Ecosystem Status Report 2020

Aleutian Islands

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Bering Sea, Aleutian Islands, and Gulf of Alaska

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North Pacific Fishery Management Council
605 W. 4th Avenue, Suite 306
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Aleutian Islands 2020 Report Card

Region-wide

- The North Pacific Index (NPI) was strongly positive from fall 2019 into 2020 due to the relatively high sea level pressure in the region of the Aleutian Low, which was displaced to the northwest, over Siberia, and caused **persistent warm winds from the southwest**. Positive NPI is expected during La Niña but its magnitude was greater than expected, though not as large as in 2018.
- The Aleutians Islands region experienced **suppressed storminess through fall and winter 2019/2020** across the region, favoring seabird foraging.
- The **Alaska Stream appears to have been relatively diffuse** on the south side of the eastern Aleutian Islands for the eighth consecutive year. This is unusual in an area characterized by discrete and intense events. Low eddy kinetic energy prevailed throughout the chain.
- Although the **sea surface temperatures cooled off in 2020, relative to the 2014–2017 warm period, the overall temperature was still warm** due to heat retention throughout the water column. The eastern Aleutians Islands was under an almost year long heatwave during 2019, which was significantly less intense in the central and western islands. Temperatures during 2020 were moderate across the archipelago.

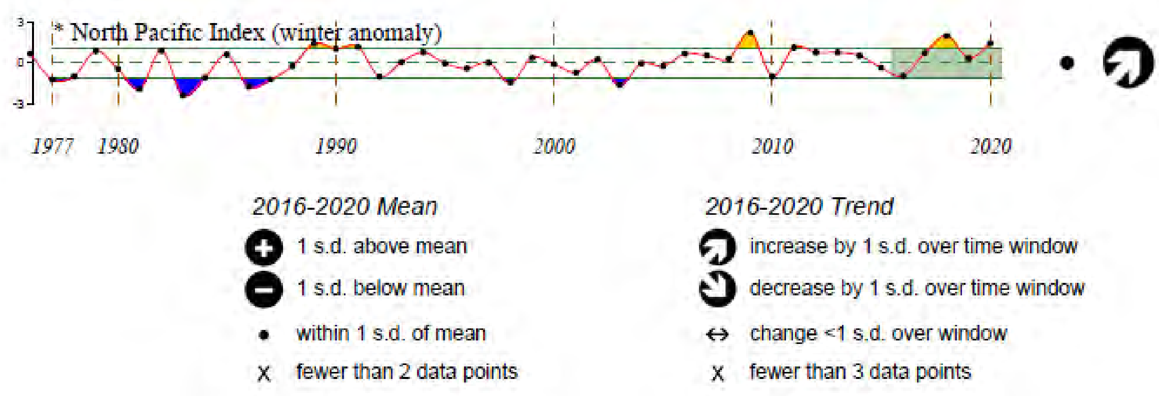

Figure 1: The winter North Pacific Index time series, updated to 2020.

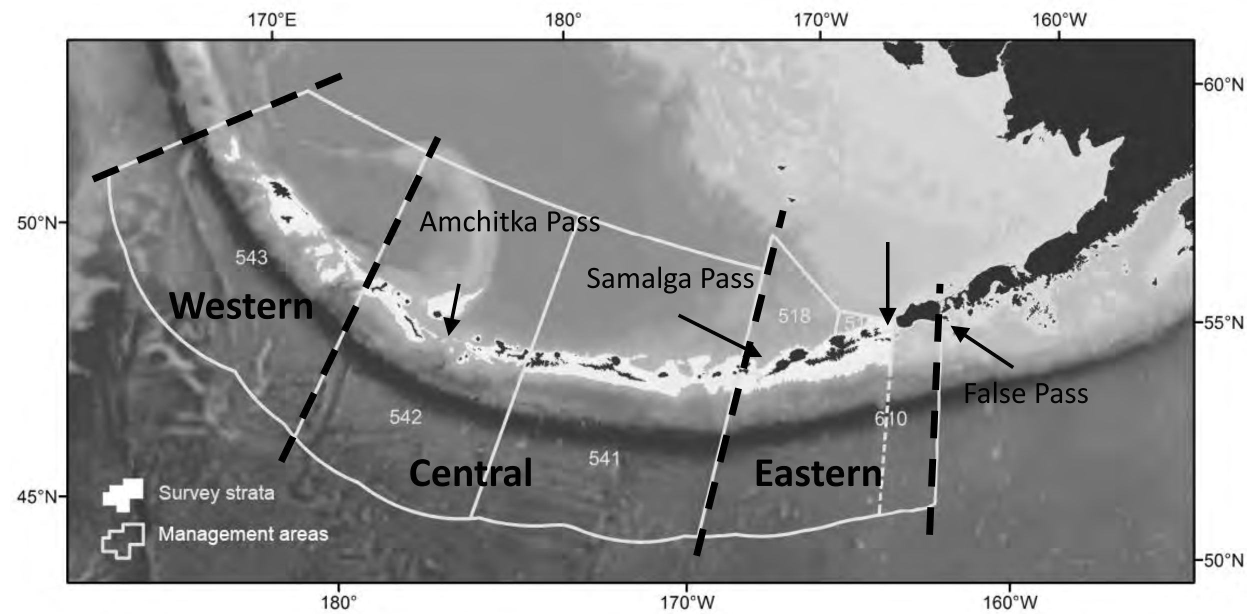

Figure 2: The Aleutian Islands ecoregions

Western Aleutian Islands Ecoregion 2020

- Temperatures have been much milder in this area, offering a potential refuge for populations from farther east where heatwaves have occurred in recent years. While cooling at the surface, **warm water still prevailed in subsurface layers 100-250 m deep** during 2020.
- The reproductive success of five planktivorous seabird species at Buldir Island was average to high in 2019, indicating that **overall zooplankton availability was sufficient to support reproductive success in 2019 and potentially other plankton eating commercial species**.
- Forage fish trends, as indicated in tufted puffin chick meals, have varied over the long term, with episodic peaks lasting 1–2 years. In general, sand lance have been absent since 2009, and age-0 gadids have not been seen in great abundance since 2006. Tufted puffins experienced reproductive failures in 2017 and 2018, but had average reproductive success in 2019, signaling potentially favorable condition for fish foragers. Both horned puffins and glaucous winged gulls had high reproductive success, suggesting that **forage fish availability was diverse and sufficient to raise chicks in 2019, and potentially other fish eating predators and commercially important groundfish**.
- Steller **sea lion numbers remained below their long-term mean** when last estimated in 2019, although there has been no significant trend in the past 5 years. The 2016 estimate was the lowest in the time series.
- There are no schools in the western Aleutian Islands ecoregion.

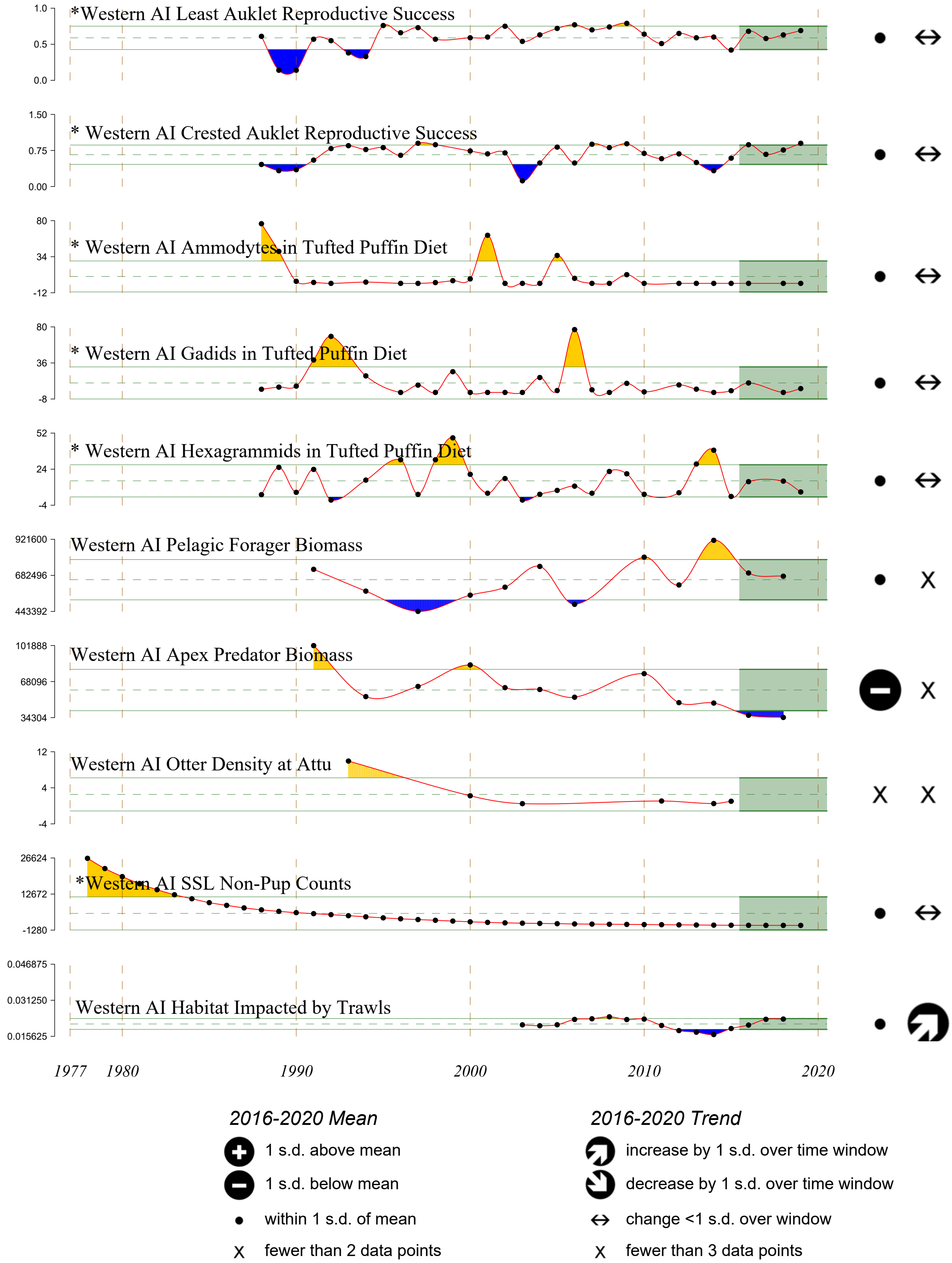

Figure 3: Western Aleutian Islands ecoregion indicators. * indicates time series updated in 2019 — there were no 2020 updates

Central Aleutian Islands Ecoregion 2020

- The most recent data available for **sea otters show no trend** but is from 2015. There is some concern in the region as to their current population trend; however updated assessments should be available next year.
- Counts of non-pup **Steller sea lions remain below the long term mean**, however the population is either stable or slightly increasing; though the trend is not the same in all rookeries.
- Both Adak and Atka **schools in the central Aleutian Islands have experienced a slight uptick over the past 2 years**, getting away from the 10-student threshold that risks closure of the schools, thereby offering more stability to families living in those communities.

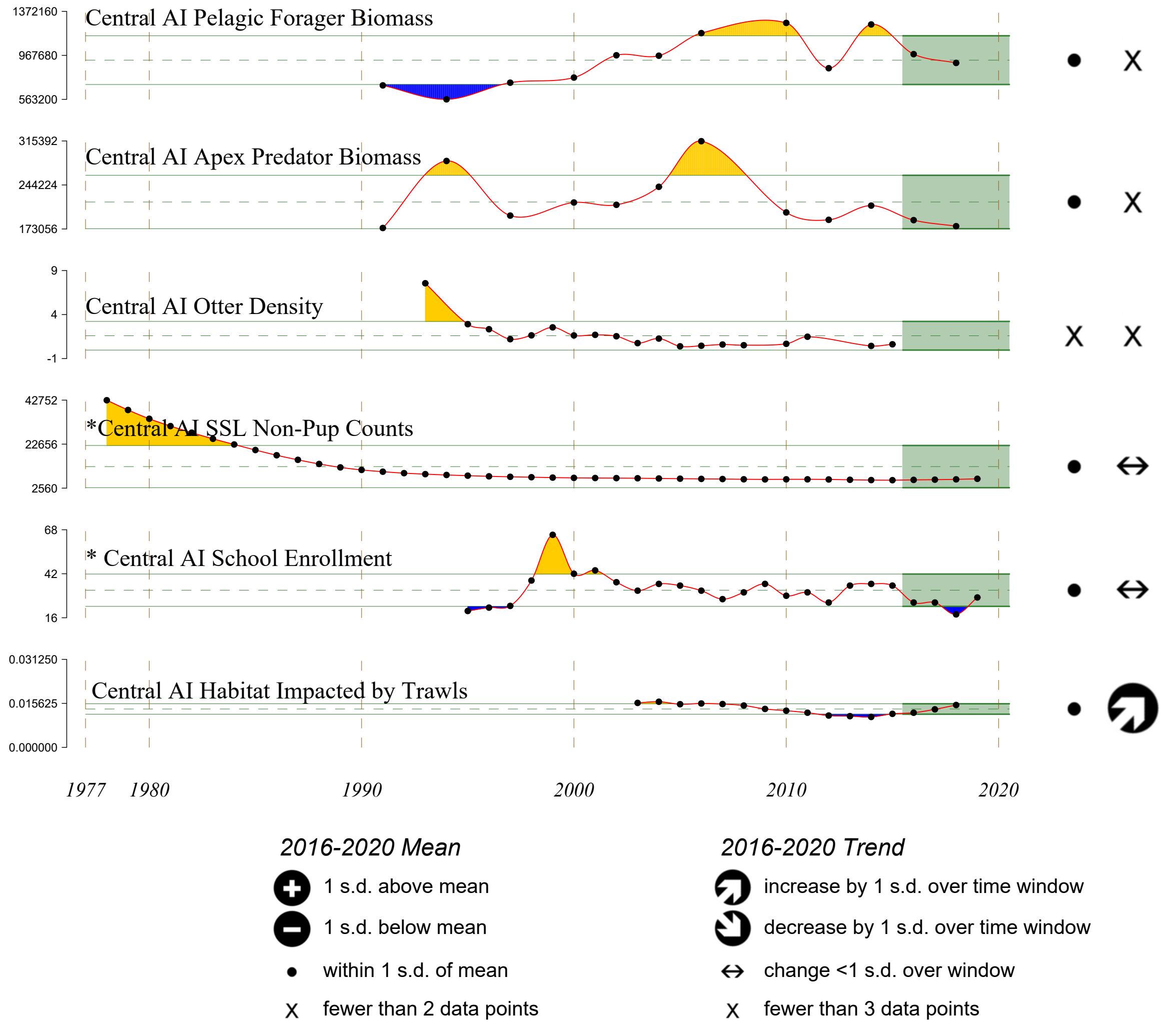

Figure 4: Central Aleutian Islands ecoregion indicators. * indicates time series updated in 2019 —there were no 2020 updates.

Eastern Aleutian Islands Ecoregion 2020

- Although the time trends for the fish indicators don't show it, **four out of six monitored fish-eating or piscivorous seabird species had high reproductive success in 2019**, while the rest had an average year. Together, this made 2019 one of the most successful years in recent history; despite the year-long marine heatwave in this ecoregion. This **broad reproductive success across species signaled favorable environmental conditions** to feed and raise chicks, as well as **potentially increased fish prey availability for other predators, including commercial groundfish**.
- There are no available data for sea otters in the eastern Aleutians ecoregion.
- In contrast to the other regions in the Aleutian Islands, **non-pup counts of Steller sea lions continue to steadily increase**. The recent estimates in 2019 have been above the long-term mean and are continuing an increasing trend. Counts were largely stable through the 1990s, but have been increasing a rate of 2% per year, offsetting the declines observed in the other regions of the Aleutian Islands.
- **School enrollment has increased since the recent low enrollment in 2014–15**. This primarily reflects trends in Unalaska, whereas the small communities have either closed schools (Nikolski) or are at risk of closure (False Pass and Akutan).

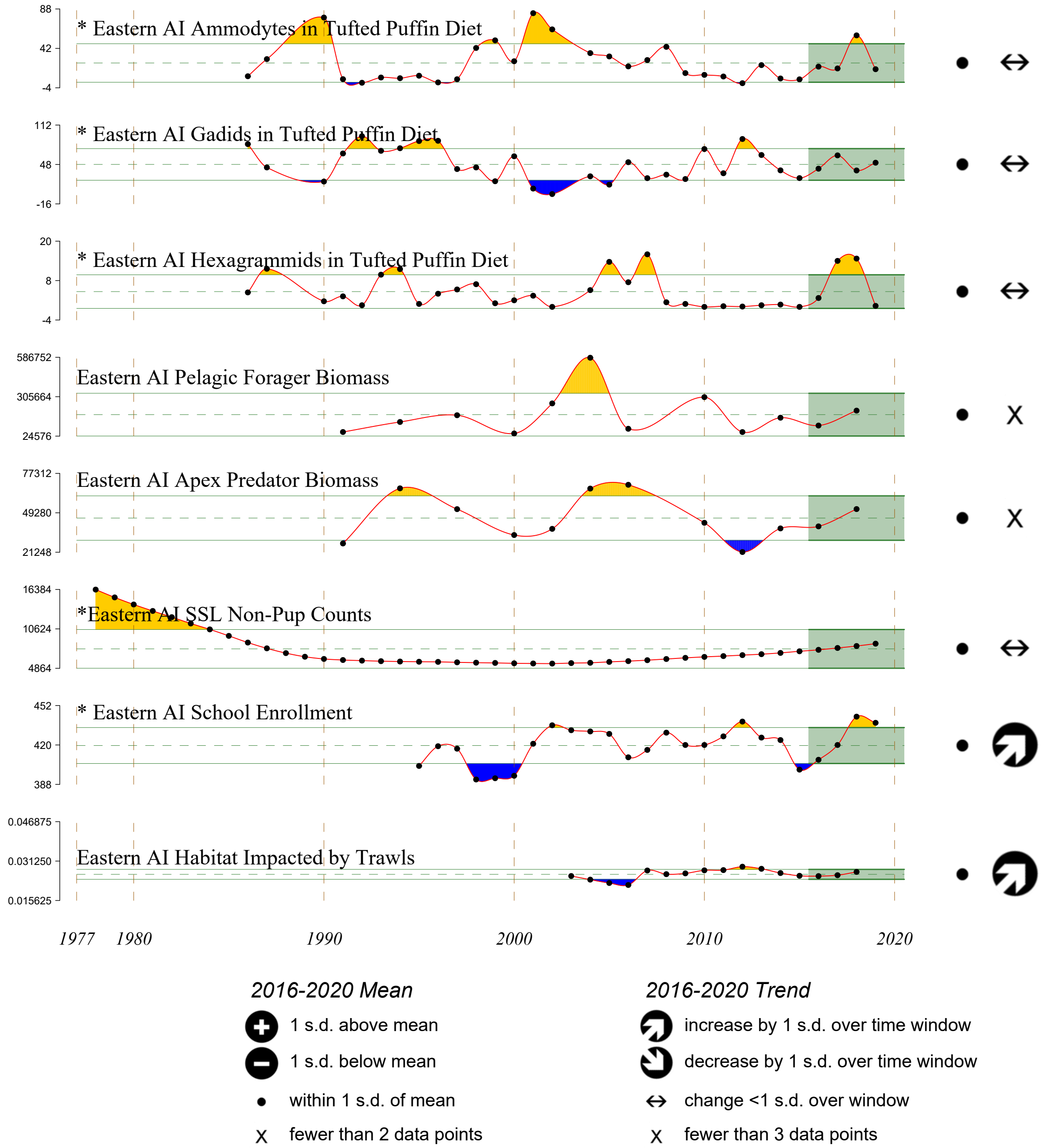

Figure 5: Eastern Aleutian Islands ecoregion indicators. * indicates time series updated in 2019 — there were no 2020 updates.

Executive Summary of Recent Trends in the Aleutian Islands

This section contains links to all new and updated information contained in this report. The links are organized within three sections: Physical and Environmental Trends, Ecosystem Trends, and Fishing and Fisheries Trends.

Physical and Environmental Trends

North Pacific

- The North Pacific atmospheric-ocean climate system during fall 2019 to summer 2020 returned to near average or average conditions across the region despite some warm temperatures that persist in subsurface waters (p. 33).
- The prominent sea surface temperature anomalies during 2019–20 were positive and highest in the eastern Aleutians. The negative phase that the NPGO has been in since 2012–2013 seems to coincide with several other physical and biological processes in the region, such as the low kinetic energy in the eastern Aleutians. The eddy kinetic pattern is shown to be distinct in each of the three regions of the Aleutians (p. 38).
- Despite coherent regional patterns, distinct processes are shown to prevail in each area, with the western Aleutians perhaps offering a thermal refuge for species or populations from farther east. In general, climate conditions seems to have less extreme events throughout the archipelago when compared with the rest of the LMEs in Alaska (p. 38).
- The North Pacific Index (NPI) was strongly positive from fall 2019 into 2020 due to the relatively high sea level pressure in the region of the Aleutian Low, which was displaced to the northwest, over Siberia. This caused persistent warm winds from the southwest over the Bering Sea last winter (p. 35).
- The North Pacific Gyre Oscillation (NPGO), while still negative, recovered from the decline in 2017 to early 2018, implying that flows in the Alaska portion of the Subarctic Gyre might be increasing (p. 33).

Aleutian Islands

- The Aleutians Islands region experienced suppressed storminess through fall and winter 2019/2020 with predominant winds from the southwest (p. 36).
- The Alaska Stream continues to be relatively diffuse on the south side of the eastern Aleutian Islands (p. 50).

- Eddy kinetic energy in the Aleutian Islands region has been low from the fall 2012 through 2020, indicating the likelihood of smaller than average fluxes of volume, heat, salt, and nutrients through Amukta Pass (p. 50).
- A new satellite-derived SST indicator presents seasonal anomalies over time in the Aleutian Islands ecoregions, as well as indications of a a marine heatwave and further characterization of the regional patterns. The western Aleutians ecoregion is shown to be consistently cooler than the eastern Aleutians and less subject to marine heatwaves (p. 40).
- Sea surface temperature values cooled to normal during the present year, a welcome cooling particularly in the eastern Aleutians (p. 40).
- Continued warmer subsurface temperatures may impact Atka mackerel ontogeny. Sea surface temperature was the most determinant variable of larval habitat in the modeling exercise done to define Essential Fish Habitat in Alaska (p. 46).

Ecosystem Trends

- The NPGO has been negative for eight years consecutively (p. 33), as has the eddy kinetic energy in the eastern Aleutian Islands (p. 50) .
- Kamchatka pink salmon, with its increasing record abundance in odd years, may exert a biennial predation pressure on copepods which cascades through the system; recent research shows that seabird reproductive success, otolith growth in Atka mackerel, and potentially Pacific ocean perch show such biennial response (p. 32).
- Length-weight residuals continue to be negative for most groundfish. The trend started in 2012 for several, coinciding with the negative NPGO and low EKE in the eastern Aleutians. Negative fish condition also means several key prey fish such as Atka mackerel and pollock have been of less quality as prey for 8 years now, which might be cascading to apex predators as well. Condition below the mean is most marked in Pacific cod, northern rockfish, Pacific Ocean perch and arrowtooth flounder (p. 56)
- In the Western ecoregion the reproductive success of planktivorous auklets has been higher than average for the past five years. (p.63)
- Steller sea lions continue their decades-long decline in this ecoregion, albeit offset by increases in the easternmost rookeries and in some in the central Aleutians. (p. 71).
- The overall reproductive success of both plankton and fish eating seabirds in 2019 signals a potential increased variety of prey availability, adequate to rear chicks. This is further supported by a positive anomaly in copepod community size, which would also have benefited young-of-the-year fish as well as forage fish (p. 63).
- In general, seabirds in the Aleutians did not experience widespread failures as they did in the Gulf of Alaska did during the marine heat wave of 2019. The above-average year of reproductive success for seabirds in 2019, despite the marine heat wave in the east and the record high abundance of pink Kamchatka salmon point to more than physical drivers throughout the ecosystem, and highlight the role of prey availability. In addition to increased bioenergetic costs which may also play a role in the below average condition of fish, inter- and intra-specific competition with and among rockfish might also contribute to the below average fish condition. The high abundance of both Pacific ocean perch and Kamchatka pink salmon, bothof which feed on copepods, might also contribute periodically the competition for planktonic prey. The reproductive success of the 2019 season offsets the poor reproductive success of seabirds in 2018 at Buldir Island (western AI) and the mixed success at Aiktak Island (eastern AI). In addition to high reproductive success, several species also had earlier hatching dates, potentially signaling an early spring bloom throughout the region (p. 63).

- The western AI Steller sea lion adult population decreased rapidly at approximately -7% per year. Sub-area population trends improved to the east, through to the western Gulf of Alaska, where the annual trend was approximately +4% per year. Regional trends in pup production are similar to trends in non-pup counts, with continued relatively steep declines in the western AI, a less steep decline in the central AI, and improvement in the eastern AI (p. 71), Figure 3).
- New indicators keeps track of strandings of marine mammals and seabirds, as part of new contributions. The low frequency of strandings and die-offs in the Aleutians seems to be a combination of fewer observations, and also less extreme conditions (p. 74).

Fishing and Fisheries Trends

- Since 1993, discards and discard rates of groundfish in federally-managed Alaskan groundfish fisheries have generally declined across the trawl pollock, non-pollock trawl, and fixed gear sectors in the Aleutian Islands. To date in 2018, discard levels across all sectors appear to be consistent with levels during the previous 5-year period (p. 80).
- Non-target catch of Scyphozoan jellyfish in trawl fisheries in the Aleutian Islands remains high since 2017. The catch of structural epifauna (sponges, corals, and bryzoans) was variable, but has continued a slight increase from 2017 to 2019, following a substantial increase in 2017 (p. 82).
- In 2019, the incidental catch of seabirds in Aleutian Islands groundfish fisheries was seven times higher than estimates from 2018 (804 birds), and was about three times higher than the 2010–2018 average of 717 birds. The increase is largely explained by the large number of shearwaters caught. This high bycatch coincides with a widespread shearwater die-off throughout the North Pacific in 2019 (p. 84).
- Unemployment rates in Aleutian Islands fishing communities from 1990 to 2017 continue to be lower than state and national rates, reflecting stability in the commercial fishing and seafood processing industries (p. 99).
- As of 2019, the total population including all Aleutian Island communities was 5,989 people. The eastern AI has had the most steady population increase between 1880 and 2015, whereas the central AI experienced fluctuations and some communities have remained at approximately the same level since 2010. The western AI has had no residents since 2011 (p. 102).
- While Unalaska schools in the eastern Aleutian Islands have maintained relatively stable enrollment since 1996, Nikolski, Akutan, and False Pass have diminished dramatically and are no longer viable. Both Adak and Atka schools in the central Aleutian Islands have experienced declining enrollment, with only 18 and 10 students enrolled, respectively (p. 105).

Contents

* indicates contribution updated in 2020
† indicates new contribution

List of Tables

List of Figures

Aleutian Islands Ecosystem Assessment

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The primary intent of this assessment is to summarize and synthesize historical climate and fishing effects on the shelf and slope regions of the Aleutian Islands (AI) from an ecosystem perspective, and to provide an assessment of the possible future effects of changes in the climate and fishing on ecosystem structure and function. The Ecosystem Considerations section of the Groundfish Stock Assessment and Fishery Evaluation (SAFE) report provides the historical perspective of status and trends of ecosystem components and ecosystem-level attributes using an indicator approach. For the purposes of management, this information must be synthesized to provide a coherent view of ecosystems effects in order to clearly recommend precautionary thresholds, if any, required to protect ecosystem integrity. The eventual goal of the synthesis is to provide succinct indicators of current ecosystem conditions. In order to perform this synthesis, a blend of data analysis and modeling is required annually to assess current ecosystem states within the context of its history, as well as past and future climate.

The Aleutian Islands ecosystem assessment area

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 border at 170°E.

The three Aleutian Islands ecoregions are defined from west to east as follows (Figure 8). 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 7). There is more vertical mixing as well as bidirectional flow in the passes. This delineation also aligns with studies suggesting there is a biological boundary at this point based on differences in chlorophyll, zooplankton, fish, seabirds, and marine mammals (Hunt and Stabeno, 2005).

The eastern Aleutian Islands ecoregion spans 170°W to False Pass at 164°W. The passes in this ecoregion are characteristically narrow, shallow and long, with lateral mixing of water and northward flow. The prominent source is from the Alaska Coastal Current, with a strong freshwater component. This area encompasses the NPFMC fishery management areas 518, 517 (EBS) and the western half of 610 (GOA).

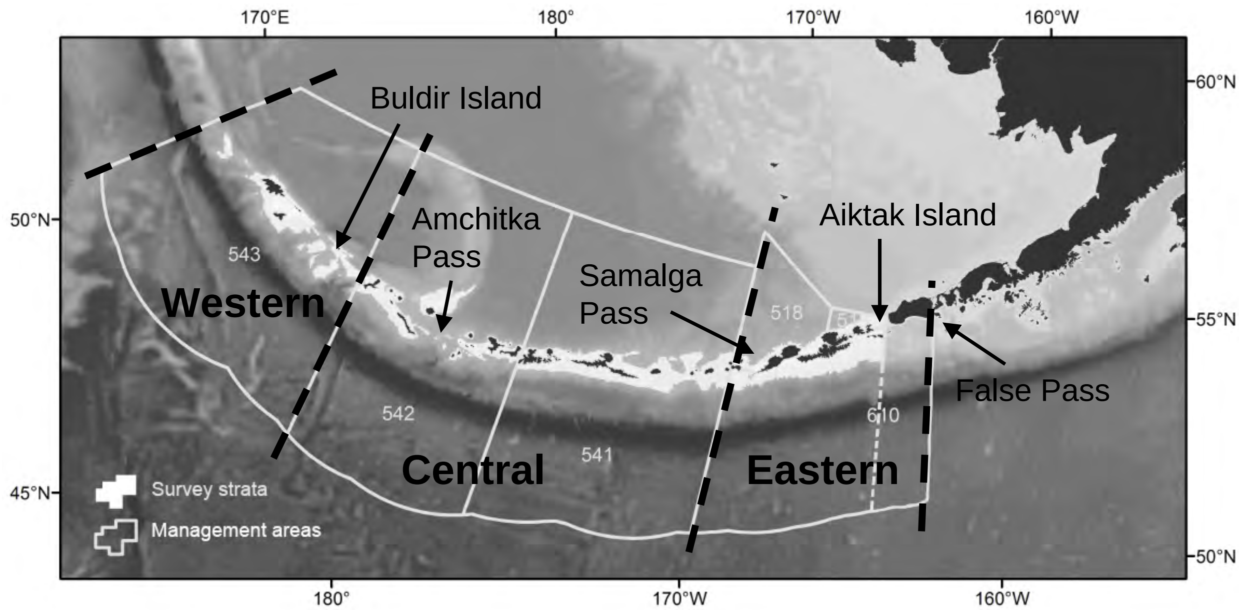

Figure 6: The three Aleutian Islands assessment ecoregions.

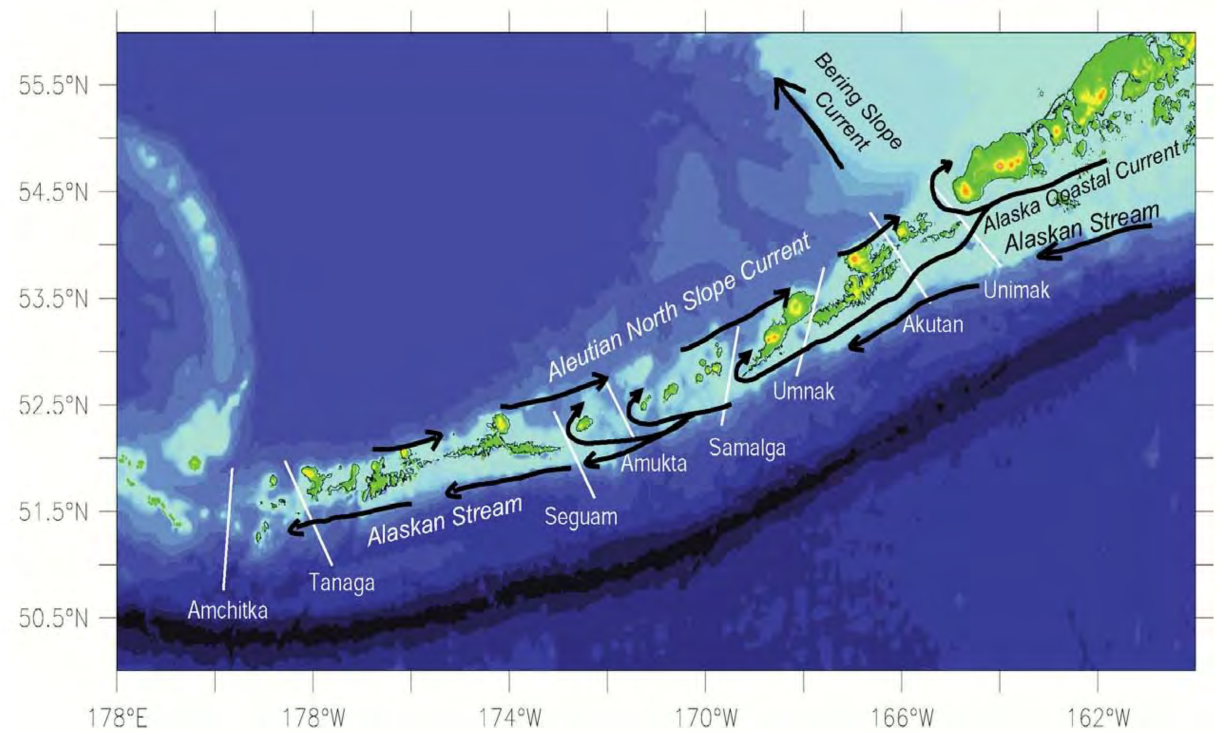

Figure 7: Ocean water circulation in the Aleutians. Currents are indicated with black lines. Passes are indicated with white lines. Image from Carol Ladd.

Summary

This year, due to the COVID-19 pandemic, most surveys and fieldwork were cancelled, so there are no biological indicators updated for 2020. The new information in this assessment is largely from remote-sensing, updated analysis of 2019 data, and local observations. Whenever possible we included data for 2019 as an update from the previous 2018 Aleutian Islands Ecosystem Status Report. Cancelled surveys and data streams include:

1. AFSC AI 2020 biennial bottom trawl survey, which provides data for:
    (a) Aleutian Islands Trawl Survey Water Temperature Analysis
    (b) Jellyfish in the Bottom Trawl Survey
    (c) Aleutian Islands Groundfish Condition
    (d) Distribution of Rockfish Species in the Aleutian Islands
    (e) Miscellaneous Species in the Aleutian Islands
    (f) Stability of Groundfish Biomass in the Aleutian Islands
    (g) Mean Length of the Fish Community in the Aleutian Islands
    (h) Mean Lifespan of the Fish Community in the Aleutian Islands

2. AMNWR seabird monitoring, which provides data for:
    (a) Hatching dates at Buldir and Aiktak
    (b) Reproductive success at Buldir and Aiktak
    (c) Seabird diets—tufted puffin chicks diets
    (d) Seabirds die-offs (contribute data to overall dataset)
3. AFSC Steller sea lion surveys, which provides data for:
    (a) Counts of non-pups at rookeries and haul-outs
    (b) Counts of pups at rookeries and haul-outs
4. COASST year-round citizen scientists surveys, which provide data for:
    (a) Seabird die-offs
    (b) Beached bird relative abundance
5. Fish and Wildlife Survey periodic sea otter survey that was planned this year.

Most of what we can say about the Aleutians Islands ecosystem is based upon biological trends. There are large gaps in knowledge about the local physical processes and, as a result, their impact on biological processes. These gaps are largely due to geographic reality. For example, persistent cloudiness and strong currents preclude obtaining comprehensive satellite-derived data and the use of various unmanned underwater vehicles. In addition to the sheer distances involved in surveying the island chain that make comparing west-east trends in indicators such as bottom temperature difficult due to difference in timing of oceanographic surveys across the region, the archipelago is also influenced by different processes in the eastern than in the western Aleutians. 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 sea lion abundances may be responding to physical indicators such as bottom 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, narrow shelf relative to the entire ecosystem, and strong oceanographic input mean that some metrics commonly used as ecosystem indicators in other systems may not be as informative in the Aleutians. Therefore, our synthesis of ecosystem indicators by necessity includes speculation.

