Abbreviated Ecosystem Status Report 2025

GULF OF ALASKA

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QR code for NOAA Alaska Fisheries Science Center's Ecosystem Status Reports webpage[1]. Time series from the report cards are also available[2].

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

[2] https://alaskaesr.psmfc.org

Purpose of the Abbreviated Ecosystem Status Report 2025

This document is intended to provide the North Pacific Fishery Management Council, including its Scientific and Statistical Committee (SSC) and Advisory Panel (AP), with information on ecosystem status and trends as they relate to the Gulf of Alaska Pacific cod and Cook Inlet coho salmon stocks. This information provides context for the SSC's acceptable biological catch (ABC) and overfishing limit (OFL) recommendations, as well as the Council's final total allowable catch (TAC) determination for these stocks.

This 2025 Ecosystem Status Report is an abbreviated version of the annual Gulf of Alaska Ecosystem Status Report. The Report includes ecosystem indicators that reflect the current status and trends of ecosystem components, which range from physical oceanography to biology. Many indicators are based on data collected from NOAA's Alaska Fishery Science Center surveys. All are developed by, and include contributions from, scientists at NOAA, other U.S. federal and state agencies, academic institutions, tribes, nonprofits, and other sources. The Report does not include the full suite of expected contributions and syntheses, due to the lapse in government appropriations in the fall 2025. The ecosystem information in this report will be integrated into the annual harvest recommendations for GOA Pacific cod and Cook Inlet coho salmon through inclusion in stock assessment-specific risk tables (Dorn and Zador, 2020), and relevant presentations to the Council and associated bodies. The SSC is the primary audience for this report, as the final ABCs are determined by the SSC, based on biological and environmental scientific information through the stock assessment and Tier process[3,4]. TACs may be set lower than the ABCs due to biological and socioeconomic information. Thus, this Report may also be presented to the AP and Council to provide ecosystem context to inform TAC as well as other Council decisions.

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

Ecosystem Assessment: The Status of the Gulf of Alaska 2025

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Last updated: January 2026

This Assessment reflects the recognition that the western and eastern GOA ecosystems (divided at 147 °W) have substantial differences (Waite and Mueter, 2013; Mueter et al., 2016). The GOA is characterized by topographical complexity, including islands, deep sea mounts, a continental shelf interrupted by large gullies, and varied and massive coastline features such as Cook Inlet, Prince William Sound, Copper River, and Cross Sound, which bring both freshwater and nutrients into the GOA. The topographical complexity leads to ecological complexity, such that species richness and diversity differ from the western to eastern GOA. Thus, local effects of ecosystem drivers may swamp basin-wide signals. With this in mind, we highlight differences in the ecosystem state for the western and eastern GOA ecoregions in the Report Cards and Assessment.

Summary

The Gulf of Alaska's (GOA) 2025 marine ecosystem was characterized by warm waters at the surface and at depth for much of the year, with signs of reduced lower trophic level production, relative to 2024. Fewer signs of warm water impacts were observed in higher trophic levels. The warm water came from two sources: warm waters in the northwest Pacific transported via strong winter winds from the west onto the shelf, and from upwelled warm waters at the center of the North Pacific subarctic gyre. The La Niña event in the winter of 2024/2025 increased gyre circulation bringing these warm upwelled waters onto the shelf and did not result in the anticipated cooling associated with past La Niña's. The GOA had characteristics of a warm ecosystem (including similarities to 2019, the most recent year dominated by warmer waters), especially within the faster-responding lower trophic levels. Examples of these warm characteristics included a phytoplankton community dominated by smaller-celled organisms indicating less efficient energy transfer, increased biomass of smaller copepods versus larger copepods, increased frequency of harmful algal blooms, and reduced body condition in certain groundfish species and Glacier Bay humpback whales. Numerous indicators reflected a productive system at higher trophic levels, perhaps due to delayed food web impacts, including elevated biomass of lipid-rich euphausiids, continued presence of certain forage fish species (capelin, and Sita and Craig populations

of herring), and above-average seabird reproductive success. In considering similarities to the 2014 – 2016 GOA ecosystem, associated with the decline of the GOA Pacific cod population, similarities exist in bottom temperature and lower trophic level indicators, but these similarities did not occur throughout the ecosystem. Many ecosystem responses to the 2014 – 2016 marine heaywave were only observed to occur in 2015, the second consecutive year of the event (e.g., decline of capelin and herring and seabird die-offs). Sea surface temperatures in the fall of 2025 continued to be above or near the marine heatwave threshold, making the rapid dissipation of heat (especially at depth) less likely. The possibility of a continued response to extended warming in the GOA shelf marine ecosystem in 2026 could include cumulative effects that extend further through the food web.

Gulf of Alaska Shelf 2025

Ocean surface temperatures were warmer than average across the GOA shelf in the winter, spring, and fall at surface and at depth. Surface and shelf bottom water temperatures ranged from 4.8°C (surface)/ 5.4°C (100m) in February in Shelikof Strait, to summer temperatures of 13.5°C (surface) in eastern GOA shelf waters and 5.6°C (∼200m) in GOA shelf waters (Ocean Temperature Synthesis, p.32). Surface temperatures exceeded the marine heatwave threshold for most of Dec. 2024-June 2025 in the western GOA and Dec. 2024-May 2025 in the eastern GOA, cooled in the summer, and then warmed close to or above marine heatwave conditions again from August through November of 2025 (Lemagie and Callahan, p.32).

Two sources of warm water led to the shelf conditions in 2025: warm waters transported via strong winter winds from the northwest Pacific onto the shelf, and upwelled at the center of the North Pacific subarctic gyre (offshore GOA shelf) (where warmer than average waters have remained at depth since 2024) (Lemagie et al., p.18). The transport of the upwelled warm waters on the shelf was supported by enhanced winter and spring counter-clockwise circulation and surface transport in the GOA, as expected during strong Aleutian Low pressure systems (Lemagie et al., p.18). The negative NGAO climate index signified strong upwelling at the center of the subarctic gyre (offshore GOA), and the positive GOADI climate index signified strong coastal downwelling, transporting the warm waters to depth on the shelf (Pages and Hauri, p.56). Winds were often stronger than average (Lemagie et al., p.18), and eddies were stronger along the shelf edge in the regions off Kodiak and Haida Gwaii (Cheng, p.50). The modeled northward surface transport in southeast AK, from the Papa Trajectory Index, ended in the furthest north of the time series, reflecting strong surface transport (Stockhausen, p.53). The 2025 larval survival of slope spawning arrowtooth flounder, Pacific halibut, and rex sole may have increased due to the enhanced transport to preferred coastal habitat.

Indicators of the zooplankton prey base for upper trophic levels in 2025 were mixed but potentially limiting for zooplankton-feeding groundfish (e.g., pollock, Pacific ocean perch, dusky rockfish, northern rockfish, and larval groundfish). The body condition (weight at given length) of adult pollock, Pacific ocean perch, dusky rockfish, and northern rockfish were below average (Prohaska and Rohan, p.130), and krill–eating humpback whales also had poor body condition (Gabriele et al., p.174). However, zooplanktivorous seabird reproductive success in the western (Chowiet Island) and central GOA (Middleton Island) was above average (Seabird Synthesis, p.160), and larval pollock spring condition was relatively good in Shelikof Strait (Porter et al., p.93) indicating adequate prey availability. Catches of spring larval pollock, P. cod, arrowtooth flounder, and P. sandlance were lower than average in the Shelikof Strait region, which could reflect poor environmental conditions or prey availability or both (Rogers et al., p.89). Energy density of juvenile pink, coho, and sockeye salmon was above average, indicating good nutrition in Icy Strait, SE Alaska (Fergusson and Strasburger, p.122). The total spring zooplankton biomass observed in the northern GOA was more than one standard deviation below average, driven by low biomass of large and small copepods but with above average euphausiid biomass (Hopcroft, p.79), whereas above-average biomass of small copepods was observed in the spring in Shelikof Strait (Kimmel et al., p.72). The reduced spring zooplankton prey-base aligns with a spring phytoplankton community dominated by smaller-celled organisms, characteristic of less efficient energy transfer (Hennon p.67), a change from the more diatom-dominated communities of 2021 – 2024.

Prey availability for fish-eating groundfish (e.g., P. cod, sablefish, arrowtooth flounder, yelloweye rockfish) varied by forage species, with potential limitations apparent in Pacific cod and numerous rockfish body condition. Capelin, which are valuable prey for seabirds, marine mammals, and piscivorous groundfish, continue to be present in the GOA after a prolonged population decline after the 2014 - 2016 marine heatwave (Whelan et al., p.96, Siple, p.142). Sitka and Craig herring populations continue to have relatively elevated populations supported by the strong 2016 and 2020 year classes (Hebert et al., p.105). Age-0 pollock, a common prey in western GOA, juvenile salmon in SE Alaska, and P. sandlance had very low abundance in 2025 (Rogers et al., p.89, Strasburger et al., p.118, and Whelan et al., p.96). The aggregate forage community, was abundant enough to support upper trophic levels, as shown by piscivorous, diving seabirds (common murres and tufted puffins) having above-average/average reproductive success across the GOA (Drummond et al., p.160, Whelan et al., p.96), but P. cod and numerous rockfish had below-average body condition (potentially due to limited prey availability). The forage fish community would be a section of the food web to monitor in 2026 if the warm conditions persist, given their aggregate decline in the 2014-2016 marine heatwave event (Arimitsu et al., 2021).

The total preliminary GOA 2025 commercial salmon fishery reported landings returned to moderate levels, following the 4th lowest year of total salmon commercial catch in the GOA in 2024 (Whitehouse, p.115). While higher pink salmon returns added to the increase, as expected in odd years, various metrics of salmon population dynamics and marine survival, including for pink salmon, continued a below-average, multi-year trend. These trends potentially reflect cumulative effects of challenging environmental conditions from the past few years. Catch of juvenile salmon in the Icy Strait (SE Alaska) survey in 2025 continued a below-average trend since the mid-2010s (Strasburger et al., p.118). SE Alaska pink salmon juvenile indices and commercial harvests remained below average in 2025 (Strasburger et al., p.118), and 2025 had the 15th lowest pink salmon returns to Auke Creek since 1980 (Vulstek and Russell, p.126). Length and energy density of juvenile salmon in Icy Str. indicate approximately average to below-average foraging success and predation risk (Fergusson and Strasburger, p.122). CPUE of juvenile coho salmon in Icy Strait, SE Alaska, in the summer continued to be below average for the last 8 years (Strasburger et al., p.118). Preliminary coho ocean age-0 marine survival (percentage of ocean age-0 coho per smolt (escapement only) by smolt year) in Auke Bay, SE Alaska, continued a declining trend and was below average for a 3rd year (Vulstek and Russell, p.126). Preliminary marine survival indices of 2025 coho salmon (ocean age-0 and age-1 harvest plus escapement) in Auke Bay continued to be below average for the 11th year (Vulstek and Russell, p.126). While the environmental causes of these various trends are challenging to pinpoint in these species that spend a number of years in freshwater and marine environments, they signify cumulative environmental stressors, many of which trace back to the mid 2010's, on these ecologically important species.

Looking Ahead to 2026

The large-scale ocean dynamics in the North Pacific Ocean are proving less predictable for GOA shelf conditions in recent years. The National Multi-Modeling Ensemble (NMME) and La Niña conditions for winter 2025/2026 indicate cooling surface temperatures in the winter (Lemagie et al., p.18, Bond et al., p.26). Conversely, the Sitka air temperature index predicts integrated water column temperatures at GAK1 (northern GOA) to be warmer than average in 2026 (Hennon p.28). The past two years (2024, 2025) have had unexpected thermal conditions relative to those predicted based on the ENSO index and the NMME. Given the build-up of heat throughout the water column in the GOA shelf and gyre, there is potential for the system to remain warm in 2026, regardless of cooling pressures. If warm ocean temperatures persist into 2026 (including at depth on the shelf), the ecological response observed in 2025 at lower trophic levels may become apparent further up the food web with cumulative impacts across 2025 and 2026.

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Climate: A mean Aleutian Low pressure system was established in winter, likely associated with advection of warmer air over the Gulf of Alaska from the south, and warm ocean currents from the western North Pacific. In spring, strong eastward and northward wind anomalies persisted, often associated with upwelling in the basin. Over this period, warm temperature anomalies from 100 – 200 m depth at Ocean Station Papa decreased in magnitude. The La Niña event did not coincide with cooler temperatures as expected over the winter of 2025. Seasonal winds were stronger than average, and varied in direction, which can increase the transfer heat between the atmosphere and the ocean, including below the relatively thin surface mixed layer where the ocean mass can store heat at inter-seasonal and inter-annual timescales.

Ocean Temperature: A stronger North Pacific gyre and stronger winds increased upwelling at the center of the gyre (Pages and Hauri in this Report, p.56), which typically brings cooler waters from depth up to the surface and potentially onto the shelf. In the winter of 2025, warmer SST anomalies occured in the offshore waters reflecting the upwelling of warmer waters that had remained at depth since 2024. These warm waters were transported onto the shelf and strong coastal downwelling spread the heat to deeper shelf waters. The warmth at surface and at depth was recorded across the shelf from remote sensing and various surveys from winter, spring, summer and fall (including Shelikof Str. in the winter and spring, Seward Line in the spring, summer, Icy Str in the summer, and the western and eastern GOA shelf in the summer, Temperature Synthesis in this Report, p.32). The GOA experienced prolonged periods in marine heatwave status through the winter, spring, and fall (Lemagie et al., in this Report, p.32). These warm temperatures are predicted to transition to cooler sea surface temperatures across the GOA shelf (National Multi-model Ensemble Model, Bond et al., in this Report, p.26, and result in approximately 0.7 textsuperscriptoC warmer than the mean at GAK1 (near Seward) in the northern GOA (Sitka air temperature prediction, Hennon p.28), in alignment with a fall transition to La Niña conditions.

Ocean Transport: Increased surface transport alongshelf and potentially across shelf transport was reflected in numerous metrics. Strong winds (Lemagie et al., in this Report, p.18) and increased gyre strength (Pages in this Report, p.56) led strong counter-clockwise circulation on the GOA shelf (Stockhausen in this Report, p.53). The increased circulation produced stronger coastal downwelling (Pages in this Report, p.56) and stronger eddies along the slope in the Sitka and Kodiak regions (Cheng in this Report, p.50).

Climate

State of the North Pacific Ocean

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Last updated: September 2025

Overview:
Sea surface temperatures (SST) and sea ice data from the NOAA High-resolution Blended Analysis of Daily SST and Ice (OI SST V2[5]), with 10-m wind data from the NCEP/NCAR Reanalysis II[6] from September 2024 – August 2025 are described across eight regions of the North Pacific Ocean and U.S. Arctic (Figure 1). The SST anomalies are relative to mean conditions over the period of 1991 – 2020. At the writing of the previous Ecosystem Status Report in Autumn 2024, cool conditions associated with La Niña were anticipated to develop over the winter, associated with cool conditions, although La Niña did not fully develop over the tropical Pacific (Figure 2). Storms, particularly in December and February, contributed to a strong mean winter Aleutian low pressure system (Figure 3). Strong mid-latitude winds and mean low pressure centered around Kodiak Island also persisted into the spring.

Ocean surface temperatures were cooler than average in the autumn (Figure 4). For example, over the Bering Sea shelf, this is attributed to a deep mixed layer and near-to-above mean heat content when integrated over the water column. The onset of seasonal winds saw a transition back to warm SST temperature anomalies over most of the North Pacific region as the water column heat was mixed back into the surface layer. Sea ice and SST conditions in winter and spring may be characterized as a competition between cooling influences of strong winds that acted to advance sea ice southward and also to mix and entrain often cooler waters from depth in the surface ocean layer and the warming influences from positive air and subsurface temperature anomalies and enhanced transport of warmer waters from the southern parts of the region. Although the specific mechanisms in this balance varied by region, the processes that retained near-surface ocean heat prevailed and warm temperature anomalies generally persisted over much of the region through the spring, with warmth observed in the SST and in the subsurface ocean. *Western Coastal Gulf of Alaska*. Following the autumn of 2024 where SST was near the historical mean, ocean temperatures along the western coastal Gulf of Alaska were anomalously warm in the winter through spring throughout the surface layer of the water column (Figure 4). The mean wind conditions were favorable for downwelling of warm surface waters in the coastal region and local air temperatures were elevated above the historical mean through May 2025. In June and July strong winds and cooler than average local air temperatures may have contributed to dampening the SST anomalies over the western coastal Gulf of Alaska in early summer, but by August SST was >1°C above the historical mean over most of the coastal Gulf of Alaska.

Eastern Coastal Gulf of Alaska.Warm conditions along the eastern coastal Gulf of Alaska were similar

[5]https://psl.noaa.gov/data
[6]https://psl.noaa.gov/data

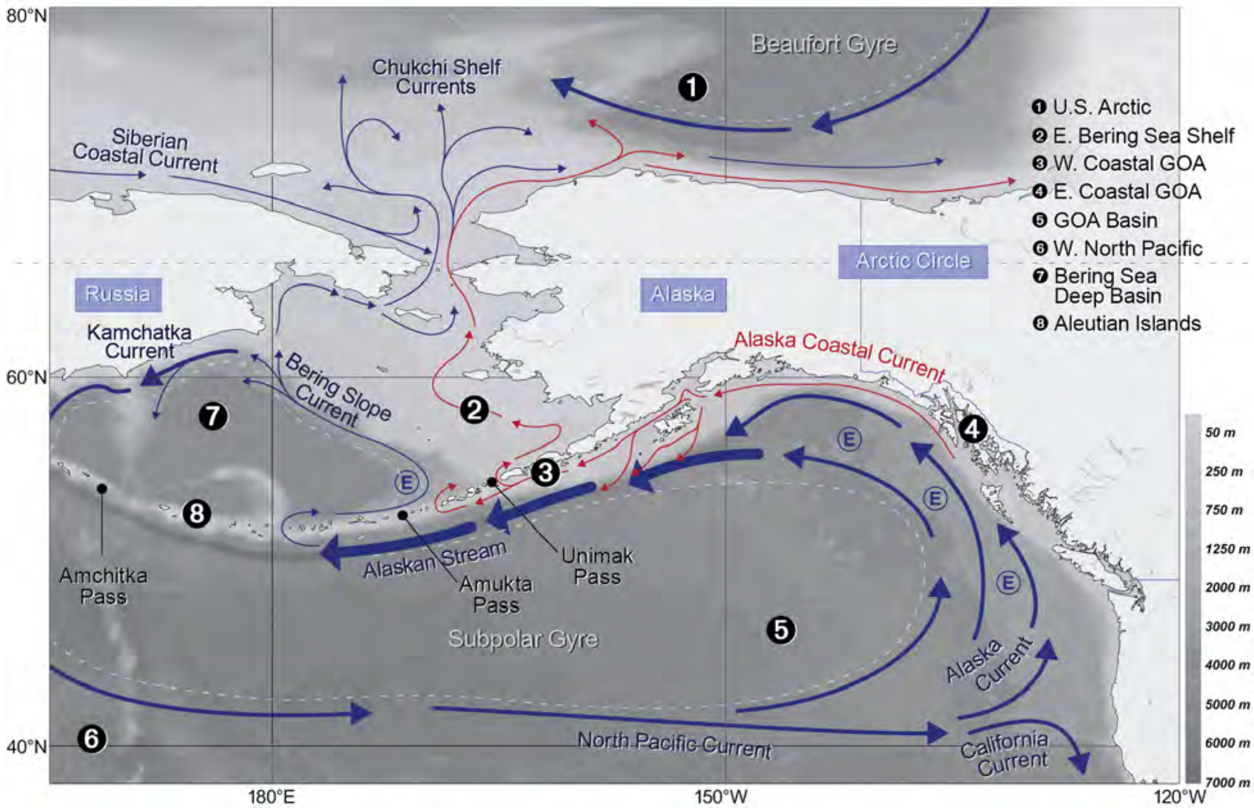

Figure 1: Geographic regions of interest, ocean bathymetry, and mean currents across the North Pacific and U.S. Arctic. Figure courtesy of Sarah Battle, PMEL.

to those along the western coastal region early in 2025 (Figure 4). The mean wind conditions were favorable for downwelling of warm surface waters in the coastal region and local air temperatures were elevated above the historical mean through April. Strong winds and cool air temperatures may have contributed to alleviating the warm SST anomalies in May and June, but by July and August the warm SST developed over the North Pacific and the eastern coastal Gulf of Alaska was no exception.

Gulf of Alaska Basin. The surface temperature anomalies were dynamic over the Gulf of Alaska basin from autumn into the winter of 2024 – 2025 (Figure 4). Seasonal winds were stronger than historical averages, and varied in direction, which can increase the transfer heat between the atmosphere and the ocean–and below the relatively thin surface mixed layer where the ocean mass can store heat at inter-seasonal and inter-annual timescales. A mean Aleutian Low pressure system was established in winter (Figure 3), likely associated with advection of warmer air over the Gulf of Alaska from the south, and warm ocean currents from the western North Pacific. In spring, strong eastward and northward wind anomalies persisted, often associated with upwelling in the basin. Over this period, warm temperature anomalies from 100 – 200 m depth at Ocean Station Papa decreased in magnitude, but not enough to erode the warm anomalies at depth that had persisted since the previous summer (*e.g.*, Figure 5). SST remained near or above historical averages through the summer, reaching up to 2°C above average in August as the winds slackened and seasonal stratification established itself.

Eastern Bering Sea Shelf. Strong summer winds in 2024 had maintained a deep mixed layer, and

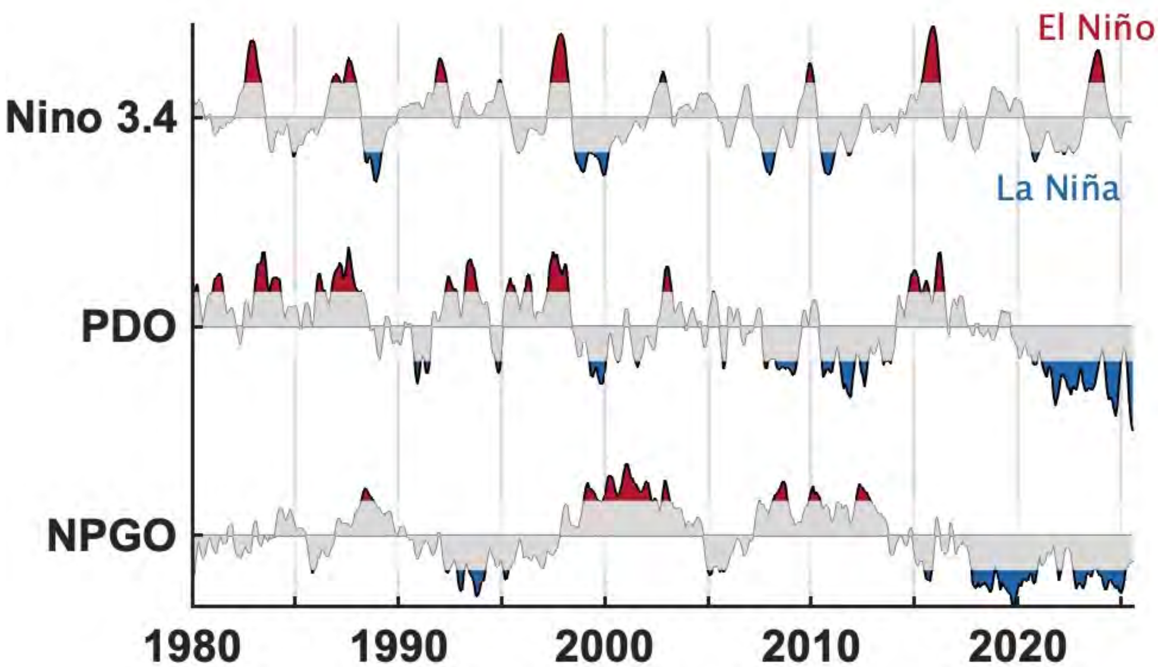

Figure 2: Time series of three commonly used indices for relating patterns across the Alaska marine ecosystem, including the NINO3.4 index for the state of the El Niño/Southern Oscillation, the Pacific Decadal Oscillation (PDO) index, and the North Pacific Gyre Oscillation (NPGO) index, from 1980 to present. Each monthly index is normalized using a 30-year climatology from 1991 – 2020 and smoothed using a 3-month running mean. Red and blue shading indicates positive and negative values outside of one standard deviation, respectively. Lighter shaded areas are within one standard deviation of the 30-year climatology. Additional information on these indices can be found on the NOAA Physical Sciences Laboratory website[7].

correspondingly, cooler than average surface temperatures over the Bering sea shelf which lasted through October 2024 (Figure 4). The onset of seasonal winds mixed the heat content that was retained in the water column. Seasonal sea ice advance was a competition between the acceleration driven by winds from the north and melting over the anomalously warm waters. There were also reversals due to strong winds from the south and east, notably in mid-December and mid-February. South and east wind anomalies over the shelf can both drive the sea ice directly, and enhance northward oceanic heat advection onto the shelf via Ekman transport. This balance between ocean and atmospheric forces also characterized the spring over the eastern Bering sea shelf, as the warm SST anomalies persisted south of the ice edge and winds from the north maintained the ice extent at around 60°N. The seasonal ice retreat and wind anomalies from the west along the Aleutian Islands in May and June, 2025, helped contribute to a return to cool or near-normal SST over the shelf going into the summer.

Aleutian Islands. In autumn 2024, warm SST anomalies >3°C dominated the western north Pacific south of the Aletuain Islands, centered around 40 – 45°N. Strong subsurface warming has persisted over the central North Pacific Ocean since 2020, captured by ocean indices such as the PDO and marine heatwave statistics (Figure 2 and Lemagie and Callahan, p.32). While the greatest magnitude anomalies remained south of the Aleutian Islands, warm SST anomalies of up to 1°C persisted over the region into the summer of 2025. This heat persisted despite strong winds, which can deepen the mixed layer and entrain cooler waters towards the surface, which could be contributed by ocean-atmosphere heat fluxes, cumulative storage of heat at depth, and anomalous ocean currents.

Status and trends:
The anomalously warm sea surface temperatures over much of the North Pacific since autumn 2024 was particularly prominent in strength and extent by July and August 2025 (Figure 3). Above-average seasonal SST anomalies extending over most of the mid-latitude Western Pacific, with peak magnitudes above 2°C, have persisted since the winter of 2019 – 2020, a pattern that is represented by the negative PDO index over the last 6 years (Figure 2). Despite warm anomalies expanding into the coastal eastern Pacific throughout the summer, the equatorial Pacific has remained in an ENSO-neutral state in 2025 as of September.

The mean atmospheric conditions over the winter of 2024 – 2025 were similar to the previous 5 years. Indicators of the mean winter sea level pressure over the North Pacific indicate a moderately strong Aleutian Low, whether integrated from November through March, or only in January and February when the pressure system is most consistently developed (e.g., NPI and AL indices, Figure 6). The center of the mean Aleutian low pressure was located south of 51°N, so its longitude was not registered by the AL_{lon} index this past winter. In the spring, the development of a strong North Pacific high pressure and a mean low pressure centered around Kodiak Island resulted in unseasonably strong winds over the Gulf of Alaska and Bering Sea (Figure 3). Through the summer, the persistence of the mean high pressure over the North Pacific was also associated with anomalous eastward winds over the North Pacific between 40 – 50°N and towards the northeast over the southern Bering Sea.

The Aleutian Low Index (ALI; Figure 6) is based on the areas where sea level pressure (SLP) is less than or equals to 1000hPa in the North Pacific region (40 – 60°N, and 160E – 160°W). Aleutian Low is a statistical low, which exists in winter only. Details can be found in Wang and Lemagie (2024)). The Aleutian low is a key driver of the Pacific storm track and cyclones that form in the North Pacific tend to follow the path of the Aleutian low. The position and strength of the low determine whether these cyclones move northward into the Bering Sea or remain in the mid-latitudes. A strong Aleutian low brings more storms - stronger winds - to the Bering Sea, leading to increased precipitation. The Aleutian Low during the past winter was positioned farther south than its usual location, resulting in more storms affecting the North American continent instead of the Bering Sea.

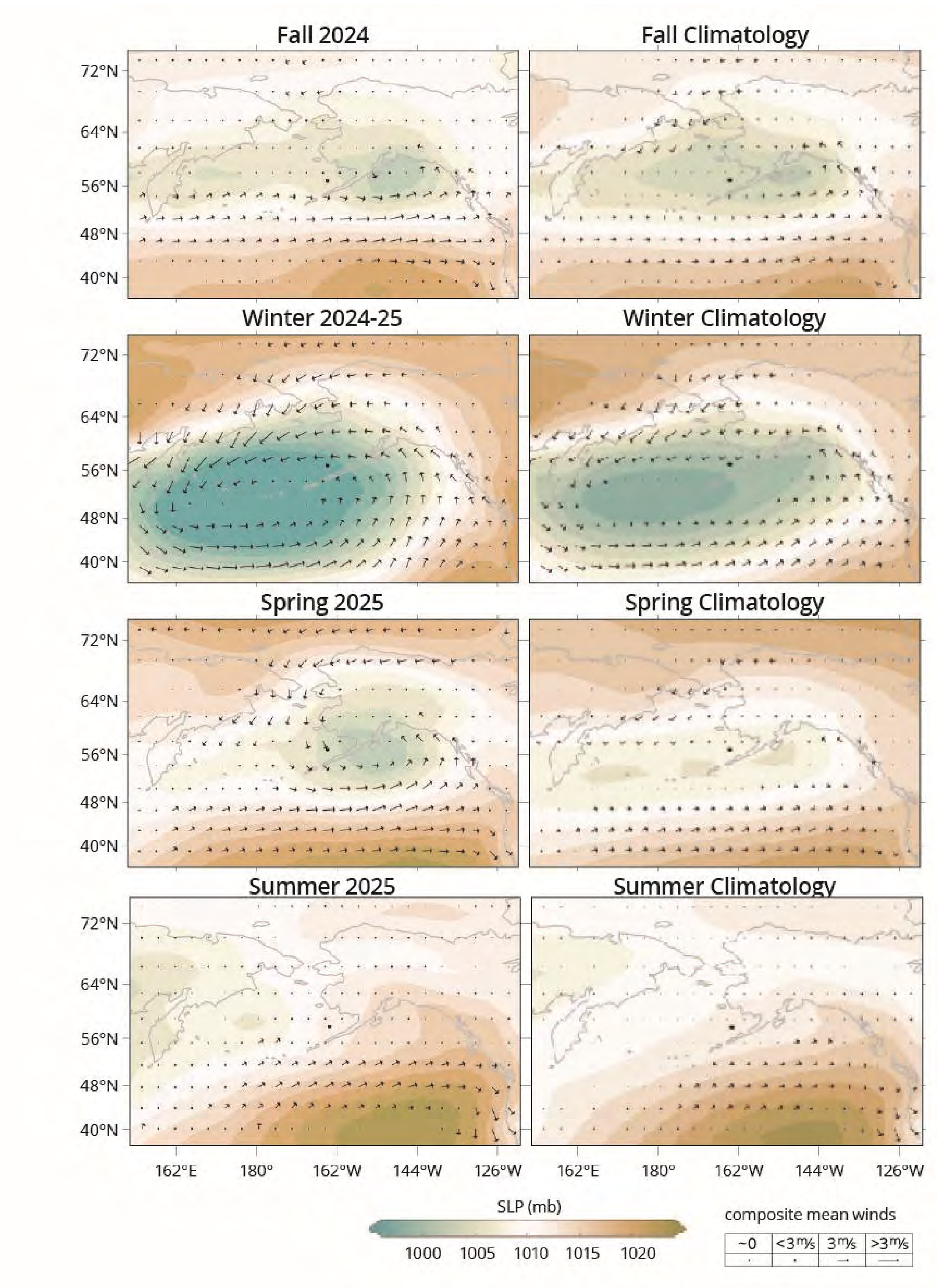

Figure 3: On the left, Seasonal SLP and mean winds for autumn (Sep–Nov 2024), winter (Dec 2024–Feb 2025), spring (Mar–May 2025), and summer (Jun–Aug 2025). On the right, climatologies of seasonal mean SLP and wind calculated from 1991 – 2020. Data are from the NCEP/NCAR Reanalysis II; both are available from NOAA's Physical Sciences Laboratory.

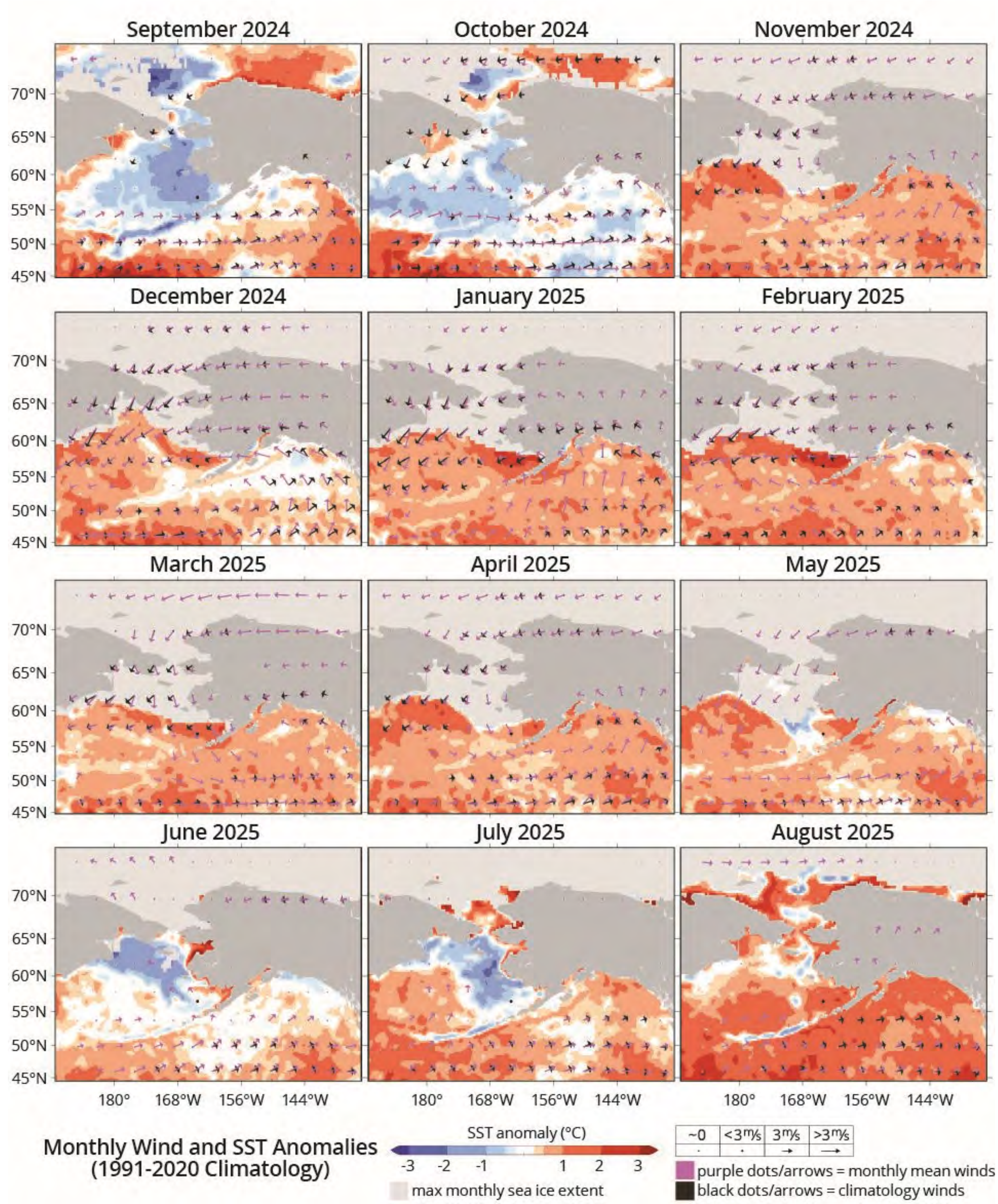

Figure 4: Monthly mean maps of sea surface temperature (SST) anomalies and surface winds. Monthly climatological winds (black) are compared to monthly mean winds (purple). The climatological period is from 1991 – 2020. SST data are from the NOAA High-resolution Blended Analysis of Daily SST and Ice (OISST), and 10-m wind data are from the NCEP/NCAR Reanalysis II; both are available from NOAA's Physical Sciences Laboratory. Figure courtesy of Sarah Battle, PMEL.

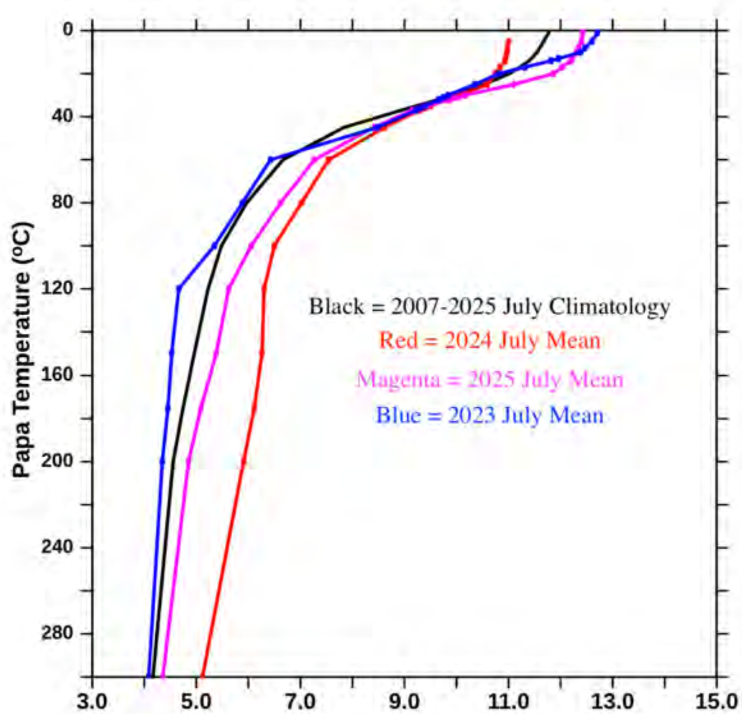

Figure 5: Subsurface temperatures in the North Pacific from the long time series measurements of ocean climate station Papa (50.1°N, 144.9°W). The July monthly climatology is shown in black, compared to July mean temperatures from 2023 (blue), 2024 (red), and 2025 (magenta). Figure courtesy of Dongxiao Zhang, UW/PMEL.

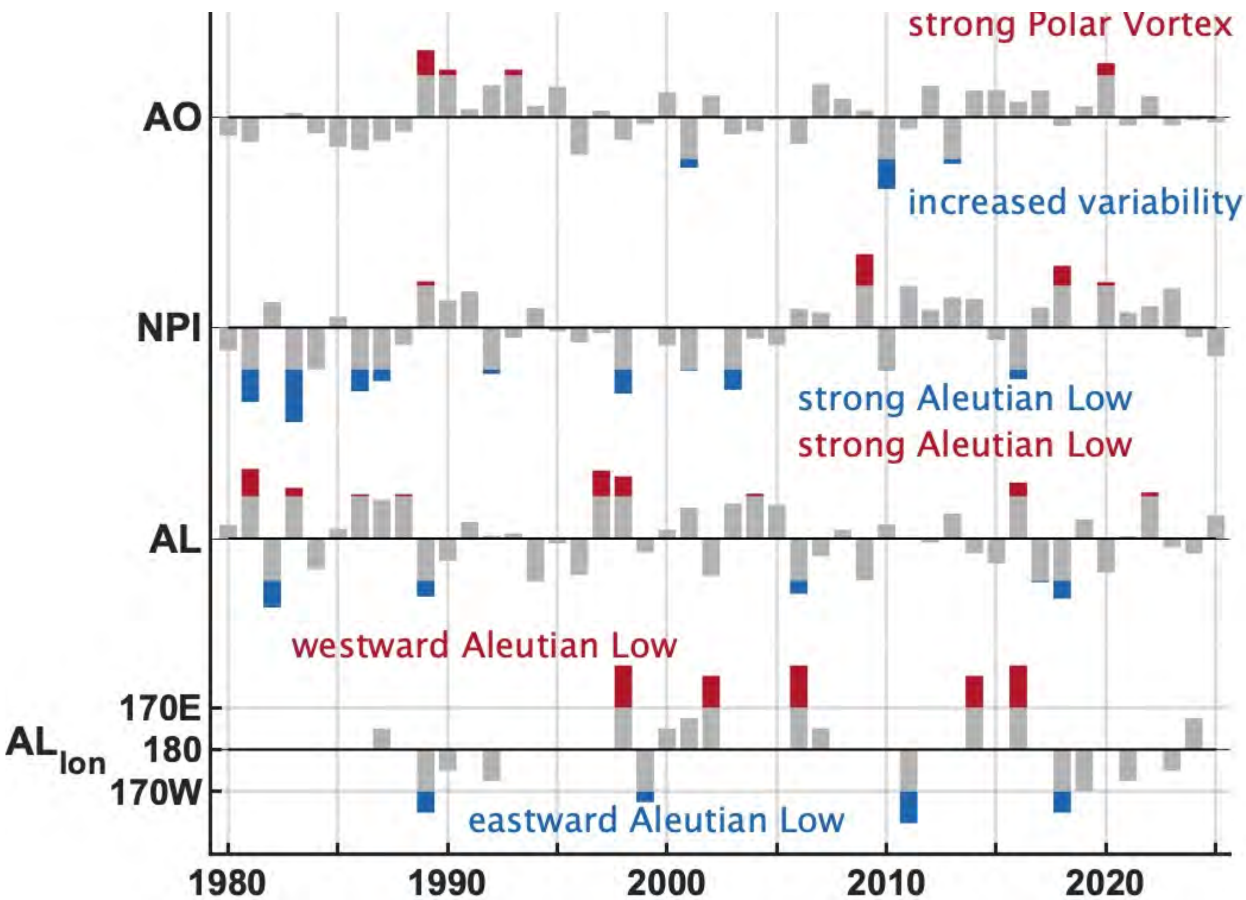

Figure 6: Time series of four indices for relating atmospheric patterns across the Alaska marine ecosystem, including the Arctic Oscillation (AO), North Pacific Index (NPI), Aleutian Low index (AL), and Aleutian Low center longitude (AL_{lon}) from 1980 to present. The AO and NPI indices are averaged over the winter period from November to March, while the two Aleutian Low indices are calculated as averaged over the months of January and February. The NPI and AL are normalized using a 30-year climatology from 1991 – 2020. Red and blue shading indicates positive and negative values, respectively, outside of a threshold value (AO $= \pm 1$, $AL_{lon} = \pm 170°$) or of one standard deviation from the mean (NPI and AL). Additional information on these indices can be found on the NOAA Physical Sciences Laboratory website[8].

Seasonal Projections from the National Multi-Model Ensemble (NMME)

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Description of indicator: The climate prediction center/ NCEP provides monthly statements on the recent evolution, status and prediction of El Niño Southern Oscillation (ENSO)[9]. La Niña conditions emerged in September 2025, and are currently present and favored to persist through December 2025 - February 2026, with a transition to ENSO-neutral likely in January-March 2026 (55% chance as of October 27, 2025)[10]. Equatorial sea surface temperatures (SSTs) are mostly below average across most of the Pacific Ocean. Atmospheric anomalies over the tropical Pacific Ocean are consistent with La Niña. The North American Multi-Model Ensemble is also in agreement, and La Niña is expected to remain weak. A weak La Niña would be less likely to result in conventional winter impacts.

Seasonal predictions of SST anomalies from the National Multi-Model Ensemble (NMME) are shown in Figure 7. An ensemble approach incorporating different models is particularly appropriate for seasonal and interannual predictions. 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 predictions of other variables, are available at the NCEP website[11].

There is a strong contrast between the cold La Niña in the tropics and the much warmer North Pacific (Figure 7). This combination is not often seen in the past, with similar conditions observed in 2022, 2020, 2013 and 1993[12]. It turns out that the North Pacific is warming at a greater rate than most of the rest of world's mid-latitude regions; the mechanisms and implications of these changes, including a negative state of the PDO, are attracting the attention of the climate community (e.g., Klavans et al., 2025).

The one month lead NMME forecast for November-December-January shows positive temperature anomalies averaging 0.5°C expected though most of the Bering Sea, with anomalies of up to 1°C in the western Aleutians and south of the south of the central and eastern Aleutians. During January through March 2026 (three month lead forecast), both the central/western Aleutian Islands and central Bering Sea basin are expected to warm up, with positive temperature anomalies of 1°C. Continued and increasing warm anomalies of 1°C extending through most of the Bering Sea Basin are predicted for March through April. Near normal SST values are expected in the southeast Bering Sea shelf from

[9] https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf
[10] https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.shtml
[11] https://www.cpc.ncep.noaa.gov/products/NMME/seasanom.shtml
[12] https://www.severe-weather.eu/long-range-2/winter-2025-2026-outlook-colder-season-forecast-for-united-states-canada-europe-fa/

January onwards. Most of the Gulf of Alaska is expected to remain close to mean temperatures during this entire period (November - April) except for the westernmost area of the Gulf of Alaska where warm anomalies averaging 0.5°C are expected November 2025 to January 2026.

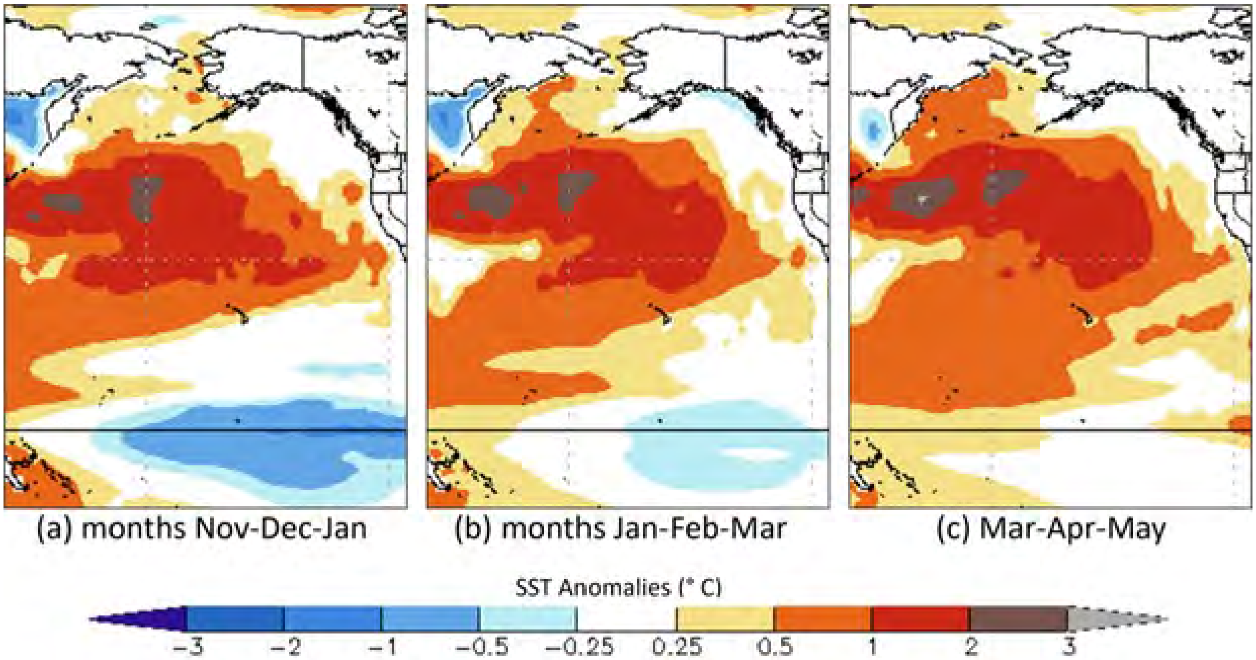

Figure 7: Predicted SST anomalies from the NMME model for Nov–Dec–Jan (1-month lead) for the 2025 – 2026 season, Jan–Feb–Mar (3-month lead), and Mar–Apr–May (5-month lead) 2026.

Predicted Ocean Temperatures in Northern Gulf of Alaska

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Last updated: October 2025

Description of indicator: Air temperatures in Sitka, AK are dominated by the marine climate. Danielson et al. (2022) found Sitka air temperatures had a weak but significant predictive power for integral coastal water column temperatures in the following year at the nearshore station (GAK1) of the Seward Line Transect, in northern GOA ($r^2 = 0.37$, $p < 0.05$). This predictive power can be explained by Sitka's 'upstream' location of GAK1 along the Alaska Coastal Current. Records of Sitka air temperatures exist since 1850 and GAK1 has recorded ocean temperatures since 1970. The anomalies for both GAK1 oceanic temperature and Sitka air temperature are seasonally adjusted, and relative to the long-term average (1970-present for GAK1).

Status and Trends: The 2026 integrated water column temperatures for the nearshore GAK1 station of the Seward Line transect are predicted to be warmer than average based on 2025 Sitka air temperatures. The average Sitka air temperature through August 12th, 2025 was ∼1.1 °C warmer than the long-term average (Figure 8). If the anomalies observed through 2025 persist (i.e., Sitka air temperatures in Sep. to Dec. remain ∼1.1 °C above seasonal averages), we could expect whole water column GAK1 temperatures in 2026 to be $\sim 0.7 \pm 0.5$ °C above average (Figure 9). The GAK1 full water column depth-averaged temperature is 6.24 °C for the period of record. Based on the anomalies observed thus far through 2025, GAK1 integrated ocean temperatures (± 1SD) are predicted to range from 6.5 to 7.5 °C (centered on 7.0 °C).

Factors influencing observed trends: Both Sitka air temperature and GAK1 water temperature are impacted, in part, by large scale climate systems. Detrended (decadal trend removed) Sitka air temperature anomalies are positively correlated with the Multivariate ENSO Index (MEI) and Pacific Decadal Oscillation (PDO) ($p > 0.001$ for both) (Figure 10). While there is a tighter correlation between detrended Sitka air temperature anomalies and PDO, there is a marked departure within the last several years, where an extended negative state of PDO has also coincided with relatively warm air temperatures. The long-term trend is for more than a 1-degree change in the mean over the 50 years

Implications: Warm surface waters in the GOA are generally associated with earlier peak spring phytoplankton blooms, earlier Pacific cod hatch timing (Laurel et al., 2023), and a change in the zooplankton community. The duration and intensity of warming can have cascading effects across the trophic levels of the marine food web.

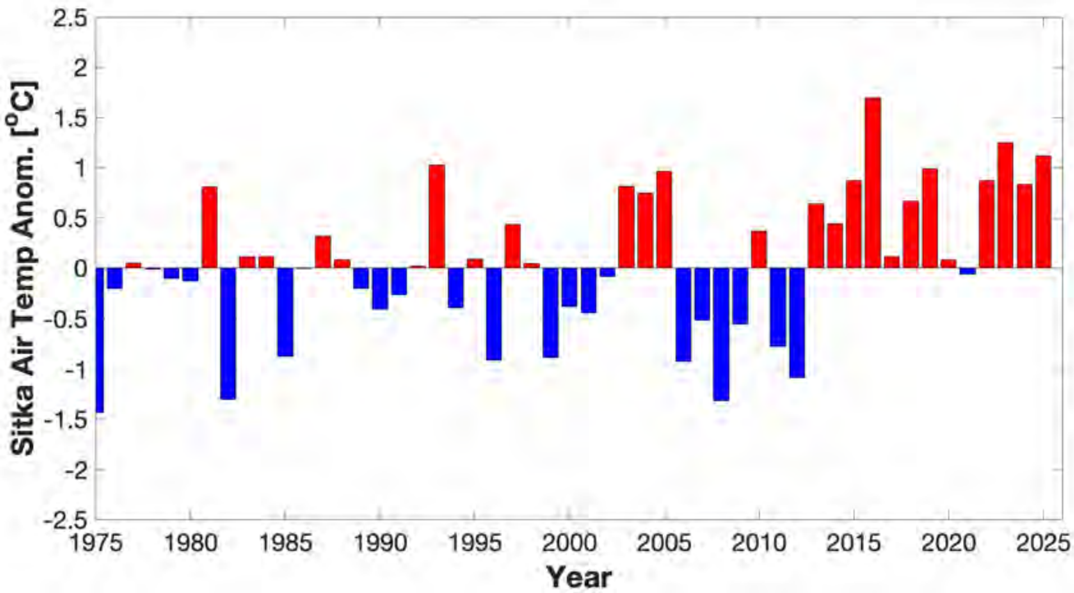

Figure 8: Annual averages of monthly temperature anomalies (seasonal climatology removed) Sitka, Alaska air temperature (entire record is 1828 – 2025; figure shows 1975 to present). Records are shown relative to a 50-year baseline computed over 1970 – 2025, updated from Danielson et al. (2022).

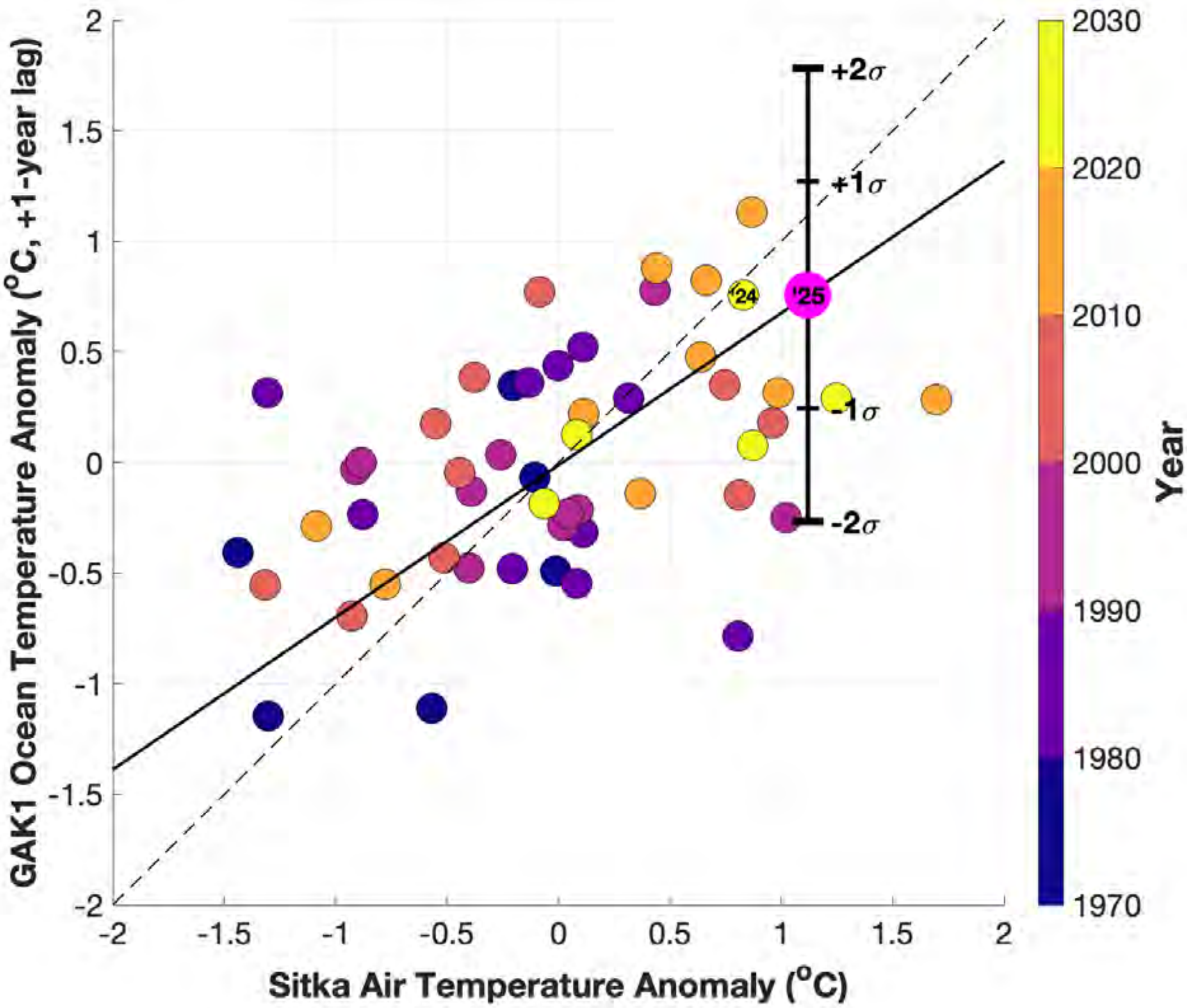

Figure 9: Relationship between the detrended annual Sitka air temperature anomaly (x axis) and the following-year whole water column ocean average temperature anomaly measured at station GAK1 (y axis), with a +1 year lag compared to Sitka. Dashed black line shows a 1:1 slope and the solid black line is the least squares best fit line between the two records. Both anomalies are referenced to the average temperature from the early 1970s to present (1971 for GAK1, 1973 for Sitka air). The blue to yellow dots show each yearly comparison between Sitka air anomaly and the next year's GAK1 anomaly. The pink dot shows the 2025 air temperature anomaly (through August 12th, 2025). The error bars show one and two standard deviations of variability from the trend line (solid black line, the dashed line is 1:1), for bounds on the expected water temperature at GAK1 in 2026.

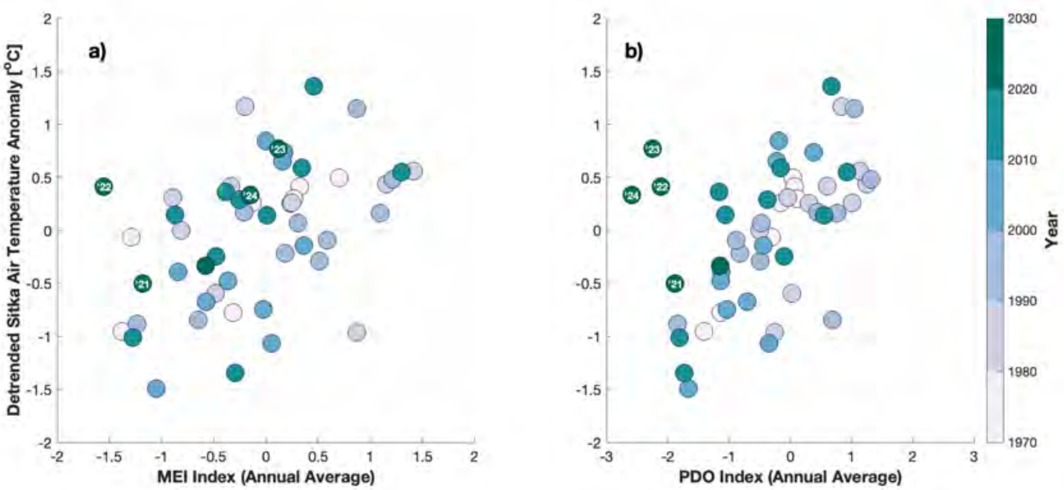

Figure 10: a) The relationship between the detrended (decadal trend removed) annual anomalies of Sitka air temperature and the annually-averaged MEI index (a) and the Pacific Decadal Oscillation (b). Color shows the decade of comparison, with recent years labelled.

Ocean Temperature: *Synthesis

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Last updated: September 2025

Description of indicator: Ocean temperature can vary sub-regionally, due to differences in circulation, freshwater runoff, wind-driven mixing, and other oceanographic drivers (Bograd et al., 2005). Local temperatures can influence survival or condition of critical life history periods of certain species, such as salmon in the inside waters of southeast Alaska. Year-to-year changes in temperatures can influence physiological processes of fish (e.g., metabolic rates and growth rates), fish distribution (Yang et al., 2019), trophic interactions, availability of spawning habitat (Laurel and Rogers, 2020), and energetic value of prey (Von Biela et al., 2019). Extended periods of elevated SST for greater than 5 consecutive days are defined as marine heat waves (MHWs), which can drastically influence ecosystem dynamics (Bond et al., 2015; Hobday et al., 2016). Sea surface temperature (SST) is a foundational characteristic of the marine environment and temperature dynamics impact many biological processes. Extended periods of increased SST can drastically influence ecosystem dynamics (Bond et al., 2015; Hobday et al., 2016).

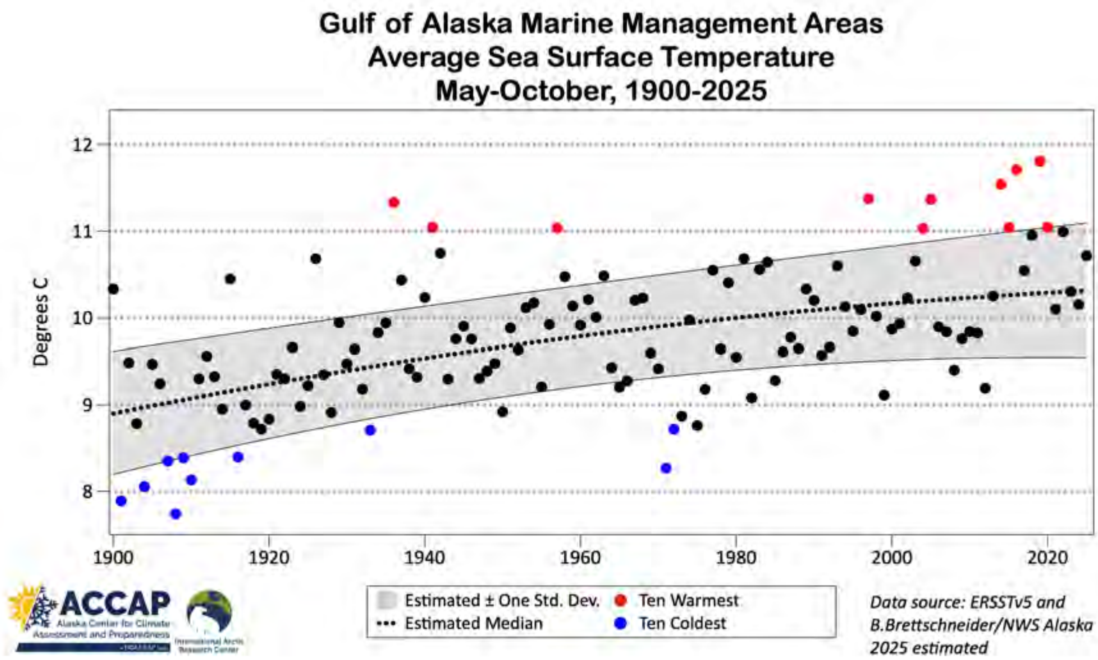
In recent years, warm water events have become so frequent in the world's oceans that a new method for describing them has been formalized. We consider marine heatwaves (MHWs) to occur when SST exceeds a particular threshold for five or more days. That threshold is the 90 th percentile of temperatures 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 90 th percentile threshold for a given day and the baseline temperature for that day. If the threshold is exceeded, the event is considered *moderate*, *strong* (2 times the difference between then threshold and normal), *severe* (3 times the difference between the threshold and normal), or *extreme* ($\leq$ 4 times the difference) (Hobday et al., 2018).This section presents a collection of empirically collected temperature measurements from 2021 spring and summer surveys.

In this section we describe trends in ocean temperature at surface and at depth throughout the GOA. We first show 2025 GOA sea surface temperatures (averaged across the shelf) in context of long-term trends (1900-present) using NOAA's Extended Reconstructed SST V5 data[13]. We then present satellite-derived sea surface temperatures for 2025, averaged across the western GOA and eastern GOA shelf. This is followed by a description of trends observed across multiple GOA sub-regional surveys conducted in the winter, spring, and summer of 2025. We then show observations related to marine heatwave conditions. Detailed methods are listed at the end of the contribution.

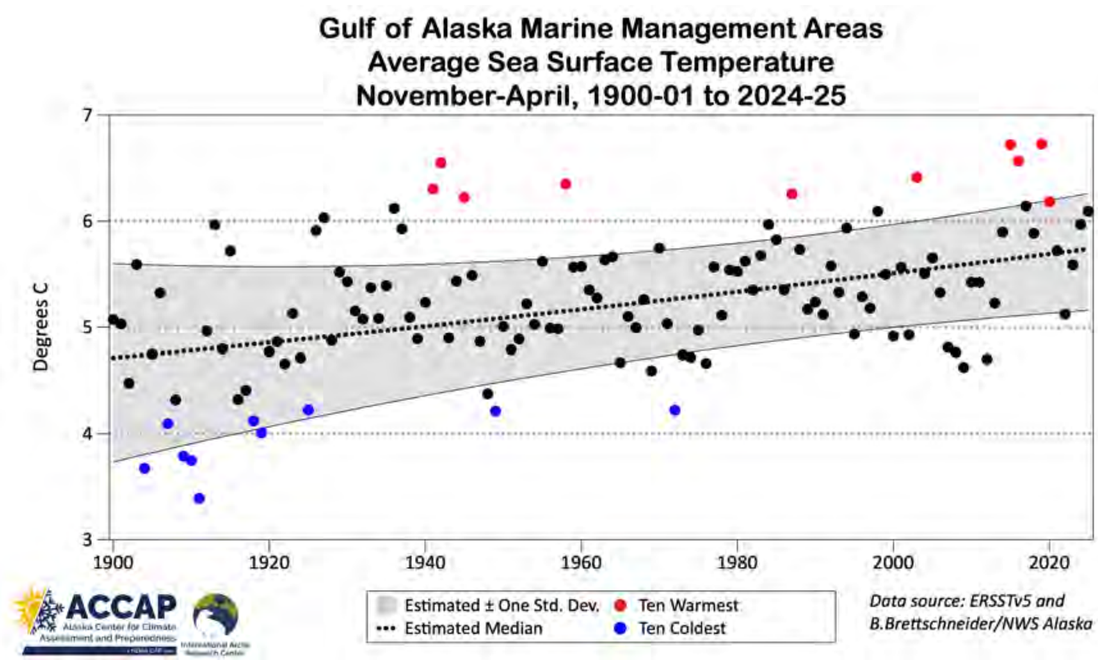
Status and trends:

Long-term sea surface temperatures (1900 – 2025): Summer (May - Oct.) sea surface temperatures (Figure 11) over the GOA shelf (10 m - 200 m) were warmer than the long-term median (1900 – 2024). It should be noted the May-Oct 2024 mean SST was estimated by using the observed May-August temps and then assuming Sept. and Oct. sea surface temperatures will be at the 1991–2020 mean. Sept. and Oct. sea surface temperatures were warmer than average likely causing this result to be an underestimate. The overall trend in summer temperatures show a warming during the first decades of the 20 th century followed by an extended period of little long-term trend, with substantial warming resuming in the late 1990s. In contrast, Winter (Nov.- April) temperatures show much less warming over the past 123 years. However, the past winter's (Nov. 2024 – April 2025) SST was among the warmest 15 winters in this time series.

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



(a) Summer (May - Oct.)



(b) Winter (Nov. - April)

Figure 11: Sea surface temperatures for the Gulf of Alaska from 1900 – 2025 for (a) summer (May-Oct.) and (b) winter (Nov.-April). Presented here are the quantiles representing $\pm$ 1 standard deviation of a Gaussian distribution and for completeness the median calculated using constrained B-Spline regression.

Winter 2025: Satellite-derived surface water temperatures fro winter 2025 were warmer than winter 2024 in the western GOA and similar to 2024 in the eastern GOA in 2024, both above average (baseline:

1985 – 2014) (Figure 12). At a smaller regional scale, observed temperatures were warmer than survey-specific average including at the surface (4.78 ±0.39°C; baseline 1980 – 2024) and aroud 100m (5.44 ± 0.33°C; baseline 2001 – 2024) temperatures were slightly below the long-term means of these time series (3.54 °C and 4.23 °C, respectively) for the acoustic-trawl survey of Shelikof Strait (Figure 13). The absolute difference between surface and deep temperatures measured in this survey have increased in recent years (since 2016).

Spring 2025: In the western GOA, relatively warm surface (1 – 5 m) and deep (100 – 150 m) water temperatures extended from the Shumagin Islands to the Shelikof Strait, intensifying in the shallower shelf waters northeast of Kodiak Island (Figures 14, 16). Average temperatures in NOAA's EcoFOCI surveyed area reached 7.25°C (± 0.02°C) at the surface and 5.86°C (± 0.01°C) at depth, indicating that conditions were comparable to the notably warm years of 2015 and 2019, which were approximately 2-3°C above the long-term mean. These warm anomalies mark a sharp contrast to the relatively average or cooler spring conditions observed in 2013, 2021, and 2023. Satellite-derived surface spring temperatures showed the warm winter waters persisted above-average through approximately June in the western GOA and May in the eastern GOA (baseline: 1985 – 2014; Figure 12).

Summer 2025: The summer surface waters in the western and eastern GOA cooled to approimately average in June, July, and early August, as observed by the NOAA Bottom trawl survey (baseline: 1990 – 2024) and satellite data (baseline: 1985 – 2014) (Figures 15, 12). The heat at depth on the shelf remained above-average, persisting from the winter and spring (Figure 15).

Fall 2025: Sea surface temperatures observed via satellite data warmed to above-average temperatures in late August and the heat persisted through the end of November (Figures 15, 12).

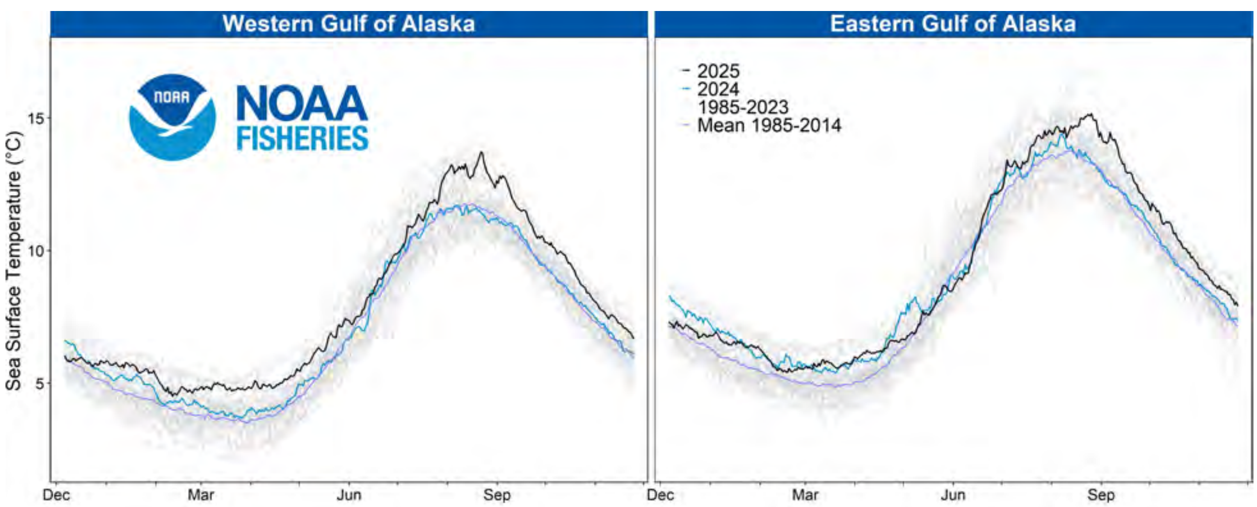


Figure 12: Daily sea surface temperatures (SST) for the western GOA and eastern GOA. Lines illustrate the daily SST for 2025 through December 2 (black), the daily SST for 2024 (blue), the 30-year (1985 – 2014) mean SST for each day (purple), and daily SST for each year of the time series (1985 – 2023; gray). Details are in the "Methods" section at the end of this contribution.

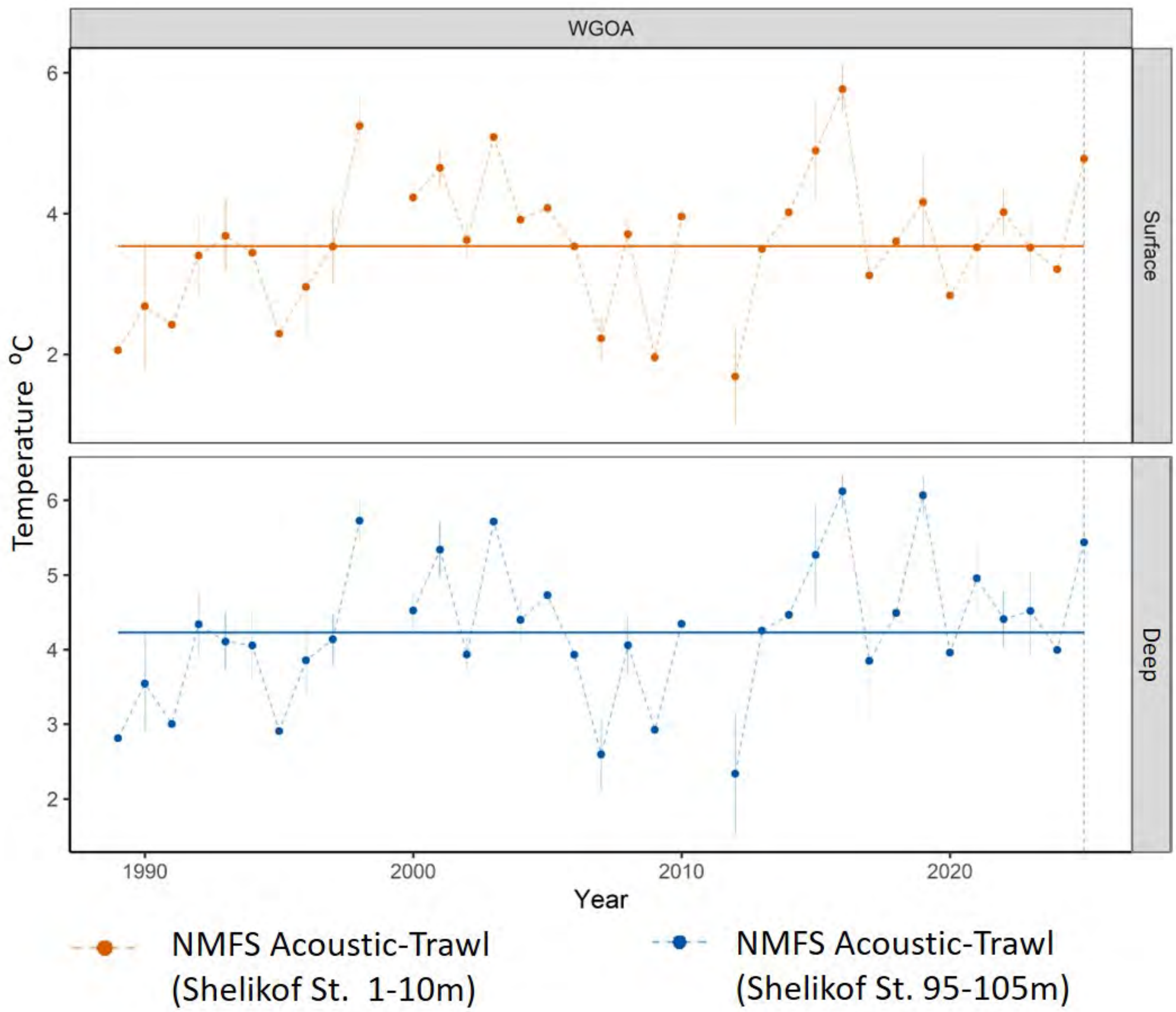


Figure 13: Average winter 'surface' (1 – 10 m) and 'deep' (95 – 105 m; blue) temperature (°C) at trawl locations during acoustic-trawl surveys of Shelikof Strait from 1980 (surface) and 2001 (depth) to 2025. Error bars indicate 1 standard deviation. The dashed vertical line are current year measurements. Details are in the "Methods" section at the end of this contribution.

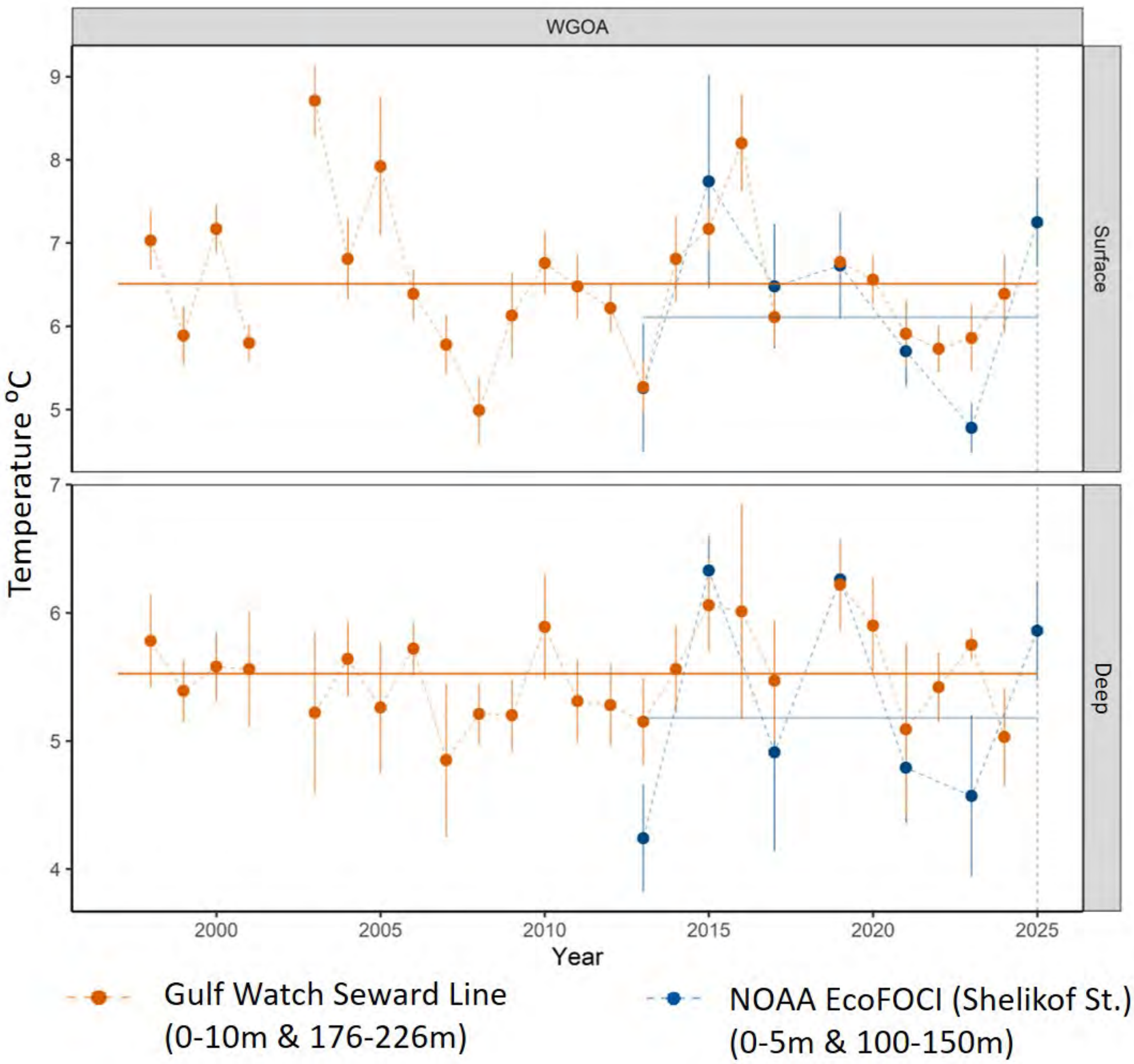


Figure 14: Observed spring temperatures at surface and depth from the AFSC EcoFOCI spring (May-June, alternating years) larval survey and the Gulfwatch Alaska spring (May) Seward Line survey. The vertical dashed line are current year measurements. Multiple surveys are shown to reflect commonalities or differences in trends, primarily due to temporal and spatial coverage. Survey details are in the "Methods" section at the end of this contribution.

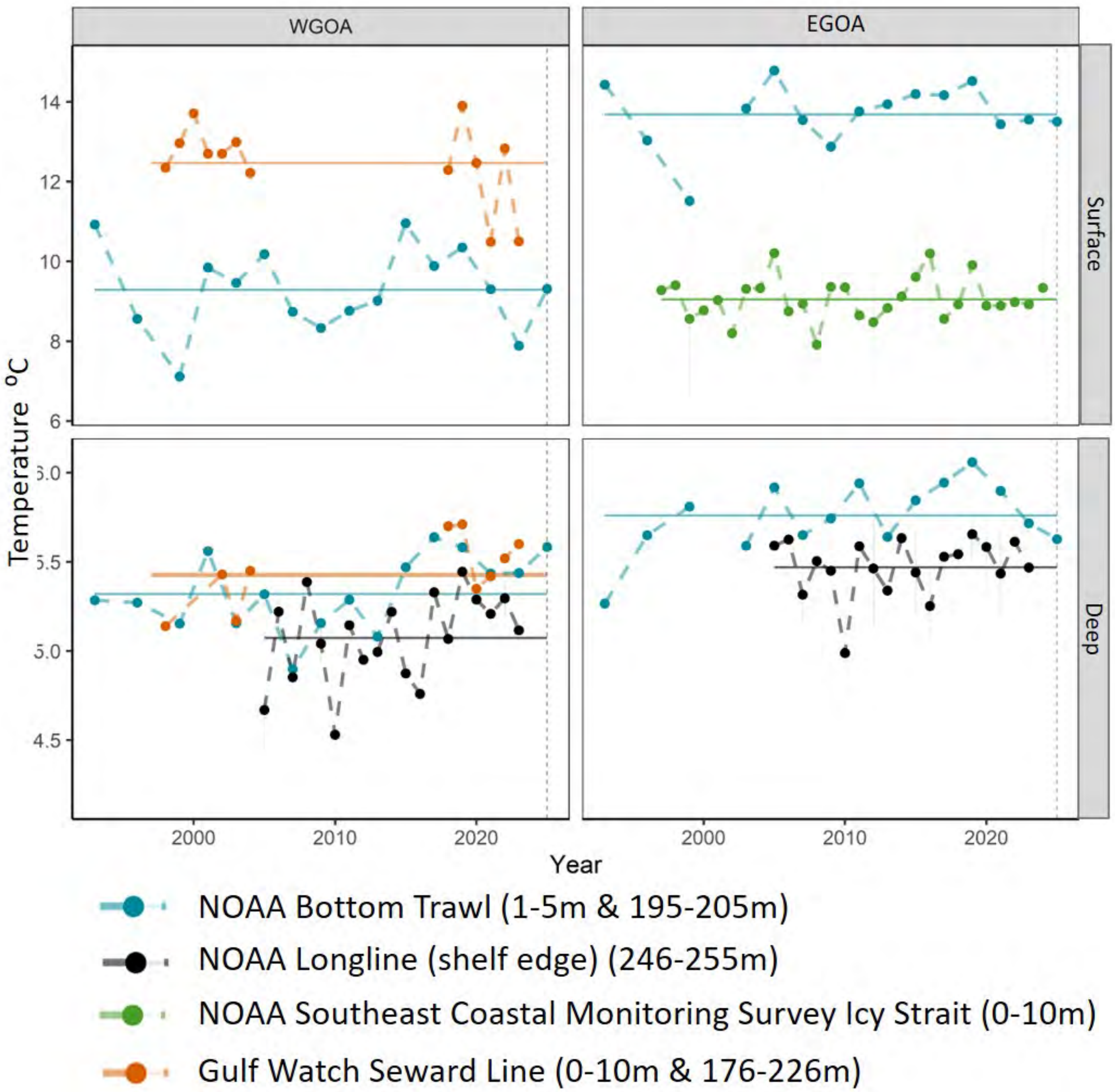


Figure 15: Observed summer temperatures at surface and depth from the AFSC Bottom Trawl Survey (alternating years, May - Sep.), AFSC Longline Survey (western GOA: June, eastern GOA: August), AFSC Southeast Alaska Coastal Monitoring (SECM Survey; May - Aug.), ADF&G Large Mesh Trawl Survey (Jun./Jul.), and the Gulfwatch Alaska summer(July) Seward Line survey. Multiple surveys are shown to reflect commonalities or differences in trends, primarily due to temporal and spatial coverage. The vertical dashed line are current year measurements. Survey details are in the "Methods" section at the end of this contribution.

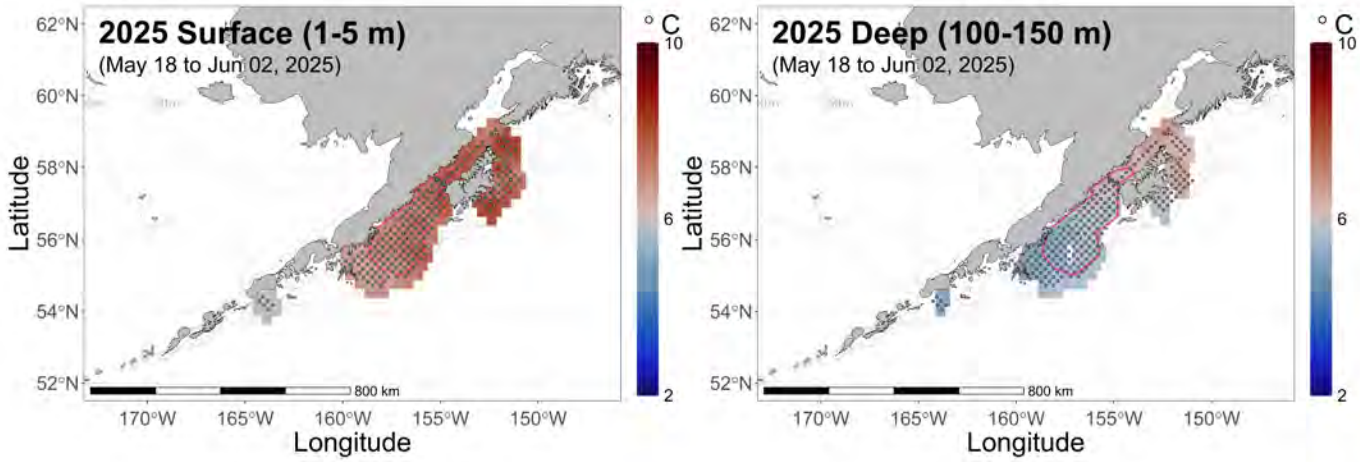


Figure 16: Observed surface (1–5 m) and deep (100–150 m) temperatures measured during the spring EcoFOCI GOA survey from May 18-June 2, 2025. Red polygon delineates the "core" region, where sampling was most consistent across the time series. Survey details are in the "Methods" section at the end of this contribution.

Marine Heat Waves: The western GOA surface temperatures were at or near marine heatwave status for most of the winter, spring, and fall of 2025. The eastern GOA surface temperatures were at or near marine heatwave status for most of the winter, early spring, and fall (Figures 17 and 18). The number of days in heatwave status was similar to 2014 and 2020 in the western GOA, although this value is underestimated as the figure ends in Sept 2025 and does not include the warm fall (Figure 18). The number of marine heatwave days in the eastern GOA was similar to 2024 and 2022, although also considered an understimate as the fall was not included in this estimation (Figure 18). An important ecological consideration with marine heatwaves is the extent of a particular area that experiences the warm conditions, and whether there may be thermal refugia for species within that domain. Large periods of the spring 2025 had $>$ 50% of the satellite pixels (5 km grid) in the western GOA experiencing a marine heatwave. This eastern GOA, had shorter periods of time time in which marine heatwaves exceeded $>$ 50% of the area (Figure 19).

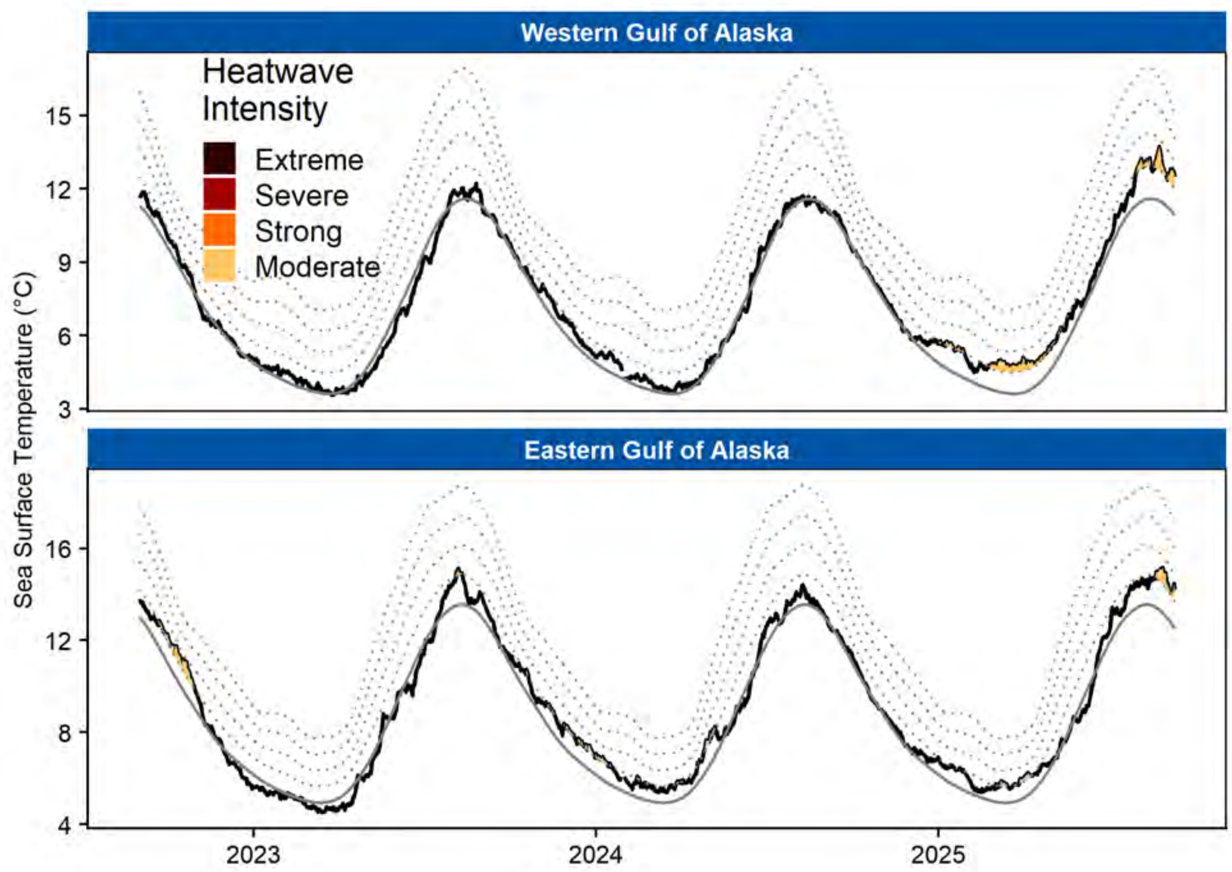


Figure 17: Marine heatwave (MHW) status from Sep. 2020 through Sept. 2025. Filled (yellow) areas depict MHW events. Black lines represent the 30-year baseline (smoothed line; 1985 – 2014.) and observed daily sea surface temperatures (jagged line). Faint gray dotted lines illustrate the MHW severity thresholds in increasing order: if the threshold is exceeded, the event is considered *moderate*, *strong* (2 times the difference between then threshold and normal), *severe* (3 times the difference between the threshold and normal), or *extreme* ($\leq$ 4 times the difference) (Hobday et al., 2018).

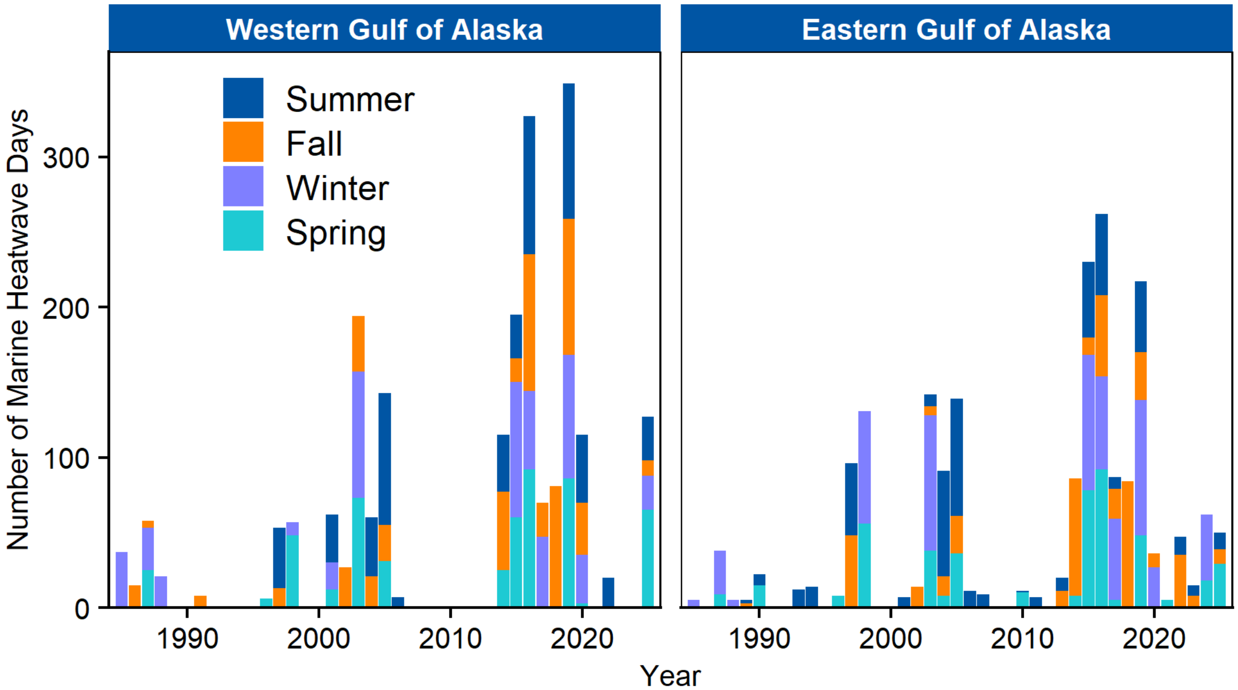


Figure 18: Number of days during which marine heatwave conditions persisted in a given year, through September, 2025. Seasons are summer (Jun. - Aug.), fall (Sept. - Nov.), winter (Dec. - Feb.), spring (Mar. - Jun.). Years are shifted to include complete seasons so December of a calendar year is grouped with the following year to aggregate winter data (e.g., Dec. 2021 occurs with winter of 2022).

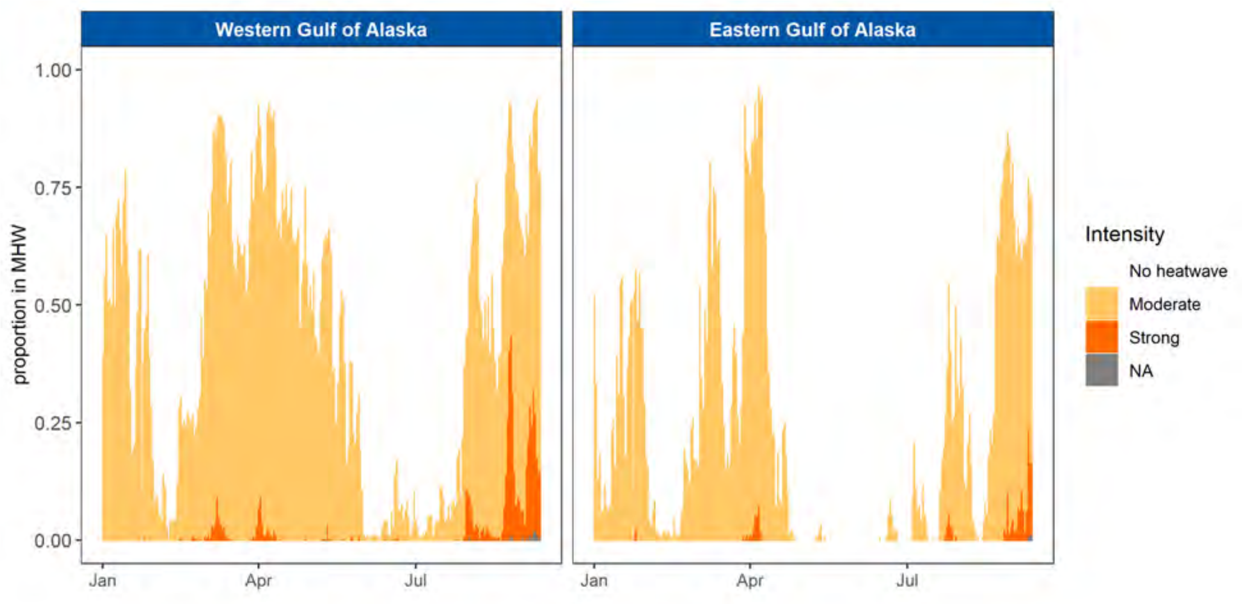


Figure 19: Proportion of region in heatwave status, through September, 2025. Heatwave status calculations were performed on each 5 x 5 km grid cell within the Gulf of Alaska. This figure shows a five day rolling average of the proportion of cells within each region that are in heatwave status.

