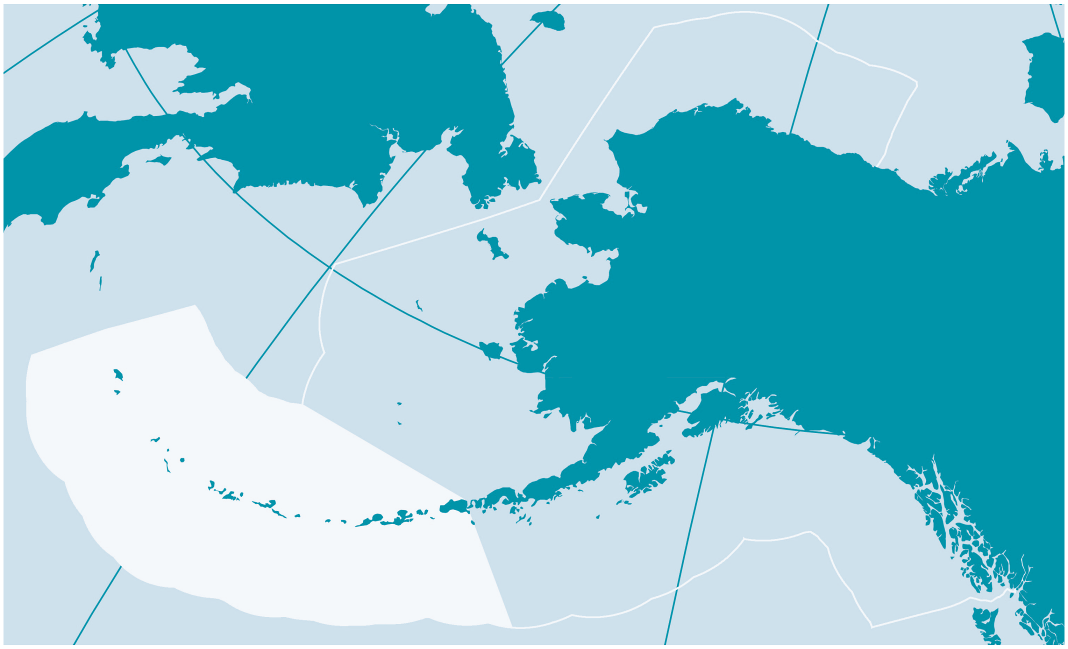
Ecosystem Status Report 2022

ALEUTIAN ISLANDS



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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 and as well as other Council decisions. Additional background can be found in the Appendix (p. 125).

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

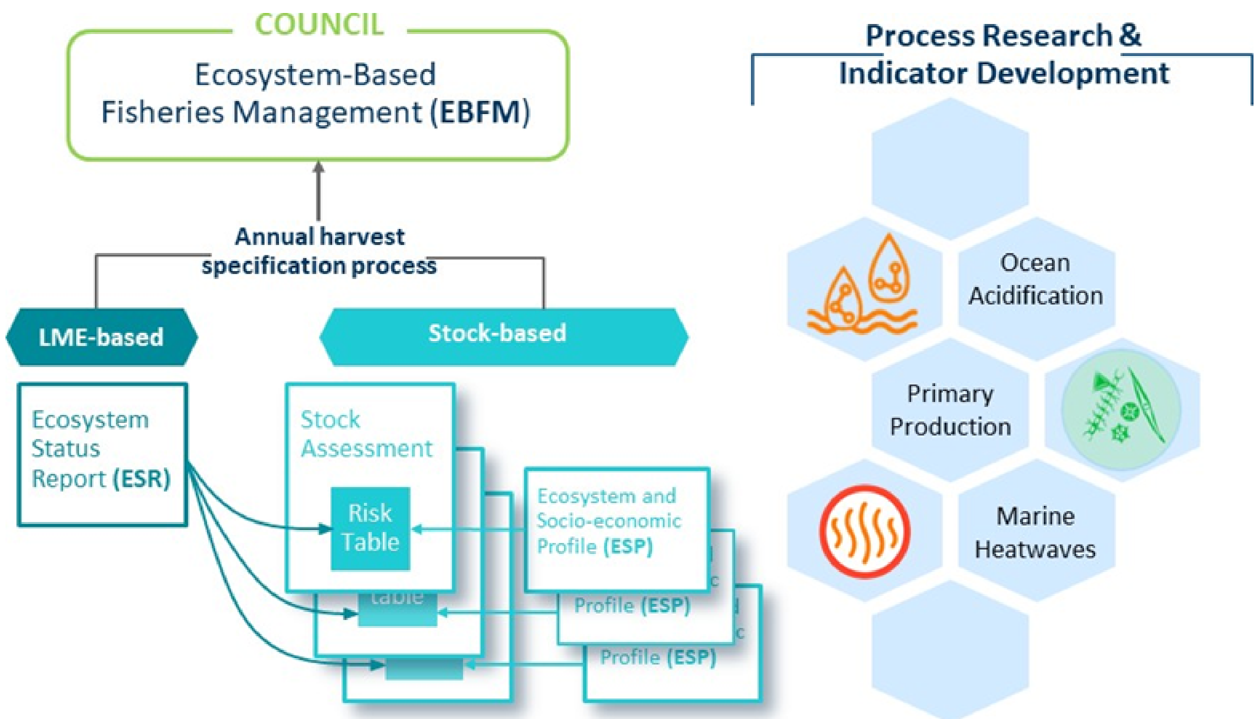

Figure 1: Ecosystem information mapping to support Ecosystem-Based Fisheries Management through Alaska's annual harvest specification process. The 'honeycomb' on the right shows examples of ecosystem indicators that are provided to Ecosystem Status Reports (ESRs) at the Large Marine Ecosystem (LME) scale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

Aleutian Islands 2022 Report Card

For more information on individual Report Card Indicators, please see Description of Report Card indicators (p. 133). For more information on the methods for plotting the Report Card indicators, please see "Methods Description for Report Card Indicators" (p. 138).
* indicates Report Card information updated with 2022 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.

Region-wide

- The **North Pacific Index (NPI)** effectively represents the state of the Aleutian Low. Above (below) average winter (November - March) NPI values imply a weak (strong) Aleutian Low and generally calmer (stormier) conditions. The NPI has been positive during 5 of the last 6 winters, with the exception being the winter of 2018-2019. The systematically positive state of the NPI (i.e., weak Aleutian Low) is consistent with the overall decline in the PDO during the interval.
- The Aleutians Islands region experienced **suppressed storminess through fall and winter 2021/ 2022** across the region, potentially favoring foraging of plankton-eating seabirds (Bond et al., 2011).

Western Aleutian Islands

- The reproductive success of least and crested auklets, planktivorous seabirds at Buldir Island was above the long-term average in 2022, indicating that **overall zooplankton availability was sufficient to support seabird reproductive success in 2022 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 general, *Ammodytes* (sand lance) increased in seabird diets to the time series mean after been absent since 2010; age-0 gadids (pollock mostly), decreased below the time series average after last year's peak; and hexagrammids (primarily Atka mackerel) were below the time series mean, decreasing from last year. We note tufted puffins had average reproductive success (compared to above average last year) and fed mostly on squid and sculpins, thus signaling **potentially favorable conditions for fish foragers** though not as favorable as last year. Not shown here, squid comprised 34% and sculpins 23% of tufted puffin chick meals. Likewise, 42% of horned puffin chick meals were composed of Atka mackerel. There were no seabird diets collected in 2020.
- The **pelagic fish foraging guild biomass increased above the time series mean** from 2018 to 2022. The increasing trend was due to increases in Atka mackerel, Pacific Ocean perch and northern rockfish biomass.
- The **overall biomass of the fish apex predator foraging guild continued its long term decline** driven by Pacific halibut and Kamchatka flounder. The decrease was somewhat offset by increases in the biomass of rougheye/ blackspotted rockfish, other skates, Pacific cod and large sculpins compared to those in 2018.
- Steller **sea lion numbers continue to decline**, with no signs of recovery. Non-pups have declined 97% since 1984.

- The amount of area trawled was not updated this year and there are no schools in the western Aleutians.

Central Aleutian Islands

- The **pelagic fish foraging guild biomass increased** overall from 2018 to 2022. Both Atka mackerel and northern rockfish increased while walleye pollock and Pacific Ocean perch decreased.
- The **fish apex predator foraging guild biomass decreased signficantly** from 2018 to 2022 to its lowest recorded level. All groups decreased except for rougheye/ blackspotted rockfish.
- Counts of non-pup **Steller sea lions remain 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, the easternmost is potentially increasing (but survey was fairly incomplete here) and the middle one is stable.
- The amount of area trawled was not updated this year
- School enrollment bottomed out in Alaska during 2020-2021, and it **did not recover in the 2021-2022 school year**. School enrollment decreased by 2 in Adak from 15 to 13, where 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 and Atka are at increasing risk of closure. Decreasing enrollment trends impact the stability to families living in those communities. This indicator is updated annually with data from the previous year.

Eastern Aleutian Islands

- As indicated by their percent in the composition of tufted puffin chick meals **forage fish were more abundant than last year** with *ammodytes* (sand lance) near the time-series mean, and both gadids (pollock) and hexamgrammids (Atka mackerel) increasing to above and at the time series mean, respectively. Notably sablefish contributed to chick meals, supporting evidence that sablefish continue to do well in the ecoregion. Gadids were more common through the 1990s while hexagrammids are uncommon in this region. There were no seabird diets collected in 2020.
- The survey estimated biomass of pollock and northern rockfish increased 71% each compared to 2018, driving an **increase in fish pelagic forager biomass** from 2018 to 2022. In sharp contrast, Atka mackerel decreased to one of its lowest biomass in the area.
- **Fish apex predator foraging guild biomass remained close to the time series mean with a slight decrease** driven by Kamchatka flounder biomass in 2022 compared to 2018. Prior to this year, the guild biomass had been consistently increasing from its lowest point in 2012.
- Steller sea lions were surveyed in 2022, however counts in the eastern Aleutians are still being verified.
- **School enrollment fell for the third year in a row**. This is the lowest on the time series and is driven by the trend at Unalaska Elementary. 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 with 11 students and Akutan with 20). As in the case in 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.
- The amount of area trawled was not updated this year

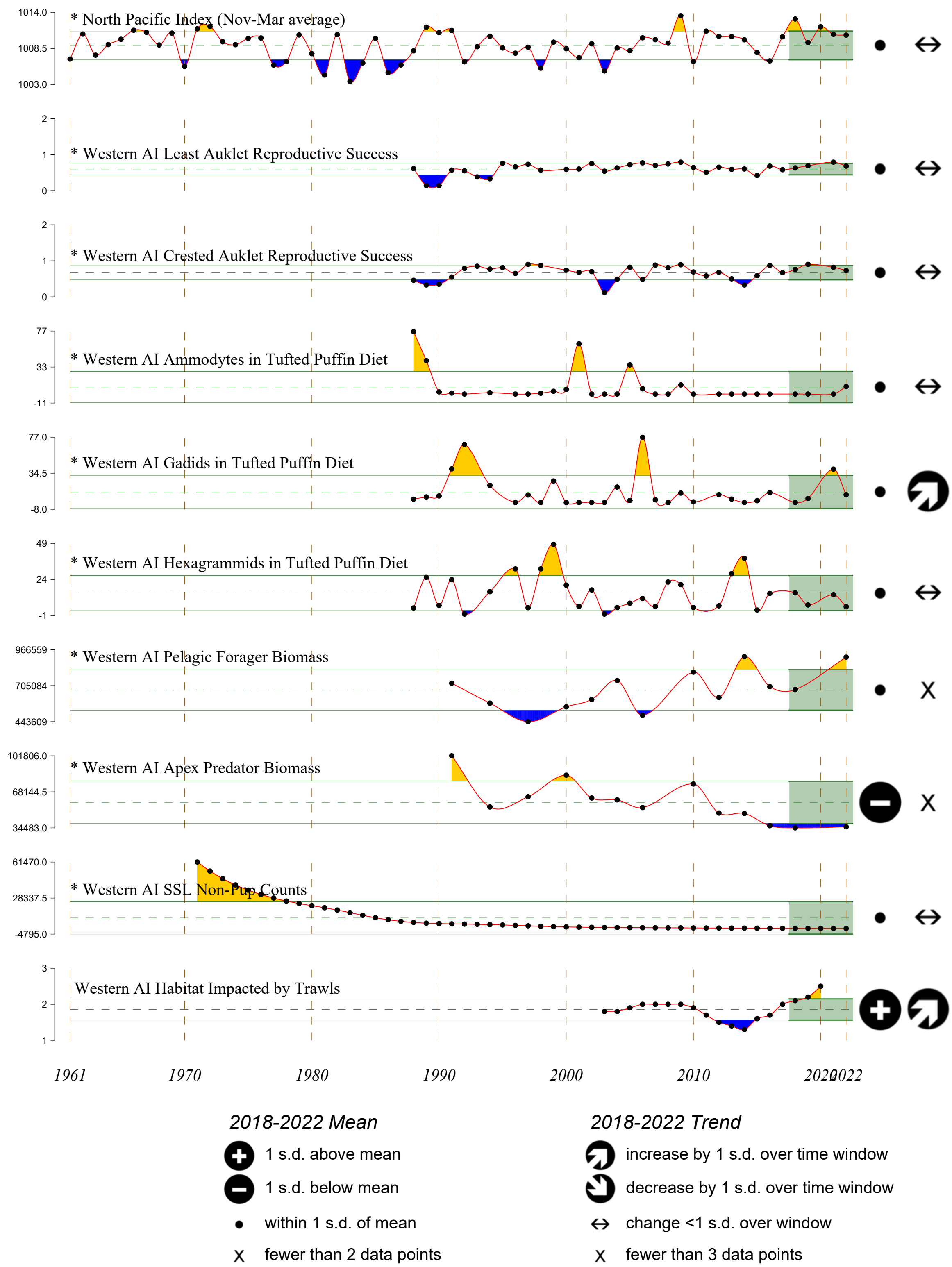

Figure 2: Region-wide and Western Aleutian Islands indicators. *indicates time series updated with 2022 data

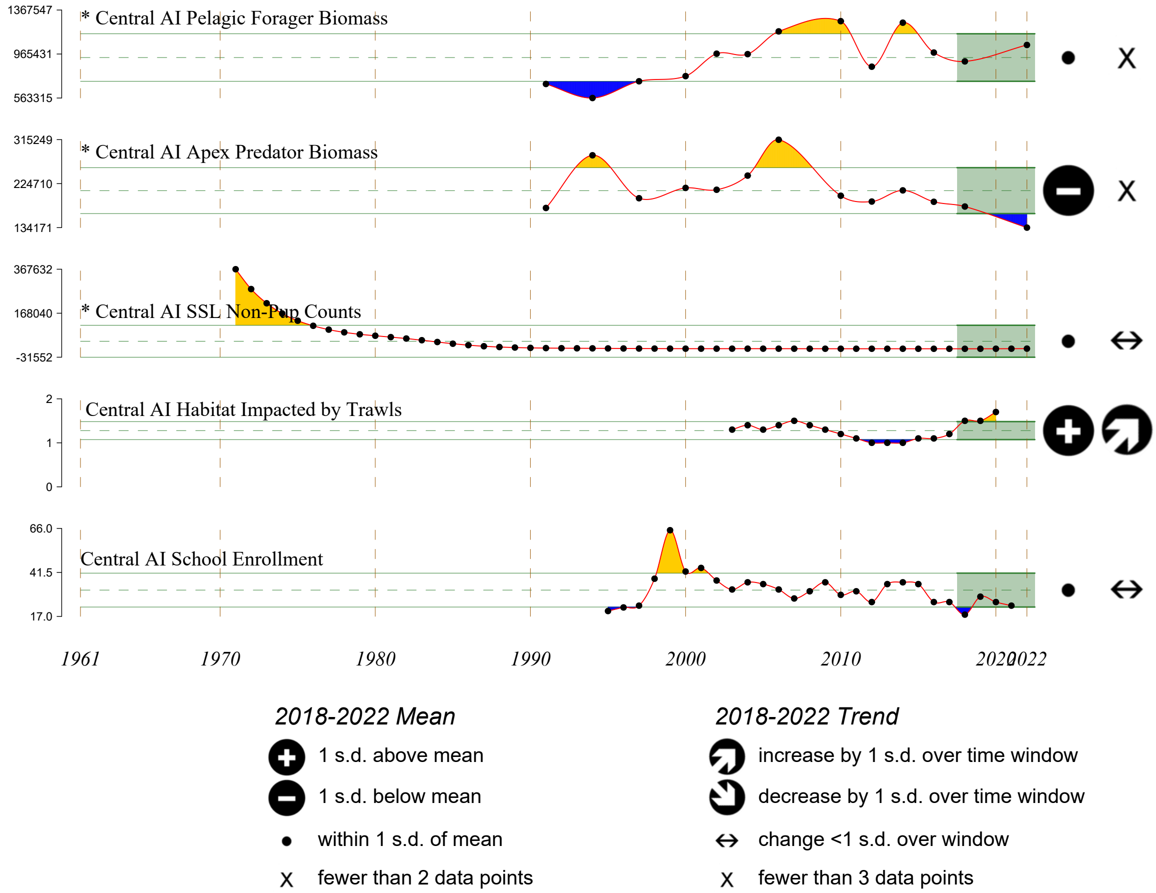

Figure 3: Central Aleutian Islands indicators. * indicates time series updated with 2022 data

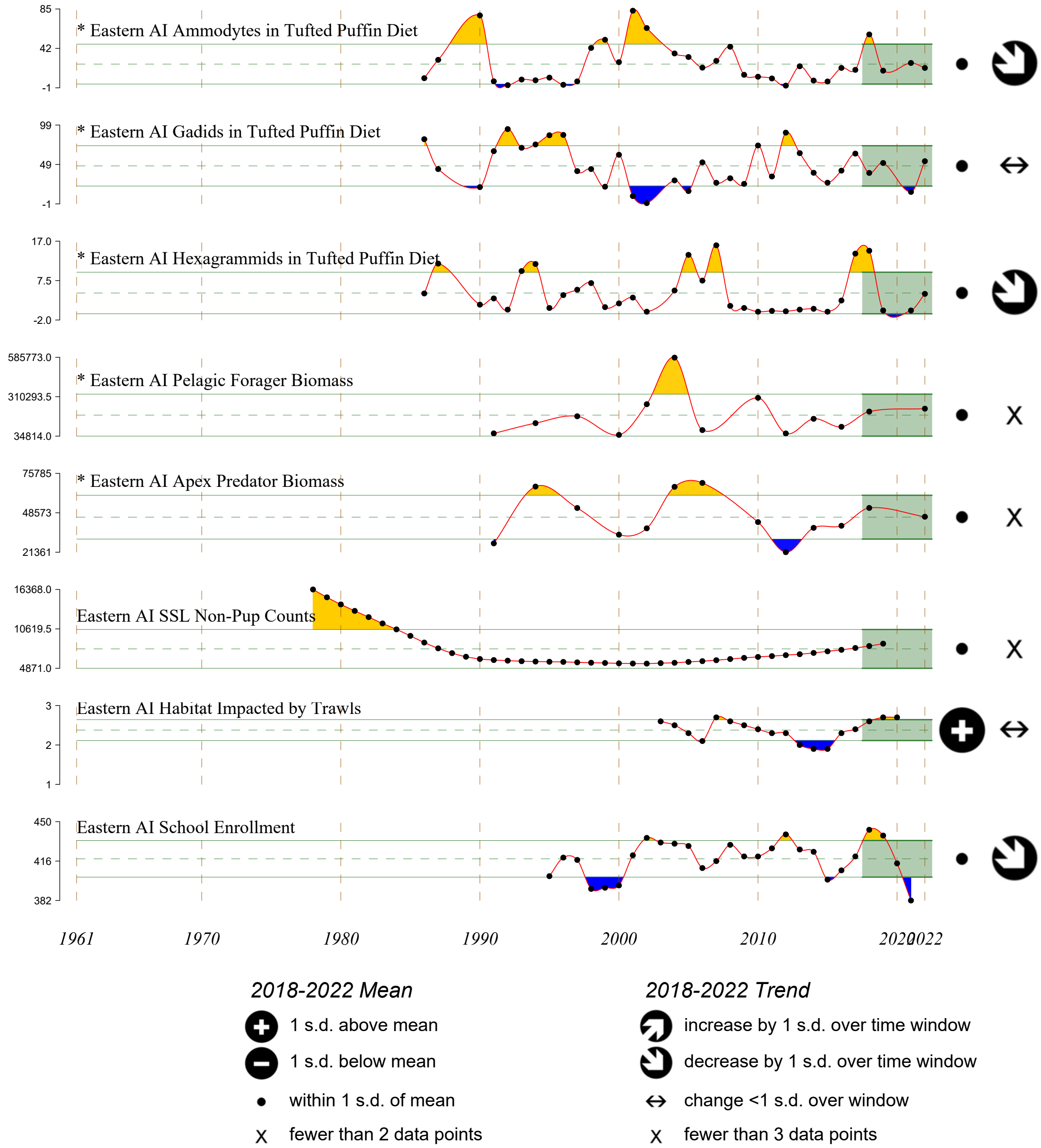

Figure 4: Eastern Aleutian Islands indicators. * indicates time series updated with 2022 data

Ecosystem Assessment

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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.

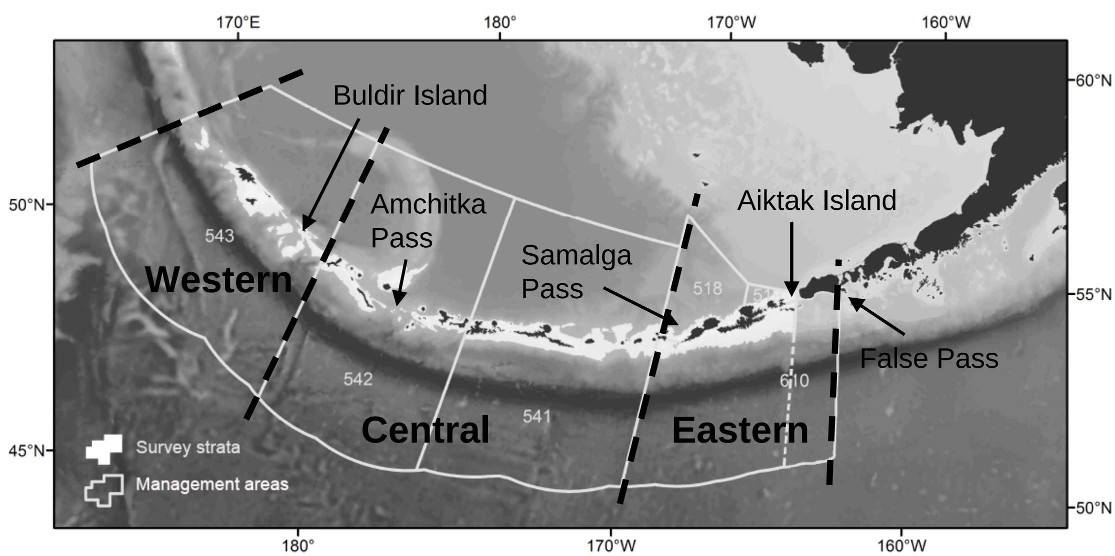

Figure 5: The three Aleutian Islands assessment ecoregions.

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 North Pacific Fishery Council fishery management 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 North Pacific Fishery Council fishery management 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 area, 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

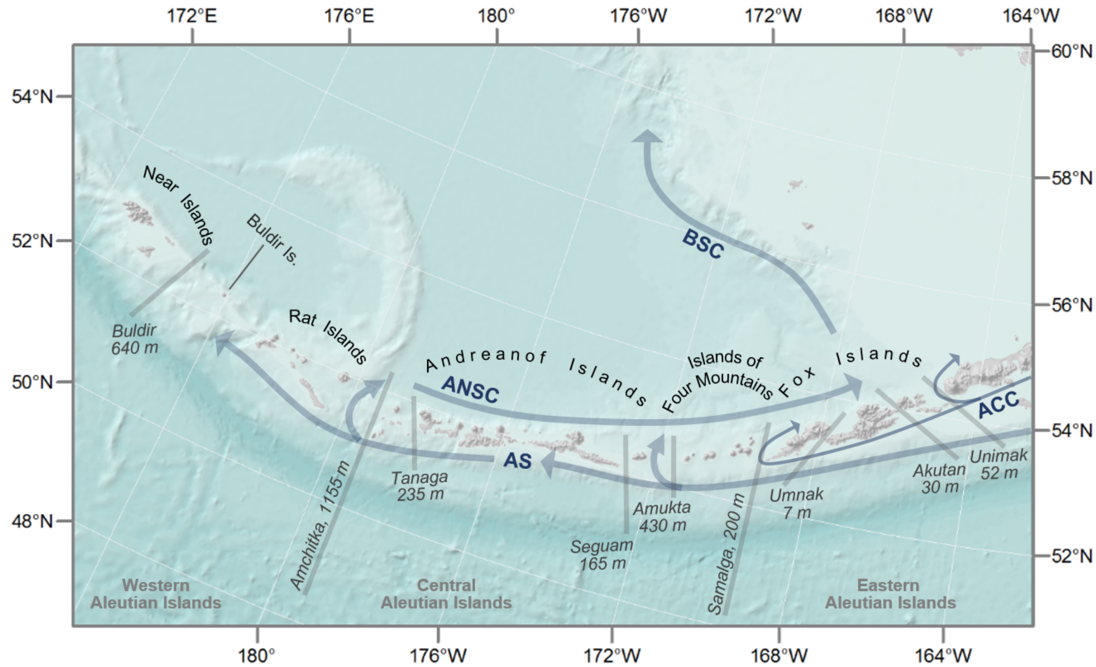

Figure 6: Ocean water circulation in the Aleutians. Currents are indicated with black lines. Currents are indicated by grey arrows. Selected passes are indicated by straight light grey lines

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 NPFMC fishery management areas 518, 517 (EBS) and the western half of 610 (GOA).

Aleutian Islands Ecosystem Assessment

In the Aleutian Islands as a whole, there are large gaps in knowledge about the local physical processes due largely to geographic constraints. For example, persistent cloudiness 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.

The Alaska Fisheries Science Center completed the standard bottom trawl and Steller sea lion surveys in 2022. There was no bottom trawl survey in 2020 due to COVID-19. Indicators from the bottom trawl and Steller sea lion surveys were last updated in 2018. During 2022, operational impacts due to COVID-19 had a negligible effect on information used in this report, due in large-part to effective mitigation strategies put in place to protect the health and safety of field research personnel and communities. The Alaska Fisheries Science Center's Ecosystem Status Reports are informed by the continuation of survey- and lab-based data streams, as well as information contributed through new and existing partnerships.

Current Conditions 2022

The past year was characterized by continuing moderate La Niña conditions and a continued negative PDO phase that followed the marine heat wave years of 2014-16 in the NE Pacific ocean. The weak Aleutian Low is consistent with the decline in the PDO during this time (Figure 7) The expected decrease in sea surface temperature to average levels through winter and early spring 2022 materialized in fall 2021 and early December, but temperatures then increased to a sustained moderate or higher heatwave level through September 2022. This was particularly the case during winter and summer in the western and central Aleutians, with this year recorded as one of the warmest on record and summer marine heatwaves periodically reaching severe levels in the western Aleutians (Figure 15). Mid-depth and bottom temperatures were above average in 2022, as they have been since 2014. Winds during winter 2022 favored northward flow through Unimak Pass, and a strong eddy (the first since 2012) remained in the eastern Aleutians from the second half of 2021 through the first half of 2022, also favoring higher nutrients and fluxes through Unimak Pass. The NPGO index has remained negative since late 2013, while the PDO changed to a negative phase in 2020 and the NPI has been positive (i.e. weak Aleutian Low) five out of the last 6 winters (except winter 2018-2019). Jointly, these indices suggest physical conditions that support increased zooplankton availability (Bond et al., 2011; Goyert et al., 2018).

Seabirds at Buldir (western Aleutians) and Aiktak (eastern Aleutians) Islands had average or early hatch dates and average or above-average reproductive success, indicating favorable foraging conditions across a broad spectrum of prey from zooplankton to forage fish prey (Figure 40). While groundfish condition was slightly improved compared to previous years, the condition of all species except for southern rock sole remained below average, indicating that their prey resources were limiting. In general, pelagic forager groundfish seem to be doing better on average than apex predator piscivorous fish feeding close to the bottom. For example, the abundances of most apex predator groundfish (large flatfish and Pacific cod) decreased compared to that observed during the last survey in 2018, while the abundance of all the main pelagic-foraging groundfish (rockfish and Atka mackerel) increased.

2022 was a low abundance year for Eastern Kamchatka pink salmon, indicating that there was likely less competition for prey and weaker trophic cascades than have been shown in years of high abundance of pink salmon (Springer and van Vliet, 2014; Batten et al., 2018; Springer et al., 2018). The notable steep increases in Eastern Kamchatka pink salmon abundance trends in 2009 for high abundance years and in 2014/2016 for low abundance years, has made a biennial signal potentially driven by the extreme shifts in pink salmon abundance more noticeable across ecosystem components. For example, there is a newly noted biennial signal in primary productivity as measured by satellite chl-a (often a proxy for phytoplankton biomass) that may present further support for ecosystem-wide impacts of pink salmon (Figure 22).

The western DPS (distinct population segment) of Steller sea lions as a whole began to rebound in 2002 from an earlier declining trend. However, regional trends tell a different story in the Aleutian Islands and in the Gulf of Alaska. West of Samalga Pass, sea lion counts have shown little to no signs of recovery, including with the new counts this year. Steller sea lion non pups and pup counts continue to decline in the western Aleutians. In contrast, counts in the central Aleutians as a whole continued a stable trend. However, this was due to an apparent increase in counts in the easternmost central Aleutians that offset the declines observed in the westernmost central Aleutians (Figure 45)

Lastly, paralytic shellfish toxins were 3.4x above the regulatory limit in 2022, which is substantially lower compared to toxins observed at 75x the limit in Unalaska during 2021. Despite the decrease, paralytic shellfish toxins continue to pose a risk to human health and food webs in the region (Figure 51). More details on this year's trends are in the regional highlights section below.

Multi-year patterns

Overall, there seem to be three major drivers of the multi-year patterns observed across the Aleutian Islands: persistent warm conditions, increasing pink salmon abundance, and increasing Pacific Ocean perch abundance. Jointly, these factors might indicate a transition of the ecosystem to a new state. The likelihood and detection of such a transition may depend on how long the current conditions prevail. Analyzing the food web to see if predator/prey relationships have changed over time would help to determine whether or when such a transition occurs. This would require both more diet sample collections (from fish, birds, and mammals), as well as analysis, to inform the underlying changes in the structure of the ecosystem. The data-poor nature of this ecosystem relative to the eastern Bering Sea or Gulf of Alaska, , including the biennial schedule of the bottom trawl surveys (in low pink abundance years), limits the ability to identify the extent of cascading or cumulative effects of these drivers.

Persistent warm conditions since 2013: Surface to bottom waters have remained above the long term mean since 2013/14, the cause of which is not fully understood (Figure 19). The warm temperatures can be attributed in part to slower at-depth processes, involving several mechanisms, such as weaker wind/mixing, warmer air temperature, and advection of warm water from the North Pacific Ocean, the relative importance of which is hard to assess without a detailed heat budget analysis. Other aspects of the physical environment continue to show variability. For example, a large eddy formed in the eastern Aleutian Islands this year (Figure 21).Phytoplankton have also shown notable patterns but have often remained in lower abundances over the same time period. Both large diatoms and satellite chl-a (increased in 2021 from the previous year. However, satellite chl-a decreased again this year, reverting to a generally lower-than-average abundance that began in 2010-2014. This coincides with the decrease in satellite chl-a observed in the off-shelf region of the eastern Bering Sea (Hennon et al, EBSESR 2022). Cumulatively, these conditions suggest that there has been lower productivity across the system, concomitant with increased bioenergetic needs for fish, faster growth rates for zooplankton and larvae, and shorter incubation periods for eggs due to the warm conditions. These changes in bioenergetics and development rates can potentially lead to mismatches between egg hatching/larvae release and prey availability, which can negatively affect recruitment. Fish condition has remained below the mean since 2012 (Figure 30), which also indicates that fish are not meeting their optimal bioenergetics needs. Note that the beginning of the period of lower fish condition and satellite chl-a seem to coincide with the step increase of Eastern Kamchatka pink salmon in 2009 and 2014/16 for odd and even year-classes, respectively.

Eastern Kamchatka pink salmon abundance in odd years continues to increase: The biennial pattern of high pink salmon abundance in odd years and low abundance in even years continues. This year was also the second-highest abundance on record for even year-classes (Figure 28). However, since 2009, high abundances of odd year-classes have doubled and even tripled (315 million adult fish) compared to prior levels of around 100 million fish. Low abundance [even] years reached the 100 million fish mark in 2016 and 2018 (perhaps related to higher temperatures mentioned above) but also had a notable increase in 2014 from previous years (48 million compared 24 million in 2012 and 14 million and 10 million in 2010 and 2008 respectively). In 2020, pink salmon abundance decreased to pre-2014 levels, perhaps due to low availability of prey as the large meso-zooplankton negative anomaly would suggest (Figure 25). Several papers report that the pink salmon biennial pattern seems to be cascading through the system by consuming zooplankton which impacts fish growth (Atka mackerel, citealtMatta2020), and food available for seabirds (Zador et al., 2013; Springer and van Vliet, 2014; Springer et al., 2018). The following indicators tracked in this ESR also show a biennial pattern: satellite chl-a (lower in even years), catch estimates of age-2 Atka mackerel (Lowe et al 2022), age 3+ number of fish in the Pacific Ocean perch stock assessment (Spencer et al. 2022 hatch time of tufted puffins (earlier in odd years), and bycatch of all seabirds combined (increases in years of high pink salmon abundance and decreases during low pink salmon abundance, Figure 55). The timing of some of these biennial patterns coincides with the step changes in Eastern Kamchatka pink salmon abundance, perhaps suggesting that a threshold has been reached where potential ecosystem impacts increase. Interestingly, the biennial pattern seen in age-2 Atka mackerel catch has not been observed in recruitment estimates or surveys. The biennial pattern in puffins indicates they find more favorable conditions in winter/ spring when Eastern Kamchatka pink salmon is low, however the abundance of pink salmon does not correlate with their reproductive success in a given year. Further evaluation is needed to assess the influence of Eastern Kamchatka pink salmon in the system.

Rockfish have replace Atka mackerel and pollock as the main pelagic foragers: The increase of rockfish across the Aleutians has slowly changed the ratio of Atka mackerel/pollock to northern rockfish/Pacific ocean perch, with rockfish now contributing a higher percent of the local biomass across the archipelago. Stock assessment estimates support rockfish remaining dominant, although decreasing. An ecosystem state where sustained high biomass of Pacific Ocean perch and northern rockfish may be outcompeting or displacing pollock and Atka mackerel would signal a return to conditions that existed before Pacific Ocean perch was heavily fished by the foreign fleets. The effect of rockfish dominance on the ecosystem is best captured by the mean lifespan of the groundfish community, a proxy for the mean turnover rate of species (Figure 49). Mean lifespan has increased from 35 years in the 1980s to 60 years in 2018-22. Longer-lived species help to dampen the effects of environmental variability, and in ecological terms, increases the stability of the ecosystem (see Figure 47). The persistent low fish condition suggest that Pacific Ocean perch and northern rockfish could potentially be experiencing density dependence. Also, rockfish prefer habitats with vertical structure (Rooper 2019), particularly deep coral and sponges, and may be exerting spatial pressure on other fish in this habitat. This in turn might lower the availability of Atka mackerel and pollock to other predators such as Pacific cod, whose diet shows small amounts of Atka mackerel consumed in NMFS areas 543 ad 542 in 2016 and 2018, but an increase in area 541. It is unclear whether this change in pelagic foragers (Figure 66) has contributed to the decline of harbor seals (AI ESR 2021) and/or Steller sea lions .

Western Aleutians

Sustained high temperatures particularly in winter and summer, resulted in a sustained moderate marine heat wave which at times reached strong and severe levels in May and July-Aug 2022 (Figure 12). This led to a prolonged marine heat wave through early September with most of the region affected by the high temperatures. SST briefly subsided to average through October and are currently slightly above the long term mean but below the heat wave threshold. This reprieve from high temperatures during fall was also observed last year. The heatwave has potential impacts during the spawning season of Atka mackerel when they move to shallower areas. It may have raised temperatures close to 11-11.5°C, the upper limit of the observed temperatures during and after Atka mackerel spawning. Atka mackerel nests are typically found between 32–144 m depth (Lauth et al., 2008) potentially making the shallowest nests more vulnerable to the heat wave. The fall temperature reprieve could potentially offset the impact on incubation times. Bottom temperatures averaged 4.4°C, well below the lethal temperature of 15°C. Eddie kinetic energy was slightly below average but close to the long-term mean, suggesting low fluxes of nutrients, heat and salt through the passes (Figure 21). Satellite-derived chl-a concentration, was below average throughout spring, and improved somewhat in fall (Figures 22, 23).

The persistent decline in fish condition in the region may be indicative of a variety of factors: poor prey quality, low availability of prey and/or density dependence. Based on biomass estimates from the 2022 bottom trawl survey compared to 2018 estimates, apex predator abundance increased 3% overall. This increase was driven by Pacific cod (20%), rougheye/ blackspotted rockfish (84%) and large sculpins (2%), while all large flatfish decreased. The below average fish condition of Pacific cod and arrowtooth flounder suggests that they experienced either poor prey quality and/or low availability of prey. In contrast, the overall biomass estimate of pelagic foragers increased 35%. This increase was driven by Pacific ocean perch and Atka mackerel (33% and 58%), while pollock decreased 63%. The fish condition for all three was below average, and while this would suggest low quality and/or availability of prey, in the case of Pacific ocean perch it may also be due to density dependence, given its increasing biomass trend.

In general, fish-eating seabirds (tufted and horned puffins, thick-billed murres, glaucous winged gulls) had successful reproduction during 2022, continuing the improvement from already-favorable conditions in 2019, which had been preceded by poor reproductive success. Tufted puffin chick diets at Buldir were mainly composed of Irish lord (23%) and squids (35%), while horned puffin chick diets there were primarily composed of Atka mackerel (42%). The dominance of species in puffin chick diets concurs with stable or increasing biomass of these species based on bottom trawl survey data. Long-term average hatch dates for fish-eating seabirds are between mid-June to late July (Dragoo et al., 2019), along with average hatching periods of 30 to 42 days. This year hatch dates of fish eating seabirds were earlier or average, suggesting prey were available in the early spring and potentially for commercial groundfish as well. Zooplankton-eating seabirds (auklets) serve as indicators of zooplankton production; their reproductive success has been above average since 2019, including this year. These species feed their chicks mainly euphausiids and copepods. Their earlier or average hatch dates this year suggests favorable foraging conditions throughout the preceding months. The increase of rockfish in seabird diets observed in 2021 was not observed this year, as *Sebastes spp.* was only 1% of the chicks' diets. It will be interesting to see if the increase in age-0 rockfish in chick diets in 2021 lines up with future estimates of 2021 rockfish age-classes.

Steller sea lion numbers in the western Aleutians (Rookery Complex Area 1) continued to decline and show no signs of recovery. Pup numbers in this region have declined 95% since their peak in 1984 (38 years); non-pups declined 97% over the same time period. Non-pups have declined 99% since 1971, which is the earliest modeled count for this region. The Buldir rookery has entirely disappeared. Just over 5,000 non-pups were counted in 1979. Since 2010, counts have ranged from 0–28 (Fritz et al., 2013). The decline in Steller sea lion counts coincides with the overall low fish condition in the region, which makes for poor prey quality for sea lions. Although Steller sea lions can dive to at least 400m, the increase in biomass of rockfish at depths within 100-200 meters, where a large portion of Atka mackerel, pollock and Pacific cod are found, may decrease their ability to easily find their preferred prey.

