the risk tables. The fishery performance category serves to represent any concerns related to the recommended ABC that can be inferred from commercial fisheries performance. Importantly, these concerns refer to indications of stock status, not economic performance.

In Briefs were started in 2018 for EBS, 2019 for GOA, and 2020 for AI. These more public-friendly, succinct versions of the full ESRs are now produced in tandem with the ESRs.

In 2019, risk tables were completed for all full assessments. Ecosystem scientists collaborated with stock assessment scientists to use the Ecosystem Status Reports to help inform the ecosystem concerns in the risk tables. Some ecosystem information can also be used to inform concerns related to the population dynamics of the stock. Initially, there were 4 levels of concern from no concern to extreme. In 2023 (and revised in 2024), based on a recommendation from the SSC, the levels of risk were reduced to 3: Level 1 ("Normal"), Level 2 (Increased concern), and Level 3 (Extreme concern). For stock assessments which include an Ecosystem and Socioeconomic Profile (ESP), the ESP is also used to inform the ecosystem risk column as well as the population dynamics and fisheries performance columns.

Ecosystem and Socioeconomic Profiles (ESPs) were initiated in 2017 (sablefish) and ESR editors began working closely with ESP teams in 2019 (starting with GOA walleye pollock); these complimentary annual status reports inform groundfish management and alignment in research that feeds these reports increases efficiency and

[24]The Arctic report is under development

collaboration between ecosystem and stock assessment scientists.

This report represents much of the first three steps in Alaska's IEA: defining ecosystem goals, developing indicators, and assessing the ecosystems (Figure 60). The primary stakeholders in this case are the North Pacific Fishery Management Council. Research and development of risk analyses and management strategies is ongoing and will be referenced or included as possible.

/vspace15 points It was requested that contributors to the Ecosystem Status Reports provide actual time series

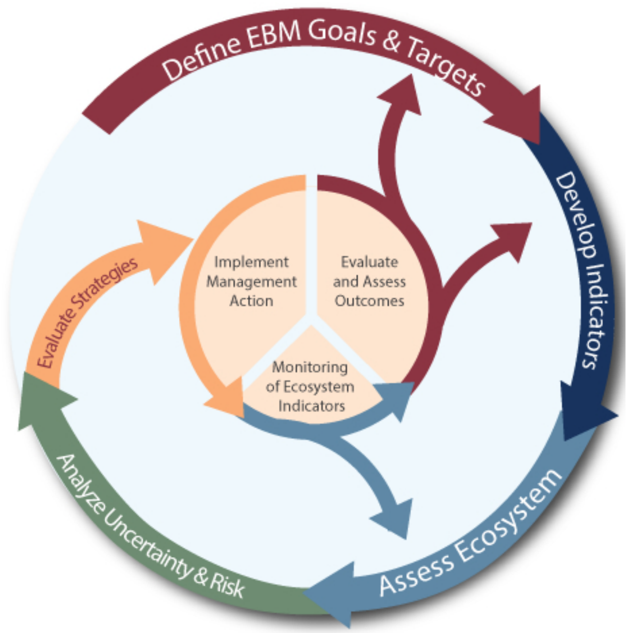

Figure 60: The IEA (integrated ecosystem assessment) process.

data or make them available electronically. The Ecosystem Status Reports and data for many of the time series presented within are available online at: `https://alaskaesr.psmfc.org/`. These reports and data are also available through the NOAA-wide IEA website at: `https://www.integratedecosystemassessment.noaa.gov/ecosystem-status-reports`.

