Proposed Ecosystem and Socioeconomic Profile of the Atka mackerel stock in the Bering Sea and Aleutian Islands

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September 2025

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This report may be cited as:

Sullivan, J.Y., Dame, R., Shotwell, S.K., Karp, M., Callahan, M. McDermott, S.F., Matta, B., Ortiz, I. 2025. Proposed Ecosystem and Socioeconomic Profile of the Atka mackerel stock in the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage, AK.

Executive Summary

Environmental and Socioeconomic Profiles (ESPs) have been developed for numerous commercially important and data rich stocks in Alaska (e.g. Alaska sablefish, Gulf of Alaska [GOA] pollock, and GOA and Bering Sea and Aleutian Islands [BSAI] Pacific cod), and are now a well-recognized tool for synthesizing and testing ecosystem and socioeconomic linkages within the stock assessment process (Shotwell et al. 2020).

Justification

An ESP was initially recommended for BSAI Atka mackerel by the BSAI Groundfish Plan Team in 2019 with support from the Scientific and Statistical Committee (BSAI Nov 2019, SSC Dec 2019), and this recommendation was reconfirmed in 2024 (BSAI Nov 2024, SSC Dec 2024). The national initiative prioritization scores for BSAI Atka mackerel are overall high because Atka mackerel is a Steller sea lion prey species (Hollowed et al., 2016).

Atka mackerel (*Pleurogrammus monopterygius*) are a commercially and ecologically significant species in the Aleutian Islands marine ecosystem, warranting the development of an ESP. As a fully utilized species with its Total Allowable Catch (TAC) consistently harvested, Atka mackerel are a critical target fishery in this management region. However, key uncertainties in their life history and recruitment dynamics challenge effective stock assessment. They do not recruit to the fishery until age-3, making estimates of recruitment, natural mortality, and other age-based processes highly uncertain. Moreover, they are poorly surveyed by conventional methods due to their diel migration patterns, tidal influences, preference for rocky habitat, and patchy distribution, all of which leads to high variability in survey indices. Given the vast and remote nature of the Aleutian Islands, ecosystem surveys in this region are sparse, and there is little direct information on the early life stages of Atka mackerel. An ESP will allow the integration of data from external sources, including oceanographic and biological time series data from the Aleutian Islands Ecosystem Status Report, auxiliary ecosystem surveys, and habitat-based analyses, to fill knowledge gaps. Such an approach would enhance understanding of Atka mackerel early life history, recruitment dynamics, and ecosystem interactions, ultimately leading to more robust management decisions.

Timeline

September 2025: Present proposed ESP indicator suite for the BSAI Atka mackerel stock to the BSAI Groundfish Plan Team (GPT).

November 2026: Present a full BSAI Atka mackerel ESP to coincide with the next BSAI Atka mackerel stock assessment.

Summary

This document proposes a suite of environmental, ecological, and socioeconomic indicators intended to support future monitoring and process-informed assessment of Atka mackerel in the BSAI. Unlike a full ESP, this proposal does *not* include a full status and trends assessment, indicator evaluation (e.g., traffic light, Bayesian adaptive sampling), or management implications. Instead, the primary objective is to establish a foundation for future monitoring and assessment efforts by outlining biologically plausible indicators, relevant life stages, and spatially structured hypotheses.

Each environmental/ecosystem indicator is accompanied by a description of its ecological relevance, associated life stage(s), spatial domain, and data sources. When possible, the indicator suite is spatially structured to reflect key oceanographic and biological gradients across the eastern, central, and western Aleutian Islands. This spatial framework is designed to support development of regionally specific, biologically informed hypotheses about recruitment variability, condition, and fishery performance. To support transparency and future refinement, we also include a section under each indicator on *Caveats and Knowledge Gaps*, which outlines known limitations, assumptions, and opportunities for improvement or further research.

In addition to ecological and environmental drivers, this document proposes a set of socioeconomic and value-added indicators developed in collaboration with the Alaska Fisheries Science Center's Economic and Social Sciences Research Program. These include first-wholesale price and value trends, TAC utilization by area, export patterns, and community employment indicators. Together, these metrics provide context for understanding market dynamics, fleet behavior, and community engagement in the Atka mackerel fishery.

While not intended to directly inform short-term management decisions, the goals of this ESP proposal are to build a shared understanding of the environmental and ecological processes that may influence Atka mackerel productivity, and to identify key data streams that could be integrated into future modeling efforts. As an example, we will present a subset of simplified dynamic structural equation models (DSEM) using these indicators during the accompanying Groundfish Plan Team presentation, demonstrating how they could be incorporated into the Structural Causal Enhanced Assessment Model (SCEAM) framework to support more process-informed, climate-resilient stock assessment and management in the future (Champagnat et al., in review).

Proposed Environmental and Ecosystem Indicators

Life History

Overview and Regional Context

Atka mackerel are a demersal schooling fish found throughout the Aleutian Islands and parts of the Bering Sea. They are ecologically important as forage for marine predators like Steller sea lions (*Eumetopias jubatus*) and are fully utilized by a directed bottom trawl fishery. The species shows strong site fidelity and is tightly associated with high-energy passes and rocky substrates, which influence adult distribution, spawning behavior, and larval retention. Their life history is closely intertwined with the unique biogeography of the Aleutian archipelago, which spans over 1,500 km and exhibits steep east-west gradients in temperature, productivity, and physical oceanography (Hunt and Stabeno, 2005). These gradients are shaped by interactions among the Alaska Stream, Aleutian North Slope Current, and Alaska Coastal Current, combined with the region's complex bathymetry and strong tidal mixing (Stabeno et al., 2009, Stabeno et al., 1999). As a result, Atka mackerel populations experience regionally distinct environmental conditions that influence all stages of their life cycle. These spatially distinct environmental gradients intersect with species-specific life history traits to shape Atka mackerel ecology and recruitment dynamics. Table 1 summarizes key ecological information by life history stage, and Figure 1 provides a conceptual model of survival bottlenecks and ecosystem processes affecting each stage, highlighting the direction and relative strength of hypothesized environmental influences.

Spawning and Early Development

The reproductive cycle of Atka mackerel includes three key phases: territory establishment, spawning, and brooding (Lauth et al., 2007a). In early June, mature adult males stop schooling and begin aggregating on rocky substrates in high-current habitats to establish nesting territories within larger nesting colonies (Lauth et al., 2007a). These colonies are located in depths of 20–144 m and are often within trawl exclusion zones, which may provide partial protection during reproduction (Cooper and McDermott, 2011, Lauth et al., 2007b).

Spawning occurs between late July and mid-October, peaking in early September (Lauth et al., 2007a). Females spawn an average of 4.6 egg batches over the 12-week season (McDermott et al., 2007). Nest site selection is influenced by light penetration, wave surge, kelp density, and the presence of green sea urchins, which eat eggs and may limit the depth range of suitable spawning habitat (Lauth et al., 2007b). During brooding, eggs are vulnerable to predation from cottids, other hexagramids, Atka mackerel of both sexes (a form of heterocannibilism), and males from their own nest, a common phenomenon in species with parental care known as filial cannibalism (Canino et al., 2008, Yang, 1999, Zolotov, 1993). Males guard nests of fertilized, adhesive eggs that develop from October through January in temperatures ranging from 3.9-9.9°C in the Aleutian Islands (Lauth et al., 2007b). Egg development is strongly temperature dependent: lower temperatures extend incubation (up to 169 days at 1.6°C in laboratory settings), while warmer temperatures accelerate development (39 days at 12.2°C) (Guthridge and Hillgruber, 2008). Temperatures above 15°C can be lethal to embryos. While warmer temperatures accelerate development, reducing vulnerability to predators, they may also increase metabolic demand and dependence on synchronized prey availability. Because the range of incubation temperatures observed in Aleutian nesting colonies has historically remained relatively stable (typical spawning grounds observed in Lauth et al., 2007b were 4.0-5.5°C), we hypothesize that episodic or prolonged warming events like marine heatwaves (MHW), like those experienced in late summer and fall in the Aleutians from 2014 to 2023 (Ortiz and Zador, 2024), may push temperatures beyond the species' optimal thermal window, potentially leading to reduced egg viability and/or mismatched timing of prey availability with first-feeding larvae.

Larval Dispersal and Age-0 Ecology

Larvae hatch between mid-October and mid-January (Lauth et al., 2007a). Their early survival is governed by temperature, food availability, and advection and retention of larvae. Larvae may be entrained in Aleutian passes or advected into the Bering Sea basin via the Alaska Stream and Aleutian North Slope Current. By spring and summer, young-of-the-year (YOY) or age-0 Atka mackerel are commonly found in the surface waters of the Bering Sea basin, where they feed pelagically on copepods and euphausiids. Their growth during this period is rapid but highly dependent on prey quality and oceanographic conditions that govern transport and foraging success.

Temperature plays a dual role in shaping the early life stages of Atka mackerel, influencing both larval development and the structure of the surrounding ecosystem. Warmer temperatures accelerate embryonic and larval development, potentially shortening the duration of vulnerability to predation or starvation (Pepin, 1991). However, this benefit is counterbalanced by increased metabolic demands, which heighten the need for timely and adequate prey availability. Elevated temperatures also alter the timing, magnitude, and species composition of primary and secondary producers. These changes can lead to reduced availability or quality of zooplankton prey, particularly the lipid-rich copepods and euphausiids critical for larval growth and condition (Fisher et al., 2020, Batten et al., 2018). In anomalously warm years, shifts in zooplankton community structure toward smaller, less nutritious species have been documented across the North Pacific (Batten et al., 2018). One of the central frameworks for understanding these effects is the match-mismatch hypothesis (Cushing, 1990), which proposes that larval survival is highest when first feeding coincides with peak abundance of appropriately sized prey. In the case of Atka mackerel, larvae hatch between October and January and likely depend on a timely supply of phytoplankton, copepod nauplii, or other small zooplankton shortly after yolk absorption (Table 1). A mismatch in this timing due to MHWs, shifts in bloom timing, or altered zooplankton phenology could result in food limitation and high early mortality, even in otherwise productive systems.

Advection and dispersal are especially relevant in the Aleutians, where complex current systems, including the Alaska Stream, Aleutian North Slope Current, and mesoscale eddies, may determine whether larvae are retained in productive island passes, transported into productive feeding ground, or swept into offshore, oligotrophic waters. Despite their ecological importance, direct observations of larval and age-0 Atka mackerel in the Aleutians are extremely rare. No surface trawl surveys are conducted in this region. However, summertime surface trawl surveys in the Bering Sea, such as Bering Arctic Subarctic Integrated Survey (BASIS; Murphy et. al., 2003a) and the North Pacific Anadromous Fish Commission (NPAFC; Murphy et al., 2003b; personal communication, Kentaro Honda, Fisheries Resources Institute, Japan Fisheries Research and Education Agency), have consistently captured age-0 Atka mackerel broadly distributed across the Bering Sea basin in waters deeper than the 50-meter isobath and within the upper 50 meters of the water column. This distribution suggests that some larvae may be advected northward from spawning sites and dispersed widely into oceanic habitats. These observations raise critical questions about whether the age-0 Atka mackerel observed offshore in the Bering Sea are destined to recruit successfully, or if recruitment is primarily derived from individuals retained in nearshore Aleutian habitats.

Predation is likely a major source of mortality for age-0 Atka mackerel, although direct studies of their predators remain limited (Table 1). Seabird diet data confirm that horned puffins (*Fratercula corniculate*), tufted puffins (*Fratercula cirrhata*), and other seabirds consume age-0 Atka mackerel, particularly in nearshore island habitats such as Buldir Island (Springer et al., 1999; personal communication, Nora Rojeck, Alaska Maritime National Wildlife Refuge, U.S. Fish and Wildlife Service). Age-0 Atka mackerel have been observed to exhibit diel vertical migration, occupying deeper depths during the day and moving shallower at night, based on paired day and night surface trawl surveys (Murphy et al., 2003a). This behavioral pattern likely mirrors that of their zooplankton prey, including copepods and euphausiids, many of which also migrate vertically in response to light and predation risk (e.g., Schabetsberger et al., 2000). Such behavior may reduce susceptibility to certain visually hunting predators, but the extent of this protection remains unknown.

Energetics and body condition are also key indicators of survival potential in early life stages. Poor nutritional status, whether due to insufficient prey or suboptimal prey quality, can impair swimming performance, reduce escape responses, and limit successful transition to juvenile stages (Buckley et al., 1999). Diet samples from the 2004 BASIS survey showed age-0 Atka mackerel feeding on a variety of mesozooplankton, including copepods, euphausiids, and amphipods, suggesting some dietary flexibility. However, the energy density of these prey items can vary widely. Year-to-year differences in prey composition and quality likely contribute to interannual variation in condition indices (e.g., length-weight residuals). Currently the only recurring age-0 Atka mackerel body condition index comes from puffin chick diets at Buldir Island in the western Aleutians, serving as a valuable proxy for early survival potential in this remote ecosystem.

In addition to predation and food availability, competition with other zooplanktivores may influence the survival and growth of age-0 Atka mackerel. One emerging hypothesis is that pink salmon (*Oncorhynchus gorbuscha*), particularly the Kamchatka stock, exert top-down pressure on the Aleutian zooplankton community through intense foraging during their oceanic phase. In years of high pink salmon abundance, declines in zooplankton biomass and concurrent increases in phytoplankton have been observed, suggesting a trophic cascade (Batten et al., 2018). These effects are particularly visible due to the species' strong biennial cycle, which creates contrasting conditions between odd and even years. When pink salmon numbers declined sharply in 2013, for example, zooplankton biomass rebounded, reinforcing the trophic cascade hypothesis. This pink salmon-driven trophic shift has been associated with a wide range of ecological responses across taxa, including Atka mackerel growth (Matta et al., 2020). The extent to which these findings suggest that pink salmon may compete directly or indirectly with age-0 Atka mackerel for key zooplankton prey, particularly during years when energy-rich euphausiids and large copepods are scarce, remains unknown.

Together, the processes of temperature-dependent development, prey dynamics, physical transport, predation, and condition form a conceptual model of recruitment variability in Atka mackerel. Though much remains unknown due to limited direct observation, especially in the early life stages, the integration of theoretical frameworks and indirect data sources supports the development of testable, spatially-explicit hypotheses within the ESP framework.

Pre-recruit Transition to Nearshore and Adult Ecology

Between ages 1 and 2, Atka mackerel begin returning to nearshore waters and are occasionally observed in trawl fisheries and surveys at depths of 0-200 m. These pre-recruits continue to feed primarily on copepods, euphausiids, and amphipods, although myctophids and other small fish begin to appear in their diets (Yang, 1999). As they move into more structured coastal environments, they encounter new predation risks from piscivorous groundfish such as Pacific cod (*Gadus macrocephalus*) and arrowtooth flounder (*Atheresthes stomias*; Livingston et al., 2017), as well as from marine mammals including northern fur seals (*Callorhinus ursinus*) and Steller sea lions (Kajimura, 1984; NMFS, 1995; Sinclair and Zeppelin, 2002; Sinclair et al., 2013). These pre-recruits may also face competition for zooplankton prey from Kamchatka pink salmon and rockfish species such as northern rockfish (*Sebastes polyspinis*) and Pacific ocean perch (*Sebastes alutus*). The trophic impacts of pink salmon in particular may contribute to zooplankton suppression during high-abundance years, potentially affecting Atka mackerel condition and growth (Matta et al., 2020).

By age-3, Atka mackerel recruit fully to the fishery and to NOAA bottom trawl surveys, typically at depths of 100-200 m. At this stage, they are subject to environmental variability, fishing mortality, and ecological interactions that shape their contribution to spawning biomass. Adults display strong site fidelity and typically return to the same rocky, high-energy habitats within island passes and shelf edges to spawn (Lauth et al., 2007b; McDermott et al., 2005). They continue to feed primarily on copepods and euphausiids, along with some fish (Yang, 1999). They have similar predators to age-1 and age-2 Atka mackerel, including Steller sea lions, Pacific cod, and arrowtooth flounder. Adults display strong daytime activity, moving off the bottom into the water column, presumably to feed, while remaining closely associated with the benthos at night (Nichol and Somerton, 2002). These behaviors likely contribute to reduced vulnerability to predators and gear during nighttime hours and may reflect the vertical migration patterns of their prey.

Growth patterns in adult Atka mackerel vary strongly across the Aleutian archipelago and reflect east-to-west differences in prey quality and environmental conditions (Rand et al., 2010, Lowe et al., 1998). Rand et al. (2010) found that the observed longitudinal size cline in Atka mackerel (larger fish in the east and smaller fish in the west) is best explained by differences in food quality rather than food quantity or temperature. For instance, Atka mackerel at Seguam Pass (eastern Aleutians) consumed more energy-dense euphausiids and forage fish, whereas fish from Amchitka Island (central Aleutians) relied more heavily on copepods, which are lower in energy content. These feeding differences are likely tied to regional productivity and may influence individual growth trajectories and reproductive potential.

Reproductive traits also vary by region. Females in the eastern Aleutians mature at larger sizes and slightly older ages than those in the central Aleutians (Cooper et al., 2010, McDermott and Lowe, 2007). Estimates of length and age at 50% maturity (L_{50} and A_{50}) show that eastern AI females mature at a fork length of approximately 34.91 cm and age 3.74 years, compared to 32.84 cm and 3.25 years in the central AI. Atka mackerel from Seguam Pass also showed higher potential and realized fecundity at length or age than those from Amchitka Island, with batch number instead of batch size driving regional differences in reproductive output (McDermott et al., 2011). This study showed that growth and length-weight also differed significantly between areas, emphasizing the importance of body condition and local foraging success in determining reproductive potential. Variability in prey energy content, regional growth rates, and condition should therefore be considered when forecasting recruitment or evaluating spatial management strategies.