Central Aleutians

Similar to the Western Aleutians, the central Aleutians were under a moderate marine heat wave through most of the year, at times reaching strong or severe levels. Overall, the region experienced a particularly warm winter and summer during 2022. The heat waves, however, were less extensive than those in the western Aleutians (Figure 12). Sea surface temperatures have subsided since mid-September, remaining slightly above average but below the heat wave threshold. In this ecoregion, bottom temperatures have been above the ecosystem-wide mean temperature several times, such as during 2010, 2006, and 2004. This year again, the average bottom temperature was slightly higher than in the other regions. Mid-water temperatures (100-300 m) from the longline survey were cooler than in 2016, but warmer than those observed in 2012 and earlier. Eddy kinetic energy north of the islands is usually the lowest in magnitude compared to those in the western and eastern Aleutians. In this area, events are characterized either by multiyear or continuous eddies of low intensity. In 2022 eddy kinetic energy was generally above its long-term average except for a brief period during early winter, indicating potentially above-average flux of nutrients and heat across the passes. Phytoplankton biomass, as represented by chl-a concentration, was generally below average (Figures 22 and 23).

Steller sea lion counts in the rookery complex areas (RCAs) 2-5 had mixed trajectories, with counts improving from west to east. Non-pups and pups were stable in the region . However, counts in the two western RCAs (2 and 3) declined for both pups (-5.10% and -5.38%, respectively) and non-pups (-3.55% and -3.14%). RCA 4 was stable for all age-sex classes. Counts in RCA 5 increased (4.09% y-1; 95% CI 0.86 – 7.98). However, the survey in this area was fairly incomplete as it missed one rookery and several haul out sites. Further data is necessary to confirm whether this is a true increase.

Groundfish survey biomass estimates for apex predators decreased 24% overall in the area compared to 2018 except for large sculpins. The overall survey estimate of the pelagic forager groundfish guild biomass increased driven by Atka mackerel and to some degree by northern rockfish. Within this guild, the biomass of Pacific ocean perch and walleye pollock decreased (25 and 50% respectively). This is the only area where walleye pollock condition improved in 2018 and 2022, as did that of southern rock sole. There are no seabird surveys in this area.

School enrollment bottomed out at the state level in Alaska during 2020-2021 and did not recover in the Central Aleutians during the 2021-2022 school year. Barring renewed activity by the now-closed processing plant, and the potential to be a hub for clean energy (fuel) along the great circle route, the future stability of the community and school is uncertain.

Eastern Aleutians

This area encompasses the islands east of Samalga Pass. As in 2021, sea surface temperatures in the eastern Aleutians during 2022 were not as high during winter as in the western and central Aleutians. The marine heat wave periods were also shorter, primarily restricted to summer, and of lower intensity, as most were considered moderate with only a few short events considered strong. That said, overall sea surface temperature during 2022 was mostly higher than in 2021, except for August–September 2021 when temperatures rose sharply. In contrast, late August–September 2022 temperatures were above the mean but below the heat wave threshold level (Figures 12 and 13). Mid-water temperature profiles for 2022 show a warm band of water between 150-250 m with cooler temperatures above and below (Figure 17). The predominant wind pattern blowing from the west to the east during 2022 favored flows through Unimak Pass. Eddy kinetic energy, which is typically driven by a strong pulse eddy in this area, was significantly higher this year, breaking the generally low strength observed since 2012 (Figure 21). Spring phytoplankton biomass, as suggested by chla-a concentration, was above the climatological mean south of the islands in May, but otherwise also below average (Figure 23).

Fish-eating seabirds, such as murres, puffins and gulls, all had above average reproductive success. No auklets (primarily zooplankton-eaters) were surveyed in the region. Storm-petrels, which feed on a mix of invertebrates and zooplankton, had average to above average reproductive success. Fork-tailed storm-petrels earlier hatch dates but average reproductive success. Leach's storm-petrels had both average hatch dates and average reproductive success (Figures 40, 38). There were few reports of dead seabirds (20-50 birds) in Cold Bay and Unalaska (Figure 42). While these indicators suggest good availability of forage fish to rear chicks and potentially for fish-eating groundfish, there were no data collected on planktivorous seabirds. However storm petrels and murrelets, which feed on fish, invertebrates and zooplankton, had average or above average reproductive success. While it is unclear whether the conditions were as favorable for obligate zooplankton-eating seabirds as for fish-eating seabirds, the overall reproductive success suggests there was enough prey to support combined diets. Tufted puffins chick diets were primarily pollock (51%) followed by Pacific sand lance (21%), indicating that forage fish were available to foraging seabirds. Steller sea lions were surveyed in 2022, but counts are still being analyzed. Previous counts suggest that the sea lion populations have been recovering in this area.

Increases in survey biomass estimates of northern rockfish and pollock offset decreases of Pacific ocean perch and Atka mackerel, for an overall 10% increase in pelagic foragers biomass compared to 2018. In contrast, overall apex predator fish biomass decreased, with the exception of arrowtooth flounder, Pacific cod and large sculpins (Figure 66). While the condition of Pacific cod sampled in the survey was above the long term average, condition remained below average for the other sampled species (Figure 30)

Shellfish samples from several locations including Little Priest Rock in Summer Bay, Unalaska are collected weekly and analyzed for harmful algal blooms. Monitoring indicated that peak toxin levels occurred during June this year. Blue mussels had toxins only 3.4x above the regulatory level (Figure 51), which is the lowest documented in the past three years. Public awareness efforts continue in the area to minimize impacts on human health. Lastly, school enrollment declined in 2020-21 and did not recover in 2021-22. The decrease in the eastern Aleutians enrollment was driven by a large decline at Unalaska Elementary. All other schools (Akutan, False Pass, and Unalaska Jr. and Senior High School) had increased enrollments.

Contents

* indicates contribution updated in 2021, † 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, or some other type of non-standard ecosystem indicator.

Bottom Trawl and Steller Sea Lion Surveys—update from 2018

The Alaska Fisheries Science Center completed the standard bottom trawl survey of the Aleutian Islands by the Groundfish Assessment Program of the Resource Assessment and Conservation Engineering Division. The survey is conducted biennially during even years and had not been conducted since 2018 due to COVID-19. In 2022, still dealing with COVID-specific travel and isolation considerations, the staff, contractors, and volunteers overcame a number of logistic hurdles to complete this summer's survey. This is the only fish survey that covers the Aleutian Islands—420 bottom trawl stations along 1700 km from Unimak Pass to Stalemate Bank. The survey provides the groundfish indicators, which comprise one third of all the indicators for the ESR.

The Steller sea lion surveys are led by the Alaska Ecosystems Program of the Marine Mammal Laboratory. This is the only regular marine mammal survey conducted every other year in the Aleutians and had not been conducted since 2018 due to COVID-19. The survey counts pups (approx. 1 month old) and non-pups on terrestrial rookery and haulout sites and are conducted in late June through mid-July after approximately 95% of all pups are born. The survey provides one of four marine mammal indicators for the ESR.

We recognize the effort and commitment of all involved, and appreciate their contributions to this ESR.

Contributed by: Ivonne Ortiz
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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 at: http://access.afsc.noaa.gov/reem/ecoweb/index.php

Biophysical Synthesis

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Last updated: October 2022

Climate Summary A variety of sea level pressure (SLP) distributions relative to their seasonal norms occurred in the North Pacific atmosphere-ocean climate system during autumn 2021 through summer 2022. Lower than average SLP in the Gulf of Alaska (GOA) during autumn 2021 was accompanied by northwesterly wind anomalies and cooling on the southeast Bering Sea shelf; a transition to strongly positive SLP anomalies south of the GOA during the winter of 2021–22 resulted in a reversal in the wind anomalies for much of the North Pacific. Mostly positive SLP anomalies prevailed in the middle latitudes of the North Pacific accompanied by positive sea surface temperature (SST) anomalies. The presence of relatively cool to near-average SSTs in Alaskan waters from late 2021 into 2022 for the most part follows a multi-year interval of mostly above-average temperatures. It is unclear the extent to which the atmospheric circulation of the North Pacific was impacted by external factors, but the period of interest here did include the co-occurrence of moderate La Niña conditions in the tropical Pacific. The PDO was negative, in large part due to long-standing positive SST anomalies in the western and central North Pacific. The climate models used for seasonal weather predictions indicate that La Niña is more likely than not to persist through the remainder of 2022. These models as a group are indicating SST distributions in early 2023 that include slightly warmer than average temperatures for the western AI.

Climate indices: The NPGO index has remained negative since late 2013, while the PDO changed to a negative phase in 2020 and the NPI has been positive (i.e. weak Aleutian Low) five out of the last 6 winters (except winter 2018-2019). Jointly, these indices suggest physical conditions that support increased zooplankton availability ((Bond et al., 2011; Goyert et al., 2018). These conditions in general have been suggested as favorable for seabird productivity.

Ocean Temperature: Long-term sea surface temperatures (1900-2022) show both summer and winter temperatures have been increasing across the Aleutians, particularly since the 1980s during the summer. These trends show at least a 1°C increase to date. Sea surface temperatures remained above the baseline mean (1985-2014) in all ecoregions. 2022 was the second warmest year on record following 2014. The western and central Aleutians were under a moderate to at times severe marine heatwave through August. For mid-depth and bottom temperatures, surveys since 2014 have generally been warmer than previous years with the exception of 1997 which was comparable with the thermal anomalies observed in 2014 and 2016. The 2022 AI profile suggests a return to slightly cooler conditions relative to 2016 and is similar to 2018, but is still amongst the warmer years from our record, with warm anomalies penetrating deeper and distributed more extensively across the Aleutian archipelago than in 2014.. The increased temperatures can increase metabolic rates, thus increasing the food required by fish. Likewise, higher temperatures have been documented to increase growth rates, and decrease incubation periods and zooplankton development, potentially impacting the phenology of various organisms and increasing the risk for mismatch between hatching/ larval periods and prey/ size spectrum availability.

Ocean transport: Winter to early spring EKE in 2022 in the western-most Aleutian box is near its long-term average but the EKE indices in the other central and eastern Aleutians are significantly above their mean seasonal cycles and long-term averages. In particular, winter to spring EKE in the eastern-most box is the 2nd highest in the record (only slightly below its value in 1997). This favors increased heat and nutrient fluxes.

Primary Production and Zooplankton: The available data indicate that chl-a was below average in the AI for much of spring 2022, with overall mean concentrations comparable to the previous two lowest years in the observed timeseries, 2016 and 2018. There is marginal evidence for a negative trend in spring AI chl-a across the MODIS time series, which would indicate a lower productivity. The copepod community size anomaly has been negative in each season sampled since summer 2016 (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.

Introduction

We provide an overview of the physical oceanographic conditions impacting the Aleutian Islands, describe conditions observed from fall 2021 through summer 2022, and place 2022 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. Climate Overview: Climate Indices
2. Regional Highlights
3. North Pacific Climate
4. Seasonal Projections of SST from the National Multi-Model Ensemble (NMME)
5. Long Term Sea Surface Temperatures
6. Regional Sea Surface Temperatures
7.Regional Mid Water and Bottom Temperature
8. Ocean Transport: Eddies in the Aleutian Islands
9. Primary Production: Satellite chl-a
10. Zooplankton; Continuous Plankton Recorder data

1. Climate Overview

Climate indices provide a means of characterizing the state of the North Pacific atmosphere-ocean system. The focus here is on five commonly used indices: the NINO3.4 index for the state of the El Niño/Southern Oscillation (ENSO) phenomenon, PDO index (the leading mode of North Pacific SST variability), North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO) and Arctic Oscillation (AO). The time series of these indices, with the application of three-month running means, from 2012 into spring/summer 2022 are plotted in Figure 7. Four indices are most relevant to the AI: the NINO3.4, the PDO and the NPI and the NPGO.

The NINO3.4 index has been negative from spring 2020 through summer 2022, with values commensurate with a La Niña of moderate intensity during the winter and spring of 2022. While a slow return to more normal conditions in the tropical Pacific is anticipated, it is more likely than not that at least weak La Niña conditions will remain into the upcoming winter of 2022-23. If so, that will be the third ENSO-negative winter in a row; that has occurred just twice before in the last 50 years.

The PDO continued to be in a negative phase following its strongly positive state during the major Northeast Pacific marine heat wave of (MHW) of 2014-16. The PDO attained a value less than -2 near the end of the 2021 calendar year, moderated during the winter and early spring of 2022, and then decreased again to a value of about -2 during summer 2022. As compared with the previous year, there was more or less persistence in the warm temperatures in the western and central portion of mid-latitudes of the North Pacific; the SST anomalies in the Alaskan waters portion of the PDO spatial pattern also contributed to the negative sense of the index in late 2021 and early 2022.

The state of the Aleutian low can be encapsulated by the NPI, with negative (positive) values signifying relatively low (high) SLP. The NPI has been positive from autumn 2021 into the following winter, with particularly large values from November 2021 through January 2022. A brief reversal occurred in February 2022, with the return of weakly positive values during the spring and early summer of 2022. The NPI has been positive during 5 out of the last 6 winters, with the exception being the winter of 2018-19. The systematically positive state of the NPI, i.e., weak Aleutian low is consistent with the overall decline in the PDO during the interval.

The NPGO has also been relatively persistent, with a long-term decline beginning in late 2012 resulting in consistently negative values since 2017. The negative phase of the NPGO is generally accompanied by warmer than normal upper ocean temperatures south of Alaska between 35 and 50°N and is associated with high SLP over the GOA and low SLP in the vicinity and northeast of the Hawaiian Islands. There was some moderation in the NPGO during the summer into early autumn of 2021, with the resumption of more negative values again late in 2021.

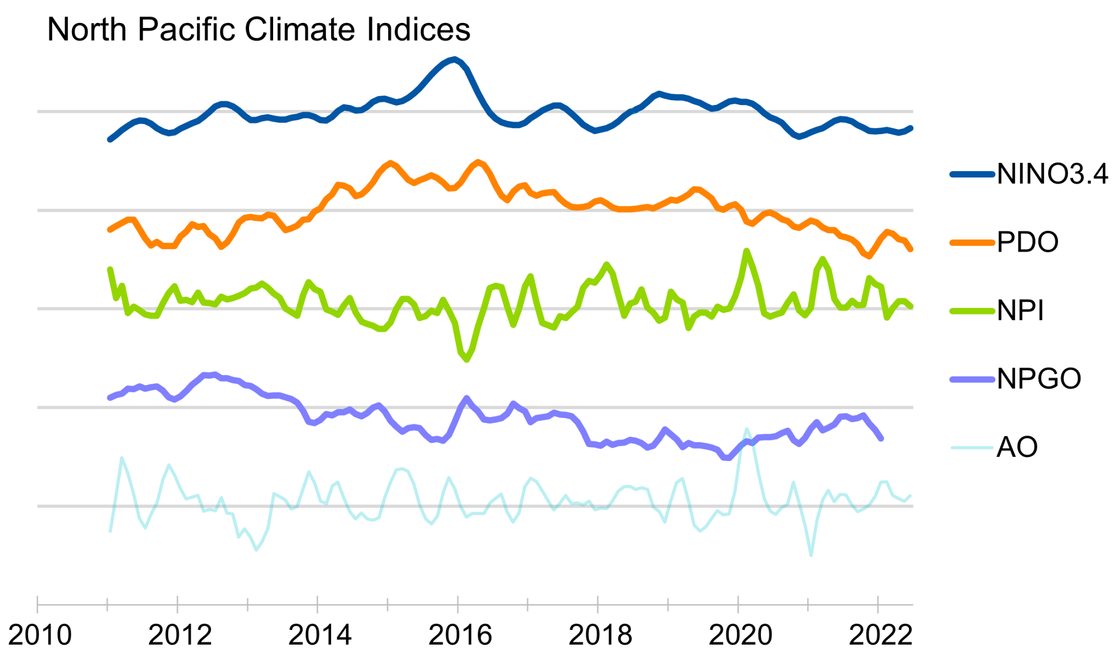


Figure 7: Time series of the NINO3.4, PDO, NPI, NPGO, and AO indices (ordered from top to bottom) for 2011–2022. Each time series represents monthly values that are normalized using a climatology based on the years of 1981–2010, and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 5 standard deviations. More information on these indices is available from NOAA's Physical Sciences Laboratory at `https://psl.noaa.gov/data/climateindices/`.

2. *Regional Highlights*

Aleutian Islands. The near-surface waters of the Aleutian Islands were generally warmer than normal, especially during winter 2021-22 and summer 2022 in the western portion of the chain. These warm waters were accompanied by relatively shallow upper mixed layer depths in 2022. The mean wind anomalies during the winter of 2021-22 were associated with enhanced northward flow through Unimak Pass.

Gulf of Alaska. The western portion of coastal GOA underwent a warming in early 2022 of about 1°C relative to seasonal norms to bring it to near normal temperatures by June 2022; a similar progression occurred in the eastern coastal GOA resulting in slightly above normal temperatures in summer 2022.The coastal GOA experienced a slow start to the wet season in autumn 2021, especially in the west, followed by a relatively wet winter and spring in 2022. Warmer than normal weather prevailed in the coastal GOA during summer 2022.

Alaska Peninsula. The coastal waters in the vicinity of the Alaska Peninsula were cooler than normal, based on averages for the period of 1991-2020, during the winter and spring of 2022, especially on the north side over the southeastern Bering Sea shelf. The cool waters are consistent with the cold air temperatures that occurred from November 2021 into February 2022, with the exception of a brief period of record-setting warm temperatures in late December 2021. The spring and summer air temperatures in 2022 were near seasonal norms in an overall sense.

Bering Sea deep basin. Warm air and upper ocean temperature anomalies prevailed in the western, deep portion of the Bering Sea during the winter and spring of 2022. The winter was also relatively stormy. Despite the enhanced wind mixing, the heat fluxes at the air-sea interface appear to have been weaker than normal, and upper mixed layer depths were less than normal in spring 2022, according to GODAS. This was especially the case in the southern portion of the Bering Sea basin. The waters in the western portion of this region off the east coast of the Kamchatka Peninsula remained warmer than normal through the summer of 2022.

3. North Pacific Climate

North Pacific Sea Level Pressure and Sea Surface Temperature Anomalies contributed by Nick Bond

The state of the North Pacific climate from autumn 2021 through summer 2022 is summarized in terms of seasonal mean sea level pressure (SLP) and sea surface temperature (SST) anomaly maps. The SLP and SST anomalies are relative to mean conditions over the period of 1991–2020. The SLP data are from the NCEP/NCAR Reanalysis project; the SST data are from NOAA's Extended SST V5 (ERSST) analysis. Both data sets are made available by NOAA's Physical Sciences Laboratory (PSL) at `https://www.psl.noaa.gov/cgi-bin/data/composites/printpage.pl`.

Status and Trends: Autumn (Sep—Nov, 2021): The SST anomaly pattern (Figure 8a) included prominent negative SLP anomalies in the northeastern Gulf of Alaska (GOA) extending southward off the coast of the Pacific Northwest, and weaker positive anomalies in an arc from the Sea of Okhotsk and western Bering Sea through the central North Pacific to the waters offshore of California. This SLP distribution resulted in anomalous winds from the northwest for the southeast Bering Sea shelf and enhanced storminess for the GOA.

The winter (Dec-Feb) of 2021-22 featured a large region of strongly positive SLP anomalies in the northeast Pacific centered south of the GOA, and much weaker negative SLP anomalies extending from the Sea of Okhotsk to the Hawaiian Islands. The accompanying wind anomalies included suppressed westerlies across the central and eastern North Pacific between roughly 25°N, 45°N (Figure 8 b), and was also associated with a dearth of landfalling storms into Oregon and California. On the other hand, enhanced westerlies were present across the eastern North Pacific farther north, implying anomalous equatorward Ekman transports in the upper ocean mixed layer.

Much weaker SLP anomalies in the mean were present in the NE Pacific during the spring (Mar-May) of 2022 (Figure 8 c). Higher than normal SLP occurred between roughly 25°N and 45°N across the basin with weak negative SLP anomalies in the GOA. The latter in combination with relatively high SLP in the northwestern Bering Sea resulted in anomalous winds from the north of about 2 m s^{-1} for the southeastern Bering Sea shelf.

The summer (Jun-Aug) of 2022 included mostly negative SLP anomalies in the mid-latitude North Pacific, with the exception of a region of positive anomalies located south of the Alaska Peninsula (Figure 8 d). The winds during this period included anomalies of about 1.5 to 2.5 m s^{-1} from the northwest in the western Aleutian Island region, and southerly (downwelling-favorable) anomalies of about 2 m s-1 along the coast of Northern California and Oregon; generally weak wind anomalies prevailed in the eastern Bering Sea and GOA.

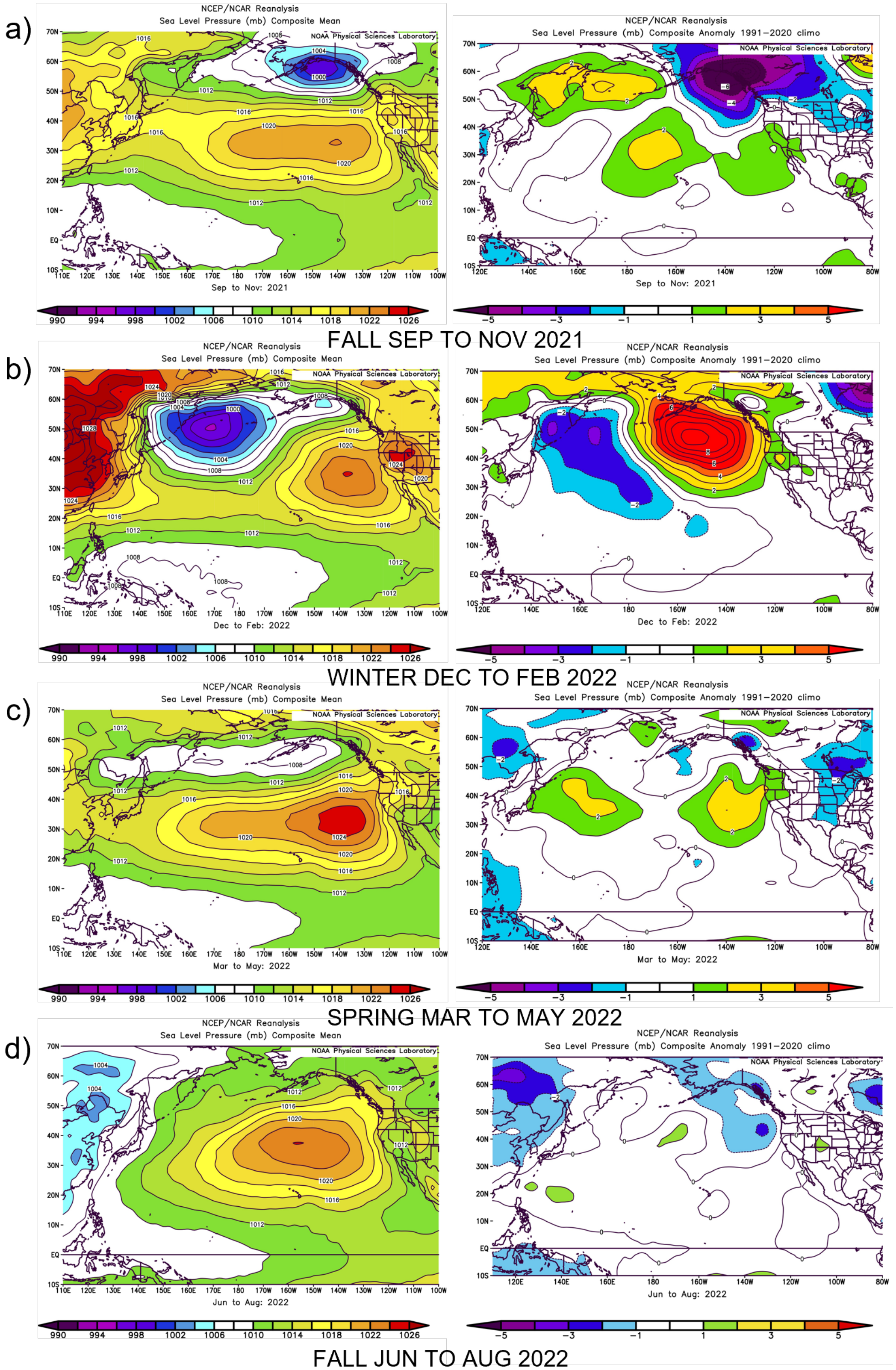


Figure 8: Left, right, Top to bottom: SLP mean and anomalies (hPa) for September-November 2021, December 2021-February 2022, March-May 2022, June-August 2022.

The SST anomaly pattern during autumn (Sep-Nov) of 2022 (Figure 9) included cooler than normal SSTs for the GOA and the sub-tropical North Pacific from the Hawaiian Islands to California; warm water with peak anomalies exceeding 2°C was present in the central North Pacific between about 25°N and 45°N. The central and eastern tropical Pacific was cooler than normal in association with weak-moderate La Niña conditions.

The overall distribution of SST anomalies persisted through the winter (Dec-Feb) of 2021-22 (Figure 9). This period did feature development of quite cold SSTs in the southeastern Bering Sea shelf, with temperatures on the inner shelf more than 2°C colder than normal. La Niña remained present, with the most prominent anomalies occurring in the eastern tropical Pacific.

The large-scale SST anomaly pattern for the North Pacific was more or less static through spring (Mar-May) of 2022 (Figure 9). There were some changes since the previous season including intensification of the warm anomaly in the waters north of the Hawaiian Islands, a decline in the magnitude of the negative anomaly on the southeastern Bering Sea shelf, and essentially elimination of the cold water in the GOA. La Niña continued in the tropical Pacific.

The summer (Jun-Aug) of 2022 brought modest warming of the waters offshore of western North America from Northern California to the Bering Sea (Figure 9). This warming can be attributed in part to the aforementioned downwelling favorable winds along the coast of the Pacific Northwest, and relatively warm weather/air temperatures in coastal Alaska. The tropical Pacific remained cooler than normal, with the most prominent anomalies near the dateline.

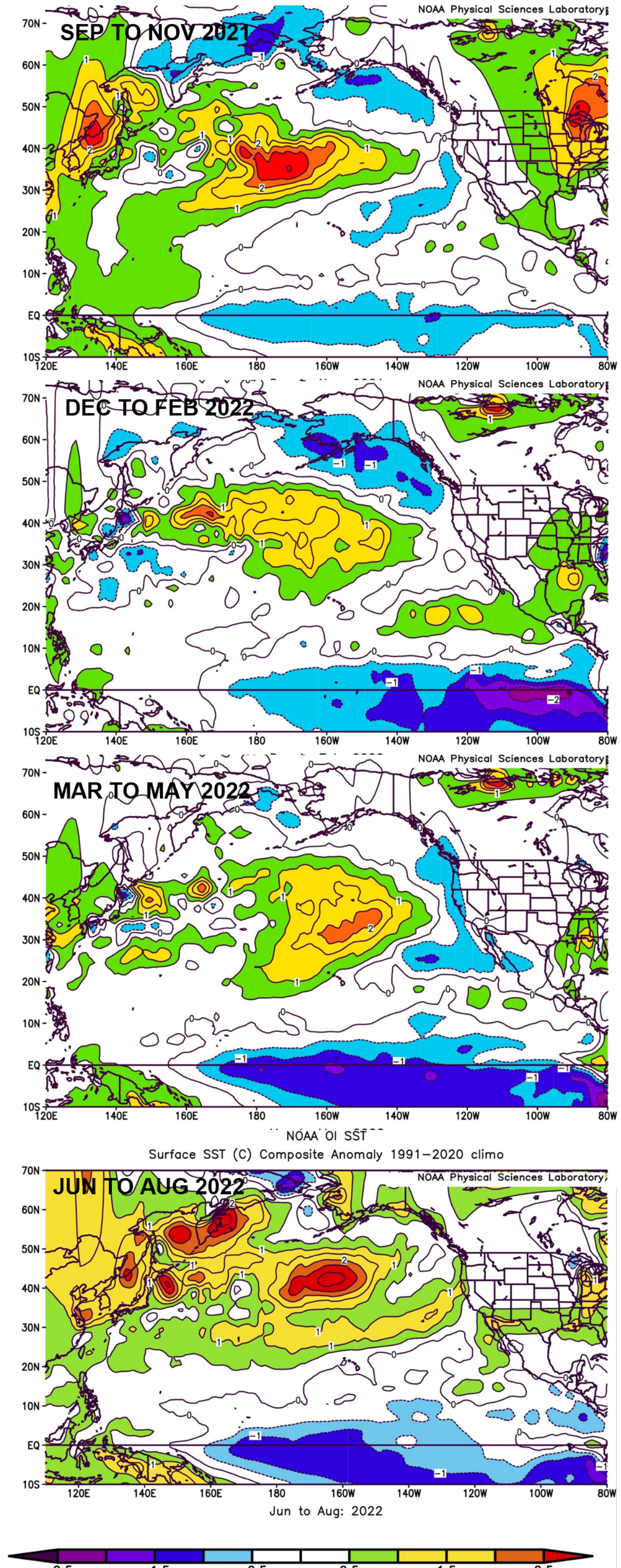


Figure 9: SST anomalies for autumn (September–November 2021), winter (December 2021–February 2022), spring (March–May 2022), and summer (June–August 2022).

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

Seasonal projections of SST from the National Multi-Model Ensemble (NMME) are shown in Figure 10a–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[3].

Status and Trends: These NMME forecasts of three-month average SST anomalies indicate a continuation of a large region of relatively warm water in the central and western North Pacific through the end of the calendar year (Oct-Dec 2022; Figure 10). Near-average temperatures are predicted for Alaskan waters with the exception of the western Aleutian Islands, where positive anomalies are predicted. The models also are indicating an atmospheric circulation pattern that would bring enhanced storminess to the GOA. The ensemble of model predictions for December 2022 through February 2023 is quite similar to that of the earlier period, with the exception of cooling for the GOA (Figure 10 as compared with climatological norms. This change is consistent with what has occurred in past La Niña winters; the models as a group are predicting tropical Pacific temperatures commensurate with a weak-moderate La Niña. The projection for February through April of 2023 features a rather static pattern in the SST anomalies aside from weakening of the equatorial Pacific cold anomalies.

The Aleutian Low tends to be weaker during La Niña years, and the ongoing La Niña is forecasted through February 2023, with a breakdown of the cold phase into next Spring, and a 54% chance for ENSO-neutral in February–April 2023[4].

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

[4] https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.shtml

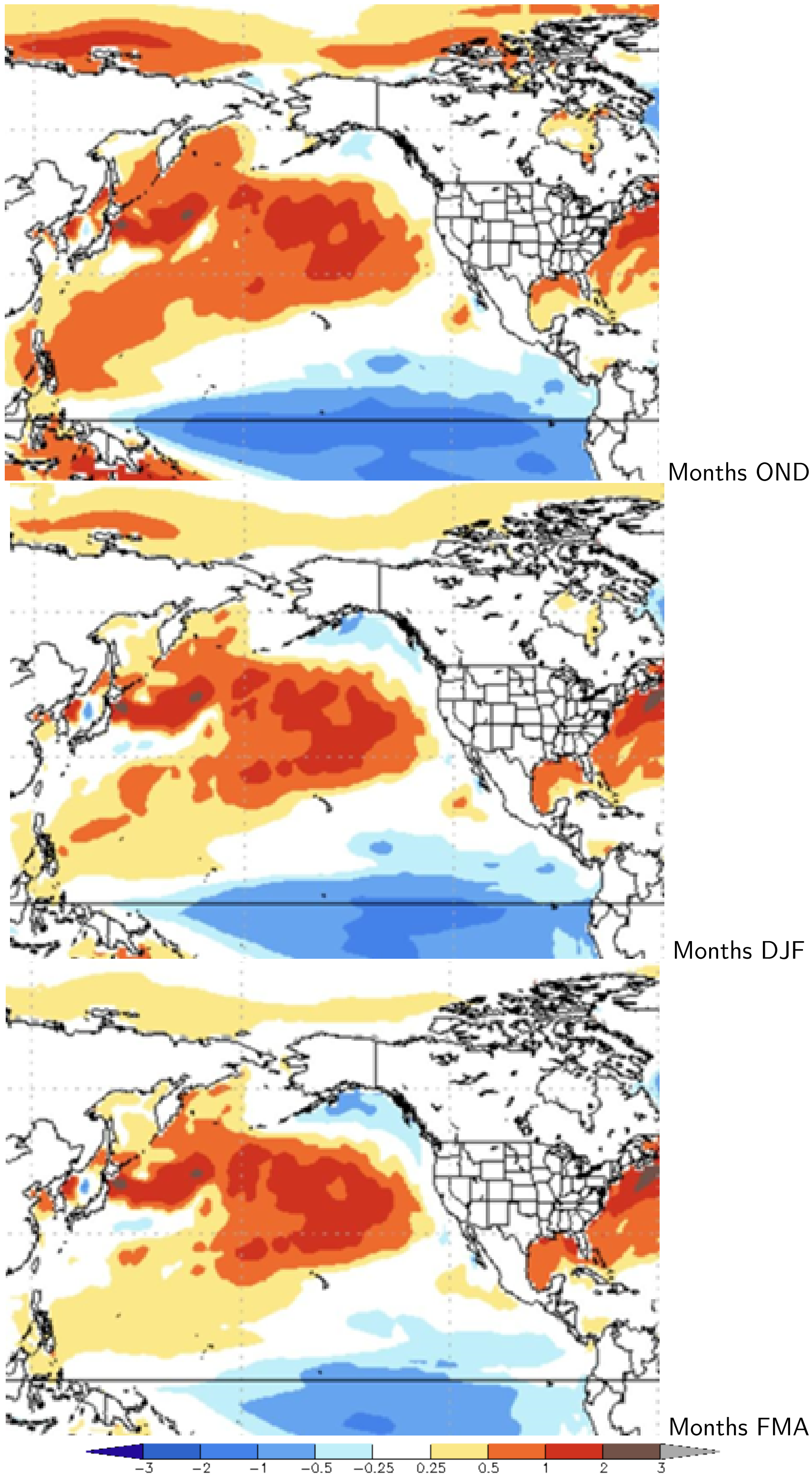


Figure 10: Predicted SST anomalies from the NMME model for OND (1-month lead), DJF (3-month lead), and JFM (4-month lead) for the 2021–2022 season.

5. Regional Long-term Sea Surface Temperature

Sea surface temperatures in the Aleutian Islands can be calculated using NOAA's Extended Reconstructed SST V5 data [5]. ERSST is a global monthly sea surface temperature dataset produced at 2 x 2 resolution starting in 1854. Statistical processes are used to 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 nd western AI separately, but regions were combined due to reduced subregional sample sizes and similar trends across the three ecoregions.

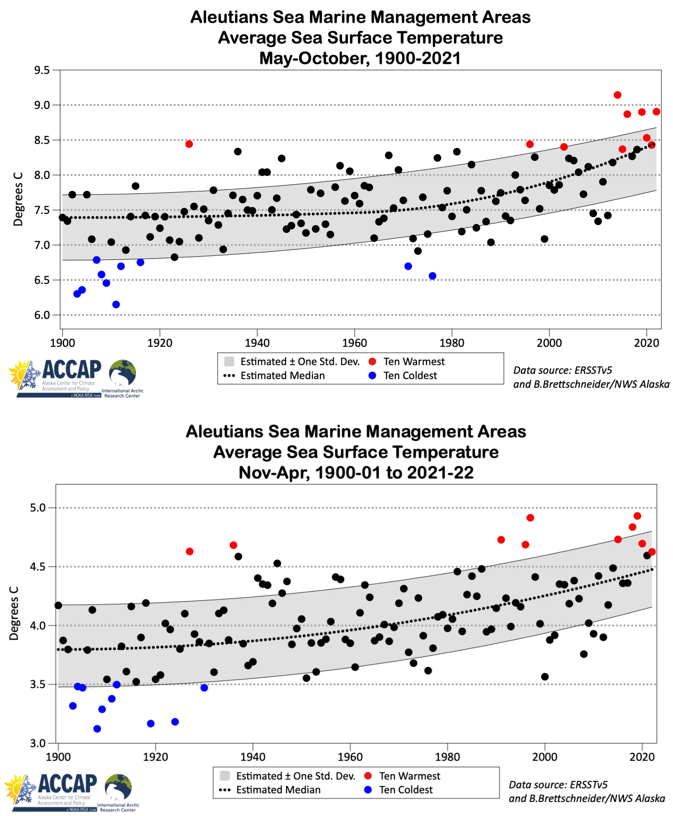


Figure 11: Sea surface temperatures for the Aleutian Islands from 1900–2022 for (a) summer (May–Oct) and (b) winter (Nov–Apr). Presented here are the quantiles representing ± 1 standard deviation of a Gaussian distribution and for completeness the median calculated using constrained B-Spline regression.

Status and Trends: Summer (May–Oct) sea surface temperatures (Figure 11 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 122 years.

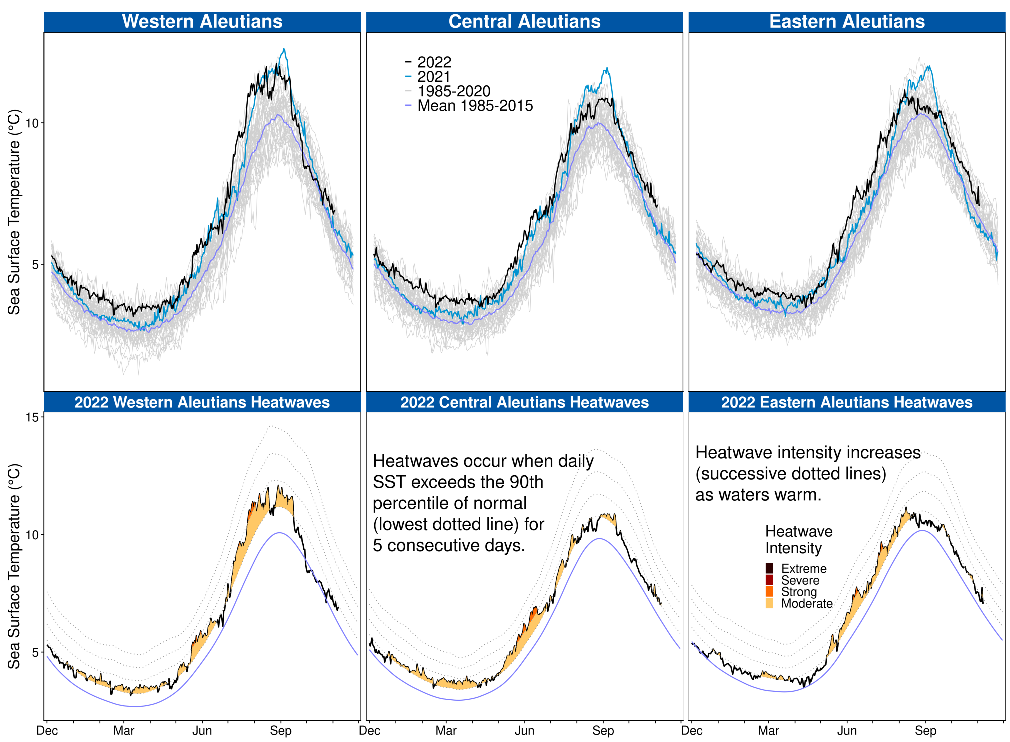
The surface waters in the Aleutian Islands have been warming since 1900. This analysis provides context for the short-term sea surface temperature time series presented elsewhere in this report (see Sea Surface Temperature, p.35). The seasonal difference in warming trends is not determined but could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

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

'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.

6. Regional Sea Surface Temperature and Marine Heatwaves

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 2006), feeding rates (Sanford 2002, Clements 2020), and food web composition (Barth 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 (Figure 12). 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.



NOAA Coral Reef Watch data, courtesy National Environmental Satellite, Data, and Information Service (Updated: 11-08-2022)
Data are modeled satellite products and periodic discrepancies or gaps may exist across sensors and products.
Contact: matt.callahan@noaa.gov

Figure 12: Annual sea surface temperatures and 2021 marine heatwave status for Aleutian Islands ecosystem regions. Data extends through September 17, 2021. Note that heatwave intensity is based on thresholds determined by the difference between the mean and the 90th percentile temperature (Hobday et al., 2018), thus while the September 2021 temperatures are the highest in the time series, the heatwave status is only "strong".

Satellite SST data (source: NOAA Coral Reef Watch Program) were accessed via the NOAA CoastWatch

West Coast Node ERDDAP server `https://coastwatch.pfeg.noaa.gov/erddap/griddap/NOAA_DHW.html` for April 1985–October 2022. Daily SST data were averaged within the western (west of 177°W), central (170°W–177°W), and eastern (165°W–170°W) Aleutian Islands. The earliest complete 30-year time series (1985 – 2014) was used as the baseline period for mean and standard deviation comparisons (see (Hobday et al., 2018; Schlegel et al., 2019) for discussions of baseline choices). 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 13). Detailed methods are online, including maps of the spatial strata and querying satellite data with R (`github.com/jordanwatson/EcosystemStatusReports`).

