Appendix 3D. Ecosystem and Socioeconomic Profile of the Sablefish stock in Alaska - Report Card

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Table of Contents

Executive Summary

The ecosystem and socioeconomic profile (ESP), is a standardized framework for compiling and evaluating relevant stock-specific ecosystem and socioeconomic indicators. It also communicates linkages and potential drivers of the stock within the stock assessment process (Shotwell et al., 2023a). The ESP process creates a traceable pathway from the initial development of indicators to management advice and serves as an on-ramp for developing ecosystem-linked stock assessments.

The ESP report card provides data updates to the most recent year available of the indicator suite created in the initial full ESP (Shotwell et al., 2019). For more information regarding the ecosystem and socioeconomic linkages for this stock, please refer to the last full ESP and most recent report card documents (Shotwell et al., 2019, Shotwell et al. 2023b). These documents are available as an appendix within the Alaska Sablefish stock assessment and fishery evaluation (SAFE) reports.

Management Considerations

The following are summary considerations from recent updates to the ecosystem and socioeconomic indicators evaluated for Alaska sablefish:

Acceptable Biological Catch (ABC) Information:

- Surface temperatures in the Gulf of Alaska (GOA) and southeastern Bering Sea (SEBS) remain below average, with no heatwave events in the GOA, implying potentially slower larval sablefish growth.
- Lower energy near Aleutian passes implies reduced retention in suitable habitats and reduced transport through these passes to nursery environments along the Aleutian chain.
- In 2023, the zooplankton community size was above average in the eastern GOA but below average in the western GOA, implying variable feeding conditions for larval and young-of-the-year (YOY) sablefish.
- Although the size of YOY sablefish observed in seabird bill loads increased, it remained below average, while growth was average in 2024.
- Catch-per-unit-effort (CPUE) for sablefish in nearshore surveys has declined since the peak in 2020, but remains above average. Length frequencies continue to reflect the 2019 year class, with no evidence of new cohorts.
- High counts of small (~age-1) sablefish from the BSAI fishery and above average from the GOA bottom trawl survey in 2023 suggest a strong 2022 year class. However, fishery counts were low in 2024.
- Condition of the 2019 year-class (2023 data) and condition of large adult females in the longline survey were high in 2023, suggesting adequate prey resources for maturing and spawning fish.
- The spatial overlap between sablefish migrating to adult slope habitats and the arrowtooth flounder population, as measured by incidental catch, decreased to slightly below average.
- Incidental catch of sablefish in non-sablefish targeted fisheries decreased to a time series low in the GOA in 2024 and also decreased in the BSAI, although it remained above average.
- The condition of adult female sablefish in GOA fisheries declined slightly in 2024 but remained above average, though sample sizes were smaller compared to previous years.

Total Allowable Catch (TAC) Information:

- Retained catch increased by 34% in 2022, reaching a historical peak of approximately 25 thousand metric tons (mt). In 2023, retained catch decreased slightly (-3%), but remained above one-standard deviation of the historical range.
- The proportion of sablefish caught by the Individual Fishing Quota (IFQ) fishery that were less than 2 pounds and greater than 7 pounds decreased while the proportion of sablefish in the 2 to 3 and 3 to 4 pound size categories increased.

- Ex-vessel prices of sablefish reached a new historical low of $1.53 per pound, decreasing by 63% from the 2014 to 2018 average, and remained under one standard deviation of the historical range for the fourth consecutive year.
- Size-specific sablefish ex-vessel prices have declined since 2017 (excluding a spike in 2022) for each size category. It appears, however, that the 2023 and 2024 average ex-vessel price for the 5 to 7 pound and greater than 7 pound size categories declined more quickly than smaller size categories.
- Year-over-year increases in TAC have outpaced increases in total catch, causing statewide TAC utilization to fall below one standard deviation of the historical range, despite record high total catch levels since 2022.
- As of October 2024, TAC utilization is below the historical average for each subregion and below one standard deviation of the historical range for each subregion, excluding the Bering Sea and West Yakutat.
- Decreases in the average price per-pound, coupled with stable levels of retained catch, caused ex-vessel revenues of sablefish to decrease below one-standard deviation of the historical range for the fourth of the past five years.
- The regional quotient, based on vessel registration residence, is declining for the Seattle Metropolitan Statistical Area (MSA) and, seemingly, is being replaced by Sitka. If we analyze the regional quotient based on landings port, Sitka, Seward, and Kodiak, remain the top participating communities in the sablefish fishery with Kodiak and Seward declining in recent years.

Modeling Considerations

The following are the summary results from the most recent intermediate (Shotwell et al., 2023b) and advanced stage ecosystem monitoring analyses for Alaska sablefish:

- The highest ranked predictor variables for sablefish recruitment, based on the importance methods in the intermediate stage indicator analysis were summer juvenile sablefish CPUE from the ADF&G large mesh survey and the spring SST in the SEBS (inclusion probability > 0.5).
- A state-space growth model that incorporates age, year, and cohort correlations indicated potential declines in weight-at-age in response to recent large recruitment events.
- A spatially explicit life cycle model, coupled with results from an individual based model for Alaska sablefish, is currently under development to understand ecosystem drivers of movement and improve recruitment projections.

Assessment

Ecosystem and Socioeconomic Processes

We summarize important processes that may be helpful for identifying productivity bottlenecks and dominant pressures on the stock with a conceptual model detailing ecosystem processes by life history stage (Figure 3D.1) and economic performance (Table 3D.1). Please refer to the last full ESP document (Shotwell et al., 2019) for more details.

Indicator Suite

The following list of indicators for Alaska sablefish is organized into categories: three for ecosystem indicators (larval to YOY, juvenile, and adult) and three for socioeconomic indicators (fishery informed, economic, and community). The indicator name and short description are provided in each heading. For ecosystem indicators, we include the proposed sign of the overall relationship between the indicator and a stock assessment parameter of interest (e.g., recruitment, natural mortality, growth), where relevant, and specify the lag applied if the indicator was tested in the ecosystem intermediate stage indicator analysis (see section below for more details). Each indicator heading is followed by bullet points that provide information on the contact and citation for the indicator data, the status and trends for the current year, factors influencing those trends, and implications for fishery management. The following nomenclature was used to describe these indicators:

- "Average": Used if the value in the time series is near the long-term mean (dotted green line in figure 3D.2).
- "Above average" or "Below average": Used if the value is above or below the mean but was within 1 standard deviation of the mean (in between solid green lines in Figure 3D.2).
- "Neutral": Used in Table 3D.2 for any value within 1 standard deviation of the mean.
- "High" or "Low": Used if the value was more than 1 standard deviation above or below the mean (above or below the solid green lines in Figure 3D.2).

This update focuses on new developments since the last ESP (Shotwell et al., 2023b). For detailed information regarding these ecosystem and socioeconomic indicators and the proposed mechanistic linkages for Alaska sablefish, please refer to the previous ESP documents (Shotwell et al., 2019-2023b). Time series of these indicators are provided in Figure 3D.2a (ecosystem indicators) and Figure 3D.2b (socioeconomic indicators).

The full ESP process evaluates the indicator suite as a whole when the ESP is first created (Shotwell et al., 2023a). Report card documents maintain all these indicators but may require some modifications each year to ensure delivery of the best scientific information available.

New indicators in the 2024 suite include:

- Eddy kinetic energy from the Amchitka Pass area to represent transport to the Bering Sea.
- Number of hauls in the fishery that caught small (≤ 350 mm) sablefish in 0-100 m depth as an estimate of age-1 year class.
- Retained catch (total catch minus discards) from the fishery
- TAC utilization from the fishery.

Modified indicators include:

- Change in annual heatwave extent now covers the full Gulf of Alaska (GOA) to the exclusive economic zone (EEZ), including seamount habitats rather than just the central GOA shelf.

- Annual sablefish size of YOY at Middleton Island in seabird bill loads, replacing the growth indicator.

Note: These modifications will preclude direct comparison with previous ESP indicator time series.

Removed indicators:

- Chlorophyll *a* derived indicators (concentration and peak timing of the spring bloom) were temporarily removed due to a product discrepancy that requires further evaluation.
- Summer euphausiid abundance indicator was removed, as no updates have been available since 2019 and future updates are unknown.
- Arrowtooth flounder total biomass was removed, being redundant with the sablefish incidental catch in the arrowtooth fishery indicator.
- Catch-per-unit-effort (CPUE) of the fishery (both combined and pot gear) were removed because this information is now included in the Alaska sablefish operational stock assessment model (Goethel et al., 2023).

We have also included **value-added products** to more fully explore some of the indicators in the suite to allow for a more in depth interpretation of the indicator. New products this year include:

- Historical and inseason sablefish prices and landings, categorized by size.
- TAC utilization by subregion.
- Revenue shares in the sablefish fishery by sector and gear type.
- Regional quotients for communities with the greatest historical value and landings of sablefish.

For more details on these value-added products, please see the Economic and Social Science Research Program (ESSR) 2024 report.

Ecosystem Indicators:

1. Larval to YOY Indicators (Figure 3D.2a.a-g)

a. Annual Heatwave GOA Model: An annual marine heatwave index is calculated from daily sea surface temperatures from 1985 through present using data from the NOAA Coral Reef Watch Program. Daily mean sea surface temperature data were processed to obtain the marine heatwave cumulative intensity value (MHWCI) (Hobday et al., 2016), where we defined a heat wave as 5 days or more with daily mean sea surface temperatures greater than the 90th percentile of the January 1985 through December 2015 time series. The spatial resolution is 5 km satellite sea surface temperatures aggregated over the Alaska exclusive economic zone (EEZ) followed by annual summation of a cumulative heatwave index in degree Celsius days. The proposed sign of the relationship to recruitment is positive.
    - Contact: Matt Callahan
    - Status and trends: Marine heatwaves have been largely absent at this GOA spatial scale, except for significant events in 1997, 2005, 2014–2016, and 2019. The absence of heatwaves has continued since 2021.
    - Factors influencing trends: Generally, cool conditions are related to winter balances between heat loss, coastal runoff, and stratification, while warm conditions are associated with El Nino events (1998, 2003, and 2016) and marine heatwaves (Janout et al., 2010). The selection of baseline years affects heatwave detection.
    - Implications: The absence of marine heatwaves implies cooler conditions which may impact growth during the early life history stages of sablefish.

b. Spring Temperature Surface GOA Satellite: Late spring (May-June) daily sea surface temperatures (SST) on a 5 km grid averaged over the GOA (NMFS areas 610-650, no depth restriction) (Watson, 2020) from the NOAA Coral Reef Watch Program which provides the

Global 5km Satellite Coral Bleaching Heat Stress Monitoring Product Suite Version 3.1, derived from CoralTemp v1.0. product (NOAA Coral Reef Watch, 2018), 1985 to present. Code available at: https://github.com/jordanwatson/ESP_Indicators. This seasonal and spatial distribution coincides with the peak larval timing for sablefish in surface waters and where the bulk of the sablefish population is located. Proposed sign of the relationship to recruitment is positive.