During 2019–2020, the state of the North Pacific atmosphere-ocean system featured the continuance of warm sea surface temperature anomalies in the Gulf of Alaska with an almost year-long marine heat wave in 2019 that decreased significantly towards the west, with subsurface warmer temperatures throughout the chain that reached the western Aleutians. Bottom trawl survey temperatures from 2019 support model results from the Global Ocean Data Assimilation System that show the persistence of subsurface warmer temperatures in the 100–250 m deep layer that have stayed statistically above the long-term mean. The warm temperatures can be attributed in part to slower at-depth processes. In 2020, the surface temperatures cooled, and climate indices were near average, potentially offering more favorable environmental conditions for biota relative to recent years.

Newly estimated indices show eddies have a distinctly different signature across the island chain, with discrete, strong events characterizing the east and multiple or multi-year but less intense events towards the west. The role of these eddies and how they are processed within the system are yet to be understood, as stocks and overall populations are subject to the dynamics in the east and the west throughout their life cycle. Eddy kinetic energy has remained low since 2013 in the east, and this coincides with the North Pacific Gyre Oscillation more than with the North Pacific Index, which is typically the more characteristic index of the region. Model results suggest moderate increases in the strength of the Alaskan Stream Current increases flow through the eastern passes such as Amukta, while stronger flows carry the current westward, decreasing flows through the eastern passes and increasing them through the wider and deeper passes prevalent in the central and western Aleutians.

With average or close to average climate conditions throughout, 2020 is expected to be a return to more favorable conditions for the biological components of the Aleutian Islands ecosystem.

Biological summary through 2019 In general, warmer temperatures increase bioenergetic costs for ectothermic fish, and all else being equal, prey consumption must increase to maintain fish condition. These increased bioenergetic costs and consumption demands may partly explain why the observed body condition of several commercial groundfish (adult pollock, Pacific cod, northern rockfish and Pacific ocean perch) has been lower than the survey mean since 2012, as last measured by length-weight residuals during the biennial summer bottom trawl survey during 2018. We note however, that for Pacific Ocean perch and northern rockfish, intraspecific competition might be a contributing factor, as their abundance increased and appears to have now stabilized at high biomasses (e.g. Pacific Ocean perch) that now surpass that of Atka mackerel and pollock combined. While Pacific Ocean perch condition has also been lower than the long term mean, it has decreased less than that of the rockfish. The poorer condition of fish, particularly of species such as Atka mackerel and pollock that when small serve as prey for piscivorous seabirds and apex fish predators like Pacific cod and arrowtooth flounder, also means that that their quality as prey has decreased, with potential cascading effects on their predators.

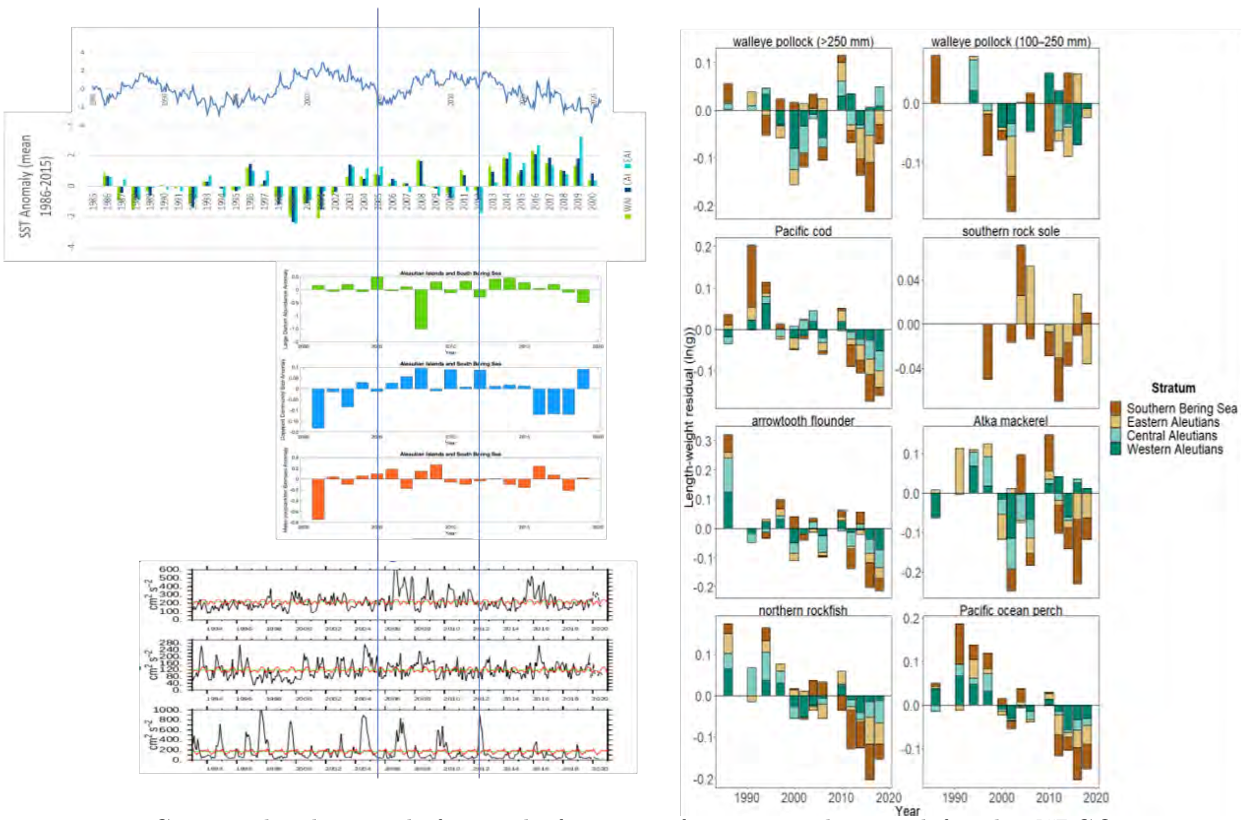

Figure 8: Compared indicators before and after 2012, from top to bottom left side: NPGO, summer SST by AI region, CPR, EKE (top WAI, middle CAI, bottom, EAI), right side, Fish Condition.

Warmer temperatures may also impact ontogenesis of Atka mackerel eggs (Lauth et al., 2007). Surface temperature was found to be the most important determinant of egg and larval stage distribution of commercial fish in Alaska based on the distribution models used to define EFH. For many of the commercial groundfish for which the youngest age in the stock assessment is 4 years old or older, effects of this sustained warmer temperature on recruitment will not be immediately apparent.

These generally unfavorable conditions seem to be improving, as seabirds—both plankton and fish-eating species—had earlier to average hatch dates and average to above-average reproductive success in 2019. This seems particularly true for surface-feeding seabirds which have been shown to respond more consistently with changes in their phenology as warmer temperatures bring earlier spring blooms. This flexibilty and higher response to fluctuations in the environment is also coherent with the lower response to variable environmental conditions that is observed in fish and seabirds used to generally more stable processes at depth throughout their lifespan.

In addition to physical drivers, Kamchatka pink salmon (a new indicator this year), with a marked biennial signal in their abundance that peaks in odd years, has been shown to be correlated with copepod abundance, otolith growth in Atka mackerel, planktivorous seabird reproductive success (Batten et al., 2018; Matta et al., 2020; Springer and van Vliet, 2014), and potentially, Pacific ocean perch young of the year. With record abundance in 2019 and an increasing trend over the past decade, their potential for competitive impacts on prey availability for other groundfish and cascading ecosystem effects warrants consideration. This competitive impacts may differ for fish feeding in shallow versus deeper waters as other biological processes may confound physical forcing driven by surface temperatures or may have a lagged effect in deeper waters. While, in general, Kamchatka pink salmon abundance correlates with a lower copepod abundance in off years, 2019 was an exception, as shown by the CPR timeseries which shows an increase in the mean size of the copepod community and its abundance - as supported by the decreased biomass of large diatoms which signals a potential increased predation pressure from copepods. With a potential cascading effect on plankton feeding species and young-of-year fish, this may partly explain the success of fish feeding seabirds in 2019. Understanding the interplay of vertical and horizontal spatial variability in food-web and oceanographic dynamics is particularly relevant given the higher reliance on plankton in the western Aleutians versus more piscivorous and invertivore feeding habits of fish and seabirds towards the eastern Aleutians.

The largest total biomass of both fish apex predators and pelagic foragers is located in the central Aleutians, the ecoregion with the largest shelf area under 500m. The lowest apex predator biomass is located in the western Aleutians whereas that of pelagic foragers is found in the eastern Aleutians. This pattern has been consistent since 1991, though individual species group fluctuations do not necessarily follow the same behavior. Finally, the increase of Pacific Ocean perch biomass and its stable high population, might be driving some spatial dynamics, where it may be encroaching onto other species' habitats, as seen by the estimated increase in the area occupied shown in the Pacific Ocean perch stock assessment. This increase in abundance and area occupied may be the cause of the increased bycatch of Pacific Ocean perch.

Western Ecoregion In the western ecoregion, the reproductive success of planktivorous auklets, serving as indicators of zooplankton production, was above average during 2019. Both least and crested auklets hatched chicks earlier than the long term average. These species feed their chicks mainly euphausiids and copepods, respectively. Parakeet, whiskered, and crested auklets all had high reproductive success in 2019, while that of least auklets was average. While the overall timing of breeding for fish-eating seabirds was average in 2019, their reproductive success varied. Glaucous-winged gulls and horned puffins had high reproductive success, tufted puffins and thick billed murres had average reproductive success, and common murres failed. There was an increase in the variety of fish brought back to feed tufted puffin chicks. Increased diversity in chick diets may indicate that more favored prey were less available. There was a slight increase in the proportion of gadids fed but lower proportions of hexagrammids (likely age-0) and *Ammodytes*. It is still unknown whether the high number of hexagrammids seen in 2013 and 2014 possibly indicated high recruitment in Atka mackerel, as their overall abundance has been in decline since 2006. Steller sea lion non-pup counts continue to decline with the lowest estimated numbers yet in 2019. The diet of Steller sea lions consists primarily of commercially fished species, many of which seem to have had poorer body condition in recent years. The declining Steller sea lion trends in both numbers and birth rates are topics of active research, and prey quality may play a role in their lack of recovery.

Central Ecoregion There was a slight increase in Steller sea lions non-pup estimates in 2019, which although small, have been consistent since 2015. School enrollment was slightly higher, pointing perhaps to more stable conditions for families in the area. The increase was driven by both students in Adak and Atka.

Eastern Ecoregion Pollock and Pacific Ocean perch commonly comprise more than half the pelagic foraging fish biomass observed in the bottom trawl survey, and 2019 was no exception. There are almost no northern rockfish in this area, but Pacific Ocean perch has been increasing their spatial extent, as seen by the estimated area occupied in the Pacific Ocean perch stock assessment. All the piscivorous seabirds species monitored for reproductive timing at Aiktak Island in Unimak Pass, hatched chicks early or on average in 2019, signaling favorable foraging conditions in the region. Reproductive success was high for red-faced cormorants, thick-billed murres, and puffins. This is despite the low forage fish availability of sandlance *Ammodytes*, gadiids and hexagrammids as suggested by the 2019 diets of tufted puffin chicks. Chick-provisioning patterns suggest puffins are responding to changes in forage fish availability. As in the west, the diversity of fish prey in puffin diets increased in 2019, possibly indicating that more favored prey were less available. Planktivorous auklets are not as numerous in the eastern ecoregion as in the central and western ecoregion and are not monitored in the Eastern ecoregion. School enrollment dropped slightly in 2019 compared to 2018, but is still above the long-term mean, possibly indicating more stable conditions for families.

Ecosystem Indicators

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 could be rrregularly updatable 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. Winter North Pacific Index anomaly relative to the 1961–2000 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. Sea otter counts
6. Steller sea lion non pup counts (juveniles and adults)
7. Percent of shelf <500m deep trawled
8. K-12 enrollment in Aleutian Islands schools

Winter North Pacific Index The North Pacific Index (Trenberth and Hurrell, 1994), the area weighted mean sea level pressure over the region 30° - 65°N, 160°E - 140°W, is a widely used measure of the intensity of the Aleutian Low. A negative winter (November - March) NPI anomaly implies a strong Aleutian Low and generally stormier 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 anually.

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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 indictor 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 indicaros 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 8) 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 1.

Table 1: 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	

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 (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.

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Sea otter counts Sea otter (*Enhydra lutris*) counts were selected as a representative of the nearshore Aleutian environment. The >300 islands which make up the Aleutian chain provide extensive nearshore habitat. Sea otters are an integral component of the coastal ecosystems in which they occur. Sea otter predation limits the distribution and abundance of their benthic invertebrate prey, in particular herbivorous sea urchins. Otter-induced urchin declines increase the distribution and abundance of kelp in Alaska (Estes and Duggins, 1995) and in other areas of their range (Breen et al., 1982; Kvitek et al., 1998). This trophic cascade initiated by sea otters has indirect effects on other species and processes. Kelp forests are more productive than habitat without kelp (a.k.a. "sea urchin barrens"), fixing 3-4 times more organic carbon through photosynthesis (Duggins et al., 1989). This increased primary production results in increased growth and population size of consumers such as mussels and barnacles (Duggins et al., 1989). Rock greenling (*Hexagrammos lagocephalus*), a common fish of the kelp forests of the Aleutian Islands, are an order of magnitude more abundant in kelp forests than in sea urchin barrens (Reisewitz et al., 2006). Kelp forests likely function as nearshore habitat for other Aleutian Islands fish, such as the related Atka mackerel (*Hexamgrammos monopterygius*). Sea otter impacts on kelp forests also influence the behavior and foraging ecology of other coastal species such as Glaucous Winged Gulls (Irons et al., 1986) and Bald Eagles (Anthony et al., 2008).

Sea otter survey methods are detailed in Doroff et al. Doroff et al. (2003). Skiff-based surveys of sea otters were conducted several times during 2003, 2005, 2007, 2009 and 2011 at Amchitka Island, Kiska and Little Kiska Islands, Attu Island, Agattu Island, Rat Island and the Semichi Islands when viewing conditions were good to excellent (Beaufort sea state of 1-2, and .1 km of clear visibility at sea level). Full surveys were not conducted in 2011 at Kiska and Little Kiska Islands, in 2003 at Rat Island, and in 2005 and 2011 at the Semichi Islands. Two or more observers counted sea otters from a 5.2-m skiff as it was run parallel to shore along the outer margins of kelp (*Alaria fistulosa*) beds at 15-22 km/h. Sea otters were counted with the unaided eye, using binoculars to confirm sightings or to count animals in large groups. The shoreline of each island was divided into contiguous segments, each 3-10 km in length and separated by distinctive topographic features (e.g., prominent points of land). Counts were recorded separately for each section. To maximize the time series available for this assessment, only counts of otters at Attu are presented for the Western ecoregion and counts at Amchitka for the Central ecoregion. Surveys are periodic, not on an annual basis.

Contributed by Tim Tinker, formerly of USGS

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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Noteworthy formerly Hot Topics

This section replaces the previously-named Hot 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.

COVID-19 Pandemic

The COVID-19 pandemic, also known as the coronavirus pandemic, is an ongoing global pandemic of coronavirus disease 2019 (COVID-19).to control the spread of the disease nationally and across the globe have included lockdowns and quarantines, which in many cases precluded the annual surveys conducted by agencies, universities, citizen scientists, communities, and other partners. As such, most of the data included in this report refers to 2019. Data for 2020 is included for the Integrated Physical Factors (satellite-derived data or model output), seabird die-offs, marine mammal strandings, fish stock sustainability, and groundfish discards.

COVID-19 Pandemic in Alaska

Alaska Governor Dunleavy declared a state of emergency on 11 March 2020 and the first confirmed case occurred on 12 March 2020. Restaurants, bars, breweries, and food trucks all closed beginning on 18 March 2020, which may have limited some amount of seafood sales in some communities, however, the large scale and global nature of Alaska fisheries means that restaurant closures throughout the lower 48 and globally are more likely to impact Alaska seafood sales. The Governor announced on 23 March 2020 that "All people arriving in Alaska, whether resident, worker or visitor, are required to self-quarantine for 14 days and monitor for illness. Arriving residents and workers in self-quarantine, should work from home, unless you support critical infrastructure (see Attachment A)." Fishing and processing businesses are included in Attachment A as "essential businesses", which allowed many fishing operations to continue in 2020, albeit at a substantial cost to the harvesting and processing industries in Alaska to maintain a safe working environment for their employees and minimize spread to local community residents. More information on the actions of the State of Alaska in response to this crisis can be found on the State of Alaska webpage for COVID-19 Health Mandates `https://covid19.alaska.gov/health-mandates/`.

Industry has reported that they have spent over $50 million`https://www.alaskaseafood.org/covid-19-impact-reports/` to reduce the risk of COVID-19 transmission among harvesters, processors, and the local communities while still providing important seafood for the U.S. and international markets as well as providing food security for many Alaskans. The seafood industry has been fairly successful in Alaska limiting virus spread, but they had to deal with a substantial reduction in transportation options in many Western Alaska and Aleutian Islands communities and limited ability to switch crews throughout the fishing seasons to date. The NMFS Alaska Regional Office has been instrumental in devising solutions with industry to allow the continuation of fishing operations and limit the need for fisheries closures which would otherwise lead to vessel downtime and higher crew turnover increasing the risk of COVID-19 transmission.

Given this unprecedented disruption to the industry in 2020, AFSC has developed a series of in-season ex-vessel revenue projections for 2020 to provide the NPFMC, industry, and the public with more near real-time economic information for the annual groundfish harvest specifications process for 2021. The new section can be found in the Groundfish Economic SAFE report, where one can find more details on data, methods, and species-specific 2020 (January–September) ex-vessel revenue projections in the BSAI and GOA.

Harmful Algal Blooms

Shellfish testing in the Aleutian Islands and Alaska Peninsula showed unprecedented levels of paralytic shellfish toxins in shellfish. In Unalaska, consumption of blue mussels and snails resulted in a community member fatality in July. The total toxin load of a sample of the blue mussels that were consumed was 11,200 g/100g (140 times the regulatory limit) and the snails consumed were 287 g/100g (∼3x above the regulatory limit). Amaknak Island in Unalaska Bay also had samples with toxicity slightly above the limit, blue mussels 2.8x and snails 1.4x. Weekly shellfish samples were taken in 17 locations throughout the Aleutian and Alaska Peninsula region and results are still being analyzed.

In addition to Unalaska, west of the Aleutians the Kamchatka Peninsula also had a major toxic event last September, where octopi, seals and other fauna, died due to the high toxicity level of a harmful algal bloom. The event also caused sickness and corneal burns in people surfing and/or swimming in the area. While no events have been recorded extensively in the islands, it is of note that HABs of high toxicity occurred at both ends of the archipelago.

Processing Plant closes in Adak

The fish processing plant on Adak was previously operated by Seattle-based Icicle Seafoods but closed in 2013. The city bought the processing equipment at auction to keep it on the island. However the plant was closed again in 2020. The potential for reopening the plant will depend on the current development of a BSAI Pacific cod trawl CV cooperative style Limited Access Privilege Program. The closure may set back the stability needed in the central and western Aleutians to maintain services, a stable population, and attract long term residents.

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`

Physical Environment Synthesis

Integrated Physical Factors Information

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Synthesis *In 2020 all climate indices are at or near average conditions except for the NPGO index, which has been negative since late 2013. There is an overall coherence throughout the Aleutians with SST above the mean and increased marine heat wave days since 2013, and persistent subsurface warm temperatures since 2016. This last is shown in the GODAS 100–250 m deep layer maps from 2016–2019 which are consistent with the bottom trawl water temperature analysis going to 2018. Despite this coherence, regional differences are evident: i) the regional SST indicator gives a generally consistent picture with large-scale OISST fields in the North Pacific—warmest conditions are in the eastern Aleutian Islands which also show the largest positive anomalies of the three regions in autumn 2019 and summer 2020, moderate positive anomalies are consistent across regions in winter and spring 2020; ii) the almost year-long moderate marine heat wave of 2019 in the eastern Aleutians, was considerably shorter and less intense in the central Aleutians and even less so in the western Aleutians and iii) the eddy kinetic energy (EKE) shows a distinct regional pattern with low EKE since 2012 in the eastern Aleutians which are characterized by high-intensity distinct eddy events, and less intense but consecutive or prolonged multi-year eddies characteristic in the north and south of the central and western Aleutians respectively.*

Implications for ecosystem dynamics and productivity as it pertains to fisheries management: In general, higher ambient temperatures incur bioenergetic costs for ectothermic fish such that, all else being equal, prey consumption must increase to maintain fish condition. Thus, the persistent higher temperatures may be considered a negative indicator for many groundfish but warmer should still be considered within the thermal tolerance of each species. The higher temperatures increasing bioenergetic costs and consumption demands beyond what may be available, may partly explain why the observed body condition of several commercial groundfish has been lower than the survey mean since 2012. Warmer temperatures can also impact ontogenesis of Atka mackerel eggs. Temperature is an important determinant of essential fish habitat and sea surface temperature in particular has been found to be the most important determinant of egg and larval stage distribution of commercial fish in Alaska. For many of the commercial groundfish for which the youngest age in the stock assessment is 4 year old or older, effects of this sustained warmer temperature on recruitment will not be apparent.

Introduction

We provide an overview of the physical oceanographic conditions impacting the Aleutian Islands, the conditions observed during 2020, and place 2020 in context to recent years. The physical environment has implications for 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:

Sections:
1. North Pacific Climate Overview and Regional Highlights
2. Winds (North Pacific Sea Level Pressure)
3. Sea Surface Temperatures, Marine Heatwaves and NMME Forecast
4. Trawl Survey Water Temperature Analysis and GODAS Subsurface Temperatures
5. Eddies in the Aleutian Islands—FOCI

1. Climate Overview

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Climate indices provide an alternative means of characterizing the state of the North Pacific atmosphere-ocean system. The focus here is on five commonly used indices, of which the first three are potentially the most relevant to the AI: the NINO3.4 index for the state of the El Niño/Southern Oscillation (ENSO) phenomenon, the Pacific Decadal Oscillation index (PDO the leading mode of North Pacific SST variability), the North Pacific Index (NPI, area-weighted sea level pressure over the region 30–65°N, 160°E–140°W), the North Pacific Gyre Oscillation (NPGO, 2nd dominant mode of sea surface height variability in the Northeast Pacific), and the Arctic Oscillation (AO). The time series of these indices from 2009 into spring/summer 2019 are plotted in Figure 9. The dominant atmosphere-ocean relationship in the North Pacific is one where atmospheric changes lead changes in sea surface temperatures by one to two months. However, strong ties exist with events in the tropical Pacific, with changes in tropical Pacific SSTs leading SSTs in the north Pacific by three months). The NPGO is significantly correlated with previously unexplained fluctuations of salinity, nutrients and chlorophyll-a measured in long-term observations in the California Current (CalCOFI) and Gulf of Alaska (Line P). The AO is characterized by winds circulating counterclockwise around the Arctic at around 55°N latitude; during a positive phase, colder air is confined across polar regions; in a negative phase, winds becomes weaker which allows an easier southward penetration of colder, arctic airmasses and increased storminess into the mid-latitudes. For each time series discussed below, the analysis is based on the monthly values that are normalized using a climatology based on the years of 1981–2010. This climatology is what are considered the long-term average or ”normal” conditions.

The NINO3.4 index was positive during 2019 through April 2020. Its magnitude was slightly above 0.5 from fall 2019 through early spring 2020, implying that equatorial Pacific ocean temperatures just reached the threshold NOAA uses to indicate El Niño conditions. It was the second boreal winter in a row meeting that threshold; it was somewhat weaker than its predecessor during the winter 2018-19, and much weaker than the extreme event of 2015–16.

The PDO declined from a three-month average value of about +1 in summer 2019 to -0.7 in March 2020. This decline was associated with a combination of modest cooling along the west coast of North America and warming in the middle latitudes of the North Pacific west of the dateline, relative to seasonal norms. The latter region underwent cooling during the late spring and summer of 2020, resulting in an overall SST anomaly pattern that little resembles that of the PDO, and a near neutral value for that climate index.

The NPI effectively represents the state of the Aleutian low, with negative (positive) values signifying relatively low (high) SLP. The NPI tended to be weakly negative during the summer of 2019 before entering

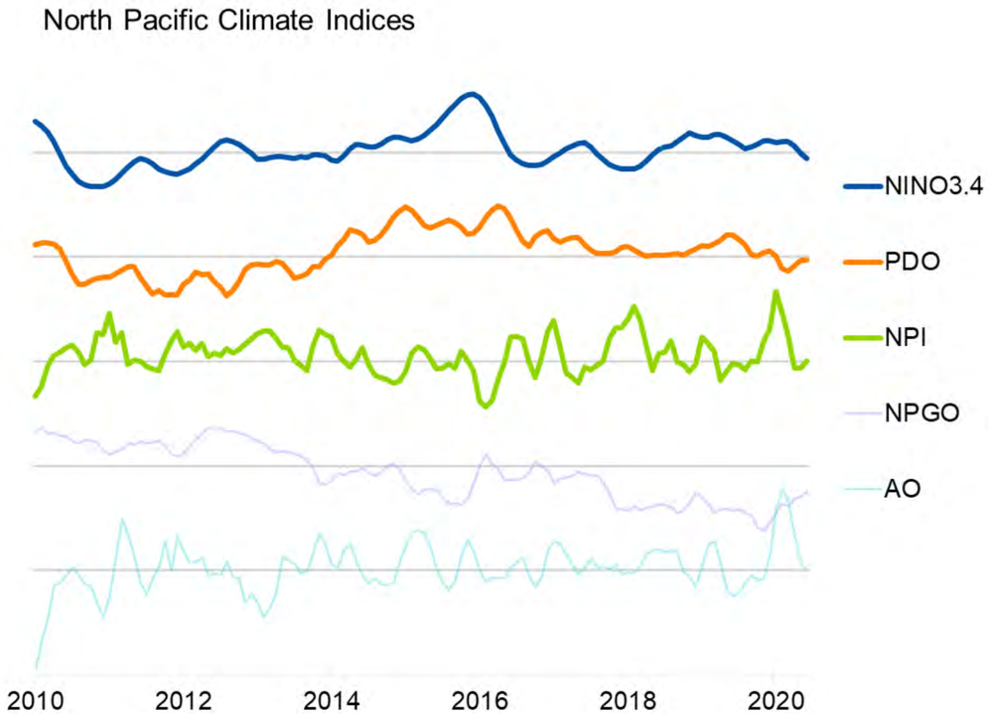


Figure 9: Time series of the NINO3.4, PDO, NPI, NPGO, and AO indices (ordered from top to bottom) for 2010–2020. Each time series represents monthly values that are normalized using a climatology based on the years of 1981–2010, and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 2 standard deviations. More information on these indices is available from NOAA's Physical Sciences Laboratory at `https://psl.noaa.gov/data/climateindices/`.

a strongly positive phase during the winter of 2019–20. This was especially the case in February 2020, during which the average SLP in the region used to specify the NPI was the greatest on record for the month. The Aleutian low tends to be stronger, i.e., the NPI is negative, during El Niño. This is opposite to what occurred in the winter of 2019–20, and to a lesser extent in the previous winter of 2018–19. The NPI relaxed back to a near average state in the summer of 2020.

The NPGO continued its multi-year decline from strongly positive in 2012 to strongly negative in the fall of 2019, with the extreme value of about -3 representing a record minimum for the period of record extending back to 1950. This index subsequently increased during the first half of 2020, but remained substantially negative. The negative sense of the NPGO generally includes 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.

The AO represents a measure of the strength of the polar vortex, with positive values signifying anomalously low pressure over the Arctic and high pressure over the North Pacific and North Atlantic at a latitude of roughly 45 °N. As for the NPI, early 2020 was highly unusual with a peak value of the AO approaching +4 standard deviations in terms of a seasonal (3-month) mean. This set-up helped bring about the coldest winter (Dec–Feb) for Alaska as a whole since 1998–99, with mean temperatures on the order of 6 °C colder than those during 5 of the 6 winters immediately preceding. A marked decline in the AO occurred during the spring of 2020 to near neutral values in summer 2020.

NP Climate Summary. The North Pacific atmosphere-ocean climate system during autumn 2019 through summer 2020 featured generally higher than average sea level pressure and above-average upper ocean temperatures south of Alaska. The anomalously high pressure was especially prominent during the winter of 2019–20 and coincided with an intense polar vortex, as indicated by a strongly positive state for the Arctic Oscillation. This regional atmospheric circulation pattern occurred despite the co-existence of weak-moderate El Niño conditions in the tropical Pacific, with the latter usually accompanied by a strong Aleutian low, i.e., negative sea level pressure anomalies. The sea surface temperature pattern during the period considered here represented a strongly negative state of the North Pacific Gyre Oscillation, particularly during the latter portion of 2019; the Pacific Decadal Oscillation transitioned from moderately positive in summer 2019 to moderately negative during much of 2020. The climate models used for seasonal weather predictions are indicating elevated odds (∼85%) of La Niña for the winter of 2020–21. Model projections for early 2021 indicate that sea surface temperatures in the North Pacific are likely to remain warmer than average in the central North Pacific south of 50ºN, with near-average temperatures for the central and eastern Aleutians and southeast Bering Sea shelf, and typical to slightly cool temperatures for the northern Gulf of Alaska.

2. Regional Highlights

Aleutian Islands. The Aleutian Islands experienced relatively warm weather in the early fall of 2019 with then a transition to more average air temperatures in winter 2020. The weather was quite variable in spring followed by a warm summer in 2020. The western portion of the Aleutian Islands tended to be relatively stormy in winter and spring 2020, with the central and eastern portions of this region on the quiet side, in large part due to an Aleutian low that was much weaker than usual. The sub-surface marine heat wave noted below for the GOA and Alaska Peninsula extended westward, past the eastern and central Aleutians, including the western Aleutians. According to the National Centers for Environmental Prediction Global Ocean Data Assimilation System (GODAS), NOAA's operational ocean analysis, and considering temperatures in the 100 to 250 meters layer relative to historical averages, the western Aleutians have not been as warm as farther east, but have nonetheless remained above the historical norms as have the central and eastern Aleutians since about 2016. There are relatively few direct sub-surface observations to constrain the GODAS analysis in this region, but these results seem to be supported when compared to water column temperatures estimated from the bottom trawl survey conducted by the AFSC in the Aleutians (see corresponding section below).

Gulf of Alaska. The coastal GOA featured slightly warmer than average air temperatures from fall 2019 through the winter of 2019–20. There were slightly reduced wind speeds during this period, but also onshore-directed flow anomalies, resulting in greater precipitation than usual for most of the coastal watersheds of the GOA. The freshwater runoff in this region appears to have included slightly elevated flows on many rivers with a greater tendency for higher flows on the smaller streams. The GOA coastal winds anomalies were in a clockwise sense (upwelling-favorable) from late 2019 through spring 2020. The near surface ocean temperatures in the GOA were generally on the warm side, especially early in the period considered here and offshore of the shelf break. It bears mentioning that a prominent marine heat wave (MHW) occurred in the sub-surface waters (depths between roughly 100 and 250 meters) of the central and western GOA in mid-late 2019, followed by marked cooling during 2020. This warm water at depth originated off the British Columbia coast and in part represents a lingering effect of the extreme NE Pacific MHW of 2014–16. This conjecture is based on temperatures from NOAA's Global Ocean Data Assimilation System (GODAS), which uses a numerical ocean model that ingests real-time surface and sub-surface observations to monitor three-dimensional physical oceanographic conditions. The data considered here was downloaded using the application at `apdrc.soest.hawaii.edu`. Air temperatures in the vicinity of the Alaska Peninsula were mostly warmer than average, especially during autumn 2019 and summer 2020, with more typical temperatures from late winter through much of spring 2020. Wind speeds were on the whole lower than average. The SSTs were also on the warm side, but not to an extreme, with positive anomalies on the order of 0.5 to 1°C in coastal areas. The warmth at depth noted above for the GOA extended southwestward along the shelfbreak on the south side of the Alaska Peninsula during summer and fall of 2019, with rapid cooling beginning near the end of 2019 continuing into 2020 bringing more normal temperatures.

Bering Sea deep basin. The western, deep portion of the Bering Sea experienced anomalous winds from the west off the eastern tip of Siberia during much of the winter of 2019-2020, resulting in cooling to average SSTs after a warm fall in 2019. The weather in spring was variable, with some warming of the upper portion of the water column relative to seasonal norms. There is the suggestion that some of this warming can be attributed to warm water south of the Alaska Peninsula being transported through Unimak Pass and other gaps in the eastern Aleutian Island chain and subsequently being entrained in the northward flowing Bering Slope current along the eastern Bering Sea shelf break. But again, direct measurements are scant and it is highly uncertain whether the GODAS product can properly account for the processes that result in the transport of Pacific water into the Bering Sea, and the subsequent fate of this water. At any rate, by summer 2020 the upper part of the water column in the deep basin of the Bering Sea was relatively warm in the north and cool in the south.

2. Wind

North Pacific Sea Level Pressure Anomalies

Lead contributor Nick Bond, *nicholas.bond@noaa.gov*

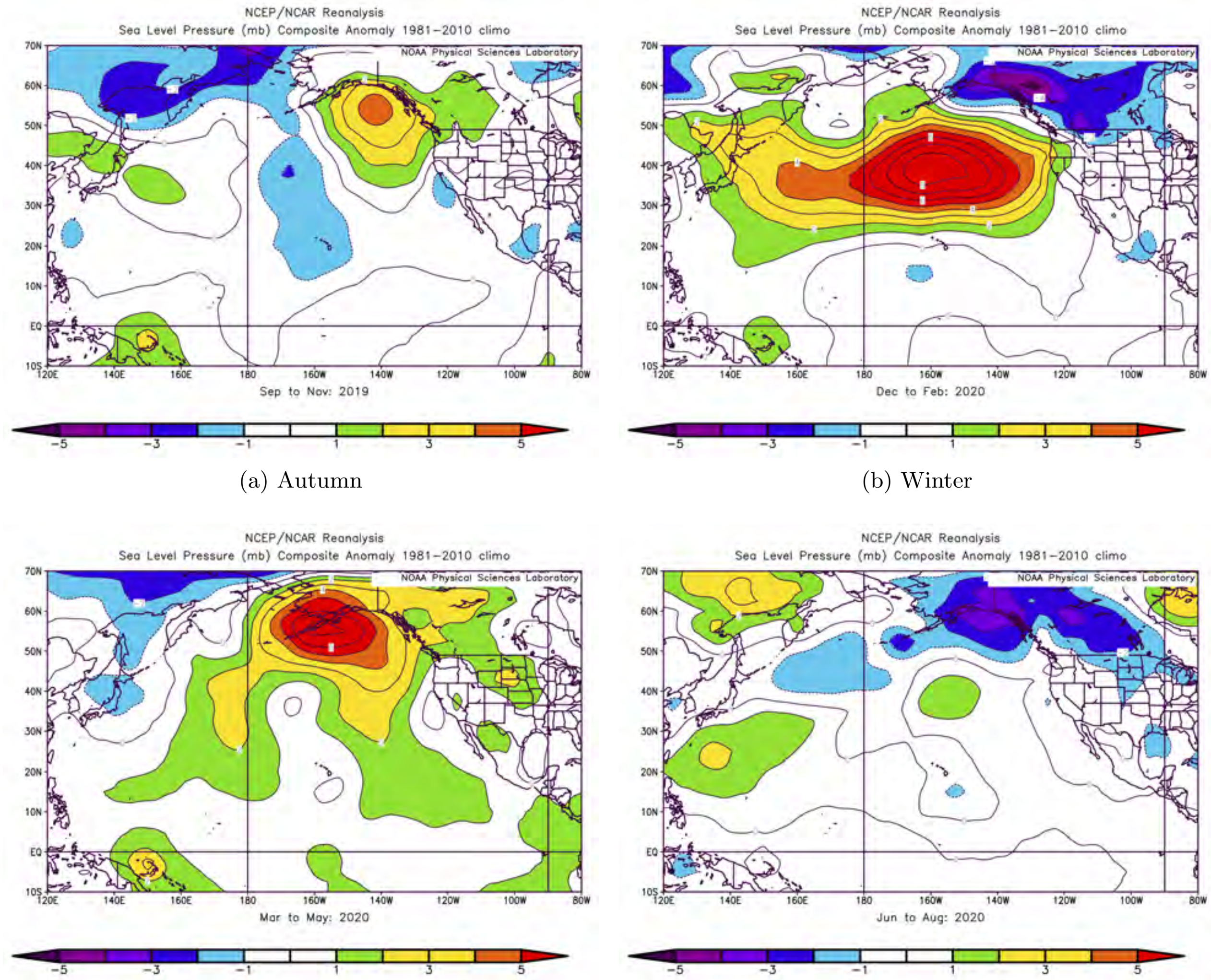
The state of the North Pacific climate from autumn 2017 through summer 2018 is summarized in terms of seasonal mean sea surface temperature (SST) and sea level pressure (SLP) anomaly maps. The SST and SLP anomalies are relative to mean conditions over the period of 1981–2010. The SST data are from NOAA's Optimum Interpolation Sea Surface Temperature (OISST) analysis; the SLP data are from the NCEP/NCAR Reanalysis project. Both data sets are made available by NOAA's Earth System Research Laboratory (ESRL) at `https://www.psl.noaa.gov/cgi-bin/data/composites/printpage.pl`.