Warm water events have become so frequent in the world's oceans that a new method for describing them has been formalized and is widely used (Hobday et al., 2016). A MHW occurs when SST exceeds a particular threshold for five or more days. That threshold is the 90th percentile of temperatures for a particular day of the year based on a 30-year baseline (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 baseline ("normal") temperature for that day. When the threshold is exceeded, the event is considered moderate, strong (2 times the difference between the threshold and normal), severe (3 times the difference), or extreme (4 times the difference; Hobday et al. 2018). MHW indices were developed using the heatwaveR package (Schlegel and Smit, 2018). New this year, we also use MHW status at a 5x5 km resolution (source:`https://coralreefwatch.noaa.gov/product/marine_heatwave/`, aggregated within the AKFIN database) to examine the spatial extent of heatwaves within each region throughout the year.

Status and Trends

All three Aleutian regions experienced a warm 2022 with waters in or near MHW status beginning in winter and continuing through spring and summer (Figure 12). After a very hot summer in 2021, Fall temperatures were near normal but that reprieve from MHWs was short lived. At no point since December 2021 has the SST dipped below the seasonal average in any Aleutian region. MHW categories were predominately moderate, with strong MHWs appearing in May, June, and July.

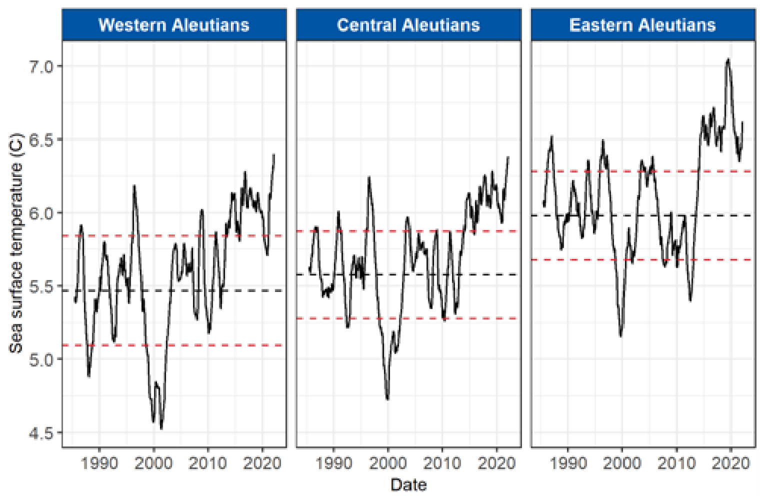


Figure 13: Time series trend (i.e., seasonality and noise removed) of sea surface temperatures. Horizontal dashed lines represent the mean (black) and standard deviation from the mean (red) during the earliest complete 30-yr baseline period (1985-2014). The trend is an annual moving average, with the latest date in March 2022, thus the current marine heatwave is not detected in this plot

Generally, all three regions have trended towards anomalously warm (>1 SD from the long term mean) conditions over the last 8 years (Figure 13). In 2022, both the western and central Aleutians have reached the highest annual moving average SST in the time series record (Figure 13). MHWs have occurred periodically throughout the SST time series but with greater frequency during the last few years (Figure 14). Though 2022 still has four months remaining, it already has the highest number of MHW days of any year in the central Aleutians and the 2nd highest in the western Aleutians. Of the three regions, the eastern Aleutians had the fewest number of MHW days in 2022

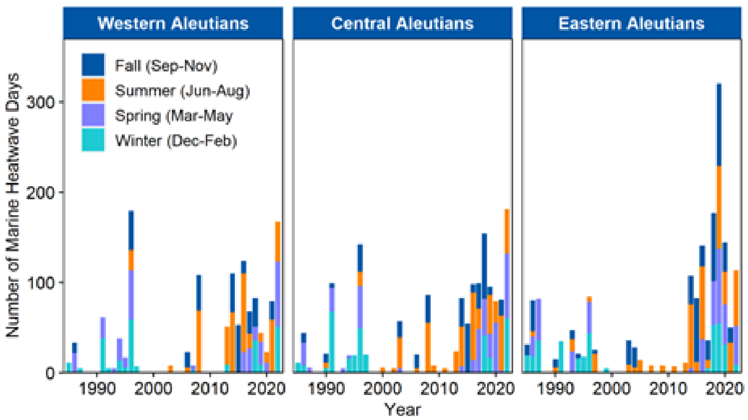


Figure 14: Number of days during which marine heatwave conditions persisted in a given year. Seasons are summer (Jun–Aug), fall (Sept – Nov), winter (Dec – Feb), spring (Mar – Jun). Years are shifted to include complete seasons so December of a calendar year is grouped with the following year to aggregate winter data (e.g., Dec 2020 occurs with winter of 2021). Data extends through August 31, 2022.

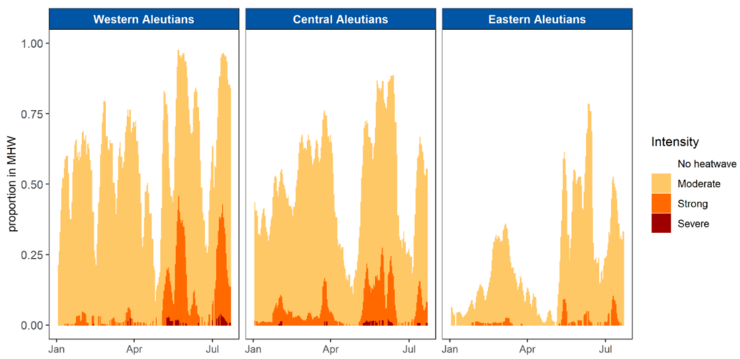


Figure 15: Proportion of region in heatwave status. Heatwave status calculations were performed on each 5 x 5 km grid cell within the Aleutian Islands. This figure shows a five day rolling average of the proportion of cells within each region that are in MHW status. Data extends through August 2022

MHWs may occur when a large portion of a region is in moderate heatwave status, or when a smaller portion of a region is in a higher MHW category (Figure 15).During parts of May and July, almost the entire western Aleutians was in MHW status. MHWs in the eastern Aleutians tended to be triggered by warm water in a smaller portion of that region. Also, while the average temperature is higher towards the eastern Aleutians, the variability in each region is very similar. This means the temperature triggering a MHW would be higher towards the east, but the probability of a MHW occurrence is similar across regions.

Factors influencing observed trends: Many factors can influence SSTs and the formation of MHWs, including a suite of weather, climatic, and oceanographic factors (Holbrook, 2019). Meanwhile, defining or contextualizing MHWs depends upon the selection of baseline years (1985–2014). As long term climate change leads to warmer temperatures, the baseline will change as well, requiring consideration of how baseline selection affects our interpretation of deviations from normal and thus, events like MHWs (Jacox et al., 2019; Schlegel, 2019). The more warm years that are included in the baseline, the warmer that baseline will appear.

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.

7. Mid-Water and Bottom Temperatures

Contributors Kevin Siwicke, Cecilia O'Leary, Ned Laman

LONGLINE SURVEY

Subsurface temperature can be a useful indicator for tracking long term ecosystem trends (i.e., static, cooling, or warming). The Alaska Fisheries Science Center (AFSC) has been conducting an annual longline survey since 1987 to sample groundfish from the upper continental slope annually in the Gulf of Alaska, during odd years in the Bering Sea, and during even years in the Aleutians. More details related to this survey can be found in Siwicke (2022). Beginning in 2005, a temperature (depth) recorder (TDR SBE 39 (Seabird Electronics) has been attached directly to the middle of the longline, with a second TDR being attached deeper starting in 2019. The TDR records water temperature and depth every 10 seconds, and the downcast is processed to 1-m increments via the double parabolic method used by the World Ocean Atlas 2018 ((Reiniger and Ross, 1968; Locarnini et al., 2019).

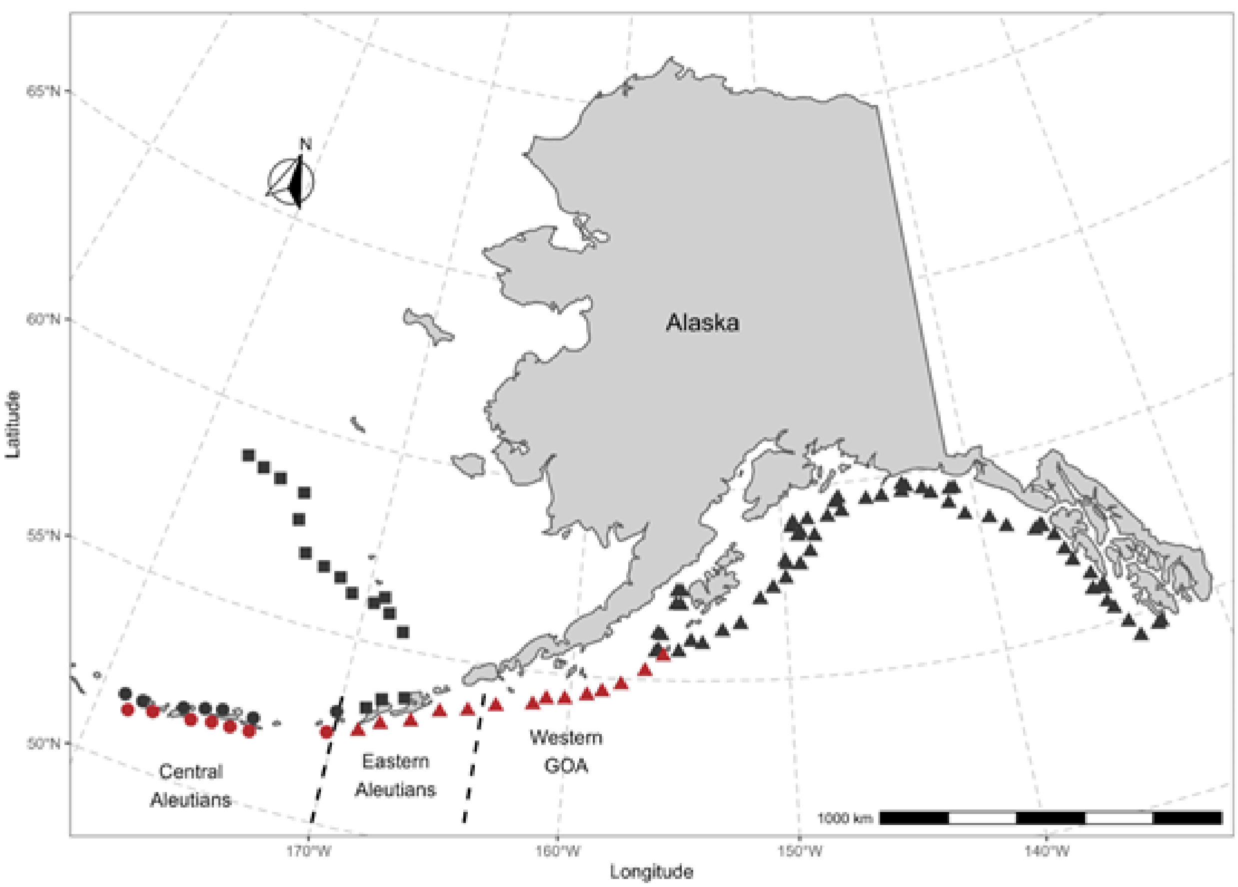


Figure 16: Longline survey in the Bering Sea (squares, odd years), the Aleutians (circles, even years) and GOA (triangles, every year). Stations shown in red are the ones used for the longitudinal comparison of mid-depth temperature from 180°W to 154°W

There are 22 stations sampled by the AFSC longline survey located within the Aleutians ESR region (14 in the central Aleutians and 8 in the eastern Aleutians, Figure 16). In even years, sampling begins from east to west on the north of the central Aleutian Islands, then west to east on the south of the central Aleutian Islands. Every year, four stations are sampled on the south of the eastern Aleutians Islands and continue to the Gulf of Alaska. Here we include the stations sampled south of Aleutians through the western GOA from 180°W to 154°W (Figure 16) for a longitudinal comparison of mid-water temperature along the continental slope (Figure 17).

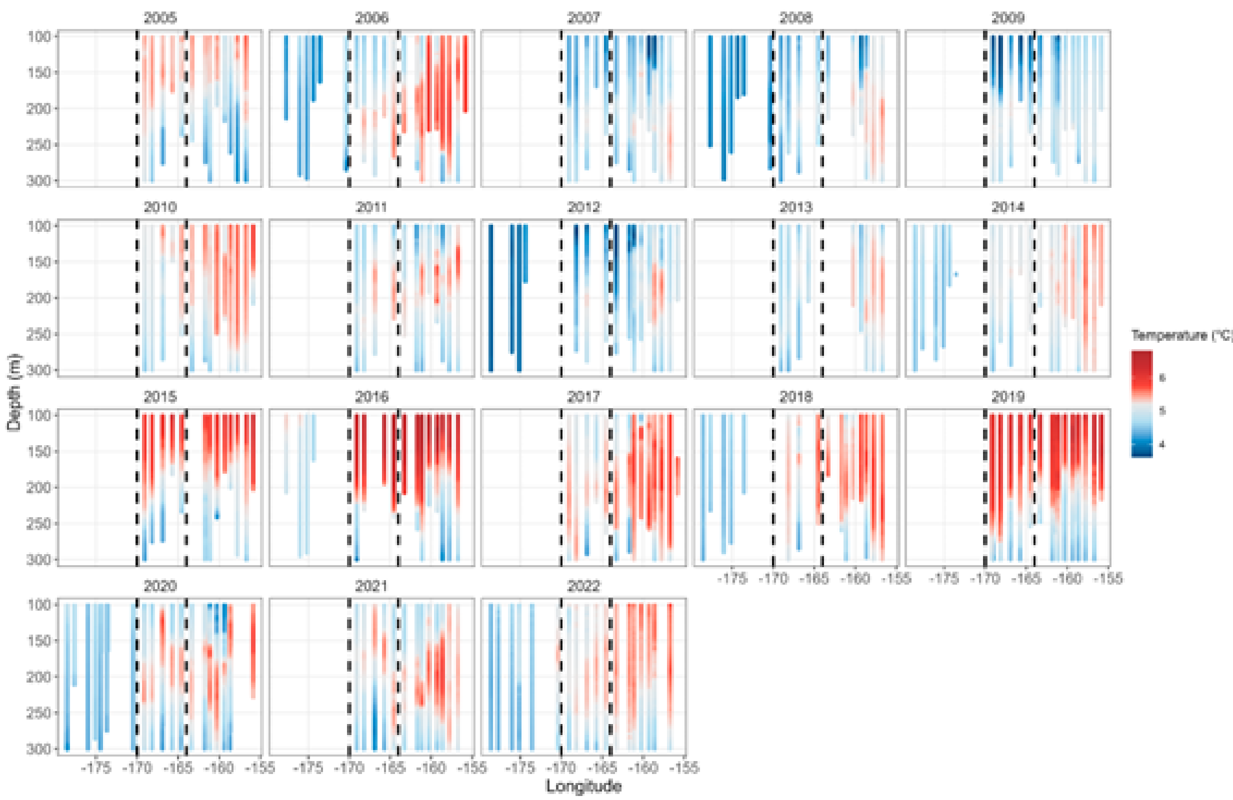


Figure 17: Temperature depth profiles (101–300 m) longitudinally along the continental slope for stations sampled during the first two legs of the longline survey and south of the Aleutian Chain. Vertical dashed lines at 170°W (-170) denote the boundary between the central and eastern Aleutians and 164°°W (-164) denotes the boundary between the eastern Aleutians and western Gulf of Alaska.

Status and trends: Longitudinal cross sections of temperature from 101-300 m depth along the continental slope south of the Aleutians show how water masses interact in this region (Figure 17). These temperature profiles are a snapshot from the month of June, and do not capture many of the dynamics of this region; however, they are representative of the thermal conditions that the survey experienced. As expected, there is a temperature gradient from east to west with colder temperatures towards the west. Although temperatures warmer than 6°C reached deeper than 100 m in the GOA during the 2014-2016 heatwave, this does not seem to be the case for water west of 170-172°W coinciding with Samalga and Amukta Passes (the easternmost deep wide pass) which are believed to be a biogeographical boundary (particularly the first one). This is most evident in 2020 when temperatures around 5°C were recorded east but not west of 172°W. However, waters west of 170-172°W seem to have remained warmer than temperatures seen in 2012 and earlier. Subsurface water temperatures in 2022 were similar in magnitude to 2021, continuing an extended period of above average temperatures, but note the warmer temperatures at mid-depth (200 m) in the eastern Aleutians, differs from the warmer waters on the surface in the western GOA

Factors influencing observed trends: Colder temperatures above warmer waters at 200 m were recorded through 2009 and in 2012, however this pattern changed in 2013 and seems to have remained.

Implications: Changes in vertical distribution of temperatures can affect vertical distribution of groundfish, impacting their availability as prey, but also their impact as predators. Changes in the vertical distribution of temperature can also create a mismatch between preferred seafloor habitat characteristics and preferred temperatures. The changes in temperature in general can affect primary and secondary productivity, which combined with changes in vertical distribution of groundfish can have cascading effects through the food-webs for fish, seabirds and marine mammals

TRAWL SURVEY WATER COLUMN AND BOTTOM TEMPERATURE

Since 1994, water temperature data have routinely been collected during the Aleutian Islands Bottom Trawl Survey conducted by the Alaska Fisheries Science Center Resource Assessment and Conservation Engineering Division Groundfish Assessment Program (von Szalay et al., 2017). There were three triennial AI bottom trawl surveys between 1994 and 2000; since 2000 the surveys have been conducted biennially (except in 2008 and 2020 when the AI bottom trawl surveys were skipped).

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) that is in use today replaced the Brancker XL200 data logger (Richard Brancker Research, Ltd., Kanata, Ontario, Canada) which had been in use since 1993. The analyses presented here utilize bathythermic data collected on AI bottom trawl surveys since 1994.

Historically, the RACE bottom trawl survey has begun in late spring (late May to early June) and proceeded 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., 2017). In 2002 and 2006, our typical sampling progression was partially reversed with the later season survey sweeping from west to east. 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 complicating inter-annual comparisons.

To account for the influence of changing day length on water temperatures over the course of the summer and to make inter-annual comparisons more meaningful, an attempt was made to remove the effect of collection date on water temperature by standardizing all RACE-GAP AI bottom trawl collection dates to a median survey date. This was achieved using generalized additive modeling (GAM) to estimate the effects of collection date on temperature at depth across survey areas and years. The resulting model was used to predict temperature at depth at the historic median survey day for all RACE-GAP AI survey trawl hauls of July 10. Residuals from this GAM were added to the predicted median day temperature-at-depth to produce estimates of thermal anomaly from the model prediction at each station in all survey years and plotted along the longitudinal span of the AI survey area. To facilitate visualization, these temperature estimates were averaged over systematic depth bins in $\frac{1}{2}$-degree longitude increments. Depth gradations were set finer in shallower depths and broader in deeper depths (e.g., 5 m bins between 0 and 100 m, 10 m bins between 100 and 200 m, and 100 m bins between 200 and 500 m) to capture the rapid changes anticipated in surface waters of temperature with depth. To further stretch the color ramp and enhance the visual separation of the near-surface temperature anomalies (between about 4 and 10°C and $<$ 100 m), predicted temperature anomalies $\geq$7.5°C and $\leq$3.5°C were fixed at 7.5 and 3.5°C (e.g., a 12.5°C temperature anomaly was recoded as 9.5°C for the graphic representation).

Status and trends: The warmest anomalies across the AI typically occurred near the surface (less than 50m) and their depth of penetration beyond the surface varied between years (Figure 18). During the warmest years in the record (2014 and 2016), the warmer anomalies penetrated to 100 m or deeper. There were also some temporally persistent and spatially consistent features in these anomaly plots. Warm, near-surface temperature anomalies were commonly found around the Island of Four Mountains, between Seguam Pass (173°W), Amchitka Pass (179°W), and west of Buldir Pass (175°E). Cooler temperatures were consistently observed at depths greater than 100 m near Seguam Island (172.5°W), which is a particularly striking feature during colder years (e.g., 2010, 2012). Warmer years were dominated not only by warmer surface anomalies, but by deeper penetration of warmer waters across the breadth of the archipelago. The last three survey years in the AI have generally been warmer than previous years with the exception of 1997 which was comparable with the thermal anomalies observed in 2014 and 2016. The 2022 AI profile suggests a return to slightly cooler conditions relative to 2016 and is similar to 2018, but is still amongst the warmer years from our record, with warm anomalies penetrating deeper and distributed more extensively across the Aleutian archipelago than in 2014. The marked differences amongst survey years and the warm and cold year patterns help to illustrate the highly variable and dynamic oceanographic environment found in the Aleutian archipelago.

Factors influencing observed trends: These observations and the thermal anomalies modeled from them represent a brief spatial and temporal snapshot of water temperatures collected during RACE-GAP bottom trawl surveys in the AI. Since each temperature bin represents data collected over a relatively short time as the vessels moved through an area, it is difficult to draw general conclusions, since short term events such as storms, tidal exchange, or freshwater runoff greatly affect local water temperatures.

More recent, and larger scale, phenomena may have longer-lasting implications on water temperatures in the region. The thermal signal caused by the "Ridiculously Resilient Ridge"[6] of atmospheric high pressure that helped to establish the persistent warm water "Blob" in the Northeast Pacific during 2014 and 2015 (Bond et al., 2015; Di Lorenzo and Mantua, 2016), and which likely intensified the El Niño Southern Oscillation (ENSO) event of 2015–2016 (Levine and McPhaden, 2016), probably influenced the temperatures observed on our 2016 survey. Daily plots of sea surface temperature anomalies (SST)[7] show warmer surface waters extending from east to west during the summer of 2016. Due to these and other sources of variation not accounted for in the temperature model presented here, here (e.g., these data are not corrected for tidal flux), caution should be exercised when interpreting these results.

Implications: Horizontal (Figure 18) and vertical (Figure 19)) temperatures appear to differentiate adequately between colder and warmer years in the series. During colder years (e.g., 2000 and 2012), the relatively homogeneous profiles, with warmer anomalies restricted to shallower depths and colder temperatures closer to the surface, suggest more pronounced thermal stratification and potentially a shallower mixed layer. Warmer years are characterized by deeper penetration and broader distribution of warm anomalies across the archipelago. Compared with other years in our record, the last four survey years (2014, 2016, 2018, 2022) suggests a warming trend in the AI.

The strength and persistence of various oceanographic features in the AI are anticipated to influence ecological processes there. The depth and horizontal dispersion of the mixed layer affect primary production in this region (Mordy et al., 2005). 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). Work on habitat-based delineation of essential fish habitat (EFH) in the AI and eastern Bering Sea have demonstrated that water temperature can be an important determinant of EFH for many groundfish species (Laman et al., 2017, 2018; Turner et al., 2017). Eddies are also believed to play a major role in the transport of both heat and nutrients into the Bering Sea through the Aleutian passes (Maslowski et al., 2008). Phenomena such as these must influence both AI and Bering Sea ecosystems and fish populations. By considering inter-annual differences in water temperatures and their implications, we can better utilize our survey data to understand the state of fish populations in the AI.

[6] "The extraordinary California dry spell continues: 2013 will probably be the driest year on record". http://www.weatherwest.com/archives/1021

[7] http://www.ospo.noaa.gov/Products/ocean/sst/anomaly/index.html

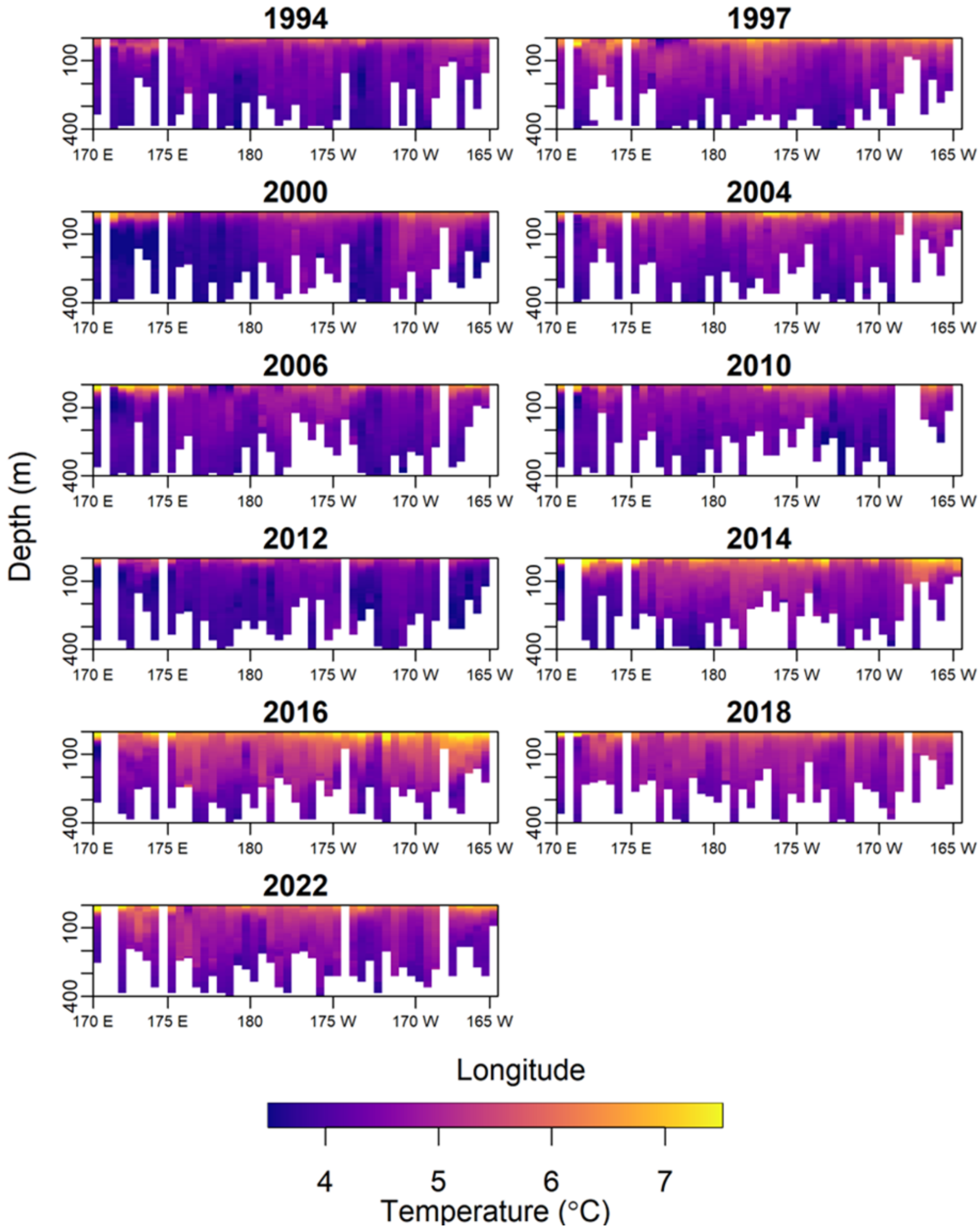


Figure 18: Median-survey-date-standardized, generalized additive model (GAM) predicted thermal (°C) anomaly profiles from water temperature measurements collected on Aleutian Islands [mostly biennial] bottom trawl surveys (1994–2018); to visually enhance near-surface temperature changes, values ≤3.5°C or ≥7.5°C were fixed at 3.5 or 7.5°C and the y-axis (depth) was truncated at 400 m though maximum collection depth was ca. 500 m.

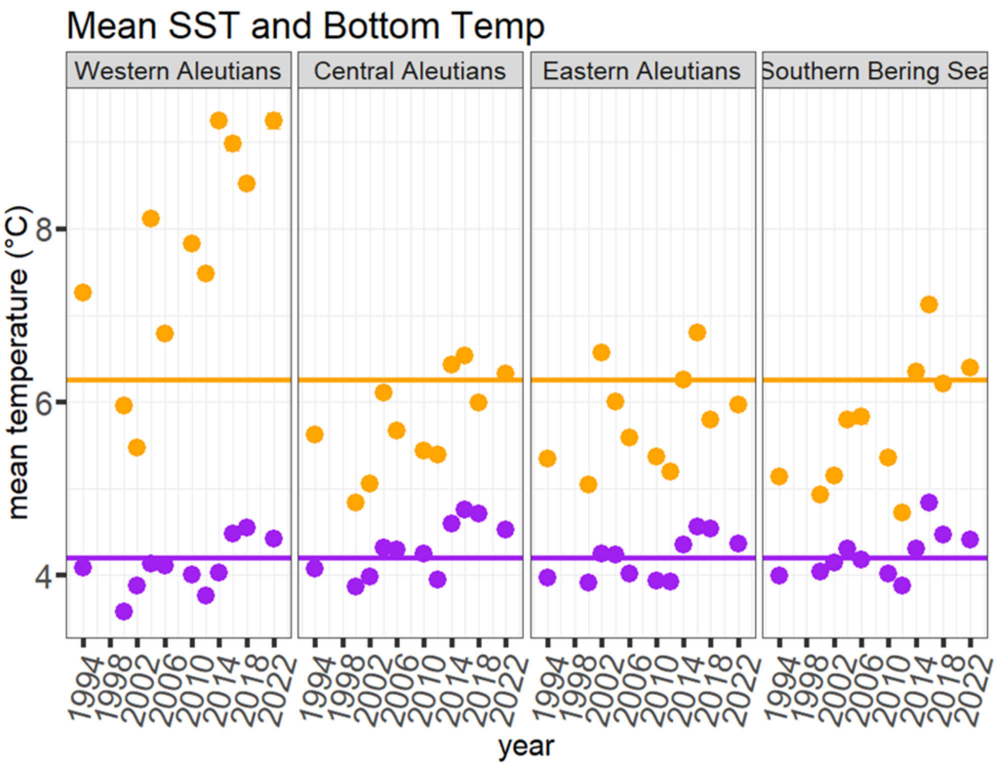


Figure 19: Mean annual sea surface (orange points) and bottom temperature (purple points; °C) from 1994 – 2022 from the Aleutian Islands bottom trawl surveys relative to the twenty year average sea surface or bottom temperature (orange and purple horizontal lines; 1994 – 2014). Error bars indicate the standard deviation around the annual average.

8. 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 20. Eddies in the Alaskan Stream south of the Aleutian Islands and east of ~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 20) 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 20). 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) (`http://www.marine.copernicus.eu`).

The most recent data were downloaded on August 8, 2022 so our daily time series now covers 1/1/1993 to 8/08/2022 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 20) and monthly climatology (Figure 21) shown below are averaged over 1993-2021 (period with full year coverage).

Status and trends: In the western Aleutian Islands, (Figure 21, top panel), EKE in months of 2022 is slightly lower but close to its long-term mean. This pattern has continued since the summer of 2020. EKE was low until 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 2017.

EKE north of the Aleutian Islands near Amchitka Pass in 2022 (Figure 21, middle panel)) was generally above its long-term average except for a brief period in early winter. Note this area is north of the AI chain and generally has lower EKE than the eastern and western boxes.

Particularly strong eddies were observed south of Amukta Pass (Figure 21, bottom panel) in 1997, 1999, 2004, 2006/2007, 2009/2010, and summer 2012. is significantly above long-term average from the 2nd half of 2021 to the 1st half of 2022, when an eddy passed by; right now it is slightly below average because the eddy has moved out of the box.

Factors causing trends: 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 decline trend since 2011), and it is unknown whether the relationship between mean

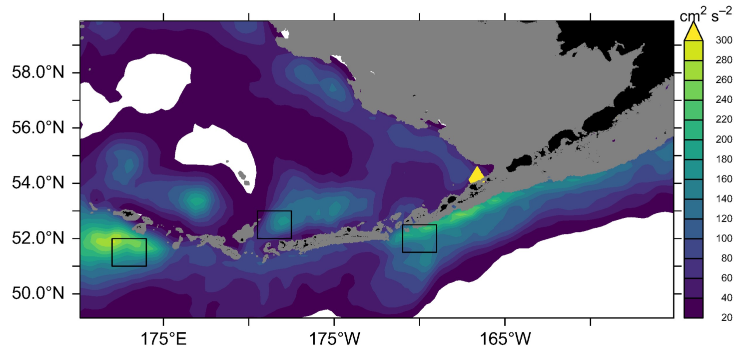


Figure 20: Eddy Kinetic Energy computed from satellite sea surface height (SSH) averaged over January 1st, 1993 – December 31st, 2021. Squares denote regions over which EKE was averaged for Figure 21.

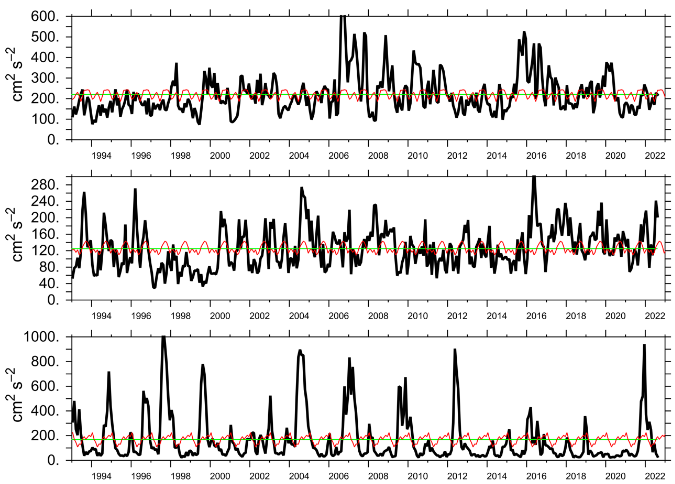


Figure 21: Eddy kinetic energy (cm^2 s^{-2}) averaged over boxes shown in Figure 20 (panels from the top to the bottom correspond to west to east boxes). Plotted are monthly EKE time series over the entire time period (black), monthly climatology of EKE (red) and the long-term mean of EKE (green straight line) averaged in year 1993-2021.

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. EKE is near or below its long-term average in 2021 in all regions along the AI chain even though the anomalies are not particularly strong, thus these fluxes likely have been smaller since fall 2012.

6. Primary Production: Satellite-derived chl-a

Contributed by Noel Pelland and Matt Calahan,

Description of Indicator: Surface chlorophyll ("chl-a"), often interpreted as a proxy of phytoplankton biomass or abundance in the surface ocean, can be an important indicator for bottom-up ecosystem processes and resources available at the base of the marine food web (e.g., Ware and Thomson (2005)). Previous ESRs for the Aleutian Islands (AI) have highlighted a need to better understand variability in surface chl-a, relationships to large-scale physical changes, and potential significance to the distribution, abundance, and reproductive success of higher trophic level organisms. This indicator focuses on the first of these needs, investigating chl-a in the AI at large spatial and temporal scales, during the spring and fall bloom.

Specifically, we show spatial averages of chl-a in non-coastal areas of the AI, along with spatial patterns of monthly chl-a deviations from climatology. These estimates are constructed from 8-day composite MODIS Aqua 4km chl-a images in April–June (spring) and August-October (late summer/fall), obtained from the NOAA CoastWatch West Coast Regional Node [8] from 2003 to 2022.

Data from each composite image are averaged within Alaska Department of Fish and Game Groundfish Statistical Areas [9] ("SAs"). SAs of area >2500 km2 only are retained for data availability. This excludes data in some shelf areas in the central and eastern Aleutians. Averages within SAs are then used to compute spatial averages across the AI in each 8-day image, along with a composite seasonal cycle of chl-a across years. Confidence bounds for 8-day averages within SAs, monthly anomalies within SAs, and average chl-a across the ecosystem overall, are based on bootstrap sampling of 8-day images that are fully resolved or nearly so.

As of the present update (8/18/22), MODIS data are unavailable for four images in Spring 2022 (4/11, 4/19, 6/22, 6/30) due to MODIS update issues and file formatting. We are in communication with CoastWatch while they update their files as available. Confidence bounds on mean anomalies within SAs in April and June 2022 are larger as a result of these missing data.

Status and trends: Though provisional, the available data indicate that chl-a was below average in the AI for much of spring 2022, with overall mean concentrations comparable to the previous two lowest years in the observed time series, 2016 and 2018 (Figure 22a, b). Although four weeks of the spring period are missing in 2022, examining previous years shows that the time period of the missing data (middle two weeks of April, latter two weeks of June) are not particularly likely to contain missing blooms; the period of climatological peak concentrations (late April through early June) is well resolved. However, this interpretation is of course subject to updating as additional data are processed. It is possible that blooms were missed in the images not yet obtained from MODIS.

The spatial structure of anomalies in May suggest that, even during periods when AI-average chl-a approached the climatological mean values in Spring 2022, this was the result of very high chl-a in a small portion of the ecosystem (in the Alaska Stream east of 187°E, and some areas south of this (Figure 23b) – most of the remaining area had negative anomalies. Monthly anomalies averaged by SA are mostly not significant in April and June 2022 (Figure 23a, c), reflecting the absence of two images in each month

In contrast, chl-a was above average in late summer/fall of 2021, similar to concentrations observed in fall of 2020 (Figure 22c,d). Above average chl-a was concentrated in the eastern AI in August (Figure 23d), in much of the AI south of the Aleutians in September (Figure 23e), and was moderately below average or near-neutral for much of the AI in October (Figure 23f).

At present (8/18/22) there is equivocal/marginal evidence for a negative trend in spring AI chl-a across the MODIS time series. With the provisional 2022 results, spring maximum spatial-average AI chl-a has a linear trend of -0.064 mg m^{-3} yr^{-1} ($r^2 = 0.252$, $p = 0.024$, two-sided t-test, 18 DOF), 2003-2022, while spring average chl-a has a trend of -0.014 mg m^{-3} yr^{-1}($r^2 = 0.183$, $p = 0.059$). These statistical tests do not take into account

[8] https://coastwatch.pfeg.noaa.gov/data.html
[9] https://www.adfg.alaska.gov/index.cfm?adfg=fishingCommercialByFishery.statmaps

uncertainty in the observations themselves (i.e., any confidence intervals around each year's maximum or mean spatial-average chl-a). This obviously bears continued monitoring as more MODIS data are processed, and also should be evaluated with OC-CCI delayed-time data when possible.

Factors causing observed trends: Light and nutrient availability, temperature, grazing pressure (Batten et al., 2018), turbulence intensity, and stratification are all significant factors that may affect phytoplankton growth, biomass, and chlorophyll concentrations. Specific factors that have skill in describing the AI chl-a time series shown in Figure 22 have not been identified at present. Further research would be needed to parameterize and explore previously-identified mechanisms acting specifically on chl-a, such as mixing in the Aleutian passes (Mordy et al., 2005).

The contrast between conditions observed in late summer/fall 2021, and spring 2022, is consistent with the lack of interannual correlation in chl-a between these two seasons noted in the 2021 AI ESR. As also noted in the 2021 ESR, negative spring chl-a anomalies in 2016 and 2018 were relatively spatially uniform (data not shown); the spring 2022 data that are available (Figure 23a–c) are generally consistent with this as well, suggesting large-scale forcing of these anomalies. Reasons underlying high chl-a in the Alaska Stream and far southeastern AI are unclear but may relate to advection or eddy-induced stirring and mixing (Prants et al., 2019).

Implications: The continued negative to neutral chl-a anomalies at large scales in the AI spring bloom period since 2016 warrant further monitoring and investigation. The broad correspondence between this period and the time period of elevated SSTs in the AI is clearly compelling and could be explored at finer scales for quantitative evidence. Elevated SSTs can enhance thermal stratification and consequently the amount of turbulence energy needed to mix the water column to an equivalent depth; this could have implications for nutrient supply to the surface ocean, which is one possible link to low chl-a.

It should be emphasized that at present, there is very limited understanding as to the bottom-up consequences of lower chl-a for zooplankton, forage fish, seabirds, and marine mammals in the AI. There is a suggestion in neighboring shelf ecosystems that fall chl-a can be important to overwinter survival of young-of-the-year forage fish (Ladd and Stabeno, 2012) but it is unknown if similar relationships occur in the AI.