Past reports and all groundfish stock assessments are available at: `https://www.fisheries.noaa.gov/alaska/population-assessments/north-pacific-groundfish-stock-assessments-and-fishery-evaluation`

Appendix II. Responses to Comments from the Scientific and Statistical Committee (SSC)

December 2023 and October 2024 meetings

December 2023 SSC Final Report to the NPFMC

C-3 and C-4 GOA Ecosystem Status Reports

The SSC received presentations from Elizabeth Siddon (NOAA-AFSC) for the eastern Bering Sea (EBS), Ivonne Ortiz (University of Washington) for the Aleutian Islands (AI), and Bridget Ferriss (NOAA-AFSC) for the Gulf of Alaska (GOA). Christopher Tran (Aleut Community of St. Paul Island) and Terese Vicente (Kuskokwim River Inter-Tribal Fish Commission) provided public testimony on the EBS ESR. There was no public testimony for the AI or GOA ESRs. The SSC thanks the ESR authors for their continued progress in collecting a large number of indicators and summarizing this information to better understand the status of marine ecosystems that support federally managed fisheries off Alaska. The SSC appreciated the structure of the reports, especially the consolidated information provided in the Report Card, Ecosystem Assessment, Noteworthy Topics, and Indicator Summary sections. The SSC acknowledges the continued value of the graphics in each report and separate "In Briefs" that visually translate how information is incorporated into Council processes and to inform broader audiences.

Thank you. We want to acknowledge the effort and thank all those involved in collecting, analyzing, interpreting, and communicating the observations included in these reports.

The SSC finds no major ecosystem concerns from 2023, but items that are noteworthy include low productivity in the Bering Sea, continued warm conditions in the western Aleutian Islands, mixed recovery from recent heatwaves in the GOA, and potential effects of El Niño in 2024.

General comments applicable to all three ESRs

The SSC thanks the authors for their responses to SSC comments and continued efforts to further integrate and synthesize indicators in ways that are most relevant to understanding potential effects on managed stocks. There appear to be different seasonal warming patterns among the ESR regions with winter warming more prominent in the EBS, winter and summer in the AI, and summer in the GOA. This will affect recruitment of different groundfish species, depending on seasonality of early life stages, and is another aspect by which to sustain efforts in addressing prior comments from the SSC regarding how different species might respond to changing temperatures. ***The SSC appreciates the inclusion of case studies in this year's document addressing life stage phenology and temperature thresholds, and encourages continued efforts along these lines***

The authors agree these case studies of phenology and temperature can be useful and will continue to explore their integration into ESRs when applicable and when resources are available.

The SSC suggests more focus on multi-year patterns and whether they are similar to other periods during the time series. *This moves us beyond comparing the current year to previous years. The SSC recommends these comparisons are independent of warm or cold stanzas so that there is no a priori determination and to account for possible changes in climate-biology relationships*

Response: The Eastern Bering Sea included a new borealization index in 2024 that addresses changes in ecosystem state relative to the shifts in marine community composition. The GOA ESR will include an updated ecosystem state analysis based on Ferriss et al. (Submitted) in 2025.

The SSC recommends considering options for identifying step changes in times series that might indicate a new "baseline" or "regime" for that indicator. *These efforts might also be relevant for time series beyond the ESRs. The SSC recognizes the sensitivity of referring to regime changes and management implications, however it is important to be vigilant of step changes in metrics and how to adapt to them.*

The eastern Bering Sea Ecosystem Assessment addresses the ecosystem response (both SEBS and NBS) to the shift from interannual variability (prior to 2000) to the recent prolonged warm period to the return to average thermal conditions since 2021.

The Eastern Bering Sea included a new borealization index in 2024 that addresses changes in ecosystem state relative to the shifts in marine community composition. The GOA ESR will include an updated ecosystem state analysis based on Ferriss et al. (2025) in 2025.

The Aleutian Islands Ecosystem Assessment has addressed biennial patterns, and shifts in ecosystem structure potentially related to either the step increase of Eastern Kamchatka pink salmon as well as a shift in pelagic foragers now dominated by rockfish, which might be relaled but not driven by climate. Likewise, it has looked at shifts in diets. We welcome the feedback and will strive to increase the focus on multi-year patterns.

Several recent publications note that the position of the Aleutian Low affects climate in the Bering Sea. All three ESRs share the North Pacific Index contribution which reflects the strength of the Aleutian Low. Whereas current atmospheric pressure anomaly maps in ESRs show the average position of the Aleutian Low graphically, its mean position cannot be compared to previous years. ***The SSC recommends that ESR authors evaluate ways to present a time series of the position of the Aleutian Low for this contribution.***

The three ESRs included a new contribution this year from Muyin Wang that describes the strength and position of the Aleutian Low Likewise, We worked with Emily Lemagie, the new lead of the climate overview, to include new graphics of climate conditions that represent the Aleutian Low climatology and current year.