- Contact: Matt Callahan
- Status and trends: Spring sea surface temperatures were high or above average from 2014-2022 but decreased to below average in 2023 and 2024.
- Factors influencing trends: Many weather, climate and oceanographic factors influence sea surface temperatures (Holbrook et al., 2019). Generally, cool conditions are related to winter balances between heat loss, coastal runoff, and stratification, while warm conditions are associated with El Nino events and marine heatwaves (Janout et al., 2010).
- Implications: Sablefish have a rapid growth during the larval stage, develop large pectoral fins to assist with swimming ability in the surface waters, and delayed bone-development in their jaws which restricts them to prey that is small and prevalent (Deary et al., 2019). Their peak residence in surface waters matches with the onset of the zooplankton bloom and when warmer conditions typify a longer food web, sablefish may better utilize this abundant prey resource over other groundfish species.

c. Spring Temperature Surface SEBS Satellite: Late spring (May-June) daily sea surface temperatures (SST) on a 5 km grid averaged over the southeastern Bering Sea (deeper than 10 m) (Watson, 2020) from the NOAA Coral Reef Watch Program which provides the Global 5km Satellite Coral Bleaching Heat Stress Monitoring Product Suite Version 3.1, derived from CoralTemp v1.0. product (NOAA Coral Reef Watch, 2018), 1985 to present. Code available at: https://github.com/jordanwatson/ESP_Indicators. This seasonal and spatial distribution coincides with the peak larval timing for sablefish in surface waters and the northern edge of the sablefish population. Proposed sign of the relationship to recruitment is positive and the time series is not lagged for the intermediate stage ecosystem monitoring analysis (see details below).

- Contact: Matt Callahan
- Status and trends: Spring sea surface temperatures were the highest in the time series or well above average from 2014-2022, but appear to be on a declining trend since 2021 and have recently decreased to below average in 2024.
- Factors influencing trends: Sea surface temperatures in the Bering sea are strongly influenced by sea ice and stratification, particularly over the middle shelf where surface and bottom temperature dynamics can be decoupled much of the year (Ladd and Stabeno, 2012).
- Implications: Sablefish have a rapid growth during the larval stage, develop large pectoral fins to assist with swimming ability in the surface waters, and delayed bone-development in their jaws which restricts them to prey that is small and prevalent. Their peak residence in surface waters matches with the onset of the zooplankton bloom and when warmer conditions typify a longer food web, sablefish may better utilize this abundant prey resource over other groundfish species. Anomalously warm spring surface waters in the SEBS may allow this northern edge of the sablefish habitat to be more suitable than it ever was historically.

d. Annual Eddy Kinetic Energy Amchitka Satellite: Annual eddy kinetic energy (EKE) calculated from sea surface height near Amchitka Pass (region 2) as a measure of mesoscale energy in the ocean system (Ladd, 2020). Suite of satellite altimeters provides sea surface height. The Ssalto/Duacs altimeter products were produced and distributed by the Copernicus Marine and Environment Monitoring Service (CMEMS) (http://www.marine.copernicus.eu). Data available from 1994 to present. Note while an "annual average" is computed for the current year, data are only available up to July, so it is not a full year's average. Proposed sign of the relationship to recruitment is positive.

- Contact: Wei Cheng
- Status and trends: The annual EKE near Amchitka Pass has generally been above the long-term average since 2016. Strong positive anomalies existed from late 2021 through late 2023. Data for 2024 are not complete but do show reduced energy compared to the same time period in 2023.
- Factors influencing trends: Eddies in the western Aleutian Islands are less studied but are presumably related to the strength of the Alaska Stream which in turn is forced by large scale atmospheric forcing and the North Pacific gyre, although this is an area of ongoing research.
- Implications: A lower energy period implies reduced retention in suitable habitat for young-of-the-year sablefish and reduced transport through the Aleutian passes to suitable nearshore nursery environments throughout the Aleutian chain along the Aleutian North Slope Current.

e. Annual Copepod Community Size EGOA Survey: Continuous Plankton Recorders (CPRs) have been deployed in the North Pacific routinely since 2000. Two transects are sampled seasonally, both originating in the Strait of Juan de Fuca, one sampled monthly (~Apr-Sept) which terminates in Cook Inlet, the second sampled 3 times per year (in spring, summer and autumn) which follows a great circle route across the Pacific terminating in Asia. The CPR is described comprehensively by Richardson et al. (2006). Anomaly time series of the copepod community size have been calculated as follows: A monthly mean value for each region is first calculated. Each sampled month's mean is then compared to the long-term mean of that month (calculated using the geometric mean) and an anomaly calculated (Log10). The mean anomaly of all sampled months in each year is calculated to give an annual anomaly. Proposed sign of the relationship to recruitment is negative.

- Contact: Clare Ostle
- Status and trends: On the eastern side of the oceanic Gulf of Alaska the copepod community size anomaly was mostly negative in the last 8 years, but it has oscillated to a positive anomaly in 2017 and 2023.
- Factors influencing trends: The Pacific Decadal Oscillation (PDO) monthly values were often negative in 2017 causing a lower annual mean value compared to the years of 2014-2016, which had experienced a marine heat wave (DiLorenzo and Mantua, 2016). 2023 also had a negative PDO and Oceanic Nino Index (ONI) which might have influenced the copepod community, leading to an increase in larger copepod species for this year. In warm conditions smaller species tend to be more abundant and the copepod community size index reflects this and was mostly negative throughout the marine heat wave periods of 2014-2016, and 2018-2020.
- Implications: 2023 appears to show an increase in copepod community size in the eastern Gulf of Alaska. A larger copepod community size implies a shorter food web chain and higher abundance of larger prey resources for larval sablefish in the oceanic habitat as they transit to the nearshore. Due to their delayed bone-development, larval sablefish are restricted to smaller prey and may not be able to utilize the larger prey resources as efficiently, potentially resulting in reduced YOY condition upon reaching the nearshore environment and lower overwinter survival.

f. Annual Copepod Community Size WGOA Survey: Continuous Plankton Recorders (CPRs) have been deployed in the North Pacific routinely since 2000. Two transects are sampled seasonally, both originating in the Strait of Juan de Fuca, one sampled monthly (~Apr-Sept) which terminates in Cook Inlet, the second sampled 3 times per year (in spring, summer and autumn) which follows a great circle route across the Pacific terminating in Asia. The CPR is described comprehensively by Richardson et al. (2006). Anomaly time series of the copepod community size have been calculated as follows: A monthly mean value for each region is first calculated. Each sampled month's mean is then compared to the long-term mean of that month (calculated using the geometric mean) and an anomaly calculated (Log10). The mean anomaly of all sampled months in each year is calculated to give an annual anomaly. Proposed sign of the relationship to recruitment is negative.

- Contact: Clare Ostle
- Status and trends: On the western side of the oceanic Gulf of Alaska the copepod community size anomaly was mostly negative in the last 8 years, but it has oscillated to a positive anomaly in 2017 and 2019. In 2023, the size anomaly was negative, as it has been for the last 4 years.
- Factors influencing trends: The Pacific Decadal Oscillation (PDO) monthly values were often negative in 2017 causing a lower annual mean value compared to the years of 2014-2016, which had experienced a marine heat wave (DiLorenzo and Mantua, 2016). 2023 appears to be another warm year despite a negative PDO and Oceanic Nino Index (ONI). In warm conditions smaller species tend to be more abundant and the copepod community size index reflects this and was mostly negative throughout the marine heat wave periods of 2014-2016, and 2018-2020.
- Implications: The decrease in copepod community size implies a longer food web chain and higher abundance of smaller prey resources for larval sablefish in the oceanic habitat as they transit to the nearshore. Due to sablefish delayed bone-development and restriction to smaller prey, this could result in good condition upon reaching the nearshore environment and increased overwinter survival.

g. Annual Sablefish Size YOY Middleton Survey: Rhinoceros auklet (*Cerorhinca monocerata*) bill loads at Middleton Island in the Gulf of Alaska (59.4375°N, 146.3277°W) are monitored by collecting bill-loads from chick-provisioning adults, during late-June until early or mid-August, depending on breeding phenology. GPS-tracking data suggest the foraging range of seabirds at Middleton varies across years but can be approximated by a 100 km radius from the colony. Diet samples consist of whole prey specimens from one or more prey species. Whole fish are identified and measured for length and weight upon collection. From samples of age-0 sablefish collected in diets over the chick rearing period, growth rate is calculated using the relationship between mean fish length and Julian date for each year, except in 1994 when data were omitted because of low sample size and effort conducted over only a short period of time. From this relationship we can also predict length for each year on the median sampling date (July 24). This is a value-added indicator that also includes growth and size indicators together for comparison (Figure 3D.3). DOI: https://doi.org/10.5066/P94KVH9X. Proposed sign of the relationship to recruitment is positive and the time series is not lagged for the intermediate stage ecosystem monitoring analysis (see details below).

- Contact: Mayumi Arimitsu
- Status and trends: When 2024 data were added to this year's model, we found that the interaction between Julian Day and year explains the majority of variability in age-0 sablefish length (OLS: $F = 27.82$, $p < 0.001$, $R^2 = 0.87$). During 2024 the age-0 sablefish predicted length (90 mm) was below average (-9 mm) on the median sampling date (Jul 24). In 2024 age-0 sablefish growth (1.9 mm/day) and the growth index anomaly (-0.01 mm/day) was near the long-term average.
- Factors influencing trends: The 2024 indices are based on measurements of 21 fish sampled on eight different days between June 25 and August 9. A total of 344 bill load samples were collected in 2024. Size of age-0 sablefish at the end of July is important because frequency of occurrence of age-0 sablefish in seabird diets is positively related to predicted fish length ($p < 0.001$). Seabirds may avoid age-0 sablefish that are too small,

either because they can't sense them as easily or because they prefer higher energy food, resulting in lower provisioning rates than would be if the fish were larger in size during the chick rearing stage.

- Implications: Age-0 sablefish are not well sampled by other survey methods, and so time series of age-0 sablefish condition (size and growth) derived from seabird diet monitoring at Middleton Island are among the longest available from any Alaska location. Size and growth of age-0 sablefish may provide an early indication of recruitment because these indices may be related to spawn timing, local prey conditions, or survival of the cohort. Size index values were above average during the marine heatwave years (2014-2019), and below average most years during the cool stanza prior to the heatwave (2008-2013).

2. Juvenile Indicators (Figure 3D.2a.h-j)

h. Summer Sablefish CPUE Juvenile Nearshore GOAAI Survey: Sablefish CPUE (kg per km towed) in the Central and Western Gulf of Alaska and Eastern Aleutian Islands, from the Alaska Department of Fish and Game (ADF&G) annual large-mesh bottom trawl surveys, 1988 to present (Spalinger and Silva, 2023). This is a value-added indicator that also includes CPUE indicators by district (Figure 3D.4, top graph) and length distributions by year (Figure 3D.4, bottom graph). Proposed sign of the relationship to recruitment is positive and the time series is lagged three years for the intermediate stage ecosystem monitoring analysis (see details below).
    - Contact: Kally Spalinger
    - Status and trends: Sablefish CPUE (kg per km towed) in the ADF&G large-mesh survey continued to decline in 2024 from a high observed in 2020, but remains slightly above the average survey CPUE over the time series. The high CPUE for 2020-2021 were largely driven by catches in the Kodiak area, while high CPUE in 2018, 2019, 2022 was up in all areas of the survey. There was also an increase in catches in the eastern Aleutians in 2021. In 2023 CPUE decreased in all areas and in 2024 CPUE continued to decrease in Kodiak and Chignik but increased in the Aleutians (Figure 3D.5, top graph). Length frequencies from 2020 are similar to those in 2015 and 2017 suggesting a strong 2019 year-class similar to 2014 and 2016. The length frequencies from 2021 through 2024 match the growth of the 2019 cohort to age-2, -3, and -4, but do not show any new cohorts at age-1 (Figure 3D.5, bottom graph).
    - Factors influencing trends: Amount of sablefish caught in the survey is likely influenced by interannual variability in the spatial distribution of the stock and influx from recent large year classes. This survey likely contains a mix of different aged sablefish from age-1 through age-3 or age-4, and so the CPUE index is an index of cohort strength across the previous 3-4 years. Sablefish lengths generally consist of fish between ages 2-4 and can be considered an index of sablefish juveniles in the nearshore prior to returning to adult habitat (Spalinger, 2015).
    - Implications: The early to late juvenile stage of sablefish are not well sampled by other survey methods. The ADF&G large-mesh bottom trawl survey may be useful as an early signal of overwinter and nearshore residency success for the early to late juvenile stage of sablefish. When combined with the length frequencies, this survey is useful for identifying continued survival of sablefish throughout their residency in the nearshore before transitioning to the slope adult environment.

i. Summer Sablefish CPUE Juvenile GOA Survey: Anomalies of the length composition extrapolated to the population of juvenile sablefish (<=350 mm, likely age-1) collected on summer bottom-trawl surveys from 1984 to present. This indicator is only updated on odd years due to the biennial sampling schedule of the GOA bottom trawl survey. This data is not used in the operational stock assessment model (>400 mm). Proposed sign of the relationship to recruitment is positive.