Factors influencing observed trends: The Gulf of Alaska was warmed by warm waters advected from the northwestern Pacific Ocean in the winter 2025 in addition to warm waters upwelled in the central North Pacific subtropical gyre and being brought onto the GOA shelf through increased circulation. Coastal downwelling transported these warm surface waters to depth on the shelf.

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

Implications: The GOA shelf surface waters have been warming since 1900. Summer temperatures are primarily driving this warming trend. The seasonal difference in warming trends are not determined but could be due to changes in stratification, precipitation and freshwater runoff, cloud cover, circulation or other oceanographic and atmospheric drivers. 'Above' or 'below' average surface temperatures, as reported in shorter-term time series in this report, may have different meaning if considered relative to the longer-term time series presented here. The thermal responses of species in the GOA marine ecosystem must be considered in terms of these longer-term shifts in temperature, to understand better their response to changing temperatures. As of this report, surface temperatures are predicted to cool in the winter/spring 2025 (Lemagie and Callahan in this report, p.32).

Methods:

Long-term Sea Surface Temperature: Sea surface temperatures in the Gulf of Alaska can be calculated using NOAA's Extended Reconstructed SST V5 data[14]. ERSST is a global monthly sea surface temperature dataset produced at 2 ° x 2 ° resolution starting in 1854. Statistical processes are used to infill data sparse/missing areas and standardize the many ways that ocean surface temperatures have been collected and reported over the decades. However, known problems remain, especially pre-1900 and in the WW2 era and in general in Arctic and Southern Oceans. Constrained B-Spline regression used here is a form of nonparametric quantile regression using quadratic splines. This approach allows for conditional estimates of any quantile of interest. Initial analyses examined eastern and western GOA separately (divided 147 °W) but the regions were combined due to reduced subregional sample sizes and similar trends across the western and eastern shelf.

AFSC EcoFOCI Spring Larval Survey: EcoFOCI conducts biennial surveys in spring (May-June) and summer (August-September) in the Western Gulf of Alaska, targeting early life stages of fishes and their prey. At each sampling station, a bongo net array is towed obliquely from surface to 100 m (spring) or 200 m (late summer), or to 10 m off bottom in shallower waters. Attached to the wire above the bongo frame is a Seabird FastCAT profiler which measures temperature, salinity, and depth. Up casts were processed and used to generate maps and time-series of temperatures at the surface and at 100–150 m depth using the custom R package FastrCAT[15]. While surveys have been ongoing for multiple decades, time-series are provided here for the most recent 6 surveys with similar survey extent. In 2023, the spring survey dates were May 16–21, 2023 and the summer survey dates were September 4–12, 2023. Due to crew staffing shortages and reduced ship time, the Shelikof Strait was not able to be sampled in 2023 and no summer survey was conducted in 2021.

AFSC Bottom Trawl Survey: Since 1993, water column temperatures have been routinely recorded during Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering Groundfish Assessment Program (RACE-GAP) GOA bottom trawl surveys using bathythermograph data loggers attached to the headrope of the bottom trawl net. In 2003, a SeaBird (SBE-39) microbathythermograph (Sea-Bird Electronics, Inc., Bellevue, WA) replaced the Brancker XL200 data logger (Richard Brancker Research, Ltd., Kanata, Ontario, Canada) which had been in use from 1993 to 2001 (Buckley et al., 2009). The analyses presented here combine these two types of bathythermic data; the downcast data from each RACE-GAP trawl haul were isolated and used to inform our models.

Spatial and temporal coverage of the GOA RACE-GAP summer bottom trawl surveys has varied from year to year. Starting dates have ranged from the middle of May to the first week in June, and survey end dates ranged from the third week in July to the first week in September. The number of vessels employed, the areal extent, and the maximum depth of the GOA survey have all varied among survey years (e.g., water temperatures were not collected from the eastern GOA in 1993 and 2001, stations in the deepest GOA stratum [700–1000 m] have been sampled in just 5 of the last 13 surveys). Since the GOA survey sweeps from west to east over the late spring and summer, the expectation is a trend toward warmer water temperatures collected late in the summer in southeast Alaska compared with those collected in the western GOA in late spring; this anticipated trend is expected to be particularly pronounced in the upper layers of the water column. 2023 temperatures were not standardized to account for the effect of collection date as in past years.

Gulfwatch Alaska Seward Line Survey: Since 1998, hydrographic transects have been completed in May

[14]https://psl.noaa.gov/data/gridded/data.noaa.ersst.v5.html
[15]https://github.com/Copepoda/FastrCAT

(typically during the first 10 days of the month) along a sampling line that extends from the mouth of Resurrection Bay near Seward to the outer continental slope of the northern GOA. Data analyzed here are water column profile data that have been averaged over the top 100m of the water column to provide an index of upper water column heat content on the northern GOA shelf.

AFSC Southeast Coastal Monitoring Survey (Icy Strait): Temperature has been collected annually in Icy Strait during monthly (May to August) fisheries oceanography surveys conducted by the Southeast Coastal Monitoring (SECM) project of Auke Bay Laboratories, AFSC. The Icy Strait Temperature Index (ISTI, °C) is the average temperature of the upper 20 m integrated water column.

Satellite Data: Satellite SST data and 5 km grid mhw status from the NOAA Coral Reef Watch Program were accessed via the Alaska Fisheries Information Network (AKFIN) for January 1985 - September 2023. Daily SST data were averaged within the western (147 °W– 164 °W) and eastern (133 °W – 147 °W) Gulf of Alaska for depths from 10m – 200m (i.e., on the shelf). Detailed methods are online[16] and Watson and Callahan (2021) describes the automation of sst aggregation in depth.

We use the earliest complete 30-year time series (1985–2014) as the baseline period for mean and standard deviation comparisons although the guidance on such choice varies across studies (Hobday et al., 2018; Schlegel et al., 2019). Three notable differences exist between the current marine heatwave indicators and those previously presented to the North Pacific Fishery Management Council (detailed in Barbeaux et al., 2020*b*). First, the current indicator uses a different NOAA SST dataset, with a slightly different time period (beginning mid-1985 instead of mid-1982) and spatial resolution (the current indicator has finer spatial resolution and thus, more data points within the same region). Given the shorter time series, the 30-year baseline period is necessarily different (1986–2015 instead of the previous 1983–2012). Finally, the previous indicator was bounded spatially to target management of Pacific cod in the GOA, whereas the current indicator is bounded spatially by the ESR regions for a broader comparison.

AFSC Summer Longline Survey: The Alaska Fisheries Science Center (AFSC) has been conducting a longline survey since 1987 to sample groundfish from the upper continental slope annually in the GOA, during odd years in the Bering Sea (BS), and during even years in the Aleutian Islands (AI). More details related to this survey can be found in (Siwicke, 2022). The survey samples the GOA from west to east for the western portion of the region during the second half of June before transiting to Ketchikan and sampling from east to west and ending southwest of Kodiak Island in late August. Beginning in 2005, a temperature (depth) recorder (TDR) has been used for the purpose of measuring in-situ bottom temperature at each station. There are 71 stations sampled by the AFSC longline survey located within the GOA ESR region (41 in the western GOA and 30 in the eastern GOA), but sometimes units fail, so not all stations are successfully sampled every year.

The TDR used is an SBE 39 (Seabird Electronics) which is attached directly to the middle of the longline, with a second TDR being attached deeper starting in 2019. The TDR records water temperature and depth every 10 seconds, and the downcast is processed to 1-m increments via the double parabolic method used by the World Ocean Atlas 2018 (Reiniger and Ross, 1968; Locarnini et al., 2019). The mean of the temperature while the TDR is on the bottom is a point estimate of the bottom temperature while the longline is fishing (which is usually two to six hours), and the range of temperatures recorded can be useful in interpreting how much variation occurs at a station.

The mean temperature from 1-m increment depths over the 246–255 m depth range was selected as an

[16] `https://github.com/MattCallahan-NOAA/ESR/tree/main/SST`

index for subsurface temperature because this layer was shallow enough to be consistently sampled across space and time and also deep enough to be below thermoclines and mixed layer dynamics. The depth of the profile does not always reach $\sim$ 250 m depth, but sample sizes have improved since 2019 because the second TDR deployment could be used if the first was unsuccessful or too shallow. Temperatures were weighted relative to the area of the depth-stratified regions the survey stations were in, which are described in Echave et al. (2013).

NOAA Acoustic-Trawl Survey: The MACE program conducts annual acoustic-trawl surveys of pre-spawning walleye pollock (*Gadus chalcogrammus*) in Shelikof Strait in the northern Gulf of Alaska in March (for detailed methods see McGowan et al., 2024). Temperature profiles are measured at survey trawl locations (from near surface to the deepest depth reached by the trawl) using a temperature-depth probe (SBE 39, Sea-Bird Scientific) attached to the trawl headrope. Trawls are not conducted at fixed locations, but are conducted opportunistically throughout the survey area where acoustic backscatter is present and are used to scale the backscatter to the nearest haul's species composition and length distribution for survey estimates of pollock biomass and abundance. Near-surface temperature is also measured along transects at a depth of approximately 1.4 m with a sensor in the flow thru scientific computing system (SBE 38, Sea-Bird Scientific). These higher resolution measurements are available for some but not all past surveys. In surveys where they are available, the averages of these higher-resolution measurements are highly correlated with averages of similar measurements at the more widely-spaced trawl locations. Therefore, we feel confident in reporting the trawl location near-surface temperatures as representative of survey-wide near-surface temperatures.

Gulf of Alaska summer bottom trawl survey bottom temperature

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Last updated: October 2025

Description of indicator: This indicator provides estimated mean bottom temperature, maps of bottom temperature, and maps of bottom temperature anomalies based on summer (May to September) Gulf of Alaska bottom trawl surveys from 1993 to 2025 that were conducted by the NOAA Alaska Fisheries Science Center's Groundfish Assessment Program. Bottom temperature data have been routinely collected during Gulf of Alaska bottom trawl survey hauls since 1993. Bottom temperature measurements were obtained using temperature-depth recorders attached 0.5 – 1 m behind the headrope of the trawls. A Brancker XL200 temperature-depth recorder (Richard Brancker Research, Ltd., Kanata, Ontario, Canada) was used from 1993 to 2001 and a SeaBird SBE-39 temperature-depth recorder (Sea-Bird Scientific, Bellevue, Washington, USA) was used from 2003 to 2025. The depth range, timing and duration, and number of stations sampled by the survey varied among years due to variation in resources available to conduct the surveys. Additional information about survey sampling and data processing are provided in Siple et al. (2024).

Annual bottom temperature grids were generated for the GOA bottom trawl survey area (nominal depth range: nearshore at $\sim$ 10 m to 1,000 m) using spatial linear models that were fitted to bottom temperature data from individual hauls. For each year, a Gaussian spatial linear model was fitted to bottom temperature (response variable) with a spatial random effect (Matérn covariance with geometric anisotropy) and a fixed effect of log-transformed bottom depth as predictors using the R package *spmodel* (Dumelle et al., 2023). Bottom temperatures were predicted throughout the GOA bottom trawl survey area at 1 x 1 km resolution using a bathymetry grid derived from 100 x 100 m resolution GOA bathymetry (Zimmermann et al., 2019). Annual mean bottom temperatures for the western and eastern GOA ESR ecoregions were calculated for each year as the means of all 1 x 1 km grid cells whose centers were within the ecoregions. Bottom temperature anomaly (Z-score) maps were calculated as cell-wise anomalies relative to the 20-year reference period (1993 to 2013; Equation 1),

$$Z_{y,i} = \frac{\widehat{T_{y,i}} - \underline{\underline{T_{r,i}}}}{\sigma_{r,i}} \tag{1}$$

where $Z_{y,i}$ is the anomaly for grid cell i i in year y, $\widehat{T_{y,i}}$ is predicted bottom temperature, $\underline{T_{r,i}}$ is mean predicted temperature for the reference period (1993 to 2013) and $\sigma_{r,i}$ is the predicted standard deviation for the reference period. Annual subregion (western GOA and eastern GOA) anomalies were calculated relative to the grand mean from 1993 to 2013. For both cell-wise and subregion anomalies, positive values indicate that temperatures were higher than the reference period mean and negative values indicate that temperatures were lower than the mean.

GOA bottom trawl survey temperature time series for the western and eastern GOA have been presented in past GOA ESRs, but this indicator derived from estimated bottom temperature grids is new for 2025. Bottom trawl survey temperatures were reported in the GOA ESR for the surface (0 – 5 m) based on mean haul-level surface temperatures and 195 – 205 m ("deep") based on mean haul-level temperatures from temperature observations collected within that depth range. Temperatures had been calculated for specific depths and subregions because mean temperature and the magnitude of temperature variability differs among depths, spatially, and over the months of survey sampling, meaning simple averages across the survey can obscure temperature variation. The spatial linear model approach in this contribution accounts for this variation by explicitly modelling spatial covariance and depth-dependent variation to estimate bottom temperatures at 1 x 1 km resolution.

Status and Trends: In 2025, mean bottom temperatures in the western (6.21 °C) and eastern (6.25 °C) GOA were above average (> 1 standard deviation) when compared to the 1993 to 2013 reference period mean (Figure 20). From 1993 to 2013, the mean bottom temperatures in the western and eastern GOA were 5.49 °C and 5.94 °C, respectively. The above-average bottom temperature in 2025 represents a departure from the past two surveys in 2021 and 2023 that observed near-average bottom temperatures (within 1 standard deviation of the 1993 to 2013 mean). Bottom temperature maps show

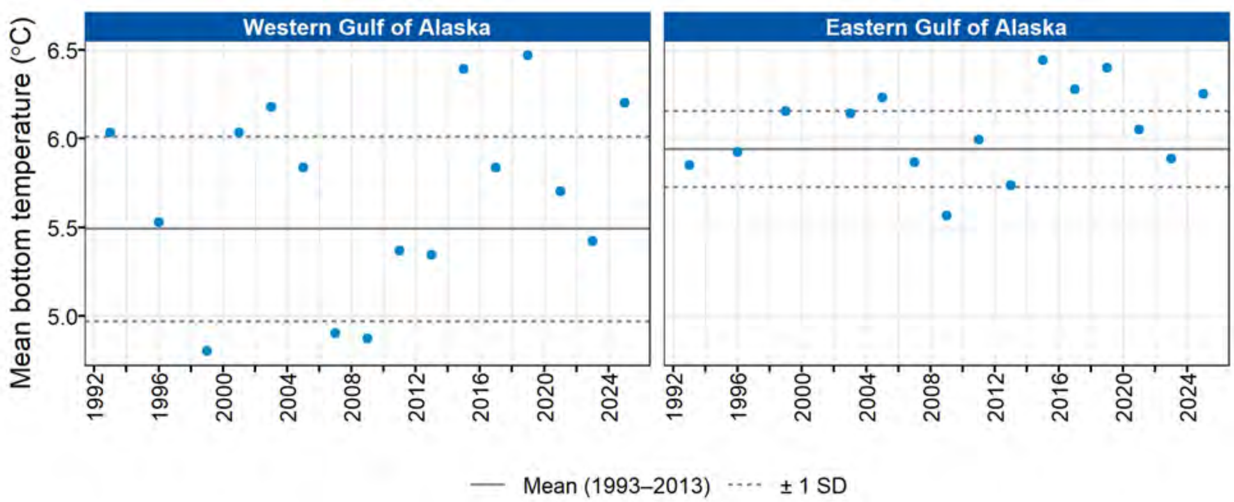

Figure 20: Mean summer bottom temperatures in Ecosystem Status Report western and eastern Gulf of Alaska subregions from 1993 to 2025 estimated from NOAA/AFSC Groundfish Assessment Program bottom trawl survey data. Circles denote annual mean temperatures calculated from gridded bottom temperature estimates. Solid and dashed horizontal lines respectively denote the 1993–2013 time series mean ± one standard deviation.

temperatures in 2025 were generally warmer throughout the GOA than during the last two surveys (2021 and 2023) and the 1993 to 2013 mean (Figure 21). The warmest bottom temperatures were generally observed in shallow near-shore areas (e.g., Cook Inlet) and the coldest temperatures were along the continental slope at bottom depths > 200 m. Bottom temperatures increased from west to east—the direction in which the bottom trawl survey samples— due in part to the accumulated effects of solar heating. Spatial bottom temperature anomaly maps show that the magnitude of temperature anomalies encountered by bottom trawl surveys differ across the GOA within a year (Figure 22). In 2025, GOA bottom temperature anomalies were at least one standard deviation warmer than the 1993 to 2013 mean across much of the GOA between the Islands of Four Mountains and Cross Sound as shown by Z-score anomaly maps. However, temperatures in the eastern GOA between Cross Sound and

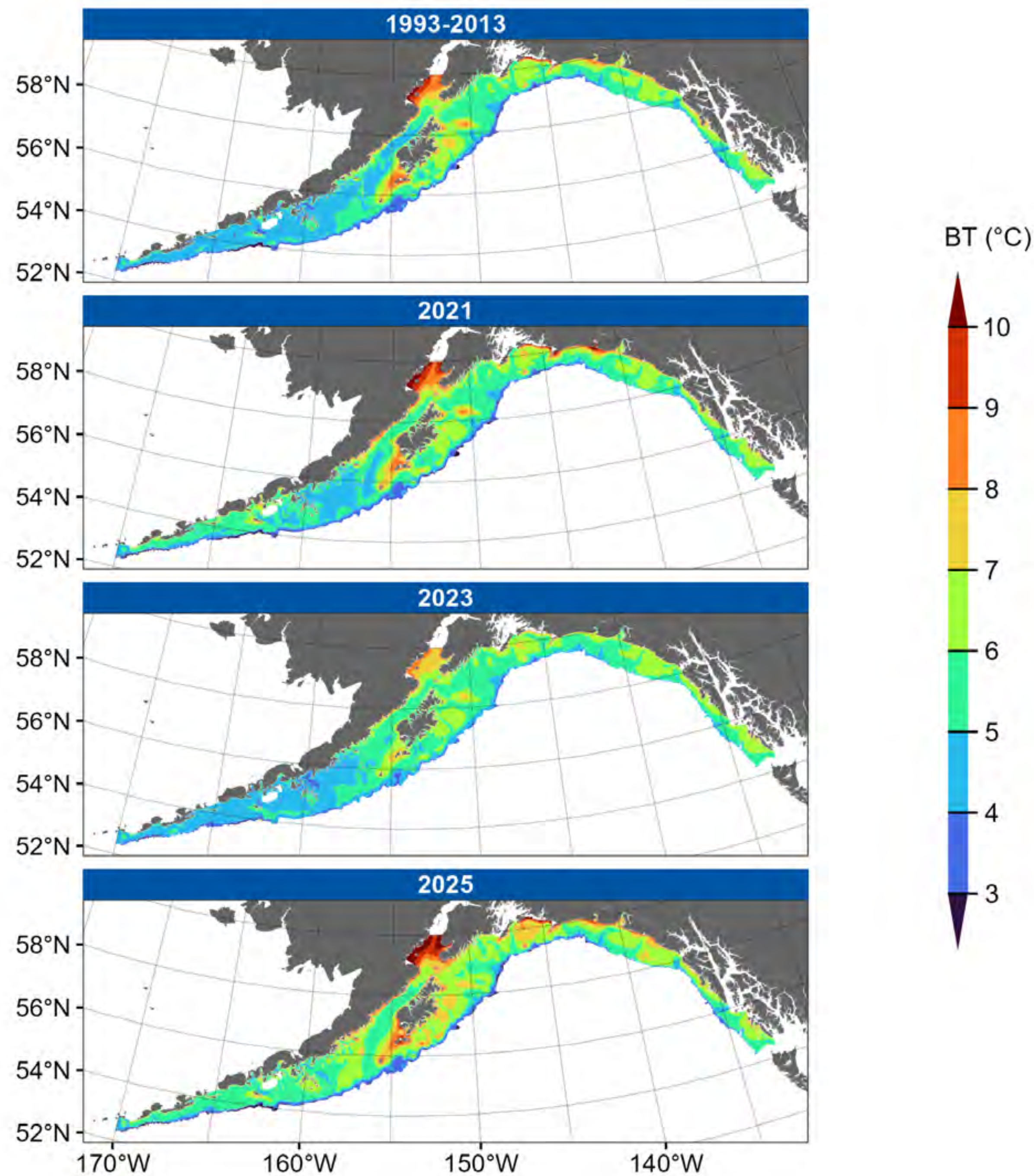

Figure 21: Maps of summer bottom temperatures in the NOAA/AFSC Gulf of Alaska bottom trawl survey area estimated from NOAA/AFSC Groundfish Assessment Program bottom trawl survey data. Panels show mean bottom temperature for the 1993 to 2013 reference period and for the last three surveys (2021, 2023, and 2025).

Dixon Entrance were near-average, with much of the area within one standard deviation of the reference period mean.

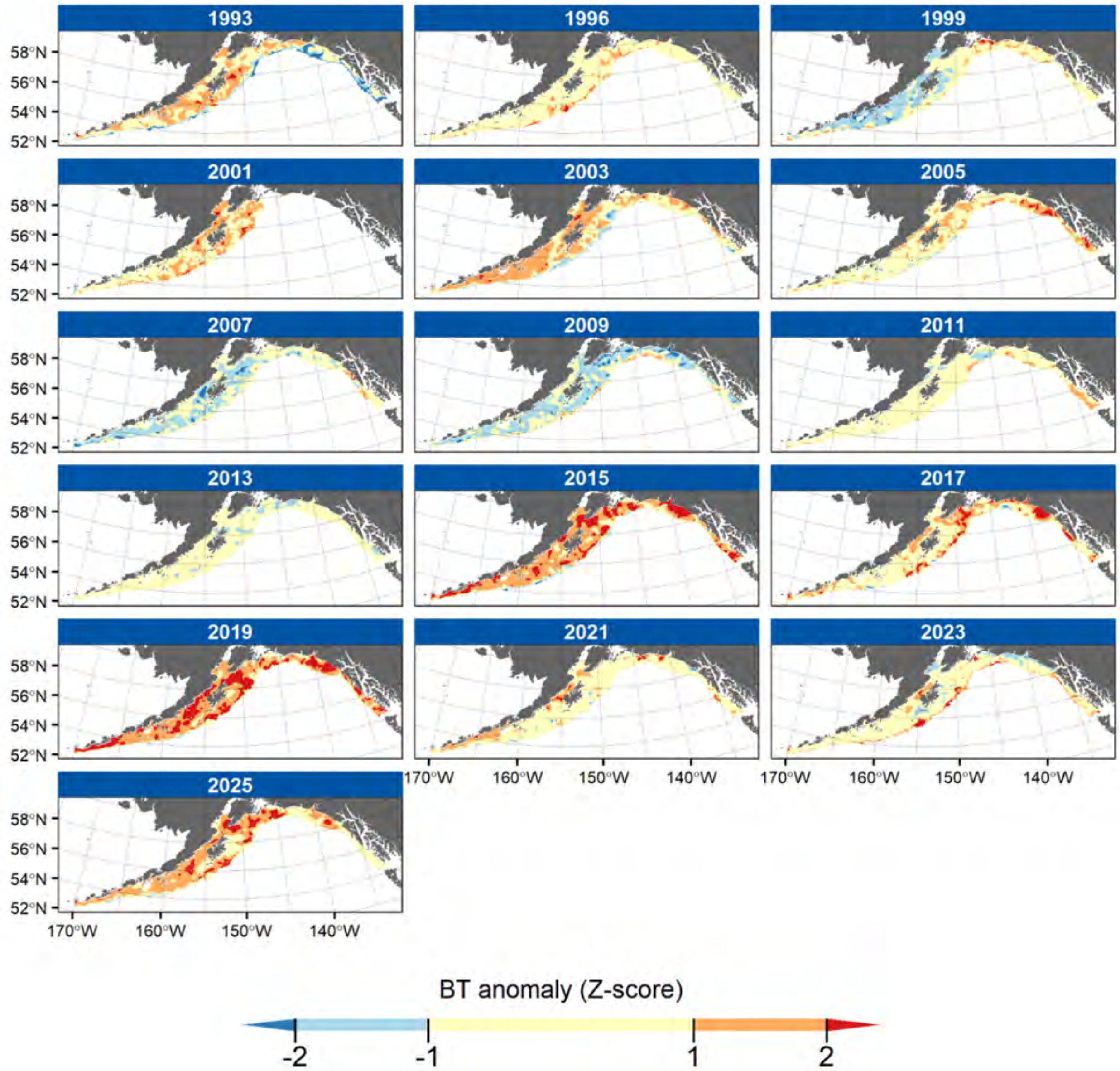

Figure 22: Maps of summer bottom temperature anomalies (Z-scores) relative to the 1993 to 2013 reference period in the NOAA/AFSC Gulf of Alaska bottom trawl survey area as estimated from NOAA/AFSC Groundfish Assessment Program bottom trawl survey data. Negative values indicate colder than average temperatures and positive values indicate warmer than average temperatures.

Implications: Temperature variation can have substantial impacts on the structure and function of the GOA ecosystem as demonstrated by widespread and persistent effects of the 2014 – 2016 marine heatwave (Suryan et al., 2021). Changes in temperature have been implicated in distribution shifts for different life stages of commercially important fish stocks that are encountered in bottom trawl surveys (Yang et al., 2019), although responses may differ by subregions within the GOA (Li et al., 2019).

Higher temperatures have been linked to reduced productivity of GOA Pacific cod (Barbeaux et al., 2020*b*; Laurel et al., 2023) and walleye pollock (Rogers et al., 2021) as a result of habitat compression, lower growth rates, and elevated mortality. Temperature variation may also affect the growth and size at maturity of commercially important groundfishes such as Pacific cod and walleye pollock (Goldstein et al., In Press).

Eddies

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Description of indicator: Eddies in the northern GOA have been shown to influence distributions of nutrients (Ladd et al., 2009, 2005, 2007), including dissolved iron (Crusius et al., 2017; Ladd et al., 2009), phytoplankton (Brickley and Thomas, 2004), and ichthyoplankton (Atwood et al., 2010). In addition, the settlement success of arrowtooth flounder (Goldstein et al., 2020), the feeding environment for juvenile pink salmon (Siwicke et al., 2019), and the foraging patterns of fur seals (Ream et al., 2005) can be influenced by the presence of eddies. Eddies propagating along the slope in the northern and western GOA are generally formed in the eastern Gulf in autumn or early winter (Okkonen et al., 2001) and are sometimes associated with gap winds from Cross Sound (Ladd and Cheng, 2016). Using altimetry data from 1993 to 2001, Okkonen et al. (2003) found that strong, persistent eddies occurred more often after 1997 than in the period from 1993 to 1997. Ladd (2007) extended that analysis to 2006 and found that, in the region near Kodiak Island (Figure 23; region c), eddy energy in the years 2002 – 2004 was the highest in the altimetry record. The Ssalto/Duacs altimeter products were produced and distributed by the Copernicus Marine and Environment Monitoring Service (CMEMS)[17].

Since 1992, a suite of satellite altimeters has been monitoring sea surface height. Eddy kinetic energy (EKE) can be calculated from gridded altimetry data (Ducet et al., 2000), giving a measure of the mesoscale energy in the system. A map of eddy kinetic energy in the GOA averaged over the altimetry record (updated from Ladd, 2007) shows four regions with local maxima (labeled a, b, c and d in Figure 23). The first two regions are associated with the formation of the Haida (a) and Sitka (b) eddies. Eddies that move along the shelf-break often feed into the third and fourth high EKE regions (c and d). By averaging EKE over the regions, we obtain an index of energy associated with eddies in these regions (Figure 24).

The most recent data were downloaded on August 23, 2024 providing daily time series from 1/1/1993 to the present on a 0.25 ° longitude x 0.25 ° latitude grid. Original data set is global, but we subset it to 150 °E – 125 °W and 40 °N – 72 °N during downloading. Data from 1993 to 2020 is the reprocessed product whereas data from 2021 onward is "NRT" (near real time). Maps of long-term mean EKE (Figure 23) and monthly climatology of regional EKE (Figure 24, red line) are computed using data from 1993 to 2023 (period with full year coverage).

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

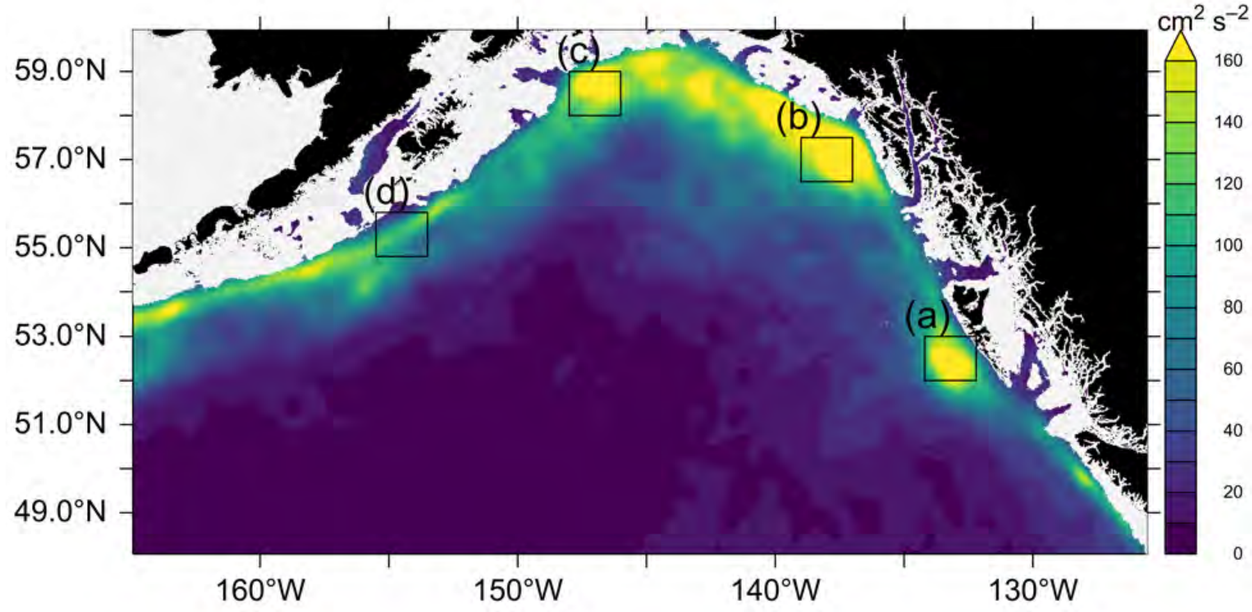

Figure 23: Long-term mean (January 1993 – August 2025) of eddy kinetic energy (EKE; cm ^{2} s $^{-2}$) based on satellite altimetry. EKE hot spots in the eastern GOA are associated with Haida (region a) and Sitka (region b) eddies. Region c and d are named northern GOA and western GOA (northern GOA and western GOA), respectively. EKE averaged over each of the regions (a to d) is shown on Figure 24.

Status and trends: Strongly above normal eddy kinetic energy (EKE) is apparent for regions a) and c) in the Gulf of Alaska during spring, the peak season for EKE (judging by the climatological seasonal cycle; Figure 24). The EKE was slightly above normal in region b). This would be consistent with a stronger than normal gyre circulation which sets up strong cross-shelf sea surface height gradients, promoting eddy formation. Formation of shelf-break eddies in the Gulf of Alaska is also related to local forcing such as freshwater input and gap winds. These forcing acts on the background seasonal sea level gradient. Other modes of climate variability (such as ENSO and PDO) also influence sea level gradients, although ENSO, PDO, and gyre oscillation are not totally independent of each other.

EKE has well defined mean seasonal cycles in the eastern and central GOA (Figure 23, regions a-c) with similar phasing (high in winter/spring and low in summer/fall), suggesting their formation mechanisms are inter-related. In contrast, EKE in the western GOA (Figure 23, region d) does not have a well-defined mean seasonal cycle, by it tends to be higher in spring and fall than in the other seasons, suggesting different eddy formation mechanisms in the western GOA.

Factors influencing observed trends: In the eastern Gulf of Alaska, interannual changes in surface winds (related to the Pacific Decadal Oscillation, El Niño, and the strength of the Aleutian Low) modulate the development of eddies (Combes and Di Lorenzo, 2007; Di Lorenzo et al., 2013). Regional scale gap-wind events may also play a role in eddy formation in the eastern Gulf of Alaska (Ladd and Cheng, 2016). In the western Gulf of Alaska, variability is related both to the propagation of eddies

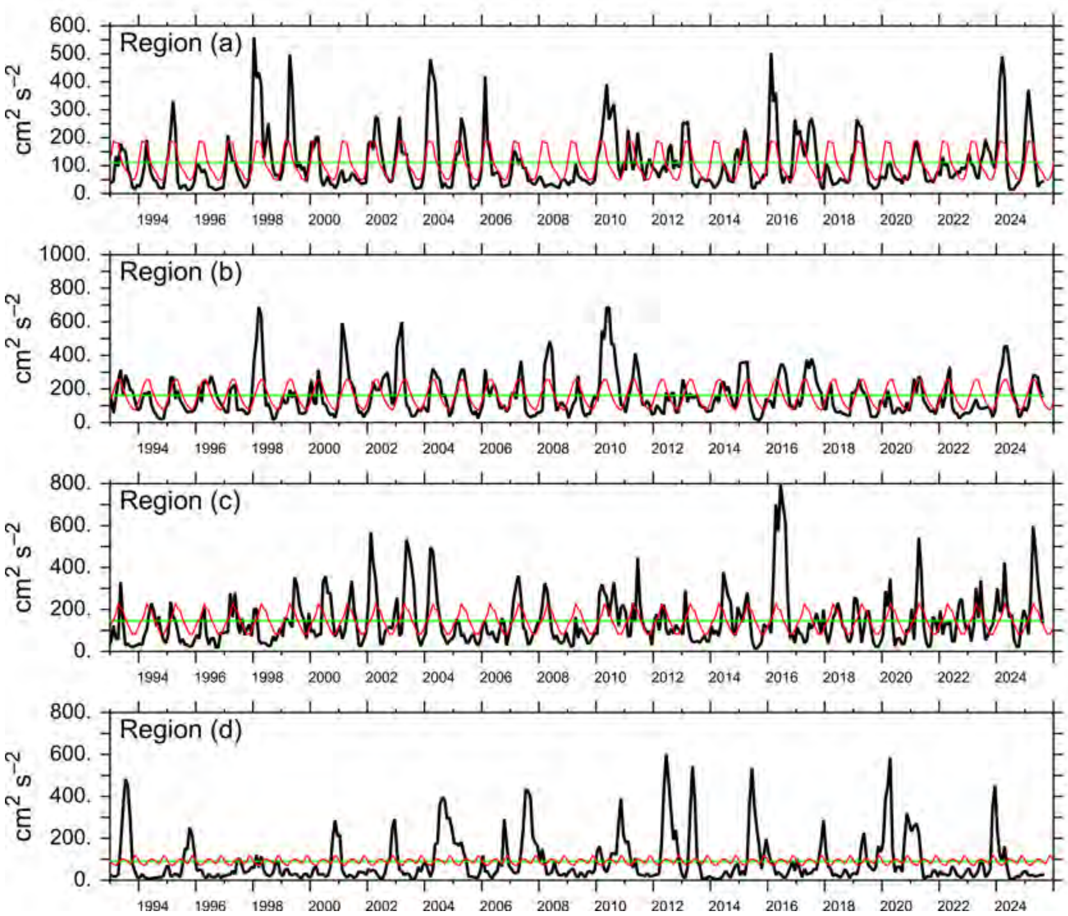

Figure 24: Eddy kinetic energy (cm ^{2} s $^{-2}$) averaged over regions shown in Figure 23. Results shown include monthly averages through August 23, 2005 (black line), monthly climatology from year 1993 – 2025 (red line), and long-term average over the entire time period (green straight line).

from their formation regions in the east and to intrinsic variability. Previous studies suggest that eastern GOA eddy activities (regions a and b) are related to large-scale forcing such that downwelling favorable wind anomalies along the Alaskan coast can generate positive SSH anomalies which promote formation of anticyclonic eddies. Downwelling favorable winds tend to happen during positive phases of PDO, but the correspondence between eddy activities and ENSO events is not always strong. ENSO associated forcing effects can be both local (via local wind anomalies) and remote (via coastal trapped waves arriving from lower latitudes and generate SSH anomalies along the Alaska coast). In comparison, interannual variability of eddies in the western GOA (region c and region d) tends to happen intrinsically and is not necessarily associated with large-scale forcing, although eddies from the eastern GoA could also arrive here.

Implications: Eddies sampled in 2002 – 2004 were found to contain different ichthyoplankton assemblages than surrounding slope and basin waters indicating that eddies along the slope may influence the distribution and survival of fish (Atwood et al., 2010). Carbon isotope values suggest that cross-shelf exchange due to eddies may be important to the marine survival rate of pink salmon (Kline, 2010). And eddies may result in enhanced settlement and recruitment for arrowtooth flounder (Goldstein et al., 2020).

Ocean Surface Currents – Papa Trajectory Index

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Last updated: July 2025

Description of indicator: The Papa Trajectory Index (PTI) provides an annual index of near-surface water movement variability, based on the trajectory of a simulated surface drifter released at Ocean Station Papa (50 °N, 145 °W; Figure 25). The simulation for each year is conducted using the "Ocean Surface CURrent Simulator" (OSCURS[18]). Using daily gridded atmospheric pressure fields, OSCURS calculates the speed and direction of water movement at the ocean's surface at the location of a simulated surface drifter. It uses this information to update the position of the simulated drifter on a daily basis over a specified time period. For the index presented here, OSCURS was run for 90 days to simulate a surface drifter released at Ocean Station Papa on December 1 for each year from 1901 to 2024 (trajectory endpoints years 1902 – 2025).

Status and trends: The ending latitude for the 2024/25 trajectory, and thus its PTI value, was the highest since 1991/92–although similar high values also occurred in the intervening time period in 2011/12 and 2015/16 (Figure 25). In general, the trajectories fan out northeastward toward the North American continent. The 2021/22 was among the relatively few that initially moved strongly to the southeast and ended south of Ocean Station PAPA while the trajectoriesy for 2022/23 and 2023/24 were fairly typical among the time series. In this respect, the latter 2022/23 trajectoriesy represented a return to more "average" winter atmospheric conditions.

The PTI time series (Figure 26) indicates high interannual variation in the north/south component of drifter trajectories, with an average between-year change of greater than 4° and a maximum change of greater than 13° (between 1968/1969 – 1969/1970). The change in the PTI between 2015/2016 and 2016/2017 was the largest since 1968/69 – 1969/70, while the changes between 2010/2011 and 2011/2012, and between 2020/2021 and 2021/2022, represent reversals with slightly less, but diminishing, magnitude. Such swings, however, were not uncommon over the entire time series. The PTI has been below the mean for six of the nine previous years, but the 2024/25 value (as noted above) was the largest since 1991/92 (baseline 1968 – 2025).

Over the past century, the filtered (5-year running average) PTI has undergone five complete oscillations with distinct crossings of the mean, although the durations of the oscillations are not identical: 26 years (1904 – 1930), 17 years (1930 – 1947), 17 years (1947 – 1964), 41 years (1964 – 2005), and 10 years (2005 – 2015). The filtered index indicates that a shift occurred in the mid 2000s to predominantly southerly anomalous flow following a ∼25 year period of predominantly northerly anomalous flow. This was indicative of a return to conditions (at least in terms of surface drift) similar to those prior to the 1977 environmental regime shift, although this cycle ended rather quickly, as the filtered PTI crossed the mean in the opposite direction in 2011. A similar shift back to an anomalous southerly flow appears to have occurred in 2016. Given recent reslts, the filtered PTI is expected to shift back, at least in

[18]http://oceanview.pfeg.noaa.gov/oscurs

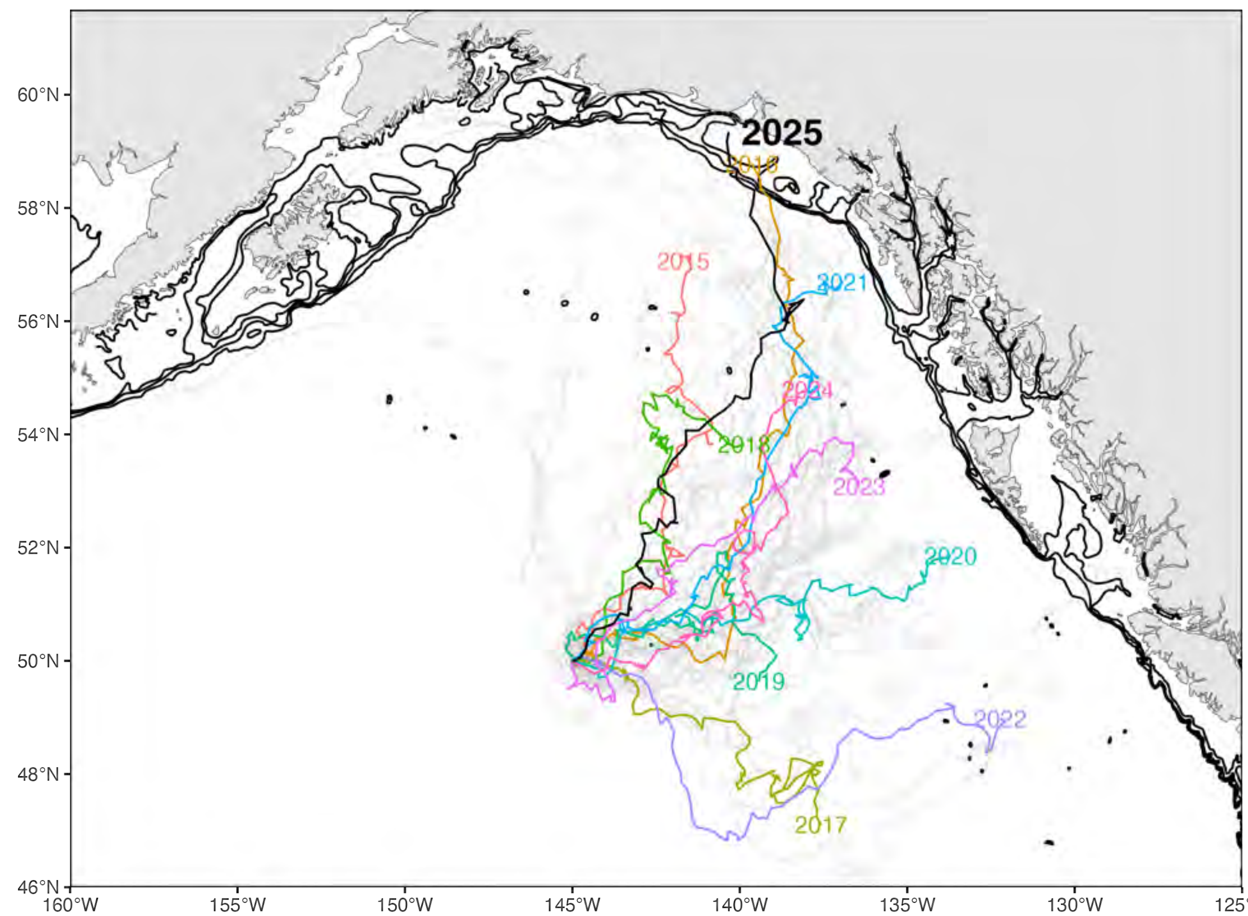

Figure 25: Simulated surface drifter trajectories for winters 1968 – 2025 (endpoint year). End points of 90-day trajectories for simulated surface drifters released on Dec. 1 of the previous year at Ocean Station Papa are labeled with the year of the endpoint (50°N, 145°W). The trajectory in black is 2024/2025 (most recent), those in color end in 2015/2016 – 2023/2024, and those in gray end prior to 2014/2015.

the short-term, to a positive phase in 2026. Since 2005, the PTI appears to be fluctuating on a much shorter time scale (10 years per mean crossing) than previously.

Factors influencing observed trends: Individual trajectories reflect interannual variability in regional (northeast Pacific) wind patterns which drive short-term changes in ocean surface currents, as well as longer term changes in atmospheric forcing that influence oceanic current patterns on decadal time scales.

Implications: The year-to-year variability in near-surface water movements in the North Pacific Ocean has been shown to have important effects on the survival of walleye pollock (*Gadus chalcogrammus*) by affecting its spatial overlap with predators (Wespestad et al., 2000), as well as to influence recruitment success of winter spawning flatfish in the eastern Bering Sea (EBS; Wilderbuer et al., 2002). Filtered PTI values greater than the long-term mean are indicative of increased transport and/or a northerly shift in the Alaska Current, which transports warm water northward along the west coast of Canada and southeast Alaska from the south and consequently plays a major role in the GOA's heat budget. Interdecadal changes in the PTI reflect changes in ocean climate that appear to have widespread impacts on biologi-

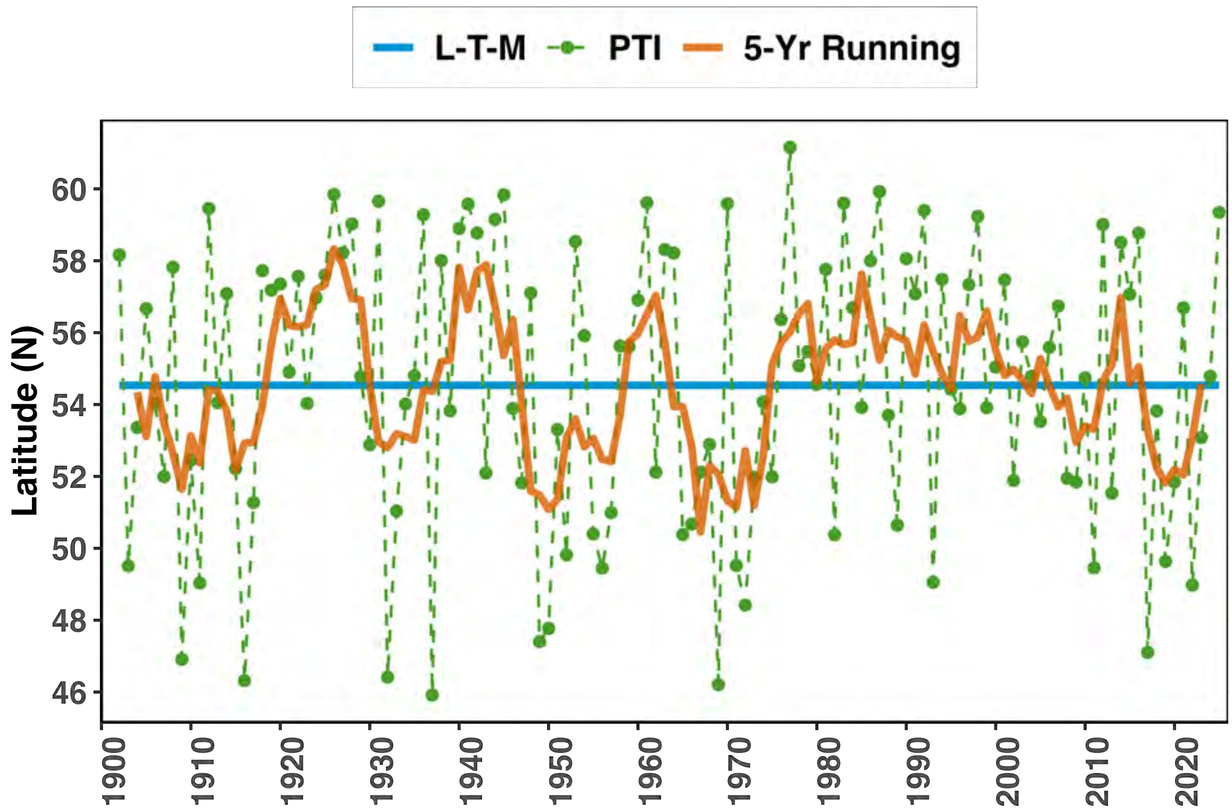

Figure 26: Annual, long-term mean (blue line), and 5-year running mean (orange line and squares) of the Papa Trajectory Index time series end-point latitudes (dotted green line and points) for 1902 – 2025 winters.

cal variability at multiple trophic levels (King, 2005). There is strong evidence that the productivity and possibly the carrying capacity of the Alaska Gyre, and of the continental shelf, were enhanced during the "warm" regime that began in 1977. Zooplankton production was positively affected after the 1977 regime shift (Brodeur and Ware, 1992), as were recruitment and survival of salmon and demersal fish species. Recruitment of rockfish (Pacific ocean perch) and flatfish (arrowtooth flounder, halibut, and flathead sole) also increased. However, shrimp and forage fish such as capelin were negatively affected by the 1977 shift (Anderson, 2003). The reduced availability of forage fish may have contributed to the decline in marine mammal and seabird populations observed after the 1977 shift (Piatt and Anderson, 1996).

Northern Gulf of Alaska Oscillation and Gulf of Alaska Downwelling index

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Last updated: July 2025

Description of indicator: The Gulf of Alaska is characterized by persistent offshore upwelling and coastal downwelling. This results in negative sea surface height (SSH) anomalies offshore and positive SSH anomalies on the continental shelf area.

The Northern Gulf of Alaska Oscillation (NGAO) index describes the strength of the cyclonic circulation in the Gulf of Alaska, and therefore, the intensity of the offshore upwelling in the Alaskan gyre (Hauri et al., 2021). The NGAO corresponds to the primary mode of variability, identified through Empirical Orthogonal Function (EOF) decomposition performed on SSH anomalies (with trends and monthly climatology removed). A positive NGAO phase is characterized by a weak cyclonic circulation leading to weak offshore upwelling and therefore brings less cold, acidic and de-oxygenated waters to the sub-surface. A negative NGAO phase is characterized by a strong cyclonic circulation leading to strong offshore upwelling that brings cold, acidic and de-oxygenated waters to the sub-surface.

The Gulf of Alaska Downwelling Index (GOADI) quantifies the intensity of positive coastal SSH anomalies in the Gulf of Alaska, indicating the strength of coastal downwelling (Hauri et al., 2024). This index is derived from the second mode of variability identified by Empirical Orthogonal Function (EOF) decomposition, applied to SSH anomalies after removing trends and monthly climatology. The GOADI serves as a measure of the intensity of coastal downwelling and, consequently, acts as a proxy for the intrusion of deep water onto the continental shelf's seafloor. A positive GOADI phase is characterized by high SSH anomalies and strong downwelling, making deep water intrusions less likely. During a negative GOADI phase SSH anomalies are low in the shelf area, leading to weaker downwelling that permits intrusion of cold, salty, deoxygenated, and acidic deep water onto the shelf.

Status and trends: Northern Gulf of Alaska Oscillation (NGAO) — The NGAO index remained predominantly negative throughout 2025 (since 2021), with a brief, weak positive spike during from Dec 2024 to Feb 2025 (Figures 27 and 28). This suggests a strong subpolar gyre, which in turn drives significant offshore upwelling. This intensified upwelling transports cold, acidic, nutrient-rich, and oxygen-depleted waters from the deeper layers to the surface offshore. Additionally, a stronger subpolar gyre results in a shift of the boundary between offshore and coastal waters closer to the shore. In other words, the outer shelf limit is pushed nearer to the coast, meaning locations such as GAK9 (on the outer shelf) may be more influenced by offshore waters.

Gulf of Alaska Downwelling Index (GOADI): — The GOADI switched from negative to strongly positive in November 2024 and persists in that state through July 2025 (Figure 27 and and 28), indicating strong coastal downwelling, which limited the intrusion of deep water onto the continental shelf. As a result, bottom waters on the shelf were likely warmer and more oxygenated in 2025 (similar to 2023) compared to 2024, when the GOADI index was negative and coastal downwelling weakened. Additionally, the positive winter index suggests higher Ekman transport across the shelf.

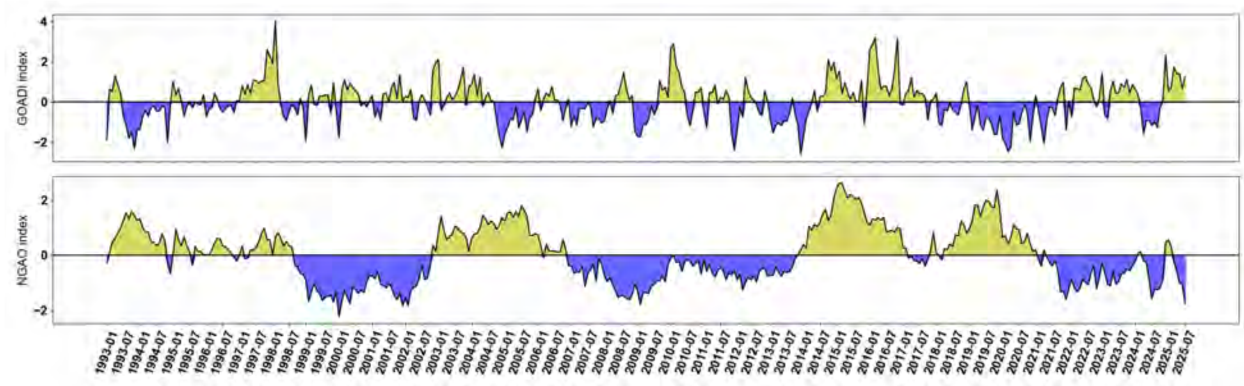

Figure 27: Time-series of the Gulf of Alaska Downwelling Index (top) and the Northern Gulf of Alaska Oscillation (bottom) from 1993–2025. The Northern Gulf of Alaska Oscillation (NGAO) index represents the intensity of offshore upwelling in the Alaskan gyre (updated from Hauri et al., 2021) and is derived from the first mode of variability in SSH anomalies, explaining 24% of the total variance and 50% of SSH variance in offshore areas. The Gulf of Alaska Downwelling Index (GOADI) measures the intensity of coastal downwelling, based on the second mode of variability in SSH, which accounts for 10% of the total variance and 60% of SSH variance on the continental shelf (updated from Hauri et al., 2024).

Factors influencing observed trends: Ocean circulation in the Gulf of Alaska Gyre, can influence the oceanographic characteristics (dissolved oxygen, pH, temperature, salinity) that can cumulatively impact groundfish habitat, affecting distribution and potentially survival (Hauri et al., 2024). A positive GOADI indicates stronger coastal downwelling, limiting intrusion of deeper waters onto the shelf bottom that are low in dissolved oxygen, more acidic, cooler temperature, and more saline. Negative NGAO indicates stronger upwelling in the central GOA gyre due to stronger gyre circulation, bringing deeper waters that are low in dissolved oxygen, more acidic, cooler temperature, and more saline up to the surface in the central gyre (offshore) and potentially onto the shelf.

Implications: Decreased DO at depth may limit the availability of deeper waters as refuge from warmer temperatures. Some deeper-dwelling slope adult groundfish, including thornyhead (*Sebastolobus* spp.; 100 – 1,200m), rougheye (*S. aleutianus*), blackspotted (*S. melanostictus*; 300 – 500m), and shortraker rockfish (*S. borealis*; 300 – 400m), already live in reduced oxygen environments. A decrease in DO in those habitats may drive shifts in distribution to shallower waters (Thompson et al., 2023). Ocean acidification has the potential to adversely affect populations of sensitive species and the fisheries on which they depend; Tanner crab catch and profits, for example, are predicted to decline as pH levels drop below critical levels (Punt et al., 2016). OA thresholds for salmon have yet to be exceeded anywhere in the Gulf of Alaska other than in deeper waters in the southwest which are outside the range of those species. Although the vast majority of the benthic waters in the Gulf of Alaska are below critical thresholds for both Tanner crab juveniles and pteropods, there is not as yet significant intrusion of these waters into the habitats of these species. Tanner crab juveniles generally settle in shallow waters in the Gulf of Alaska (Ryer et al., 2015) where currently the pH levels are above pH 7.8, while pteropods are generally present in the plankton at relatively shallow depths. Currently there is no evidence to suggest that OA is significantly affecting any known species in the Gulf of Alaska (including Tanner crab and red king crab), in part due to this spatial refuge. However, given current trends it is likely that intrusion of low pH waters into the habitats of the species will become a more frequent occurrence with likely negative consequences (Bednaršek and Ohman, 2015). Additionally, other environmental stressors, such

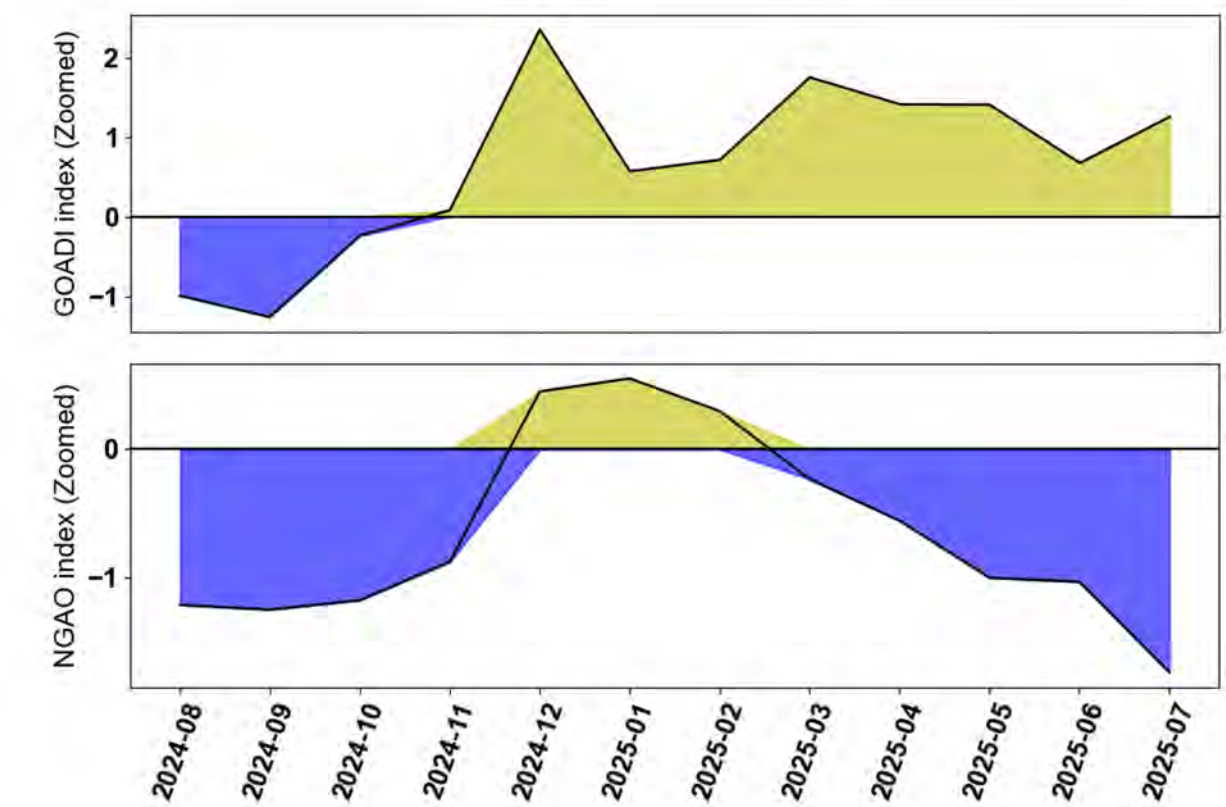

Figure 28: Time-series of the Northern Gulf of Alaska Oscillation and the Gulf of Alaska Downwelling Index from fall 2024 to fall 2025. The Northern Gulf of Alaska Oscillation (NGAO) index (A) represents the intensity of offshore upwelling in the Alaskan gyre (updated from Hauri et al., 2021) and is derived from the first mode of variability in SSH anomalies, explaining 24% of the total variance and 50% of SSH variance in offshore areas. The Gulf of Alaska Downwelling Index (GOADI) measures the intensity of coastal downwelling, based on the second mode of variability in SSH, which accounts for 10% of the total variance and 60% of SSH variance on the continental shelf (updated from Hauri et al., 2024).

as increasing temperature or decreasing dissolved oxygen, can synergistically interact with OA effectively lowering thresholds and making organisms more vulnerable (e.g., Swiney et al., 2017).

Habitat

Structural Epifauna

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Last updated: September 2025

Description of indicator: Structural epifauna groups considered to be Habitat Area of Particular Concern (HAPC) biota include sponges, corals, and anemones. A HAPC is a specific area designation for a type of habitat that plays an important role in a species' life cycle, and that is sensitive, rare, or vulnerable. The taxonomic groups that are included in this indicator include: sponges, corals (including fan-type coral taxa as well as hard or hydrocoral taxa, but not including sea pens), sea pens (Pennatuloideans), and sea anemones. Sea pens are a superfamily of corals but are considered separately here because they do not require hard substrate and are found in sandy or soft substrates (Stone et al., 2023).

NOAA Alaska Fisheries' Resource Assessment and Conservation Engineering Division's Groundfish Assessment Program (RACE/GAP) fishery-independent summer bottom trawl surveys in the Gulf of Alaska (GOA) are designed to assess populations of commercially and ecologically important fishes and invertebrates. Since 1990, we have deployed the same standardized trawl gear (footrope and trawl net) in the GOA bottom trawl survey. As a result, biomass indices from the survey are expected to capture real changes in the abundance of species and life history stages available to the gear, particularly when trends persist over time. Catch and effort data collected in these surveys were used to estimate regional and subarea (NMFS statistical areas 610, 620, 630, 640, 650) indices of abundance (biomass in kilotons) and confidence intervals for each taxonomic group. This was achieved by fitting a multivariate random effects model (REM) to subarea design-based index of abundance time series. Indices were calculated for the entire standardized survey time series (1990 to 2025). Design-based indices of abundance were calculated using the *gapindex* R package (Oyafuso, 2025) and REM were fitted to the time series using the rema R package (Sullivan and Balstad, 2022). Code and data used to produce these indicators are provided in the *esrindex* R package and repository (Rohan, 2025).

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

This year, subarea biomass estimates were calculated using the *gapindex* R package (Oyafuso, 2025), which uses the Wakabayashi et al. (1985) method to estimate design-based abundance index means and coefficients of variation (CVs) from catch (kg) and effort data (area swept; ha) collected during Aleutian Islands summer bottom trawl surveys. Then, abundance index time series means and confidence intervals were estimated by fitting a multivariate random effects model (REM) to NMFS statistical area biomass estimates and CVs using the R package *rema* (Sullivan and Balstad, 2022; Sullivan et al., 2022) to account for process error in indicator time series. This estimation method was implemented for eastern Bering Sea and Aleutian Islands ESRs in 2024. The transition from reporting biomass by INPFC subarea to NMFS statistical area reflects a restratification of the Gulf of Alaska survey for 2025 in which bottom trawl survey stratum boundaries align with NMFS statistical area boundaries (Oyafuso et al., 2022). The code and methods to calculate abundance indices and fit REM to time series are implemented in the R package *esrindex* (Rohan, 2025).

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

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

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

Status and Trends: A few general patterns are discernible among the epifaunal groups summarized here (Figure 29). All species groups had abundances similar to the previous sampling period in 2023 with slight increases in the abundance of sponges and sea pens and slight decreases in the abundance of coral and anemones. The most dramatic changes over time for this group of taxa occur in the sponges which are prevalent in bottom trawl survey hauls throughout the Gulf of Alaska (GOA) and occur in 40 – 50% of catches from each subarea. Their abundance estimates have been declining since 2019, although the estimated abundance is slightly higher in 2025 than the previous sampling year. The abundance of corals and sea anemones also showed declines in recent years though this decline has been more gradual than the decline of sponges. Corals were historically most abundant in southeast Alaska (NMFS Area 650), contrasting with the pattern of abundance observed with sponges and anemones (Figure 30), and are not common in our trawl catches, even in areas where their abundance is higher. Sea anemones appear to be more abundant in the western GOA (NMFS Areas 610 – 630) though they are relatively common across the survey area, occurring in 40 – 50% of trawl catches throughout the survey areas. Sea pens are neither common nor abundant in GOA trawl catches though we have episodically caught them in high abundance in the Chirikof district (NMFS Area 620). The abundance trend for sea pens appears to have increased in the early part of the time series prior to 2003 and then become generally stable after that point in time.

Factors influencing observed trends: The Gulf of Alaska's Bottom Trawl Survey sampling tool (trawl net) was not designed to capture sessile invertebrates and does not sample this fauna well. Therefore, we recommend some caution when interpreting these trends in biomass. In a recent study, species distribution models based on bottom trawl survey data were evaluated using underwater camera survey data independently collected from 2010 – 2022. While the density calculated using visual observations from the underwater camera surveys was significantly correlated to the density predicted by bottom trawl surveys, trawl data were found to be poor at explaining variability in coral and sponge density (Rooper et al., 2025). Deep-water corals and sponges are known to be vulnerable to both the impacts of fishing and changing ocean conditions. These taxa are vulnerable to bottom contact fishing gear (Koslow et al., 2000; Heifetz et al., 2009) and the effect of fishing will depend on the taxa size and shape, bottom type characteristics and type of fishing gear (Collie et al., 2000; Kaiser et al., 2006). Ocean conditions in the

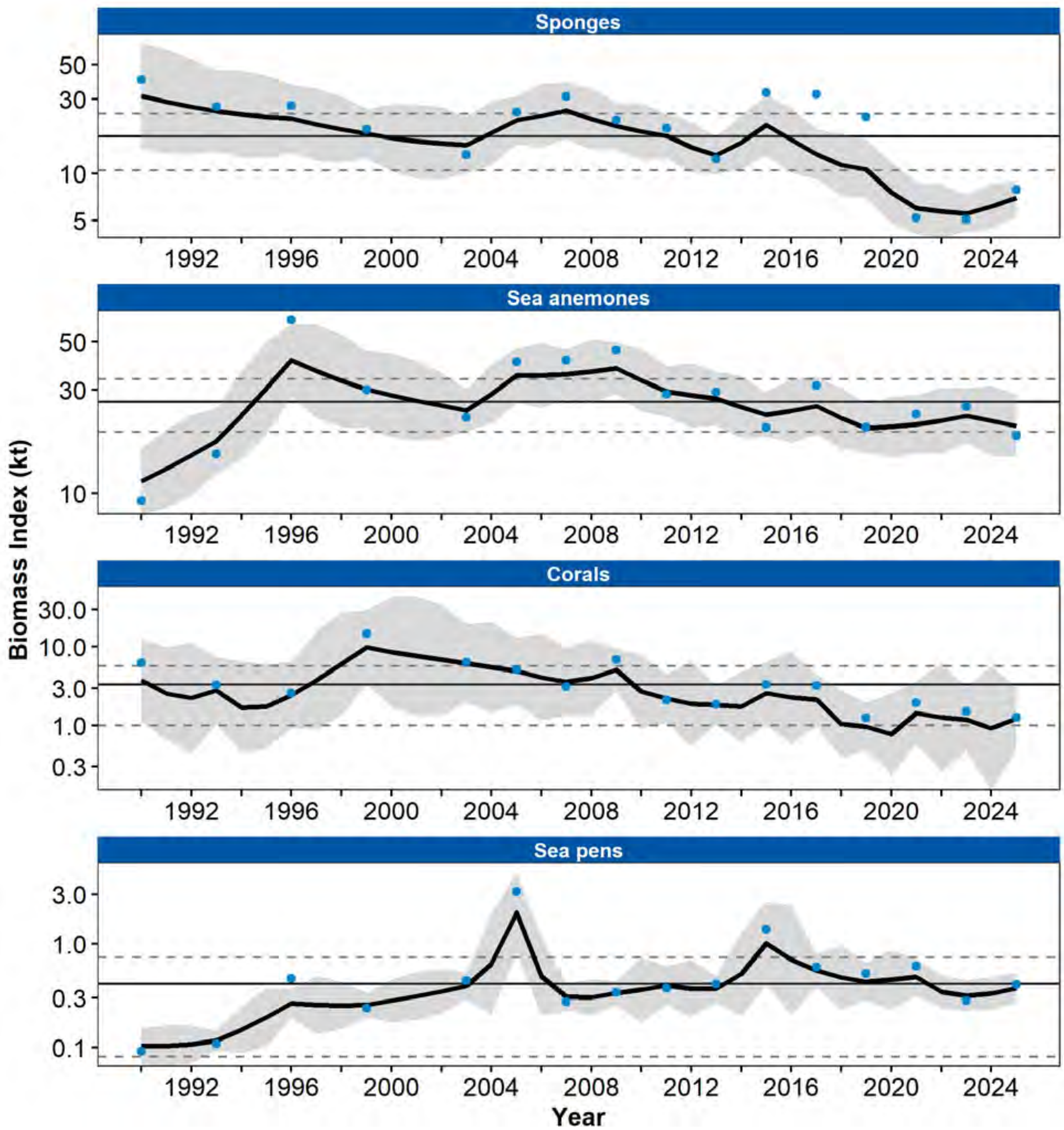

Figure 29: Biomass index of structural epifauna (sponges, sea anemones, corals, and Pennatulaceans) from AFSC/RACE summer bottom trawl surveys of the Gulf of Alaska from 1990 to 2025. Panels show the observed total survey biomass (blue points), standard error (vertical error bars), biomass index time series mean (solid black line), 95% confidence interval (gray shading), overall time series mean (solid gray line), and one standard deviations from the mean (dashed grey line). Y-axis is on a log-scale.

Gulf of Alaska that may impact the abundance of these groups include changes in temperature, water chemistry, and changes in the movement and speed of ocean currents. Recent climatic events including warm water anomalies observed in 2013 – 2016 and 2018 – 2020 (Bond et al., 2015; Di Lorenzo and Mantua, 2016; Hauri et al., 2024) have almost certainly impacted some of these sessile populations.

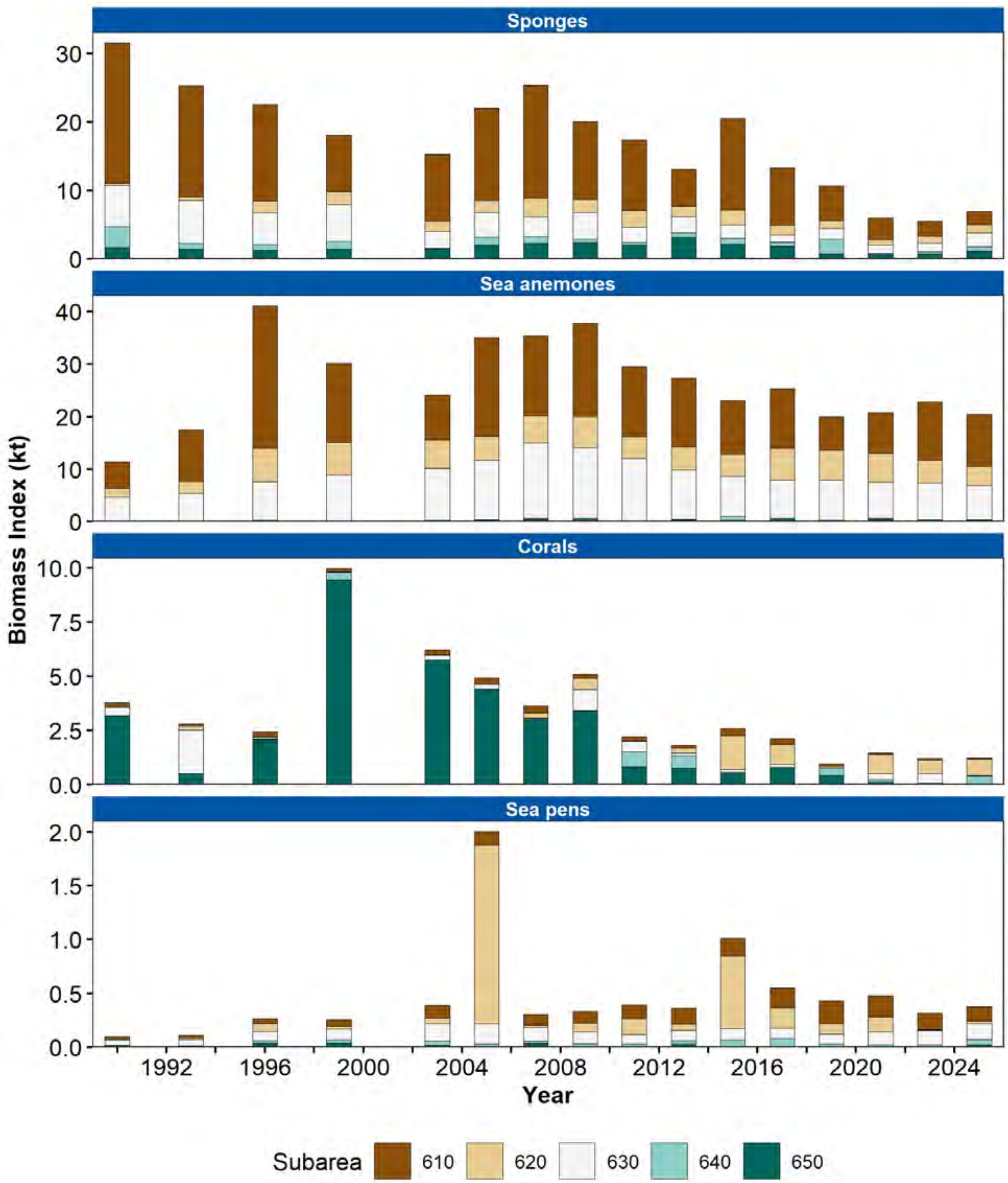

Figure 30: Biomass index of structural epifauna (sponges, sea anemones, corals, and Pennatulaceans) in NMFS Statistical Areas in the Gulf of Alaska (610 - Shumagin, 620 - Chirikof, 630 - Kodiak, 640 - West Yakutat, 650 - Southeast Outside) estimated from RACE Groundfish Assessment Program summer bottom trawl survey data from 1990 to 2025. Colors denote NMFS statistical areas.

Bottom temperatures measured during bottom trawl surveys indicate that temperatures in 2025 were generally warmer in the GOA than previous surveys and higher than historic averages in the western and central GOA (Ref this year's ESR). In addition, some structural epifauna, like most corals, have carbonate skeletons that are likely to be negatively impacted by changing water chemistry. In addition, changes to currents is likely to impact the food that is available to these filter feeding organisms. Non-motile HAPC organisms are particularly sensitive to these changes in the benthic environment.

Implications: The association of many commercially important groundfish species with high relief habitat containing structure-forming invertebrates like coral and sponge is documented. Structurally complex habitat provides a refuge from strong currents, protection from predators, spawning habitat, and may act to increase prey resources (Carlson and Haight, 1976; Carlson and Straty, 1981; Lauth et al., 2007). In Alaska, the three most commercially important rockfishes, Pacific ocean perch (*Sebastes alutus*), northern rockfish (*S. polyspinis*), and dusky rockfish (*S. variabilis*) have all been documented to have strong associations with this habitat type (Carlson and Straty, 1981; Rooper et al., 2007; Rooper and Martin, 2011; Conrath et al., 2019). The decline in biomass indices for sponges, anemones, and corals is concerning given these associations with commercially important fish species. Trends of declining sponge abundance are particularly troubling and this trend is also found in Gulf of Alaska observer records of catch of non-target species in groundfish fisheries in the Gulf of Alaska (Whitehouse and Gaichas, 2025). In addition, underwater camera survey data collected between 2019 – 2022 (Rooper et al., 2025; Jones et al., 2021) has revealed dead sponges in multiple areas of the Gulf of Alaska (Goddard, personal communication). All of this evidence together indicates a need to better understand how deep-sea sponge habitats may be changing within this region. Although the unknown catchability and the grouping of many species into large taxonomic groups limit the amount of interpretation that is possible from these results, these surveys are conducted in a standardized manner and the multi-year trends in these large taxa groups are an indication of a decline in the habitat available to rockfishes and other species. Given the limitations of interpretation of these data, gathering additional information from other data sources, particularly visual data sources, would be valuable in understanding the mechanisms and implications of observed trends. The final report of the 2020 – 2024 Alaska Coral and Sponge Initiative summarizes recent deep-sea coral and sponge research and provides an extensive list of research priorities (Conrath et al., 2025).

Primary Production

Satellite-derived Chlorophyll-a Trends

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Last updated: September 2025

Description of indicator: Phytoplankton provide basal resources for secondary consumers like zooplankton and larval fish. During spring, a large bloom occurs once the upper surface of the water column stratifies, and light intensity becomes strong enough to support phytoplankton growth. This bloom takes advantage of abundant nutrient stores remaining in surface waters after winter storms when phytoplankton activity is low. The spring bloom is critical for nourishing zooplankton, which in turn provide food for fish populations. The timing and magnitude of a phytoplankton bloom varies annually and may play an important role in the success of cohorts each year. We used 8-day composite satellite chlorophyll *a* (chla) data from the Ocean Colour ECV project[19]. We average concentrations from April–June, across the eastern and western GOA (divided at 147^0W), to capture the conditions during the spring bloom. The coastal areas of focus (on the continental shelf; depths 10 – 200m) coincide with major fish and zooplankton feeding and spawning areas. We summarized the mean chlorophyll value through spring (Figure 32), in addition to the magnitude of the annual spring event (Figure31). A persistent consideration with satellite-based chlorophyll data is the effect of cloud cover, which precludes quality data collection. On average, about 25% of data was missing during the spring periods examined for each year, which adds uncertainty to our assessments. Coverage for 2025 had an average of 92% in the western GOA and 81% in the eastern GOA.

Status and trends: The spring bloom progresses from inshore to offshore for the eastern GOA, while the western GOA is more complex. Both regions exhibit high inter-annual variability for the whole time series (time series: 1998 – 2025).

Bloom Timing and Peak Magnitude, Figure 31: In 2025, the peak bloom in the western GOA was slightly lower than the mean peak bloom (2025 - 3.14 mg m^{-3} vs mean peak of 3.63 mg m^{-3}), while bloom timing was right at the mean (May 21). For the eastern GOA, the peak bloom was below the mean (2025 - 2.41 mg m^{-3} vs mean peak – 4.28 mg m^{-3}). Additionally, the eastern GOA bloom appeared to occur late, about a month after the mean timing (2025 June 14, compared to an average date of May 14).

Seasonal Chlorophyll Means, Figure 32: The seasonal mean (April –June) in western GOA was slightly

[19]https://climate.esa.int/en/projects/ocean-colour/

above average (2025 – 1.73 mg m^{-3} vs long-term mean -1.62 mg m^{-3}). For eastern GOA, the long-term chlorophyll mean was somewhat below average (2025 1.47 mg m^{-3} vs avg. 1.60 mg $^{-3}$). Mean chla values in both regions were within one standard deviation of their means for 2025.

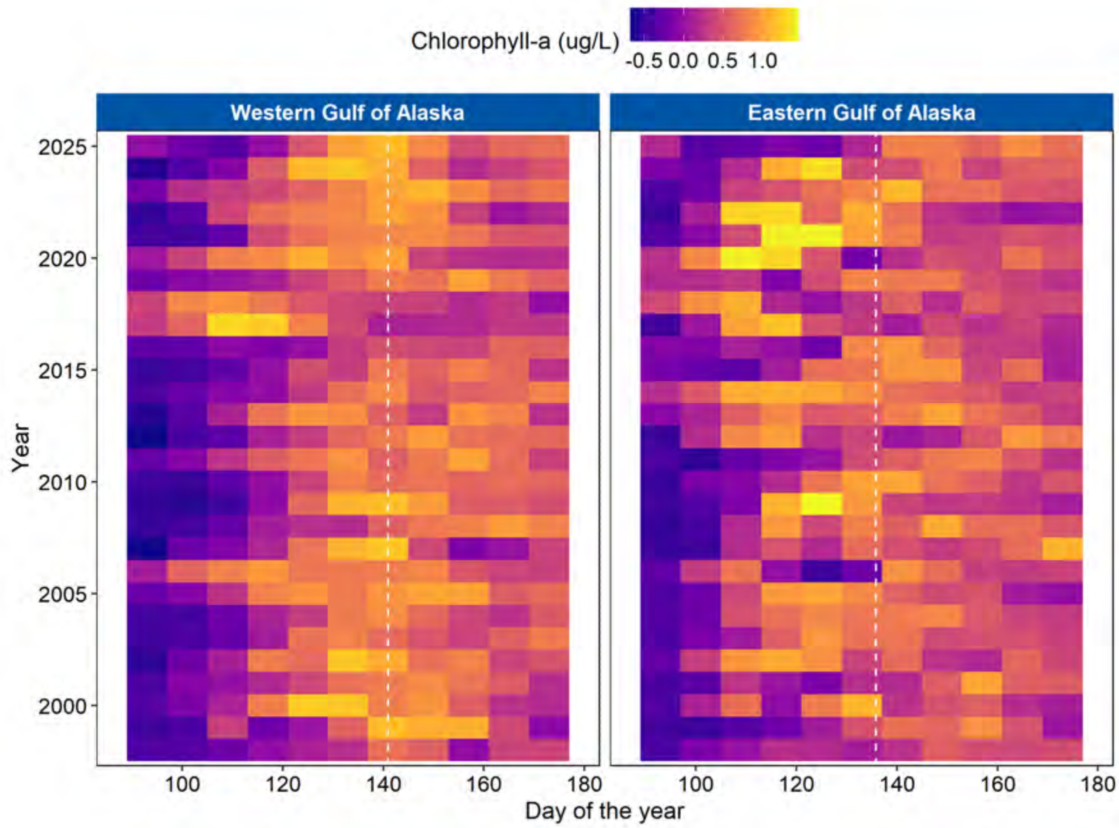

Figure 31: Average 8-day composite chlorophyll concentrations (log-transformed) for the western and eastern GOA. The brightest (yellow) color within each year will represent the peak bloom (less bright yellow reflects a lower peak). All years are on the same color scale. Vertical dashed lines illustrate the mean day of the year of spring bloom timing for the western (day 142; approximately May 21) and the eastern (day 135; approximately May 14) Gulf of Alaska. For reference, days of year 100 and 180 fall around April 9 and June 30, depending on leap years.

Factors influencing observed trends: Given the complexity of phytoplankton, a number of factors may be contributing to variations in chlorophyll-a concentrations. Mesoscale eddies play a large role in the GOA chlorophyll patterns offshore of the continental shelf, with evidence of influence via eddy-moderated shelf-slope exchange creating phytoplankton 'hot spots' over the shelf (Okkonen et al., 2003). Additionally, spring runoff and ambient nutrient concentrations can affect timing of blooms over the shelf (Waite and Mueter, 2013). It is unclear why the eastern GOA bloom timing was considerably late this year, but it's notable that cloud cover was increased in the eastern GOA during April and May, which may have skewed composite data.

Implications: Timing and magnitude of peak chlorophyll concentrations are important for gauging general food availability for zooplankton and are thus also relevant for many of the planktivores that rely on zooplankton. In the eastern GOA, chlorophyll inter-annual variations are correlated with zooplankton biomass, which in turn are correlated with annual catch yields of resident fishes (Ware and Thomson,

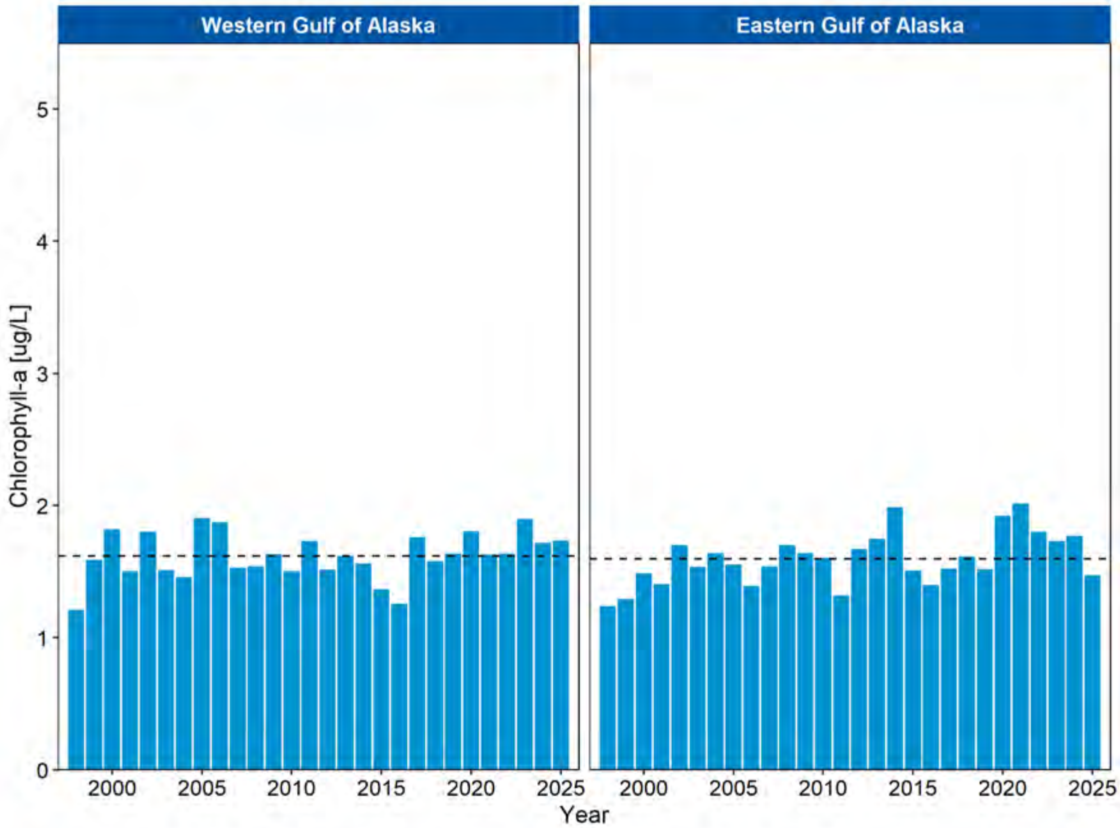

Figure 32: Average spring (April-June) chlorophyll-a concentrations based Ocean Colour ECV satellite 8 day composites for the western and eastern GOA. The horizontal dashed line is the long-term mean (2003– 2024). *A persistent consideration with satellite-based chlorophyll data is the effect of cloud cover, which precludes quality data collection. Satellite coverage was lower during April and May in the eastern GOA, which adds uncertainty to our assessments.

2005). Factors affecting phytoplankton blooms can be complicated, and more extensive work is required to resolve any direct connections between groundfish recruitment and chlorophyll concentrations. Implications of the late bloom in the eastern GOA are unclear, although low chlorophyll during April and May could affect young and growing fish during this time. It should be noted that smaller geographic areas in addition to depth-averaged in-situ data as opposed to remotely sensed data can show vastly different trends (Seward line). Overall, western GOA chlorophyll concentrations appeared relatively average for 2025, while eastern GOA was on the low side.

Seward Line May Phytoplankton Size Index

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Last updated: September 2025

Description of indicator: Since 1998, hydrographic transects have been completed in May (typically during the first 10 days of the month) along a sampling line that extends from the mouth of Resurrection Bay near Seward to the outer continental slope of the northern Gulf of Alaska. Episodically beginning in 2001 and annually beginning in 2011, chlorophyll-a (chl-a) in two size fractions ($<$20 μm and $>$20 μm) as well as total chl-a have been measured at 6 – 7 depths (0 to 50 or 75 m) at stations spanning the continental shelf and offshore waters. Data provided here are an index of size composition of the phytoplankton shelf community originally developed by Suzanne Strom of Western Washington University. The index is computed from depth-integrated shelf station chl-a values for each early May cruise, and is equal to the fraction total chl-a found in the large ($>$20 μm) size class (i.e., chl-$a_{>20}$/ chl-a_{total}). In most cases 9 stations are averaged to generate the index. High values of the size index correspond to diatom-dominated communities, while low values of the size index correspond to phytoplankton communities dominated by small flagellates and cyanobacteria. Comparison with remote sensing-based estimates of spring bloom timing and magnitude shows that the size index is a predictor of two important aspects of the spring bloom. 1) When the index is $\leq$ 0.25, meaning that small cells strongly dominate, the spring bloom begins and peaks relatively late in the year. 2) When the index is $\geq$ 0.5, meaning that large cells comprise half or more of the total chl-a, the value of the index is strongly correlated ($r^2 = 0.65$) with the cumulative magnitude of the spring bloom (April – June) as measured by remote sensing.

Status and trends: No long-term secular trend is evident in the phytoplankton size index, although there is a suggestion that variance has increased in recent years. The marine heatwave years of 2014 – 2016 show the lowest values in the time series, with the (lesser) heatwave year of 2019 also showing a low value. *This year (2025) had a value that was comparable to a marine heatwave year which suggested that warmer than average temperature in the proceeding winter caused a smaller cell-dominated spring bloom*. This contrasts strongly to the past few years (2021 – 2024) which had some of the high to moderately high index values consistent with the spring diatom blooms.

Factors influencing observed trends: The mix of resource availability (light, micro- and macronutrients) and top-down controls leading to shifts in the spring size index is under active investigation. Spring water temperature per se probably has little direct influence, as the temperature range observed is small relative to the physiological tolerance of these phytoplankton.

Implications: High values of the size index correspond to diatom-dominated communities, which are known to provide high amounts of lipid-rich prey for zooplankton (i.e., copepods, euphausiids). Low values of the size index correspond to phytoplankton communities dominated by small flagellates and cyanobacteria, which are less available to large zooplankton and may lead to less efficient transfer of primary production to higher trophic levels. A late spring bloom could lead to timing mismatches between the emergence/development of important zooplankton grazers and the availability of diatom prey, which would have negative effects on transfer of production to higher trophic levels. Conversely,

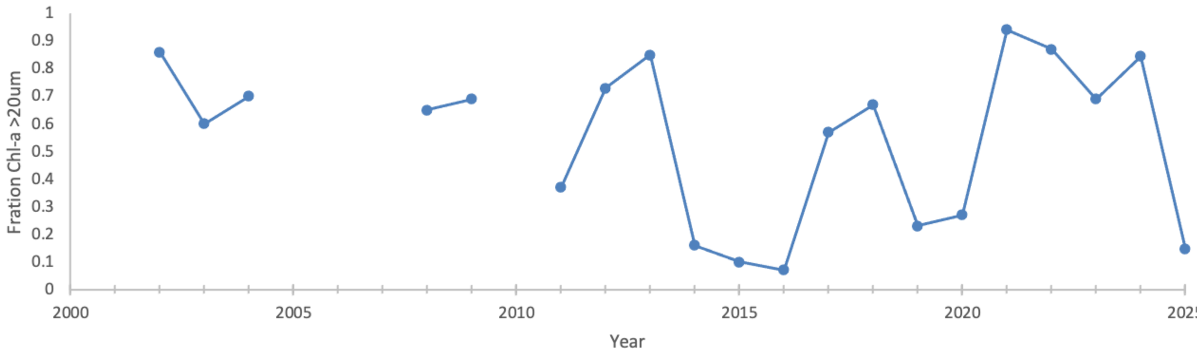

Figure 33: May 2001–2025 time series of phytoplankton size index (fraction of total chl-a present in cells >20 μm) for the Seward Line shelf stations.

a larger spring bloom introduces more primary production into the ecosystem in a form that can be efficiently transferred to higher trophic levels in the water column and the benthos.

Zooplankton

Continuous Plankton Recorder Data from the North-east Pacific, 2002–2024

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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 three regions (Figure 34); the abundance per sample of large diatoms (the CPR retains large, hard-shelled phytoplankton so while a proportion of the community is not sampled, the data are internally consistent and may reveal trends), meso-zooplankton biomass (estimated from taxon-specific weights and abundance data) and mean copepod community size (see Richardson et al., 2006 for details but essentially the length of an adult female of each species is used to represent that species and an average length of all copepods sampled calculated) as an indicator of community composition. Anomaly time series of each index have been calculated as follows: A monthly mean value for each region is first calculated. Each sampled month's mean is then compared to the long-term geometric 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 indices are calculated separately for the oceanic eastern GOA, oceanic western GOA (divided at 147 °W), and the Alaskan shelf southeast of Cook Inlet (Figure 34). Only the red points within the shaded boxes in Figure 34 are included in the calculations (for example the red points on the shelf outside the shaded box were considered too small a sample size to adequately represent conditions). The oceanic eastern GOA regions have better sampling resolution than the Alaskan shelf and oceanic western GOA region as both transects intersect here. This region has been sampled up to 8 times per year with some months sampled twice. The Alaskan shelf region is sampled 5 – 6 times per year by the north-south transect and the western GOA region is sampled 36 times per year, mostly by the east-west transect. The North Pacific CPR survey is supported by a consortium comprising the North Pacific Research Board, the Exxon Valdez Oil Spill Trustee Council through Gulf Watch Alaska, Fisheries and Oceans Canada, the North Pacific Marine Science Organisation and the Marine Biological Association, UK.