The SSC appreciates the one to five month lead forecasts of expected El Niño effects in Alaska. Given that as of November 9, 2023, the NOAA National Center for Environmental Prediction suggests a 35% chance of a historically strong El Niño this winter, ***the SSC encourages continued monitoring of El Niño development and potential ecosystem affects, especially in the GOA.***

The ESR team monitored the El Niño event through the winter of 2023/2024 including satellite-derived sea surface temperatures, NOAA's winter acoustic-trawl survey in Shelikof Strait, and most thoroughly, through presentations of various monitoring, industry, and communitycommmnity observations at our spring Preview of Ecosystem and Economic Conditions workshop. By May the ENSO index had already transitioned from a positive (El Niño) to a neutral value, and the impacts of the El Niño were appearing to be more moderate in AK than some predicted. If the impacts had been more extreme, the ESR team was prepared to discuss developing impacts with the Council at their June or October meeting (if requested).

The SSC notes that the ESR process has matured over several decades to effectively use ecosystem trends to inform annual specifications and ***encourages the use of trans-disciplinary approaches for linking ESR and ESPs to stock assessments in the future. The GOA pollock assessment was suggested as a potential case study, particularly in contrasting differences in the strength of 2018 vs. 2019 year classes.***

A research model is presented in the Gulf of Alaska walleye pollock assessment Appendix 1E (Monnahan et al., 2024) that explores incorporating environmental data into the GOA pollock stock assessment. This model embeds a dynamic structural equation model (DSEM) into the assessment, and uses complex causal relationships among eight environmental indicators (sourced from the GOA Ecosystem Status Report and GOA pollock Ecosystem and Socio-economic Profile) to explain recruitment variation. Preliminary results are encouraging, with strong statistical evidence that this approach can substantially reduce unexplained recruitment variation and improve short-term projections like those used for management.

The SSC further discussed the process of selecting and refining indicators to minimize redundancy and ensure key information is included.

The ESR team continues to refine the process of minimizing redundancy while ensuring a holistic perspective based on spatially- and temporally-restricted datasets. Some redundancy is intentionally baked into the process to ensure data are available in alternating years when NOAA surveys are not conducted (even years for GOA and odd years for AI). In addition, Ferris et al. 2025 conducted a dynamic factor analyses on a subset of ESR time-series to identify those that produce a common trend over time, informing the potential reduction of redundancy.

The SSC supports the process where indicators are brought forward by authors and integrated into Council documents to inform NS1, NS2, NS4 and NS8 issues where appropriate. Additionally, the SSC suggests that workshops (see General Assessment Comments) or modeling could be used as part of the process to help identify indicators. ***It was promising to see some socioeconomic indicators in the Aleutian Islands ESR (school enrollment) and the SSC encourages ESR authors to collaborate with other social scientists about other potential indicators.***

The ESR team continues to be a part of broader discussions on the identification of effective social and economic indicators and the most appropriate tools with which to communicate them to the Council (i.e., ESR, ESP, Economic SAFE, ACEPO).

The SSC notes that many satellite-derived chlorophyll-a time series have a declining trend. To be certain these reflect real, in situ conditions, ***the SSC recommends that ESR authors work with contributors of these metrics to identify what calibration efforts have occurred, what additional calibrations might be needed, and how interpretation of the satellite time series might be affected.***

We asked Jens Nielsen and Matt Callahan and they provided the following response: "We thank the SSC for this comment. Contributors have continued to cross-validate globcolour satellite chla data from globcolour that is used in the annual ESRs with both single sensor data (e.g., VIIRS) and another combined product (i.e., OC-CCI). While contributors have done similar cross-product comparisons in the past - these were prior to 2023. In 2024, new cross-product comparisons showed relatively larger discrepancies among products than those from previous years. Consequently, contributors have paused contributions of satellite-derived chla trends to this year's ESRs until they have confidently resolved what is causing these discrepancies. They noted all combined (multi satellite sensor) chla products that are currently available are from external sources. Unfortunately that limits the ability to directly apply calibrations and corrections to the satellite data products."