- Contact: Kalei Shotwell
- Status and trends: Age-1 sablefish in the AFSC bottom trawl survey were above average in 2023 (2022 year class) similar to 2001 (2000 year class).
- Factors influencing trends: Amount of small sablefish caught in the survey is likely influenced by interannual variability in the spatial distribution of the stock and influx from recent large year classes.
- Implications: These small lengths from the bottom trawl survey are not used in the operational sablefish model and could be used as an index of future cohort strength. The above average 2023 composition could represent a stronger 2022 year class than average.

j. Annual Small Sablefish Incidental Hauls EBS Fishery: The number of pelagic and non-pelagic trawl hauls fishing <= 100-m depth in the Eastern Bering Sea that caught sablefish with an extrapolated average sablefish weight <= 0.5 kg, selected to reflect an age-1 sablefish. Proposed sign of the relationship to recruitment is positive.
    - Contact: Kevin Siwicke
    - Status and trends: Count of hauls with small (likely age-1) sablefish have been historically low for much of the time series, with the exception of the 2000 year class, until the recent large recruitment years at the onset of the marine heatwave in 2014. Large haul counts include 2015, 2017, 2020 and 2023. There have not been any hauls with small sablefish in 2024, though the fishery is not yet complete.
    - Factors influencing trends: Historically these small fish have mostly been caught in the first few months of the year and encountered spatially north of Unimak Pass (Siwicke and Echave, 2024).
    - Implications: Evidence of small sablefish (<=0.5 kg) as incidental catch in the upper 100 m reflects the age-1 sablefish and may indicate a strong year class in the year prior. The large haul counts of 2023 may indicate a strong 2022 year class that have yet to be observed in the trawl or longline surveys.

<u>3. Adult Indicators (Figure 3D.2a.k-n)</u>

k. Summer Temperature 250m GOA Survey: Summer temperature profiles were recorded during the annual longline survey along the continental slope using an SBE39 (Seabird Electronics) attached to the groundline (Siwicke, 2022). Interpolation between actual depth recordings in a profile was conducted using weighted parabolic interpolation (Reiniger and Ross, 1968). The mean temperature of 1-m interpolations from 246 to 255 meters was used as the station level value, and these are treated as regional replicates to determine a area-weighted mean temperature at 250-m depth for the western, central, and eastern GOA sablefish management areas (for more details, see Siwicke, 2022). This GOA index is the mean of the annual anomalies from each sablefish management area, and because this time series is still short (< 20 years), the long-term mean is still being updated every year. The 250-m depth was selected to represent deeper water at the shelf-slope break where adult sablefish are typically sampled. Annual values come from this extent: Latitude (54.4 to 59.6) and Longitude (-157.8 to -134.0) and the survey is conducted by the Marine Ecology and Stock Assessment (MESA) program, Auke Bay Laboratories, Alaska Fisheries Science Center. There was no update for this indicator in 2024 due to cancellation of the longline survey. Proposed sign of the relationship to recruitment is negative.
    - Contact: Kevin Siwicke
    - Status and trends: The 2023 trend is down from 2022, but this was the seventh consecutive year with above average subsurface temperature.
    - Factors influencing trends: Subsurface waters below mixed layers can absorb and store heat. These changes do not occur at the same timescales as changes in surface water temperatures, often showing delayed responses by a year or more. These temperature

changes are also very small compared to surface waters. The warmer that subsurface waters become, the less cooling capacity they have to absorb heat from surface waters.
- Implications: Implications of changes in subsurface temperatures are not well known, but could impact sablefish biology, species distributions, or prey presence, quality, and abundance. The lower variability of subsurface temperatures compared to surface temperatures may provide a buffer during spawning and egg deposition for sablefish.

l. Summer Sablefish Condition Female Age4 GOA Survey: Summer sablefish condition for age-4, immature female sablefish. Body condition was estimated using a length-weight relationship (Laman and Rohan, 2020) from data collected randomly for otoliths in the annual GOA AFSC longline survey (legs 2-7 including slope and cross gully stations), 1996 to present. Proposed sign of the relationship to recruitment is positive.
    - Contact: Jane Sullivan
    - Status and trends: This indicator is lagged by one year because it relies on age data, which take longer to provide. The condition of age-4 immature females was high in 2023 reflecting a comparable high large adult female condition in 2023 for the survey and fishery.
    - Factors influencing trends: Factors related to condition of age-4, immature female sablefish in 2023 might include improved environmental conditions (e.g., cooling temperatures in the GOA), or an increase in prey availability or prey quality.
    - Implications: Above average condition for age-4, immature female sablefish in 2023 might relate to faster maturation and somatic growth rates, or increased survival.

m. Annual Sablefish Incidental Catch Arrowtooth Target GOA Fishery: Incidental catch in tons of sablefish in the GOA arrowtooth flounder fishery. Proposed sign of the relationship to recruitment is negative and the time series is lagged three years for the intermediate stage ecosystem monitoring analysis (see details below).
    - Contact: Kalei Shotwell
    - Status and trends: Incidental catch estimates of sablefish in the GOA arrowtooth flounder fishery increased to very high levels in 2017-2020 but have decreased since and are now slightly below average in 2024, similar to 2016.
    - Factors influencing trends: Decreasing incidental catch of sablefish in the arrowtooth flounder fishery can be due to lower levels of spatial overlap between the arrowtooth and sablefish populations or changes in the magnitude, spatial distribution, gear and other aspects of the groundfish harvesting effort. Overlap metrics between the fishery and the survey may be a useful comparison for understanding trends.
    - Implications: Given the caveats on influential factors, the decrease in incidental catch suggests that the recent large sablefish year classes have moved off the continental shelf into adult sablefish habitat on the slope and may no longer be competing with or experiencing high levels of predation by arrowtooth flounder.

n. Summer Sablefish Condition Female Adult GOA Survey: Summer sablefish condition for large adult (>=750 mm) female sablefish. Body condition was estimated using a length-weight relationship (Laman and Rohan, 2020) from data collected randomly for otoliths in the annual GOA AFSC longline survey (legs 2-7 including slope and cross gully stations), 1996 to most recent survey. There was no update for this indicator in 2024 due to cancellation of the longline survey. Proposed sign of the relationship to recruitment is positive and the time series is not lagged for the intermediate stage ecosystem monitoring analysis (see details below).
    - Contact: Jane Sullivan
    - Status and trends: The condition of large adult (>=750 mm) female sablefish has been highly variable for the past decade but often below average to low. Condition improved from low in 2022 to high in 2023.

- Factors influencing trends: Factors influencing the condition of large adult (>=750 mm) female sablefish in 2023 could include improved environmental conditions, increase in prey availability or prey quality, or reduced inter- or intra-specific competition relative to 2022.
- Implications: Improved condition indicators for large adult (>=750 mm) female sablefish in 2023 could translate into a lower likelihood of skip spawning, increased somatic growth rates, or increased survival rates relative to 2022.

Socioeconomic Indicators:

1. Fishery Informed Indicators (Figure 3D.2b.a-c)

a. Annual Sablefish Incidental Catch GOA Fishery: Incidental catch estimates of sablefish in tons from the GOA fisheries excluding the sablefish fishery.
   - Contact: Kalei Shotwell
   - Status and trends: These catches are primarily from the rockfish, halibut, and arrowtooth flounder trip targets which have all declined since 2022. A notable increase in incidental catch occurred in the pollock bottom trawl during 2018-2020 but has decreased to low levels from 2021 to present.
   - Factors influencing trends: Incidental catch in groundfish fisheries is influenced by the magnitude, spatial distribution, gear and other aspects of groundfish harvesting effort, as well as the size distribution, abundance, vertical spatial, and temporal distribution of the sablefish stock.
   - Implications: Rapid changes of incidental catch may imply shifting distribution of the sablefish population into non-preferred habitat, which could increase competition and predation for sablefish, particularly with the influx of the recent large year classes. Additionally, this catch could be viewed as an early indicator of large year classes or confirmatory of previously estimated year classes.

b. Annual Sablefish Incidental Catch BSAI Fishery: Incidental catch estimates of sablefish in tons from the BSAI fisheries excluding the sablefish fishery.
   - Contact: Kalei Shotwell
   - Status and trends: Incidental catch declined in 2024 to above average from a period of high catches in 2019-2023. These catches are primarily from the rockfish, Kamchatka, and arrowtooth flounder trip targets in the BSAI and represents a shift from the higher incidental catches from the BSAI midwater pollock trip targets in 2019-2021.
   - Factors influencing trends: Incidental catch in groundfish fisheries is influenced by the magnitude, spatial distribution, gear and other aspects of groundfish harvesting effort, as well as the size distribution, abundance, vertical spatial, and temporal distribution of the sablefish stock.
   - Implications: Rapid changes of incidental catch may imply shifting distribution of the sablefish population into non-preferred habitat, which could increase competition and predation for sablefish, particularly with the influx of the recent large year classes. Additionally, this catch could be viewed as an early indicator of large year classes or confirmatory of previously estimated year classes.

c. Annual Sablefish Condition Female Adult GOA Fishery: Annual sablefish condition for large adult (>=750 mm) female sablefish in the GOA sablefish fishery. Body condition was estimated using a length-weight relationship (Laman and Rohan, 2020) from data collected randomly for otoliths in the annual GOA fishery, 1999 to present. Proposed sign of the relationship to recruitment is positive.
   - Contact: Jane Sullivan

- Status and trends: The condition of large adult (>=750 mm) female sablefish was above average in 2024 and only slightly decreased from 2023.
- Factors influencing trends: The condition of large adult (>=750 mm) female sablefish in 2024 could be indicative of above average environmental conditions (e.g., temperatures have been cooling in the GOA for the last several years), or reflect above average conditions related to prey availability, prey quality, or competition in the GOA.
- Implications: Condition indicators for large adult (>=750 mm) female sablefish in 2024 are slightly lower but not statistically different from 2023. An above average condition may correlate with lower rates of skip spawning, increased somatic growth rates, or increased survival.