Status and trends: The diatom abundance anomaly for the shelf region and western Gulf of Alaska was positive for 2021 – 2024 (relative to a baseline of 2002 – 2023) having been negative in 2020 (Figure 35). On the eastern side of the oceanic Gulf of Alaska the diatom anomaly was negative in 2024. The

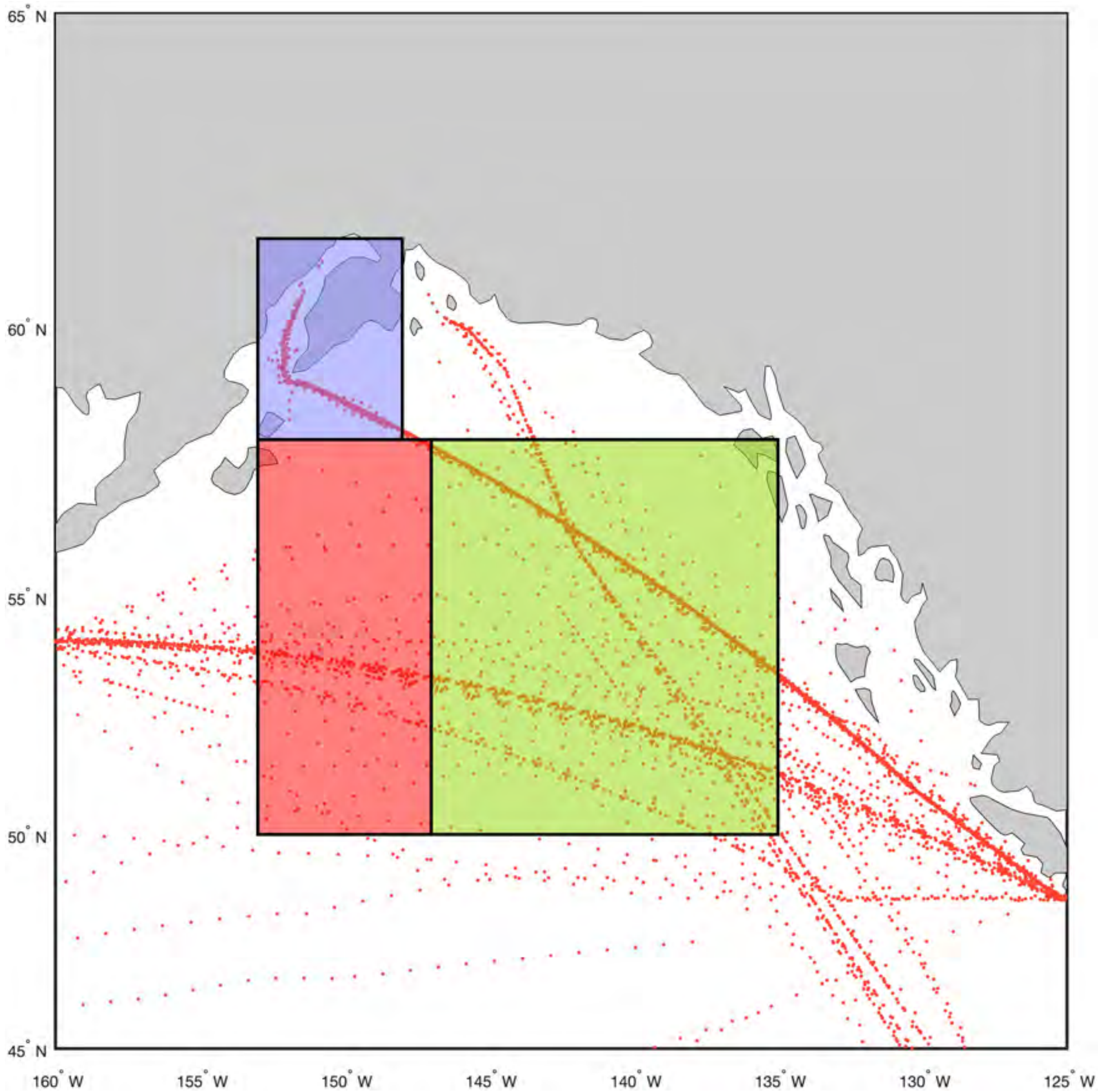

Figure 34: Location of the data used in this report, highlighted as Alaskan shelf (blue rectangle), eastern oceanic Gulf of Alaska (green rectangle), and western oceanic Gulf of Alaska (magenta rectangle). Red dots indicate actual sample positions (note that for the shelf region the multiple transects overlay each other almost entirely).

copepod community size anomaly was negative in 2024 in the Alaskan Shelf and western side of the gulf of Alaska, but it was positive in the eastern side. Zooplankton biomass anomalies were positive in both the Shelf and eastern Gulf of Alaska regions in 2023 and 2024, while the anomaly has remained negative in the western side of the Gulf of Alaska since 2019.

Factors influencing observed trends: 2024 had a mean negative Pacific Decadal Oscillation (PDO), however conditions were still warm in recent years. In warm conditions smaller species tend to be more abundant and the copepod community size index reflects this and was mostly negative throughout the marine heat wave periods of 2014 – 2016 (Di Lorenzo and Mantua, 2016), and 2018 – 2020 and in 2023 and 2024 in the shelf region. The large diatom abundance was positive in 2024 in the shelf and western regions. It is unclear what has led to the increase in diatom abundance, but it could be due to

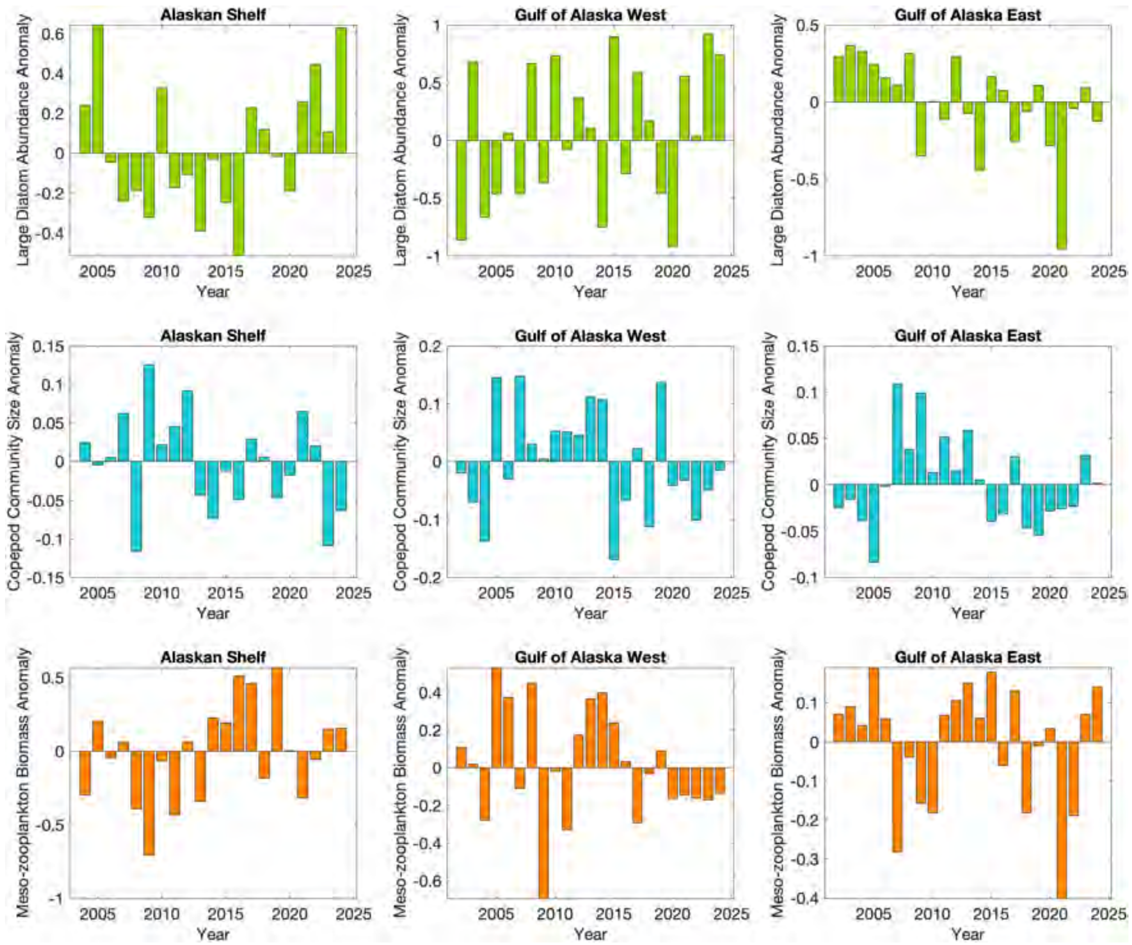

Figure 35: Annual anomalies of three indices of lower trophic levels (see text for description and derivation) for all three regions shown in Figure 34. Note that sampling of the shelf region did not begin until 2004.

a reduction in grazing pressure.

Implications: Each of these variables is important to the way that ocean climate variability is passed through the phytoplankton to zooplankton and up to higher trophic levels. 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 organisms to their predators. Changes in abundance or biomass, together with size, influences availability of prey to predators.

Current and Historical Trends for Zooplankton in the Western Gulf of Alaska

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Last updated: September 2025

Description of indicator: AFSC implemented a Rapid Zooplankton Assessment (RZA) to provide leading indicator information on zooplankton abundance trends in Alaska's Large Marine Ecosystems in 2015 (Kimmel et al., 2024). The RZA is a rough count conducted at sea from paired 20/60 cm oblique bongo tows and provides a preliminary estimates of zooplankton abundance (Kimmel et al., 2024). The RZA uses standard zooplankton processing methods to enumerate zooplankton into three categories: small copepods $<$ 2 mm (example species: *Acartia* spp., *Oithona* spp., and *Pseudocalanus* spp.), large copepods $>$ 2 mm (example species: *Calanus* spp. and *Neocalanus* spp.), and euphausiids $<$ 15 mm (example species: *Thysanoessa* spp.). Small copepods were counted from the 153 μm mesh, 20 cm diameter net and large copepods and euphausiids were counted from the 505 μm mesh, 60 cm diameter net. Detailed taxonomic information on these groups is provided after laboratory processing has been completed (approximately one year post survey) and abundance indices are updated with laboratory processed counts in the following year. All current survey year zooplankton abundance estimates are derived from the RZA.

Methodological changes: This year we have made changes to the zooplankton contribution. First, we are no longer reporting euphausiid abundances as we are developing an acoustic index for EcoFOCI surveys. This will provide a more accurate abundance index for euphausiids moving forward as bongo net estimates are considered less reliable for abundance estimation due to net avoidance (Hunt et al., 2016). We made a minor change in the mapping of the current year's RZA data to allow for better visual comparisons across surveys. We now report abundance estimates in $\log_{10}$ number m^{-2} for all three taxonomic groups. This has the effect of keeping the scales more conistent from both within and between surveys. Second, we have standardized the annual abundance indices for each coarse taxonomic group using spatiotemporal modeling (Shelton et al., 2014; Thorson and Kristensen, 2016). This approach better accounts for spatial variability arising from different sampling regimes across years as the spatial coverage and timing of the survey may differ between years (Anderson et al., 2022). Standardized indices provide an area-weighted population index predicted from a model covering a specified grid area and are therefore independent of sampling locations that vary annually. We used the *sdmTMB* package in R (Anderson et al., 2022) to develop the strandardized, annual abundance indices based on prior work demonstrating the effectiveness of spatiotemporal modeling for exploring the seasonal dynamics of *Calanus marshallae/glacialis* in the Bering Sea (Thorson et al., 2020). All models accounted for spatial random fields and independent spatiotemporal fields using stochastic partial differential equation (SPDE) approximation to Gaussian random fields with Gaussian Markov random fields (Lindgren et al., 2011). Annual abundance indices were modeled using year as a factor and may or may not include a smoother, day-of-year effect to account for shifts in sample collection times year to year. Day-of-year was standardizd to day 135 ($\sim$ 15 May) for the spring index and day 248 ($\sim$ 5

September) for the summer/fall index. The spatial area used to estimate the spring and summer/fall indices for the Gulf of Alaska remains unchanged from prior years' spatial area and is the same used to estimate larval abundance indices (see larval abundance contribution). Zooplankton data were modeled using the Tweedie distribution (to account for zero-inflated data) or the lognormal distribution and included spatial random effects and spatiotemporal random effects (Anderson et al., 2022). The entire, area-weighted abundance summer over 20 km^2 grid cells is then estimated for each zooplankton group and reported as an annual time-series.

We completed a spring larval survey from 17 May to 4 June 2025. Here, we show maps from the 2025 survey and an updated spring long-term time-series for the western Gulf of Alaska that include processed data for 2024 and an RZA estimate of abundance for 2025. The summer age-0 survey was not conducted, therefore no data are able to be presented for this survey.

Status and trends: Both small and large copepod abundances during the spring larval survey showed minimal spatial variability (Figure 36). Small copepods were very abundant, above 1 standard deviation of the long-term mean, in 2025 (Figure 37). This continues a trend that began in 2012, where small copepod abundances have been elevated during the spring. In contrast, large copepods were low with increased abundances in the region just southwest of Kodiak Isalnd and modeled abundances were below average relative to the long-term mean (Figure 37)

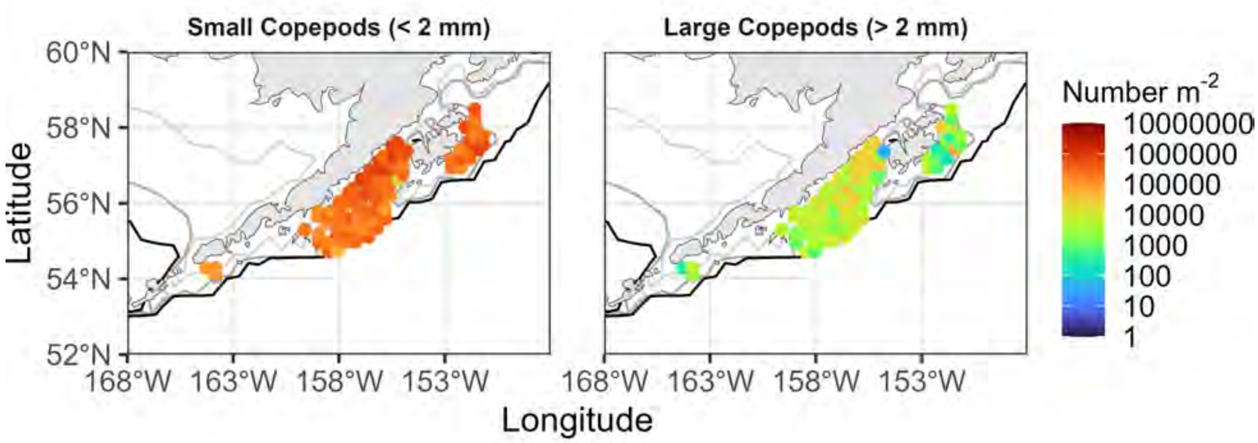

Figure 36: Maps show the abundance of small (left) and large copepods (right) estimated by the rapid zooplankton assessment during the spring larval survey in 2025. X indicates a sample with abundance of zero individuals m^{-2}. Bathymetry is shown by light gray (50 m), medium gray (100 m), and black (200 m) lines.

Factors influencing observed trends: Warm spring temperatures resulted in high abundances of small copepods, which have been observed since 2012 and coinciding with the marine heat wave conditions that occurred in 2014 – 2016 and 2019. Temperatures during spring of 2025 were at or near heatwave values. Small copepod abundances increase during warm conditions because small copepods have multiple generations per year, faster turnover times, and metabolic rates that scale less dramatically with temperature than large copepods (Kiörboe and Sabatini, 1995). Large copepods were a mixture of *Neocalanus* spp. and *Calanus marshallae* and overall abundances were low relative to the long-term time-series (Figure 37). Warm temperatures tend to reduce *Neocalanus* spp. numbers as they may enter diapause earlier in the spring under warm conditions. The abundances of *C. marshallae* typically

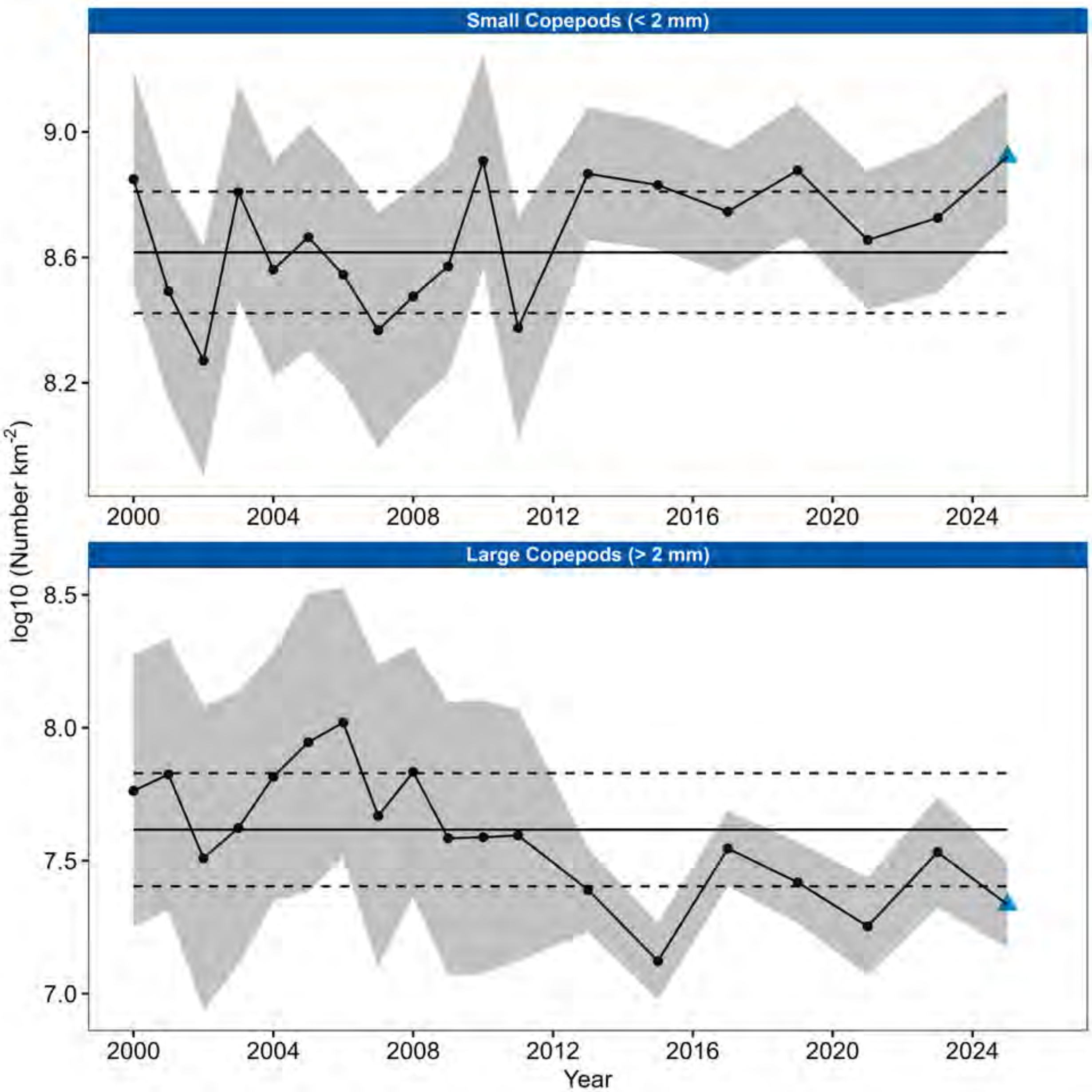

Figure 37: Standardized annual abundance indices for the spring updated to 2025. Annual, area weighted abundance estimate (black circles), abundance estimate based on RZA data (blue triangle), upper and lower confidence intervals of the estimates (shaded area), mean abundance for the total data record (solid black line), and ± 1 standard deviation of the mean abundance for the total data record (dashed lines).

increase in warmer springs (Kimmel and Duffy-Anderson, 2020), however this was not observed in 2025. This may be related to the timing of the survey combined with warmer temperatures impacting *C. marshallae* phenology and/or mortality.

Implications: Zooplankton are an important prey base for larval and juvenile fishes in spring and summer. Small copepod numbers remained high indicating that there is likely a sufficient number of nauplii and smaller copepods available as prey for larval fishes during spring. Note the small copepod proportion does not include nauplii (the primary prey for early larval fishes) and a decline in nauplii did occur during the recent marine heatwave (Rogers et al., 2020). The lack of large copepods is less relevant in spring when larval fishes predominate; however, it may indicate that the system timing for larger copepods is changing or may indicate shifts in overall productivity (Kimmel and Duffy-Anderson, 2020). Thus, phenological changes that have been detected for walleye pollock in the western GOA (Rogers et al., 2018) may also be occurring for copepods. It will be interesting to see if the low abundances of *C. marshallae* persist or rebound, as was observed in 2017 after the 2014 – 2016 marine heatwave when abundances increased. A lack of large copepods and euphausiids in the Gulf of Alaska leads to age-0 walleye pollock diet shifts where less energetically dense prey items are consumed (Lamb and Kimmel, 2021). However, there was no age-0 survey in 2025, so we have no data on large copepod numbers in the summer/fall. Recent summer abundance numbers for large copepods have been near the long-term mean, even during recent marine heatwave years. In conclusion, we suggest the zooplankton community in the western GOA in 2025 showed similar abundances to recent marine heatwave years in the spring.

Euphausiids in the Western Gulf of Alaska

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Last updated: September 2025

Description of indicator: Euphausiid biomass, length, and species composition from the 2025 Gulf of Alaska spring larval survey were estimated using acoustic and net sampling data. Euphausiid acoustic backscatter was identified using methods developed by Ressler et al. (2012), (Simonsen et al., 2016), and updated by Levine et al. (In Prep). Euphausiid backscatter was integrated within 5 nautical mile (nmi) grid cells along the survey track line. Backscatter measurements were then converted to units of abundance and biomass using data from Methot trawl samples. Mean euphausiid length from the trawl samples was used to estimate the acoustic target strength of individual krill using a Gulf of Alaska-specific target strength model (Lucca et al., 2021, as parameterized in Levine et al. (In Prep), allowing for conversion from backscatter to abundance. Biomass (wet weight; g m^{-2}) was then calculated from wet weight to length relationships (Harvey et al., 2012; note that all measurements in Harvey et al., 2012 were done on eastern Bering Sea *Thysanoessa inermis*, *T. raschii* and *T. longipes specimens*.

Status and trends: Euphausiids were present throughout the survey area with the highest biomass appearing on the south western end of Shelikof strait (Figure 38). Biomass was generally higher inshore as opposed to offshore. The mean biomass was 55.4 g m^{-2} across the total survey area. *T. inermis* were the dominant species throughout the survey area, with *T. spinifera* and *E. pacifica* in greater numbers in the north east Shelikof strait and the north side of Kodiak (Figure 39). The mean size of all species caught in the Methot trawls was 14 mm.

Factors influencing observed trends: This is the first acoustic-trawl estimate of euphausiid biomass in the spring for the Gulf of Alaska, although there is a timeseries of euphausiid backscatter and trawl data from summer acoustic-trawl surveys collected with the same methods dating back to 2003 (Simonsen et al., 2016; Ressler, 2019). Although these data are preliminary, the spatial distribution and species composition are consistent with previous research (Simonsen et al., 2016; Ressler, 2019). Mean lengths were smaller than the 18.9 mm documented by Simonsen et al. (2016), which can be partially attributed to sampling earlier in the year and recently spawned animals in the spring vs summer.

Implications: This is the first biomass estimate in the spring for the Gulf of Alaska and therefore it is difficult to place these results in context without comparison data through time. With additional work, these data can be compared to summer time series data from Simonsen et al. (2016) and Ressler (2019). Future contributions will likely involve a combination of classified euphausiid backscatter from past surveys to observe trends over time, as well as biomass estimates for future surveys that involve Methot trawl sampling.

Knowledge of euphausiid abundance is relevant because both forage fish and juveniles of commercially important fish species use euphausiids as an important prey source, therefore information on their relative population size is useful to assess system productivity and standing stock. Trends in euphausiid distribution and abundance have been noted as particular gap in our understanding of the ecosystem,

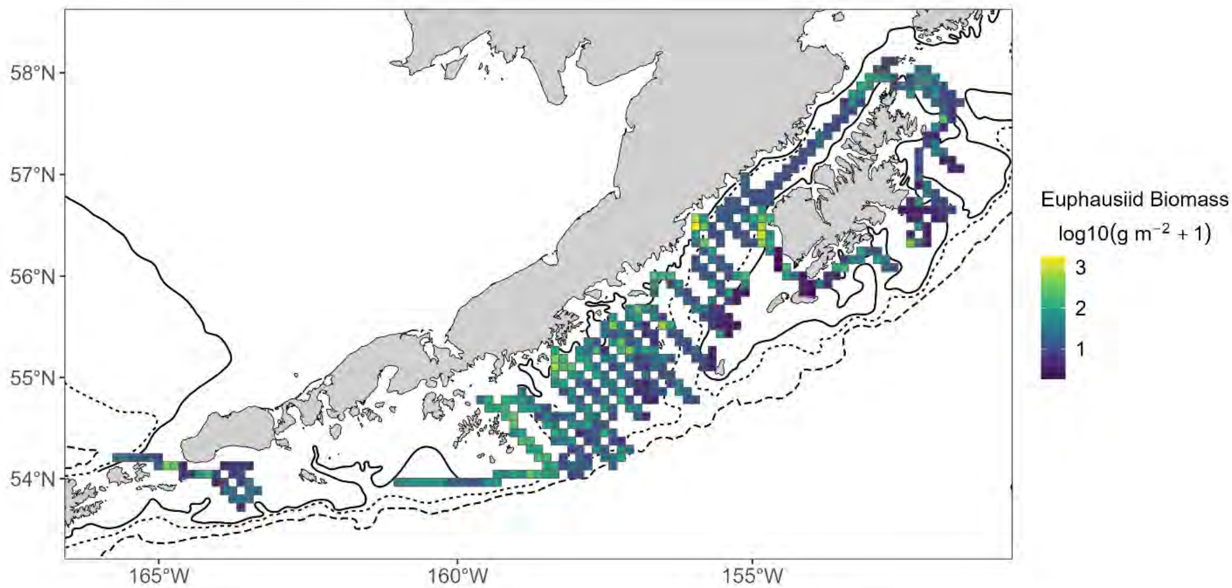

Figure 38: Map shows the biomass estimated during the spring larval survey in 2025. Bathymetry is shown by solid (100 m), dotted (200 m), and dashed (1000 m) lines.

therefore these metrics would be useful for both ecosystem-based fisheries management and system modeling. Due to their position in the food web linking primary producers to fish, shifts in euphausiid population sizes will impact the food web. These impacts would translate into population level effects beyond fish, including birds (Hunt et al., 2002; Nishizawa et al., 2017), marine mammals (Witteveen et al., 2015) and humans.

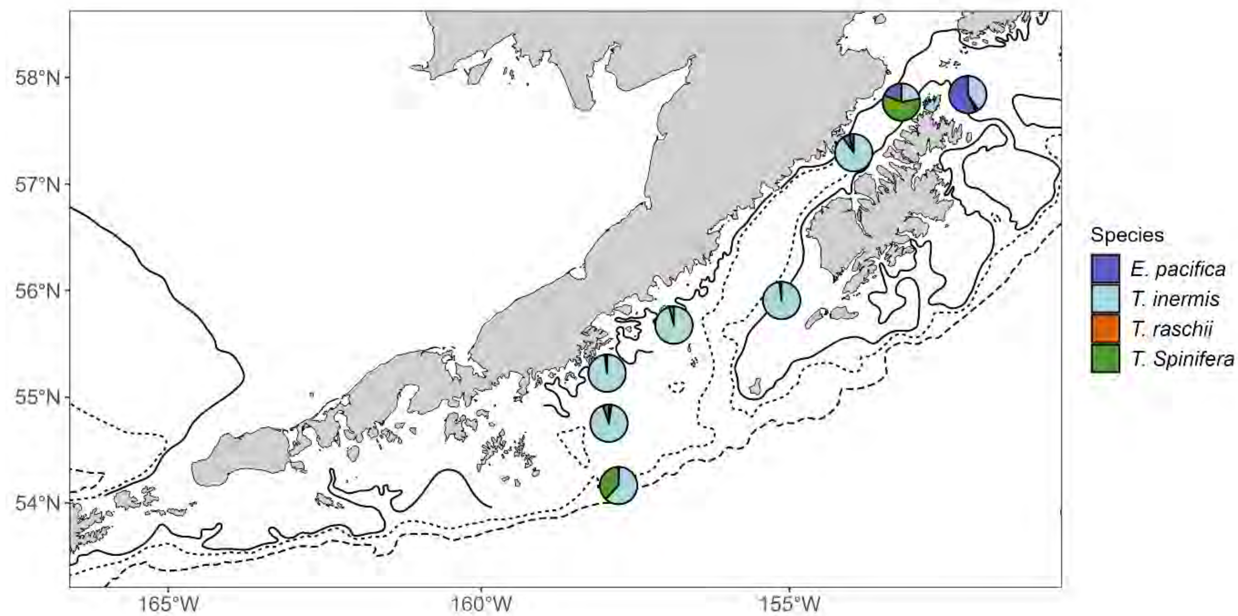

Figure 39: Map shows euphausiid species composition during the spring larval survey in 2025. Bathymetry is shown by solid (100 m), dotted (200 m), and dashed (1000 m) lines.

Spring and Fall Large Copepod and Euphausiid Biomass: Seward Line

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Last updated: September 2025

Description of indicator: Transects have been completed south of Seward Alaska typically during the first 10 days of May and during mid-September for over 25 years to determine species composition, abundance and biomass of the zooplankton community. Data is averaged over the top 100 m of the water column to provide estimates of wet-weight biomass of zooplankton summarized here for all small copepods, larvaceans and pteropods retained by a 0.15mm mesh net and a 0.5mm mesh net for large copepods & euphausiids (a.k.a. krill). These categories represent key prey for a variety of fish, marine mammals, and seabirds.

Status and trends: Large copepod biomass during May is impacted by spring temperatures, because they grow faster and therefore individuals are older/larger when waters are warmer, however a strong spring bloom can also favor faster growth, and a weak bloom slow growth. By September most large calanoids have descended into offshore waters and their biomass is greatly reduced, making krill relatively more important. Smaller-bodied copepod biomass shows less change between seasons. Preliminary analysis suggests large calanoid biomass was still lower than normal in 2025 continuing a 3-year run of low values (baseline 1998 – 2024, Figures 40 and 41. Observations suggest the body-size of the large copepods was below average and that historically dominant *Neocalanus flemingeri* has been overtaken by *N. plumchrus* on the shelf while *N. cristatus* dominated biomass off the shelf. Small copepod biomass during May 2005 was below average (Figures 40 and 42). The biomass of small copepods in September 2025 was well below average too and continues several years that have been low. Both larvaceans and pteropods are highly variable across years, neither were particularly abundant during 2025 or 2026.

In contrast, May euphausiid biomass appears to be negatively impacted by warm springs, with peaks in May often driven by high abundances of their larval stages when conditions are favorable. Continued growth and recruitment often lead to higher biomass by September. May of 2025 continues a string of above-average biomass, although confidence intervals are broad with the means poorly constrained for 2023. September biomass for euphausiids has been roughly average for the past 5 years, although no biomass estimate is available for September 2023 due to equipment failures, and 2025 data will not be available until December.

Factors influencing observed trends: Temperatures during spring 2025 were about 0.5C warmer than the 28-year thermal mean along the Seward Line during spring, while 2021 – 2023 were below average. Septembers of 2021 and 2024 have ranged from roughly average to below average, while 2025 was a full degree above average.

Implications: While high biomass of larger zooplankton does not guarantee success of species dependent upon them (due to a variety of other factors), low biomass does make predator success challenging. Changes in the mixture (and energetic content) of species contributing to overall biomass may be of consequence to specific predators. While biomass of large copepods has remained slightly below

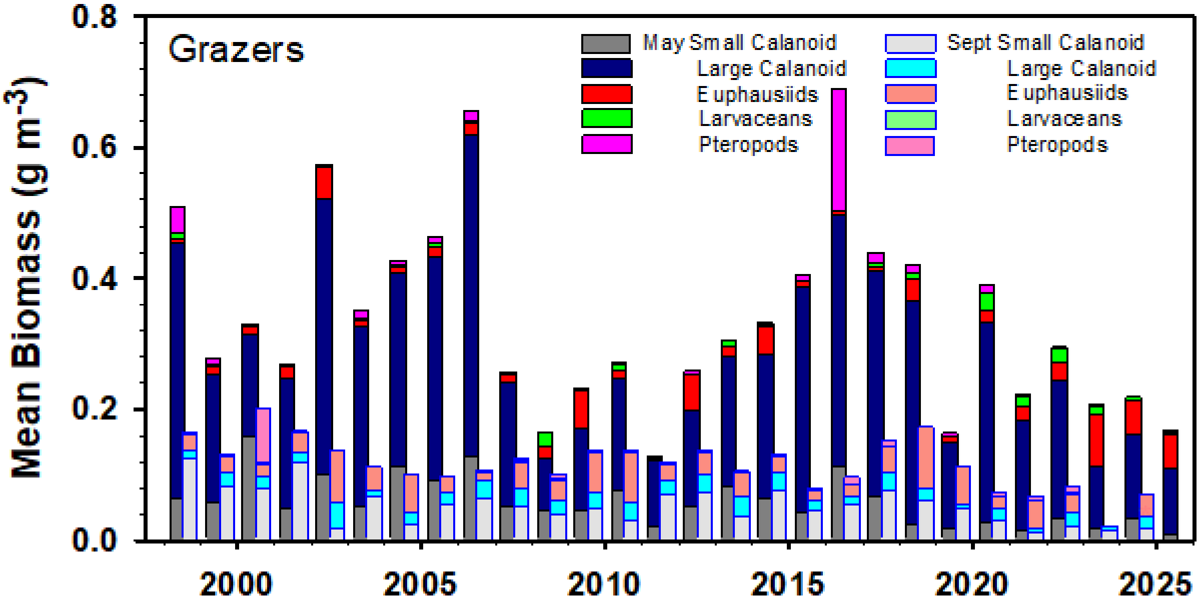

Figure 40: Biomass of zooplankton along the Seward Line sampled using a 0.15mm during days and a0.5-mm mesh at night. Transect means are calculated on power-transformed data. Data for 2022 – 2025 is only available from a subset of stations and may change as more stations are completed.

average, the mixtures of species appears to be undergoing long-term change. Many fish species larval stages are dependent initially on small-bodied copepods that have now been scarcer for 2025. The above-average biomass of euphausiids during May 2023 – 2025 suggests their predators may have more favorable feeding conditions compared to years when their biomass was low, but this prey resource has not remained high throughout the summer into fall.

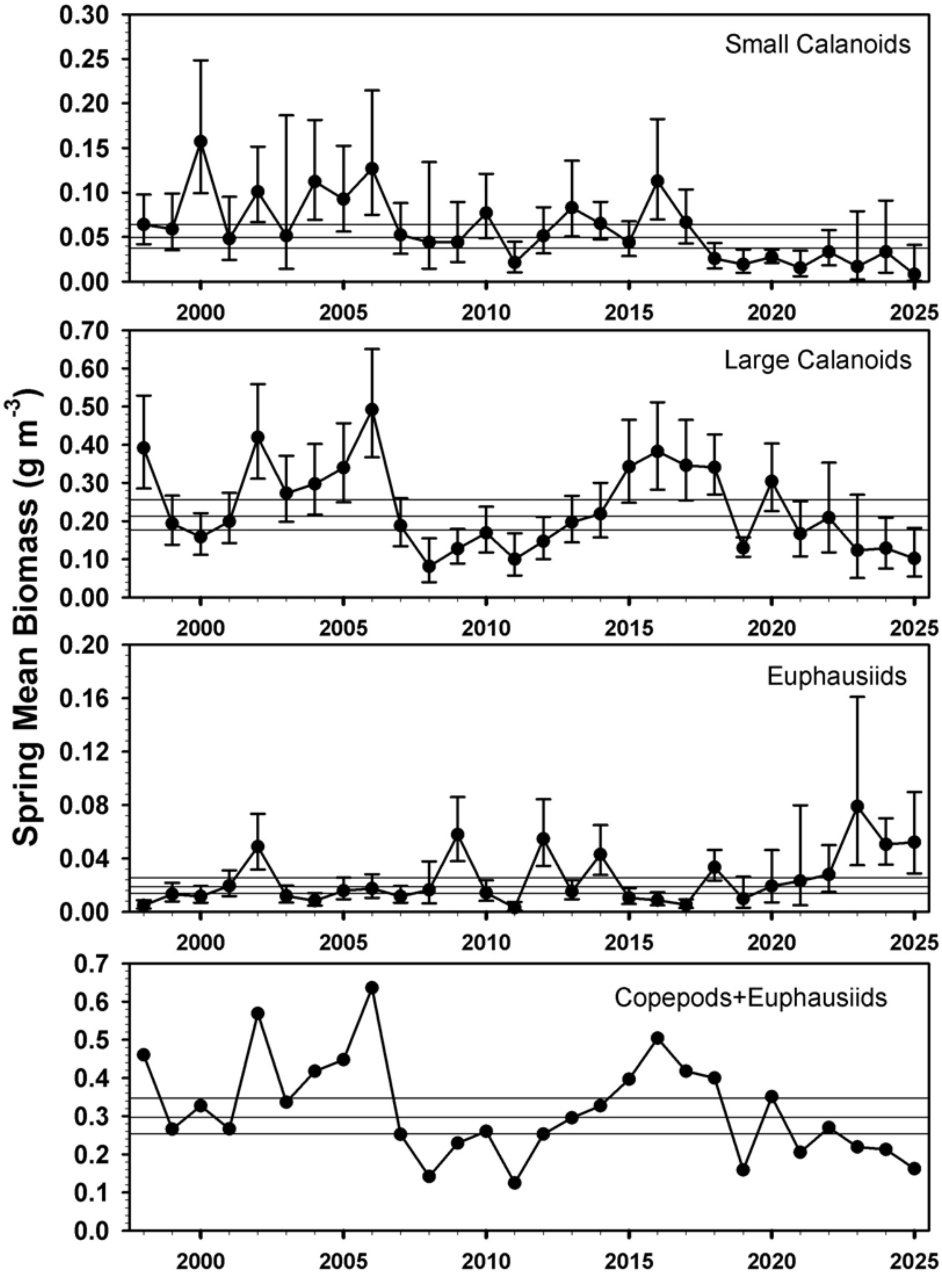

Figure 41: Biomass of zooplankton along the Seward Line sampled during the spring, using a 0.15mm during days and a0.5-mm mesh at night. Transect means are calculated on power-transformed data. Data for 2022 – 2025 is only available from a subset of stations and may change as more stations are completed.

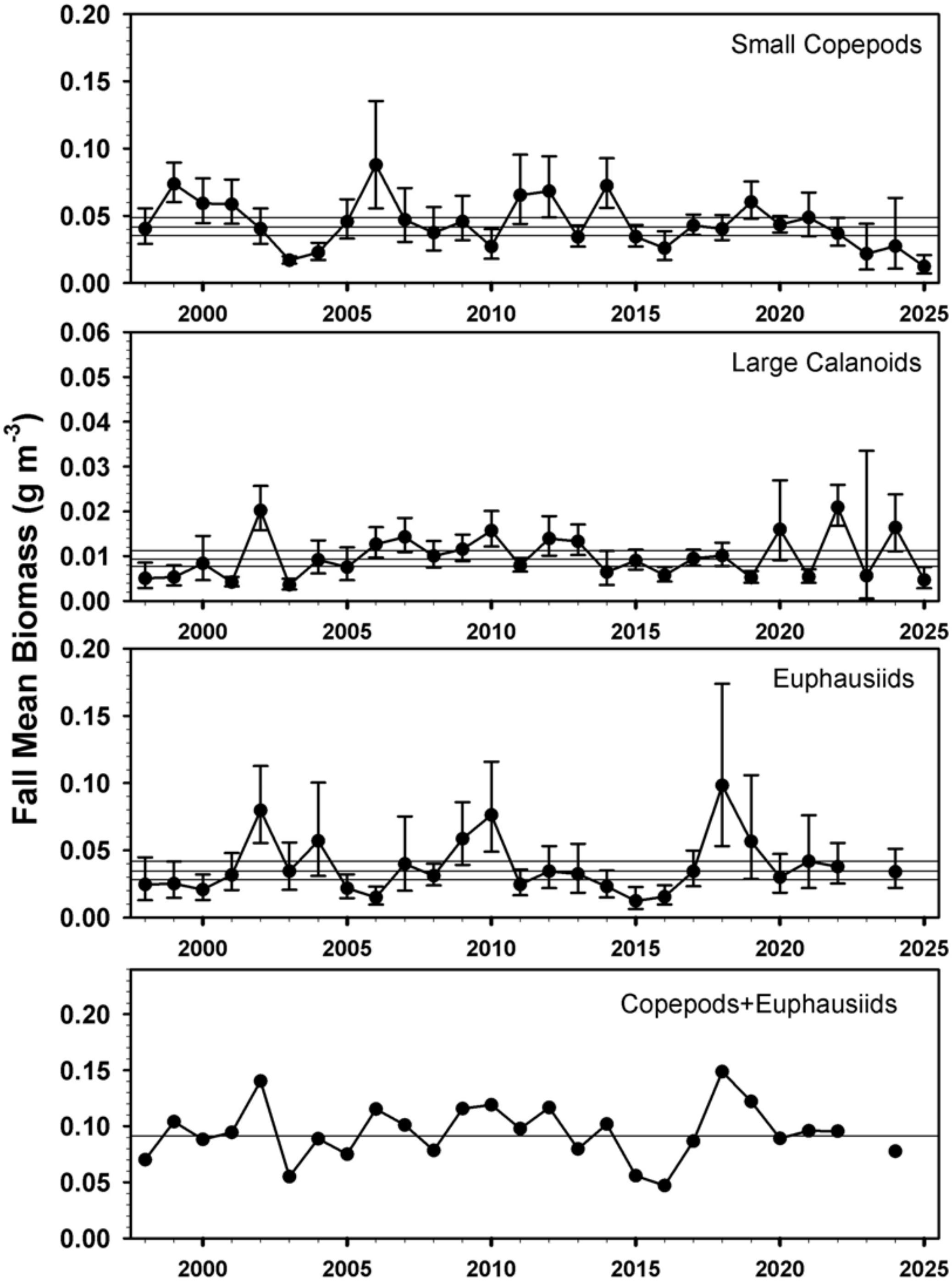

Figure 42: Biomass of zooplankton along the Seward Line sampled during the fall, using a 0.15mm during days and a0.5-mm mesh at night. Transect means are calculated on power-transformed data. Data for 2022 – 2025 is only available from a subset of stations and may change as more stations are completed.

Zooplankton Nutritional Quality Trends in Icy Strait, Southeast Alaska

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Last updated: September 2025

Description of indicator: The Southeast Coastal Monitoring project (SECM, Auke Bay Laboratories, AFSC) has been investigating how climate change may affect Southeast Alaska nearshore ecosystems in relation to juvenile salmon and associated biophysical factors since 1997 (Murphy et al., 2020; Fergusson et al., 2020*a*). Spring/summer zooplankton lipid content data have been collected annually in Icy Strait since 2013.

This report presents 2025 zooplankton mean lipid content (% wet weight) anomalies for specific taxa in relation to the 13-year trend in Icy Strait. Total percent lipid content was determined using a modified colorimetric method (Van Handel, 1985).

This report presents 2024 zooplankton mean lipid content (% wet weight) anomalies for specific taxa in relation to the 12-year trend in Icy Strait. Taxa examined were chosen based on their importance to larval and juvenile fish diets (Fergusson et al., 2020*b*; Sturdevant et al., 2012). These taxa include: large and small calanoid copepods, *Calanus marshallae* and *Pseudocalanus* spp., respectively, young euphausiids (furcillia and juveniles), and *Themisto pacifica* (hyperiid amphipod). Total percent lipid content was determined using a modified colorimetric method (Van Handel, 1985). Percent lipids of multiple zooplankton taxa over time represents trends in prey quality available to higher trophic levels and their energetic response to climate and ocean conditions. For fish feeding on these zooplankton taxa, the average to positive lipid anomalies indicates positive nutritional quality.

Status and trends: Trends from 2013 to 2025 for all taxa showed mean percent lipids ranging from 0.01% to 27%. In 2025, percent lipid anomalies for small and large copepods were positive, but showed a decrease from 2024 values (Figure 43). Percent lipid anomalies for the amphipod *T. pacifica* were above average continuing the increasing trend in lipid content since 2023. Percent lipid anomalies for young euphausiids were average.

Factors influencing observed trends: The 2025 sampling occurred during NEP25A, a pronounced marine heatwave that began in early May and now spans nearly 8 million km^2 of the Northeast Pacific, including the Gulf of Alaska (NOAA Marine Heatwave Tracker "Blobtracker"). NEP25A is the fourth-largest Northeast Pacific marine heatwave by area since satellite monitoring began in 1982 and has expanded rapidly since late July. Such widespread upper-ocean warming typically alters phytoplankton bloom timing, zooplankton prey availability, and species composition.

However, inside waters of Southeast Alaska, including Icy Strait, appear to provide partial thermal refuge during these basin-scale warm events. Recent analyses (Brooks et al., 2025) show that nearshore channels with strong freshwater influence can remain cooler and less saline than adjacent offshore Gulf of Alaska waters, buffering salmon and their prey from extreme temperature stress. These conditions likely help sustain favorable phytoplankton–zooplankton dynamics and facilitate lipid accumulation.

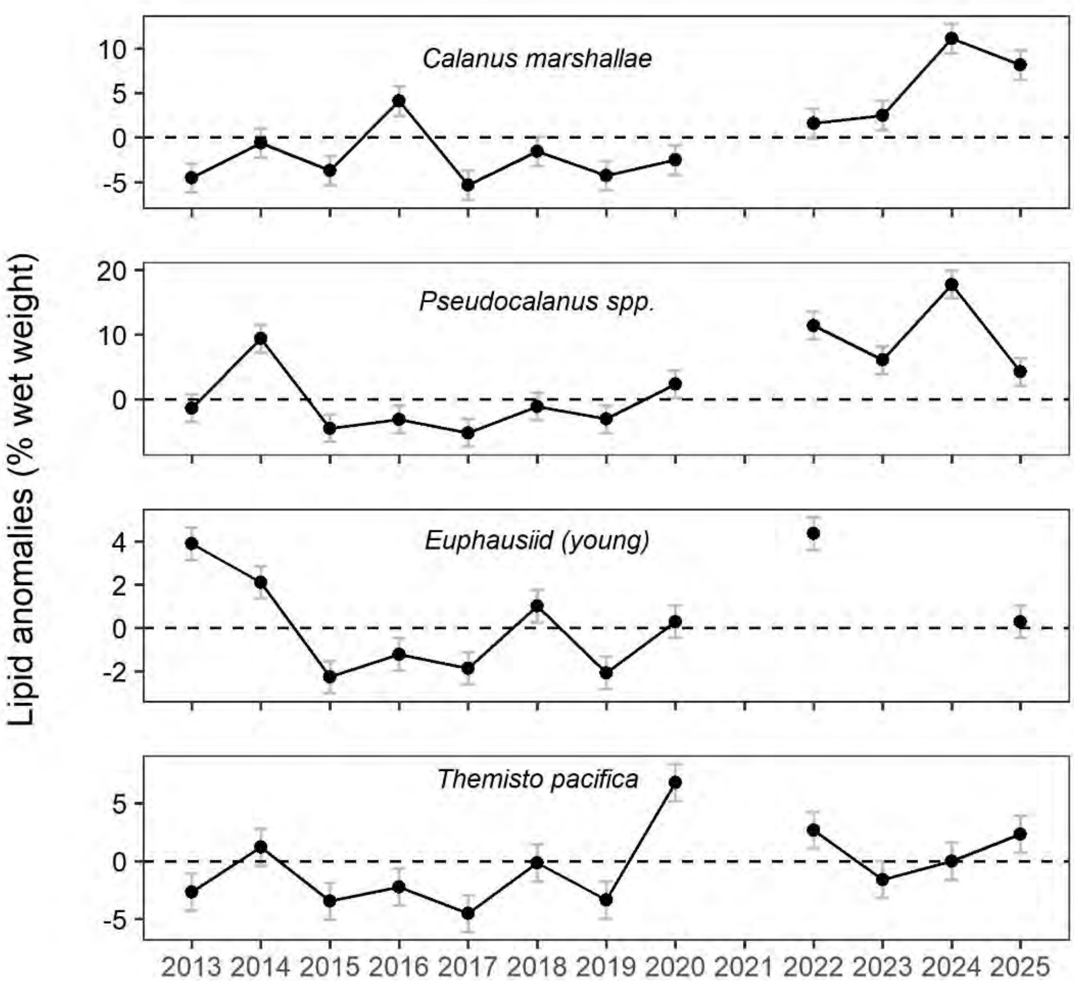

Figure 43: Lipid content (% wet weight) anomalies with error bars (standard error) from key zooplankton taxa collections in Icy Strait, AK by the Southeast Coastal Monitoring project, 2013–2025. The dashed line represents the time series mean lipid content. There are no data for 2021 and no data for euphausiids in 2023 or 2024.

Other processes, advection of nutrient-rich waters, freshwater discharge, and top-down control by predators, remain important, but in 2025 the combined influence of the NEP25A marine heatwave and the mitigating effects of Southeast Alaska's inside-water thermal refuge appear to be relevant.

Subarctic zooplankton communities are influenced by physical and biological factors including basin-scale events, water temperature and salinity, advection, freshwater discharge, phytoplankton community and abundance (zooplankton food), and predator abundance (top-down control). Changes in the zooplankton community influence the food web and trophic relationships, which may alter fish growth and recruitment. For example, a complete restructuring of the North Sea zooplankton community's copepod population was observed after the 1990's regime shift (Beaugrand, 2004) that eventually propagated up the food web (Alvarez-Fernandez et al., 2012). In the Bering Sea, high-lipid copepods are more abundant during cold years relative to warm years, when lower-lipid copepods dominate the prey field (Coyle et al., 2011). The abundance of high-lipid copepods has been trophically linked to the overwinter survival of Bering Sea age-0 pollock (Heintz et al., 2013). During cold years in the Bering Sea, juvenile pollock enter winter with a higher energy content, reached by consuming a lipid-rich diet, which can drive recruitment success of age-1 pollock relative to recruitment during warm years.

Implications: The zooplankton nutritional quality in 2025 suggest positive feeding conditions for larval and juvenile stages of commercially and ecologically important species of fish (e.g., pollock, salmon, and herring) that reside in Icy Strait. These favorable prey conditions may enhance growth, survival, and recruitment, providing an important ecological signal for regional assessments.

Sea Jellies

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Last updated: September 2025

Description of indicator: Jellyfish are an important component of plankton communities and an active focus of ecological research in Alaska. Jellyfish act as both predators and competitors of fish, especially early life history stages (Purcell and Arai, 2001). Thus, fluctuations in jellyfish abundance may affect ecosystem dynamics and fish abundance through indirect (e.g., competition for prey) and direct (e.g., predation) interactions with forage fishes and other commercially and ecologically important species. Since 1991, the RACEs Groundfish Assessment Program's (GAP) fishery-independent bottom trawl survey in the Gulf of Alaska has deployed standardized trawl gear (footrope and bottom trawl net) across the survey region. Therefore, biomass index trends for jellyfish are likely to reflect changes in the abundance of species and life history stages that are available to the survey, especially if trends are sustained over time (Decker et al., 2023).

Regional and subarea (NMFS statistical areas 610, 620, 630, 640, 650) indices of abundance (biomass in kilotons) and confidence intervals were estimated for each taxonomic group by fitting a multivariate random effects model (REM) to subarea design-based index of abundance time series that were calculated from RACE Groundfish Assessment Program (GAP) summer bottom trawl survey catch and effort data. Indices were calculated for the entire standardized survey time series (1990 to 2025). Design-based indices of abundance were calculated using the *gapindex* R package (Oyafuso, 2025) and REM were fitted to the time series using the *rema* R package (Sullivan and Balstad, 2022). Code and data used to produce these indicators are provided in the *esrindex* R package and repository (Rohan, 2025).

Methodological Changes: Methods for calculating this indicator have been updated for this year, as described in the Gulf of Alaska Structural Epifauna contribution (Conrath in this Report p.59).

Status and trends: In the GOA, jellyfish biomass has declined from its recent time series high in 2019 (Figure 44). The 2025 biomass for jellyfish is approximately the same as in 2023, with the exception of an increase in the Kodiak subarea (NMFS Area 630; Figure 45). Subarea biomass generally increases from west to east across the GOA. Biomass in the past three surveys (2021 – 2025) has declined in the western GOA (Shumagin and Chrikof [NMFS Areas 610 and 620]]), increased in the central GOA (Kodiak and Yakutat [NMFS Areas 630 and 640]), and remained relatively stable in southeast Alaska [NMFS Area 650].

Factors influencing observed trends: The primary habitat for these animals is open water and, therefore, the pattern of biomass increasing from west to east could reflect different biophysical conditions across the GOA survey area such as ocean temperature, water circulation and food availability (Brodeur et al., 2008). These key mechanisms directly influence population dynamics of jellyfish, affecting every stage from growth to reproduction and survival (Robinson et al., 2014). Alternatively, the observed patterns could reflect jellyfish productivity throughout the summer since the bottom trawl survey samples from west to east over the course of the summer (May to August). Comparatively, in a recent analysis of

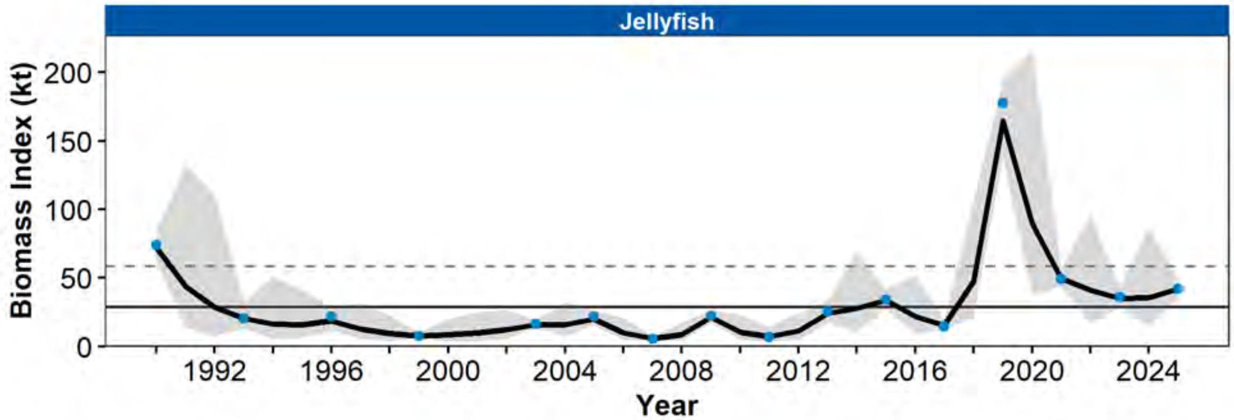

Figure 44: Biomass index (kilotons) of jellyfish from RACE Groundfish Assessment Program summer bottom trawl surveys of the Gulf of Alaska from 1990 to 2025 showing the observed survey biomass index mean (blue points), random effects model fitted mean (solid black line), 95% confidence interval (gray shading), overall time series mean (solid horizontal line), and horizontal dashed gray lines representing one standard deviation from the mean.

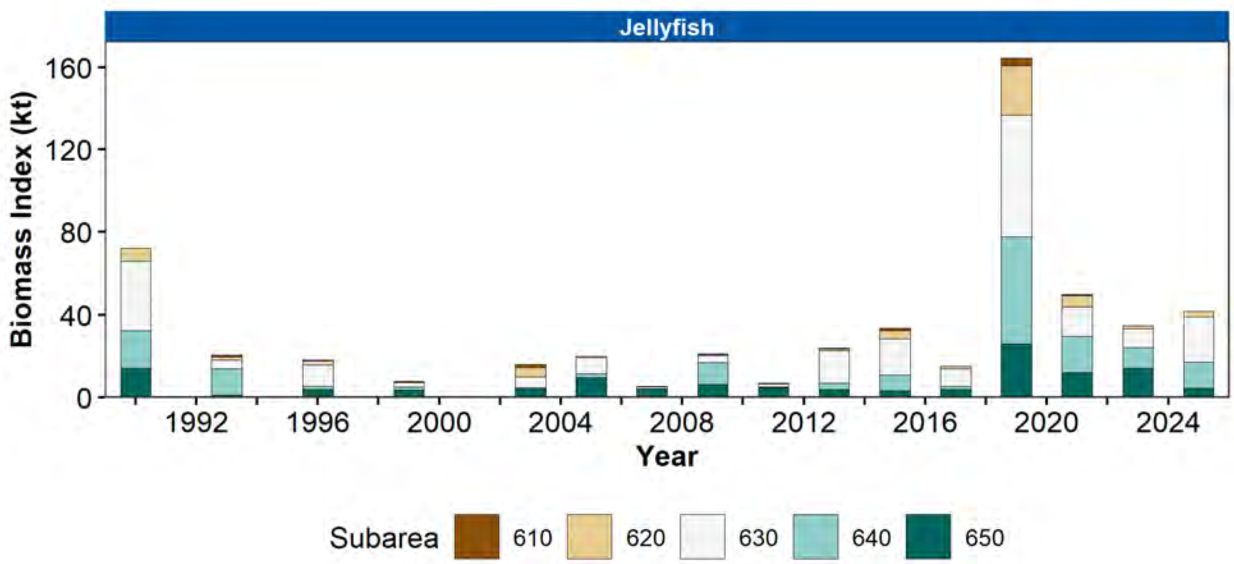

Figure 45: Biomass index (kilotons) of jellyfish in NMFS Statistical Areas in the Gulf of Alaska (610 - Shumagin, 620 - Chirikof, 630 - Kodiak, 640 - West Yakutat, 650 - Southeast Outside) estimated from RACE Groundfish Assessment Program summer bottom trawl survey data from 1990 to 2025. Colors denote NMFS statistical areas.

observed fishery catch data that combines catches from both benthic and pelagic gear showed jellyfish had biomass peaks in 2012, 2015, and 2016, as well as 2019 (Whitehouse and Gaichas, 2024). This may reflect jellyfish being more often observed in pelagic gear than benthic gear.

Implications: Jellyfish represent a critical trophic link, serving as a significant dietary component for commercially important fish species such as prowfish, rockfishes, walleye pollock, sablefish, and grenadiers (Brodeur et al., 2021). Jellyfish also compete with planktivorous fishes for the same prey resources, reducing the amount of food available to them (Purcell and Arai, 2001). With a continuing decrease from the 2019 peak abundance in jellyfish biomass, there may be a direct impact on fish populations and ecosystem dynamics.

Ichthyoplankton

Larval Fish Abundance

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Last updated: August 2025

Description of indicator: The Alaska Fisheries Science Center's (AFSC) Ecosystems and Fisheries Oceanography Coordinated Investigations Program (EcoFOCI) conducts spring larval fish surveys in the Gulf of Alaska (GOA), with annual sampling from 1981 -– 2011 and biennial sampling thereafter (Matarese et al., 2003, Ichthyoplankton Information System[20]). In 2025, the EcoFOCI survey occurred from May 18 – June 2 and sampled 197 stations. A subset of data from a consistently sampled time window (mid-May through early June) and area (Fig. 46) has been developed into time series of relative abundance. While quantitative data require a year for full laboratory processing and verification, Rapid Larval Assessments are conducted for 7 taxa by sorting samples at sea, allowing us to provide provisional time-series updates in the year of collection. The 2025 data will be updated and are subject to change once laboratory processing is completed. Estimates of mean larval catch per 10 m^2 were produced by fitting spatiotemporal generalized linear models with tweedie error distributions, using the R package sdmTMB (sdmTMB; Anderson et al., 2022).

We further present a multispecies indicator to capture shared dynamics of the larval community. Larval catch time series were analyzed using Bayesian dynamic factor analysis (R package bayesDFA; Ward et al., 2019) and a single trend was extracted. Data were log-transformed and Z-scored prior to analysis. Loading estimates for each time series denote if a species is positively or negatively correlated with the common trend.

Status and trends: In 2025, larval abundances were low for most taxa, with the exception of rockfishes and Southern rock sole (Figure 47). Walleye pollock, Pacific cod, arrowtooth flounder, and Pacific sand lance were all at or near record lows. For pollock and cod in particular, abundance has been exceptionally low for 5 of the last 6 sampled (odd numbered) years, with the exception of 2017. Southern rock sole abundance was approximately average, consistent with the last three years of observations, while rockfish (*Sebastes* spp.) abundance was high.

The DFA trend was the lowest on record in 2025, reflecting the low abundances highlighted above (Figure 48). Pollock, cod, northern rock sole, and Pacific sand lance all loaded significantly (positively) on this trend, whereas southern rock sole loaded negatively. Time series of rockfishes and arrowtooth flounder were less clearly associated with the common trend. The common trend has been negative since 2015.

[20] https://apps-afsc.fisheries.noaa.gov/ichthyo/index.php

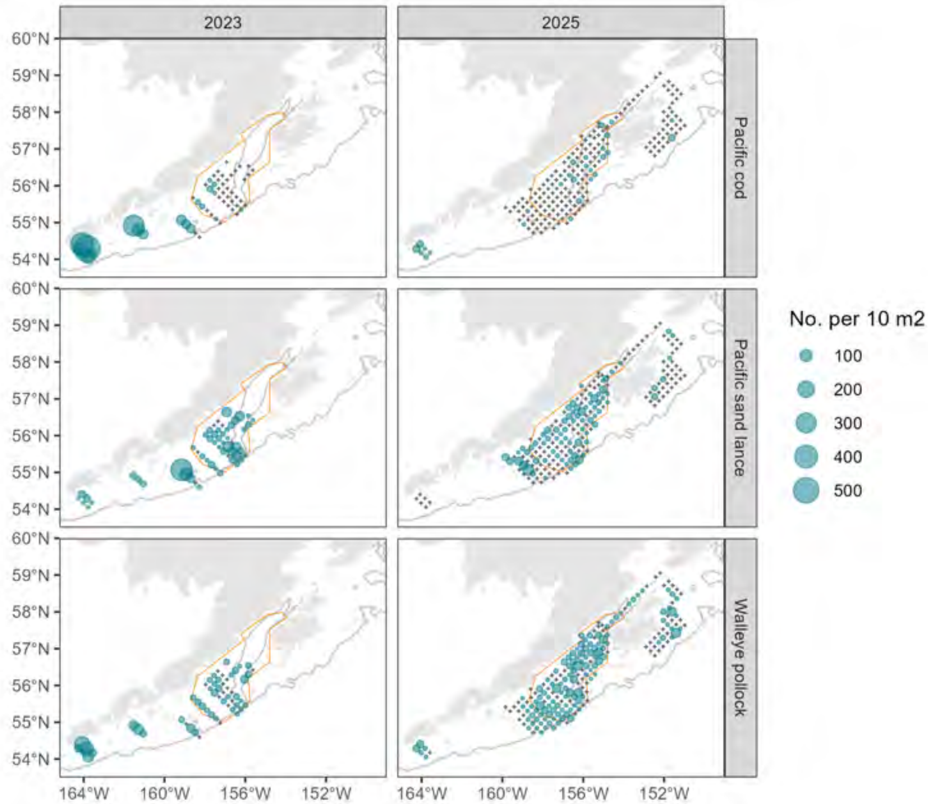

Figure 46: Abundance of larval Pacific cod, Pacific sand lance, and walleye pollock on the EcoFOCI spring larval survey for 2023-2025. The at-sea rapid counts were used to generate the distribution for 2025 whereas quantitative laboratory data are shown for 2023. The orange polygon indicates the consistently sampled "core area" from which time-series are estimated.

Factors influencing observed trends: Sea surface temperatures in the Gulf of Alaska were above average during the winter and spring of 2025, which has been associated with lower abundances of late winter and early-spring spawners in recent years. These species include Pacific cod, pollock, and northern rock sole (Doyle et al., 2009; Laurel and Rogers, 2020). The two taxa with high abundance in 2025 were southern rock sole and rockfishes, which spawn in late spring to summer. The DFA results confirm that species with a common spawning strategy tend to covary in their larval abundance, consistent with findings of Doyle et al. (2009). The DFA trend is significantly negatively correlated with temperature ($r = -0.56$, $p < 0.01$), consistent with lower abundances of the winter/spring spawners in warmer years. Temperature could affect larval abundance estimates through effects on egg or larval survival (Laurel and Rogers, 2020) as well as through effects on phenology (Rogers and Dougherty, 2019). If species spawn and hatch earlier in warmer years, availability of larvae to the late-spring EcoFOCI survey may vary, with effects varying depending on spawning strategy. A preliminary assessment for pollock suggests that larval size was slightly above average in 2025, potentially indicating earlier spawning; however, other years with similar size structure had average or even high larval abundance. This suggests that timing/survey availability alone is insufficient to explain the observed larval abundance trends.

Implications: Ichthyoplankton surveys can provide early-warning indicators for ecosystem conditions and recruitment patterns in marine fishes. In both 2015 and 2019, low abundances of walleye pollock and Pacific cod larvae were the first indicators of failed year-classes for those species (Litzow et al.,

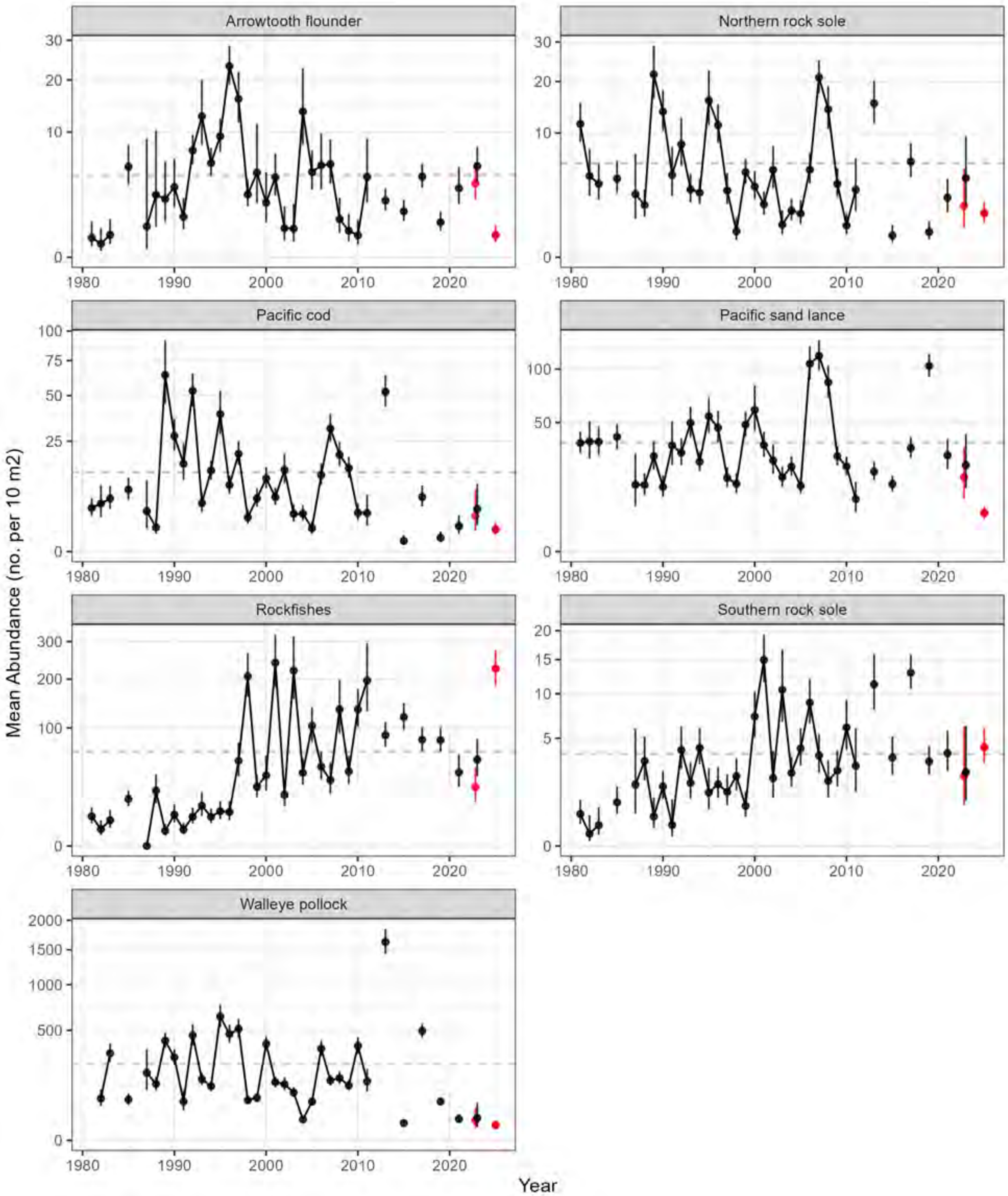

Figure 47: Interannual variation in late spring larval fish abundance in the Gulf of Alaska. The larval abundance index is expressed as the mean density (no. 10 m $^{-2}$), and the long-term mean is indicated by the dashed line. Error bars show $\pm$ 1 SE. The 2025 values (red) are from the at-sea Rapid Larval Assessment and are subject to change. Values from the 2023 RLA are shown for comparison with 2023 lab-verified data.

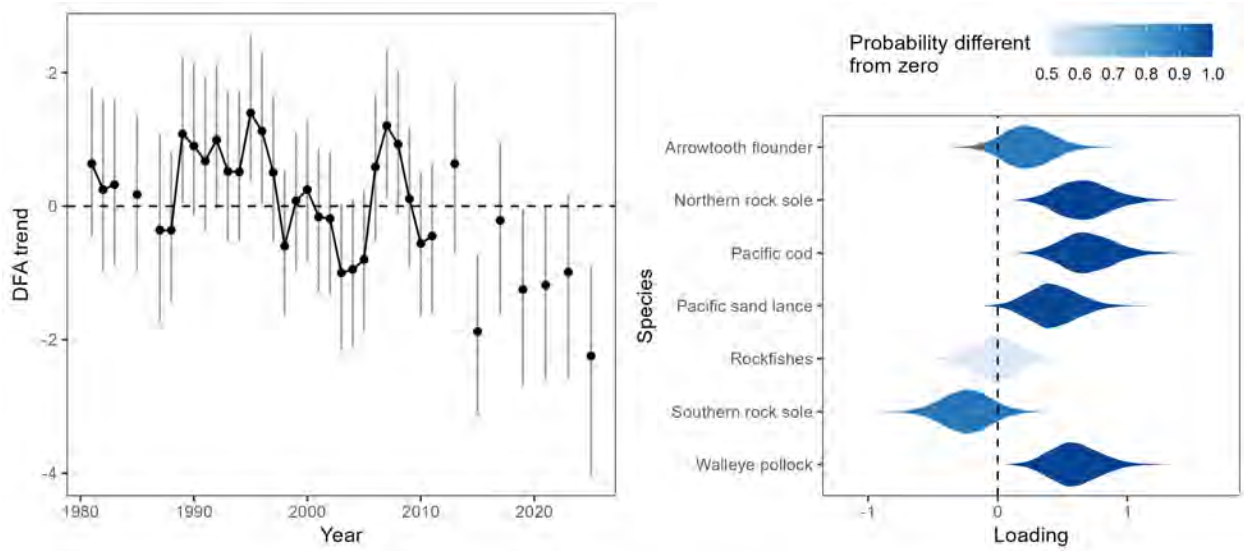

Figure 48: Estimated shared trend of the multispecies larval DFA and loadings of the 7 larval fish taxa on the time trend.

2022). In 2025, abundance of walleye pollock and Pacific cod larvae were again low, suggesting another poor year class. The low abundance of gadid larvae, combined with low to average abundance of the other indicator species (except rockfishes), suggests poor to average forage for piscivorous predators, including seabirds, who rely on larval and juvenile fish.

Forage Fish and Squid

Morphometric Condition of Walleye Pollock Larvae

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Last updated: August 2025

Description of indicator: The morphometric condition of walleye pollock larvae in the western GOA was assessed using the ratio of the body depth at anus (BDA) to standard length (SL). The BDA:SL ratio, hereafter called Condition Ratio (CR), was used to show the spatial distribution of larval condition. The CR is based on the observation that for two fish larvae of similar size, the larva in poorer condition is "skinnier" (smaller BDA) than the larva in better condition (larger BDA), resulting in a smaller CR. For Atlantic cod (*Gadus morhua*) larvae, CR was sensitive to environmental surroundings, including prey abundance (Koslow et al., 1985). The CR for pollock larvae was calibrated using fed (good condition) and starved (poor condition) larvae reared in the laboratory at 3° and 6°C ($n = 263$). The CR of larvae in good condition (mean 0.0635 ± 0.0088, SL 5.96 - 11.17 mm) was significantly larger than the ratio of larvae in poor condition (mean 0.0525 ± 0.0053, SL = 4.89 - 6.15 mm; t-Test, $p < 0.001$). The mean CR for laboratory-reared larvae in good condition was used to classify the condition of pollock larvae in the western GOA, with CRs ≥ 0.0635 indicating good condition and larvae in poor condition having smaller CRs. EcoFOCI conducted an ichthyoplankton survey in the western GOA in the late spring from mid-May to early June 2025. At each station, digital photographs were taken of up to 15 randomly selected pollock larvae collected from a 60 cm bongo net tow, and larvae were later measured using image analysis software. Mean CR for all larvae measured at a station was used to determine larval condition at that location.

Status and trends: Morphometric condition of pollock larvae ($n = 196$) was assessed from 96 stations located throughout the western GOA. Larvae with the largest CRs tended to be located on the northeastern side of Kodiak Island where the largest larvae and warmest temperatures in the upper 50 m of the water column occurred (depth range where a majority of pollock larvae are located, Kendall et al., 1995, Figures 49, 50). Larvae in poor condition occurred at only one station that was located in the southwestern most area (Figure 49). Larvae there were small (mean SL = 6.1 mm), and tended to have smaller CRs than larvae collected elsewhere (Figure 49).

Factors influencing observed trends: Nearly all pollock larvae analyzed were in good condition, and this may be attributed to a favorable environment and to size of the larvae. Mean upper water column temperatures ranged from 5.3° to 7.7° C at stations where larvae were collected, and that range of temperatures is shown to be favorable for survival of pollock larvae (5° to 8° C; Kim et al., 2022). Small-size copepods (< 2 mm) were distributed throughout the area surveyed and their abundance was above average (see Kimmel et al. 2025, p.72), indicating that prey for larvae were plentiful. The

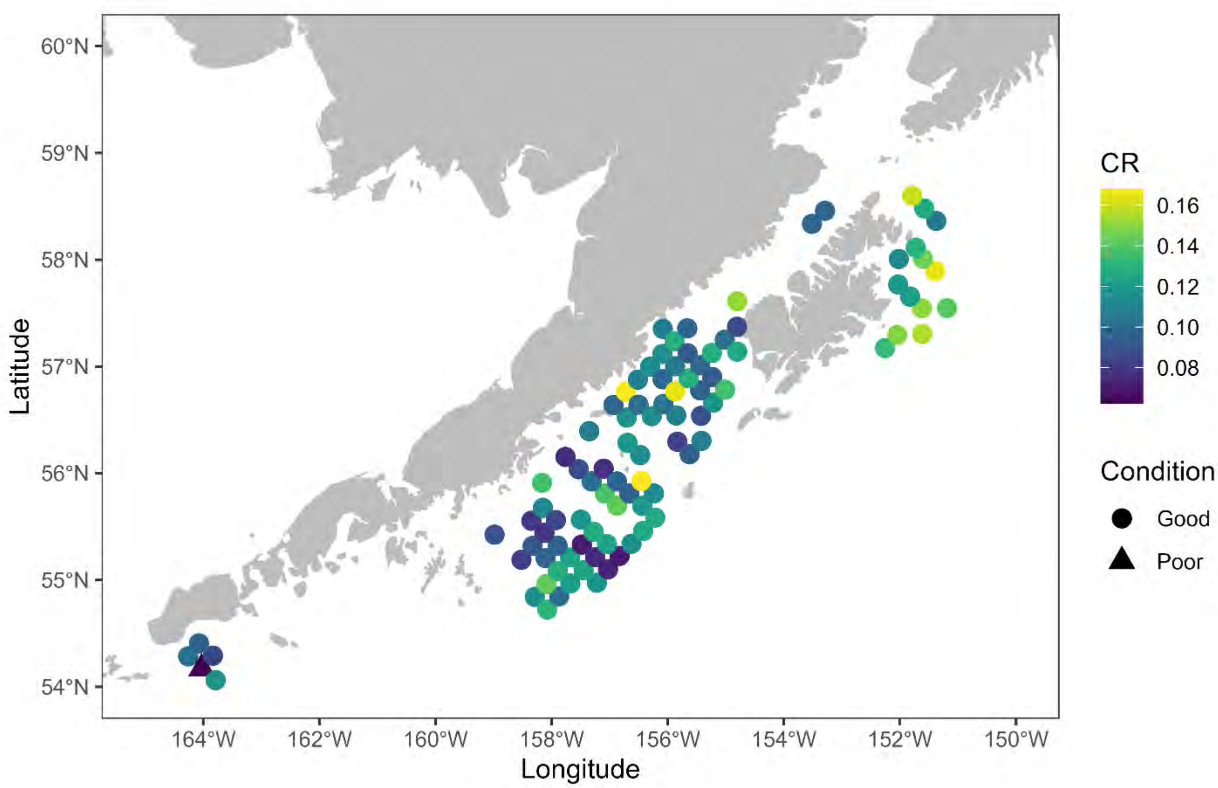

Figure 49: Mean condition ratio (CR), and locations of pollock larvae in good or poor condition in the western Gulf of Alaska, spring 2025. Mean CR for each station was used to classify that location as having larvae in good or poor condition (see text).

majority of larvae assessed for condition (70%) were $\geq$ 6.5 mm SL and pollock larvae of those sizes are less vulnerable to starvation than smaller individuals (Theilacker et al., 1996), increasing the likelihood that they will be in good condition.

Implications: Virtually all larvae analyzed were in good condition, and that could indicate a favorable environment for larval survival, as temperatures were relatively warm and prey were abundant. Additionally, larval sizes showed that the majority of pollock larvae had already passed through the critical

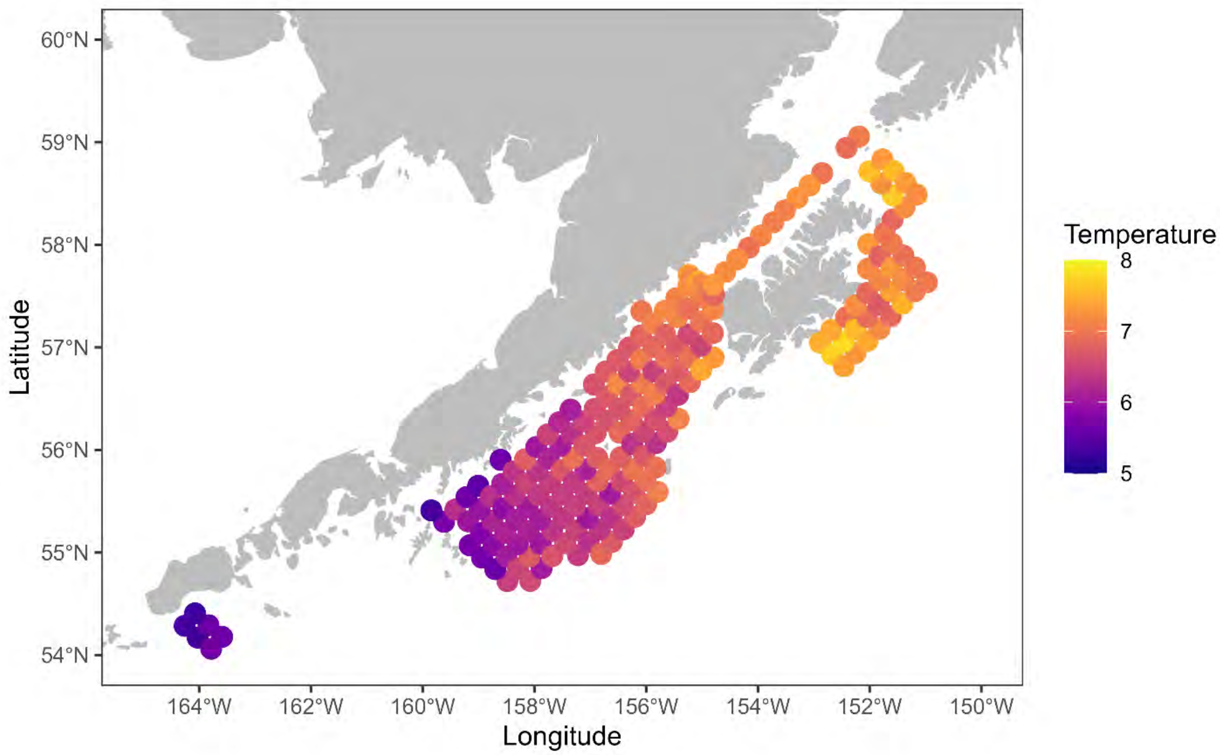

Figure 50: Mean water temperature in the upper 50 m of the water column in the western Gulf of Alaska. That depth range is where a majority of pollock larvae are located (Kendall et al., 1995).

first feeding period when the larvae are most vulnerable to starvation and mortality rates are highest (Theilacker and Porter, 1995; Bailey et al., 1996). Larval pollock abundance was low in 2025 (see Rogers et al., 2025, p.89). Factors that could have contributed to their low abundance are high mortality during early life, and warmer than average temperatures that caused pollock to spawn early and thus, the main group of larvae was advected out of the survey area. Pollock in good condition during their first year of life does not necessarily imply high recruitment. Champagnat et al. (2025) tested various pollock recruitment models for the Gulf of Alaska, and found that young-of-year pollock in good condition had a negative effect on recruitment. They concluded that there may be missing causal pathways in the link between young-of-year condition and pollock recruitment in those models.

Seabird Diets in the Gulf of Alaska 1978 – 2024

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Last updated: October 2025

Description of indicator: Description of Indicator: Seabird diet data span more than 45 years (1978 – 2025) and >3000 km in the Gulf of Alaska (GOA) and Aleutian Islands (Figure 51). Puffins (tufted puffins *Fratercula cirrhata*, horned puffins *F. corniculata*, rhinoceros auklets *Cerorhinca monocerata*, hereafter "puffins") and black-legged kittiwakes *Rissa tridactyla* (hereafter, kittiwakes) feed primarily on small pelagic schooling fish, juvenile groundfish, and mesopelagic species (Hatch et al., 2023; Sydeman et al., 2017; Piatt et al., 2018)). Puffin diets are monitored annually at 4 western GOA colonies and one eastern GOA colony by the U.S. Fish and Wildlife Service Alaska Maritime National Wildlife Refuge monitoring program and by the Institute for Seabird Research and Conservation (ISRC) as part of the USGS Gulf Watch Alaska forage fish monitoring program[21]. western GOA colonies include Aiktak, located at Unimak Pass, Chowiet and Suklik, located in the Semidi Islands along the Alaska Peninsula, and Middleton Island at the shelf break offshore of Prince William Sound. The eastern GOA colony is St. Lazaria near Sitka. At Middleton, surface-feeding kittiwake diets are also sampled by ISRC as part of the Gulf Watch Alaska forage fish monitoring program. We updated time series plots of frequency of occurrence (proportion of samples with at least one fish per species per year) for puffin diets (Figure 52) and relative frequency (frequencies scaled to proportions of all species) for Middleton Island kittiwakes (Figure 53), to provide indices of forage fish availability over time.

Energy-rich and densely schooling small pelagic species, especially Pacific capelin (*Mallotus catervarius*) and Pacific sand lance (*Ammodytes personatus*), are preferred prey for puffins in the GOA (Figure 52). Pacific herring (*Clupea pallasii*) have become more important in puffin diets to the east of 151 °W longitude, including in the western GOA offshore of Prince William Sound and in the eastern GOA near Sitka (Figure 52). Age-0 sablefish (*Anoplopoma fimbria*) are sampled by seabirds more infrequently than other species, but they are prevalent in some years especially at Middleton (Figure 52). Age-0 walleye pollock (*Gadus chalcogrammus*) are consistently sampled by seabirds at the far western GOA colony at Aiktak (Figure 52). Collectively, puffin diets provide information on prey communities across large marine ecosystems and context for multidecadal changes in upper trophic-level biology and ecology in Alaska. Additional information about seabird diet collection efforts and data from long-term monitoring sites in Alaska are available at Hatch et al. (2023) and Turner et al. (2024).

Status and trends: Sampling effort during 2025 included puffin diet samples (bill loads: Aiktak = 46, Chowiet/Suklik = 129, Middleton = 365) and kittiwake samples (regurgitations: Middleton = 1169). Sampling effort on St. Lazaria during 2025 was limited by a bear on the colony. Puffin diets at long-term monitoring sites around the GOA show that sand lance peaked in diets during the mid-1990's then declined in the mid-2000's through the 2014 – 2016 marine heatwave (Figure 52). Following the heatwave, sand lance experienced a short-lived recovery, albeit to a lower level than in the late-1990's to early-2000's, owing to a strong cohort in 2016 - but have declined again in recent years (Figure 52).

[21] https://gulfwatchalaska.org

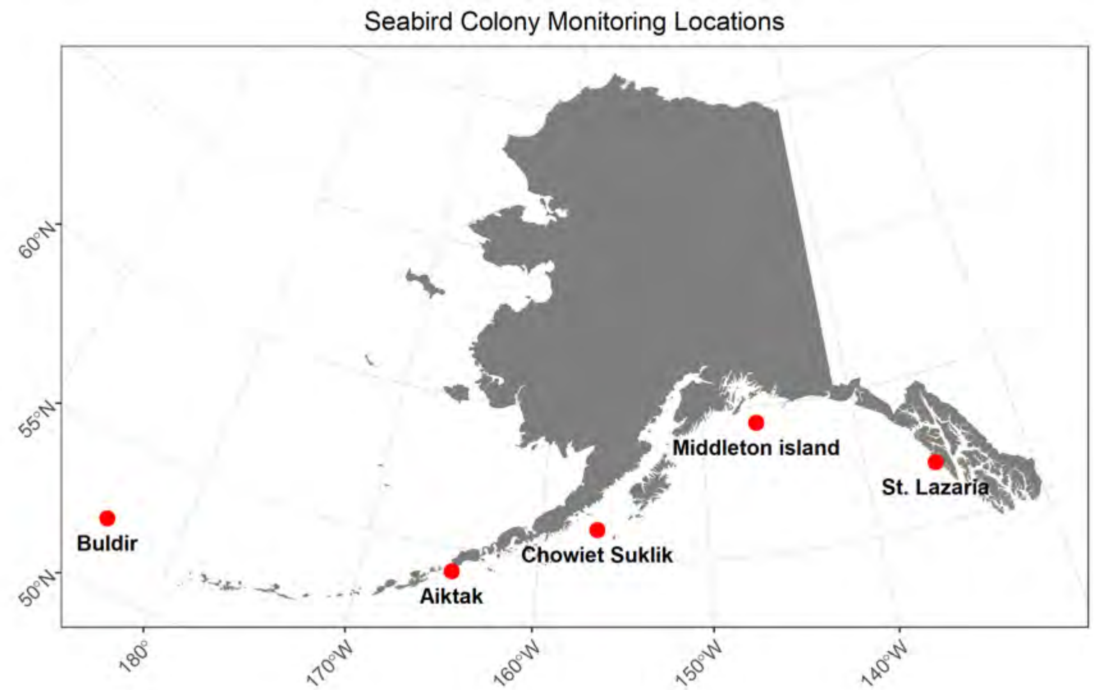

Figure 51: Map of long-term (1978 – 2025) monitoring locations of puffin diets at five colonies in the Gulf of Alaska and Aleutian Islands. Monitoring is conducted annually by the U.S. Fish and Wildlife Service Alaska Maritime National Wildlife Refuge and Institute for Seabird Research and Monitoring. Data and monitoring information is available in Hatch et al. (2023) and Turner et al. (2024).

Kittiwake diets at Middleton also show similar trends in sand lance indices during spring (Apr-May) and summer (Jun-Aug), with a post-heatwave recovery and decline to low frequencies for the last few years (Figure 53).

In contrast, puffin diets across the GOA (Figure 52) and especially kittiwakes at Middleton (Figure 53) show that capelin availability has increased over the last few years following a population collapse during the 2014 – 2016 marine heatwave (Figure 52). In the eastern GOA, capelin indices started trending higher starting in 2022 – 2024. Representative data for 2025 were not available for the eastern GOA colony.

Herring have been increasing in puffin diets at Middleton only since other preferred species (capelin and sand lance) have become less frequent in diets (Figure 52). In 2025 the herring index at Middleton (western GOA) increased compared to 2024. Frequencies of greenlings have remained generally high in puffin diets at colonies other than Aiktak after the 2014 – 2016 marine heatwave (Figure 52). Age-0 sablefish increased in diets during 2025 at two western GOA colonies and one eastern GOA colony, but indices have been low in 2023-2024 (Figure 52).

Factors influencing observed trends: GOA sand lance and capelin are known to fluctuate in seabird diets, with sand lance associated with warmer temperatures and capelin associated with cooler temperatures (Sydeman et al., 2017). Combining diets of different predators (rhinoceros auklets, horned puffins, tufted puffins) at the Semidi Complex (Chowiet and Suklik) may contribute to differences among western GOA sites because rhinoceros auklets at Chowiet seem to be accessing a locally available and stable source of sand lance which overwhelms the signal in years when tufted puffins and horned puffins at Suklik (5 km away from Chowiet) were not sampled. Trends of sand lance and capelin appear to track closely at Aiktak and Middleton. GOA capelin populations crashed during the marine heatwave (Arimitsu et al., 2021) but have been recovering since 2021 (western GOA - Aiktak) or 2022 (eastern GOA – St. Lazaria) (Figure 52). A citizen science project ([22]) has helped to document capelin spawning events around Alaska since the heatwave, with 2023 standing out for reports of beach spawning events in Kodiak, Cook Inlet, Kachemak Bay, Gustavus, and Sitka. During 2025 there were reports of capelin beach spawning and/or large aggregations of mature fish in coastal areas of Glacier Bay, Kachemak Bay/Port Graham, and Sitka.

Implications: With consistent monitoring over time and multi-institutional coordination, puffin diets provide innovative indicators for ecosystem-based fisheries management in Alaska.

[22] https://www.usgs.gov/media/images/capelin-flyer

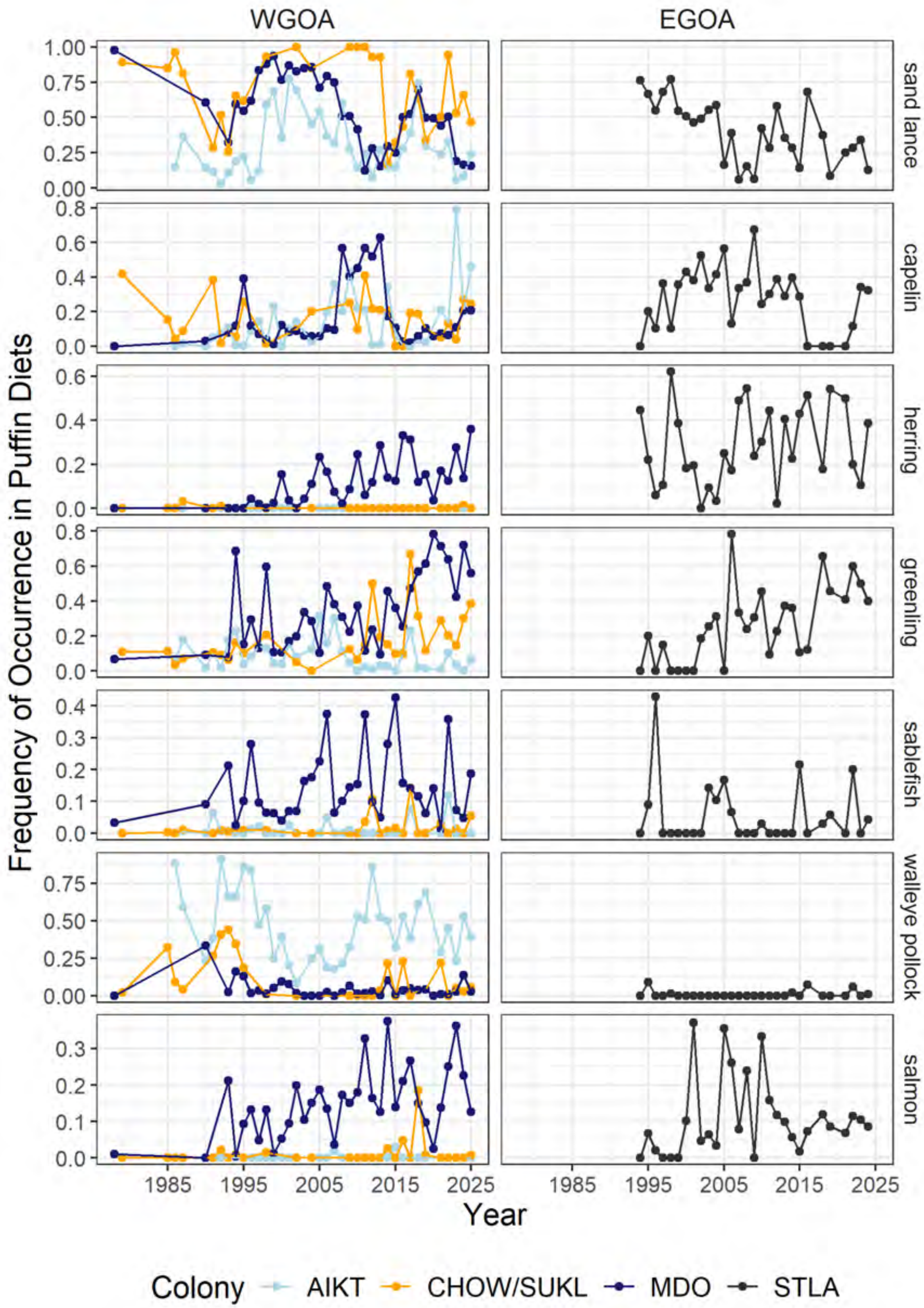

Figure 52: Time series of forage fish indices (frequency of occurrence, proportion of samples containing one or more of each species) derived from puffin diets in the western Gulf of Alaska (WGOA) at the Chowiet and Suklik (CHOW/SUKL) and Middleton Island (MDO), and the eastern Gulf of Alaska (EGOA) colonies at St. Lazaria (STLA).

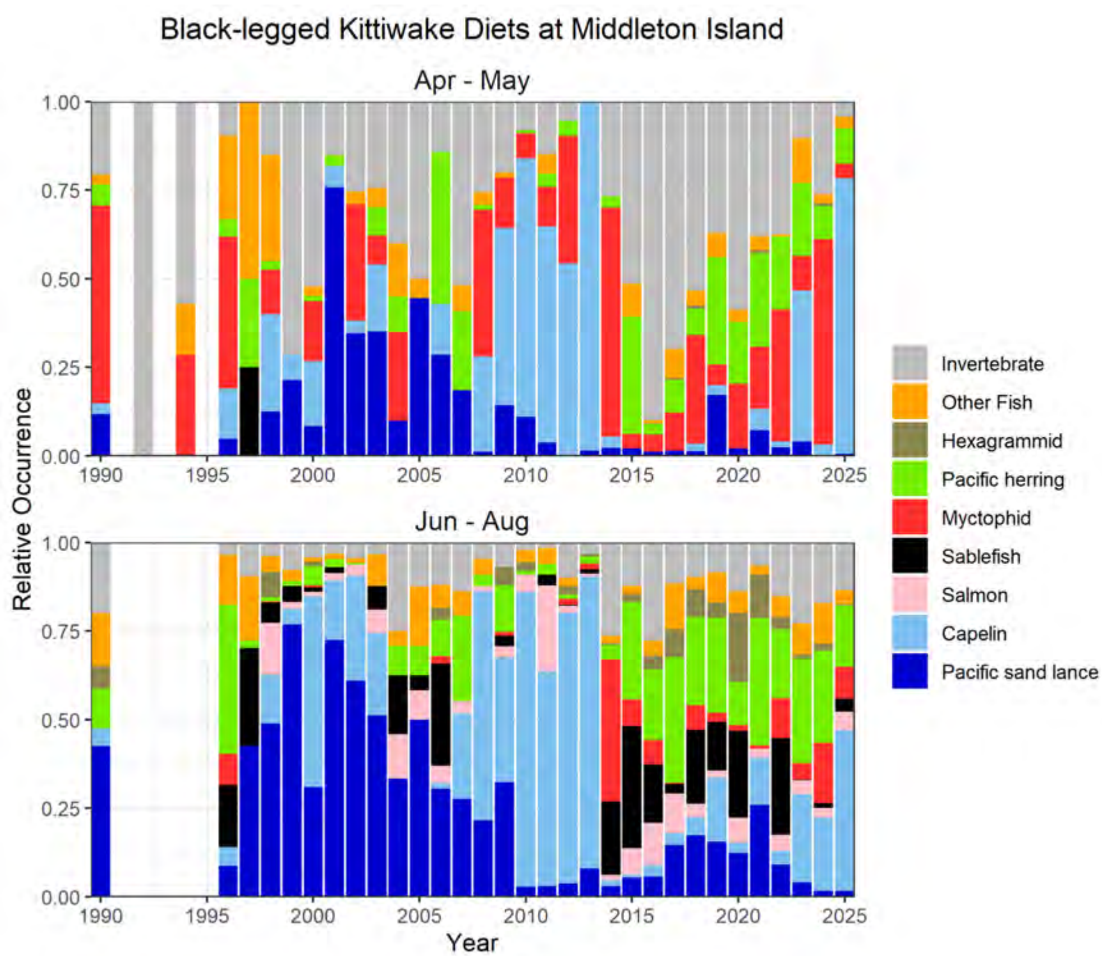

Figure 53: Black-legged kittiwake diet composition at Middleton Island, Alaska during spring and summer months.