BSAI Ecosystem Status Reports

Aleutian Islands

The SSC expressed appreciation for the hard work that went into this ESR. As a particularly data-poor region, not all datasets were updated for 2023 in the report cards, but valuable ecosystem information was presented. Notably, the year started with the warmest winter on record since 1900 based on long-term sea surface temperatures, with persistent warm conditions over the past 10 years. Other indicators suggest that there were decreased fluxes of heat and nutrients from deeper water and through the Aleutian Island passes. Multi-year patterns since 2013/14, including increasing East Kamchatka pink salmon abundance, increasing Pacific ocean perch (POP) abundance, and declining Atka mackerel abundance appear linked to a thermal regime shift characterized by sustained warmer temperatures at mid-depth and surface, combined with and lower productivity. To further understand the ecological implications of a potential shift in community structure, ***the SSC supports dedicated***

ecosystem studies in the AI. For example, analyses of the food web could be used to see if predator/prey relationships have changed over time, which would help to determine if observed changes reflect a broader transition in the ecosystem. Additionally, any opportunities to survey the AI during odd years (when Kamchatka Pink salmon abundances peak biennially) would be valuable (see the AI ESR section of the December 2022 SSC report for additional discussion).

The authors thank the SSC for their support and continue to look for partners and new studies in the Aleutian Islands. We are hopeful of renewed efforts in collaboration with the Pacific marine Environmental Laboratory and the Alaska Department of Fish and Game and will continue to work towards a contribution on groundfish diets for all three Alaska ESRs. In the absence of bottom trawl surveys during odd-numbered years, we continue to explore other data sources available annually, such as seabird and fisheries-dependent data.

The SSC suggests that, considering the apparent importance of these interactions, the authors consider moving East Kamchatka pink salmon indicators and POP indicators into the report cards. For pink salmon, it was discussed that additional information on biomass may be valuable*, as pink salmon represent about 70% of returning adult salmon abundance in the North Pacific (all species), but about 25% of the biomass when considering adults and immatures. Other patterns included declines in fish condition, particularly for Pacific cod, with a coincident shift in diet to less fish and more invertebrate prey. Conditions did vary regionally and were more favorable for some species in the eastern AI compared to the western AI.*

The authors relayed the need for biomass information and Gregg Ruggerone (EK pink salmon contributor) has now included biomass plots. In this year's assessment, the authors have placed that biomass in context with historical levels of EK pink salmon and biomass of AI groundfish stocks. For the report cards, we will be evaluating how to best update the report cards with new information, not only POP/rockfish and pink salmon biomass, but temperature and seabird information as well.

textit**The SSC appreciated the noteworthy section synthesizing published research on the optimal temperature ranges for eggs of Pacific cod, walleye pollock and Atka mackerel.**

We will continue updating information on thermal thresholds of AI groundfish as they become available. We incorporate this information in the evaluation of the ecosystem considerations within the risk tables for each stock.

October 2024 SSC Report Draft to Council

C1 BSAI Crab

Ecosystem Status Report Preview

The SSC received presentations by Elizabeth Siddon (NOAA-AFSC), Bridget Ferriss (NOAA-AFSC), and Ivonne Ortiz (University of Washington) previewing the Ecosystem Status Reports (ESR) for the Eastern Bering Sea (EBS), the Gulf of Alaska (GOA) and the Aleutian Islands (AI). The SSC appreciates the authors and contributors providing near real-time data that are within months to days of collection. This is only possible because of the dedication of the ESR team, the rapport they have fostered with data contributors, and the value placed on this information by all involved in the Council process. Thank you. We want to acknowledge the effort and thank all those involved in collecting, analyzing, interpreting, and communicating the observations included in these reports.