2. Economic Indicators (Figure 3D.2b.d-g)

d. Annual Sablefish Retained Catch AK Fishery: Total weight, measured in metric tons, of sablefish caught and brought to shore for processing (not including discards)
    - Contact: Russel Dame
    - Status and trends: A large increase in retain catch occurred in 2022, reaching a new historical high of 25 thousand mt. Total sablefish landings have declined slightly in 2023, by less than 3%, from 2022 levels but remain above one standard deviation of the historical range and greater than all pre-2022 values.
    - Factors influencing trends: Sablefish TAC increased year-over-year between 2018 and 2024 with significant increases in 2021 and 2022. Increases in TAC, coupled with increases in biomass and a transition to primarily pot gear, allowed vessels to retain more sablefish than in the past. Additionally, in 2022, ex-vessel prices of many Alaskan seafood products increased, including sablefish. The increase in price may have incentivized vessels to harvest more fish with increases in TAC.
    - Implications: As most sablefish caught in Alaska are exported, increases in retained catch contributed to an increased global supply (Table 3D.1c). Without similar levels of increased demand for sablefish products, the large increase in retained catch in 2022 may be a partial cause for the reduction in the average ex-vessel and first wholesale price per-pound seen in 2023 (Table 3D.1a & Table 3D.1b). Since retained catch remained relatively stable (-3%) from 2022 to 2023, ex-vessel and wholesale prices may continue to decrease further in 2024.

e. Annual Sablefish Real Ex-vessel Price Fishery: Average real ex-vessel price per pound of sablefish measured in millions of dollars and inflation adjusted to 2023 USD.
    - Contact: Russel Dame
    - Status and trends: The 2023 average price per pound of sablefish, $1.53, has decreased by 32% from the 2022 average and is 63% less than the 2014 to 2018 average. Sablefish prices are below the one standard deviation of the historical range for the fourth consecutive year, reaching the lowest average price per pound in recent history.
    - Factors influencing trends: The ex-vessel price of sablefish is highly correlated with the export price. With increases in the global supply of sablefish, due to increases in Alaskan retained catch and Russian exports, export prices have begun to decline causing negative impacts on the ex-vessel price of sablefish.
    - Implications: Declines in ex-vessel prices of sablefish may affect the behavior of vessels targeting sablefish. With lower prices and increased cost, the profit margin of vessels targeting sablefish will decline, potentially causing them to target other species caught with similar gear types and a higher profit margin. Alternatively, vessels may begin to target larger sablefish with a higher price, avoiding areas with small sablefish.

f. Annual Sablefish TAC Utilization AK Fishery: Total annual catch of sablefish in Alaska as a percentage share of the annual TAC set for all Alaska.

- Contact: Russel Dame
- Status and trends: Statewide TAC utilization has decreased year-over-year since 2019, falling to under one standard deviation of the historical range. In-season TAC utilization trends by subarea (Figure 3D.8) are lower than the 2023 levels for many subareas, suggesting that TAC utilization may decrease further in 2024.
- Factors influencing trends: The maximum retained amount (used in TAC setting) was modified in 2016. Soon thereafter, estimated sablefish biomass increased causing year-over-year increases in TAC levels since 2019. The increase in TAC each year has outpaced retained catch despite retained catch reaching a historical high in 2022.
- Implications: TBD

g. Annual Sablefish Real Ex-vessel Value Fishery: Annual estimated real ex-vessel value measured in millions of dollars and inflation adjusted to 2023 USD.
   - Contact: Russel Dame
   - Status and trends: The 2023 ex-vessel value of sablefish has declined by 35% from the 2022 value, reaching $81 million, and is 18% less than the mean between 2014 and 2018 (Table 3D.1a) falling below one standard deviation of the historical range for the fourth out of the past five years.
   - Factors influencing trends: Ex-vessel revenue increased significantly in 2022 as a result of a large increase in retained catch from 2021 levels coupled with a slight increase in the average price per pound. The increase in global supply may have partially caused the significant decline in ex-vessel prices in the following year which, coupled with a slight reduction in 2023 retained catch, led to a decrease in 2023 ex-vessel revenue.
   - Implications: Reductions in ex-vessel revenue, similar to reductions in ex-vessel prices, may cause vessels to substitute to other species that can be caught with similar gear types with higher profit margins.

<u>3. Community Indicators</u>

An analysis of commercial processing and harvesting data may be conducted to examine sustained participation for those communities substantially engaged in a commercial fishery. The Annual Community Engagement and Participation Overview (ACEPO) report evaluates engagement at the community level and focuses on providing an overview of harvesting and processing sectors of identified highly engaged communities for groundfish and crab fisheries in Alaska (Wise et al., 2022). We further refine these indicators at the stock level in the next section.

Indicator Monitoring Analysis

Ecosystem and socioeconomic indicators are monitored through distinct workflows, depending on the management decisions they are intended to inform. These workflows are defined for each indicator suite in the following sections.

Ecosystem Monitoring

Ecosystem indicators undergo up to three stages of statistical analysis (beginning, intermediate, and advanced) to monitor their impact on stock health (Shotwell et al., 2023a). The beginning stage is a relatively simple evaluation by traffic light scoring. This evaluates the indicator value from each year relative to the mean of the whole time series and includes the proposed sign of the overall relationship between the indicator and the stock health. The intermediate stage uses importance methods related to a stock assessment parameter of interest (e.g., recruitment, growth, catchability). These regression techniques provide a simple predictive performance for the parameter of interest and are run separate from the stock assessment model. They provide the direction, magnitude, uncertainty of the effect, and an estimate of inclusion probability. The advanced stage is used for providing visibility on current research ecosystem models and may be used for testing a research ecosystem linked stock assessment model where output can be compared with the current operational stock assessment model to understand information on retrospective patterns, prediction performance, and comparisons to model outputs.

Beginning Stage: Traffic Light Test

The scores are summed by the ecosystem indicator categories and divided by the total number of indicators available in that category for a given year (see Shotwell et al., 2023b for method details). The ecosystem scores over time provide a history of stock productivity and comparison of indicator performance (Figure 3D.3). We also provide a five-year indicator status table with a color for the relationship with the stock (Table 3D.2).

Overall, the ecosystem indicators score in 2024 decreased from the previous year to average (Figure 3D.3, black line). By category, the larval indicators remained average while the juvenile and adult indicators decreased from above average to average (Figure 3D.3, green, blue, purple lines).

Intermediate Stage: Importance Test

Bayesian adaptive sampling (BAS) was used to quantify the association between hypothesized ecosystem predictors and sablefish recruitment estimated in the operational stock assessment, and to assess the strength of support for each hypothesis (see Shotwell et al., 2023b for methods details). We provide the mean relationship between each predictor variable and the estimates of sablefish recruitment over time (Figure 3D.6, top left), with error bars describing the uncertainty (95% confidence intervals) in each estimated effect and the marginal inclusion probabilities for each predictor variable (Figure 3D.6, top right). We also provide model predicted fit (1:1 line, Figure 3D.6, bottom left) and average fit across the recruitment time series subset (1996-2019, Figure 3D.6, bottom right). A higher probability indicates that the variable is a better candidate predictor of sablefish recruitment.

The highest ranked predictor variables (inclusion probability > 0.5) based on this process are the summer juvenile sablefish CPUE from the ADF&G large mesh survey (inclusion probability > 0.9) and the spring SST in the SEBS (inclusion probability > 0.5) (Figure 3D.6). The direction of these effects were consistent with the proposed overall relationship with recruitment. These indicators are marked with an asterisk (*) in Table 3D.2 and may assist with evaluation of the indicator suite within the risk table.

Many indicators were removed from the BAS analysis due to limitations around missing data, collinearity, and short time series. Incorporating additional importance methods in this intermediate stage indicator analysis may be useful for evaluating the full suite of indicators and may allow for identifying more robust indicators for potential use in the operational stock assessment model. A new study uses the sablefish ESP indicator suite (Shotwell et al., 2022) and sablefish recruitment from the operational stock assessment model (Goethel, et al., 2022) to investigate the strengths and weaknesses of multiple statistical approaches for evaluating indicators (Oke et al., *In prep*.). Along with BAS, this study also evaluates generalized additive models (GAM), boosted regression trees (BRT), and dynamic factor analysis (DFA) paired with state-space regression. The non-BAS methods also identified SST and several juvenile abundance indicators as being strongly correlated with sablefish recruitment (Oke et al., *In prep*) and provide support for evaluating these strong candidate indicators within an ecosystem linked research model in the future.

Advanced Stage: Research Model Test

Several research ecosystem models have been developed or are being developed for Alaska sablefish. We provide a short description of those current or proposed models along with citations where relevant.

A state-space growth model that incorporates age, year, and cohort correlations was developed for Alaska sablefish to examine the potential for time and cohort-specific trends in weight-at-age (Cheng et al., 2023, Cheng et al., 2024). The growth model indicated reductions in growth during recent periods, likely due to density-dependent responses following large recruitment events. Estimates of time-varying weight-at-age were integrated into a research stock assessment model, and revealed lower estimates of spawning stock biomass in recent years.

A Spatially Integrated Life Cycle (SILC) model is in development for sablefish that pairs output from an individual based model (IBM) with a spatial statistical catch-at-age assessment model. The overall objective is to parse the movement and survival of sablefish in their first year and incorporate the impact of spatially explicit environmental and predation processes on juveniles and adults. The sablefish IBM has been updated to include temperature relationships in the early life stages (Gibson et al., 2023) as part of an exploration of the impact of seamounts on connectivity to the nearshore settlement environment. Information on connectivity from spawning to nursery areas will likely be used in the SILC model configuration. Once the SILC model is developed and published, regional estimates of recruitment could be generated and linked with appropriate indicators to explain spatial shifts in the sablefish population.

In the future, highly ranked predictor variables from the intermediate stage could be further evaluated in this advanced stage by integrating within the stock assessment model to evaluate predictor performance and estimate risk probabilities. The juvenile ADF&G CPUE index continues to have a high inclusion probability in the importance tests and could be used directly in the model as a survey for age-1 plus sablefish (or a range of ages). Alternatively, several of the age-0 and age-1 indicators could be combined with the ADF&G CPUE through a causal model approach using dynamic structural equation modeling (Thorson et al., 2024) and then integrated directly within the operational assessment (Monnahan et al., 2024). Subject matter experts that provide the ESP indicators could help develop and refine the causal model using information gathered from process research. Utilizing indicators as indices directly inside the model would have the desirable property of influencing ABC recommendations in a neutral way by reducing uncertainty in the model, whereas risk tables and other adjustments can only reduce ABC.

Another way that the ESP may be used to forward an advanced research model is to include environmental forcing or ecosystem information in future projections. Previous work (Shotwell et al., 2014) had identified SST as a potential driver of recruitment and demonstrated the potential benefits of including these in short-term projections (1-5 years). A new generic projection model has been developed for NPFMC stocks that has been applied using SST for sablefish (M. Veron, *pers. commun.*). The most recent BAS results identified SST in the SEBS as being highly related to recruitment. This index is currently generated from satellite data but could be replaced in the future by SST from the Bering 10K ROMS-NPZ model (Kearney et al., 2020) that has been validated for the SEBS with bottom trawl survey temperatures. The SST hindcast and forecast from the ROMS-NPZ model could be used as a covariate on the recruitment deviations in an ecosystem model run and compared to the operational projections to evaluate the impact of temperature on the stock 1-5 years into the future. Projections from the ROMS-NPZ model could also be evaluated at various intervals into the future under high and low emission scenarios to gain an understanding of stock fluctuations in a changing climate.

Socioeconomic Monitoring

We present four socioeconomic indicators and three fishery informed indicators that depict a historical time-series of key socioeconomic information for the Alaskan sablefish fishery. Each indicator uses historical data through 2023. A one-year lag is presented to account for post-season adjustments of vessel revenues (and submission deadlines of COAR Buying reports, our primary economic data source) and to capture the end-of-year retained catch information. Select socioeconomic indicators have an associated indicator (Figure 3D.7 through Figure 3D.10) that provides additional detail and context at a more granular level than state- or fishery-wide. Similar to the four socioeconomic and fishery informed indicators, each associated indicator uses a historical time-series to analyze information at a region, gear, or size specific level. Select associated indicators, where stated, use in-season data through October 2024 to provide the most current information available.