Justification for ESP Spatial Structure

Given the steep physical and biological gradients across the Aleutians, the ESP includes three index sites that represent the dominant biogeographic and oceanographic regions: Seguam Pass, Amchitka Pass, and Agattu Island. Seguam marks the eastern-to-central transition zone and is characterized by high productivity, complex bathymetry, and dynamic larval transport. Amchitka represents central Aleutian conditions and offers a long-standing dataset on spawning, growth, and environmental variability. Agattu, located in the western Aleutians, provides a contrasting regime with cooler temperatures (though temperatures have warmed in this region in recent years), lower productivity, and potentially distinct early life history bottlenecks. These sites serve as spatial anchors for monitoring and interpreting ecosystem indicators relevant to Atka mackerel ecology. Throughout the ESP, environmental and biological indicators are, when possible, generalized to the eastern Aleutian Islands (EAI, Seguam), central Aleutians (CAI, Amchitka), and western Aleutians (WAI, Agattu).

This spatial structure is consistent with broader conceptual frameworks on recruitment dynamics. Doyle and Mier (2012) emphasize that recruitment variability arises from interactions between species-specific early life history traits and regionally distinct oceanographic processes. For Atka mackerel, key life history traits, such as substrate-attached eggs, a protracted male brooding phase, and a neustonic larval stage (Matarese et al., 2003), interact with spatially heterogeneous conditions like strong tidal mixing, variable eddy activity, and localized prey fields. Rather than assuming a uniform driver of recruitment across the Aleutians, the ESP supports regionally explicit, process-based hypotheses that reflect how physical and ecological context shapes recruitment potential. This approach helps ensure that life-stage specific exposure to environmental variability, not just broad-scale trends, informs monitoring and management of this ecologically and commercially important species.

Ecosystem Indicators

Fall Sea Surface Temperature (Figure 2)

Contact: Matt Callahan

Data: Late summer to fall (August 15-Nov 15) daily sea surface temperatures (SST) on a 5 km grid, averaged over three index sites: Seguam Pass (52.0-52.3°N, 173.0-172.2°W), Amchitka Pass (51.4-51.8°N, 179.0-178.0°W), and Agattu Island (52.3-52.9°N, 173.0-174.0°E). These regions correspond to the eastern, central, and western Aleutian Islands, respectively, and were selected to represent spatial gradients in physical oceanography relevant to Atka mackerel ecology. Data are sourced from the NOAA Coral Reef Watch Program, using the Global 5km Satellite Coral Bleaching Heat Stress Monitoring Product Suite, Version 3.1, derived from CoralTemp v1.0 (NOAA Coral Reef Watch, 2018). This product provides gap-free, globally consistent SST estimates based on satellite remote sensing, and is available from 1985 to present. Code available at: https://github.com/MattCallahan-NOAA/ESR-ESP/tree/main/SST/ESP/ai_atka

Relevant Life History Stage(s): Eggs (primary), Spawners

Relevant Spatial Extent: WAI, CAI, and EAI

Description: Elevated fall SSTs are expected to negatively affect Atka mackerel recruitment (lag-2), particularly through impacts on egg development, viability, and brooding success. Atka mackerel spawn from late July to mid-October, and males guard demersal, adhesive eggs through the fall and early winter. Egg incubation is highly temperature dependent: warmer water accelerates development, potentially reducing the brooding period and vulnerability to predation (Guthridge and Hillgruber, 2008), but temperatures exceeding the species' physiological tolerance can lead to increased mortality. Laboratory studies show that incubation periods range from 169 days at 1.6°C to just 39 days at 12.2°C, with 15°C proving lethal (Guthridge and Hillgruber, 2008). Historically, incubation temperatures in Aleutian nesting colonies have remained within a relatively narrow range (typical spawning grounds observed in Lauth et al., 2007b were 4.0-5.5°C), suggesting that abrupt warming events or MHWs may exceed the species' thermal window and reduce egg survival.

In addition to direct thermal stress, warmer incubation temperatures may cause eggs to hatch earlier in the season, before primary and secondary production peaks. This could result in a temporal mismatch between newly hatched larvae and the availability of appropriately sized zooplankton prey. Such mismatches are a well-documented mechanism of recruitment failure in marine fish species (Cushing, 1990), and may be particularly important for Atka mackerel larvae, which rely on abundant copepod nauplii shortly after yolk absorption. The timing of larval hatching relative to prey fields is especially critical given that fall-to-winter productivity is highly variable and light-limited in the Aleutians. Thus, warming-driven shifts in hatch timing could compound the risks posed by increased metabolic demands and reduced prey quality, further reducing survival during early life stages. These concerns are heightened by the recent sequence of MHW events observed during summer and fall (June-November) in the Aleutians from 2014 to 2023 (Ortiz and Zador, 2024). Thus, fall SST serves as an ecologically meaningful covariate for evaluating environmental constraints on Atka mackerel reproductive success.

Caveats and Knowledge GAPs: Although fall SST is a useful proxy for temperature trends, it may not fully represent the thermal environment experienced by Atka mackerel eggs and brooding males. Spawning typically occurs in high-flow passes with strong vertical mixing, likely reducing stratification and aligning surface and nest-depth temperatures more closely than in stratified systems (Lauth et al., 2007b). Still, daily SST anomalies may not capture short-term thermal extremes that exceed physiological thresholds. A MHW index focused on the intensity, duration, and timing of extreme warm events may better reflect episodic thermal stressors affecting brooding success, egg viability, and adult behavior. Incorporating MHW metrics could enhance the ecological relevance of this indicator and better align with hypothesized recruitment bottlenecks linked to thermal stress.

Spring Eddy Kinetic Energy (Figure 3)

Contact: Wei Cheng

Data: Average annual Eddy Kinetic Energy from April-June. A definition of regional index sites and the source data is available in the most recent Aleutian Islands Ecosystem Status Report (Ortiz and Zador, 2024).

Relevant Life History Stage(s): YOY

Relevant Spatial Extent: WAI, CAI, and EAI

Description: Eddy kinetic energy (EKE) is a prominent feature of the Aleutian marine environment and serves as an index of the strength and frequency of mesoscale eddies (Ortiz and Zador, 2024). These rotating water masses influence a range of physical processes, including lateral exchange, vertical mixing, and heat transport, and are most prevalent in spring when downwelling-favorable winds relax and allow anticyclonic eddies to form. While the specific biological consequences of EKE for Atka mackerel remain uncertain, particularly in terms of larval transport or zooplankton prey distribution, we hypothesize that EKE may play a more consistent and regionally distinct role in shaping spring temperature regimes. We expect EKE temperature effects to occur in-year (i.e., lag-0).

In the EAI, where island passes are narrow and geomorphology favors vertical exchange, high EKE is generally associated with increased upwelling and cooler spring temperatures. This is due in part to enhanced flow between the Gulf of Alaska and Bering Sea via the Alaska Stream and Aleutian North Slope Current, which can inject deeper, colder waters into surface layers. In contrast, the CAI and WAI are characterized by wider passes that facilitate more horizontal exchange. In these regions, high EKE is typically associated with the lateral intrusion of warmer offshore water masses, leading to warmer spring sea surface temperatures.

In summary, although eddies likely contribute to nutrient uplift, primary productivity, and transport, especially around their peripheries, our current understanding does not yet support region-specific hypotheses linking EKE directly to larval retention or prey fields for Atka mackerel. For now, the clearest ecological signal is that EKE influences spring temperature patterns in a regionally distinct manner, which may, in turn, shape early developmental conditions and metabolic demands for YOY Atka mackerel.

Caveats and Knowledge Gaps: EKE serves as an indirect proxy for eddy activity and strength, but the mechanistic pathways by which eddies influence larval dispersal, prey fields, or survival remain unclear. Fine-scale variation in eddy structure and their localized effects on temperature, productivity, and larval transport dynamics are not fully captured in the current index. Future refinements could include collaborative analyses with oceanographers to better characterize region-specific vertical and horizontal exchange processes, and to evaluate potential linkages between EKE and the physical and biological drivers hypothesized to influence Atka mackerel early life history.

Spring Sea Surface Temperature (Figure 4)

Contact: Matt Callahan

Data: Spring to summer (April-June) daily SST on a 5 km grid, averaged over three index sites: Seguam Pass (52.0–52.3°N, 173.0–172.2°W), Amchitka Pass (51.4-51.8°N, 179.0-178.0°W), and Agattu Island (52.3-52.9°N, 173.0-174.0°E). These regions correspond to the eastern, central, and western Aleutian Islands, respectively, and were selected to represent spatial gradients in physical oceanography relevant to Atka mackerel ecology. Data are sourced from the NOAA Coral Reef Watch Program, using the Global 5km Satellite Coral Bleaching Heat Stress Monitoring Product Suite, Version 3.1, derived from CoralTemp v1.0 (NOAA Coral Reef Watch, 2018). This product provides gap-free, globally consistent SST estimates based on satellite remote sensing, and is available from 1985 to present. Code available at: https://github.com/MattCallahan-NOAA/ESR-ESP/tree/main/SST/ESP/ai_atka

Relevant Life History Stage(s): Larvae, YOY

Relevant Spatial Extent: WAI, CAI, and EAI

Description: Elevated spring SSTs are expected to negatively affect Atka mackerel recruitment at all index sites (lag-1). This expectation is based on two primary mechanisms: (1) increased metabolic demands at higher temperatures may exceed the energetic intake possible from available prey, particularly if conditions fall outside the species' optimal thermal window, and (2) warmer temperatures are known to shift the timing, composition, and quality of zooplankton communities, which are essential prey for early life stages. In the North Pacific, anomalously warm years have been linked to declines in lipid-rich copepods and euphausiids, and a shift toward smaller, less nutritious zooplankton species (Coyle et al., 2011, Batten et al., 2018; Fisher et al., 2020). These bottom-up effects, coupled with the match-mismatch framework (Cushing, 1990), suggest that high spring SSTs could reduce the availability of suitable prey at critical developmental stages, increasing mortality risk for age-0 Atka mackerel.

Caveats and Knowledge Gaps: As currently presented, spring SST may not fully capture fine-scale mismatches between larvae and zooplankton prey availability, particularly if regional differences in bloom timing or productivity pulses are not aligned with larval development. While SST is hypothesized to influence both larval metabolism and prey phenology, its utility as a standalone indicator may be limited without concurrent measures of chlorophyll or zooplankton abundance. Initial analyses of satellite-derived chlorophyll-a were inconclusive due to persistent cloud cover, but future work in collaboration with oceanographers could help improve the timing and ecological relevance of spring productivity indicators. Observations of Atka mackerel larvae in the western Gulf of Alaska and southeastern Bering Sea (Matarese et al., 2003) also suggest that consideration of broader spatial and temporal windows may be needed to capture larval dynamics beyond the Aleutian passes currently sampled.

Zooplankton: Continuous Plankton Recorder Data from the Aleutian Islands and southern Bering Sea (Figure 5)

Contact: Clare Ostle

Data: These indicators summarize the basin-wide zooplankton community structure across the Aleutian Islands and southern Bering Sea during the summer growing season. Zooplankton data are derived from the Continuous Plankton Recorder (CPR) program and span the same spatial domain used in the Aleutian Islands Ecosystem Status Report (Ortiz and Zador, 2024). Samples are collected during CPR tows, with each tow covering approximately 10 nautical miles and filtering ~3 m^3 of seawater.

Three indicators are included:

1. CPR Euphausiids
2. CPR Large copepods(>= 2 mm)
3. CPR Small copepods (< 2 mm)

Zooplankton are identified and counted through a combination of quantitative and semi-quantitative methods: all individuals ≥ 2 mm are picked from the silk for full identification and enumeration, while those < 2 mm are counted via standardized traverse methods. Values represent the mean annual number of individuals per CPR sample, reported as individuals per 3 m^3 of seawater. For detailed methodology, see Richardson et al. (2006).

Relevant Life History Stage(s): YOY to Adult

Relevant Spatial Extent: Combined Aleutians Islands and Southern Bering Sea

Description: Zooplankton abundance and species composition are critical determinants of food availability and prey quality for Atka mackerel across multiple life stages. Larvae and age-0 juveniles are assumed to feed primarily on smaller copepods, euphausiids, and amphipods, while older juveniles and adults shift toward higher-energy prey such as large copepods, euphausiids, and forage fish (Yang, 1999, Rand et al., 2010). Years with elevated abundances of euphausiids and large copepods are associated with faster growth in adults, likely due to higher lipid content and better prey energy density (Mazur et al., 2007, Rand et al., 2010).

This CPR-derived zooplankton index provides insight into bottom-up processes affecting Atka mackerel growth, fecundity, and recruitment potential. Interannual fluctuations in zooplankton communities may also reflect broader climate-driven shifts in ocean productivity or competition with other pelagic predators, such as Kamchatka pink salmon. This indicator is particularly useful for evaluating prey-mediated mechanisms underlying regional differences in Atka mackerel productivity and population dynamics.

Caveats and Knowledge Gaps: The CPR samples are collected along fixed transects that may not align with Atka mackerel habitats, limiting the spatial resolution across the Aleutians and southeastern Bering Sea. Future collaboration with the data provider could help evaluate the spatial representativeness of the data and improve interpretation of seasonal and interannual variability in prey fields.

Zooplankton: Euphausiid and Copepods Proportions in Atka Mackerel Diets from the Aleutians Bottom Trawl Survey (Figure 6)

Contact: Kerim Aydin

Data: This indicator is derived from stomach content data collected during NOAA's biennial Aleutian Islands bottom trawl survey. The dataset includes the nominal proportion-by-weight of euphausiids and copepods in Atka mackerel diets, aggregated by region (EAI, CAI, WAI) and survey year. Diet samples were obtained from trawl-caught individuals and analyzed as part of ongoing ecosystem studies (Livingston et al., 2017).

Two diet composition indicators are included:

1. Proportion-by-weight of euphausiids
2. Proportion-by-weight of copepods

Relevant Life History Stage(s): YOY to Adult (primary)

Relevant Spatial Extent: WAI, CAI, and EAI

Description: Zooplankton abundance and species composition are critical indicators of food availability and prey quality for Atka mackerel across YOY, juvenile, and adult life stages. Age-0 fish are believed to feed primarily on small copepods, euphausiids, and amphipods, while older juveniles and adults increasingly rely on larger, energy-rich prey such as large copepods, euphausiids, and forage fish (Yang, 1999; Rand et al., 2010). Years with higher proportions of euphausiids in adult diets are associated with faster growth and improved condition, likely due to the higher lipid content and caloric density of these prey (Mazur et al., 2007, Rand et al., 2010). These changes may result from bottom-up processes such as climate-driven shifts in productivity, or from top-down pressures such as competition with other planktivorous species like Kamchatka pink salmon. By tracking regional and temporal variation in euphausiid and copepod diet proportions, the index supports evaluation of prey-mediated mechanisms contributing to growth, fecundity, and recruitment. It also serves as a key piece of evidence for understanding spatial differences in Atka mackerel condition and reproductive output across the Aleutian Islands.

Caveats and Knowledge Gaps: Current diet indicators derived from Atka mackerel stomach contents are based on nominal proportions by weight and do not account for the uneven, spatially patchy sampling of Atka mackerel across survey strata. This may lead to biased regional estimates if diet samples are not representative of the full population distribution. Additionally, sample sizes vary across years and regions, and prey identification is often coarse. Future improvements could include standardizing for sampling effort, incorporating stomach fullness, and developing indices that integrate zooplankton intake across multiple planktivorous taxa.

Auklet Reproductive Success as a Measure of Zooplankton Availability (Figure 7)

Contact: Nora Rojek

Data: This indicator is derived from long-term monitoring of seabird reproductive success at Buldir Island in the western Aleutian Islands, conducted by the Alaska Maritime National Wildlife Refuge (U.S. Fish and Wildlife Service) in collaboration with the U.S. Geological Survey Alaska Science Center. The monitored species include least auklet (*Aethia pusilla*), crested auklet (*Aethia cristatella*), parakeet auklet (*Aethia psittacula*), and whiskered auklet (*Aethia pygmaea*), all of which are obligate zooplanktivores. Adult auklets return to nests with zooplankton prey stored in their expandable gular pouches (throats), which can be expressed for diet analysis by gently massaging the throat area. Chick provisioning and reproductive success are assessed annually during the breeding season, with a consistent methodology used across species and years. Reproductive success is calculated as the number of fledged chicks per nest divided by the number of eggs per nest. Due to the similar nesting phenology and diet of these species, reproductive success metrics are combined to produce a composite index representing local zooplankton availability during the chick-rearing period.

Relevant Life History Stage(s): YOY to adult

Relevant Spatial Extent: WAI only (Buldir)

Description: Auklets are highly sensitive indicators of zooplankton availability in the western Aleutians. As foragers that rely on predictable access to lipid-rich prey (e.g., copepods and euphausiids) to provision chicks, auklet breeding success provides an ecologically meaningful proxy for the abundance and accessibility of zooplankton near Buldir Island. Years with high reproductive success suggest favorable foraging conditions and sufficient prey biomass to support chick growth. Conversely, late hatch dates and low breeding success, as observed in crested, parakeet, and whiskered auklets during recent years, point to delayed or limited availability of zooplankton prey. Although least auklets showed higher reproductive output in some years, the overall decline in reproductive success across species likely reflects regional reductions in zooplankton abundance or shifts in prey composition. Used in conjunction with other indicators (e.g., direct measures of zooplankton and fish condition), auklet reproductive success provides important insight into the base of the food web and its capacity to support higher trophic levels in this region.

Caveats and Knowledge Gaps: This indicator is limited to one island and may not be representative of the full area. Additionally, reproductive success is influenced by multiple factors beyond local zooplankton availability. These include breeding condition (linked to overwinter foraging), storm frequency, nest site quality, and interspecific differences among auklets. As such, declines may not always reflect prey limitation and this indicator should be interpreted with caution. Future analyses combining chick diet samples with reproductive metrics might help clarify zooplankton-driven effects.