Presenters provided an overview of the Alaska-wide climate, showing a transition from El Niño conditions in early 2024 to anticipated La Niña in late fall, with projected near normal sea surface temperatures through March 2025 in all regions, except for cool temperatures in the eastern GOA and warm temperatures in the Western Aleutian Islands. The GOA had only a moderate response to the relatively strong El Niño, and there are no concerns for groundfish or their prey at this time. One concern requiring further investigation was that pink salmon had unexpectedly low returns. ***The SSC recommended investigating potential competitive interactions associated with changes in pink salmon abundance, in addition to potential bottom-up effects on upper trophic levels. The SSC also notes the importance of considering biomass in addition to numbers when evaluating the potential effects of the salmon populations on other ecosystem components.***

The GOA ESR includes a brief literature review of pink salmon competitive interactions in the pink salmon noteworthy contribution. The editor will more thoroughly investigate the topic in the 2025 ESR.

The Aleutian Islands ESR continues to report on the impacts of pink salmon and monitors/ looks for biennial patterns within the data. Greg Ruggerone, the author of the eastern Kamchatka pink salmon contribution, has now included biomass plots which are put in context in the assessment.

Appendix III. Report Card Indicator Descriptions

The suite of indicators that form the basis for the Aleutian Islands Report Cards was selected to provide a comprehensive view of the Aleutian Island ecosystem reflecting across trophic levels from the physical environment to top predators and humans, as well as both the nearshore and offshore environments. Ideally, they would be regularly updated across all ecoregions (Western, Central and Eastern), thereby characterizing a global attribute with local conditions. Although a single suite of indicators was chosen for the entire ecosystem, not all are available or applicable in each of the three ecoregions. The final selection reflected the limitations of available data sets for the Aleutian Islands ecosystem.

1. North Pacific Index Nov-Mar mean
2. Reproductive anomalies of planktivorous least auklet and crested auklets as indicators of zooplankton productivity
3. Proportions of Ammodytes, gadids, and hexagrammids in tufted puffin chick diets
4. Apex predator and pelagic forager fish biomass indices
5. Steller sea lion non pup counts (juveniles and adults)
6. Percent of shelf <500m deep trawled
7. K-12 enrollment in Aleutian Islands schools

North Pacific Index (NPI) winter average (Nov-Mar):

The North Pacific Index (Trenberth and Hurrell, 1994), the area weighted mean sea level pressure over the region was selected as the single most appropriate index for characterizing the climate forcing of the Bering Sea. The NPI is a measure of the strength of the Aleutian Low, specifically the area-weighted sea level pressure (SLP) for the region of 30° - 65°N, 160°E - 140°W. Above (below) average winter (November - March) NPI values imply a weak (strong) Aleutian Low and generally calmer (stormier) conditions.

The advantage of the NPI include its systematic relationship to the primary causes of climate variability in the Northern Hemisphere, especially the El Ni no-Southern Oscillation (ENSO) phenomenon, and to a lesser extent the Arctic Oscillation (AO). It may also respond to North Pacific SST and high-latitude snow and ice cover anomalies, but it is difficult to separate cause and effect.

The NPI also has some drawbacks: (1) it is relevant mostly to the atmospheric forcing in winter, (2) it relates mainly to the strength of the Aleutian Low rather than its position, which has also been shown to be important to the seasonal weather of the Bering Sea (Rodionov et al., 2007), and (3) it is more appropriate for the North Pacific basin as a whole than for a specific region (i.e., Bering Sea shelf).

Implications: For the Bering Sea, the strength of the Aleutian Low relates to wintertime temperatures, with a deeper low (negative SLP anomalies) associated with a greater preponderance of maritime air masses and hence warmer conditions. It has been suggested that correlations between a strong Aleutian Low and decreased seabird productivity in the Aleutian Islands may be due to decreased prey (zooplankton) availability (Bond et al., 2011). Also, stormier conditions may make seabird foraging more difficult for both surface-feeding and pursuit-diving seabird species. The winter index is the average NPI from November through March (year of January), and the anomalies are normalized by the mean (8.65) and standard deviation (2.23) for 1961-2000. Data is updated every month, indicator is updated annually.