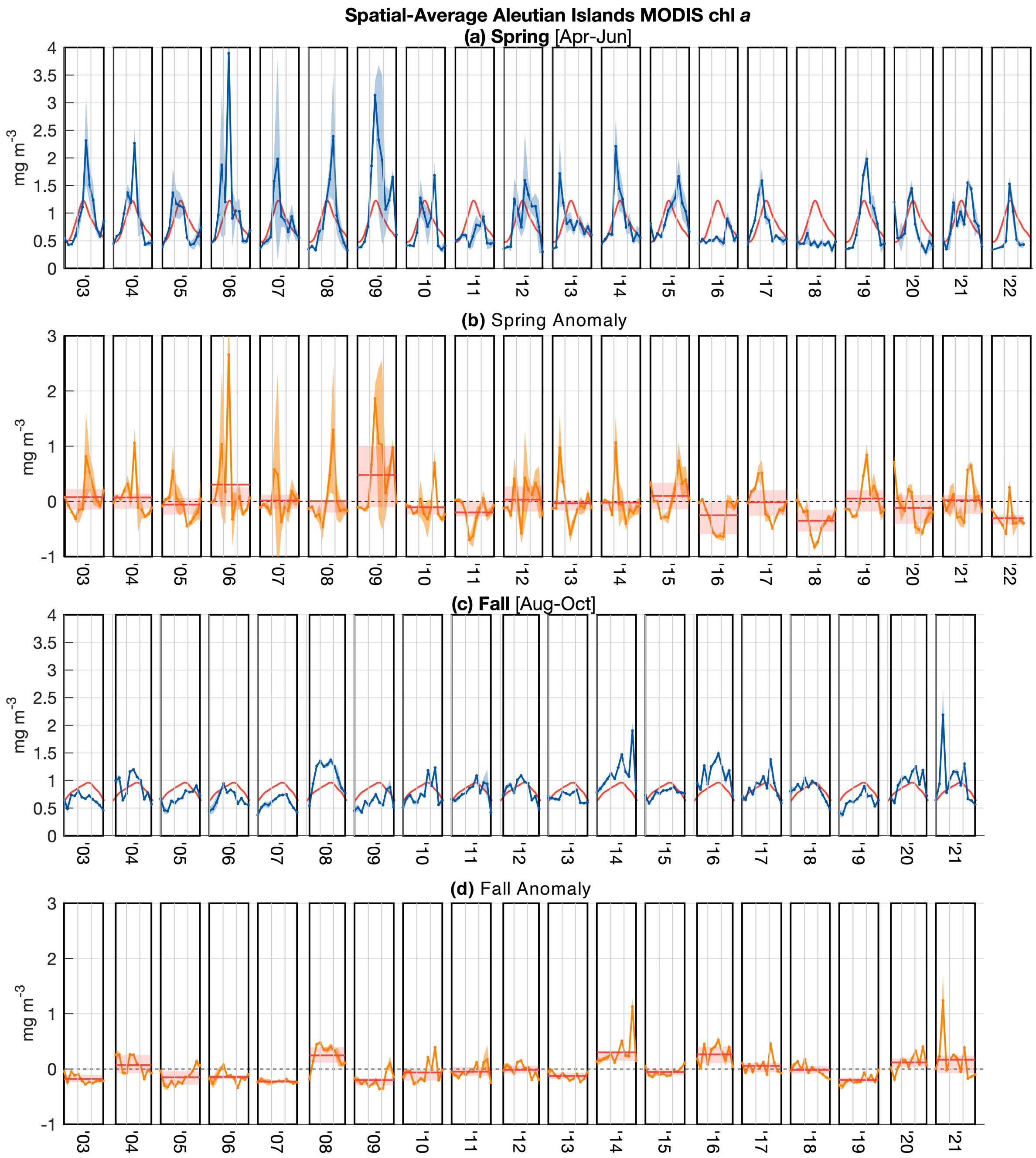


Figure 22: Time series of spatial-average Aleutian Islands chlorophyll a in MODIS 8-day composites, for the months of (a)-(b) April to June, and (c)-(d) August to October. Panels (a) and (c) show the full time series, while (b) and (d) show anomalies from a composite seasonal cycle (red line in (a)/(c)). In (b) and (d), red line and shading respectively indicate the mean and interquartile range of anomalies in each year. Gray shading indicates (preliminary) 95% confidence bounds. Light gray lines delineate monthly boundaries.

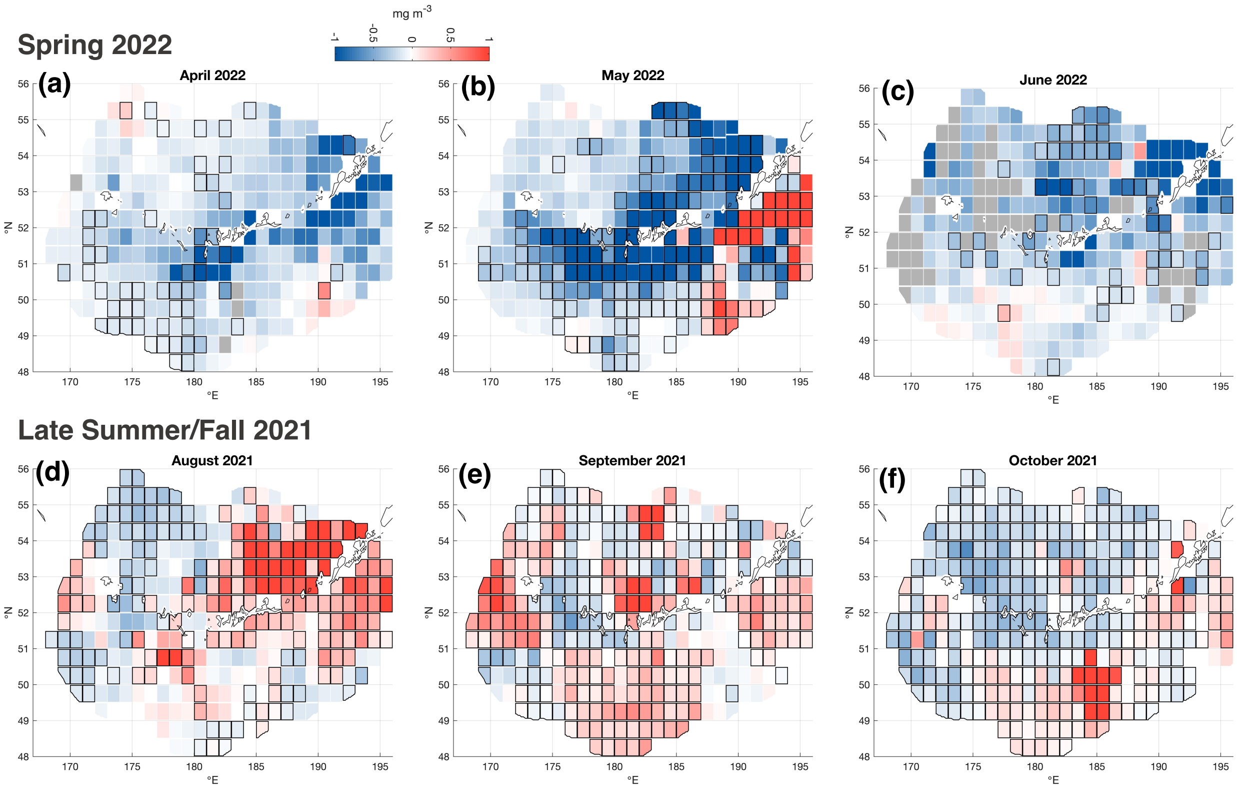


Figure 23: Spatial patterns in monthly-average anomalies from the seasonal cycle, April–June 2022 (top row) and August-October 2021 (bottom row). Anomalies are composed from data averaged with Alaska Department of Fish and Game Statistical Areas, restricted to areas of size >2500 square kilometers. Areas with a black boundary have a monthly anomaly exceeding the 95% confidence bounds. Gray shading indicates areas not sampled within a given month.

7. 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 24): 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 (geometric mean) is first calculated. Each sampled month is then compared to the mean of that month (calculated using the geometric mean) and an anomaly calculated (Log_{10}). 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.

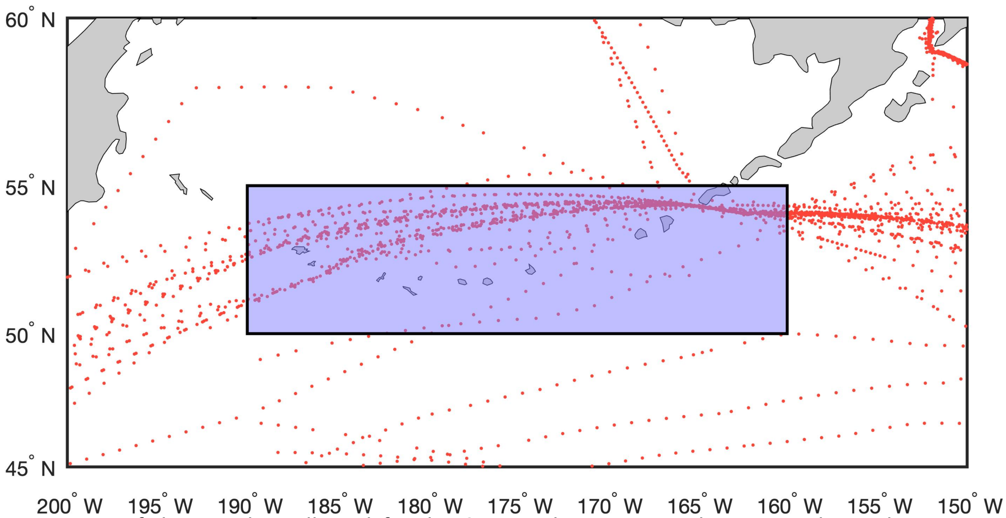


Figure 24: Location of the samples collected for the CPR analysis. Dots indicate actual sample positions and may overlay each other.

Status and trends: Figure 25 shows that the annual mesozooplankton biomass remained negative in 2021, but that the copepod community size and diatom abundance presented a positive annual anomaly. However the copepod community size was only slightly positive.

Factors influencing observed trends: 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 25 contains data from spring and autumn as well as summer the alternating pattern is clear. The zooplankton data in Figure 25 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 2016 (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 (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 availability of prey to predators.

Figure 25: Annual anomalies of three indices of lower trophic levels from CPR data (from top to bottom): Large diatom abundance, copepod comunity size and meso-zooplankton biomass (see text for description and derivation) for region shown in Figure 24.

Habitat

Structural Epifauna in the Aleutian Islands Ecosystem

Contributed by Ned Laman
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Last updated: October 2022

Description of indicator: Biota considered to be Habitat Areas of Particular Concern (HAPC) are structural epifauna that include groups of seapens/seawhips, corals, anemones, and sponges. The biennial RACE Groundfish Assessment Program (GAP) bottom trawl survey in the Aleutian Islands (AI) does not sample the density of HAPC fauna well, but does seem to capture spatial trends in presence or absence in areas surveyed (Rooper, et al., 2016; Rooper, et al., 2018). Survey effort in rough or rocky areas where these groups are likely to be more abundant is limited. The gears used by the Japanese vessels in the surveys prior to 1991 were quite different from the survey gear used aboard U.S. vessels in subsequent surveys, and so likely resulted in different catch rates for many of these groups. For each taxonomic group, the largest catch over the time series was arbitrarily scaled to a value of 100 and all other values were scaled to it. The standard error (± 1) was weighted proportionally to the CPUE to get a relative standard error. Sponges include unidentified Porifera, 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 pennatulaceans include sea pens and sea whips.

Status and trends: A few general patterns are clearly discernible (Figure 26). Sponges are caught in most tows >80%) in the AI west of the southern Bering Sea. Interestingly, the frequency of occurrence of sponges in the southern Bering Sea is relatively high, but sponge abundance is much lower there than to the west. The sponge estimates for the 1983 and 1986 surveys are much lower than other years. This lower sponge estimate is likely due to (1) the use of different gear in those years, including large tire gear that limited the catch of most sponges and (2) to inconsistencies in the resolve to identify and quantify sponges at that time. 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). The 2022 results suggest declines in the eastern and central Aleutians and a slight increase in the western Aleutians.

Soft corals occur in relatively few tows, except in the eastern AI where they occur in about 20% of tows. Their abundance time series is dominated by a couple of years (1986 in the western Aleutians and 1991 in the central Aleutians).

Sea anemones are also relatively common in survey catches ($\sim$20–40% of tows) but abundance trends are not clear for most areas. In the southern Bering Sea, abundance and frequency of occurrence of sea anemones in 2022 appears to be declining (western, central, and eastern Aleutians) or has stabilized at very low levels (southern Bering Sea). 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. In 2022, there were slight increases in the abundance of sea pens in the eastern AI and southern Bering Sea.

Factors causing the 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. 2018). 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, however, no studies have been conducted to determine potential recovery or expansion of populations due to the closures. As indicated by the 2022 bottom trawl survey, temperature time series (O'Leary, page 43), temperatures for the last four biennial surveys have been warmer than long-term historical averages. Non-motile HAPC organisms are sensitive to these changes in the benthic environment.

Implications: The RACE GAP AI bottom trawl survey is not particularly good at representing abundance trends for these groups of HAPC taxa. However, the bottom trawl surveys are reasonably adept at capturing presence or absence trends as indicated by recent distribution model validation studies for the species groups. The recent declines in sponge, gorgonians and hydrocorals in the western and central Aleutian Islands should continue to be monitored.

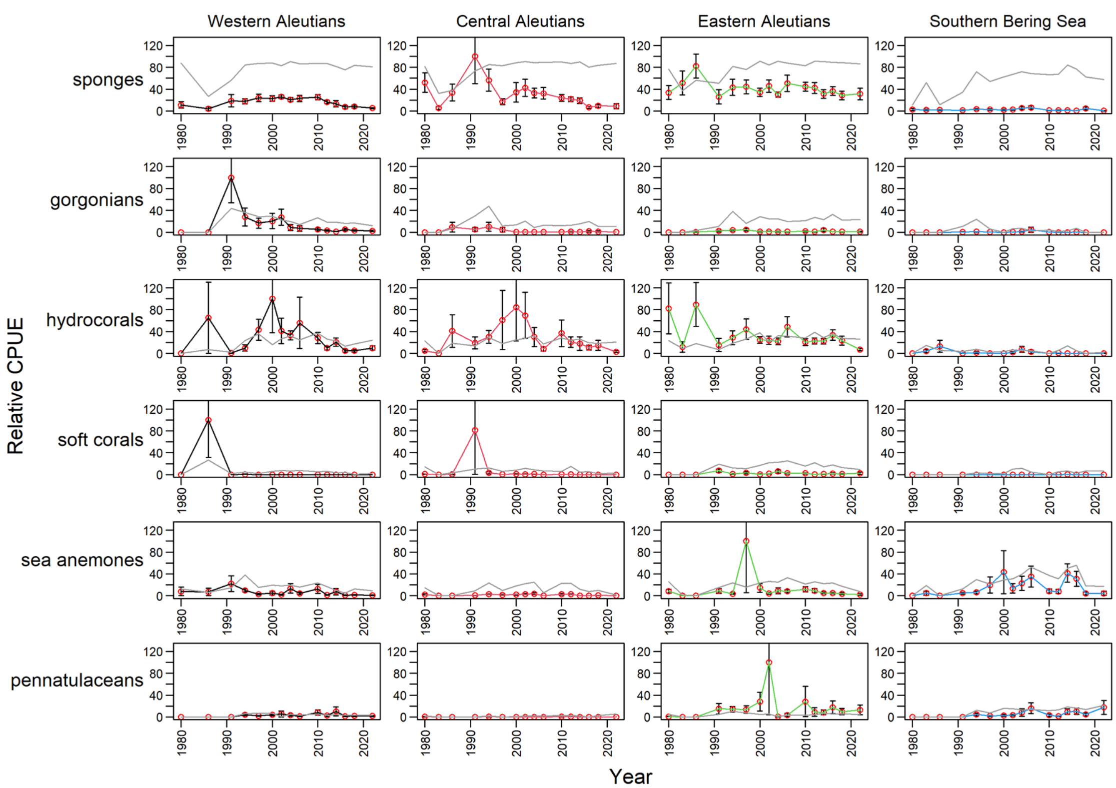

Figure 26: Mean CPUE of structural epifauna that form Habitat Areas of Particular Concern by area from RACE Groundfish Assessment Program bottom trawl surveys in the Aleutian Islands from 1980 through 2022. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches.

Jellyfish

Jellyfish in the Aleutian Islands

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Last updated: October 2022

Description of indicator: The RACE Groundfish Assessment Program (GAP) bottom trawl surveys in the Aleutian Islands (AI) are designed primarily to assess populations of commercially important fish and invertebrates. However, many other species are identified, weighed, and counted during the course of these surveys and these data may provide a measure of relative abundance for some of these species. Jellyfish are likely not sampled thoroughly and in a representative manner by our trawl gear due to their fragility and potential for catch in the mid-water during net deployment or retrieval. Therefore, jellyfish encountered in our trawl catches may or may not reflect their true abundance in the AI. The fishing gear used aboard the Japanese vessels that participated in all AI surveys prior to 1990 was very different from the gear used by all vessels since and likely influenced jellyfish catch rates on those surveys. Jellyfish catches in each year were scaled to the largest catch over the time series (which was arbitrarily scaled to a value of 100). The standard error ($\pm$1 SE) was weighted proportionally to the catch per unit effort (CPUE) to produce a relative SE. The percentage of catches with jellyfish present in the survey bottom trawl hauls was also calculated.

Status and trends: Jellyfish mean CPUE is typically higher in the western and eastern AI than in other areas (Figure 27). The frequency of jellyfish occurrence in trawl catches is generally from 20–60% across all areas, but has been variable. The 2006 AI survey experienced peak biomasses in all survey areas, whereas the 1992 survey had high abundance in the western AI only. Jellyfish CPUE and frequency of occurrence increased in 2022 relative to 2018. Frequency of jellyfish occurrence in trawl catches in 2022 exceeds that of the next highest previous survey (2016), but mean CPUE in 2022 remains below the 2016 CPUE levels.

Factors causing the trends: Unknown.

Implications: The 2022 increase in CPUE and frequency of occurrence of jellyfish is in contrast to the decline in occurrence and abundance between 2016 and 2018. Some of the warmest mean temperatures recorded on our AI surveys occurred in 2016 and 2018. While water temperatures were relatively cooler in 2022, the mean surface and bottom temperatures measured at the trawl net remained above the long term 20-year average. Temperatures are also indicative of water flow in the AI, where water movement is directly influenced by the Aleutian Passes so that it is difficult to attribute any one environmental factor to the patterns observed in jellyfish CPUE and occurrence.

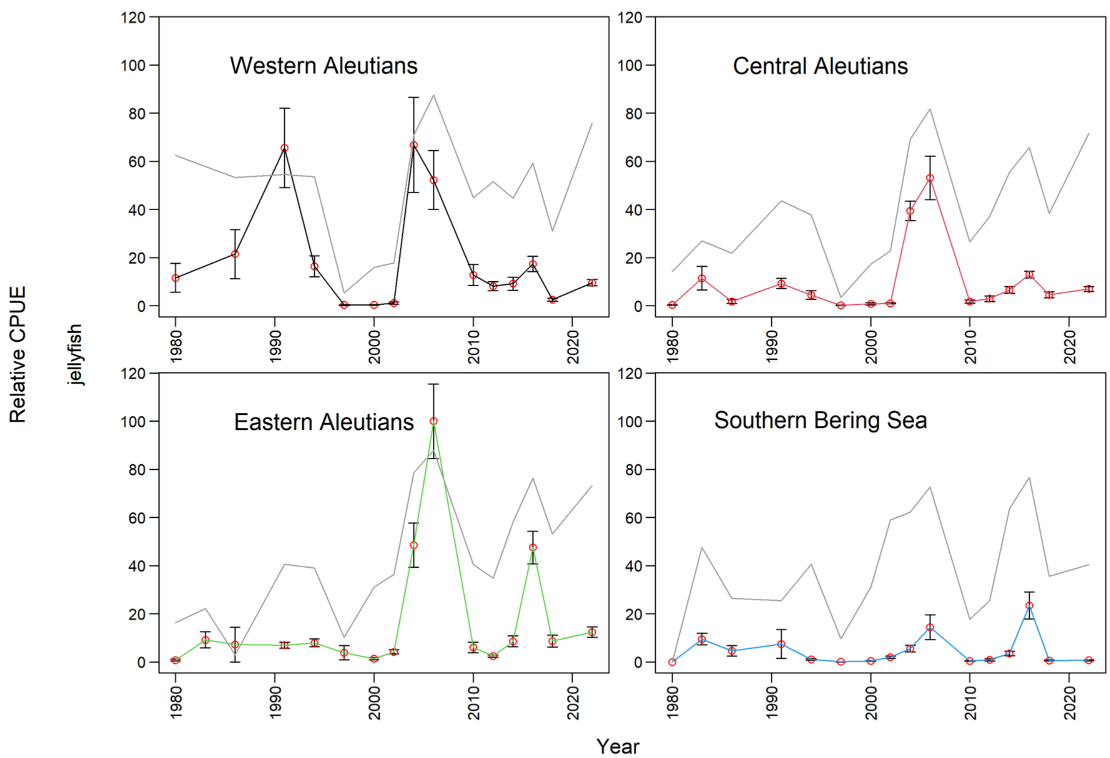

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Figure 27: Relative mean CPUE of jellyfish species by INPFC area from RACE Groundfish Assessment Program bottom trawl surveys in the Aleutian Islands from 1980 through 2022. Error bars represent relative standard errors. The gray lines represent the percentage of non-zero catches.

Salmon

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

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Last updated: 17 September 2022

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 155°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 (south of the Aleutian Islands). 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 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 28). 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 (33 million adults). From 2011 to 2021, abundance averaged 200 million salmon in odd-numbered years and 67 million salmon in even-numbered years. The largest run on record occurred in 2019 ($\sim$315 million adults), followed by the small run in 2020 ($\sim$29 million adult fish) that was less than recent even-year runs.In 2022, preliminary data indicate a run just above 100 million pink salmon, indicating a return to relatively large even-year runs for this region. During odd years (2015, 2017, and 2019), Eastern Kamchatka pink salmon represented 40% of total pink salmon returning from the North Pacific compared with 18% during even years (2016, 2018, and 2020).

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), of which approximately 75% were pink salmon (Ruggerone et al., 2021). Preliminary harvest data from Alaska and Russia (e.g. both eastern and western Kamchatka) suggest pink salmon abundance returning from the North Pacific in 2021 may have exceeded abundances in all previous years since detailed record keeping began in 1925. Furthermore, abundance of non-native pink salmon in the Atlantic Ocean continues to increase every odd-numbered year, raising concerns for native species (Hindar et al. 2020).

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). However, 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 followed by a return to typical even-year abundance in 2020

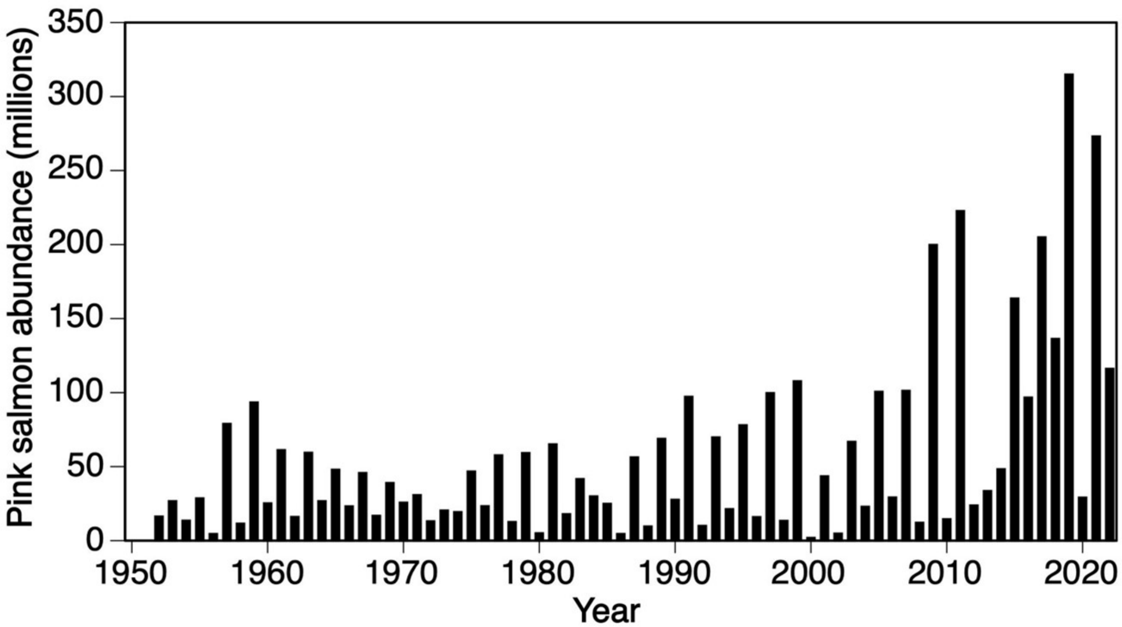

Figure 28: Time series of Eastern Kamchatka pink salmon abundance, 1952–2022. Values include catch and spawner abundances. Sources: (Ruggerone and Irvine, 2018), (Ruggerone et al., 2021). The 2022 value is based on preliminary harvest data (S. Zolotukhin, VNIRO, pers. communication).

(Figure 28). Odd-year abundances quickly recovered after 2013 to record numbers in 2019 and near record numbers in 2021.

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. 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. The 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), Yukon/Kuskokwim/Nushagak Chinook salmon (Ruggerone et al., 2016*b*), otolith growth of Atka mackerel (Matta et al., 2020), and reproduction of seabirds (Zador et al., 2013; 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.

Bristol Bay sockeye salmon, which inhabit the Aleutian Islands Ecosystem, was a primary exception to the unprecedented decline of all other salmon species in 2020. In 2020, harvests of Bristol Bay sockeye salmon were exceptional, and in 2021 Bristol Bay sockeye set a record high abundance (66 million adult fish; T. Sands, ADF&G, pers. communication). 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*a*). 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 greater early marine growth and survival in the warming Bering Sea, a benefit that overwhelms the adverse effect of pink salmon during later marine life (Connors et al., 2020).

Groundfish

Aleutian Islands Groundfish Condition

Contributed by Cecilia O'Leary and Sean Rohan[1], [1]Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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Last updated: October 2022

Description of indicator: Morphometric condition indicators based on length-weight relationships characterize variation in somatic growth and can be considered indicators of prey availability, growth, general health, and habitat condition (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 (Paul et al., 1997; Boldt and Haldorson, 2004).

The new model-based relative condition indicator (VAST relative condition) is the ratio of fish weight-at-length relative to the time series mean based on annual allometric intercepts, a_{year}, in the length-weight equation $W = aL^b$, W is mass (g), L is fork length (cm), i.e., condition=a_{year}/mean a. Relative condition greater than one indicates better condition (i.e., heavier per unit length) and relative condition less than one indicates poorer condition (i.e., lighter per unit length)

The historical length-weight indicator based on residuals of the length-weight relationship represents how heavy a fish is per unit body length relative to the time series mean ((Brodeur et al., 2004). Positive length-weight residuals indicate better condition (i.e., heavier per unit length) and negative residuals indicate poorer condition (i.e., lighter per unit length) (Froese 2006). Fish condition calculated in this way reflects realized outcomes of intrinsic and extrinsic processes that affect fish growth which can have implications for biological productivity through direct effects on growth and indirect effects on demographic processes such as, reproduction, and mortality (e.g., Rodgveller 2019; Barbeaux et al. 2020).

The model-based relative condition indicator was estimated using a spatiotemporal model with spatial random effects, implemented in the software VAST v3.8.2 (Grüss et al. 2020, Thorson 2019). Allometric intercepts, a_{year}, were estimated as fixed effects using a multivariate generalized linear mixed model that jointly estimated spatial and temporal variation in a and catch per unit effort (CPUE; numbers of fish per area swept). Density-weighted average a_{year} is a product of population density, local a, and area. Spatial variation in a_{year} was represented using a Gaussian Markov random field. The model approximates a_{year} using a log-link function and linear predictors (Grüss et al. 2020). Parameters were estimated by identifying the values that maximize the marginal log-likelihood.

The historical indicator was estimated from residuals of linear regression models based on a log-transformation of the exponential growth relationship for all years where data were available from 1984 to 2022. A unique slope (b) was estimated for each stratum to account for spatial-temporal variation in growth and bottom trawl survey sampling. Strata were delineated based on International North Pacific Fisheries Commission (INPFC) stratum boundaries for the Southern Bering Sea, Eastern Aleutian Islands, Central Aleutian Islands, and Western Aleutian Islands (Figure 29). Length-weight relationships for 100–250 mm fork length (1–2 year old) walleye pollock were established independent of the adult life history stages caught. Bias-corrected weights-at-length (log scale) were estimated from the model and subtracted from observed weights to compute individual residuals per fish. Length-weight residuals were averaged for each INPFC stratum and weighted in proportion to stratum biomass based on stratified area-swept expansion of summer bottom trawl survey CPUE. Average length-weight residuals were compared by stratum and year to evaluate spatial variation in fish condition. Combinations of stratum and year with <10 samples were used for length-weight relationships but excluded from indicator calculations.

Both condition factors were calculated for paired lengths and weights of individual fishes were examined from the Alaska Fisheries Science Center biennial Resource Assessment and Conservation Engineering (AFSC/RACE)

Groundfish Assessment Program's (GAP) bottom trawl survey of the Aleutian Islands (AI). Analyses focused on walleye pollock (*Gadus chalcogrammus*), Pacific cod (*Gadus macrocephalus*), arrowtooth flounder (*Atheresthes stomias*), southern rock sole (*Lepidopsetta bilineata*), Atka mackerel (*Pleurogrammus monopterygius*), northern rockfish (*Sebastes polyspinis*), and Pacific ocean perch (*Sebastes alutus*) collected in trawls with satisfactory performance at standard survey stations. (Figure 29).

Methodological Changes: The historical length-weight residual indicator (used in 2020 and 2021) and the new VAST relative condition indicator (Grüss et al., 2020) are both presented this year to allow comparison between methods. Overall, trends were similar between historical and new indicators based on the strong correlation ($r > 0.87$) between indicators for most species (Figs. 3–4). An exception to this strong correlation between the two indices was southern rock sole ($r = 0.57$), where there was a large difference between the historical and the new indices in 1998, a year when all length-weight samples ($n = 10$) were collected at a single station. Southern rock sole are almost exclusively caught in the southeastern Bering Sea in Aleutian years, a restricted spatial distribution likely impacting the historical condition indices and leading to a more precise current index as it accounts for spatially and temporally unbalanced sampling. Mean estimates and confidence intervals for the new condition indicator are likely more reliable than the historical indicator. The new indicator affords more precise expansion of individual samples to the population. Also, it accounts better for the spatially and temporally unbalanced sampling that is characteristic of historical bottom trawl survey data due to changes in sampling protocols (e.g., transition from historical sex-and-length stratified to current random sampling).

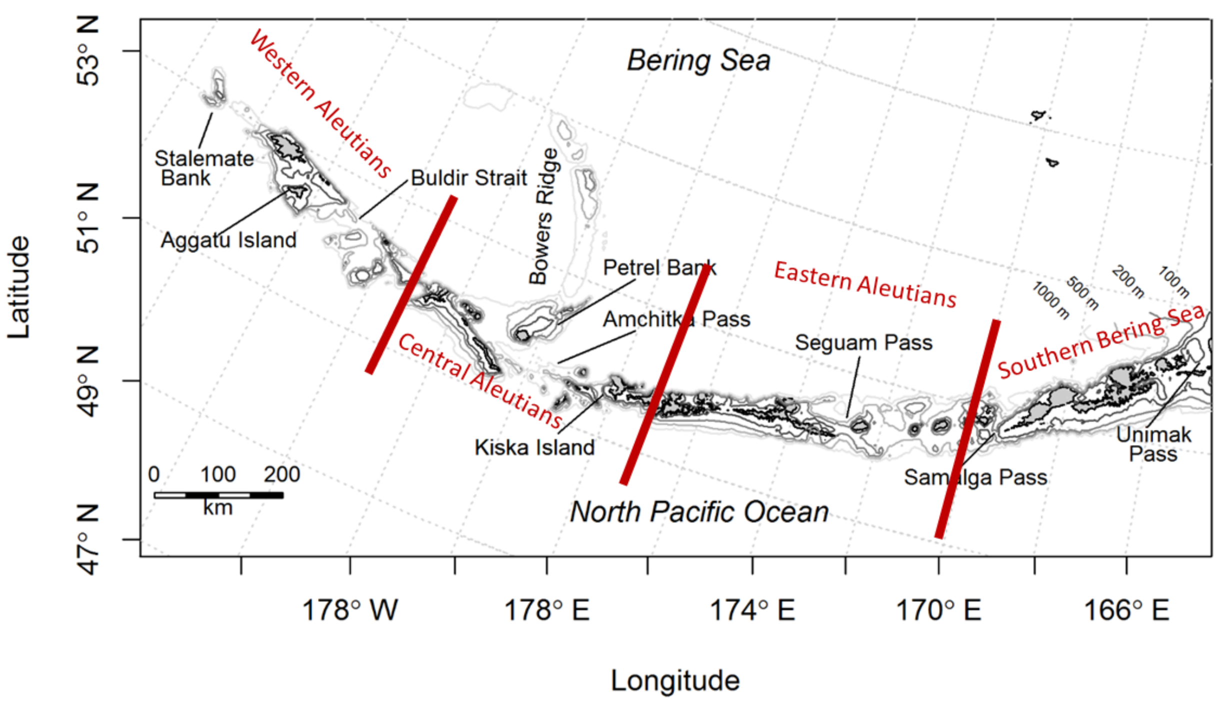

Figure 29: NMFS summer bottom trawl survey strata in the Aleutian Islands. Red lines demarcate Aleutian Islands INPFC Areas. The Central and Eastern Aleutians INPFC areas together correspond to the Central Aleutians ecoregion in this report. Similarly, the Southern Bering Sea INPFC area corresponds to the Eastern Aleutian ecoregion in this report.

Status and trends: Body condition varied amongst survey years for all species considered (Figure 30). Prior to 2010, the AI bottom trawl survey was characterized by condition cycling between positive and negative values through the years. Condition of most species since 2012 has primarily been below the long term average or neutral. Exceptions occur for 100–250 mm walleye pollock in 2016 and Atka mackerel in 2012 where the residual body condition is neutral or slightly positive. Overall, walleye pollock have fluctuated around the mean and are near the average in 2022. Walleye pollock > 250 mm had above average condition in 2010 and declined from 2010–2016, but were near average condition in 2018 and 2022. Atka mackerel showed above average condition in 2010, declined to below average by 2014, but have been near average since 2016. Southern rock sole residual body condition is trending positive in the Aleutians since 2012. Southern rock sole are near the time series mean in 2022. Pacific cod, northern rockfish, arrowtooth flounder, and Pacific ocean perch were above or near average condition in 2010, but subsequently had declining conditions through 2018. These species were in better condition in 2022 than 2018, but are still below their time series means. Notably, in 2022, residual body condition remained at neutral or became slightly more positive than the condition values since 2010 for all species considered, although the body condition of all species besides southern rock sole remain below the long term average for both the historical and model-based index.