Age-0 Atka Mackerel Condition in Puffin Chick Diets (Figure 8)

Contact: Nora Rojek and Mayumi Arimitsu

Data: This indicator tracks annual variation in the body condition of age-0 Atka mackerel based on fish sampled from horned puffin and tufted puffin chick diets at Buldir Island, located in the western Aleutian Islands (WAI). Condition is estimated using residuals from a length-weight regression applied to individual fish measured during seabird food habits studies conducted by the Alaska Maritime National Wildlife Refuge (U.S. Fish and Wildlife Service) and the U.S. Geological Survey Alaska Science Center.

Only Hexagrammid individuals ≥90 mm total length are included due to ongoing species identification challenges (personal communication, Mayumi Arimitsu, Gulf Watch Alaska); individuals <90 mm exhibit distinct length-weight relationships and are assumed to be other greenling species (e.g., kelp or rock greenling) based on expert opinion. We limited the analysis to years with ≥10 samples, resulting in eight usable years between 1999 and 2021: 1999, 2000, 2002, 2008, 2013, 2014, 2019, and 2021.

Relevant Life History Stage(s): YOY

Relevant Spatial Extent: WAI only (Buldir)

Description: Body condition is a critical indicator of early life survival potential, as it integrates the effects of food availability, prey quality, and environmental conditions experienced during the pelagic juvenile stage. Juvenile Atka mackerel primarily consume mesozooplankton such as copepods, euphausiids, and amphipods, but the energetic quality and availability of these prey varies (Mazur et al., 2007). For example, lipid-rich euphausiids may promote faster growth and better condition than lower-quality prey like small copepods. Poor condition, as reflected in lower weight-at-length residuals, can increase chances of starvation, reduce predator avoidance, and lower the likelihood of successful overwintering (reviewed in Sogard, 1997).

Although these diet-based condition estimates are geographically limited to the WAI, they provide a valuable proxy for regional foraging conditions and energy accumulation during the critical age-0 period. Condition data are hypothesized to be positively correlated with Atka mackerel recruitment at a one-year lag, as fish in better condition are more likely to survive overwintering and recruit to the age-1 stage. Given the remoteness of the Aleutians and the rarity of direct age-0 sampling, this seabird-derived indicator offers a unique and ecologically relevant window into early life history dynamics.

Caveats and Knowledge Gaps: There are caveats to this unique dataset. This indicator is geographically limited to a single colony at Buldir Island and reflects puffin foraging in a restricted portion of the western Aleutians. Species identification is limited to Hexagrammids ≥90 mm, which introduces taxonomic uncertainty and excludes potentially relevant size classes. Furthermore, puffin foraging locations and prey selection may not fully reflect Atka mackerel availability or condition across their broader juvenile habitat. Sample sizes vary by year, and the threshold of ≥10 individuals may still yield limited representativeness. While we acknowledge the limitations of the dataset, these data provide the only long-term, recurring condition index for juvenile Atka mackerel in the Aleutian Islands ecosystem. The available years include high contrast in Atka mackerel recruitment estimates and were found to be highly positively correlated with recruitment (rho=0.7; Figure 8).

Kamchatka Pink Salmon Abundance (Figure 9)

Contact: Gregory T. Ruggerone

Data: This indicator tracks the annual abundance of Eastern Kamchatka pink salmon, which represent the dominant pink salmon stock migrating through the Aleutian Islands Ecosystem. Abundance estimates are derived from escapement and catch data reported by Russian fisheries agencies and collaborators. Although other pink salmon stocks from Alaska, Japan, and Russia may occur in this region, Eastern Kamchatka pink salmon are the primary contributors based on historical tagging and recovery studies (Takagi et al., 1981).

Abundance is reported annually and exhibits a strong biennial pattern due to the species' fixed two-year life cycle. Odd-numbered years consistently show much higher abundance, with recent estimates exceeding 300 million adults in some years. These trends are used as a proxy for potential ecosystem-level effects in the Aleutians and Bering Sea, particularly related to zooplankton availability and trophic interactions.

Relevant Life History Stage(s): YOY to Adult

Relevant Spatial Extent: Combined Aleutians Islands and Bering Sea

Description: Eastern Kamchatka pink salmon are hypothesized to exert strong top-down control on mesozooplankton in the Aleutian Islands Ecosystem and southern Bering Sea (Ortiz and Zador, 2023). Their abundance has been negatively correlated with growth and condition of Atka mackerel (Matta et al., 2020), as well as with growth and reproductive success of other zooplanktivores such as tufted puffins (Springer and van Vliet, 2014).

Pink salmon migrate through the Aleutians in large numbers during spring and summer, potentially coinciding with YOY, juvenile, and adult Atka mackerel. They feed heavily on copepods, euphausiids, and other mesozooplankton, introducing the potential for competition with Atka mackerel at multiple life history stages. The strong biennial pattern in pink salmon abundance has been associated with trophic cascades: in years of high pink salmon abundance, zooplankton declines and shifts in composition have been observed (Batten et al., 2018), potentially reducing prey availability and quality for Atka mackerel and other predators. Pink salmon runs have increased dramatically since 2009, with recent peak years exceeding historical baselines by 2-3 times. These steep increases may have crossed an ecosystem threshold, triggering detectable impacts across trophic levels (Ortiz and Zador, 2023). This indicator provides important context for evaluating potential top-down drivers of variability in Atka mackerel recruitment, growth, and condition. While causality remains to be established, the strong synchrony between pink salmon abundance and other ecosystem indicators suggests that competition for zooplankton prey may be an important process shaping Atka mackerel productivity in the Aleutians.

Caveats and Knowledge Gaps: Pink salmon abundance is a coarse, stock-level estimate that does not directly measure overlap or foraging impact in the Aleutians. Migration timing, spatial overlap with Atka mackerel, and diet composition may vary interannually and are not quantified. Trophic linkages remain hypothetical. More targeted observations of the spatiotemporal overlap between the two species, or modeling of pink salmon diet and movement through the Aleutians would enhance understanding.

Rockfish Biomass (Figure 10)

Contact: Jane Sullivan

Data: This indicator tracks the combined biomass of Pacific ocean perch and northern rockfish based on standardized Aleutian Islands bottom trawl survey data. Biomass estimates are derived from NOAA's biennial bottom trawl survey and are smoothed using a state-space random walk time series model implemented in the *rema* R package (Sullivan et al., 2022, Sullivan and Balstad, 2024). The model provides region-specific biomass estimates with a single pooled process error standard deviation across all four regions to quantify interannual variability. Biomass is reported in metric tons and reflects the relative availability of rockfish as mid-trophic-level consumers and competitors of Atka mackerel in the Aleutian Islands.

Relevant Life History Stage(s): YOY to Adult

Relevant Spatial Extent: WAI, CAI, EAI, and southern Bering Sea (SBS)

Description: Pacific ocean perch and northern rockfish are long-lived, planktivorous species that feed on copepods, euphausiids, and other mesozooplankton. Their diets overlap with Atka mackerel throughout much of their life cycle. As their biomass has increased across the Aleutian Islands, these rockfish species have gradually replaced Atka mackerel and walleye pollock (*Gadus chalcogrammus*) as dominant pelagic foragers (Ortiz and Zador, 2023). This shift reflects a broader change in ecosystem structure, with rockfish now contributing a higher proportion of pelagic biomass throughout the archipelago.

Rockfish dominance has several ecological implications. First, competition for zooplankton prey may suppress growth or condition in Atka mackerel, especially in years of low productivity or high pink salmon abundance. Second, rockfish prefer structurally complex habitats like coral and sponge (Rooper et al., 2019), which may displace other species, including Atka mackerel, from preferred foraging grounds or shelter. As a result, the availability of Atka mackerel to predators such as Pacific cod may be reduced, a pattern observed in declining Atka mackerel proportions in Pacific cod diets in the CAI and WAI in recent years (Ortiz and Zador, 2023). As dominant planktivores, these rockfish increasingly consume a significant share of euphausiids and large copepods, key zooplankton resources that historically supported Atka mackerel, walleye pollock, and other forage fish (Ortiz and Zador, 2023). Their growing biomass, particularly when coupled with high pink salmon abundance, may be intensifying competition with Atka mackerel, and in turn may be a driver of variability in Atka mackerel recruitment, growth, and condition.

Caveats and Knowledge Gaps: This indicator aggregates two rockfish species with overlapping but distinct ecologies. Biomass is derived from trawl surveys, which may under-sample steep, rocky habitats preferred by rockfish. Furthermore, consumption rates, diet overlap, and spatial overlap with Atka mackerel are not well quantified. Incorporating diet studies or changes in spatial overlap through time between Atka mackerel, Pacific ocean Perch, and northern rockfish could improve this indicator.

Pacific Cod Biomass (Figure 11)

Contact: Jane Sullivan

Data: This indicator tracks the biomass of Pacific cod based on standardized Aleutian Islands bottom trawl survey data. Biomass estimates are derived from NOAA's biennial bottom trawl survey and are smoothed using a state-space random walk time series model implemented in the *rema* R package (Sullivan et al., 2022, Sullivan and Balstad, 2024). The model provides region-specific biomass estimates with a single pooled process error standard deviation across all four regions to quantify interannual variability. Biomass is reported in metric tons and reflects the relative predation pressure on Atka mackerel throughout the Aleutian Islands.

Relevant Life History Stage(s): YOY to Adult

Relevant Spatial Extent: WAI, CAI, EAI, and southern Bering Sea (SBS)

Description: Pacific cod are one of the primary groundfish predators of Atka mackerel in the Aleutian Islands. Diet analyses reveal that Atka mackerel are predominantly consumed by larger Pacific cod, typically those exceeding 60 cm fork length (Yang, 1999). The mean standard length of Atka mackerel consumed by Pacific cod was 22.6 ± 5.7 cm, with prey sizes ranging from 11 to 33 cm. These lengths correspond primarily to YOY, pre-recruit, and small adult Atka mackerel, highlighting Pacific cod biomass as a predation indicator with potential impacts on recruitment strength and adult biomass.

Over time, Pacific cod diets have shifted from being fish-dominated to increasingly composed of invertebrates such as shrimp and squid (Ortiz and Zador, 2023). This shift is most pronounced in the central and western Aleutians and is not observed east of Samalga Pass. Notably, Atka mackerel have not been replaced by other fish prey in diets, underscoring their continued importance as a food source for Pacific cod (Ortiz and Zador, 2023). The declining fish-to-invertebrate prey ratio and lower total prey biomass per predator weight suggest that Pacific cod are encountering reduced prey availability or prey quality. These changes may reflect broader ecosystem pressures, including competition for zooplankton prey from high abundances of rockfish and Kamchatka pink salmon, and long-term warming since 2014 in the Aleutians that may have altered foraging conditions. These factors could lead to compounded stress on both Pacific cod and their prey, especially Atka mackerel.

Caveats and Knowledge Gaps: Although Pacific cod are a major predator of Atka mackerel, their predation rate varies by size, season, and region. Diet data suggest a shift to invertebrates in some regions, which may obscure direct effects on Atka mackerel. Additionally, predator-prey interactions may be modulated by prey availability, environmental conditions, and Pacific cod condition. A multi-species framework could improve understanding of natural mortality sources.

Additional Indicators in Development or Under Consideration

1. Aleutian Low (e.g., North Pacific Index, winter Aleutian Low anomalies, or location): measures of basin-wide climate variability may help explain variability in temperature, storminess, current strength – all of which could affect survival during early life history stages
2. Steller Sea Lions: predation indicator on pre-recruits, adults
3. Body condition using bottom trawl survey and/or fishery data – indicator of feeding conditions
4. Mean weight in the fishery: indicator of fishery performance, and potentially recruitment
5. Standardized fishery CPUE: indicator of fishery performance, and potentially relative abundance
6. Area occupied using bottom trawl survey and/or fishery data: potential indicator for habitat use

Proposed Socioeconomic Indicators

Russel Dame

In collaboration with the Economic and Social Science Research Program

We propose the use of three socioeconomic indicators and three value-added socioeconomic indicators to help communicate economic and community drivers of the Atka mackerel fishery in the BSAI. Additionally, we propose the inclusion of two Economic Performance Report (EPR) tables to contextualize the state of the fishery by providing historical data on the first-wholesale market and global export market. These socioeconomic indicators and value-added socioeconomic indicators reflect trends in Atka mackerel markets, Total Allowable Catch (TAC) utilization, and community involvement to help inform TAC decisions. Below is a brief description of each new socioeconomic indicator and EPR table, the data source(s), variables, and methodology used to calculate each indicator along with a graphical and tabular preview of initial results.

We will utilize three data sources to calculate the proposed socioeconomic indicators: 1) the Alaska Commercial Operators Annual Report (COAR), 2) the NMFS AKRO catch accounting system (CAS) and 3) the Economic Data Report (EDR) program. The COAR considers purchasing information from land-based and at-sea processors, and other first buyers of raw seafood products, including gear types and product delivery conditions. Data from COAR requires additional processing to consider post-season adjustments (such as end-of-year bonuses) and prices of at-sea processors. For these reasons, and the submission deadline, COAR information is available with a one-year lag. In other ESPs, such as the sablefish ESP, we used ADF&G eLandings fish ticket data for in-season ex-vessel price and value observations. While eLandings data is reported by shoreside and at-sea processors, the "price" field is not mandatory and is often left blank by at-sea processors as there is no ex-vessel "transaction" occurring prior to processing. Due to a significant portion of Atka mackerel being caught and processed by the Amendment 80 fleet and at-sea processors, we do not have in-season data on prices that is representative of the Atka mackerel fishery. The NMFS AKRO CAS data provides in-season observations on landings by species, vessel type, and gear type. This data is integrated with eLandings data to extrapolate information for unobserved vessels, described in greater detail in Cahalan et al. (2014). The EDR program is a mandatory annual reporting requirement for the Amendment 80 fleet. Since the implementation of the Amendment 80 program, the EDR data collection program has collected comprehensive economic data of the entire Amendment 80 fleet. Although we do not have comprehensive economic data on all vessels participating in the Atka mackerel fishery, EDR data represents a significant portion of activity from the Atka mackerel fishery.

Socioeconomic Indicators

First-wholesale price per-pound

This indicator reports a timeseries of the yearly average first-wholesale price per-pound of Atka mackerel between 2003 and 2024 (Figure 12). The first-wholesale price represents the price received from a buyer after the fish has been processed and first sold into the market. Since most Atka mackerel are caught by the

Amendment 80 fleet and processed at-sea, a representative ex-vessel price is not available. In instances like this, we typically assume that the ex-vessel price is a fixed proportion of the first-wholesale price. This approximation, however, may not be applicable for all groundfish species. For these reasons, we choose to only show the observable first-wholesale price in this report. This indicator is calculated as the sum of the total first-wholesale value divided by the sum of the total processed product weight within a single year using COAR data.

The average first-wholesale price per-pound of Atka mackerel has increased rapidly between 2003 and 2014. In 2003, the first-wholesale market price was $0.37 per-pound and climbed to a historical high of $1.38 per-pound in 2014. Prices declined the following two-years before rebounding to $1.37 in 2017. Since 2017, the average first-wholesale price declined year-over-year reaching $0.91 per-pound in 2021, falling below the historical mean for the first time since 2010 but remained within one-standard deviation of historical data. In the following two-years, prices began to increase, rising to $1.06 per-pound in 2023 before falling to $0.99 per-pound in 2024. The 2024 average first-wholesale price per pound is above the historical mean and remains within one standard deviation of historical data.

First-wholesale value

Similar to the first-wholesale price per-pound indicator, this indicator shows a timeseries of the first-wholesale value of Atka mackerel between 2003 and 2024 (Figure 13). The first wholesale value represents the total amount paid to the processor after initial processing. As discussed above, we are reporting the first-wholesale value, as opposed to the ex-vessel value, of the Atka mackerel fishery because most Atka mackerel are landed by the Amendment 80 fleet and are processed by at-sea processors which do not have an observable ex-vessel value or price. We calculate the first-wholesale value as the sum of all Atka mackerel sales within a given year using COAR data.

The first-wholesale value of Atka mackerel increased between 2003 and 2010 before plateauing the subsequent two years. In 2013, the first-wholesale value sharply declined to the lowest value since 2007 before increasing year-over-year until 2018, reaching a historical high of $130.6 million. Similar to the average first-wholesale price per-pound, the first-wholesale value declined each following year until 2021 ($71.5 million), but remained above the historical mean, before increasing the following three years. In 2024, the first-wholesale value of Atka mackerel reached $94 million, remaining above the historical mean for the ninth consecutive year and within one-standard deviation of historical data.

Total Allowable Catch Utilization

This indicator will present a timeseries of the percentage of Total Allowable Catch (TAC) that is landed statewide for the full fishery at the end-of-year including CDQ and non-CDQ allocation for all sectors and gear type (Figure 14). We use data from the NMFS AKRO CAS to calculate total Atka mackerel landings. This data contains historical and in-season observations. This indicator, however, illustrates the end-of-year statewide TAC utilization resulting in a one-year lag. For in-season and historical area-specific weekly TAC utilization, see Section 2.a below. We calculate TAC utilization as the end-of-year landings divided by the end-of-year allocation. Landings considers targeted and incidental catch as well as discards at the processor and estimated discards at-sea. Historically, Atka mackerel TAC has been fully utilized reaching a TAC utilization >95% for 17 of the last 22 years and has remained above 90% each year within our data, excluding 2013 (89.4%) and 2022 (87.4%).