Fisheries-independent Survey-based Indices of Forage Fishes in the Gulf of Alaska

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Last updated: September 2025

Description of indicator: Forage fish are key prey for a variety of groundfish, as well as seabirds and marine mammals. As a result, changes in forage fish abundance and body condition can affect the productivity of higher-trophic level consumers (e.g., Sigler and Csep, 2007; Piatt et al., 2020; Robinson et al., 2024). Individual species of forage fish respond differently to environmental conditions (e.g., Gorman et al., 2018; Robards et al., 2002). The North Pacific Fishery Management Council has identified several forage fish species or groups of species for federal management. This indicator consists of data from seven forage taxa: Pacific herring (*Clupea pallasii*), Pacific capelin (*Mallotus catervarius* or *Mallotus villosus*), eulachon (*Thaleichthys pacificus*), sand lance (*Ammodytes* spp.), Myctophids (family Myctophidae), Pacific sandfish (*Trichodon trichodon*), and pricklebacks (family Stichaeidae). Among these taxa, Pacific herring and eulachon are the most dominant in bottom trawl survey catches, followed by capelin and Pacific sandfish.

Since 1990, the RACE Groundfish Assessment Program (GAP) has conducted annual fishery-independent summer bottom trawl surveys in the GOA using standardized trawl gear and methods. Biomass index trends from GAP surveys are likely to reflect changes in the abundance of species and life history stages that are available to the survey, especially if trends are sustained over time.

Regional and subarea (NMFS statistical areas 610, 620, 630, 640, 650) indices of abundance (biomass in kilotons) and confidence intervals were estimated for each taxonomic group by fitting a multivariate random effects model (REM) to subarea design-based index of abundance time series that were calculated from RACE Groundfish Assessment Program (GAP) summer bottom trawl survey catch and effort data. Indices were calculated for the entire standardized survey time series (1990 to 2025). Design-based indices of abundance were calculated using the *gapindex* R package (Oyafuso, 2025) and REM were fitted to the time series using the *rema* R package (Sullivan and Balstad, 2022). Code and data used to produce these indicators are provided in the *esrindex* R package and repository (Rohan, 2025).

Methodological Changes: Methods for calculating this indicator have been updated for this year, as described in the Gulf of Alaska Structural Epifauna contribution (Conrath in this Report, p.59).

Status and trends: Several forage fish sampled by the bottom trawl survey in 2025 showed an increase in estimated abundance compared to the previous survey (2023). Across the full GOA survey area, estimated biomass was above +1SD for herring, and at or below -1SD for Pacific sandfish and for myctophids (Figure 54). The largest increase in herring biomass was observed in the Kodiak area (NMFS statistical area 630). Sand lance, myctophids, eulachon, and herring all showed increases compared to 2023: the largest increases in biomass for sand lances and eulachon also occurred around Kodiak, and myctophids increased in West Yakutat (NMFS statistical area 640) and Southeast Outside (NMFS statistical area 650). Eulachon continue to have the highest biomass in the Kodiak area as well

(Figure 55). Eulachon biomass has also continued to increase in the Southeast Outside region (NMFS statistical area 650), where they were above +1SD in 2023 and 2025.

Biomass indices declined between 2023 and 2025 for capelin, sandfish, and pricklebacks (Figure 54). Capelin biomass has historically been highest in the Kodiak district. Their biomass according to the bottom trawl survey has been declining since 2021, and despite an increasing trend in the winter acoustic survey in 2023 (McGowan, 2023) and anticipated increases in capelin abundance based on winter acoustic surveys (Darin Jones, *pers. comm.*), the bottom trawl survey index showed a continued decline in 2025. Capelin were still above +1 SD in the Shumagin area (NMFS statistical area 610) but within 1 SD of the mean in all other areas and declining overall. Sandfish were low in abundance across the whole survey region and remain within 1SD across all the statistical areas. Pricklebacks were above +1 SD in the Shumagin area, below -1 SD in the Kodiak area, and within 1SD of the long-term mean everywhere else. **Factors causing observed trends:** In the GOA, herring and sand lance have been observed to positively respond to warm environmental conditions, while capelin increase during cooler periods (McGowan et al., 2019). A marine heatwave in 2014 – 2016 led to anomalously high temperatures throughout the Gulf and capelin and herring (Arimitsu et al., 2021). Sand lance have responded positively to warmer temperatures in the past (Speckman et al., 2005; Sydeman et al., 2017; Thompson et al., 2019), but did not recover as expected during the 2014 – 2016 heat wave (Von Biela et al., 2019), so it is unclear what their expected response may be to higher temperatures.

Higher temperatures are likely to influence trends in forage fish biomass; directly by influencing forage fish recruitment, distribution, and metabolic demand, and indirectly via the changing energetic requirements of their predators. For many GOA forage species including herring and sand lance, past increases in temperature led to higher metabolic needs among their predators, resulting in changes to food web structure and energy transfer (Suryan et al., 2021; Holsman and Aydin, 2015).

Implications: Recent increases in the biomass of herring, eulachon, and sand lances may mean more availability of forage fish for humpback whales (Witteveen et al., 2008) and other predators. Forage species in the Gulf have been shown to exhibit a portfolio effect, where asynchronous variation in abundance among the forage groups leads to a more stable prey base (Arimitsu et al., 2021). Higher densities of prey may also lead to increased calving rates and calf survival for humpback whales.

In addition to the effect of changes in forage biomass on the rest of the food web, nutrient content of forage species can also affect their genetic contribution to the ecosystem. For example, during the marine heat wave in 2014 – 2016, the declines in capelin, sand lance and herring were associated with concurrent decreases in the nutritional content of sand lance (Von Biela et al., 2019), indicating that the environmental conditions affecting density can also impact the value of these prey fish for their predators and drive changes in food web structure.

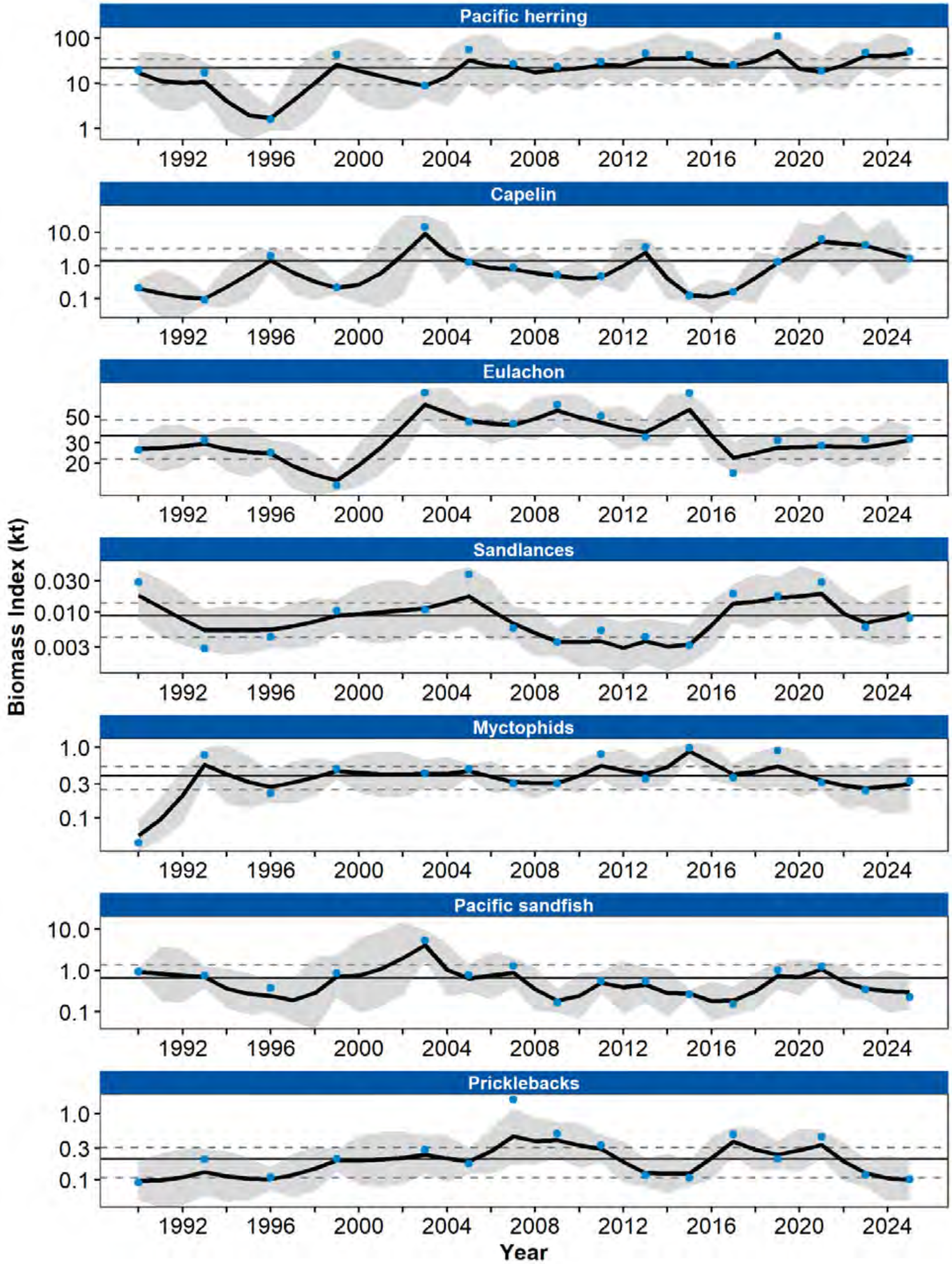

Figure 54: Biomass index of Forage Fish (Pacific herring, capelin, eulachon, sandlances, myctophids, Pacific sandfish, pricklebacks) from RACE Groundfish Assessment Program summer bottom trawl surveys of the Gulf of Alaska from 1990 to 2025. Panels show the observed survey biomass index mean (blue points), random effects model fitted mean (solid black line), 95% confidence interval (gray shading), overall time series mean (solid gray line), and horizontal dashed gray lines representing one standard deviation from the mean. All are plotted on a log10 scale to better show the full range of values.

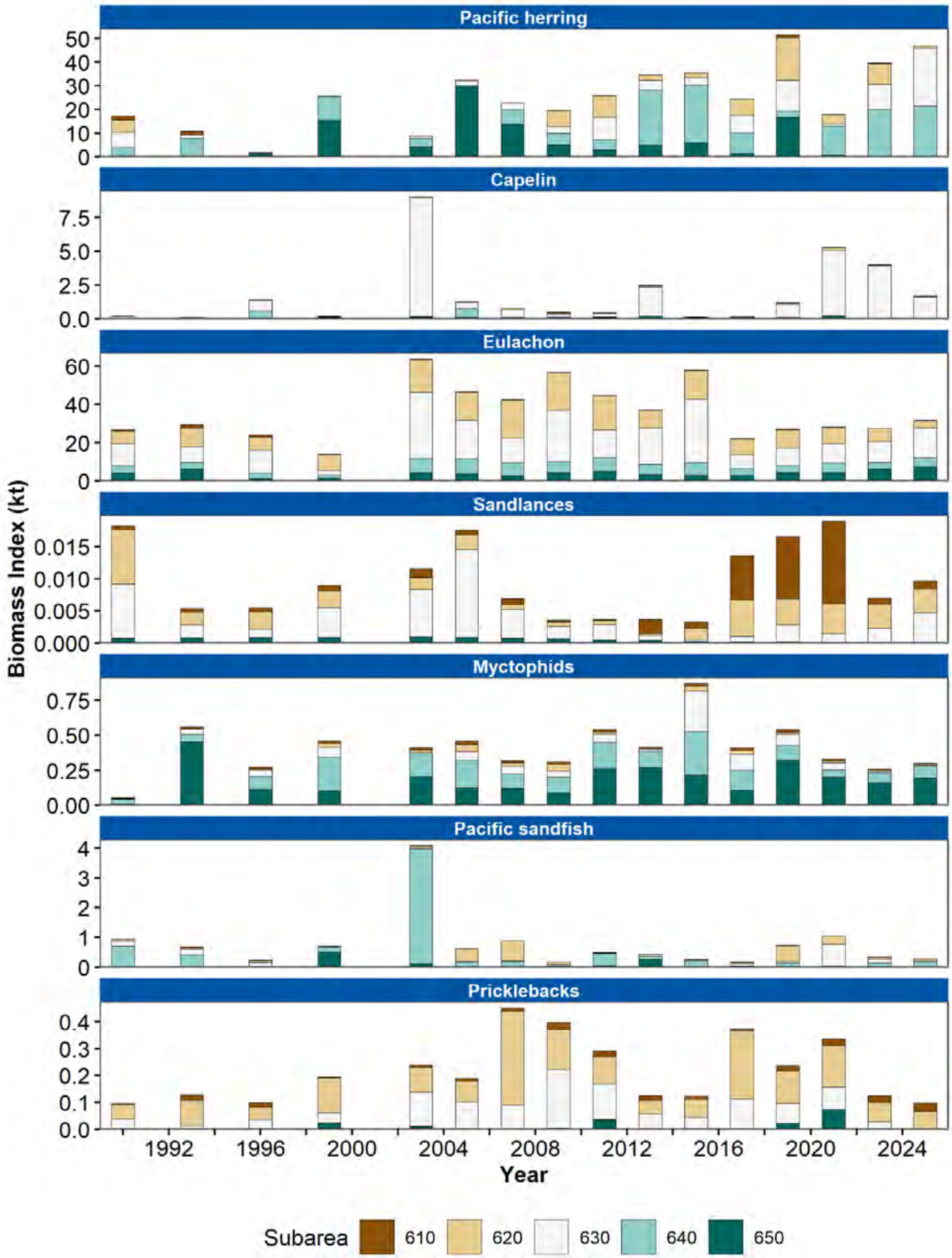

Figure 55: Biomass index of Forage Fish (Pacific herring, capelin, eulachon, sandlances, myctophids, Pacific sandfish, pricklebacks) in the Gulf of Alaska estimated from RACE Groundfish Assessment Program summer bottom trawl survey data from 1990 to 2025. NMFS subareas are shown as different colors (610 - Shumagin, 620 - Chirikof, 630 - Kodiak, 640 - West Yakutat, 650 - Southeast Outside).

Southeast Alaska Herring

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Last updated: September 2025

Description of indicator: Pacific herring (*Clupea pallasii*) stocks that reside in Southeast Alaska waters are defined on a spawning area basis. In recent decades there have been nine spawning areas where spawning events have typically been annual and meaningful in size in terms of potential for commercial exploitation. These spawning areas include Sitka Sound, Craig, Seymour Canal, Hoonah Sound, Hobart Bay-Port Houghton, Tenakee Inlet, Ernest Sound, West Behm Canal, and Kah Shakes-Cat Island (Figure 56). Indices of abundance for these stocks are represented by annual estimates of mature (pre-spawning) herring biomass prior to spring fisheries. Biomass is estimated either by surveys (two-stage surveys that include aerial surveys for milt along shoreline and spawn deposition SCUBA dive surveys for estimating egg abundance) converted to spawning herring biomass or statistical catch-at-age models that incorporate survey estimates (Figure 57). Sitka Sound and Craig are considered "outside stocks" as they are exposed directly to Gulf of Alaska waters, while all others except Kah-Shakes are considered "inside stocks" and less exposed to open ocean influence (Kah Shakes/Cat Island is not distinctly outside or inside). Monitoring of spawning stock size has been conducted at some of these areas for over 50 years by the Alaska Department of Fish and Game, primarily by combining estimates of egg abundance from surveys with herring age and size information (Hebert, 2022). However, starting in 2016, spawn deposition SCUBA surveys became limited due to budget cuts and low mileage of milt observed during aerial surveys. In most of the seven inside spawning stocks, it was evident the low mileage of spawn observed from aerial surveys would not result in the stock making threshold that would support a commercial fishery. Beginning in 2024, aerial surveys were reduced to four of the seven inside stocks with monitoring of the remaining three stocks conducted as budgets allowed. Spawn deposition surveys for inside stocks continued to be conducted on an as-needed basis and have only occurred for the Tenakee and Kah Shakes stocks (Figure 57). The reduction in aerial surveys was due primarily to budget cuts but also due to low spawning biomass for some areas and decline in demand for commercial sac roe harvest. As a result, while the indices for Sitka Sound and Craig extend through 2024, the combined index for the seven other stocks ends in 2015 because all seven stocks were not surveyed annually (Figure 57). Although the nine areas account for a large proportion of the spawning biomass in Southeast Alaska in any given year, they do not represent the entirety of herring spawning activity in Southeast Alaska, as numerous smaller spawn events are observed in other areas throughout Southeast Alaska.

However, little or no stock assessment activity occurs for these smaller spawning events other the occasional aerial observation while in route to survey other areas, documentation on satellite imagery, or reports by other entities. The herring that spawn in all areas of Southeast Alaska are believed to be affected by the broad-scale physical and chemical characteristics of Gulf of Alaska waters, though the spawning areas directly exposed to the open coast (Sitka Sound, Craig, and possibly Kah Shakes-Cat Island) may be affected the greatest or the soonest. Herring that spawn in the inside waters may be affected more by localized changes to inside waters.

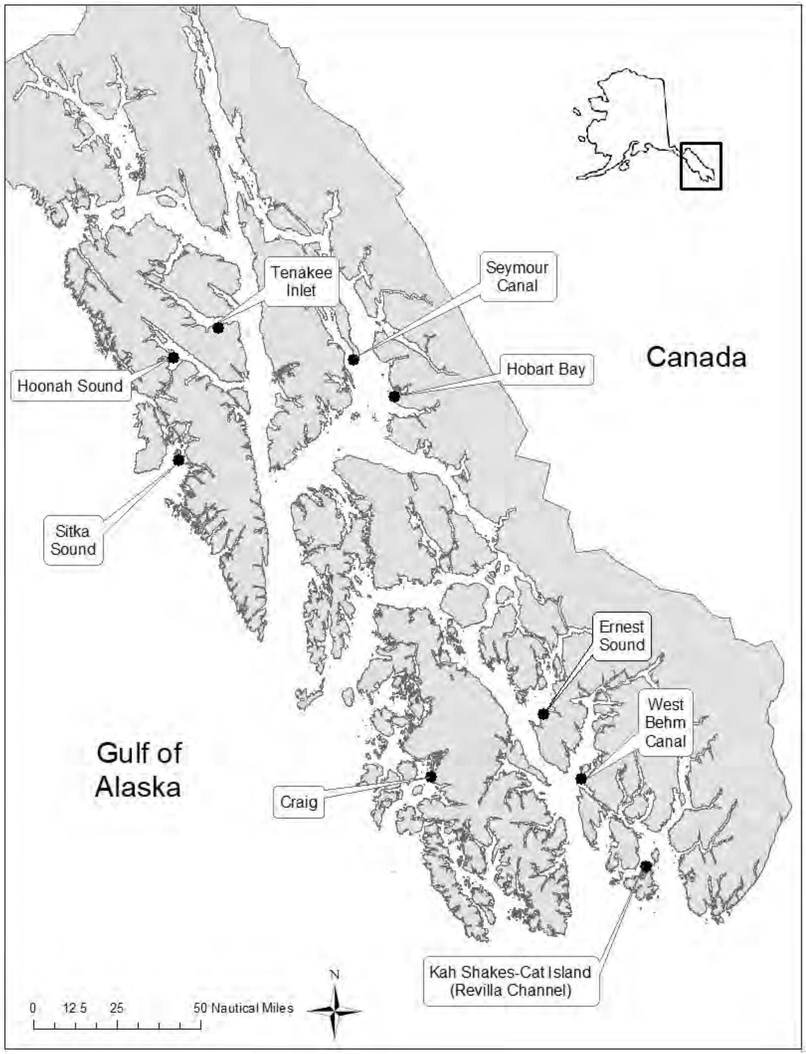

Figure 56: Location of nine Pacific herring spawning locations, historically surveyed in Southeast Alaska.

Status and trends: Mature biomass for Sitka Sound and Craig herring remains at a high level through 2024, as the extremely large 2016-year class (age-8 in 2024) continues to support these stocks. The 2019 age-3 recruitment event is by far the largest recruit class in the Sitka Sound and Craig model time-series (since 1976 for Sitka Sound and since 1988 for Craig). The 2023 age-3 recruitment (2020-year class) was also relatively high. For Sitka Sound, the addition of 2024 data and a change in model parameterization (an additional time block for estimating natural mortality from 2022 – 2024) resulted in a lower 2023 mature biomass estimate than the previous year's model and a decreasing model trajectory for the last few years (Figure 57). However, despite these changes, recent recruitments have continued to support high relative biomass for both Sitka and Craig stocks (Figure 57).

Although industrial-scale herring reduction fisheries and foreign fisheries operated in Southeast Alaska beginning in the early 1900s, with catch peaking in 1935, the most reliable estimates of biomass exist from those data collected by the State of Alaska within the last 50 years, which are discussed here. Prior to Alaska statehood (1959), herring fisheries were first managed and studied by the U.S. Department of Commerce, Bureau of Fisheries, in the 1930s, then by the U.S. Department of the Interior, Fish and

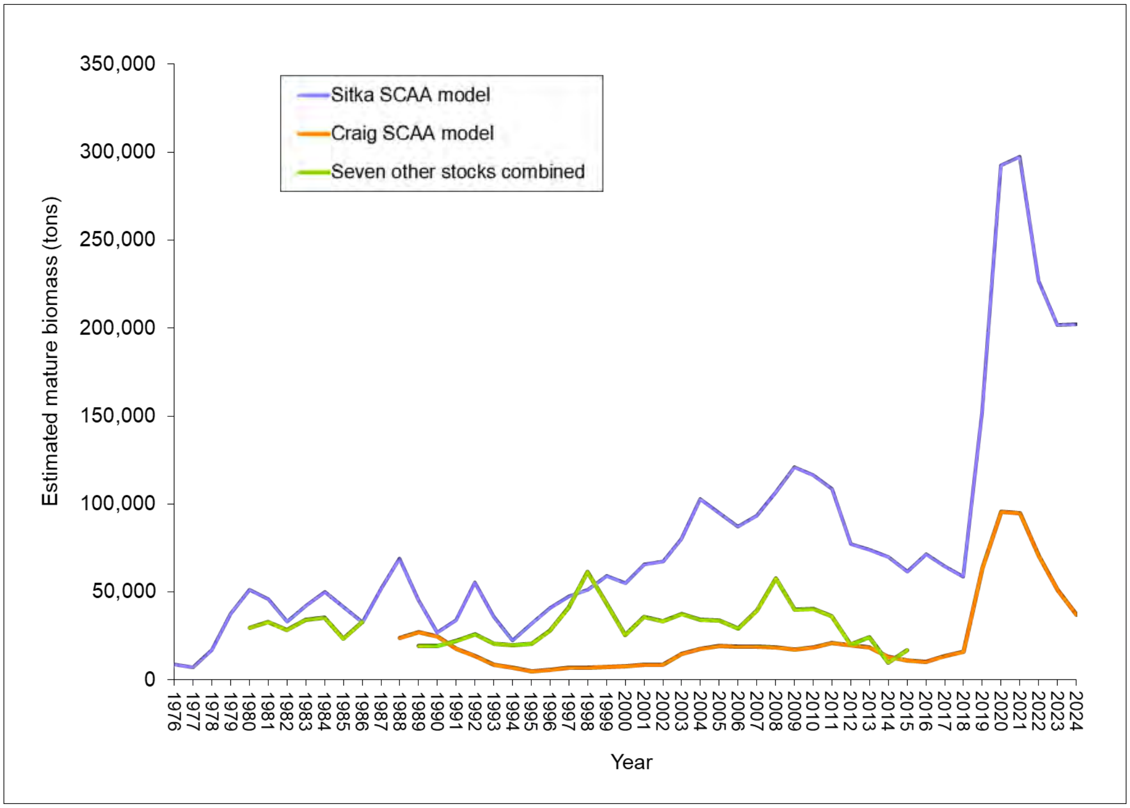

Figure 57: Estimated mature herring biomass (i.e., pre-fishery biomass) and forecasts for herring spawning areas historically surveyed in Southeast Alaska. Biomass estimates for Sitka Sound and Craig are based on integrated statistical catch-at-age models (the Sitka model starts in 1976 and Craig model starts in 1988). For all other stocks, biomass estimates are based on spawn deposition or hydroacoustic estimates, which began in different years, but for simplicity are shown starting in 1980. Estimated combined annual mature herring biomass (including and excluding Sitka) at major southeastern Alaska spawning areas, 1980 – 2011. For years 1987 – 1988 and 2016 – 2024, biomass estimates for the combined seven stocks were excluded from the plot because estimates were not made for all stocks in those years.

Wildlife Service, in the 1940s and 1950s. Over the past 50 years, the Sitka Sound and Craig herring stocks have increased in biomass, whereas other Southeast stocks have been variable and are currently at relatively low levels (Figure 57). Following low biomass in the 1970's and a period of intermediate biomass during the 1980s through the mid-1990s, Sitka Sound herring increased to a high level between 2008 and 2011. Craig and other Southeast stocks were variable until 2011. Southeast stocks then declined substantially until around 2016 – 2018, but Sitka Sound and Craig, the two largest and most consistently abundant stocks, declined moderately during this time. Both stocks increased dramatically in 2019 to historic levels following the highest recruitment of age-3 herring documented for these areas. The large 2016 year class has been documented across the Gulf of Alaska in aerial surveys of age-1 herring in Prince William Sound (Pegau et al. 2022), high mean frequency of occurrence of age-0 and age-1 herring in the diets of both diving and surface feeding birds at Middleton Island in 2016 and 2017 (Arimitsu et al. 2021), and age-3 herring in age composition samples and population abundance indices of mature herring in Prince William Sound (Pegau et al. 2022), Southeast Alaska and Kodiak Island (Hebert and Dressel 2022). Biomass levels for most stocks in Southeast Alaska other than Sitka Sound and Craig are not well known because of survey reductions, but aerial surveys and limited spawn deposition surveys suggest that these stocks remain at relatively low levels compared to spawn mileage observations since 1980. However, there are indications that some stocks may be increasing over the past several years.

Factors influencing observed trends: Herring abundance is known to fluctuate dramatically over years, and is susceptible to environmental influences (e.g., Toresen, 2001). The underlying causes for the overall increase in herring biomass in Sitka Sound and Craig and indications of continued low abundance for other stocks are not known but may be due to multiple factors. Recent shifts in water temperatures may have affected herring food sources, life history, spawn timing, and metabolism. Additional contributing factors may include fluctuating population levels of predatory marine mammals, such as humpback whales and Stellar sea lions (Muto et al., 2016; Fritz et al., 2016*b*), and varying levels of predatory fish. While commercial fishing has occurred during some years for some inside water stocks, the similarity in declines among inside water stocks, which for some occurred in the absence of fishing, emphasizes that environmental factors may have contributed to the declines.

The high mature biomass in Sitka Sound observed in 2024 was due to the continued presence of the unprecedented high 2016-year class, but also due to another high age-3 recruitment observed in 2023 (i.e., 2020-year class). Both of these year classes hatched during notable marine heat waves documented in the Northeast Pacific Ocean (Gentemann et al., 2017; Amaya et al., 2020). As ocean temperature has been positively correlated with recruitment in Atlantic herring (*Clupea harengus*) (Toresen, 2001), and Pacific herring (Zebdi and Collie, 1995), the marine heat waves may have led to success of these year classes by providing favorable early-life marine conditions. While the age-3 recruitment for the Craig stock in 2023 was high relative to other years in the recruitment time series, it was much lower than that observed in 2019. Consequently, the biomass of the Craig stock declined between 2022 and 2023, although it remained at a relatively high level. Age-3 recruitment estimated for 2024 was moderate in Sitka and low in Craig; however, this was based on a single year observing the cohort (i.e., 2021-year class), and full understanding of that cohort's strength will not be known until another year or two of data has been collected.

Implications: The high herring biomass along the outer coast has persisted for six years through 2024 and is expected to remain at a relatively high level in 2025 as the strong 2016 and 2020 year classes continue to contribute; however, the 2016 year class will be age-9 in 2025 and may decline more quickly at this relatively old age. Marine species that may benefit are numerous and include those that rely on adult or juvenile herring, such as demersal fishes, humpback whales, salmon and eagles, and those that consume herring eggs, such as gray whales, scoters, and gulls. The high biomass may also benefit traditional subsistence harvests, which have great cultural importance and are shared widely (Sill and Barnett, 2023), and commercial fisheries, which are economically important to fishermen, seafood processors and communities in and around the areas of Sitka Sound and Craig/Klawock and beyond. In contrast, the persistent low biomass for inside water stocks may hinder or cause behavior shifts in herring predators and subsistence activities in these areas and will continue to restrict commercial fishery opportunities until stocks rebound to higher levels. However, because adult Pacific herring are known to migrate seasonally up to hundreds of kilometers from their natal grounds (Flostrand et al., 2009; Roundsfell and Dahlgren, 1935) it is plausible that the very high herring abundance originating from outside waters may contribute to the forage base for marine species of inside waters of Southeast Alaska during feeding and overwintering months, thereby buffering the impact of continued low spawning biomass in inside waters to some degree.

Southeast Alaska Eulachon

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Last updated: September 2025

Description of indicator: In Southeast Alaska, eulachon (*Thaleichthys pacificus*) are a culturally and biologically important anadromous fish. Eulachon populations have declined throughout their range since the 1990's and today all populations south of the Nass River in British Columbia have been severely depleted or extinct (Hay and Mccarter, 2000). There are at least thirty-five rivers in Alaska where eulachon are known to spawn (Moffitt et al., 2002); however, it is thought that most runs are either unknown or anecdotal (Betts, 1994). To better understand the eulachon spawning population in northern Southeast Alaska the Chilkoot Indian Association initiated a mark-recapture study on the Chilkoot River in 2010. In 2014 this was complemented with the addition of environmental DNA (eDNA) sampling at the Chilkoot River. Furthermore, in 2017 eDNA sampling was expanded to include the Berners, Lace and Antler Rivers in Berners Bay and the Skagway and Taiya Rivers near Skagway, AK in partnership with the Skagway Traditional Council. In 2022 the use of eDNA to monitor eulachon spawning populations was expanded to include the Unuk River in southern Southeast Alaska in partnership with the Ketchikan Indian Community and US Forest Service. And in 2023 the Southeast Alaska Eulachon Monitoring Network was further expanded with eDNA monitoring on the Situk and Ahrnklin Rivers near Yakutat in partnership with the Yakutat Tlingit Tribe and US Forest Service (Figure 58).

Status and trends: In 2025, eulachon populations in southeast Alaska saw a range of returns from some below average to some above average (Table 1). In recent decades a decline in eulachon populations has increased concern about the health of eulachon across their range. In 2007 the Cowlitz Indian Tribe petitioned the National Marine Fisheries Service (NMFS) to list eulachon under the Endangered Species Act. And in May 2010, the southern Distinct Population Segment (SDP) including California, Oregon, and Washington was listed as "threatened" under the Endangered Species Act (NOAA, 2010). In May 2011 the Canadian Committee on the Status of Endangered Wildlife listed three British Columbia populations for protection including the Central Pacific Coast, Fraser River, and Nass/Skeena River populations (COSEWIC, 2011). In Southeast Alaska there has been limited monitoring of eulachon spawning populations. The Forest Service has conducted aerial surveys along the Unuk River since 2001 and a mark-recapture population estimate on rivers within Berners Bay from 2004 – 2008. However, these studies only represent a small portion of the eulachon spawning habitat in Southeast Alaska. On the rivers north of Berners Bay there was no population data being collected until the Chilkoot Indian Association initiated a mark-recapture study in 2010 out of concern for declining eulachon populations elsewhere and a lack of data available.

The mark-recapture population estimate for the Chilkoot river near Haines, Alaska has seen a wide range in eulachon spawning abundance; estimates have ranged from a couple hundred thousand to over 20 million (Figure 59). 2024 was the last year the Chilkoot Indian Association conducted the mark-recapture portion of its eulachon monitoring program. All future monitoring is being conducted solely

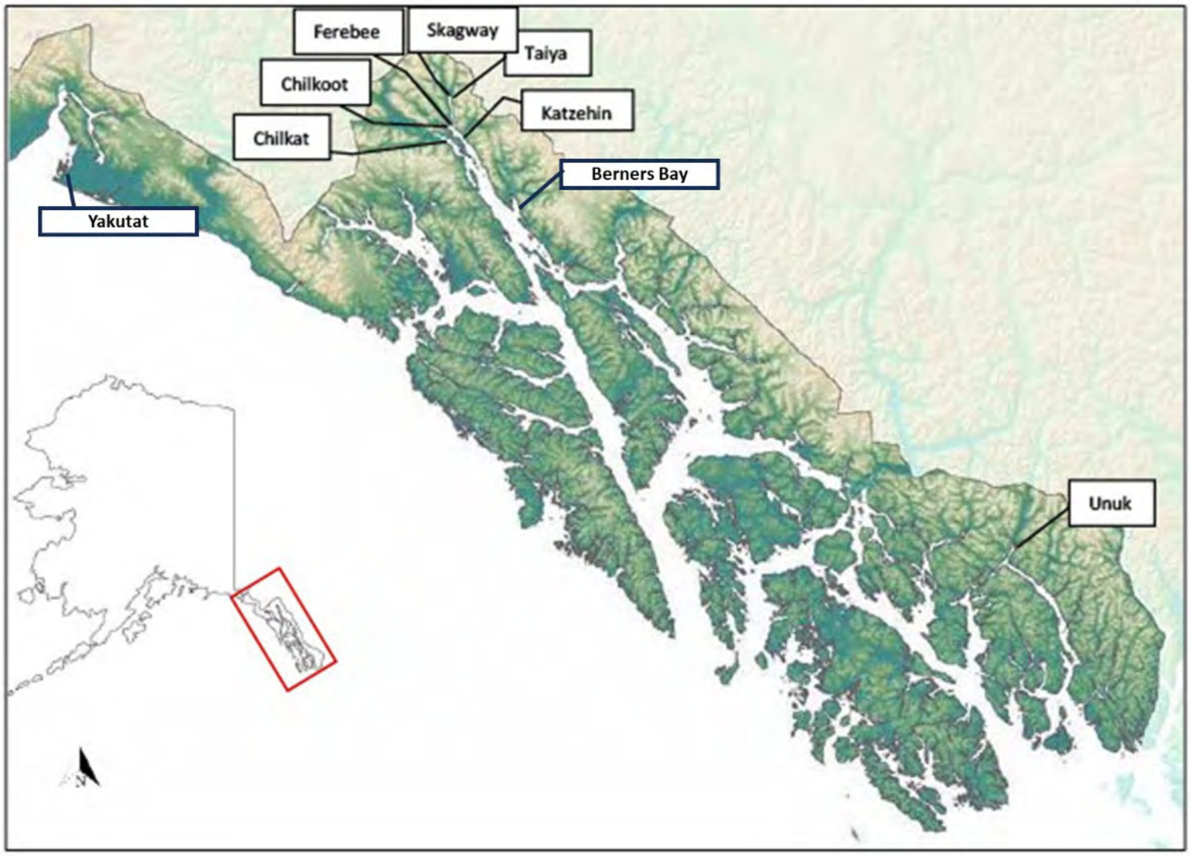

Figure 58: Location of Eulachon eDNA population monitoring sites in 2025.

using environmental DNA (eDNA).

The eulachon eDNA surveys were conducted at the Chilkoot River from 2014 – 2025. The ease of collecting eDNA samples (i.e., only one technician necessary to collect samples) and the sensitivity of the methods allowed for eDNA surveys to be conducted in years when the mark-recapture method was not at the Chilkoot River (2020 – 2022). The eDNA concentration at the Chilkoot River followed similar trends to the mark-recapture data in the years that the methods coincided. The log eDNA rate for 2024 indicates that the return was average compared to the previously monitored years (baseline 2014 – 2024) (Figure 60). 2025 eDNA results are still pending.

The regional population structure of eulachon initiated the need to begin a regional population monitoring effort in 2017 through the use of eDNA. The 2025 eDNA data is still pending for Chilkoot, Chilkat, Ferebee, Katzehin, Taiya, Skagway, and Berners Bay sites, but the regional trends observed are depicted in Table 1. Most noteworthy of the 2025 eulachon spawning returns is the above-average returns on the Unuk River. This was above what had been observed in over 10 years, according to local knowledge.

Eulachon monitoring on the Unuk River conducted by the Ketchikan Indian Community in partnership with the US Forest Service was impacted by federal travel restrictions in 2025. Three sampling events took place in 2025 at the Unuk River, but all occurred before the presumed peak of the run. Observations

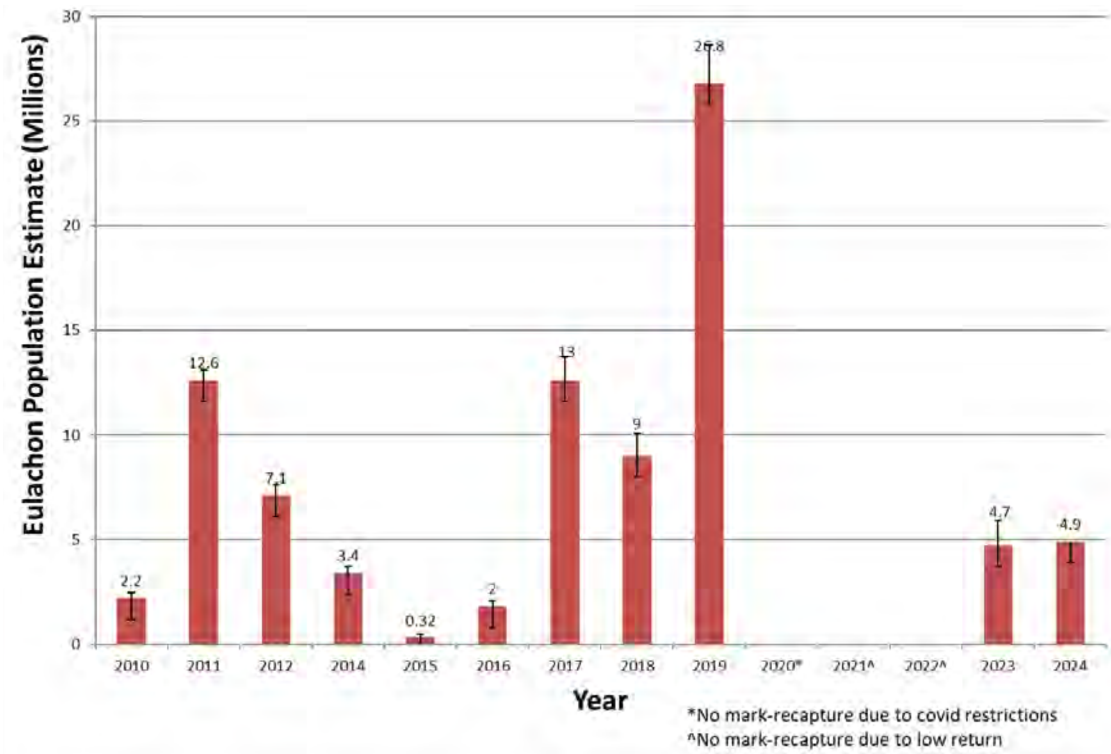

Figure 59: Eulachon population estimate on the Chilkoot River using mark-recapture method. Error bars represent 1 standard deviation. *No mark-recapture survey conducted in 2020 due to covid-19 restrictions. ^No survey conducted in 2021 and 2022 due to lack of return.

Table 1: 2025 Southeast Alaska eulachon return observations

River	Adjacent community	2024 Eulachon Return Observations
Chilkoot	Haines	Average
Chilkat	Haines	Average
Ferebee	Haines	Unknown/observations difficult
Katzehin	Haines	Unknown/observations difficult
Taiya	Skagway	Below average
Skagway	Skagway	Below average
Berners Bay	Juneau	Average
Unuk	Ketchikan	Above average
Situk	Yakutat	Below average
Ahrnklin	Yakutat	Below average

from locals on the ground during the 2025 run indicated that it was a sizeable run, larger than had previously been observed in the last 10 years (Figure 61).

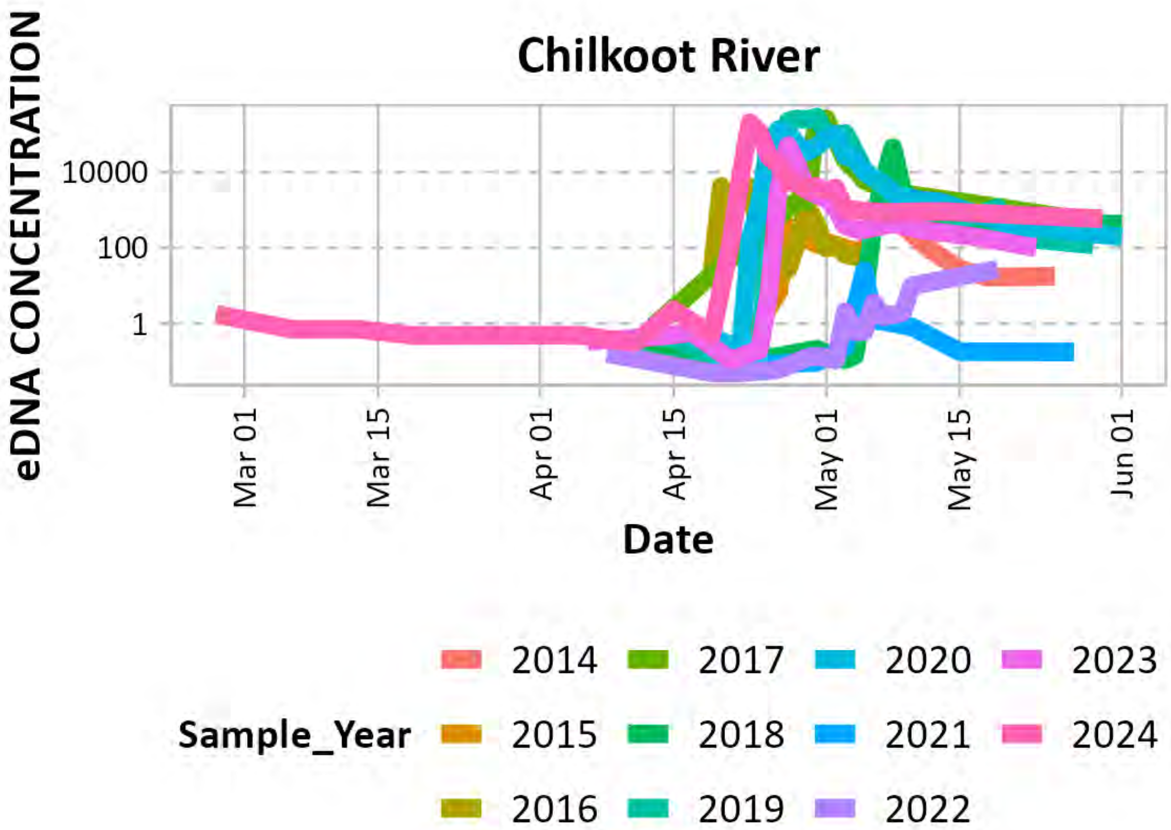

Figure 60: Chilkoot River log eDNA rate (flow-corrected) for 2014 – 2024.

Yakutat area eulachon monitoring conducted by the Yakutat Tlingit Tribe showed lower than average eulachon returns at the Situk and Arhnklin Rivers (Figure 62)

Factors influencing observed trends: Eulachon populations are sensitive to environmental influences and the annual spawning population at a river can vary substantially (Olds et al., 2016). Additionally, there is little known about the life history of eulachon (Spangler, 2002), which makes assessing trends between parent-year and offspring difficult. It is thought that eulachon in Alaska are approximately two to five years of age at spawning (Spangler, 2002). Most eulachon are thought to be semelparous (Clarke et al., 2007), however it has been observed that eulachon do move back into the marine environment after spawning.

Implications: Anecdotal information and traditional knowledge indicate that eulachon spawning populations have historically varied in abundance (Olds et al., 2016). The limited timeseries of data available on eulachon spawning populations across the Southeast Alaska region limits any inference into the health of the overall health of the eulachon population. Continued, and expanded monitoring will be necessary to reliably assess the overall eulachon spawning population. A decline in the eulachon population in Southeast Alaska would have adverse impacts both culturally and ecologically. Eulachon have

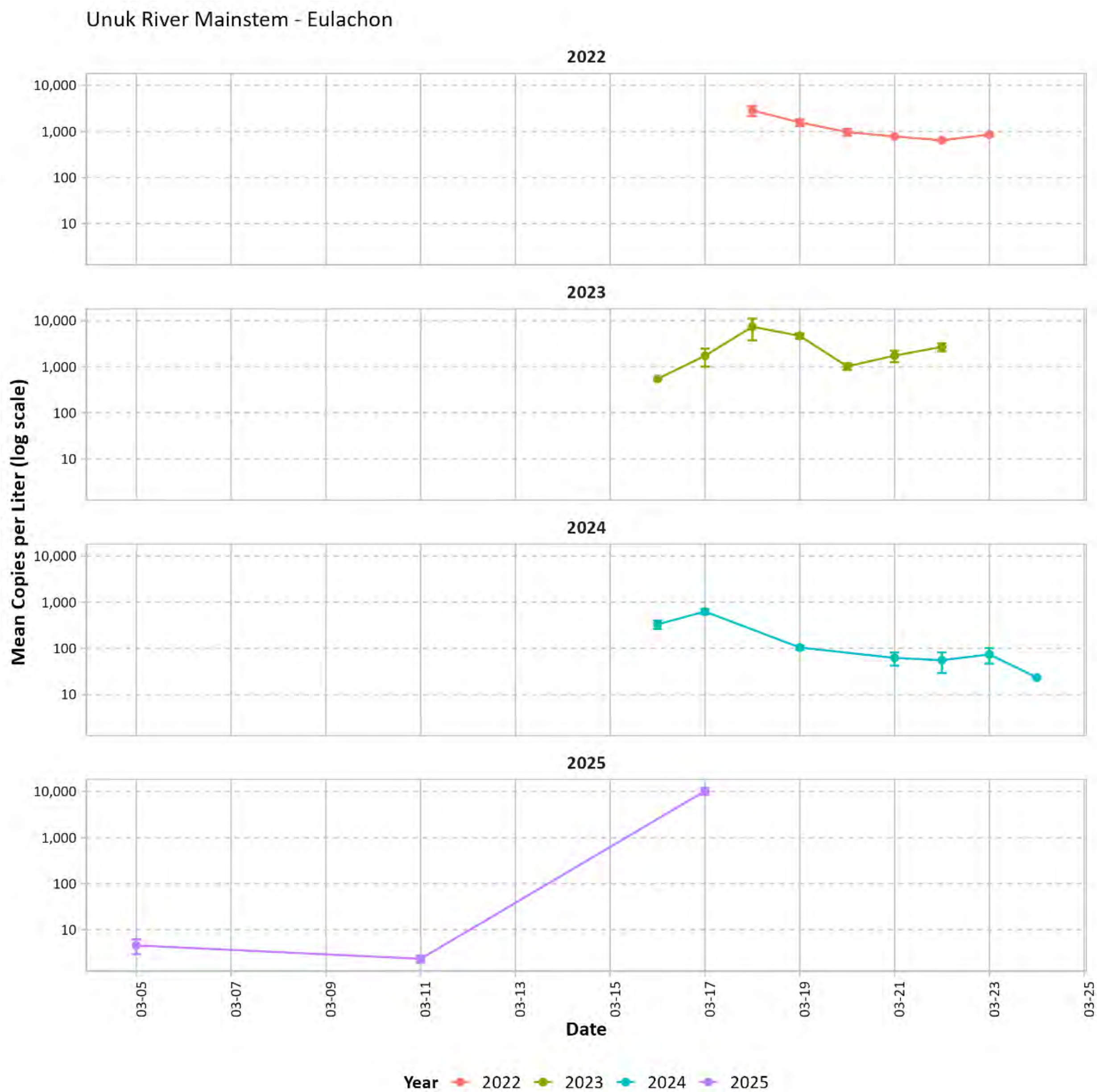

Figure 61: Unuk River Eulachon eDNA Concentration (2022 – 2025). Ketchikan Indian Community

been termed the "salvation fish" by Northwest Coast Native peoples and eulachon oil was the most important trade item on a network of 'grease trails' between coastal and interior peoples (Moody and Pitcher, 2010). Today, eulachon are a still a valued subsistence resource. Additionally, eulachon are an important prey item for sea birds and marine mammals. Eulachon spawn prior to the breeding season for many predators, thus providing a high-energy resource at an energetically demanding time (Sigler et al., 2004).

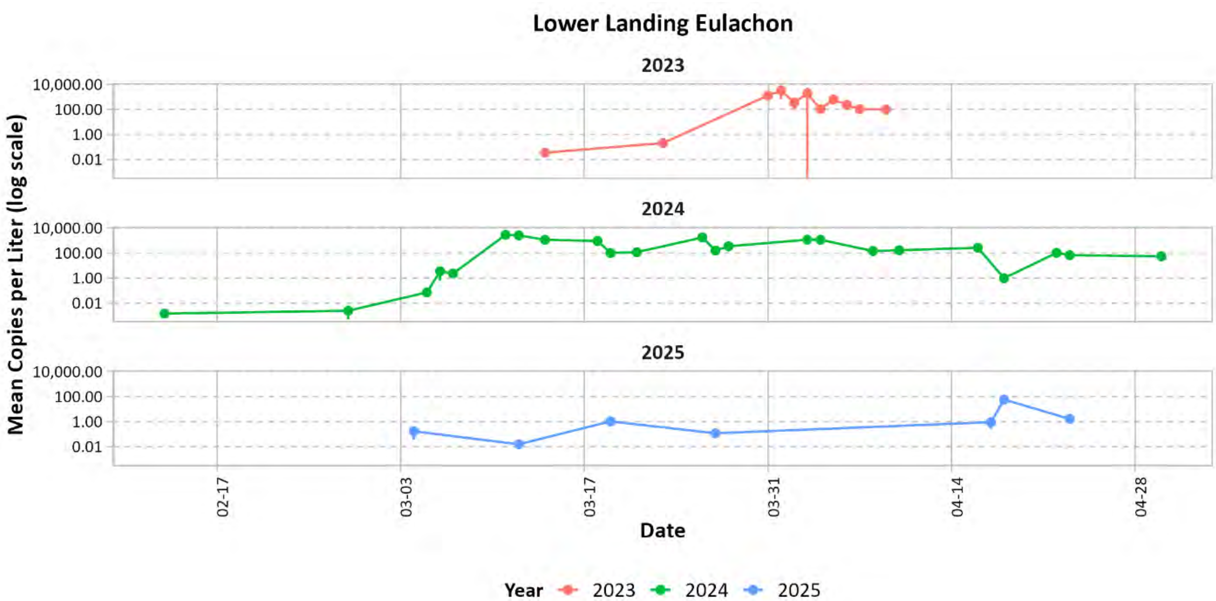

Figure 62: Situk River (Yakutat) eulachon eDNA monitoring (2023 – 2025). Yakutat Tlingit Tribe.

Salmon

Trends in Alaska Commercial Salmon Catch

Contributed by George A. Whitehouse, Cooperative Institute for Climate, Ocean, and Ecosystem Studies (CICOES), University of Washington, Seattle, WA
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Last updated: October 2025

Description of indicator: This contribution provides historic and current commercial catch information for salmon of the Gulf of Alaska. This contribution summarizes data and information available in current Alaska Department of Fish and Game (ADF&G) agency reports (e.g., Gleason et al., 2025) and on their website [23].

Pacific salmon in Alaska are managed in four regions based on freshwater drainage basins[24], Southeast/Yakutat, Central (encompassing Prince William Sound, Cook Inlet, and Bristol Bay), Arctic-Yukon-Kuskokwim, and Westward (Kodiak, Chignik, and Alaska peninsula). ADF&G prepares harvest projections for all areas rather than conducting run size forecasts for each salmon run. There are five Pacific salmon species with directed commercial fisheries in Alaska; they are sockeye salmon (*Oncorhynchus nerka*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), Chinook salmon (*O. tshawytscha*), and coho salmon (*O. kisutch*).

Status and trends: *Statewide*—Combined catches from directed fisheries on the five salmon species have fluctuated over recent decades but in total have been generally strong statewide (Figure 63a). The salmon commercial harvests from 2024 totaled 103.5 million fish, which was 32.2 million less than the preseason forecast of 135.7 million fish. In particular, the 2024 total commercial harvest of 40 million pink salmon was below the harvest projection of 69 million. While the 2025 harvest data are not yet final, preliminary data from ADF&G for 2025 indicates a statewide total commercial salmon harvest of about 170 million fish (as of 22 September), which is below the preseason projection of 214.6 million fish. Individually, the preliminary statewide pink salmon harvest of 99.5 million fish is approximately 38 million below the projected harvest.

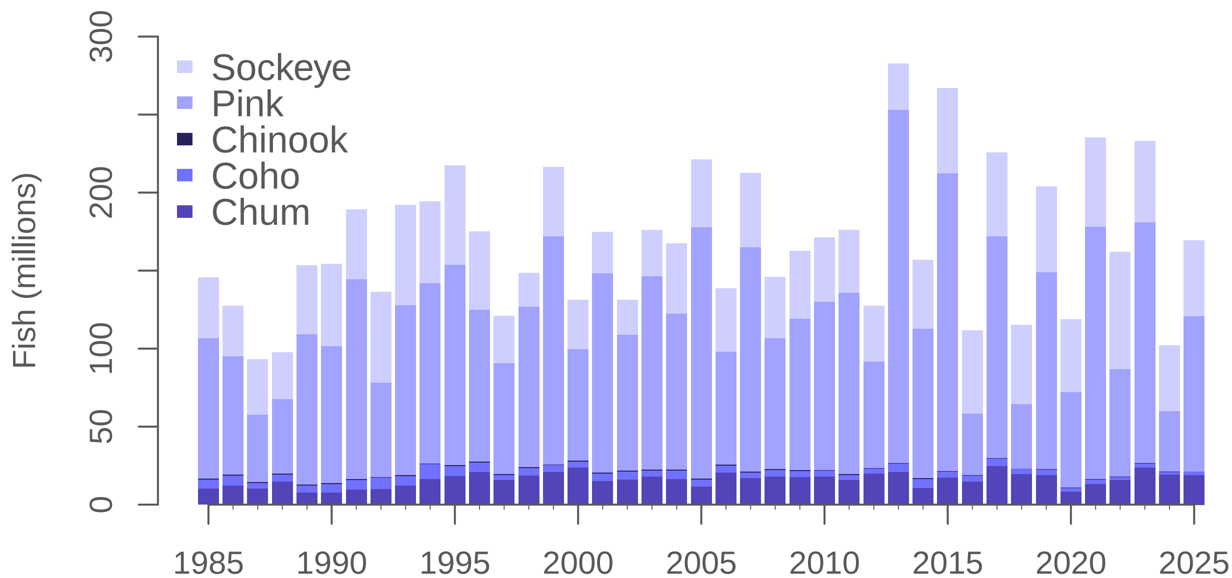
Gulf of Alaska–The total commercial salmon harvests in the Gulf of Alaska are dominated by pink salmon which follow a cycle of strong odd years and weak even years (Figure 63b). In the Prince William Sound Area of the Central region, the 2024 pink salmon harvest continued to follow the pattern of weak even years with a harvest of 9.9 million fish which was well below the 5-year, even-year average of 26.1 million fish. Preliminary harvest numbers for 2025, indicate maintenance of the strong odd-year pattern with a commercial harvest of about 44 million pink salmon in the Prince William Sound Area.

In the Southeast region, the 2024 commercial salmon harvests totaled 38.2 million fish, which was below the recent 10-year average harvest of 41 million fish. The 2024 harvest of 20.1 million pink salmon was greater than the preseason forecast of 19.2 million fish. Preliminary data for 2025 from ADF&G indicates

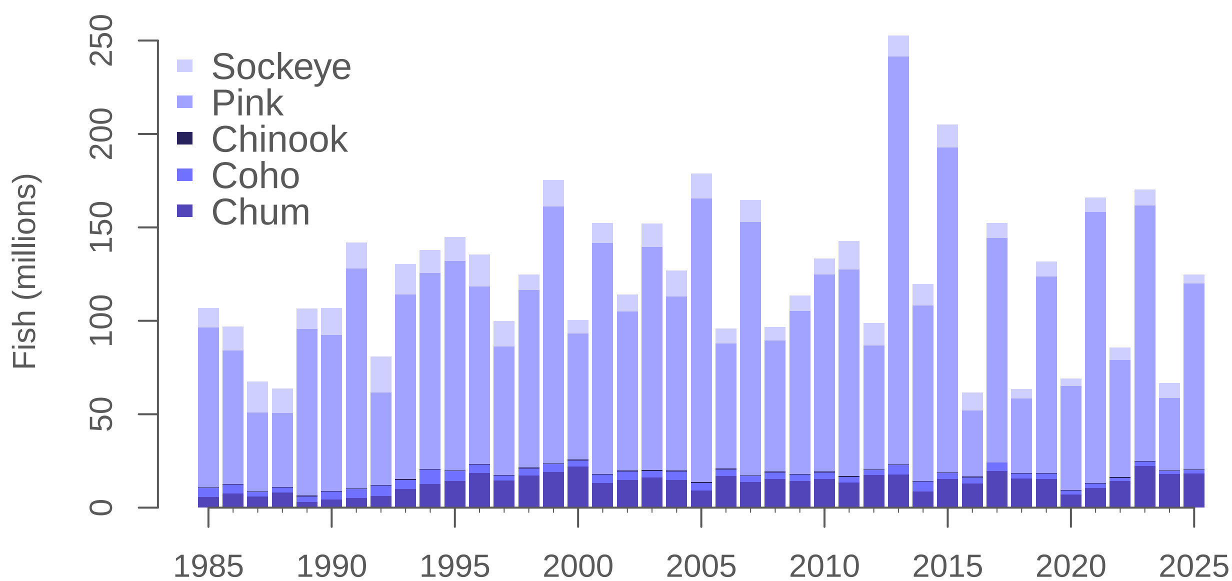
[23] https://www.adfg.alaska.gov/
[24] https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmonareas

the catch of pink salmon in the Southeast Region will be below the preseason projection of 29 million fish.

In the Kodiak management area, the 2024 total commercial salmon harvest of 9.5 million fish was below the recent 10-year average harvest of 23.5 million fish. The 2024 sockeye salmon commercial harvest of 1.6 million was below the recent 10-year average of 2.5 million fish. The 2024 chum salmon harvest of 498,000 fish was below the projected harvest of 593,000 fish. Preliminary data from ADF&G on the 2025 commercial harvest in the Kodiak management area indicates an increase in total harvest to about 36.6 million fish, including about 34 million pink salmon.



(a) Alaska



(b) Gulf of Alaska

Figure 63: Contemporary commercial salmon catches from Alaska statewide (a) and GOA (b), 1985-Sept 2025. Values from 2025 are preliminary. (Source: ADF&G, `http://www.adfg.alaska.gov`. ADF&G not responsible for the reproduction of data, subsequent analysis, or interpretation.)

Factors influencing observed trends: Historically, pink salmon catches increased in the late 1970s to the mid-1990s and have generally remained high in all regions in the last decade (Figure 63a). While both natural and hatchery populations return to Prince William Sound, a large majority of the returning fish are hatchery fish, upwards of up to one half billion are released from four hatcheries (Kline et al., 2008). Pink salmon have an abbreviated life cycle, consisting of three phases 1) brood year, 2) early marine year, and 3) return year (Kline et al. 2008). Interannual variation in Alaska statewide total salmon abundance is partly due to the even-year, odd-year cycle in pink salmon, which typically have larger runs in odd years. Pink salmon run strength is established during early marine residence and may be influenced by diet and food availability (Cooney and Willette, 1997). Survival rates of Alaska pink salmon are positively related to sea surface temperatures and may reflect increased availability of zooplankton prey during periods with warmer surface temperatures (Mueter and Norcross, 2002). Chinook runs have been declining statewide since 2007. Size-dependent mortality during the first year in the marine environment is thought to be a leading contributor to low Chinook run sizes (Beamish and Mahnken, 2001; Graham et al., 2019).

Implications: Salmon have important influences on Alaska marine ecosystems through interactions with marine food webs as predators on lower trophic levels and as prey for other species such as Steller sea lions. In years of great abundance, salmon may exploit prey resources more efficiently than their competitors, affecting the body condition, growth, and survival of competitors (Ruggerone et al., 2003; Toge et al., 2011; Kaga et al., 2013; Rand and Ruggerone, 2024). In odd years when pink salmon are most abundant they can initiate pelagic trophic cascades (Batten et al., 2018) which may negatively impact the population dynamics of several other species, including other salmonids, forage fishes, seabirds, and whales (Ruggerone et al., 2023). A biennial pattern in seabird reproductive success has been attributed to a negative relationship with years of high pink salmon abundance (Springer and van Vliet, 2014). Directed salmon fisheries are economically important for the state of Alaska. The trend in total statewide salmon catch in recent decades has been for generally strong harvests despite annual fluctuations and lower catches for some species in specific management areas.

Juvenile Salmon Abundance in Icy Strait, Southeast Alaska

Contributed by Wesley Strasburger[1], Emily Fergusson[1], Andrew Piston[2], Teresa Fish[2]
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Last updated: September 2025

Description of indicator: Juvenile salmon catch-per-unit-effort (CPUE), zooplankton abundance and quality, and oceanographic conditions are collected during the Southeast Coastal Monitoring (SECM) surveys (Fergusson et al., 2021; Murphy et al., 2021). SECM data are used in a variety of research applications; however, the information on juvenile salmon (*Oncorhynchus spp.*) CPUE is a key data product from the survey due to its use in harvest and run forecast models (Murphy et al., 2019). SECM surveys and salmon forecast models (Brenner et al., 2021) are part of a cooperative research effort by NOAA's Alaska Fisheries Science Center (AFSC) and the Alaska Department of Fish and Game (ADFG). This research supports salmon management in the U.S./Canada Pacific Salmon Treaty Northern Boundary area, including Southeast Alaska (SEAK) domestic fisheries.

Juvenile salmon CPUE indices are constructed from surface (0 – 23 m) rope-trawl catches in Icy Strait, the northern migratory corridor between the inside waters of SEAK and the Gulf of Alaska. CPUE indices are the peak monthly average log-transformed catch per 20-min trawl set in Icy Strait during the months of June and July. Data have been standardized to the long-term mean to visualize anomalies. These indices are adjusted for fishing-power differences between the survey vessels that have conducted SECM surveys over time (Wertheimer et al., 2010). CPUE data for Chinook (*Oncorhynchus tshawytscha*), chum (O. keta), coho (*O. kisutch*), pink (*O. gorbuscha*), and sockeye (*O. nerka*) salmon are included in Figure 64.

Status and trends: Peak CPUEs in 2025 remained near or below average for every species, extending the broad negative regime that began in the mid-2010s 64). Pink, chum, and sockeye salmon indices again showed strongly negative anomalies, consistent with a decade-long decline from early-period highs. Coho and Chinook remained well below their long-term means, with 2025 CPUEs comparable to or slightly lower than 2024.

Commercial harvest data (metric tons), standardized to long-term means, display the same cross-species pattern (Figure 65). Pink salmon harvests, after the exceptional 2013 peak, have stayed predominantly negative; 2025 catch remained well below average despite modest odd-year improvements in 2021 and 2023. Chum harvests show a long-term decrease from their late-1990s highs through 2022, with a substantial rebound in 2023 and 2024, (especially by catch number, not shown here). Sockeye harvests likewise trace a step-down pattern, while coho and Chinook harvests continue the sustained negative phase that began around 2015.

The close agreement between juvenile CPUE and commercial catch anomalies—both in timing and direction—provides strong evidence that the Icy Strait CPUE index captures processes influencing regional salmon production and subsequent harvest.

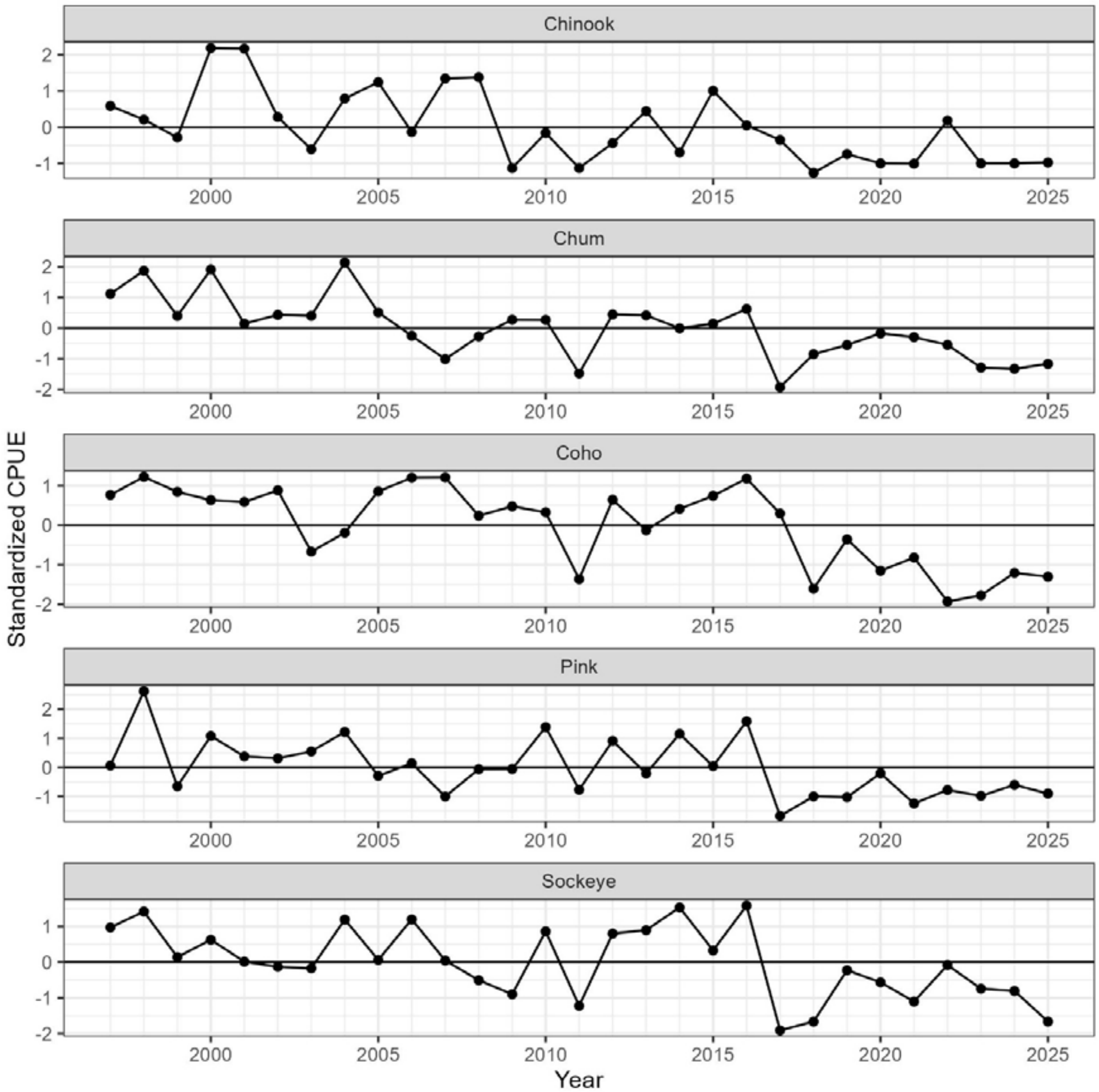

Figure 64: Standardized catch-per-unit-effort (CPUE) of juvenile salmon during Southeast Coastal Monitoring surveys in Icy Strait, 1997–2025.The CPUE index is the peak monthly average catch rate during the months of June and July. The ADFG is not responsible for the reproduction of data, subsequent analysis, or interpretation.

Factors influencing observed trends: Multiple factors contribute to the variation in juvenile salmon catch rates over time, and their relative importance differs by species. Early life-history ecology and mortality remain the primary factors influencing juvenile CPUE; however, spawner abundance and the migratory patterns of juveniles can also affect year-to-year variation.

- Pink salmon: Even-year escapement goals were frequently not met from 2012 through 2020 in the northern inside region of SEAK (Piston and Heinl, 2020 and unpublished ADFG data). Despite some improvement in escapement in 2022 and 2024 juvenile indices remained low in 2023 and 2025 and stayed well below the long-term mean, reflecting persistent limits to early marine survival and migration success.

- Chum salmon: Hatchery fish typically account for ∼90 % of the SEAK chum harvest, so brood escapement exerts little influence on juvenile catch rates. The below-average juvenile CPUE coupled with exceptionally high adult harvests in 2023 – 2024 suggests that early marine survival was stronger than expected in those brood years. Taken together, these observations indicate that variation in early marine survival, rather than freshwater production, remains the primary driver of recruitment, though recent strong survival events show this process can be highly episodic.
- Sockeye salmon: Spend at least one year in freshwater before migrating to sea; both freshwater production and early marine survival contribute to declining catch rates and harvests.
- Coho and Chinook salmon: Juvenile CPUE for both species has remained negative since the mid-2010s, and commercial catches continue to track those declines. Extended residence in inside waters and differing offshore habitats may dampen the direct strength of the CPUE–harvest linkage, but the direction of change is consistent.

Implications: The sustained negative phase across both juvenile CPUE and adult harvests indicates a multi-species productivity regime shift in Southeast Alaska beginning around 2015 – 2017, coincident with the 2014 – 2016 Gulf of Alaska marine heatwave and subsequent warm-ocean conditions.

- Pink salmon juvenile indices and commercial harvests both remain well below average in 2025, underscoring continued poor marine survival despite brief odd-year improvements.
- Chum salmon catches show no durable rebound , emphasizing the central role of unfavorable marine conditions.
- Sockeye salmon continue a long-term gradual decline in both juvenile CPUE and harvest.
- Coho and Chinook salmon exhibit persistent below-average CPUE and harvest, confirming that low juvenile production now translates directly to reduced fishery yield. Together, these indicators demonstrate that early life-history survival and marine ecosystem conditions are contributing to regional salmon production, and that Icy Strait CPUE remains a valuable, timely predictor of Southeast Alaska harvest potential.

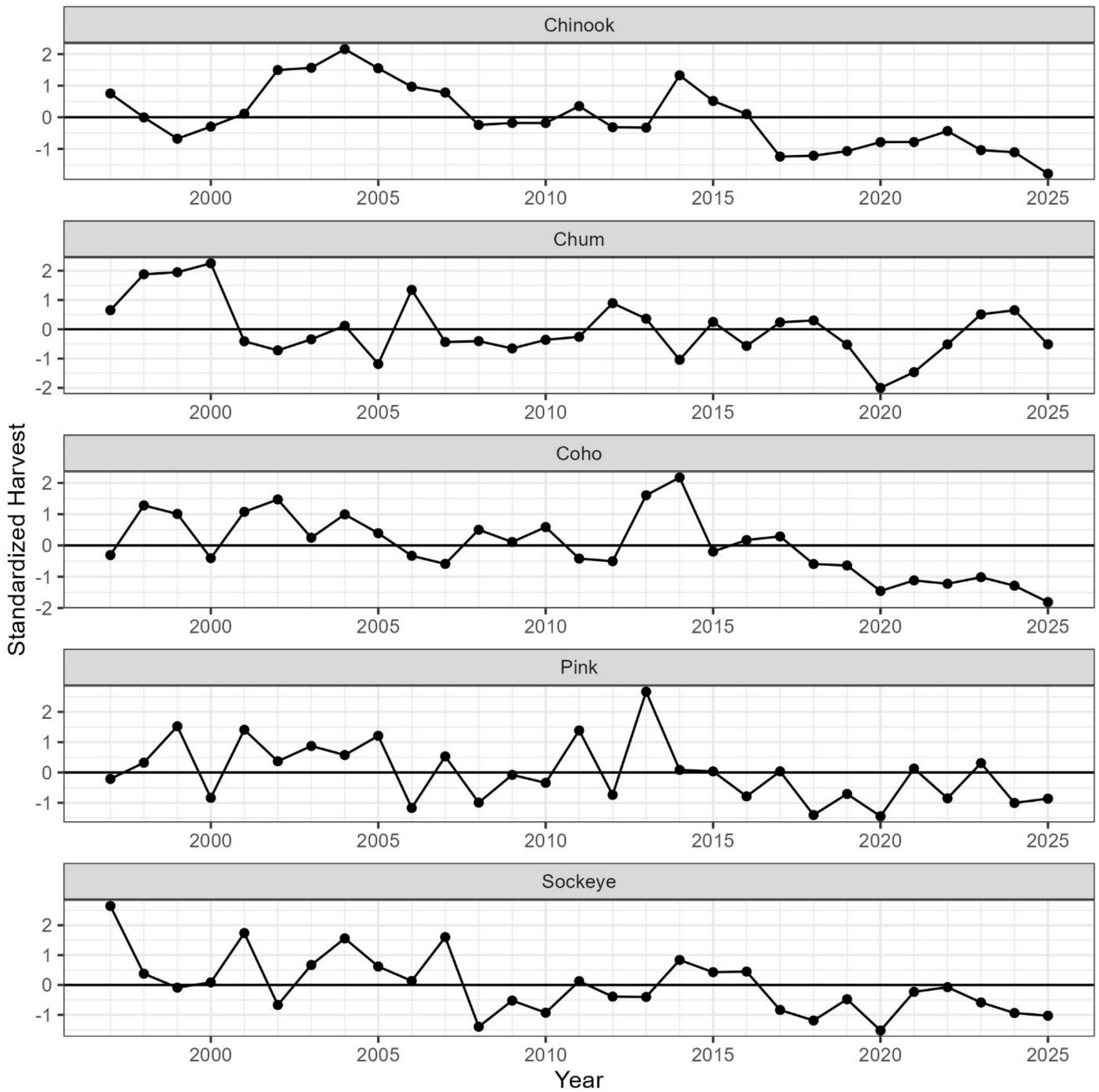

Figure 65: Standardized commercial harvest (metric tons) of salmon in Southeast Alaska, 1997–2025. Harvest data through 2024 are from ADFG (`https://npafc.org/statistics/`); 2025 harvests are preliminary from ADFG (`https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.bluesheet`).

Juvenile Salmon Size and Condition Trends in Icy Strait, Southeast Alaska

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Last updated: September 2025

Description of indicator: The Southeast Coastal Monitoring project (SECM, Auke Bay Laboratories, AFSC) has been investigating how climate change may affect southeastern Alaska nearshore ecosystems in relation to juvenile salmon (*Oncorhynchus* spp.) and associated biophysical factors since 1997 (Fergusson et al., 2020*a*; Murphy et al., 2020). Juvenile pink (*O. gorbuscha*), chum (*O. keta*), sockeye (*O. nerka*), and coho (*O. kisutch*) salmon size and nutritional condition data have been collected annually in Icy Strait during monthly (June and July) fisheries oceanographic surveys. This report presents July 2025 size (fork length) and energy density data in relation to the past 29-year trend from Icy Strait.

During early marine entry and residency, juvenile salmon must grow quickly to avoid predation while also acquiring enough lipid reserves to survive winter when food is severely limited (Beamish and Mahnken, 2001; Moss et al., 2005). The record low numbers of out-migrating juvenile pink and coho salmon in 2017 through 2019 may have resulted from low escapements in the previous years and/or low freshwater survival (Murphy et al., 2020). Size trends (fork length) over time represent differences in growth, migration routes, and timing of hatch, outmigration, and hatchery releases of the fish in response to climate and ocean conditions during early marine residency. Energy density trends over time can represent the condition of juvenile salmon and other taxa in response to climate and ocean conditions during their early marine residency.

Status and trends: In 2025, juvenile salmon fork-length anomalies were at or below the 1997 – 2024 average for all four species (Figure 66). Juvenile pink and chum salmon remained below average, similar to 2024 values, while sockeye and coho salmon increased from below-average to near average-size.

Energy density anomalies (ED, kJ/g dry weight) varied among the four juvenile salmon species (Figure 67). Pink salmon ED stayed above average and similar to 2024 levels. Chum and sockeye salmon showed slight increases and remained above average. Coho salmon ED remained just below average, consistent with the previous four-year trend.

Factors influencing observed trends: Conditions in 2025 reflected a complex system between a major northeast Pacific marine heatwave and localized thermal refugia inside southeast Alaska. The 2025 sampling occurred during NEP25A, a pronounced marine heatwave that began in early May and now spans nearly 8 million km² of the Northeast Pacific, including the Gulf of Alaska (NOAA Marine Heatwave Tracker "Blobtracker"). NEP25A is the fourth-largest Northeast Pacific marine heatwave by area since satellite monitoring began in 1982 and has expanded rapidly since late July. Such widespread upper-ocean warming typically alters phytoplankton bloom timing, zooplankton prey availability, and species composition.

However, inside waters of Southeast Alaska, including Icy Strait, appear to provide partial thermal refuge during these basin-scale warm events. Recent analyses (Brooks et al., 2025) show that nearshore channels with strong freshwater influence can remain cooler and less saline than adjacent offshore Gulf of Alaska waters, buffering salmon and their prey from extreme temperature stress. These conditions likely help sustain favorable energy density and facilitate lipid accumulation.

Other processes, advection of nutrient-rich waters, freshwater discharge, and top-down control by predators, remain important, but in 2025 the combined influence of the NEP25A marine heatwave and the mitigating effects of Southeast Alaska's inside-water thermal refuge appear to be relevant.

Implications: The length anomalies observed in 2025 for juvenile salmon continue to reflect the colder water temperatures experienced in their early marine residency in Icy Strait. Larger fish generally have increased foraging success and a decreased predation risk resulting in higher survival.

Based on the 2025 length frequency results relative to the long-term averages by species, juvenile salmon are entering the Gulf of Alaska in 2025 with below-average size. However, these fish are entering the Gulf of Alaska with average to positive energy stores which may contribute to higher survival and escapement especially as it pertains to their overwinter survival when food is limited. Therefore, further growth and survival will be dependent on favorable over-winter conditions in the GOA, which don't seem likely with the current NEP25A event.

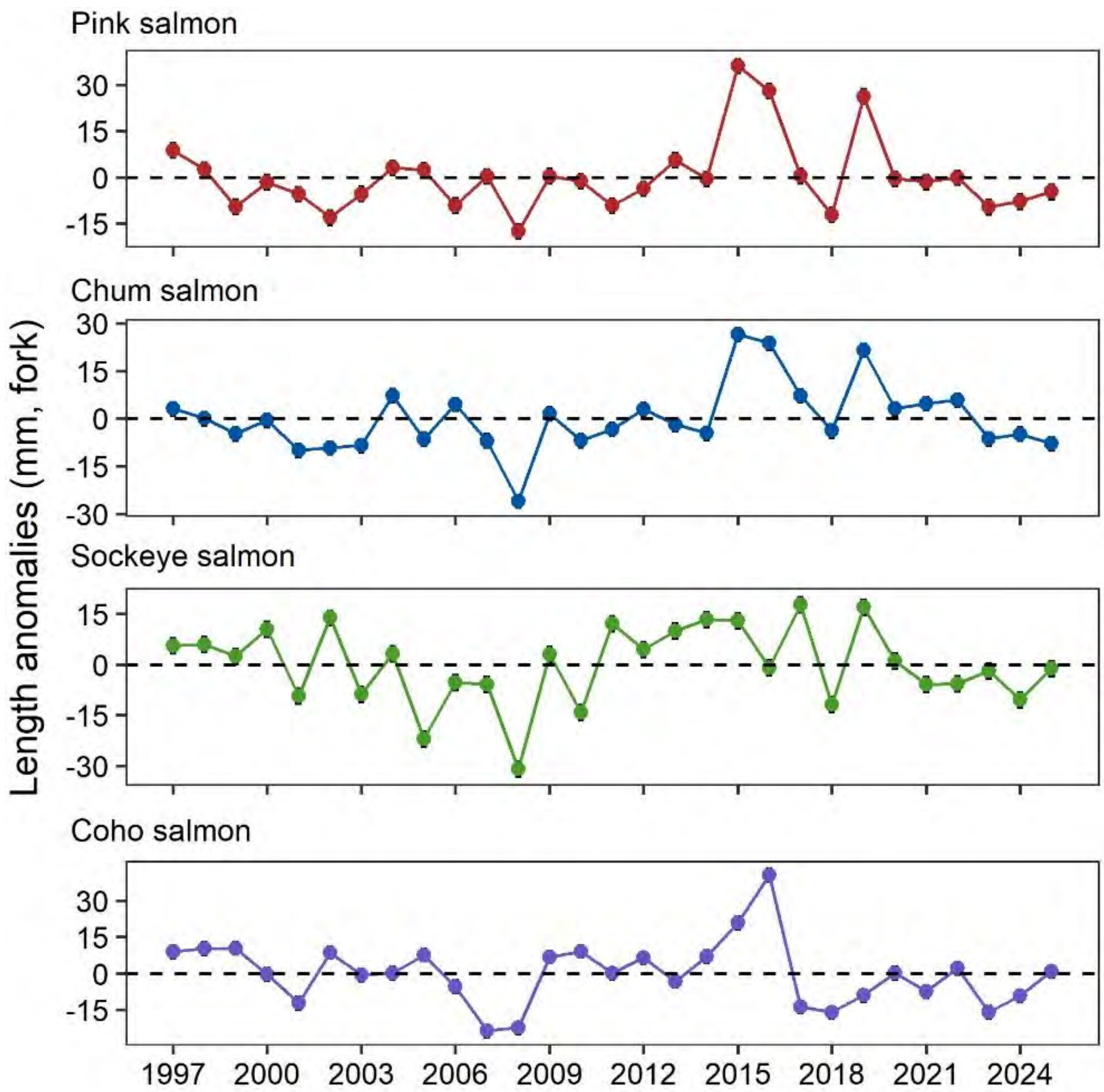

Figure 66: Average fork length anomalies (mm; ± 1 standard error) of juvenile salmon captured in Icy Strait, AK by the Southeast Coastal Monitoring project, 1997 – 2025. Time series average is indicated by the dashed line.

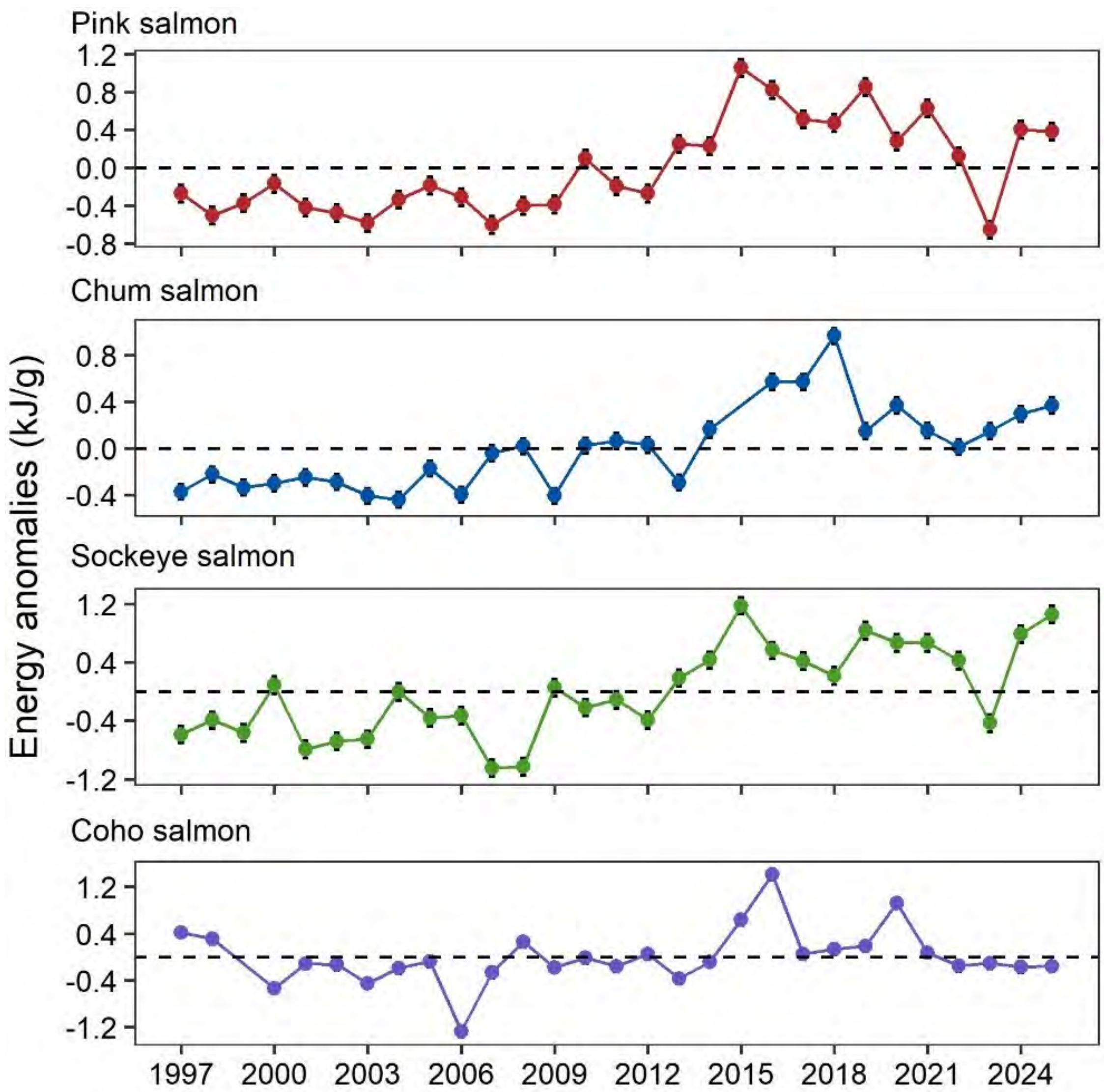

Figure 67: Average energy density anomalies (kJ/g, dry weight; ± 1 standard error) of juvenile salmon captured in Icy Strait, AK by the Southeast Coastal Monitoring project, 1997 – 2025. The dashed line indicated the time series average.

Trends in Survival of Coho, Sockeye, and Pink Salmon from Auke Creek, Southeast Alaska

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Last updated: September 2025

Description of indicator: The time series of marine survival estimates for wild coho, sockeye, and pink salmon from the Auke Creek Weir in Southeast Alaska is the most precise and longest-running continuous series available in the North Pacific. Auke Bay Laboratory began monitoring wild salmon survival in 1980. The Auke Creek weir structure facilitates near-complete capture of all migrating sockeye smolt and returning adults and is the only weir capable of such precision on a wild system in the North Pacific. All coho salmon smolts leaving the Auke Lake watershed have been counted, subsampled for age and length, and injected with coded wire tags (CWT). These migrating fish included those with both 1 and 2 freshwater annuli and 0 or 1 ocean annuli. Coho marine survival is estimated as the number of adults (harvest plus escapement) per smolt. The index is presented by smolt (outmigration) year. It is the only continuous marine survival and scale data set in the North Pacific that recovers all returning age classes of wild, CWT coho salmon as ocean age 0 and 1. The precision of the survival estimate was high due to 100% marking and high sampling fractions that minimized the variance in the survival estimate and made the series an excellent choice for model input relating to nearshore and gulf-wide productivity. While no stock-specific harvest information is available for Auke Creek sockeye and pink salmon for a direct estimation of marine survival, the precision of this long-term dataset is still unmatched, and the series is an excellent choice for model input relating to nearshore and gulf-wide productivity.

Status and trends: The historical trends show marine survival of wild coho salmon from Auke Creek varies from 5.2% to 45.0%, with an average survival of 20.5% from smolt years 1980 – 2024 (Figure 68a). Marine survival for 2024 was the fifteenth lowest on record at 16.1% and overall survival averaged 11.6% over the last 5 years and 10.3% over the last 10 years. The survival index for ocean age-0 coho varies from 0.2% to 11.2% from smolt years 1980 – 2024 (Figure 68b).

Productivity of wild sockeye salmon smolts from Auke Creek varies from 1619 to 33616, with an average productivity of 15279 from ocean entry years 1980 – 2025. In 2025 there were 3780 outmigrant smolts, the third lowest on record (Figure 68c). Escapement of wild sockeye salmon from Auke Creek has varied from 325 to 6123, with an average escapement of 2468 from return years 1980 – 2025. The 2025 season saw the eleventh lowest escapement of sockeye salmon to Auke Creek with 1326 returning adults (Figure 68d).

Marine survival of wild pink salmon from Auke Creek varies from 1.1% to 53.3%, with an average survival of 11.6% from ocean entry years 1980 – 2024 (Figure 68e). Marine survival for the 2024 ocean entry year was 3.2% and overall survival averaged 15.2% over the last 5 years and 12.0% over the last 10 years. 2025 saw the fifteenth lowest return of pink salmon to Auke Creek with 3002 returning adults (Figure 68f).

Factors influencing observed trends: Factors influencing observed trends in coho survival include:

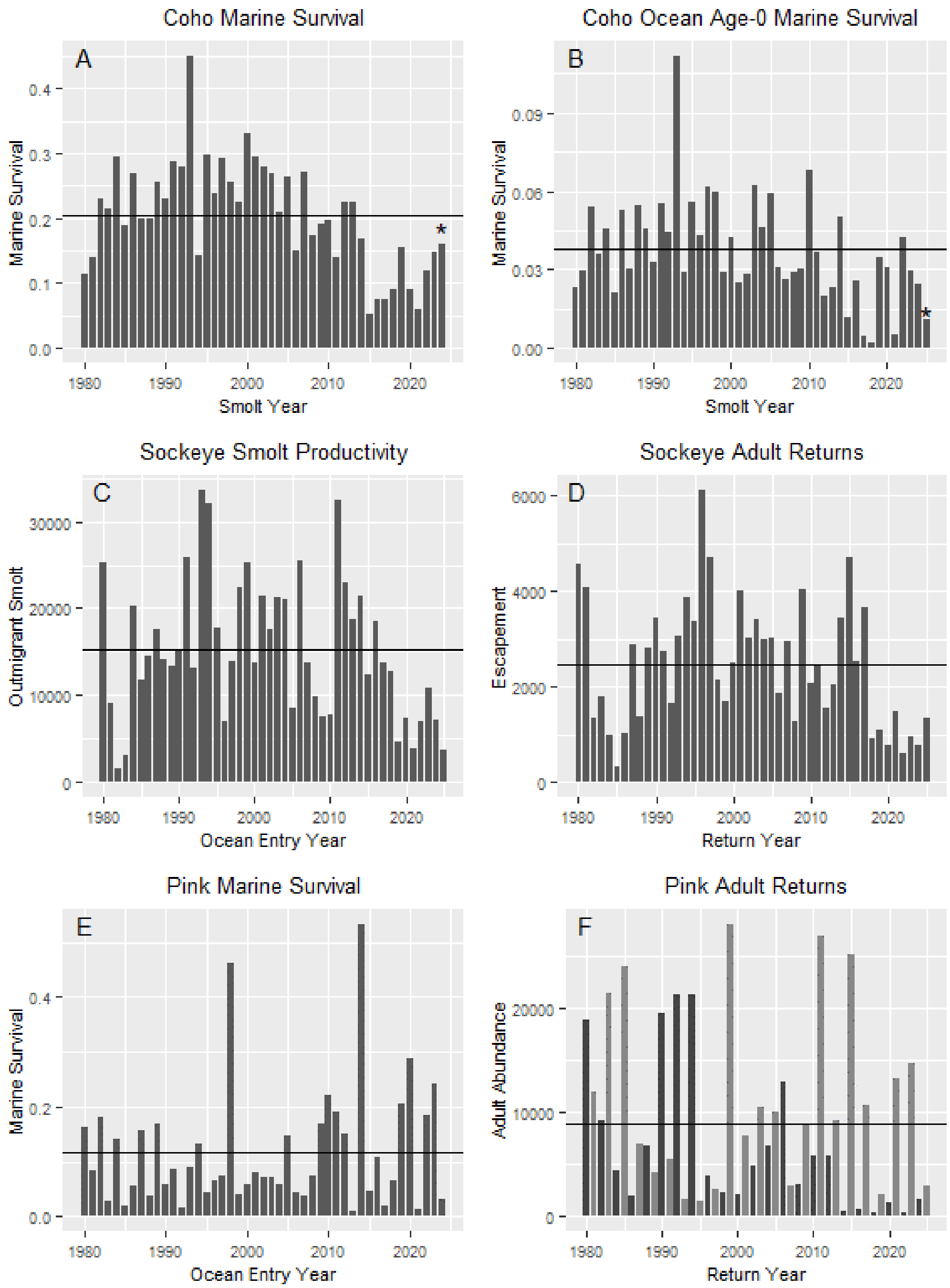

Figure 68: Auke Creek (SE Alaska) salmon marine survival and productivity indices. Coho salmon are represented by total marine survival (ocean age-0 and age-1 harvest plus escapement) (A), and percentage of ocean age-0 coho per smolt (escapement only) by smolt year (B). Sockeye salmon are represented by smolt productivity by ocean entry year (C) and adult returns (D). Pink salmon are represented by marine survival index is represented by ocean entry year (E) and adult returns by year (F). Return year 2025 data are denoted with an asterisk as these may change by the end of the year. For coho, sockeye and pink indices, the solid, horizontal line indicates the 1980 – 2025 average.

smolt age, smolt size, migration timing, fishery effort and location, and marine environmental conditions (Briscoe et al., 2005; Robins, 2006; Malick et al., 2009; Kovach et al., 2013*a*). Coho salmon marine survival is influenced by a number of life history parameters such as juvenile growth rate and size, smolt age and smolt ocean entry timing (Weitkamp et al., 2011). Recent studies have shown that climate change has shifted the median date of migration later for juveniles. Recent studies have shown that climate change has shifted the median date of migration later for juveniles and earlier for adults (Kovach et al., 2013*a*). The marine survival of Auke Creek coho reflects nearshore rearing productivity and, as such, is utilized to infer regional trends in coho salmon productivity as one of four indicator stocks utilized by the Alaska Department of Fish and Game to manage coho salmon over all of southeast Alaska (Shaul et al., 2011). The marine survival of Auke Creek coho salmon and growth inferred by scales samples is influenced and reflective of broad scale oceanographic indices in the Gulf of Alaska (Briscoe et al., 2005; Robins, 2006; Malick et al., 2009; Orsi et al., 2013).

Sockeye salmon marine survival has been influenced by trends that include: smolt age, smolt size, migration timing, predation, and marine environmental conditions. Age and size at saltwater entry, along with regional sea surface temperate have been shown to influence juvenile mortality at ocean entry (Yasumiishi et al., 2016). Within the Auke Creek watershed, a system undergoing rapid climatic change, climate-induced phenological shifts have been shown to influence a trend of later migration of sockeye adults and age-1.0 smolts, while age-2.0 smolts are trending earlier (Kovach et al., 2013*a*; Shanley et al., 2015). Additionally, positive effects of temperature have been observed on sockeye biomass and length of age-2.0 smolts in the Auke Creek system (Kovach et al., 2014). In Southeast Alaska, sablefish have been observed to prey upon juvenile sockeye in early summer before more abundant food resources become available (Sturdevant et al., 2009).