Retained catch represents the total weight of sablefish (excluding discards), measured in metric tons, that is caught and processed. For this reason, total catch will always be greater than retained catch (Table 3D.1a). Retained catch increased rapidly in 2022, reaching a new historical high of 25.1 thousand metric tons, before a slight decline in 2023 to 24.4 thousand metric tons (-3%). The significant increase in retained catch in 2022 and 2023 may be a result of year-over-year increases in TAC coupled with high levels of incidental catch in the BSAI and GOA and increases in the estimated biomass. Partially due to the increase in retained catch, the average ex-vessel price per-pound decreased to a new low of $1.53 per-pound. This is a 32% decline from 2022 levels and a 62% decrease from the 2014-2018 average (Table 3D.1a). Additional observations have been made on the increased catch of small sablefish which may be driving down prices further. In Figure 3D.7, we use in-season e-landings (fish tickets) data provided by ADF&G to analyze landings and prices by size categories. Unlike COAR Buying reports, in-season e-landings data does not account for post-season adjustments. Interpretation of this associated indicator should be made with the caveat that prices may be different from finalized COAR prices. We do, however, find the trends to be the same each year between COAR and in-season e-landings data. Additionally, this indicator only considers the IFQ fishery as the catcher-processor fleet does not size sablefish and limited size-specific information is available for the trawl fleet. Trends presented in Figure 3D.7 suggest that the proportion of sablefish in the <2 pound and >7 pound size categories have been declining in recent years and are being replaced by sablefish in the 2 to 3 pound and 3 to 4 pound size categories. We also find that the average price per-pound is declining for all size categories, but a sharper decline is occurring in the 5 to 7 pound and >7 pound size categories relative to all other size categories.

With declines in the average price per pound and retained catch, the 2023 ex-vessel revenue of $81 million has significantly declined (-35%) from 2022 levels. Despite 2023 retained catch being more than two-times greater than the 2014-2018 average, total ex-vessel value is below the mean within the same time period and less than one-standard deviation of the historical range. We provide greater insight into the revenue share by sector, gear type, and region in Figure 3D.8. Sablefish revenue is primarily generated within GOA and catcher vessels (Table 3D.1a). Prior to 2019, hook-and-longline (HAL) was the primary gear type but, in 2020, the use of pot gear overtook HAL. Similarly, within the BSAI, catcher vessels generate the largest share of revenue, although catcher vessels and catcher processors approached parity in 2023, with pot gear being the primary gear type.

Approximately 85% of statewide TAC was utilized each year prior to 2016. In 2019 and 2020, high levels of incidental catch from the pollock and Amendment 80 fleets caused TAC utilization to increase beyond 100% (Figure 3D.2b). Statewide TAC increased year-over-year since 2014, but significant increases occurred in 2021 (42% from 2020) and 2022 (32% from 2021). Since 2021, TAC utilization has continued to fall year-over-year despite higher than average retained catch. In 2023, TAC utilization fell below one-standard deviation of the historical range for the first time. Statewide sablefish TAC, however, is allocated by subregions. To account for subregion-specific TAC and TAC utilization, we present Figure 3D.9. Figure 3D.9 uses in-season landings data from the Catch Accounting System to report the cumulative percentage of TAC utilization by week for each subregion. TAC utilization in 2024 is lower than the historical mean for all subregions and less than 2023 levels for the Aleutian Islands, Western GOA, and Southeast. Although 2024 is not over and additional sablefish landing may continue, historical catch tends to level off in early November, suggesting that the 2024 statewide TAC utilization will remain below the historical average.

Many coastal communities participate in the sablefish fishery. To illustrate the participation by coastal communities (determined by vessel owner registration residence and landings port) in the sablefish fishery, we developed two regional quotient metrics based on total landings and total value (Figure

3D.10). The regional quotient measures the share, or proportion, of total landings and total value that are associated with a specific community. Since 2008, two communities, the Seattle MSA and Sitka, had the highest regional quotient by vessel owner registration residence. Recently, the Seattle MSA regional quotient has been declining while Sitka and Homer have been increasing in the same time period. When we define a community by the landing port, three communities, Sitka, Kodiak, and Seward, have the highest regional quotient ranging between 10% and 25% in any given year. Following these three communities, Petersburg and Juneau have a regional quotient of approximately 5%, on average, with all other communities having a regional quotient less than 2.5%, on average.

Data Gaps and Future Research Priorities

While current indicator assessments offer a valuable set of proxy indicators, there are notable areas for improvement. The list below summarizes the data gaps and future research priorities for this ESP by ecosystem and socioeconomic category. For more details, please refer to previous ESP documents (Shotwell et al., 2019-2023b).

Ecosystem Priorities

- Development of high-resolution remote sensing (e.g., transport estimates, primary production estimates) or regional ocean model indicators (e.g., bottom temperature, dissolved oxygen, stratification, nutrient dynamics, prey fields) to assist with data gaps for several survey-derived indicators or discontinued indicators.
- Refinement to existing indicators that were only partially specialized for sablefish:
    - Spring zooplankton phenology from seasonal sampling and its relationship to sea surface temperature to more directly link prey availability/composition to larval growth potential
    - More specific locations of eddy formation or transport along the major current systems
    - Phytoplankton indicators tuned to the spatial and temporal distribution of sablefish larvae, and phytoplankton community structure information (e.g., hyperspectral information for size fractionation)
    - Species and stage specific composition data for copepod prey (rather than arbitrary "large" or "small" cutoff) with lipid content (or some measure of prey quality)
    - Daily growth estimates for YOY sablefish to help estimate spawn timing, local prey conditions, or overwinter survival
    - Nearshore temperature time series, other forage time series to complement the ADF&G large mesh bottom trawl survey sablefish CPUE indicator
    - Condition or any diet analyses of the small (<=350 mm) sablefish in the AFSC bottom trawl surveys, or the small (<=0.5 kg) incidentally caught sablefish in the fishery
    - Juvenile habitat suitability indicator based on combination of several indicators included in the suite (surface and bottom temperature, prey/predator abundance, upwelling, along- or cross-shelf transport)
    - Maturing (age 4) and adult sablefish diet analysis, energetics analysis and a refined condition index to account for the allometric growth of sablefish
    - Evaluation of the spatial and temporal distribution overlap between competitors/predators and sablefish on the survey and of different fisheries to provide insight on predation or competition pressures and determine the quality of the annual spawning stock.
    - Information from laboratory studies (e.g., time to starvation in first feeding larvae, reproductive potential, egg quality, skip spawning) to help refine indicators or identify thresholds, including lagged effects where possible.
- Development of large-scale indicators from multiple data sources (e.g., zooplankton surveys) to determine a relative trend by region.

- Increased sampling of weights and analysis of diet data on surveys to improve condition indicators. This would help:
    - Identify causal mechanisms for shifting condition of pre-spawning sablefish in both the survey and the fishery and the potential impact on spawning potential
    - Increase understanding of the relationships between condition and spawning by region and identify the link between body condition and productivity
    - Update the Ecopath model (Aydin et al., 2007) that initially estimated predation and consumption rates for sablefish and other groundfish
    - Provide inference about competition and predation if other species were also updated in the Ecopath model
    - Allow for a more detailed synthesis of gut contents to generate time series indicators of stomach fullness or energy content per individual sablefish
    - Allow for considering morphometric or physiological impacts on condition in pre- versus post-spawning individuals and individuals that exhibit skipped spawning to measure energetic costs of spawning.
    - Increase understanding on the impacts of shifting spatial distribution and evaluate whether there are any regional impacts on sablefish condition during spawning
- Updated sablefish IBM (Gibson et al., 2023) could be used to spatially tune physical and lower trophic indicators to more accurately reflect sablefish early life history distributions.
- Refinement of the SILC model to create regional estimates of recruitment to provide insight into a selection of relevant indicators by region for future analyses.
- Summary indicators of tagging data or output from the research spatial model would be helpful for understanding movement dynamics and shifts in the spatial distribution of the stock.

Socioeconomic Priorities

- Re-evaluation of fishery informed indicators to potentially include:
    - Fleet characteristics (e.g., number of active vessels, number of processors)
    - Spatial distribution measures (e.g., center of gravity, area occupied)
- Consideration on how to include local knowledge, traditional knowledge, and subsistence information to understand recent fluctuations in stock health, shifts in stock distributions, or changes in size or condition of species in the fishery per SSC recommendation.
- Re-evaluation of community level indicators to highlight coastal communities that are most reliant on the historical use of sablefish per SSC recommendation.
    - Assessment of the vulnerability of coastal communities most reliant on the historical use of sablefish to changes in stock, market, and climate dynamics and interactions.

As indicators are improved or updated, they may replace those in the current set of ecosystem or socioeconomic indicators to allow for refinement of the indicator analyses and potential evaluation of performance and risk. Incorporating additional importance methods in the intermediate stage indicator analysis may also be useful for evaluating the full suite of indicators and may allow for identifying robust indicators for potential use in the operational stock assessment model. The annual request for information (RFI) for the groundfish and crab ESPs will include these data gaps and research priorities that could be developed for the next ESP assessment (please contact Kalei Shotwell at kalei.shotwell@noaa.gov for more details).

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Tables

Table 3D.1a: Sablefish ex-vessel data from Alaska Fisheries. Total catch (federal and state) (kts, thousand of tons), catch in federal fisheries (thousand metric tons), ex-vessel value (million US$), price (US$ per pound), number of vessel, and the proportion of vessels that are catcher vessels, average and most recent 5 years.

	2014-2018 Average	2019	2020	2021	2022	2023
Total catch (kt)	12.6	17.5	20.0	22.2	28.1	26.2
Retained catch (kt)	11.2	13.0	14.1	18.7	25.1	24.4
Value (M US$)	$98.45	$73.30	$51.42	$82.98	$124.12	$81.09
Price/lb (US$)	$4.11	$2.60	$1.72	$2.09	$2.26	$1.53
% value GOA	95.26%	92.46%	88.64%	88.70%	83.64%	79.34%
Vessels (#)	293	268	264	266	276	266
Proportion CV (%)	87.39%	87.16%	85.72%	84.78%	80.85%	74.02%

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).

Table 3D.1b: Sablefish first-wholesale data from Alaska Fisheries. Production (thousand metric tons), value (million US$), price (US$ per pound), and head and gut share of production, average and most recent 5 years.

	2014-2018 Average	2019	2020	2021	2022	2023
Quantity (K mt)	6.48	7.94	7.93	11.26	16.00	15.37
Value (M US$)	$103.18	$86.18	$69.54	$110.66	$167.54	$112.42
Price/lb (US$)	$7.22	$4.93	$3.98	$4.46	$4.75	$3.32
H&G share (%)	97.36%	93.70%	94.45%	93.23%	93.94%	93.69%

Source: NMFS Alaska Region At-sea and Shoreside Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table 3D.1c: Sablefish global catch (thousand metric tons), U.S. and AK shares of global catch; WA & AK export volume (thousand metric tons), value (million US$), price (US$ per pound) and the share of export value from trade with Japan and China, average and most recent 5 years.