The SLP pattern during autumn (Sep–Nov) 2019 (Figure 10a) featured a positive anomaly center over the Gulf of Alaska (GOA), and negative anomalies from the Sea of Okhotsk to the eastern tip of Siberia. The southeasterly wind anomalies accompanying the GOA positive SLP anomaly contributed to the quite warm SST anomalies mentioned below; this SLP anomaly was also associated with upwelling-favorable wind anomalies in the northern and eastern GOA, continuing southward along the British Columbia coast.

The winter (Dec–Feb) of 2019–20 featured a large SLP anomaly centered between the Hawaiian Islands and mainland Alaska (Figure 10b) with a peak value approaching 10 mb, which represents an anomaly of extreme magnitude. This pattern implies substantial suppression of the storminess between 30 and 50°N across the North Pacific, especially east of the dateline. It also indicates wind anomalies from the west on the north side of the SLP anomaly center, particularly for the GOA, and hence anomalous equatorward Ekman transports for the upper ocean mixed layer in that region.

Relatively high SLP continued to dominate the central and eastern North Pacific through spring (Mar–May) of 2020 Figure 10c, with a positive anomaly center exceeding 8 mb located just south of the Alaska Peninsula. The circulation around this high SLP center brought anomalous winds with a component from the south over the eastern and northern Bering Sea. It also implies a continuation of westerly wind anomalies for the central GOA, and upwelling-favorable northwesterly wind anomalies for the coastal regions of the eastern GOA and British Columbia. The distribution of anomalous SLP resulted in modest wind anomalies from the southwest for much of the North Pacific west of the dateline.

The distribution of SLP anomalies across the North Pacific during summer (Jun–Aug) of 2020 is shown in Figure 10d. Low pressure occurred over the GOA with higher pressure to the south between Alaska and the Hawaiian Islands in a similar sense to that of the previous winter, but with much weaker magnitudes. The SLP over the western North Pacific was lower than normal north of about 35°N and higher than normal from northeast of the Philippines to east of Japan with peak anomaly magnitudes of 1–2mb.



(a) Autumn

(b) Winter

(c) Spring

(d) Summer

Figure 10: SLP anomolies for autumn (September–November 2019), winter (December 2019–February 2020), spring (March–May 2020), and summer (June–August 2020).

3. Sea Surface Temperature

Sea Surface Temperature

Lead contributor Nick Bond, *nicholas.bond@noaa.gov*

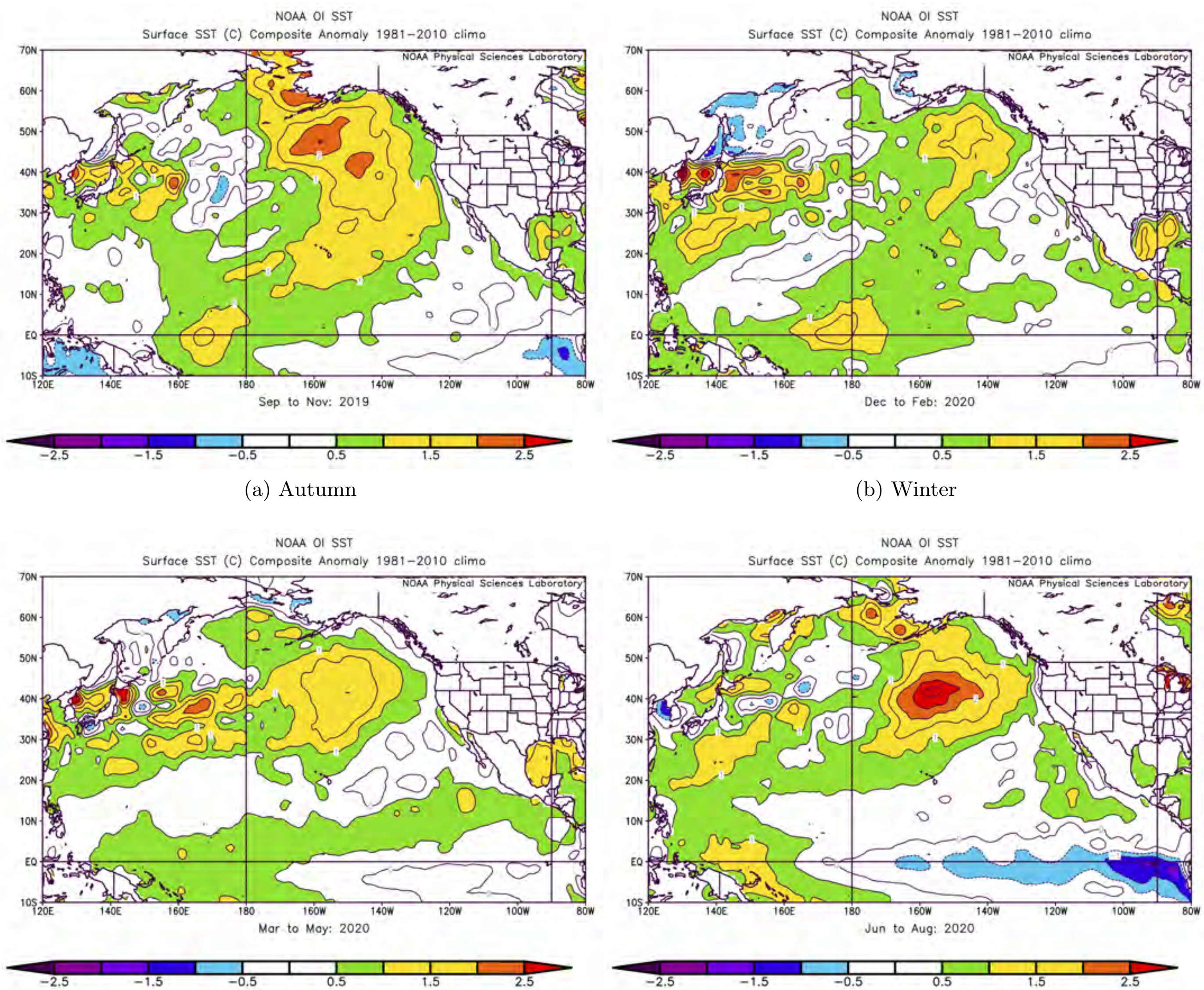
The SST anomalies are relative to mean conditions over the period of 1981–2010; the SST data are from NOAA's Optimum Interpolation Sea Surface Temperature (OISST) analysis. The data set is made available by NOAA's Physical Sciences Laboratory (PSL) at `https://www.psl.noaa.gov/cgi-bin/data/composites/printpage.pl`.

The SST during the autumn of 2019 (Figure 11) was warmer than average for almost the entirety of the eastern North Pacific Ocean. Warm conditions also occurred in the western North Pacific between 30 and 45°N from the Korean Peninsula to 160°E. Especially prominent positive anomalies extended from the Chukchi Sea to a broad region between the Hawaiian Islands and the Pacific coast. The magnitude of the SST anomalies exceeded 2°C over much of the southeast Bering Sea shelf and south of the Gulf of Alaska (GOA). Warmer than average but more moderate SSTs were present along the west coast of North America from California to the northern GOA. The lesser anomalies in this coastal strip are consistent with the upwelling-favorable wind anomalies discussed in the previous section. It is noted that temperatures at depth (roughly 100 to 250 meters) in the western GOA were considerably warmer than average during autumn 2019 from a historical perspective (not shown). The equatorial Pacific had a patch of SST anomalies greater than 1°C just west of the dateline but otherwise near average temperatures.

The distribution of SST anomalies during winter (Dec–Feb) of 2019–2020 (Figure 11), relative to the previous fall season, featured moderation in the magnitudes of the positive anomalies south of mainland Alaska, and considerable cooling on the southeast Bering Sea shelf. The latter conditions represent a marked contrast with the warm to extremely warm winters of that region during the 5 preceding years. Cooling in the central and southern Gulf of Alaska is consistent with the anomalous westerlies and equatorward Ekman transports, noted above, drawing cooler water from north to south in the surface layer. The equatorial Pacific included a patch of SST anomalies slightly greater than 1°C near the dateline in association with a weak El Niño of the central Pacific or "Modoki" variety.

The spring (Mar–May) of 2020 included relatively warm SSTs throughout much of the North Pacific (Figure 11). The water that was more than 1°C warmer than usual south of Alaska increased in area from the previous season. There was also a substantial increase in temperatures in the southeastern Bering Sea, relative to seasonal norms, accompanying a rapid retreat of sea ice driven by southerly wind anomalies. The coastal waters of western North America from the GOA to Northern California had near average temperatures. The weak El Niño of the previous winter continued to fade, with some warmth remaining along the equator west of the dateline and near average conditions in the east.

The large-scale SST anomaly pattern in the North Pacific during the summer (Jun–Aug) of 2020 (Figure 11) featured mostly continued warmth east of the dateline between Alaska and the Hawaiian Islands. Cooling in an overall sense occurred west of the dateline, relative to the previous spring, with the development of negative anomalies from the western Aleutians to the entrance to the Sea of Okhotsk, and a diminishing of positive anomalies between about 30 and 45°N. Prominent warm anomalies on a smaller spatial scale developed on the southeast Bering Sea shelf and in the southeastern Chukchi Sea along the northwest coast of Alaska. Cold SSTs were present in the eastern equatorial Pacific, with the vestiges of the warm temperatures of the past winter and spring confined to the far western portion. The latter portion of this period featured the development of positive SST anomalies of substantial magnitude (1.5–2°C) in the central and western GOA. This warming was associated with wind anomalies from the north; this kind of flow in summer tends to bring relatively warm and dry air off of mainland Alaska over the water, resulting in enhanced warming during this time of year.



(a) Autumn

(b) Winter

(c) Spring

(d) Summer

Figure 11: SST anomolies for autumn (September–November 2019), winter (December 2019–February 2020), spring (March–May 2020), and summer (June–August 2020).

Regional Sea Surface Temperature and Marine Heatwaves

Lead contributor Jordan Watson, *jordan.watson@noaa.gov*

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. Extended periods of elevated SST above seasonal expectations are known as marine heat waves (MHWs) (Bond et al., 2015; Hobday et al., 2016). Trends in SST and MHWs are presented here throughout the Aleutian Islands ecosystem regions.

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`. Daily SST data were averaged within the western (west of 177°W), central (170°W–177°W), and eastern (163°W–170°W) Aleutian Islands. While the data in this case have been aggregated spatially within each region, the Coral Reef Watch dataset was selected (instead of the OISST time series) because of the finer spatial resolution, which could support finer spatial scale analyses in the future. The earliest complete 30-year time series (1986–2015) was used as the baseline period for mean and standard deviation comparisons (Hobday et al., 2018; Schlegel et al., 2019) for discussions of baseline choices. Detailed methods are online, including maps of the spatial strata and querying satellite data with R `(github.com/jordanwatson/EcosystemStatusReports/tree/master/SST)`. 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) is also provided to better illustrate the long term trends in SST data (Edullantes, 2019).

Warm water events have become so frequent in the world's oceans that a new method for describing them has been formalized. A marine heatwave 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 (average, or "normal") temperature for that day. When the threshold is exceeded, the event is considered *moderate, strong* (2 times the difference between then threshold and average), *severe* (3 times the difference between the threshold and normal), or *extreme* ($\geq$4 times the difference) (Hobday et al., 2018). MHW indices were developed using the heatwaveR package (Schlegel and Smit, 2018).

Status and Trends

During the winter (Dec – Feb) and spring (Mar – Jun) of 2020, SST in all three regions of the Aleutians was generally more aligned with 2019 than with longer term average temperatures (Figure 12). Summer temperatures however, tended more towards or below average in the western and central Aleutians while the eastern Aleutians remained a bit warmer, though still cooler than 2019.

Generally, all three regions have trended towards anomalously warm (>1 SD from the long term mean) conditions over the last few years, though the western Aleutians may be trending nearer to average conditions. Meanwhile, the central and eastern Aleutians both continue their anomalously warm conditions, especially in the eastern Aleutians where SST is generally warmer.

MHWs have occurred periodically throughout the SST time series but with greater frequency during the last few years. In each of the most recent 8 years, at least one MHW event has occurred in each of the three Aleutian Islands regions, with the greatest duration of events occurring in the eastern region. In all three regions, events frequently persist across more than one season. Notably though, the year with the most MHW days in both the western and central Aleutians was 1996. Strong El Niño conditions occurred in 1996–1997 and may have been a factor during this time but notably, the MHW did not persist appreciably into 1997 so this may suggest a weak relationship.

Implications

Sea surface temperature is a foundational characteristic of the physical marine environment and temperature dynamics can impact many biological processes. Based on extensive analysis of unique species-region-season-life-stage combinations, (Laman et al., 2018) concluded sea surface temperature was the most important determinant of egg and larval stage distribution. (Barbeaux et al., 2020) demonstrated marine heatwave impacts on marine fish 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 populations here, continued warm periods are concerning for the predictability of fish populations and recruitment, and different impacts can be expected across the Aleutians given the distinct regional differences across the AI. Stronger impacts may be expected in the Eastern AI where there have been a greater number of marine heatwave days and the SST has increased the most during the past recent years.

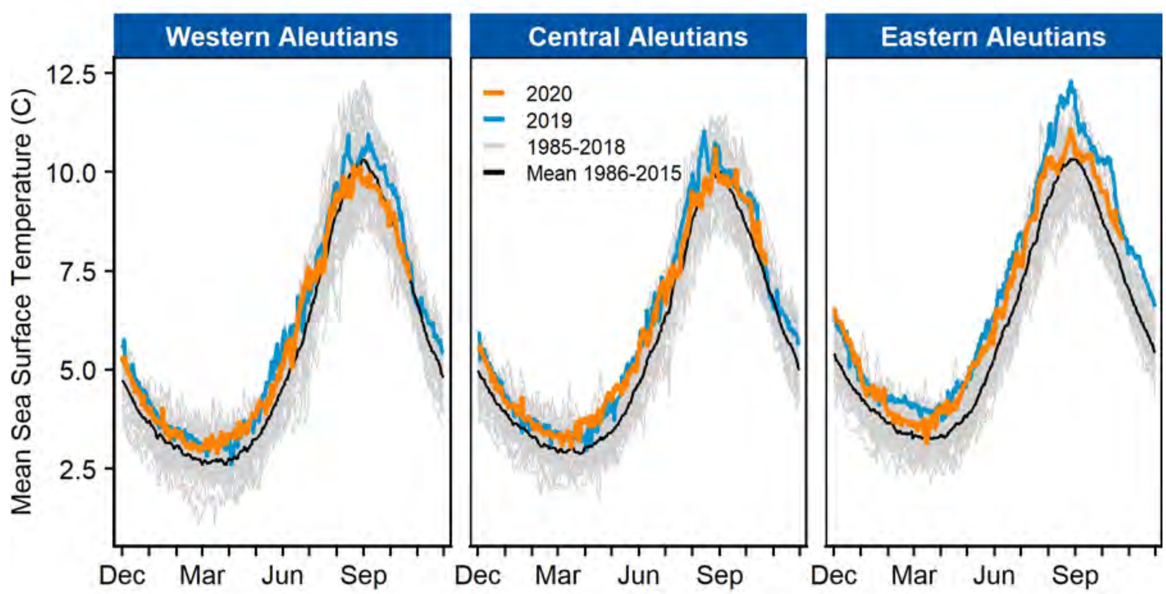


Figure 12: Mean SST for the western (left), central (middle) and eastern (right) Aleutian Islands. The most recent year (2019–2020; through October 25) is shown in orange, winter 2018/2019 is shown in blue, and the historical mean is shown in black. Individual years in the time series are shown in gray.

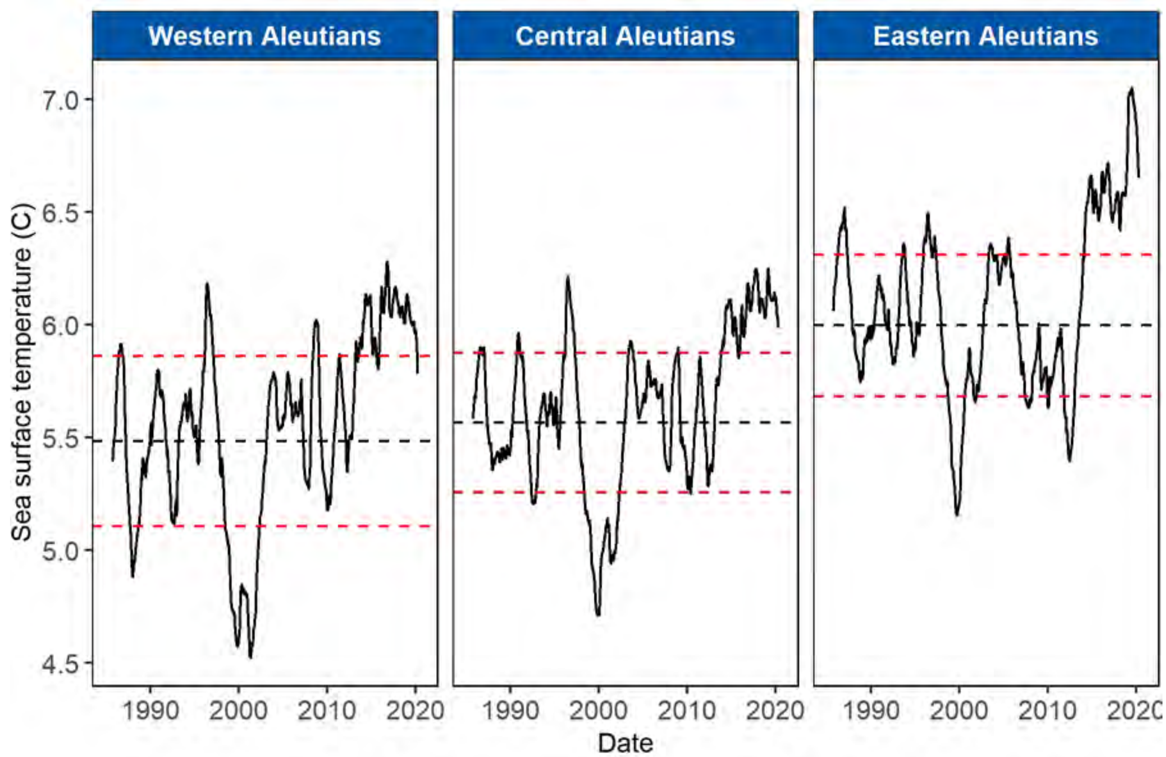


Figure 13: Time series trend (i.e., seasonality and noise removed) of sea surface temperatures. Horizontal dashed lines represent the mean (black) and standard deviation from the mean (red) during the earliest complete 30-yr baseline period (1986–2015).

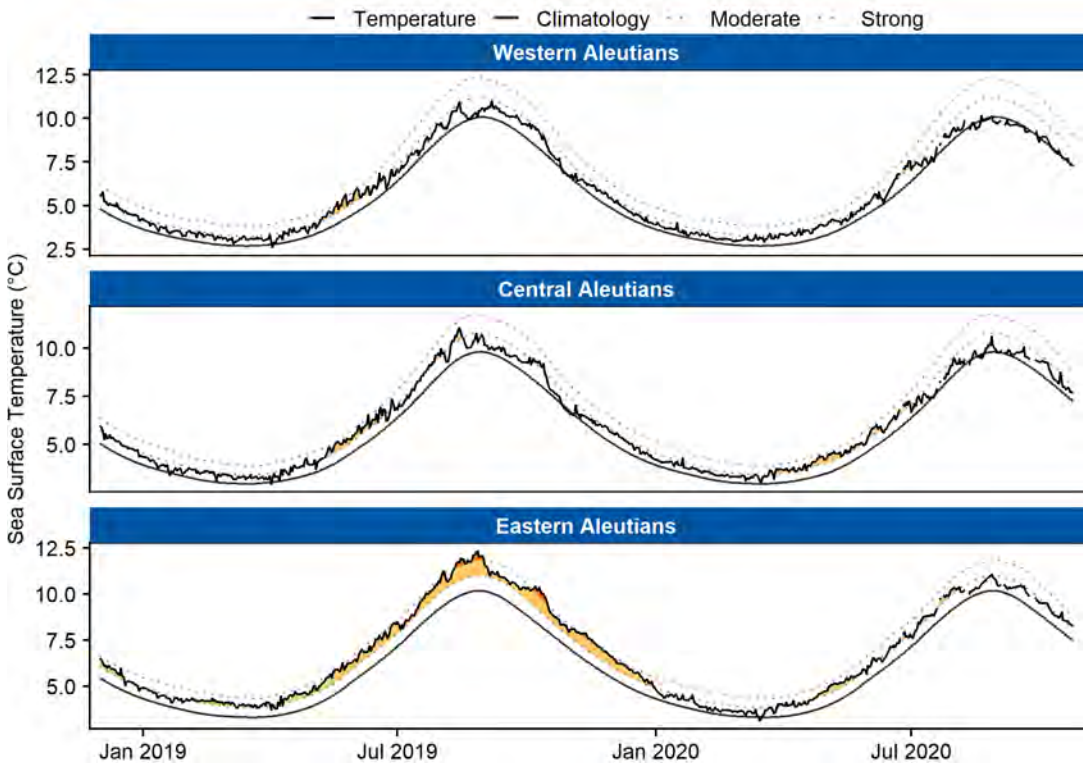


Figure 14: Marine heatwave (MHW) status during the last three years. Filled (yellow) areas depict MHW events. Black lines represent the 30-year baseline (smoothed line) and observed daily sea surface temperatures (jagged line). Faint grey dotted lines illustrate the MHW severity thresholds in increasing order (moderate, strong)

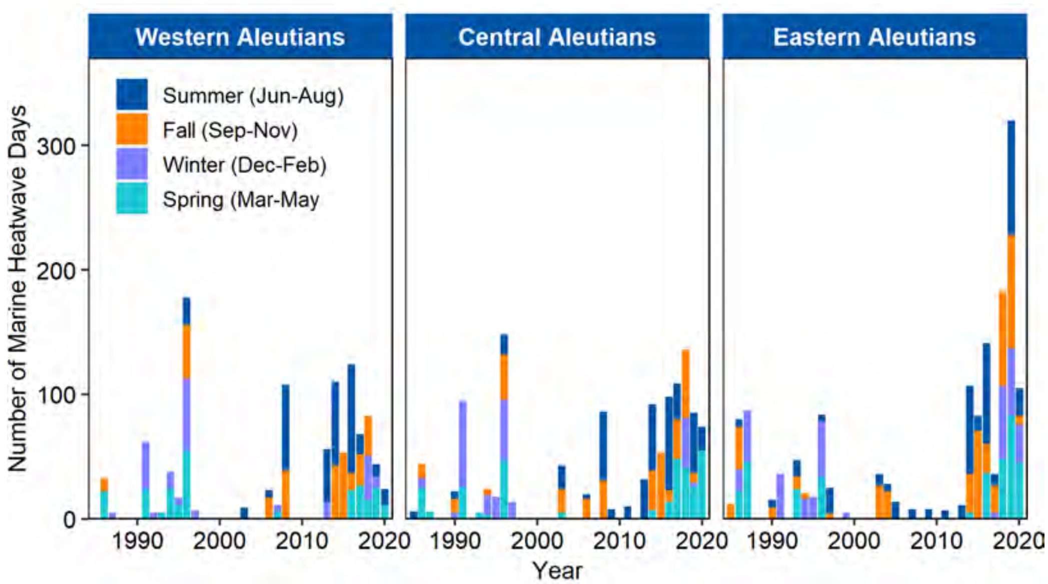


Figure 15: Number of days during which marine heatwave conditions persisted in a given year. Seasons are summer (Jun–Aug), fall (Sept—Nov), winter (Dec—Feb), spring (Mar—May). Years are shifted to include complete seasons so December of a calendar year is grouped with the following year to aggregate winter data (e.g., Dec 2019 occurs with winter of 2020).

SST Projections from the National Multi-Model Ensemble
Last updated October 2020

Lead contributor Nick Bond, *nicholas.bond@noaa.gov*

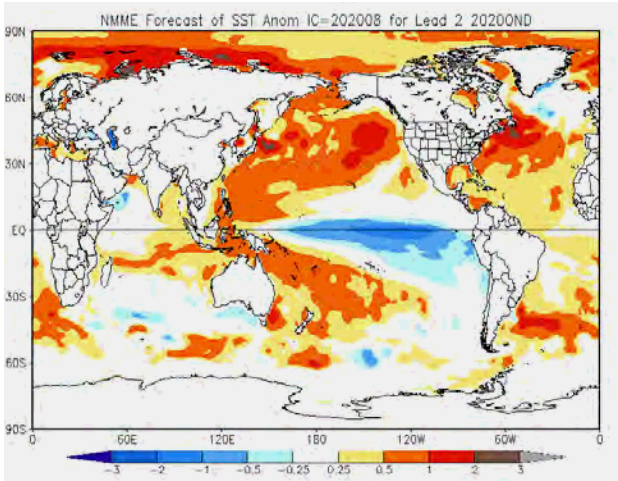
Seasonal projections of SST from the National Multi-Model Ensemble (NMME) are shown in Figure 16a–c. An ensemble approach incorporating different models is appropriate for seasonal and longer-term simulations; the NMME represents the average of eight climate models. The uncertainties and errors in the 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[1].

First, the projections from a year ago are reviewed. The model forecasts from August 2019 for the following fall and winter indicated a continuation of positive SST anomalies south of Alaska and moderation of the initially warmer conditions along the Alaska coast from the Alaska Peninsula to the SE Alaska panhandle. The sense of the evolution in the anomalies for the coastal waters of Alaska was correct, but for the models as a whole, the predictions indicated less cooling, relative to seasonal norms, than was observed. In addition, the models predicted winter conditions that were warmer than observed for the Bering Sea shelf; the longer-term forecasts for late winter into spring were superior. Anomalies of weak to moderate magnitude were forecast and observed for the Aleutian Island region, with the model forecasts being too warm in the western portion. With regards to the tropical Pacific, the models failed to fully account for the weak central Pacific El Niño that was present in fall 2019 into early 2020, but did properly predict near neutral conditions in spring 2020. Qualitatively, these model projections do not have quite as much overall skill as in the previous 4 years, but the signs of the SST anomalies were forecast correctly for most locations.

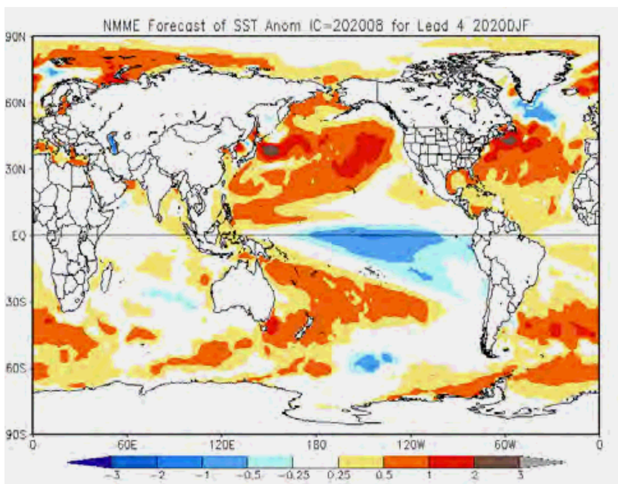
The NMME forecasts of three-month average SST anomalies indicate a continuation of a large region of warm water between Alaska and the Hawaiian Islands through the end of 2020 (Oct–Dec 2020; Figure 16a). The predictions also indicate warm SSTs for the Alaska Peninsula and Aleutian Islands. Conversely, the coastal waters of the GOA are predicted to have near normal temperatures. A band of cold SST is projected in the tropical Pacific commensurate with that of a weak-moderate La Niña.

The overall pattern of SST anomalies across the North Pacific is maintained through the periods of December 2020–February 2021 (Figure 16b) and February–April 2021 (Figure 16c) with mostly decreases in the magnitude of anomalies, especially on the eastern Bering Sea shelf. The near coastal waters of the GOA are forecast to become slightly cooler than normal, consistent with atmospheric circulation anomalies being forecast for the North Pacific that feature a weaker Aleutian low than usual (i.e., positive SLP anomalies south of the Alaska Peninsula). The SLP pattern being forecast is similar to what was observed in the winter of 2019–2020 but of considerably weaker amplitude (not shown). La Niña does tend to be accompanied by atmospheric anomalies resembling those associated with the sets of predictions shown here, but it is uncertain whether the perturbation in the tropical Pacific will yield a substantial response in the North Pacific. The model forecasts indicate a moderation of cold conditions in the tropical Pacific by spring 2021. Coming out of the winter of 2020–2021, they suggest mostly near average temperatures along the coast from British Columbia to the Alaska Peninsula, modestly warm conditions on the eastern Bering Sea shelf (i.e., light ice year), and slightly warm SSTs for the central and western Aleutian Islands.

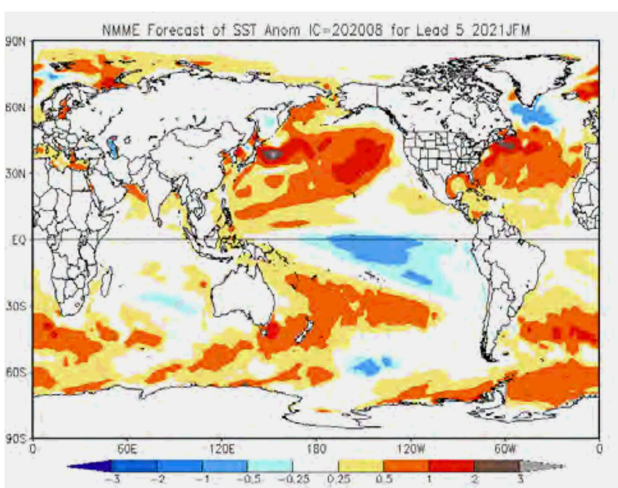
[1] `http://www.cpc.ncep.noaa.gov/products/NMME/`



(a) Months OND



(b) Months DJF



(c) Months FMA

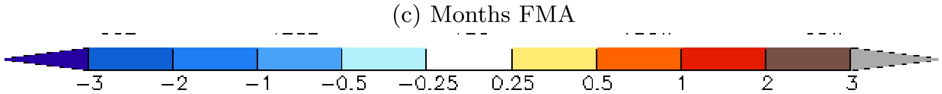


Figure 16: Predicted SST anomalies from the NMME model for OND (1-month lead), DJF (3-month lead), and JFM (4-month lead) for the 2019–2020 season.

4. Aleutian Islands Trawl Survey Water Temperature Analysis

Aleutian Islands Survey Water Temperature Analysis and GODAS subsurface Temperature

Lead contributors Ned Laman, *ned.laman@noaa.gov* and Nick Bond *nicholas.bond@noaa.gov*
Last updated: October 2018 survey; GODAS October 2020

Description of indicator: 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 when there was no AI bottom trawl survey).

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.

The bottom trawl survey has historically begun in late spring (late May to early June) and proceeds 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 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 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. To facilitate visualization, these temperature estimates were averaged over systematic depth bins in ½ degree longitude increments. Depth gradations were set finer in shallower depths and broader in deeper depths (e.g., 0–3 m bin, 3–5 m bin, 5 m bins between 5 and 100 m and 25 m bins between 300 and 450 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).

A comparison of the annual GODAS subsurface temperature anomalies (12 month averages centered on June) in normalized form for the years of 2016 to 2019 shows the variance in the temperatures in the 100–250 meter deep layer that was considered is quite low, and so in a normalized sense, the warm anomalies the last few years are substantial. These temperature data have not been de-trended, but other years in the past decade, e.g. 2013, had anomalies that were near-zero or slightly negative over sizable regions. The years 2010 and 2012, both with cooler temperature in the water column, are included for comparison purposes and verify correspondence between the water temperature analysis and GODAS estimates in cold as well as warm conditions. The seasonal cycle is much weaker at depth than near the surface, thus annual anomalies are not expected to be very sensitive to the season.

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 17. 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 2018 AI profile suggests a return to slightly cooler conditions relative to 2016, 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 bottom trawl surveys in the AI. Each temperature bin represents data collected over a relatively short time as the vessels moved through an area. Thus, 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" 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) show warmer surface waters extending from east to west during the summer of 2016 (`http://www.ospo.noaa.gov/Products/ocean/sst/anomaly/index.html`). Due to these and other sources of variation not accounted for in the temperature model presented here, caution should be exercised when interpreting these results.

Implications: 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.

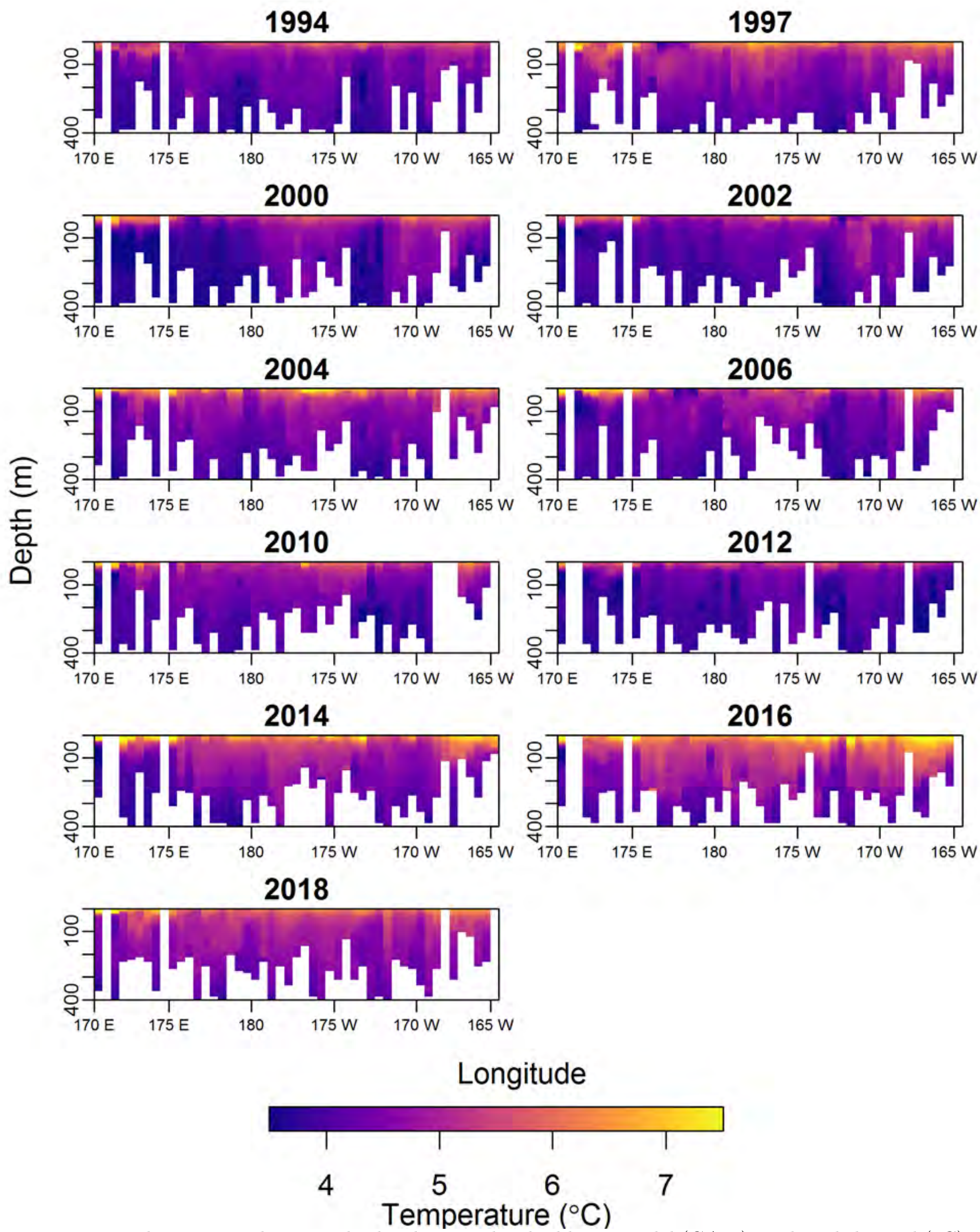


Figure 17: Median-survey-date-standardized, generalized additive model (GAM) predicted thermal (°C) anomaly profiles from water temperature measurements collected on Aleutian Islands [mostly biennial] bottom trawl surveys (1994–2018); to visually enhance near-surface temperature changes, values ≤3.5°C 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.