Socioeconomic Value-Added Indicators

Weekly Total Allowable Catch Utilization by Area

Total Allowable Catch (TAC) for Atka mackerel is allocated by sector and area. The Amendment 80 sector represents a majority of TAC allocation while the remainder of TAC is allocated between CDQ Trawl and Incidental Catch Allowance (ICA), the Jig fishery, and the BSAI trawl limited access fishery. After investigating TAC utilization by sector and area, we determined that it was most useful to group TAC utilization across sectors but separate by area. This value-added indicator (Figure 15) illustrates the historical weekly TAC utilization by area between 2016 and 2024 and weekly TAC utilization by area through the most recent full week of the current calendar year (August 30). We calculate TAC utilization as the weekly cumulative sum of area-specific landings, including CDQ and non-CDQ landings, divided by the end-of-year area-specific quota allocation. The end-of-year area-specific quota allocation accounts for in-season reallocations from the ICA representing the annual quota by area.

This value-added indicator suggests that the Central (CAI) and Western Aleutian Islands (WAI) historically reach ~100% of TAC utilization while there is higher variance in TAC utilization from the Bering Sea/East Aleutian Islands (BSEAI). In the CAI and WAI, TAC utilization through the end of August 2025 is below the historical average through August but does not appear to have reached a plateau suggesting that TAC may still be fully utilized but later in the calendar year than in the past. In the BSEAI, TAC utilization through the end of August 2025 reached a historical high through August, excluding 2024, suggesting that TAC may be fully utilized and reach end-of-year historical levels sooner than in the past. Providing historical and in-season area-specific TAC utilization may be helpful to the Council when determining changes in TAC allocations across areas and inform industry of the in-season trends in areas.

Share of Export Value and the Average Export Price Per-Pound of Atka Mackerel by Country

A significant portion of Atka mackerel is sold into the global market. Table 2 contains information on the global market, including production from the U.S., Japan, and Russia, aggregate export value, volume, and price, and the share of export value attributed to Japan. The Council and industry, however, may be interested in export data that is disaggregated by country for a more comprehensive analysis. We use trade data that is published by the Foreign Trade Division of the U.S. Census Bureau to illustrate the share of Atka mackerel export value by country. Since 2002, Atka mackerel exports have gone to Japan, China, or South Korea, excluding a small volume of exports to Vietnam in 2019 and Thailand in 2021. Figure 16 illustrates the share of Atka mackerel export value going to Japan, China, and South Korea and the associated yearly average export price-per pound between 2003 and 2024. We chose to remove the share of export volume going to each country since the trends are very similar to the share of export value.

We can see that Japan is the dominant export market for Atka mackerel, importing over 60% of Alaskan Atka mackerel exports each year (excluding 2011). Since 2021, the share of Atka mackerel exports to Japan has begun to decline but Japan continues to remain the primary trade partner. Export share to South Korea has steadily rose during this same time period but continues to be less than China's export share. A notable finding from this indicator is the relatively stable export price per-pound of Atka mackerel from Japan and China since 2013. The export price per-pound of Atka mackerel to South Korea has followed a similar historical trend to Japan and China but has begun to steadily decline since 2015 while little change has been seen from Japanese and Chinese markets.

Employee Count and Proportion of Employment by Community

As mentioned above, a majority of Atka mackerel is harvested by the Amendment 80 fleet and processed at-sea. For this reason, we cannot create a regional or local quotient, like in other groundfish ESPs, that illustrates the reliance on a given fishery from communities. We propose utilizing the employee count and the share of employee count by community collected by the EDR program to help illustrate community reliance on the Atka mackerel fishery. A caveat to this indicator, however, is it only considers data from the Amendment 80 fleet, not other vessels that harvest Atka mackerel, and does not consider indirect employment outside of the Amendment 80 fleet. We present the employment count and the share of employee count by community between 2015 and 2023 (Figure 17). The 2024 data is currently being prepared and will be available in the coming weeks. This figure is similar to Figure 9.13 in the 2024 Groundfish Economic SAFE, but only considers Amendment 80 vessels that harvest Atka mackerel as opposed to the full Amendment 80 fleet. Since 2015, the employee count has steadily dropped each year, excluding a small increase in 2019, to approximately 250 employees in 2023. The largest share of employees are Seattle residents. Alaska residents represent approximately 3% to 5% of the employee share between 2018 and 2023.

Economic Performance Report Tables

We present two EPR tables: 1) Atka mackerel first-wholesale market data (Table 3) and 2) U.S. trade and global market data (Table 2). Both EPR tables report yearly observations from the previous five years and a historical five-year average (2015-2019). Table 3 reports fishery-wide totals of the number of vessels harvesting Atka mackerel, the first-wholesale production weight, value, and price per-pound, and the share of all value from products sold as head and gut (H&G). Since most Atka mackerel is harvested by the Amendment 80 fleet, we also report this data for a subset of Amendment 80 vessels that harvested Atka mackerel. Pacific Ocean perch and Pacific cod are often harvested by Amendment 80 vessels that catch Atka mackerel. We report the first-wholesale production weight and the first-wholesale price per-pound for each of these species for a subset of the Amendment 80 fleet that harvested Atka mackerel to show the production of potential substitute species.

The U.S. trade and global market EPR table reports the global production of Atka mackerel and the share of global production that is attributed to the U.S., Japan, and Russia, the export volume, value, and price from the U.S., the percentage of U.S. export value that is exported to Japan, and the Yen to U.S. Dollar exchange rate. Global production and the share of global production attributed to each country is compiled from the Food and Agriculture Organization's (FAO) Global capture production quantity database.[1] The deadline for countries to compile and report their annual fisheries capture data to the FAO is August 31. The FAO then validates and compiles each country's data before publishing the data in the Global capture production quantity database in March of the following year. For example, 2024 capture data is due to the FAO on August 31, 2025 and that data is then published in the database in March 2026. For this reason, there is a two-year lag on global production data reported in this EPR table. Export production, value, and price data and the share of total export value attributed to Japan is collected from the Foreign Trade Division of the U.S. Census Bureau. This database considers all exports from the U.S., which for Atka mackerel is almost exclusively Alaska production. Since Japan is the primary trade partner for Atka mackerel, we report the Yen to the U.S. Dollar exchange rate. Fluctuations in the Japanese exchange rate can change the relative price of Alaskan seafood and become an important driver of the global Atka mackerel market.

Acknowledgements

We would like to thank all the contributors for their timely response to requests and questions regarding their data, report summaries, and manuscripts. We thank the staff of the survey programs for rapid turnaround of data to facilitate timely uptake and incorporation into this document. We also thank the reviewers of this report (Patrick Malecha), the Groundfish Plan Teams, and the SSC for their helpful insight on the development of this report and future reports. We thank the Alaska Fisheries Information Network and neXus Data Solutions teams for their extensive help with data management and processing for this report. Finally, we are grateful to Ruth Christiansen and Daniel Kusakari of Ocean Peace Inc. for their feedback on socioeconomic indicators.

[1] FAO's Global capture production Quantity database

Literature Cited

Batten, S.D., Raitsos, D.E., Danielson, S., Hopcroft, R.R., Coyle, K. and McQuatters-Gollop, A. (2018). Interannual variability in lower trophic levels on the Alaskan Shelf. Deep Sea Research II. 147, 58–68.

Cooper, D. W., S. F. McDermott and J. N. Ianelli. 2010. Spatial and temporal variability in Atka mackerel female maturity at length and age. Marine and Coastal Fisheries, 2:329-338. http://www.tandfonline.com/doi/abs/10.1577/C09-45.1

Cooper, D. and McDermott, S., 2011. Seasonal, small-scale distribution of Atka mackerel in the Aleutian Islands, Alaska, with respect to reproduction. *Marine and Coastal Fisheries*, *3*(1), pp.10-20. https://doi.org/10.1080/19425120.2011.558439

Coyle, K.O., Eisner, L.B., Mueter, F.J., Pinchuk, A.I., Janout, M.A., Cieciel, K.D., Farley, E.V. and Andrews, A.G., 2011. Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the oscillating control hypothesis. *Fisheries Oceanography*, *20*(2), pp.139-156

Cushing, D.H., 1990. Plankton production and year-class strength in fish populations: an update of the match/mismatch hypothesis. In *Advances in marine biology* (Vol. 26, pp. 249-293). Academic Press.

Doyle, M.J., Rugen, W.C., and Brodeur, R.D. 1995. Neustonic ichthyoplankton in the western Gulf of Alaska during spring. Fish. Bull. 93: 231–253.

Doyle, M.J. and Mier, K.L., 2012. A new conceptual framework for evaluating the early ontogeny phase of recruitment processes among marine fish species. *Canadian Journal of Fisheries and Aquatic Sciences*, *69*(12), pp.2112-2129.

Fisher, J., Kimmel, D., Ross, T., Batten, S., Bjorkstedt, E., Galbraith, M., Jacobson, K., Keister, J., Sastri, A., Suchy, K. and Zeman, S., 2020. Copepod responses to, and recovery from, the recent marine heatwave in the Northeast Pacific. *PICES Sci. 2019: Notes Sci. Board Chair*, *28*, p.65.

Guthridge, J.L. and N. Hillgruber. 2008. Embryonic development of Atka mackerel (*Pleurogrammus monopterygius*) and the effect of temperature. Pages 43-65 *in* S. F. McDermott, M. Canino, N. Hillgruber, D. W. Cooper, I. Spies, J. Guthridge, J. N. Ianelli, P. Woods. 2008. Atka mackerel *Pleurogrammus monopterygius* reproductive ecology in Alaska. North Pacific Research Board Final report, 163p.

Hollowed, A.B., Aydin, K., Blackhart, K., Dorn, M., Hanselman, D., Heifetz, J., Kasperski, S., Lowe, S. and Shotwell, K., 2016. Discussion paper stock assessment prioritization for the North Pacific fishery management council: methods and scenarios. Report to NPFMC Groundfish Plan Teams. September 2016. https://www.npfmc.org/wp-content/PDFdocuments/meetings/AFSC-HQ_Discussion_Paper.pdf.

Hunt, G. L., and P. J. Stabeno. 2005. Oceanography and ecology of the Aleutian Archipelago: spatial and temporal variation. Fisheries Oceanography 14:292–306.

Lauth, R.R. and Blood, D.M., 2007. Description of embryonic development of Atka mackerel (Pleurogrammus monopterygius). *Fishery Bulletin*, *105*(4), p.571.

Lauth, R.R., J. Guthridge, D. Nichol, S.W. Mcentire, and N. Hillgruber. 2007a. Timing and duration of mating and brooding periods of Atka mackerel (*Pleurogrammus monopterygius*) in the North Pacific Ocean. Fish. Bull., U.S. 105:560-570. http://fishbull.noaa.gov/1054/lauth.pdf

Lauth, R.R., S.W. Mcentire, and H.H. Zenger, Jr. 2007b. Geographic distribution, depth range, and description of Atka mackerel *Pleurogrammus monopterygius* nesting habitat in Alaska. Alaska Fish. Res. Bull. 12:165-186. http://www.adfg.state.ak.us/pubs/afrb/vol12_n2/lautv12n2.pdf

Livingston, P.A., Aydin, K., Buckley, T.W., Lang, G.M., Yang, M.S. and Miller, B.S., 2017. Quantifying food web interactions in the North Pacific–a data-based approach. *Environmental Biology of Fishes*, *100*(4), pp.443-470.

Lowe, S.A., D.M. Van Doornik, and G.A. Winans. 1998. Geographic variation in genetic and growth patterns of Atka mackerel, *Pleurogrammus monopterygius* (Hexagrammidae), in the Aleutian archipelago. Fish. Bull. U.S. 96:502-515.

Matarese, A.C., Blood, D.M., Picquelle, S.J., and Benson, J.L. 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). US Dep. Commer. NOAA Prof. Paper NMFS 1.

Mazur, M. M., M. T. Wilson, A. B. Dougherty, A. Buchheister, and D. A. Beauchamp. 2007. Temperature and prey quality effects on growth of juvenile walleye pollock *Theragra chalcogramma* (Pallas): a spatially explicit bioenergetics approach. Journal of Fish Biology 70:816–836.

McDermott, S.F., Cooper, D.W., Guthridge, J.L., Spies, I.B., Canino, M.F., Woods, P. and Hillgruber, N., 2011. Effects of maternal growth on fecundity and egg quality of wild and captive Atka mackerel. *Marine and Coastal Fisheries*, *3*(1), pp.324-335.

McDermott, S.F., K.E. Pearson and D.R. Gunderson. 2007. Annual fecundity, batch fecundity, and oocyte atresia of Atka mackerel (*Pleurogrammus monopterygius*) in Alaskan waters. Fish Bull. 105:19-29.

McDermott, S.F. and S.A. Lowe. 1997. The reproductive cycle of Atka mackerel, *Pleurogrammus monopterygius*, in Alaska waters. Fish. Bull. U.S. 95:231-333.

Murphy, J., N. Davis, O. Ivanov, M. Rohr, S. Elmajjati, and Barber ,W. 2003a. Cruise report of the 2002 F/V Northwest Explorer BASIS survey in the Bering Sea, September-October. (NPAFC Doc. 676 Rev. 1) 23 p. NMFS, Auke Bay Laboratory, Juneau, AK; School of Aquatic & Fishery Sciences, University of Washington; Pacific Fisheries Research Centre (TINRO-Centre), Vladivostok; Alaska Quaternary Center, University of Alaska Fairbanks; Institute of Marine Science, University of Alaska Fairbanks.

Murphy, J. , O. Temnykh, and Azumaya, T. 2003b. Trawl Comparisons by the Northwest Explorer, TINRO, and Kaiyo Maru, September, 2002. (NPAFC Doc. No. 677) 20 p. NMFS, Auke Bay Laboratory, Juneau, AK, USA; Pacific Fisheries Research Centre (TINRO-Centre), Vladivostok, Russia; and Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro, Japan.

Nichol D.G., Somerton D.A. 2002. Diurnal vertical migration of the Atka mackerel *Pleurogrammus monopterygius* as shown by archival tags. Mar Ecol Prog Ser 239: 193-207.

NMFS. 1995. Status review of the Unites States Steller sea lion (*Eumetopias jubatus*) population. National Marine Mammal Laboratory, Alaska Fishery Science Center, National Marine Fisheries Service, 7600 Sand Point Way, NE, Seattle, WA 98115.

Ortiz, I. and S. Zador. 2024. Ecosystem Status Report 2024: Aleutian Islands, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Ortiz, I. and S. Zador. 2023. Ecosystem Status Report 2023: Aleutian Islands, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Pepin, P., 1991. Effect of temperature and size on development, mortality, and survival rates of the pelagic early life history stages of marine fish. *Canadian Journal of Fisheries and Aquatic Sciences*, *48*(3), pp.503-518.

Rand, K. M., D. A. Beauchamp, and S. A. Lowe. 2010. Longitudinal growth differences and the influence of diet quality on Atka mackerel of the Aleutian Islands, Alaska: using a bioenergetics model to explore underlying mechanisms. Marine and Coastal Fisheries 2:362-374. https://doi.org/10.1577/C09-046.1

Richardson, A.J., Walne, A.W., John, A.W.G., Jonas, T.D., Lindley, J.A., Sims, D.W., Stevens, D. and Witt, M., 2006. Using continuous plankton recorder data. *Progress in Oceanography*, *68*(1), pp.27-74.

Rooper, C.N., Goddard, P. and Wilborn, R., 2019. Are fish associations with corals and sponges more than an affinity to structure? Evidence across two widely divergent ecosystems. *Canadian Journal of Fisheries and Aquatic Sciences*, *76*(12), pp.2184-2198.

Schabetsberger, R., Brodeur, R.D., Ciannelli, L., Napp, J.M. and Swartzman, G.L., 2000. Diel vertical migration and interaction of zooplankton and juvenile walleye pollock (Theragra chalcogramma) at a frontal region near the Pribilof Islands, Bering Sea. *ICES Journal of Marine Science*, *57*(4), pp.1283-1295.

Shotwell, S.K., Blackhart, K., Cunningham, C., Fedewa, E., Hanselman, D., Aydin, K., Doyle, M., Fissel, B., Lynch, P., Ormseth, O. and Spencer, P., 2023. Introducing the ecosystem and socioeconomic profile, a proving ground for next generation stock assessments. *Coastal Management*, *51*(5-6), pp.319-352.

Sinclair, E.H., D.S. Johnson, T.K. Zeppelin, and T.S. 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.

Sinclair E.H. and T.K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). Journal of Mammalogy 83(4):973-990.

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 pages E1800–E1888.

Springer, A.M., Piatt, J.F., Shuntov, V.P., Van Vliet, G.B., Vladimirov, V.L., Kuzin, A.E. and Perlov, A.S., 1999. Marine birds and mammals of the Pacific Subarctic Gyres. *Progress in Oceanography*, *43*(2-4), pp.443-487.

Sogard, S.M. 1997. Size-selective mortality in the juvenile stage of teleost fishes: a review. Bull. Mar. Sci. 60(3): 1129–1157.

Stabeno, P. J., J. D. Schumacher, and K. Ohtani. 1999. The physical oceanography of the Bering Sea: A summary of physical, chemical, and biological characteristics, and a synopsis of research on the Bering Sea. Pages 1–28 in T.R. Loughlin and K. Ohtani, editors. Dynamics of the Bering Sea, a summary of physical, chemical, and biological characteristics, and a synopsis of research on the Bering Sea. North Pacific Marine Science Organization (PICES), University of Alaska Sea Grant, AK-SG-99-03.

Stabeno, P. J., C. Ladd, and R. K. Reed. 2009. Observations of the Aleutian North Slope Current, Bering Sea, 1996–2001. Journal of Geophysical Research: Oceans 114.

Sullivan, J., and L. Balstad. 2024. 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. Github. 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. Technical report, Plan Team Report, Joint Groundfish Plan Teams, North Pacific Fishery Management Council. 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Walline, P.D., 1981. Distribution of ichthyoplankton in the eastern Bering Sea during June and July 1979. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, U.S. Department of Commerce. NWAFSC Processed Report 81-03.