	2014-2018 Average	2019	2020	2021	2022	2023
U.S. Share of Global Catch (%)	88%	86%	88%	87%	90%	-
AK share of global (%)	60%	60%	66%	68%	71%	-
Export quantity (K mt)	6.24	6.21	6.69	8.11	12.32	11.20
Export value (M US$)	$83.17	$68.01	$68.23	$86.36	$131.34	$101.41
Export price/lb (US$)	$6.05	$4.97	$4.63	$4.83	$4.84	$4.11
Japan value export (%)	64.95%	64.68%	72.43%	72.99%	63.43%	67.50%
China value share (%)	17.30%	18.00%	18.39%	18.05%	19.36%	13.33%
Exchange rate, (Yen/Dollar)	111.67	109.01	106.77	109.76	131.50	140.49

Note: Exports include production from outside Alaska fisheries
Source: FAO Fisheries & Aquaculture Dept. Statistics http://www.fao.org/fishery/statistics/en (Canadian catch for 2018 from personal communication with DFO). 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 3D.2: First stage ecosystem indicator analysis for sablefish, including indicator title and the indicator status of the last five years. The indicator status is designated with text, (greater than = "high", less than = "low", or within 1 standard deviation = "neutral" of the long-term mean). Fill color of the cell is based on the proposed sign of the overall relationship between the indicator and the stock (blue or italicized text = good conditions for the stock, red or bold text = poor conditions, white = average conditions). A gray fill and text = "NA" will appear if there were no data for that year.

Indicator category	Indicator	2020 Status	2021 Status	2022 Status	2023 Status	2024 Status
Larval to YOY	Annual Heatwave GOA Model	neutral	neutral	neutral	neutral	neutral
	Spring Temperature Surface GOA Satellite	*high*	neutral	neutral	neutral	neutral
	* Spring Temperature Surface SEBS Satellite	*high*	neutral	neutral	neutral	neutral
	Annual Eddy Kinetic Energy Amchitka Satellite	neutral	neutral	*high*	*high*	neutral
	Annual Copepod Community Size EGOA Survey	neutral	neutral	neutral	neutral	NA
	Annual Copepod Community Size WGOA Survey	neutral	neutral	*low*	neutral	NA
	Annual Sablefish Size YOY Middleton Survey	neutral	**low**	neutral	**low**	neutral
Juvenile	* Summer Sablefish CPUE Juvenile Nearshore GOAAI Survey	*high*	*high*	*high*	neutral	neutral
	Summer Sablefish CPUE Juvenile GOA Survey	NA	neutral	NA	neutral	NA
	Annual Small Sablefish Incidental Hauls EBS Fishery	*high*	neutral	neutral	*high*	neutral
Adult	Summer Temperature 250m GOA Survey	neutral	neutral	**high**	neutral	NA
	Summer Sablefish Condition Female Age4 GOA Survey	neutral	*high*	**low**	*high*	NA
	Summer Sablefish Condition Female Adult GOA Survey	neutral	neutral	**low**	*high*	NA
	Annual Sablefish Incidental Catch Arrowtooth Target GOA Fishery	neutral	neutral	neutral	neutral	neutral

* Indicator has inclusion probability > 0.5 in the intermediate stage importance test.

Figures

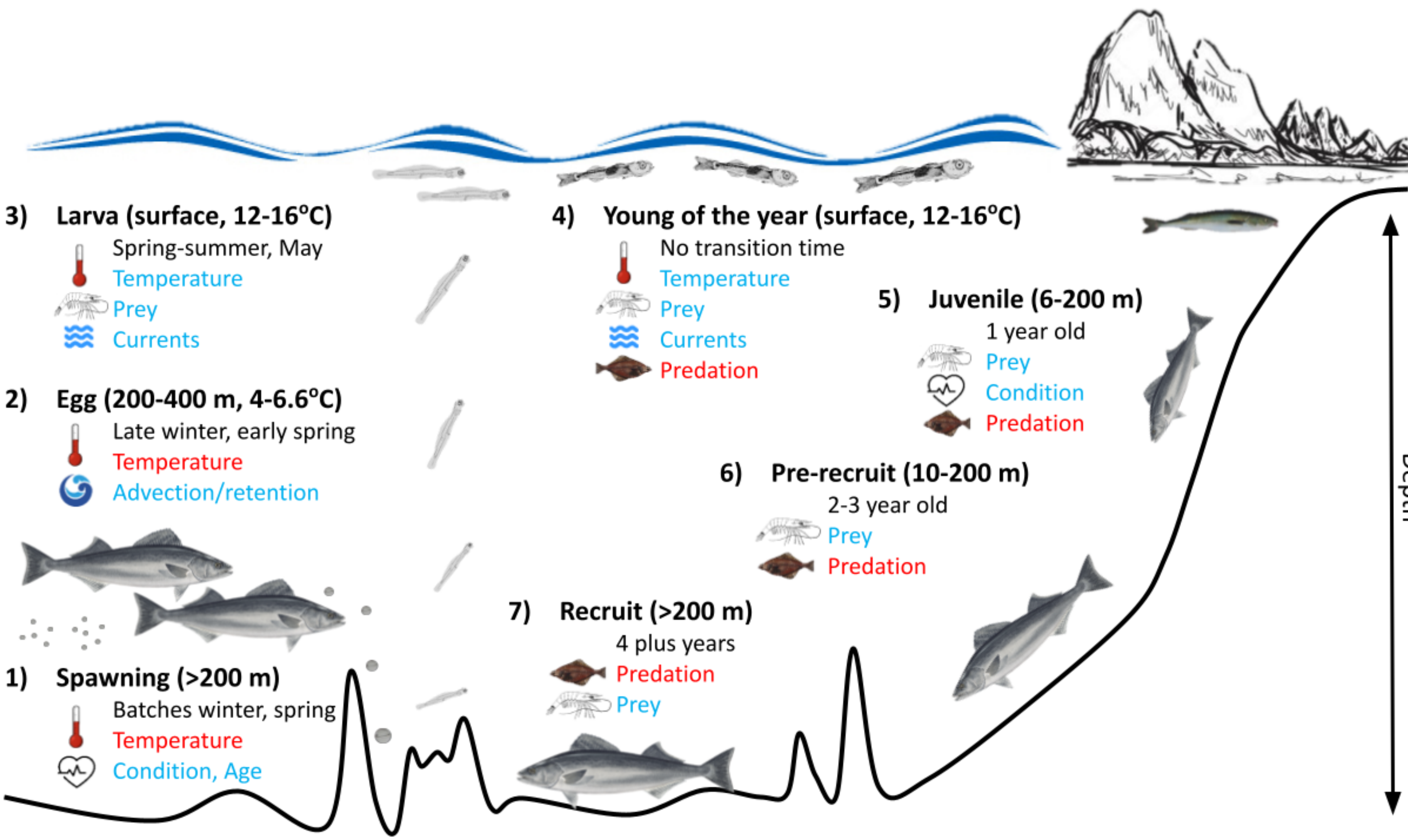

Figure 3D.1: Life history conceptual model for sablefish summarizing ecological information and key ecosystem processes affecting survival by life history stage. Red text indicates that increases in the process negatively affect survival of the stock, while blue text means that increases in the process positively affect survival.

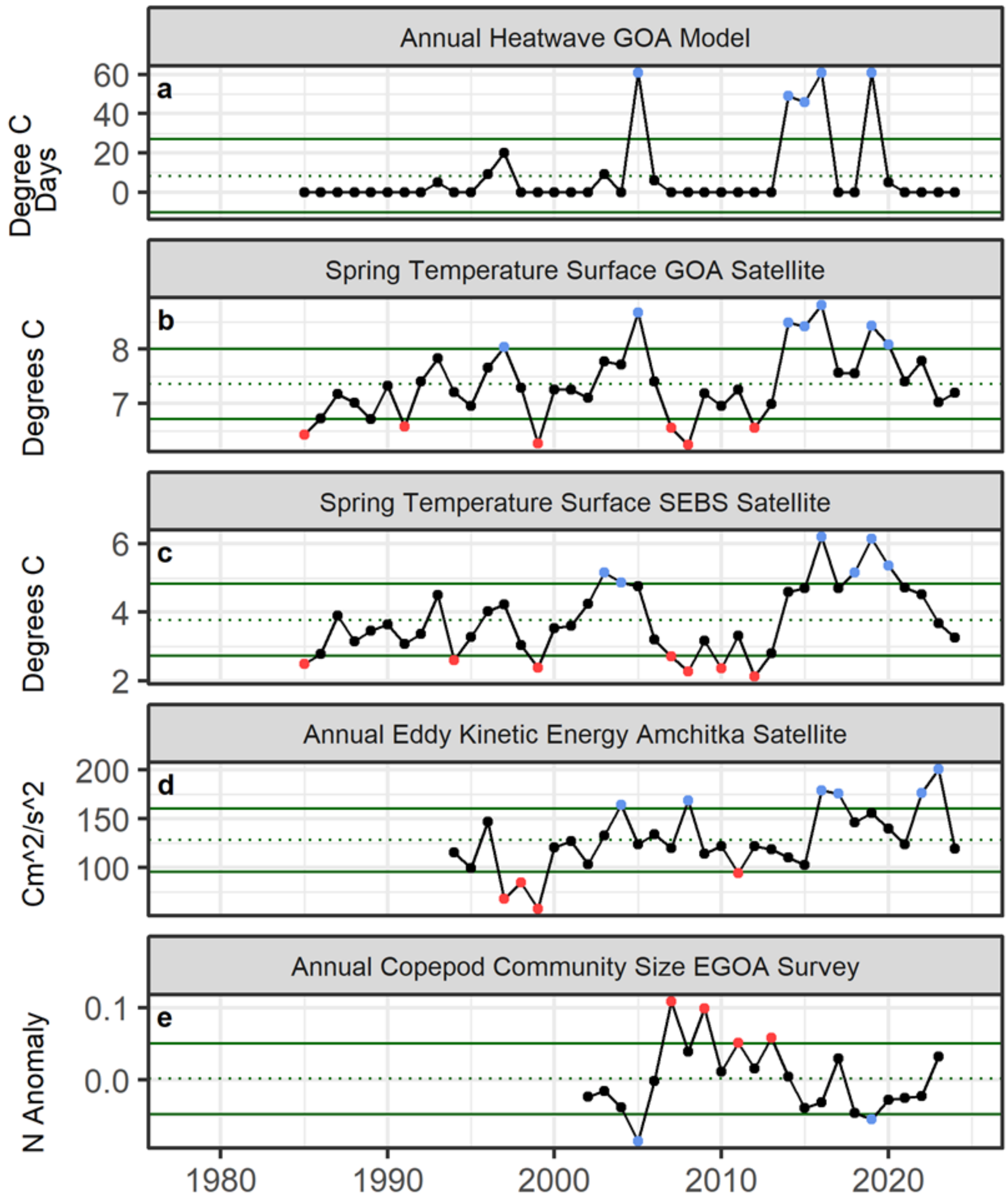

Figure 3D.2a: Selected ecosystem indicators for sablefish with time series ranging from 1977 – present. Upper and lower solid green horizontal lines represent 1 standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series. Dots in the time series are colored if above or below 1 standard deviation of the time series mean and the color represents the proposed relationship for stock (blue for good conditions, red for poor conditions), black circle for neutral.