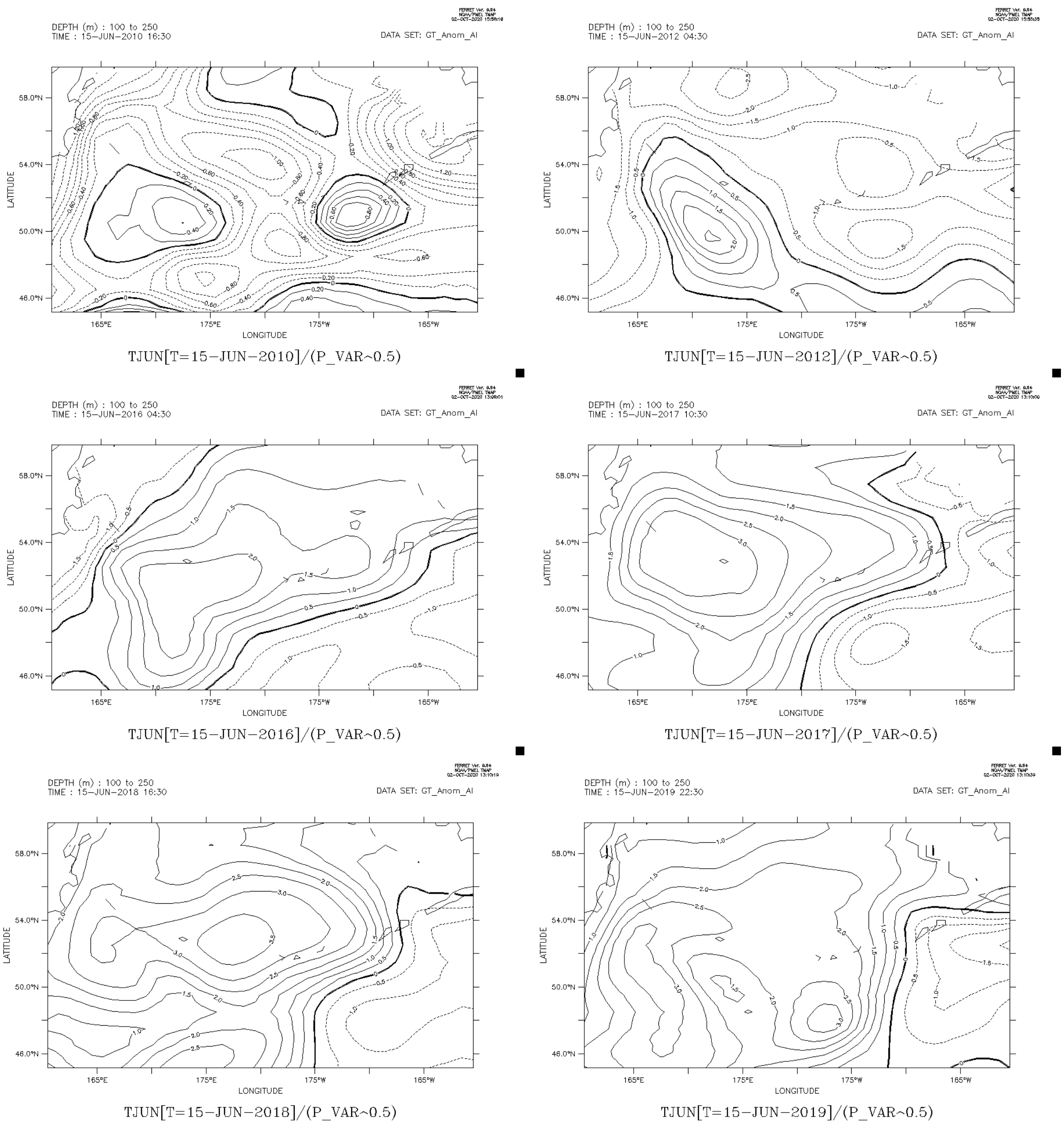


Figure 18: GODAS subsurface temperature anomaly layer 100–250m deep for years (left to right, top to bottom) 2010, 2012, 2016, 2017, 2018 and 2019.

5. Eddies in the Aleutian Islands

Eddies in the Aleutian Islands
Lead contributor Carol Ladd, *carol.ladd@noaa.gov*
Last updated: October 2020

Description of indicator: High 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 19. Eddies in the Alaskan Stream south of the Aleutian Islands and east of ∼180º (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 could impact flow in the Aleutian North Slope Current (Stabeno et al., 2009) and Bering Slope Current (Ladd, 2014) as well as influencing 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 19) 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 19). 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 passess as well as phytoplankton and zooplankton distributions.

Status and trends: In the western Aleutian Islands, (Figure 20, top panel), 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 (Figure 20, middle panel) is much lower than the two highlighted regions south of the islands (note differing vertical axes between plots). Eddy energy was higher than average in this region during 2000–2008 and again in 2016 but has been relatively low since then.

Particularly strong eddies were observed south of Amukta Pass (Figure 20, bottom panel) in 1997, 1999, 2004, 2006/2007, 2009/2010, and summer 2012. Eddy energy in the region has been low from the fall 2012 through 2020.

Eddy energy in the region has been low from the fall 2012 through 2020. 19) indicating the occurrence of frequent, strong eddies in the region. The average EKE in the region 171ºW–169ºW, 51.5º–52.5ºN (Figure 20 provides an index of eddy energy likely to influence the flow through Amukta Pass. Particularly strong eddies were observed south of Amukta Pass in 1997, 1999, 2004, 2006/2007, 2009/2010, and summer 2012. Eddy energy in the region has been low from the fall 2012 through 2018.

Factors causing trends: The causes of variability in EKE are currently unclear and a subject of ongoing research.

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, 2009/2010, and summer 2012. These fluxes likely have been smaller since fall 2012.

The Ssalto/Duacs altimeter products were produced and distributed by the Copernicus Marine and Environment Monitoring Service (CMEMS) (`http://www.marine.copernicus.eu`).

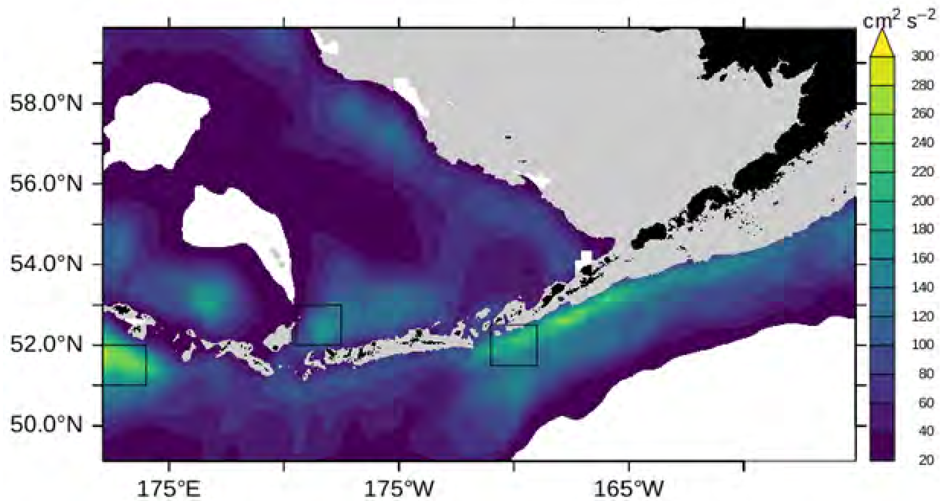


Figure 19: Eddy kinetic energy averaged over January 1993–December 2019 calculated from satellite altimetry. Squares denote regions over which EKE was averaged for Figure 20

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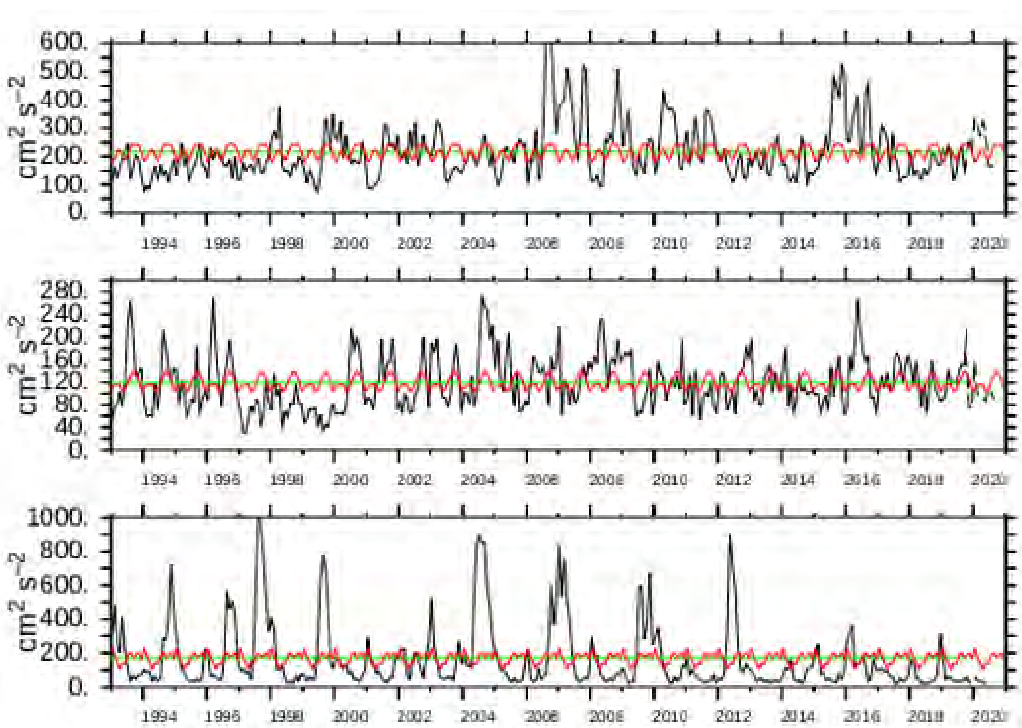

Figure 20: Eddy kinetic energy averaged over regions shown in Figure 19 from east to west. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line) : mean over entire time series.

Satellite derived Chl-a and Spring bloom timing

Lead contributor Jordan Watson,*jordan.watson@noaa.gov*
Last updated: October 2020

Both chlorophyll-a concentration [µg/L] and timing of the spring bloom by Julian day were estimated. However, satellite chlorophyll-a data are heavily impacted by cloud cover and the data availability in this case was considered insufficient to provide a reliable estimate of either indicator. The gridded dataset for each 8 day MODIS chlorophyll-a composite was downloaded from (`coastwatch.pfeg.noaa.gov/erddap/griddap/erdMBchla8day.html`) and averaged for each of the Aleutian Islands regions. To estimate coverage, the maximum number of possible data points was calculated and multiplied by twelve, as there are twelve 8-day composite dates within the April–June period. The coverage increased from west to east, but the mean proportion of maximum possible data points across all regions was 20%–30% (Figure 21). As a reference, the data coverage threshold for the Bering Sea was 66% and coverage in the Gulf of Alaska regions averaged about 75%.

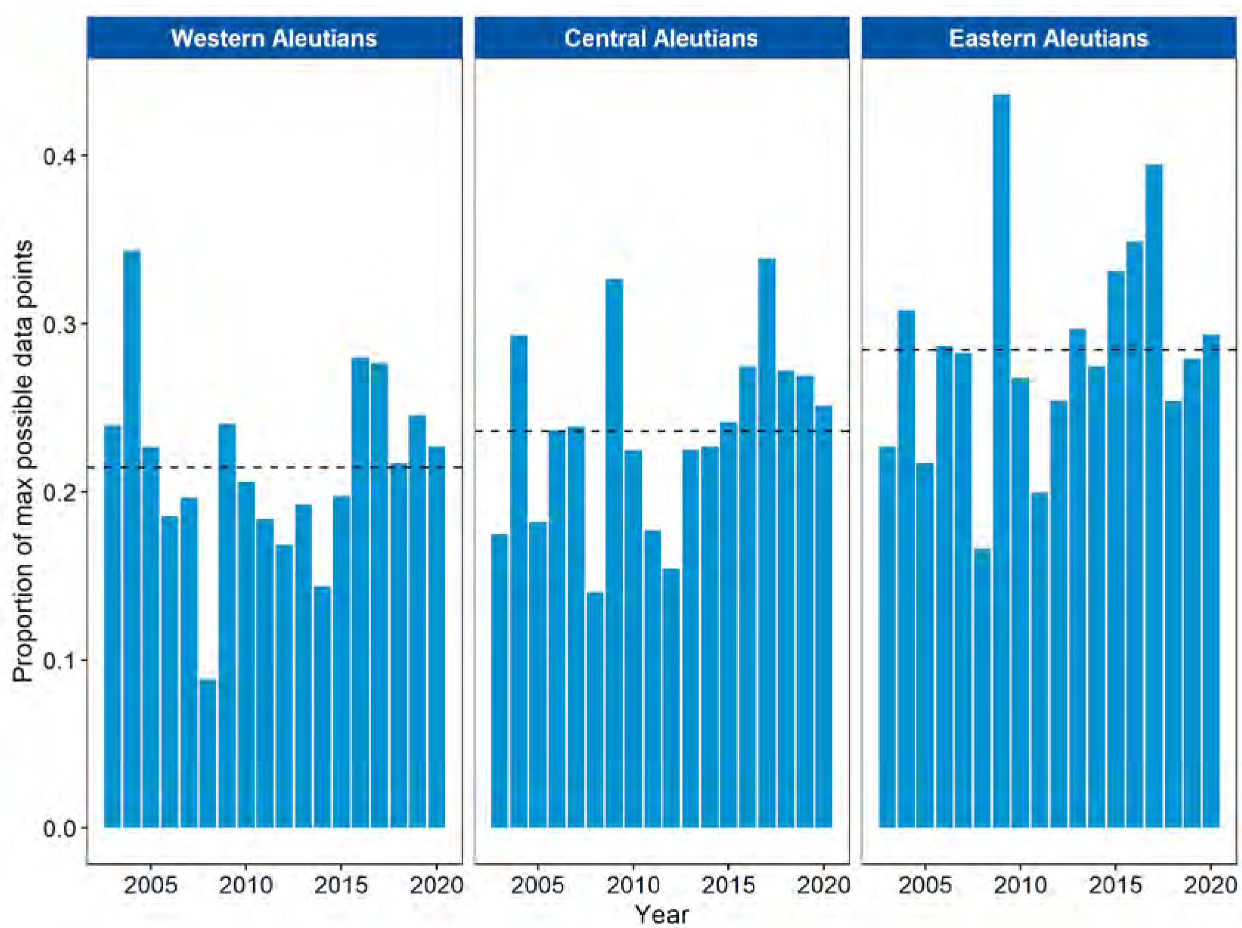

Figure 21: Proportion of the possible chlorophyll-a data available for the western, central and eastern Aleutian Islands by year. The horizontal dashed line is the mean for each region over all years.

Primary Production

There are no updates to primary production indicators in this year's report. See the contribution archive for previous indicator submissions at: `http://access.afsc.noaa.gov/reem/ecoweb/index.php`

Zooplankton

Continuous Plankton Recorder Data from the Aleutian Islands and southern Bering Sea through 2017

Contributed by Clare Ostle[1] and Sonia Batten[2]
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Last updated: August 2020

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 22): 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 (Richardson et al., 2006) 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 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.

Status and trends: Figure 23 shows that the copepod community size and mesozooplankton biomass anomalies for 2019 were positive, whereas they had been negative in 2018. The mean diatom abundance anomaly was strongly negative in 2019, which could be linked to increased predation.

Factors influencing observed trends: Recent analysis of summer CPR data in this region has revealed alternating (and opposing) patterns 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 23 contains data from spring and autumn as well as summer the alternating pattern is clear until 2012. The zooplankton data in Figure 23 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 2015–2017 so we are not certain if their influence on the plankton continues, nor how to tease out the simultaneous influence of ocean climate. However, the copepod community size anomaly has been negative in each season sampled since summer 2014, which suggests a real increase in the relative abundance of smaller species, potentially because of warmer than normal conditions.

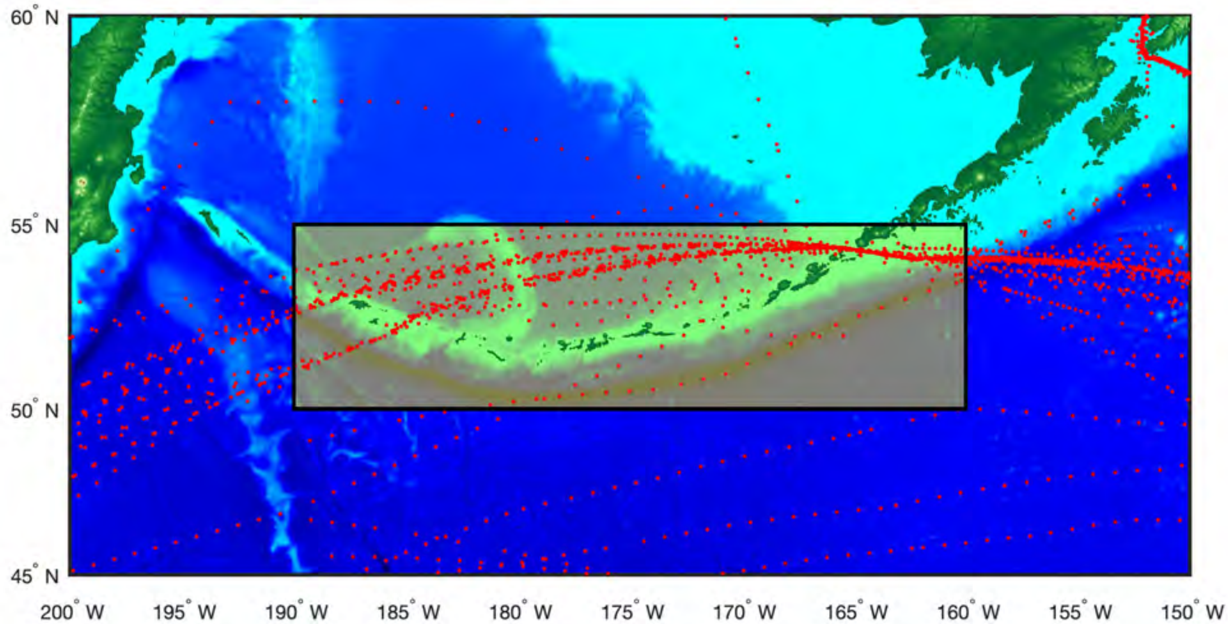

Figure 22: Location of the samples collected for the CPR analysis. Dots indicate actual sample positions and may overlay each other.

Implications: This region appears to be subjected to top down influence by pink salmon as well as bottom up forcing by ocean climate, which is particularly challenging to interpret. Changes in community composition (e.g. abundance and composition of large diatoms, prey size as indexed by mean copepod community size) may reflect changes in the nutritional quality of the organism to their predators. Changes in abundance or biomass, together with size, influences availability of prey to predators. For example, while mesozooplankton biomass anomalies were positive during the last 3 years, the reduced average size of the copepod community suggests that the biomass was packaged into numerous, but small, prey items. This may require more work by predators to obtain their nutritional needs.

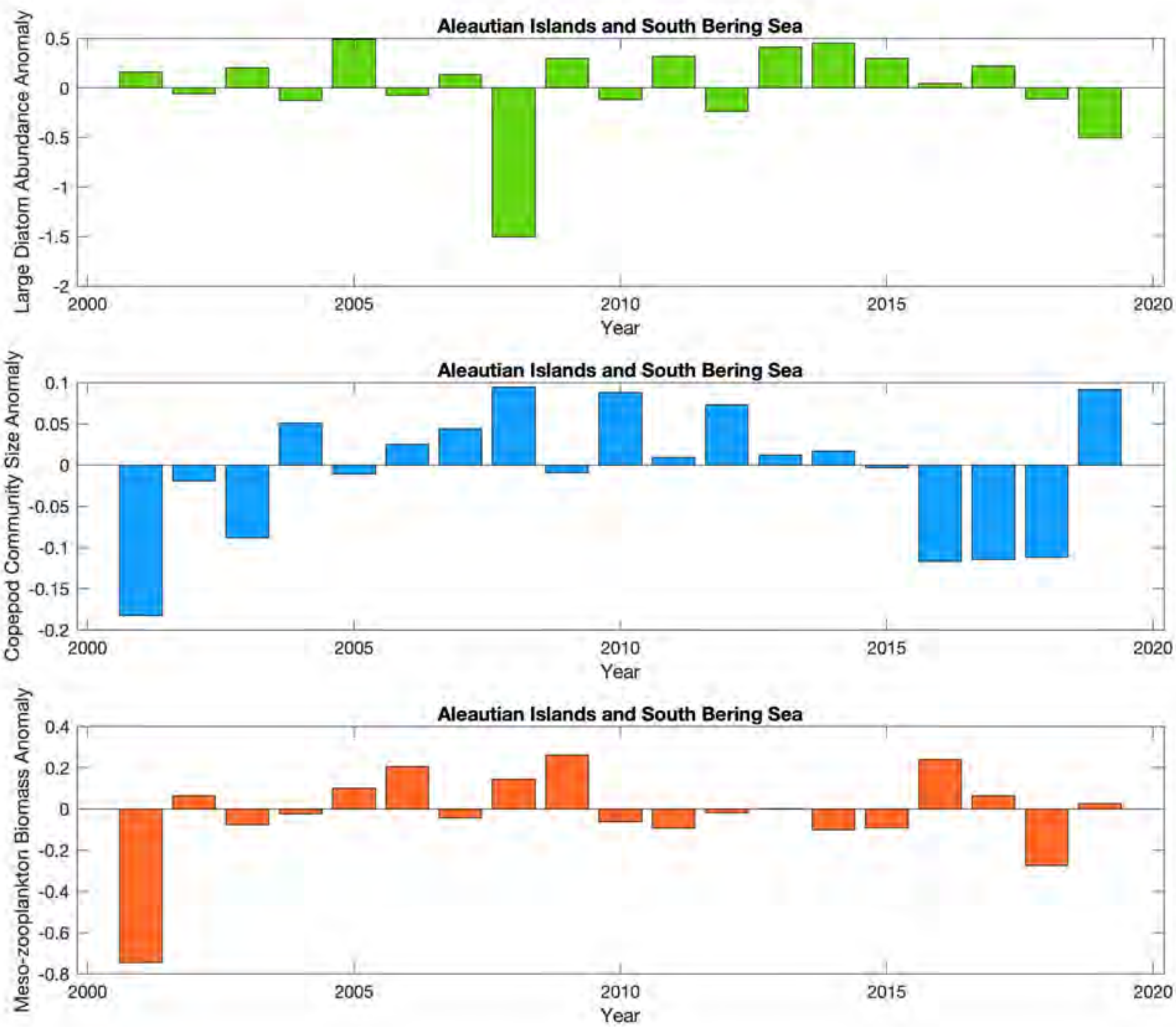

Figure 23: Annual anomalies of three indices of lower trophic levels from CPR data (see text for description and derivation) for region shown in Figure 22.

Groundfish

Aleutian Islands Groundfish Condition

Contributed by Ned Laman 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 2020

Description of indicator: Residual body condition computed from a long-term average of length-weight-based body condition is an indicator of variability in somatic growth (Brodeur et al., 2004) and represents how heavy a fish is per unit body length. As such, it can be considered an indicator of ecosystem productivity. Positive residual body condition is interpreted to indicate fish in better condition (heavier per unit length) than those with negative residual body condition indicating poorer condition (lighter per unit length). Overall body condition of fishes likely reflects fish growth which can have implications for their subsequent survival (Paul et al., 1997; Boldt and Haldorson, 2004).

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. Data were combined in the International North Pacific Fisheries Commission (INPFC) strata; Southern Bering Sea, Eastern Aleutian Islands, Central Aleutian Islands, and Western Aleutian Islands (Figure 24).

Length-weight relationships for each of the seven species were estimated within each stratum across all years where data were available (1984–2018). From a linear regression of log-transformed exponential growth, $W{=}aL^b$, where W is weight (g) and L is fork length (mm). A different slope was estimated for each stratum to account for spatial-temporal variation in growth and bottom trawl survey sampling. 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 stratum and weighted in proportion to INPFC stratum biomass based on stratified area-swept expansion of summer bottom trawl survey catch per unit effort (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.

Methodological changes: The method used to calculate groundfish condition this year (2020) differs from previous years in that: 1) different regression slopes were estimated for each stratum, 2) a bias-correction was applied to predict weights prior to calculating residuals, 3) stratum mean residuals were weighted in proportion to stratum biomass, 4) stratum-year combinations with sample size <10 were not used in indicator calculations, and 5) the NBS had its own length-weight regression. As in previous years, confidence intervals for the condition indicator reflect uncertainty based on length-weight residuals, but are larger due to differences in sample sizes and stratum biomasses among years. Confidence intervals do not account for uncertainty in stratum biomass estimates.

Status and trends:: Residual body condition varied amongst survey years for all species considered (Figure 25). The updated computational methods used to calculate this year's residual body condition indexes returned different values than those reported in the last Aleutian Islands Ecosystem Considerations document (Zador and Ortiz, 2018). The patterns of above or below average residual condition observed in 2018 largely

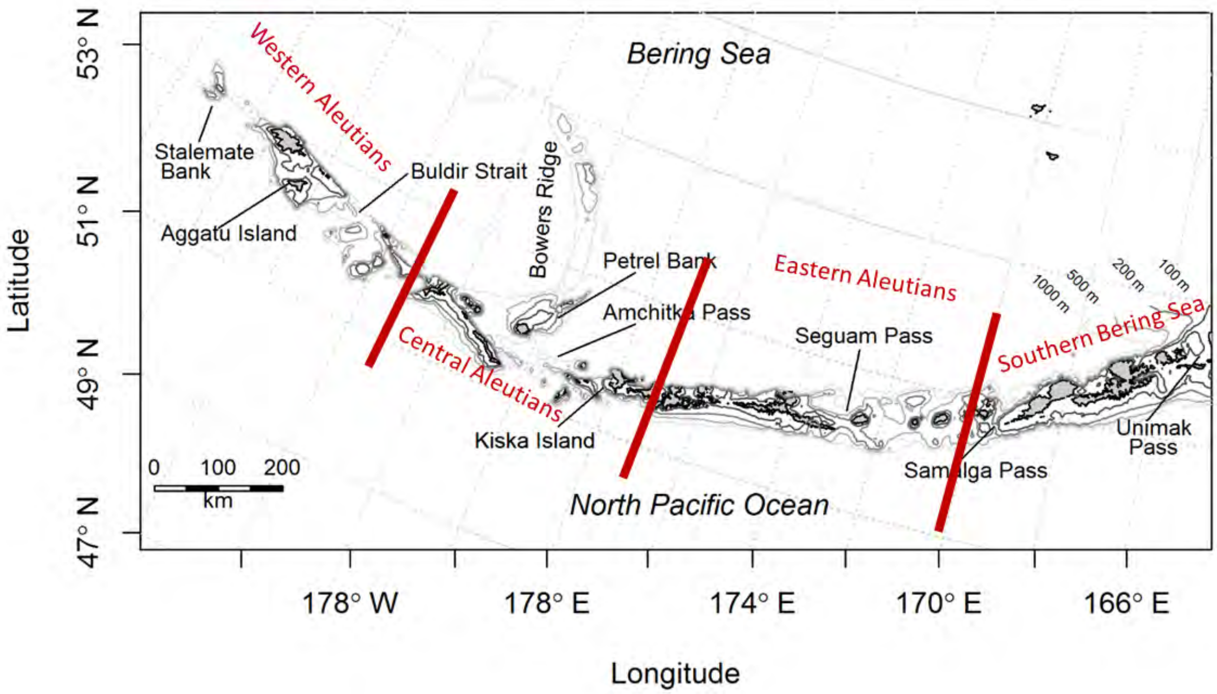

Figure 24: NMFS summer bottom trawl survey strata in the Aleutian Islands. Red lines demarcate Aleutian Islands INPFC Areas. The Central and Eastern Aleutians INPFC areas together correspond to the Central Aleutians ecoregion in this report. Similarly, the Southern Bering Sea INPFC area corresponds to the Eastern Aleutian ecoregion in this report.

match those generated here from the updated computations, but with notable reductions in the magnitude of the residuals from the latter in most years. The lower magnitude results come from using stratum-specific regression coefficients and samples weighted in proportion to biomass which reduces the influence of spatio-temporal variation in sampling intensity on the residuals. Some exceptions to the pattern tracking observed for the majority of cases are instances when residual condition switched from above to below average (>250 mm pollock in 1993 and 2015 and 100–250 mm pollock in 2010) and an instance when 100–250 mm pollock (2016) condition switched from below average to above. Condition of most species since 2010 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. Southern rock sole residual body condition is trending positive in the Aleutians since 2012. The period prior to the 2010 AI bottom trawl survey is characterized by body condition indicators cycling between positive and negative values through the years.

The general pattern of below average residual body condition index across recent survey years for the Aleutian Islands as described above was mostly reflected in the spatial condition indicators across INPFC strata (Figure 26). In some instances, stratum-specific condition was above average when the overall annual condition was below average (e.g., in the Central and Western Aleutians for Atka mackerel in 2014 and for >250 mm walleye pollock in 2016). The relative contribution of stratum-specific residual body condition to the overall trends (indicated by the height of each colored bar segment) does not demonstrate a clear pattern, although for many species, changes in body condition were synchronous amongst strata within years. The strata represented by southern rock sole and 100–250 mm walleye pollock condition indicators varied through time but it is unclear whether this was due to variation in fish distribution or sampling effort.

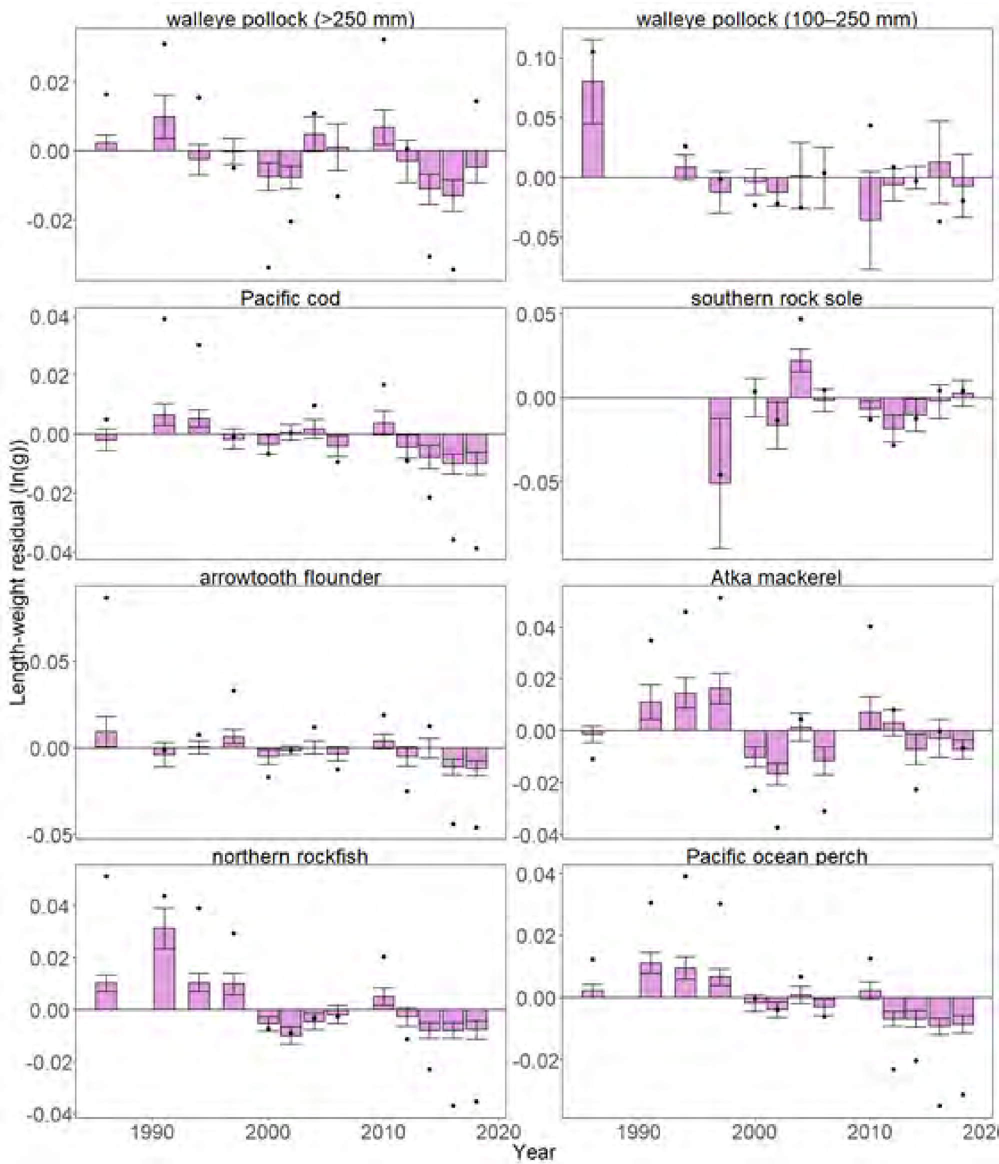

Figure 25: Biomass-weighted residual body condition index across survey years (1984—2018) for seven Aleutian Islands groundfish species collected on the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering Groundfish Assessment 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.

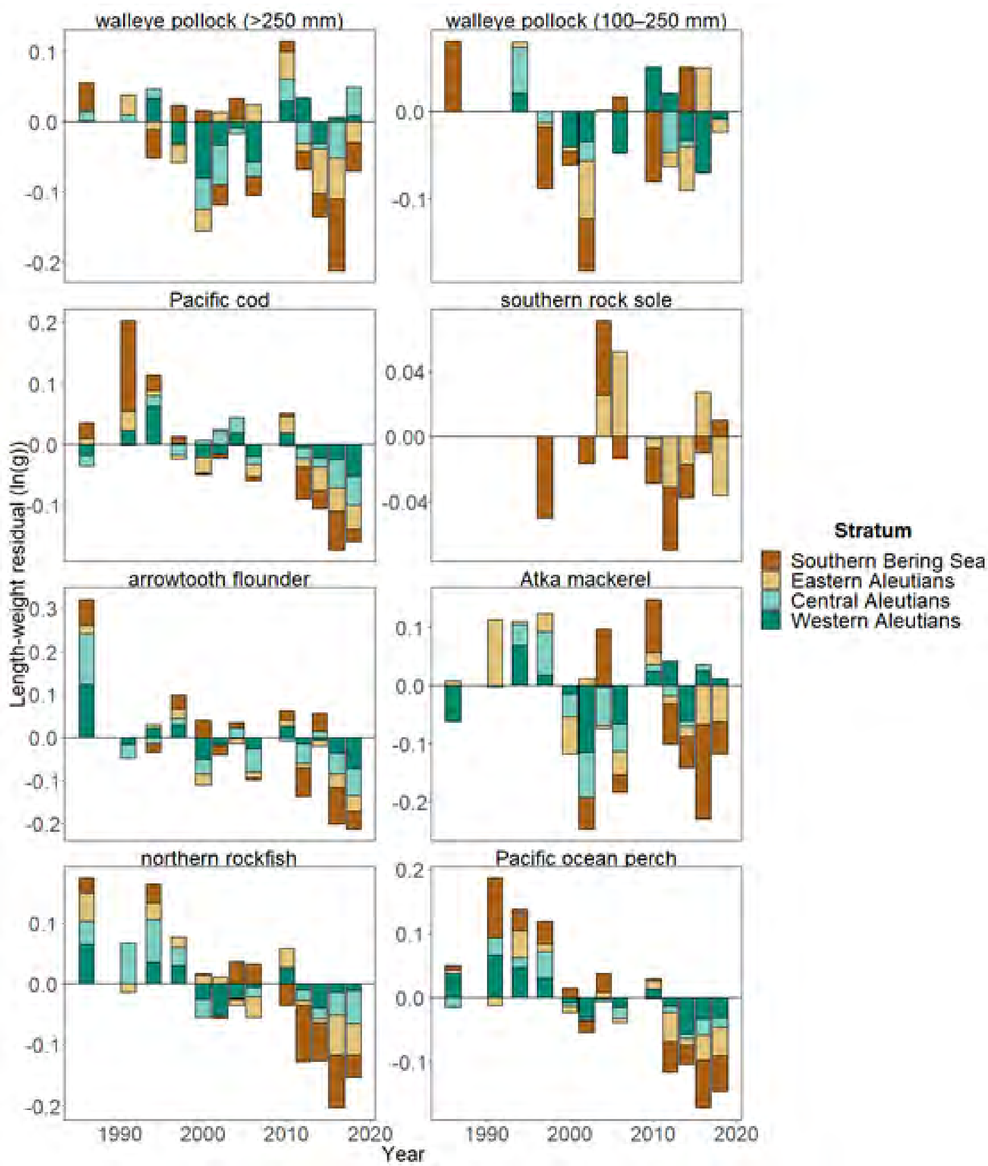

Figure 26: Residual body condition index for seven Aleutian Islands groundfish species collected on the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering Groundfish Assessment Program (RACE-GAP) standard summer bottom trawl survey (1984–2018) grouped by International North Pacific Fisheries Commission (INPFC) statistical sampling strata.