Factors that have influenced these observed trends in pink salmon survival include: migration timing, fishery effort and timing, predation, growth rates, maintained genetic variation, and stream conditions. Within the Auke Creek system, a system undergoing rapid climatic change, climate-induced phenological shifts have been shown to influence the trend of earlier migration of both the early and late run of pink adults, as well as juvenile fry migration (Kovach et al., 2013*b*; Shanley et al., 2015). The effect of fishing pressure on pink salmon has some obvious effects on marine survival, as well as, unapparent impacts including decreases in body weight, variations in length, increases in earlier-maturing fish, and increases in heterozygosity at PGM (Hard et al., 2008). As pink salmon are one of the most numerous and available food sources of larger migrating juvenile salmon and other marine species, their early marine survival can be heavily impacted by predation (Parker, 1971; Landingham et al., 1998; Mortensen et al., 2000; Orsi et al., 2013). One resistance to this predation is that pink salmon fry are able to quickly outgrow their main predators of juvenile coho and sockeye salmon and become unavailable as a food resource do to their size (Parker, 1971). During juvenile development, the local conditions of stream discharge and temperature are strong determinants of egg and fry survival. In addition, many of these influencing factors have been shown to have a genetic component that can strongly influence survival (Geiger et al., 1997; McGregor et al., 1998; Kovach et al., 2013*a*).

Implications: The marine survival index of coho, sockeye and pink salmon at Auke Creek is related to ocean productivity indices and to important rearing habitats shared by groundfish species. The productivity and escapement indices of Auke Creek salmon provide an opportunity for the examination of annual variation in habitat quality of rearing areas and general ocean conditions and productivity. Ocean age-0 coho leave freshwater in May through June and return in August through October, the same time sablefish are moving from offshore to nearshore habitats. In contrast, ocean age-1 coho salmon occupy those nearshore habitats for only a short time before entering the Gulf of Alaska and making a long migratory loop. They return to the nearshore habitats on their way to spawning grounds after the first winter that age-0 sablefish spend in nearshore habitats. The relative growth and survival of ocean age-0 and age-1 coho salmon from Auke Creek may provide important proxies for productivity, overwintering survival of sablefish, and recruitment of sablefish to age-1. Within Southeast Alaska, sockeye salmon productivity and escapement are of great interest to the Pacific Salmon Commission with relation to the Transboundary and Northern Boundary areas and indices such as Auke Creek help in assessment. As a result of these implications, the productivity and escapement of Auke Creek sockeye salmon provide valuable proxies for Gulf of Alaska and Southeast Alaska productivity and may provide insight to the overwintering survival and recruitment of sablefish and other groundfish species. Due to the one ocean year life history of pink salmon, we are able to use their marine survival as a proxy for the general state of the Gulf of Alaska. Additionally, as pink fry are a numerous food resource in southeast Alaska, their abundance and rate of predation allow for insights into the groundfish fisheries. Pink fry have been shown to be an important food resource for juvenile sablefish, making up a large percentage of their diet (Sturdevant et al., 2009, 2012). The growth and marine survival of Auke Creek pink salmon provide valuable proxies for Gulf of Alaska and southeast Alaska productivity, as well as the overwintering survival and recruitment of sablefish.

Groundfish

Groundfish Condition in the Gulf of Alaska

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Last updated: September 2025

Description of indicator: Length-weight residuals represent how heavy a fish is per unit body length and are an indicator of somatic growth variability (Brodeur et al., 2004). Therefore, length-weight residuals can be considered indicators of prey availability, growth, general health, and habitat condition (Blackwell et al., 2000; Froese, 2006). Positive length-weight residuals indicate better condition (i.e., heavier per unit length) and negative residuals indicate poorer condition (i.e., lighter per unit length) (Froese, 2006). Fish condition calculated in this way reflects realized outcomes of intrinsic and extrinsic processes that affect fish growth, which can have implications for biological productivity through direct effects on growth and indirect effects on demographic processes, such as reproduction and mortality (e.g., Rodgveller, 2019; Barbeaux et al., 2020*b*).

The groundfish morphometric condition indicator is calculated from paired fork lengths (mm) and weights (g) of individual fishes that were collected during bottom trawl survey of the Gulf of Alaska (GOA) which were conducted by the Alaska Fisheries Science Center biennial Resource Assessment and Conservation Engineering (AFSC/RACE) - Groundfish Assessment Program's (GAP). Fish condition analyses were applied to walleye pollock (*Gadus chalcogrammus*), Pacific cod (*Gadus macrocephalus*), arrowtooth flounder (*Atheresthes stomias*), southern rock sole (*Lepidopsetta bilineata*), northern rockfish (*Sebastes polyspinis*), Pacific ocean perch (*Sebastes alutus*), dusky rockfish (*Sebastes variabilis*), shortraker rockfish (*Sebastes borealis*), rougheye rockfish (*Sebastes aleutianus*), sharpchin rockfish (*Sebastes zacentrus*), flathead sole (*Hippoglossoides elassodon*), Dover sole (*Microstomus pacificus*), and rex sole(*Glyptocephalus zachirus*). All species were collected in trawls with satisfactory performance at standard survey stations. Data were combined by the NMFS Statistical Reporting Areas; Shumagin (610), Chirikof (620), Kodiak (630), West Yakutat (640) and Southeast Outside (650) (Figure 69).

To calculate indicators, length-weight relationships were estimated from linear regression models based on a log-transformation of the exponential growth relationship, $W = aL^b$, where W is weight (g) and L is fork length (mm) for all areas for the period 1990 – 2025. Unique intercepts (a) and slopes (b) were estimated for each species, survey stratum, sex, and interaction between stratum and sex to account for sexual dimorphism and spatial-temporal variation in growth and bottom trawl survey sampling. Length-weight relationships for 100 – 250 mm fork length walleye pollock (corresponding with ages 1 – 2 years) were calculated separately from adult walleye pollock ($>$ 250 mm). Residuals for individual fish were obtained by subtracting observed weights from bias-corrected weights-at-length that were estimated from regression models. Length-weight residuals from each stratum were aggregated and weighted proportionally to total biomass in each stratum from area-swept expansion of mean bottom-trawl survey catch per unit effort (CPUE; i.e., design-based stratum biomass estimates). Variation in fish condition

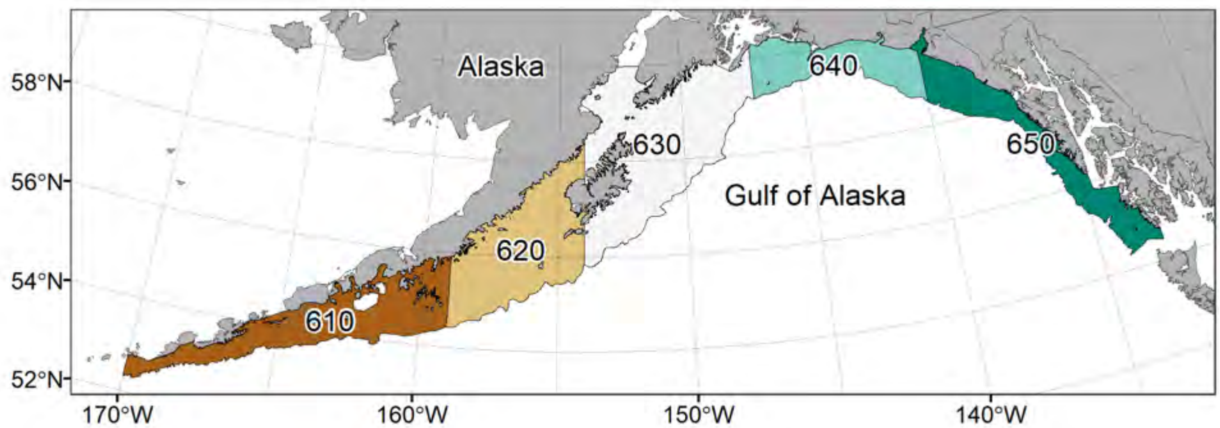

Figure 69: National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center Resource Assessment and Conservation Engineering (AFSC/RACE) Groundfish Assessment Program (GAP) Gulf of Alaska summer bottom trawl survey area with NMFS Statistical Reporting Areas demarcated.

was evaluated by comparing average length-weight residuals among years. To minimize the influence of unrepresentative samples on indicator calculations, combinations of species, stratum, and year with a sample size < 10 were used to fit length-weight regressions but were excluded from calculating length-weight residuals. Morphometric condition indicator time series, code for calculating the indicators, and figures showing results for individual species are available through the akfishcondition R package and GitHub repository[25].

Status and trends: Fish condition, indicated by length-weight residuals, has varied over time for all species examined in the GOA (Figures 70 and 71). Fish condition in nine of the fourteen species investigated in 2025 (adult walleye pollock ($\geq$ 250 mm), small walleye pollock (100 – 250 mm), Pacific cod, Pacific ocean perch, northern rockfish, dusky rockfish, arrowtooth flounder, northern rock sole, and Dover sole) was similar to the values observed in 2023. Condition increased in rougheye rockfish, continuing a trend observed since 2021. Fish condition declined for blackspotted rockfish, flathead sole, southern rock sole and rex sole, compared to the values observed in 2023. Shortraker rockfish and sharpchin rockfish length-weight samples were not collected in 2025, but both had shown a decline in recent years. The average fish condition of the fourteen species examined in 2025 was generally negative, with average condition for most species falling below the 1990 – 2025 time series mean. The exceptions were rougheye rockfish, whose mean condition was above the time series mean, and arrowtooth flounder, whose mean condition was roughly the same as the time series mean.

The general patterns of above- and below-mean body condition for fish examined in the GOA in 2025 were spatially consistent across NMFS Statistical Reporting Areas (Figures 72 and 73). For all but three species in 2025, fish condition was negative across all NMFS areas. Rougheye rockfish, the only species exhibiting positive fish condition in 2025, showed positive condition in Shumagin (610) and southeast outside (650), but negative condition in Kodiak (630) and West Yakutat (640). Arrowtooth flounder had negative fish condition in all NMFS areas observed except Chirikof (620) and Kodiak (630). Adult walleye pollock exhibited negative fish condition in all NMFS areas observed except Shumagin (610).

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

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. Following an unprecedented warming event from 2014 – 2016 (Bond et al., 2015; Stabeno and Bell, 2019; Barbeaux et al., 2020*b*), there has been a general trend of warming ocean temperatures in the survey area and sea surface temperature anomaly data continue to reflect temperatures above average historical conditions through 2023; these warmer temperatures could be affecting fish growth conditions in this region. 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. Recorded changes attributed to the marine heatwave included species abundances, sizes, growth rates, weight/body condition, reproductive success, and species composition (Suryan et al., 2021). Warmer ocean temperatures can lead to lower energy (leaner) prey, increased metabolic needs of younger fish, and therefore slower growth for juveniles, as observed in Pacific cod (Barbeaux et al., 2020*b*). Additionally, spatial and temporal trends in fish growth over the season become confounded with survey progress since the first length-weight data are generally collected in late May and the bottom trawl survey is conducted throughout the summer months moving from west to east. In addition, spatial variability in residual condition may also reflect local environmental conditions that influence growth and prey availability in the areas surveyed (e.g., local differences in average cross-shelf transport of heat via eddies reported this year in International Pacific Halibut Commission (IPHC) regions).

Implications: Variations in body condition likely have implications for fish survival. The condition of GOA groundfish may 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 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 or even regional growth patterns. In the future, it may be more informative to examine body condition by life history stage (e.g., early juvenile, subadult, and adult phases), age, or sex.

Below-average body condition for many GOA species over the last four to five 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 2014 – 2016 marine heatwave (Bond et al., 2015; Stabeno and Bell, 2019) has been followed by subsequent years with elevated water temperatures (Barbeaux et al., 2020*b*; NOAA, 2021) which may be influence changes in fish condition in the species examined. It should be noted that while many GOA species' body condition remained below average this year, most species' condition improved relative to 2021; southern rock sole, dusky rockfish, Pacific cod, walleye pollock adults, and sharpchin rockfish were the exceptions. 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 GOA.

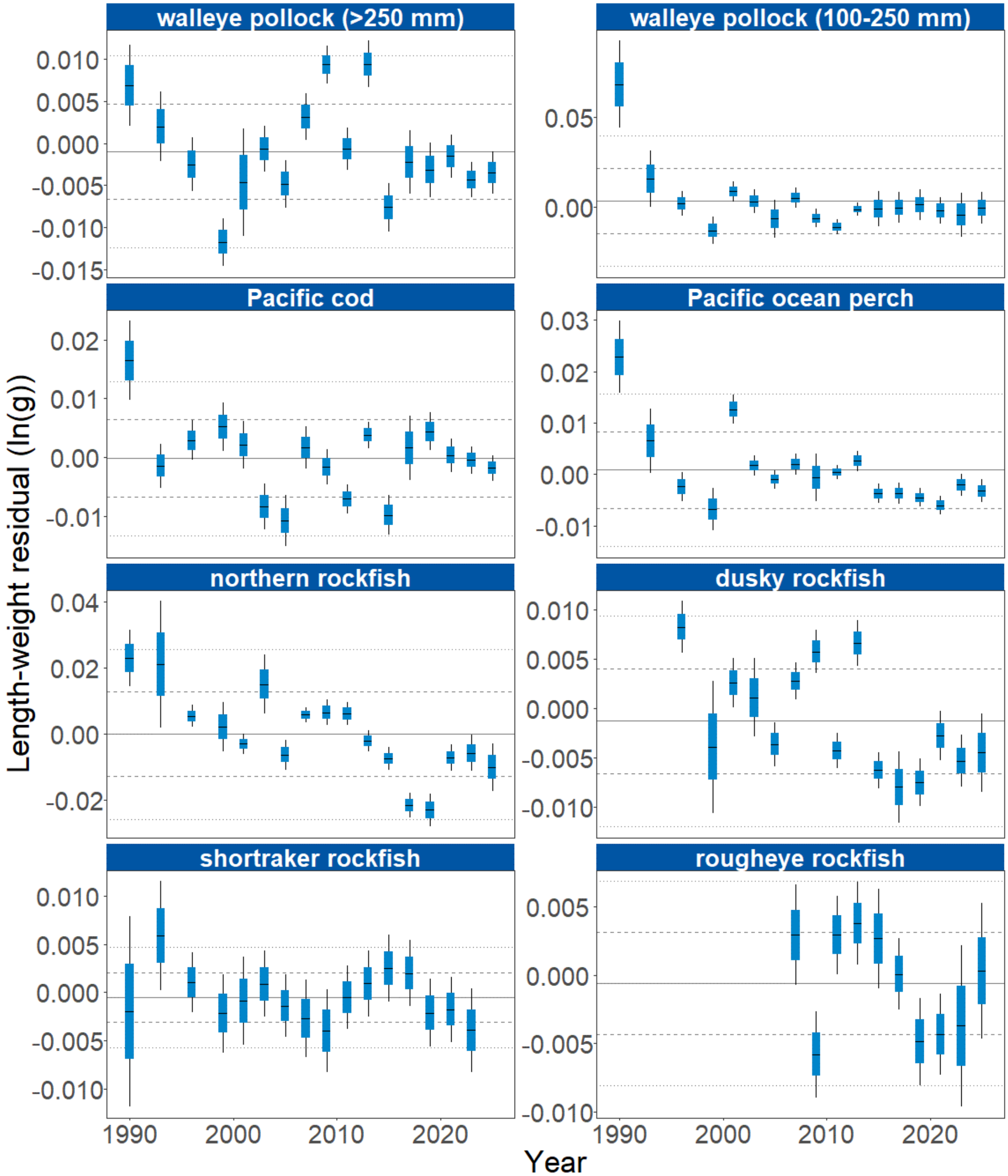

Figure 70: Biomass-weighted residual body condition index across survey years (1990 – 2025) for sixteen Gulf of Alaska groundfish species collected on the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center Resource Assessment and Conservation Engineering (AFSC/RACE) Groundfish Assessment Program (GAP) standard summer bottom trawl survey. Filled bars denote weighted length-weight residuals, error bars denote two standard errors. Horizontal lines denote the time series mean (solid) and one (dashed) and two (dotted) standard deviations from the mean.

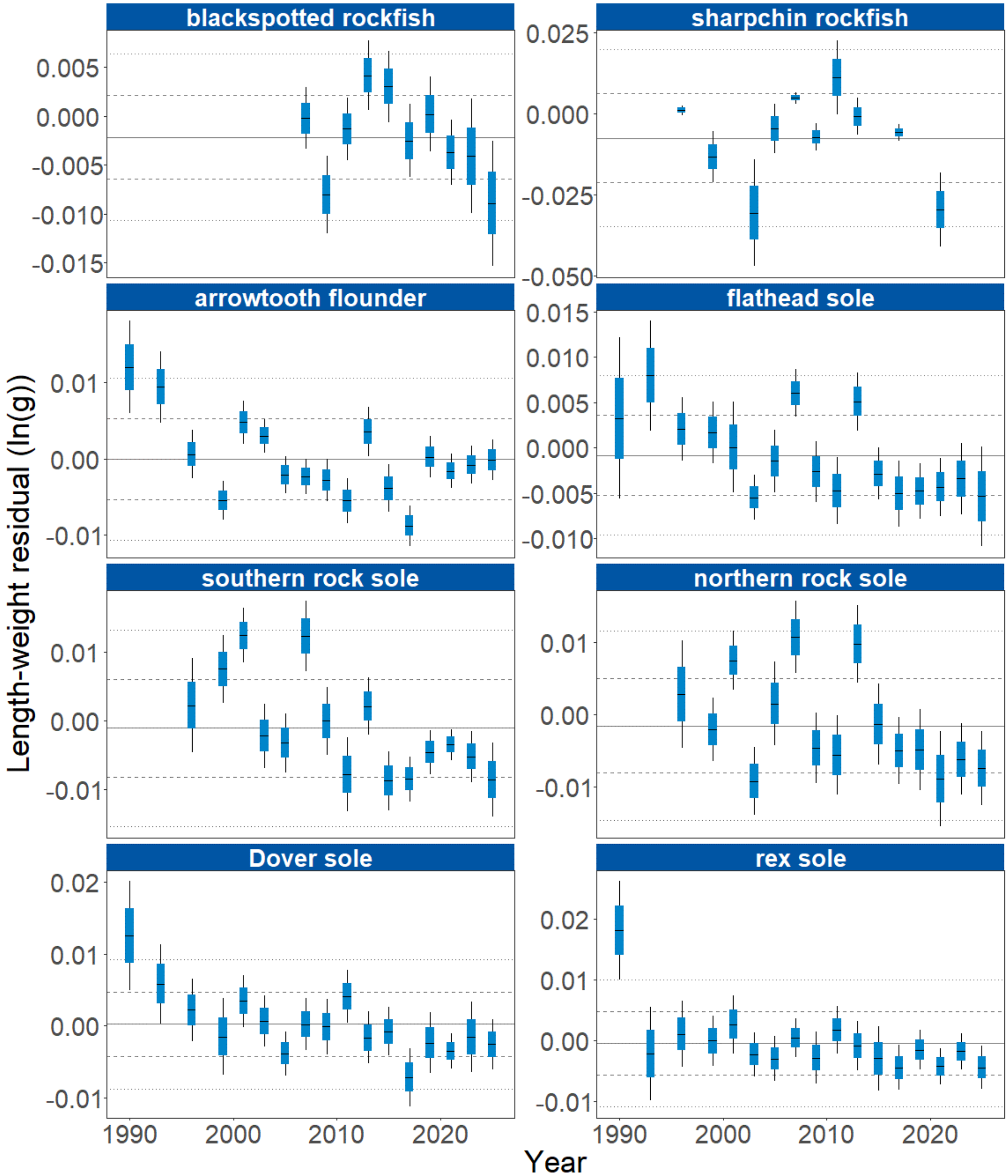

Figure 71: Biomass-weighted residual body condition index across survey years (1990 – 2025) for sixteen Gulf of Alaska groundfish species collected on the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center Resource Assessment and Conservation Engineering (AFSC/RACE) Groundfish Assessment Program (GAP) standard summer bottom trawl survey. Filled bars denote weighted length-weight residuals, error bars denote two standard errors. Horizontal lines denote the time series mean (solid) and one (dashed) and two (dotted) standard deviations from the mean.

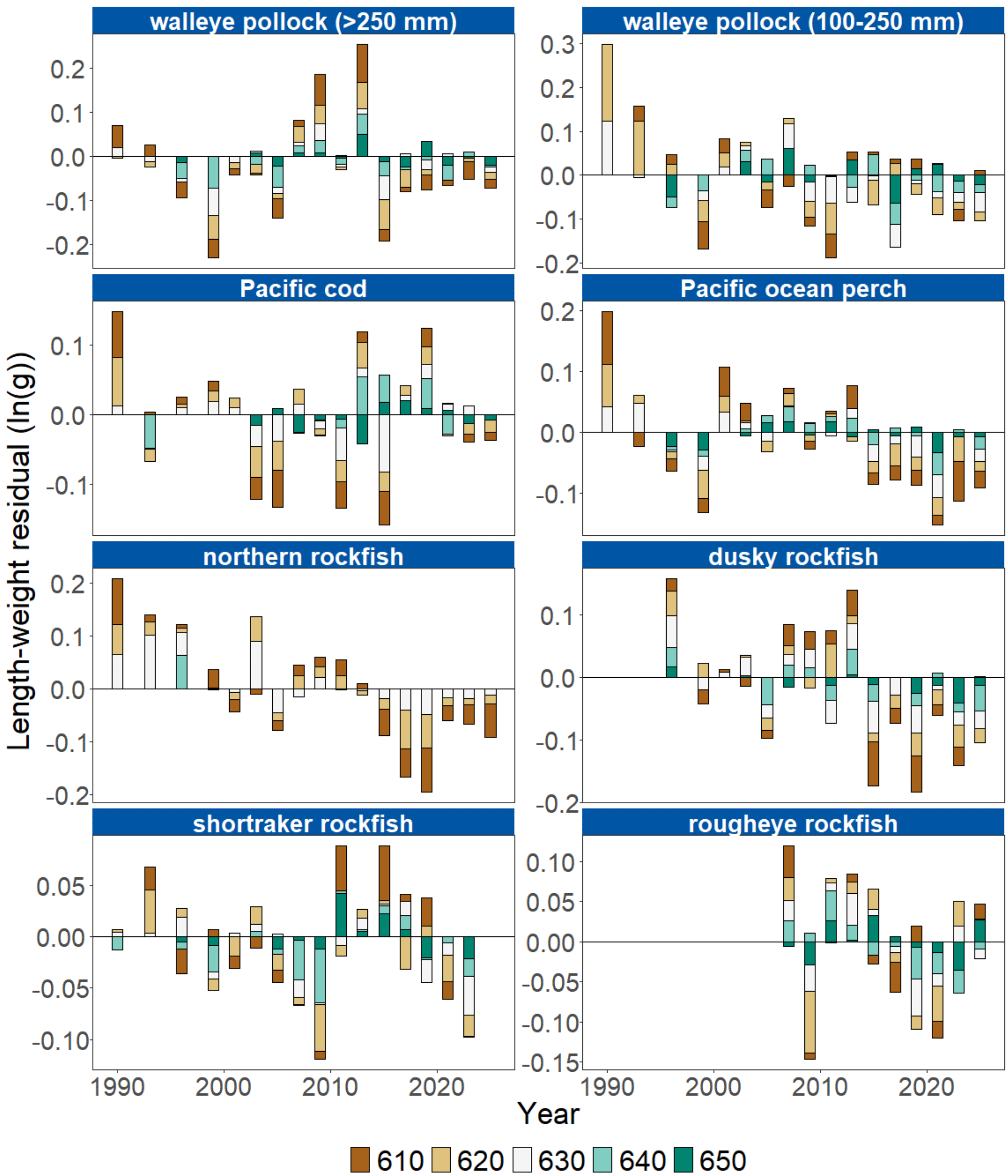

Figure 72: Residual body condition index for sixteen Gulf of Alaska groundfish species collected on the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center Resource Assessment and Conservation Engineering (AFSC/RACE) Groundfish Assessment Program (GAP) standard summer bottom trawl survey (1990 – 2025) grouped by NMFS Statistical Reporting Area.

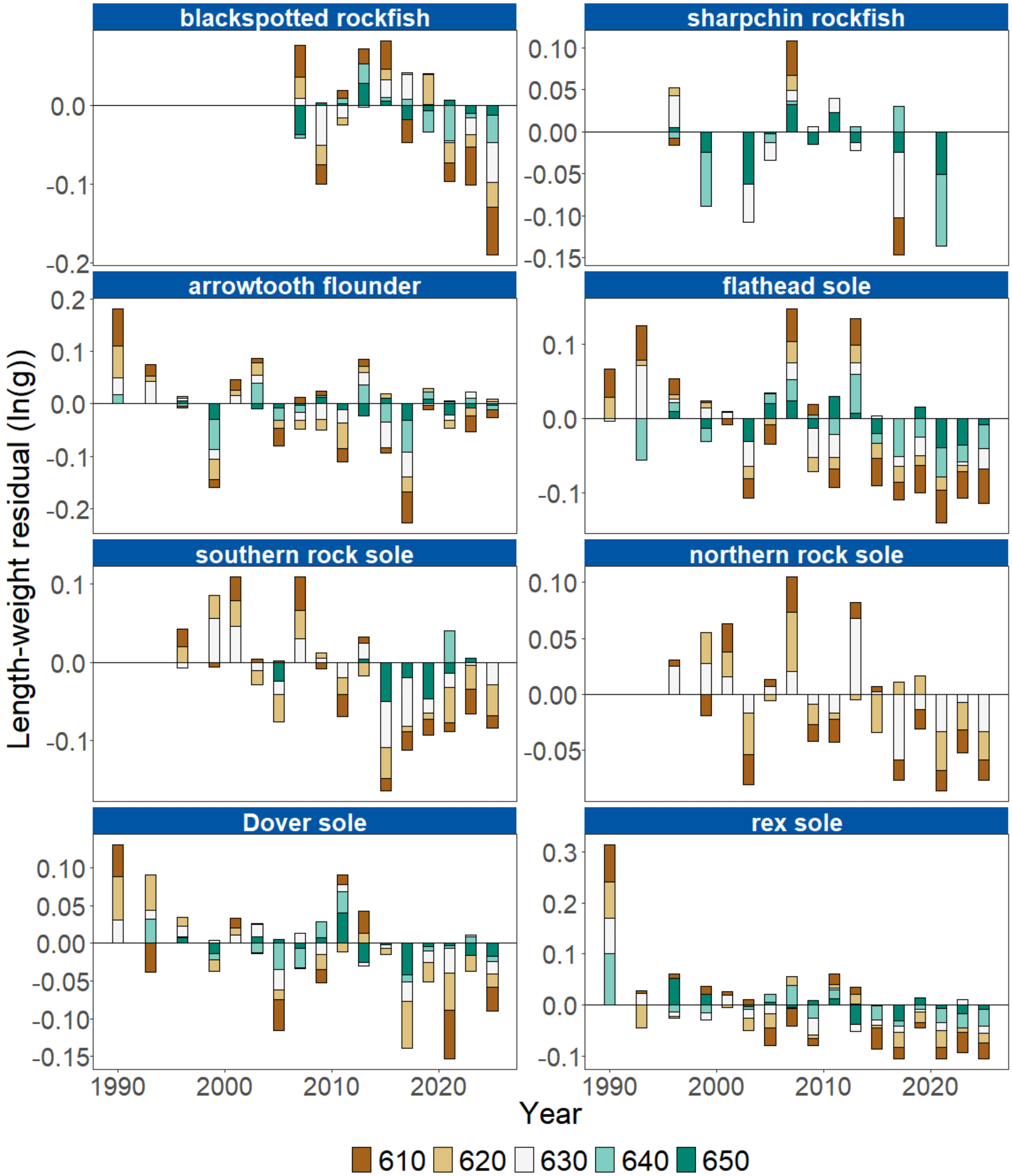

Figure 73: Residual body condition index for sixteen Gulf of Alaska groundfish species collected on the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center Resource Assessment and Conservation Engineering (AFSC/RACE) Groundfish Assessment Program (GAP) standard summer bottom trawl survey (1990 – 2025) grouped by NMFS Statistical Reporting Area.

ADF&G Gulf of Alaska Trawl Survey

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Last updated: September 2025

Description of indicator: The Alaska Department of Fish and Game conducts an annual trawl survey for crab and groundfish in Gulf of Alaska targeting areas of crab habitat around Kodiak Island, the Alaska Peninsula, and the Eastern Aleutian Islands (Spalinger and Silva, 2025). Parts of these areas have been surveyed annually since 1984, but the most consistent time series begins in 1988. The trawl survey uses a 400-mesh eastern otter trawl constructed with stretch mesh ranging from 10.2 cm in the body, decreasing to 3.2 cm in the codend. Constructed ideally to sample crab, it can also reliably sample a variety of fish species and sizes, ranging from 15 cm to adult sizes, but occasionally capturing fish as small as 7 cm for some species. While the survey covers a large portion of the central and western Gulf of Alaska, results from Kiliuda and Ugak Bays (inshore) and the immediately contiguous Barnabas Gully (offshore) are generally representative of the survey results across the region (Figure 74).

In 2025, a total of 49 stations were sampled from July 6 through July 14. The survey catches (mt/km) from Kiliuda and Ugak Bays and Barnabas Gully were summarized by year for selected species groups (Figure 75). Using a method described by Link et al. (2002), standardized anomalies, a measure of departure from the mean catch (kg) per distance towed (km), were also calculated for selected species including arrowtooth flounder *Atheresthes stomias*, flathead sole *Hippoglossoides elassodon*, Tanner crab *Chionoecetes bairdi*, Pacific cod *Gadus macrocephalus*, skates, walleye pollock *G. chalcogrammus*, and Pacific halibut *Hippoglossus stenolepis* (Figure 4). Temperature anomalies were calculated using average bottom temperatures recorded for each haul from 1990 to 2025 (no data for 2024, see western GOA summer temperatures in this Report, p.38).

Status and trends: The 2024 survey data showed an increase in overall biomass in both the inshore and offshore stations (Figure 75). Arrowtooth flounder and Tanner crab have been the predominant species in the ADF &G trawl survey catches in the last 3 years. In 2024, arrowtooth slightly increased while Tanner crab significantly decreases in both the inshore and offshore stations. Flathead sole and starfish increased in the inshore stations, while gadids and starfish showed slight increases in the offshore stations. Of the starfish group, *Pychnopodia helianthoides* (sunflower sea star) continues to be the predominant starfish species in both inshore and offshore stations. Increases in the number of small animals indicate this species may be recovering from the significant die off that started in 2014. A sharp decrease in survey overall biomass is apparent from 2007 to 2017 from the years of record high catches occurring from 2002 to 2005.

Prior to the start of our standard trawl survey in 1988, Ugak Bay was the subject of an intensive seasonal trawl survey in 1976 – 1977 (Blackburn, 1977). Today, the Ugak Bay species composition is markedly different than in 1976. Red king crabs (*Paralithodes camtschaticus*) were the main component of the catch in 1976 – 1977, but now are nearly non-existent. Flathead sole, skate, and gadid catch rates have all increased roughly 10-fold. While Pacific cod made up 88% and walleye pollock 10% of the gadid catch in 1976 – 1977, catch compositions have reversed with Pacific cod making up 14.7% of catch, down from 19.4% in 2023, and walleye pollock 85.3% in 2024. an increase from 80.6% in 2023.

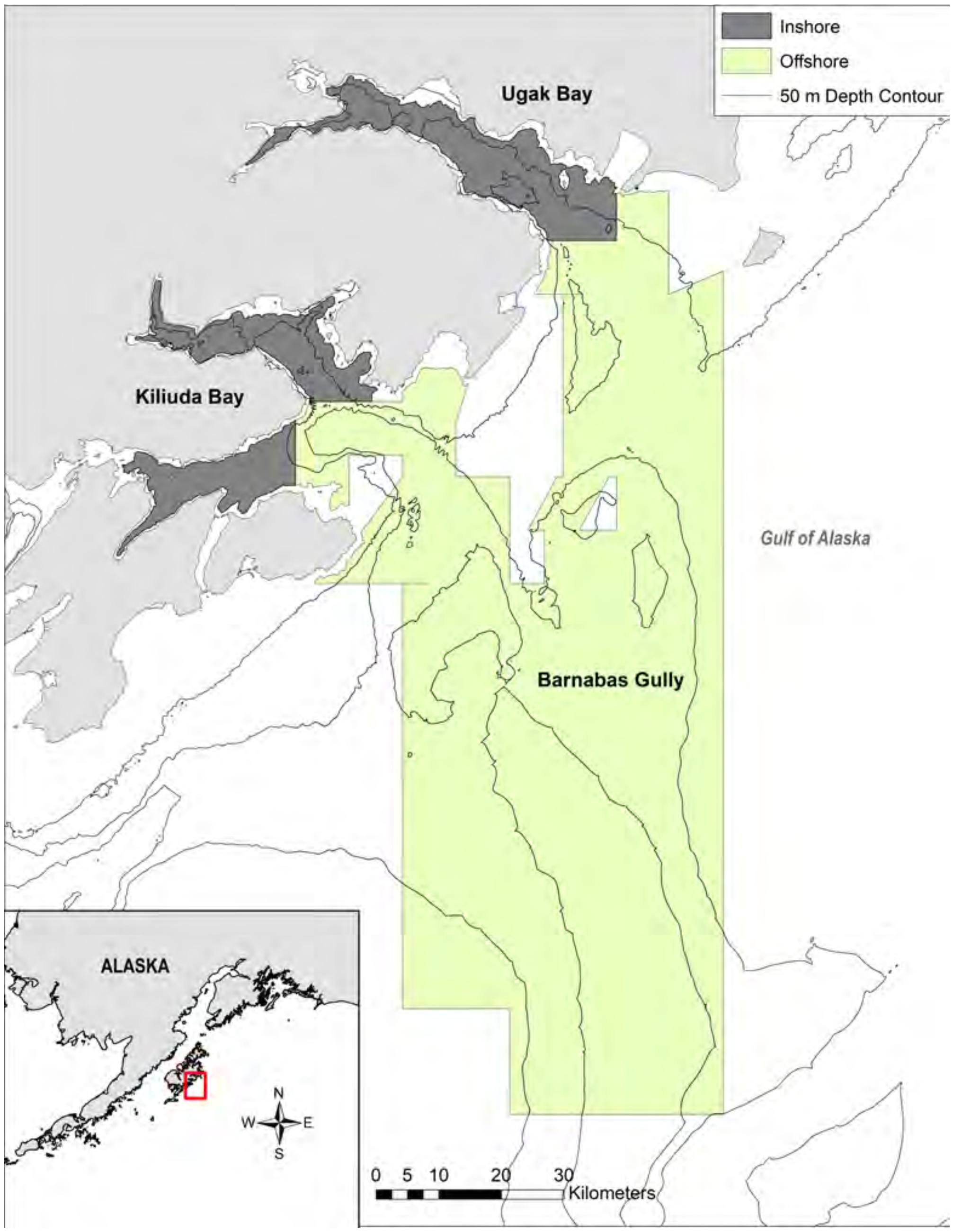


Figure 74: Kiliuda Bay, Ugak Bay, and Barnabus Gully survey areas used to characterize inshore (dark gray, 14 stations) and offshore (light gray, 36 stations) trawl survey results, Kodiak, Alaska.

The catches of flathead sole, Pacific cod, Pacific halibut, and walleye pollock continue to have below-average anomaly values (baseline 1988 – 2022) for both the inshore and offshore stations, while arrowtooth and skates were above average in both inshore and offshore stations in 2024 (Figure 76). Tanner crab dropped below average in both the inshore and the offshore stations signaling the decline of a large recruitment class first observed in 2018 (Spalinger and Silva, 2024).

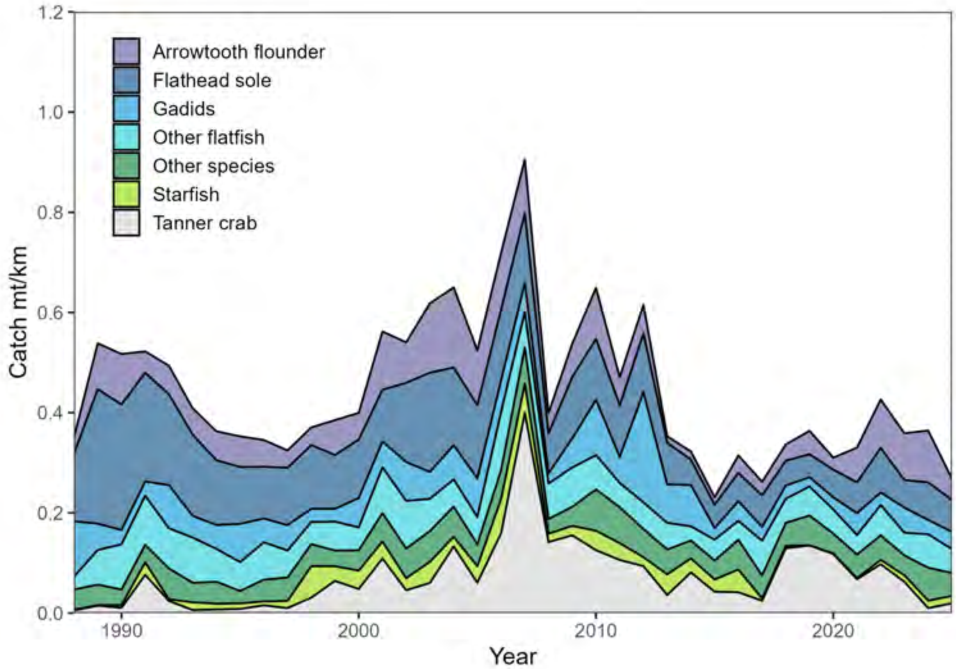
Summer temperature anomaly values for both inshore and offshore stations were below average in

2023 (no data for 2024) in contrast to the previous year (see western GOA summer temperatures in this Report, p.38). The higher-than-average temperatures in past years frequently occurred during moderate and strong El Niño years[26].

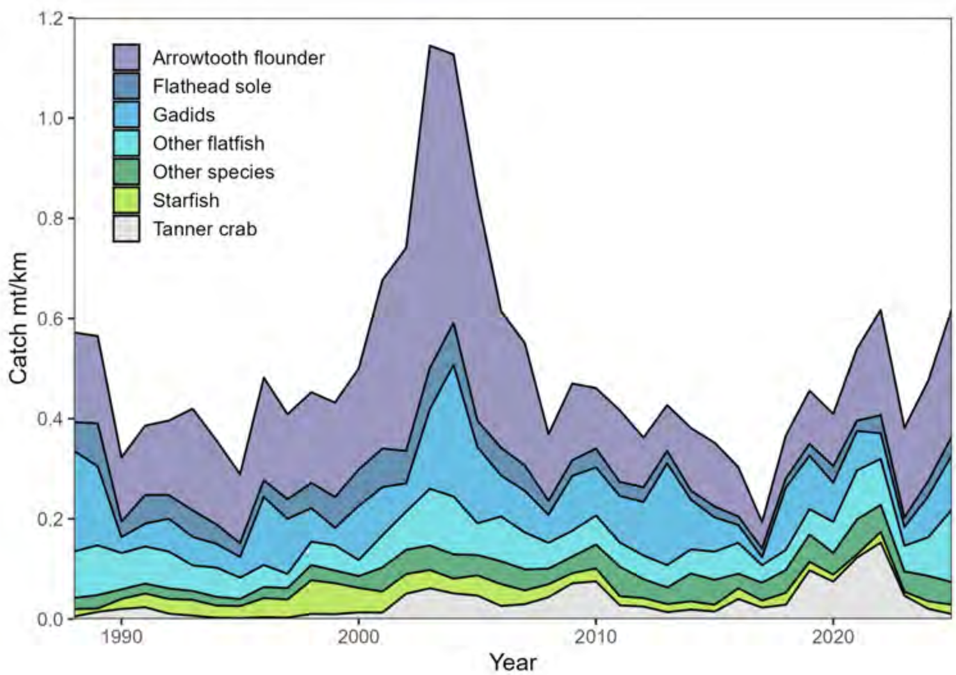
Factors influencing observed trends: It appears that significant changes in volume and composition of the catches on the east side of Kodiak are occurring, but it is unknown to what extent predation, environmental changes, and fishing effort are contributing. The lower overall catch from 1993 to 1999 (Figure 75) may reflect the greater frequency of El Niño events on overall production, while the period of less frequent El Niño events, 2000 to 2003, corresponds to years of increasing production and correspondingly higher catches. Lower than average temperatures were recorded from 2006 to 2009 along with decreasing overall abundances in 2008 and 2009. This may indicate a possible lag in response to changing environmental conditions or some other factors may be affecting abundance that are not yet apparent. Declines in Pacific cod abundance during the 2014 – 2016 period of the anomalously warm water event in the GOA were well documented (Barbeaux et al., 2020*a*; Suryan et al., 2021). Recent increases in Tanner crab abundance are likely influenced by the decrease in predation during years with lower-than-average Pacific cod, arrowtooth flounder, flathead sole, and halibut catches.

Implications: Although trends in abundance in the trawl survey appear to be influenced by major oceanographic events such as El Niño, local environmental changes, predation, movements, and fishery effects may influence species specific abundances. Monitoring these trends is an important process used in establishing harvest levels for state water fisheries. These survey data are used to establish guideline harvest levels of state managed fisheries and supply abundance estimates of the nearshore component of other groundfish species such as Pacific cod and pollock. Decreases in species abundance will most likely be reflected in decreased guideline harvest levels.

[26] `http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml`



(a) Kiliuda and Ugak Bay



(b) Barnabas Gully

Figure 75: Total catch per km towed (mt/km) of selected species from Kiliuda and Ugak Bays (a) and Barnabas Gully (b) survey areas off the east side of Kodiak Island, 1988– 2025.

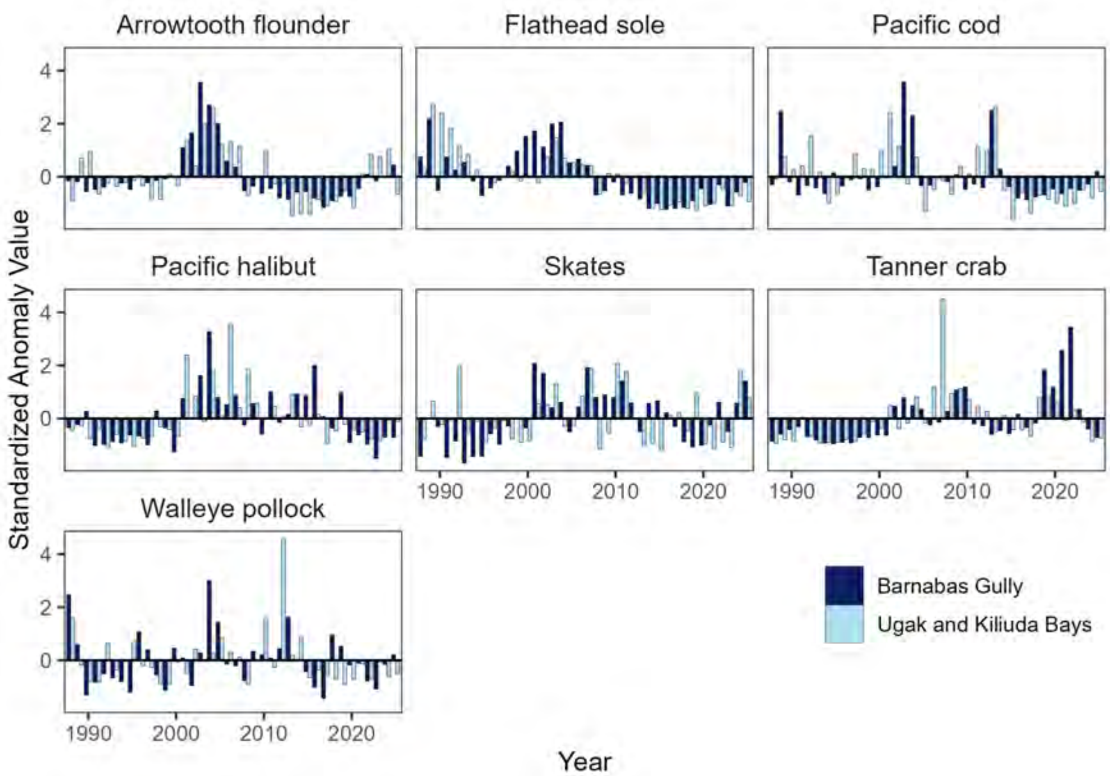


Figure 76: A comparison of standardized anomaly values based on catch (kg) per distance towed (km) for selected species caught from 1988 to 2025 in Barnabas Gully and Kiliuda and Ugak Bays during the ADF&G trawl survey, Kodiak.

Distribution of Rockfish Species along Environmental Gradients

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Last updated: September 2025

Description of indicator: This indicator characterizes the distribution of rockfish population density as the center-of-gravity along three gradients (geographical position, depth, bottom temperature) in the Gulf of Alaska (GOA) based on summer bottom trawl survey data collected from 1990 to 2025. In a previous analysis of rockfish from 14 bottom trawl surveys in the GOA and Aleutian Islands, six species or species assemblages were defined based on similarities in their distributions along geographical position, depth, and temperature gradients: Pacific ocean perch, shortraker rockfish, northern rockfish, dusky rockfish, the rougheye-blackspotted rockfish complex, and shortspine thornyhead (Rooper 2008). The 180 m and 275 m depth contours were major divisions between rockfish assemblages inhabiting the shelf, shelf break, and lower continental slope. Another noticeable division was between species centered in southeastern Alaska and those found in the northern GOA and Aleutian Islands.

In these time series, the mean-weighted distributions (also known as the center-of-gravity) of six rockfish taxa along gradients of geographical position, depth and temperature were calculated for the GOA. The indicators represent design-based mean position (presented as latitude and northings, and longitude and eastings), depth and temperature, weighted by the rockfish CPUE in units of biomass per area swept. A weighted mean for each spatial or environmental variable was computed for each survey year as:

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

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

$$SD = \sqrt{\frac{(\sum_{i=1}^{N} f_i(x_i - \bar{x}))^2}{\frac{(M-1)}{M}\sum_{i=1}^{N} f_i}},$$

where N is the total number of tows, M is the number of tows with positive catches, and $\overline{x}$ is the weighted mean CPUE. These indices can be used to monitor the distributions of major components of the rockfish fisheries along these spatial and environmental gradients to detect changes or trends in rockfish distribution.

In 2001, the Yakutat and Southeast Alaska International North Pacific Fisheries Commission (INPFC) districts were not sampled due to budgetary constraints. Thus, 2001 is excluded from the analysis. Dusky rockfish were identified with low confidence prior to 1999, and therefore all years prior were excluded in the analyses for this species. Code used to produce indicator estimates and figures is available[27].

[27] https://github.com/afsc-gap-products/goa-rockfish-cog/tree/main

Methodological Changes: The fundamental approach for calculating GOA rockfish distribution indicators has not changed in 2025; however, some aspects of the analysis and visualizations have been updated. In previous years, linear models were used to estimate trends in the weighted mean depth, temperature, and distance from Hinchenbrook Island over time. Now, these trends are reported as time series with uncertainty for visual evaluation of short- and long-term patterns, and weighted mean latitude and longitude are presented in 'sparkle plots' (bivariate scatterplots with error bars in both axis dimensions).

Status and trends: Several trends were observed with rockfishes along the three spatial and environmental gradients examined in the GOA time series through 2025 (Figures 77 and 78). The dominant trend in distribution of northern and dusky rockfishes has been a shift to the southwest, when evaluating center of gravity trends along both axes of geographic position (Figure 77). While dusky rockfish have generally shifted southwest since 1999, in 2025 the distribution had a large shift northeast. From 1990 to 2003, northern rockfish were the furthest northeast of the time series; the distribution then moved southwest, reaching its most southwest distribution in 2021. Since 2021, northern rockfish have shifted slightly northeast.

The other species displayed more stochastic variation in their position which was characterized by shorter-term shifts that later reverted to the opposite direction. Pacific ocean perch has continued to shift eastward since 2021 and had a slight northern shift in 2025. The rougheye-blackspotted rockfish complex has moved slightly south in general since 1990 with high variability along the east-west axis. In 2025, the rougheye-blackspotted rockfish complex shifted westward, compared to earlier years. Shortraker rockfish shifted northeast from 2013 to 2025, but estimates were highly variable and uncertain. Shortspine thornyhead have shifted southwest since 1993 and have remained consistent in their position.

The mean-weighted depth distributions of Pacific ocean perch, northern rockfish, and shortraker rockfish have gradually become shallower throughout the time series (Figure 78). The shortspine thornyhead distribution deepened from 1990 to 2009 and has since trended shallower with high variability. The rougheye/blackspotted rockfish complex remained relatively constant in their depth distribution over the time series with the exception of moving deeper in 2015 to 2017.

Deeper-dwelling taxa (shortspine thornyhead, shortraker rockfish, and rougheye/blackspotted rockfishes) exhibited less variation in temperature distribution than shallower species (Figure 78). Northern and dusky rockfish were distributed at their highest temperatures in 2003 and lowest in 2007. All species have trended toward occupying warmer temperatures since 2007. Pacific ocean perch, dusky rockfish, and northern rockfish had the largest shift in the mean-weighted temperature distributions from 2023 to 2025 with increases of 0.4 to 1.6°C.

Factors causing observed trends: In the GOA, most rockfish spatial distributions appear to be relatively consistent although there is evidence the distribution of the two shallowest species (northern and dusky rockfishes) may have shifted southwest over the time series. Factors that may influence these trends in rockfish distribution include variability in the survey catch due to the distribution of rockfish species, changing oceanographic conditions (Li et al., 2019; Yang et al., 2019), and shifts in either age composition or productivity of these species. Movement is generally more limited for rockfish than other fishes (Love et al. 2002), but can influence distribution at finer scales. Rockfishes tend to have patchy distributions and for some species estimates of abundance can be driven by a few large catches (Williams et al., 2024). In these cases, the estimate of the center of gravity will shift towards the location and environmental conditions in which these catches occurred. This may explain some of the variability in distribution we see in the center of gravity estimates.

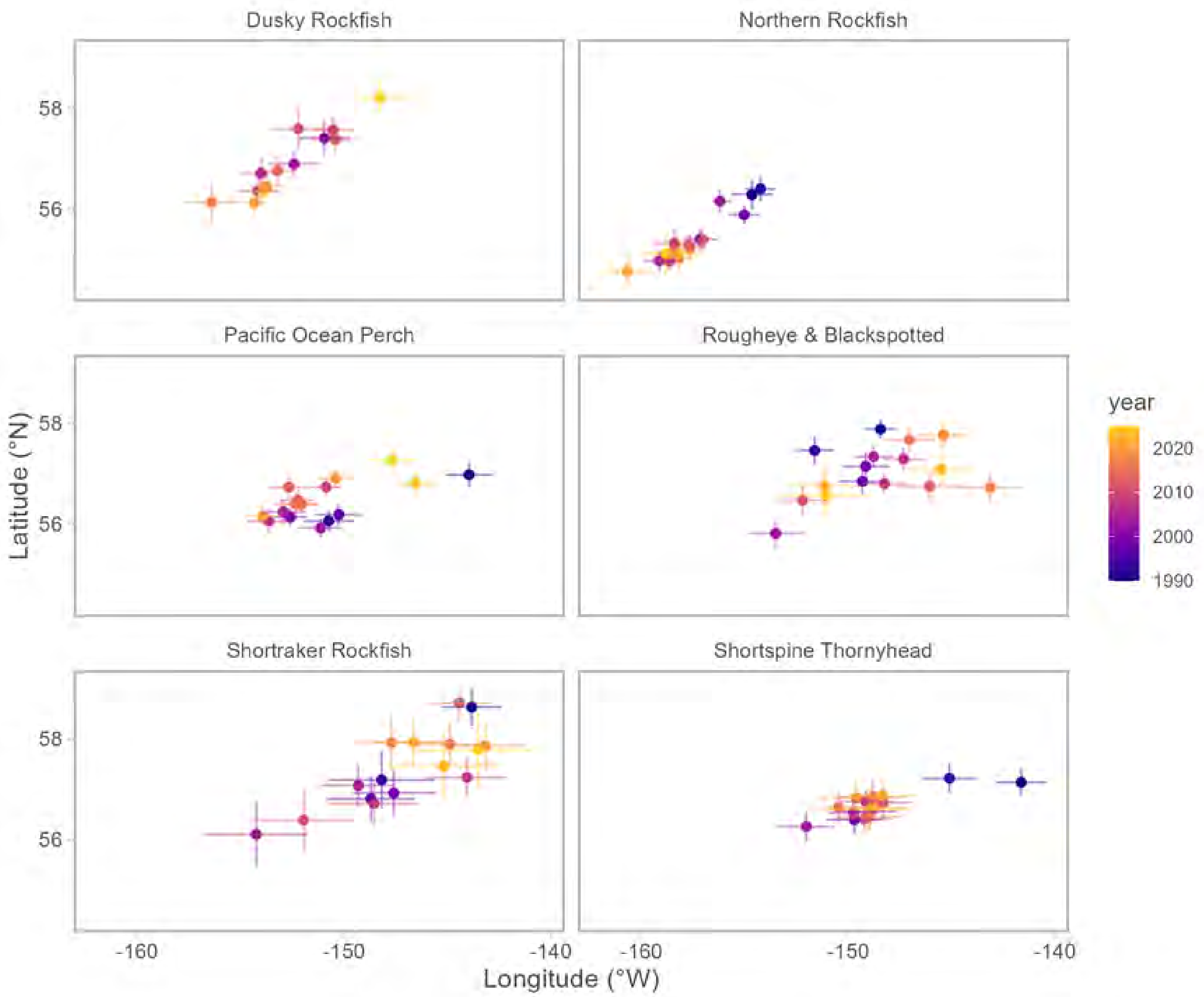

Figure 77: Weighted mean distribution (center-of-gravity) of rockfish taxa in the Gulf of Alaska, with respect to spatial variables from 1990 to 2025. Points represent the mean and lines represent one standard deviation from the mean latitude and longitude.

Changing oceanographic conditions in the GOA have been documented with marine heatwaves observed in 2013 – 2016 and 2018 – 2020 (Bond et al., 2015; Hauri et al., 2024). The increase in the number of extreme events has compounding environmental effects that include increased temperature, acidity, and changes in carbonate chemistry (Hauri et al., 2024). One possible driver of distribution shifts is changes in oceanography, particularly increasing temperature. While temperatures at greater depths along the slope tend to remain more constant than along the shelf, significant warming was observed during the mid-late 2010s. Bottom temperatures estimated from bottom trawl survey data in 2025 were generally warmer throughout the GOA with the most widespread warm anomalies observed in the western GOA. The general pattern of shallow near-shore areas being warmer and having more variation than continental slope areas at deeper depths continued in 2025 (Rohan in this Report, p.46). Given the broad range of depths occupied by the species and assemblages examined here, the extent of change experienced is likely different for each taxa.

The depth distributions for these species and assemblages have shifted slightly throughout the time series.

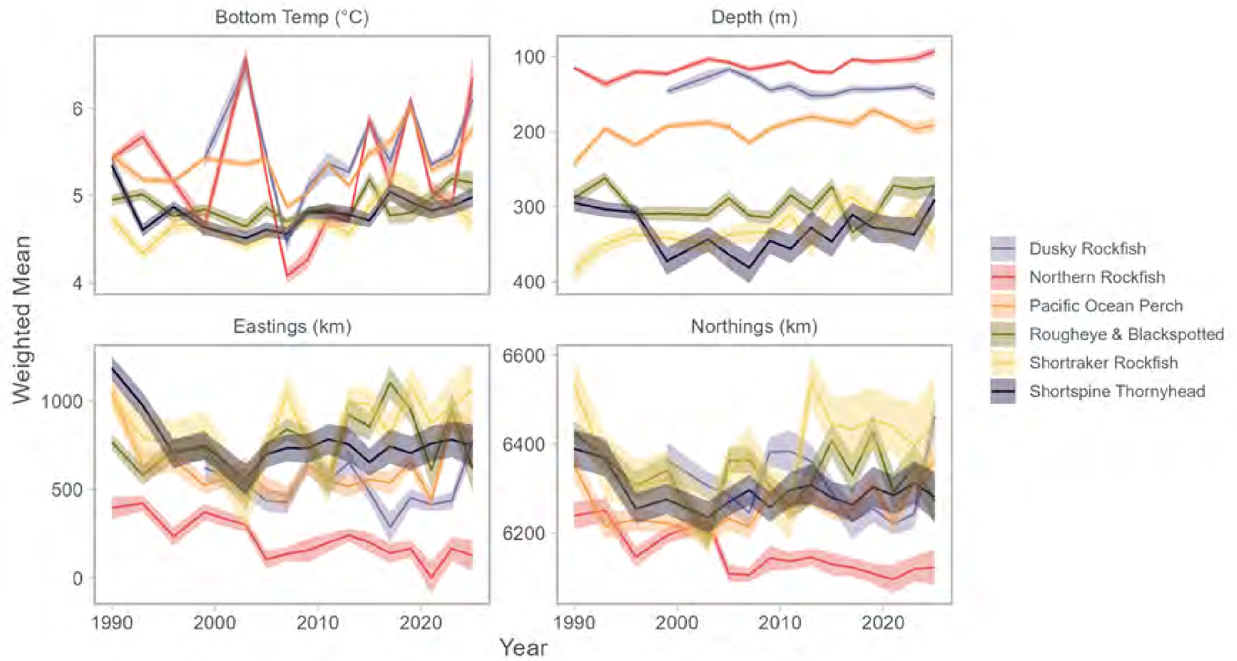

Figure 78: Time series of weighted mean distribution (center-of-gravity) of rockfish taxa in the Gulf of Alaska with respect to spatial and environmental variables from 1990 to 2025.

It is generally hypothesized that with warming temperature conditions there would be a shift to deeper habitats as species seek thermal refugia (Li et al., 2019; Yang et al., 2019), but the observed change has been toward shallower depths over time. Rockfishes tend to have limited movement, high generation times, long lifespans and affinity for fixed physical bottom structure (Love et al. 2002, Rooper et al. 2019), characteristics that may result in slow or limited responses to temperature changes. Interestingly, the shallower species began experiencing warmer temperatures much earlier than the 2014 – 2016 marine heat wave.

The geographic shifts and more subtle changes in depth distribution could also be explained by changing productivity or density dependence. Productivity may change over space to cause these patterns directly, or indirectly through expansion or contraction into marginal habitats. For example, Pacific ocean perch populations have increased over the time series until 2025 (Kapur et al., 2023) which may have led to them occupying a wider geographic or depth range. Finally, age composition can influence distribution in species that have ontogenetic habitat shifts (for rockfish species described here, typically in the form of occupying deeper depths at older ages).

Implications: The trends in the mean-weighted distributions of rockfishes should continue to be monitored, with special attention to mechanisms that could explain the shifting geographic distributions, fluctuating population sizes, and changing productivity of these commercially important species. Reproductive success and the rate of skipped spawning in some of these rockfish species has been shown to be variable between years and this variability may be related to changing oceanographic conditions (Conrath et al., 2019; Conrath and Hulson, 2021). The 2014 – 2016 marine heat wave affected the reproductive success of other GOA groundfish (Rogers et al., 2021) and likewise these oceanographic changes may have influenced rockfish productivity through shifts in recruitment and growth. Changes in the geographic distribution of species may influence their availability to some fishing ports more than others, so larger distribution shifts should be noted when evaluating the influence of environmental changes on local communities. Given the complex geography and bathymetry of the GOA and ecological differences among rockfish species, it is unlikely that there will be shifts that are consistent across all species, thus socioeconomic considerations in management may need to be species- or assemblage-specific.

Trends in Groundfish Biomass

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Last updated: October 2025

Description of indicator: Examining trends in survey-estimated biomass multiple groundfish species in the Gulf of Alaska can identify broadscale changes in the marine ecosystem. Common trends across species within similar functional groups can indicate shared responses to environmental conditions, including changes in physical habitat suitability (e.g., temperature, dissolved oxygen) and prey availability. In addition, identifying trends in biomass within the groundfish community can inform food web dynamics with respect to predation pressure and energy flow.

The data are collected from the NOAA AFSC Gulf of Alaska bottom trawl survey (Siple et al., 2024). The survey has been conducted using the same randomized stratified design and season (late May to early August) every three years from 1990 – 1999 and then alternating years (odd years) to 2023. Annual design-based estimates of population biomass estimates are provided by the AFSC groundfish assessment program[28] accessed from the AKFIN database[29]. Species selected for this contribution are listed below, and include those supporting federally managed commercial groundfish fisheries, in addition to Pacific halibut (*Hippoglossus stenolepis*). In some years species-specific estimates were not available due to low confidence in ability to consistently identify that species during earlier years.

1. Flatfish: arrowtooth flounder (*Atheresthes stomias*), Pacific halibut (*Hippoglossus stenolepis*), northern rock sole (*Lepidopsetta polyxystra*), southern rock sole (*Lepidopsetta bilineata*), Dover sole (*Microstomus pacificus*), rex sole (*Glyptocephalus zachirus*), and flathead sole (*Hippoglossoides elassodon*).
2. Rockfish: Pacific ocean perch (*Sebastes alutus*), northern rockfish (*Sebastes polyspinis*), dark rockfish (*Sebastes ciliates*), dusky rockfish (*Sebastes variabilis*), rougheye rockfish (*Sebastes aleutianus*), blackspotted rockfish (*Sebastes melanostictus*), shortraker rockfish (*Sebastes borealis*), shortspine rockfish (*Sebastolobus alascanus*), and yelloweye rockfish (*Sebastes ruberrimus*).
3. Roundfish: walleye pollock (*Gadus chalcogrammus*), Pacific cod (*Gadus macrocephalus*), sablefish (*Anoplopoma fimbria*).
4. Skates: big skate (*Beringraja binoculata*) and longnose skate (*Beringraja rhina*).

Status and trends: The groundfish species with the highest biomass (mt) in the Gulf of Alaska bottom trawl survey in 2025 were (in descending order) arrowtooth flounder, walleye pollock, Pacific

[28]Design-Based Production Estimates generated by the gapindex R package (NOAA Fisheries Alaska Fisheries Science Center, Groundfish Assessment Program, 2024)
[29]`https://github.com/MattCallahan-NOAA/gapproductssynopsis/tree/main/ESR`

ocean perch, Pacific cod, Pacific halibut, flathead sole, and sablefish (Figure 79). Arrowtooth flounder returned to the top biomass in 2025, for the first time since 2017. Pacific ocean perch declined from highest biomass to third highest in 2025.

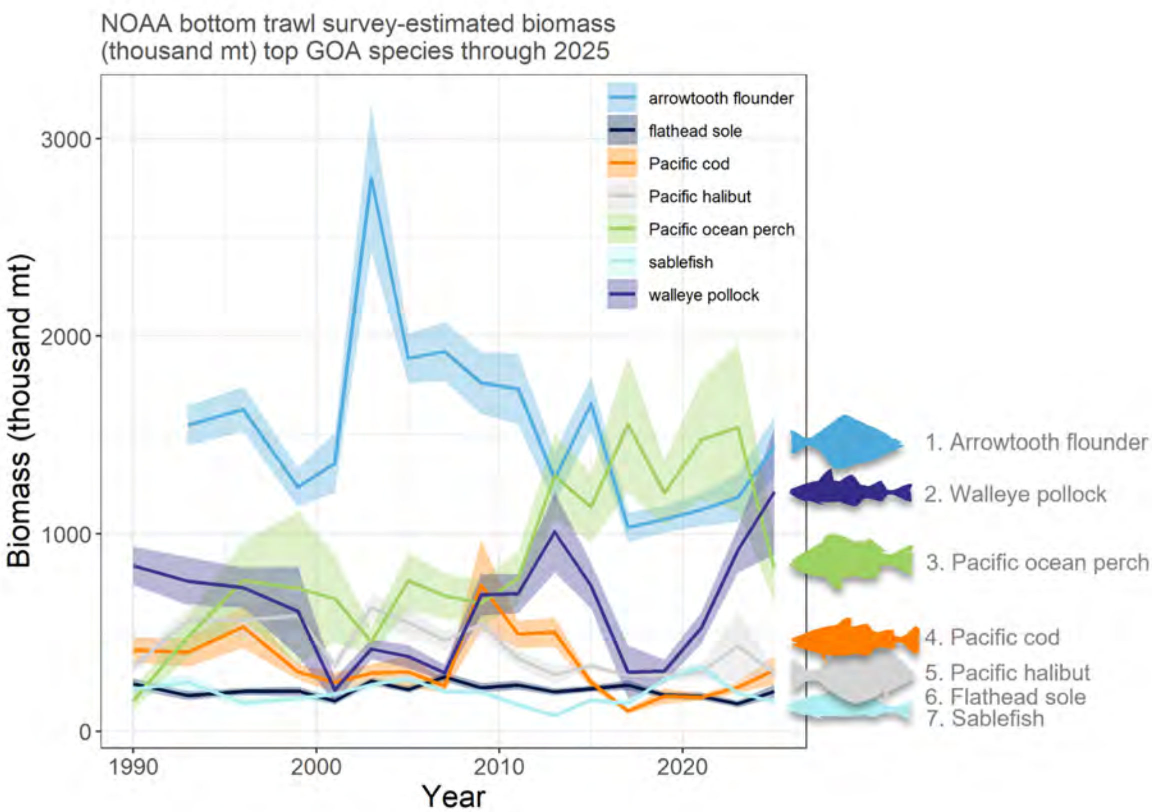

Figure 79: Design-based estimates of survey biomass (mt) of groundfish species with the highest biomass in the Gulf of Alaska bottom trawl survey in 2025. Shaded area representes $\pm$ 1 standard deviation (not shown for groups $>$ 1 stocks). The NOAA AFSC bottom trawl survey is conducted from May-August every three years from 1990 – 1999 and every 2 years 2001 – 2025

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Factors influencing observed trends: The biomass estimates of groundfish species in the NOAA AFSC Gulf of Alaska bottom trawl survey reflect changes in population size but can be influenced by changes in catchability. Specifically, spatial availability to the survey may be changing due to changes in species distributions. The roundfish species show a mixture of responses to the 2014 – 2016 marine heatwave, including a biomass decline (P. cod, walleye pollock) and biomass increase (sablefish, adults of which generally reside deeper than surveyed habitat). The biomass of some species respond more rapidly to large recruitment classes or environmental changes (e.g., walleye pollock) while other more long-lived species are typically less variable on the short-term (e.g., rockfish). Some under-exploited species experiencing long-term declining biomass (e.g., Dover sole) indicate potential environmental drivers causing changes in population size or distribution (and thus availability to the survey). The recent decline in sablefish could be due to the large year classes after 2016 maturing and moving off the shelf (and survey area) to deeper slope habitat. The short-term variable survey biomass of rockfish (long-lived species) may be due to changes in catchability or distribution.

Implications: The increase in arrowtooth flounder and decrease in Pacific ocean perch, as two of the more abundant species in the bottom trawl catch, can indicate ecological implications for the GOA marine food web. Arrowtooth flounder are piscivorous and predominantly prey on juvenile walleye pollock, other fishes, euphausiids and shrimps. Pacific ocean perch are planktivorous, predominantly feeding on copepods and euphausiids. Common trends across species with similar functional groups can indicate responses to environmental conditions including physical conditions (temperature, dissolved oxygen) and prey availability.

Environmental Conditions Experienced by Groundfish

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Last updated: October 2025

Description of indicator: Ocean conditions can influence fish survival, distribution, growth, and productivity of groundfish. Some fish are able to change depth or horizontal distribution in response to changing conditions, while others are more restricted in their ability to move (Pinsky2020). Identifying ocean temperatures experienced by fish species can indicate potential impacts on their population.

The fish biomass, fish location, and bottom temperature data are collected from the biannual NOAA AFSC bottom trawl survey in the Gulf of Alaska (Pinsky et al., 2020). The survey has been conducted using the same randomized stratified design, May-August, from 1990-1999 (every three years) and then alternating years (odd years) through 2023. The haul-specific bottom temperature, location, and species' biomass are analyzed using the spatio-temporal modelling package tinyVAST (Thorson et al., 2024). We specifically fit a spatial index standardization model (sensu Thorson, 2019 using a log-linked Tweedie distribution, an annual varying intercept, a spatial Gaussian Markov random field (GMRF), and a spatio-temporal GMRF independently for each year. We then calculate the average temperature utilization by calculating the area-expanded average temperature, weighted at each location by the predicted density for a given species. This metric is analogous to the center-of-gravity used previously as a spatial indicator for distribution shifts, except it calculates distribution with respect to a covariate that varies over time (i.e., temperature instead of geographic coordinates). It therefore integrates both changes in temperature across the landscape, as well as species distribution shifts among years.

Species selected for this contribution are listed below and include those supporting federally managed commercial groundfish fisheries, those that are relatively well-sampled by the survey.

1. Flatfish: Alaska plaice (*Pleuronectes quadrituberculatus*), arrowtoowth flounder (*Atheresthes stomias*), Pacific halibut (*Hippoglossus stenolepis*), northern rock sole (*Lepidopsetta polyxystra*), southern rock sole (*Lepidopsetta bilineata*), Dover sole (*Microstomus pacificus*), rex sole (*Glyptocephalus zachirus*), and flathead sole (*Hippoglossoides elassodon*), and Pacific halibut (*Hippoglossus stenolepis*).

2. Pelagic rockfish: Pacific ocean perch (*Sebastes alutus*) and dusky rockfish (*Sebastes variabilis*),

3. Shelf rockfish: northern rockfish (*Sebastes polyspinis*), yelloweye rockfish (*Sebastes ruberrimus*), and sharpchin rockfish (*Sebastes zacentrus*)

4. Slope rockfish: blackspotted rockfish (*Sebastes melanostictus*), shortspine rockfish (*Sebastolobus alascanus*) and rougheye rockfish (*Sebastes aleutianus*), and shortraker rockfish (*Sebastes borealis*)

5. Roundfish: walleye pollock (*Gadus chalcogrammus*), Pacific cod (*Gadus macrocephalus*), and sablefish (*Anoplopoma fimbria*)

6. Skates: big skate (*Beringraja binoculata*) and longnose skate (*Beringraja rhina*).

Status and trends: All reported species increased in their average experienced temperature in the summer of 2025, most warmer than 2023 and 2021 surveys (Figures 80, 81, 82, and 83). The deeper species (slope rockfish and potentially older sablefish) experienced warmer tehmperatures than 2023 indicating warm ocean temperatures extended from the surface down to the upper slope. The species that eperienced the largest increases (¿1 °C) from the previous survey in 2023 include AK plaice (7.1 °C, SE 0.36), big skate (7.6 °C, SE 0.14) and northern rock sole (6.7 °C, SE 0.22).

The species that experienced moderate increases (0.5 to 1 °C) include P. cod (6.5°), walleye pollock (6.1 °), arrowtooth flounder (6.2 °), flathead sole (6.7 °), P. halibut (6.8 °), rex sole (5.9 °), southern rock sole (6.6 °), dusky rockfish (5.7 °), northern rockfish (5.7 °), yelloweye rockfish (5.9 °), and yellowfin sole (6.8 °).

Species that experienced ¡0.5 ° change include sablefish (4.9 °), AK skate (6 °), blackspotted rockfish (4.6 °), rougheye rockfish (5.8 °), P. ocean perch (5.3 °), sharpchin rockfish (5.8 °), shortraker rockfish (4.8 °), and shortspine thornyhead rockfish (4.9 °).

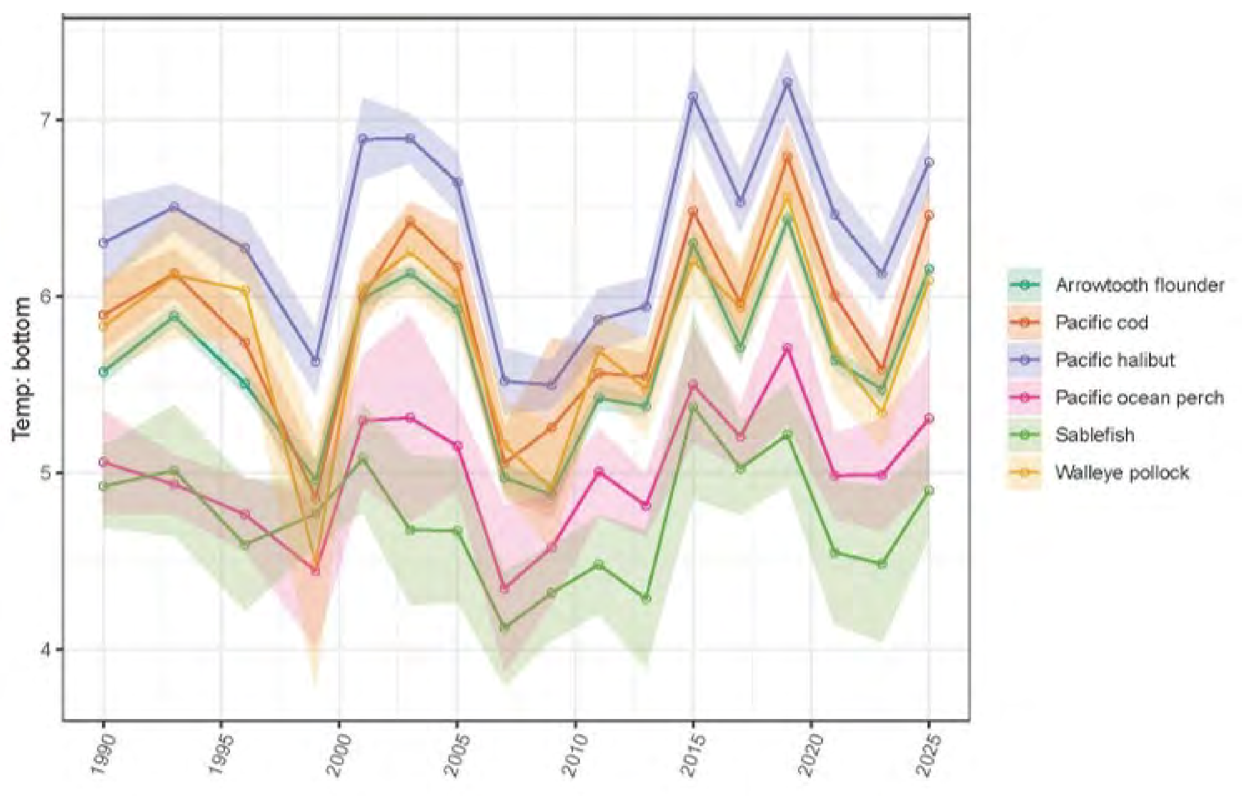
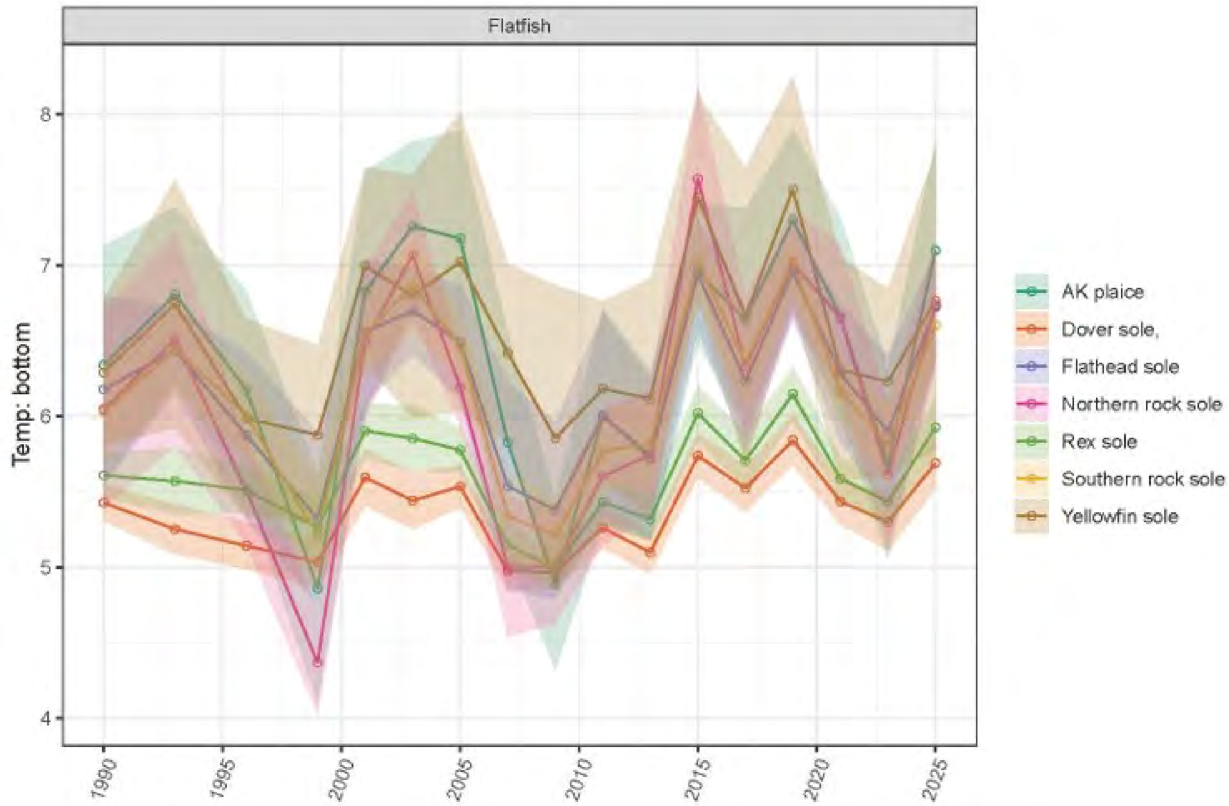


Figure 80: Time series of the mean temperatures experienced by key groundfish in the Gulf of Alaska. Figures are produced by combining AFSC bottom trawl survey catch data with bottom temperature obtained from the NOAA Fisheries bottom trawl survey.

Factors influencing observed trends: Gulf of Alaska ocean temperatures in 2025 were warm at the surface and at depth, due to a combination of strong gyre circulation and upwelling of warm water at depth, and strong downwelling along the coast. The warm waters persisted at the surface and at depth across the shelf for most of the year, with some 'average' surface temperatures in late spring/early summer. The temperatures experienced by these groundfish species reflect a warming habitat from the last survey in 2023 with little refuge.

Ocean temperatures at depth on the Gulf of Alaska shelf can be influenced by mixing from the surface (particularly in the stormier and less stratified winter), coastal downwelling that transfers warmer surface waters to depth, and deep water intrusion that brings cooler water from the continental slope onto the shelf bottom. El Niño events (e.g., winters of 2023/2024, 2016) are associated with warmer surface waters while La Niña events (e.g., 2020 – 2023) are associated with cooler surface waters. The 2014 – 2016 marine heatwave persisted long enough that the warm surface water mixed to the shelf bottom. Over the longer-term, the Gulf of Alaska ocean temperatures are warming (see Thoman, p.32). Deeper dwelling species, such as slope rockfish and Dover sole, experience more stable ocean temperatures, but could have less ability to move away from stressful conditions due to being close to other environmental thresholds, such as low dissolved oxygen.

Implications: Knowing the temperatures experienced by commercially important fish species can identify time periods in which fish exceed optimal thermal windows for survival. It can also give insight into implications for fish growth in the summer months. These data provide insight into their ability to adapt to challenging conditions, such as moving to cooler areas in warmer years.



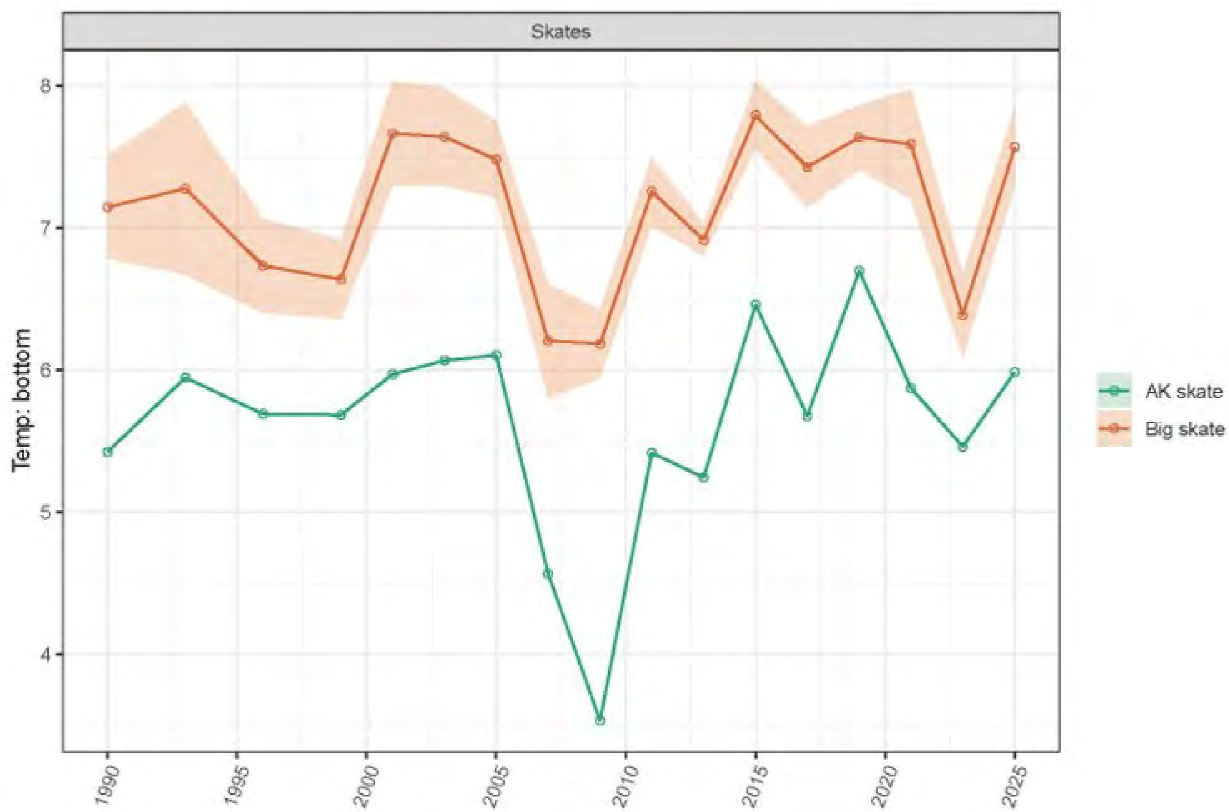


Figure 81: Time series of the mean temperatures experienced by flatfish species in the Gulf of Alaska. Figures are produced by combining AFSC bottom trawl survey catch data with bottom temperature obtained from the NOAA Fisheries bottom trawl survey.

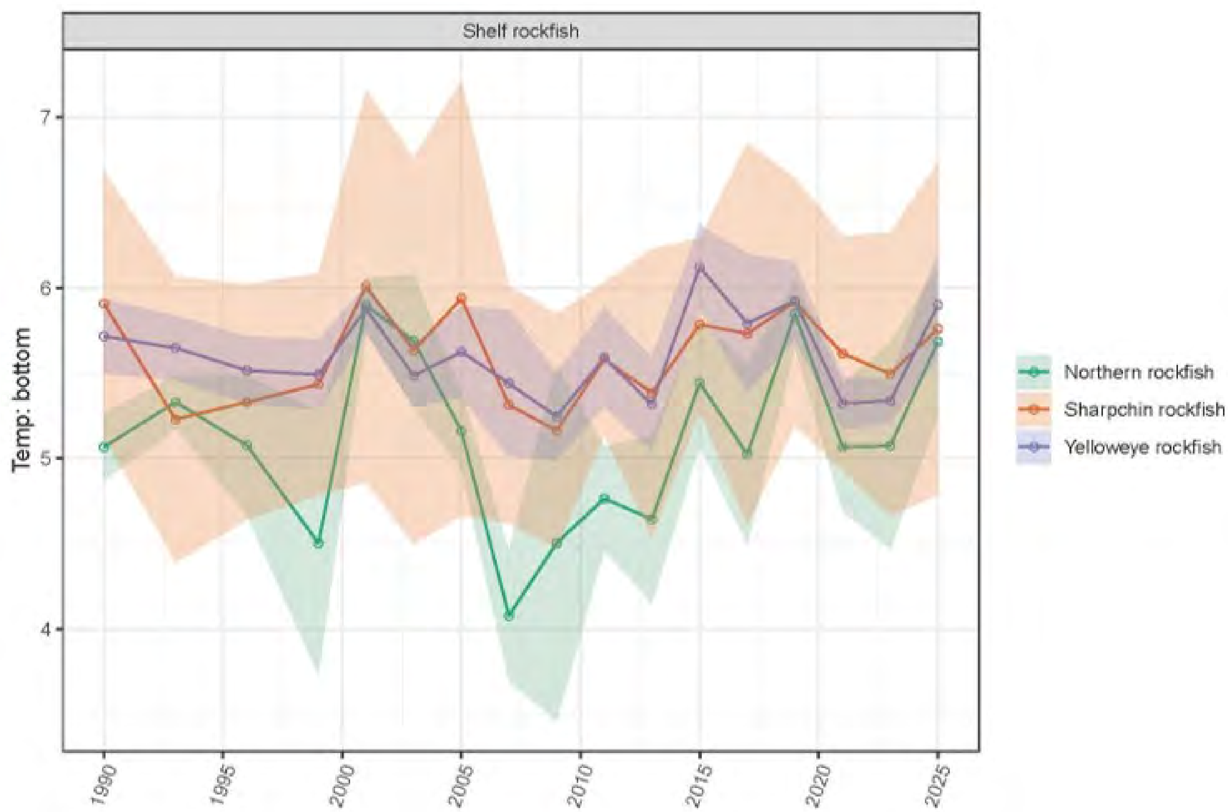


Figure 82: Time series of the mean temperatures experienced by shelf rockfish species in the Gulf of Alaska. Figures are produced by combining AFSC bottom trawl survey catch data with bottom temperature obtained from the NOAA Fisheries bottom trawl survey.

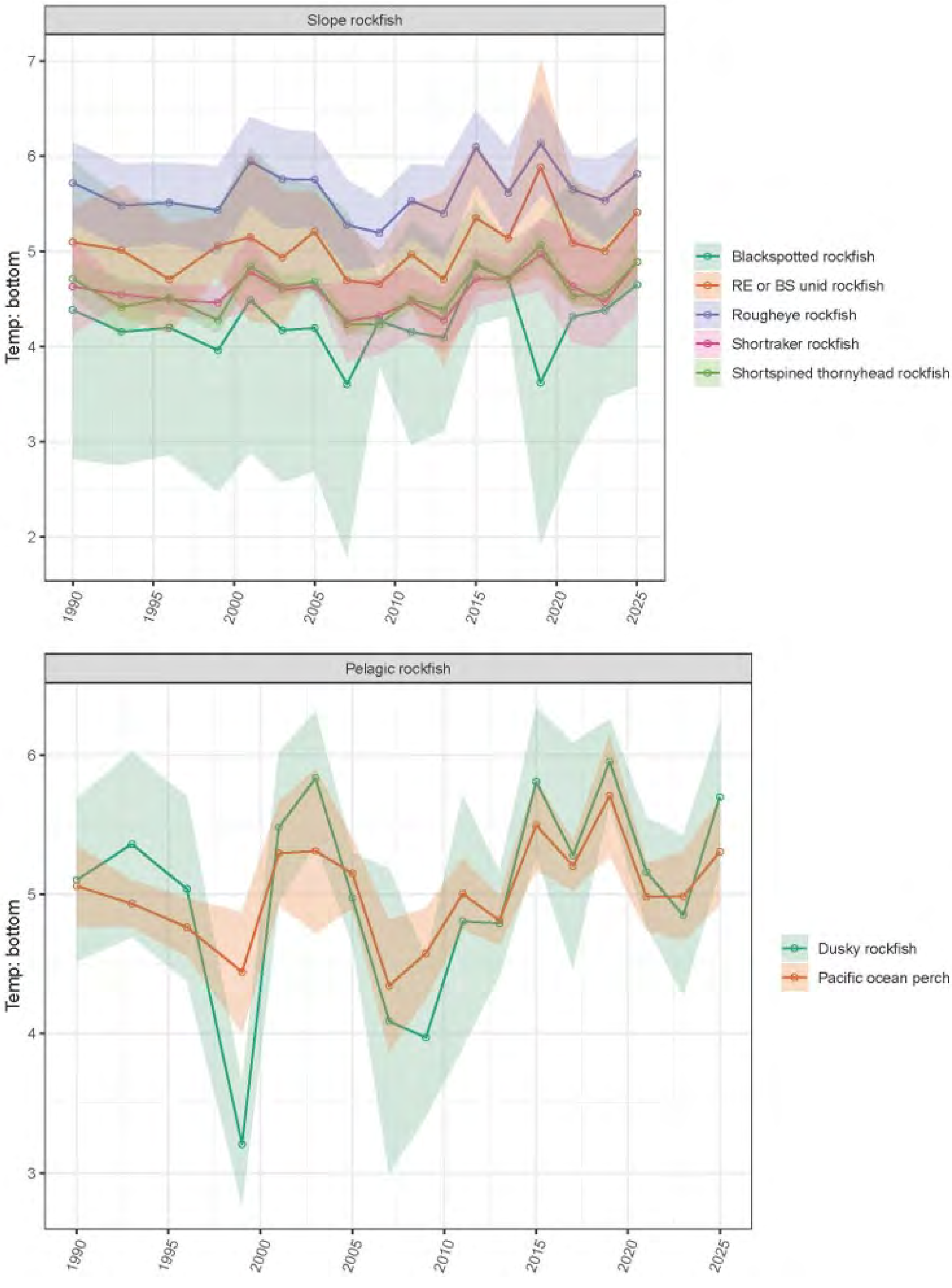


Figure 83: Time series of the mean temperatures experienced by slope and pelagic species in the Gulf of Alaska. Figures are produced by combining AFSC bottom trawl survey catch data with bottom temperature obtained from the NOAA Fisheries bottom trawl survey.

Benthic Communities and Non-target Fish Species

Miscellaneous Species — NOAA Bottom Trawl Survey

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Last updated: September 2025

Description of indicator: Benthic species are widely recognized as reliable ecosystem indicators because of their sensitivity to environmental fluctuations (Tampo et al., 2021) and their central role in marine food webs (Griffiths et al., 2017)). Accordingly, shifts in their abundance are often interpreted as signals of broader changes in environmental conditions and ecosystem functioning (Godson et al., 2022; Salas et al., 2006). The benthic fauna presented here are categorized into four taxonomic groups: eelpouts (family Zoarcidae), poachers (family Agonidae), shrimps (infraorder Caridea), and sea stars (class Asteroidea). Within eelpouts, biomass is dominated by the shortfin eelpout (*Lycodes brevipes*) and the wattled eelpout (*L. palearis*), with the Bering eelpout (*L. beringi*) contributing to a lesser extent. The biomass of poachers is primarily composed of sturgeon poachers (*Podothecus accipenserinus*), with sawback poachers (*Sarritor frenatus*) and blackfin poachers (*Bathyagonus nigripinnis*) constituting a smaller proportion. The biomass of shrimps is largely Alaskan pink shrimp (*Pandalus eous*) and sidestripe shrimp (*Pandalus dispar*), whereas the biomass of sea stars are primarily comprised of mud stars (*Ctenodiscus crispatus*) and the common rose star (*Crossaster papposus*). Considered alongside commercially targeted and formally assessed species, these taxa provide valuable ecological context for interpreting the overall status of the Gulf of Alaska (GOA) ecosystem. Since 1990, the biennial RACE Groundfish Assessment Program's fishery-independent summer bottom trawl survey in the Gulf of Alaska has deployed standardized trawl gear (footrope and trawl net) across the survey region. As a result, biomass indices from the survey are expected to capture real changes in the abundance of species and life history stages available to the gear, particularly when trends persist over time.

Regional and subarea (NMFS statistical areas 610, 620, 630, 640, 650) indices of abundance (biomass in kilotons) and confidence intervals were estimated for each taxonomic group by fitting a multivariate random effects model (REM) to subarea design-based index of abundance time series that were calculated from RACE Groundfish Assessment Program (GAP) summer bottom trawl survey catch and effort data. Indices were calculated for the entire standardized survey time series (1990 to 2025). Design-based indices of abundance were produced using the *gapindex* R package (Oyafuso, 2025) and REM were fitted to the time series using the *rema* R package (Sullivan and Balstad, 2022). Code and data used to produce these indicators are provided in the *esrindex* R package and repository (Rohan, 2025).

Methodological Changes: Methods for calculating this indicator have been updated for this year, as described in the Gulf of Alaska Structural Epifauna contribution (see Conrath in this Report, p.59).

Status and trends: Shrimps and sea stars have exhibited notable fluctuations over the survey time series (Figure 84). Shrimp biomass remained relatively stable during the early years (1990 – 2002) but declined sharply, reaching a minimum in 2008. Since then, shrimp populations have rebounded, with biomass steadily increasing through 2021, largely driven by growth in the Kodiak subarea (NMFS Area 630; Figure 85). Recent estimates suggest that shrimp biomass is near the time series mean, with the largest biomass primarily in the Chirikof (NMFS Area 620) and Kodiak subareas. In contrast, sea stars showed population growth in the initial survey years (1990 – 1999) before experiencing a steady decline through 2019, primarily driven by trends in the Chirikof region. Since 2019, sea star biomass appears to be recovering, a trend supported by 2025 data, with populations increasing mainly in the Shumagin and Chirikof regions relative to previous years.

Eelpouts and poachers show considerable year-to-year variability in annual biomass observations, making long-term trends difficult to identify. On average, both groups are consistently encountered across years, with biomasses fluctuating around their respective means. While eelpouts are generally distributed across all regions, eelpout biomass increased in the Shumagin subarea (NMFS Area 610) and decreased in the Chirikof subarea from 2023 to 2025. Poacher biomass has historically been concentrated in the Shumagin and Kodiak regions, but populations have not rebounded from a decline in the Kodiak area in 2017 and have since been found primarily in the Shumagin region.

Factors influencing observed trends: We hypothesize that thermal conditions and ecosystem productivity documented in the GOA may be contributing to the trends found in all four taxonomic groups since the mid-late 2010s. Many of these taxa are known to be sensitive to thermal stress (Anderson, 2000; Brodte et al., 2006), and sea stars in particular have been subjected to an outbreak of wasting disease, presumably triggered by such temperature shifts. However, other factors, such as changes in prey or predator dynamics, disturbance, or a combination of effects may also be contributing to these patterns. Further investigation of these non-target benthic taxa is needed to provide a more robust understanding of the mechanisms responsible for the biomass trends documented here.

Implications: These taxa form an important dietary component for many commercially valuable species, including Atka mackerel (*Pleurogrammus monopterygius*), Pacific cod *Gadus macrocephalus*, and king crabs *Paralithodes* sp.). Consequently, shifts in their biomass could substantially alter trophic dynamics and trigger ecosystem-wide effects. Focused research on the population ecology of these groups would help clarify links between population metrics and the overall health of the region.