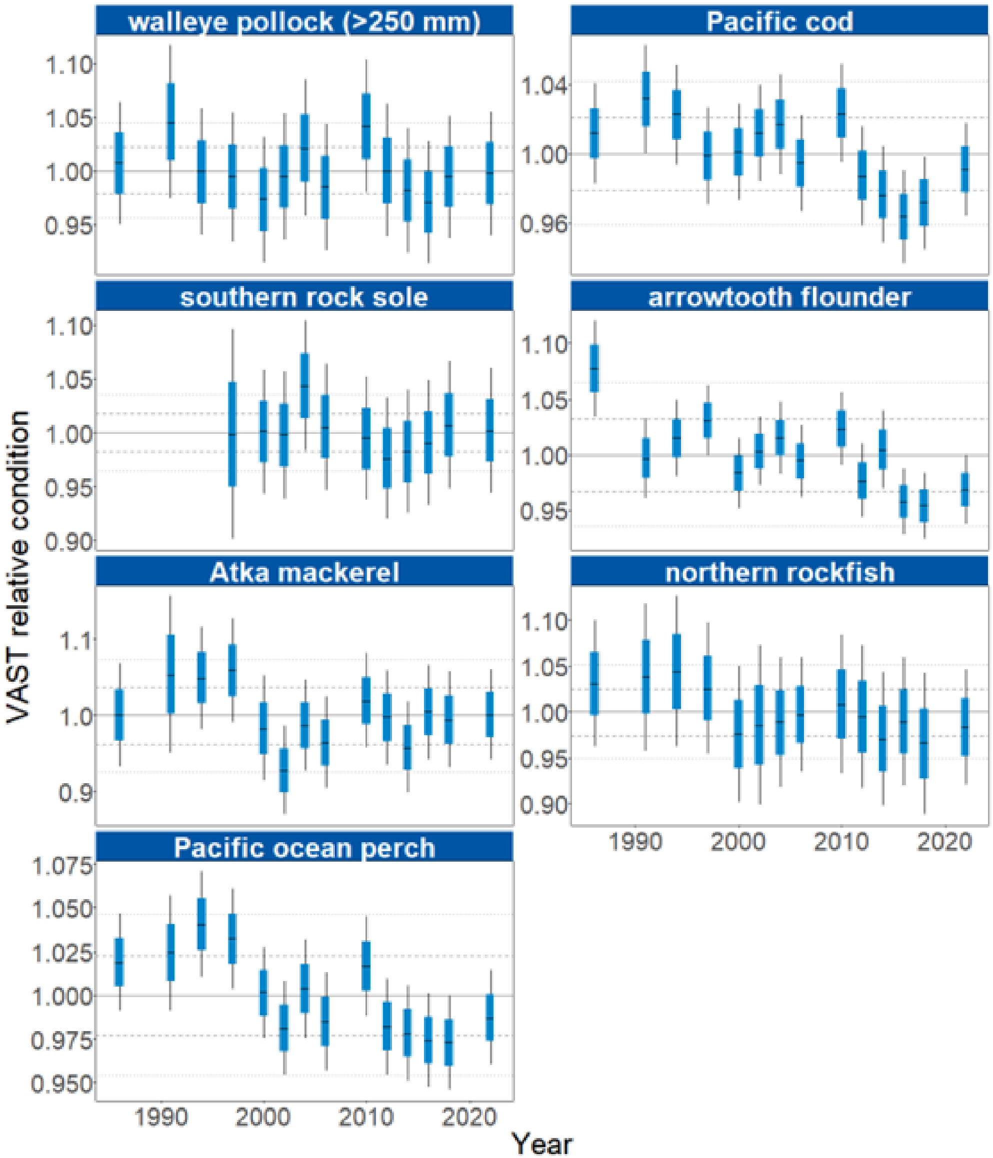

Figure 30: Weighted length-weight residuals for seven groundfish species collected during AFSC/RACE GAP standard summer bottom trawl surveys of the Aleutian Islands, 1986-2022. Filled bars denote weighted length-weight residuals using this year's indicator calculation. Error bars denote standard errors, thin black lines are 2 standard errors and thick blue boxes are 1 standard error

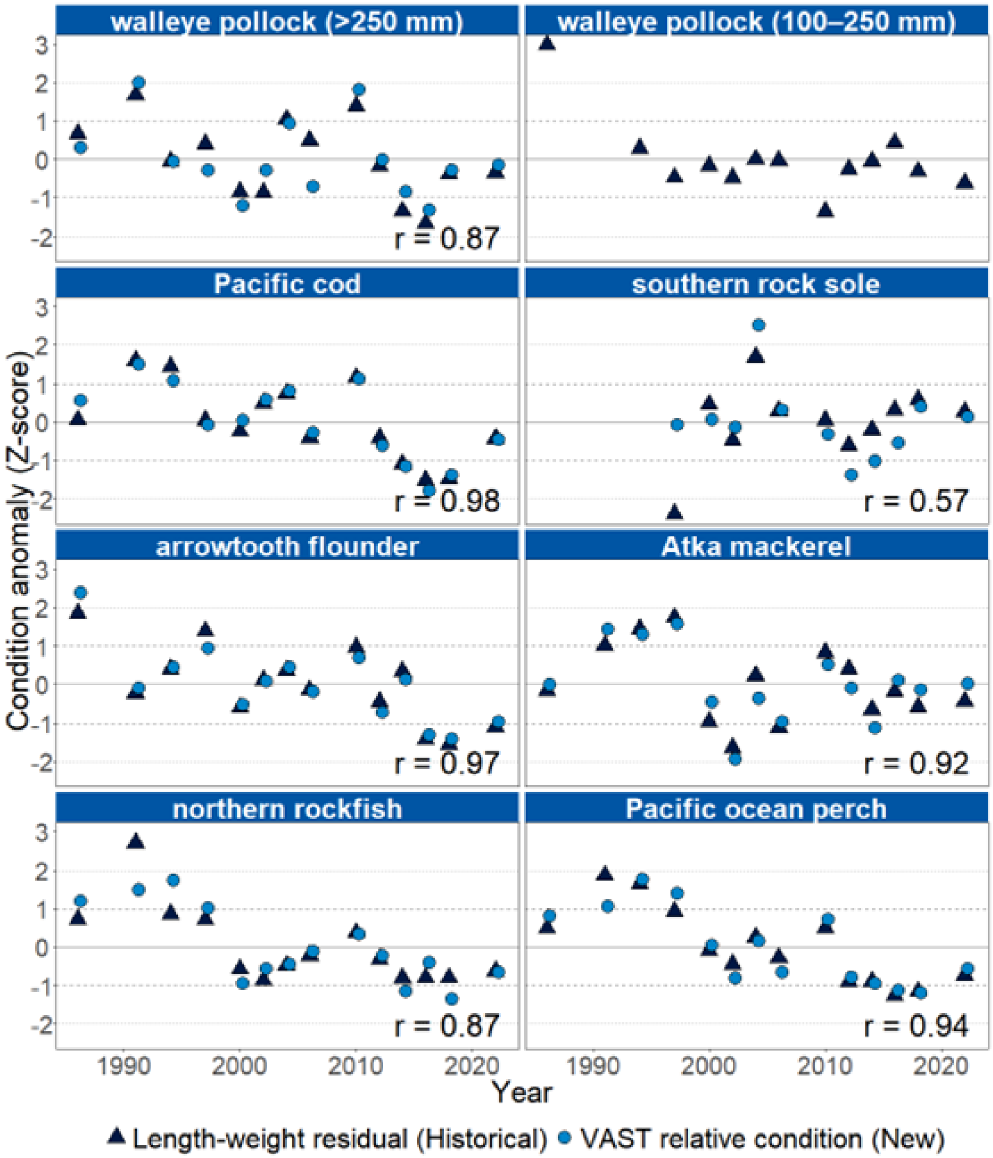

Figure 31: Length-weight residuals for groundfish species and age 1–2 walleye pollock (100–250 mm) collected during AFSC/RACE GAP summer bottom trawl surveys of the Aleutian Islands from 1986-2022. Black triangles denote the historical lenght-weight residual condition indicator and blue circles indicate the VAST relative condition indicator. Reported r values are the results of the Pearson's correlation

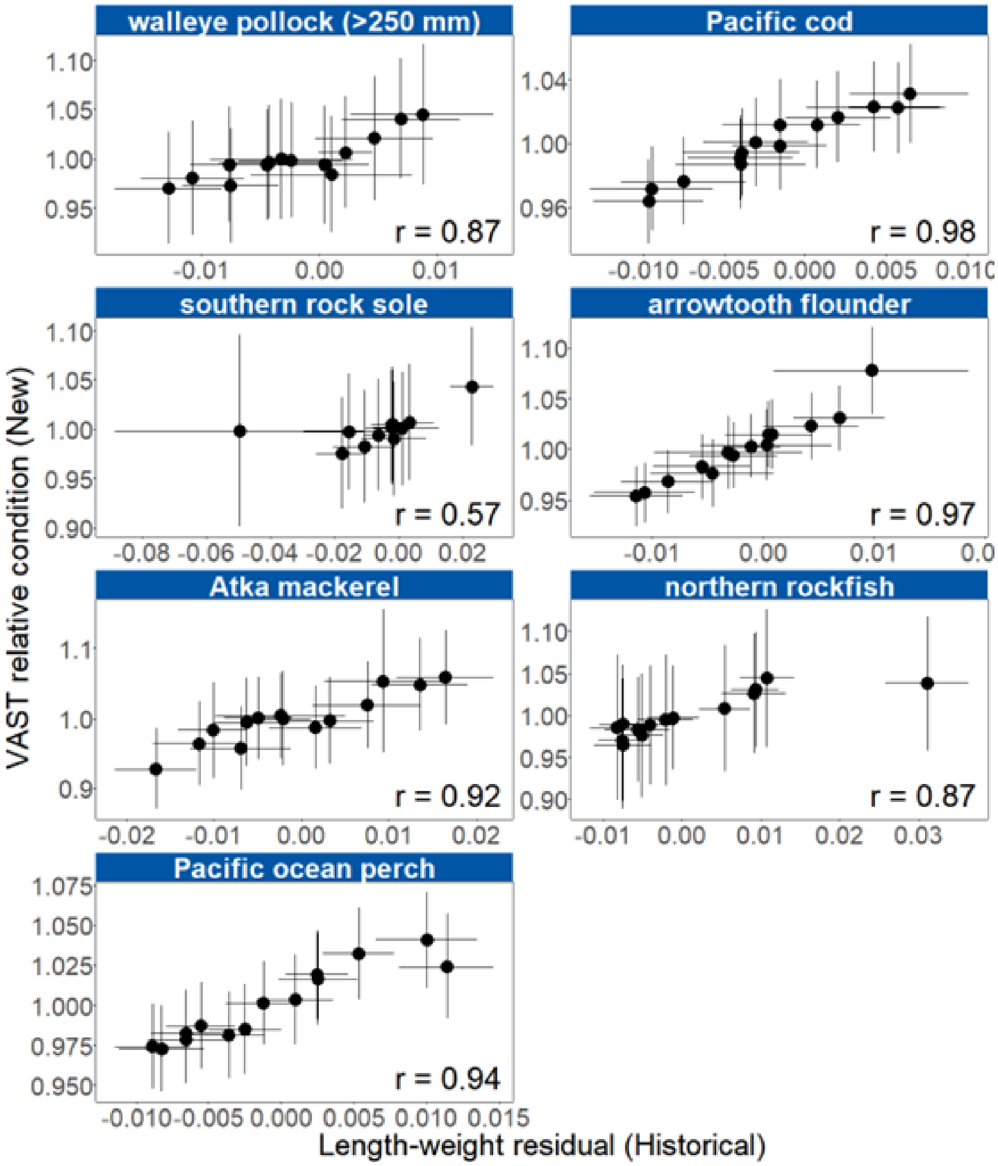

Figure 32: Length-weight residual condition based on length-weight residuals versus VAST condition for the Aleutian Islands. Points denote the mean, error bars denote two standard errors.

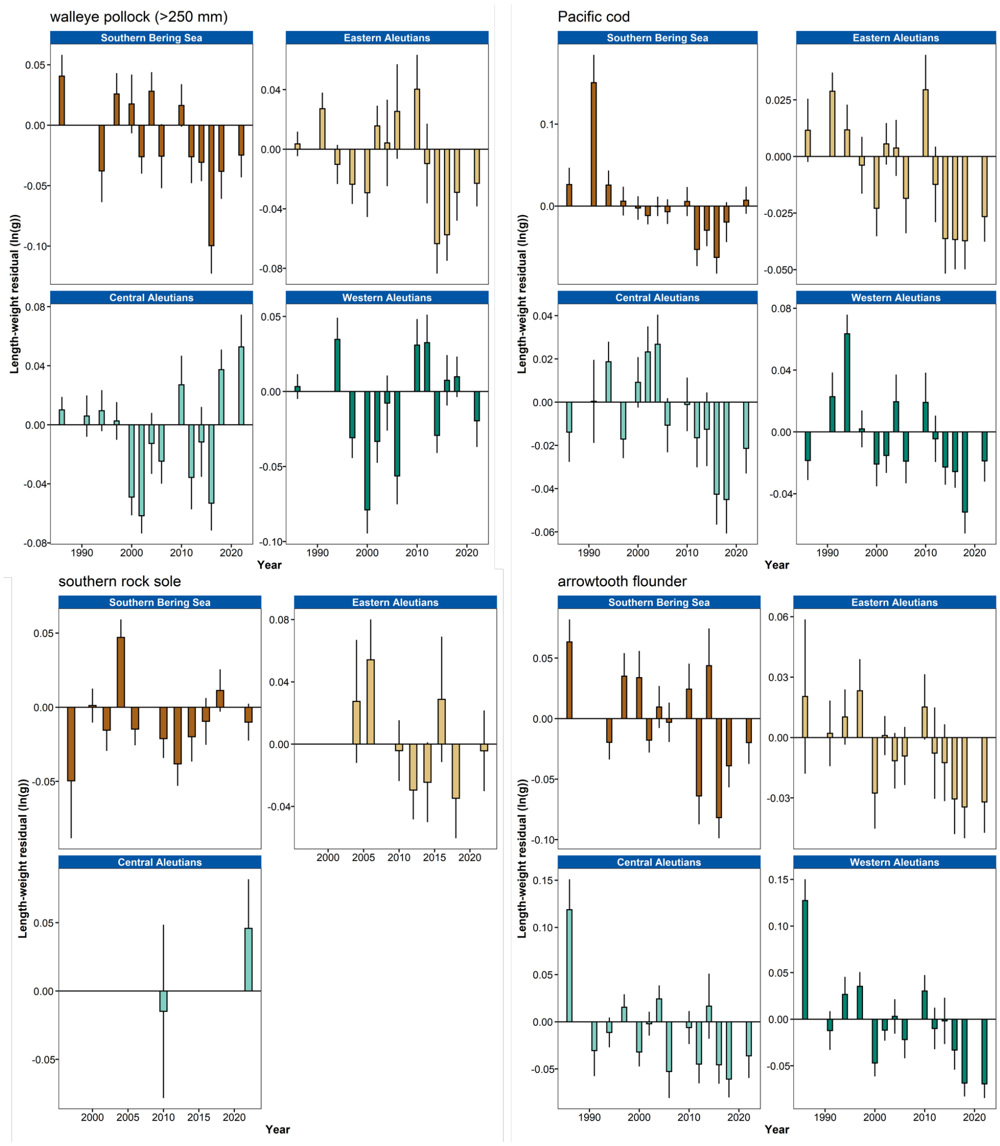

Figure 33: These plots were provided by the authors and are based on the previous method. We provide those here for comparison purposes and to provide the region-specific fish condition. Biomass-weighted residual body condition index across survey years (1984—2018) for seven Aleutian Islands groundfish species collected on the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering Groundfish Assessment Program (RACE-GAP) standard summer bottom trawl survey. Filled bars denote weighted length-weight residuals using this year's indicator calculation, error bars denote two standard errors, points denote the mean of the unweighted length-weight residual from the previous year's (2018) ESR.

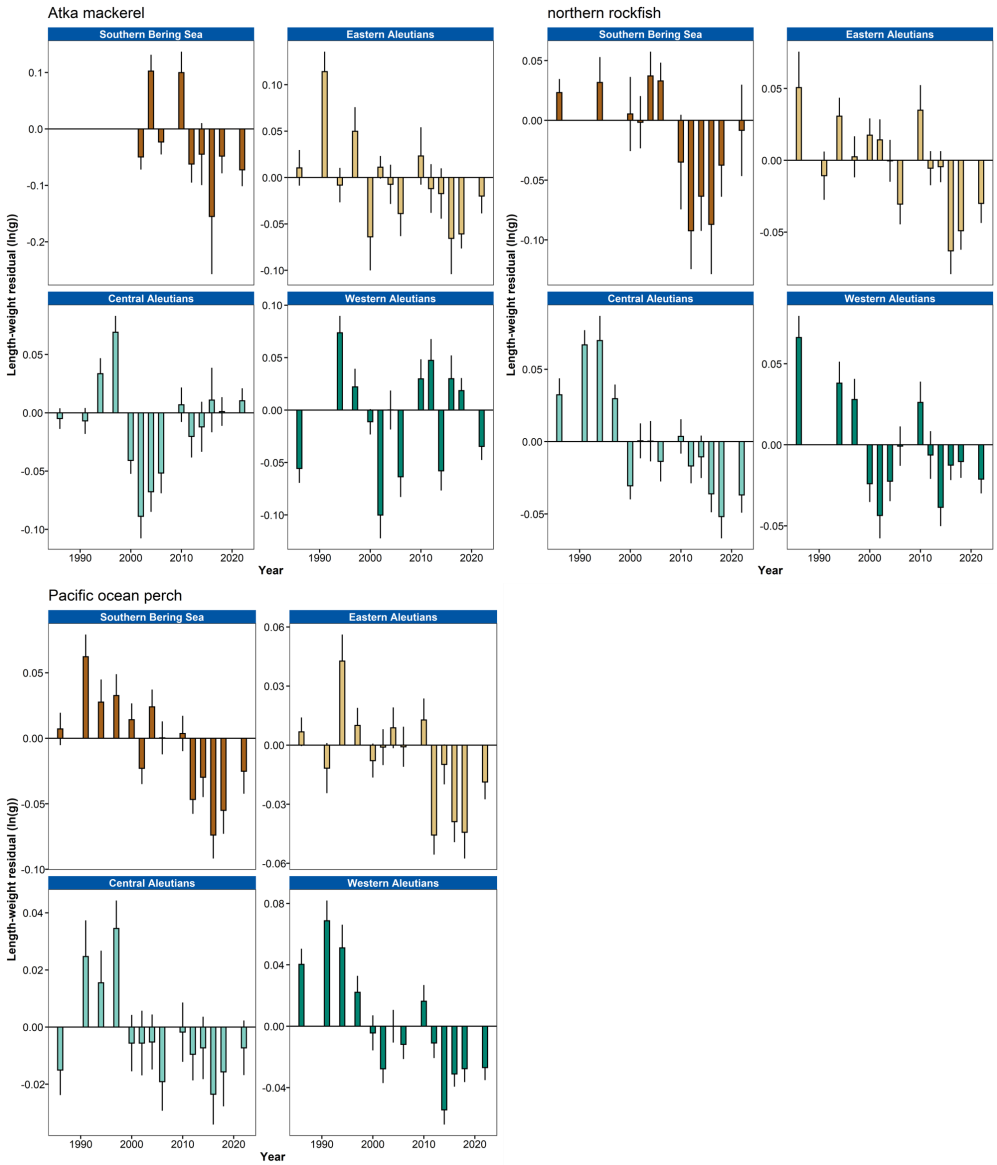

Figure 34: These plots were provided by the authors and are based on the previous method. We provide those here for comparison purposes and to provide the region-specific fish condition. Biomass-weighted residual body condition index across survey years (1984—2018) for seven Aleutian Islands groundfish species collected on the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering Groundfish Assessment Program (RACE-GAP) standard summer bottom trawl survey. Filled bars denote weighted length-weight residuals using this year's indicator calculation, error bars denote two standard errors, points denote the mean of the unweighted length-weight residual from the previous year's (2018) ESR.

Factors influencing observed trends: Several factors could affect morphological condition, including water temperature. Since the Warm Blob in 2014 (Bond et al., 2015; Stabeno and Bell, 2019), there has been a general trend of warming ocean temperatures in the survey area through 2022 that could affect fish growth conditions there. 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.

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. We can expect some fish to exhibit seasonal or ontogenetic movement patterns during the survey months. Effects of survey timing on 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 survival 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 toward lowered body condition for many Aleutian Islands species from 2010 to 2018 RACE/AFSC GAP bottom trawl surveys (i.e., increasingly negative length-weight residuals) is a potential cause for concern. However, the increase in body condition for all groundfish species in 2022 may portend a reversal of the trend. Recent downward trends in body condition could indicate poor overwinter survival or may reflect the influence of locally changing environmental conditions depressing fish growth, local production, or survivorship. Indications are that the 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. 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: The new model-based condition indicator (VAST relative condition) will be further explored for biases and sensitivities to data, model structure, and parameterization. Specifically, the 100–250 mm walleye pollock VAST relative condition indicator model does not converge, and so further model structure and parameterization research is needed. Research is also being planned and implemented across multiple AFSC programs to explore standardization of statistical methods for calculating condition indicators, and to examine relationships among putatively similar indicators of fish condition (i.e., morphometric, bioenergetic, physiological). Finally, we plan 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 in the Aleutian Islands Bottom Trawl Surveys

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Last updated: October 2022

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 (*Sebastes* spp.) species along the three environmental gradients (depth, temperature, and position) 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.

Status and trends: 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. 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 1°C temperature envelope.

Factors causing 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. The increasing abundance in Pacific ocean perch and rougheye-blackspotted rockfish complex in the AI over time could be explained by the expansion of distribution into shallower habitats by these two species complexes. For the rockfish with more static population trends, such as northern and shortraker rockfish, 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 2022.

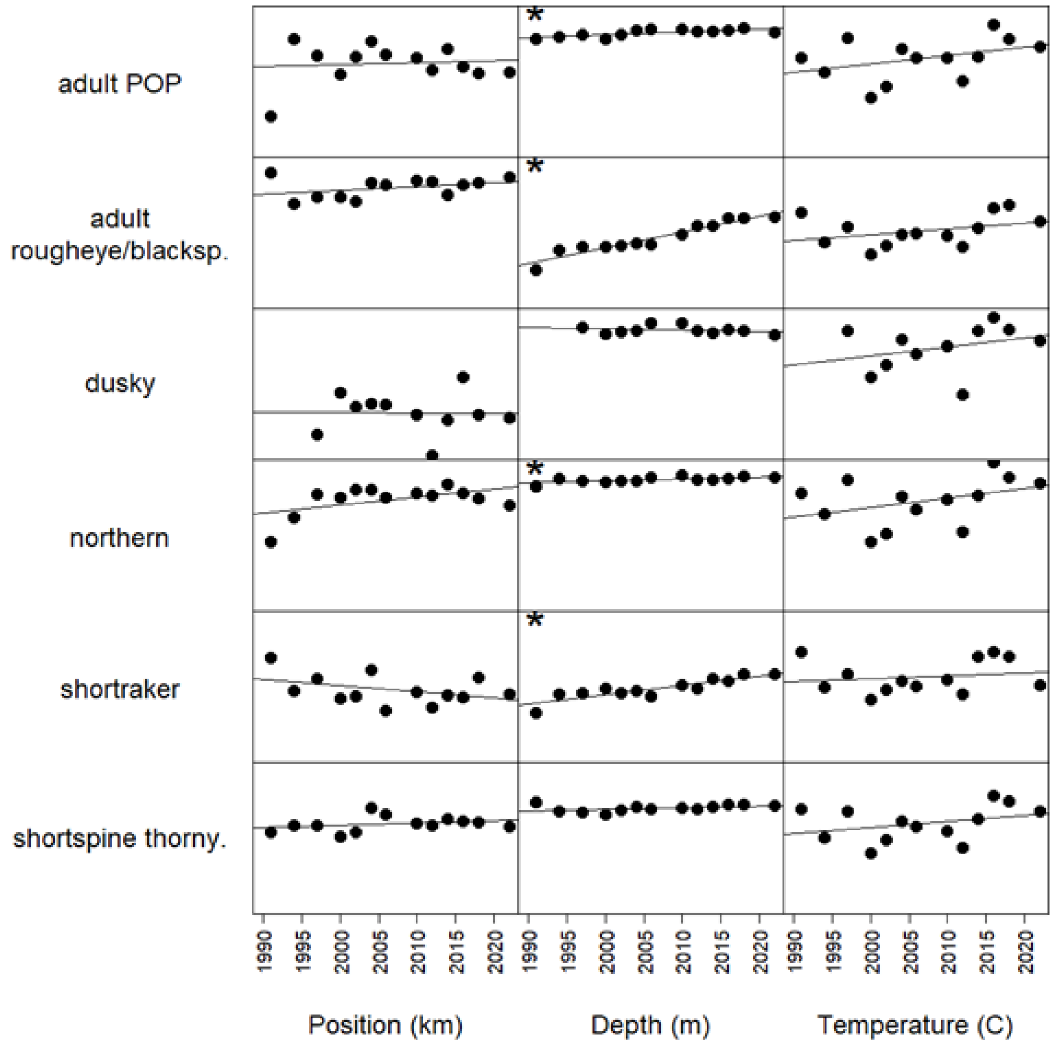

Figure 35: Plots of mean weighted (by catch per unit effort) distributions of six rockfish species-groups along three environmental variables in the Aleutian Islands. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance from Hinchinbrook Island, Alaska, with positive values west of this central point in the trawl surveys and negative values in southeastward. Asterisk indicates significant trend over the time series.

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 the previous two surveys in 2016 and 2018, all five rockfish groups were found at the highest mean-weighted temperature in the time series. However, in 2022, the occupied mean-weighted temperature for each rockfish group was lower than the previous two surveys. 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 Species—Aleutian Islands

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Last updated: October 2022

Description of indicator: RACE bottom trawl surveys in the Aleutian Islands (AI) are designed primarily to assess populations of commercially important fish and invertebrates. However many other species are identified, weighed and counted during the course of these surveys and these data may provide a measure of relative abundance for some of these species. Many of these species are not sampled well by the gear or occur in areas that are not well sampled by the survey (hard, rough areas, mid-water etc.) and are therefore encountered in small numbers which may or may not reflect their true abundance in the AI. The fishing gear used aboard the Japanese vessels that participated in all AI surveys prior to 1991 was very different from the gear used by all vessels since. This gear difference almost certainly affected the catch rates for some of these species groups. Apparent abundance trends for a few of these groups are shown in Figure 36. For each species group, the largest catch over the time series was arbitrarily scaled to a value of 100 and all other values were similarly scaled. The standard error ($\pm$ 1) was weighted proportionally to the CPUE to get a relative standard error.

Status and trends: : Echinoderms are frequently captured in all areas of the AI survey, occurring in 80–90% of all bottom trawl hauls. Echinoderm mean CPUE is typically higher in the central and eastern AI than in other areas, although frequency of occurrence in trawl catches is consistently high across all areas. Echinoderm CPUE has been stable in the western and eastern Aleutians since 2018 and declined in the central Aleutians and southern Bering Sea in 2022. Eelpout CPUEs have been stable and low in the western Aleutians and southern Bering Sea, but declined in 2022 in the central and eastern Aleutians. Eelpouts generally occur in <10% of survey hauls across all areas. Poachers occur in a relatively large number of tows across the AI survey area (about 30–40% consistently), but mean CPUE trends are unclear and abundance appears low. A shrimp time series has been calculated since 2016 that shows a variable pattern of abundance through time. Shrimp CPUE in 2022 was lower in the western AI, low and similar to abundance in 2018 in the central and eastern Aleutians, and appeared to increase in the southern Bering Sea.

Factors influencing observed trends: Unknown

Implications: AI survey results provide limited information about abundance or abundance trends for these species due to problems in catchability. Therefore, the indices presented are likely of limited value to fisheries management. These species are not typically commercially important, but the trends in shrimp especially should be monitored as these are an important prey base for benthic commercial species.

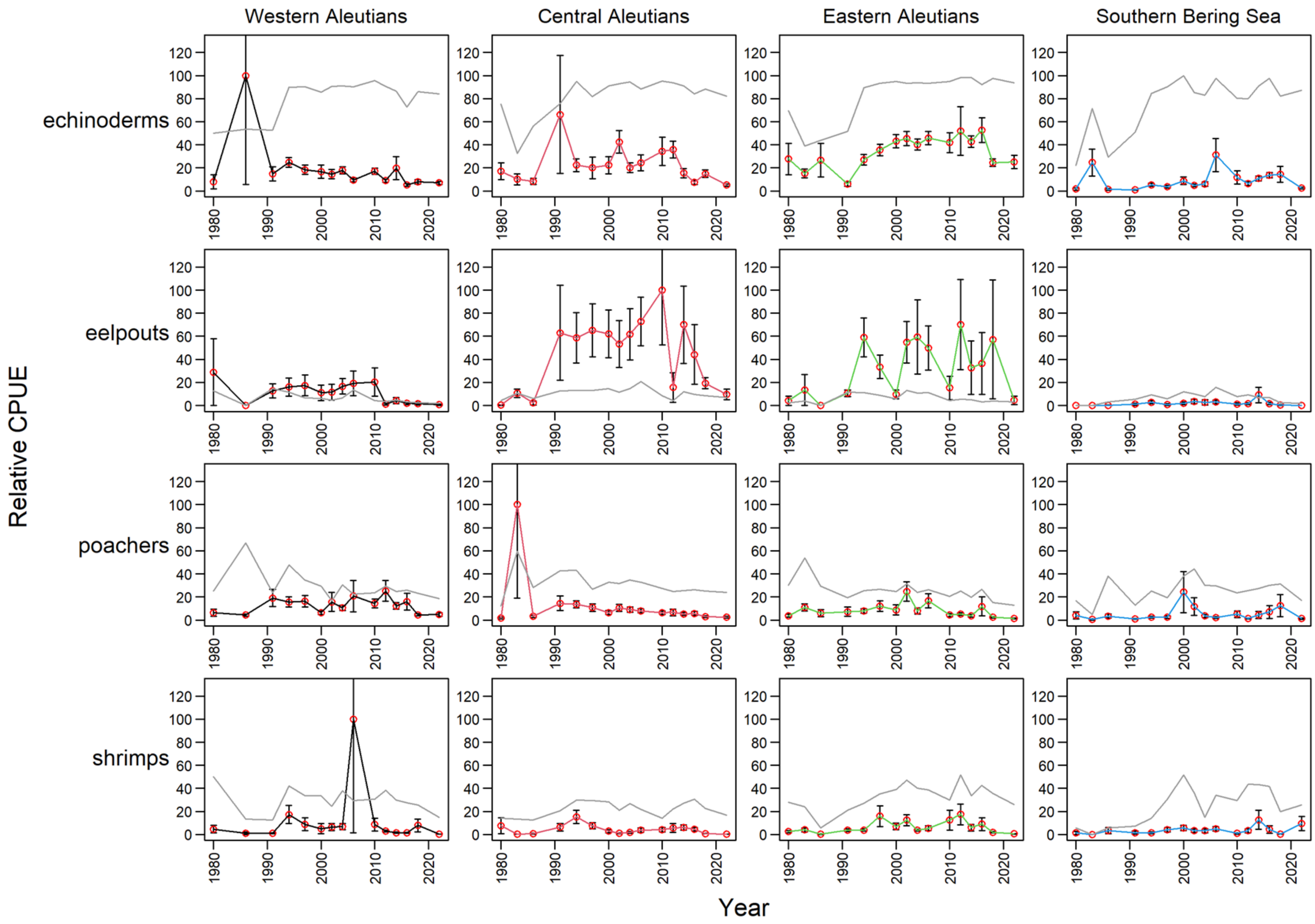

Figure 36: Relative mean CPUE of miscellaneous species by area from RACE bottom trawl surveys in the Aleutian Islands from 1980 through 2016. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches. The Western, Central, and Eastern Aleutians correspond to management areas 543, 542, and 541, respectively. The Southern Bering Sea corresponds to management areas 519 and 518.

Seabirds

Integrated Seabird Information

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Last updated: October 2022

Synthesis: *Most seabirds in the Aleutians feed offshore, so population and reproductive trends at breeding colonies can reflect conditions in the pelagic ocean environment. In 2022, the timing of breeding was average or earlier for all seabird species monitored at both Buldir and Aiktak Islands. This indicates favorable foraging conditions during the months preceding the breeding season, which typically starts in early June. This contrasts with last year when hatch dates for fish eating seabirds were either average or later than average. The earlier hatch dates in 2022 may have been favored by higher availability of copepods, as this is a low abundance year for Eastern Kamchatka pink salmon which feed on them.*

Both plankton and fish-eating species also had an exceptionally successful reproductive season at both Buldir in the western Aleutians and Aiktak in the eastern Aleutians in 2022, presumably indicating uniformly high prey availability for both nearshore and offshore foragers, surface feeders, and divers. Reproductive success has been average or above-average since 2019 (there were no surveys in 2020) except for fork-tailed storm petrels at Buldir (2019, 2021) and Leach's storm petrels (2021) at Aiktak. Both of these species feed on fish and invertebrates. The generally average to above-average reproductive success across species suggests sustained favorable foraging conditions during summer across a wide spectrum of plankton and fish prey as well as a variety of habitats.

Jointly, the negative NPGO and PDO as well as positive NPI in the past three years seem to have favored foraging conditions for seabirds, both through creating conditions that support increased zooplankton production and less stormy winters, which are more favorable for seabird foraging. The Aleutian Low tends to be weaker during La Niña years, and the ongoing La Niña is forecasted to continue through February 2023, followed by a 54% chance for ENSO-neutral in February–April 2023.

No large or unusual seabird die-offs were documented via standardized beach-based surveys. Opportunistic reports of beached birds included low numbers of migratory seabirds that have nesting colonies in the Aleutians. Estimated bycatch of all seabirds in groundfish and halibut fisheries increased in 2021, continuing the biennial pattern observed since 2014 and coinciding with a high abundance year of Eastern Kamchatka pink salmon.

The influence of pink salmon abundance on seabirds in Alaska can be observed in both reproductive timing and potentially bycatch, but they do not seem to drive die-offs. This contrasts with the shearwater colonies in Australia where pink salmon has been found to correlate to occasional mortality events and abundance of short-tailed shearwaters.

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 provide an assessment of the status of seabirds in the Aleutian Islands during 2022.

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

1. i) timing of breeding, which reflects ecosystem conditions prior to breeding,
2. ii) reproductive success, which reflects feeding conditions during the breeding season and/or system phenology, and
3. iii) 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 37). 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 37: 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 AND REPRODUCTIVE SUCCESS (BULDIR AND AIKTAK)

The breeding timing of tufted puffins nestings at Buldir has been shown to vary with the high/low biennial runs of Kamchatka pink salmon (Springer and van Vliet, 2014), where high pink salmon numbers (odd years) correlated with later hatch dates. In 2022, tufted puffins mean hatch date (although the sample size was small) was earlier than the long-term mean, concurring with a low abundance (even) year for pink salmon. The higher number of nests with eggs at the beginning of the breeding season during even years since 1999/2000, further supports the hypothesis that puffins in general are in better condition upon arrival at their colonies during years when pink salmon abundance is low.(Figure 39). The deviation from this pattern that occurred in 2018, when the few birds that returned to breed failed, was likely due to lagged effects due to the widespread, prolonged marine heatwave from 2014–2016 (JF et al., 2020).

The long-term average hatch dates for seabirds at Buldir fall between mid-June to late July (Dragoo et al., 2019), along with average hatching periods of 30 to 42 days. In general, earlier hatch dates indicate favorable conditions for seabirds in the preceding seasons (winter/spring). The overall average or earlier hatch dates at both Buldir and Aiktak suggest that there were favorable foraging conditions during winter/spring 2022 for both plankton and fish foragers. (Figure 38).

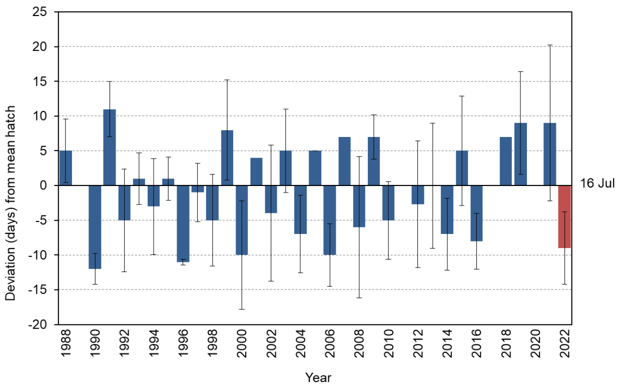


Figure 39: Yearly hatch date deviation (from the 1988–2020 average of 15 July) for tufted puffins at Buldir Island, Alaska. Negative values indicate earlier than mean hatch date, positive values indicate later than mean hatch date. Error bars represent standard deviation around each year's mean hatch 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.

Seabird reproductive success in 2022 was average to above average for all species monitored at both colonies. This includes diving, fish eating seabirds (common and thick-billed murres, tufted and horned puffins), mixed foragers (kittiwakes and storm-petrels, consume mix of fish and invertebrate), and near-obligate planktivores (auklets). Of particular note at Buldir, all auklet species had above average reproductive success; black-legged kittiwakes, Leach's storm-petrel, and parakeet auklet had the third highest reproductive success of all years monitored. At Aiktak, murres did extremely well, with second and third highest years for common and thick-billed murres, as well as second highest year for horned puffins and leach's storm-petrels (see Figure 41). Chick rearing in the Aleutians extends through August and September (Jones, 2020, Bond et al., 2020, Piatt and Kitaysky, 2020, Gatson and Hipfner, 2020) and the average and above-average reproductive success across Buldir and Aiktak for fish and plankton eating seabirds indicates widespread prey availability through summer.

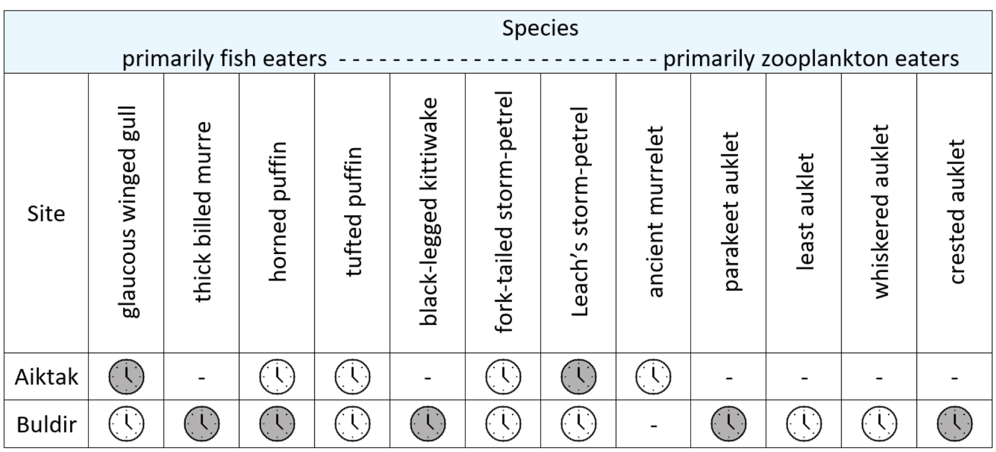


Figure 38: Seabird relative breeding chronology in 2021 compared to long-term averages for past years at Aiktak and Buldir islands. White clock indicates hatching chronology was >3 days earlier than average. Gray clock within 3 days of average. Black clock <3 days later than average. Dashes indicate species not monitored at a site or for which sample size too small for comparison.

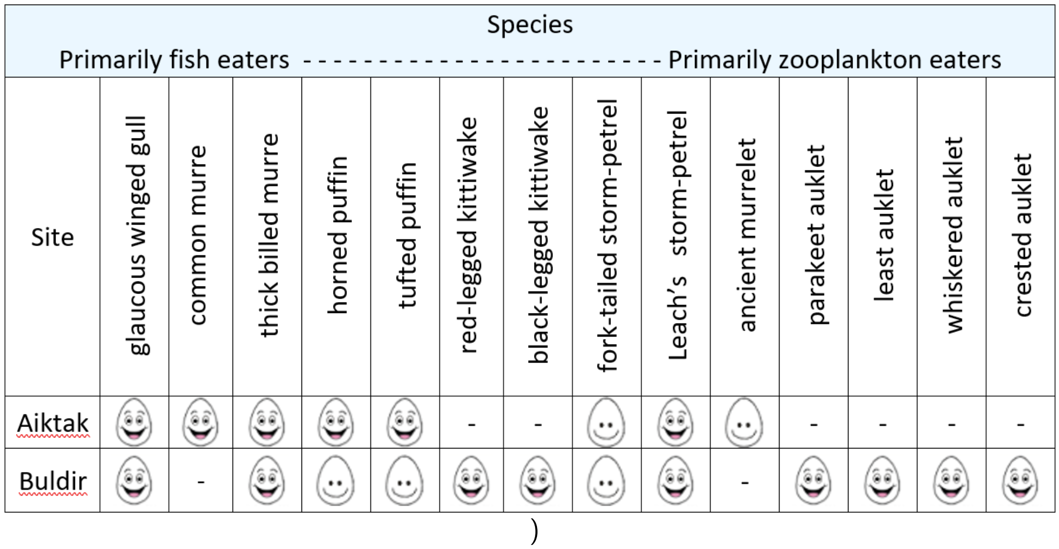


Figure 40: Seabird reproductive success in 2022 compared to long-term means for past years at Aiktak and Buldir islands. Big smiley face indicates reproductive success >1 SD above the long term mean, smiley indicates within 1 SD of long term mean, frowny face indicates >1 SD below long term mean, and broken faces indicate failure, which is considered values at or near zero. Dashes indicate species not present or monitored at a site or for which sample size too small for comparison.

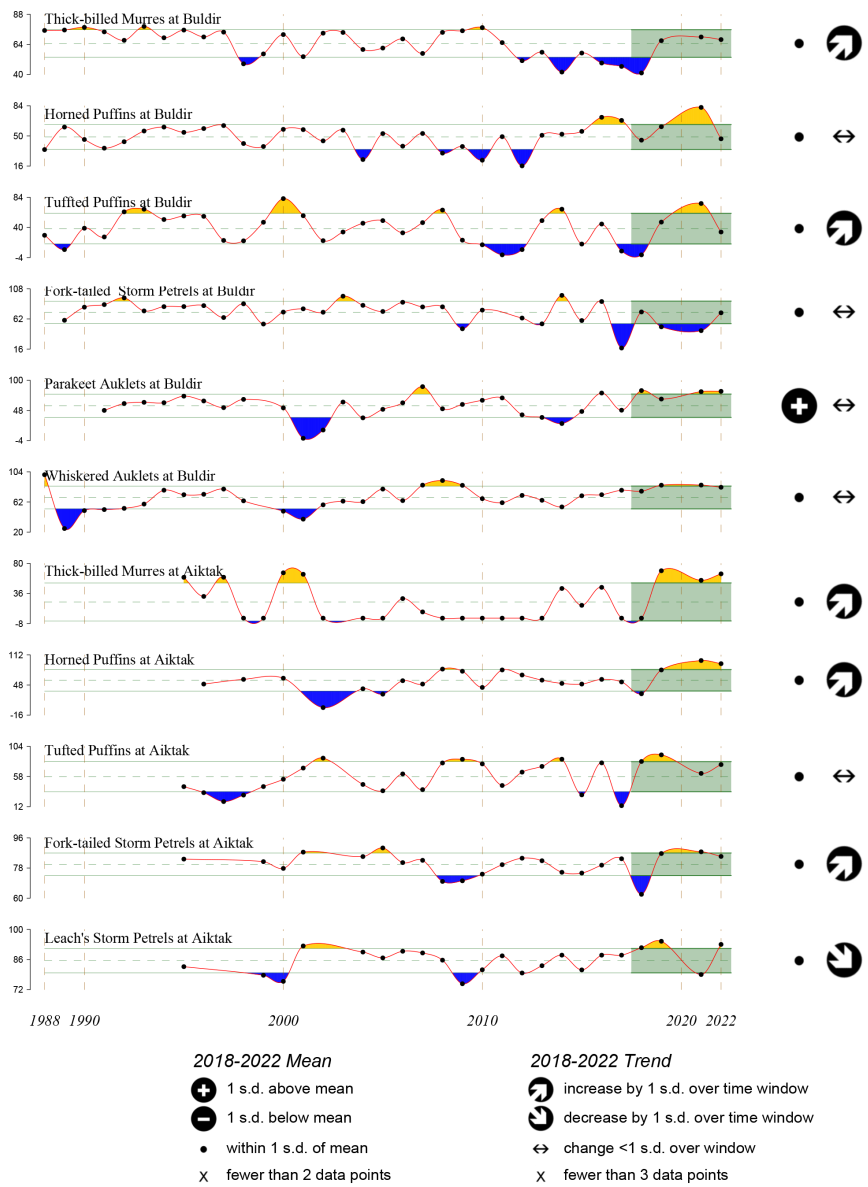


Figure 41: Time series of seabird reproductive success through 2021 at Buldir and Aiktak Islands

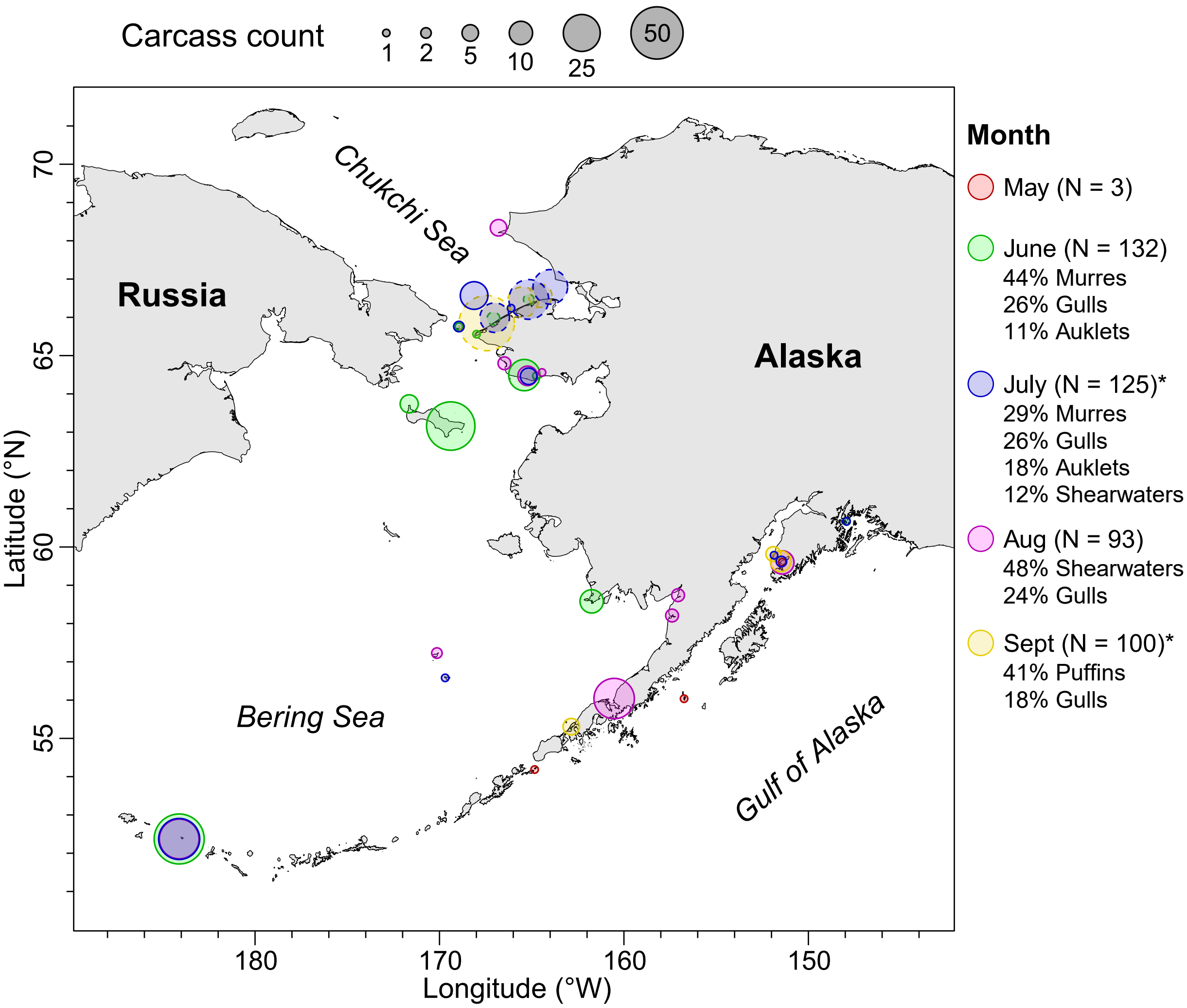
POPULATION INFORMATION—MORTALITY

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 COASST and regional partners during the summer of 2022. These reports (mapped in Figure 42) 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.