Factors influencing observed trends: Factors that could affect residual fish body condition presented here include temperature, trawl survey timing, stomach fullness, movement in or out of the survey area, or variable somatic growth. Since the Warm Blob in 2014 (Bond et al., 2015; Yang et al., 2019), there has been a general trend of warming ocean temperatures in the survey area through 2018 that could be affecting fish growth conditions there. 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. The updated condition analyses presented here begin to, but do not wholly account for spatio-temporal variability in the underlying populations sampled.

Implications: Variations in body condition likely have implications for fish survival. In Prince William Sound, the condition of herring prior to the winter may influence their survival (Paul and Paul, 1999). The condition of Aleutian Islands groundfish may similarly contribute to survival and recruitment. 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.

The trend toward lowered body condition for many Aleutian Islands species over the last 3–4 RACE/AFSC GAP bottom trawl surveys is a potential cause for concern. It 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; Yang et al., 2019) has been followed by subsequent years with elevated water temperatures (e.g., (Barbeaux and Hollowed, 2018; Laman et al., 2018)) 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.

Salmon

†*The Expanding Role of Eastern Kamchatka Pink Salmon in the Aleutian Islands Ecosystem

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Last updated: August 2020

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. 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 the fixed two-year life history of pink salmon.

Status and trends: Eastern Kamchatka pink salmon is an exceptionally abundant population of wild pink salmon, especially in odd-numbered years (Figure 27). 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 2009 to 2019, abundance averaged 190 million salmon in odd-numbered years and 64 million salmon in even-numbered years. The largest run on record occurred in 2019 (∼315 million adults). During 2015, 2017, and 2019, Eastern Kamchatka pink salmon represented about forty percent of total pink salmon returning from the North Pacific. As a species, pink salmon represent nearly seventy percent of all Pacific salmon (Ruggerone and Irvine, 2018); exceptional abundances occurred in 2018 and 2019 — the highest two consecutive years of abundance since detailed record keeping began in 1925.

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 (Figure 27). Odd-year abundances quickly recovered to record numbers in recent years.

Implications: Pink salmon is the smallest species of Pacific salmon (as mature adults), but they grow exceptionally fast, consume many prey, and potentially affect growth and survival of other species. The unique biennial pattern of pink salmon in this region allows for 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 increase (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

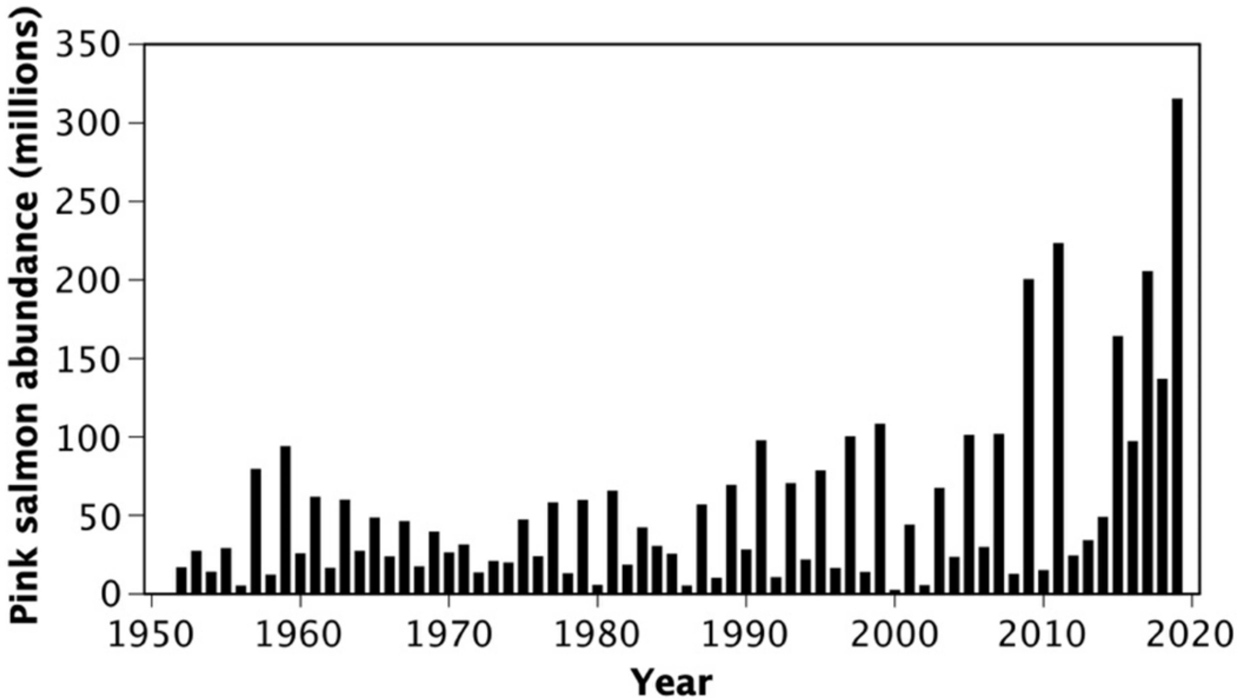


Figure 27: Time series of Eastern Kamchatka pink salmon abundance, 1952–2019. Values include catch and spawner abundances. Source: (Ruggerone and Irvine, 2018) with updates.

the Aleutian Island region has been be documented in the growth, survival, and abundance of Bristol Bay sockeye salmon (Ruggerone et al., 2003; Connors et al., 2020) and Yukon/Kuskokwim/Nushagak Chinook salmon (Ruggerone et al., 2016), growth of Atka mackerel (Matta et al., 2020), and reproduction of seabirds SpringerVliet2014 that occupy the Aleutian Islands Ecosystem..

Seabirds

Integrated Seabird Information

Contributors: Nora Rojek, Heather Renner,Alaska Maritime National Wildlife Refuge, Homer, AK
Timothy Jones, Jakie Lindsey, Hillary Burgess, Coastal Observation and Seabird Survey Team, COASST
Kathy Kuletz U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, AK

Last updated: October 2020

Synthesis: *Most seabirds in the Aleutians feed offshore and hence reflect conditions in the pelagic ocean environment. Both plankton and fish-eating species did well reproductively in 2019, particularly the fish-eating species which had been doing poorly in recent years. In 2019, the timing of breeding was average or earlier for most seabird species at both Buldir (WAI) and Aiktak (EAI). The exception was tufted puffins (diving fish-eating species) at Buldir, for which timing was later than the long-term mean, although they still had a successful reproductive season. While planktivorous seabird reproductive success remained generally within normal range in terms of reproductive success, the exceptionally successful reproductive season for fish-eating seabirds in 2019, particularly at Aiktak, may indicate that environmental changes returned to more favorable conditions. This may be due to a potential increase in the size of the copepod community (CPR, AI ESR) which may have benefitted young-of-the-year fish or forage fish as well. This is despite the almost year-long marine heatwave in the EAI in 2019 and record high Kamchatka pink salmon abundance, which might compete with seabirds and other fish for copepods (Springer and van Vliet, 2014; Zador et al., 2013). The increased copepod size and early hatching dates for some seabird species together might signal an earlier spring bloom, to which surface feeding seabirds as well as seabirds with long breeding seasons are more sensitive to than diving species and those with short breeding seasons (Descamps et al., 2019). These conditions and the overall reproductive success across the Aleutians may indicate a more favorable environment not only for seabirds but potentially for both plankton and fish eating commercial groundfish as well in the Aleutian Islands, no large-scale mortality events have been recorded in 2019 or 2020 (so far), based on monthly beach surveys in the Aleutian Islands.*

Description of indicator: Seabirds are suitable indicators of variations in food supply, and their breeding performance reflects conditions in the marine environment. Here we provide an overview of environmental impacts to seabirds and what that 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 2019 and seabird die-offs in 2020.

We present information in three main sections as indicators of processes at different spatiotemporal scales: i) timing of reproductive stages which reflects ecosystem conditions prior to breeding, ii) reproductive success which reflects feeding conditions during the breeding season; and/or system phenology), and iii) population information which encompasses environmental and ecosystem effects at broader and temporal scales. Each type of information is presented for seabirds based on their feeding strategy and main prey: that is surface or diving seabirds feeding on fish or plankton (Figure 28)

Most seabirds feed offshore, as opposed to nearshore, regardless of their feeding strategy or prey. The western Aleutians is also dominated by planktivorous seabirds, while the central Aleutians next to Samalga Pass and the eastern Aleutians have a larger proportion of seabirds feeding on fish.

	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 28: Feeding strategy, prey and habitat of the main seabird species monitored annually by AM-NWR in the Aleutian Islands, based on Byrd et al. (2005)

Status and trends

Timing of seabird reproductive stages (Buldir and Aiktak)

Timing of breeding in 2019 was average or earlier than the long-term mean for most seabird species at both sites except for tufted puffins at Buldir, which were later than long-term mean (Figure 29).

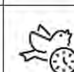
	Species											
	Primarily fish species - Primarily zooplankton eaters											
Site	glaucous winged gull	thick billed murre	horned puffin	tufted puffin	black-legged kittiwake	fork-tailed storm- petrel	Leach' s storm-petrel	ancient murrelet	parakeet auklet	least auklet	whiskered auklet	crested auklet
Aiktak		-			-				-	-	-	-
Buldir								-				

Figure 29: Seabird relative breeding chronology in 2019 compared to long-term averages for past years at Aiktak and Buldir islands. White bird indicates hatching chronology was >3 days earlier than average. Gray bird within 3 days of average. Black bird <3 days later than average. Dashes indicate species not monitored at a site or for which sample size too small for comparison.

Reproductive success (Aleutian Islands Buldir and Aiktak)

Time series of annual breeding success and phenology (and other parameters) are available from two annually monitored colonies in the Aleutian Islands: Buldir (western Aleutians) and Aiktak (eastern Aleutians). Unfortunately, no data were collected in 2020 at these sites due to travel restrictions related to the COVID-19 pandemic.

Seabird reproductive success was generally average to above average for most species in both the western and eastern Aleutians in 2019 (Figure 30). Diving fish-eating seabirds (common and thick-billed murres, tufted and horned puffins) had average to high reproductive success in 2019, except for common murres at Buldir. Black-legged kittiwakes and storm-petrels (which consume a mix of fish and invertebrates) and auklets (which are near-obligate planktivores) showed average to above average success rates, except for fork-tailed storm-petrels at Buldir. At Buldir, tufted puffins had average reproductive success in 2019 following two years of complete failure. At Aiktak, success for both tufted puffins and Leach's storm-petrels was the highest ever recorded for these species at this site.

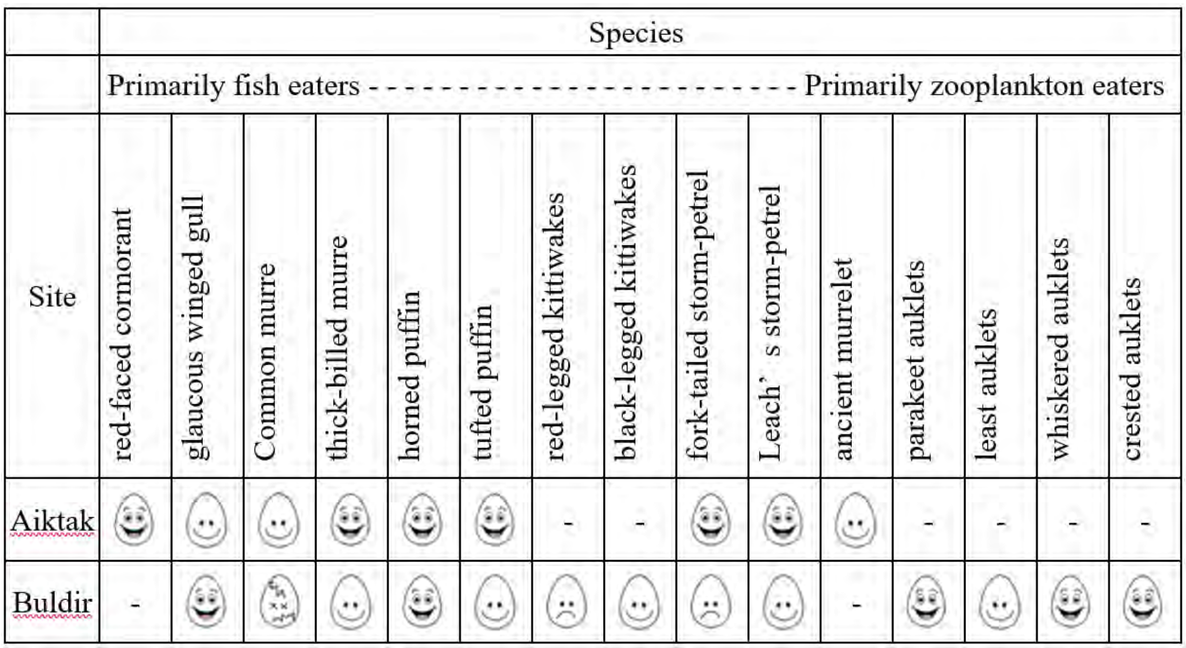


Figure 30: Seabird reproductive success in 2019 compared to long-term means for past years at Aiktak and Buldir islands. Big smiley face indicates above average reproductive success, smiley indicates average, frowny face indicates below average, and broken face indicates failure. Dashes indicate species not monitored at a site or for which sample size too small for comparison.

Population information

Historically, seabird die-offs are not uncommon in Alaska, but are seldomly reported from the Aleutian Islands. Where most surveys are conducted by AMNWR. During 2020, at least 320 seabird carcasses were reported on Alaska beaches statewide, which is lower than numbers reported in summers of 2017-2019. Recorded species included puffins, murres, kittiwakes, shearwaters, and auklets. Of those, only a few were found near Dutch Harbor, Unalaska Island. In 2019, thousands of short-tailed shearwaters were counted during a large mortality event farther east along the Alaska Peninsula and Bristol Bay region, but few birds were found (in August) in the Aleutians during that year. In 2019 survey effort was similar to the previous years, but the beached bird encounter rate reported was less than any year after 2015.

Beached bird relative abundance: surveys/beaches, bird encounter rates

In 2020, COASST did not conduct monthly surveys. In 2019 COASST survey effort was similar to the previous years, but the beached bird encounter rate reported was less than any year after 2015.

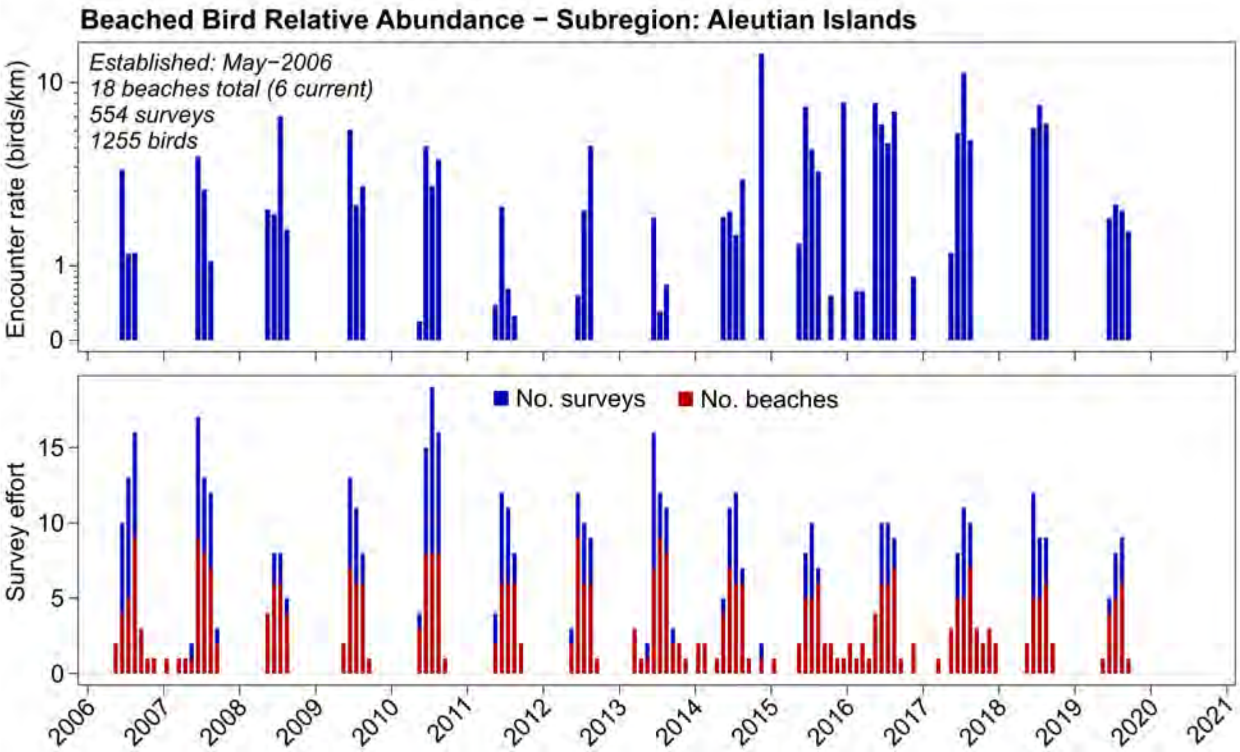


Figure 31: Month-averaged beached bird abundance, standardized per km of survey effort, for the Aleutian Islands. The top panel shows the month-averaged encounter rate (ER: birds per km). The bottom panel shows survey effort at the monthly scale. No surveys were conducted in 2020.

Outside of monthly COASST surveys, opportunistic reports of beached birds were submitted to COASST and regional partners during the summers of 2020 and 2019. These reports (mapped in Figure 32) layer contributions by community members in remote coastal locations on top of reports by citizen scientists.

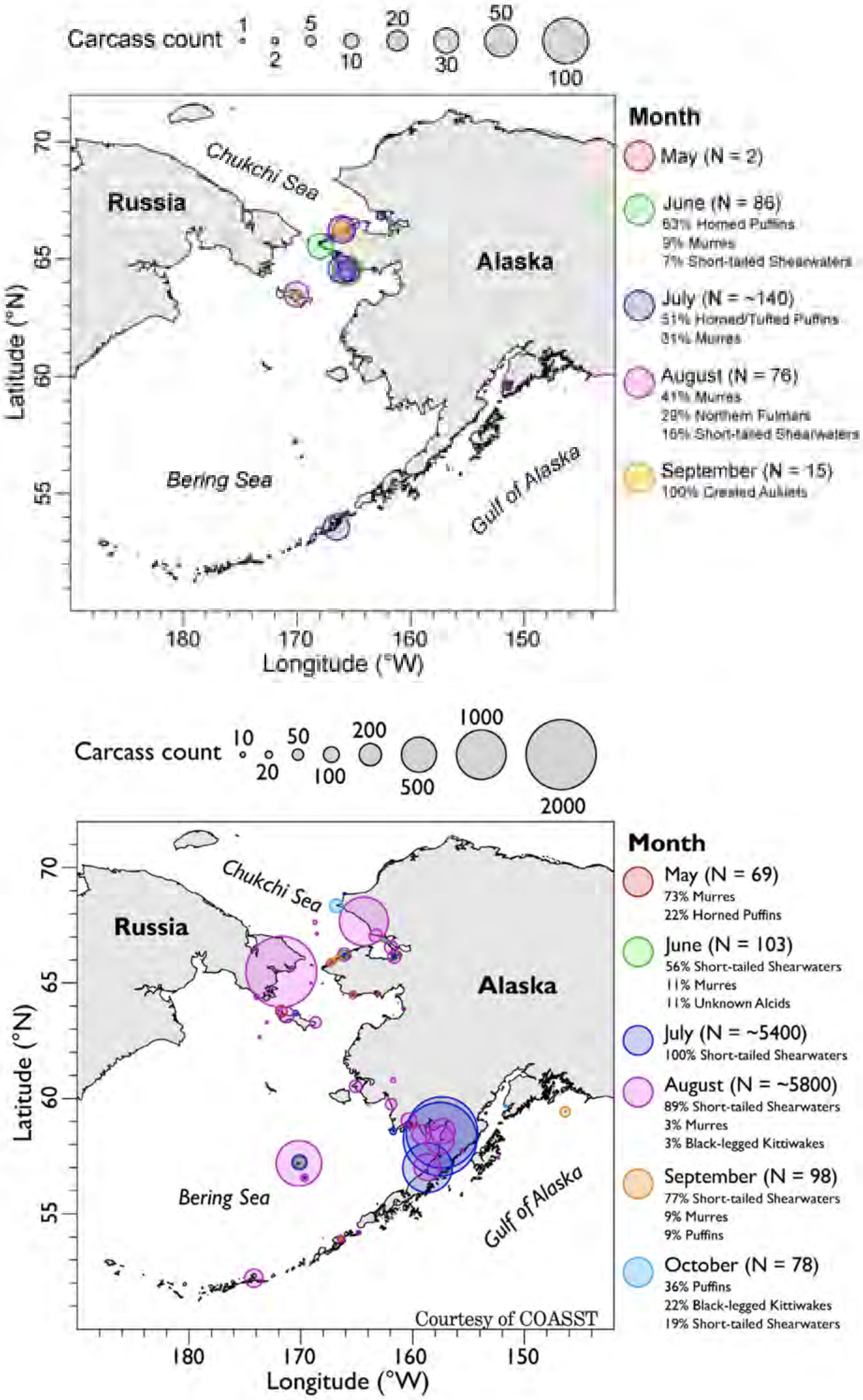


Figure 32: Opportunistic reports of seabird carcass show the extent and magnitude of seabird die-off events in Alaska in 2020 and 2019. Top panel: 2020; bottom 2019. Map provided by Coastal Observation Seabird Survey Team (COASST) `www.coasst.org`, with data from COASST participants, NPS staff, and coastal community members reporting to ADFG, USFWS, UAF-Alaska Sea Grant, and Kawerak, Inc.

Factors influencing observed trends: In general, seabirds in the Aleutians did not experience widespread reproductive failures like they did in the Gulf of Alaska during the 2014-2016 marine heat wave. However, many fish-eating seabirds did poorly or had mixed success in recent years, while planktivorous seabirds have remained generally within normal range.). In 2019, fish-eating seabirds were successful, which may indicate that environmental conditions became more favorable despite the almost year-long marine heatwave in the EAI in 2019 (Figure 30). This may be due to a potential increase in the size of the copepod community (CPR, AI ESR) that may have benefited young-of-the-year fish or forage fish as well. The increase in copepod abundance is supported by the decrease in diatom biomass. Overall, the seabird indicators suggest that zooplankton availability continues to be sufficient at both sites, and that forage fish prey numbers increased in 2019 to support chick-rearing at Buldir. The generally earlier hatching dates also provide support for favorable conditions for seabird foraging.

Implications: Reproductive activity of central-place foraging seabirds can reflect ecosystem conditions at multiple spatial and temporal scales. In general, tufted puffins can adapt their foraging to what is available. After complete reproductive failure in 2018 at Buldir, tufted puffins returned to average success in 2019, which suggests prey (that includes forage fish and squid) were more available in the western Aleutians for chick rearing. In 2019, ecosystem conditions appeared to be favorable for the majority of breeding seabirds in both the western and eastern Aleutians. This signals foraging conditions for both plankton and fish-eating commercial groundfish were probably favorable in 2019.

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 Aleutians include Buldir Island in the western Aleutians and Aiktak Island in the eastern Aleutians. The refuge monitors breeding chronology, productivity and/or population parameters for indicator species representing four major feeding guilds: 1) diving fish-feeders (e.g., common and thick-billed murres, horned and tufted puffins), 2) surface fish-feeders (e.g., black and red-legged kittiwakes), 3) diving plankton feeders (e.g., parakeet and least auklets), and 4) surface plankton feeders (e.g., Leach's and fork-tailed storm-petrels).

   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 30 of seabird productivity at these sites, success categories (depicted with egg icons) were determined using a nonparametric bootstrap approach. For each species and location, using all previous years' data, mean bootstrap quartiles were generated using 1000 bootstrap samples and delineated as follows:

   (a) Way above average: current year's values above the mean 75th percentile received "big smiley" faces;
   (b) Average: current year's values between the mean 25th–75th percentile received "smiley" faces; III.
   (c) Below average: current year's values below the mean 25th percentile received "frowny" faces;
   (d) Complete failure: current year's values below .01 received "broken" faces.

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

Marine Mammals

†Sea Otters in the Aleutian Islands

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Last updated: September 2020

Description of indicator: Sea otter (*Enhydra lutris*) counts were selected as representative of the nearshore Aleutian environment. The >300 islands which make up the Aleutian chain provide extensive nearshore habitat. Sea otters are an integral component of the coastal ecosystems in which they occur. Sea otter predation limits the distribution and abundance of their benthic invertebrate prey, in particular herbivorous sea urchins (*Strongylocentrotus polyacanthus*). Otter-induced urchin declines increase the distribution and abundance of kelp in Alaska (Estes and Duggins, 1995) and in other areas of their range (Breen et al., 1982; Kvitek et al., 1998). This trophic cascade initiated by sea otters has indirect effects on other species and processes. Kelp forests are more productive than habitat without kelp (a.k.a. sea urchin barrens), fixing 3–4 times more organic carbon through photosynthesis (Duggins et al., 1989). This increased primary production results in increased growth and population size of consumers such as mussels and barnacles (Duggins et al., 1989).

The southwest (SW) northern sea otter (NSO) distinct population segment (DPS) is divided into 5 management units (MU), two of which are within the geographic region of this report: Western Aleutian Islands and Eastern Aleutian Islands (Figure 33).

Status and trends:

Western Aleutians MU In 1992 and 2000, select islands were surveyed with twin engine aircraft (Doroff et al., 2003).Aerial survey data indicated a decline of 17.66% (±2.98%) in sea otter densities from 1992—2000 for the islands of Adak, Amchitka, Attu, Kagalaska, Little Kiska, and the Semichi Islands (Doroff et al., 2003).

Due to logistical constraints, population trends are monitored using skiff surveys at five of the more remote islands (index sites) in the Western Aleutians MU. A Bayesian state-space trend analysis (Clark and Bjørnstad, 2004) based on those skiff surveys from 1993 to 2003 indicated that population trends were strongly negative, with an average rate of decline of approximately 20% per year (USFWS, 2013). Since then, the Service has conducted skiff-based trend surveys in the Western Aleutians in 2011 and 2015. Results from these surveys are currently being analyzed and should be published in 2021.

The Alaska Fish and Wildlife Service was planning on conducting boat-based sea otter surveys and an ecological function survey in the Western Aleutians MU in 2020. However, this was rescheduled to 2021 due to COVID-19.

Eastern Aleutians MU The Eastern Aleutians MU was surveyed from 1957 to 1965 (Kenyon, 1969). There were two small populations totaling 41 otters observed in 1962 in the Fox and Krenitzin Islands (Kenyon, 1969). By the time of the next aerial survey in 1992, SW Northern Sea Otters (NSO) were present throughout Fox and Krenitzin (Evans et al., 1997). A similar survey was conducted in 2000, and SW NSO abundance had declined from 1992 by an estimated 55 % in the MU (Doroff et al., 2003). In 2017, the Service conducted an aerial survey to determine a new population estimate for this MU. The updated population estimate is expected to be published in early 2021.

Factors influencing observed trends: SW NSOs have been surveyed with a variety of methods over the years and the specific survey method used in the field constrains subsequent statistical modeling and inferences on population trends. The Service cautions comparing abundance and density estimates across years due to the different survey methodologies and statistical approaches applied to estimate these metrics.

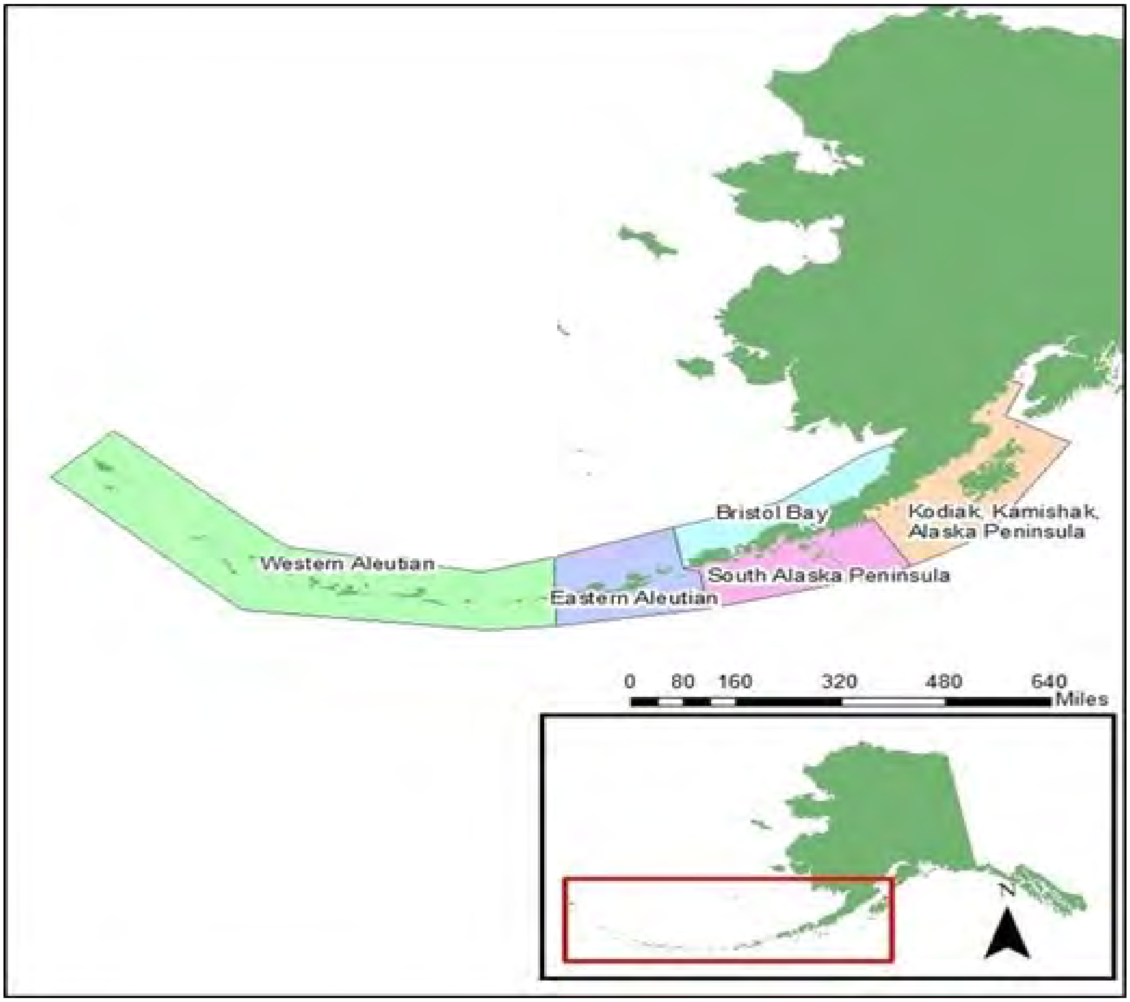

Figure 33: The Southwest sea otter distinct population segment (DPS) broken up into 5 different management areas

New information on 4 of the 5 MUs are expected to be published in 2021.

Implications: The lack of sea otters as an apex predator in some areas of the Western Aleutians suggest there will continue to be an ecosystem driven by species such as the herbivorous sea urchins which will continue to degrade the structural habitat of fishes and invertebrates (Bodkin et al., 2002). As noted by (Rasher et al., 2020), recovery of the sea otters in the Aleutians is important as they "effectively buffer their system against a climate-induced decline of its structural foundation".

†*Steller Sea Lions in the Aleutian Islands

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Last updated: August 2020

Description of indicator: Counts of adult and juvenile Steller sea lions (*Eumetopias jubatus*) are used in the Aleutian Island ecosystem assessment to represent the status of a large, K-apex piscivorous predator whose diet consists primarily of commercially-fished species. During the summer breeding season, sea lions aggregate on land, usually their natal rookery site, to breed and birth pups (Fritz et al., 2016). During the non-breeding season, sea lions disperse and can range widely throughout the North Pacific Ocean, especially juveniles and males. The Marine Mammal lab (MML) conducts annual population surveys during the peak of the breeding season to collect counts throughout their range in Alaska (Fritz et al., 2016) (Figure 34). Challenging survey conditions usually mean there are data gaps for sites that cannot be surveyed. MML uses agTrend (Johnson and Fritz, 2014) to fill in the missing data to model counts we would expect if we surveyed all sites and also used in estimated annual rates of change (i.e., trend). MML does not report abundance estimates but rather count estimates of animals hauled out on land and therefore, non-pup counts do not account for animals at-sea during the survey. Pup counts do not account for those animals born (or that died) before (or after) the survey; however, since pups do not take to the water until they are older (∼1 month), this count is considered a census.

Steller sea lions pup production and non-pup counts reported here is for the US portion of the endangered western Distinct Population Segment (DPS) rookery cluster areas (RCAs) 1–6: area 1 comprises the western Aleutians region, areas 2–5 the central Aleutians region and area 6 the eastern Aleutians and Bering Sea shelf region (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 (Fritz et al., 2016).

Declines in Steller sea lion populations were first observed in the 1970s, with the steepest declines occurring in the mid-1980s. Since the early 2000s, the western DPS began to rebound as a whole, but has continued to decline west of Samalga Pass (Aleutian Islands) with little or no signs of recovery (Sweeney et al., 2019). Between 2002 and 2019, non-pup and pup counts for the total western DPS in Alaska increased at a rate of 1.82% per year (95% CI 1.29–2.38% per year) and 1.63% per year (95% CI 1.12–2.16% per year), respectively.