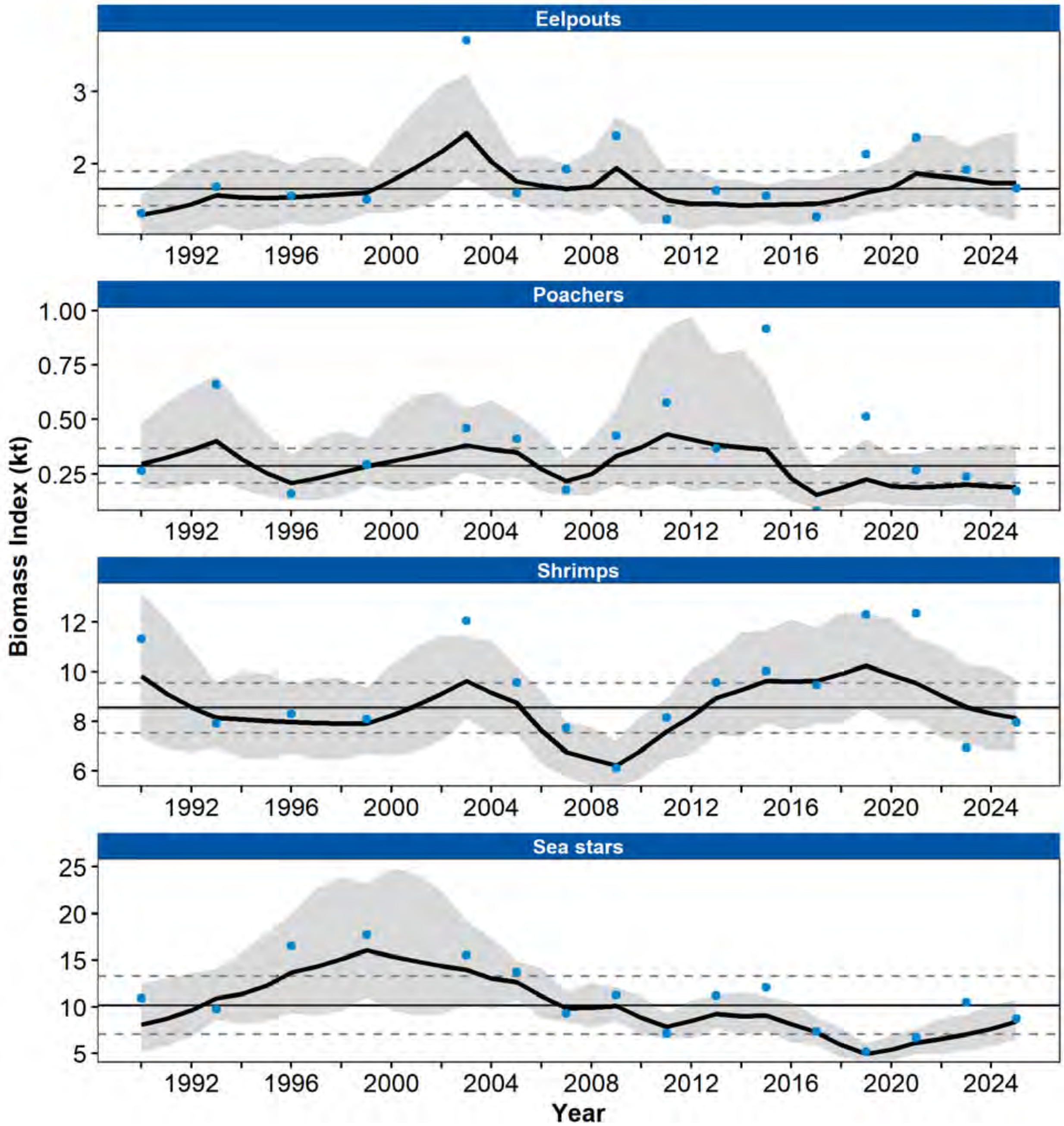

Figure 84: Biomass index (kilotons) of miscellaneous benthic fauna (eelpouts, poachers, shrimps, sea stars) from RACE Groundfish Assessment Program summer bottom trawl surveys of the Gulf of Alaska from 1990 to 2025. Panels show the observed survey biomass index mean (blue points), random effects model fitted mean (solid black line), 95% confidence interval (gray shading), overall time series mean (solid gray line), and horizontal dashed gray lines representing one standard deviation from the time series mean.

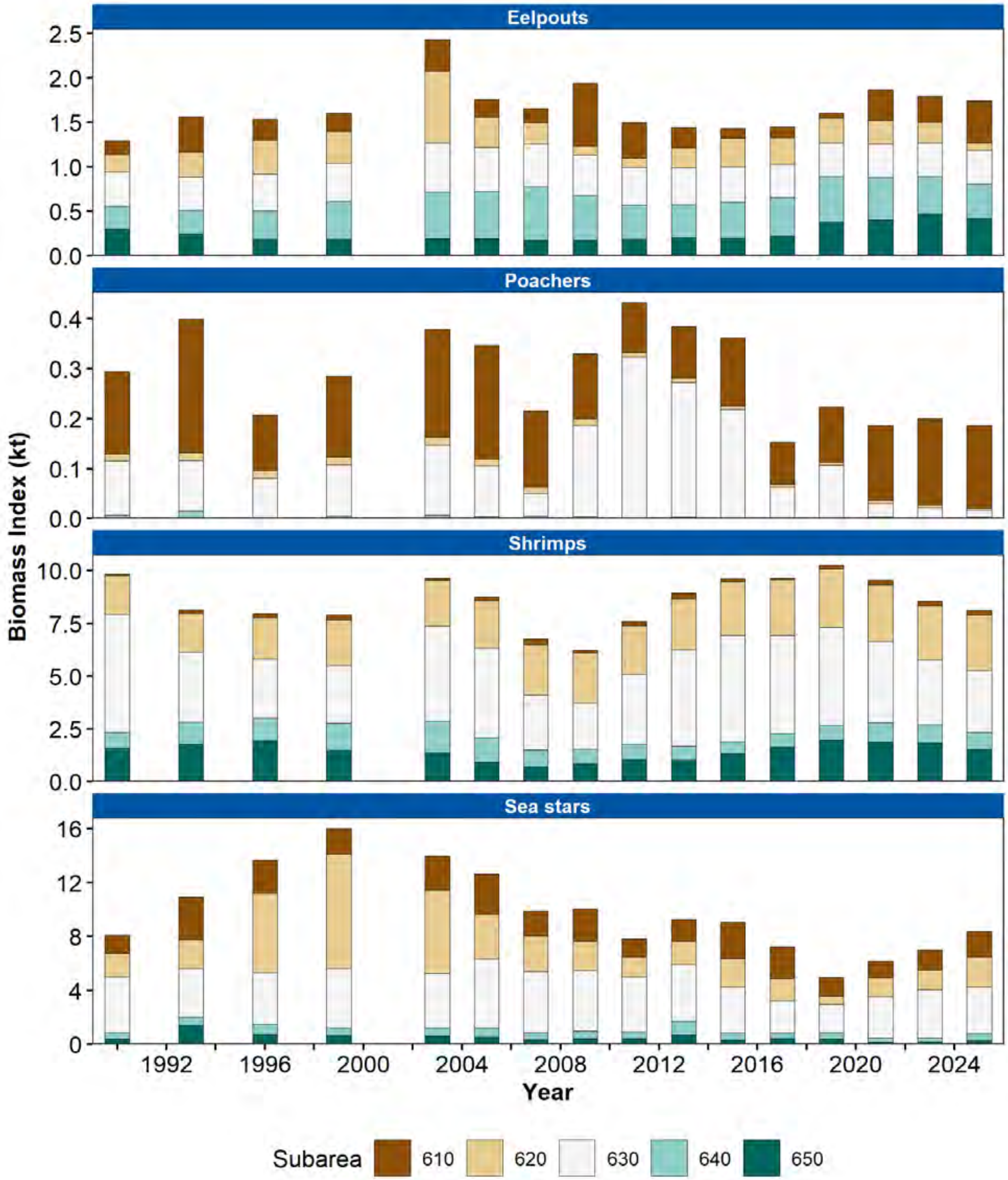

Figure 85: Biomass index (kilotons) of miscellaneous benthic fauna (eelpouts, poachers, shrimps, sea stars) in NMFS Statistical Areas in the Gulf of Alaska (610 - Shumagin, 620 - Chirikof, 630 - Kodiak, 640 - West Yakutat, 650 - Southeast Outside) estimated from RACE Groundfish Assessment Program summer bottom trawl survey data from 1990 to 2025. Colors denote NMFS statistical areas.

Seabirds

Seabird Synthesis

Contributed by Daniel Cushing[1], Brie Drummond[2], Scott Hatch[3], Robert Kaler[4], Elizabeth Labunski[4], John F. Piatt[5], Heather Renner[2], Florence Sullivan[6], and Shannon Whelan[3]
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Summary Statement: Indicators of seabird reproduction indicate approximately above-average environmental conditions in the Gulf of Alaska, in 2025, with early hatch dates indicating warm spring ocean conditions (Figure 86). A few elevated encounters of dead black-legged kittiwakes in Homer/Kachemak Bay and trends in seabird distribution in the northern GOA are potential warnings of stressors in the ecosystem. Most of the reported seabird data represent western and central GOA in 2025 (and not eastern GOA).

Reproductive success for fish-eating seabirds across the GOA (an indicator of sufficient forage fish as prey) was above average in the western GOA (Chowiet Isl.) and below average for pelagic cormorants (Middleton Isl.) and rhinoceros auklets in the central GOA (Middleton Isl.). The presence of capelin as a valuable prey resource may have supported the high reproductive success of the piscivorous surface feeding seabirds (e.g., black-legged kittiwakes) (Whelan in this Report, p.96). Zooplankton-eating seabirds had close to one standard deviation above-average reproductive success across the GOA in 2025 (limited eastern GOA data), reflecting higher availability of zooplankton biomass in the spring. The hatch timing was early to very early for most seabirds reported, another indicator of adequate prey availability. The early spring hatch timing could also reflect earlier phenology in the lower trophic levels (earlier onset of stratification, earlier spring bloom, zooplankton phenology) that can occur in warm winter/spring ocean conditions in the GOA.

The distribution of seabirds provides a potential warning of less ideal feeding conditions in spring 2025. Seabirds observed on the Seward Line spring survey (central GOA cross shelf transect) were less evenly distributed across the shelf than 2024, with some reductions in the outer shelf and slope regions. Generally, a dispersed nature of the surveyed distribution indicates a more available prey base. Additionally, in times of high capelin availability, black-legged kittiwakes on Middleton Isl. forage closer to the island, but in 2025 ranged further nearshore than previous years of capelin abundance. It is unknown if the 2025 distribution reflects the beginnings of a compressed seabird distribution into the inner domain during lower productive marine heatwave years (2014-2016). Implications for groundfish include sufficient to good zooplankton (e.g., prey for juvenile groundfish and adult Pacific ocean perch, walleye pollock, dusky rockfish) and forage fish (e.g., prey for sablefish, Pacific cod, arrowtooth flounder) prey resources to meet metabolic needs in 2025. The indicators of early spring phenology could reflect the potential for a mismatch in timing between groundfish larvae and availability of small zooplankton as prey (Rogers in this Report, p.89).

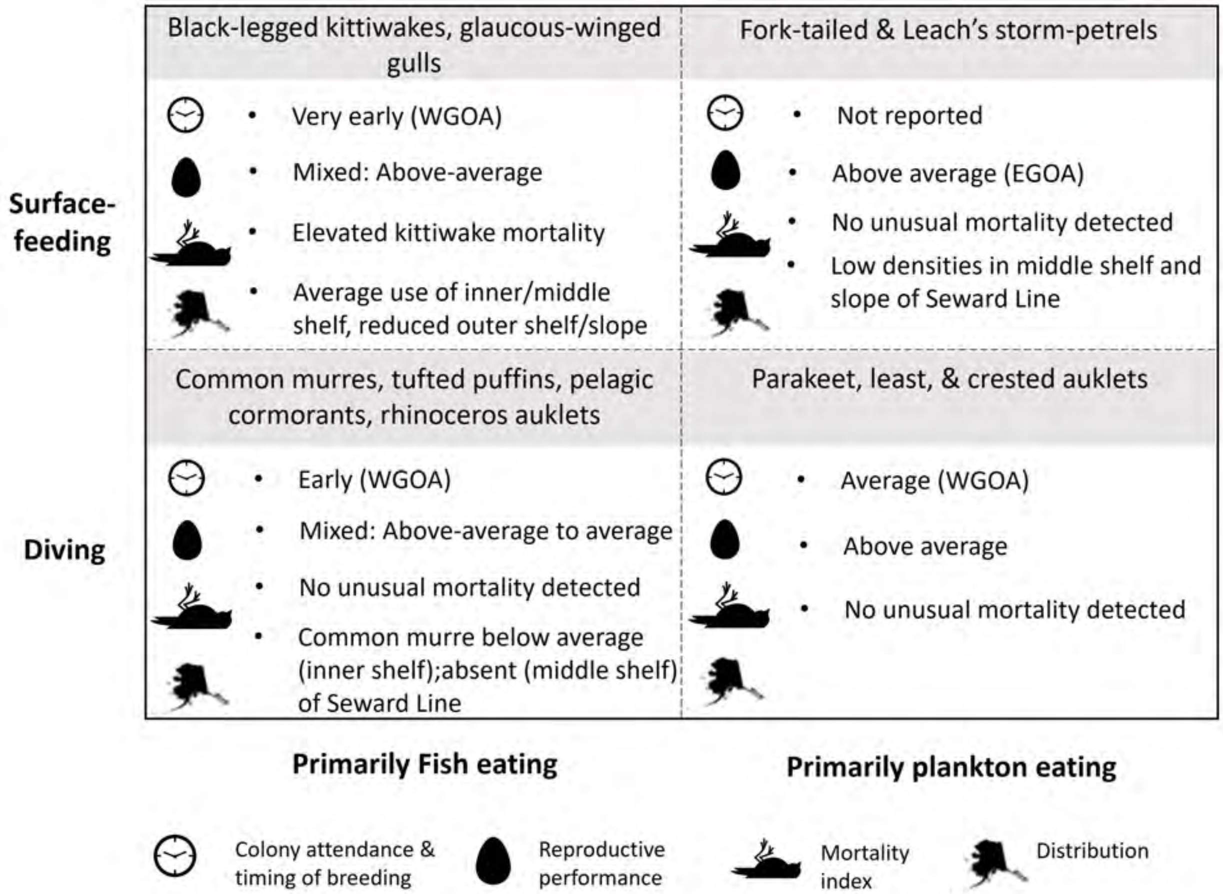

Figure 86: Summary of 2025 indicators for timing of breeding, reproductive performance, mass mortality events, and distribution of seabird feeding guilds (surface-feeding and diving, fish and plankton-eating) in the Gulf of Alaska.

Description of indicator: Seabirds are sensitive indicators of changes in the productivity of marine ecosystems, and their populations can signal processes affecting the availability of prey for commercial fish stocks (Warzybok et al., 2018). From field data and observations collected by government, university and non-profit partners, we provide a summary of the best available data on seabird productivity in the Gulf of Alaska in 2025. We forefront environmental impacts on seabirds (e.g., heatwaves) and interpret changes in seabird mortality, attendance, and reproduction as a reflection of ecosystem productivity and prey availability (Koehn et al., 2021).

In this synthesis, we divide seabirds by preferred prey: fish or plankton, and foraging location: deep or surface because each group responds to a different part of the ocean ecosystem. To describe the status of seabird groups we use three types of information that represent different spatial and temporal scales of seabird responses:

1. **Breeding timing** can represent conditions prior to breeding and/or phenological variation in the environment. Birds arriving to breed at a later date can reflect poor winter and/or spring foraging

conditions, or later peaks in ocean productivity. This metric is defined as the hatch date for data from USFWS and Middleton Isl.

2. **Reproductive success** which can represent food availability around the colony during the breeding season (summer), with a lower number of fledged chicks generally reflecting a decrease in the local abundance of high-quality prey. This metric is defined as the following:
   - The ratio of fledged chicks to eggs for murres, auklets, puffins, and storm-petrels (USFWS)
   - The ratio of nests producing fledglings to nests for black-legged kittiwakes (USFWS)
   - Chicks fledged per laying pair for pelagic cormorants on Middleton Isl. (ISRC)
   - Late-stage chicks per egg for rhinoceros auklets on Middleton Isl. (ISRC)
   - Chicks fledged per pair for black-legged kittiwakes on Middleton Isl. (ISRC)
3. **Mortality** which gives insight into environmental and ecosystem impacts beyond breeding colonies and the breeding season. Unusual mortality events in the Gulf of Alaska have been linked to declines in prey abundance and quality during recent marine heatwaves (Piatt et al., 2020).
4. **Distribution** which provides area-specific and season-specific index of use as a function of physical environmental drivers that affect the characteristics of the habitat and influence the distribution and availability of prey.

Status and trends:

Primarily fish-eating, surface feeding seabirds: Fish-eating, surface feeding seabirds in the Gulf of Alaska include black-legged kittiwakes *Rissa tridactyla* and glaucous-winged gulls *Larus glaucescens*. These species feed on small schooling fish that are available at the surface (e.g., sand lance, sablefish, capelin and herring), making them potential indicators of processes affecting juvenile groundfish that migrate to the surface to feed.

Breeding timing: *Breeding timing was very early in the western GOA in 2025*. In the western GOA (Chowiet Isl. and Middleton Isl.), hatch dates in spring 2025 were close to or greater than one standard deviation earlier than 2024 for black-legged kittiwakes and glaucous-winged gulls (Figure 87). Black-legged kittiwakes on Middleton Isl (mean hatching date was June 28) breeding timing was early in the season (Chowiet Isl. baseline 1990 – 2023; Middleton Isl. baseline 1996 – 2024). Hatch timing on St. Lazaria Isl (Eastern GOA) was not reported in 2025 (Figure 88).

Reproductive success: *Reproductive success was above average in 2025*. Black-legged kittiwakes (Chowiet Isl.) increased to above-average (baseline 1990 – 2024) reproductive success in 2025, after two below-average years (Figure 89). Black-legged kittiwakes on Chowiet Isl. experienced reproductive failure in 2023 after a record high (baseline 1989 – 2023) in 2022. Naturally foraging kittiwakes on Middleton Isl. increased to above-average breeding productivity (0.82 chicks fledged per pair; Figure 89), possibly due to the increased proportion of energy-rich capelin *Mallotus villosus* in their diets.

Mortality: *A few elevated encounters of dead black-legged kittiwakes in Homer/Kachemak Bay in 2025* based on beach surveys in the Western Gulf of Alaska (Figures 91, 92). Like much of Alaska, beach surveys show a late summer, post-breeding mortality pattern. A single day, unusual mortality event of black-legged kittiwakes in Homer/ Katchemak Bay occurred in August, increasing the monthly average of observed dead seabirds in the GOA (Figure 92).. This should not be considered indicative of the state of black legged kittiwakes throughout the GOA. No other large-scale mortality events were recorded by beached bird surveys. On Middleton Island, black-legged kittiwakes were observed exhibiting symptoms consistent with avian botulism in 2025. This disease was first documented on the island in 2021 and has been observed every year since then, however fewer birds have been affected since the larger 2021 – 2022 die-offs.

Distribution: *Average middle-shelf use; decreased use of the slope domain*. Historical GPS-tracking shows that kittiwakes tagged on Middleton Isl. tended to forage close to the island when capelin were abundant prior to the heatwave, then expanded their foraging range during and after the heatwave (Osborne et al., 2020). Despite the high occurrence of capelin in the 2025 kittiwake diets (Whelan in this Report, p.96), GPS tracking showed variable foraging distances. Though shorter, more local foraging has increased in recent years, 2025 foraging trips still often extended to mainland Alaska and the entrance to Prince William Sound throughout the breeding season.

Along the Seward line transect, in the northern Gulf of Alaska, in the spring of 2025, black-legged kittiwake densities remained near average on the inner shelf and middle shelf. Densities of kittiwakes remained below average on the outer shelf and decreased to well below average in the oceanic domain (continental slope), after reaching a time series high densities in 2024 (Figure 93).

Primarily fish-eating, diving seabirds: Fish-eating, diving seabirds in the Gulf of Alaska include common murres *Uria aalge*, rhinoceros auklets *Cerorhinca monocerata*, tufted puffins *Fratercula cirrhata* and pelagic cormorants *Urile pelagicus*. The status of this group is impacted by changes in the availability of small, schooling fish up to 90 m (300 feet) below the surface, making them potential indicators of feeding conditions that may affect fish-eating groundfish species.

Breeding timing: *Breeding timing was early in the western GOA in 2025*. Breeding timing of these seabirds on Chowiet Isl. was generally earlier than the time series average (baseline: 1990 – 2024) with the exception of thick-billed murres (Chowiet Isl.) and pelagic cormarants (Middleton Isl.) (Figure 87). Common murres continue a multi-year trend of hatch times one standard deviation earlier than average. The mean hatching date of rhinoceros auklets (June 19) was earlier than average, while the mean hatching date of pelagic cormorants (June 28) was close to average on Middleton Island in 2025. (Figure 87). Hatch timing on St. Lazaria Isl (Eastern GOA) was not reported in 2025 (Figure 88).

Reproductive success: *Reproductive success was above-average (western GOA peninsula) to average (central GOA) to average/above average (southeast AK) for fish-eating, diving seabirds in 2025.* In the western GOA, the reproductive success of this group of seabirds remained close to one standard deviation above average on Chowiet Isl. in 2025, with the exception of horned puffins (the down year of a biannual pattern) (Figure 89). Breeding success of rhinoceros auklets and pelagic cormorants was below average on Middleton Island in 2025 (Figure 90). In the eastern GOA, common murres and thick-billed murres on St. Lazaria Isl. continued a multi-year trend of slightly above average reproductive success (baseline 1994 – 2024; Figure 90).

Mortality index: *No large-scale mortality event was recorded for fish-eating, diving seabirds based on beach surveys in the western GOA in 2025.* This marks 9 years since the mass mortality event of common murres linked to the 2014 – 2016 marine heatwave (Figure 92).

Distribution: *Common murres densities decreased along Seward Line).* Densities of common murres along the Seward Line, northern GOA, in spring 2025 decreased to below average on the inner shelf (Figure 93). Murres were absent from the middle shelf after reaching a 9 year high in 2024. An influx of murres into coastal waters preceded an unprecedented mass-mortality event during the winter of 2015 – 2016. Following this dieoff event, spring densities of murres on the middle shelf were below average from 2016 – 2023.

Primarily plankton-eating seabirds: Plankton-eating seabirds in the Gulf of Alaska include surface-feeding species such as Leach's and fork-tailed storm-petrels (*Hydrobates leucorhous*, *Hydrobates furcatus*), and diving species such as least auklets (*Aethia pusilla*), crested auklets (*Aethia cristatella*), and parakeet auklets (*Aethia psittacula*). The status of these groups is impacted by changes in zooplankton production, making them potential indicators of feeding conditions that may affect planktivorous groundfish species, including the larvae and juveniles of fish-eating species.

Breeding timing: *Breeding timing was average in western GOA.* In the western GOA, Parakeet auklets breeding timing decreased to average on Chowiet Isl. (baseline: 2002 – 2024; Figure 87). Hatch timing on St. Lazaria Isl (Eastern GOA) was not reported in 2025 (Figure 88).

Reproductive success: *Reproductive success was above average for plankton-eating seabirds in 2025.* In the western GOA (Chowiet Isl.), the reproductive success of parakeet auklets continued a four-year increase to greater than one standard deviation above average (baseline: 1998-2024), potentially reflective of local foraging conditions around the colony (Figure 89). In eastern GOA, earlier breeding St. Lazaria fork-tailed were not reported in 2025 and later breeding Leach's storm-petrels increased greater than one standard deviation above-average success (baseline starting in 1994 and 1995 respectively) (Figure 90).

Mortality index: *No large-scale mortality event was recorded for plankton-eating seabirds based on beach surveys in the Gulf of Alaska in 2025.* In 2025, auklet carcasses observed during COASST surveys were able to be verified to the auklet subgroup, but not species. They were not found in abundances suggestive of unusual/elevated mortality (Figure 92). Crested auklets last appeared dead on beaches, 2015 – 2016, following the marine heatwave; no least auklets have been found in the Gulf of Alaska since monitoring was established (2006).

Distribution: *Decrease in density in outer shelf and slope, along Seward Line.* Densities of fork-tailed storm-petrels along the Seward Line, northern GOA, in spring 2025 continued to be well below average on the middle shelf, and decreased from 2024 to below average in the outer shelf and the oceanic domain (Figure 93).

Factors influencing trends and implications for ecosystem productivity: Seabirds represent different aspects of prey resources, depending on species-specific life histories and foraging characteristics. Rhinoceros auklets can represent a broader spatial range of foraging conditions, given their ability to dive and broad foraging range. Kittiwakes have more variable reproductive performance in response to short-term environmental fluctuations, while murres have more consistent breeding patterns, indicative of broader foraging conditions and more extreme events. Early breeding timing can indicate increased prey availability, however other environmental and phenological aspects can influence this metric. The distribution of seabirds observed during the Seward Line spring survey can reflect spatial trends in prey availability, such as compression closer to shore during the lower productive marine heatwave years of 2014 – 2016. The three seabird colonies summarized in this section span the Gulf of Alaska shelf from west (Chowiet Isl.), central (Middleton Isl.), to east (St. Lazaria Isl). Seabird diet data, relevant to reproductive success and timing and distribution, are presented in the Seabird-Derived Forage Fish Indicators chapter of this Report (Whelan et al., p.96).

The absence of common murres on the middle shelf and their low abundance on the inner shelf during spring 2025 is consistent with continued lack of recovery. An influx of murres into coastal waters preceded an unprecedented mass-mortality event during the winter of 2015 – 2016. Following this dieoff event, spring densities of murres on the middle shelf were below average from 2016 – 2024. While densities of both kittiwakes and storm-petrels were high over the continental slope during spring 2024, suggesting enhanced availability of oceanic prey, densities of both species were below average in these domains during 2025.

On Middleton Island, the relatively early breeding phenology of black-legged kittiwakes was likely driven by high availability of capelin in spring. Breeding success was markedly higher among surface-foraging black-legged kittiwakes relative to the two diving species (pelagic cormorants and rhinoceros auklets). Though capelin were higher in kittiwake diets in 2025, capelin comprised a similar proportion of biomass in rhinoceros auklet diets in both 2024 and 2025 (Whelan et al. in this Report, p.96). Rhinoceros auklets and pelagic cormorants on Middleton island may be more sensitive to the decline in availability of Pacific sand lance, relative to surface-foraging kittiwakes (Whelan et al. in this Report, p.96).

The increased reproductive performance of zooplankton-eating seabirds would indicate that zooplankton prey were adequate to meet the reproductive needs of these bird species, despite mixed zooplankton survey trends in 2025. Spring zooplankton surveys in the western GOA observed mixed trends in small zooplankton biomass, a decrease in large zooplankton, and increased euphausiids (Hopcroft in this Report, p.79 and Kimmel et al. in this Report, p.72).

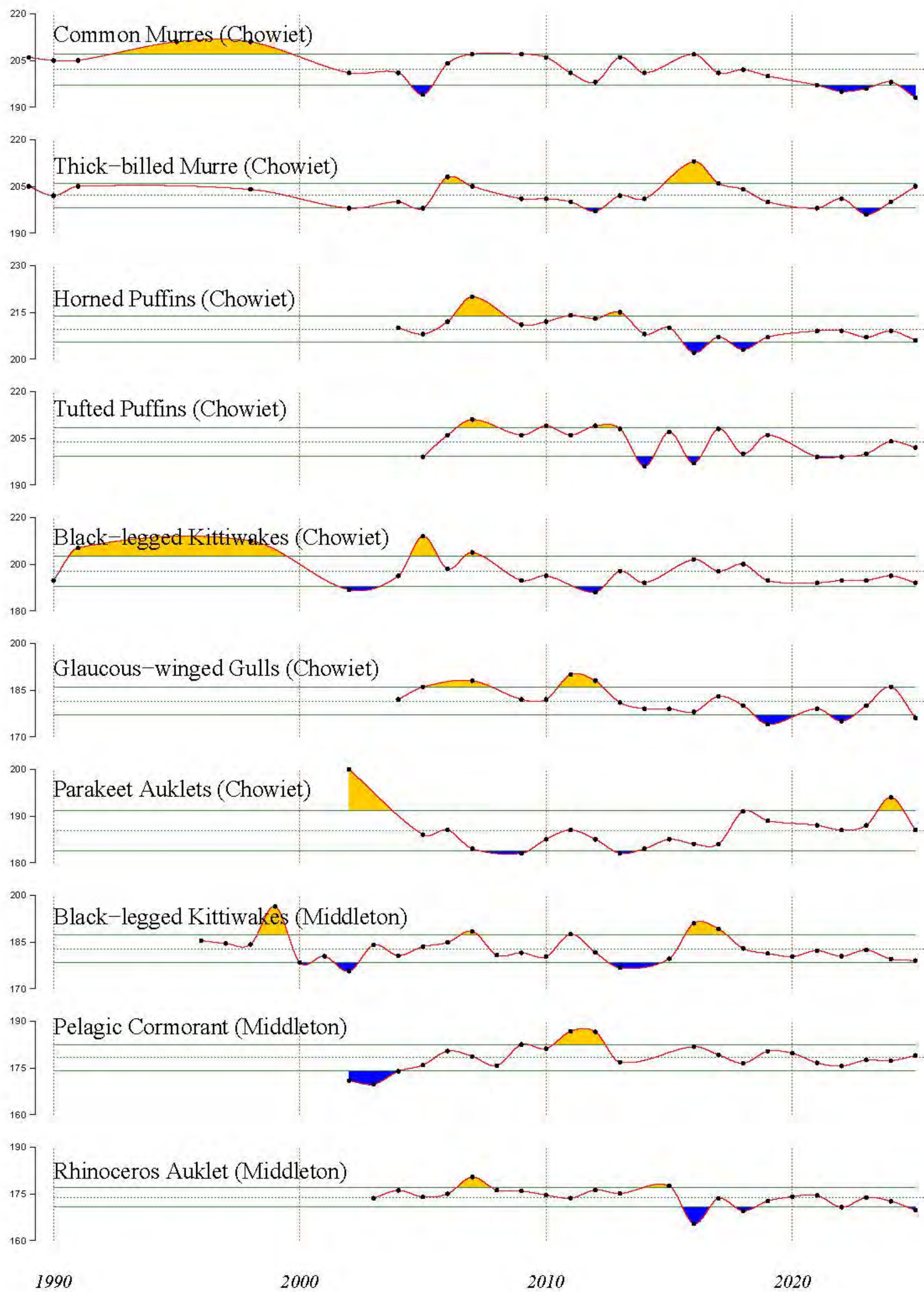

Figure 87: Reproductive timing of western Gulf of Alaska piscivorous (common murres, thick-billed murres, horned puffins, tufted puffins, black-legged kittiwakes) and planktivorous (parakeet auklets) seabird species on Chowiet Isl. and Middleton Isl. The dashed line is the long-term average and solid green lines are $\pm$ 1 SD. Yellow/blue shading indicates values greater than 1 SD above/below the mean. Data provided by the U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge and the Institute for Seabird Research and Conservation.

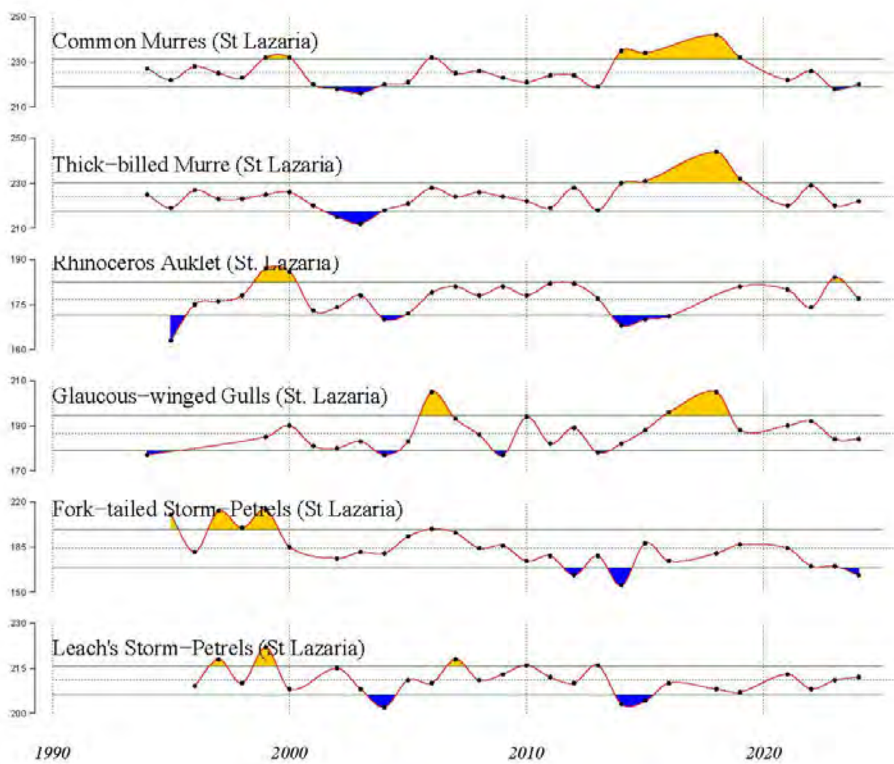

Figure 88: Reproductive timing of eastern Gulf of Alaska piscivorous (common murres, thick-billed murres, rhinoceros auklets, glaucous-winged gulls) and planktivorous (fork-tailed storm-petrels, Leach's storm-petrels) seabird species on St. Lazaria Isl. The dashed line is the long-term average and solid green lines are $\pm$ 1 SD. Yellow/blue shading indicates values greater than 1 SD above/below the mean. Data were not available for 2025. Data provided by the U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge.

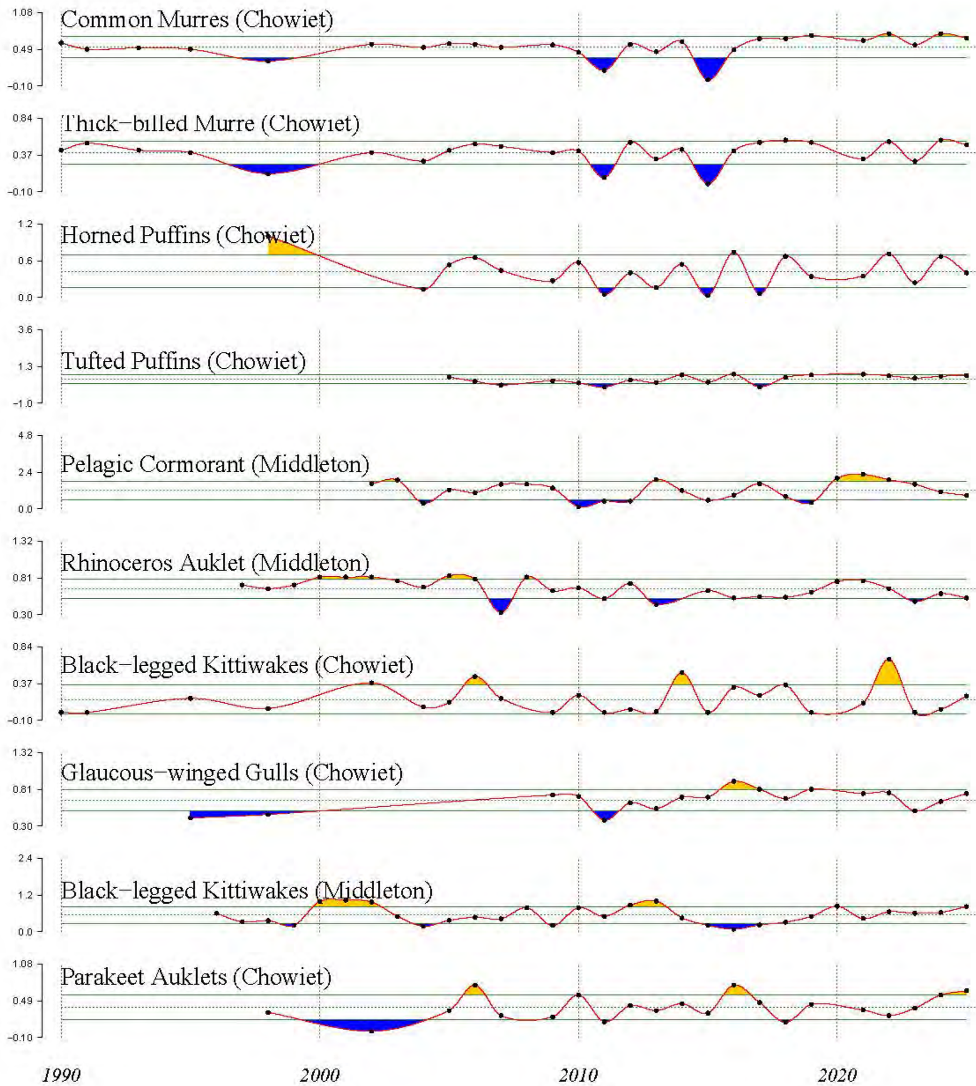

Figure 89: Reproductive success of western Gulf of Alaska piscivorous (common murres, thick-billed murres, horned puffins, tufted puffins, pelagic cormorants, rhinoceros auklets, black-legged kittiwakes) and planktivorous (parakeet auklets) seabird species on Chowiet Isl. and Middleton Isl. The dashed line is the long-term average and solid green lines are ± 1 SD. Yellow/blue shading indicates values greater than 1 SD above/below the mean. Data provided by the U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge and the Institute for Seabird Research and Conservation.

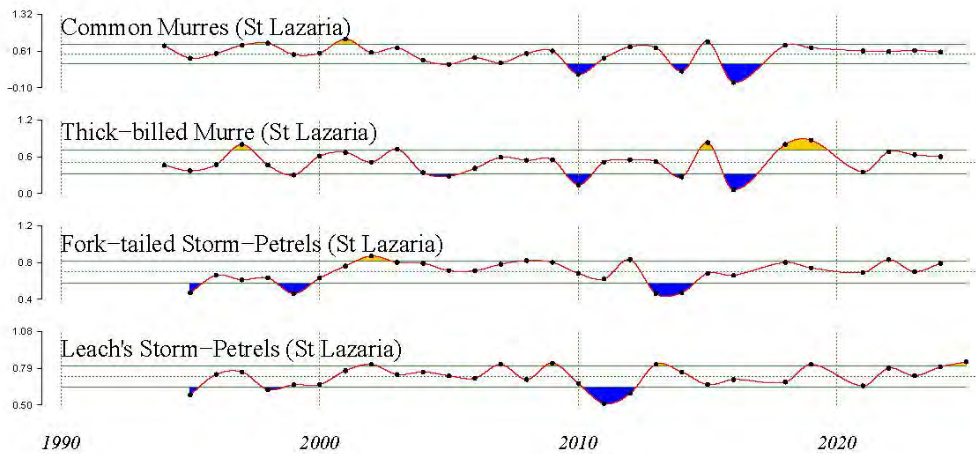

Figure 90: Reproductive success of eastern Gulf of Alaska, piscivorous (common murres, thick-billed murres) and planktivorous (fork-tailed storm-petrels, Leach's storm-petrels) seabird species on St. Lazaria Isl. The dashed line is the long-term average and solid green lines are ± 1 SD. Yellow/blue shading indicates values greater than 1 SD above/below the mean. Only Leach's storm-petrels were updated in 2025. Data provided by the U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge.

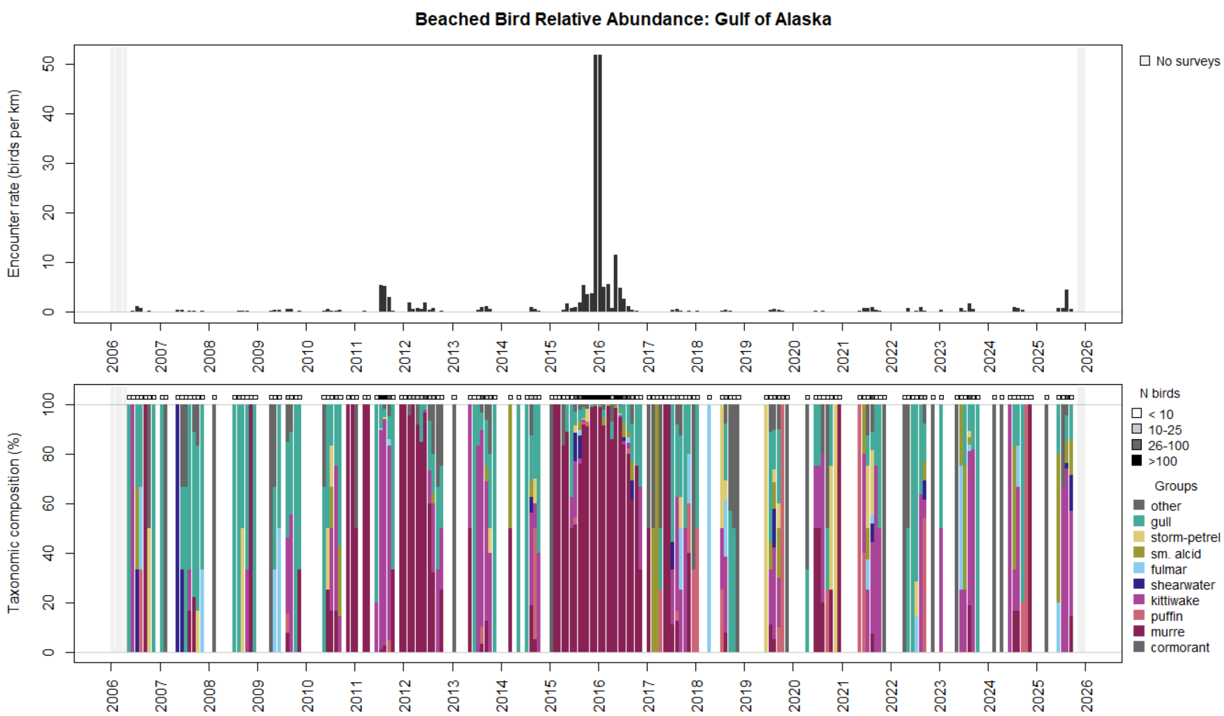

Figure 91: The relative abundance of beached birds encountered per km of beach surveyed by citizen scientists in the Gulf of Alaska. Data indicate regional trends, but are biased toward more accessible beaches in areas of higher human population density. Light gray shading indicates time-periods where surveys were not performed. Figure provided by the Coastal Observation and Seabird Survey Team (COASST), October 2025.

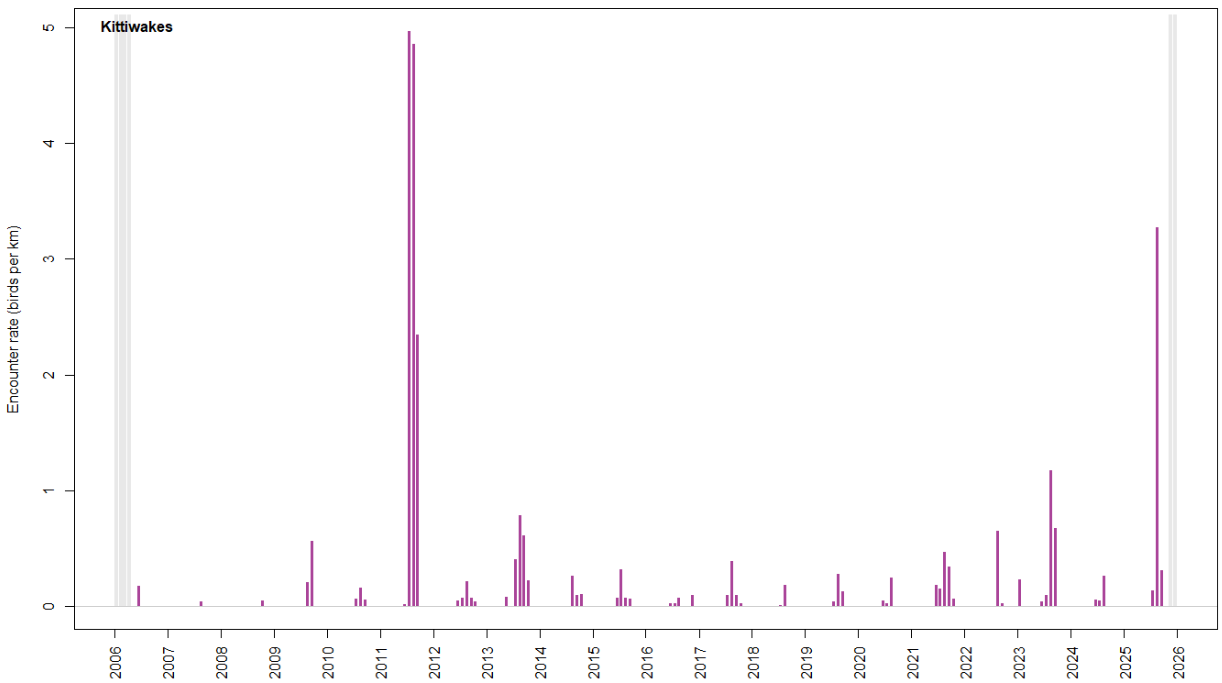

Figure 92: The number of black-legged kittiwakes (primarily fish-eating, surface feeding) encountered per km of beach surveyed by citizen scientists in the Gulf of Alaska. Data indicate regional trends, but are biased toward more accessible beaches in areas of higher human population density. A single day hyper-local wreck event in Homer Alaska is reflected in the August 2025 encounter rate. Light gray shading indicates time-periods where surveys were not performed. Figure provided by the Coastal Observation and Seabird Survey Team (COASST), October 2025.

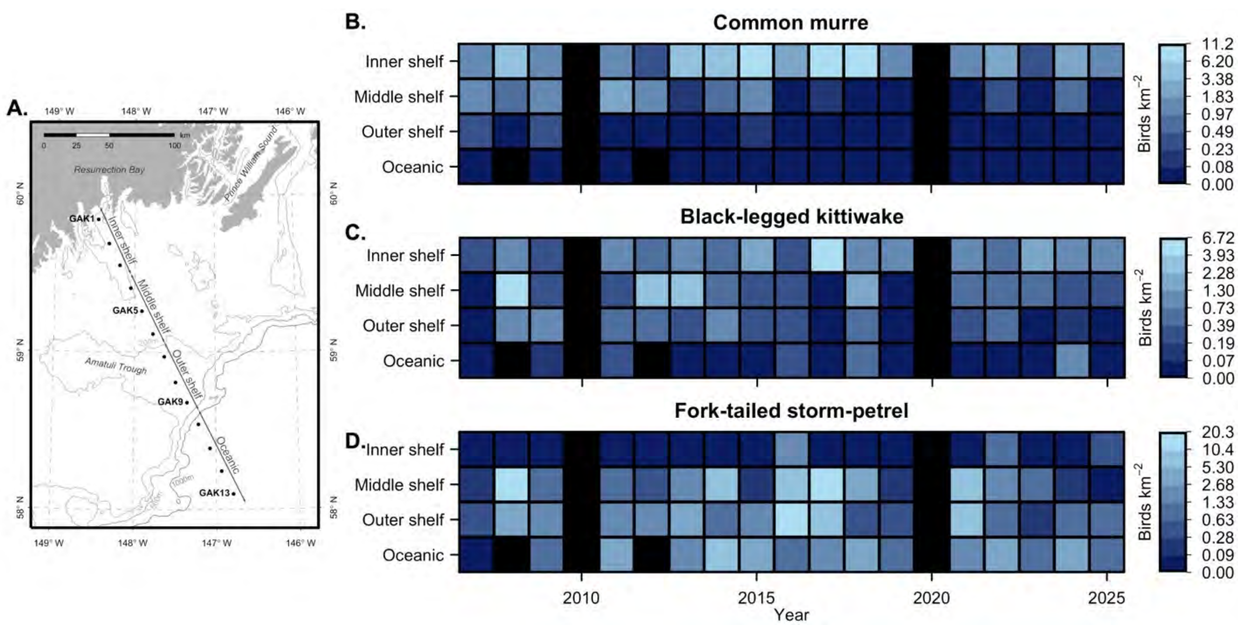

Figure 93: The spring Seward Line in the Northern Gulf of Alaska, and four domains used for analysis (A). Mean densities (birds km^{-2}) of common murres, black-legged kittiwakes, and fork-tailed storm-petrels within domains during spring Seward Line cruises, 2007 – 2025 (B-D). Black indicates no seabird surveys were conducted. Figure provided by University of Alaska, Fairbanks, and US Fish and Wildlife Service, Migratory Birds – Alaska.

Methods:

- The Coastal Observation and Seabird Survey Team (COASST) and regional partners provided a standardized measure of relative beached bird abundance collected by citizen scientists.Carcass identifications are verified using collected measurements and photographs. Basis data (carcass count, identity and condition information) are used to create a baseline (long-term normal) against which unusual events can be compared. Information for the two most data-rich species are included in this Report: common murres and black-legged kittiwakes, representatives of the diving, fish eating group and the surface feeding, fish eating group respectively. Note that data collection is biased toward accessible beaches close to human population centers.

- The Institute for Seabird Research and Conservation (ISRC) provided data on breeding timing and/or reproductive performance of pelagic cormorants, rhinoceros auklets and black-legged kittiwakes on Middleton Island. These data have been collected since the mid-1990s, including an experiment involving feeding a group of kittiwakes to highlight the effect of food availability on the reproductive performance of wild-foraging birds.

- The USFWS Migratory Birds used vessel-based seabird surveys conducted as a component of multidisciplinary sampling of the Seward Line, during spring (typically the first 10 days of May), 2007 – 2025, to examine cross-shelf distribution of three selected seabird species representative of their foraging guild: common murre (diving, primarily feed on forage fish during the summer breeding season but also feed on small nektonic invertebrates such as euphausiids and squid, especially during the non-breeding period), black-legged kittiwake (surface-feeding, primarily feed forage fish and other small nektonic invertebrates, with a higher proportion of fish during the breeding season) and fork-tailed storm-petrel (surface feeding, primarily feed on zooplankton and ichthyoplankton, also small fish). Seabird surveys were conducted while the vessel was underway using USFWS survey protocol and subsequently divided into ∼3 km transects for analysis. For each year, transects within 10 km of each of the 13 stations along the Seward Line were used to calculate densities (birds km^{-2}) for each species within each station-centered cell; these station-centered values were then averaged within each of 4 domains (Inner shelf, Middle shelf, Outer shelf, Oceanic). We considered observations within the lowest decile of the data to be “well below average”, the lowest tercile to be “below average”, the middle tercile to be “near average”, the upper tercile to be “above average” and the upper decile to be “well above average”.

- The USFWS Alaska Maritime National Wildlife Refuge has monitored seabirds at colonies around Alaska in most years since the early to mid-1970’s. Time series of annual breeding success and phenology (and other parameters) are available from over a dozen species at eight Refuge sites in the GOA, Aleutian Islands, and Bering and Chukchi Seas. Monitored colonies in the GOA include Chowiet (Semidi Islands), East Amatuli (Barren Islands), and St. Lazaria (southeast Alaska) islands.

Marine Mammals

Trends in Humpback Whale Calving in Glacier Bay and Icy Strait

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Description of indicator: Humpback whale (*Megaptera novaeangliae*) reproductive success in Glacier Bay and Icy Strait can be considered an indicator of changes in prey quantity and/or quality available for groundfish in the eastern Gulf of Alaska because groundfish and humpback whales target the same lipid-rich prey *i.e.*, forage fish and euphausiids.

Annually since 1985, Glacier Bay National Park biologists have used consistent methods and levels of effort from June 1 – August 31 to photographically identify individual humpback whales and document their reproductive parameters in Glacier Bay and Icy Strait (Gabriele et al., 2017). We match each year's photographs of the flukes and dorsal fin of each whale to curated catalogs of identified individuals. We document the survival and reproductive status of Glacier Bay and Icy Strait whales when they are elsewhere in the North Pacific using the collaborative Southeast Alaska Database and Happywhale.com automated humpback whale fluke identification system (Cheeseman et al., 2023). Individual sightings from research collaborators are reported with their permission. From these data, we document 1) crude birth rate (CBR) (defined as the number of calves divided by the total whale count); 2) within-season calf survival and 3) opportunistic observations of the body condition of cows and calves. We explore factors such as the return of calves in subsequent years, female age at first calving, and female calving intervals that provide context for the CBR.

Status and trends:
Crude Birth Rate: We observed six calves in 2025 (Table 2). Our preliminary whale count for 2025 was 157 whales, therefore, the 2025 preliminary humpback whale crude birth rate (CBR) was 3.8% (Table 2, Figure 94). The number of whales and the number of calves are both much lower than in 2024. This year's CBR is far below the long-term average CBR (9.2%, 1985 – 2013) observed before the Northeast Pacific marine heatwave (PMH, Di Lorenzo and Mantua, 2016; Walsh et al., 2018; Holbrook et al., 2019), and below the post-PMH mean (6.7%, Table 2, Figure 94).

Within-season calf survival: All of the 2025 calves were with their mother on our final observations of the cow/calf pairs for the season, thus we documented no mid-season calf mortalities (Table 2). However, five of the six cow/calf pairs were not sighted after the first week of August, having apparently left the study area. Notably, this summer we resighted the 2024 calf of female #1846, whose absence during a late September 2024 observation led to speculation about mid-season mortality (Gabriele et al., 2024). The documented survival of this whale reinforces the concept that an absent calf in the fall may indicate temporary separation or weaning rather than calf mortality.

Body condition of cows and calves: Five of the six mothers were noted to be in poor body condition throughout the summer, based on protruding scapulas or low amounts of nuchal fat, caudal to their blowholes. All of the 2025 calves appeared to be in relatively good body condition with a healthy amount of nuchal fat. None of the calves had the questionable skin conditions that we noted in several 2024 calves (Gabriele et al., 2024)).

Calf return and recruitment: Four of the 2024 calves were sighted as yearlings; two were documented in our study area (#2780 and #1846_calf_2024) and two were sighted elsewhere by citizen science contributors to Happywhale (#2778 in Sitka Sound, by Captain Gary's Sikta Adventures and others, and #2787, by Condor Cruises off Santa Barbara, California). We continue to document the survival of numerous calves born between 2019 – 2023 in the study area or elsewhere, but it is notable that only one of the 22 calves born during or right after the PMH (in 2014 – 2018) is known to have survived (#2772, an individual from the Mexico Distinct Population Segment (DPS) which was less affected by the PMH than the Hawai'i DPS; Cheeseman et al., 2024) (Table 2).

Age at first calving: Two of this year's cohort of mothers had their first known calf; #2324, age 15, and #2582 whose age is unknown. Female #2324 has a complete sighting history, except when she was a yearling, therefore we would have detected any previous calves that accompanied her to the study area. She was reported to be accompanied by a calf at age 12 during a March 2022 citizen science sighting in Hawai'i, however this could not be confirmed, and when we observed her in the study area in summer 2022, she did not have a calf. Age 15 is higher than the average of 11 – 12 years that was documented for this population using data from 1985 – 2014 (Gabriele et al., 2007, 2017). Note that in 2024, we erroneously reported the age at first calving for three females (Gabriele et al., 2024). The correct ages for the 2024 first-time mothers are as follows: #2310 was 17 years old and has a complete sighting history; #2032 was 17 years old and #2055 was 16 years old. The latter two females have incomplete sighting histories and may have had a calf in years that they were not sighted.

Calving intervals: The four mothers in 2025 who had prior calves had apparent calving intervals of 2 – 4 years, which is within the normal range for this population (Baker et al., 1987; Gabriele et al., 2017).

Factors influencing observed trends: The simplest explanation for the low CBR in 2025 is that the record high number of females with a calf in 2024 (Table 2) left fewer females available to have a calf in 2025, given the 2 – 3 year mean calving interval for this population (Gabriele et al. 2017). This effect is exacerbated by the number of adult females (and males) that are presumed to have died during and after the PMH, estimated at 58 whales in Glacier Bay and Icy Strait alone (Neilson et al., 2024, Neilson In Prep). The poor body condition of most mothers suggests that feeding conditions are making it difficult for these females to regain the substantial resources that they use in reproduction (van Aswegen et al., 2025), but are sufficient for mid-season calf mortality to remain rare (Table 2).

Implications: The profound ecological effects of the PMH and its aftermath (e.g., Von Biela et al., 2019; Piatt et al., 2020; Arimitsu et al., 2021; Frankel et al., 2021; Suryan et al., 2021; Gabriele et al., 2022) are still reflected in Southeast Alaska humpback whale reproduction and recruitment. The PMH induced a 6-year period of low humpback whale calf survival, low productivity, and negligible recruitment that began in 2014 (11 years ago) (Gabriele et al., 2022) which is also the mean age at first calving for this humpback whale population (Gabriele et al., 2007, 2017). We surmise that the absence of the cohort of females that would be expected to produce their first calf in 2025 – 2031 will be reflected in low CBRs for years to come. Moreover, if the PMH trophic disruption continues to alter the age at first calving, as suggested by our past few years' observations, that too may affect long-term population growth. Food limitation has been associated with delayed onset of reproduction in

Table 2: Humpback whale calf production and survival in Glacier Bay & Icy Strait, Alaska. Crude birth rate is calculated by dividing the number of calves by the total number of whales in June-August. In this table, the 2025 crude birth rate is based on a preliminary total number of whales in 2025. The Northeast Pacific marine heatwave occured from 2014 – 2016.*Calves that do not show their flukes are much harder to re-identify in future years. **The median age at which juveniles tend to return to the study area is 3 years (Gabriele et al., 2017). *** Calf absences in the fall might indicate weaning or temporary separation rather than calf mortality.

Time Period	Number of Calves (June-Aug)	# Fluke-identified Calves (June-Aug)*	Crude Birth Rate (%)	Number of Calves Lost in Mid-summer (%)	# Calves Resighted in Later Years (%)**
1985–2013	mean 9.1	191	mean 9.2	8 (4%)	128 (67%)
2014	14	6	7.9	5 (36%)	1
2015	5	1	3.0	0	0
2016	0	0	0.0	0	0
2017	2	1	1.5	1 (50%)	0
2018	1	0	1.0	1 (100%)	0
2019	2	1	1.3	0	1
2020	12	8	7.4	0	4
2021	11	8	6.5	1(9%)	3
2022	6	2	3.6	0	2
2023	11	8	6.4	0	3
2024	24	16	12.8	0	4
2025	6	2	3.8	0	NA

ungulates (J.M. et al., 2000) and would not be unexpected for post-PMH whale populations. Previous work demonstrated that recruitment from within, as opposed to immigration, has been the foundation of humpback whale population growth in the Glacier Bay – Icy Strait area (Pierszalowski et al., 2016). All of these factors suggest reduced humpback whale population growth in the coming years, even if feeding conditions are favorable. The CBR and explanatory factors seem likely to reflect groundfish prey availability in prior feeding seasons, although other factors are likely at play.

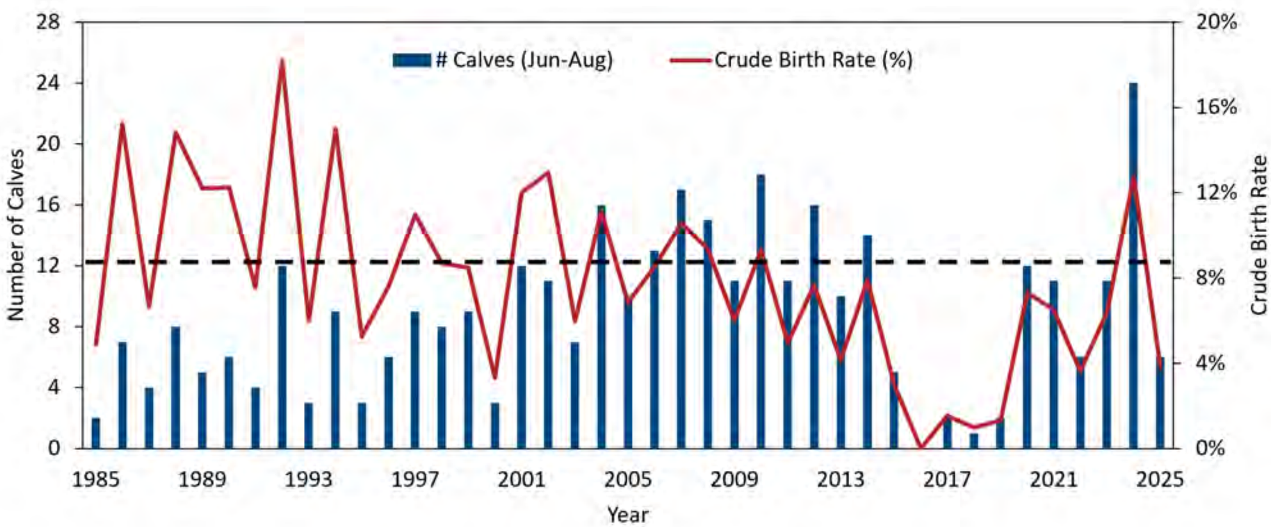

Figure 94: Annual number of calves (blue bars) and crude birth rate (CBR, red line) in Glacier Bay-Icy Strait, 1985-2025. CBR is calculated by dividing the number of calves by the total number of whales identified in June-August each year. The preliminary CBR for 2025 is 3.8% based on a preliminary whale count of 157 individually identified whales during the monitoring period. The dotted line indicates the long-term mean CBR of 9.2% observed 1985-2013, prior to the Northeast Pacific marine heatwave.

Steller Sea Lions

Contributed by Katie Sweeney and Tom Gelatt, Alaska Ecosystem Program, Marine Mammal Lab, Alaska Fisheries Science Center, NOAA Fisheries
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Last updated: August 2025

Description of indicator: Steller sea lions serve as an indicator species as a large apex, piscivorous predator that spans a broad geographic range. Depending on the area, a large portion of the Steller sea lion diet generally includes one or more of three commercial groundfish species: Atka mackerel, Pacific cod, and walleye pollock (Sinclair et al., 2013; Fritz et al., 2019; Maniscalco, 2023).

In Alaska, Steller sea lions span the southern coastline from southeast Alaska to the western Aleutian Island chain, and into some sites in the Bering Sea (Young et al., 2024). The species is divided into two populations at the 144°W longitudinal line (near Cape Suckling): the eastern and western Distinct Population Segments (DPSs). The Gulf of Alaska (GOA) geographic area is comprised of four Steller sea lion regions: eastern, central and western GOA regions (western DPS), and southeast Alaska region (eastern DPS; Figure 95). The range of eastern DPS Steller sea lions extends from southeast Alaska and down along the west coast of Canada and the United States.

During the non-breeding season, sea lions disperse and can move widely throughout the North Pacific Ocean, especially juveniles and males. During the summer breeding season, sea lions aggregate on land, usually at their natal rookery site, to breed and give birth. The Marine Mammal Laboratory (MML) conducts annual population surveys during the peak of the breeding season to collect counts throughout the population range in Alaska[30]. Generally, survey effort in Alaska alternates between the GOA and Aleutian Islands. Challenging survey logistical factors and weather can result in sites being missed. MML uses the R package agTrend (Johnson and Fritz, 2014; Gaos et al., 2021) to interpolate counts for the missed sites and model estimated counts (an index of population abundance) and trends for defined geographic areas.

A note about agTrend model outputs—MML does not report abundance estimates but rather agTrend derived modeled counts (an index of population abundance) and trends. The model outputs do not account for non-pups (juveniles and adults) at-sea during the survey. As pups do not take to the water until they are older (>1 month), pup counts are considered a census but do not account for pups that were born or died after the survey. Adding non-pup to pup counts represents a minimum population estimate (N_{min}; Young et al., 2024).

Two types of estimates are generated with agTrend and generally MML reports predicted counts and trends unless otherwise indicated:

1. Realized counts—Uses the standardized variance of raw counts at each site throughout the time series to estimate survey counts we could expect to collect if we had completely surveyed all sites. Therefore, the more complete the survey, the more similar raw counts are to realized counts. When available, MML uses realized counts that have not been "smoothed" (i.e., predicted counts) to report on changes over time. 2. Predicted counts—Uses the model fit to estimate count values that would be predicted at a site in a given year if it were surveyed. For trend analyses, predicted counts are more

[30] https://www.fisheries.noaa.gov/alaska/marine-mammal-protection/steller-sea-lion-survey-reports

appropriate because they account for both measurement and process error.

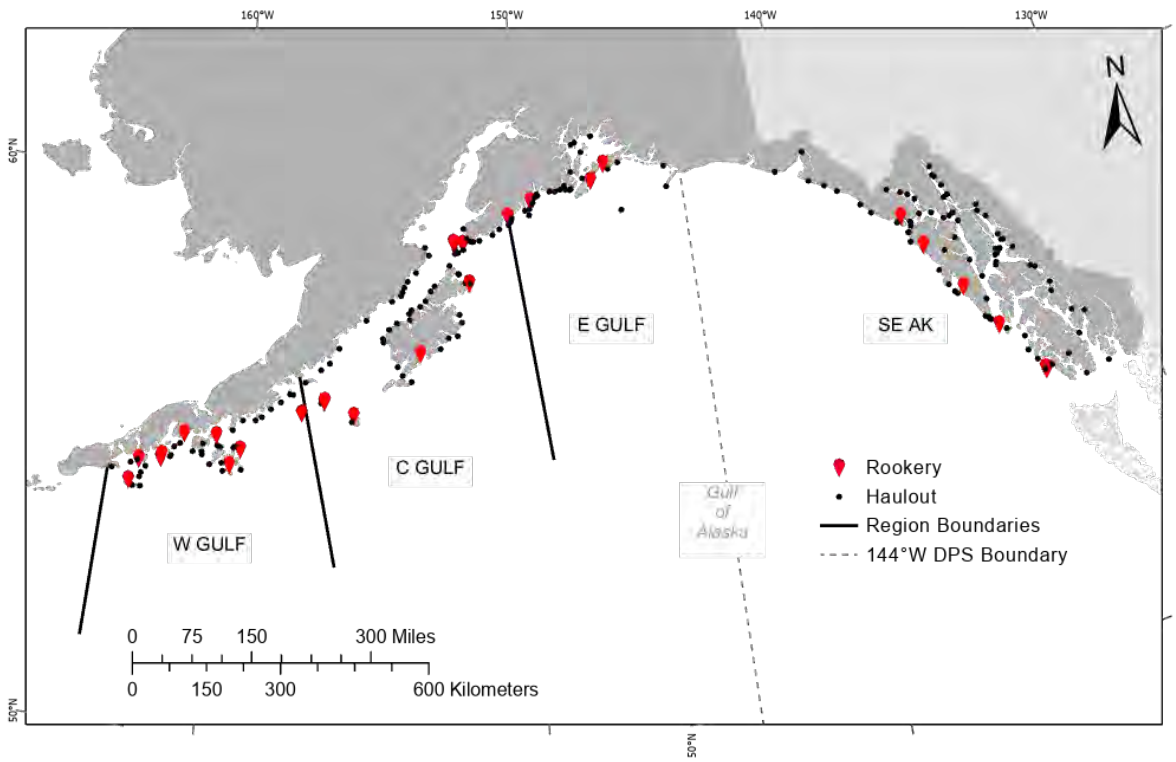

Figure 95: Map of Steller sea lion known rookery and haulout sites in the western (W), central (C), and eastern (E) Gulf of Alaska (GULF) regions and southeast Alaska (SE AK, eastern DPS; (Fritz et al., 2016*a*)).

Status and trends: In 2024, MML conducted a crewed aircraft survey in the GOA (Sweeney et al., 2025). The southeast Alaska region was not included in order to focus effort towards a complete survey of all three GOA regions in the western DPS given this area had not been surveyed since 2021. The 2025 crewed aircraft survey was cancelled due to budget limitations, which was the first time in 22 years this survey was not conducted (with exception of in 2020 which was cancelled due to COVID).

Steller sea lion population declines were first recorded in the 1970s, with the steepest beginning in the mid-1980s (Fritz et al., 2016*b*). The total western DPS in Alaska began to rebound in 2002, however, there are contrasting regional trends throughout. West of Samalga Pass, sea lions have shown no signs towards recovery and continue to decline or remain stable. The GOA regions began to increase in the early 2000s and maintained relatively steady rates of increase until anomalous trends began to be recorded in 2017, initiated by the 2014 – 2016 Pacific Marine Heatwave (PMH; McHuron et al., 2024; Suryan et al., 2021; Sweeney et al., 2017. Hastings et al. (2023) reported reduced survival during and after the PMH from brand data in the central and eastern GOA regions.

Modeling all count data through 2025 (unpublished data, MML), we report modeled counts and trends from 2010 to 2015. This is the first time western DPS non-pups in Alaska have been statistically stable (0.62% y^{-1}; 95% confidence interval [CI] -0.05 – 1.30) since the population began to rebound in the early 2000s (Table 3). The Alaskan western DPS pup counts increased 0.69% y^{-1} (95% CI 0.10 – 1.29), between 2010 and 2025. Overall, young juvenile survival did not vary among regions, but has gradually decreased over time (Warlick et al., 2023).

The following analyses were derived from modeling count data up to and including the 2024 Steller sea lion count surveys (Sweeney et al., 2025). Between 2009 and 2024, the aggregated eastern, central, and western GOA regions non-pup and pup counts increased 1.68 and 1.15% y^{-1}, respectively (Figure 96). During this same time period (2009 – 2024), for the first time in the GOA since the historical decline, the eastern GOA region non-pups declined (-1.88%y^{-1}; 95% CI: -3.78 – -0.11%y^{-1}) and pups remained stable (0.16%y^{-1}, 95% CI: -1.23 – 1.59; Figure 97). Among all western DPS regions, pup survival was the lowest in the eastern GOA region (Warlick et al., 2023). In contrast, this region had the highest survival among yearlings and age-2 individuals.

For the same 15-year period, the central GOA region non-pups and pups increased (2.52 and 1.27%y^{-1}, respectively). The western GOA, a region that was previously steadily increasing and had shown relatively minimal impacts from the PMH (McHuron et al., 2024; Sweeney et al., 2017), was stable for non-pups (0.76%y^{-1}, 95% CI: -0.31 – 1.88) while pups increased (1.27%y^{-1}, 95% CI: 0.24 – 2.23).

Steller sea lion diet data is rather limited, especially in the last decade. The most recent data is from hard parts analysis from scat samples collected from 1990 to 2009 in the central and western GOA (Sinclair et al., 2013). Generally, in the winter from 1990 to 2009, sea lion diet was dominated by walleye pollock and Pacific cod, especially in the western GOA. Pacific cod and sandlance had an even greater frequency of occurrence in the 2000s. In the 1990s, summer diet in the western GOA was more diverse with salmonids, walleye pollock, and then sandlance dominating. In the 2000s, there was an increase in sandlance, Pacific cod, and rocksole. In the central GOA in the 1990s, the dominant prey species were walleye pollock, salmonids, and then arrowtooth. In the 2000s, salmonids became more important and walleye pollock declined.

Table 3: Annual rates of change (% y-1 with ±95% credible intervals [CI]) of Steller sea lion non-pup and pup counts over a 15-year period. We modeled trends for the aggregated Gulf of Alaska (GOA) and the western (W), central (C), and eastern (E) GOA regions individually (2009–2024; Sweeney et al., 2025), as well as the total western DPS in Alaska (2010–2025; unpublished data, MML).

Area/Region	Rate	Non-pup -95%CI	Non-pup -95%CI	Rate	Pup -95%CI	Pup +95%CI
GOA (Aggregated)	0.09	-0.34	0.55	0.36	-0.55	1.34
W GOA	-6.90	-7.53	-6.21	-4.34	-5.50	-3.10
C GOA	-0.83	-1.62	0.07	-0.90	-2.72	1.00
E GOA	1.90	1.35	2.41	1.69	0.73	2.67

Factors influencing observed trends: Since 2017, many studies have shown the anomalous impacts to Steller sea lion counts, survival, pup production, diet, and potentially movement, caused by the PMH (Suryan et al., 2021; McHuron et al., 2024; Hastings et al., 2023; Maniscalco, 2023; Warlick et al., 2023). There was an observed reduction in pup production in the eastern (33.5%) and central (17.4%) GOA regions in 2017 (compared to 2015), with less significant declines observed in southeast Alaska (McHuron et al., 2024). Pup production in the eastern and central GOA rebounded in 2019, suggesting failure to pup was also a contributing factor (McHuron et al., 2024). Reductions in pup production

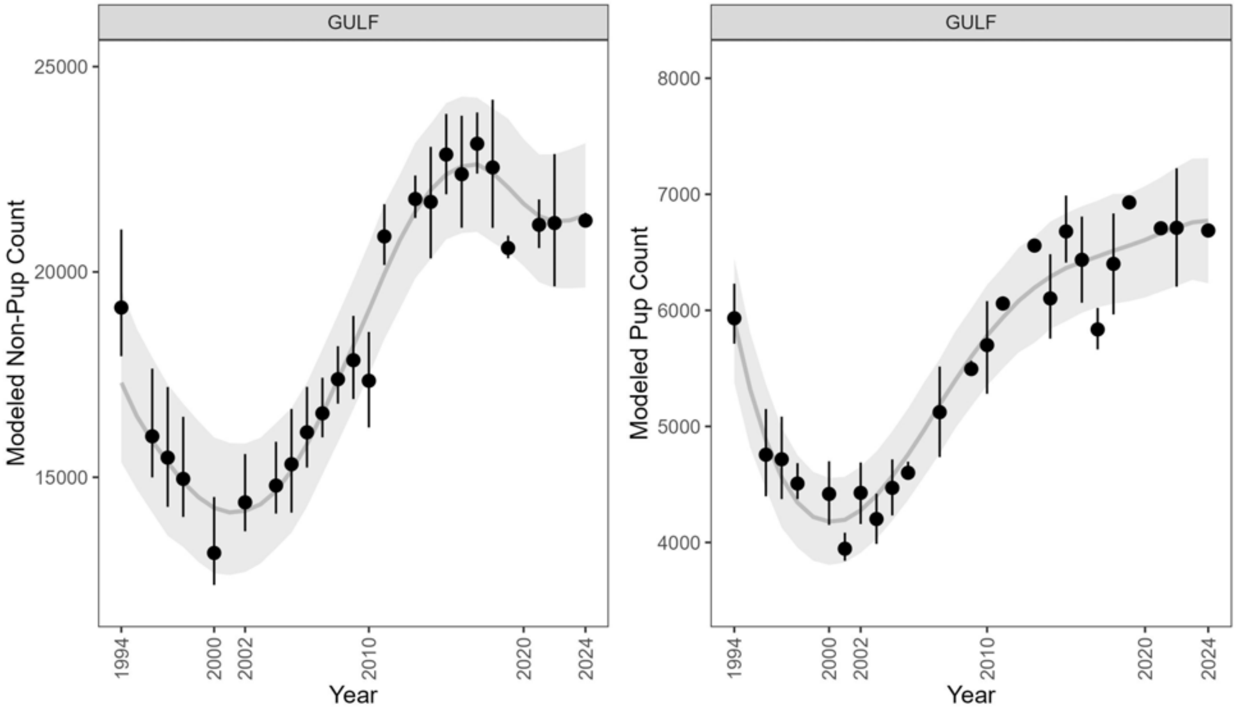

Figure 96: Steller sea lion modeled non-pup and pup counts of the aggregated regions within the Gulf of Alaska (GULF), 1994–2024 (Sweeney et al., 2025). Realized counts are represented by points and vertical lines (±95% credible intervals). Predicted counts are represented by the gray line and shaded area (±95% credible intervals).

typically result from failure to become pregnant, termination of the fetus during pregnancy, or female mortality. Hastings et al. (2023) found evidence of reduced adult female survival in these three regions. (Warlick et al., 2023) reported that generally, pup production has decreased over time in the western DPS.

These changes in population dynamics correspond to changes in abundance and quality of important sea lion prey species in the area (Maniscalco, 2023; Suryan et al., 2021), such as, Pacific cod (abundance declined 53% from 2016 to 2017 and 71% between 2015 and 2017 (Barbeaux et al., 2020*b*), capelin, sandlance, and herring (McHuron et al., 2024). Prey availability in winter is thought to be a key factor in energy budgets of sea lions, especially for pregnant females and those supporting a pup and/or juvenile (National Marine Fisheries Service, 2013). Females have smaller blubber stores than males and require more accessible availability of prey to sustain themselves, their fetus, and/or their pup or juvenile (Boyd, 2000; Malavaer, 2002; Winship et al., 2002; Williams, 2005).

Most recently, Maniscalco (2023) collected scat samples during the winter from sites in the eastern GOA region (in the vicinity of Resurrection Bay and Chiswell Island) from 2014 – 2015 and 2017 – 2018 ("post-PMH"). The most notable prey species found at a higher rate post-PMH were polychaetes, Pacific sandlance, sculpins, skates, and snailfishes, while capelin was much less frequent followed by Pacific herring and walleye pollock (Maniscalco, 2023). Maniscalco (2023) observed a 12% increase in diet diversity post-PHW; inversely, sea lion counts at the sampling sites declined 33%. This suggested that a change to a more diverse diet negatively impacted abundance. Summer breeding season counts and population demographics indicated sea lions (likely adult females and juveniles) atypically moved

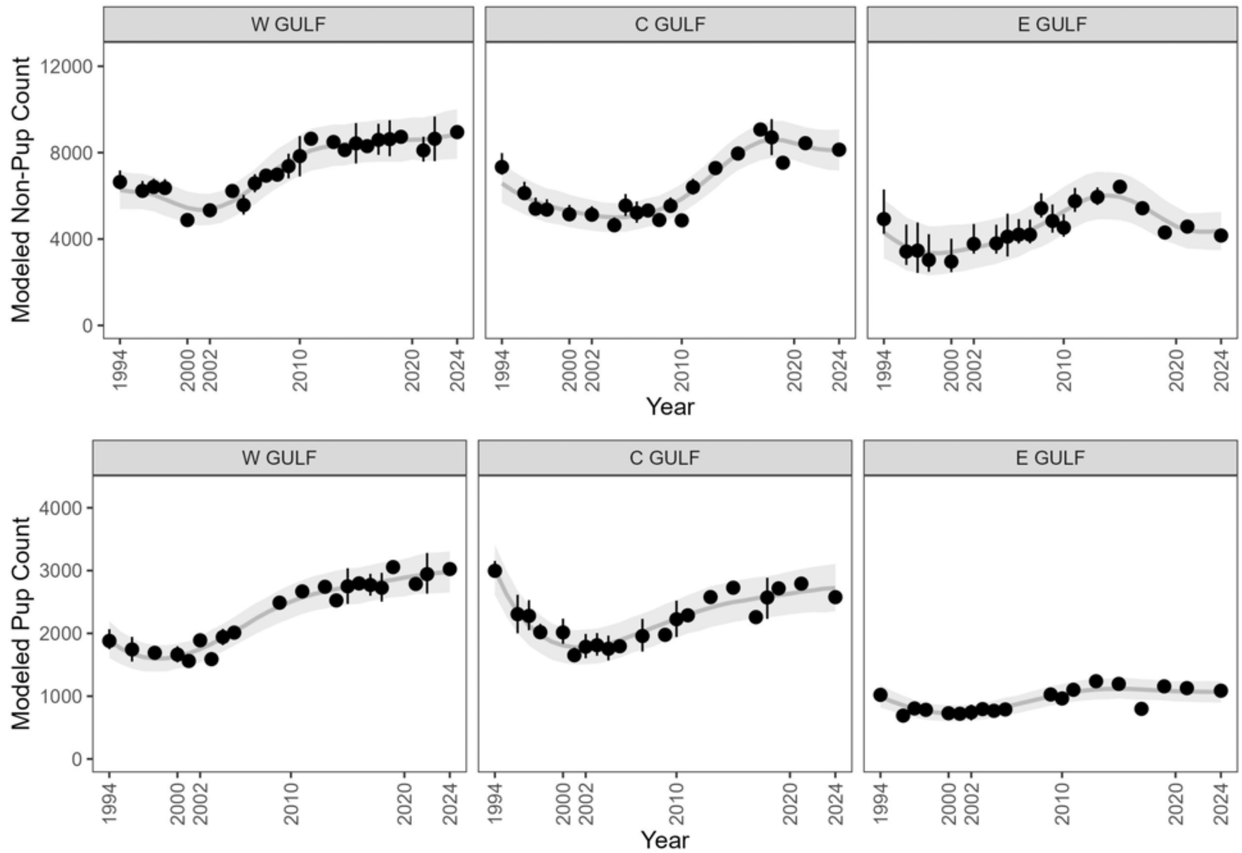

Figure 97: Steller sea lion modeled non-pup and pup counts of the western (W-), central (C-), and eastern (E) Gulf of Alaska (GULF) regions, 1994–2024 (Sweeney et al., 2025). Realized counts are represented by points and vertical lines (±95% credible intervals). Predicted counts are represented by the gray line and shaded area (±95% credible intervals).

from the eastern to the central GOA between 2015 and 2017 (Sweeney et al., 2017; McHuron et al., 2024).

Implications: The NOAA Fisheries western DPS Steller sea lion 5-year review in 2020 sustained the endangered listing status, largely driven by declines in the Aleutian Islands, incomplete information of the Russian subpopulation, and the uncertainty of the cause of declines (Service, 2020). Another 5-year plan is currently being conducted by the NOAA Fisheries Alaska Regional Office. As an endangered species, the status of Steller sea lions has potential to impact and influence fishery management decisions. The stability of non-pups in the western DPS in Alaska, continued declines in the Aleutian Islands, and perturbations in the GOA since 2017 prove that this endangered population is still sensitive and susceptible to threats. Further and continued research into the future is necessary to understand survival, pup production, movements, diet, and counts of this endangered population.

Ecosystem or Community Indicators

Intertidal Ecosystem Indicators in the Northern Gulf of Alaska

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Description of indicator: Nearshore monitoring in the Gulf of Alaska (GOA) provides ongoing evaluation of status and trends of more than 200 species associated with intertidal and shallow subtidal habitats (Suryan et al., 2023). The spatial extent of sampling includes 21 sites distributed across four regions in the northern GOA: western Prince William Sound (WPWS), Kenai Fjords National Park (KEFJ), Kachemak Bay (KBAY), and Katmai National Park and Preserve (KATM). Since 2018, we have reported on one physical indicator (intertidal water temperature; U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska - Inventory and Monitoring Network, and University of Alaska Fairbanks - College of Fisheries and Ocean Sciences, 2016) and three biological indicators monitored annually beginning in 2005 – 2012. Respectively, these indicators represent key nearshore ecosystem components of primary production (algal cover; U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska Inventory and Monitoring Network, 2022), prey abundance (mussel density; U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska Inventory and Monitoring Network, 2016), and predator abundance (sea star density; U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska Inventory and Monitoring Network, 2022). The algal cover indicator used is percent cover of rockweed (*Fucus distichus*) in quadrats sampled at the mid intertidal level (1.5 m). Intertidal prey are represented by density estimates of large ($\geq$ 20 mm) Pacific blue mussels (*Mytilus trossulus*) sampled quantitatively within mussel beds. The nearshore predator abundance indicator is density of sea stars, estimated along an approximately 200 m ^{2} transect at each rocky intertidal monitoring site. Indicators are presented as annual anomalies compared to the long-term mean of the data record, which is an average across sites within each region. KEFJ was not sampled in 2025 due to the lack of staffing and resources available.

Status and trends: In 2025, at the time of data collection (mid-summer), the three regions sampled (WPWS, KBAY, KATM) remained warmer than average. In the past, nearshore water temperature across the GOA from Prince William Sound to the Alaska Peninsula were elevated from 2014 through 2016 across all regions and into 2017 in WPWS and KEFJ (Figure 98). These results confirm that the 2014-2016 Pacific marine heatwave (PMH) in the GOA was expressed in intertidal zones in addition to known patterns in open ocean environments (Danielson et al., 2022). While temperatures returned to cooler conditions in 2017, another heat spike was recorded in all regions starting in 2018, which was punctuated with a brief cooling across all regions in 2020, although highly variable with more pronounced cooling in KATM and KBAY and minimal cooling in WPWS and KEFJ. Warming then continued through 2020 in all regions until 2021. In general, it has been anomalously cool or close to average temperatures across all four regions (except for a warm period that was short in duration in 2022) since 2021. However, the first half of 2025 (time of data logger retrieval), all regions were anomalously warm. In addition, higher among-region temperature variability persists, which was not observed prior to the heat wave.

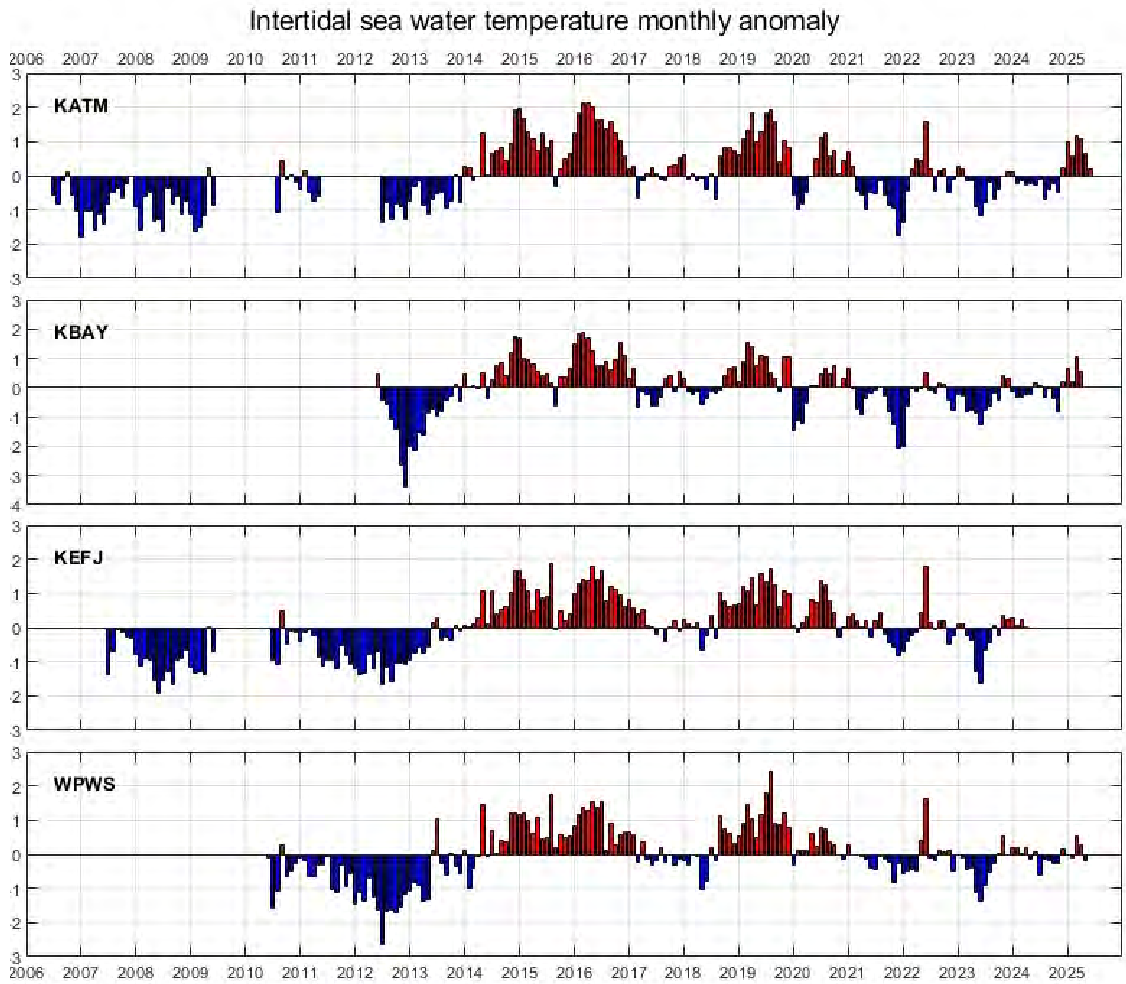

Figure 98: Monthly intertidal water temperature anomalies at the 0.5 m tide level four regions of the western Gulf of Alaska (west of 144˚W), western Prince William Sound (WPWS; 2011 – 2025), Kenai Fjords National Park (KEFJ; 2008 – 2024), Kachemak Bay (KBAY; 2013 – 2025), and Katmai National Park adjacent to Shelikof Strait (KATM; 2006 – 2025). 2025 data included are January to June for KATM, January to April for KBAY, and Jan-May for WPWS. KEFJ was not sampled in 2025. Data are available in U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska Inventory and Monitoring Network (2016).

Of the three regions sampled in 2025, only KATM had above-average percent cover of *Fucus*. The KATM region showed consistently negative values since the PMH through 2023, only becoming positive in 2024 and remaining so in 2025. KEFJ had negative anomalies that started in 2014 and ended in 2021, with 2022 – 2024 being positive; however, KEFJ was not sampled in 2025. *Fucus* in WPWS has had negative values since 2016 (except for 2019), which have persisted through 2025. KBAY did not show any specific trend over time with roughly average *Fucus* cover without a noticeable response to temperature fluctuations. However, it should be noted that in all regions, the variability around the mean appears to be decreasing among regions during more recent years (Figure 99).

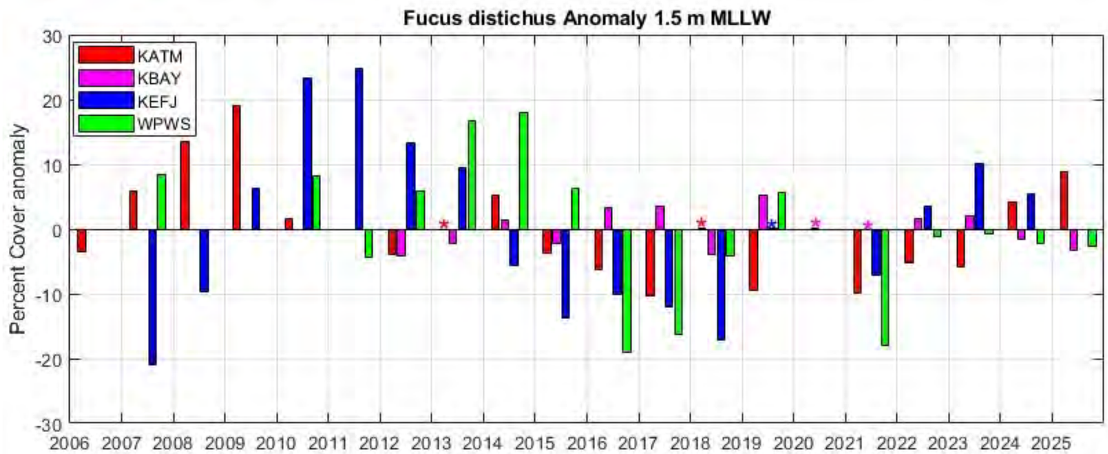

Figure 99: Percent cover anomalies for rockweed (*Fucus distichus*) in four regions of the western Gulf of Alaska, WPWS (2007, 2010 – 2019, 2021 – 2025), KEFJ (2008 – 2019, 2021 – 2024), KBAY (2012 – 2025), and KATM (2006 – 2010, 2012 – 2019, 2021 – 2025). WPWS, KEFJ and KATM were not sampled in 2020 due to COVID-19. KEFJ was not sampled in 2025. Note: years when anomalies are very close to zero and bars are not clearly visible are indicated by an asterisk. Data are available in U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska Inventory and Monitoring Network (2022).

In 2025, large mussel densities ($\geq$ 20 mm) in all three regions sampled had negative anomalies compared to long-term means (Figure 100). However, trends in densities of large mussels were variable across the regions. For example, KATM experienced negative anomalies in the density of large mussels, concurrent with positive to strongly positive anomalies in sea star abundance. This trend continued through 2025 (Figures 100 and 101). Patterns in the other regions are less clear. KBAY had positive large mussel anomalies through 2023 but had strongly negative anomalies in 2024 and 2025. Conversely, WPWS was the only region in 2024 with a positive large mussel anomaly, the first positive anomaly observed in this region since 2018 (Figure 100), but negative in 2025. Historically, large mussel densities ($\geq$ 20 mm) showed an overall positive trend across regions consistent with timing of the PMH, in this case switching from generally negative prior to 2014 to positive for the regional long-term mean after 2014 (Figure 100); this is an opposite response compared to algal cover and sea stars (Figures 99 and 101). Variability in mussel abundance at these regional spatial scales supports our conclusion that, in the absence of broad-scale perturbations like the PMH or SSW, other variables and local conditions become the primary drivers of mussel abundance (Bodkin et al., 2018; Traiger et al., 2022; LaBarre et al., 2007).

In 2025, sea star density, species distribution and size distributions were measured in three of the four regions. A slight negative density anomaly was observed in WPWS in 2025. However, positive density anomalies indicated that KBAY was far above average compared to the long-term mean density. KATM density continues to be strongly positive through 2025 as well (Figure 101).

Data from 2025 also showed that variability in sea star composition among (and within) regions has

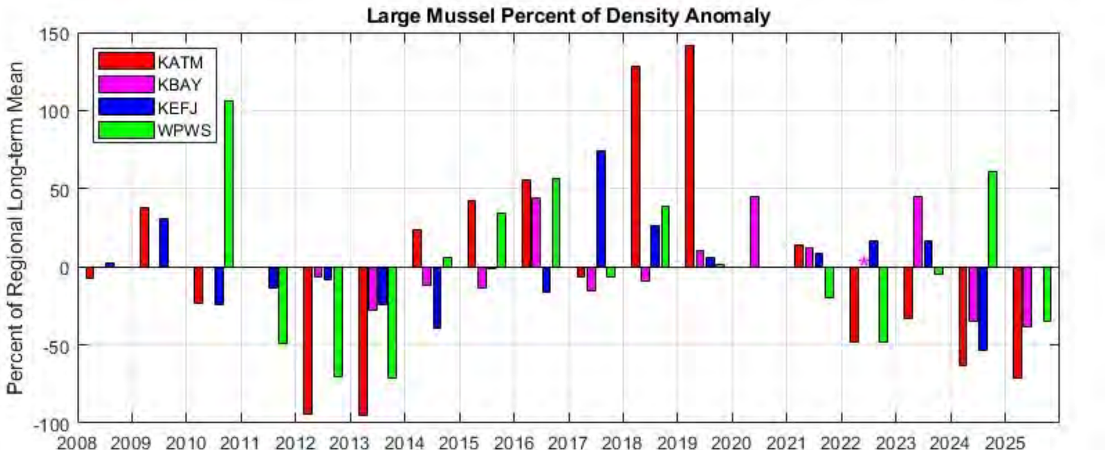

Figure 100: Percent of density anomalies for large mussels ($\geq$ 20 mm) in four study regions spanning the northern Gulf of Alaska. WPWS (2010 – 2019, 2021 – 2025), KEFJ (2008 – 2019, 2021 – 2024), KBAY (2012 – 2025), and KATM (2008 – 2010, 2012 – 2019, 2021 – 2025). Note: KBAY anomaly in 2022 was close to 0, hence the lack of clearly visible bar for KBAY in 2022 (symbolized by an asterisk in 2022). KEFJ was not sampled in 2025. Data are available in U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska Inventory and Monitoring Network (2016).

increased. In KATM, *Evasterias* previously dominated the sea star assemblage with 66% in 2024 but was only 46% in 2025 and *Pisaster* accounted for 45% (up from 32% in 2024). In WPWS, *Dermasterias* continues to be the dominant species with 65% (an increase from 54% in 2024) followed by *Pycnopodia* at 26% (down from 32% in 2024), *Evasterias* at 6% (down from 10% in 2024), and *Pisaster* continuing at 4%. In KBAY, sea star densities were the highest recorded since monitoring began in KBAY, although it should be noted that this was mostly driven by a single site in this region (Elephant Island). Orthasterias was proportionally dominant at 64% in 2023, but that proportion declined to 8% in 2024 and 7% in 2025. *Evasterias* dominated the observed sea star assemblage in 2025 with 90% (up from 83% in 2024 and a significant increase from 14% in 2023). Historically, variability in density and species composition of sea stars differed greatly among regions through 2015. Starting between 2015 and 2017, densities declined and remained strongly negative across all regions through 2019 (Figure 101), with average to below-average densities continuing through 2021. Declines were likely due to sea star wasting (Konar et al., 2019), possibly exacerbated by the PMH (Harvell et al., 2019). 2024 was the first and only year since monitoring began that all four regions exhibited positive anomalies, although to varying degrees. Variability in the sea star assemblage among regions and across years within regions may be an indication of the ecosystem returning to one dominated by local-scale conditions as opposed to being driven by large-scale perturbations such as sea star wasting and the PMH.