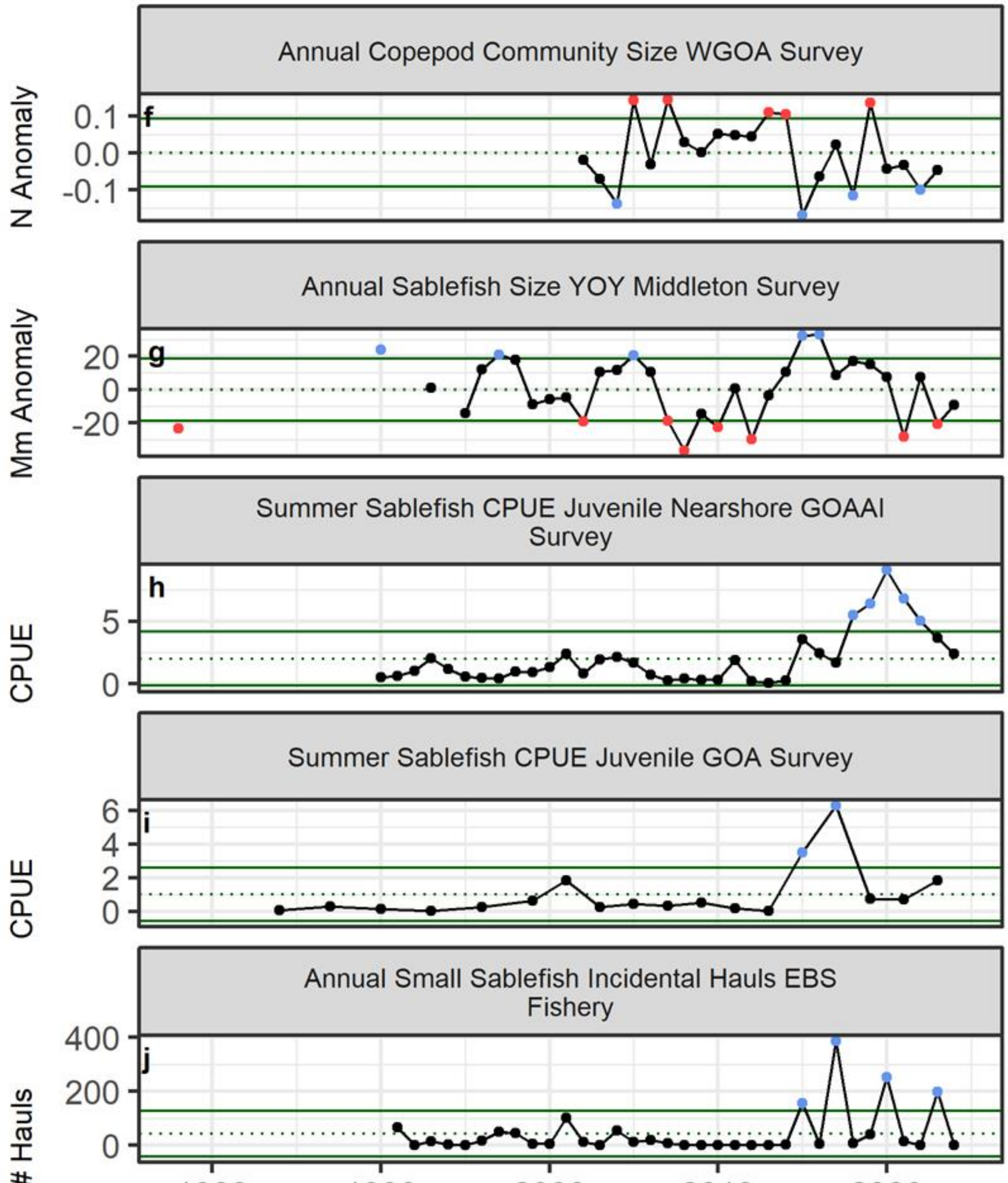

Figure 3D.2a (cont.): Selected ecosystem indicators for sablefish with time series ranging from 1977 – present. Upper and lower solid green horizontal lines represent 1 standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series. Dots in the time series are colored if above or below 1 standard deviation of the time series mean and the color represents the proposed relationship for stock (blue for good conditions, red for poor conditions), black circle for neutral.

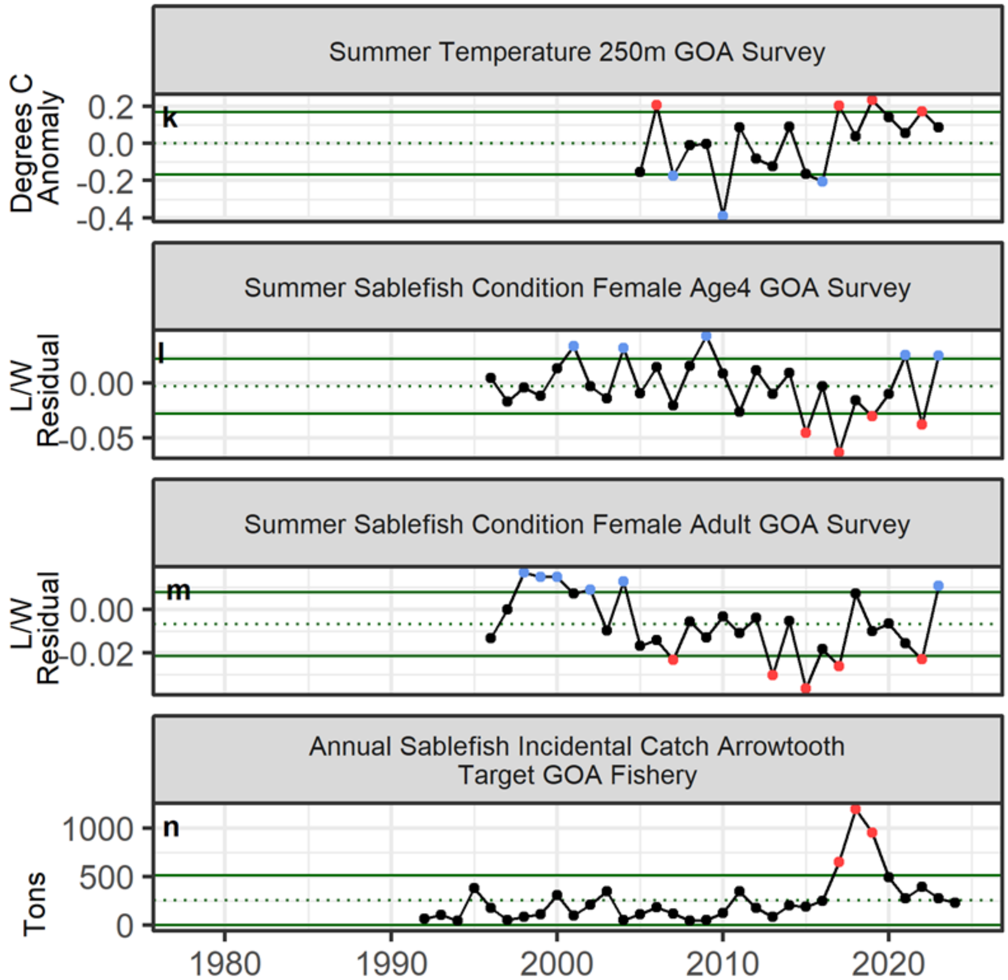

Figure 3D.2a (cont.): Selected ecosystem indicators for sablefish with time series ranging from 1977 – present. Upper and lower solid green horizontal lines represent 1 standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series. Dots in the time series are colored if above or below 1 standard deviation of the time series mean and the color represents the proposed relationship for stock (blue for good conditions, red for poor conditions), black circle for neutral.

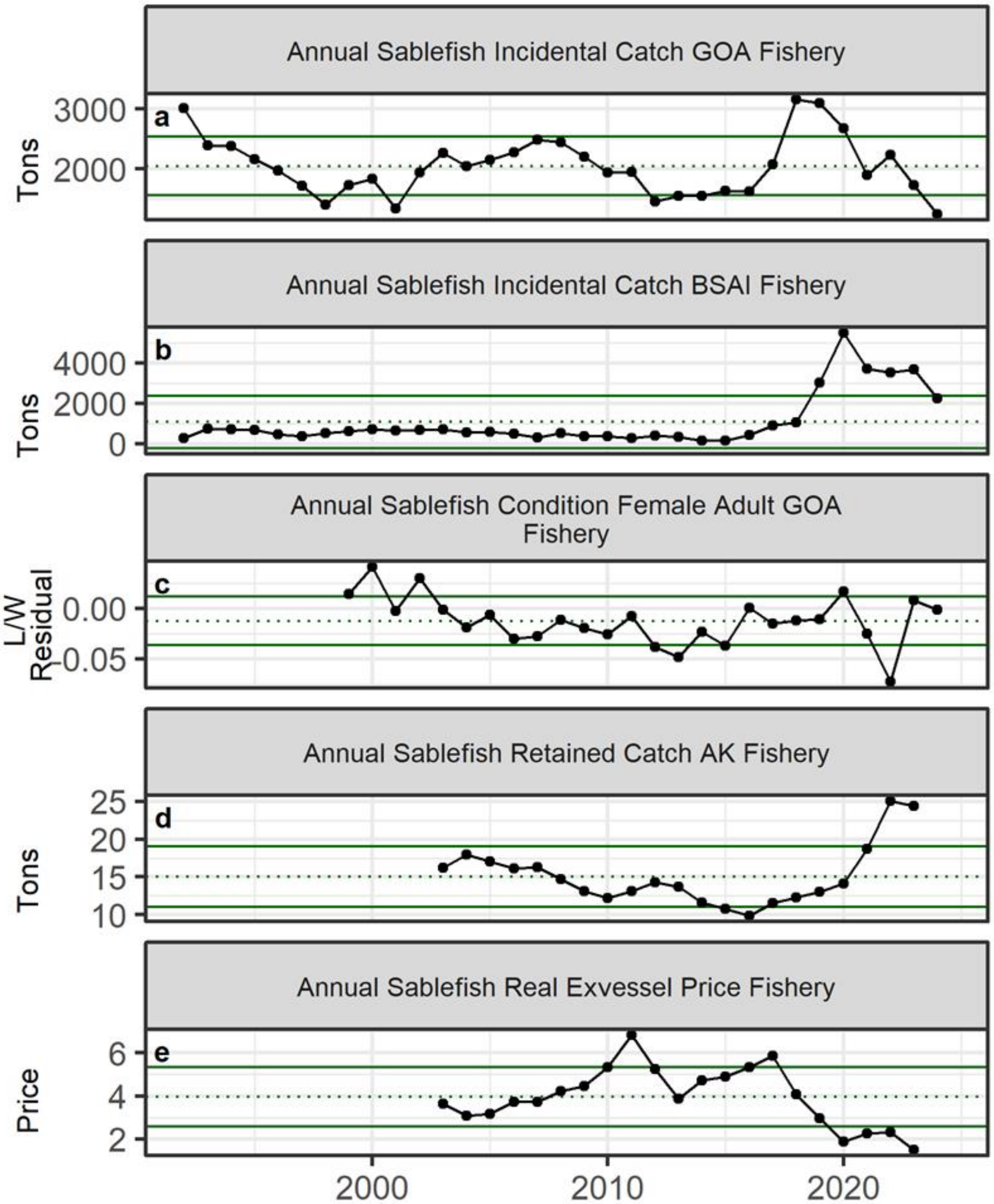

Figure 3D.2b: Selected socioeconomic indicators for sablefish with time series ranging from 1977 – present. Upper and lower solid green horizontal lines represent 1 standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series.