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Reproductive anomalies of planktivorous least auklet and crested auklets

Least auklets (*Aethia pusilla*) and crested auklets (*A. cristatella*) are small, abundant seabirds that nest in the Aleutian Islands. The USFWS stations field biologists to monitor auklet chick diets and reproductive success annually at Buldir Island and less frequently at other islands on which they occur. Both species are planktivorous and dive to capture their prey. Least auklet chick diets are mainly composed of *Neocalanus cristatus*, *N. plumchrus*, and *N. flemingeri*. Crested auklet chick diets consist of mainly Euphausiacea and *N. cristatus*. Due to the lack of time series of direct measurements of zooplankton in the Aleutian Islands, the team selected reproductive anomalies of least and crested auklets as indicators of copepod and euphausiid abundance, respectively. Reproductive anomalies were selected as the metric of interest instead of chick diets because reproductive success is an integrative indicator of ecosystem productivity and forage for planktivorous commercially-fished species. Surveys are conducted on an annual basis.

Reproductive success is defined as the ratio of number of nest sites with a fledged chick to the number of nest sites with eggs. In the Western ecoregion, reproductive success of least and crested auklets have been recorded annually at Buldir Island with the exception of 1989, 1999 and 2020. In the Central ecoregion, reproductive success was monitored annually at Kasatochi Island from 1996-2007. In 2008 a volcanic eruption covered the monitored colony in ash, disrupting breeding. This indicator was dropped in 2020 as it is unknown when auklets will nest there again and if so, whether observations will continue. Data were provided by the Alaska Maritime National Wildlife Refuge.

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Proportions of hexagrammids, gadids, and Ammodytes *in tufted puffin chick diets*

Tufted puffins (*Fratercula cirrhata*) are medium-sized seabirds that nest in varying densities throughout the Aleutians. The USFWS stations field biologists to monitor puffin chick diets annually at Buldir and Aiktak Islands (Figure 5) and less frequently at other Aleutian islands on which they occur. Puffins carry multiple prey items in their bills when they return to their colonies to feed their chicks. Forage fish and squid comprise most of puffin chick diets. In the absence of direct measures of forage fish abundance, time series of percent biomass of hexagrammids, gadids, and *Ammodytes* in puffin chick meals were selected as indicators of forage fish recruitment and system-wide productivity. Surveys are conducted on an annual basis.

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Apex predator and pelagic forager fish biomass indices

We present two foraging guilds to indicate the status and trends for fish in the Aleutian Islands: apex predators and pelagic foragers. Each is described in detail below. This guild analysis was based on the time series available as part of the NOAA summer bottom trawl survey for the Aleutian Islands (Western and Central ecoregions) and the Aleutian Islands and Gulf of Alaska combined (Eastern ecoregion). These two guilds are based on the aggregation of Aleutian species by trophic role, habitat and physiological status. The species included in each guild are listed in Table 6.

Time series for the Western and Central ecoregions are based on data collected from the AI bottom trawl survey, which is conducted every other year during even years. The Eastern ecoregion time series is a composite of the Aleutian Islands survey, which samples the northern portion of the islands, and the Gulf of Alaska survey, which samples the southern portion. Since surveys in these two areas are conducted in different years, the biomass estimates represent the closest pair of years pooled together to get a total biomass estimate for the shelf region

Table 6: Species included in foraging guild-based fish biomass indices for the Aleutian Islands

Fish Apex Predators	Pelagic Fish Foragers
Pacific cod	Atka mackerel
Pacific halibut	Northern Rockfish
Arrowtooth flounder	Pacific ocean perch
Kamchatka flounder	Walleye pollock
Rougheye rockfish	
Blackspotted rockfish	
Large sculpins	
Skates	

(0-500m). This time series excludes deep-water species such as sablefish and grenadiers, as most are found deeper than the trawl survey samples. The Team acknowledges that these would be good to include, but that the trawl survey does not sample them well.