Between May and September 2022, most reports of carcasses in the Aleutian Islands were from AMNWR seasonal surveys (using COASST protocols) at Buldir, Adak, and Aiktak Islands. These surveys are indicated with bubbles in Figure 42. The number of carcasses reported in 2022 is not indicative of a major die-off event in this region. Similar maps from years with large-scale mortality events in other Alaskan regions depicted thousands of birds, including thousands of which were reported outside of COASST surveys.

Monitoring by the Coastal Observation and Seabird Survey Team (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 634 surveys have taken place across 18 beaches; in 2022, 32 surveys took place across 6 beaches located mainly in the Eastern Aleutians. Detailed methods for beached bird surveys can be found in Jones (2019).

In 2022, surveyors reported average numbers of carcasses across beaches in the Aleutian Islands, despite normal survey effort. 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 gulls and small alcids (e.g. auklets), as shown in Figure 43 (see also table in Figure 44).



* : species composition is of birds identified to species/group. However, in July/Sept a large proportion (38%, 83%) of birds were unidentified

Note: Circles represent reports of seabird carcass abundance and are not standardized for variable observer effort among locations. The absence of reports in certain locations may indicate gaps in current knowledge OR an actual absence of bird carcasses. Reports from aerial surveys (dashed circles) are distinguished from other beach-based reports (solid circles) due to major differences in area observed.

Figure 42: Map of seabird carcass reports for Alaska during May-September 2022. Data provided by COASST participants and NPS staff, and coastal community members reporting to ADFG, USFWS, UAF-Alaska Sea Grant, and Kawerak, Inc. Bubble sizes indicate number of carcasses counted (between 1 and 50) and bubble color indicates month of report. Species composition is reported monthly, aggregated into species groups.

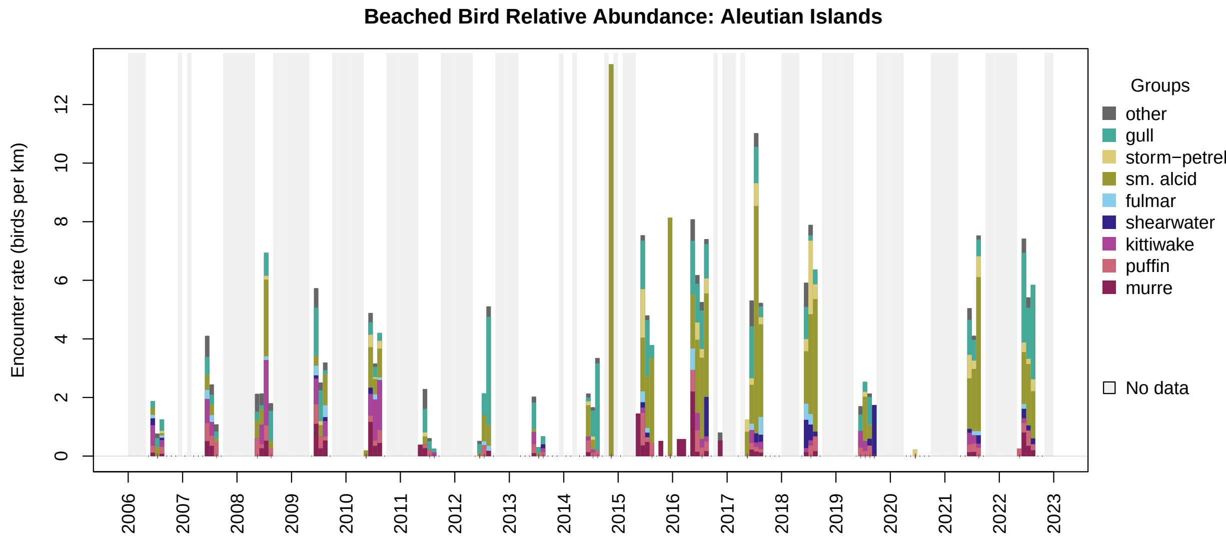


Figure 43: Month-averaged beached bird abundance, standardized per km of survey effort, for the Aleutian Islands. Species groups (gull, storm-petrel, small alcid, fulmar, shearwater, kittiwake, puffin, murre) are depicted with different colors within each bar, with gray bars indicating months where no survey was conducted. Credit: COASST

year	Bird total	Murres	Puffins	Kitti-wakes	Shear-waters	Fulmars	Small alcids	Storm petrels	Gulls	Other marine
2006	37	2	5	9	3	2	5	1	9	1
2007	70	8	13	12	0	5	9	0	11	12
2008	83	6	8	22	0	1	27	1	12	6
2009	95	16	10	12	2	6	14	1	24	10
2010	148	22	10	50	2	4	34	8	13	5
2011	27	4	3	1	0	0	2	1	10	6
2012	51	1	3	0	0	2	12	0	30	3
2013	28	1	4	5	1	0	2	0	13	2
2014	95	1	5	2	0	0	57	2	25	3
2015	109	12	9	1	2	3	48	9	23	2
2016	150	13	11	7	8	2	62	9	30	8
2017	141	3	3	5	4	6	84	9	19	8
2018	125	2	5	2	11	6	59	20	12	8
2019	42	0	5	4	5	0	13	1	12	2
2020	1	0	0	0	0	0	0	1	0	0
2021	120	2	6	6	3	2	65	13	18	5
2022	107	8	7	1	4	1	31	5	45	5

Figure 44: Number of carcasses encountered on beaches surveyed by COASST in the Aleutian Islands

Seabird bycatch rates have been shown to be related to environmental conditions and bird abundance (Bi et al. 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 (Figure 55), with higher bycatch coinciding with years of high Eastern Kamchatka pink salmon. This biennial pattern is not evident in the relative abundance of beached birds. Also, 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 summer 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). Estimated shearwater bycatch has increased since 2017, with higher estimates in odd years, again coinciding with high abundance of pink salmon.

Factors influencing observed trends: In 2022, all seabirds monitored at sites in the western and eastern Aleutians had a good breeding season with many having above average reproductive success. The timing of breeding was early for many species and within the average for others, which suggests widespread zooplankton and small fish abundance during spring and summer 2022 throughout the Aleutians. Bond et al. (2011) suggested that correlations between a strong Aleutian Low and decreased seabird productivity in the Aleutian Islands may be due to decreased prey (zooplankton) availability and found a higher NPGO index corresponded with lower reproductive success. The NPGO index has remained negative since late 2013, while the PDO changed to a negative phase in 2020 and the NPI has been positive (i.e. weak Aleutian Low) five out the last 6 winters (except winter 2018-2019). Jointly, these indices suggest increased zooplankton availability and favorable conditions for seabird productivity, particularly in the last three years and offsetting the potential negative impacts on seabird prey from above-average temperatures observed since 2014 from surface to bottom (see Figures 13 and 19).

Implications: Reproductive activity of central-place foraging seabirds can reflect ecosystem conditions at multiple spatial and temporal scales. This year all monitored species did well to above average. This suggests that foraging conditions for both plankton and fish-eating commercial groundfish may have been favorable in 2022. The average number of beach carcasses found on surveyed beaches also suggest that there were favorable conditions in the area. Finally, the influence of pink salmon abundance on seabirds in Alaska can be observed in both reproductive timing and bycatch, but they do not seem to drive die-offs. This implies that the same might be true for groundfish, where pink salmon might influence some processes but not drive their abundance or reproduction. However, as seabird bycatch rates appear to increase in odd years, it seems advisable to ensure seabird bycatch reduction measures/ devices are in place during odd years.

Methods

1. AMNWR: The Alaska Maritime National Wildlife Refuge has monitored seabirds at colonies around Alaska in most years since the early- to mid-1970's. Monitored colonies in the Aleu- tians include Buldir Island in the western Aleutians and Aiktak Island in the eastern Aleu- tians. The Refuge monitors breeding chronology, productivity and/or population parameters for indicator species representing four major feeding guilds: 1) diving fish-feeders (e.g., com- mon 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. 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 40 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. COASST: The Coastal Observation and Seabird Survey Team (COASST) provided a stan- dardized 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 abun- dance 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.

3. Seabird Reproductive time series: Based on data from AMNWR above, shown with respect to the average of the entire time series. (note AMNWR uses the mean of previous year only i.e. does not include the current year).

Marine Mammals

Steller Sea Lions in the Aleutian Islands

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Last updated: October 2022

Description of indicator: As a large apex, piscivorous predator that ranges across a broad geographic range, the Steller sea lion serves 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).

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; Figure 34). Challenging survey conditions usually means there are data gaps for sites that cannot be surveyed. MML uses the R package, agTrend (Johnson and Fritz, 2014; Gaos et al., 2021) to interpolate counts for the missed sites and estimate modeled counts (an index of population abundance) and trends for defined geographic areas.

In Alaska, Steller sea lion 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). Rookery cluster area 1 is equivalent to the western AI region, CAI is comprised of RCAs 2–5, and RCA 6 is comprised of the eastern AI except for these sites: Kaligigan, Aiktak, Ugamak complex, Tigalda, Unimak sites Cape Lutke and Cape Lazaref). The entire range of the western DPS extends to Russia and Japan (Muto et al. 2020).

A note about agTrend and SSL 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 (note: the 2021 aerial survey memo to the record reports agTrend counts derived from the original model). Modeled counts are used to represent the 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.

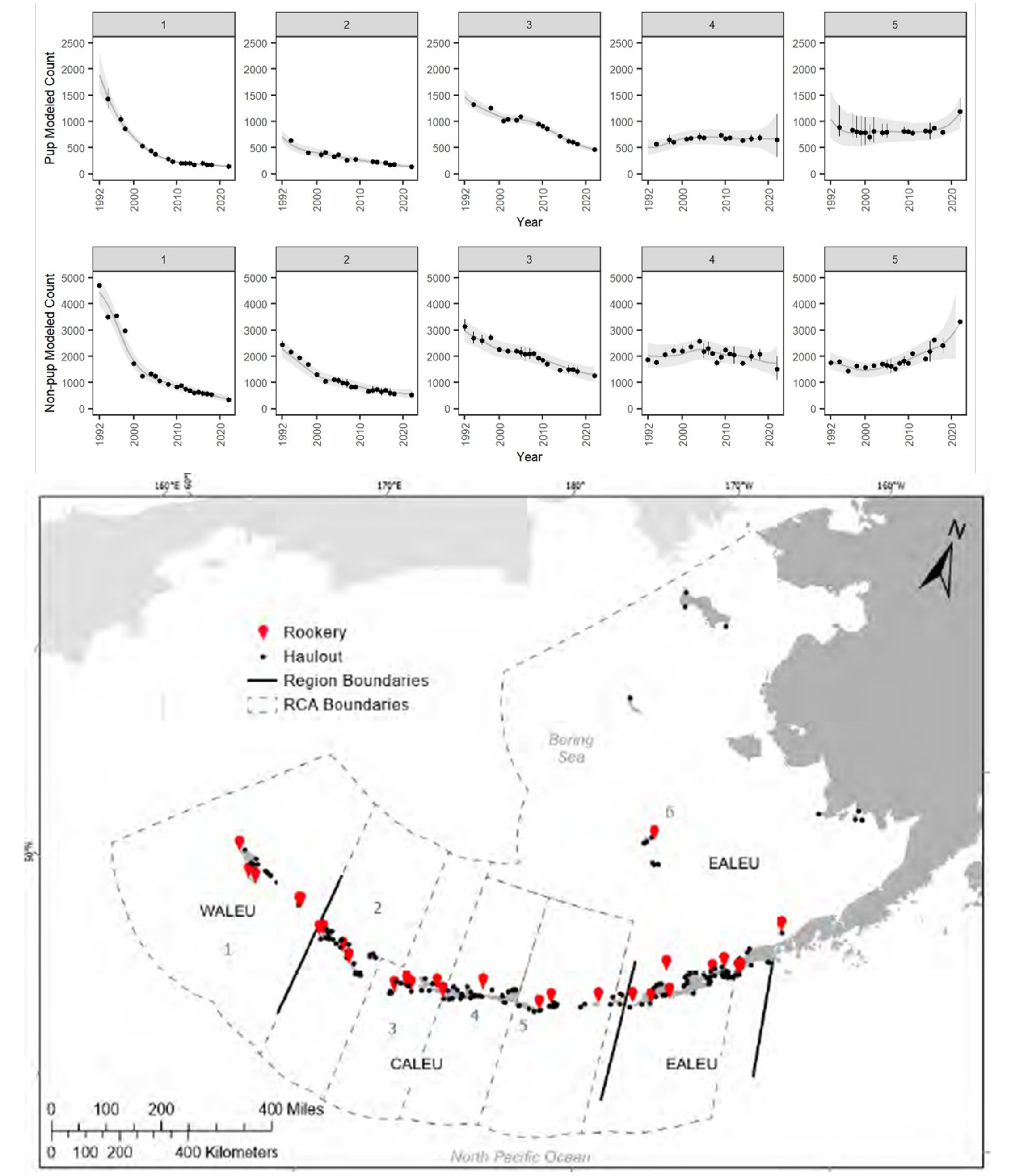

Figure 45: Map of Steller sea lion rookeries and haulouts for rookery cluster areas (RCAs) 1–6 and time series (1978–2019) of Non-Pups and Pups at each RCA covering the Aleutian Islands.

Status and trends: Declines in Steller sea lion populations were first observed in the 1970s, with the steepest declines occurring in the mid-1980s. The western DPS as a whole began to rebound in 2002 however, regional trends tell a different story in the Aleutian Islands, and since 2017, in the GOA. West of Samalga Pass, sea lion counts have showed little to no signs of recovery, while the eastern Aleutian Island region (hereafter sea lion Aleutian Island regions will be referred to as AI) began to recover in the early 2000s (Sweeney et al., 2019).

In 2022, MML surveyed the eastern, central, and western AI regions. Counts were finalized for the central and western AI regions to share in this report (eastern AI counts are still being counted). Most of the western AI region had not been surveyed since 2018 because of the COVID-19 pandemic (cancelling the 2020 survey). Similarly, most of the central AI region had not been surveyed since 2018, and even earlier for many sites west of Adak because of increased survey difficulty and inclement weather.

In the western DPS in Alaska between 2007 and 2022, non-pup and pup counts increased 1.41% y-1 (95% CI 0.63–2.23) and 1.06% y-1 (95% CI 0.46–1.66), respectively (MML unpublished data). In the previous report, the eastern AI region was reported to be increasing from 2002 and 2018, for non-pups (2.38% y-1) and pups (1.78).

Annual trends from 2007 to 2022 (unpublished data) showed the central AI region was stable for non-pups (0.05% y-1, 95% CI -1.63–1.91) and pups (-1.27% y-1, 95% CI -2.65–0.35). However, the two western RCAs 2 and 3 were declining for both pups (-5.10 and -5.38, respectively) and non-pups (-3.55 and -3.14). RCA 4 was stable for all age-sex classes. RCA 5 was increasing (4.09% y-1; 95% CI 0.86-7.98) however, the survey in this area was fairly incomplete (one rookery and several haulout sites missed) resulting in large confidence intervals. More information is necessary to know if this is a true increase. The western AI region (RCA 1) continued to decline significantly for pups (-4.11) and non-pups (-6.45) and shows no sign of recovery in MML history. Pups in this region have declined by 95% since the peak in 1984 (38 years) and non-pups by 97% since 1984. The non-pup peak count was observed in 1971 (the earliest modeled counts for this region) and has declined 99% since then. In this region, the 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, 2013).

Factors influencing observed trends: (Fritz et al., 2019) found no evidence to support correlations between population trend and certain diet metrics—diet diversity, species mix, and energy density—and suggested that if nutrition is a driver of the decline, then it appears that other factors may be acting. Pacific cod and Atka mackerel are two of the primary prey species of Steller sea lions in the central and western Aleutian Islands (Sinclair et al., 2013; Tollit et al., 2017). Summer diets in these declining areas were largely dominated by Atka mackerel, whereas non-breeding season diets showed greater 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)).

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 2010). Females have smaller blubber stores (than males) and require availability of prey nearby to sustain themselves and their fetus and/or nurse their pup or juvenile (Boyd, 2000; Malavaer, 2002; Winship et al., 2002; Williams, 2005). In the increasing eastern Aleutian Islands region, (Rand et al., 2019) reported dense and consistent aggregations of Atka mackerel; however, in the western Aleutian Islands region, this important prey species was more spread out over a larger area. 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).

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 2011, the Pacific cod and Atka mackerel fisheries were closed and then re-opened in 2014. In the western Aleutian Islands region, realized counts indicated that there was a period of stability in this region from 2014 to 2016 (and potentially an increase in pup counts), followed by a continued decline after 2016 (Sweeney et al., 2018). There are no studies proving or disproving a correlation between fisheries, sea lion population trends, and prey availability in the Aleutian Islands.

Implications: If sea lions are not thriving in areas where they once did and are vacating these habitats in search of other optimal habitats, then this is cause for concern not only for Steller sea lions in the AI regions, but as a possible indication of unfavorable foraging, environmental or other ecological conditions throughout the area. NOAA Fisheries published the Steller sea lion 5-year review (of the endangered listing under the Endangered Species Act) and concluded to continue the endangered listing status (NMFS 2020). This conclusion was driven largely by declines in the Aleutian Islands, the uncertainty as to the cause, and the recent declines in the Gulf of Alaska sea lion regions. The status of Steller sea lions has potential to influence fishery management decisions as this is an endangered species that is not showing signs of recovery. Overall, the continued declines in the Aleutian Islands indicates this protected endangered species is still at risk and susceptible to threats.

Marine Mammal Strandings

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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.

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 partial or full necropsy. 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 112c 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 fall under the Marine Mammal Health and Stranding Program Permit No. 18786.

Status and trends: The number of confirmed strandings in Alaska has increased over time. As of August 31, 2022, 190 confirmed stranded marine mammals have been reported for the year in Alaska; two occurred in the Aleutian Islands region. Reported strandings in the Aleutian Islands since 2017 varied between years without an overall pattern or consistent increase in reports. The 2022 stranding data includes confirmed strandings reported between January 1, 2022 and August 31, 2022. These data are preliminary and the details may change as we receive additional information. (Figure 46).

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 with areas with higher human population densities. There have been relatively few reported stranded marine mammals in the Aleutian Islands (Figure 46), likely due to the remoteness of the area and the low and sporadic population throughout the Aleutian Islands. The number of stranded marine mammals are likely grossly underestimated as observations are opportunistic and without consistent effort. Further, given the low number of strandings, unusual events such as the mass strandings of Stejeneger's beaked whales in 2017 and 2018 `http://www.north-slope.org/`

	2017	2018	2019	2020	2021	2022*
Fin whale				1		
Gray whale	1	1				
Humpback whale	3	2		1	2	
Killer whale	2				2	1
Sperm whale	1	2				
Steineger's beaked whale	7	8	1			
Baids beaked whale						1
Unidentified whale	3	2	4		1	
Unidentified cetacean					1	
Total cetaceans	17	15	5	2	6	
Harbor seal		1				
Northern fur seal	5					
Ringed seal	1	6			1	
Steller sea lion	2		6	3	4	
Total pinnipeds	8	7	6	3	5	
Total Cetaceans and Pinnipeds	25	22	11	5	11	2

Figure 46: Reported stranded NMFS marine mammal species for the last five years in the Aleutian Islands by species and year.

`assets/images/uploads/NOAA_NMFS_ringed-seals-health-eval-2017-2018.pdf` or the 2018 ice seal Unusual Mortality Event (28 individuals) can have large influence on variability between years in this area.

Other factors that may influence the number and species of marine mammals being reported include changing populations of some species including the increase in northern fur seals using Bogoslof Island for breeding and the declining western Distinct Population Segment of Steller sea lions. Further, the number of stranded marine mammals in an area can vary due to potential conflict with fishery resources either directly through prey competition or indirectly through interactions with fishing gear such as increased whale entanglements in cod pot gear.

Implications: Marine mammal strandings have bee increasing in later years, often signaling change sin the environment. It is important to keep track of and have a sense of the regular number of strandings in the area to provide a context to massive mortality events and to identify whether some suite of species are more vulnerable than others and what they have in common. Cumulatively these commonalities may give clues to ecosystem-wide changes.

Ecosystem or Community Indicators

Stability of Groundfish Biomass

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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 1989 survey did not occur and the AI was not surveyed again until 1991, leaving a 5 year gap. Also, the 2008 and 2020 surveys did not occur leaving 4 year gaps. Additionally, the 1980 data were not available at the time this indicator was prepared so the time series begins in 1983. Since 10 years of data are required to calculate this metric, the indicator values start in 2010, the tenth time the Aleutian Islands were surveyed over the time series examined (1983–2022)

Status and trends: The stability of groundfish biomass with rockfish included is 7.3 in 2022 and has been increasing since 2014. Without rockfish, the stability of groundfish biomass has gradually decreased from a high of 4.9 in 2010 to 3.6 in 2022.

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 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. The first two years of the trawl survey (1983 and 1986) were years dominated by walleye pollock. In subsequent years Atka mackerel had a higher biomass index than walleye pollock. The biomass index for Atka mackerel is generally more variable than the index for walleye pollock. This has resulted in the gradually decreasing values of this indicator over the time period examined.

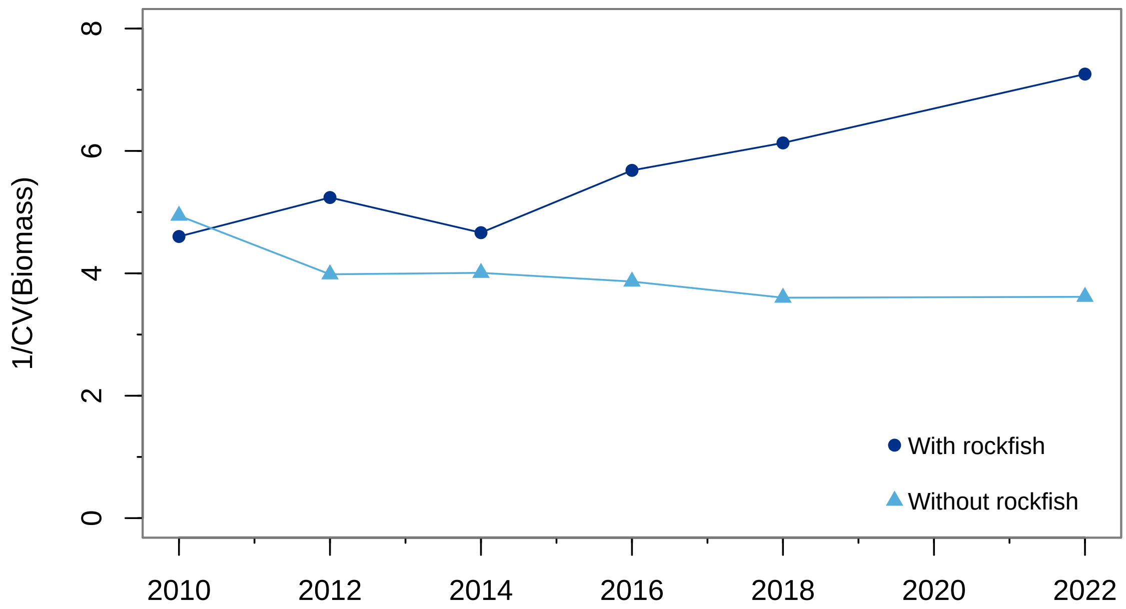

Figure 47: The stability of groundfish in the Aleutian Islands, represented by the inverse biomass coefficient of variation (1 divided by the coefficient of variation of total groundfish biomass (1/CV[B]). Ten years of data are required to calculate this metric, so this time series begins in 2010 after the tenth occurrence of the NMFS/AFSC summer bottom-trawl survey over the time period examined (1983–2022).

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

Mean Length of the Fish Community

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Description of indicator: The mean length of the groundfish community tracks fluctuations in the size of groundfish over time. This size-based indicator is thought to be 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 1989 survey did not occur and the AI was not surveyed again until 1991, leaving a 5 year gap. Also, the 2008 and 2020 surveys did not occur leaving 4 year gaps. The 1980 data was not available at the time this indicator was prepared, so it begins with 1983.

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 GOA and have their lengths regularly sampled (for complete survey details see von Szalay and Raring 2020). 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.

New this year, 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 2022 is 37.7 cm. This is down one cm from 2018 and is just greater than the long term mean of 37.5 cm (Figure 48). 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, excluding rockfish, is 40.1 cm. This is 2 cm less than 2018 but greater than the long-term mean of 39.6 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.

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 mean length of the community. Environmental factors could also influence fish growth and mean length by effecting 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 (1983–2022) 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.

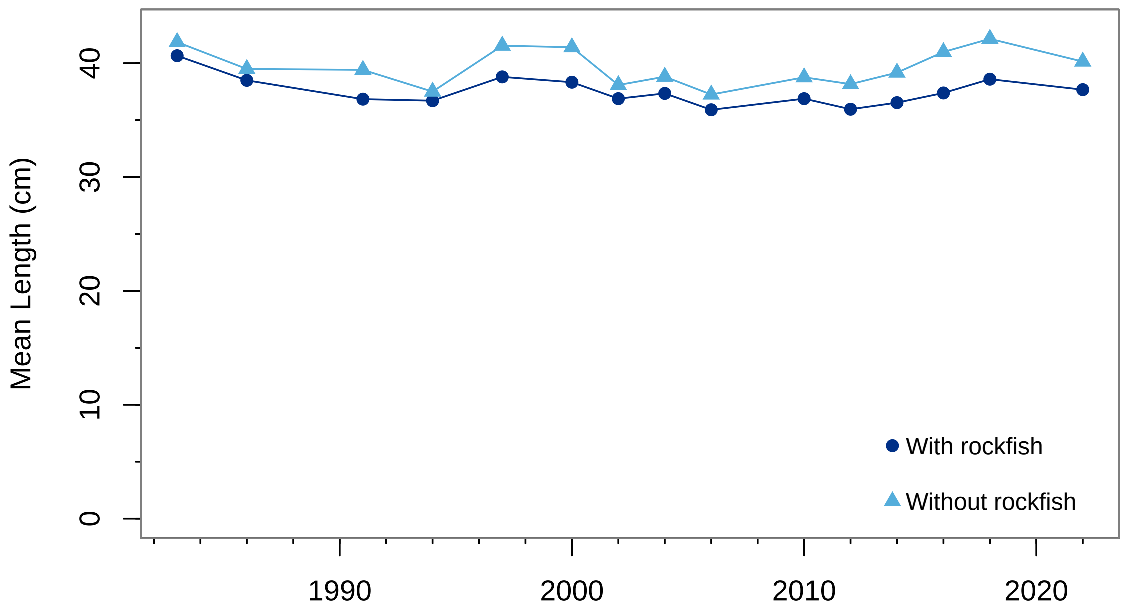

Figure 48: Mean length of the groundfish community sampled during the NMFS/AFSC summer bottom-trawl survey of the Aleutian Islands (1983-2022). The groundfish community mean length is weighted by the relative biomass of the sampled species.

Mean Lifespan of the Fish Community

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Last updated: October 2022

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)(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[10] . 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 and Raring 2020). 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 1989 survey did not occur and the AI was not surveyed again until 1991, leaving a 5 year gap. Also, the 2008 and 2020 surveys did not occur leaving 4 year gaps. The 1980 data was not available at the time this indicator was prepared, so it begins with 1983.

New this year, rockfish are included in this indicator, including dusky rockfish, northern rockfish, Pacific ocean perch, rougheye rockfish, shortraker rockfish, shortspine thornyhead, and other emphSebastes. 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: *With rockfish*—The mean lifespan of the Aleutian Islands demersal fish community in 2022 is 62.1 which is down from 63.6 in 2018 and above the long term mean of 50.7 over the years 1983–2022. This indicator has generally trended upward from a low of 33.1 in 1994 to a peak of 68.5 in 2012.

Without rockfish—The mean lifespan of the groundfish community, excluding rockfish, is 21.4, which is down from 22.7 in 2018 but remains above the long-term mean of 20.9. 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 (1983–1994) 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

[10]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

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).

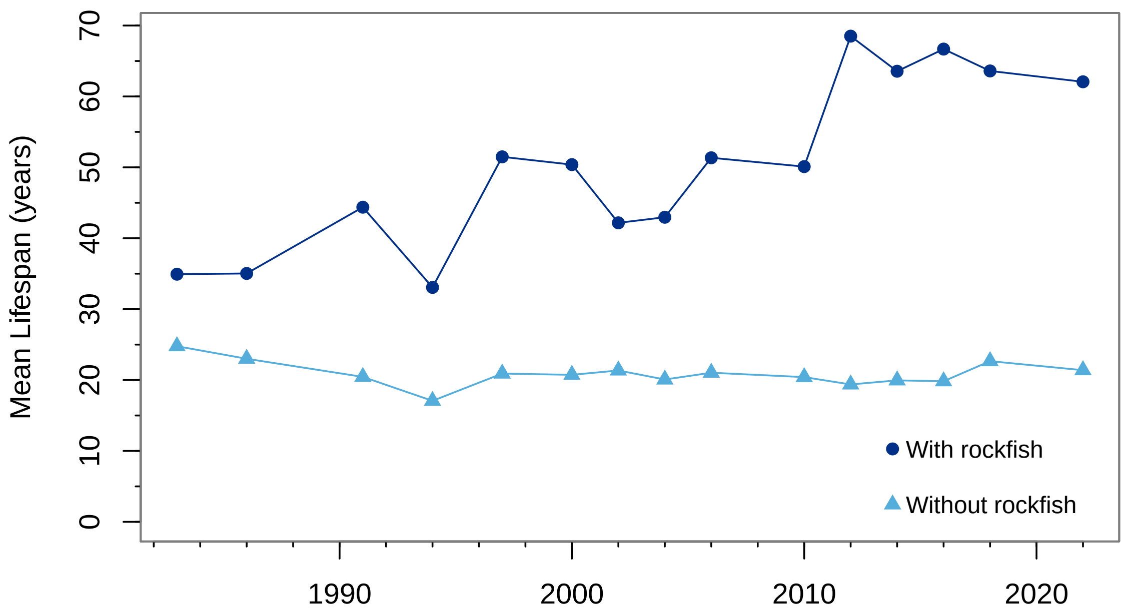

Figure 49: The mean lifespan of the Aleutian Islands groundfish community, weighted by biomass indices calculated from the NMFS/AFSC summer bottom-trawl survey (1983-2022).

Disease Ecology Indicators

Harmful Algal Blooms in the Aleutian Islands

Contributed by Thomas Farrugia[1],Chandra Poe[2],Matt Smith[3], Caroline van Hemert[3], Bruce Wright[4]

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Last updated: October 2022

Sampling Partners:

Alaska Ocean Observing System	UAF Alaska Sea Grant
Alaska Veterinary Pathologists	Aleutian Pribilof Island Association
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*	NOAA Kasitsna Bay Lab
NOAA WRRN-West	North Slope Borough
Organized Village of Kake*	Organized Village of Kasaan*
Petersburg Indian Association*	Qawalangin Tribe of Unalaska
Sitka Tribe of Alaska*	Skagway Traditional Council*
Southeast Alaska Tribal Ocean Research	Sunaq Tribe of Kodiak*
Woods Hole Oceanographic Institution	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 since (Ostasz, 2001) (see DHSS fatality report: `https://aoos.org/wp-content/uploads/2019/06/DHSS_PressRelease_PSPFatality_20200715.pdf)`). 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.

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.

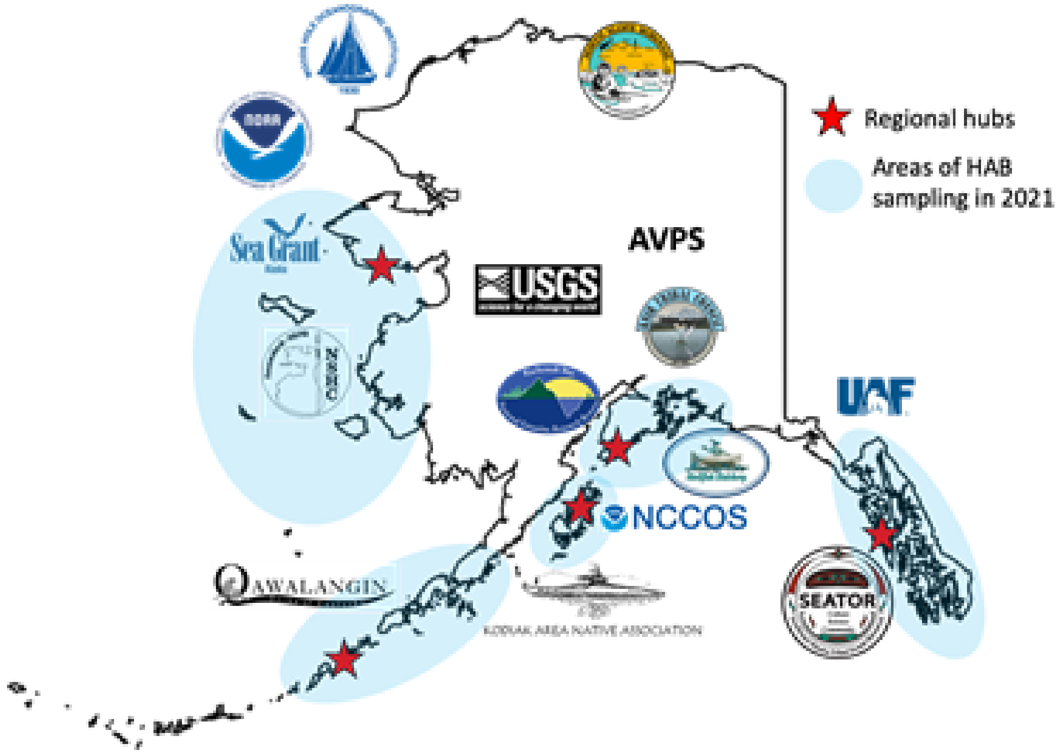

Figure 50: Map of sampling areas and sampling partners in 2021

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 to reduce human health risk (top map, Figure 50). 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 on methods can be found on the Alaska HAB Network website [11] or through the sampling partners listed above.

Status and trends: Alaska Region: Results from shellfish and phytoplankton monitoring showed an overall lower presence of harmful algal blooms (HABs) throughout all regions of Alaska in 2022 compared to 2021, 2020 and 2019. . However, bivalve shellfish from areas that are well known for having PSP levels above the regulatory limit, including Southeast Alaska and Unalaska, continued to have samples that tested above the regulatory limit (particularly from March to September) albeit less frequently than since 2019. Over the last few years, the dinoflagellate Dinophysis (which may cause Diarrhetic Shellfish Poisoning, DSP) has become more common and abundant in water samples, and 2022 continued that trend.

We are seeing a geographic expansion of areas that are sampling for phytoplankton species, so the decrease in the number of HABs detected may be more related to generally cooler water temperatures, especially in the Gulf of Alaska. In the north, a detailed survey of HABs from the northern Bering Sea to the western Beaufort Sea was conducted. This is the first-ever extensive survey of HABs in this region.

The Alaska Department of Environmental Conservation tests bivalve shellfish harvested from classified shellfish growing areas meant for the commercial market for marine biotoxins including paralytic shellfish toxin (PST,

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

tested by mouse bioassay and post-column oxidation) in all bivalve shellfish and domoic acid specifically in razor clams. The Environmental Health Laboratory (EHL) also does testing for research, tribal, and subsistence use.The EHL is the sole laboratory in the state of Alaska certified by the FDA to conduct regulatory tests for commercial bivalve shellfish. To date in 2022, the EHL has analyzed 371 commercial samples (DA: 0, PST: 371) and 723 non-commercial samples (DA: 537, PST: 186).

The 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). In April 2022, an Epidemiology Bulletin describing cases was released [12]

More information about PSP and other shellfish poisoning can be found on the SOE website[13].