Factors influencing observed trends: During the PMH, negative anomalies of *Fucus* in three of the four regions and negative anomalies of sea stars across all regions were coincident with warm water temperatures in nearshore areas. The decline in sea star abundance across the Gulf was likely due to sea star wasting (Konar et al., 2019), first detected south of Alaska in 2013 and generally thought to be exacerbated by warm water temperature anomalies (Eisenlord et al., 2016; Harvell et al., 2019). Recent work by Prentice et al. (2025) determined the bacterium, Vibria pectenicida, as the causative agent of SSW. This finding may allow researchers to determine the persistence of V. pectenicida in the environment and examine what conditions (such as warming waters) may increase transmission. Warming waters and concurrent declines in sea stars were associated with increased mussel densities across our study

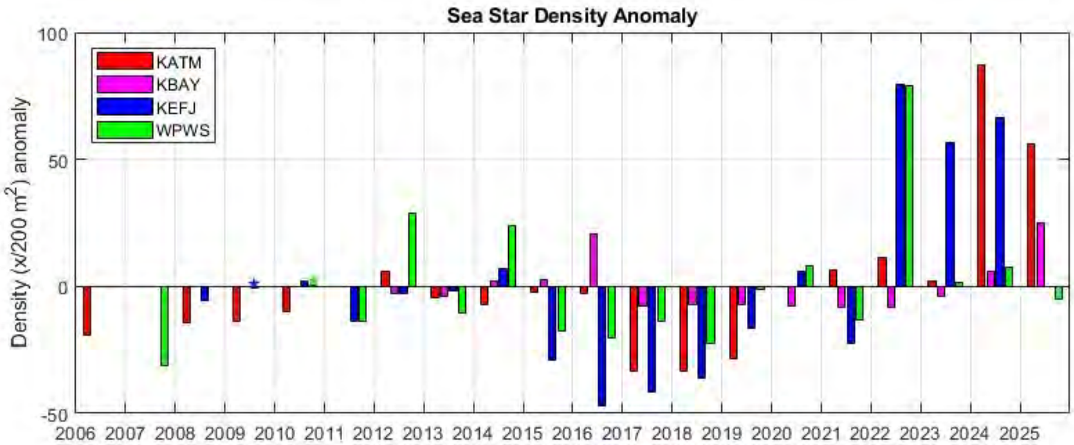

Figure 101: Density anomalies of sea stars (primarily *Dermasterias imbricata*, *Evasterias troschelii*, *Pisaster ochraceus*, and *Pycnopodia helianthoides*) in four study areas spanning the northern Gulf of Alaska. WPWS (2007, 2010 – 2025), KEFJ (2008 – 2019, 2021 – 2024), KBAY (2011 – 2025), and KATM (2006, 2008 – 2010, 2012 – 2019, 2021 – 2025). KEFJ was not sampled in 2025. Note: years when anomalies are very close to zero and bars are not clearly visible are indicated by an asterisk. Data are available in U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska Inventory and Monitoring Network (2022).

regions (Traiger et al., 2022), with a general trend of algal dominated systems turning more into invertebrate dominated systems (Weitzman et al., 2021). This pattern is similar to those observed in other rocky intertidal systems of the North Pacific following the recent large-scale temperature perturbations (Meunier et al., 2024). However, as nearshore waters appeared to cool starting in 2021, large increases in *Fucus* percent cover in KBAY and WPWS have not occurred (Figure 99). KATM is the exception, with *Fucus* increasing in 2024-2025, after negative anomalies being observed since 2014. Nearshore data indicated that the first half of 2025 had anomalously warm water temperatures in the intertidal. It is unknown whether this warm water pattern will persist and what ecosystem responses may occur. Even with average to low cover of *Fucus* continuing to provide open space for mussel settlement, high densities of large mussels have not persisted through time. Higher densities of sea stars have occurred in recent years, but further examination of species distribution and size distribution may provide insights as to changes in community structure. We have documented that these nearshore communities can be driven by large-scale perturbations such as the PMH and SSW with similar responses across the GOA. We have also documented diverse community structure under local conditions, in the absence of large-scale perturbations.

Implications: Collectively, these indicators suggest that in the presence of large-scale perturbations, responses in the nearshore community tend to be consistent throughout much of the western GOA, including areas both inside (WPWS, KBAY) and outside (KEFJ and KATM) of protected marine waters. As noted, a comprehensive analysis of rocky intertidal community structure was completed post-PMH, indicating a change of autotroph-macroalgal dominated communities to heterotroph-filter-feeder communities, ultimately resulting in a homogenization of community structure across all four regions (Weitzman et al., 2021). Concurrently, we found that the loss of sea stars likely contributed to the increase in large mussel density due to a decline in predation pressure from sea stars (Traiger et al., 2022). However, as large-scale perturbations subside, we hypothesize that nearshore communities will tend to be structured by more local-scale conditions. With warming again evident in 2025 across all regions sampled, we may observe consistent community responses across the GOA.

Intertidal and nearshore ecosystems provide valuable habitat for early life stages of various commercially important species in the GOA, including Dungeness crab (*Metacarcinus magister*), Pacific cod (*Gadus macrocephalus*), salmonids, and several species of rockfish (*Sebastes* spp.). Our indicators suggest that some nearshore biological responses to the PMH appeared to continue into 2021 in some regions and could have affected recruitment and survival of species whose life stages rely on nearshore habitat. For some metrics, evidence of a return to more average conditions in nearshore habitats suggests that PMH effects, both positive and negative, are dissipating. A major pattern that is emerging, however, is that the differences in abundance for these biological indicators across regions appear to be larger than they were before the PMH. Marine heatwaves are expected to become more common and widespread as a consequence of climate change (Frölicher et al., 2018) and synergistic phenomena, like invertebrate disease outbreaks, predation and marine heatwaves may also drive apparent shifts in rocky intertidal communities (Meunier et al. 2024). Furthermore, we also hypothesize that in the long-term, we may see responses of nearshore-reliant, upper trophic level species (such as sea otters and sea ducks) to shifts in prey availability from changing ocean conditions across the GOA. **Disclaimer:** Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Foraging Guild Biomass

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Last updated: October 2025

Description of indicator: Foraging guilds are non-taxonomic groups of species with similar diet compositions (Root, 1967). We present time trends in biomass of two foraging guilds in the eastern and western GOA: motile epifauna and apex predators. Foraging guild biomass is based on catch data from the NMFS/AFSC biennial summer bottom-trawl survey of the GOA shelf and upper continental slope, modified by an Ecopath-estimated catchability coefficient that takes into account the minimum biomass required to support predator consumption (see Appendix 1 in Boldt, 2007 for complete details). The GOA groundfish survey was conducted on a triennial basis from 1984 through 1999. Starting in 2001 the survey has been conducted on a biennial basis; however, the eastern GOA was not surveyed in 2001. Surveys prior to 1990 preceded some of the standardized survey practices, therefore those survey years are not included in this indicator. The foraging guild biomasses are reported separately for the western and eastern GOA. We use the division between the Kodiak and West Yakutat sub-regions in the AFSC bottom trawl survey strata to separate the western and eastern GOA, which aligns with the ESR regions and NPFMC regulatory area divisions.

In 2025, the AFSC implemented new survey strata for the GOA bottom trawl survey and reduced the total survey area by 1.4%. Several stations where successful hauls had been conducted over the time series were included in the trimmed stratum areas and are no longer a part of this index. The new strata have different depth distributions than the previous strata design, resulting in different stratum areas. For example, the shallowest strata in previous design extended to a depth of 100 m, while in the updated design the shallowest strata extends down to 50 m, in most survey sub-regions (e.g., Shumagin, Chirikof). Previously, we limited trawl survey data included in this survey index to stations less than 500 m depth, due to fewer stations having been sampled in deeper strata, and those strata having not been sampled in all years a survey was conducted. With the new strata design it is no longer practical to use this same maximum depth cutoff. Thus, we now limit stations included to those $<$ 701 m depth. Collectively, these differences represent a discontinuity in this survey index. Therefore, in the figures we do not connect the 2025 data point to 2023 with a line to highlight these changes.

Status and trends: Motile epifauna in the east GOA is below the long-term mean, while motile epifauna in the west GOA is nearly equal their long-term mean (Figure 102). Apex predators in the west GOA are below their long-term mean, while apex predators in the east are above their long-term mean (Figure 102).

Western GOA Motile epifauna: The biomass of motile epifauna increased from 2021 to 2025 and is just above the long-term mean (1990 – 2025). The biomass of this guild is dominated by hermit crabs, brittle stars, other echinoderms, and octopus. In 2025, hermit crab biomass increased 20%, while brittle

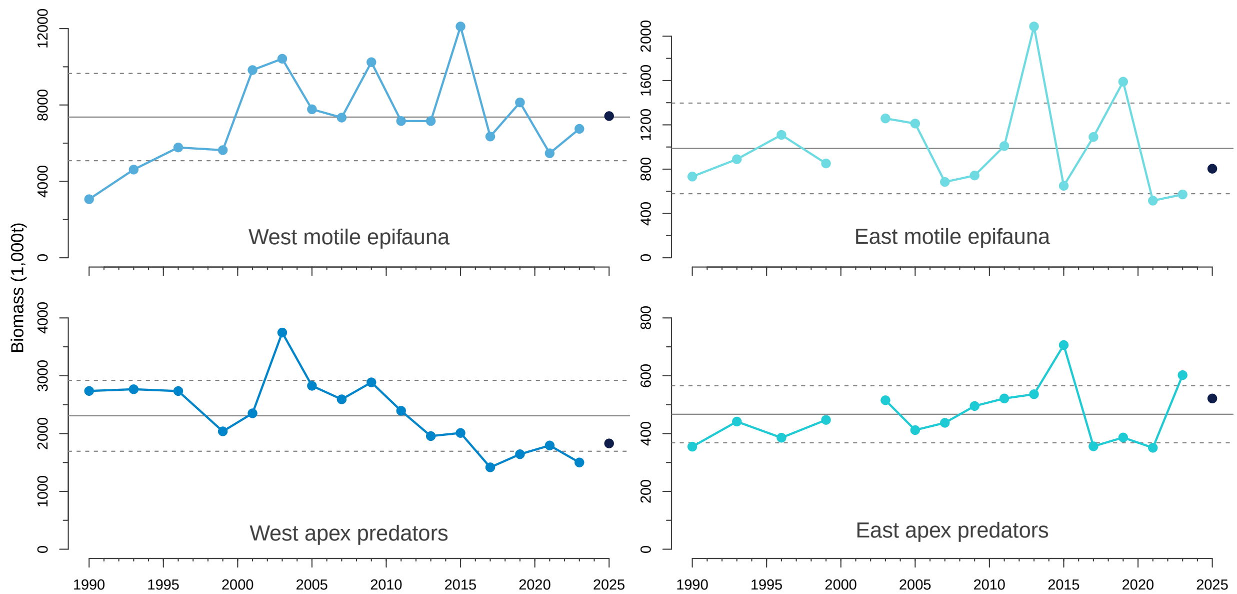

Figure 102: Biomass trends of motile epifauna and apex predator foraging guilds in the western and eastern GOA. The 2025 point not connected to 2023 with a line due to changes in survey methodology (data from the NMFS AFSC biennial summer bottom trawl survey). The dashed line is the long-term mean and solid straight lines are ± 1 standard deviation.

stars and other echinoderms decreased by 6% and 1%, respectively.

Western GOA Apex predators: The biomass of apex predators in the western GOA increased 22% from 2023 to 2025 and is within one standard deviation below the long-term mean. The biomass trends for apex predators are primarily driven by arrowtooth flounder, Pacific cod, Pacific halibut, and sablefish. All four species are below their long-term means. However, arrowtooth flounder, Pacific halibut, and Pacific cod all increased from 2023 to 2025.

Eastern GOA Motile epifauna: The biomass of motile epifauna in the eastern GOA has increased from 2023 to 2025 and is below the long-term mean. Eelpouts, hermit crabs, brittle stars, and other echinoderms are dominant components of this guild. Brittle stars, hermit crabs, and other echinoderms have increased from 2023 to 2025.

Eastern GOA Apex predators: The biomass of apex predators in the eastern GOA has decreased 13% from 2023 to 2025 and is above the long-term mean. Apex predator biomass in the eastern GOA is primarily driven by arrowtooth flounder and Pacific halibut. From 2023 to 2025, arrowtooth flounder biomass increased by 13% while Pacific halibut decreased by 51%.

Factors influencing observed trends: The 2014–2016 marine heatwave followed by multiple years of moderately warm conditions has had lasting impacts across trophic levels in the GOA (Suryan et al., 2021) and may be a contributing factor in the current lower apex predator biomass in the western GOA. The marine heatwave was a major perturbation to pelagic primary and secondary production throughout the GOA altering phenology, community composition, and abundance at lower trophic levels (Batten et al., 2018; Suryan et al., 2021). These changes may have impacted the abundance and energetic content of key pelagic forage fish that are critical prey to apex predators (Arimitsu et al., 2021). Pacific cod are a prominent component of the apex predator guild in the GOA. The marine heatwave and its attendant ecosystem effects reduced the amount of suitable spawning and larval habitat for Pacific cod, increased their metabolic demands, and reduced the quantity and quality of prey available to Pacific cod helping explain their low abundance in the years following the heatwave (2017 – 2021) (Barbeaux et al., 2020*b*; Laurel and Rogers, 2020; Laurel et al., 2021).

Apex predators in the western GOA have remained well below their long-term mean while there was a sharp increase in apex predators in the eastern GOA in 2023 to well above their long-term mean. Arrowtooth flounder are a primary driver of the apex predator foraging guild in both the western and eastern GOA, accounting for 57% and 65% of apex predator biomass in 2025 respectively, and their biomass trends help explain the guild trends. In the western GOA, arrowtooth increased from 2023, while in the eastern GOA their biomass decreased.

The motile epifauna guilds in both eastern and western GOA are within one standard deviation of their long-term means. Interannual variation in motile epifauna biomass is primarily driven by short-term fluctuations in dominant groups, including hermit crabs, brittle stars, other echinoderms, and eelpouts.

Implications: The biomass of apex predators in the western GOA has remained low in the years since the marine heatwave warrants continued monitoring of apex predator status and the status of key prey groups.

Stability of Groundfish Biomass

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Last updated: October 2025

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

The biomass index for groundfish species was calculated from the catch of the NMFS/AFSC biennial summer bottom-trawl survey of the Gulf of Alaska (GOA). Initially, the GOA groundfish survey was conducted on a triennial basis from 1984 through 1999. Starting in 2001 the survey has been conducted on a biennial basis; however, the eastern GOA was not surveyed in 2001. Surveys prior to 1990 preceded some of the standardized survey practices, therefore those survey years are not included in this indicator. Since 10 years of data are required to calculate this metric, the indicator values start in 2011 for the western GOA and in 2013 for the eastern GOA, the tenth time the regions were surveyed in the trawl survey time series (1990 – 2023).

In 2025, the AFSC implemented new survey strata for the GOA bottom trawl survey and reduced the total survey area by 1.4%. Several stations where successful hauls had been conducted over the time series were included in the trimmed stratum areas and are no longer a part of this index. The new strata have different depth distributions than the previous strata design, resulting in different stratum areas. For example, the shallowest strata in previous design extended to a depth of 100 m, while in the updated design the shallowest strata extends down to 50 m, in most survey sub-regions (e.g., Shumagin, Chirikof). Previously, we limited trawl survey data included in this survey index to stations less than 500 m depth, due to fewer stations having been sampled in deeper strata, and those strata having not been sampled in all years a survey was conducted. With the new strata design it is no longer practical to use this same maximum depth cutoff. Thus, we now limit stations included to those $<$ 701 m depth. Collectively, these differences represent a discontinuity in this survey index. Therefore, in the figures we do not connect the 2025 data point to 2023 with a line to highlight these changes.

This indicator specifically applies to the portion of the demersal groundfish community efficiently sampled with the trawling gear used by NMFS during the summer bottom-trawl survey of the GOA (for complete survey details see Siple et al., 2024). Species that are predominately found in the pelagic environment (e.g., capelin, pelagic smelts), are infrequently encountered (e.g., sharks, grenadiers, myctophids), or otherwise not efficiently caught by the bottom-trawling gear are excluded from this indicator. The survey index used here is the same as that used for the foraging guild biomass indices in the "Foraging Guild Biomass" contribution (Whitehouse in this Report, p.189) and in the report card (not produced in 2025).

Several species of pelagic forage fishes are abundant in the GOA and their populations may vary substantially which could drive the value of this indicator. While many species of pelagic forage fish are occasionally encountered during the survey, most are not consistently sampled well enough to be included in the survey index, such as sandlance, capelin, and other pelagic smelts. Herring and eulachon are included in the survey index, so this indicator is presented with and without herring and eulachon to highlight their influence on indicator value.

Status and trends: The stability of groundfish biomass in the western Gulf of Alaska is at a time series high for the series with eulachon and herring and near the time series high for the series without herring and eulachon (Figure 103, circles). Both series have generally trended upward since 2007. When herring and eulachon are removed, this indicator has slightly higher values from 2007 – 2017 (Figure 103, triangles), and follows the same overall trends of the indicator with herring and eulachon. From 2019 to 2023, the series with eulachon and herring has higher stability.

In the eastern Gulf of Alaska, this indicator has been stable over the time series with only minor fluctuations between survey years (Figure 103, right panel). Over 2009–2021, when herring and eulachon are excluded from the indicator, the values are slightly lower indicating more variability in total groundfish biomass (Figure 103, right panel, triangles). In 2023 both series increased to time series high values and remain approximately equal to those values in 2025.

Factors influencing observed trends: Fishing is expected to influence this metric as fisheries can selectively target and remove larger, long-lived species effecting population age structure (Berkeley et al., 2004; Hsieh et al., 2006). Larger, longer-lived species can become less abundant and be replaced by smaller shorter-lived species (Pauly et al., 1998). Larger, longer-lived individuals help populations to endure prolonged periods of unfavorable environmental conditions and can take advantage of favorable conditions when they return (Berkeley et al. 2004). A truncated age-structure could lead to higher population variability (CV) due to increased sensitivity to environmental dynamics (Hsieh et al., 2006).

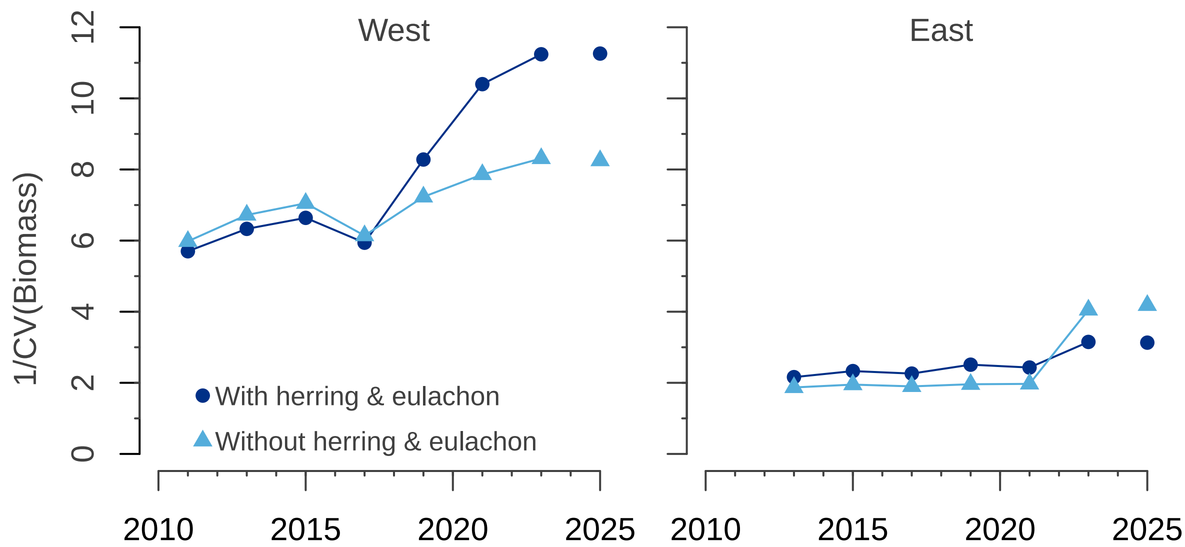

Figure 103: The stability of groundfish in the western and eastern GOA represented with the inverse biomass coefficient of variation (1/CV[B]). Ten years of data are required to calculate this metric, so this time series begins in 2011 for the western GOA and in 2013 for the eastern GOA (no survey in 2001) after the tenth occurrence of the NMFS/AFSC summer bottom-trawl survey. The circles are the series with herring and eulachon included in the index, and the triangles are the same series without herring and eulachon. The 2025 point not connected to 2023 with a line due to changes in survey methodology.

Interannual variation in this metric could also be influenced by interannual variation in species abundance in the trawl survey catch, and patchy spatial distribution for some species. This metric, as calculated here with trawl-survey data, reflects the stability of the groundfish community that is represented in the catch of the GOA summer bottom-trawl survey. In general, as total biomass decreases, species spatial distribution may contract or have increasingly isolated patches, both of which may lead to increased CV (Shin et al., 2010).

The index of groundfish stability in the western GOA with herring and eulachon included, reached its highest level in 2023, reflecting the relative stability of the groundfish biomass index in the most recent ten survey years. POP and herring are both biomass dominant species in the western GOA and have had contrasting biomass dynamics since 2017, where one species had relatively high biomass while the other was low and vice versa. The net result of these contrasting biomass dynamics was for very stable total biomass in the series with herring and eulachon included.

This indicator has lower values in the eastern GOA than in the western GOA for both series, with and without herring and eulachon. While greater variability in groundfish biomass in the eastern GOA has resulted in lower overall indicator values than in the western GOA, the level of variability has been relatively steady from 2009 to 2021, resulting in the nearly flat trajectories. There was a sharp increase in herring in the eastern GOA survey index from 2021 to 2023, which led to the series without herring surpassing the series with herring included.

Implications: The stability of groundfish biomass in the eastern GOA has been relatively constant over the time series and the stability in the western GOA has been increasing. The groundfish biomass in the eastern GOA is less stable than the west and may be more sensitive than the western GOA to perturbations.

Mean Length of the Fish Community

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Last updated: October 2025

Description of indicator: The mean length of the groundfish community tracks fluctuations in the size of groundfish over time. This size-based indicator is thought to be sensitive to the effects of commercial fisheries because larger predatory fish are often targeted by fisheries and their selective removal would reduce mean size (Shin et al., 2005). This indicator is also sensitive to shifting community composition of species with different mean sizes. Fish lengths are routinely recorded during the biennial bottom trawl survey of the Gulf of Alaska. Initially the survey was conducted on a triennial basis from 1984 to 1999 before switching to a biennial schedule in 2001; however, the eastern GOA was not surveyed in 2001. Surveys prior to 1990 preceded some of the standardized survey practices, therefore those survey years are not included in this indicator.

In 2025, the AFSC implemented new survey strata for the GOA bottom trawl survey and reduced the total survey area by 1.4%. Several stations where successful hauls had been conducted over the time series were included in the trimmed stratum areas and are no longer a part of this index. The new strata have different depth distributions than the previous strata design, resulting in different stratum areas. For example, the shallowest strata in previous design extended to a depth of 100 m, while in the updated design the shallowest strata extends down to 50 m, in most survey sub-regions (e.g., Shumagin, Chirikof). Previously, we limited trawl survey data included in this survey index to stations less than 500 m depth, due to fewer stations having been sampled in deeper strata, and those strata having not been sampled in all years a survey was conducted. With the new strata design it is no longer practical to use this same maximum depth cutoff. Thus, we now limit stations included to those $<$ 701 m depth. Collectively, these differences represent a discontinuity in this survey index. Therefore, in the figures we do not connect the 2025 data point to 2023 with a line to highlight these changes.

Species-specific mean lengths are calculated for groundfish species from the length measurements collected during the trawl survey. The mean length for the groundfish community is calculated with the species-specific mean lengths, weighted by biomass indices (Shin et al., 2010) calculated from the bottom-trawl survey catch data. The survey index used here is the same as that used in the "Foraging Guild Biomass" contribution (Whitehouse in this Report, p.189) and in the Report Card (not completed in 2025). This indicator specifically applies to the portion of the demersal groundfish community efficiently sampled with the trawling gear used by NMFS during the summer bottom-trawl survey of the GOA and have their lengths regularly sampled (for complete survey details see Siple et al., 2024). This includes species of skates, flatfishes, roundfishes (e.g., cods, sculpins, eelpouts), and rockfish. Species that are predominately found in the pelagic environment (e.g., capelin, pelagic smelts), are infrequently encountered (e.g., sharks, grenadiers, myctophids) or otherwise not efficiently caught by the bottom-trawling gear are excluded from this indicator.

Several species of pelagic forage fishes are abundant in the GOA and their populations may vary substantially which could drive the value of this indicator. While many species of pelagic forage fish are occasionally encountered during the survey, most are not consistently sampled well enough to be included in the survey index, such as sandlance, capelin, and other pelagic smelts. Herring and eulachon are included in the survey index, so this indicator is presented with and without herring and eulachon, to examine their influence on the indicator state and trends.

Status and trends: *With herring and eulachon*—The mean length of the groundfish community in the western Gulf of Alaska is 36.8 cm, down from 38.7 cm in 2023, and is below the long-term mean of 37.9 cm (Figure 104, left panel, circles). In the eastern Gulf of Alaska, the mean length of the groundfish community is 31.5 cm, down from 33.2 cm 2023, and is above the long-term mean of 30.3 cm (Figure 104, right panel circles).

Without herring and eulachon—The mean length of the groundfish community in the western GOA with herring and eulachon excluded is only slightly higher (Figure 104, left panel, triangles) than when they are included. In the eastern GOA there is a larger difference between the status of the two series, with the series without herring and eulachon being higher (Figure 104, right panel, triangles). The value in the eastern GOA in 2025 is 33 cm and is above the long-term mean of 32.4 cm.

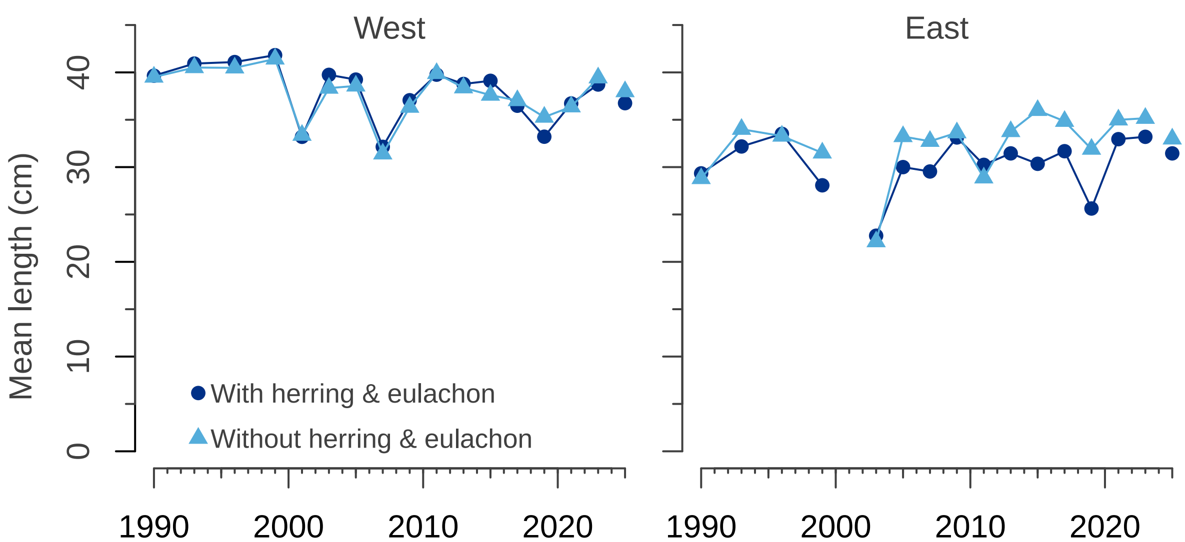

Figure 104: Mean length of the groundfish community sampled during the NMFS/AFSC summer bottom-trawl survey of the Gulf of Alaska (1990 – 2025). The groundfish community mean length is weighted by the relative biomass of the sampled species. The circles represent the indicator series with herring and eulachon included and the triangles are the indicator series without herring and eulachon. The 2025 point not connected to 2023 with a line due to changes in survey methodology.

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

Environmental factors could also influence fish growth and mean length by effecting the availability and quality of food, or by direct temperature effects on growth rate. The decline in this indicator from 2015 to 2019, in both series in both the western and eastern GOA coincided in time with the "blob" marine heatwave. The indicator values in all four series have increased since 2019.

Fluctuations in this indicator are in part due to variation in the biomass indices of forage species who have shorter mean lengths. In the eastern GOA, herring have mean lengths shorter than much of the groundfish community, are a dominant component of the biomass index and can have large fluctuations in abundance from year to year. Years with low mean groundfish length in the eastern GOA typically coincide with years of higher than average herring biomass. When herring are removed from this indicator, the values are higher. The similarity in series values in the western GOA, regardless of whether herring and eulachon are included, is in part due the relative prominence of other forage species with shorter lengths, such as pricklebacks (Stichaeidae) and Pacific sandfish (*Trichodon trichodon*).

In the series without herring and eulachon in the eastern GOA, recent low indicator values in 2003 and 2011 were years with high biomass of other forage fish including pricklebacks and Pacific sandfish.

Implications: The mean length of the groundfish community in the western and eastern GOA has been generally stable over the bottom-trawl time series (1999 – 2025). Low indicator values are broadly attributed to peaks in the biomass index of smaller, shorter-lived forage species. The downward trend from 2015 – 2019 aligned with the presence of warmer water ("the blob") but the indicator has since increased.

Mean Lifespan of the Fish Community

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Last updated: October 2025

Description of indicator: The mean lifespan of the community is a proxy for the turnover rate of species and communities and reflects the resistance of the community to perturbations (Shin et al., 2010). Lifespan estimates of groundfish species regularly encountered during the NMFS/AFSC biennial summer bottom-trawl survey of the Gulf of Alaska were retrieved from the AFSC Life History Database[31]. The groundfish community mean lifespan is weighted by the relative biomass of groundfish species sampled during the summer bottom-trawl survey (Shin et al., 2010). Initially, the GOA bottom trawl survey was conducted triennially from 1984 to 1999, and then switched to a biennial schedule beginning in 2001; however, the eastern GOA was not surveyed in 2001. Surveys prior to 1990 preceded some of the standardized survey practices, therefore those survey years are not included in this indicator. The survey index used here is the same as that used in the "Foraging Guild Biomass" contribution (Whitehouse in this Report, p. 189) and in the Report Card (not completed in 2025).

In 2025, the AFSC implemented new survey strata for the GOA bottom trawl survey and reduced the total survey area by 1.4%. Several stations where successful hauls had been conducted over the time

[31]https://apps-afsc.fisheries.noaa.gov/refm/reem/lhweb/index.php

series were included in the trimmed stratum areas and are no longer a part of this index. The new strata have different depth distributions than the previous strata design, resulting in different stratum areas. For example, the shallowest strata in previous design extended to a depth of 100 m, while in the updated design the shallowest strata extends down to 50 m, in most survey sub-regions (e.g., Shumagin, Chirikof). Previously, we limited trawl survey data included in this survey index to stations less than 500 m depth, due to fewer stations having been sampled in deeper strata, and those strata having not been sampled in all years a survey was conducted. With the new strata design it is no longer practical to use this same maximum depth cutoff. Thus, we now limit stations included to those < 701 m depth. Collectively, these differences represent a discontinuity in this survey index. Therefore, in the figures we do not connect the 2025 data point to 2023 with a line to highlight these changes.

This indicator specifically applies to the portion of the demersal groundfish community efficiently sampled with the trawling gear used by NMFS during the summer bottom-trawl survey of the GOA (for complete survey details see Siple et al., 2024). This includes species of skates, flatfishes, roundfishes (e.g., cods, sculpins, eelpouts), and rockfish. Species that are predominately found in the pelagic environment (e.g., capelin, pelagic smelts), are infrequently encountered (e.g., sharks, grenadiers, myctophids) or otherwise not efficiently caught by the bottom-trawling gear are excluded from this indicator.

Several species of pelagic forage fishes are abundant in the GOA and their populations may vary substantially which could drive the value of this indicator. While many species of pelagic forage fish are occasionally encountered during the survey, most are not consistently sampled well enough to be included in the survey biomass index, including sandlance, capelin, and other pelagic smelts. Herring and eulachon are included in the survey index, so we have recalculated this indicator with and without herring and eulachon, to examine their influence on the indicator state and trends.

Status and trends: The mean lifespan of the western GOA demersal fish community in 2025 with herring and eulachon included is 27.6, which is down from 31.3 in 2023, and is the lowest value over the time series (Figure 105, left panel, circles). When herring and eulachon are excluded from the series, the indicator status and trends follows the same general pattern.

In the eastern GOA, the mean lifespan in 2025 with herring and eulachon included is 35.1, down from 42.2 in 2023 (Figure 105, right panel, circles). When herring and eulachon are removed from the series, the indicator values are shifted higher but follow similar overall trends. Both series in the eastern GOA are above their long-term means.

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

In the western GOA, recent low indicator values in 2001, 2003, 2007, and 2019 were years with high biomass indices for Pacific herring, eulachon, and other managed forage species (e.g., pricklebacks (Stichaeidae), Pacific sandfish (Trichodon trichodon), etc.) which reduced the mean lifespan for the groundfish community. The recent low indicator values in 2023 and 2025 are due to decreases in the biomass index of POP. High values in mean lifespan are driven by higher biomass indices of long-lived species, including POP, dusky rockfish, and sablefish. In the eastern GOA, low mean lifespan in 1999,

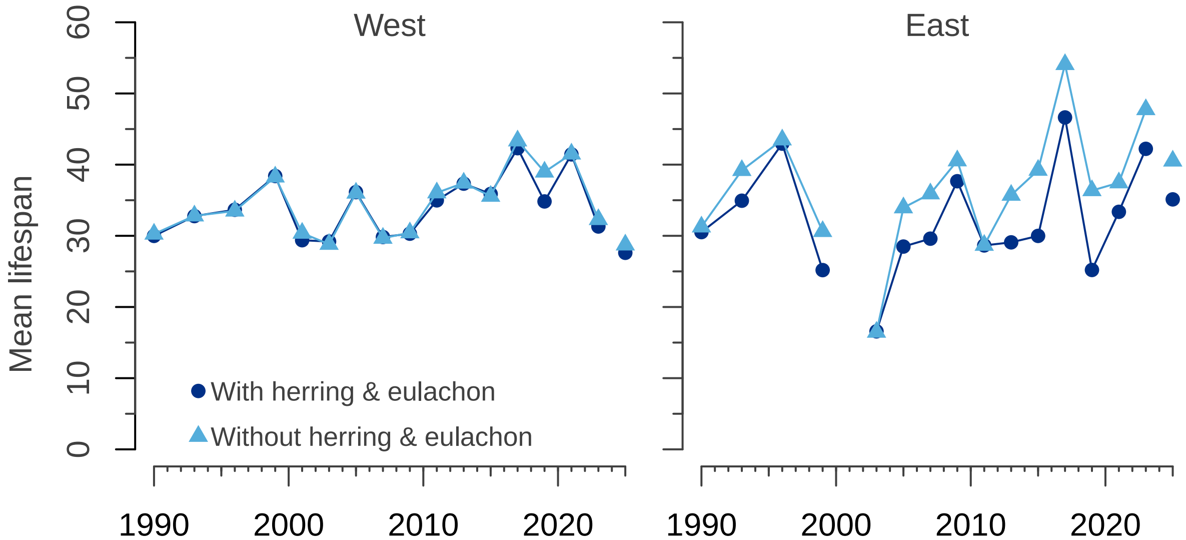

Figure 105: The mean lifespan of the eastern and western Gulf of Alaska demersal fish communities, weighted by a biomass index calculated from the NMFS/AFSC summer bottom-trawl survey. The circles represent the indicator series with herring and eulachon included and the triangles are the indicator series without herring and eulachon. The 2025 point not connected to 2023 with a line due to changes in survey methodology.

2003, and 2019 in the series with herring and eulachon corresponded to years with high biomass indices for Pacific herring and/or other managed forage fish (Figure 1, right panel, circles). The high mean lifespans in 1996, 2009, 2017, and 2023 in the series with herring and eulachon corresponded to years with below-average herring biomass and/or high biomass in long-lived rockfish, such as POP. When herring and eulachon are excluded, high mean lifespans in the eastern GOA in 2009, 2017, and 2023 were driven by long-lived rockfishes, including POP, shortraker rockfish, rougheye/blackspotted rockfish, and shortspine thornyhead (Figure 105, right panel, triangles).

Implications: The groundfish mean lifespan in the GOA has shown interannual variability over the time series, with years of low indicator values corresponding to years with high biomass indices for shorter-lived forage species, such as herring and other managed forage fish, and/or lower biomass for longer-lived species, such as POP. Species that are short-lived are generally smaller and more sensitive to environmental variation than larger, longer-lived species (Winemiller, 2005). Longer-lived species help to dampen the effects of environmental variability, allowing populations to persist through periods of unfavorable conditions and to take advantage when favorable conditions return (Berkeley et al., 2004; Hsieh et al., 2006).

Disease & Toxins Indicators

Harmful Algal Blooms

Contributed by Thomas Farrugia[1], Gulce Kurtay[2], Kari Lanphier[3], Shannon Cellan[3], Bruce Wright[4], Jackie McConnell[4], Kim Schuster[5], Rosie Masui[5], Andie Wall[6], Isaiah Dela Cruz[6], Allison Carl[7].

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Last updated: September 2024

Sampling Partners:

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

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

Description of indicator: Alaska's most well-known and toxic harmful algal blooms (HABs) are caused by *Alexandrium* spp. and *Pseudo-nitzschia* spp. *Alexandrium* produces paralytic shellfish toxins (PST) which can cause paralytic shellfish poisoning (PSP) and has been responsible for five deaths and over 100 cases of PSP in Alaska since 1993 (State of Alaska, 2022). Analyses of paralytic shellfish toxins are commonly reported as μg of toxin/100 g of tissue, where the FDA regulatory limit is 80 μg/100g. Toxin levels between 80 μg - 1000 μg/100 g are considered to potentially cause non-fatal symptoms, whereas levels above 1000 μg/100g ($\sim$12x regulatory limit) are considered potentially fatal.

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

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

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

As a way of detecting these harmful species in Alaska and using them as an ecosystem status indicator, we have started to develop a monitoring program using Imaging FlowCytoBots[32] (IFCBs). IFCBs are connected to the flow-through seawater system of research vessels and sample 5mL approximately every 20 minutes. These samples are run through a flow cell and images are taken of individual particles up to 150 μm in size. In 2025, the Alaska Ocean Observing System (AOOS) deployed two IFCBs on research vessels that transited through Alaskan waters between Prince William Sound and the Chukchi Sea (Figure 106).

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

The State of Alaska tests all commercial shellfish harvest, however there is no state-run shellfish testing program for recreational and subsistence shellfish harvest. Regional programs, run by Tribal, agency, and university entities, have expanded over the past five years to provide test results to inform harvesters and researchers and reduce human health risk. All of these entities are partners in the Alaska Harmful Algal Bloom Network which was formed in 2017 to provide a statewide approach to HAB awareness, research, monitoring, and response in Alaska. More information can be found on the Alaska HAB Network website[33] or through the sampling partners listed above.

Status and trends:

Alaska Region: Results from shellfish and phytoplankton monitoring in 2025 showed an uptick in the presence of harmful algal blooms (HABs) and toxins in some regions of Alaska compared to 2024, although the longer-term trends show evidence that fewer toxins have been detected the last couple of years compared to 2019 – 2021 (Figure 107). Bivalve shellfish from areas that are well known for having PSP levels above the regulatory limit, including Southeast Alaska and the Aleutians, continued to have

[32] `https://ahab.aoos.org/ifcb/`
[33] `https://ahab.aoos.org`

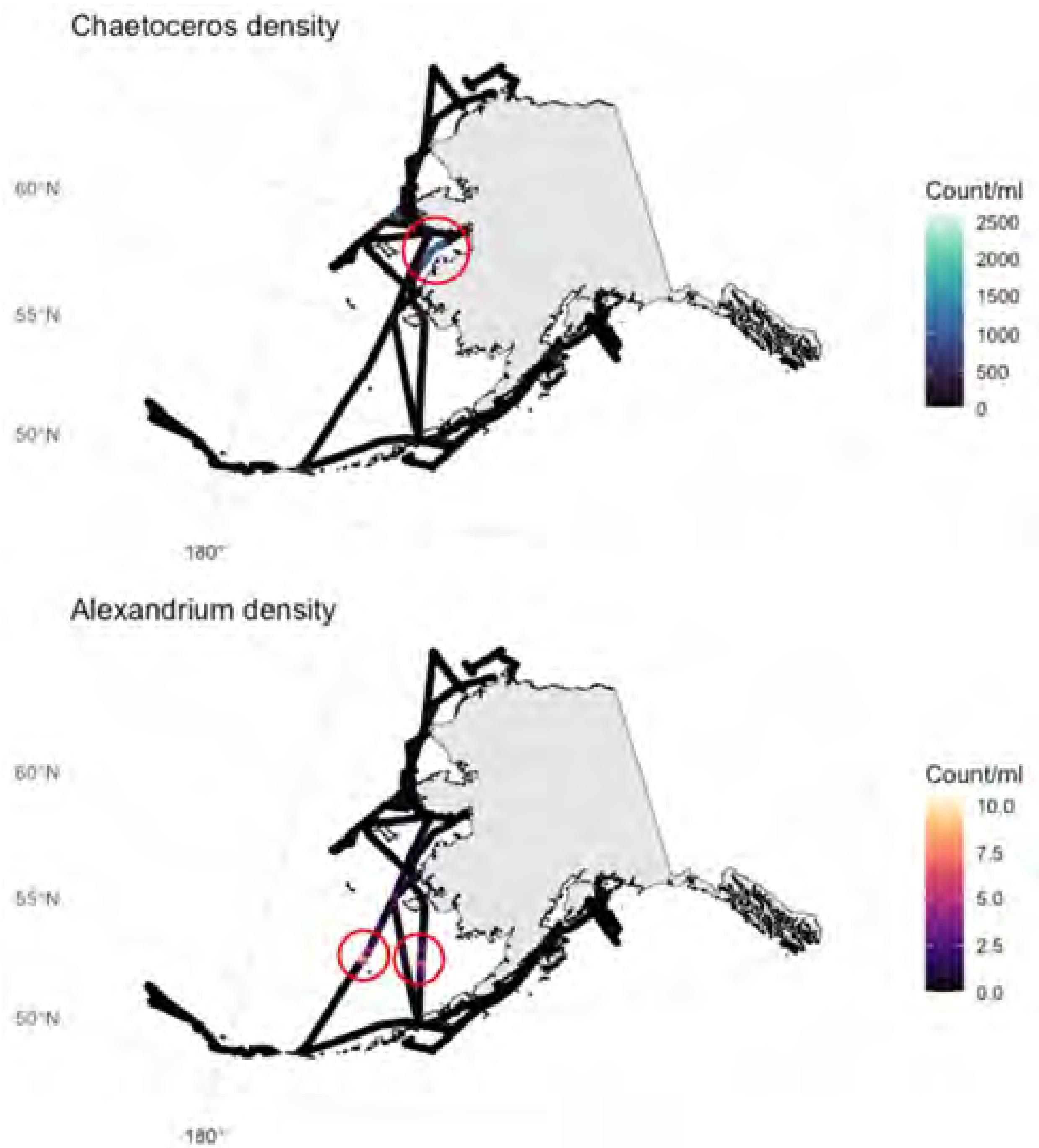

Figure 106: Tracks of the two IFCBs deployed on research vessels during June-September 2025. Colors represent the densities of Chaetoceros (above) and Alexandrium (below) detected by the IFCBs. Red circle highlight areas of high densities. .

samples that tested above the regulatory limit. In Southeast Alaska, the first blue mussels tested above the regulatory level for PSTs at one of the earliest date in the 10-year time series (April 8, 2025). In Southwest Alaska, fewer blue mussels tested above the regulatory level than in 2024, and values were not as elevated as last year. However, bloom events of both *Pseudo-nitzschia* and *Alexandrium* were detected in Kachemak Bay, and water temperatures were higher than last year. So far, 2025 seems to have been a little less active for blooms and toxin levels compared to 2021, 2020 and 2019, but areas continue to have HAB organisms in the water, and shellfish testing above the regulatory limit. Sea surface temperature remains elevated in parts of Alaska well into the fall, and the HABs season usually ends in December. Over the last few years, the dinoflagellate *Dinophysis* has become more common and abundant in water samples, and 2025 continued that trend. We are also seeing a geographic expansion of areas that are sampling for phytoplankton species.

Thanks to the deployment of two IFCBs that sampled for over 120 days total in Alaskan waters, several HABs were detected, including of *Alexandrium* and *Chaetoceros*. *Chaetoceros* are a diatom that do not produce toxins, but can mechanically damage fish gills during blooms and lead to fish kills. Blooms of *Alexandrium* were detected in the SE Bering Sea, and blooms of *Chaetoceros* were detected in the northern Bering Sea as well as along the Aleutian Islands. The *Alexandrium* bloom in the SE Bering was in a similar location as one that was detected in 2024. We hope that future development of the IFCB program will allow for even more monitoring of HABs across all of Alaska.

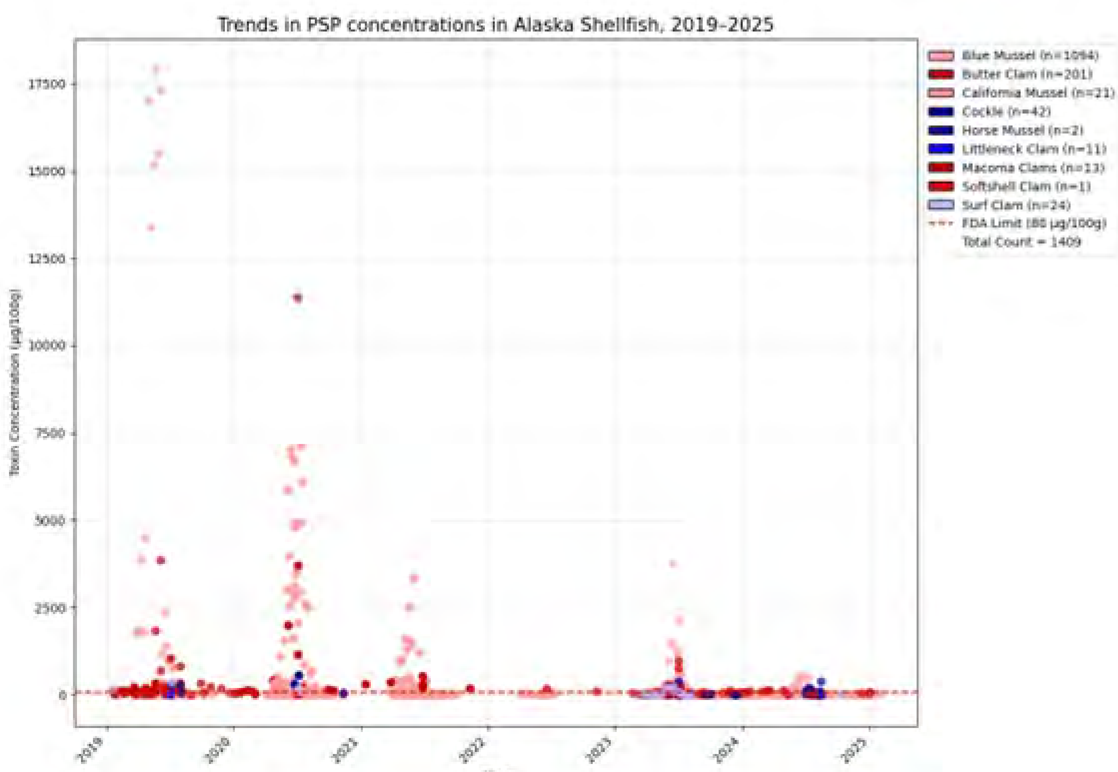

Figure 107: Paralytic shellfish toxin levels for multiple shellfish species collected throughout Alaska from 2019 to 2025, and tested by the Alaska DEC Environmental Health Lab using the mouse bioassay or high-performance liquid chromatography testing method. Data from the Knik Tribe of Alaska.

Eastern GOA:

Southeast Alaska —The Southeast Alaska Tribal Ocean Research (SEATOR) Consortium is composed of partner Tribes who help safeguard their communities by monitoring HABs and shellfish toxins. Tribal environmental staff collect phytoplankton data and test shellfish for PSTs in their local waters. SEATOR partners gather a variety of subsistence shellfish species, including littlenecks, cockles, butter clams, and blue mussels, with blue mussels serving as an indicator species to provide near real-time information relevant to other shellfish. In 2025, SEATOR partners collected over 150 blue mussel samples for PST testing, analyzed at the Sitka Tribe of Alaska Environmental Research Laboratory (Figure 108). PST levels vary across Southeast Alaska by location and season. This year, the Skagway Traditional Council recorded the highest toxicity in a blue mussel sample, with concentrations exceeding 2,000 μg of toxin per 100 grams of tissue, well above the regulatory limit of 80 μg. In Sitka, a low-intensity but long-duration bloom resulted in blue mussels testing above the regulatory threshold from April 8 through May 20, peaking at just over 200 μg per 100 grams of tissue. By contrast, six of the eleven Tribes who tested blue mussel samples in 2025 did not have any blue mussel samples that exceeded the regulatory limit. For more information, please refer to the SEATOR website[34]. (Kari Lanphier, SEATOR and Shannon Cellan, Sitka Tribe of Alaska)

The Knik Tribe's Harmful Algal Blooms (HABs) project, Paralytic Shellfish Poisoning Risk Management, is a nineteen-year initiative conducted in collaboration with the Alaska Department of Environmental Conservation's (ADEC) Environmental Health Laboratory. The project monitors subsistence harvests, particularly blue mussels, to assess the occurrence and progression of harmful algal blooms in samples submitted from across Alaska. Paralytic shellfish toxin (PST) concentrations are analyzed using either mouse bioassay or high-performance liquid chromatography (HPLC). Knik Tribe field technicians, stationed from Southeast Alaska to the Aleutian Islands, collect blue mussel samples weekly year-round, as mussels serve as the primary indicator species for bloom initiation, duration, and severity. Other species of interest are also collected for analysis. Additional samples are received from partner projects (e.g., ADF&G, USFWS, NPS). In total, the Knik Tribe processes and analyzes approximately 1,500 samples annually, mostly via HPLC to quantify PST congeners.

The highest PST levels observed to date in 2025 were in hermit crabs from Juneau. On May 26, six samples of hermit crabs from different beaches in the area consistently exceeded the FDA limit, with the highest concentration reaching 3,080 μg/100 g. During the same sampling event, Dungeness crab hepatopancreas (commonly known as crab butter) from Juneau measured 1,640 μg/100 g.

In salmon, digestive tracts, kidneys, and livers frequently exceeded the FDA regulatory limit. For example, samples collected from pink salmon in Upper Cook Inlet on July 18, 2025, contained 92.7 μg/100 g in digestive tracts, 82 μg/100 g in kidneys, and 81.8 μg/100 g in livers. To date, salmon muscle (flesh) has not tested above the FDA limit. For more information, all results are posted on the Tribe's website[35]. (Bruce Wright and Jackie McConnell, Knik Tribe).

Western GOA:

The Chugach Regional Resources Commission (CRRC) and the Alutiiq Pride Marine Institute (APMI) have been conducting phytoplankton and shellfish monitoring at seven locations in Lower Cook Inlet and in the Prince William Sound since 2021. In August 2025 they established an eighth sample location in the City of Whittier in Prince William Sound. The monitoring program found elevated levels of *Alexandrium* spp. in one sample from eastern Prince William Sound in May of 2025; blue mussel samples collected during this time were found to be above the regulatory limit and Tribes in the area were notified. *Pseudo-nitzschia* spp. were observed in low levels throughout the sampling region and were found in elevated

[34]https://seator.org/
[35]https://www.kniktribe.org/alaska-knik-tribe-paralytic-shellfish-poisoning

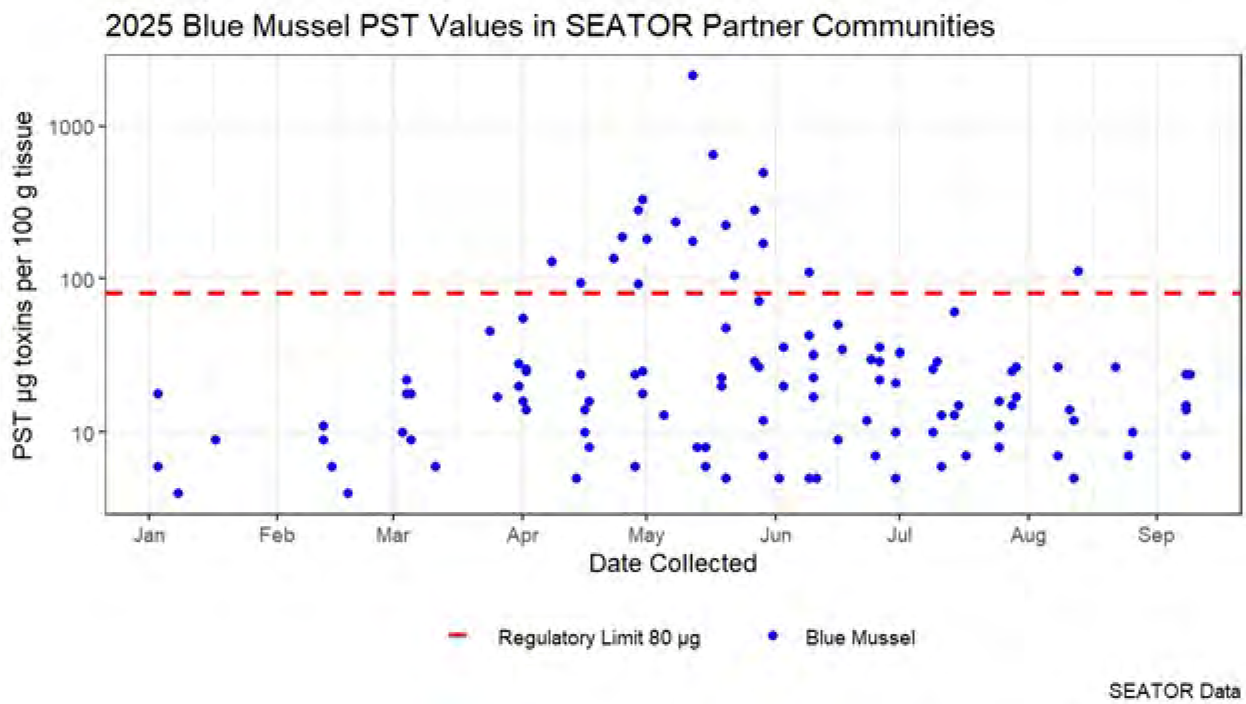

Figure 108: Paralytic shellfish toxin levels in blue mussels tested by the Southeast Alaska Tribal Ocean Research (SEATOR) and Sitka Tribe of Alaska (STA) around 15 different communities. The red horizontal dashed line represents the FDA regulatory limit is 80μg/100g. Testing for these data was done using the ELISA testing method.

levels in one sample from Seward in July of 2025, however domoic acid concentrations in blue mussels were found to be below the regulatory limit. Domoic acid is frequently observed in low levels but has not been found above the regulatory limit in any samples since inception of the monitoring program. APMI has also established the capacity for in-house testing using a receptor binding assay for total saxitoxin concentration and will continue to process samples into fall and over winter. Phytoplankton and toxin testing data can be found on the Alutiiq Pride Marine Institute website[36]. (Allison Carl, CRRC)

The Kachemak Bay National Estuarine Research Reserve (KBNERR) collected and identified phytoplankton in 419 samples from 28 different locations so far in 2025. Species of concern were detected at elevated levels in samples starting in the beginning of July, with a *Pseudo-nitzschia* bloom taking place throughout Kachemak Bay and occurring at the same time as a seabird die off event and marine mammal mortalities. Starting in September the program saw elevated levels of *Alexandrium* cells in the Inner Bay, which correlated with toxic blue mussels collected in the area tested through the Alaska Harmful Algal Bloom Network. The program is currently still finding *Alexandrium* cells in a wide range of samples throughout the Kachemak Bay area. The phytoplankton monitoring program is supported by partner organizations and community monitors representing commercial, recreational, and subsistence harvesters in the area. These two HAB events were likely precipitated by water temperatures in Kachemak Bay that were higher than in previous years, with the seasonal increase in water temperature happening earlier than usual (Figure 109). (Rosie Masui and Kim Schuster, KBNERR)

The Kodiak Area Native Association's (KANA) Environmental Department has taken 93 phytoplankton

[36]https://www.alutiiqprideak.org/hab-watch

samples in 2025 and has identified *Pseudo-nitzschia* sp., *Dinophysis* sp., and *Alexandrium* sp. in 33, 5, and 10 samples, respectively. *Alexandrium* spp. were observed as present or elevated in early May at all 3 sampling sites, and reappeared at these levels in late July through August. Biweekly blue mussel samples were tested by the Sitka Tribe of Alaska, and were found to have toxin levels above the regulatory limit in August and September (Figure 110). Temporary monitoring sites were added to track the bloom during this time. The maximum toxin level detected was 962 μg/100g on September 5th, over 10x the regulatory limit. In addition to the baseline toxin monitoring, 14 samples from community members were submitted for free toxin testing as part of KANA's harvest and hold program. More information on KANA's sampling program for HABs is available on their website[37]. (Andie Wall and Isaiah Dela Cruz, Kodiak Area Native Association)

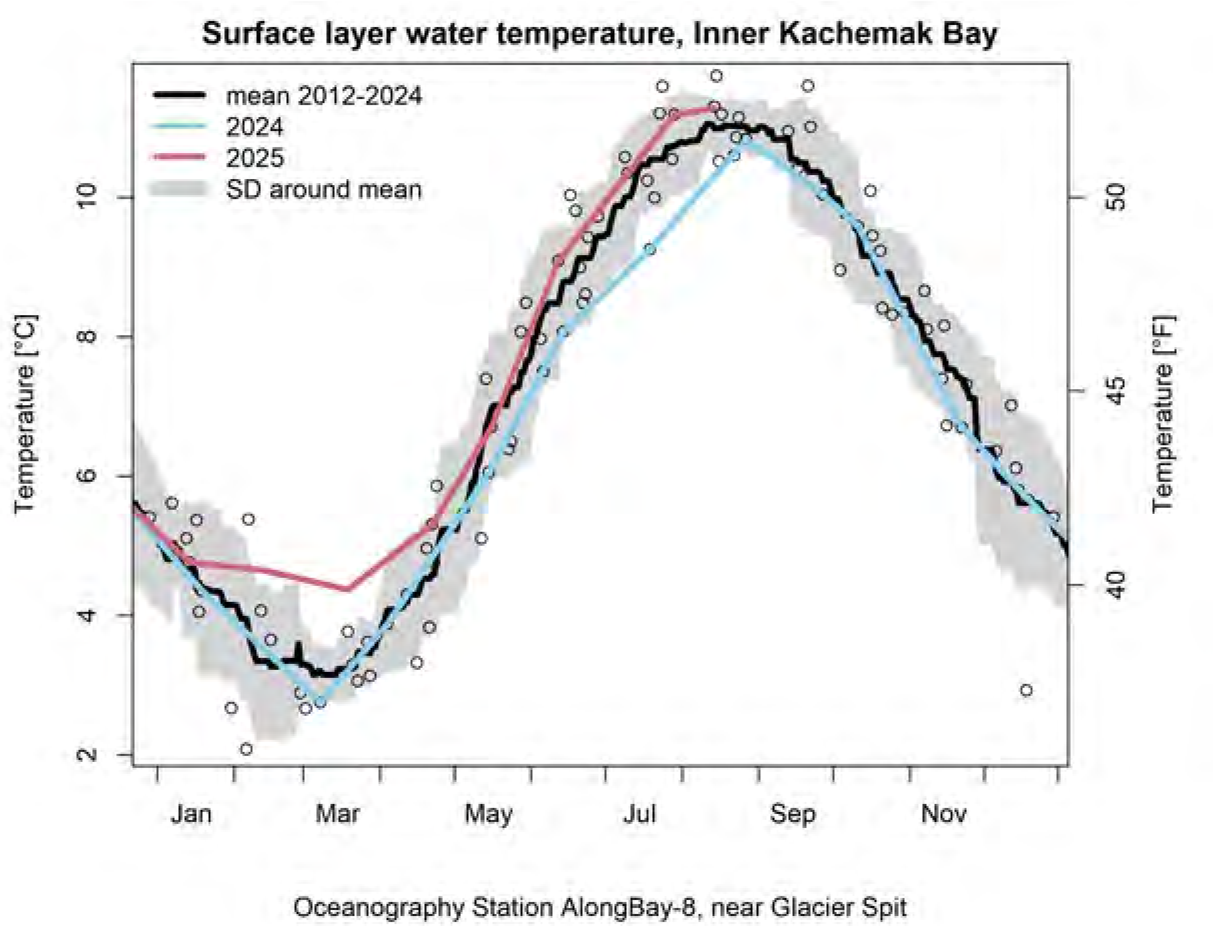

Figure 109: Mean water temperatures from the surface layer (down to 15 m) in Kachemak Bay. Figure by Martin Renner using KBNERR SWMP data at the Homer Harbor).

Factors influencing observed trends: HABs pose a risk to human health when present in wildlife species that people consume, including shellfish, birds and marine mammals. Research across the state is attempting to better understand the presence and circulation of HABs in the food web. HAB toxins have been detected in stranded and harvested marine mammals from all regions of Alaska in past years (Lefebvre et al., 2016). A multi-disciplinary statewide study funded by NOAA's ECOHAB pro-

[37] https://kodiakhealthcare.org/what-we-do/community-services/environmental-management/

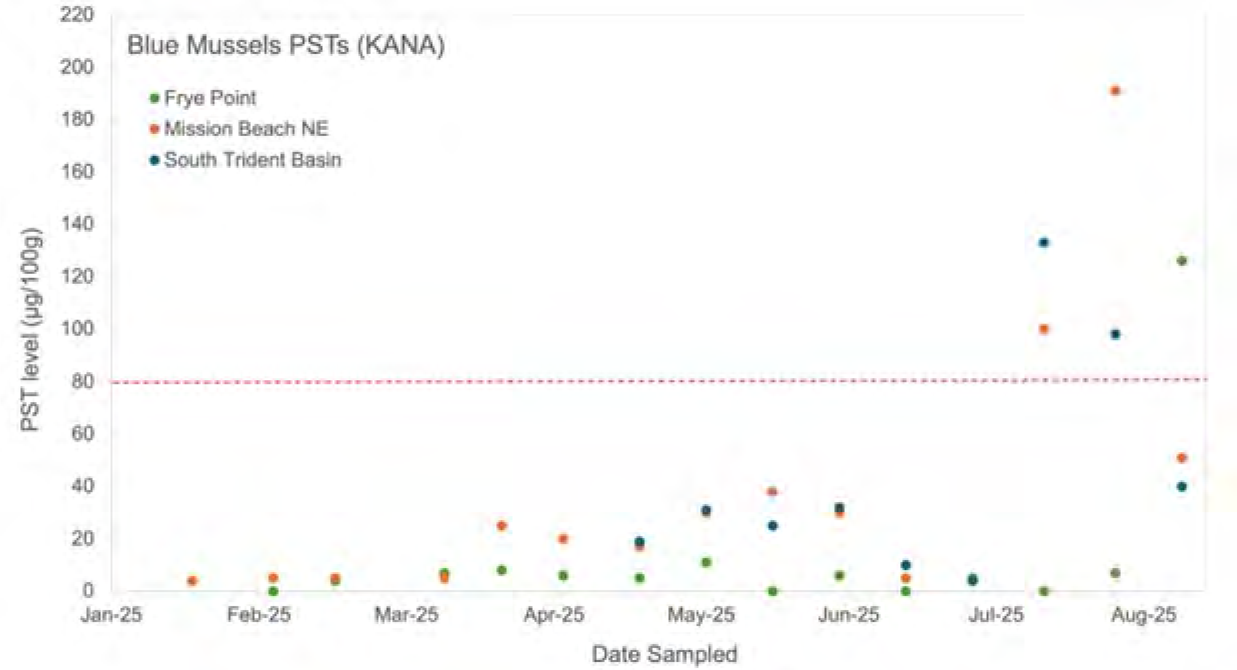

Figure 110: Paralytic shellfish toxin levels in blue mussels from Kodiak collected by the Kodiak Area Native Association and tested by the Sitka Tribe of Alaska (STA). The red horizontal dashed line represents the FDA regulatory limit is 80μg/100g. Testing for these data was done using the ELISA testing method.

gram is underway and encompasses ship-based sediments samples, water samples, zooplankton samples, krill samples, copepod samples, multiple species of fish, bivalves, and the continuation of sampling subsistence-harvested and dead stranded marine mammals.

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

The Alaska Department of Health, Section of Epidemiology (SOE) continues to partner with the AHAB network. Nurse consultants join in on the monthly meetings and collaborate with stakeholders so they can be made aware of reportable illness such as Paralytic shellfish Poisoning (PSP). SOE published an Epidemiology Bulletin describing cases of PSP from 1993 – 2021[38]. More information about PSP and other shellfish poisoning can be found on the SOE website[39].

[38]https://epi.alaska.gov/bulletins/docs/b2022_05.pdf
[39]https://health.alaska.gov/en/education/shellfish-poisoning/

“Mushy” Halibut Syndrome Occurrence

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Last updated: September 2025

Description of indicator: Mushy Halibut Syndrome was first detected in GOA halibut in 1998. When prevalent, it is most often observed in smaller halibut of 15–20 lbs in the Cook Inlet area, but has also been noted in Kodiak, Seward, and Yakutat. Alaska Department of Fish and Game (ADF&G) describes the typical condition consisting of fish having large areas of body muscle that are abnormally opaque and flaccid or jelly-like. The overall body condition of these fish is usually poor, and often they are released because of the potential inferior meat quality. Data are collected through searches of ADF&G fishing reports[40]) and queries to IPHC and ADF&G staff. Incidence of mushy halibut is reported opportunistically in recreational fishing reports and by port samplers, and may not represent true trends. In particular, for these types of qualitative indicators, absence of reporting does not prove absence in the environment.

Status and trends: In 2025, there were some sightings of mushy halibut by charter fishermen early in the spring (pers. comm. Marian Ford, ADF&G). There were no mentions in the ADF&G central Alaska fishing reports. Increased prevalence occurred in 2005, 2011, 2012, 2015, and 2016. It was apparently absent in 2013 and 2014. Since 2017 there have been very few to no reports of mushy halibut.

Factors influencing observed trends: The condition is considered a result of nutritional myopathy/deficiency, and thus may be indicative of poor prey availability for halibut when it is prevalent. According to ADF&G, the Cook Inlet and Homer/Seward areas are nursery grounds for large numbers of young halibut that feed primarily on forage fish that have recently declined in numbers. Stomach contents of smaller halibut now contain mostly small crab species. Whether this forage is deficient, either in quantity or in essential nutrients is not known. However, mushy halibut syndrome is similar to that described for other animals with nutritional deficiencies in vitamin E and selenium. This muscle atrophy would further limit the ability of halibut to capture prey, possibly leading to further malnutrition and increased severity of the primary nutritional deficiency. Also, as the reporting for this indicator is opportunistic and subject to observation error, it may not reflect true prevalence or absence in the ecosystem.

Implications: The relatively few reports of mushy halibut since the end of the 2014–2016 marine heatwave in the GOA may indicate that foraging conditions for young halibut have been more favorable in recent years. However, the absence of mushy halibut reports during the 2019 heatwave year suggests there there is not a simple link between environmental conditions and the prevalence of this condition.

[40] http://www.adfg.alaska.gov/sf/fishingreports/

Fishing Indicators

Time Trends in Non-Target Species Catch

Contributed by George A. Whitehouse[1] and Sarah Gaichas[2]
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Last updated: August 2025

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

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

The catch of non-target species/groups from the GOA includes the reporting areas 610, 620, 630, 640, 649, 650, and 659[41]. 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 trend in the catch of jellies in from 2020 – 2024 has been generally flat, with the time series low in 2022. The catch of Scyphozoan jellies in the GOA has been variable from 2011 – 2020, with peaks in 2012, 2015, 2016, and 2019 (Figure 111). Scyphozoan jellies are primarily caught in the pollock fishery. The catch of structural epifauna gradually increased from 2011 to 2016, and has since trended downward to the time series low in 2023 and remained low in 2024. Sea anemones comprised the majority of the structural epifauna catch from 2011 – 2019, and in 2024, and were co-dominant with unidentified corals and bryozoans from 2020 – 2022. Sponges were the dominant component of structural epifauna catch in 2023. Structural epifauna has primarily been caught in hook and line and non-pelagic trawl fisheries. The catch of assorted invertebrates increased from 2012 to a peak in 2015 then decreased each year to a low in 2021 and has remained low through 2024. Sea stars dominate the assorted invertebrate catch, accounting for more than 76% of the total assorted invertebrate catch in each year. Sea stars are caught primarily in pot and hook and line fisheries.

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

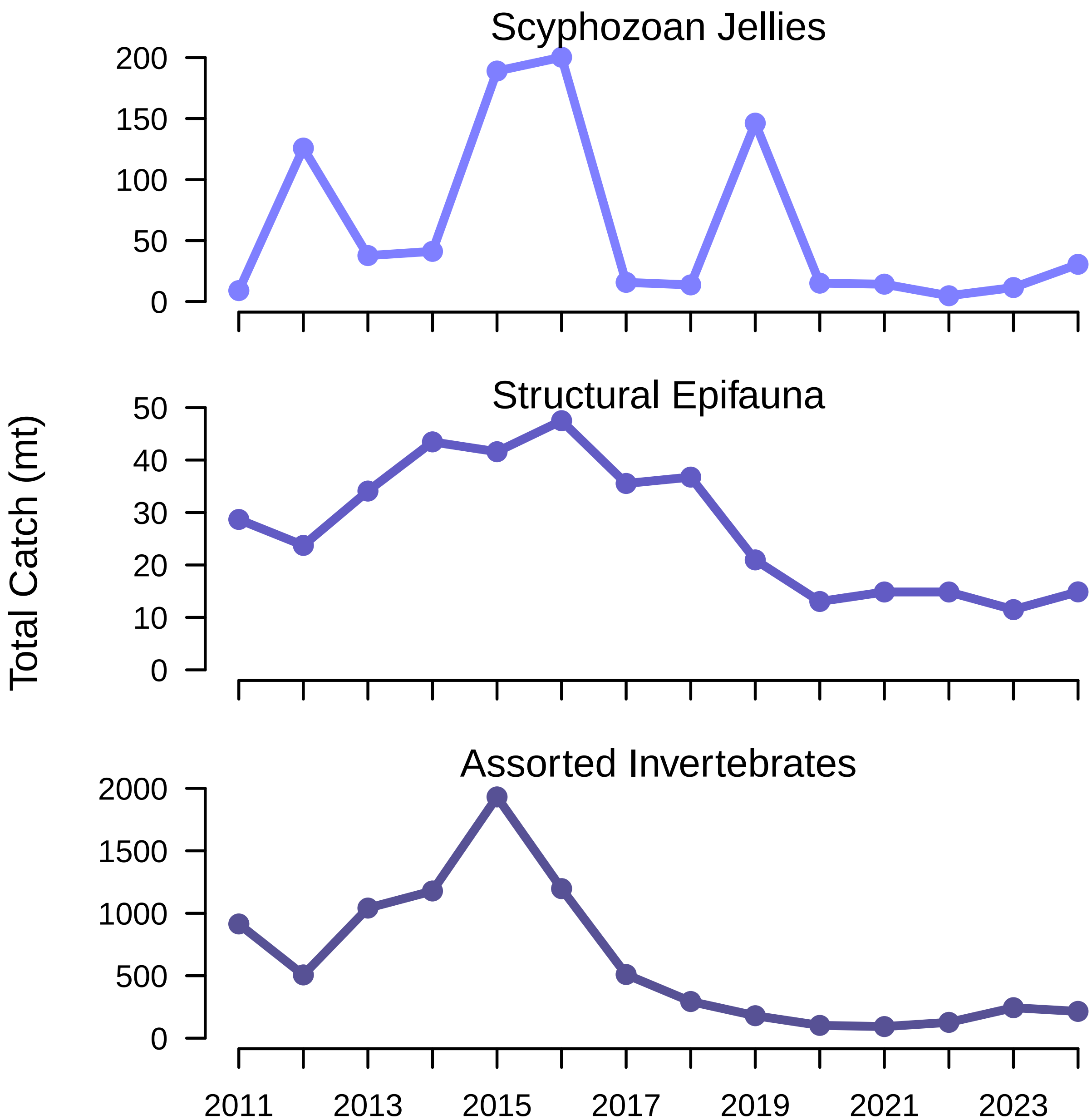

Figure 111: Total catch of non-target species (tons) in the GOA groundfish fisheries (2011 – 2024). Note the different y-axis scales between species groups.

Factors influencing observed trends: The catch of non-target species may change if fisheries change, if ecosystems change, or both. Because non-target species catch is unregulated and unintended, if there have been no large-scale changes in fishery management in a particular ecosystem, then large-scale signals in the non-target catch may indicate ecosystem changes. Catch trends may be driven by changes in biomass or changes in distribution (overlap with the fishery) or both.

Jellyfish population dynamics 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). The lack of a clear trend in the catch of scyphozoan jellies may reflect interannual variation in jellyfish biomass or changes in the overlap with fisheries.

Implications: The catch of structural epifauna and assorted invertebrates is very low compared with the catch of target species. Abundant jellyfish may have a negative impact on fishes as they compete with planktivorous fishes for prey resources (Purcell and Sturdevant, 2001), and may prey upon the early life history stages (eggs and larvae) of fishes (Purcell and Arai, 2001; Robinson et al., 2014). Additionally, jellyfish may be an important prey resource for predators, including commercially important groundfishes (Brodeur et al., 2021).

Sustainability (for consumptive and non-consumptive uses)

Fish Stock Sustainability Index

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Last updated: August 2025

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[42]. 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.

In the GOA region there are 14 FSSI stocks including sablefish. The assessment for sablefish is based on aggregated data from the GOA and BSAI regions. Additionally, in Alaska there are 26 non-FSSI stocks, three ecosystem component species complexes, and Pacific halibut, which are managed under an international agreement. Two of the non-FSSI crab stocks in the BSAI region are overfished but are not subject to overfishing. None of the other non-FSSI stocks are known to be subject to overfishing, are overfished, or known to be approaching an overfished condition. For more information on non-FSSI stocks see the Status of U.S. Fisheries webpage[43].

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

Status and trends: The GOA FSSI remains at 86.6% in 2025 (consistent since 2023), an increase from 84.8% in 2022 (Figure 112). As of June 30, 2025, none of the GOA groundfish stocks or stock complexes are subject to overfishing, are known to be overfished, or known to be approaching an overfished condition (Table 4). Points continue to be deducted for the shortraker rockfish stock, the demersal shelf rockfish complex, and the thornyhead rockfish complex for unknown status determinations and not estimating B/B_{MSY}.

The overall Alaska FSSI remains at 90% in 2025. The index generally trended upwards from 80% in 2006 to a high of 94% in 2018, then trended downward to 88.2% in 2022 (Figure 113). It has increased incrementally to 89% in 2023 and 90% in 2024 and 2025.

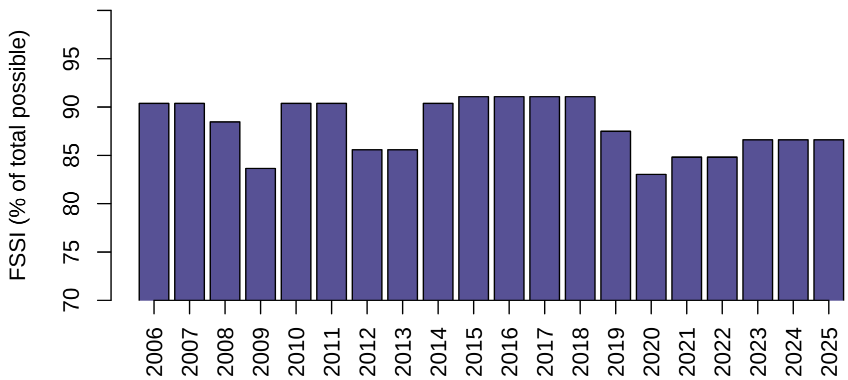

Figure 112: The trend in GOA FSSI from 2006 through 2025 as a percentage of the maximum possible FSSI. The maximum possible FSSI is 140 from 2006 to 2014, 144 from 2015 to 2019, and 140 since 2020. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website. All scores are reported through the second quarter (June) of each year, and are retrieved from the NOAA Fishery Stock Status Updates[44].

Table 4: GOA FSSI stocks under NPFMC jurisdiction updated June 2025 adapted from the NOAA Fishery Stock Status Updates[45]. See FSSI and non-FSSI Stock Status Table on the Fishery Stock Status Updates webpage for definitions of stocks and stock complexes. The multiple B/B_{MSY} values in a given row represent western/central and eastern regions for northern and southern rock sole (shallow water flatfish) and rex sole.

Stock	Overfishing	Overfished	Approaching	Progress	B/B_{MSY}	FSSI Score
GOA Arrowtooth flounder	No	No	No	N/A	2.05	4
GOA Flathead sole	No	No	No	N/A	2.83	4
GOA Shallow water flatfish complex[a]	No	No	No	N/A	1.44/2.40/1.86/2.19	4
GOA Rex sole	No	No	No	N/A	2.79/2.19	4
GOA Blackspotted and rougheye rockfish complex[b]	No	No	No	N/A	1.73	4
GOA Shortraker rockfish	No	Unknown	Unknown	N/A	Not estimated	1.5
GOA Demersal shelf rockfish complex[c]	No	Unknown	Unknown	N/A	Not estimated	1.5
GOA Dusky rockfish	No	No	No	N/A	1.79	4
GOA Thornyhead rockfish complex[d]	No	Unknown	Unknown	N/A	Not estimated	1.5
Northern rockfish-western / central GOA	No	No	No	N/A	1.37	4
GOA Pacific ocean perch	No	No	No	N/A	1.91	4
GOA Pacific cod	No	No	No	N/A	0.90	4
Walleye pollock-western / central GOA	No	No	No	N/A	1.93	4
GOA BSAI Sablefish[e]	No	No	No	N/A	1.49	4

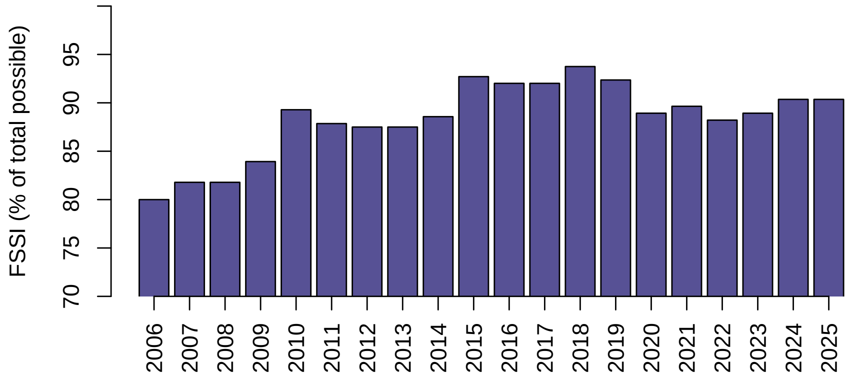

Figure 113: The trend in Alaska FSSI, as a percentage of the maximum possible FSSI from 2006 through 2025. The maximum possible FSSI is 140 for 2006 to 2015, 144 from 2015 to 2019, and 140 since 2020. All scores are reported through the second quarter (June) of each year, and are retrieved from the NOAA Fishery Stock Status Updates website[46].

Factors influencing observed trends: Since 2006, the GOA FSSI has been generally steady, fluctuating between a low of 83% in 2020 to a high of 91% from 2015–2018 (Figure 113). There were minor drops in the FSSI in 2008–2009, in 2012–2013, and 2019–2020. In 2008 and 2009, a point was lost each year for B_{MSY} walleye pollock in the western/central GOA dropping below 0.8. In 2009, an additional 2.5 points were lost for the Rex sole stock having unknown status determinations and for not estimating B_{MSY}. In 2012 and 2013, 2.5 points were lost for having unknown status determinations and not estimating B_{MSY} for the deepwater flatfish complex. The drop in 2019 was due to biomass dropping below 80% B_{MSY} for Pacific cod and sablefish. An additional point was gained in 2023 for GOA Pacific cod biomass increasing above B_{MSY}.

Implications: The majority of Alaska groundfish fisheries appear to be sustainably managed, including GOA groundfish fisheries. Until the overfished status determinations are defined for the Demersal Shelf Rockfish complex, the Thornyhead Rockfish complex, and shortraker rockfish, it will be unknown whether these stocks are overfished or approaching an overfished condition.

Skipper Science 2025 Observation Report

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Last updated: October 2025

Introduction: This report documents significant observations submitted by participants in the Skipper Science program in Alaska between April and September 2025, with the majority taking place within the summer months. The Skipper Science Partnership is a citizen science program based in Alaska's fisheries and dedicated to connecting the knowledge and experiences of fishermen and mariners to the scientific research and resource management policies affecting Alaska's coastal waters. Participants in the program are primarily small boat fishermen[47] across regions, fisheries, and gear types statewide. Using pre-made forms in the ISN Skipper Science smartphone app, participants submit observations with narrative descriptions of marine species and environmental conditions and phenomena, along with geolocation, date-time information, and optional audio, video, or fishery-specific information. Participation in the program is voluntary, with some participants rewarded for their efforts through an end of season raffle. The program serves as a bridge between those who work on the water and domain experts and policy makers, enabling on-the-water data collection and collaborative marine ecosystem research.

This report has been written specifically for submission to the Resource Ecology and Fisheries Management (REFM) Division of the National Oceanic and Atmospheric Administration (NOAA) in consideration of the forthcoming 2025 Ecosystem Status Report (ESR) published by NOAA. The report is divided into three chapters which represent themes present in the data submitted, and build on the chapters in the 2024 Skipper Science Observation Report included in the 2024 GOA ESR (Drummond et al., 2024). The chapters are organized into three sections titled "Emerging Topic", "Trends", and "Continued Research" which reflect the content of the chapters in the broader scope of citizen science data generated through Skipper Science.

Methodology: We define citizen science here as a method by which those who do not hold a formal title as a 'scientist' engage in data collection and monitoring. The main demographics of citizen scientists that currently participate in Skipper Science are commercial fishermen in small boat fisheries of various gear types and across regions in Alaska. Fisheries citizen science is a growing component of scientific processes to better inform understanding and management areas of inquiry and concern (McKinley et al., 2015). This methodology rests on the understanding that fishermen are already observing and witnessing aspects

[47]Small boat fishermen are defined here as fishermen operating vessels less than 40 feet. While these make up the majority of participants in the program, the program is not at all exclusive to small boat fisheries defined as such. Participation in the program has been shaped by areas of heavy outreach since 2021, and while it is likely to be shaped by characteristics of each fishery and region that may include vessel size, no formal analysis has been done.

of marine ecosystem health repeatedly throughout the year. Skipper Science uses this methodology to improve relationships between fishermen, scientists, and managers; facilitate communication between these groups about fisheries and marine research and management; and fill data gaps and strengthen data sets by expanding elements such as seasonality and geographic range (Bonney et al., 2021; McKinley et al., 2017; DiBattista et al., 2021).

Through the smartphone app ISN Skipper Science, users access customizable data collection forms to submit observations. All observations in this report were generated through the "Basic Observation" form, available to all users who download the app and create an account. This form was created by the Skipper Science Partnership in 2021 and refined over time with feedback from fishermen and other participants. The fields include date and time; name of the observer; species/object; ID confidence; text comments; audio recording/comments; GPS; photo and video capture/selection. All data submitted through the app goes through a quality assurance process and is read and categorized by the Skipper Science team. In addition to the app-collected data, the Skipper Science team communicated directly with participants and research scientists about several of the observations submitted in 2025, discussed in further detail within each chapter. This flexible approach to data collection that includes communication with users and scientists outside of the app provides a valuable complement to the ecosystem data possible through the data form.

The chapters and individual observations included in the report were selected by the Skipper Science team after reviewing the 2025 data based on their completeness and regional relevance. The total number of observations submitted in 2025 that are relevant to the Gulf of Alaska region has decreased over the past two years. The reasons for this drop in participation in the General Observation Program from which these observations are drawn is unknown at the time of writing this report. The Skipper Science team conducts outreach throughout the year to encourage fishermen to join the program through approaches including dock walking, presenting to and working with fishery associations, in-person events, and social media content.

Ch. 1: Citizen Science observations of sea otter abundance and distribution in Cook Inlet

Summary: Northern sea otters (*Enhydra lutris*) are a federally protected keystone species that has experienced dramatic population shifts in the Gulf of Alaska. Fifteen observations from June, July, and August 2025 document sea otter sightings in Cook Inlet. Large rafts of otters were observed outside of Kachemak Bay in an area and in group sizes not previously seen.

Introduction: The USGS has conducted aerial surveys of sea otters in the Kachemak Bay and Eastern Lower Cook Inlet, most recently in 2019 (Ballachey et al., 1987). Mapped data from these surveys shows a distribution of otters in groups of 1 – 5 in the Kachemak Bay region (Figure 115). During the summer of 2025 participants in the Skipper Science Partnership collected fifteen observations of sea otters in Cook Inlet near the mouth of Kachemak Bay. Some observations included photographs depicting individual otters and rafts of otters.

Methodology: The data discussed here were submitted by a commercial fisherman during the summer fishing season between the dates of May 1 to August 31, 2025, through the ISN Skipper Science app. Data described in this report chapter include GPS locations, species observed, date and time of observation, text comments, and photos submitted to accompany observations. Quantities of otters present in observations were estimated based on the content of the comments, and coded to reflect groups of 1, 2, 3 – 10, and 10 – 30 as a source for the estimated total number of animals observed. Text comments were analyzed for additional context for the data fields, specifically location information, number of animals, and observed behavior, and were summarized for inclusion in the report. All sea otter observations were made by a single participant between 26 June and 12 August 2025. An additional informal phone interview was conducted with the participant to clarify the submissions, with the central question being why these observations of sea otters were notable; this is included in the Discussion section. All data submitted through the form has been interpreted by the Skipper Science team to best fit the needs of this report.

Region: The observations submitted occurred in Cook Inlet, in an area northwest of Kachemak Bay off of Anchor Point between 59.6 and 59.9 °N and -151.4 and -152.2 °E. All observations appear to have occurred in waters over the continental shelf, at an estimated depth between 60 – 150 feet. Rafts were noted to generally be an estimated 3 – 4 miles offshore by the participant.

Results: A total of 15 observations of sea otter presence were logged. There were no interactions with fishing gear reported, and limited behavioral observations except for describing them as "lounging" (SSC-488487, Table 5), either alone or in groups of 2 or more. The quantity of otters observed was noted in the comments in most submissions, with an estimated total number of animals observed between 67 and 161. Table 5, below, summarizes the otter observations, including the observation code, number of otters observed and paraphrased comments, and quantity of otters. Photos accompanied many of the observations including Figure 114, which shows a raft of otters. In an informal interview, the participant who provided these observations described feeling that their numbers and locations were significant because in a lifetime of fishing in this area they do not remember seeing them this far outside of the shelter of Kachemak Bay, or in rafts this size. The first map in Figure 115 shows the locations and estimated quantity of sea otters observed through Skipper Science. The map in Figure 116 from the USGS 2017 aerial survey (Esslinger et al., 2021) shows sea otter abundance and distribution in the same area and shows smaller raft sizes.

Table 5: All observations of sea otters included in this region with observation code, date, number of otters observed and comments included in the submission.

Observation Code	Dates (2025)	Number	Comments
SSC-48484	06-26	2	Two otters observed together
SSC-48485	06-26	1	One otter lounging
SSC-48486	06-26	2	Another group of 2 otters
SSC-48487	06-26	1	Single otter
SSC-48488	06-26	3-10	3x in a group that dove as I drove by
SSC-48489	06-26	10+	Numerous otters in this area as evidenced by all my previous observations. Just saw 3x more lounging as I drove by
SSC-48496	06-30	2	Two together
SSC-48497	06-30	10	Raft of about 10 otters
SSC-48498	06-30	10+	Two rafts of otters with a total number of animals about 30
SSC-48499	06-30	10+	Another raft of otters
SSC-48517	07-03	1	Lone otter. I've seen a lot fewer otters today than previous days that I have transited this area from Homer to the fishing grounds in lower cook inlet
SSC-48521	07-07	3-10	Three animals together
SSC-48529	07-07	1	
SSC-48599	08-09	1	
SSC-48603	08-12	10+	A whole raft of otters. See photos

Figure 114: Photo submitted in 2025 of sea otters observed from a fishing vessel near Kachemak Bay in June. (SSC-48499, Table 5).

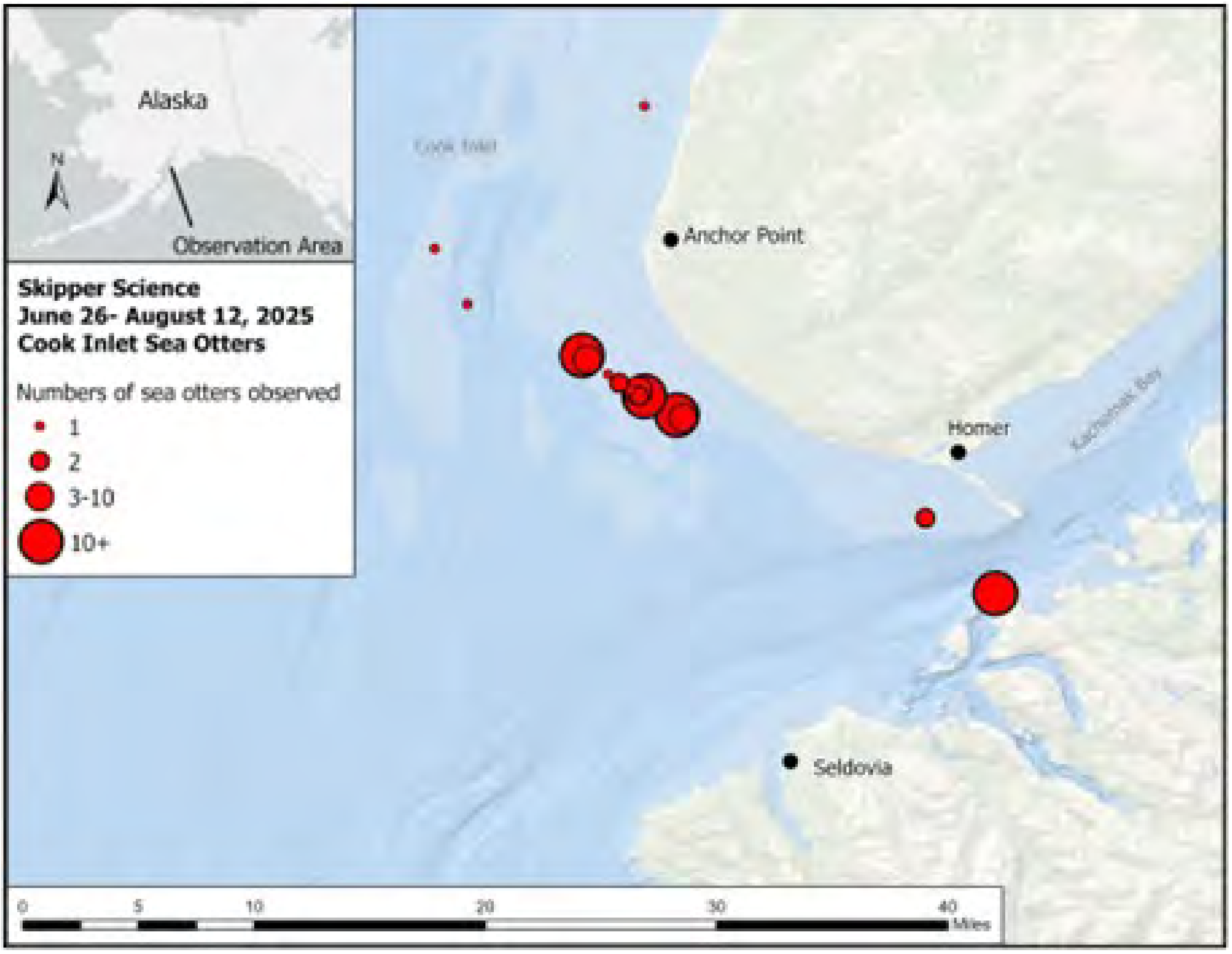

Figure 115: Locations of sea otter sightings and abundance estimates by fishermen citizen scientists through the ISN Skipper Science smartphone app, dated from 26 June-12 August, 2025.

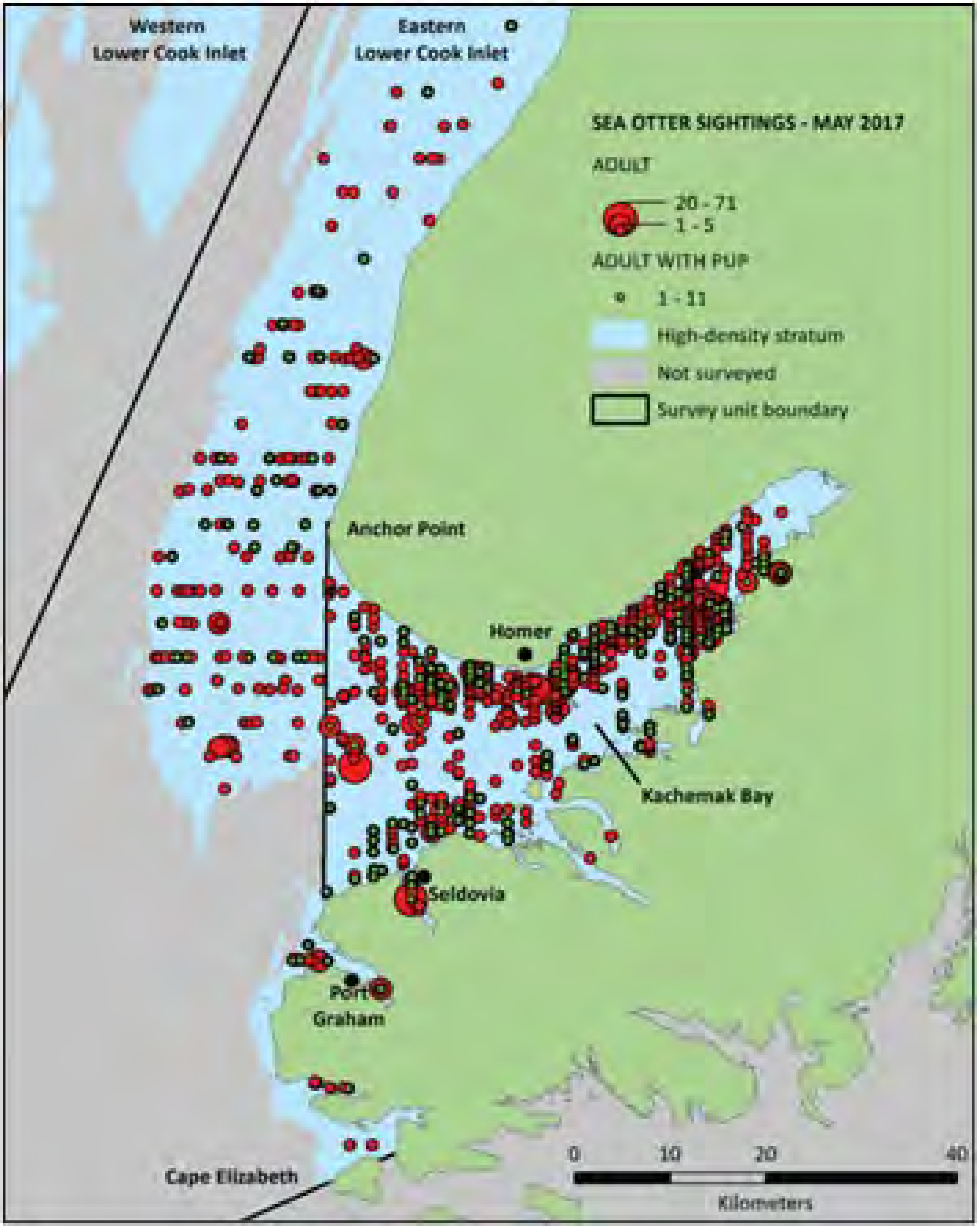

Figure 116: Sea otter sightings from May 2017 USGS aerial survey, (Esslinger et al., 2021).