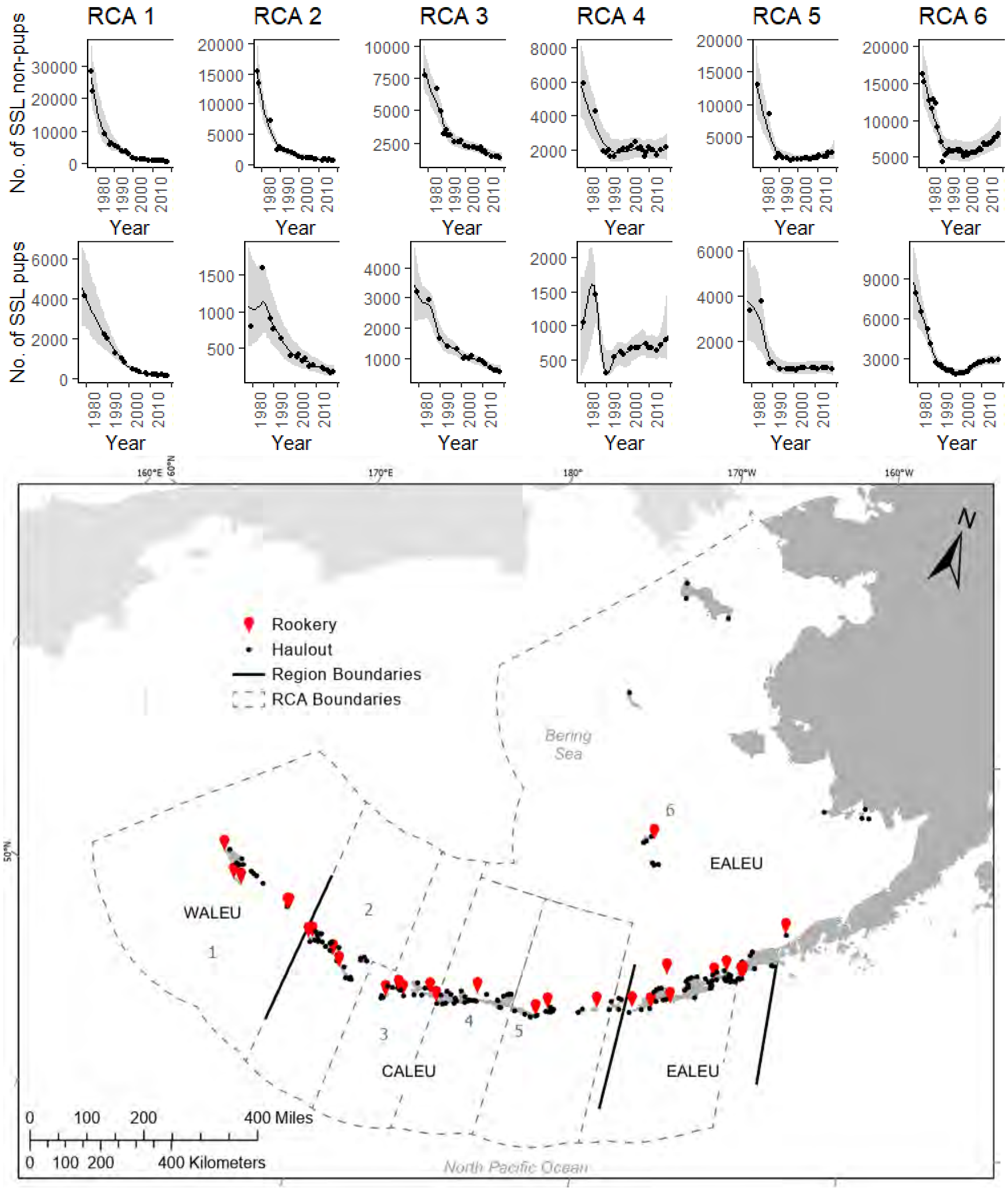

Figure 34: Map of Steller sea lion rookeries and haulouts for rookery cluster areas (RCAs) 1–6 and time series (1978-2019) of Non-Pups and Pups at each RCA covering the Aleutian Islands.

Status and trends: Hereafter sea lion Aleutian Island regions will be referred to as AI. In the combined eastern, central, and western AI regions, sea lion counts remained stable between 2002 and 2018 for non-pups (0.37%y-1, 95% CI -0.49–1.11%y^{-1}) and pups (0.12%$^{-1}$, 95% CI -0.59–0.88%$^{-1}$; (Sweeney et al., 2019)). Increases in non-pup and pup counts in the eastern AI region (1.78 and 2.38%$^{-1}$, respectively) have been largely offset by stability in non-pups (-0.53) and declines in pups (-1.6) in the central AI region; and significant declines in the western AI region (-6.47). Although the central AI region has been stable, MML has reported areas 2 and 3 within the central AI, to be in significant decline and areas 4 and 5 stable or increasing. The western AI region, area 1, has declined over 95% in the last 30 years with no signs of recovery (MML, unpublished data). In fact, Buldir Rookery in this region has entirely disappeared: a historical count reported for all sites on Buldir in 1979 was just over 5,000 non-pups; more recent counts have ranged from 0–28 since 2010 (Fritz et al., 2013).

Due to COVID-19, 2020 Aleutian Island surveys were cancelled and rescheduled for 2021.

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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Last updated: September 2020

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. Over the last five years, the AMMSN has received over 1,600 reports of stranded marine mammals within Alaska. The causes of marine mammal strandings is often unknown but some causes are disease, exposure to contaminants or harmful algal blooms, ship strikes, entanglement in fishing gear, or ingestion of marine debris.

When a stranded marine mammal is reported information is collected including species, location, age 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 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 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.

Status and trends: The number of reported strandings in Alaska has increased over time. So far in 2020, five stranded marine mammals have been reported in the Aleutian Islands, the majority of reports being from the Dutch Harbor area (Figure 35) where AMMSN members and NMFS Office of Law Enforcement are located. Reported strandings in the Aleutian Islands since 2015 varied between years without an overall pattern or consistent increase in reports (Figures 36 and 37).

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 37), 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/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 (Figure 37).

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.

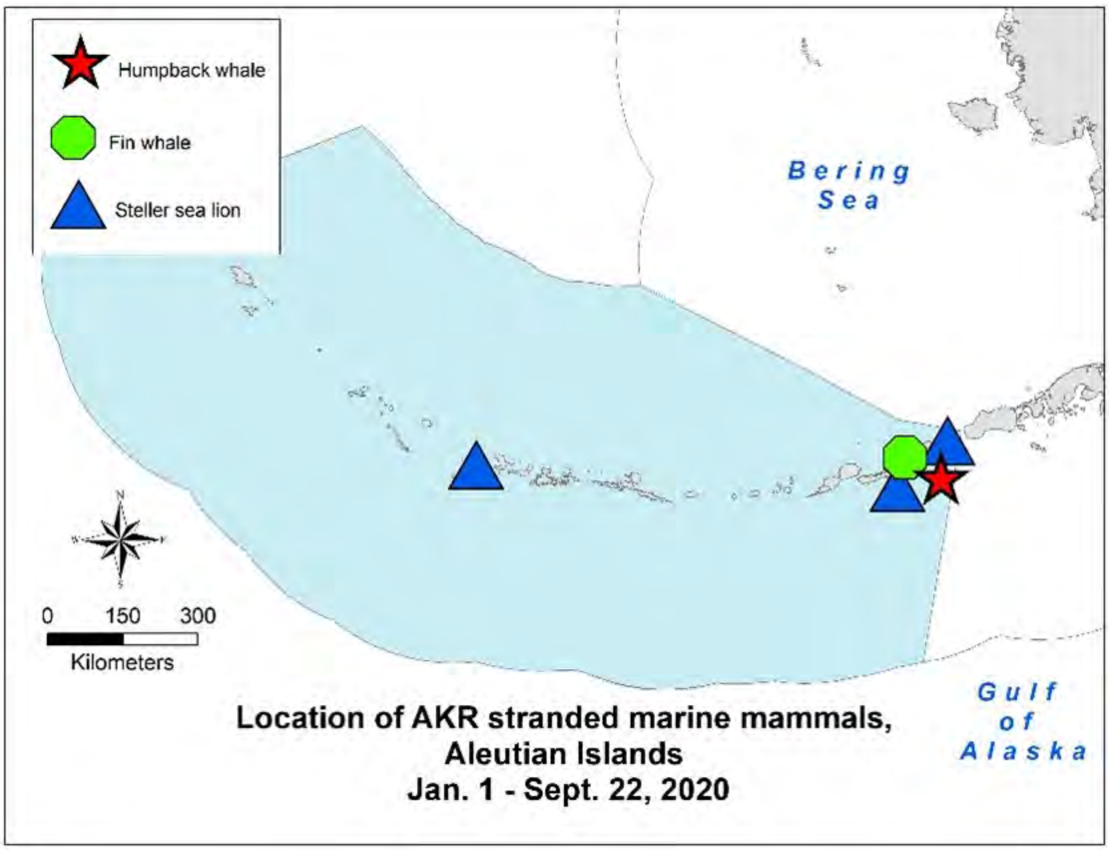

Figure 35: Reported stranded marine mammals in 2020, largely found in the Aleutian Islands near Dutch Harbor.

	2015	2016	2017	2018	2019	2020
Dall's porpoise	1					
Fin whale						1
Gray whale			1	1		
Humpback whale	1	3	3	2		1
Killer whale		1	2			
Sperm whale			1	2		
Stejneger's beaked whale			7	8	1	
Unidentified beaked whale	1					
Unidentified whale		1	3	2	4	
Total cetaceans	3	5	17	15	5	2
Harbor seal				1		
Northern fur seal	1		5			
Ringed seal	1		1	6		
Steller sea lion	6		2		6	3
Total pinnipeds	8		8	7	6	3
Total Cetaceans and Pinnipeds	11	5	25	22	11	5

Figure 36: Reported stranded NMFS marine mammal species for the last five years in the Aleutian Islands by species and year.

Year	No. E. Aleut/All AKR MM Reports
2015	3.9%
2016	1.5%
2017	8.7%
2018	6.0%
2019	1.6%
Aleutians Islands as a proportion of all AKR mm reports	

Figure 37: Reported stranded NMFS marine mammal species for the last five years in the Aleutian Islands by species and year.

Disease Ecology Indicators

†*Harmful Algal Blooms in the Aleutian Islands

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Last updated: September 2020

Sampling Partners: 2 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
Sun'aq 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 1993 (see DHSS fatality report: `http://www.dhss.alaska.gov/News/Documents/press/2020/DHSS_PressRelease_PSPFatality_20200715.pdf`). Analyses of paralytic shellfish toxins are commonly reported as of toxin/100 g of tissue, where the FDA regulatory limit is 80/100g. Toxin levels between 80–1000/100 g are considered to potentially cause non-fatal symptoms in humans, whereas levels above 1000/100g ($\sim$ 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, as well as that of humans.

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 38). 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 `https://aoos.org/alaska-hab-network/` or through the sampling partners listed above.

Status and trends: Alaska Region: Results from shellfish and phytoplankton monitoring showed a consistent presence of harmful algal blooms (HABs) throughout all regions of Alaska in 2020. Bivalve shellfish from areas that are well known for having PSP levels above the regulatory limit, including Southeast Alaska and Kodiak, continued to test above the regulatory limit, while shellfish in other areas, which have not traditionally seen high levels, had unprecedented levels, including in the Aleutian region.

Aleutian Islands: Shellfish testing in the Aleutian Islands and Alaska Peninsula showed unprecedented levels of paralytic shellfish toxins in shellfish. In Unalaska, consumption of blue mussels and snails resulted in a community member fatality in July. The total toxin load of a sample of the blue mussels that were consumed was 11,200 g/100g (140 times the regulatory limit) and the snails consumed were 287 g/100g ($\sim$3x above the regulatory limit). Amaknak Island in Unalaska Bay also had samples with toxins slightly above the limit, blue mussels 2.8x and snails 1.4x. Weekly shellfish samples were taken in 17 locations throughout the Aleutian and Alaska Peninsula region and results are still being analyzed.

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) (bottom map, Figure 38). 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 copepod, multiple species of fish, bivalves, and the continuation of sampling subsistence-harvested and dead stranded marine mammals.

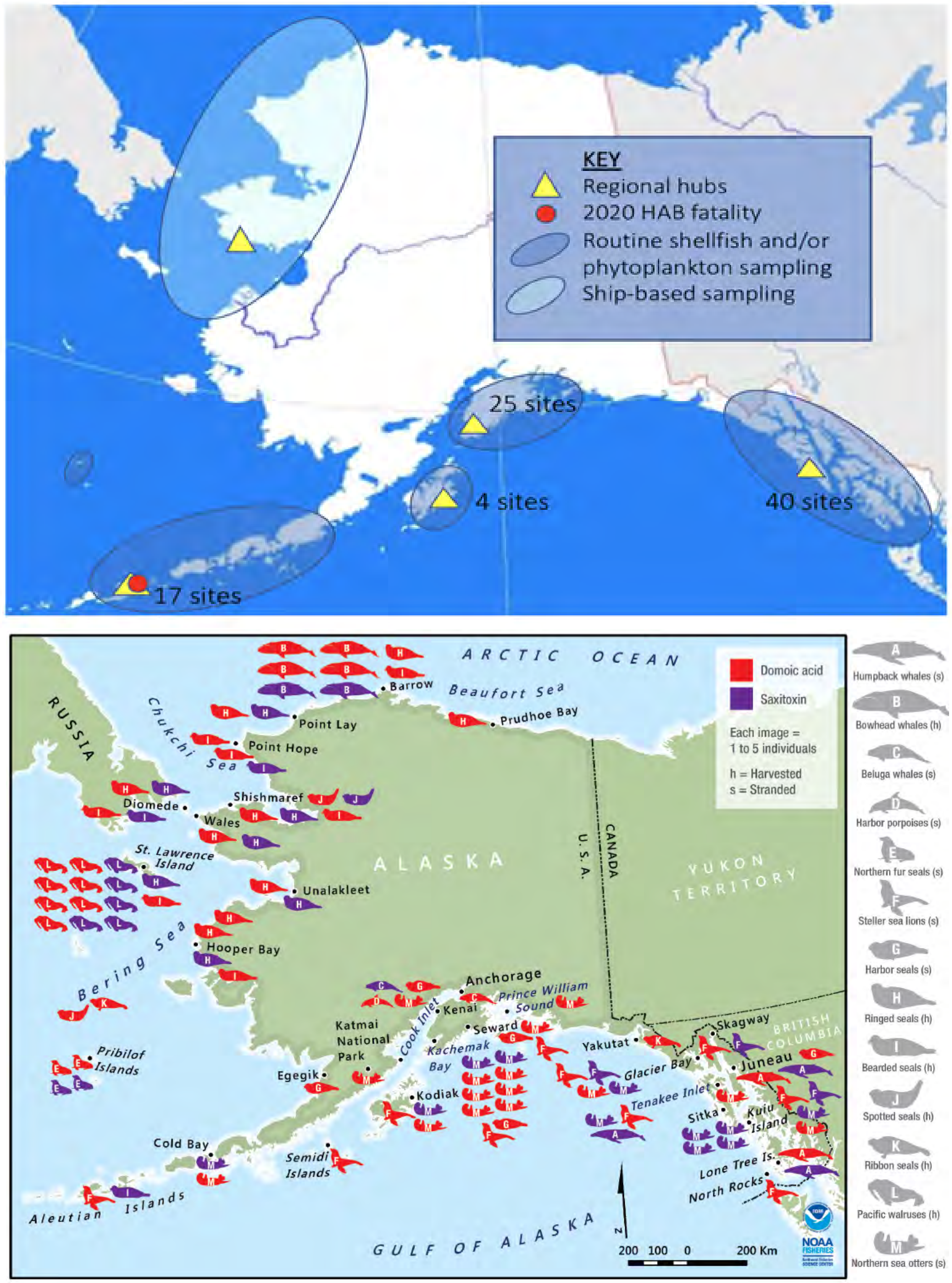

Figure 38: Top: Map of 2020 sampling efforts conducted by partners of the Alaska Harmful Algal Bloom Network (AHAB). Opportunistic sampling of marine mammal tissue and other marine species occurs statewide and is not shown here. A more detailed view of ship-based sampling will be available after the 2020 fall field season. Bottom: Algal toxins detected in stranded and harvested marine mammals suggest widespread prevalence of HABs throughout the food web in all regions of Alaska (Lefebvre et al., 2016). Updates to HAB toxin levels in Arctic/subarctic marine mammals are currently in progress.

Ecosystem-Based Management Indicators

Indicators presented in this section are intended to provide either early signals of direct human effects on ecosystem components that might warrant management intervention or to provide evidence of the efficacy of previous management actions. In the first instance, the indicators are likely to be ones that summarize information about the characteristics of the human influences (particularly those related to fishing, such as catch composition, amount, and location) that are influencing a particular ecosystem component.

Maintaining Diversity: Discards and Non-Target Catch

*Time Trends in Groundfish Discards

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Last updated: September 2020

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 39 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 39). Discard biomass in the trawl pollock sector was highest from 1995 to 1997, averaging 2330 mT annually during this period, before falling in 1998 to 215 mT and averaging 286 mT annually from 1998 to 2019. Nevertheless, the 2019 discard biomass in the sector was the highest since 2007, while discards through week 36 of 2020 have already reached 924 mT. 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 15300 mT and 15% annually from 1997 to 2007 and 4207 mT and 4% annually from 2008 to 2019. 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 (2015–2019), the annual discard biomass and discard rate in the AI fixed gear sector have averaged 1130 mT and 7%, respectively, compared to 2201 mT and 10% averaged over the longer 1993–2019 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, whereas rates in the non-pollock trawl sector have generally declined across all three subareas during this period. To date in 2020, discard biomass through week 36 is higher in both the trawl non-pollock and fixed gear sectors relative to the preceding 5-year (2015–2019) period (Figure 39).

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 increase in the volume of discards in the GOA fixed gear sector in 2013. **Implications:** Discards add to the total human impact on the biomass without providing a benefit to the nation.

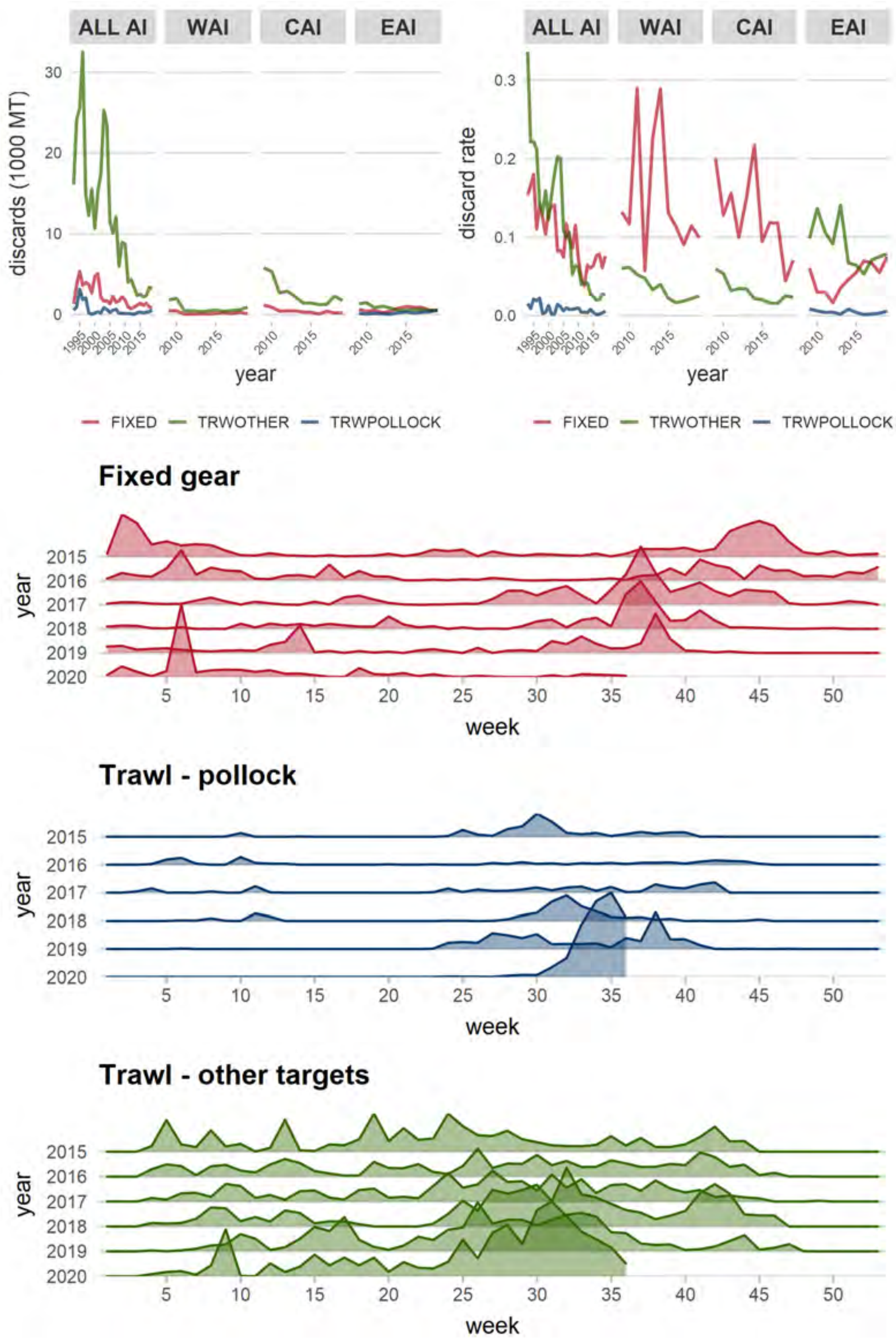

Figure 39: Total biomass and percent of total catch biomass of managed groundfish discarded in the AI fixed gear, pollock trawl, and non-pollock trawl sectors, 1993–2020 (Includes only catch counted against federal TACS).

*Time Trends in Non-Target Species Catch

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Last updated: August 2020

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. Starting with the 2013 Ecosystem Considerations Report, the three categories of non-target species we continue to track here are:

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

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 does result 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 (`https://www.fisheries.noaa.gov/alaska/sustainable-fisheries/alaska-fisheries-figures-maps-boundaries-regulatory-areas-and-zones`). 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 in 2016 and increased again to a peak value in 2017 (Figure 40). The catch of Scyphozoan jellies has decreased in 2018 and 2019. Scyphozoan jellies are primarily caught in the pollock fishery. The catch of structural epifauna in the AI has been variable from 2011–2019, with a peak catch in 2015. The catch of structural epifauna in 2016 was half of the catch in 2015, but the catch has increased in each year since 2016. Sponge comprise the majority of the structural epifauna catch, followed by corals and bryozoans. These species are primarily caught in the Atka mackerel and rockfish fisheries. The catch of assorted invertebrates in the AI increased from 2011 to 2013 then dropped sharply in 2014. The catch has remained relatively constant from 2015 to 2019. Sea stars dominate the assorted invertebrate catch in each year and are primarily caught in the Pacific cod and halibut fisheries.

Factors influencing observed trends: The catch of non-target species may change if fisheries or the

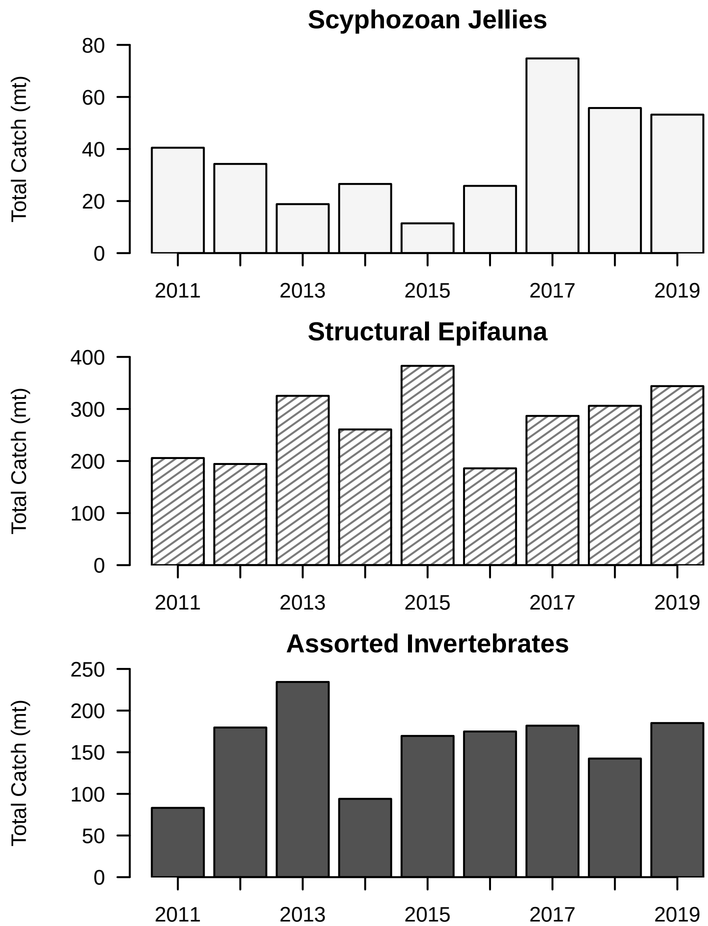

Figure 40: Total catch of non-target species (tons) in AI groundfish fisheries (2011–2019). Please note the different y-axis scales between regions and species groups.

ecosystems 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 catch of structural epifauna species and assorted invertebrates is very low compared with the catch of target species. The higher catches of scyphozoan jellies in 2017–2019 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, 2010–2019

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Last updated: August 2020

Description of indicator: This report provides estimates of the numbers of seabirds caught as bycatch in commercial groundfish fisheries operating in federal waters of the U.S. Exclusive Economic Zone of the Aleutian Islands (AI) for the years 2010 through 2019. 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 gillnet, seine, or troll fisheries. Data collection on the Pacific halibut longline fishery began in 2013 with the restructured North Pacific Observer Program.

Estimates are based on two sources of information: (1) data provided by NMFS-certified fishery observers deployed to vessels and floating or shoreside processing plants (AFSC, 2011), and (2) industry reports of catch and production. Observer deployment plans are reviewed and updated annually in the Annual Deployment Plan (the 2020 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, 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 inseason 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 two 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, (`https://www.fisheries.noaa.gov/alaska/commercial-fishing/alaska-fisheries-figures-maps-boundaries-regulatory-areas-and-zones`).

Status and trends: The number of seabirds estimated to be caught incidentally in the AI fisheries in 2019 (2,244 birds) was seven times higher than estimates from 2018 (804 birds), and were about three times higher than the 2010—2018 average of 717 birds (Table 2; Figure 41). This dramatic increase in the estimated seabird takes is primarily due to the high number of shearwaters taken in the western AI (management area 543; 1,588 birds). In 2019, the number of shearwaters was almost 15 times higher than was estimated in 2018, and was almost 11 times above the 2010–2018 average of 192 birds. As described in the Integrated Seabird Information (p. 63) of this document, this large increase in shearwater bycatch is likely attributed to the shearwater mortality event that was documented around Alaska in 2019. Aside from shearwater bycatch, there was a pronounced decrease in seabird takes in the AI fisheries in 2019. Northern fulmar were the most common species caught incidentally in the AI fisheries in 2019. The number of northern fulmars decreased by 44% compared to 2018, and was below the 2010–2018 average of 316 birds by 48%. No short-tailed albatross or Laysan albatross were reported as taken in the AI. The number of Black-footed albatross remained relatively consistent from 2018 to 2019, and was below the 2010–2018 average of 15 birds by 79% (Figure 43).

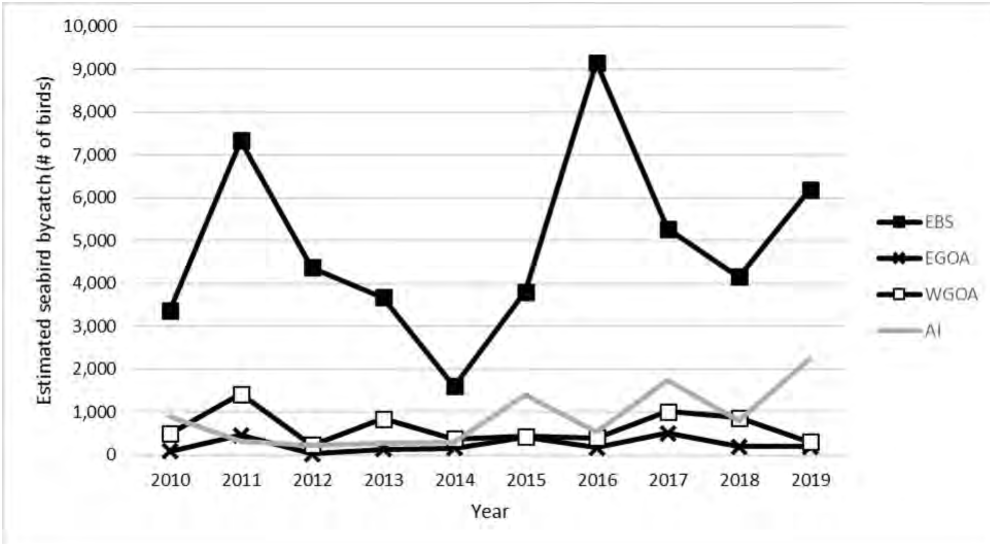

Figure 41: Total estimated seabird bycatch in eastern Bering Sea (EBS), Eastern Gulf of Alaska (EGOA), Western Gulf of Alaska (WGOA), and Aleutian Islands (AI), groundfish fisheries, all gear types combined, 2010 through 2019.

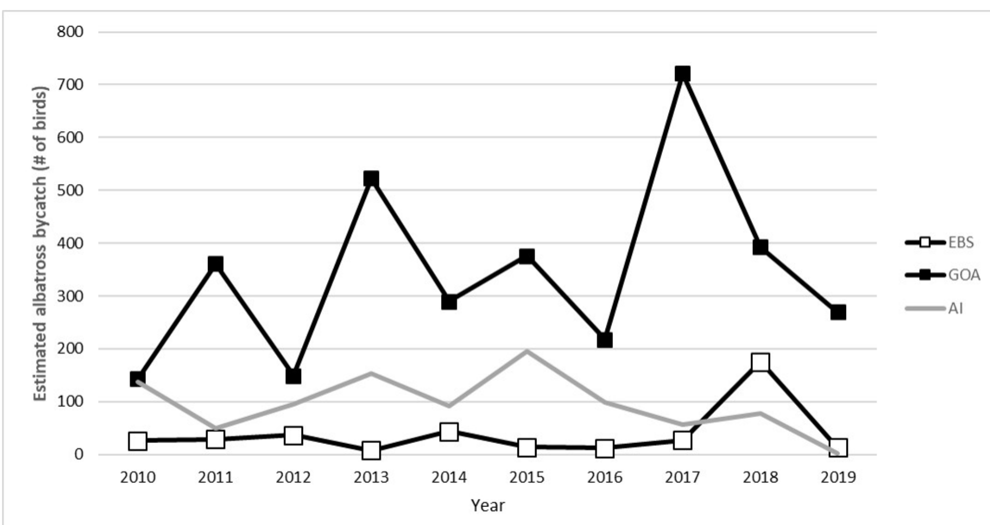

Figure 42: Total estimated albatross bycatch in eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) groundfish fisheries, all gear types combined, 2010 through 2019.

Table 2: Total estimated albatross bycatch in eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) groundfish fisheries, all gear types combined, 2010 through 2019.

Species Group	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Unidentified Albatrosses	0	0	0	0	23	0	0	0	0	0
Laysan Albatross	137	43	92	133	56	172	74	18	75	0
Black-footed Albatross	1	6	3	20	13	23	25	38	2	3
Northern Fulmar	449	83	25	61	69	1105	185	573	292	163
Shearwaters	89	63	60	6	71	28	192	1076	141	2069
Storm Petrels	0	0	0	0	0	0	0	0	177	0
Gulls	207	110	23	40	11	58	20	8	9	7
Murres	0	0	0	0	0	0	5	0	0	0
Auklets	0	0	0	0	38	5	28	11	102	0
Other Alcid	0	0	0	0	1	0	0	0	0	0
Unidentified Birds	18	7	6	13	1	1	1	14	5	2
Grand Total	901	314	211	273	285	1393	530	1793	804	2,244

BSAI Pacific cod using demersal longline, and atka mackerel and rockfish trawl fisheries are responsible for the majority of seabird bycatch in the AI—the average annual seabird bycatch for 2010 through 2018 was 4,581, 275, and 186 birds per year, respectively (Table 13 in (Krieger and Eich, 2020)). In 2019, the estimated seabird bycatch in the atka mackerel and rockfish fisheries was almost three times higher than the 2010–2018 average (1,575 birds; Table 13 in (Krieger and Eich, 2020)). Estimated seabird bycatch in the Pacific cod fishery was above the 2010–2018 average by 39% (6,349 birds; Table 13 in (Krieger and Eich, 2020)). Figure 3 shows the spatial distribution of observed seabird bycatch from 2014 – 2019 from the Pacific cod hook and line 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 three fisheries mentioned above, an estimated 35 albatross were taken per year, from 2010 through 2019 (Krieger and Eich, 2020).

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.

Vessels fishing with hook-and-line gear have traditionally been responsible for about 90% of the overall seabird bycatch in Alaska, as determined from the data sources noted above. However, 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 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 (Krieger and Eich, 2020).

Implications: Estimated seabird bycatch increased from 2018 to 2019 in the Aleutian Islands and eastern Bering Sea, but this is largely attributed to the shearwater mortality event that occurred throughout Alaska in 2019. Estimated seabird bycatch in the eastern Gulf of Alaska in 2019 remained relatively unchanged from 2018, while seabird bycatch in the western Gulf of Alaska decreased by 66% from 2018 to 2019. This was primarily due to reduced takes of northern fulmars, black-footed albatross, and gulls. These differences indicate localized changes in the Bering Sea, Gulf of Alaska, and Aleutian Islands regarding seabird distribution, fishing effort, and/or seabird prey supply, all of which could impact bycatch.

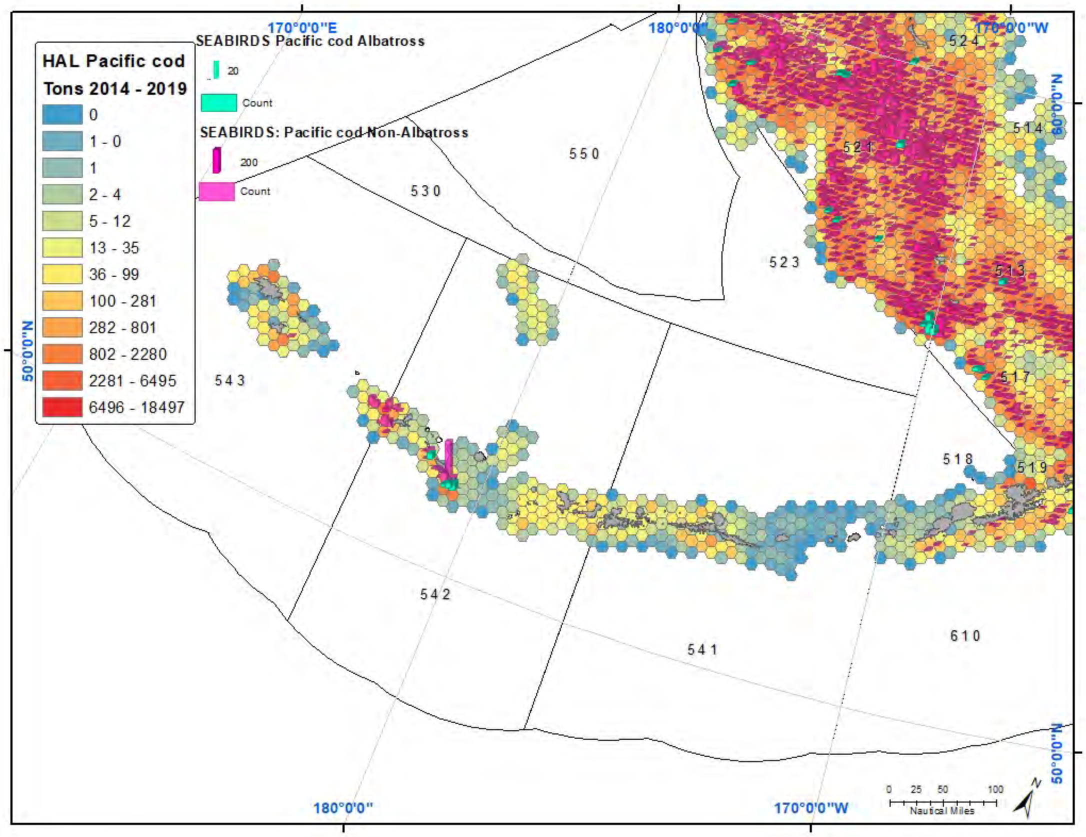

Figure 43: Spatial distribution of observed seabird bycatch from 2014 – 2019 from the Pacific cod hook and line fisheries. Colored vertical bars indicate the sum of incidental takes at a location grouped within 1/10 of a degree of latitude and longitude. Incidental takes are separated between takes of 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.

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.