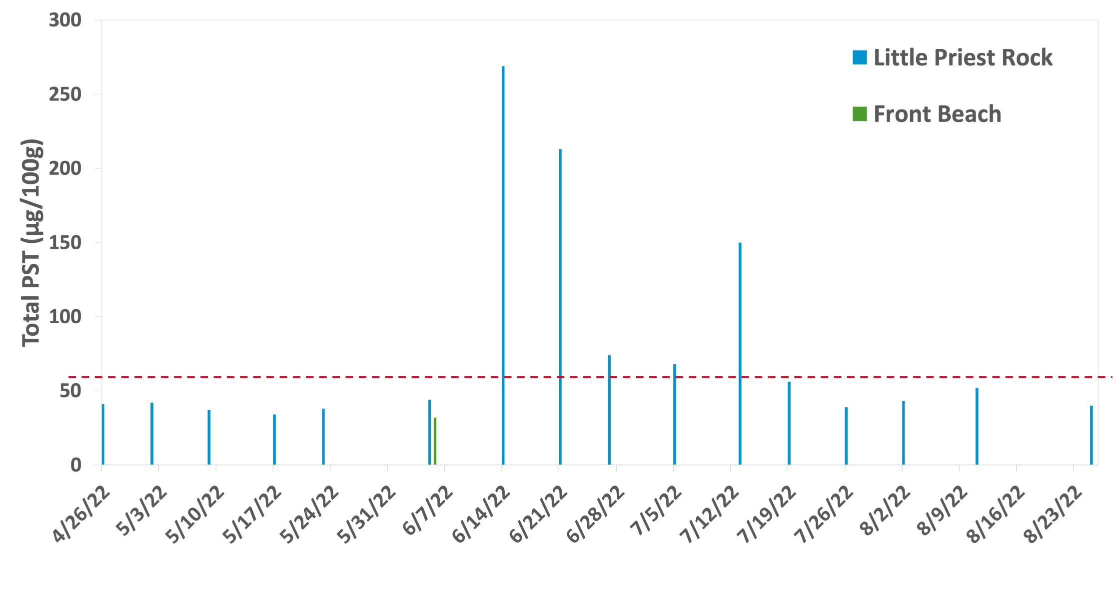

Figure 51: Paralytic shellfish toxins detected in blue mussels samples collected at three locations on Unalas. Data and figure from Qawalangin Tribe of Unalaska

Aleutian Islands: The USGS Alaska Science Center continued to test seabird tissues submitted through the National Wildlife Health Center (NWHC) for the presence of STX and domoic acid . The majority of tissues submitted in fall 2021 were below detectable levels for STX with the exception of a tufted puffin that was collected in Unalaska in July, 2020 and submitted to the NWHC in August, 2021. This bird had maximum STX concentrations of 16.9 µg/100g in gastrointestinal tissue and is suspected to have died of saxitoxicosis. Subsequent High Performance Liquid Chromatography (HPLC) analysis results are pending. (Matt Smith/Danielle Gerik/Caroline van Hemert, USGS)

Shellfish collection and testing on Unalaska by the Qawalangin Tribe of Unalaska during spring and summer indicated lower levels of PST in blue mussels during the 2022 season than in recent years. Levels exceeding regulatory limits were observed three times between May and September. These maximum values were below the amounts found in 2021, with the highest test result of 269 µg/100g (3.4x the legal limit) in June 2022 (Figure 51). (Chandra Poe, Qawalangin Tribe of Unalaska). Since 2006 the Knik Tribe has been monitoring for PSP and domoic acid at over 30 stations in Alaska, Canada and Russia. In 2022 the Knik Tribe submitted several samples, and the Alaska Department of Environmental Conservation has analyzed about 1/2 of these samples

[12] http://www.epi.alaska.gov/bulletins/docs/b2022_05.pdf.
[13] https://health.alaska.gov/dph/Epi/id/Pages/dod/psp/default.aspx

with 200 samples yet to be processed. The remaining sample results are expected in November 2022 with a final summary report due in March 2023. (Bruce Wright, Knik Tribe).

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.

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.

Fishing and Human Dimensions Indicators

Discards and Non-Target Catch

Time Trends in Groundfish Discards

Contributed by Anna Abelman, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA; and Alaska Fisheries Information Network, Pacific States Marine Fisheries Commission

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Last updated: September 2022

Description of indicator: Estimates of groundfish discards for 1993-2002 are sourced from NMFS Alaska Region's blend data, while estimates for 2003 and later come from the Alaska Region's Catch Accounting System. These sources, which are based on observer data in combination with industry landing and production reports, provide the best available estimates of groundfish discards in the North Pacific. Discard rates as shown in Figure 52 below are calculated as the weight of groundfish discards divided by the total (i.e., retained and discarded) catch weight for the relevant area-gear-target sector. Where rates are described below for species or species groups, they represent the total discarded weight of the species/species group divided by the total catch weight of the species/species group for the relevant area-gear-target sector. These estimates include only catch of FMP-managed groundfish species within the FMP groundfish fisheries. Discards of groundfish in the halibut fishery and discards of forage fish and species managed under prohibited species catch limits, such as halibut, are not included.

Status and trends: Since 1993 discards and discard rates of groundfish in federally-managed Alaskan groundfish fisheries have generally declined in the trawl pollock and non-pollock trawl sectors in the Aleutian Islands (AI), (see Figure 53). Discard biomass in the trawl pollock sector was highest from 1995 to 1997, averaging 2,330 mT annually during this period, before falling in 1998 to 215 mT and averaging 320 mT annually from 1998 to 2020. The 2020 discard biomass in this sector (1265 mT) was the highest since 2007, but decreased once again to 218 mT this year. The non-pollock trawl sector has seen the steepest declines in discard biomass and rates since 1993. Discards in this sector peaked at 32500mT in 1996 (21% discard rate); annual discard biomass and rates averaged 15,300 mT and 15% annually from 1997 to 2007 and 4,119 mT and 4% annually from 2008 to 2021. In the fixed-gear sector, the discard volume and discard rate have also declined across the AI area in general since 1993. Over the most recent 5-year period (2017–2021), the annual discard biomass and discard rate in the AI fixed gear sector have averaged 928 mT and 8%, respectively, compared to 2,102 mT and 10% averaged over the longer 1993–2020 period. When disaggregated by subarea, fixed gear discard rates in the Western (WAI) and Central AI (CAI) subareas show large interannual variation over the 10 most recent years. Discard rates in the non-pollock trawl sector have generally declined across all three subareas since 2010. To date in 2022, discard biomass through week 35 is higher in the trawl non-pollock and fixed gear sectors relative to the preceding 5-year (2017–2021) period, whereas discards in the pollock trawl gear sector are lower (Figure 53).

In the fixed-gear sector, the discard volume and discard rate have also declined across the AI area in general since 1993. Over the most recent 5-year period (2016–2020), the annual discard biomass and discard rate in the AI fixed gear sector have averaged 1,093 mT and 8%, respectively, compared to 2,166 mT and 10% averaged over the longer 1993–2020 period. When disaggregated by subarea, fixed gear discard rates in the Western (WAI) and Central AI (CAI) subareas show large interannual variation over the 10 most recent years. Discard rates in the non-pollock trawl sector have generally declined across all three subareas since 2010. To date in 2021, discard biomass through week 33 is higher in the trawl non-pollock and fixed gear sectors relative to the preceding 5-year (2016–2020) period, whereas discards in the fixed gear sector are lower (Figure 53).

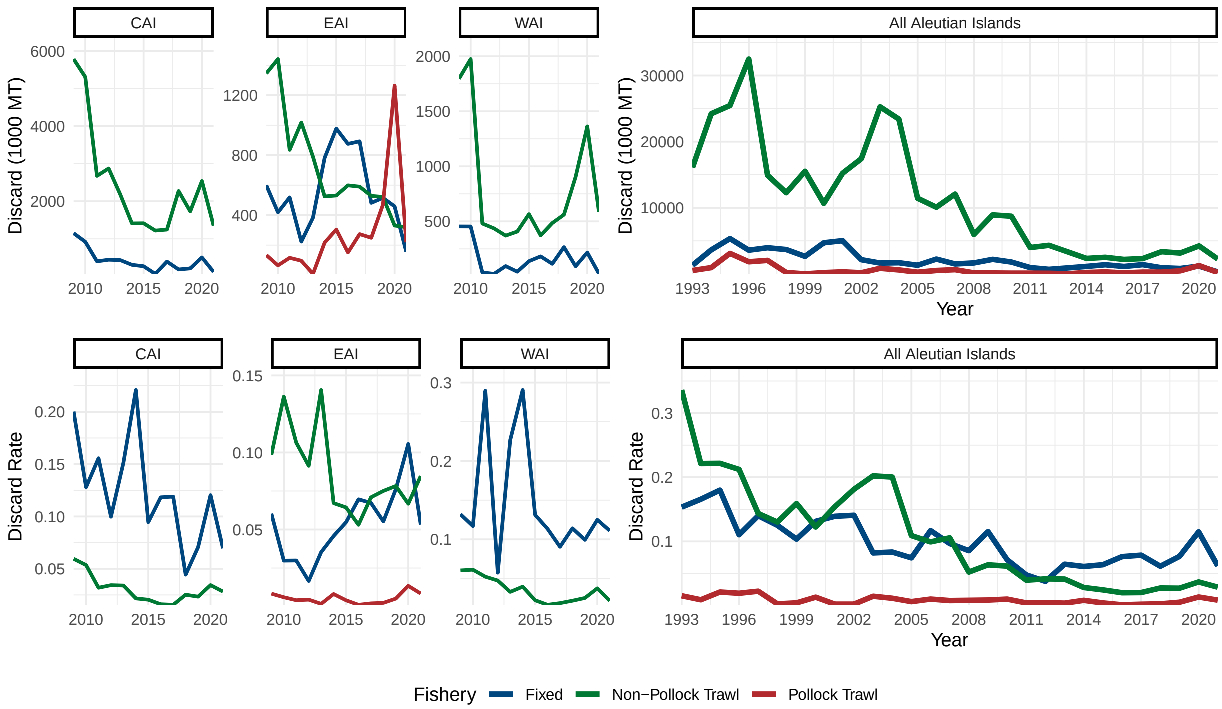

Figure 52: Total biomass and percent of total catch biomass of FMP groundfish discarded in the fixed gear, pollock trawl, and non-pollock trawl sectors for the Aleutian Islands region, 1993-2021; and for central (CAI), eastern (EAI), and western (WAI) subregions, 2009-2021. Discard rates are calculated as total discard weight of FMP groundfish divided by total retained and discarded weight of FMP groundfish for the sector (includes only catch counted against federal TACs)

.

Factors influencing observed trends: Improved-retention regulations implemented in 1998 prohibiting discards of pollock and Pacific cod help account for the sharp declines in discard rates in the GOA and BSAI trawl pollock fisheries after 1997. Discard rates in the BSAI non-pollock trawl sector had a similar decline in 2008 following implementation of a groundfish retention standard for the trawl head-and-gut fleet. Improved observer coverage on vessels less than 60' long and on vessels targeting IFQ halibut may account for the apparent increase in the volume of discards in the GOA fixed gear sector in 2013.

Additionally, the regulations 50 CFR 679.20(j) and 50 CFR 679.7(a)(5) primarily require operators of catcher vessels using hook-and-line, pot, for jig gear (fixed gear) to fully retain rockfish landings in the BSAI or GOA. These regulations, which also restricts the amount of rockfish that can enter into the market, were implemented back in March 2020 with the overall purpose of limiting total catch of rockfish.

Implications: Fishery discards adds to the total human impact on biomass without providing a benefit to the Nation and as such is perceived as "contrary to responsible stewardship and sustainable utilization of marine resources" (Kelleher, 2005). Discards may constrain the utilization of target species and increases the uncertainty around total fishing-related mortality, making it more difficult to assess stocks, define overfishing levels, and monitor fisheries for overfishing (Alverson 1994, NMFS2011, Clucas 1997). Although ecosystem effects of discards are not fully understood, discards of whole fish and offal have the potential to alter energy flow within ecosystems and have been observed to result in changes to habitat (e.g., oxygen depletion in the benthic environment) and community structure (e.g., increases in scavenger populations) (Queirolo 1995, Alverson 1994, Catchpole 2006, Zador et al. 2008). Monitoring discards and discard rates provides a means of assessing the efficacy of measures intended to reduce discards and increase groundfish retention and utilization.

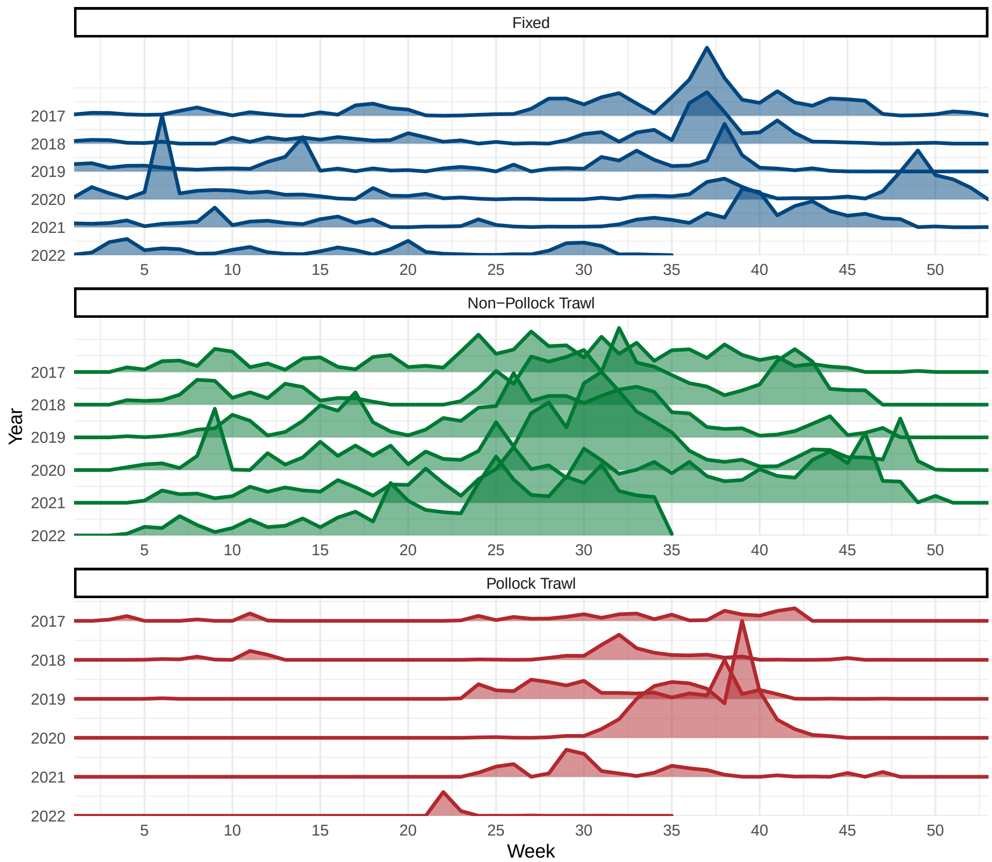

Figure 53: Total biomass of FMP groundfish discarded in the Aleutian Islands region by sector and week, 2015 - 2021 (data for 2021 is shown through week 33). Plotted heights are not comparable across sectors).

Time Trends in Non-Target Species Catch

Contributed by George A. Whitehouse[1], Sarah Gaichas[2]
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Last updated: August 2022

Description of indicator: We monitor the catch of non-target species in groundfish fisheries in the Aleutian Islands (AI). In previous years, we included the catch of "other" species, "non-specified" species, and forage fish in this contribution. However, stock assessments have now been developed or are under development for all groups in the "other species" category (sculpins, unidentified sharks, salmon sharks, dogfish, sleeper sharks, skates, octopus), some of the species in the "non-specified" group (giant grenadier, other grenadiers), and forage fish (e.g., capelin, eulachon, Pacific sand lance, etc.), therefore we no longer include trends for these species/groups here (see AFSC stock assessment website at https://www.fisheries.noaa.gov/alaska/population-assessments/north-pacific-groundfish-stock-assessments-and-fishery-evaluation). Invertebrate species associated with habitat areas of particular concern, previously known as HAPC biota (seapens/whips, sponges, anemones, corals, and tunicates) are now referred to as structural epifauna. Since 2013, the three categories of non-target species we continue to track 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).

Total catch of non-target species is estimated from observer species composition samples taken at sea during fishing operations, scaled up to reflect the total catch by both observed and unobserved hauls and vessels operating in all FMP areas. Catch since 2003 has been estimated using the Alaska Region's Catch Accounting System (Cahalan et al., 2014). This sampling and estimation process results in some uncertainty in catches, which is greater when observer coverage is lower and for species encountered rarely in the catch.

Total catch of non-target species is estimated from observer species composition samples taken at sea during fishing operations, scaled up to reflect the total catch by both observed and unobserved hauls and vessels operating in all FMP areas. Catch since 2003 has been estimated using the Alaska Region's Catch Accounting System (Cahalan et al., 2014). This sampling and estimation process results in uncertainty in catches, which is greater when observer coverage is lower and for species encountered rarely in the catch

The catch of non-target species/groups from the AI includes the reporting areas 518, 519, 541, 542, 543, and 610 [14]. 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 gradually decreased from 2011–2015, then increased from 2015 to 2020, with peaks in 2017 and 2020 (Figure 54). Scyphozoan jellies are primarily caught in the pollock fishery. The catch of structural epifauna in the AI has been variable from 2011-2021, with a peak catch in 2015. 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

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

in the AI has been variable from 2011 to 2021, 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.

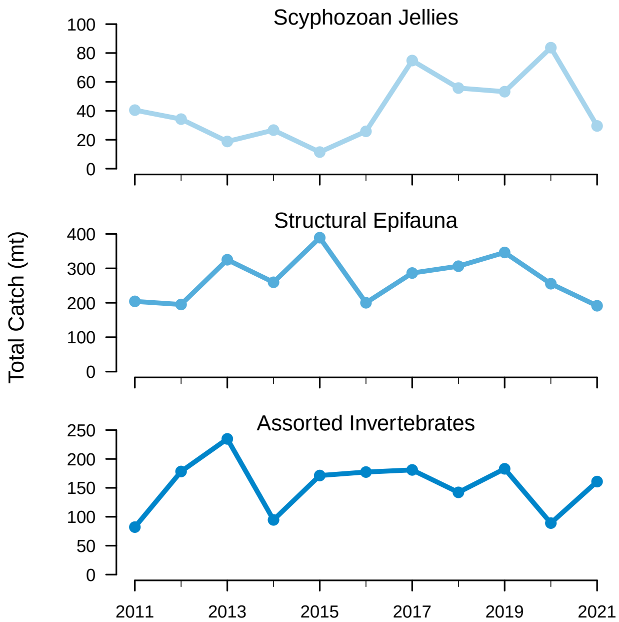

Figure 54: Total catch of non-target species (tons) in AI groundfish fisheries (2011–2020). Please note the different y-axis scales between regions and species groups.

Factors influencing observed 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).

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).

Seabird Bycatch Estimates for Groundfish Fisheries in the Aleutian Islands, 2012–2021

Contributed by Cathy Tide and Anne Marie Eich, Sustainable Fisheries Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
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Last updated: August 2021

Description of indicator: This report provides estimates of the numbers of seabirds caught as bycatch in commercial groundfish fisheries operating in waters off Alaska in the Aleutian Islands (AI) for the years 2012 through 2021 and halibut fisheries for the years 2013 through 2021. 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. Fishing gear types represented are demersal longline, pot, pelagic trawl, and non-pelagic trawl. These numbers do not apply to jig, gillnet, seine, or troll fisheries[15].

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. Observer deployment plans are reviewed and updated annually in the Annual Deployment Plan (the 2021 plan is available at: `https://www.fisheries.noaa.gov/resource/document/2020-annual-deployment-plan-observers-groundfish-and-halibut-fisheries-alaska`). The NMFS Alaska Regional Office Catch Accounting System (CAS) produces the estimates (Cahalan et al. 2014, Calahan 2010). The main purpose of the CAS is to provide near real-time delivery of accurate groundfish and prohibited species catch and bycatch information for in-season management decisions. CAS also estimates non-target species (such as invertebrates) and seabird bycatch in the groundfish fisheries. The CAS produces estimates based on these three current data sets, which may have changed over time.

Estimates of seabird bycatch from the AI include the reporting areas 610 west of 164 split, 518, 519, 541, 542, and 543, [16].

Status and trends: The number of seabirds estimated to be caught incidentally in the AI fisheries in 2021 (1,673 birds) was 356% more than estimates from 2020 (367 birds), and were 95% more than the 2012–2020 average of 859 birds (Table 1; Figure 55). This dramatic increase in the estimated seabird takes is primarily due to the low number of shearwaters taken in 2020. Aside from shearwater bycatch, seabird takes in the AI fisheries in 2021 were relatively similar to takes in 2020. The exception was northern fulmar 2021 estimated bycatch which was approximately 94% less than 2020, and was below the 2012-2020 average of 312 birds by 93%. No short-tailed albatross, black-footed albatross, or Laysan albatross were reported as taken in the AI (Figure 56).

[15] 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

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

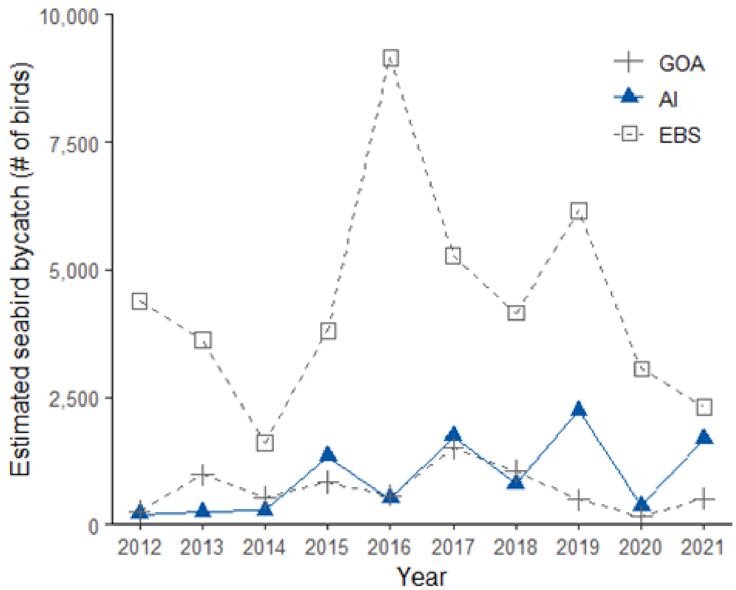

Figure 55: Total estimated seabird bycatch in eastern Bering Sea (EBS), Eastern Gulf of Alaska (EGOA), Western Gulf of Alaska (WGOA), and Aleutian Islands (AI), groundfish fisheries, all gear types combined, 2011 through 2020.

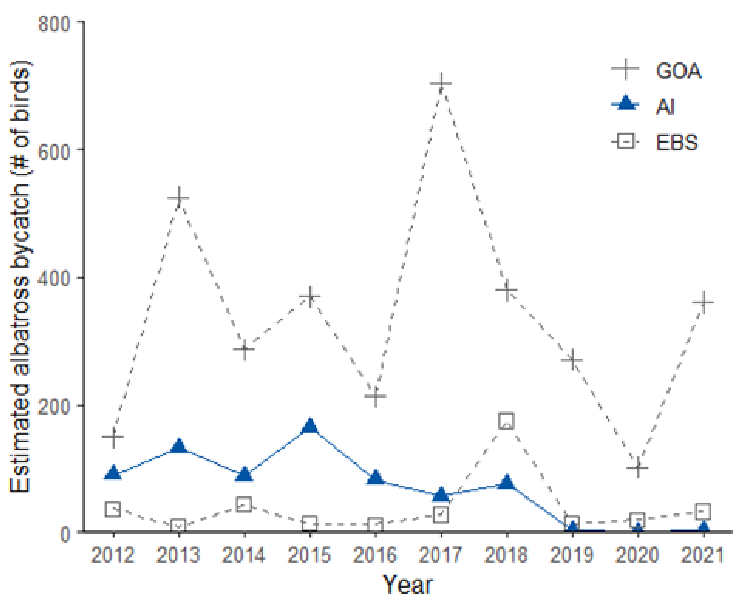

Figure 56: Total estimated albatross bycatch in eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) groundfish fisheries, all gear types combined, 2011 through 2020.

Table 1: Estimated seabird bycatch in Aleutian Islands groundfish and halibut fisheries for all gear types, 2012 through 2021 (halibut fisheries 2013 through 2021). 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
Unidentified Albatrosses	0	<1	25	0	0	0	<1	<1	0	0
Short-tailed Abatross	0	0	<1	0	0	0	0	0	<1	0
Laysan Albatross	86	116	51	143	58	18	75	<1	<1	<1
Black-footed Albatross	3	17	12	20	25	38	1	3	<1	3
Northern Fulmar	25	60	71	1,091	185	572	293	163	350	21
Shearwaters	60	6	61	24	192	1,076	141	2,069	7	1,516
Storm Petrels	0	0	0	0	0	0	177	0	0	29
Gulls	23	31	11	56	20	8	9	7	6	58
Kittiwakes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Murres	<1	0	0	0	5	<1	0	0	<1	<1
Puffin	0	0	0	0	<1	0	0	0	0	0
Auklets	<1	0	0	5	28	11	102	0	0	0
Other Alcid	0	0	0	0	0	0	<1	0	0	0
Cormorants	0	0	0	1	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	<1	0
Unidentified	6	16	1	1	1	14	5	2	3	46
Grand Total	204	246	272	1,340	514	1,737	804	2,244	367	1,673

AI Atka mackerel trawl fisheries and rockfish trawl fisheries are responsible for the majority of seabird bycatch in the AI- the average annual seabird bycatch for 2012 through 2020 was 303 and 633 birds per year, respectively (NMFS, unpublished data). 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 the rockfish fisheries was below the 2012-2020 average by 52% (304 birds; NMFS unpublished data). Figure 3 shows the spatial distribution of observed seabird bycatch from 2016 – 2021 from the Atka mackerel trawl fisheries (responsible for the greatest overall takes of seabirds in the AI) overlaid onto heat maps depicting fishing effort for the fishery.

Focusing solely on the bycatch of albatross (unidentified, short-tailed, Laysan, and black-footed) in the AI, an estimated 69 albatross were taken per year from 2012 through 2021 Table 1). Three albatross were estimated to be taken as bycatch in 2021. The number of estimated black-footed albatross and Laysan albatross has been low since 2018 and 2019, respectively.

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.

While an increase in seabird bycatch in the Aleutian Islands groundfish and halibut fisheries occurred in 2021 compared to 2020, several events occurred during the 2020 fishing seasons which may partially explain this difference. As with many other things in 2020, the COVID-19 pandemic disrupted normal fishing operations throughout Federal fisheries. In Alaska, such disruptions included lost fishing days due to closures and stand-downs (primarily at the beginning of the pandemic) and reduced market prices for fish as restaurants and other buyers were not operating at normal levels and thus were not purchasing as much fish product

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.

(Dietrich and Fitzgerald, 2010) found in an analysis of 35,270 longline sets from 2004 to 2007 that the most predominant species, northern fulmar, only occurred in 2.5% of all sets. Albatross, a focal species for conservation

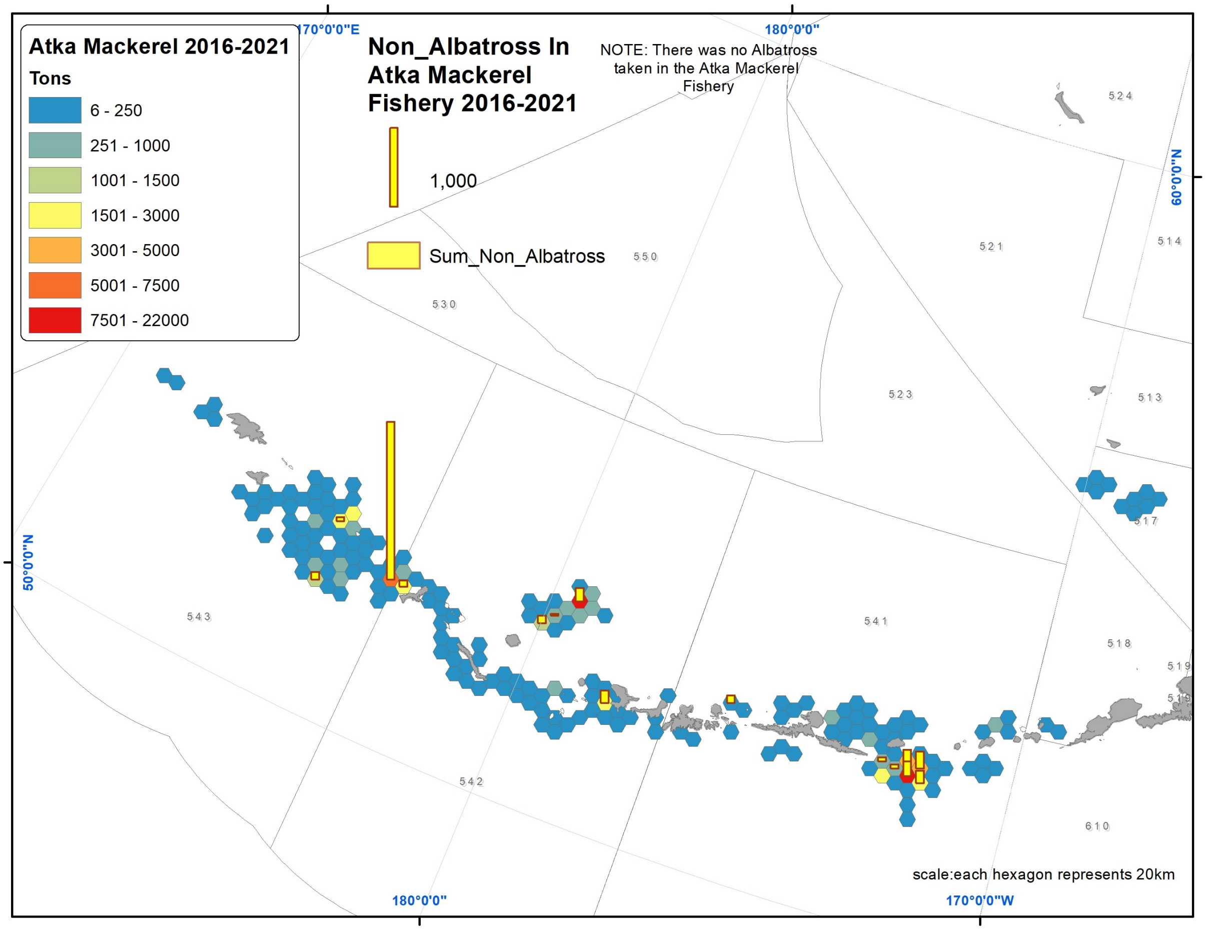

Figure 57: Spatial distribution of observed seabird bycatch from 2015–2020 from the Pacific cod hook and line fisheries. Colored vertical bars indicate the sum of incidental takes at a location grouped within 1/10 of a degree of latitude and longitude. Incidental takes are separated between takes of albatross and takes of non-albatross seabirds. Images include locations of incidental takes of seabirds overlaid on to heat maps depicting fishing effort for each relevant fishery. Note the difference of scale of observed takes of seabirds.

efforts, occurred in less than 0.1% of sets. Thus, while annual seabird bycatch estimates number in the 1,000's, given the vast size of the fishery, actual takes of seabirds remains relatively uncommon (Tide and Eich, 2022).

Implications: Estimated seabird bycatch in the Aleutian Islands groundfish and halibut fisheries in 2021 increased compared to 2020, and was among the highest estimates in the 10 year time series.

It is difficult to determine how seabird bycatch estimates and trends are linked to changes in ecosystem components because seabird mitigation gear is used in the longline fleet. There does appear to be a link between poor ocean conditions and the peak bycatch years, on a species-group basis. Fishermen have noted in some years that the birds appear starved and attack baited longline gear more aggressively. This probably indicates changes in food availability rather than distinct changes in how well the fleet employs mitigation gear. A focused investigation of this aspect of seabird bycatch is needed and could inform management of poor ocean conditions if seabird bycatch rates (reported in real time) were substantially higher than normal.

Maintaining and Restoring Fish Habitats

Area Disturbed by Trawl Fishing Gear in Alaska

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Last updated: October 2021

Description of indicator: Fishing gear can impact habitat used by a fish species for the processes of spawning, breeding, feeding, or growth to maturity. This indicator uses output from the Fishing Effects (FE) model (Smeltz et al., 2019) to estimate the area of geological and biological features disturbed in the Aleutian Islands, utilizing spatially-explicit Vessel Monitoring System (VMS) data summarized to 25km^2 grid cells in fishable depths (<1000m). The time series for this indicator is available since 2003, when widespread VMS data became available. In 2021, methods developed by the Alaska Regional Office of NMFS were used to incorporate unobserved fishing events over the entire time series (2003 – 2021) into FE analysis. Unobserved fishing events typically account for 7 - 12% of total effort in the VMS data set. For this analysis, NMFS statistical area 543 is in the western Aleutians, areas 542 and 541 are in the central Aleutians while the eastern Aleutians fall in statistical areas associated with the Bering Sea in the north and the western Gulf of Alaska in the south

Status and trends: The percent of area disturbed due to commercial fishing (pelagic and non-pelagic trawl, longline, and pot) across the Aleutian Islands has varied between 1–3% since 2003, with a slightly increasing trajectory across the three AI regions since 2015. This increase is likely due to a rise in non-pelagic trawl effort that has been higher than the 10-year average. (Figure 58). Figure 59 shows the location of the areas with the highest impact.

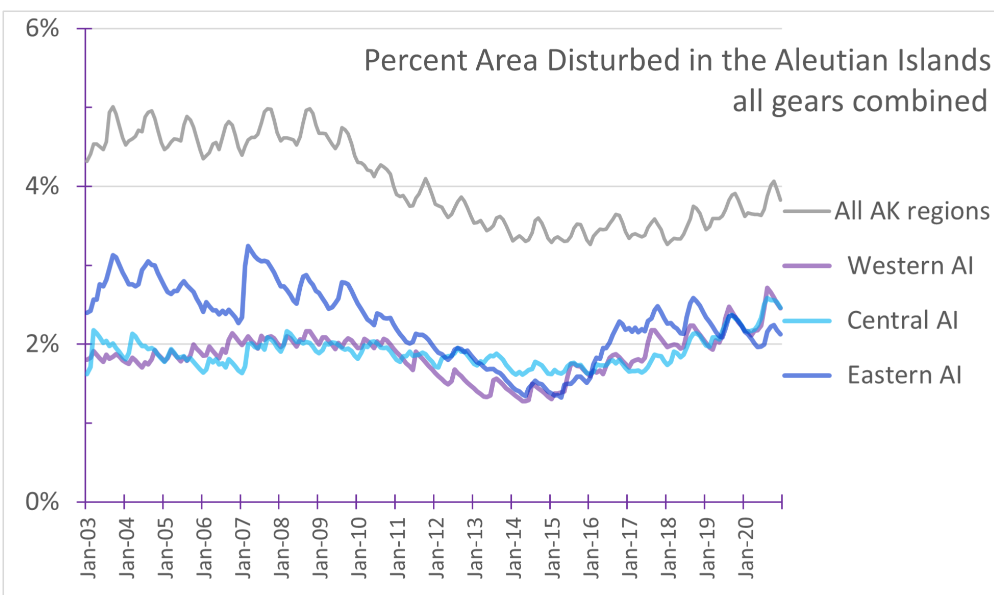

Figure 58: Percent habitat disturbance, all gear types combined, from 2003 through 2020.

Factors influencing observed trends: A seasonal component can be observed where percent area disturbed increases slightly during late summer – early fall months. The percent area disturbed in all Alaska regions combined is driven by the southern Bering Sea where percent habitat disturbance used to be around 10% at the beginning of the time series and is currently around 8%. In 2010, trawl sweep gear modifications were implemented on non-pelagic trawls in the Bering Sea, resulting in less gear contacting the seafloor and less habitat impact. Trawl sweep modifications were implemented in the Gulf of Alaska in 2014. The increase in 2007 n the eastern Aleutians is presumably an increase in yearly percent swept area in the Bering Sea but not in the Gulf of Alaska (Smeltz et al., 2019). In 2008, Amendment 80 was implemented, which allocated BSAI yellowfin sole, flathead sole, rock sole, Atka mackerel, and Aleutian Islands Pacific ocean perch to the head and gut trawl catcher processor sector, and allowed qualified vessels to form cooperatives. The formation of cooperatives reduced overall effort in the fleet while maintaining catch levels.

Trends in seafloor area disturbed can be affected by numerous variables, such as fish abundance and distribution, management actions (e.g., closed areas), changes in the structure of the fisheries due to rationalization, improved technology (e.g., increased ability to find fish, acoustics to fish near the bottom without contact), markets for fish products, and changes in vessel horsepower and fishing gear. Intensive fishing in an area can result in a change in species diversity by attracting opportunistic fish species which feed on animals that have been disturbed by fishing activity, or by reducing the suitability of habitat used by some species. It is possible that increased effort in fisheries that interact with both living and non-living bottom substrates could result in increased habitat loss/degradation due to fishing gear effects. The footprint of habitat damage varies with gear (type, weight, towing speed, depth of penetration), the physical and biological characteristics of the areas fished, recovery rates of living substrates in the areas fished, and management or economic changes that result in spatial redistribution of fishing effort.

Implications: The effects of changes in fishing effort on habitat are largely unknown, although our ability to quantify those effects has increased greatly with the development of a Fishing Effects model as a part of the 2015 Essential Fish Habitat (EFH) Review (`ftp://ftp.library.noaa.gov/noaa_documents.lib/NMFS/TM_NMFS_AFKR/TM_NMFS_FAKR_15.pdf`). The 2005 EFH FEIS and 2010 EFH 5-year Review concluded that commercial fisheries can have long-term effects on habitat; however, those impacts were determined to be minimal and not detrimental to fish populations or their habitats. These previous EFH analyses indicated the need for an improved fishing effects assessment methodology. With the development and implementation of the FE model, many of the shortcomings of previous fishing effects methods were addressed. Vessel Monitoring System data provide a much more detailed treatment of fishing intensity, allowing better assessments of the effects of overlapping effort and distribution of effort between and within grid cells. The development of a literature-derived fishing effects database has increased our ability to estimate gear-specific susceptibility and recovery parameters. The distribution of habitat types, derived from increased sediment data availability, has improved. The combination of these parameters has greatly enhanced our ability to estimate fishing impacts.

New methods and criteria were developed to evaluate whether the effects of fishing on EFH are more than minimal and not temporary on managed fish stocks in Alaska. These criteria were developed and reviewed by the Council and its advisory committees in 2016, and stock assessment authors in 2017. In April 2017, the Council concurred with the Plan Team consensus that the effects of fishing on EFH do not currently meet the threshold of more than minimal and not temporary, and mitigation action is not needed at this time.

Although the impacts of fishing across the domain are very low, it is possible that localized impacts may be occurring.

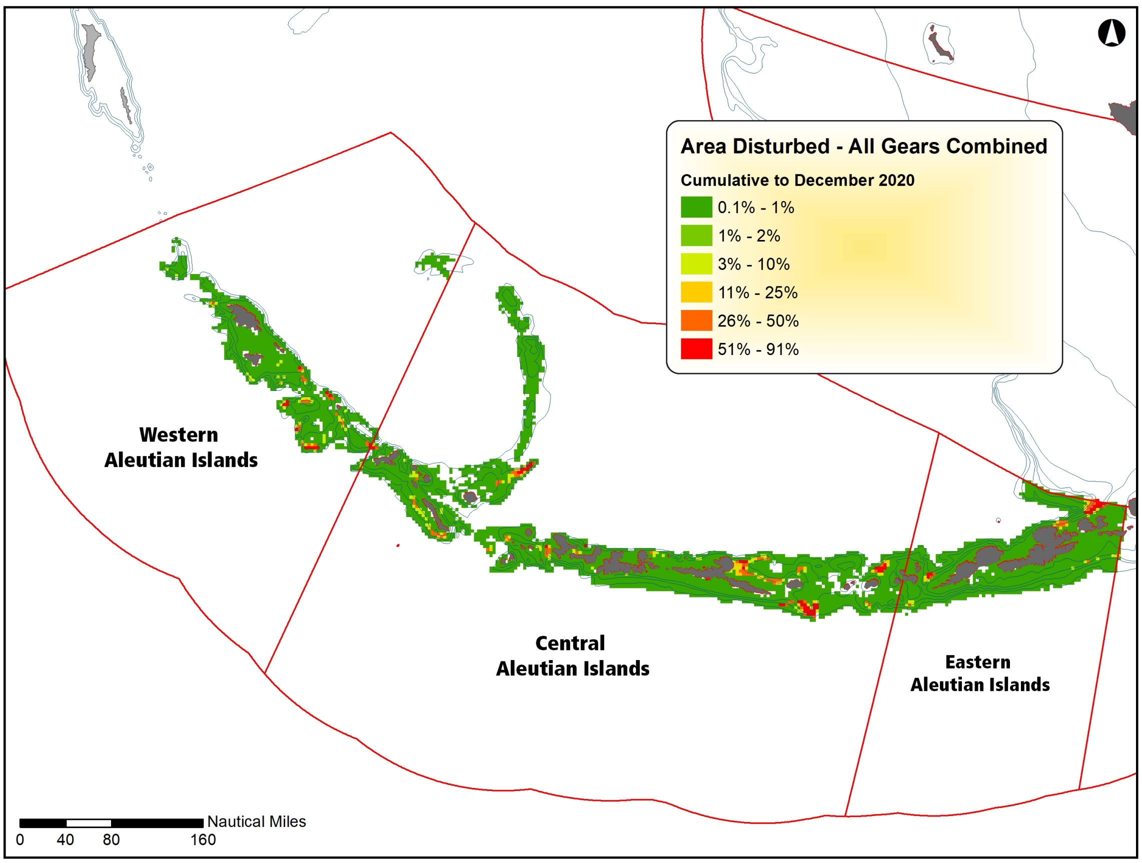

Figure 59: Map of percentage area disturbed per grid cell for all gear types. Effects are cumulative and consider impacts and recovery of features from 2003 to 2020.