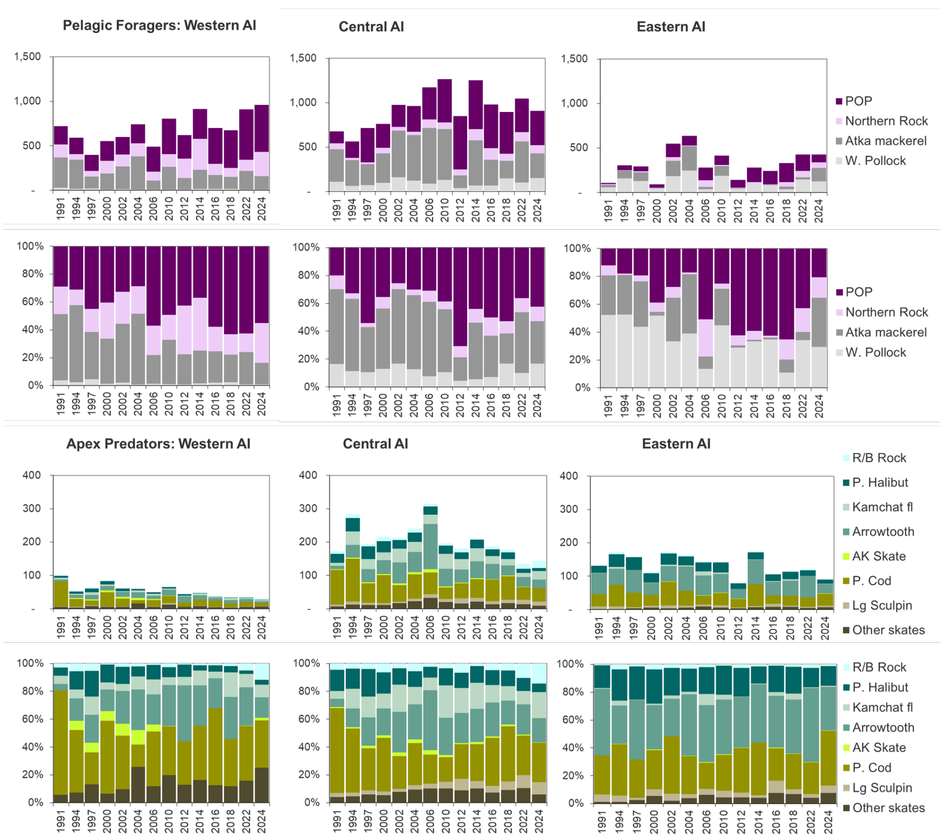

Figure 61: NOAA Alaska Fisheries Science Center's human dimensions indicators mapping

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Steller sea lion non pup counts

Counts of adult and juvenile Steller sea lions (*Eumetopias jubatus*) are used in the Aleutian Island ecosystem assessment to represent the status of an apex piscivorous predator whose diet consists primarily of commercially-fished species. The Steller sea lion inhabits coastal regions of the North Pacific Ocean, breeding in summer on terrestrial rookeries located from California north throughout the Gulf of Alaska, the eastern Bering Sea, the Aleutian Islands, Kamchatka Peninsula, Sea of Okhotsk, and the Kuril Islands (NMFS, 2010). The Steller sea lion is the world's largest member of the Otariidae family of pinnipeds. On average, Steller sea lions consume 6-10% of their body weight per day, but during lactation, energy intake by adult females may increase by as much as 3-fold (Keyes, 1968; Winship et al., 2002; Williams, 2005). Steller sea lions are generalist predators and consume a wide variety of fish and cephalopods in habitats ranging from nearshore demersal to offshore epi-pelagic, with local diets reflecting the species composition of the local fish community (Pitcher and Fay, 1982; Riemer and Brown, 1997; Sinclair and Zeppelin, 2002; Waite and Burkanov, 2006; Trites et al., 2007; McKenzie and Wynne, 2008; Fritz and Stinchcomb, 2005). In the Aleutian Islands, the diet consists largely of Atka mackerel, followed by salmon, cephalopods, Pacific cod, sculpins and walleye pollock (Sinclair and Zeppelin, 2002). Unlike phocid pinnipeds, otariids do not have large blubber (energy) stores, and as a consequence, require reliable access to predictable, local prey aggregations to thrive (Williams, 2005; Sigler et al., 2009).