Waldron, K.D. and Vinter, B.M., 1978. Icthyoplankton of the eastern Bering Sea. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, U.S. Department of Commerce. NWAFSC Processed Report.

Waldron, K.D., 1978. Icthyoplankton of the eastern Bering Sea (11 February to 16 March 1978). Northwest and Alaska Fisheries Center, National Marine Fisheries Service, U.S. Department of Commerce. NWAFSC Processed Report.

Yang, M-S. 1999. The trophic role of Atka mackerel, *Pleurogrammus monopterygius*, in the Aleutian Islands area. Fishery Bulletin 97(4):1047-1057.

Zolotov, O. G. 1993. Notes on the reproductive biology ofPleurogrammus monopterygius in Kamchatkan waters. J. Ichthyo. 33(4):25-37.

Tables

Table 1. Ecological information by life history stage for Atka mackerel.

Stage	Habitat & Distribution	Phenology	Age, Length, Growth	Energetics	Diet	Predators/Competitors
Recruit	Semi-demersal, rocky substrates, kelp, entire water column along the shelf (< 200m), strong tidal currents (Lowe and Ianelli, 2022; NPFMC 2020, Appendix D)	Recruit to the survey and fishery at age-3 yr (Lowe and Ianelli, 2022)	Max: 17 yrs (AFSC Age and Growth Program Database) 57 ♀/68 ♂ cm (AFSC Life History Database, AFSC RACEBASE and Observer Program databases) [EAI 541: L_inf=47.3, K=0.4] (Lowe et al., 1998) [CAI 542: L_inf=44.0, K=0.4] [WAI 543: L_inf=40.9, K=0.5] ↓ size-at-age east to west	3-5ºC, > 17ppt (NPFMC 2020, Appendix D)	Calanoid copepods, euphausids, myctophid fishes (Livingston et al., 2017, Rand et al., 2010, AFSC Food Habits database)	Predators: Pacific cod, arrowtooth flounder (AFSC Food Habits database), northern fur seal (Kajimura, 1984), Steller sea lions (NMFS 1995, Sinclair and Zeppelin, 2002, Sinclair et al., 2013), seabirds (Springer et al., 1999) Competitors: Eastern Kamchatka pink salmon, northern rockfish Pacific ocean perch (Ortiz and Zador, 2024, Matta et al., 2020)
Spawning	Nearshore and shelf, obligate demersal, hard rocky bottoms, 10-144 m (Lauth et al., 2007b)	Batch spawn (polygynandry), July to October (peaks in Sept) (McDermott and Lowe, 1997, Lauth et al., 2007a), males nest guard into Jan (Lauth et al., 2007a)	50% mature♀: 3.6 yr (5% mature at ~2 yr, 95% mature at 5 yr) 35.9 cm–33.6 (↓ size east to west) McDermott and Lowe (1997) (similar values reported in Cooper et al., 2010)	Low fecundity; Females avg 4.6 batches with 6,608 eggs per batch (realized fecundity; McDermott et al., 2007)	Egg cannibalism (Yang, 1999)	Predators: likely vulnerable to predation by Pacific cod and northern fur seal (NMFS 1995, Sinclair and Zeppelin, 2002, Sinclair et al., 2013)
Egg	Nearshore and shelf, demersal, adhesive eggs, rocky substrates (Lauth et al., 2007b)	Summer-Fall-early Winter, Incubation is 39-75 days (depending on temperature) (Lauth et al., 2007a)	Egg size: 2.5-2.8 mm (Lauth and Blood, 2007)	Optimal incubation unknown. Incubation inversely correlated with temperature. Hatch at 169 days at 1.6°C to just 39 days at 12.2°C, with 15°C proving lethal (Guthridge and Hillgruber, 2008). Typical spawning grounds in Lauth et al., 2007b were 4.0–5.5°C)	(none)	Predators: Cottids and other hexagrammids, cannibalism (Canino et al., 2008, Yang, 1999, Zolotov, 1993) , and to lesser extent green sea urchins (Lauth et al., 2007b)

Stage	Habitat & Distribution	Phenology	Age, Length, Growth	Energetics	Diet	Predators/Competitors
Larvae	Local retention of larvae not well understood. Some larvae transported from nearshore/shelf to Bering Sea, sampled in neuston nets near Pribilof Islands as early as Feb (Waldron, 1978)	Hatch Oct to Jan, peak in Nov (Lauth et al., 2007a)	Hatch size: ~8 mm (Matarese et al., 1989) Yolk sac larvae: 9.4-10.9 mm (Lauth and Blood, 2007) Larvae north and south of Pribilof Is. captured in neuston nets in Feb-Mar (Waldron, 1978): 12-22 mm Larvae captured in Mar-May in Western GOA (Doyle et al., 1995): 15-25 mm Larvae captured in Sea of Okhotsk 8-18 mm in Oct-Dec, most caught during dark hours (Andreeva and Shebanova, 2010) Hexagramiid spp in EBS neuston nets 9-35mm (Waldron and Vinter, 1978), 8-37 mm (Walline, 1981)	Limited data, larvae observed in 3-4ºC in Feb-Mar (Waldron, 1978)	Limited observations, exclusively from Sea of Okhotsk in Oct-Dec (Andreeva and Shebanova, 2010): Small larvae (<=10 mm): juvenile pteropod (*L.* helicina), copepod P. minutus), and phytoplankton Conscinodiscus sp. Large larvae (>10mm): same as small larvae with more large copepods (N. plumchrus, Eucalanus bungii, and Metridia okhotensis)	No data. Likely predators include seabirds and fish.
Young-of- the-year	Open ocean surface waters of Bering Sea Basin (BASIS/NPAFC surveys)	Unknown: Potentially transported southward back towards Aleutian Islands via currents	< 1 year (age-0) >9 cm total length by July in the WAI (as sampled in puffin chick diets on Buldir Is.)	Limited data, 3-5ºC reported in NPFMC (2020, Appendix D)	Calanoid copepods, euphausiids (BASIS survey)	Predators: Seabirds (see age-1 condition index from puffin check diets, N. Rojek), Pacific cod (Yang, 2019), likely other fish and marine mammals
Juvenile to Pre-recruit	Nearshore, shallow depth (0-200m), moderate tidal currents (NPFMC 2020, Appendix D)	Limited data suggest pelagic, some transitioning to benthic habitats: Occasionally encountered in BASIS and NPAFC surveys in the Bering Sea basin and near Petrel Bank, as well as in AI trawl surveys and fisheries	Limited data from AFSC RACEBASE and observer program data bases suggest age-1 and age-2 avg length is 21 cm and 28 cm ↓ size-at-age east to west (age-2: EAI 541=31cm, CAI 542=27 cm, WAI 543=27)	Limited data, 3-5ºC reported in NPFMC (2020, Appendix D)	Calanoid copepods, euphausiids (BASIS survey, AFSC Food Habits database)	Predators: Same as adults. Competitors: eastern Kamchatka Pink Salmon (Ortiz and Zador, 2024, Matta et al., 2020)

Table 2. Atka mackerel U.S. trade and global market data.

	2015-2019 Average	2020	2021	2022	2023	2024
Global production (K mt)	114.22	129.31	139.93	130.11	131.08	-
U.S. Share of global catch	53%	45%	44%	45%	50%	-
Japanese Share of global catch	21%	32%	33%	27%	24%	-
Russian Share of global catch	22%	20%	19%	24%	22%	-
Export volume (K mt)	32.89	29.72	33.13	30.89	35.69	38.7
Export value (M US$)	$91.07	$81.59	$90.04	$83.73	$97.70	$105.52
Export price (USD/lb.)	$1.26	$1.25	$1.23	$1.23	$1.24	$1.24
Japan's share of export value	69.53%	68.3%	74.5%	67.0%	70.9%	65.0%
Exchange rate, Yen/Dollar	112.29	106.77	109.76	131.5	140.49	151.37

Source: FAO Fisheries & Aquaculture Dept. Statistics http://www.fao.org/fishery/statistics/en. NOAA Fisheries, Fisheries Statistics Division, Foreign Trade Division of the U.S. Census Bureau, http://www.st.nmfs.noaa.gov/commercial-fisheries/foreign-trade/index. U.S. Department of Agriculture http://www.ers.usda.gov/data-products/agricultural-exchange-rate-data-set.aspx.

Table 3. Atka mackerel first-wholesale market data fishery-wide and subset for Amendment 80 vessels that harvest Atka mackerel.

Sector	**Species Group**		**2015-2019 Average**	**2020**	**2021**	**2022**	**2023**	**2024**
Fishery Totals	AMCK	Vessels #	17	16	18	17	18	16
		First-wholesale production (K mt)	37.22	34.19	35.63	33.91	38.74	43.15
		First-wholesale value (M US$)	$98.84	$79.07	$71.55	$75.29	$90.34	$94.05
		First-wholesale price (USD/lb.)	$1.20	$1.05	$0.91	$1.01	$1.06	$0.99
		H&G share of value	92.62%	98.9%	99.6%	99.9%	98.3%	92.5%
Amendment 80 Vessels with Atka Mackerel Landings	AMCK	Vessels #	9.4	14	14	12	14	13
		First-wholesale production (K mt)	22.74	28.17	29.61	27.88	32.58	35.51
		First-wholesale value (M US$)	$57.04	$64.68	$58.59	$61.19	$75.97	$77.77
		First-wholesale price (USD/lb.)	$1.17	$1.05	$0.93	$1.01	$1.06	$1.01
	PCOD	First-wholesale production (K mt)	4.18	5.71	3.94	4.50	6.08	6.65
		First-wholesale price (USD/lb.)	$1.34	$1.15	$1.25	$2.02	$1.49	$1.70
	POPA	First-wholesale production (K mt)	9.05	14.45	13.13	13.60	14.13	14.95
		First-wholesale price (USD/lb.)	$0.99	$0.75	$0.76	$0.98	$0.89	$0.92

Note: "AMCK" represents Atka mackerel, "PCOD" represents Pacific cod, and "POPA" represents Pacific Ocean perch. Values for PCOD and POPA do not consider landings from full Amendment 80 fleet, only Amendment 80 vessels that harvested Atka mackerel in a given year. Source: NMFS Alaska Region Blend and Catch-accounting System estimates; NMFS Alaska Region At-sea Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Figures

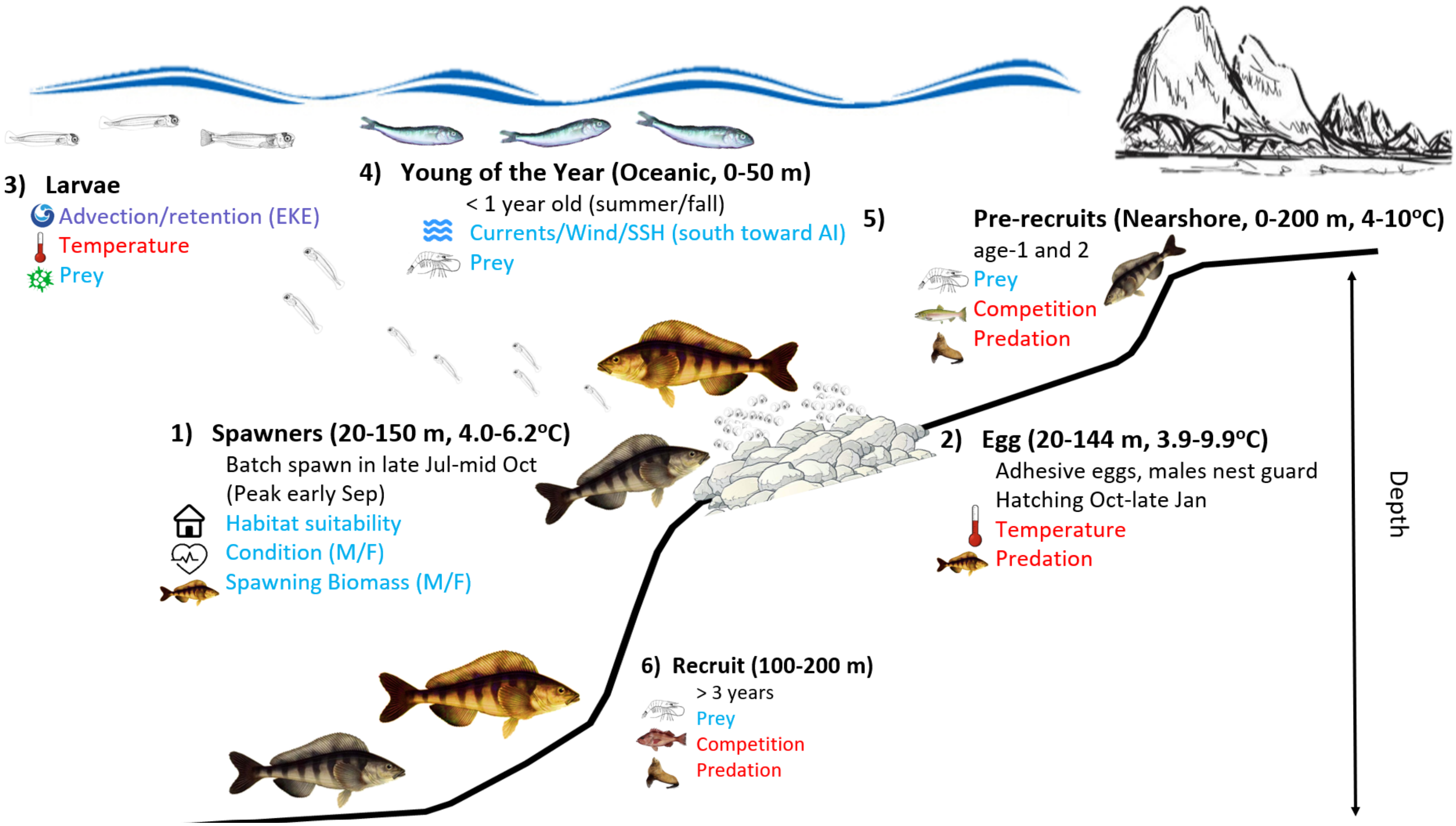

Figure 1. Life history conceptual model for BSAI Atka mackerel summarizing ecological information and key ecosystem processes affecting survival by life history stage. Red text indicates that increases in the process negatively affect survival of the stock, blue text indicates increases in the process positively affect survival, and purple indicates that the relationship is site specific.

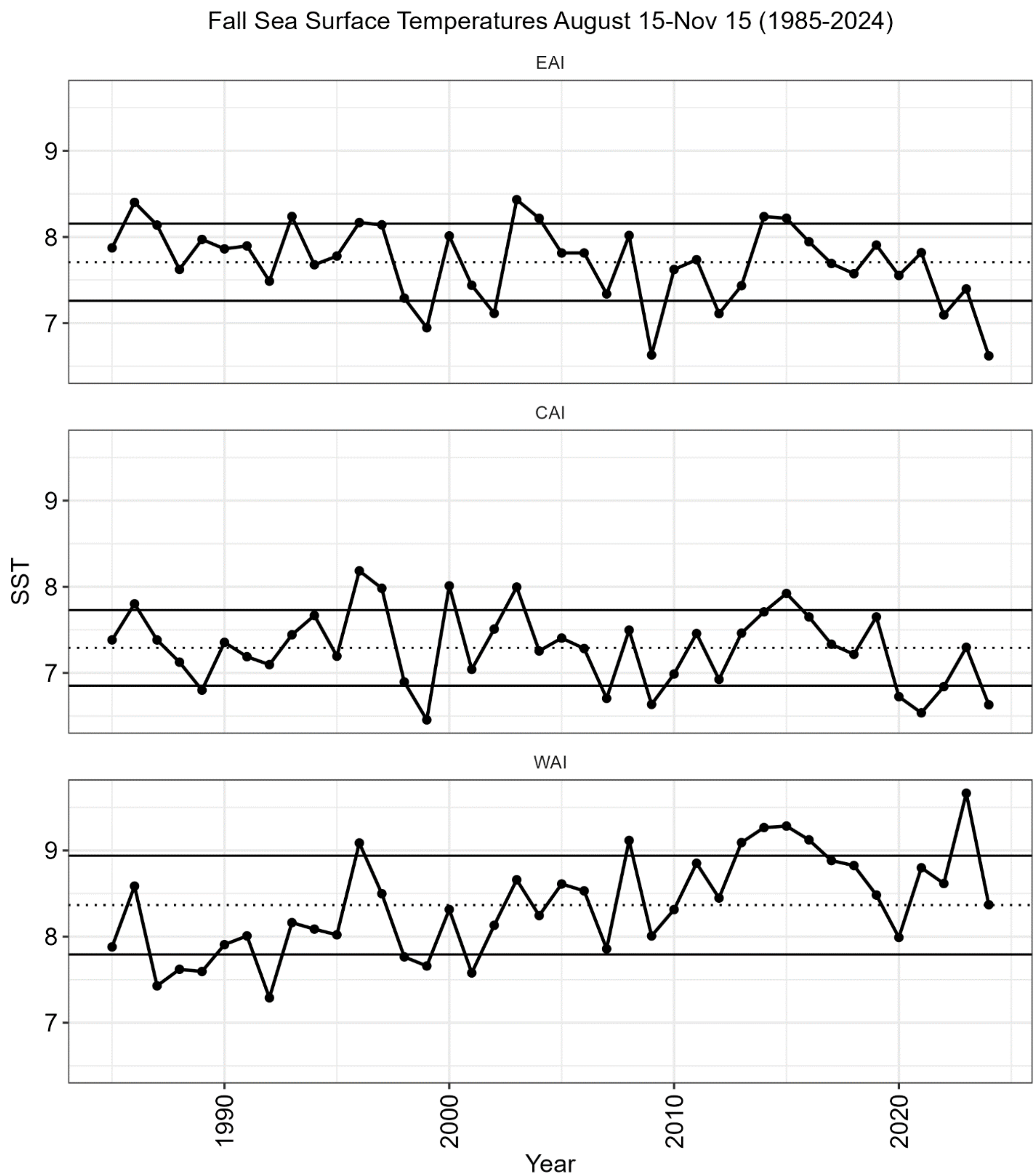

Figure 2. Fall sea surface temperature (SST) from August 15 to November 15 in the EAI, CAI, and WAI, 1985–2024. Horizontal lines represent the long-term mean (dotted) and ±1 SD (solid). Contact: Matt Callahan. Fall SST is a key covariate influencing Atka mackerel egg development and brooding conditions.