Citizen science observations of predator-prey and fishery interactions in Gulf of Alaska

Summary: In the last 4 years of citizen science data collection through the Skipper Science Partnership fishermen have consistently submitted observations of marine mammal sightings, which often include detailed descriptions of behavior including predator-prey interactions and fishery interactions with fishing gear and vessels. These observations are rich in qualitative data, spatial and temporal scope, and fishermen-based perspectives; and the consistent trend of voluntary data submission underscores the importance of these topics to fishermen and the potential for expansion on this theme in citizen science research in Alaska on these keystone species. In 2025 the trend continued with observations of sightings, observed hunting behavior, and interactions with fishery activities of marine mammals including killer whales (*Orcinus orca*), Stellar sea lions (*Eumetopias jubatus*), and harbor seals (*Phoca vitulina*).

Introduction: This chapter outlines three themes in the data from the 2025 season that included observations of killer whales engaged in predator-prey interaction close to vessels, observations of specific predation and fishery interaction in Stellar sea lions in Southeast, and an observed trend of harbor seal presence and predation and fishery interaction behavior in the Kasilof rivermouth. In previous years observations of sharks have been included within this theme, but this year only yielded marine mammal observations.

Methods: The marine mammal observations discussed in this chapter were submitted by commercial fishermen during the spring and summer fishing seasons between the dates of 1 April – 31 August, 2025 in the Cook Inlet, Kodiak, and Southeast regions of the Gulf of Alaska. Relevant form fields include GPS locations, named regions, observed species, date and time of observation, text comments, and optional fishery information, photos, or videos submitted to accompany observations. Additional qualitative information was collected through an informal phone interview after data submission. Some observations have only a few descriptors while others include long comments of several hundred words, all of which are coded and summarized in alignment with the purpose of this report by the Skipper Science team, and do not reflect technical definitions or designations of fisheries interactions that may be used in agency or other applications. As such, below are definitions used in our interpretation of the data.

Fishing Interaction: Fishing interaction was identified whenever an observation comment mentioned an interaction with marine life during fishing activities, including gear interactions, loss of fish, and marine mammal or shark presence around gear with no direct interaction. This last identifier was included considering the further context of the observation comment where the observer mentioned explicitly presence with no gear interaction or fish loss.

Predator/Prey Interaction: Predator/Prey Interaction was identified based on the description and/or behavior of the animal observed. A majority of comments noted a type of interaction while also making notes on predation by marine mammals and sharks on fish both in relation and not in relation to the fishing interaction.

Results: A total of 15 citizen science observations were submitted that included marine mammals observed in close proximity to vessels, interacting with fishing activity, or engaged in predator-prey activity. Six species of marine mammals were identified in these observations. No shark data was reported. The marine mammal species include harbor porpoise (*Phocoena phocoena*) , humpback whale (*Megaptera novaeangliae*), killer whale, Pacific white-sided dolphin (*Aethalodelphis obliquidens*), harbor seal, and Stellar sea lion. The table below (Table 6) shows the observations submitted including the region, species, summary of interaction observed and the fishery that the observer was participating in. Table 7 shows the number of reported marine mammal and shark observations from 2023 – 2025, and the number of those that included descriptions of fishery interactions. The 2025 results are further described in sections specific to each species observed.

Table 6: Citizen science observations of marine mammals engaged in predator-prey behavior, in close proximity to vessels, or interacting with fishing gear in the 2025 summer fishing season.

Observation Code Code	Region	Species	Summary	Fishery and Gear Type
SSC-48523	Cook Inlet	Harbor porpoise	Close proximity to vessel	Unknown
SSC-48522	Cook Inlet	Humpback whale	Close proximity to vessel	Unknown
SSC-48333	SE	Killer whale	Pod in close proximity to boat, following trolling line	Salmon, trolling
SSC-48519	Cook Inlet	Killer whale		
SSC-48524	Cook Inlet	Killer whale	Close proximity to vessel, more than 4 present	Salmon, gillnet
SSC-48604	SE	Killer whale	Orca predation on coho salmon, 50 meters from boat	Salmon, trolling
SSC-48362	Kodiak	Pacific whitesided dolphin	Hundreds of animals sighted	Unknown
SSC-48539	SE	Steller sea lion	Interaction with fishing gear/catch, affecting catch. Fish observed to have rake marks	Salmon, trolling
SSC-48493	Cook Inlet	Harbor seal	Close to nets, looking for salmon	Salmon, gillnet
SSC-48520	Cook Inlet	Harbor seal	Observed in harbor	Salmon, gillnet
SSC-48530	Cook Inlet	Harbor seal	4 seals catching salmon at mouth of Kasilof river	Salmon, gillnet
SSC-48531	Cook Inlet	Harbor seal	West side of east rip	Salmon, gillnet
SSC-48532	Cook Inlet	Harbor Seal	Close proximity to boat, grooming itself	Salmon, gillnet
SSC-48537	Cook Inlet	Harbor Seal	Close to nets, looking for salmon	Salmon, gillnet
SSC-48549	Cook Inlet	Harbor Seal	3 seals catching salmon at mouth of Kasilof River	Salmon, gillnet

Table 7: Total number of observations for marine mammal species and sharks with number of observations that include fishery interactions in parentheses.

Species	2023	2024	2025
Sea Lion	3(3)	3(3)	1(1)
Seal	0(0)	3(3)	7(4)
Orca	2(2)	2(2)	4(2)
Shark	6(6)	2(2)	0(0)

Harbor Seals: Four of the seven harbor seal observations described a fishery or predator-prey interaction. A number of harbor seals were seen near the mouth of Kasilof river preying on salmon, with others reported to be targeting fishing nets of salmon gillnetters in the area. In an informal interview with the participant they noted an increase in harbor seal sightings over time, with consistent and increasing behavior of seals targeting salmon in the nets of gillnetters. The observation included a comment describing how seal behavior has impacted their fishing activity by forcing them to reset their nets sometimes several times after seals descend on the net, "if you get a handful of them on the net, you won't have any fish left." (Phone interview with observer on 18 September 2025).

Killer whales: Three of the four killer whale observations in the Gulf of Alaska reported the whales in close proximity to fishing vessels. In one interaction in Southeast they were observed following the troll line to catch coho salmon off the line, "Pod of orcas lingered for about an hour on the winter chinook trolling line" (SSC-48333, Table 6). Another observation reported a young male within 50 yards of the vessel, with the observer commenting that the same pod or another was observed 2 weeks prior. A third observation in Southeast documented killer whales hunting around the fishing vessels and targeting coho, but not otherwise interacting with the fishing activity, "Completely unconcerned about our activity. Just as other encounters in the past, the group of killer whales were hunting right in and around vessels actively fishing for coho, as if they chose or targeted a group of active fishing vessels as a likely location for food" (SSC-48604, Table 6, Figure 117).

Stellar sea lion: The sole observation of a Stellar sea lion included a lengthy commentary on observed sea lion behavior observed over time. The fisherman described in great detail their experience of Stellar sea lions expertly targeting juvenile Chinook salmon caught on a troll line. They hypothesized that the sea lions have learned this behavior over time to more easily acquire their preferred prey. The participant was contacted, as well as a sea lion expert, to discuss what further data could be helpful to explore the trend of this observed behavior, but no further action was taken during the duration of the research period included for this report.

Figure 117: Photo of pod of killer whales observed between Torch Bay and Palma Bay in the Southeast region of the Gulf of Alaska (SSC-48604, Table 6).

Discussion: Both resident and transient marine mammals including but not limited to sharks, harbor seals, killer whales, and dolphins are apex predators in Alaska's coastal waters, and important indicators of ecosystem health. The 2025 data captured an increase of harbor seals in the Kasilof rivermouth, killer whale predation in Southeast and Cook Inlet, and the continued trend of Stellar sea lion interaction with fishing vessels in Southeast. It is noted that in this season there were no shark observations submitted, which in previous years have included instances of direct observation of or evidence of shark predation of fish on lines, sharks caught as bycatch, or observed in the water. It is unknown why no shark data was submitted this year. These marine mammal observations of behavior targeting fishing activity as a source of prey, and demonstrating learned behavior to expertly feed from fishing gear are consistent with previous years of data collection, and there are many informal interviews over the duration of the program with fishermen which reflect these trends. Fishermen have a unique perspective to observe marine mammals of many species, across a wide temporal and spatial range. The frequency of fishery interactions with predators that impact catch yields a high interest in fishermen collecting data regarding these topics, with high potential for a variety of targeted research projects including marine mammals possible through this methodology. The data submitted on marine mammal observations of this nature tends to be rich with qualitative elements, historical observations, and reflections and suggestions on potential research questions.

Ch 3. Citizen Science observations of stomach contents and forage fish in the Gulf of Alaska

Summary: Using a methodology developed by the Skipper Science Partnership, fishermen in 2025 collected data on the diets of salmon as they process fish. Stomach content data through this methodology provides direct data on diet composition of target species, and is complemented by additional observations of spawning and baitballs that provide data on forage fish, which we generally describe as small, nutrient-dense, schooling fish that are crucial for healthy food-webs in coastal Alaska. These two methods enable citizen science collected data that can illuminate food web dynamics, diet composition, and forage fish data important for monitoring ecosystem dynamics for commercial species. The 2025 data includes observations of stomach contents in coho salmon and herring spawn sites.

Introduction: Citizen science data collection on stomach contents of target species of salmon in the Gulf of Alaska continues in 2025, with the noted presence of a novel forage species not recognized by fishermen. Distribution and abundance fluctuations in forage fish can be important ecosystem indicators, and are noted by citizen scientists (Livingston et al., 2005). The 2025 observations of stomach contents were submitted by salmon trollers in Southeast, which is consistent with prior years as the gear type and region most likely to include stomach contents in their observations.

Region(s): Both observations of herring spawning and stomach contents occurred in the Southeast region of the Gulf of Alaska. Stomach content data collected on vessels salmon trolling in Southeast, and herring spawn observations were land-based near Sitka.

Methods: Observations were submitted in Spring and Summer 2025 by commercial fishermen in Southeast Alaska using the Basic Observation form in the ISN Skipper Science smartphone app (Table 8). Observations include GPS locations, named regions, date and time of observation, and descriptive comments; a subset of observations included photographs of stomach contents. These data were collected using an iteration on a method for analyzing the stomach content of black cod developed by the Skipper Science Partnership in collaboration with the Alaska Fisheries Science Center; designed to contribute citizen science research to research on food web dynamics in the Southeast region (Skipper Science Partnership, 2023). During outreach in the spring current and potential participants were encouraged to log observations of stomach contents, and to include an indication of measurement, target species and stomach content species ID when possible. Identification of species in stomach contents was done by the Skipper Science team based on the data in the observation and further research. Spawning events and sightings of bait balls were also encouraged to continue data collection on forage fish. Direct comments from observations are included in the data table (Table 9), which have not been paraphrased.

Results: Two observations of herring spawn events were submitted on May 14th, 2025 in the Sitka area of Kruzof island. One noted a comment that historically, spawn had not been seen in the slough near Pelican Harbor. Two observations of an unidentified fish in coho stomach contents were submitted through the app by a participant on a vessel trolling for salmon (Figure 118). The Skipper Science team attempted identification of the fish through the photos submitted in the observation, and communication with the NOAA Auke Bay Lab in Juneau, identifying the fish as a Pacific sandfish (*Trichodon trichodon*). Further communication via email on August 11, 2025 with the participant shared that this was not an isolated event. The participant shared that they continued to see the same baitfish identified as Pacific sandfish in "almost every single coho we have caught". Between the date of the email and July 10, 2025 they had caught 2,813 coho with troll gear in the region specified in the comments of the observation in Southeast. They noted that the lack of decomposition of the stomach contents at the time of dressing the coho caught, when stomach contents are generally observed. They noted, "New fish move through this area constantly, bound for icy straits and inside rivers. We have observed sandfish in every single coho, and that the sandfish is almost exclusively freshly consumed or very recently consumed, evidenced by the lack of decomposition at the time of dressing the fish. There have been other types of baitfish (mainly herring) in the stomach contents but at far greater stages of decomposition, suggesting the other types of baitfish were consumed prior to transiting this particular area" (Troller in SE AK salmon fishery, email correspondence with authors, August 11, 2025). Photos including measurement of the stomach contents are included in the observations.

Table 8: The total number of observations that noted forage fish (herring, capelin, sand lance, Pacific sandfish) in salmon stomachs in 2023, 2024, and 2025, with the total number of Skipper Science observations for each year in parentheses.

Prey Species	2023 (173)	2024 (67)	2025 (44)	Predator salmon species
Herring	6	2	0	King salmon
Capelin	1	2	0	King salmon
Sandlance	2	0	0	Coho, King salmon
Sandfish	0	0	2	Coho
Total	9	4	2	

Table 9: Forage fish and stomach content citizen science observations in 2025.

Observation Code	Species	Region
SSC-48400	Pacific Herring	SE
Comment: Thousands of herring and spawn in and around the waters of Pelican Harbor, Pelican Creek, and slough near breakwater. Elder resident reports having never witnessed herring spawn in the slough.		
SSC-48403	Pacific Herring	SE
Comment: Herring spawning Pelican Boat Harbor		
SSC-48540	Unidentified Coho stomach contents	SE
Comment: Coho were feeding on this fish off Graves Harbor/Astrolabe stretch. They may have consumed this feed last night/morning judging by decomp. These are coho that were not here yesterday so they may have come from offshore overnight. Also, big minus tide moves baitfish around and may have brought this feed in close to shore. We caught 100+ coho today that all showed up just today with this particular baitfish in their stomach.		
SSC-48589	Unidentified Coho stomach contents	SE
Comment: Trolling for coho we had coho spitting up this odd baitfish we have never seen before. Water is 54.6 degrees on the surface.		

Figure 118: Stomach contents of coho salmon caught trolling for coho in the Southeast region. These photos sparked further email communication between the observer and the AFSC, and identified as a Pacific sandfish. (SSC- 48540, SSC- 48589).

Discussion: The two observations were submitted in 2025, fewer than in 2023 or 2024 (Drummond et al., 2024). Each of the 2025 observations noted the presence of a fish in coho stomach contents that was unknown to the experienced fisherman making the observation. These observations were made, in part, because of the novelty. This demonstrates two layers of value to this citizen science data: the ecosystem food-web information from the diet data, including temporal and spatial specificity, size and quality of fish in photos; and the novel, qualitative note that this type of baitfish has not been observed previously by these fishermen. Subsequent email communication between Skipper Science, the AFSC, and the participant helped determine that the unknown fish found in coho stomach contents was likely the Pacific sandfish. This discovery is interesting because the life cycle of the sandfish as it is typically understood makes it an unusual prey for Coho in the time and location these observations were made.

Though present in 2023 and 2024, herring, capelin, and sandlance were entirely absent from observations in 2025. However, the 2025 data included several observations of herring spawning which, combined with emailed comments about decomposed herring in stomach contents quoted in results section, above, complement stomach content data from previous years.

References

Alvarez-Fernandez, S., H. Lindeboom, and E. Meesters. 2012. Temporal changes in plankton of the North Sea: community shifts and environmental drivers. Marine Ecology Progress Series **462**:21–38.

Amaya, D., A. Miller, S. Xie, and Y. Kosaka. 2020. Physical drivers of the summer 2019 North Pacific marine heatwave. Nature Communications **11**:1903.

Anderson, P. J. 2000. Pandalid shrimp as indicators of ecosystem regime shift. Journal of Northwest Atlantic Fishery Science **27**.

Anderson, P. J. 2003. Gulf of Alaska small mesh trawl survey trends, In: J.L.Boldt (Ed.), Ecosystem Considerations for 2004. Appendix C of the BSAI/GOA Stock Assessment and Fishery Evaluation Reports. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Anderson, S. C., E. J. Ward, P. A. English, and L. A. K. Barnett. 2022. sdmTMB: an R package for fast, flexible, and user-friendly generalized linear mixed effects models with spatial and spatiotemporal random fields. bioRxiv. https://doi.org/10.1101/2022.03.24.485545.

Arimitsu, M., J. Piatt, H. S., R. Suryan, S. Batten, M. Bishop, R. Campbell, H. Coletti, D. Cushing, K. Gorman, and R. Hopcroft. 2021. Heatwave-induced synchrony within forage fish portfolio disrupts energy flow to top pelagic predators. Global Change Biology **27**:1859–1878.

Atwood, E., J. K. Duffy-Anderson, J. K. Horne, and C. Ladd. 2010. Influence of mesoscale eddies on ichthyoplankton assemblages in the Gulf of Alaska. Fisheries Oceanography **19**:493–507.

Bailey, K., S. Picquelle, and S. Spring. 1996. Mortality of larval walleye pollock *Theragra chalcogramma* in the western Gulf of Alaska, 1988-91. Fisheries Oceanography **5**:124–136.

Baker, C. S., A. A. Perry, and L. M. Herman. 1987. Reproductive histories of female humpback whales (*Megaptera novaeangliae*) in the North Pacific. Marine Ecology Progress Series **41**:103–114.

Ballachey, B., D. Monson, G. Esslinger, K. Kloecker, J. Bodkin, L. Bowen, and A. Miles. 1987. 2013 update on sea otter studies to assess recovery from the 1989 Exxon Valdez oil spill, Prince William Sound, Alaska: U.S. Geological Survey Open-File Report 2014-1030, 40 p., http://dx.doi.org/10.3133/ofr20141030.

Barbeaux, S., B. Ferriss, W. Palsson, K. Shotwell, I. Spies, M. Wang, and S. Zador. 2020*a*. Assessment of Pacific Cod Stock in the Gulf of Alaska [In] Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage.

Barbeaux, S., K. Holsman, and S. Zador. 2020*b*. Marine heatwave stress test of ecosystem-based fisheries management in the Gulf of Alaska Pacific cod fishery. Frontiers in Marine Science **703**:1–21.

Batten, S. D., G. T. Ruggerone, and I. Ortiz. 2018. Pink salmon induce a trophic cascade in plankton populations in the southern Bering Sea and around the Aleutian Islands. Fisheries Oceanography **27**:548–559.

Beamish, R. J., and C. Mahnken. 2001. A critical size and period hypothesis to explain natural regulation of salmon abundance and the linkage to climate and climate change. Progress in Oceanography **49**:423–437.

Beaugrand, G. 2004. The North Sea regime shift: evidence, causes, mechanisms and consequences. Progress in Oceanography **60**:245–262.

Bednaršek, N., and M. Ohman. 2015. Changes in pteropod distributions and shell dissolution across a frontal system in the California Current System. Marine Ecology Progress Series **523**:93–103.

Berkeley, S. A., M. A. Hixon, R. J. Larson, and M. S. Love. 2004. Fisheries sustainability via protection of age structure and spatial distribution of fish populations. Fisheries **29**:23–32.

Betts, M. F. 1994. The subsistence hooligan fishery of the Chilkat and Chilkoot Rivers. Technical Paper Series **213**:1–69.

Blackburn, J. E. 1977. Demersal fish and shellfish assessment in selected estuary systems of Kodiak Island. Annual Report, OCSEAP Research Unit 512, ADF&G, Kodiak, Alaska.

Blackwell, B., M. Brown, and D. Willis. 2000. Relative Weight (Wr) Status and Current Use in Fisheries Assessment and Management. Reviews in Fisheries Science - REV FISH SCI **8**:1–44.

Blanchard, F., and J. Boucher. 2001. Temporal variability of total biomass in harvested communities of demersal fishes. Fisheries Research **49**:283–293.

Bodkin, J. L., H. A. Coletti, B. E. Ballachey, D. H. Monson, D. Esler, and T. A. Dean. 2018. Variation in abundance of Pacific blue mussel (*Mytilus trossulus*) in the northern Gulf of Alaska, 2006–2015. Deep Sea Research Part II: Topical Studies in Oceanography **147**:87–97.

Bograd, S. J., R. Mendelssohn, F. B. Schwing, and A. J. Miller. 2005. Spatial heterogeneity of sea surface temperature trends in the Gulf of Alaska. Atmosphere-Ocean **43**:241–247.

Boldt, J. 2007. Ecosystem Considerations for 2008. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands and Gulf of Alaska. North Pacific Fishery Management Council, 605 W. 4th Ave, Suite 306, Anchorage, AK 99501, https://apps-afsc.fisheries.noaa.gov/refm/docs/2007/ecosystem.pdf.

Bond, N. A., M. F. Cronin, H. Freeland, and N. Mantua. 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. Geophysical Research Letters **42**:3414–3420.

Bonney, R., J. Byrd, J. T. Carmichael, L. Cunningham, L. Oremland, J. Shirk, and A. Von Harten. 2021. Sea change: Using citizen science to inform fisheries management. BioScience **71**:519–530.

Boyd, I. 2000. State-dependent fertility in pinnipeds: contrasting capital and income breeders. Funct. Ecol. **14**:623–630.

Brenner, R., S. Larsen, A. Munro, and A. Carroll. 2021. Run forecasts and harvest projections for 2021 Alaska salmon fisheries and review of the 2020 season. Alasks Department of Fish and Game, Special Publications No. 21-07. Anchorage, AK.

Brickley, P. J., and A. C. Thomas. 2004. Satellite-measured seasonal and inter-annual chlorophyll variability in the Northeast Pacific and coastal Gulf of Alaska. Deep-Sea Research Part II-Topical Studies in Oceanography **51**:229–245.

Briscoe, R., M. Adkison, A. Wertheimer, and S. Taylor. 2005. Biophysical factors associated with the marine survival of Auke Creek, Alaska, coho salmon. Transactions of the American Fisheries Society **134**:817–828.

Brodeur, R., and D. M. Ware. 1992. Long-term variability in zooplankton biomass in the subarctic Pacific Ocean. Fisheries Oceanography **1**:32–37.

Brodeur, R. D., T. W. Buckley, G. M. Lang, D. L. Draper, J. Buchanan, and R. E. Hibpshman. 2021. Demersal fish predators of gelatinous zooplankton in the Northeast Pacific Ocean. Marine Ecology Progress Series **658**:89–104.

Brodeur, R. D., M. B. Decker, L. Ciannelli, J. E. Purcell, N. A. Bond, P. J. Stabeno, E. Acuna, and G. L. Hunt. 2008. Rise and fall of jellyfish in the eastern Bering Sea in relation to climate regime shifts. Progress in Oceanography **77**:103–111.

Brodeur, R. D., R. L. Emmett, J. P. Fisher, E. Casillas, D. J. Teel, and T. W. Miller. 2004. Juvenile salmonid distribution, growth, condition, origin, and environmental and species associations in the Northern California Current. Fishery Bulletin **102**:25–46.

Brodte, E., R. Knust, and H. O. Pörtner. 2006. Temperature-dependent energy allocation to growth in Antarctic and boreal eelpout (Zoarcidae). Polar Biology **30**:95–107.

Brooks, M., E. Fergusson, M. Rogers, W. Strasburger, and R. Suryan. 2025. Juvenile salmon body condition in Southeast Alaska is buffered during marine heatwaves. Marine Ecology Progress Series **760**:135–149.

Carlson, H., and R. Haight. 1976. Juvenile life of Pacific ocean perch, *Sebastes alutus*, in coastal fjords of Southeastern Alaska: Their environment, growth, food habits and schooling behavior. Transactions of the American Fisheries Society **105**:191–201.

Carlson, H., and R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of Southeastern Alaska. Transactions of the American Fisheries Society **43**:13–19.

Champagnat, J., C. Monnahan, J. Sullivan, J. Thorson, S. Shotwell, L. Rogers, and A. Punt. 2025. Causal models as a scientific framework for next-generation ecosystem and climate-linked stock assessments. Sciety Labs .

Cheeseman, T., J. Barlow, J. Acebes, K. Audley, L. Bejder, C. Birdsall, O. Bracamontes, A. Bradford, J. Byington, C. J., R. Cartwright, J. Cedarleaf, A. Chavez, J. Currie, R. De Castro, J. De Weerdt, N. Doe, T. Doniol-Valcroze, K. Dracott, O. Filatova, R. Finn, K. Flynn, J. Ford, A. Frisch-Jordán, C. Gabriele, B. Goodwin, C. Hayslip, J. Hildering, M. Hill, J. Jacobsen, M. Jiménez-López, M. Jones, N. Kobayashi, M. Lammers, E. Lyman, M. Malleson, E. Mamaev, P. Loustalot, A. Masterman, C. Matkin, C. McMillan, J. Moore, J. Moran, J. Neilson, H. Newell, H. Okabe, M. Olio, C. Ortega-Ortiz, A. Pack, D. Palacios, H. Pearson, E. Quintana-Rizzo, R. Barragán, N. Ransome, H. Rosales-Nanduca, F. Sharpe, T. Shaw, K. Southerland, S. Stack, I. Staniland, J. Straley, A. Szabo, T. S.,

O. Titova, J. Urban-Ramirez, M. van Aswegen, M. Vinicius, O. von Ziegesar, B. Witteveen, J. Wray, K. Yano, I. Yegin, D. Zwiefelhofer, and P. Clapham. 2024. Bellwethers of change: population modelling of North Pacific humpback whales from 2002 through 2021 reveals shift from recovery to climate response. Royal Society Open Science **11**:231462.

Cheeseman, T., K. Southerland, J. Acebes, and et al. 2023. A collaborative and near-comprehensive North Pacific humpback whale photo-ID dataset. Scientific Reports **13**:10237.

Clarke, A. D., A. Lewis, K. H. Telmer, and J. M. Shrimpton. 2007. Life history and age at maturity of an anadromous smelt, the eulachon *Thaleichthys pacificus* (Richardson). Journal of Fish Biology **71**:1479–1493.

Collie, J., S. Hall, M. Kaiser, , and I. Poiner. 2000. A quantitative analysis of fishing impacts on shelf-sea benthos. Ecology **69**:785–798.

Combes, V., and E. Di Lorenzo. 2007. Intrinsic and forced interannual variability of the Gulf of Alaska mesoscale circulation. Progress in Oceanography **75**:266–286.

Conrath, C., and P.-J. Hulson. 2021. Temporal variability in the reproductive parameters of deepwater rockfishes in the Gulf of Alaska. Fisheries Research **237**:105876.

Conrath, C., P. Malecha, J. Hoff, P. Goddard, L. Sadorus, C. Rooper, R. Waller, S. Rooney, M. Everett, W. Larson, , and J. Olson. 2025. Deep Sea Coral Research and Technology Program: Alaska Coral and Sponge Initiative 2020-2024 Final Report. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-501, 79p.

Conrath, C., C. Rooper, R. Wilborn, B. Knoth, and D. Jones. 2019. Jellyfish blooms result in a major microbial respiratory sink of carbon in marine systems. Fisheries Research **219**:1–12.

Cooney, R. T., and T. Willette. 1997. Factors influencing the marine survival of pink salmon in Prince William Sound, Alaska, page 313 . U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-29.

COSEWIC. 2011. COSEWIC assessment and status report on the Nass / Skeena Rivers population, Central Pacific Coast population and the Fraser River population *Thaleichthys pacificus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xv + 88 pp.

Coyle, K. O., L. Eisner, F. J. Mueter, A. Pinchuk, M. Janout, K. Cieciel, E. Farley, and A. Andrews. 2011. Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the Oscillating Control Hypothesis. Fisheries Oceanography **20**:139–156.

Crusius, J., A. W. Schroth, J. A. Resing, J. Cullen, and R. W. Campbell. 2017. Seasonal and spatial variabilities in northern Gulf of Alaska surface water iron concentrations driven by shelf sediment resuspension, glacial meltwater, a Yakutat eddy, and dust. Global Biogeochemical Cycles **31**:942–960.

Danielson, S. L., T. D. Hennon, D. H. Monson, R. M. Suryan, R. W. Campbell, S. J. Baird, K. Holderied, and T. J. Weingartner. 2022. Temperature variations in the northern Gulf of Alaska across synoptic to century-long time scales. Deep Sea Research Part II: Topical Studies in Oceanography **203**:105155.

Decker, M. B., R. D. Brodeur, L. Ciannelli, L. L. Britt, N. A. Bond, B. P. DiFiore, , and G. L. Hunt. 2023. Cyclic variability of eastern Bering Sea jellyfish relates to regional physical conditions. Progress in Oceanography **210**:102923.

Di Lorenzo, E., and N. Mantua. 2016. Multi-year persistence of the 2014/15 North Pacific marine heatwave. Nature Climate Change **6**:1042–1047.

Di Lorenzo, E., D. Mountain, H. Batchelder, N. Bond, and E. Hofmann. 2013. Advances in marine ecosystem dynamics from US GLOBEC: The horizontal-advection bottom-up forcing paradigm. Oceanography **26**:22–33.

DiBattista, J. D., K. M. West, A. C. Hay, J. M. Hughes, A. M. Fowler, and M. A. McGrouther. 2021. Community-based citizen science projects can support the distributional monitoring of fishes. Aquatic Conservation: Marine and Freshwater Ecosystems **31**:3580–3593.

Dorn, M., and S. Zador. 2020. A risk table to address concerns external to stock assessments when developing fisheries harvest recommendations. Ecosystem Health and Sustainability **6**:1813634.

Doyle, M. J., S. J. Picquelle, K. L. Mier, M. Spillane, and N. Bond. 2009. Larval fish abundance and physical forcing in the Gulf of Alaska, 1981-2003. Progress in Oceanography **80**:163–187.

Drummond, K., M. Reda-Williams, and L. Divine. 2024. Skipper Science 2024 Observation Report. In: Ferriss, BE 2024. Ecosystem Status Report 2024: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Ducet, N., P. Y. Le Traon, and G. Reverdin. 2000. Global high-resolution mapping of ocean circulation from TOPEX/Poseidon and ERS-1 and-2. Journal of Geophysical Research-Oceans **105**:19477–19498.

Dumelle, M., M. Higham, and J. Ver Hoef. 2023. pmodel: Spatial statistical modeling and prediction in R. PLoS ONE **18**:e0282524.

Echave, K., C. Rodgveller, and S. Shotwell. 2013. Calculation of the geographic area sizes used to create population indices for the Alaska Fisheries Science Center longline survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-253, 93 p.

Eisenlord, M. E., M. L. Groner, R. M. Yoshioka, J. Elliott, J. Maynard, S. Fradkin, M. Turner, K. Pyne, N. Rivlin, R. van Hooidonk, and C. D. Harvell. 2016. Ochre star mortality during the 2014 wasting disease epizootic: role of population size structure and temperature. Philosophical Transactions of the Royal Society B: Biological Sciences **371**:20150212.

Esslinger, G., B. Robinson, D. Monson, R. Taylor, D. Esler, B. Weitzman, and J. Garlich-Miller. 2021. Abundance and distribution of sea otters (Enhydra lutris) in the southcentral Alaska stock, 2014, 2017, and 2019: U.S. Geological Survey Open-File Report 2021–1122, 19 p.

Fergusson, E., A. Gray, and J. Murphy. 2020*a*. Annual survey of juvenile salmon, ecologically-related species, and biophysical factors in the marine waters of southeastern Alaska, May–August 2018. NPAFC Doc. 43 pp. National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), Alaska Fisheries Science Center, Auke Bay Laboratories, Ted Stevens Marine Research Institute (Available at http://www.npafc.org).

Fergusson, E., T. Miller, M. McPhee, C. Fugate, and H. Schultz. 2020*b*. Trophic responses of juvenile Pacific salmon to warm and cool periods within inside marine waters of Southeast Alaska. Progress in Oceanography **186**:102378.

Fergusson, E., J. Murphy, and A. Gray. 2021. Southeast Alaska Coastal Monitoring Survey: salmon trophic ecology and bioenergetics, 2019. NPAFC Doc. 41 pp. National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), Alaska Fisheries Science Center, Auke Bay Laboratories, Ted Stevens Marine Research Institute. http://www.npafc.org.

Flostrand, L. A., J. F. Schweigert, K. S. Daniel, and J. S. Cleary. 2009. Measuring and modelling Pacific herring spawning-site fidelity and dispersal using tag-recovery dispersal curves. ICES Journal of Marine Science **66**:1754–1761.

Frankel, A., C. Gabriele, S. Yin, and S. Rickards. 2021. Humpback whale abundance in Hawai'i: Temporal trends and response to climatic drivers. Marine Mammal Science **38**:118–138.

Fritz, L., B. Brost, E. Laman, K. Luxa, K. Sweeney, J. Thomason, D. Tollit, W. Walker, and T. Zeppelin. 2019. A re-examination of the relationship between Steller sea lion *Eumetopias jubatus* diet and population trend using data from the Aleutian Islands. Canadian Journal of Zoology **97**:1137–1155.

Fritz, L., K. Sweeney, M. Lynn, T. Gelatt, J. Gilpatrick, and R. Towell. 2016*a*. Steller sea lion haulout and rookery locations in the United States for 2016-05-14 (NCEI Accession 0129877). https://doi.org/10.7289/v58c9t7v.

Fritz, L. W., K. Sweeney, R. G. Towell, and T. W. Gelatt. 2016*b*. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) conducted in Alaska in June-July 2013 through 2015, and an update on the status and trend of the western distinct population segment in Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-321, 72 p.

Froese, R. 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology **22**:241–253.

Frölicher, T. L., E. M. Fischer, and N. Gruber. 2018. Marine heatwaves under global warming. Nature **560**:360–364.

Gabriele, C., C. Amundson, J. Neilson, J. Straley, C. Baker, and S. Danielson. 2022. Sharp decline in humpback whale (*Megaptera novaeangliae*) survival and reproductive success in southeastern Alaska during and after the 2014–2016 Northeast Pacific marine heatwave. Mammalian Biology **102**.

Gabriele, C., J. Straley, and J. Nielson. 2007. Age at first calving of female humpback whales in southeastern Alaska. Marine Mammal Science **23**:226–239.

Gabriele, C. M., J. Neilson, and H. Hoffbauer. 2024. Update on Humpback Whale Calving in Glacier Bay and Icy Strait for 2024. In: Ferriss, B.E. 2024. Ecosystem Status Report 2023: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Gabriele, C. M., J. L. Neilson, J. M. Straley, C. S. Baker, J. A. Cedarleaf, and J. F. Saracco. 2017. Natural history, population dynamics, and habitat use of humpback whales over 30 years on an Alaska feeding ground. Ecosphere **8**:e01641.

Gaos, A., L. Kurpita, H. Bernard, L. Sundquist, C. King, J. Browning, E. Naboa, I. Kelly, K. Downs, T. Eguchi, and G. Balazs. 2021. Hawksbill nesting in Hawaii: 30-Year dataset reveals recent positive trend for a small, yet vital population. Frontiers in Marine Science **8**.

Geiger, H., W. Smoker, L. Zhivotovsky, and A. Gharrett. 1997. Variability of family size and marine survival in pink salmon (*Oncorhynchus gorbuscha*) has implications for conservation biology and human use. Canadian Journal of Fisheries and Aquatic Sciences **54**:2684–2690.

Gentemann, C. L., M. Fewing, and M. Garcia-Reyes. 2017. Satellite sea surface temperatures along the West Coast of the United States during the 2014–2016 northeast Pacific marine heat wave. Arctic **44**:312–319.

Gleason, C., A. Munro, and K. Gatt. 2025. Run forecasts and harvest projections for 2025 Alaska salmon fisheries and review of the 2024 season. Alaska Department of Fish and Game, Special Publication No. 25-10, Anchorage, AK.

Godson, P. S., S. G. T. Vincent, and S. Krishnakumar. 2022. Chapter 10 - benthic organisms as an ecological tool for monitoring coastal and marine ecosystem health. In Ecology and biodiversity of benthos (pp. 337–362). Elsevier.

Goldstein, E., M. Matta, S. Rohan, and M. Siple. In Press. Ocean warming differentially impacts demographics of marine fish with contrasting life histories in two large marine ecosystems. Marine Ecology Progress Series .

Goldstein, E. D., J. L. Pirtle, J. T. Duffy-Anderson, W. T. Stockhausen, M. Zimmermann, M. T. Wilson, and C. W. Mordy. 2020. Eddy retention and seafloor terrain facilitate cross-shelf transport and delivery of fish larvae to suitable nursery habitats. Limnology and Oceanography .

Gorman, K., J. Kline, T.C., M. Roberts, F. Sewall, R. Heintz, and W. Pegau. 2018. Spatial and temporal variation in winter condition of juvenile Pacific herring (*Clupea pallasii*) in Prince William Sound, Alaska: Oceanographic exchange with the Gulf of Alaska. Deep Sea Research Part II: Topical Studies in Oceanography **147**:116–126.

Graham, C. J., T. M. Sutton, M. D. Adkison, M. V. McPhee, and P. J. Richards. 2019. Evaluation of growth, survival, and recruitment of Chinook Salmon in Southeast Alaska rivers. Transactions of the American Fisheries Society **148**:243–259.

Griffiths, J. R., M. Kadin, F. J. A. Nascimento, T. Tamelander, A. Törnroos, S. Bonaglia, E. Bonsdorff, V. Brüchert, A. Gårdmark, M. Järnström, J. Kotta, M. Lindegren, M. C. Nordström, A. Norkko, J. Olsson, B. Weigel, R. Žydelis, T. Blenckner, S. Niiranen, and M. Winder. 2017. The importance of benthic–pelagic coupling for marine ecosystem functioning in a changing world. Global Change Biology **23**:2179–2196.

Hard, J., M. Gross, M. Heino, R. Hilborn, R. Kope, R. Law, and J. Reynolds. 2008. Evolutionary consequences of fishing and their implications for salmon. Evolutionary Applications **1**:388–408.

Harley, J. R., K. Lanphier, E. Kennedy, T. Leighfield, A. Bidlack, M. O. Gribble, and C. Whitehead. 2020. The Southeast Alaska Tribal Ocean Research (SEATOR) Partnership: Addressing data gaps in harmful algal bloom monitoring and shellfish safety in Southeast Alaska. Toxins **12**:407.

Harvell, C. D., D. Montecino-Latorre, J. M. Caldwell, J. M. Burt, K. Bosley, A. Keller, S. F. Heron, A. K. Salomon, L. Lee, O. Pontier, C. Pattengill-Semmens, and J. K. Gaydos. 2019. Disease epidemic and a marine heat wave are associated with the continental-scale collapse of a pivotal predator (*Pycnopodia helianthoides*). Science Advances **5**:eaau7042.

Harvey, H. R., R. L. Pleuthner, E. J. Lessard, M. J. Bernhardt, and C. Tracy Shaw. 2012. Physical and biochemical properties of the euphausiids Thysanoessa inermis, Thysanoessa raschii, and Thysanoessa longipes in the eastern Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography **65-70**:173–183.

Hastings, K. K., T. S. Gelatt, J. M. Maniscalco, L. A. Jemison, R. Towell, G. W. Pendleton, and D. S. Johnson. 2023. Reduced survival of Steller sea lions in the Gulf of Alaska following marine heatwave. Front. Mar. Sci. **10**:1127013.

Hatch, S. A., M. L. Arimitsu, J. F. Piatt, S. Whelan, and C. E. Marsteller. 2023. Seabird Diet Data Collected on Middleton Island, Gulf of Alaska: U.S. Geological Survey data release, https://doi.org/10.5066/P93I0P67.

Hauri, C., R. Pagès, K. Hedstrom, S. Doney, S. Dupont, B. Ferriss, and M. Stuecker. 2024. More than marine heatwaves: A new regime of heat, acidity, and low oxygen compound extreme events in the Gulf of Alaska. AGU Advances .

Hauri, C., R. Pagès, A. McDonnell, M. F. Stuecker, S. Danielson, K. Hedstrom, B. Irving, C. Schultz, and S. Doney. 2021. Modulation of ocean acidification by decadal climate variability in the Gulf of Alaska. Communications Earth and Environment **2**:191.

Hay, D., and P. B. Mccarter. 2000. Status of eulachon *Thaleichtheys pacificus* in Canada. Fisheries and Oceans Canada. Canadian Stock Assessment, 2000/145.

Hebert, K. 2022. Southeast Alaska 2020 herring stock assessment surveys. Alaska Department of Fish and Game, Fishery Data Series No. 22-21, Anchorage.

Heifetz, J., R. Stone, , and S. Shotwell. 2009. Damage and disturbance to coral and sponge habitat of the Aleutian Archipelago. Marine Ecology Progress Series **397**:295–303.

Heintz, R. A., E. C. Siddon, E. V. Farley Jr, and J. M. Napp. 2013. Correlation between recruitment and fall condition of age-0 pollock (*Theragra chalcogramma*) from the eastern Bering Sea under varying climate conditions. Deep Sea Research Part II: Topical Studies in Oceanography **94**:150–156.

Hobday, A. J., L. V. Alexander, S. E. Perkins, D. A. Smale, S. C. Straub, E. C. Oliver, J. A. Benthuysen, M. T. Burrows, M. G. Donat, and M. Feng. 2016. A hierarchical approach to defining marine heatwaves. Progress in Oceanography **141**:227–238.

Hobday, A. J., E. C. J. Oliver, A. S. Gupta, J. A. Benthuysen, M. T. Burrows, M. G. Donat, N. Holbrook, P. Moore, M. Thomsen, T. Wernberg, and D. Smale. 2018. Categorizing and naming marine heatwaves. Oceanography **31**:162–173.

Holbrook, N. J., H. A. Scannell, A. Sen Gupta, J. A. Benthuysen, M. Feng, E. C. J. Oliver, L. Alexander, M. Burrows, M. Donat, A. Hobday, P. Moore, S. Perkins-Kirkpatrick, D. Smale, S. Straub, and T. Wernberg. 2019. A global assessment of marine heatwaves and their drivers. Nature Communications **10**:1–13.

Holsman, K. K., and K. Aydin. 2015. Comparative methods for evaluating climate change impacts on the foraging ecology of Alaskan groundfish. Marine Ecology Progress Series **521**:217–235.

Hsieh, C.-h., C. S. Reiss, J. R. Hunter, J. R. Beddington, R. M. May, and G. Sugihara. 2006. Fishing elevates variability in the abundance of exploited species. Nature **443**:859.

Hunt, G. L., C. Baduini, and J. Jahncke. 2002. Diets of short-tailed shearwaters in the southeastern Bering Sea. Deep-Sea Research Part II: Topical Studies in Oceanography **49**:6147–6156.

Hunt, G. L., P. H. Ressler, G. A. Gibson, A. De Robertis, K. Aydin, M. F. Sigler, I. Ortiz, E. J. Lessard, B. C. Williams, and A. Pinchuk. 2016. Euphausiids in the eastern Bering Sea: A synthesis of recent studies of euphausiid production, consumption and population control. Deep Sea Research Part II: Topical Studies in Oceanography **134**:204–222.

Jacox, M. 2019. Marine heatwaves in a changing climate. Nature **571**:485–487.

J.M., G., M. Festa-Bianchet, N. Yoccoz, A. Loison, and C. Toigo. 2000. Temporal variation in fitness components and population dynamics of large herbivores. Annual Review of Ecology and Systematics **31**:367–393.

Johnson, D. S., and L. Fritz. 2014. agTrend: A Bayesian approach for estimating trends of aggregated abundance. Methods in Ecology and Evolution **5**:1110–1115.

Jones, D., C. Rooper, C. Wilson, P. Spencer, D. Hanselman, and R. Wilborn. 2021. Estimates of availability and catchability for select rockfish species based on acoustic-optic surveys in the Gulf of Alaska. Fisheries Research **236**:105848.

Kaga, T., S. Sato, T. Azumaya, N. D. Davis, and M. Fukuwaka. 2013. Lipid content of chum salmon *Oncorhynchus keta* affected by pink salmon *O. gorbuscha* abundance in the central Bering Sea. Marine Ecology Progress Series **478**:211–221.

Kaiser, M., K. Clarke, H. Hinz, M. Austen, P. Somerfield, and I. Karakassis. 2006. Global analysis of response and recovery of benthic biota to fishing. Marine Ecology Progress Series **311**:1–14.

Kapur, M., P.-J. Hulson, and B. Williams. 2023. Assessment of the Pacific Ocean Perch Stock in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK. Available from `https://www.npfmc.org/library/safe-reports/`.

Kendall, A., L. Incze, Jr, P. Ortner, S. Cummings, and P. Brown. 1995. The vertical distribution of eggs and larvae of walleye pollock, *Theragra chalcogramma*, in Shelikof Strait, Gulf of Alaska. Fishery Bulletin U.S. **92**:540–554.

Kim, S., C.-J. Lee, H.-K. Yoo, J. Choi, S.-G. Byun, H.-J. Kim, W.-J.and Lim, and J.-S. Park. 2022. Effect of water temperature on walleye pollock (Gadus chalcogrammus) embryos, larvae, juveniles: Survival, HSP70 expression, and physiological responses. Aquaculture **554**:738136.

Kimmel, D., K. Axler, D. Crouser, H. Fennie, A. Godersky, J. Lamb, J. Murphy, S. Porter, and B. Snyder. 2024. Current and Historical Trends for Zooplankton in the Bering Sea. In: Siddon, E. 2024. Ecosystem Status Report 2024: Eastern Bering Sea, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West 3rd Ave., Suite 400, Anchorage, Alaska 99501.

Kimmel, D., and J. Duffy-Anderson. 2020. Zooplankton abundance trends and patterns in Shelikof Strait, western Gulf of Alaska, USA, 1990–2017. Journal of Plankton Research **42**:334–354.

King, J. 2005. Report of the Study Group on Fisheries and Ecosystem Responses to recent regime shifts. PICES Scientific Report No. 28.

Kiörboe, T., and M. Sabatini. 1995. Scaling of fecundity, growth and development in marine planktonic copepods. Marine Ecology Progress Series **120**:285–298.

Klavans, J., P. DiNezio, A. Clement, C. Deser, T. Shanahan, and M. Cane. 2025. Human emissions drive recent trends in North Pacific climate variations. Nature **644**:684–692.

Kline, J., T. C. 2010. Stable carbon and nitrogen isotope variation in the northern lampfish and Neocalanus, marine survival rates of pink salmon, and meso-scale eddies in the Gulf of Alaska. Progress in Oceanography **87**:49–60.

Kline, T. C., J. Boldt, E. Farley, L. J. Haldorson, and J. H. Helle. 2008. Pink salmon (*Oncorhynchus gorbuscha*) marine survival rates reflect early marine carbon source dependency. Progress in Oceanography **77**:194–202.

Koehn, L., M. Siple, and T. Essington. 2021. A structured seabird population model reveals how alternative forage fish control rules benefit seabirds and fisheries. Ecological Application **31**:e02401.

Konar, B., T. J. Mitchell, K. Iken, H. Coletti, T. Dean, D. Esler, M. Lindeberg, B. Pister, and B. Weitzman. 2019. Wasting disease and static environmental variables drive sea star assemblages in the Northern Gulf of Alaska. Journal of Experimental Marine Biology and Ecology **520**:151209.

Koslow, J., G. Boehlert, J. Gordon, R. Haedrich, P. Lorance, and N. Parin. 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. ICES Journal of Marine Science **57**:548–557.

Koslow, J., S. Brault, R. Foirnier, and P. Hughes. 1985. Condition of larval cod Gadus morhua off southwest Nova Scotia in 1983 in relation to plankton abundance and temperature. Marine Biology **86**:113–121.

Kovach, R., A. Gharrett, and D. Tallmon. 2013*a*. Temporal patterns of genetic variation in a salmon population undergoing rapid change in migration timing. Evolutionary Applications **6**:795–807.

Kovach, R. P., J. Joyce, S. Vulstek, E. Barrientos, and D. Tallmon. 2014. Earlier migration timing, decreasing phenotypic variation, and biocomplexity in multiple salmonid species. Canadian Journal of Fisheries and Aquatic Sciences **71**:799–807.

Kovach, R. P., J. E. Joyce, J. D. Echave, M. S. Lindberg, and D. A. Tallmon. 2013*b*. Earlier migration timing, decreasing phenotypic variation, and biocomplexity in multiple salmonid species. PLoS ONE **8**:e53807.

LaBarre, A., B. Konar, and K. Iken. 2007. Influence of environmental conditions on *Mytilus trossulus* size frequency distributions in two glacially influenced estuaries. Estuaries and Coasts **46**:1–16.

Ladd, C. 2007. Interannual variability of the Gulf of Alaska eddy field. Geophysical Research Letters **34**:L11605.

Ladd, C., and W. Cheng. 2016. Gap winds and their effects on regional oceanography Part I: Cross Sound, Alaska. Deep Sea Research II **132**:41–53.

Ladd, C., W. R. Crawford, C. Harpold, W. Johnson, N. B. Kachel, P. Stabeno, and F. Whitney. 2009. A synoptic survey of young mesoscale eddies in the Eastern Gulf of Alaska. Deep-Sea Research Part II **56**:2460–2473.

Ladd, C., N. B. Kachel, C. W. Mordy, and P. J. Stabeno. 2005. Observations from a Yakutat eddy in the northern Gulf of Alaska. Journal of Geophysical Research-Oceans **110**:C03003.

Ladd, C., C. W. Mordy, N. B. Kachel, and P. J. Stabeno. 2007. Northern Gulf of Alaska eddies and associated anomalies. Deep-Sea Research Part I-Oceanographic Research Papers **54**:487–509.

Lamb, J. F., and D. G. Kimmel. 2021. The contribution of diet to the dramatic reduction of the 2013 year class of Gulf of Alaska walleye pollock (*Gadus chalcogrammus*). Fisheries Oceanography doi 10.1111/fog.12557 .

Landingham, J. H., M. V. Sturdevant, and R. D. Brodeur. 1998. Feeding habits of juvenile Pacific salmon in marine waters of southeastern Alaska and northern British Columbia. Fishery Bulletin **96**:285–302.

Laurel, B., M. Hunsicker, L. Ciannelli, T. Hurst, J. Duffy-Anderson, R. O'Malley, and M. Behrenfeld. 2021. Regional warming exacerbates match/mismatch vulnerability for cod larvae in Alaska. Progress in Oceanography **193**:102555.

Laurel, B. J., A. Abookire, S. J. Barbeaux, L. Z. Almeida, L. A. Copeman, J. Duffy-Anderson, T. P. Hurst, M. A. Litzow, T. Kristiansen, J. A. Miller, W. Palsson, S. Rooney, H. L. Thalmann, and L. A. Rogers. 2023. Pacific cod in the Anthropocene: An early life history perspective under changing thermal habitats. Fish and Fisheries **24**:959–978.

Laurel, B. J., and L. A. Rogers. 2020. Loss of spawning habitat and prerecruits of Pacific cod during a Gulf of Alaska heatwave. Canadian Journal of Fisheries and Aquatic Sciences **77**:644–650.

Lauth, R., S. McEntire, and Z. J. H.H. 2007. Geographic distribution, depth range, and description of Atka mackerel Pleurogrammus monopterygius nesting habitat in Alaska. Alaska Fisheries Research Bulletin **12**:165–186.

Lefebvre, K. A., L. Quakenbush, E. Frame, K. B. Huntington, G. Sheffield, R. Stimmelmayr, A. Bryan, P. Kendrick, H. Ziel, T. Goldstein, J. A. Snyder, T. Gelatt, F. Gulland, B. Dickerson, and V. Gill. 2016. Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment. Harmful Algae **55**:13–24.

Levine, M., A. De Robertis, P. Ressler, and B. Lucca. In Prep. A revised time series of euphausiid abundance and distribution from acoustic-trawl surveys of the eastern Bering Sea shelf. NOAA Technical Memorandum.

Li, L., A. B. Hollowed, E. D. Cokelet, S. J. Barbeaux, N. A. Bond, A. A. Keller, J. R. King, M. M. McClure, W. A. Palsson, P. J. Stabeno, and Q. Yang. 2019. Subregional differences in groundfish distributional responses to anomalous ocean bottom temperatures in the northeast Pacific. Global Change Biology **25**:2560–2575.

Lindgren, F., H. Rue, and J. Lindström. 2011. An Explicit Link Between Gaussian Fields and Gaussian Markov Random Fields: The Stochastic Partial Differential Equation Approach. Journal of the Royal Statistical Society Series B: Statistical Methodology **73**:423–498.

Link, J. S., J. K. T. Brodziak, S. F. Edwards, W. J. Overholtz, D. Mountain, J. W. Jossi, T. D. Smith, and M. J. Fogarty. 2002. Marine ecosystem assessment in a fisheries management context. Canadian Journal of Fisheries and Aquatic Sciences **59**:1429–1440.

Litzow, M. A., A. Abookire, J. Duffy-Anderson, B. Laurel, M. Malick, and L. Rogers. 2022. Predicting year class strength for climate-stressed gadid stocks in the Gulf of Alaska. Fisheries Research **249**:106250.

Livingston, P., K. Aydin, J. Boldt, J. Ianelli, and J. Jurado-Molina. 2005. A framework for ecosystem impacts assessment using an indicator approach. ICES Journal of Marine Science **62**:592–597.

Locarnini, R., A. Mishonov, O. Baranova, T. Boyer, M. Zweng, H. Garcia, J. J.R. Reagan, D. Seidov, K. Weathers, C. Paver, and I. Smolyar. 2019. World Ocean Atlas 2018, Volume 1: Temperature. A. Mishonov, Technical Editor. NOAA Atlas NESDIS 81, 52pp.

Lucca, B. M., P. Ressler, H. Harvey, and J. Warren. 2021. Individual variability in sub-Arctic krill material properties, lipid composition, and other scattering model inputs affect acoustic estimates of their population. ICES Journal of Marine Science **78**:1470–1484.

Malavaer, M. 2002. Modeling the energetics of Steller sea lions (Eumetopias jubatus) along the Oregon Coast. M.S. thesis, Oregon State University, Corvallis, Oregon.

Malick, M. J., M. Adkison, and A. Wertheimer. 2009. Variable effects of biological and environmental processes on coho salmon marine survival in southeast Alaska. Transactions of the American Fisheries Society **138**:846–860.

Maniscalco, J. 2023. Changes in the overwintering diet of Steller sea lions (emphEumetopias jubatus) in relation to the 2014-2016 northeast Pacific marine heatwave. Glob. Ecol. Conserv. **43**:1–10.

Matarese, A. C., D. M. Blood, S. J. Picquelle, and J. L. Benson. 2003. Atlas of abundance and distribution patterns of ichthyoplankton from the northeast Pacific Ocean and Bering Sea ecosystems based on research conducted by the Alaska Fisheries Science Center (1972-1996).

McGowan, D. 2023. Fisheries-independent Survey-based Indices of Capelin Relative Abundance. In: Ferriss, B.E. 2023. Ecosystem Status Report 2023: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

McGowan, D., D. Jones, M. Levine, and A. McCarthy. 2024. Results of the acoustic-trawl survey of walleye pollock (*Gadus chalcogrammus*) in the Shelikof Strait, March 2022 (DY2022-04). AFSC Processed Rep. 2024-04, 66 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115. https://repository.library.noaa.gov/view/noaa/60745.

McGowan, D. W., J. K. Horne, J. T. Thorson, and M. Zimmermann. 2019. Influence of environmental factors on capelin distributions in the Gulf of Alaska. Deep Sea Research Part II: Topical Studies in Oceanography **165**:238–254.

McGregor, A. J., S. Lane, and M. Thomason. 1998. Migration timing , a life history trait important in the genetic structure of pink salmon. North Pacific Anadromous Fish Commission **1**:262–273.

McHuron, E. A., K. L. Sweeney, and B. S. Fadely. 2024. Effects of the 2014–2016 marine heatwave on Steller sea lions in the Gulf of Alaska and implications for top-down forcing. Mar. Ecol. Prog. Ser. **736**:129–145.

McKinley, D. C., A. Miller-Rushing, H. Ballard, R. Bonney, H. Brown, S. Cook-Patton, D. Evans, R. A. French, J. K. Parrish, T. B. Phillips, S. F. Ryan, L. A. Shanley, J. L. Shirk, K. F. Stepenuck, J. F. Weltzin, A. Wiggins, O. D. Boyle, R. D. Briggs, S. F. I. Chapin, D. A. Hewitt, P. W. Preuss, and M. A. Soukup. 2017. Citizen science can improve conservation science, natural resource management, and environmental protection. Biological Conservation **208**:15–28.

McKinley, D. C., A. Miller-Rushing, H. Ballard, R. Bonney, H. Brown, D. Evans, R. A. French, J. K. Parrish, T. B. Phillips, S. F. Ryan, L. A. Shanley, J. L. Shirk, K. F. Stepenuck, J. F. Weltzin, A. Wiggins, O. D. Boyle, R. D. Briggs, S. F. I. Chapin, D. A. Hewitt, and M. A. Soukup. 2015.

Investing in citizen science can improve natural resource management and environmental protection. Issues in Ecology **208**:1–27.

Meunier, Z. D., S. D. Hacker, and B. A. Menge. 2024. Regime shifts in rocky intertidal communities associated with a marine heatwave and disease outbreak. Nature Ecology & Evolution pages 1–13 .

Moffitt, S., B. H. Marston, and M. Miller. 2002. Summary of eulachon research in the Copper River Delta, 1998–2002. Alaska Deptartment of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A02–34 Anchorage.

Moody, M. F., and T. J. Pitcher. 2010. Eulachon (*Thaleichthys pacificus*): past and present. The Fisheries Centre, University of British Columbia, Canada, 18(2), 197.

Mortensen, D., A. Wertheimer, C. Taylor, and J. Landingham. 2000. The relation between early marine growth of pink salmon, *Oncorhynchus gorbuscha*, and marine water temperature, secondary production, and survival to adulthood. Fishery Bulletin .

Moss, J. H., D. A. Beauchamp, A. D. Cross, K. W. Myers, E. V. Farley Jr, J. M. Murphy, and J. H. Helle. 2005. Evidence for size-selective mortality after the first summer of ocean growth by pink salmon. Transactions of the American Fisheries Society **134**:1313–1322.

Mueter, F., S. Shotwell, S. Atkinson, B. Coffin, M. Doyle, S. Hinckley, K. Rand, and J. Waite. 2016. Gulf of Alaska Retrospective Data Analysis NPRB GOA Project Retrospective Component Final Report. 165p.

Mueter, F. J., and B. L. Norcross. 2002. Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of Alaska. Fishery Bulletin **100**:559–581.

Murphy, J., E. Fergusson, A. Piston, S. Heinl, and A. Gray. 2020. Southeast Alaska coastal monitoring survey cruise report, 2018. NPAFC Doc. 1894. 23 pp. National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), Alaska Fisheries Science Center, Auke Bay Laboratories, and Alaska Department of Fish and Game (Available at https://npafc.org).

Murphy, J., E. Fergusson, A. Piston, S. Heinl, A. Gray, and E. Farley. 2019. Southeast Alaska pink salmon growth and harvest forecast models. NPAFC Tech. Rept. 15:75-81. National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), Alaska Fisheries Science Center, Auke Bay Laboratories, and Alaska Department of Fish and Game (Available at https://npafc.org).

Murphy, J. M., A. Piston, J. Moss, S. Heinl, E. Fergusson, W. Strasburger, and A. Gray. 2021. Southeast Alaska coastal monitoring survey: salmon distribution, abundance, size, and origin, 2019. NPAFC Doc. 1970. 23 pp. Alaska Fisheries Science Center, and Alaska Department of Fish and Game. (Available at `https://npafc.org`).

Muto, M., V. Helker, R. Angliss, B. Allen, P. Boveng, J. Breiwick, M. Cameron, P. Clapham, S. Dahle, M. Dahlheim, B. S. Fadely, M. C. Ferguson, L. W. Fritz, R. C. Hobbs, Y. V. Ivashchenko, A. S. Kennedy, J. M. London, S. A. Mizroch, R. R. Ream, E. L. Richmond, K. E. W. Shelden, R. G. Towell, P. R. Wade, J. N. Waite, and A. N. Zerbini. 2016. Alaska Marine Mammal Stock Assessments, 2016. National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), Alaska Fisheries Science Center.

National Marine Fisheries Service. 2013. Status Review of The Eastern Distinct Population Segment of Steller Sea Lion (Eumetopias jubatus). 144pp + Appendices. Protected Resources Division, Alaska Region, National Marine Fisheries Service, 709 West 9th St, Juneau, Alaska 99802.

Neilson, J. L., C. M. Gabriele, and L. E. McCaslin. 2024. Glacier Bay & Icy Strait Humpback Whale Population Monitoring: 2023 Update. National Park Service Resource Brief, Gustavus, Alaska. irma.nps.gov/DataStore/DownloadFile/700644.

Nishizawa, B., K. Matsuno, E. Labunski, K. Kuletz, A. Yamaguchi, and Y. Watanuki. 2017. Seasonal distribution of short-tailed shearwaters and their prey in the Bering and Chukchi seas. Biogeosciences **14**:203–214.

NOAA. 2010. Endangered and threatened wildlife and plants: Threatened status for southern distinct population segment of eulachon. In Federal Register (Vol. 75, Issue 52). https://doi.org/10.1021/j100299a032.

NOAA. 2021. NOAA High Resolution SST data provided by the NOAA/OAR/ESRL PSL, Boulder, Colorado, USA, from their Web site at https://www.fisheries.noaa.gov/feature-story/central-gulf-alaska-marine-heatwave-watch.

Okkonen, S. R., G. A. Jacobs, E. J. Metzger, H. E. Hurlburt, and J. F. Shriver. 2001. Mesoscale variability in the boundary currents of the Alaska Gyre. Continental Shelf Research **21**:1219–1236.

Okkonen, S. R., T. J. Weingartner, S. L. Danielson, D. L. Musgrave, and G. M. Schmidt. 2003. Satellite and hydrographic observations of eddy-induced shelf-slope exchange in the northwestern Gulf of Alaska. Journal of Geophysical Research-Oceans **108**:10.1029/2002JC001342.

Olds, A. L., S. B. Moran, and M. Castellini. 2016. Integrating local and traditional knowledge and historical sources to characterize run timing and abundance of eulachon in the Chilkat and Chilkoot rivers. By Allyson Olds. Thesis Submitted in Partial Fulfillment of the Requirements for the University of Alaska, Fairbanks.

Orsi, J. A., M. Sturdevant, and E. Fergusson. 2013. Connecting the "dots" among coastal ocean metrics and Pacific salmon production in Southeast Alaska, 1997–2012. North Pacific Anadromous Fish Commission Technical Report No. 9: 260-266.

Osborne, O., P. O'Hara, S. Whelan, P. Zandbergen, S. Hatch, and K. Elliott. 2020. Breeding seabirds increase foraging range in response to an extreme marine heatwave. Marine Ecology Progress Series **646**:161–173.

Oyafuso, Z. S. 2025. gapindex: Standard AFSC GAP Product Calculations. R package version 3.0.2. https://github.com/afsc-gap-products/gapindex.

Oyafuso, Z. S., L. A. K. Barnett, M. C. Siple, and S. Kotwicki. 2022. A flexible approach to optimizing the gulf of alaska groundfish bottom trawl survey design for abundance estimation (NOAA Tech. Memo. NMFS-AFSC-434; p. 142). U.S. Dep. Commer. https://doi.org/10.25923/g5zd-be29.

Parker, R. R. 1971. Size selective predation among juvenile salmonid fishes in a British-Columbia inlet. Journal of the Fisheries Research Board of Canada **28**:1503–1510.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres. 1998. Fishing down marine food webs. Science **279**:860–863.

Piatt, J., M. Arimitsu, W. Sydeman, S. Thompson, H. Renner, S. Zador, D. Douglas, S. Hatch, A. Kettle, and J. Williams. 2018. Biogeography of pelagic food webs in the North Pacific. Fisheries Oceanography **27**:366–380.

Piatt, J., J. Parrish, H. Renner, S. Schoen, T. Jones, M. Arimitsu, K. Kuletz, B. Bodenstein, M. García-Reyes, R. Duerr, and R. Corcoran. 2020. Extreme mortality and reproductive failure of common murres resulting from the northeast Pacific marine heatwave of 2014–2016. PloS ONE **15**:e0226087.

Piatt, J. F., and P. J. Anderson. 1996. Response of Common Murres to the Exxon Valdez oil spill and long-term changes in the Gulf of Alaska marine ecosystem. American Fisheries Society Symposium **18**:720–737.

Pierszalowski, S. P., C. M. Gabriele, D. J. Steel, J. L. Neilson, P. B. Vanselow, J. A. Cedarleaf, J. M. Straley, and C. S. Baker. 2016. Local recruitment of humpback whales in Glacier Bay and Icy Strait, Alaska, over 30 years. Endangered Species Research **31**:177–189.

Pinsky, M. L., R. L. Selden, and Z. J. Kitchel. 2020. Climate-driven shifts in marine species ranges: Scaling from organisms to communities. Annual Review of Marine Science **12**:153–179.

Piston, A., and S. Heinl. 2020. Pink salmon stock status and escapement goals in Southeast Alaska through 2019. Alaska Department of Fish and Game, Special Publication No. 20-09, Anchorage.

Prentice, M., G. Crandall, A. Chan, K. Davis, P. Hershberger, J. Finke, J. Hodin, A. McCracken, C. Kellogg, R. Clemente-Carvalho, C. Prentice, K. Zhong, C. Harvell, C. Suttle, and A. Gehman. 2025. Vibrio pectenicida strain FHCF-3 is a causative agent of sea star wasting disease. Nat Ecol Evol **9**:1739–1751.

Punt, A., R. Foy, M. Dalton, W. Long, and K. Swiney. 2016. Effects of long term exposure to ocean acidification on future southern Tanner crab (*Chionoecetes bairdi*) fisheries management. ICES Journal of Marine Science **73**:849–864.

Purcell, J. E. 2005. Climate effects on formation of jellyfish and ctenophore blooms: a review. Journal of the Marine Biological Association of the United Kingdom **85**:461–476.

Purcell, J. E., and M. N. Arai. 2001. Interactions of pelagic cnidarians and ctenophores with fish: a review. Hydrobiologia **451**:27–44.

Purcell, J. E., and M. V. Sturdevant. 2001. Prey selection and dietary overlap among zooplanktivorous jellyfish and juvenile fishes in Prince William Sound, Alaska. Marine Ecology Progress Series **210**:67–83.

Rand, P., and G. Ruggerone. 2024. Biennial patterns in Alaskan sockeye salmon ocean growth are associated with pink salmon abundance in the Gulf of Alaska and the Bering Sea. ICES Journal of Marine Science **81**:701–709.

Ream, R. R., J. T. Sterling, and T. R. Loughlin. 2005. Oceanographic features related to northern fur seal migratory movements. Deep-Sea Research Part II-Topical Studies in Oceanography **52**:823–843.

Reiniger, R., and C. Ross. 1968. A method of interpolation with application to oceanographic data. Deep Sea Research **15**:185–193.

Ressler, P. 2019. Gulf of Alaska Euphausiid ("krill") Acoustic Survey. 2019. In Ecosystem Status Report 2019, Gulf of Alaska, Zador et al., ed. URL: `https://apps-afsc.fisheries.noaa.gov/REFM/REEM/ecoweb/pdf/archive/2019GOAecosys.pdf`.

Ressler, P. H., A. De Robertis, J. D. Warren, J. N. Smith, and S. Kotwicki. 2012. Developing an acoustic survey of euphausiids to understand trophic interactions in the Bering Sea ecosystem. Deep Sea Research Part II: Topical Studies in Oceanography **65–70**:184–195.

Robards, M., G. Rose, and J. Piatt. 2002. Growth and abundance of Pacific sand lance, *Ammodytes hexapterus*, under differing oceanographic regimes. Environmental Biology of Fishes **64**:429–441.

Robins, J. B. 2006. Biophysical factors associated with the marine growth and survival of Auke Creek, Alaska Coho Salmon. Masters thesis, University of Alaska Fairbanks.

Robinson, B., H. Coletti, B. Ballachey, J. Bodkin, K. Kloeker, S. Traiger, and D. Ester. 2024. Lack of strong responses to the Pacific marine heatwave by benthivorous marine birds indicates importance of trophic drivers. Marine Ecology Progress Series **737**:215–226.

Robinson, K. L., J. J. Ruzicka, M. B. Decker, R. D. Brodeur, R. J. Hernandez, J. Quinones, E. M. Acha, S.-i. Uye, H. Mianzan, and W. M. Graham. 2014. Jellyfish, Forage Fish, and the World's Major Fisheries. Oceanography **27**:104–115.

Rodgveller, C. J. 2019. The utility of length, age, liver condition, and body condition for predicting maturity and fecundity of female sablefish. Fisheries Research **216**:18–28.

Rogers, L. A., A. Deary, and K. L. Mier. 2018. Larval Fish Abundance in the Gulf of Alaska, 1981-2017.

Rogers, L. A., and A. B. Dougherty. 2019. Effects of climate and demography on reproductive phenology of a harvested marine fish population. Global Change biology **25**:708–720.

Rogers, L. A., M. Wilson, J. Duffy-Anderson, D. Kimmel, and J. Lamb. 2020. Pollock and "the Blob": Impacts of a marine heatwave on walleye pollock early life stages. Fisheries Oceanography **30**:142–158.

Rogers, L. A., M. T. Wilson, J. T. Duffy-Anderson, D. G. Kimmel, and J. F. Lamb. 2021. Pollock and "the Blob": Impacts of a marine heatwave on walleye pollock early life stages. Fisheries Oceanography **30**:142–158.

Rohan, S. 2025. esrindex: Abundance index products for Alaska ESRs. R package version 1.2.0. https://github.com/afsc-gap-products/esrindex.

Rooper, C., J. Boldt, and M. Zimmermann. 2007. An assessment of juvenile Pacific ocean perch (Sebastes alutus) habitat use in a deep-water nursery. Estuarine, Coastal and Shelf Sciences **75**:371–380.

Rooper, C., and M. Martin. 2011. Comparison of habitat-based indices of abundance with fishery independent biomass estimates from bottom trawl surveys. Fishery Bulletin **110**:21–35.

Rooper, C., K. Williams, R. Towler, P. Malecha, P. Goddard, D. Jones, and M. Sigler. 2025. Lessons learned from testing the predictions of species distribution models for deep-sea corals and sponges in the Gulf of Alaska with comparisons to other Alaska ecosystems. ICES Journal of Marine Science page FSAF189 .

Root, R. 1967. The niche exploitation pattern of the blue-gray gnatcatcher. Ecological Monographs **37**:317–350.

Roundsfell, G., and E. Dahlgren. 1935. Races of Herring, *Clupea pallasii* in Southeastern Alaska. Bulletin of the Bureau of Fisheries, U.S. Department of Commerce, Vol. XLVIII, Bulletin No. 17, U.S. Government Printing Office, Washington, D.C.

Ruggerone, G., A. Springer, G. van Vliet, B. Connors, J. Irvine, L. Shaul, M. Sloat, and W. Atlas. 2023. From diatoms to killer whales: impacts of pink salmon on North Pacific ecosystems. Marine Ecology Progress Series **719**:1–40.

Ruggerone, G. T., M. Zimmermann, K. W. Myers, J. L. Nielsen, and D. E. Rogers. 2003. Competition between Asian pink salmon (*Oncorhynchus gorbuscha*) and Alaskan sockeye salmon (*O-nerka*) in the North Pacific Ocean. Fisheries Oceanography **12**:209–219.

Ryer, C., W. Long, M. Spencer, and P. Iseri. 2015. Depth distribution, habitat associations, and differential growth of newly settled southern Tanner crab *Chionoecetes bairdi* in embayments around Kodiak Island, Alaska. Alaska Fishery Research Bulletin **113**:256–269.

Salas, F., C. Marcos, J. M. Neto, J. Patrício, A. Pérez-Ruzafa, and J. C. Marques. 2006. User-friendly guide for using benthic ecological indicators in coastal and marine quality assessment. Ocean and Coastal Management **49**:308–331.

Schlegel, R., E. Oliver, A. Hobday, and A. Smit. 2019. Detecting marine heatwaves with sub-optimal data. Frontiers in Marine Science **6**:737.

Service, N. M. F. 2020. Western Distinct Population Segment Steller sea lion Eumetopias jubatus 5-Year Review: Summary and Evaluation. 61pp. Protected Resources Division, Alaska Region, National Marine Fisheries Service, 709 West 9th St, Juneau, Alaska 99802.

Shanley, C. S., S. Pyare, M. I. Goldstein, P. B. Alaback, D. M. Albert, C. M. Beier, T. J. Brinkman, R. T. Edwards, E. Hood, and A. MacKinnon. 2015. Climate change implications in the northern coastal temperate rainforest of North America. Climatic Change **130**:155–170.

Shaul, L. K., E. Crabtree, S. McCurdy, and B. Elliott. 2011. Coho salmon stock status and escapement goals in Southeast Alaska. Alaska Department of Fish and Game, Special Publication No. 11-21 3.

Shelton, A., J. Thorson, E. Ward, and B. Feist. 2014. Spatial semiparametric models improve estimates of species abundance and distribution. Canadian Journal of Fisheries and Aquatic Sciences **71**:1655–1666.

Shin, Y., M. Rochet, S. Jennings, J. Field, and H. Gislason. 2005. Using size-based indicators to evaluate the ecosystem effects of fishing. ICES Journal of Mainer Science **62**:384–396.

Shin, Y.-J., L. J. Shannon, A. Bundy, M. Coll, K. Aydin, N. Bez, J. L. Blanchard, M. d. F. Borges, I. Diallo, E. Diaz, J. J. Heymans, L. Hill, E. Johannesen, D. Jouffre, S. Kifani, P. Labrosse, J. S. Link, S. Mackinson, H. Masski, C. Möllmann, S. Neira, H. Ojaveer, K. ould Mohammed Abdallahi, I. Perry, D. Thiao, D. Yemane, and P. M. Cury. 2010. Using indicators for evaluating, comparing, and communicating the ecological status of exploited marine ecosystems. 2. Setting the scene. ICES Journal of Marine Science **67**:692–716.

Sigler, M. F., and D. Csep. 2007. Seasonal abundance of two importance forage species in the North Pacific Ocean, Pacific herring and walleye pollock. Fisheries Research **83**:319–331.

Sigler, M. F., J. N. Womble, and J. J. Vollenweider. 2004. Availability to Steller sea lions (*Eumetopias jubatus*) of a seasonal prey resource: a prespawning aggregation of eulachon (*Thaleichthys pacificus*). Canadian Journal of Fisheries and Aquatic Sciences **61**:1475–1484.

Sill, L. A., and T. Barnett. 2023. The subsistence harvest of Pacific herring spawn in Sitka Sound, Alaska, 2022. Alaska Department of Fish and Game Division of Subsistence, Technical Paper No. 492, Douglas.

Simonsen, K. A., P. H. Ressler, C. N. Rooper, and S. G. Zador. 2016. Spatio-temporal distribution of euphausiids: an important component to understanding ecosystem processes in the Gulf of Alaska and eastern Bering Sea. ICES Journal of Marine Science **73**:2020–2036.

Sinclair, E. H., D. Johnson, T. K. Zeppelin, and T. Gelatt. 2013. Decadal variation in the diet of Western Stock Steller sea lions (*Eumetopias jubatus*). U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-248, 67 p.

Siple, M. C., P. G. v. Szalay, N. W. Raring, A. N. Dowlin, and B. C. Riggle. 2024. Data report: 2023 gulf of alaska bottom trawl survey (NOAA Tech. Memo. AFSC processed report; 2024-09). U.S. Dep. Commer. https://doi.org/10.25923/gbb1-x748.

Siwicke, K. 2022. Summary of temperature and depth recorder data from the Alaska Fisheries Science Center's longline survey (2005–2021). U.S. Dep. Commer., NOAA Tech. Memo. NMFSAFSC-437, 74 p.

Siwicke, K. A., J. Moss, B. Beckman, and C. Ladd. 2019. Effects of the Sitka Eddy on juvenile pink salmon in the eastern Gulf of Alaska. Deep-Sea Res. II **165**:348–363.

Skipper Science Partnership. 2023. 2023 Observation dataset. [Data set]. Not publicly available.

Spalinger, K., and J. Silva. 2024. Large-mesh bottom trawl survey of crab and groundfish: Kodiak, Chignik, South Peninsula, and Eastern Aleutian Management Districts, 2023. Alaska Department of Fish and Game, Fishery Management Report No. 24-09, Anchorage.

Spalinger, K., and J. Silva. 2025. Large-mesh bottom trawl survey of crab and groundfish: Kodiak, Chignik, South Peninsula, and Eastern Aleutian Management Districts, 2024. Alaska Department of Fish and Game, Fishery Management Report No. 25-16, Anchorage.

Spangler, E. 2002. The Ecology of Eulachon (*Thaleichthys pacificus*) in Twentymile River, Alaska. By E. A. K. Spangler. Thesis Submitted in Partial Fulfillment of the Requirements for the University of Alaska, Fairbanks.

Speckman, S. G., J. F. Piatt, C. V. Minte-Vera, and J. K. Parrish. 2005. Parallel structure among environmental gradients and three trophic levels in a subarctic estuary. Deep Sea Research Part II: Topical Studies in Oceanography **66**:25–65.

Springer, A. M., and G. B. van Vliet. 2014. Climate change, pink salmon, and the nexus between bottom-up and top-down forcing in the subarctic Pacific Ocean and Bering Sea. Proceedings of the National Academy of Sciences **111**:E1880–E1888.

Stabeno, P., and S. Bell. 2019. Extreme conditions in the Bering Sea (2017–2018): record-breaking low sea-ice extent. Geophysical Research Letters **46**:8952–8959.

State of Alaska. 2022. Paralytic Shellfish Poisoning — Alaska, 1993–2021. Epidemiology Bulletin No. 5, April 21, 2022. Available at: `http://www.epi.alaska.gov/bulletins/docs/b2022_05.pdf`.

Stone, R., S. Cairns, D. Opresko, G. Williams, and M. Masuda. 2023. A guide to corals in Alaska. NOAA Professional Paper NMFS 23, 413p.

Sturdevant, M., J. Orsi, and E. Fergusson. 2012. Diets and trophic linkages of epipelagic fish predators in coastal Southeast Alaska during a period of warm and cold climate years, 1997–2011. Marine and Coastal Fisheries **4**:526–545.

Sturdevant, M., M. Sigler, and J. Orsi. 2009. Sablefish predation on juvenile Pacific salmon in the coastal marine waters of Southeast Alaska in 1999. Transactions of the American Fisheries Society **138**:675–691.

Sullivan, J., and L. Balstad. 2022. rema: A generalized framework to fit the random effects (RE) model, a state-space random walk model developed at the Alaska Fisheries Science Center (AFSC) for apportionment and biomass estimation of groundfish and crab stocks. R package version 1.2.0. https://github.com/afsc-assessments/rema.

Sullivan, J., C. Monnahan, P. Hulson, J. Ianelli, J. Thorson, , and A. Havron. 2022. REMA: A consensus version of the random effects model for ABC apportionment and tier 4/5 assessments. Plan Team Report, Joint Groundfish Plan Teams, North Pacific Fishery Management Council. 605 W 4th Ave, Suite 306 Anchorage, AK 99501. https://meetings.npfmc.org/CommentReview/DownloadFile?p=eaa760cf-8a4e-4c05-aa98-82615da1982a.pdf&fileName=Tier%204_5%20Random%20Effects.pdf.

Suryan, R., M. Arimitsu, H. Coletti, R. Hopcroft, M. Lindeberg, S. Barbeaux, S. Batten, W. Burt, M. Bishop, J. Bodkin, R. Brenner, R. Campbell, D. Cushing, S. Danielson, M. Dorn, B. Drummond, D. Esler, T. Gelatt, D. Hanselman, S. Hatch, S. Haught., K. Holderied, K. Iken, D. Irons, A. Kettle, D. Kimmel, B. Konar, K. Kuletz, B. Laurel, J. Maniscalco, C. Matkin, C. McKinstry, D. Monson, J. Moran, D. Olsen, W. Palsson, S. Pegau, J. Piatt, L. Rogers, N. Rojek, A. Schaefer, I. Spies, J. Straley, S. Strom, K. Sweeney, M. Szymkowiak, B. Weitzman, E. Yasumiishi, and S. Zador. 2021. Ecosystem response persists after a prolonged marine heatwave. Scientific Reports **11**:6235.

Suryan, R. M., M. R. Lindeberg, M. L. Arimitsu, D. Esler, H. A. Coletti, R. R. Hopcroft, and W. S. Pegau. 2023. Gulf Watch Alaska: Long-term research and monitoring in the Gulf of Alaska: Open Access Government, pp.468-469, https://doi.org/10.56367/OAG-038-10678.

Sweeney, K. L., B. Birkemeier, K. Luxa, and T. Gelatt. 2025. Results of the Steller sea lion (*Eumetopias jubatus*) surveys in Alaska, June–July 2024. AFSC Processed Rep. 2025-02, 47 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Sweeney, K. L., L. Fritz, R. Towell, and T. Gelatt. 2017. Results of Steller Sea Lion Surveys in Alaska, June-July 2017. Memorandum to The Record. November 29, 2017. https://www.afsc.noaa.gov/NMML/PDF/SSL_Aerial_Survey_2017.pdf.

Swiney, K., W. Long, and R. Foy. 2017. Decreased pH and increased temperatures affect young-of-the-year red king crab (Paralithodes camtschaticus). ICES Journal of Marine Sciences **74**:1191–1200.

Sydeman, W., J. Piatt, S. Thompson, M. García-Reyes, S. Hatch, M. Arimitsu, L. Slater, J. Williams, N. Rojek, S. Zador, and H. Renner. 2017. Puffins reveal contrasting relationships between forage fish and ocean climate in the North Pacific. Fisheries Oceanography **26**:379–395.

Tampo, L., I. Kaboré, E. H. Alhassan, A. Ouéda, L. M. Bawa, and G. Djaneye-Boundjou. 2021. Benthic macroinvertebrates as ecological indicators: their sensitivity to the water quality and human disturbances in a tropical river. Frontiers in Water **3**:1–17.

Theilacker, G., K. Bailey, M. Canino, and S. Porter. 1996. Variations in larval walleye pollock feeding and condition: a synthesis. Fisheries Oceanography **5**:112–123.

Theilacker, G., and S. Porter. 1995. Condition of larval walleye pollock, *Theragra chalcogramma*, in the western Gulf of Alaska assessed with histological and shrinkage indices. Fishery Bulletin pages 33–44 .

Thompson, P. L., J. Nephin, S. Davies, A. Park, D. Lyons, C. Rooper, A. Peña, J. Christian, K. Hunter, E. Rubidge, and A. Holdsworth. 2023. Groundfish biodiversity change in northeastern Pacific waters under projected warming and deoxygenation. Philosophical Transactions of the Royal Society B **378**:20220191.

Thompson, S. A., M. García-Reyes, W. J. Sydeman, M. L. Arimitsu, S. A. Hatch, and J. F. Piatt. 2019. Effects of ocean climate on the length and condition of forage fish in the Gulf of Alaska. Fisheries Oceanography **28**:658–671.

Thorson, J. 2019. Guidance for decisions using the Vector Autoregressive Spatio-Temporal (VAST) package in stock, ecosystem, habitat and climate assessments. Fisheries Research **210**:143–161.

Thorson, J., C. Adams, E. Brooks, L. Eisner, D. Kimmel, C. Legault, L. Rogers, and E. Yasumiishi. 2020. Seasonal and Interannual Variation in Spatio-Temporal Models for Index Standardization and Phenology Studies. ICES Journal of Marine Science **77**:1879–1892.

Thorson, J., S. Anderson, P. Goddard, and C. Rooper. 2024. tinyVAST: R package with an expressive interface to specify lagged and simultaneous effects in multivariate spatio-temporal models. arXiv. https://doi.org/10.48550/arXiv.2401.10193.

Thorson, J. T., and K. Kristensen. 2016. Implementing a generic method for bias correction in statistical models using random effects, with spatial and population dynamics examples. Fisheries Research **175**:66–74.

Tobin, E. D., C. Wallace, C. Crumpton, G. Johnson, and G. Eckert. 2019. Environmental drivers of paralytic shellfish toxin producing *Alexandrium catenella* blooms in a fjord system of northern Southeast Alaska. Harmful Algae **88**:101659.

Toge, K., R. Yamashita, K. Kazama, M. Fukuwaka, O. Yamamura, and Y. Watanuki. 2011. The relationship between pink salmon biomass and the body condition of short-tailed shearwaters in the Bering Sea: can fish compete with seabirds? Proceedings of the Royal Society B-Biological Sciences **278**:2584–2590.

Toresen, R. 2001. Spawning stock fluctuations and recruitment variability related to temperature for selected herring (*Clupea harengus*) stocks in the North Atlantic. In Herring: Expectations for a New Millennium, Alaska Sea Grant College Program, volume AK-SG-01-04, pg 315-334.

Traiger, S., J. Bodkin, H. Coletti, B. Ballachey, T. Dean, D. Esler, K. Iken, B. Konar, M. Lindeberg, D. Monson, B. Robinson, R. Suryan, and B. Weitzman. 2022. Evidence of increased mussel abundance related to the Pacific marine heatwave and sea star wasting. Marine Ecology **43**:e12715.

Turner, L., M. Arimitsu, J. Piatt, G. Eckert, and C. Cunningham. 2024. Alaska Forage Fish Database (AFFD): U.S. Geological Survey data release, https://doi.org/10.5066/P9WZQJ8N.

U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska - Inventory and Monitoring Network, and University of Alaska Fairbanks - College of Fisheries and Ocean Sciences. 2016. Intertidal temperature data from Kachemak Bay, Prince William Sound, Katmai National Park and Preserve, and Kenai Fjords National Park (ver 4.0, September 2023): U.S. Geological Survey data release, https://doi.org/10.5066/F7WH2N3T.

U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska Inventory and Monitoring Network. 2016. Intertidal mussel (Mytilus) data from Prince William Sound, Katmai National Park and Preserve, and Kenai Fjords National Park (ver 5.0, August 2024): U.S. Geological Survey data release, https://doi.org/10.5066/F7FN1498.

U.S. Geological Survey - Alaska Science Center, National Park Service - Southwest Alaska Inventory and Monitoring Network. 2022. Rocky intertidal data from Prince William Sound, Katmai National Park and Preserve, and Kenai Fjords National Park (ver 2.0, October 2023): U.S. Geological Survey data release, https://doi.org/10.5066/F7513WCB.

van Aswegen, M., A. Szabo, J. Currie, S. Stack, L. Evans, J. Straley, J. Neilson, C. Gabriele, K. Cates, D. Steel, and L. Bejder. 2025. Maternal investment, body condition and calf growth in humpback whales. The Journal of Physiology **603**:551–578.

Van Handel, E. 1985. Rapid determination of total lipids in mosquitoes. Journal of the American Mosquito Control Association **1**:302–4.

Vandersea, M., S. Kibler, P. Tester, K. Holderied, D. Hondolero, K. Powell, S. Baird, A. Doroff, D. Dugan, and R. Litaker. 2018. Environmental factors influencing the distribution and abundance of *Alexandrium catenella* in Kachemak Bay and lower Cook Inlet, Alaska. Harmful Algae **77**:81–92.

Von Biela, V. R., M. L. Arimitsu, J. F. Piatt, B. Heflin, S. K. Schoen, J. L. Trowbridge, and C. M. Clawson. 2019. Extreme reduction in nutritional value of a key forage fish during the pacific marine heatwave of 2014-2016. Marine Ecology Progress Series **613**:171–182.

Waite, J. N., and F. Mueter. 2013. Spatial and temporal variability of chlorophyll-a concentrations in the coastal Gulf of Alaska, 1998–2011, using cloud-free reconstructions of SeaWiFS and MODIS-Aqua data. Progress in Oceanography **116**:179–192.

Wakabayashi, K. R., G. Bakkala, and M. S. Alton. 1985. Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May-August 1979. In R. G. Bakkala and K. Wakabayashi (Eds.), International North Pacific Fisheries Commission Bulletin (Vol. 44, pp. 7–29). International North Pacific Fisheries Commission.

Walsh, J. E., R. L. Thoman, U. S. Bhatt, P. A. Bieniek, B. Brettschneider, M. Brubaker, S. Danielson, R. Lader, F. Fetterer, and K. Holderied. 2018. The high latitude marine heat wave of 2016 and its impacts on Alaska. Bulletin of the American Meteorological Society **99**:S39–S43.

Wang, M., and E. Lemagie. 2024. Wintertime Aleutian Low Index. In: Ferriss, BE 2024. Ecosystem Status Report 2024: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Ward, E., S. Anderson, and L. Damiano. 2019. bayesdfa: Bayesian Dynamic Factor Analysis (DFA) with 'Stan'. R package version 0.1.3. https://CRAN.R-project.org/package=bayesdfa.

Ware, D. M., and R. E. Thomson. 2005. Bottom-up ecosystem trophic dynamics determine fish production in the Northeast Pacific. Science **308**:1280–1284.

Warlick, A. J., D. S. Johnson, K. L. Sweeney, T. S. Gelatt, and S. J. Converse. 2023. Examining the effect of environmental variability on the viability of endangered Steller sea lions using an integrated population model. Endang. Species. Res. **52**:343–361.

Warzybok, P., J. Santora, D. Ainley, R. Bradley, J. Field, C. P.J., C. R.D., E. M., J. Beck, G. McChesney, M. Hester, and J. Jahncke. 2018. Prey switching and consumption by seabirds in the central California Current upwelling ecosystem: Implications for forage fish management. Journal of Marine Systems **185**:25–39.

Weitkamp, L. A., J. A. Orsi, K. Myers, and R. Francis. 2011. Contrasting early marine ecology of Chinook salmon and coho salmon in Southeast Alaska: insight into factors affecting marine survival. Marine and Coastal Fisheries **3**:233–249.

Weitzman, B., B. Konar, K. Iken, H. Coletti, D. Monson, R. Suryan, T. Dean, D. Hondolero, and M. Lindeberg. 2021. Changes in rocky intertidal community structure during a marine heatwave in the northern Gulf of Alaska. Frontiers in Marine Science **8**:1–18.

Wertheimer, D., A., J. A. Orsi, E. A. Fergusson, and M. V. Sturdevant. 2010. Calibration of Juvenile Salmon Catches using Paired Comparisons between Two Research Vessels Fishing Nordic 264 Surface Trawls in Southeast Alaska, July 2009.(NPAFC Doc. 1277). Auke Bay Laboratories, Alaska Fisheries Science Center, National Marine Fisheries Service (Available at https://npafc.org).

Wespestad, V. G., L. W. Fritz, W. J. Ingraham, and B. A. Megrey. 2000. On relationships between cannibalism, climate variability, physical transport, and recruitment success of Bering Sea walleye pollock (*Theragra chalcogramma*). ICES Journal of Marine Science **57**:272–278.

Whitehouse, A., and S. Gaichas. 2025. In Time Trends in Non-Target Species Catch. In: Ferriss, B.E. 2025. Ecosystem Status Report 2025: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Whitehouse, G. A., and S. Gaichas. 2024. Time trends in non-target species catch. In: Ferriss, B.E. 2024. Ecosystem Status Report 2024: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Wilderbuer, T. K., A. B. Hollowed, W. J. Ingraham, P. D. Spencer, M. E. Conners, N. A. Bond, and G. E. Walters. 2002. Flatfish recruitment response to decadal climatic variability and ocean conditions in the eastern Bering Sea. Progress in Oceanography **55**:235–247.

Williams, B., P.-J. Hulson, and B. Ferriss. 2024. Assessment of the northern rockfish stock in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK. Available from `https://www.npfmc.org/library/safe-reports/`.

Williams, T. M. 2005. Reproductive energetic of sea lions: implications for the size of protected areas around Steller sea lion rookeries. Alaska Sealife Center, Seward, AK.

Winemiller, K. 2005. Life history strategies, population regulation, and implications for fisheries management. Canadian Journal of Fisheries and Aquactic Sciences **62**:872–885.

Winship, A. J., A. W. Trites, and D. A. S. Rosen. 2002. A bioenergetic model for estimating the food requirements of Steller sea lions (*Eumetopias jubatus*) in Alaska, USA. Marine Ecology Progress Series **229**:291–312.

Witteveen, B., A. De Robertis, L. Guo, and K. Wynne. 2015. Using dive behavior and active acoustics to assess prey use and partitioning by fin and humpback whales near Kodiak Island, Alaska. Marine Mammal Science **31**:255–278.

Witteveen, B., R. Foy, K. Wynne, and Y. Tremblay. 2008. Investigation of foraging habits and prey selection by humpback whales (*Megaptera novaeangliae*) using acoustic tags and concurrent fish surveys. Marine Mammal Science **24**:516–534.

Yang, Q., E. D. Cokelet, P. J. Stabeno, L. Li, A. B. Hollowed, W. A. Palsson, N. A. Bond, and S. J. Barbeaux. 2019. How "The Blob" affected groundfish distributions in the Gulf of Alaska. Fisheries Oceanography **28**:434–453.

Yasumiishi, E., E. Farley, G. Ruggerone, B. Agler, and L. Wilson. 2016. Trends and factors influencing the length, compensatory growth, and size-selective mortality of juvenile Bristol Bay, Alaska, sockeye salmon at sea. Marine and Coastal Fisheries **8**:315–333.

Young, N. C., A. A. Brower, M. M. Muto, J. C. Freed, R. P. Angliss, N. A. Friday, B. D. Birkemeier, P. L. Boveng, B. M. Brost, M. F. Cameron, J. L. Crance, S. P. Dahle, B. S. Fadely, M. C. Ferguson, K. T. Goetz, J. M. London, E. M. Oleson, R. R. Ream, E. L. Richmond, K. E. W. Shelden, K. L. Sweeney, R. G. Towell, P. R. Wade, J. M. Waite, , and A. N. Zerbini. 2024. Alaska marine mammal stock assessments, 2023. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-493, 327 p.

Zebdi, A., and J. Collie. 1995. Effect of climate on herring (*Clupea pallasi*) population dynamics in the Northeast Pacific Ocean: Climate change and northern fish populations., 1995, pp. 277-290, Canadian special publication of fisheries and aquatic sciences /Publication speciale canadienne des sciences halieutiques et aquatiques Ottawa ON [Can. Spec. Publ. Fish. Aquat. Sci./Publ. Spec. Can. Sci. Halieut. Aquat.], no. 121.

Zimmermann, M., M. Prescott, and P. Haeussler. 2019. Bathymetry and geomorphology of Shelikof Strait and the western Gulf of Alaska. Geosciences **9**:1–31.