Status and trend of Steller sea lion populations in Alaska are assessed using aerial photographic surveys of a series of 'trend' terrestrial haul-outs and rookeries that have been consistently surveyed each summer breeding season, when the proportion of animals hauled out is the highest during the year (Sease and York, 2003). Since 2004, NMFS has used high-resolution vertical photography (computer-controlled camera mounted in the belly of the plane) in its sea lion surveys in Alaska. This replaced the oblique, hand-held photographic techniques used from the first surveys in the 1960s and 1970s through 2002. Counts from vertical high resolution photographs were found to be 3.6% higher than those from oblique photos, necessitating the use of a correction factor to correctly compare recent counts with the rest of the time series (Fritz and Stinchcomb, 2005). Trend sites include the vast majority (>90%) of animals observed in each survey. Adults and juvenile (non-pup) numbers used for population trend assessment are sums of counts at trend sites within sub-areas or across the range of the western DPS in Alaska (NMFS, 2010). Replicate surveys conducted in the summers of 1992 and 1994 indicated that sub-area trend site counts of non-pups are stable within each breeding season (coefficients of variation of ∼5%; NMFS, unpublished data).

In our Aleutian Island ecosystem assessment, estimated counts of adult and juvenile Steller sea lions at trend sites are used to indicate the 'health' of apex piscivores whose diet consists primarily of commercially-fished species. The estimated counts are updated annually. The survey sites used in the assessment are:

- Western (172-177°E; 10 sites in the Near Island group and Buldir west of Kiska),
- Central (177°E to ∼170°W; 62 sites in the Rat, Delarof, and Andreanof Island groups, plus the Islands of Four Mountains), and
- Eastern ecoregions (163-170°W; 30 sites in the Fox and Krenitzin Islands, on Unimak Island, and on and near Amak Island in the southeastern Bering Sea)

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Habitat disturbance from trawls

This indicator uses output from the Fishing Effects (FE) model to estimate the habitat reduction of geological and biological features over the Bering Sea domain, utilizing spatially-explicit VMS data. The effects are cumulative, incorporating both estimated recovery time and disturbance. The time series for this indicator has been available since 2003, when widespread VMS data became available. The monthly value in December is used as an annual indicator, which is updated annually.

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K-12 enrollment in Aleutian Islands schools

The number of children enrolled in schools was selected as an indicator of vibrant, sustainable communities in the Aleutian Islands ecosystem. Community residents are closely tied to the ecosystem through sense of place and daily experience and activity. Enrollment statistics for kindergarten through twelfth (K-12) grades by school and region were compiled for the years 1996 through 2014 (`http://www.eed.state.ak.us/stats/`). School enrollment numbers fluctuate widely and serve to highlight the difficulties in maintaining sustainable communities within the Aleutian Islands ecosystem. Enrollment statistics are updated annually.

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Appendix IV. Methods for the Report Card Indicators

For each plot, the mean (green dashed line) and ± 1 standard deviation (SD; green solid lines) are shown as calculated for the entire time series. Time periods for which the time series was outside of this ± 1 SD range are shown in yellow (for high values) and blue (for low values).

The shaded green window shows the most recent 5 years prior to the date of the current report. The symbols on the right side of the graph are all calculated from data inside this 5-year moving window (maximum of 5 data points). The first symbol represents the "2015–2019 Mean" as follows: '+ or -' if the recent mean is outside of the ± 1 SD long-term range, '.' if the recent mean is within this long-term range, or 'x' if there are fewer than 2 data points in the moving window. The symbol choice does not take into account statistical significance of the difference between the recent mean and long-term range. The second symbol represents the "2015–2019 Trend" as follows: if the magnitude of the linear slope of the recent trend is greater than 1 SD/time window (a linear trend of >1 SD in 5 years), then a directional arrow is shown in the direction of the trend (up or down), if the change is <1 SD in 5 years, then a double horizontal arrow is shown, or 'x' if there are fewer than 3 data points in the moving window. Again, the statistical significance of the recent trend is not taken into account in the plotting.

The intention of the figures is to flag ecosystem features and the magnitude of fluctuations within a generalized "fisheries management" time frame (i.e., trends that, if continued linearly, would go from the mean to ± 1 SD from the mean within 5 years or less) for further consideration, rather than serving as a full statistical analysis of recent patterns.