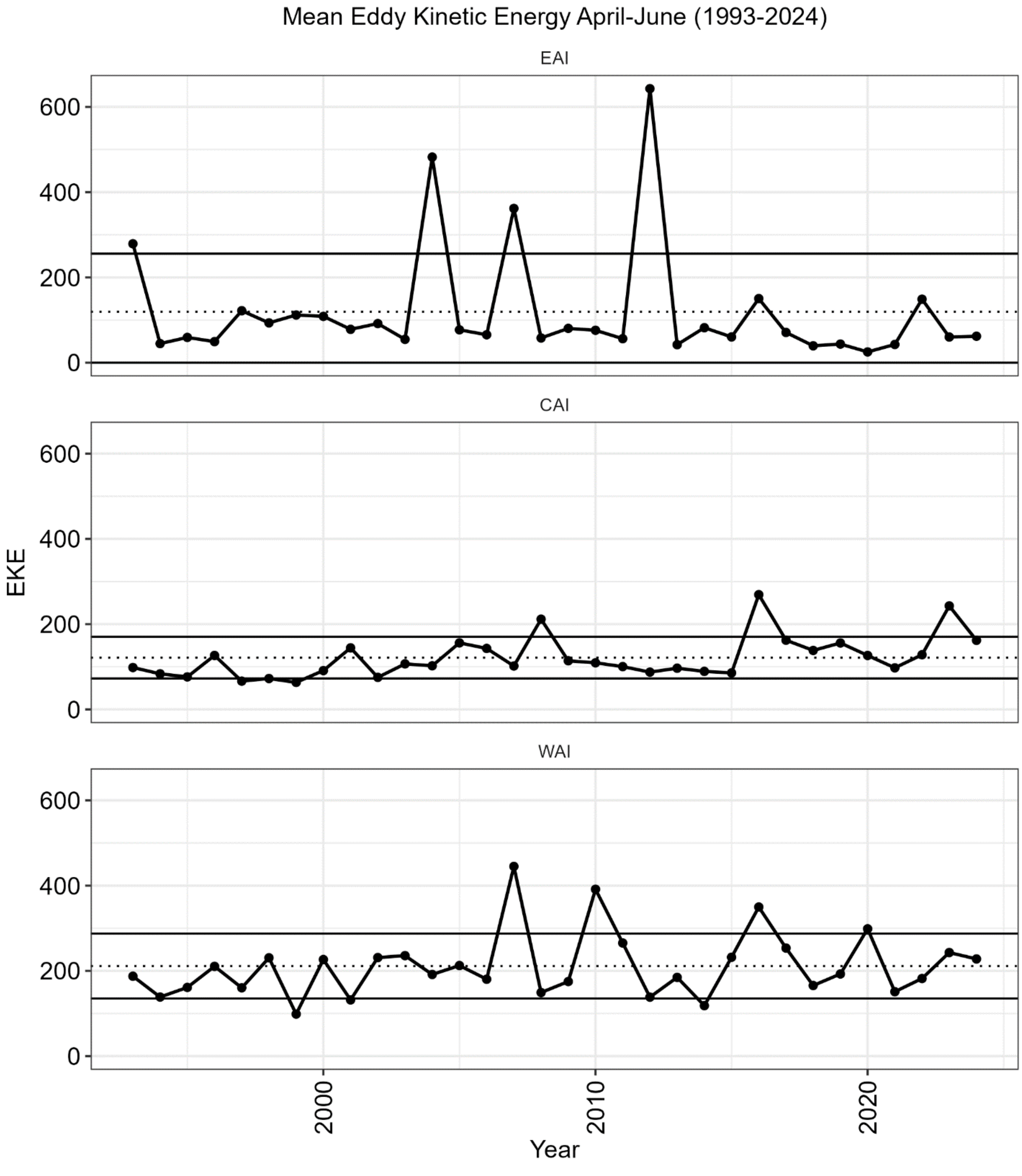

Figure 3. Spring eddy kinetic energy (EKE) for the eastern (EAI), central (CAI), and western Aleutian Islands (WAI) from April to June, 1993–2024. Horizontal lines represent the long-term mean (dotted) and ±1 SD (solid). Contact: Wei Cheng. EKE reflects mesoscale ocean dynamics and is hypothesized to influence spring temperatures and early life history conditions for YOY Atka mackerel.

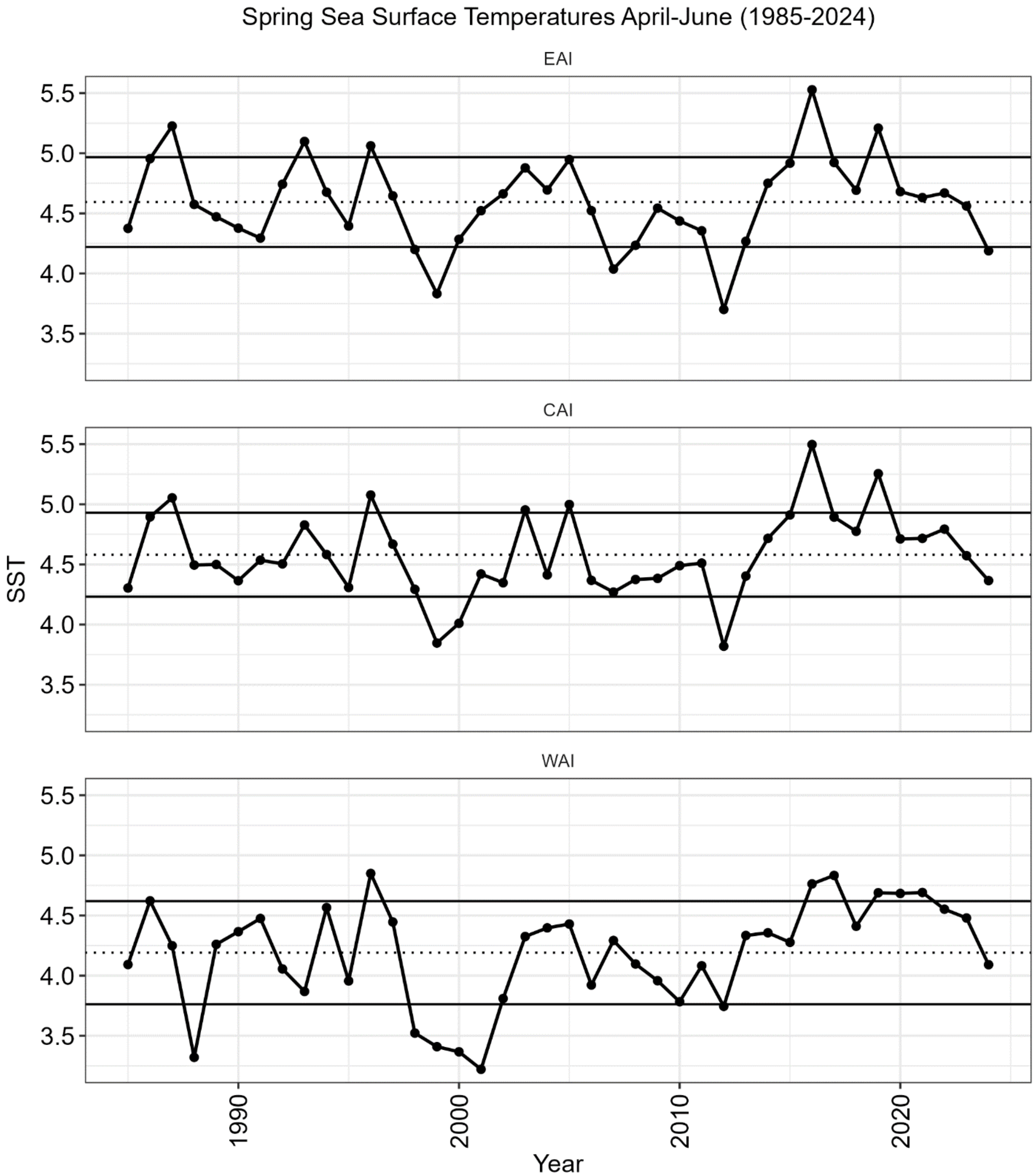

Figure 4. Spring sea surface temperature (April–June) in the EAI, CAI, and WAI from 1985 to 2024. Horizontal lines show the mean (dotted) and ±1 SD (solid). Contact: Matt Callahan. Elevated spring SST may increase metabolic demands and alter prey availability for YOY Atka mackerel.

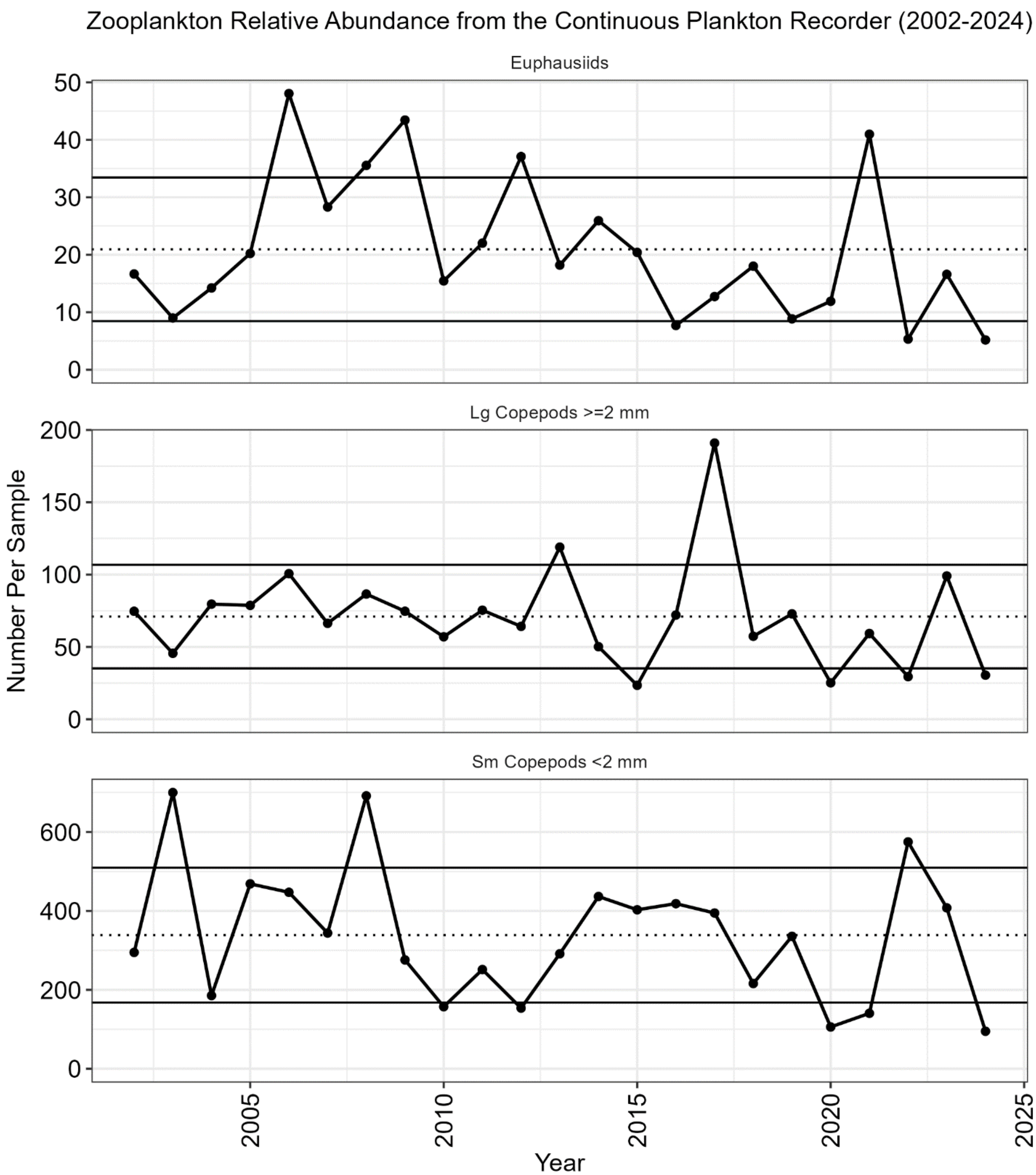

Figure 5. Zooplankton abundance from Continuous Plankton Recorder data (2002–2024) across the Aleutians and southern Bering Sea. Panels show euphausiids, large copepods (≥2 mm), and small copepods (<2 mm). Horizontal lines indicate mean (dotted) and ±1 SD (solid). Contact: Clare Ostle. These indices reflect prey field variability relevant to Atka mackerel across life stages.

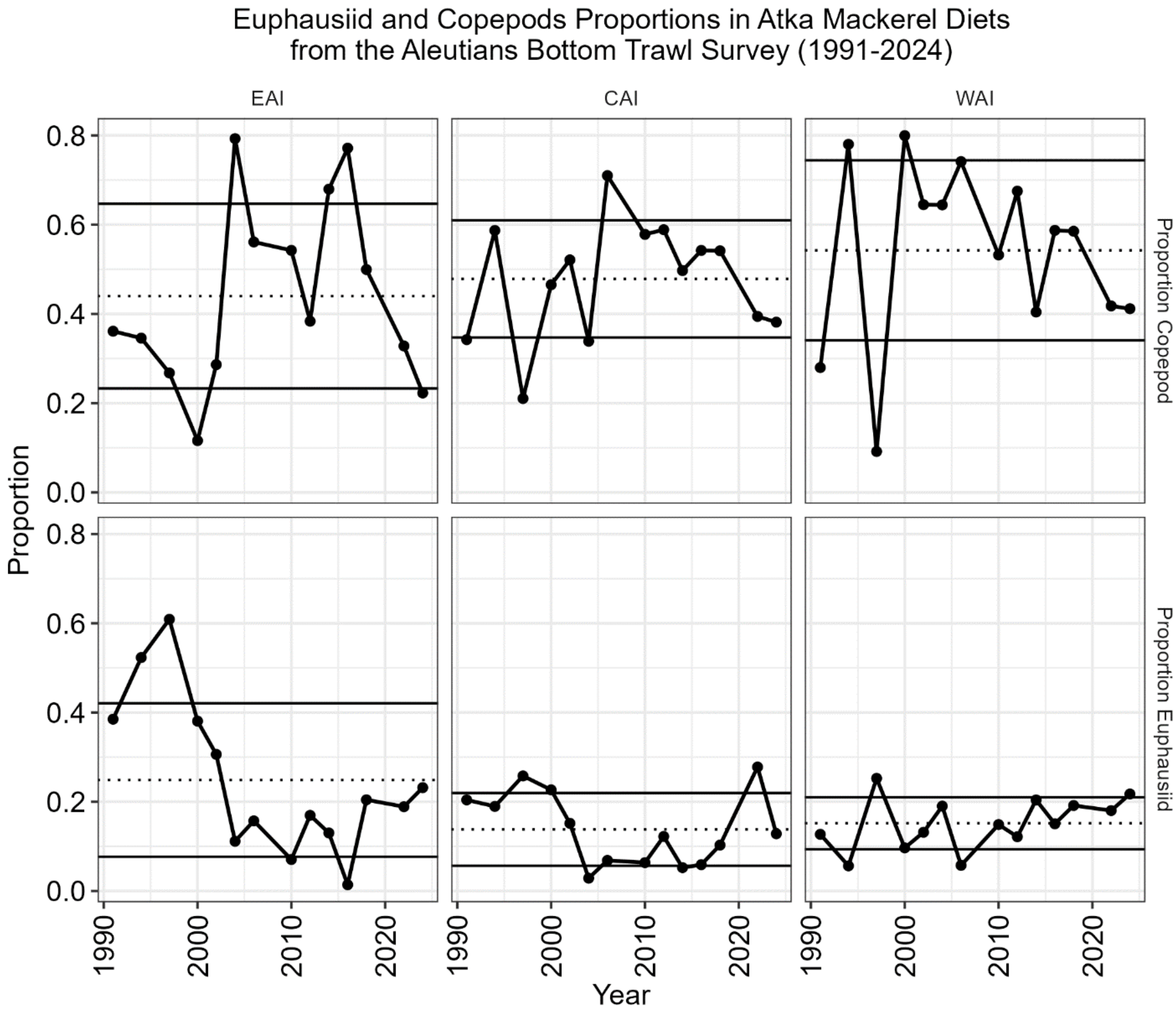

Figure 6. Proportion-by-weight of euphausiids and copepods in Atka mackerel diets based on bottom trawl surveys (1991–2024), by region (EAI, CAI, WAI). Horizontal lines show the mean (dotted) and ±1 SD (solid). Contact: Kerim Aydin. Diet proportions reflect regional and temporal variation in prey use, linked to zooplankton availability.