Sustainability (for consumptive and non-consumptive uses)

*Fish Stock Sustainability Index and Status of Groundfish, Crab, Salmon, and Scallop Stocks

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Last updated: August 2020

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[2]. 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 28 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 six of a rebuilding plan, and the North Pacific Fishery Management Council was notified that the Saint Matthew Island blue king crab stock is overfished on October 22, 2018 and have two years from this date to implement a rebuilding plan for this stock. None of the other non-FSSI stocks are known to be subject to overfishing,

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

Table 3: Summary of status for the 21 FSSI stocks in the BSAI, updated through June 2020.

BSAI FSSI (21 stocks)	Yes	No	*Unknown*	*Undefined*	N/A
Overfishing	0	21	0	0	0
Overfished	0	19	2	0	0
Approaching Overfished Condition	0	19	2	0	0

are overfished, or are approaching an overfished condition. For more information on non-FSSI stocks see the Status of U.S. Fisheries webpage[3].

Status and trends: The overall Alaska FSSI is down from 92% in 2019 to 89% in 2020 (Figure 44). Until 2019, the overall Alaska FSSI had generally trended upwards from 80% in 2006 to a high of 94% in 2018.

As of June 30, 2020, no BSAI groundfish stock or stock complex is subject to overfishing, is known to be overfished, or known to be approaching an overfished condition (Table 3). The BSAI groundfish FSSI score is 59 out of a maximum possible 64.

The BSAI king and Tanner crab FSSI is 19 out of a possible 20. One point was deducted for the Norton Sound red king crab stock's biomass decreasing to below the B/B_{MSY} threshold.

The overall BSAI score is 78 out of a maximum possible score of 84 (Table 4). The overall FSSI has generally trended upward from 74% in 2006 to 93% in 2020 (Figure 45).

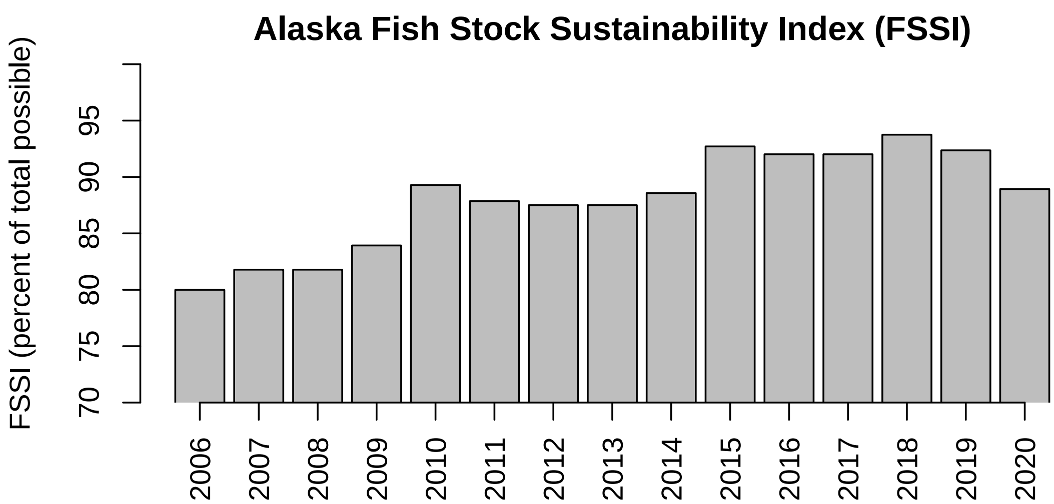

Figure 44: The trend in overall Alaska FSSI, as a percentage of the maximum possible FSSI from 2006 through 2020. The maximum possible FSSI was 140 from 2006 to 2014, 144 from 2015 to 2019, and is 140 in 2020. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website.

Factors influencing observed trends: The overall trend in Alaska FSSI has been positive from 2006 through 2019. The decrease in overall score from 2019 to 2020 is the net result of changes in the stocks included in the FSSI plus a loss of one point for the biomass of Norton Sound red king crab decreasing to below 80% of B_{MSY}. Two of the three groundfish stocks added to the BSAI FSSI in 2020 had FSSI scores of 1.5. The Aleutian Islands Pacific cod stock and the Bogoslof stock of walleye pollock lost points for not

[3] `https://www.fisheries.noaa.gov/national/population-assessments/status-us-fisheries`

having known overfished status or known biomass levels relative to their overfished levels or to B_{MSY}. All other BSAI FSSI stocks received the maximum possible score of 4 points.

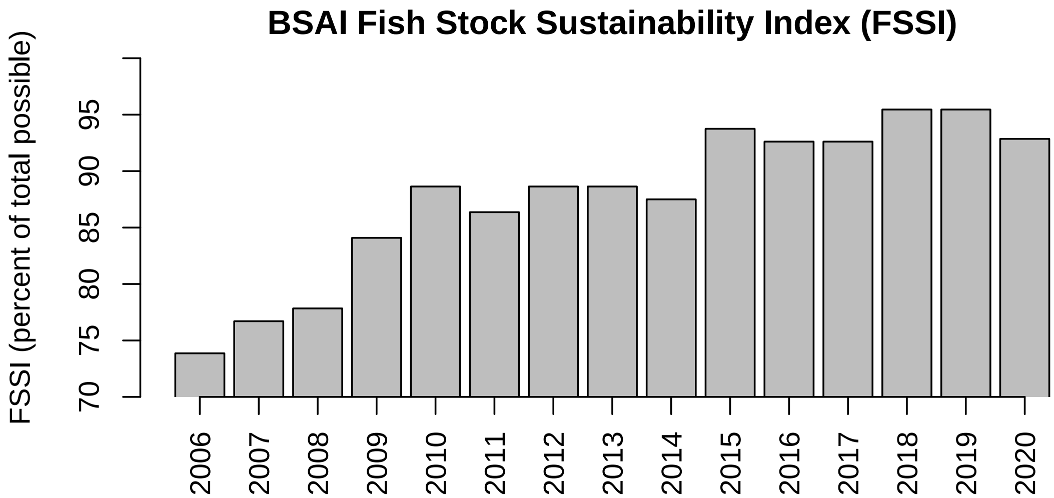

Figure 45: The trend in FSSI for the BSAI region from 2006 through 2020 as a percentage of the maximum possible FSSI. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website.

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

Table 4: BSAI FSSI stocks under NPFMC jurisdiction updated through June 2020 adapted from the Status of U.S. Fisheries website. See FSSI Endnotes 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	1.554/1.11	4
Red king crab - Bristol Bay	No	No	No	N/A	N/A	0.82	4
Red king crab - Norton Sound	No	No	No	N/A	N/A	0.68	3
Snow crab - Bering Sea	No	No	No	N/A	N/A	0.86	4
Southern Tanner crab - Bering Sea	No	No	No	N/A	N/A	1.09	4
BSAI Alaska plaice	No	No	No	N/A	N/A	1.84	4
BSAI Atka mackerel	No	No	No	N/A	N/A	1.45	4
BSAI arrowtooth Flounder	No	No	No	N/A	N/A	2.64	4
BSAI Kamchatka flounder	No	No	No	N/A	N/A	1.4	4
BSAI flathead Sole Complex[b]	No	No	No	N/A	N/A	1.89	4
BSAI rock sole complex[c]	No	No	No	N/A	N/A	2.1	4
BSAI skate complex[d]	No	No	No	N/A	N/A	1.7	4
BSAI Greenland halibut	No	No	No	N/A	N/A	1.61	4
BSAI Northern rockfish	No	No	No	N/A	N/A	1.89	4
BS Pacific cod	No	No	No	N/A	N/A	1.25	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	1.68	4
Walleye pollock - Aleutian Islands	No	No	No	N/A	N/A	1.09	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	1.9	4
BSAI yellowfin sole	No	No	No	N/A	N/A	1.94	4

Box A. Endnotes and stock complex definitions for FSSI stocks listed in Table 4, adapted from the Status of U.S. Fisheries website.

(a) The status of this stock is based on the assessment of two stocks: the Eastern and Western Aleutian Islands golden king crab stocks.

(b) Flathead sole complex consists of Flathead sole and Bering flounder. Flathead sole accounts for the overwhelming majority of the biomass and is regarded as the indicator species for the complex. The overfished determination is based on the combined abundance estimates for the two species; the overfishing determination is based on the Overfishing Limit (OFL), which is computed from the combined abundance estimates for the two species.

(c) Rock sole complex consists of Northern rock sole and Southern rock sole (NOTE: These are two distinct species, not two separate stocks of the same species). Northern rock sole accounts for the overwhelming majority of the biomass and is regarded as the indicator species for the complex. The overfished determination is based on the combined abundance estimates for the two species; the overfishing determination is based on the OFL, which is computed from the combined abundance estimates for the two species.

(d) The skate complex consists of Alaska skate, Aleutian skate, Bering skate, Big skate, Butterfly skate, Commander skate, Deepsea skate, Mud skate, Okhotsk skate, Roughshoulder skate, Roughtail skate, Whiteblotched skate, and Whitebrow skate. Alaska skate is assessed and is the indicator species for this complex.

Economic Indicators in the Aleutian Islands Ecosystem—Landings

Contributed by Benjamin Fissel[1], Jean Lee[1,2], and Steve Kasperski[1]
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Last updated: September 2020

Description of indicator: Landings are a baseline metric for characterizing commercial economic production in the Aleutian Islands. Landings are the retained catch of fish (Figure 46). Landings are plotted by functional group. While many species comprise a functional group, it is the handful of species that fishermen target that dominate the economic metrics in each group. The primary target species in the apex predators' functional group is Pacific cod, though there are some landings of non-halibut flatfish such as arrowtooth flounder. The primary target species in the pelagic foragers' functional group are Atka mackerel, Pacific ocean perch, and northern rockfish. Catch in the benthic foragers' functional group are split between flatfish such as rock sole and flathead sole, and benthic rockfish such as thornyhead and shortraker. The primary species caught in the motile epifauna functional group is king crab. Because of significant differences in the relative scale of landings across functional groups, landings are plotted in logs.

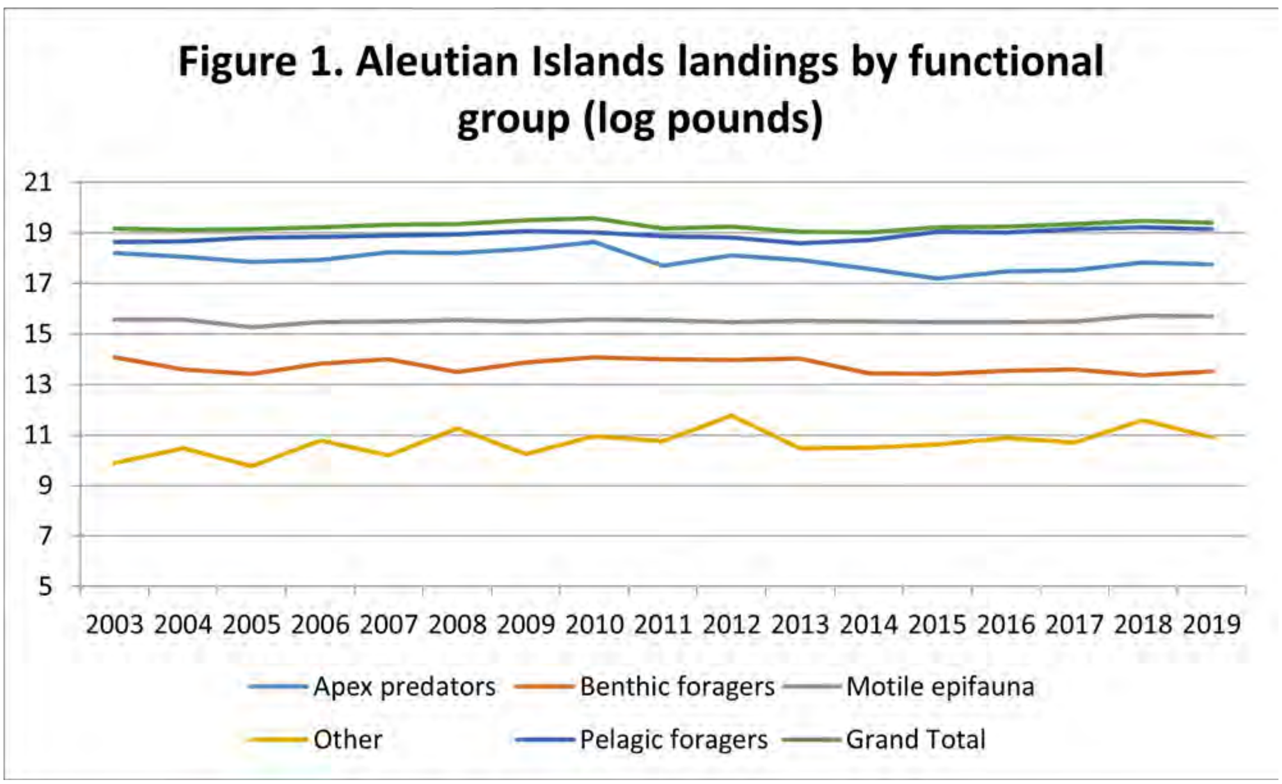

Figure 46: Aleutian Islands landings by functional group (log pounds).

Status and trends: Landings in the Aleutian Islands are primarily comprised of catch from two functional groups: pelagic foragers and apex predators. The primary species landed within the pelagic forager functional group is Atka mackerel which comprises roughly two-thirds of pelagic forager catch in the Aleutian Islands region and rockfish comprise the majority of the balance of catch. Atka mackerel landings have been fairly stable except for 2012–2015 when the Total Allowable Catch (TAC) was reduced to support populations of Steller sea lions. Landings of Atka mackerel dipped in 2019 after peaking in 2018. Pacific ocean perch, and northern rockfish landings have been increasing since 2016 and the increase in 2019 landings offset some of the decrease in from Atka mackerel for pelagic foragers as a whole. Within the apex predator functional group, Pacific cod catch constitutes 70% of the total on average but this share ranges for 50%–90% depending on both the volume of Pacific cod catch as well as the volume landed of other species. Pacific cod catches have increased in recent years, and remained strong in 2019 despite a marginal decrease from 2018 levels. Catches of apex predator flatfish increased significantly in 2009–2014, in part as a result of diverted effort from reduced Atka mackerel fishing opportunities and since have returned to more typical levels. Flatfish catches also remained strong through 2019 despite a marginal decrease from 2018 levels. Relative to the preceding three functional groups, benthic forager and motile epifauna are caught in significantly smaller quantities. Landings of both of these functional groups has remained fairly stable.

Factors influencing observed trends: Between 2008–2010, conservation based reductions in the pollock Total Allowable Catch (TAC) resulted in reduced landings for this functional group. In 2008 Amendment 80 to the BSAI groundfish FMP was implemented rationalizing the major flatfish fisheries which resulted in significant reductions in bycatch. Total catch of the groundfish that comprise the pelagic forager, apex predators, and benthic foragers' functional groups in the EBS is capped at 2 million metric tons. The sum of the Allowable Biological Catches (ABC) for these groups are typically above the cap and TACs are reduced from the ABC through negotiations at the NPFMC to meet the cap requirement. This cap system influences interpretation of trends in landings relative to their underlying stocks as changes in landings may not be the direct result of changes in biomass.

Implications: Implications: Landings depict one aspect of the raw stresses from harvesting imposed on the Aleutian Islands ecosystem's functional group through fishing. This information can be useful in identifying areas where harvesting may be impacting different functional groups in times where the functional groups within the ecosystem might be constrained. In the Aleutian Islands ecosystem, pelagic foragers make up the largest share of the catch, followed closely by apex predators, with motile epifauna and benthic foragers constituting a much smaller amount of landings in the ecosystem. Monitoring the trends in landings stratified by ecosystem functional group provides insight on the fishing related stresses on ecosystems. The ultimate impact that these stresses have on the ecosystem cannot be discerned from these metrics alone and must be viewed within the context of what the ecosystem can provide.

Profits

Economic Indicators in the Eastern Bering Sea Ecosystem—Value and Unit Value

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Last updated: September 2020

Description of indicator: Three plots are used to characterize economic value in an ecosystem context for the Aleutian Islands. Ex-vessel value is the un-processed value of the retained catch (Figure 47). Ex-vessel value can informally be thought of as the revenue that fishermen receive from the catch. First-wholesale value is the revenue from the catch after primary processing by a processor (Figure 48). First-wholesale value is a more comprehensive measure of value to the fishing industry as it includes ex-vessel value as well as the value-added revenue from processing which goes to processing sector. The first-wholesale value to total catch unit value is the ratio of value to biomass extracted as a result of commercial fish harvesting (Figure 49). The measure of biomass extracted in this index includes retained catch, discards, and prohibited species catch. This metric answers the question: "how much revenue is the fishing industry receiving per-unit biomass extracted from the ecosystem?" Figures 47 and 48 are plotted by functional group. While many species comprise a functional group, it is the handful of species that fishermen target that dominate the economic metrics in each group. The primary target species in the apex predator's functional group is Pacific cod, and to a lesser extent arrowtooth flounder. The primary target species in the pelagic foragers' functional group are Atka mackerel, Pacific ocean perch, and northern rockfish. Catch in the benthic foragers' functional group are split between flatfish such as rock sole and flathead sole, and benthic rockfish such as thornyhead and shortraker. The primary species caught in the motile epifauna functional group is king crab. Because of significant differences in the relative scale of value across functional group value is plotted in logs.

Status and trends: Ex-vessel value is the revenue from landings, consequently trends in ex-vessel value and landings are closely connected. Since 2010 ex-vessel value has been highest in the pelagic forager functional group because of higher landings and prices for the Atka mackerel and rockfish. Ex-vessel revenue of the apex predator group dropped from 2010–2015 as landings of Pacific cod decreased, and have increased since 2015 with increased landings. Halibut has significantly smaller catches than Pacific cod but because it is a high priced species, it accounts for roughly 30–40% of the ex-vessel revenue from the apex predator functional group. Halibut revenues were also declining up to 2010, rebounded in 2011–2012, and have been fairly stable since. Sablefish revenues have shown steady downward trend since 2011. Ex-vessel revenues in the motile epifauna functional group show a steady increasing trend since 2015 with increased catch volumes of king crab. Ex-vessel revenues in the benthic forager group dropped in 2014 as rockfish and flatfish catches have been moving in different directions with flatfish catch increasing and rockfish catch decreasing and rockfish have a higher price than flatfish. Benthic forager revenues have been fairly stable since 2015.

Differences in the relative level of the indices between the landings and ex-vessel value in Figure 47 reflects differences in the average prices of the species that make up the functional group. Hence, landings of pelagic foragers may be larger than motile epifauna, but motile epifauna ex-vessel value is fairly similar for several years because motile epifauna (especially king crab) commands a higher price. Ex-vessel prices are influenced by a multitude of potential factors including demand for processed products, the volume of supply (both from the fishery and globally), the first-wholesale price, inflation, fishing costs, and bargaining power between processors and fishermen. However, annual variation in the ex-vessel prices tends to be smaller than variations in catch and short to medium term variation in the landings and ex-vessel revenue indices appear similar. The long-term general increasing trend are the influence of a trend of increasing value in the first-wholesale market as well as inflation.

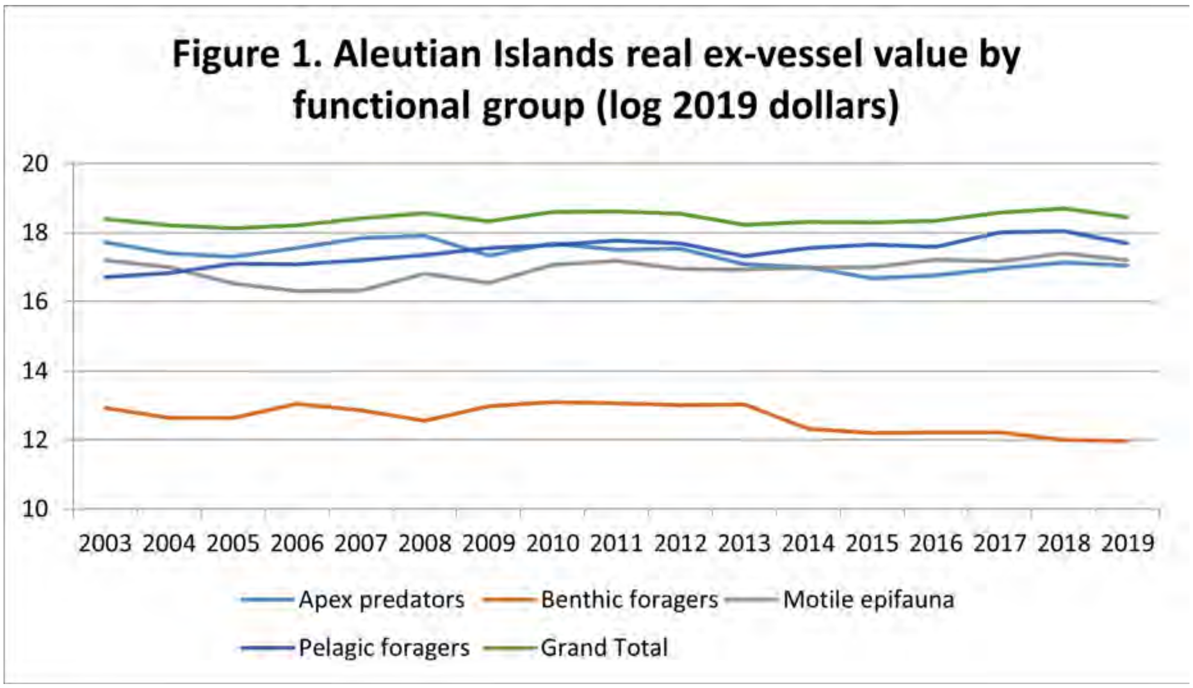

Figure 47: Aleutian Islands real ex-vessel value by functional group (log 2019 dollars).

First-wholesale value is the revenue from the sale of processed fish. Level shifts in the relative location of the first-wholesale indices compared to the ex-vessel indices are influenced by differences in the amount and types of value-added processing that is done. First-wholesale revenue by functional group in the Aleutian Islands show similar qualitative results to the ex-vessel indices. First wholesale value in the apex predator group has been decreasing over roughly the first part of decade as catches of both Pacific cod and halibut went down but have since stabilized or increased. First wholesale value in the pelagic forager group has been increasing with increasing prices for Atka mackerel and Pacific ocean perch. First-wholesale value in the benthic forager group dropped in 2014 as production of the higher valued rockfish decreased. First-wholesale value in the motile epifauna group has been suppressed in many of the years in 48 for confidentiality reasons due to an insufficient number of processors processing motile epifauna (king crab) in these years.

The first-wholesale to total catch unit value is analogous to a volumetrically weighted average price across functional groups which is inclusive of discards. However, discards represent a relatively small fraction of total catch. Because of the comparatively larger first-wholesale value from of

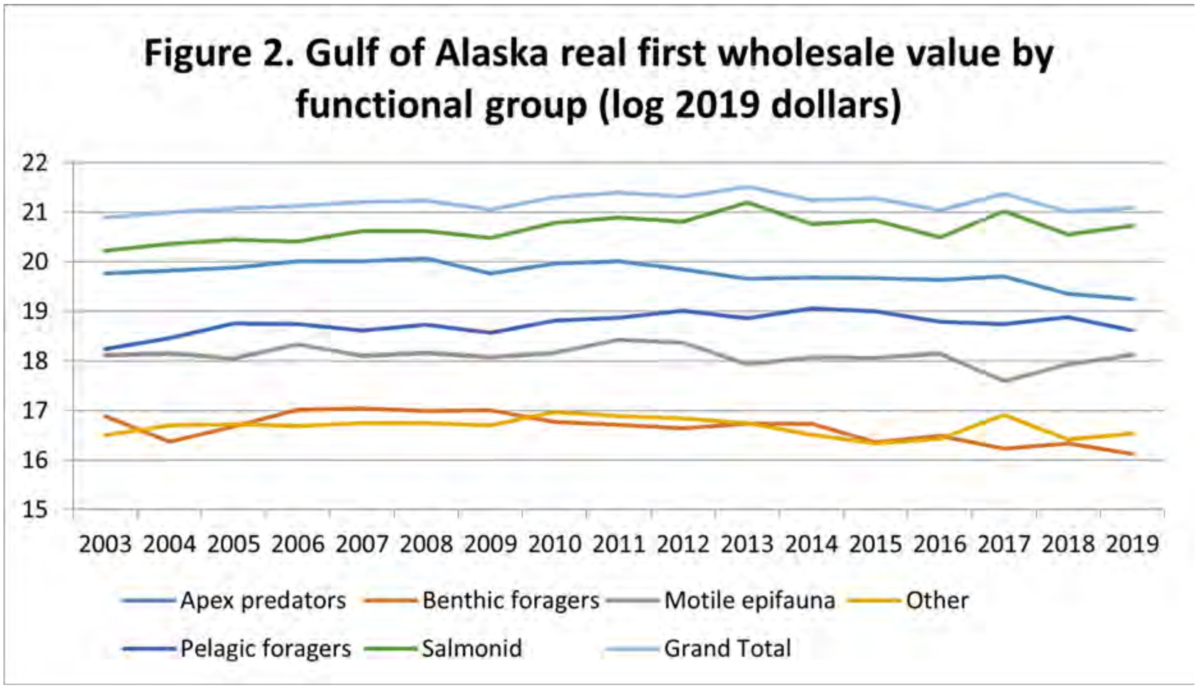

Figure 48: Gulf of Alaska real first wholesale value by functional group (log 2019 dollars).

pelagic foragers and apex predators, the unit value index is more heavily weighted towards these groups. The increase in the unit value index after 2010 is the result of increasing value from the pelagic forager which has weighted the index more heavily towards this functional group. The drop in prices in 2019 is the result of a decrease in the price for the pelagic forager group, primarily Atka mackerel, as well a drop in the crab prices in the motile epifauna group.

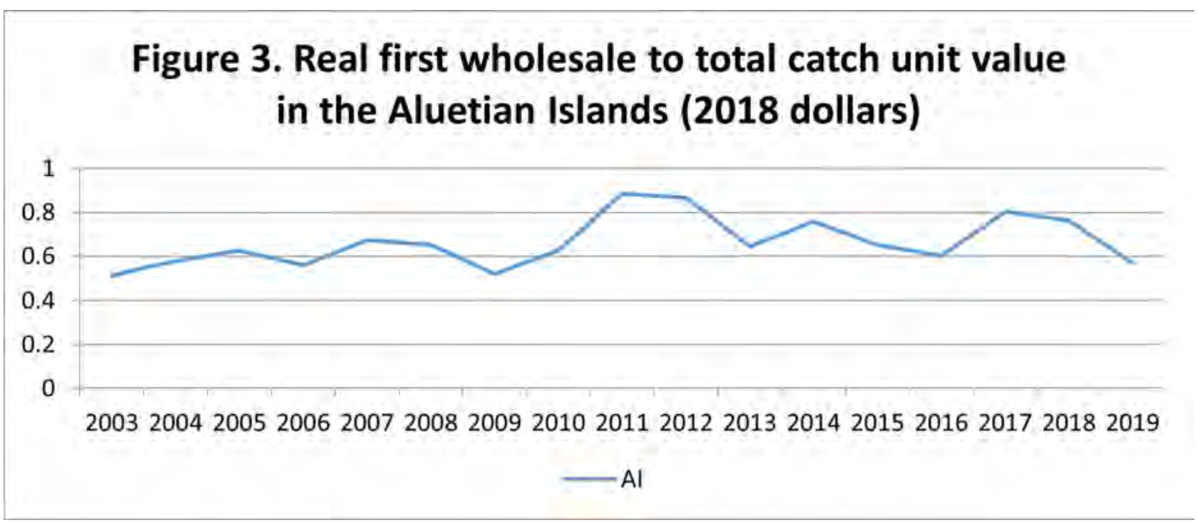

Figure 49: Real first wholesale to total catch unit value in the Aleutian Islands (2019 dollars).

Factors influencing observed trends: The reduction in revenue from 2008–2010 was the result of conservation based reductions in the pollock Total Allowable Catch (TAC). Since 2018 strong demand has put upward pressure on whitefish product prices which has filtered through to ex-vessel market. As a result, revenue increased in 2019 in the pelagic forager group despite relatively stable landings. Ex-vessel prices are influenced by a multitude of potential factors including demand for processed products, the volume of supply (both from the fishery and globally), the first-wholesale price, inflation, fishing costs, and bargaining power between processors and fishermen. However, annual variation in the ex-vessel prices tends to be smaller than variations in catch and short to medium term variation in the landings and ex-vessel revenue indices appear similar. The long-term general increasing trend is the influence of a trend of increasing value in the first-wholesale market.

First-wholesale value is the revenue from the sale of processed fish. Some fish, in particular pollock and Pacific cod, are processed in numerous product forms which can influence the generation of revenue by the processing sector. Level shifts in the relative location of the first-wholesale indices compared to the ex-vessel indices are influenced by differences in the amount and types of value-added processing that is done in each functional group.

Supply reductions in the pollock fishery which began in 2008 resulted in increased first-wholesale prices which account for the significant increase in the 2008 unit value and the relatively high level maintained through 2012. Pollock prices fell somewhat in 2013 with significant global pollock supply.

Implications: The economic metrics displayed here provide perspective on how the human component of the ecosystem feeds off of and receives value from the Aleutian Islands and the species within that ecosystem. Ex-vessel and first-wholesale value metrics are a measure of the ultimate value from the raw resources extracted and how humans add value to the harvest for their own uses. In contrast to the landings metrics that are heavily dominated by the pelagic forager and apex predator functional groups, ex-vessel revenues and to a lesser degree first wholesale revenues are more evenly distributed across functional groups, which indicates the importance of the groups with lower landings and higher prices to the fishing sector in this ecosystem.

Situations in which the value of a functional group are decreasing but catches are increasing indicate that the per-unit value of additional catch to humans is declining. This information can be useful in identifying areas where fishing effort could be reallocated across functional groups in times where the functional groups within the ecosystem might be constrained while maintaining value to the human component of the ecosystem. Monitoring the economic trends stratified by ecosystem functional group provides insight on the fishing related stresses on ecosystems and the economic factors that influence observed fishing patterns. The ultimate impact that these stresses have on the ecosystem cannot be discerned from these metrics alone and must be viewed within the context of what the ecosystem can provide.

Employment

Trends in Unemployment in the Aleutian Islands

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Last updated: August 2020

Description of indicator: Unemployment, is a significant factor in the AI and for groundfish fishery management, as most of the communities in the region rely upon fisheries to support their economies. Employment in this region is important for population retention and community viability (Rasmussen and Rudolf, 2015). Advancements in socio-ecological systems (SES) research has demonstrated the importance of incorporating social variables in ecosystem management and monitoring, and unemployment reflects the economic setting of a SES (Turner et al., 2003; Ostrom, 2007). For example, variation in resource access, availability, and/or employment opportunities may influence human migration patterns, which in turn may decrease human activity in one area of an ecosystem while increasing activity in another.

This report summarizes trends in unemployment rates over time in the Aleutian Islands chain including the eastern, central, and western ecoregions. The seven AI fishing communities included in this analysis are Attu Station, Adak, Atka, Nikolski, Unalaska/Dutch Harbor, Akutan and False Pass. Unemployment data was aggregated and weighted to account for varying community populations across the Alaska East Boroughs and Aleutians West Census Areas. Estimates are presented annually from 2010–2019 (ADLWD, 2020).

Status and trends: Unemployment rates in the AI, between 2010 and 2019, were lower than state and national rates (Figures 50–51). The eastern AI had higher unemployment rates than central AI. There is no update on the western AI population data as the one community (Attu Station) has had minimal or zero population for several years. According to the 2010 census, the population of 21 consisted of coast guard personnel who left the area when the Casco Cove Coast Guard Station was closed in August 2010.

Unemployment rates, as of 2017, were 2.29% in the eastern AI and 0.22% in central AI. The AI region has had the lowest unemployment rates of any region of Alaska since 2014, in particular, the central AI has maintained rates less than 1.0%. Unemployment in the central AI decreased 36.7% between 2010 and 2019, and decreased from 2.4% to 2.3% in the eastern AI.

Factors influencing observed trends: Alaska has experienced several boom and bust economic cycles. Peaks in employment occurred during the construction of the Alaska pipeline in the 1970s and oil boom of the 1980s, whereas unemployment peaks occurred following completion of the pipeline, during the oil bust of the late 1980s, and during the great recession of 2007–2009 (ADLWD, 2016). However, during the great recession, Alaskas employment decreased only 0.4% whereas the national drop was 4.3% partly because of the jobs provided by the oil industry (ADLWD, 2016). Employment in the Aleutian Islands is largely driven by commercial fishing and the seafood processing industries, which stabilize employment in the region. Compared to other regions of Alaska employment is stable. Most regions are forecasted to experience job loss due to reduced oil revenues (ADLWD, 2018).

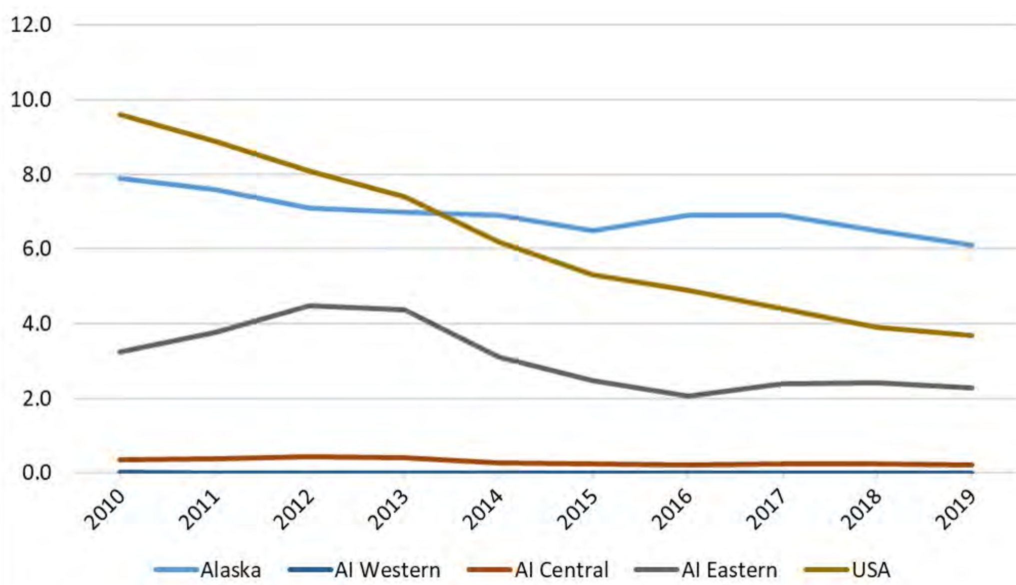

Figure 50: Unemployment rates for the western, central and eastern Aleutian Islands, Alaska, and USA, 2010–2019.

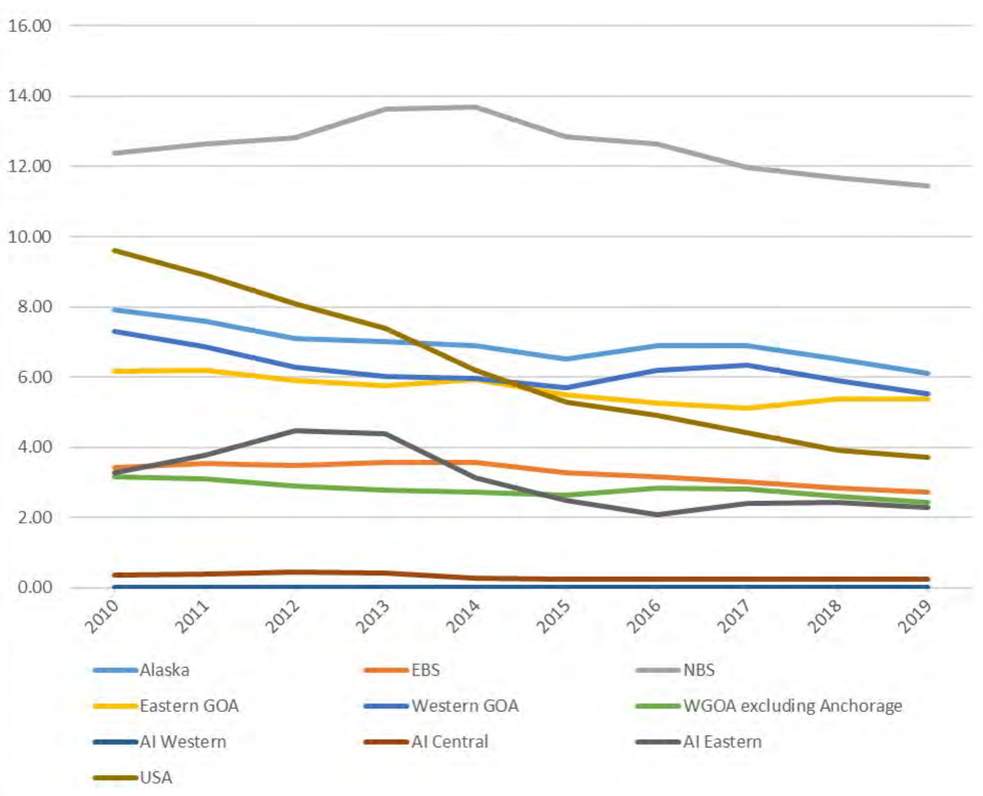

Figure 51: Unemployment rates for all regions (E is east, W is west, BS is Bering Sea, GOA is Gulf of Alaska, AI is Aleutian Islands), Alaska and USA, 2010–2019.