Areas Closed to Bottom Trawling in the Aleutian Islands

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Description of indicator: Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut) (Figure 60, Table 2). Some of the trawl closures are in effect year-round while others are seasonal. In general, year-round trawl closures have been implemented to protect vulnerable benthic habitat. Seasonal closures are used to reduce bycatch by closing areas where and when bycatch rates had historically been high.

Status and trends: Closures to scallop dredge were initially developed in 1981, and have been updated, most recently in 2018. Additional measures to protect the declining western stocks of the Steller sea lion began in 1991 with some simple restrictions based on rookery and haulout locations; in 2000 and 2001 more specific fishery restrictions were implemented (Figure 61. In 2001, over 90,000 nm^2 of the Exclusive Economic Zone (EEZ) of Alaska was closed to trawling year-round as measures to protect the prey of Steller sea lions. Additionally, 40,000 nm^2 were closed on a seasonal basis. State waters (0–3 nmi) are also closed to bottom trawling in many areas. In 2006, a suite of measures were implemented by the NPFMC to freeze the footprint of non-pelagic trawling, resulting in over 280,000nm^2 of trawl closures.

Implications: With the Arctic FMP closure included, almost 65% of the U.S. EEZ of Alaska is closed to bottom trawling. The Steller Sea Lions Trawl Exclusion Zones limit access to Atka mackerel and Pacific cod in the Aleutian Islands. These closures may concentrate fishing effort to some localized areas for mackerel and cod; however, trawling for other species in those closed areas is allowed. In many cases, SSL and other closures are overlapping. Due to these closures and concentrated fishing effort, Aleutian Island habitat disturbance in the Aleutian Islands remain low ($<$4%).

For additional background on fishery closures in the U.S. EEZ off Alaska, see Witherell and Woodby (2005). Salmon savings areas are discussed within the context of salmon byctach by (Witherell et al., 2002). Steller Sea Lion closure maps are available in the link below:
https://www.fisheries.noaa.gov/alaska/sustainable-fisheries/alaska-fisheries-figures-maps-boundaries-regulatory-areas-and-zones

Steller Sea Lion closure maps are also available here:

http://www.fakr.noaa.gov/sustainablefisheries/sslpm/atka_pollock.pdf

http://www.fakr.noaa.gov/sustainablefisheries/sslpm/pcod_nontrawl.pdf

http://www.fakr.noaa.gov/sustainablefisheries/sslpm/cod_trawl.pdf

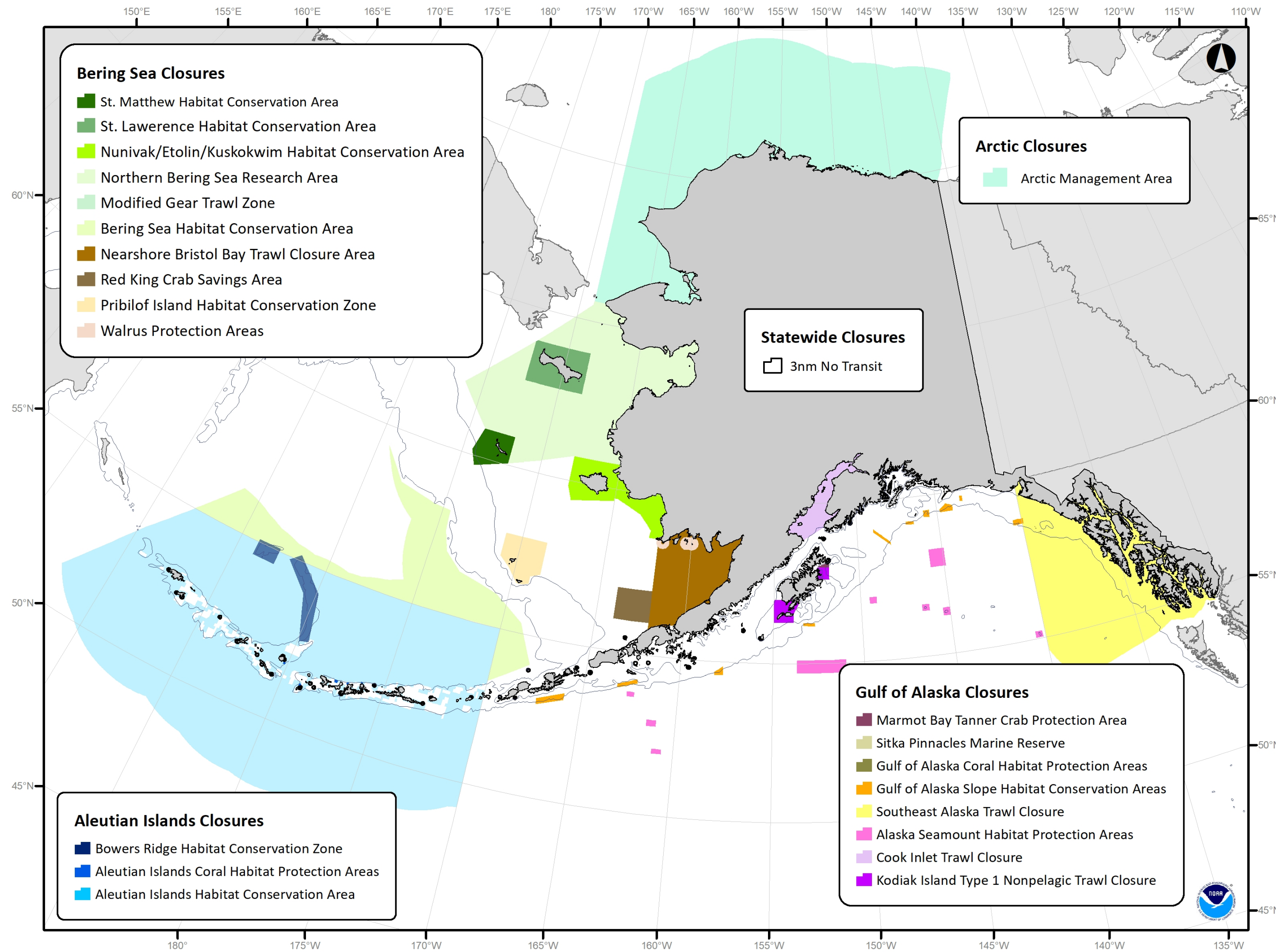

Figure 60: Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska, excluding most SSL closures.

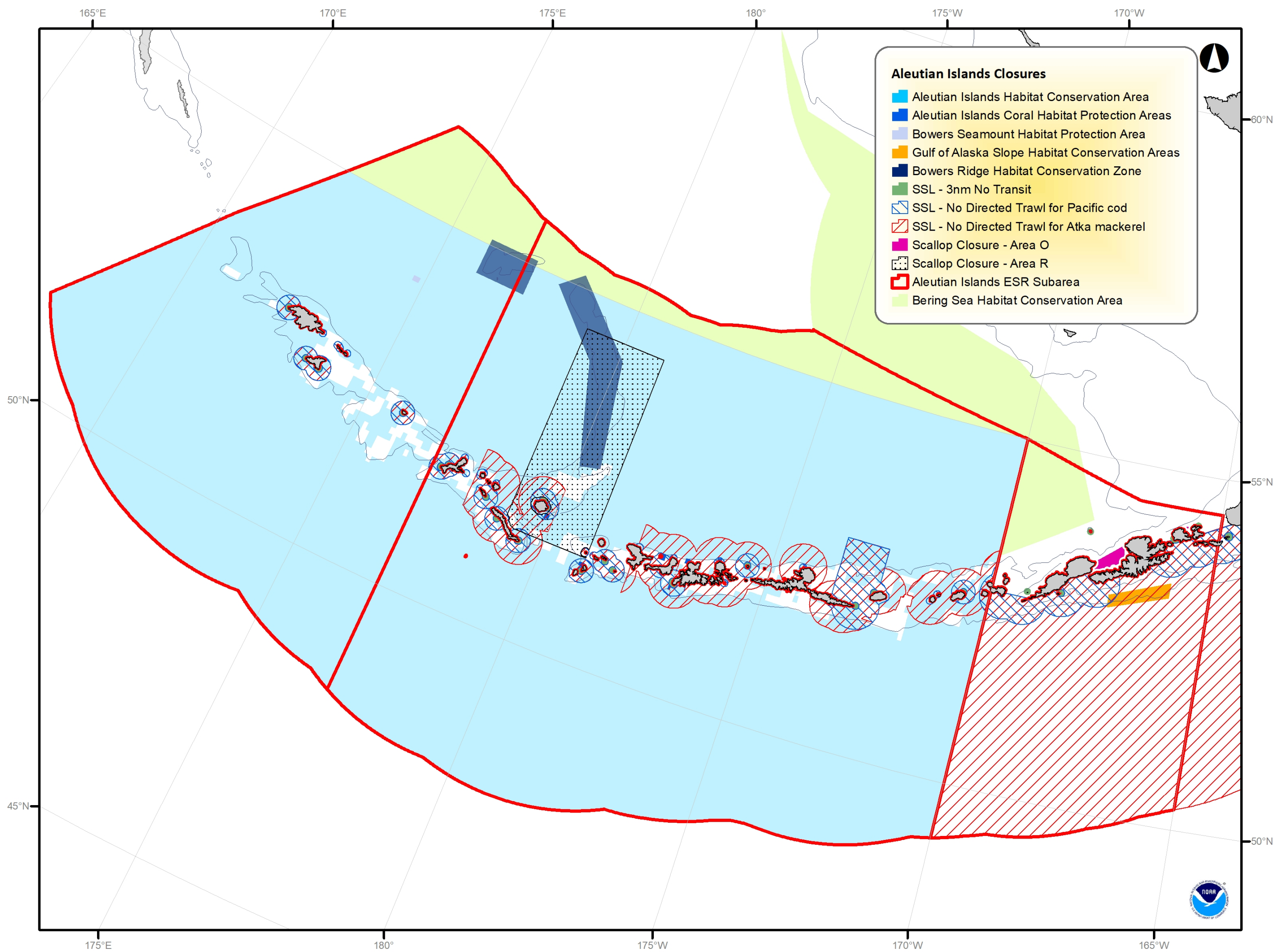

Figure 61: Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska, showing most SSL closures.

Table 2: Time series of groundfish trawl closure areas in the BSAI and GOA, that fall within the Aleutian Islands ecosystem 1995-2020. LLP= License Limitation Program; HCA = Habitat Conservation Area; HCZ = Habitat Conservation Zone.

Area	Year	Location	Season	Area size	Notes
BSAI	1995	Area 512	year-round	8,000 nm^2	closure in place since 1987
		Chinook Salmon Savings Area	trigger	9,000 nm^2	closed at 48,000 Chinook salmon
		Herring Savings Area	trigger	30,000 nm^2	trigger closure
		SSL Rookeries	seasonal ext.	5,100 nm^2	20 mile extensions at 8 rookeries
	2000	Steller Sea Lion protections			
		Pollock haulout trawl exclusion zones for EBS, AI * areas include GOA	* No trawl all year	11,900 nm^2	
			No trawl (Jan-June)*	14,800 nm^2	
			No Trawl Atka Mackerel restrictions	29,000 nm^2	
	2006	Essential Fish Habitat			
		AI Habitat Conservation Area	No bottom trawl all year	279,114 nm^2	
		AI Coral Habitat Protection Areas	No bottom contact gear all year	110 nm^2	
		Bowers Ridge Habitat Conservation Zone	No mobile bottom tending fishing gear	5,286 nm^2	
		Scallop Closure - Area R	No scallop dredge	295	initially 1981
GOA		SSL Rookeries	year-round	3,000 nm^2	10 mile no-trawl zones
	1998	Southeast Trawl Closure	year-round	52,600 nm^2	adopted as part of the LLP
	2000	Pollock haulout trawl exclusion zones for GOA* areas include EBS, AI	No trawl all year	11,900 nm^2*	
		GOA Slope Habitat Conservation Area	No bottom trawl all year	2,100 nm^2	
		GOA Coral Habitat Protection Measures	No bottom tending gear all year	13.5 nm^2	

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[17]. 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%).

The list of stocks included in the FSSI was revised in 2020 to focus on stocks of heightened commercial and recreational importance. In the Bering Sea and Aleutian Islands (BSAI), the Pribilof Islands blue king crab, Saint Matthew Island blue king crab, Pribilof Islands red king crab, and the black-spotted/rougheye rockfish stocks were removed from the FSSI and added to the group of non-FSSI stocks. The BSAI stock of Kamchatka flounder, the Aleutian Islands Pacific cod stock, and the Bogoslof stock of walleye pollock were added to the BSAI FSSI. These changes resulted in a net reduction from 22 to 21 FSSI stocks in the BSAI (See FSSI Endnotes for stock definitions). With few exceptions, groundfish species (or species complex) in the BSAI are managed as single stocks and not separately for the Bering Sea and Aleutian Islands. As such, the FSSI scores are reported for the BSAI as a whole.

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 eight of a rebuilding plan, and the Saint Matthews Island blue king crab stock is in year two of a 26-year rebuilding plan. None of the other non-FSSI stocks are known to be subject to overfishing, are overfished, or are approaching an overfished condition. For more information on non-FSSI stocks see the Status of U.S. Fisheries webpage [18].

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

Table 3: Summary of status for the 21 FSSI stocks in the BSAI updated through June 2022.

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

Status and trends: The overall Alaska FSSI generally trended upwards from 80% in 2006 to a high of 94% in 2018 (Figure 62)) and has since trended downward to 88.2% in 2022.

As of June 30, 2022, no BSAI groundfish stock or stock complex was subject to overfishing, or known to be approaching an overfished condition (Table 3). 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

The BSAI king and Tanner crab FSSI is 17 of a possible 20. One point was deducted for the Bristol Bay red king crab stock's biomass decreasing to below the B/BMSY threshold and two points were deducted for Bering Sea snow crab becoming overfished and their biomass dropping to 17% of B_{MSY}.

The overall BSAI FSSI score is 76 out of a maximum possible score of 84 (Table 4). The overall FSSI has generally trended upward from 74% in 2006 to a peak of 95.5% in 2019 but has since declined to 90.5% (Figure 63).

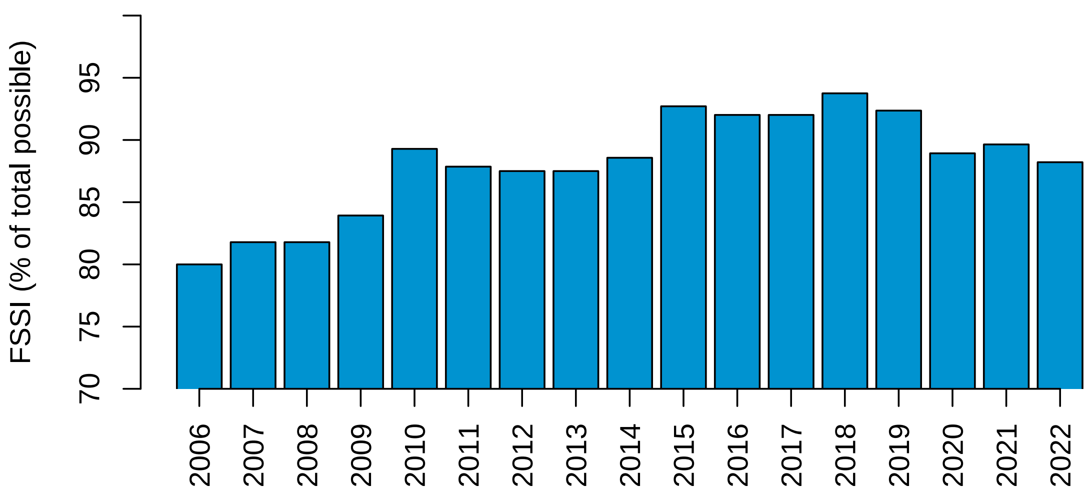

Figure 62: The trend in overall Alaska FSSI from 2006 through 2022 as a percentage of the maximum possible FSSI. The maximum possible FSSI was 140 from 2006 to 2014, 144 from 2015 to 2019, and 140 since 2020. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website: :`https://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates`.

Factors influencing observed trends: The overall trend in Alaska FSSI has been positive over much of the duration examined here (2006–2022). The decline in the Alaska total FSSI and in BSAI from 2021 to 2022 reflect the points lost for Bering Sea snow crab becoming overfished and their decreased biomass.

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

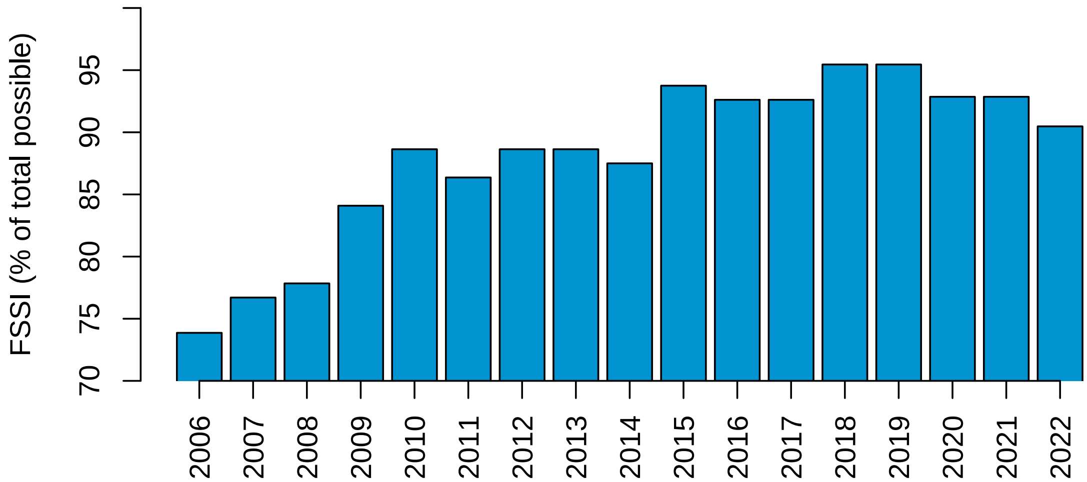

Figure 63: The trend in BSAI FSSI from 2006 through 2022 as a percentage of the maximum possible FSSI. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website: urlhttps://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates

Table 4: Table 2. BSAI FSSI stocks under NPFMC jurisdiction updated through June 2022 adapted from the NOAA Fishery Stock Status Updates webpage: https://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	Action	Progress	B_{MSY}	FSSI Score
Golden king crab - Aleutian Islands[a]	No	No	No	N/A	N/A	1.289/1.15	4
Red king crab - Bristol Bay	No	No	No	N/A	N/A	0.59	3
Red king crab - Norton Sound	No	No	No	N/A	N/A	1.07	4
Snow crab - Bering Sea	No	No	No	N/A	N/A	0.17	2
Southern Tanner crab - Bering Sea	No	No	No	N/A	N/A	0.96	4
BSAI Alaska plaice	No	No	No	N/A	N/A	1.58	4
BSAI Atka mackerel	No	No	No	N/A	N/A	1.12	4
BSAI arrowtooth Flounder	No	No	No	N/A	N/A	2.57	4
BSAI Kamchatka flounder	No	No	No	N/A	N/A	1.53	4
BSAI flathead Sole Complex[b]	No	No	No	N/A	N/A	2.08	4
BSAI rock sole complex[c]	No	No	No	N/A	N/A	1.67	4
BSAI skate complex[d]	No	No	No	N/A	N/A	2.28	4
BSAI Greenland halibut	No	No	No	N/A	N/A	1.7	4
BSAI Northern rockfish	No	No	No	N/A	N/A	2.1	4
BS Pacific cod	No	No	No	N/A	N/A	1.06	4
AI Pacific cod	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
BSAI Pacific Ocean perch	No	No	No	N/A	N/A	1.58	4
Walleye pollock - Aleutian Islands	No	No	No	N/A	N/A	1.39	4
Walleye pollock - Bogoslof	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
Walleye pollock - Eastern Bering Sea	No	No	No	N/A	N/A	1.31	4
BSAI yellowfin sole	No	No	No	N/A	N/A	1.9	4

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Appendices

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. 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 reports, one for the Gulf of Alaska, Aleutian Islands, eastern Bering Sea, and the Arctic[19].

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. 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 the Ecosystem Status Reports. In the past, concerns used to justify an ABC below the maximum calculated 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 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 or a value lower. Five risk tables were completed in 2018 as a test case. After review, the Council requested risk tables to be included in all stock assessments in 2019.

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 planned to be 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.

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 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 64). 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 data or make them available electronically. The Ecosystem Status Reports and data for many of the time series presented within are available online at: `http://access.afsc.noaa.gov/reem/ecoweb/index.php`. These reports and data are also available through the NOAA-wide IEA website at: `https://www.integratedecosystemassessment.noaa.gov/regions/alaska`.

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

[19] The Arctic report is under development

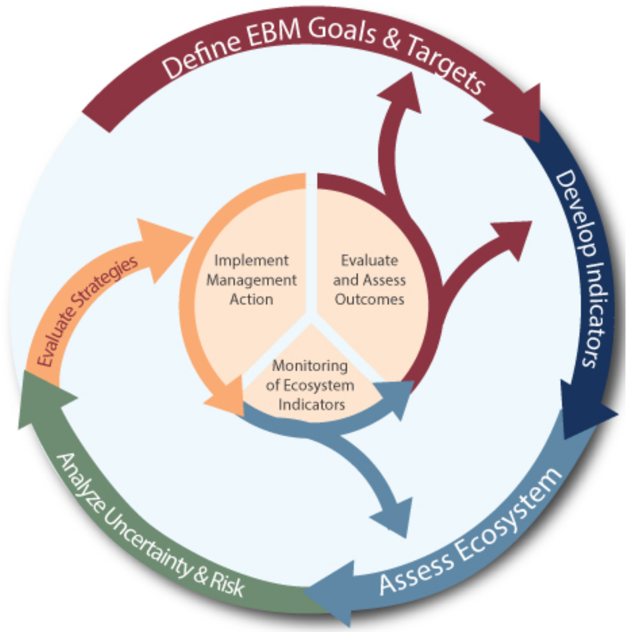

Figure 64: The IEA (integrated ecosystem assessment) process.

If you wish to obtain a copy of an Ecosystem Considerations Report version prior to 2000, please contact the Council office (907) 271-2809.

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

December 2021 and October 2022 meetings

December 2021 SSC Final Report to the NPFMC

C-3 and C-4 GOA Ecosystem Status Reports

The SSC received presentations by Elizabeth Siddon (NOAA-AFSC), Bridget Ferriss (NOAA- AFSC), and Ivonne Ortiz (UW-CICOES) on the Ecosystem Status Reports (ESRs) for the eastern Bering Sea, Gulf of Alaska, and the Aleutian Islands. The presentations were informative and highlighted the great strides that the authors and editors of the ESRs have made in producing documents that are insightful and of benefit to the management of federal fisheries off Alaska. The SSC appreciates the consistent high quality of the ESRs and their presentations. There was no public testimony.

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.

General comments applicable to all three ESRs

The general summaries and integrated sections on the physical environment and seabirds (GOA, EBS, AI), and Regional Highlights (AI) were information-dense and provided excellent syntheses of the individual reports. The SSC appreciates the efforts that went into these components of the reports. The Noteworthy Topics sections continue to highlight observations and issues that demand attention. The excision of the Executive Summary reduced redundancy and streamlined the summary portion of the ESR. The Report Card remains very useful

The SSC supports a holistic review of how economic and social science information is communicated and applied to Council decision-informing analytic products in 2022 (See Economic SAFE Section of this SSC report, and October 2021 SSC Minutes). The SSC requests that the review be transparent and inclusive, consistent with its suggestion for such a review during the October 2021 meeting. The SSC looks forward to the planned synthesis products for the Fishing and Human Dimensions section. In anticipation of this holistic review, some human dimensions indicators were not included in the 2021 report to better align the focus of the ESRs on informing next year's ABC determinations.

The response below was provided by NOAA's Alaska Fisheries Science Center Economics and Social Science Research Program.

"The AFSC Economics and Social Science Research Program (ESSRP) devised a framework [20] to help explain the economic and social information it provides in various annual reports to the NPFMC (see Figure 66). This framework has guided ESSRP's annual provision of social and economic information into NPFMC harvest specifications processes since 2021. There are several socio-economic documents produced annually by ESSRP and the placement of future social and economic indicators across these outlets will be guided by the decision the document is intended to inform (e.g., ABC/TAC/general management), the geographic and time scales of the indicator, and whether the indicator is intended to inform stock health. A SocioEconomic Aspects in Stock Assessments Workshop (SEASAW), specifically for the North Pacific, as suggested by the SSC in October 2021 is likely of interest to many, but the goals of that type of workshop are confounded by the NPFMC motion from October 201831, which states that socio-economic factors are to be considered during TAC setting but should not be incorporated into ABC recommendations. In light of this, ESSRP will not produce synthesized products for a "Fishing and Human Dimensions" section of the ESR, but will continue to provide syntheses and analyses of the economic condition of groundfish and crab fisheries in their respective economic SAFE reports as well as

[20] https://meetings.npfmc.org/CommentReview/DownloadFile?p=7a902abf-29ba-4c62-8b7e-4930eb80800b.pdf&fileName=PRESENTATION_ESSRP_GPT20210921.pdf

social conditions for communities highly engaged in FMP groundfish and FMP crab fisheries in the Annual Community Engagement and Participation Overview (ACEPO). These documents offer the appropriate length and context to address these critical socio-economic issues. ESSRP seeks to avoid duplicative effort by recreating this information in the ESR or potentially providing unusable information at the Large Marine Ecosystem (LME) scale. Stock-specific economic indicators are currently pro- vided for economic context within the stock assessment itself via the Economic Performance Report (EPR) for several stocks (including EBS pollock), or are included as an appendix. Economic and social metrics that have a direct impact on stock health (and thus ABC recommendation) could potentially be included in an ESP, except for the prohibition on doing so according to the NPFMC October 2018 motion. Therefore, relatively few social and economic metrics are included in the ESR and ESPs. However, extensive social and economic information are provided at appropriate scales in the Economic SAFE and ACEPO reports as well as available on the web via AKFIN's Human Dimensions of Fisheries Data Explorer[21]

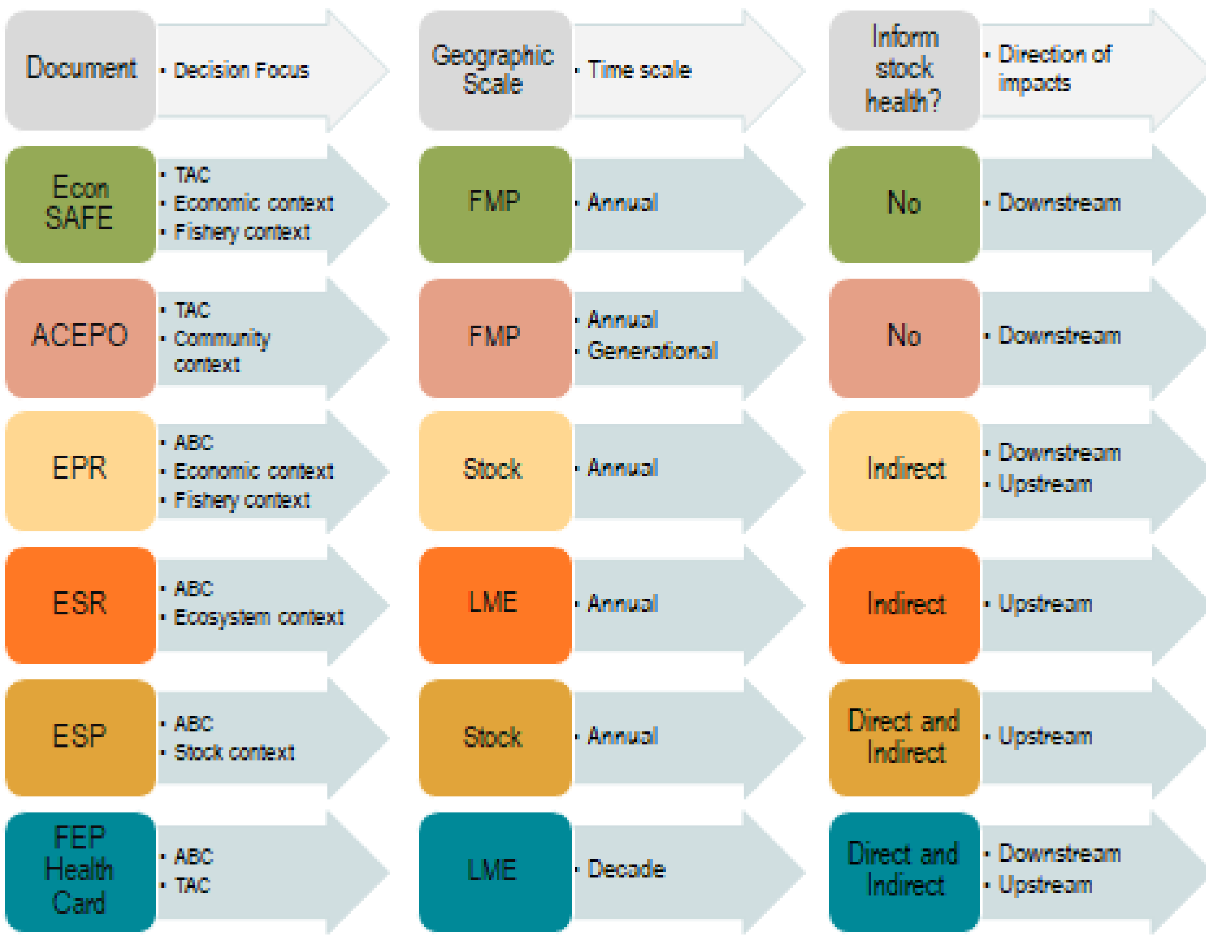

Figure 65: NOAA Alaska Fisheries Science Center's human dimensions indicators mapping

The "Purpose of the ESR" section (p.4) in each report indicates that the SSC is the primary audience (for setting ABCs/OFLs) but also the AP and Council. The SSC has frequently discussed the numerous ecosystem-related documents that are produced through the Council process and some excellent infographics have been developed to

[21] 31https://meetings.npfmc.org/CommentReview/DownloadFile?p=c93128f5-9fb8-42be-92bf-9b4c5daec17e.pdf&fileName=C2%20COUNCIL%20MOTION%20SocioEconomic.pdf32https://reports.psmfc.org/akfin/f?p=501:2000

*indicate how and when they are used and how they differ (e.g., through the Climate Change Task Force, BS FEP). While the SSC/AP/Council are the main audiences for the report, many industry and community stakeholders use the ESRs as well as the "In Briefs". **The SSC suggests including such a flow chart/infographic in this section of the ESR to visualize the process.***

An infographic has been added to the "Purpose of the Ecosystem Status Reports" section (see p. 2, Figure 1). This figure depicts the current flow of ecosystem information in the ESRs that supports 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 species-based level.

*"In Briefs" are planned for the EBS, GOA, and AI and a second outreach video is being developed - summarizing the ESR products and process. The authors have settled on a strategy that includes the annual production of "In Briefs". The authors noted there will be intermittent production of storymaps focused on specific ecosystem stories and no additional videos at this time. **The SSC is supportive of these continued efforts to disseminate ESR information to stakeholders and communities and appreciates the efforts to provide hard-copy products to remote communities where digital media may be difficult to download or otherwise access.** The SSC looks forward to hearing any feedback from end-users on how these products are used and valued. The SSC notes the ESR author participation at the recent Coastal Communities Forum in Unalaska/Dutch Harbor hosted by the Qawalangin Tribe as a potentially rich context for the two-way flow of information on ESR topics of relevance to local communities and is supportive of similar future outreach efforts whenever practicable.* In December 2021, NOAA AFSC released a short video[22] describing how ecosystem scientists work collaboratively to develop Alaska's Ecosystem Status Reports.

The ESR authors greatly appreciate the support of the AFSC Communications team to help pro- duce the "In Briefs". At this time, StoryMaps are not planned for the 2022 ESRs.

Harmful Algal Blooms

Harmful Algal Blooms (HABs) were reported from all three regions (EBS, AI, GOA), as well as in the NBS and Chukchi Sea. Toxins were detected in shellfish (GOA, AI) and marine mammal flesh (NBS, Chukchi). No human fatalities were reported in 2021.

[22] The video can be found here: https://videos.fisheries.noaa.gov/detail/videos/alaska/video/6287018070001/alaskaE2%80%99s-ecosystem-status-report:-a-collaborative-approach?autoStart=true

Aleutian Islands Ecosystem Status Reports

Issues of Concern

(1) Mercury in AI Food Webs: Relatively high total mercury concentrations have been found in Steller sea lion pups in the central and western Aleutian Islands. Exposure was in utero, and mercury is known to have deleterious impacts on fetal development. Pups with total mercury concentrations above 0.1 micrograms/g wet weight in whole blood show decreased immune function, poor antioxidant function which can lead to tissue oxidative damage during active breath-hold diving, and negative impacts on the immune system. The mercury is obtained from fish or squid prey, and the problem has been increasing over the past ten years. A similar range of mercury concentrations has also been found in Aleutian Islands harbor seals. Mercury concentrations in several fish species are significantly higher in the western Aleutian Islands compared to fish sampled to the east. Researchers at UAF are exploring the pathways of mercury through the food web through collaborations with industry (Ocean Peace, Inc.) and agency partners (MML, USFWS), and further exploring spatial and temporal patterns in this region.

(2) Plastics in AI seabirds: Phthalates, derived from plastics, were detected in 115 Aleutian Island seabirds that were tested, with concentrations varying from 3.64-–539.64 ng/g. Bird species that feed on plankton by diving had significantly higher concentrations compared to piscivores and opportunistic feeders. Additionally, ingesting marine debris can lead to seabird mortality, with the leading cause of death being obstruction of the gastro-intestinal tract. The SSC appreciates information on these topics, and notes the detection levels in fish are not of concern for human consumption and plastics are rarely found in stomach contents of fish. With the potential increasing patterns over time, ***the SSC suggests authors continue to include information on plastics and mercury in the Aleutian Islands food web in these reports where data are available****, as a baseline for detecting any future changes.*

We will continue to report on these issues as information becomes available.

Aleutian Islands Synthesis. In the Aleutian Islands, west to east winds suppressed flow through the passes, and during summer 2021, some of the warmest SSTs were recorded in the western and central Aleutians. All three Aleutian Islands regions experienced Marine Heatwaves (MHW). Throughout the Aleutian chain, eddy kinetic energy was near or below its long-term average in 2021.

The spring phytoplankton bloom was somewhat later (late May/early June) in 2021 than usual (mid-May). The Continuous Plankton Recorder record for 2020 (2021 results are not yet available) shows that copepod community size and meso-zooplankton biomass anomalies for 2020 were negative, where they had been positive in 2019. The mean diatom abundance anomaly was also negative in 2020. The low meso-zooplankton biomass may be related to the high abundance of pink salmon, but that would not explain the negative diatom anomaly. In 2021, both plankton and fish-eating seabird species had good reproductive success, and there were no remarkable die-offs reported. Recent status assessment of northern sea otters in the western Aleutians found the population to be low, but stable. In the eastern Aleutians, the northern sea otter population was larger and also stable. Harbor seals in the Aleutians have declined in recent years (8-year population trend is -131 seals per year) and is now estimated at 5,588 (+/-SE 274). The stock is not listed as Threatened or Endangered. To date in 2021, eight marine mammals were reported as stranded, mostly from the area near Dutch Harbor, where potential observers are concentrated. There was no 2021 update on the status of Steller sea lions in the Aleutian Islands.

The SSC appreciates the addition of new indicators for the ESR, but notes that there has been no integrated ecosystem study for the AI in over a decade. The AI Fisheries Ecosystem Plan is past its review time, there is no regional research plan specific to the AI, and there has been no survey since 2018. *Other than the ESR, the most comprehensive study at the ecosystem level was a special journal issue in 2005, and the FEP in 2007. This creates significant challenges for interpreting the impacts of the various indicators presented in the ESR and for fisheries management in the region.* ***The SSC strongly highlights the need for surveys in this region in 2021, and supports any efforts for taking a more integrative approach to studying this ecosystem****.*

We appreciate the support of the SSC and share their concern. We also recognize that some of these issues have been discussed and postponed due to lack of human resources to carry them out and the emphasis on other more pressing issues in Alaska. The authors would appreciate any additional support that can be provided to address these gaps and will continue to coordinate and collaborate with Council staff to move those efforts forward.

There were no surveys in the region in 2021. However, there was a survey this year, 2022. Jointly with the contributors of the Biophysical Synthesis, we have identified several potential indicators and will try to get funding for their development.

Likewise, we will try to get funding for projects addressing the proposed main drivers of currents in the ecosystem. However, as the SSC notes, these projects will continue to be stand alone projects. The researchers involved will try to coordinate to integrate the results as much as possible. We appreciate the SSC continued support for integrative approaches to study the Aleutian Islands.

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 5.

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

Fish Apex Predators	Pelagic Fish Foragers
Pacfic 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.

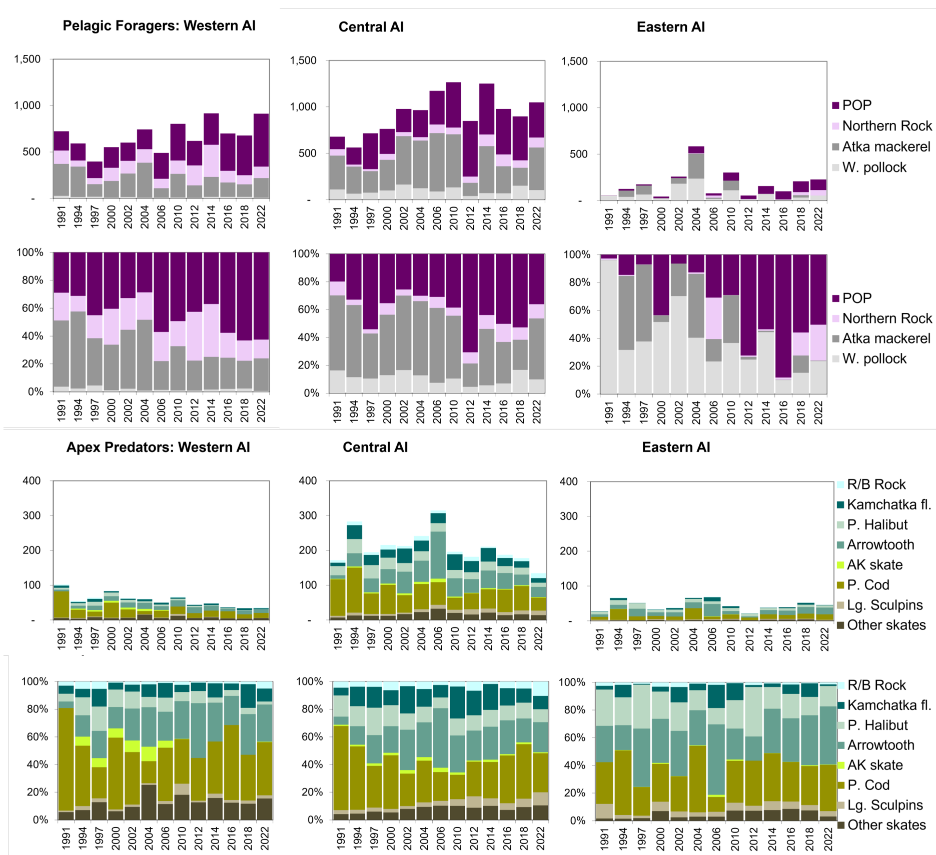

Figure 66: NOAA Alaska Fisheries Science Center's human dimensions indicators mapping

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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 of the 'health' of apex piscivores whose diet consists primarily of commercially-fished species. The estimated counts are updated annualy. 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 is available since 2003, when widespread VMS data became available. The monthly value in December is used as an annual indicator, which is updated anually.

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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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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.