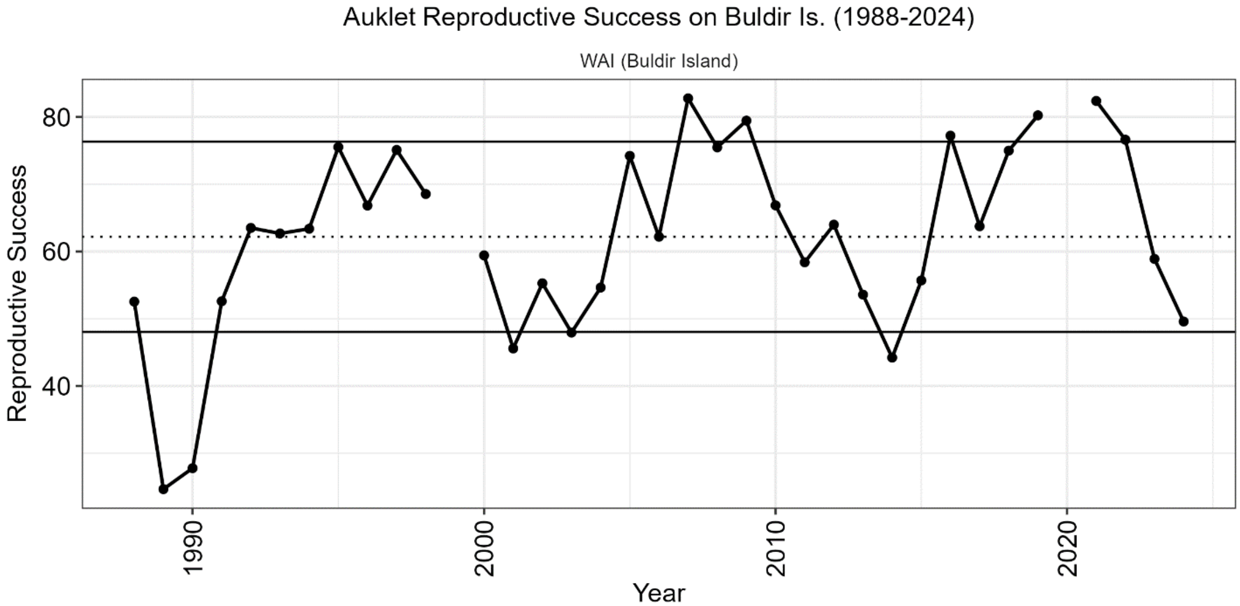

Figure 7. Combined reproductive success of four auklet species at Buldir Island (WAI) from 1988–2024. Horizontal lines represent the long-term mean (dotted) and ±1 SD (solid). Contact: Nora Rojek. Reproductive success reflects local zooplankton availability during chick provisioning.

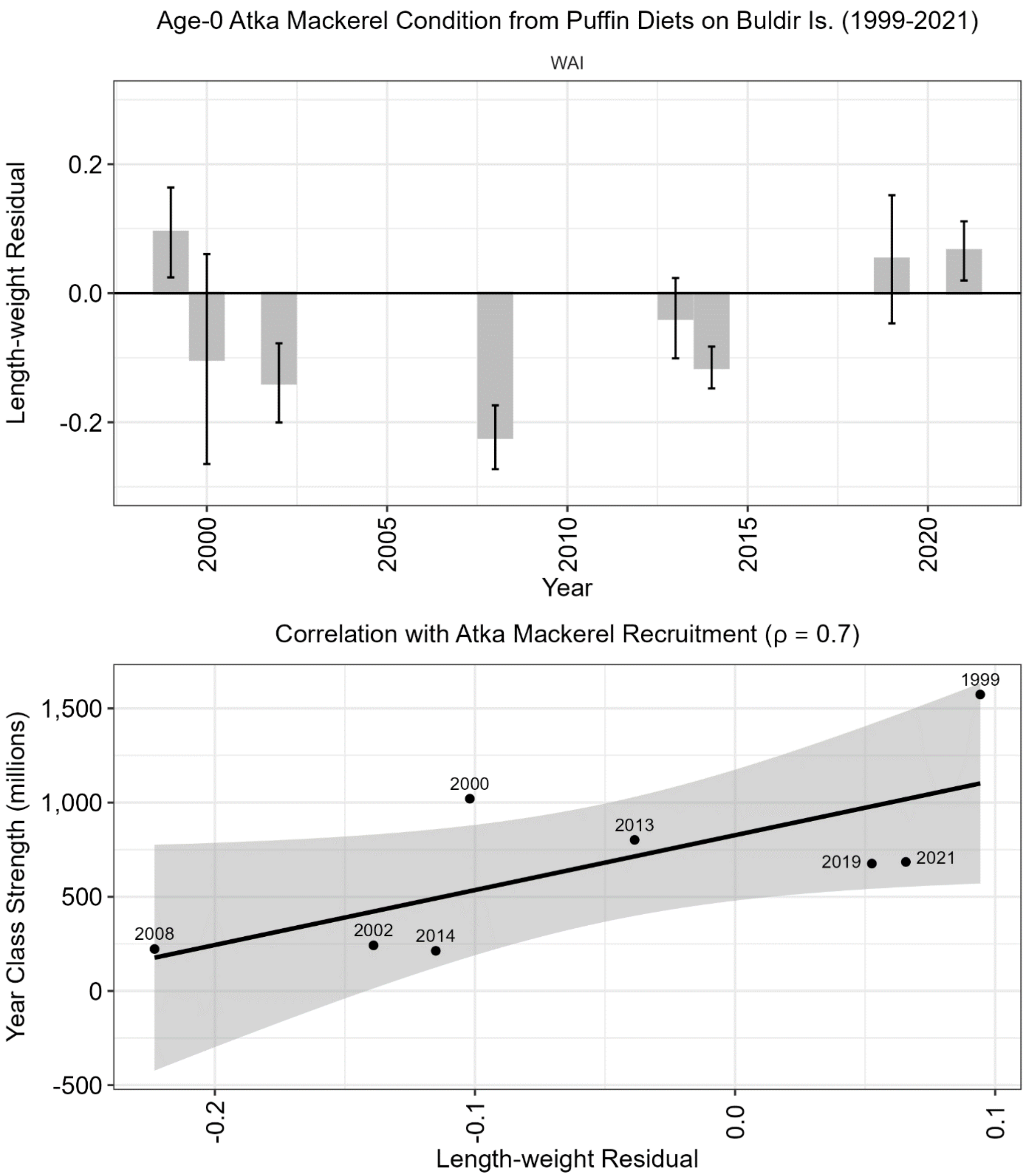

Figure 8. Top: Residual body condition (length–weight) of age-0 Atka mackerel from puffin chick diets at Buldir Island (WAI), 1999–2021. Bottom: Correlation with age-0 recruitment (ρ = 0.7). Contact: Nora Rojek. These data provide the only long-term condition index for juvenile Atka mackerel in the Aleutians.

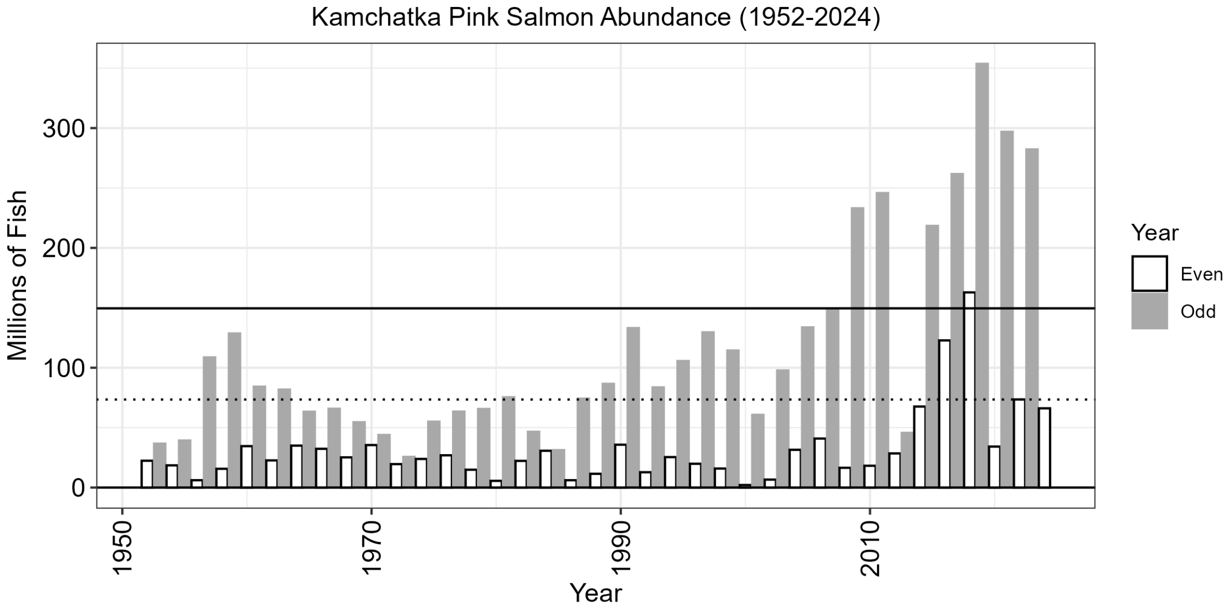

Figure 9. Abundance of Eastern Kamchatka pink salmon (1952–2024), shown separately for odd (grey) and even (white) years. Horizontal lines show the mean (dotted) and +1 SD (solid). Contact: Gregory T. Ruggerone. Eastern Kamchatka pink salmon are major consumers of zooplankton and may compete with Atka mackerel for prey.

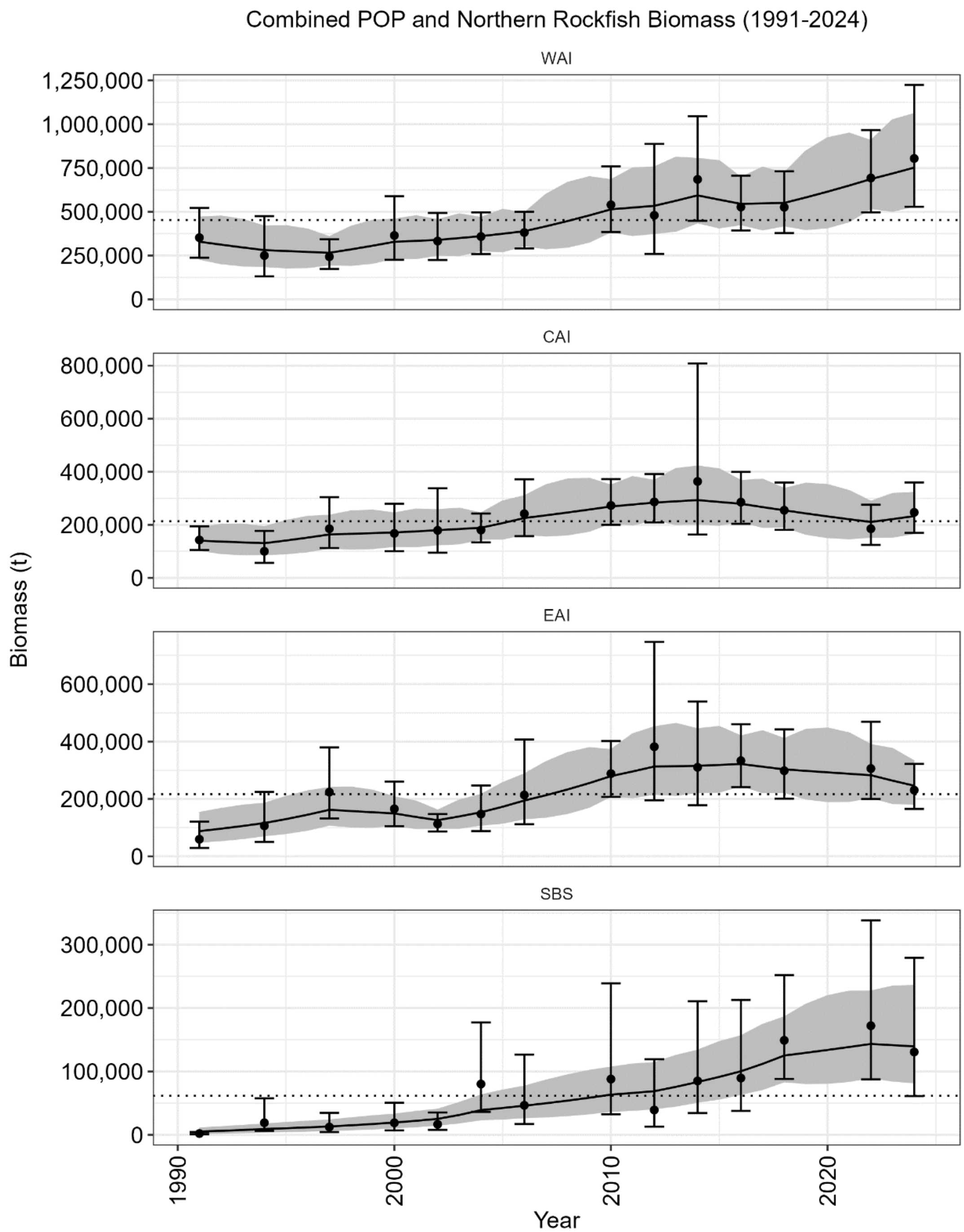

Figure 10. Combined biomass of Pacific ocean perch and northern rockfish from bottom trawl surveys (1991–2024), by region. Lines and shading show smoothed estimates and uncertainty. Contact: Jane Sullivan. Increasing rockfish biomass suggests rising competition with Atka mackerel for zooplankton prey.

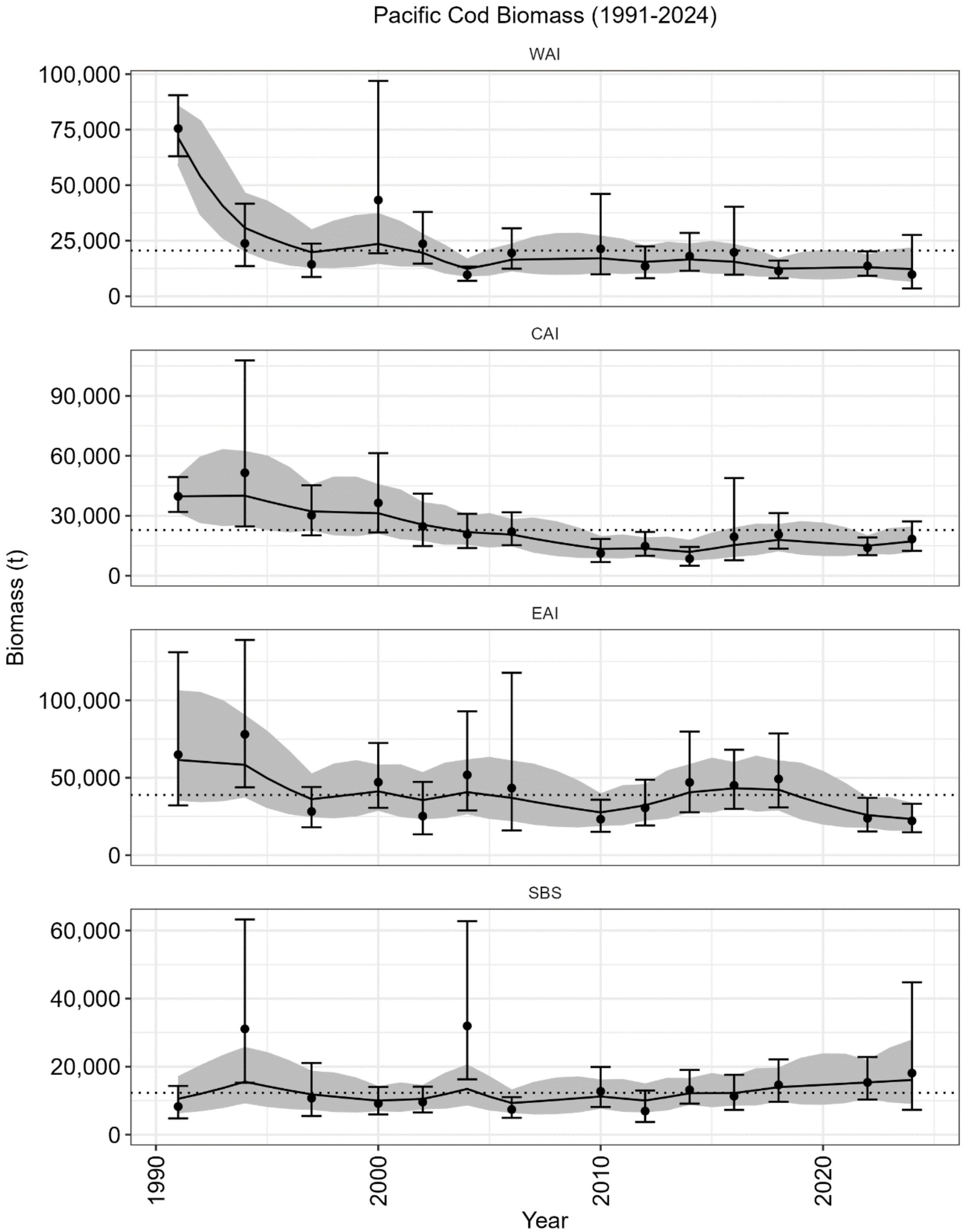

Figure 11. Pacific cod biomass estimates from bottom trawl surveys (1991–2024) in the WAI, CAI, EAI, and southern Bering Sea (SBS). Lines and shaded envelopes represent state-space model fits and uncertainty. Contact: Jane Sullivan. Pacific cod are a key predator of Atka mackerel, particularly for small pre-recruits and young adults.