Implications: Fisheries contribute to community vitality of the Aleutian Islands, and reduced fishing opportunities and employment may lead to out-migration and population decline, particularly in small communities with few job alternatives (Donkersloot and Carothers, 2016). Changes in groundfish policy and management, such as increased regulations, may have implications for these fishery-dependent communities.

Trends in Human Population in the Aleutian Islands

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Last updated: September 2020

Description of indicator: Population stability and growth are important indicators of community viability (Rasmussen and Rudolf, 2015). Human population trends in the Aleutian Islands (AI) are particularly relevant to groundfish fishery management because many communities in the region rely upon fisheries to support their local economies and to meet subsistence and cultural needs. Advancements in socio-ecological systems (SES) research has demonstrated the importance of incorporating social variables in ecosystem management and monitoring (Turner et al., 2003; Ostrom, 2007). For example, population trends may be influenced by variation in resource access or availability or employment opportunities, resulting in migration patterns which in turn may decrease human activity in one area of an ecosystem while increasing activity in another.

This section summarizes trends in human population over time in the AI. The seven AI fishing communities included in this analysis are Attu Station (western AI), Adak, Atka (central AI), Nikolski, Unalaska/Dutch Harbor, Akutan and False Pass (eastern AI). Communities were divided into two categories as part of this analysis; small (population $<$1,500); and large (population $\leq$1,500). Population was calculated by aggregating community level data between 1890 and 1990 (DCCED, 2016) and annually from 1990–2019 (ADLWD, 2020). Populations were aggregated into the western, central and eastern AI ecoregions.

Status and trends: As of 2019 the total population including all AI communities was 5,989 people. The total population of the AI has fluctuated since 1880 with the highest population increase of 374% occurring between 1960 and 1970 (Table 5 and Figure 52). The population of the AI increased from 1920 to 1940 and from 1960 to 1990. Between 1990 and 2019 the population declined by 29.6%. Notable decreases occurred between 1900 and 1910, between 1940 and 1950, and between 1990 and 2000. The eastern AI is the only region to experience steady population increase that occurred between 1880 and 2019, whereas the central and western AI have experienced large fluctuations. The western AI CDP of Attu Station has had a population of zero since 2011. Population trends of the AI are not consistent with Alaska-wide trends, where the greatest increase of 75% occurred between 1950 and 1960. Unalaska is the only large community in the AI from 2010 to 2019 (population in 2019 = 4,592). Statewide, most of the population increase was in urban areas, such as Anchorage, where 40% of Alaska's population currently resides (ADLWD, 2016, 2018).

The population of most AI communities decreased between 2010 and 2019. Population decreased in Adak and Atka (central AI) by 8.59% by 18.03% respectively; in Nikolski CDP by 5.56%, and Akutan by 3.6%. False Pass and Unalaska (eastern AI) had steady population increases during this period (20% and 4.94% respectively). Although Indigenous Americans comprise up to 82% of the population of small communities in remote areas and more Alaska Natives reside in Alaska than any U.S. state (Goldsmith et al., 2004), only 42% of the AI population identified as Alaska Native alone or in combination with another race (DCCED, 2016). The highest proportion of Native Americans was in Atka and Nikolski. There has been increased migration of Alaska Natives from rural to urban areas (Goldsmith et al., 2004; Williams, 2004*b*); the majority of population growth

Table 5: Aleutian Islands population 1880–2019. Percent change rates are decadal until 2010.

Year	Alaska	% change	AI East	% change	AI Central	% change	AI West	% change	AI Total	% change
1880	33,426		192		132		107		431	
1890	32,052	-4.1	397	106.8	132	0	101	-5.6	630	46.2
1900	63,592	98.4	488	22.9	128	-3.0		-100	616	-2.2
1910	64,356	1.2	281	-42.4	0	-99.2			281	-54.4
1920	55,036	-14.5	448	59.4	56	5,600			504	79.4
1930	59,278	7.7	465	3.8	103	83.9	29		597	18.5
1940	72,524	22.3	563	21.1	89	-13.6	44	-51.7	696	16.6
1950	128,643	77.4	365	-35.2	85	-4.5		-100	450	-35.3
1960	226,167	75.8	458	25.5	119	40			577	28.2
1970	302,583	33.8	398	-13.1	2,237	1,863			2,735	374
1980	401,851	32.8	1,611	304.8	3,408	45.8			5,019	83.5
1990	550,043	36.9	3,782	134.8	4,731	38.8			8,513	69.6
2000	626,932	14.0	5,099	34.8	408	-91.4	20		5,527	-35.1
2010	710,231	13.3	5,456	7.0	387	-5.2	21	5	5,864	6.1
2019	731,007	2.9	5,641	3.4	348	-10.1	0	-100	5,989	2.1

that has occurred in Alaska is of the Caucasian demographic (ADLWD, 2018).

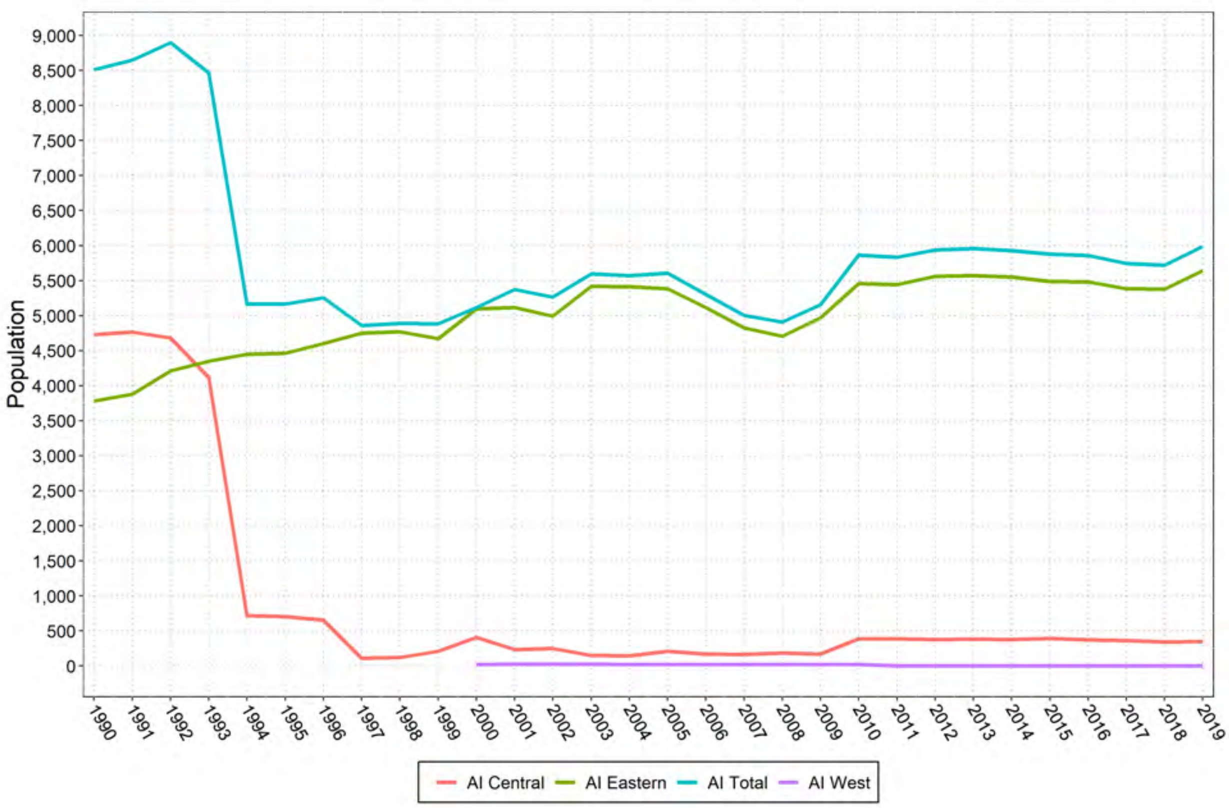

Figure 52: Population of AI ecoregions 1990–2019.

Factors influencing observed trends[4]**:** The population decrease of the AI between 1990 and 2019 (29.6%) was inconsistent with State trends (increase of 32.9%). The large decrease in population can be attributed to the closure of the Adak Naval operating base in 1997 and a general migration from small communities to economic centers. Alaska has high rates of population turnover because of migration (ADLWD, 2016). The main factors that affect population growth are natural increase (births minus deaths) and migration, with the latter being the most unpredictable aspect of population change (Williams, 2004*b*; ADLWD, 2016). In 2010, 61% of Alaska's population was born out of state (Rasmussen and Rudolf, 2015). In terms of natural growth, from 2010 to 2014 the average annual birth rate in Alaska was 1.6 per 100 people which was higher than the national rate of 1.3 (ADLWD, 2016).

Population trends in Alaska are largely the result of changes in resource extraction and military activity (Williams, 2004*b*). Historically, the gold rush of the late 19th century doubled the States population by 1900, and later WWII activity and oil development fueled the population growth (ADLWD, 2016). However, in the AI, population changes were largely driven by military activities during WWII, the establishment of Coast Guard bases, and the development of fisheries following the establishment of the EEZ (late 1970s), joint ventures (1980s), and later development of the domestic fishery in the early 1990s. Some communities in the western and central AI declined in the 1990s because of Coast Guard cut-backs and military base closures (**?**). For example, the closure of the Coast Guard base in Attu Station (during 2010) in western AI left the community abandoned. Similarly, Adak's population drastically declined after closure of the Adak Naval operating base in 1997. The influence of the fishing industry is evident in the eastern AI with Unalaska and Akutan, the most populous communities of the AI, showing landings for a substantial volume of seafood. The Aleutian Islands, and Kodiak in the Gulf of Alaska, have transient populations because of the seafood processing industry (Williams, 2004*a*). Factors that influence population shifts and migration include employment, retirement, educational choices, cost of living, climate, and quality of life (Donkersloot and Carothers, 2016).

Implications: Population shifts can affect pressures on fisheries resources, however inferences about human impacts on resources should account for economic shifts and global market demand for seafood and other extractive resources of the ecoregion. Population change in Alaska is largely fueled by increased net migration rather than natural increase, and there has been increased migration from rural to urban areas. This is evident with population decline of most small communities such as Nikolski, Atka, and Adak. AI communities are among the most transient with in-migration of foreigners working in processing plants, yet employment in fisheries is what maintains these communities, such as Unalaska and Akutan. Fisheries contribute to community vitality and changes in groundfish policy and management, such as increased regulations, may have implications for small communities of the Aleutian and Pribilof Island Community Development Association entity. Also, with almost half of the population of the AI being Native Alaskans and their long history of subsistence harvest, resource managers may benefit from working with communities holding traditional ecological knowledge (TEK) to incorporate these principles into ecosystem management (Huntington et al., 2004).

[4]See the Alaska Department of Labor and Workforce Development "Alaska Economic Trends" magazine that is published monthly for detailed information on factors influencing observed trends in the state (https://labor.alaska.gov/trends/).

K–12 School Enrollment, Graduation Rates, and Dropout Rates in Coastal Communities in the Southeastern and Northern Bering Sea

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Last updated: September 2020

Description of indicator: Ensuring the productivity and sustainability of fishing communities is a core mandate of Federal fisheries management. One indicator to evaluate community vitality is K-12 public school enrollment. Enrollments trends are of particular relevance due to the value of schools to community cohesion and identity. Declining enrollment trends, and particularly school closures, may signal that the viability of fishing communities is threatened as communities that lack public education typically experience population outmigration and a decline of public services.

Public school enrollment rates were analyzed at the community level, and then aggregated to school district enrollment rates. All data originate from the Alaska Department of Education and Early Development (`http://www.eed.state.ak.us/stats/`). In an effort to examine trends over time, data from all years available were included in the analysis. Enrollment statistics for K-12 grades by school and region were compiled for 1995–2019 (from the Alaska Department of Education and Early Development `http://www.eed.state.ak.us/stats/`). School graduation rates are based off of the four year adjusted cohort graduation rate, which was implemented in Alaska starting in 2011. Graduation rates are reported for the 2015–2019 cohorts, based upon school district. Dropout rates are reported by school district from 1990–2019. All current school locations and names were verified using the EPA EJ mapping tool (`https://ejscreen.epa.gov/mapper/)andAlaskaDepartmentofEducationwebsite(https://education.alaska.gov/)`.

Status and trends:

Southeastern Bering Sea: While the Unalaska School district in the EAI has slightly increased enrollment since 1995, Nikolski, Akutan, and False Pass school enrollments have diminished dramatically (Figure 53). Nikolski closed in 2010, and False Pass had 6 students enrolled in the 2019–2020 school year. Alaska schools lose state funding if enrollment drops below 10 students, and often close if enrollment remains below 10 students for multiple years. Akutan currently has 20 students enrolled, which is the highest enrollment has been since 1999. Graduation rates in the Unalaska and Aleutian East school districts for the last 5 cohorts have averaged 95.8%. The statewide average was 76.1% (2016) and 78.2% (2017). Dropout rates vary from 0–8% for the EAI. The Unalaska school district dropout rate has declined since 1999 and now has the lowest dropout rate compared to other ecoregions.

Adak and Atka schools in the CAI have experienced declining enrollment overall. As of the 2019–2020 school year, Adak had 18 students enrolled while Atka had 10 (Figure 54). This represents a slight increase in enrollment for both communities; however overall enrollment remains low. Both of these communities are small and extremely remote; losing a school would be detrimental. Graduation rates were at 50% in 2015, increased to 100% in 2016 and 2017, dropped to 50% in

2018 and 0% in 2019. There are no data for dropout rates from the Aleutian Region School District in the CAI.

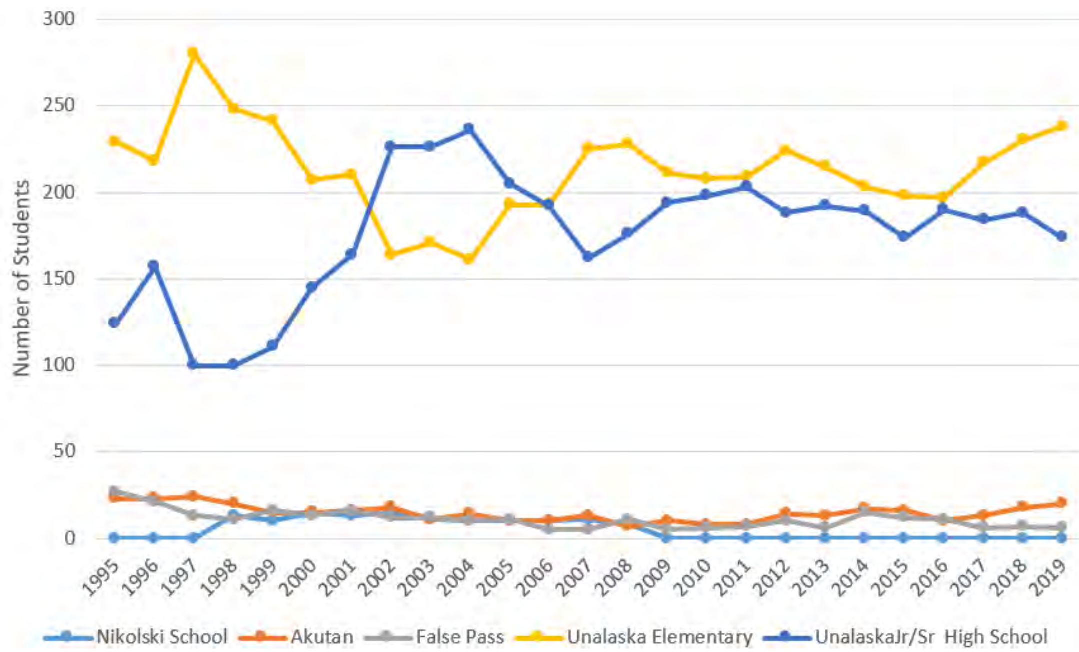

Figure 53: Eastern Aleutian Islands school enrollment 1995–2019.

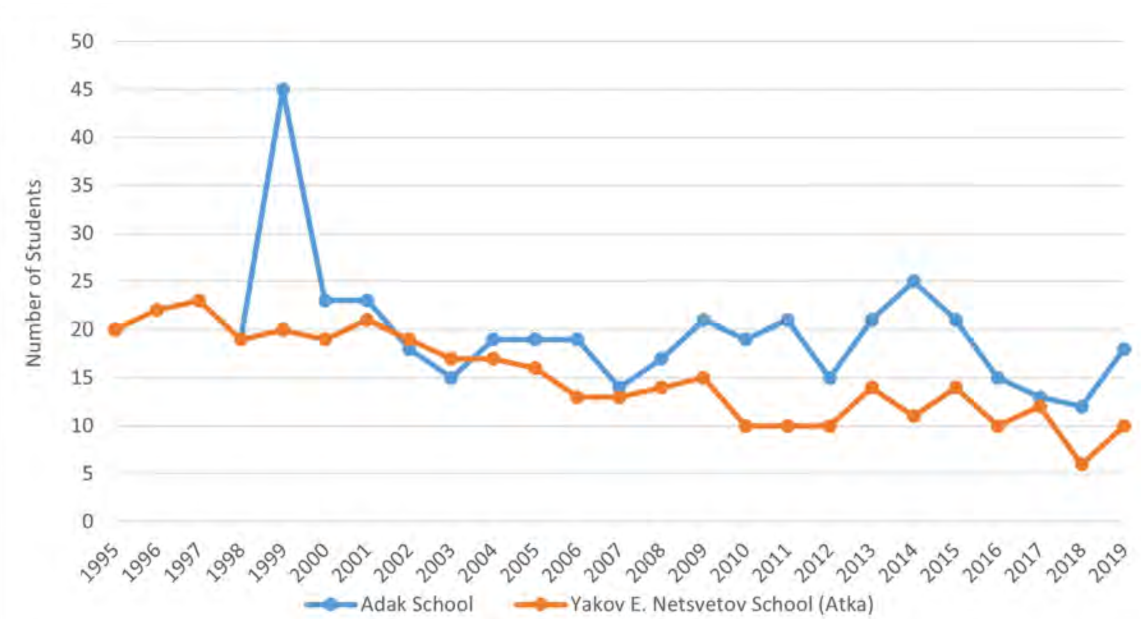

Figure 54: Central Aleutian Islands school enrollment 1995–2019.

Factors influencing observed trends:

The communities within the CAI and EAI can be considered either remote or extremely remote. Rural area schools are particularly vulnerable to closure, teacher turn over, and possible community disruption. High dependence on commercial fisheries and other natural resources may drive pop-

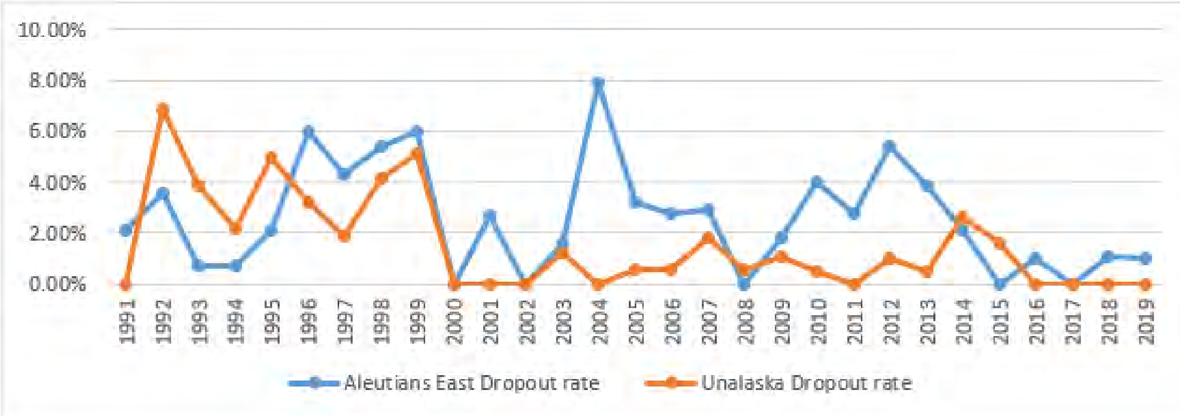

Figure 55: Dropout rates for Eastern Aleutian Islands school districts, 1991–2019.

ulation shifts according to season and availability. All schools in the Aleutian Islands, except for that in Unalaska, have fewer than 30 students enrolled, which poses a risk for educational stability. The reasons for decreasing enrollment likely include various social and economic drivers including decreasing populations, migratory patterns, resource availability, and employment.

Implications: The closure of a school in these communities would have a profound effect, further discouraging families or potential families to remain in the area, amplifying the decline of local resident populations. School closures would discourage permanent residency, even when improved employment opportunities arise. Community residents are part of the ecosystem, linked through daily informed experience and activity, and a strong sense of place. Schools are cultural centers and serve as important indicators of social and economic viability, and community well-being (Lyson, 2002; Lyson and Welsh, 2005). Within rural communities in particular, schools are valuable symbols for community identity, autonomy, and shared social values (Peshkin, 1978, 1982; Lyson and Welsh, 2005). Research indicates that school closures negatively affect communities and student achievement (Buzzard, 2016; Thorsen, 2017). Closed school buildings can be a drain on community and school district resources (Barber, 2018). Patterns of diminishing enrollment and school consolidation suggest a decrease in property values and taxes, economic opportunity, and overall decline in reported quality of life scores, as well as fragmented community systems, lost in business, and cultural cohesion, as well as declines in reported quality of life scores (Sell and Leistritz, 1997; Lyson, 2002). Some research finds the rate of participation in community organizations decreases in communities experiencing school closures (Oncescu and Giles, 2014; Sell and Leistritz, 1997). These findings suggest that reduced enrollments and school closures may flag disruptions in social cohesion, possibility leading to less vibrant and sustainable communities. Because many of these small communities are highly reliant on fisheries, school enrollment can be a strong indication of the linkage between sustainable fisheries and community well-being.

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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[5].

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 doc-

[5]The Arctic report is under development

umented 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 56). 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.

Figure 56: The IEA (integrated ecosystem assessment) process.

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

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 2019 SSC Comments

This year, as in the past, the ESRs were insightful, well-written, and well-edited. Both chapters were helpful in providing a context within which to assess the stocks of commercially harvested fish in the Federal waters off Alaska. The editors and authors have been very responsive to the comments and suggestions provided by the SSC in 2018, with many improvements evident. The SSC appreciates the positive impacts of the additional resources devoted to the ESRs. These additional resources allowed for a more in-depth analysis of recent environmental changes, such as the examination of the reappearance of the heatwave in 2019 in the Gulf of Alaska, and the extraordinary conditions in the northern Bering Sea in both 2018 and 2019

Thank you. This year we provide updates to the Eastern Bering Sea (Siddon), Gulf of Alaska (Ferriss Zador, with Rob Suryan providing coordination with Gulf Watch Alaska, and Aleutian Islands (Ortiz Zador) Ecosystem Status Reports (ESRs). We anticipate updating the Eastern Bering Sea and Gulf of Alaska ESRs in 2021 as NOAA continues to support and provide resources to these Reports.

Given the rapidly changing conditions in the EBS, there is increased need for information about the effects of climate on the carrying capacity of the EBS and GOA marine ecosystems. This need is great in both the southeastern Bering Sea and the northern Bering Sea. Likewise, there is cause for concern because the western Gulf of Alaska has remained in heatwave conditions for most of 2019, and summer sea surface temperatures were similar to the warmest temperatures during the 2014 - 2016 marine heatwave. ***The SSC strongly recommends the conduct of annual surveys of not only groundfish, but also zooplankton across the entire eastern Bering Sea and the GOA.*** *This additional coverage should not be at the expense of biennial surveys of the Aleutians and Bering Sea slope*

The AFSC has engaged in extensive survey planning and prioritization in 2020, in collaboration with the North Pacific Fisheries Management Council, in the context of responding to COVID-19 and balancing research and monitoring needs.

Comments applicable to both the EBS and the GOA ESRs

These are very long reports and it is likely that few readers will read them in their entirety. Their greatest value is in the syntheses and in the sections that focus attention on emerging ecosystem-wide problems and key messages. Presently, there are a number of areas in the ESRs where there are several overlapping contributions on the same subject. It would shorten the ESRs and make the information more comprehensible if the authors could collaborate to produce a single contribution on a given subject that summarizes the current situation. As an example, ***the SSC recommends that there be a single, short, but comprehensive (integrated) contribution on sea temperatures in each region*** *(presently, 17 Figures in the GOA ESR). The integrated section on seabirds might provide a good example. Synthesis products, presentations, discussions with assessment authors, and collaboration among contributors are among the high value outcomes of the ESR reports.*

The AI ESR took the same approach as the EBS in creating a single comprehensive contribution for physical factors in the environment with region specific sea surface temperature, marine heatwave. Likewise, there is an integrated seabird information section that is new this year.

The editors present a new "Groundfish Recruitment Predictions" section, which includes a new indicator for Pacific cod and five new indicators for walleye pollock. The SSC supports the development of these predictions based on ecosystem indicators that are firmly grounded in mechanistic relationships. Effort should be directed toward the eventual incorporation of these recruitment indicators in the assessment models. The SSC recommends that these species-specific predictions are transitioned to the ESPs (Ecosystem Socio-economic Profile) to ensure that they are considered by the stock assessment authors.

The contribution authors and Report editors are maintaining open communication with stock assessment authors and those involved in producing the ESPs. These species-specific indicators will be transitioned to the appropriate ESPs as they become available.

***The SSC strongly supports the production of the 'In Brief' versions of the ESRs** aimed at conveying a summary of ecosystem information to the public. The 'In Brief' report on the EBS from 2018 was well-received by communities, and the 2019 versions for both the EBS and GOA look excellent. The SSC continues to encourage these efforts, as well as further attempts to provide information back to the communities that have provided information for the ESR.*

Thank you. We agree! We will be producing 2020 'In Brief' versions of the EBS, GOA, and AI ESRs this year. In addition, in collaboration with AFSC communications team, we are producing story maps and short educational outreach videos to further describe the 2020 ESRs to a broader audience.

The influences on the economic and social life in Alaska's coastal communities are many and the SSC cautions against facile causal interpretations. At the same time, it would be a mistake to dismiss the indicators presented in the chapter as being disconnected from and unrelated to the Council's sphere of influence. The policy choices made by the Council and the US Congress directly influence the possibilities presented to the communities of the North Pacific. The SSC suggests that the Human Dimensions ecosystem indicators be a topic for discussion by the newly formed Social Science Planning Team.

The Report editors welcome collaborating with the Social Science Planning Team to best represent and report coastal communities and impacts of policy choices on Alaskans.

In the human dimensions section of the ESRs, the utility of a number of the indicators would be improved with the addition of a spatial dimension. Seafood production, value, and unit value indicators are presented at the EBS-level only, and unemployment is presented at the EBS and NBS levels only, which does not allow for discernment of changing patterns over time at a sub-regional or community scale. Trends in population are presented at a community level but, like observed trends of unemployment, there is no apparent nexus of changes in ecosystem- or fishery-specific variables to changes in human dimension indicators (e.g., no community level time series data on federally managed fisheries engagement are presented that would provide a perspective on potential relationships between these data and observed population trends).

Eco-regional maps with identified communities are in development and will be included in next year's ESRs. The level of analysis (e.g., EBS-level) is consistent with the ESR scope. For sub regional and community scale, this data is available in the ESP (stock specific); ACEPO (Groundfish and crab FMPs); and econ SAFE (economic information).

Overall, the human dimensions section would benefit from a series of maps that show the relationships between the various geographic units discussed and the location of communities within those geographies (and the larger ecosystem geographies). It would also be beneficial to clarify the relationship between the type of human dimensions data that are contained in ESRs, ESPs, SAFEs, the Economic SAFE, and the apparently new and to-be-defined documents that will contain the fishing community information that was removed from the current version of the Economic SAFE. This would provide clarity and consistency in meeting the data needs to address social and community focused management obligations under National Standard 2 and National Standard 8 while avoiding redundancy of effort.

Eco-regional maps with identified communities are in development and will be included in next year's ESRs. The level of analysis (e.g., EBS-level) is consistent with the ESR scope. For sub regional and community scale, this data is available in the ESP (stock specific); ACEPO (Groundfish and crab FMPs); and econ SAFE (economic information). The Economic and Social Science Research group at AFSC continues to refine and communicate this suite of documents. Examples of these efforts include presentations by Stephen Kasperski at the September 2020 Groundfish Plan Team, the November 2020 Groundfish Plan Team, and the SSC in their February meeting.

Comments Specific to the 2018 Aleutian Islands Ecosystem Status Report from the SSC review in December 2018

The SSC heard a report on the Ecosystem Status report for the Aleutian Islands from Stephani Zador and Elizabeth Siddon. There were no public comments.

The ESR was well written and the SSC understands the lack of data for the region and commends the authors on their efforts considering these limitations (e.g., in the Central Aleutian region, only 4 of the Report Card time series were updated). There continue to be concerns about the western region of the Aleutian Islands. It would seem prudent to assemble the full range of information on this region to explore the reason(s) for the population declines of harbor seals, Steller sea lions and seabirds (cormorants). Data of interest could be eddy activity, sea water temperatures, zooplankton abundance, forage species abundances, and fish condition and abundance.

Thank you. We continue to evaluate new sources of relevant information, whether as an indicator for the report card or in general. This year we have added full descriptions of the report card indicators for Sea otter density and Steller sea lions non pup counts. We also added new indicators for marine mammal strandings, sea surface temperature and expanded eddy kinetic energy to all three regions of the Aleutians. We also note that the trend observed in the western Aleutians is part of larger trends also observed in the Kuriles, Kamchatka and Near Islands.

The SSC suggests exploring the reproductive success of tufted puffins in the eastern Aleutian Islands as a measure of forage fish abundance.

We follow consumption of Atka mackerel, Ammodytes and gadids in the report card and include reproductive success of tufted puffins in Aiktak Island with the integrated seabird information.

This report might benefit from expansion of LTK to provide indicators. The SSC supports the efforts to explore the use of the LEO Network. However, only 7 observations (all from one community) *were reported through that system in 2018. The SSC supports the efforts to reach out to community members on specific ecological questions that might fill in data gaps about long-term trends in the ecosystem.*

In view of some of the drawbacks of the LEO Network (such as not being representative of LTK or the observations being neither systematic nor representative), we have opted to rather collaborate directly with communities when possible, as has been done with Harmful Algal Blooms in the Noteworthy section and in the GOA for the Integrated Seabird Information. Unfortunately, no community input seabird subsistence activities was available from Unalaska as egg hunting is not as common as in other areas. We are also planning on sending out copies of the In-Brief as a first outreach to communities to start a dialogue.

The SSC encourages the authors, if possible, to decide on a consistent time period of change that is meaningful. Report card graphs seem to have settled on 5-year window, which has a lot of pluses to it. However descriptions go back and forth between reporting change since time series was last updated (is this meaningful change or just normal variability) and long term change (which has a widely varying number of years considered, confounding interpretation).

We have tried to identify suitable environmental changes that may serve as reference periods, this is most noticeable in the Integrated Physical Factors Information. However, for several of the biological time series, such events either do not seem to have had an impact or be relevant to the life history/ source of the decline. We also think that both annual changes (admittedly better presented as anomalies or some measure as to whether they are ecologically meaningful for the population/indicator) and long term trends which reflect changes in the ecosystem should be brought up to the Council's attention to inform both tactical and strategic decisions. To separate longer term changes and better inform strategic decision making on its own, we are working on an ecosystem health status report which will focus on these issues.

The SSC noted that the different time scale of the beginnings of the datasets makes the discussion of their long term trends awkward. It would be most helpful to discuss long term trends in indicators across a consistent time period if possible (the period in which all of them can be discussed unless there's a strong biological reason not to). In "Current and Recent Ecosystem State", the SSC encourages discussion of temperatures quantitatively relative to long term mean. It is hard to tell which years are anomalies, and which are change from some recent relevant event, and which are significant.

We have tried to present the information in terms of anomalies, whenever possible, particularly in the physical environmental factors. We do note that anomalies are ideally accompanied by absolute or some other representation to provide context. Anomalies are only as useful as the underlying process it is representing is understood in its ecological context - for example, temperature anomalies do not represent the same risk to species, as this will depend on their specific thermal tolerance.

In case of sea lions, the entire time series is driven by changes occurring before 1990. If more recent trends are thought to be relevant, it should be plotted differently.

From Katie Sweeney, author of the Steller sea lions contribution: "As a whole the western DPS began to 'rebound' 2002 (varies by region but early 2000s in the GOA and E ALEU). The regions to the west have obviously not shown signs of recovery or are in decline again. I would think for the Gulf assessing trends since 2002 would be good and for the Aleutians, as far back as you can go."

The SSC noted that the Kasatochi auklet time series should be dropped as an indicator, as the volcanic eruption and subsequent substrate changes will preclude a monitoring program there for quite some time. If retained, the text in the description needs some updating – auklets have actually been breeding on Kasatochi since the year after it erupted although monitoring of reproductive success has not taken place. In description of indicators, the SSC encourages additional explanation to be added for indicators that were not updated recently (e.g., marine mammals), to clarify whether these surveys are ongoing and on what schedule.

We have dropped the auklet time series, added full descriptions of the sea otter and Steller sea lions indicators and have clarified which are regular surveys and which are periodic and/or opportunistic.

The SSC notes that oceanographic variables (e.g., temperature) are reported as indicators in the Western Aleutians and feels that these would be useful in the other ecoregions (Central and Eastern Aleutians) as well.

That particular text was from the bottom trawl temperature contribution and did indeed apply to all ecoregions although it was included in only one regional report card. This year, we have expanded the regional highlights in the climate overview, provided regional estimates for the new sea surface temperature and marine heat wave indices, and expanded the eddy kinetic energy index to the central and western Aleutians.

The SSC encourages the authors to consider whether new data could be collected that could serve as indicators to fill gaps (e.g., plankton). Some parties working regularly in the region could and would be potentially willing to collect low-cost datasets if the usefulness was fleshed out. The SSC notes that datalogger-derived datasets of sea surface temperature are available at several sites since 1997 from the Alaska Maritime National Wildlife Refuge.

We welcome any additional suggestions the SSC might have and add that, in addition to the physical environment indices based on satellite data mentioned above, we added the GODAS (Global Ocean Data Assimilation System) subsurface maps (model output), the Kamchatka pink salmon index, extended information on seabirds, added the marine mammal strandings index, and collaborated with AOOS and other entities for HABs. We note that other products/ information sources useful in other ecosystems are not viable in the Aleutians; e.g. saildrone and oculus due to the strong currents throughout the archipelago, satellite derived Chla concentration due to poor coverage (see detailed note in the section for Integrated Physical Factors Information). Also, while some partner institutions/ companies, etc. collect data, the data is mostly in raw format and most times still needs to be compiled in a proper dataset and some statistical or GIS analysis to provide useful information. We don't always have the capacity to process these datasets and continue to work on alliances and other interested parties to connect data-collectors with data analysts.

For the Sea Surface Temperature indicator (p.41), it would help if discussion was focused specifically on the Aleutian Islands – there are very broad descriptors – the "regional highlights" in the previous indicator (NPI) would be valuable. Same comment for climate indices and seasonal projections.

We have tried our best in the new Integrated Physical factors Information and welcome any suggestions you might have to improve its usefulness and readability.

The SSC is pleased to see new ecosystem indicators including the size and lifespan of groundfish.

Sadly not this year, as with many other indicators, but we appreciate your enthusiasm and support.

Methods Description 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.