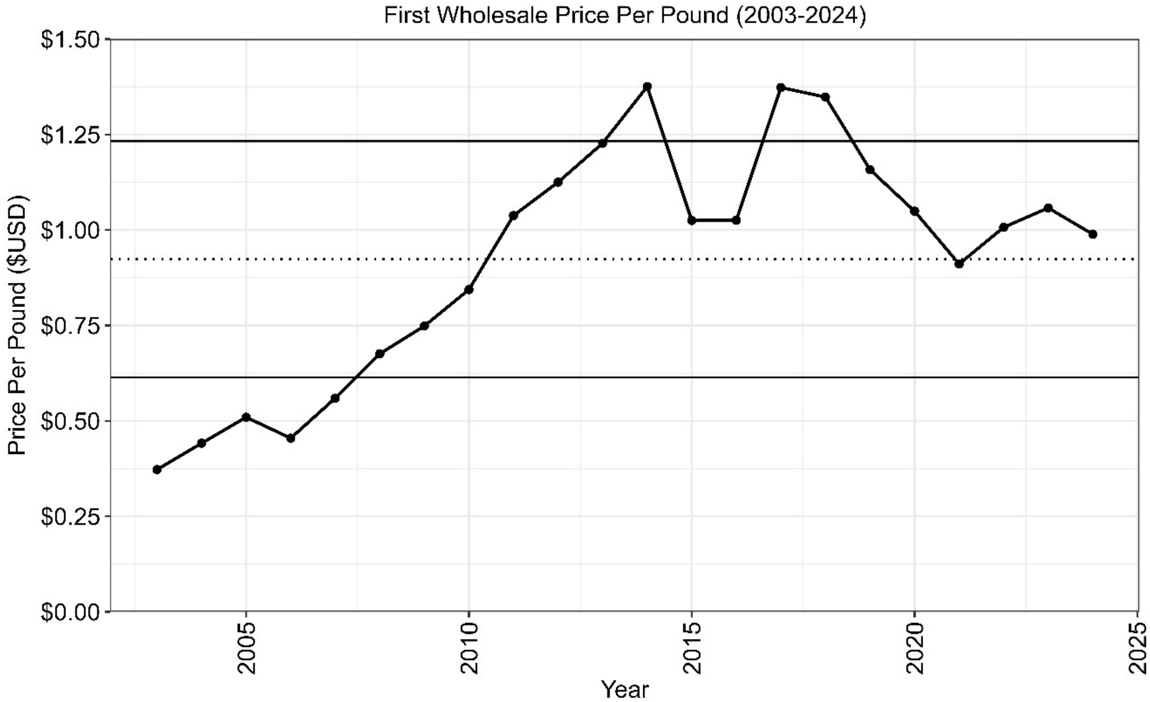

Figure 12. Average first-wholesale price per-pound for Atka mackerel. Note: The dotted line represents the mean of the full time series. Horizontal lines show the mean (dotted) and +1 SD (solid).

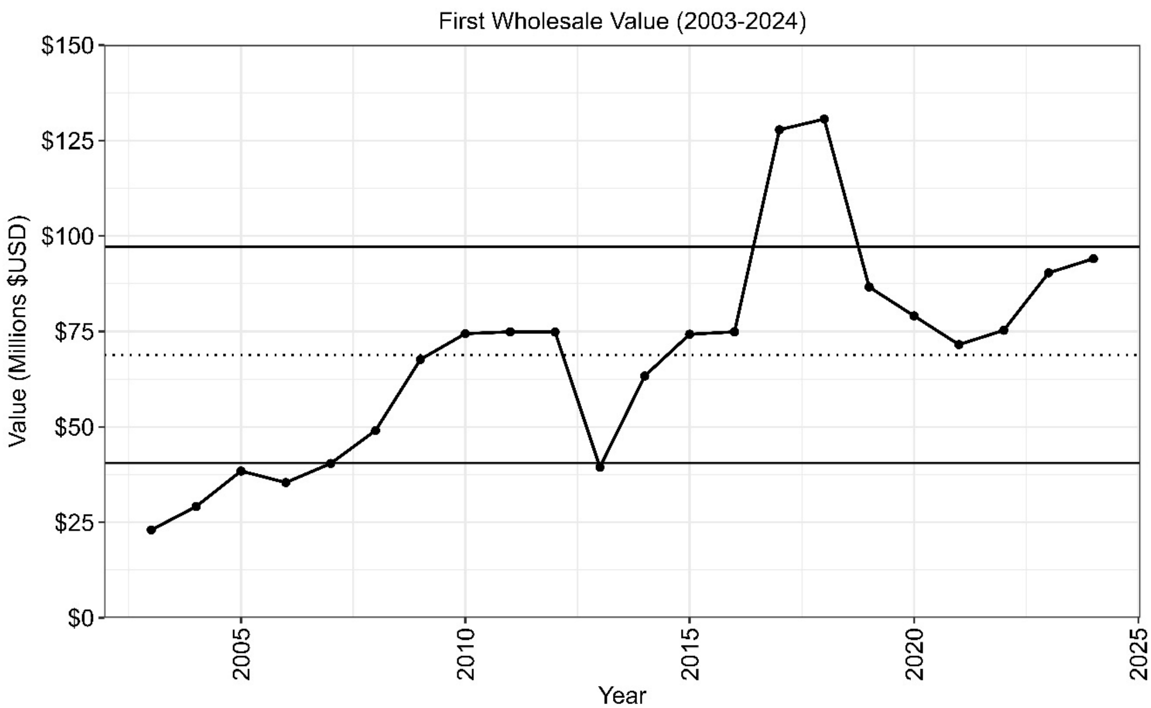

Figure 13. Average first-wholesale value for Atka mackerel. Horizontal lines show the mean (dotted) and +1 SD (solid).

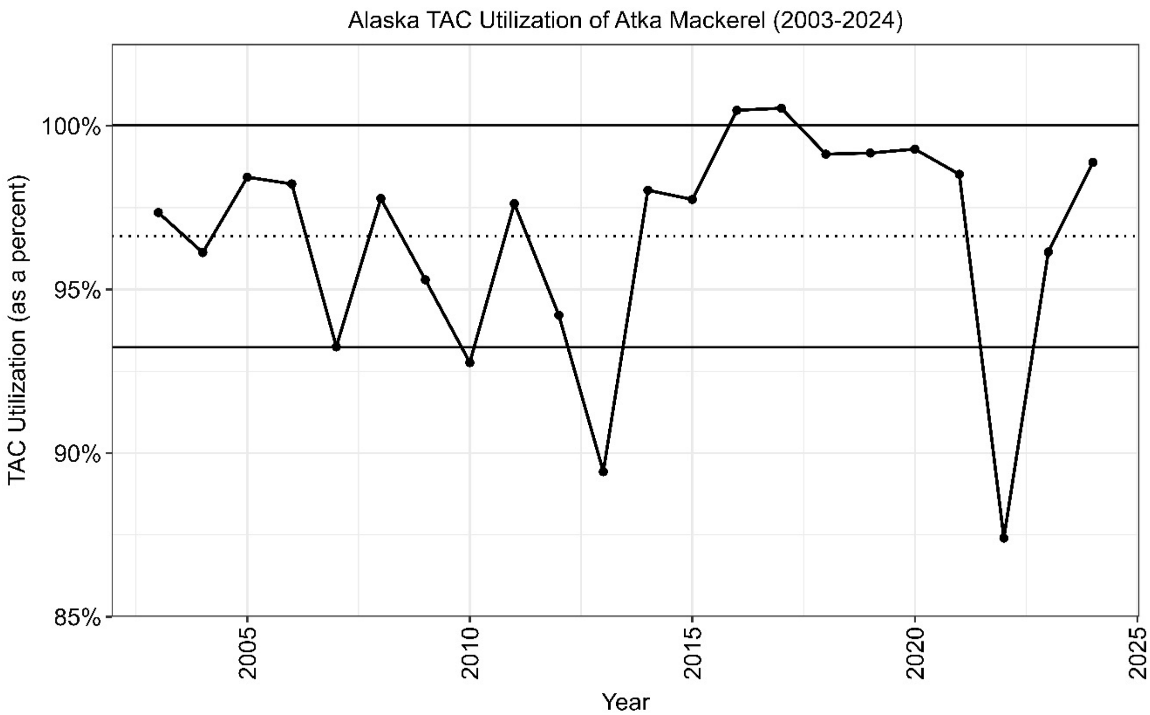

Figure 14. Statewide end-of-year TAC utilization of Atka mackerel. Horizontal lines show the mean (dotted) and +1 SD (solid).

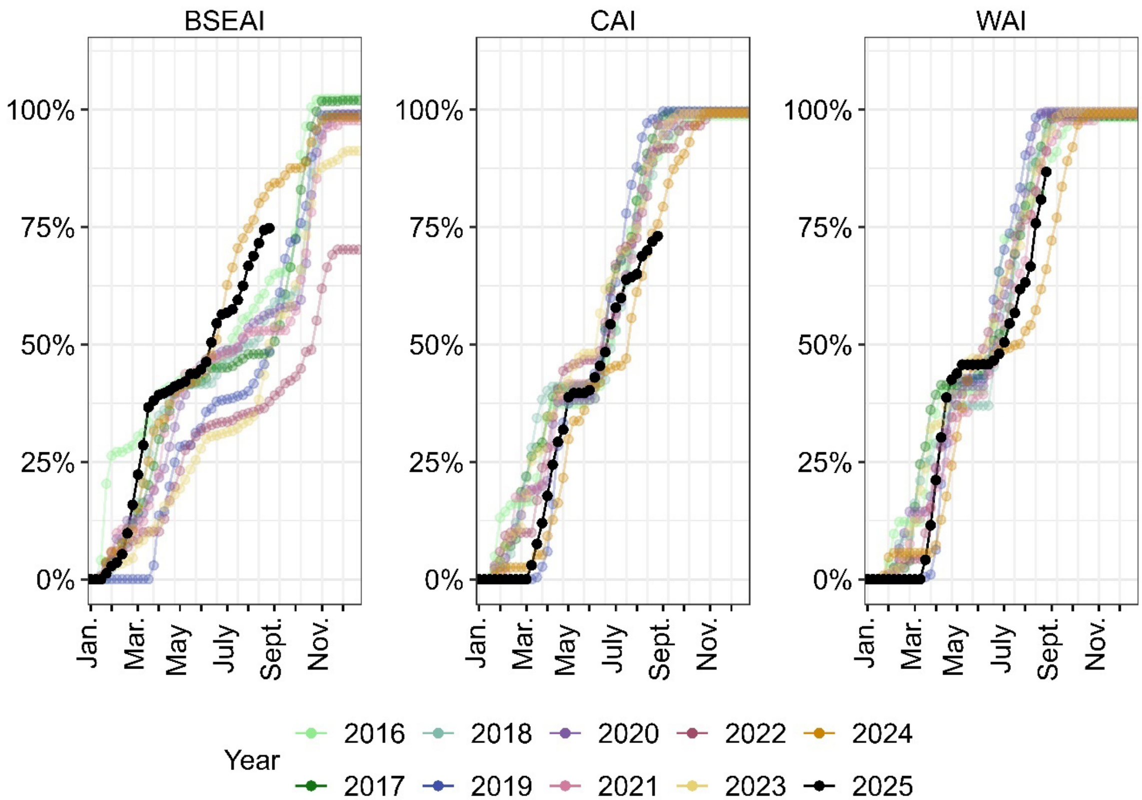

Figure 15. In-season and historical area-specific Total Allowable Catch utilization by week. Note: BSEAI = Eastern Bering Sea/Aleutian Islands; CAI = Central Aleutian Islands; WAI = Western Aleutian Islands. TAC utilization accounts for in-season reallocations from the incidental catch allowance to the Amendment 80 sector.

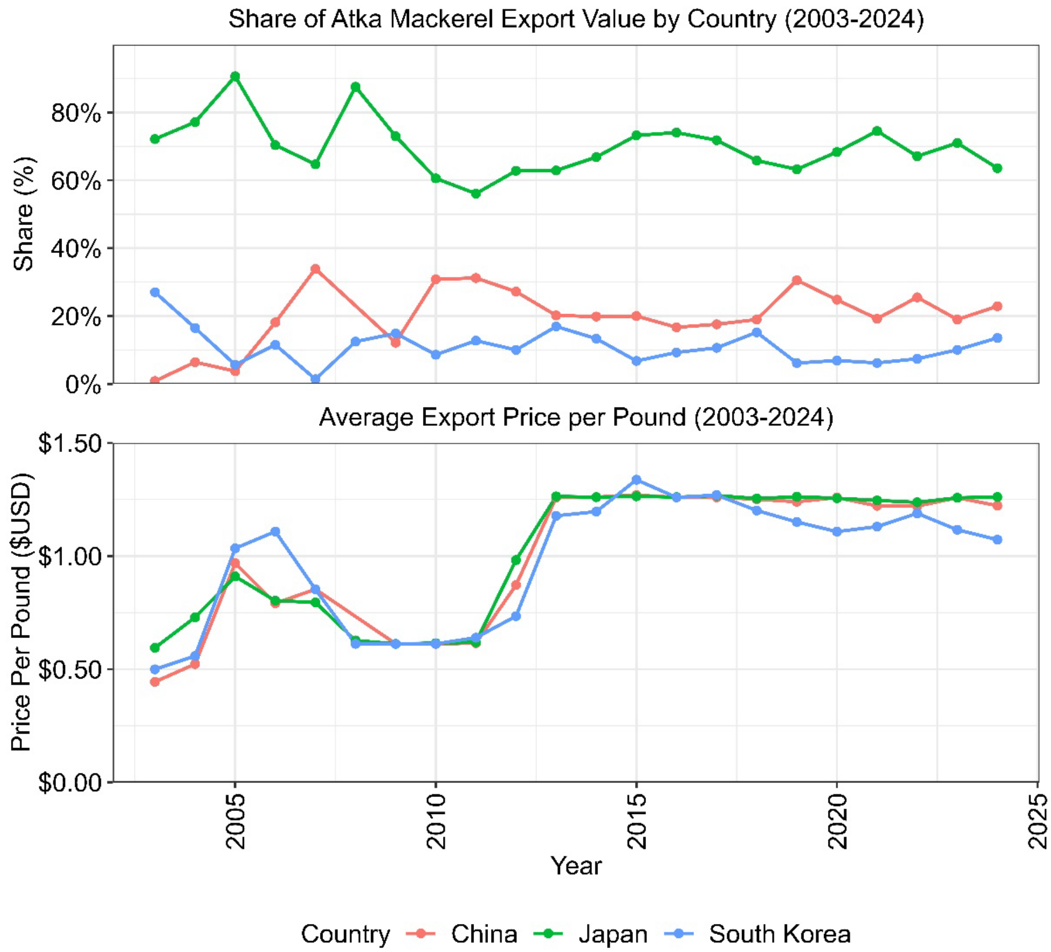

Figure 16. Share of Atka mackerel export value by country and the average annual export price per-pound.

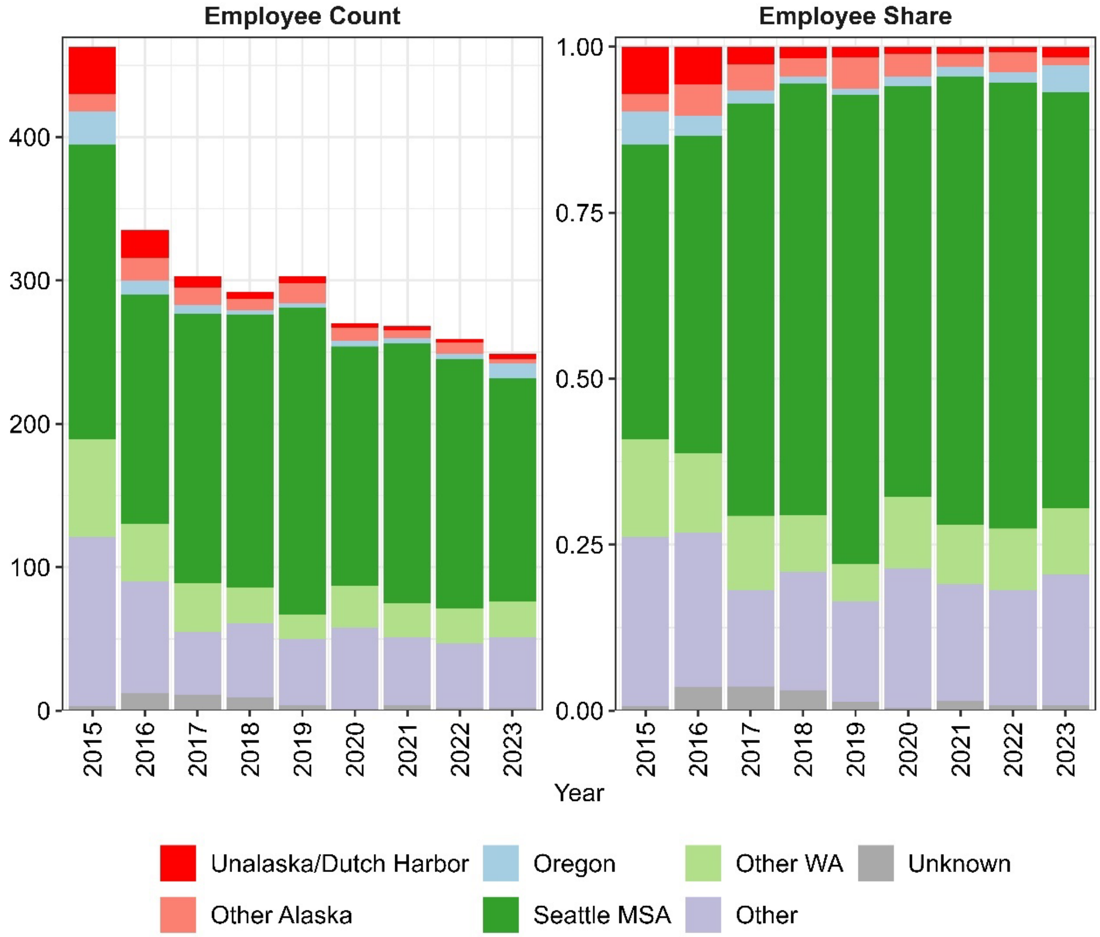

Figure 17. Employee count and share of employees by community for a subset of the Amendment 80 fleet that harvests Atka mackerel.