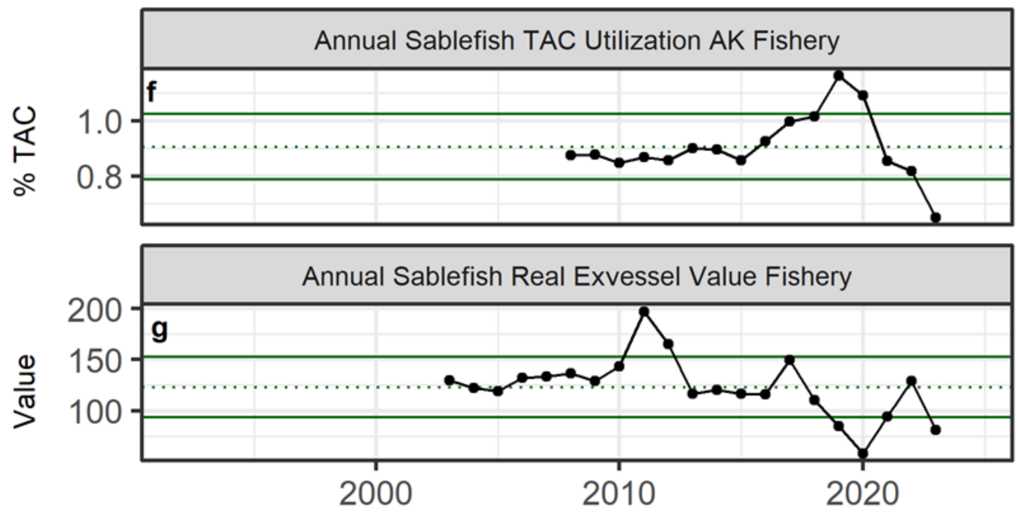

Figure 3D.2b (cont.): Selected socioeconomic indicators for sablefish with time series ranging from 1977 – present. Upper and lower solid green horizontal lines represent 1 standard deviation of the time series mean. Dotted green horizontal line is the mean of the time series.

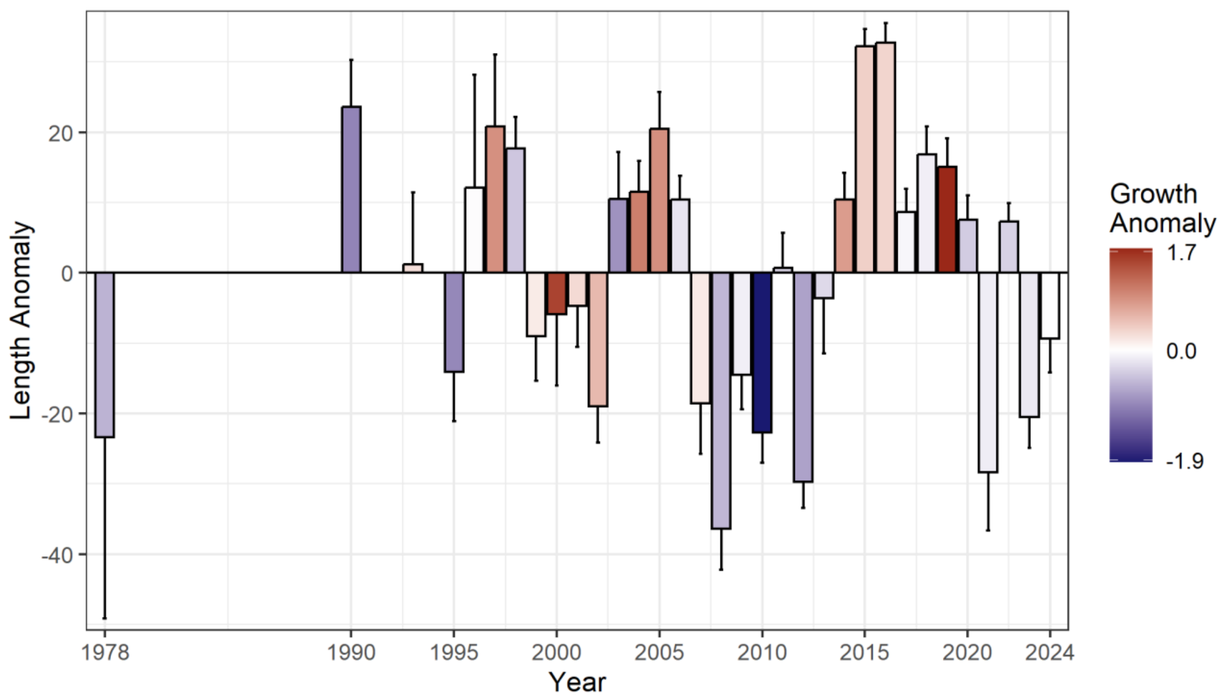

Figure 3D.3: Growth anomaly calculated from the relationship between mean fish length and Julian date and length anomaly predicted from the growth relationship on the median sampling date (July 24) for each year from Rhinoceros auklet bill loads at Middleton Island in the Gulf of Alaska.

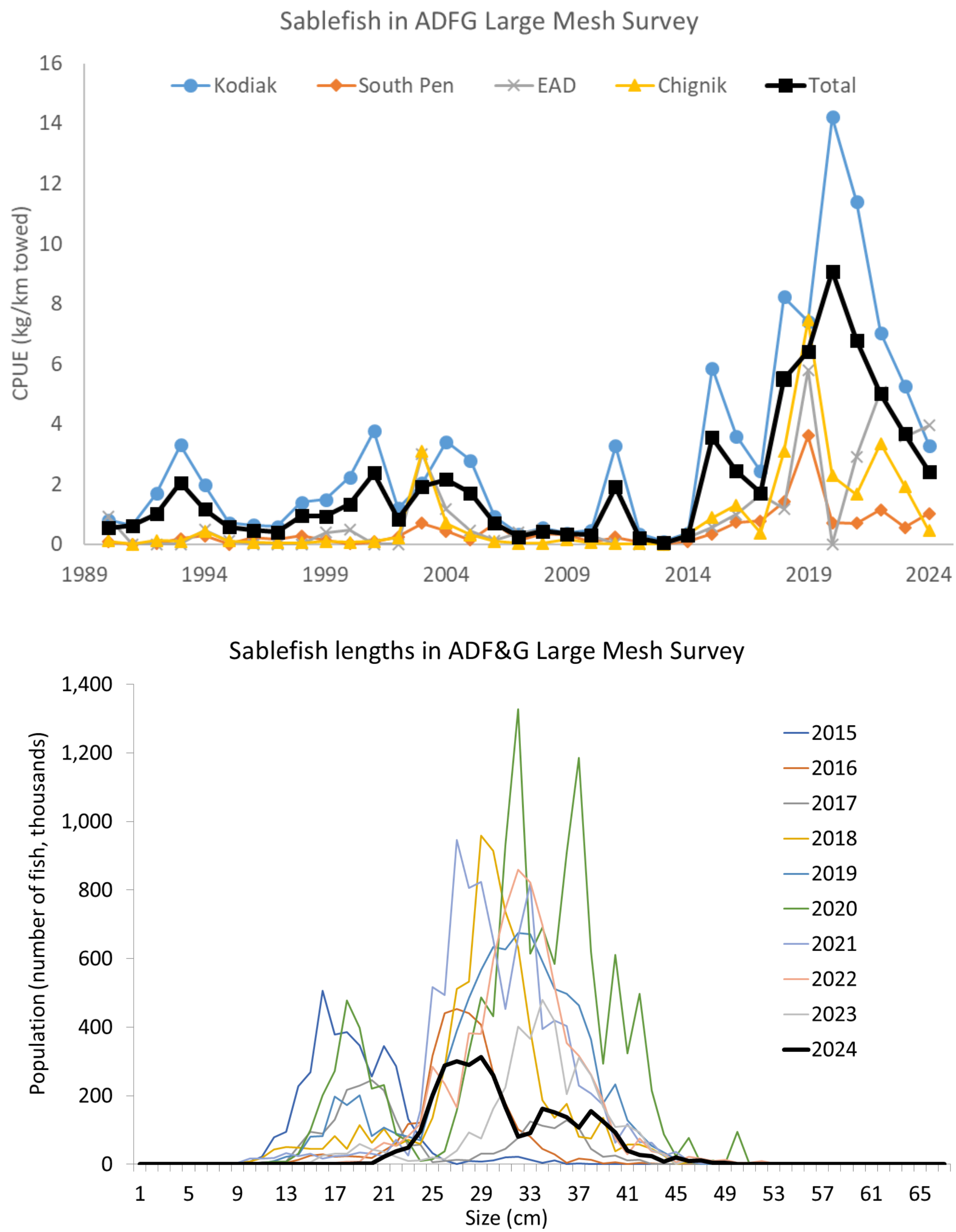

Figure 3D.4: Catch-per-unit-effort from 1990 to present (top graph) and length (cm) composition (bottom graph) from 2011 to present of sablefish in the nearshore ADF&G large-mesh survey (EAD = Eastern Aleutians District).

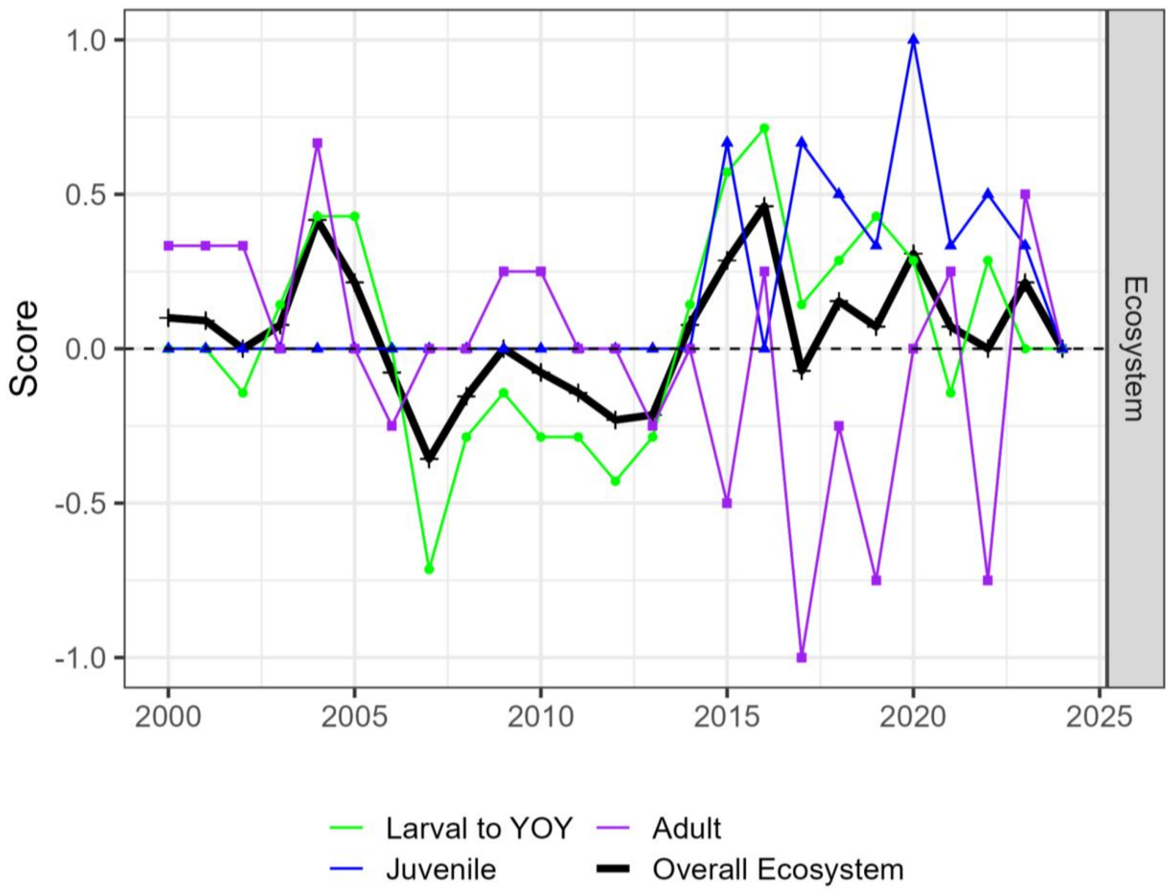

Figure 3D.5: Simple summary traffic light score by overall ecosystem and category (larval to young-of-the-year (YOY), juvenile, and adult) for ecosystem indicators from 2000 to present.

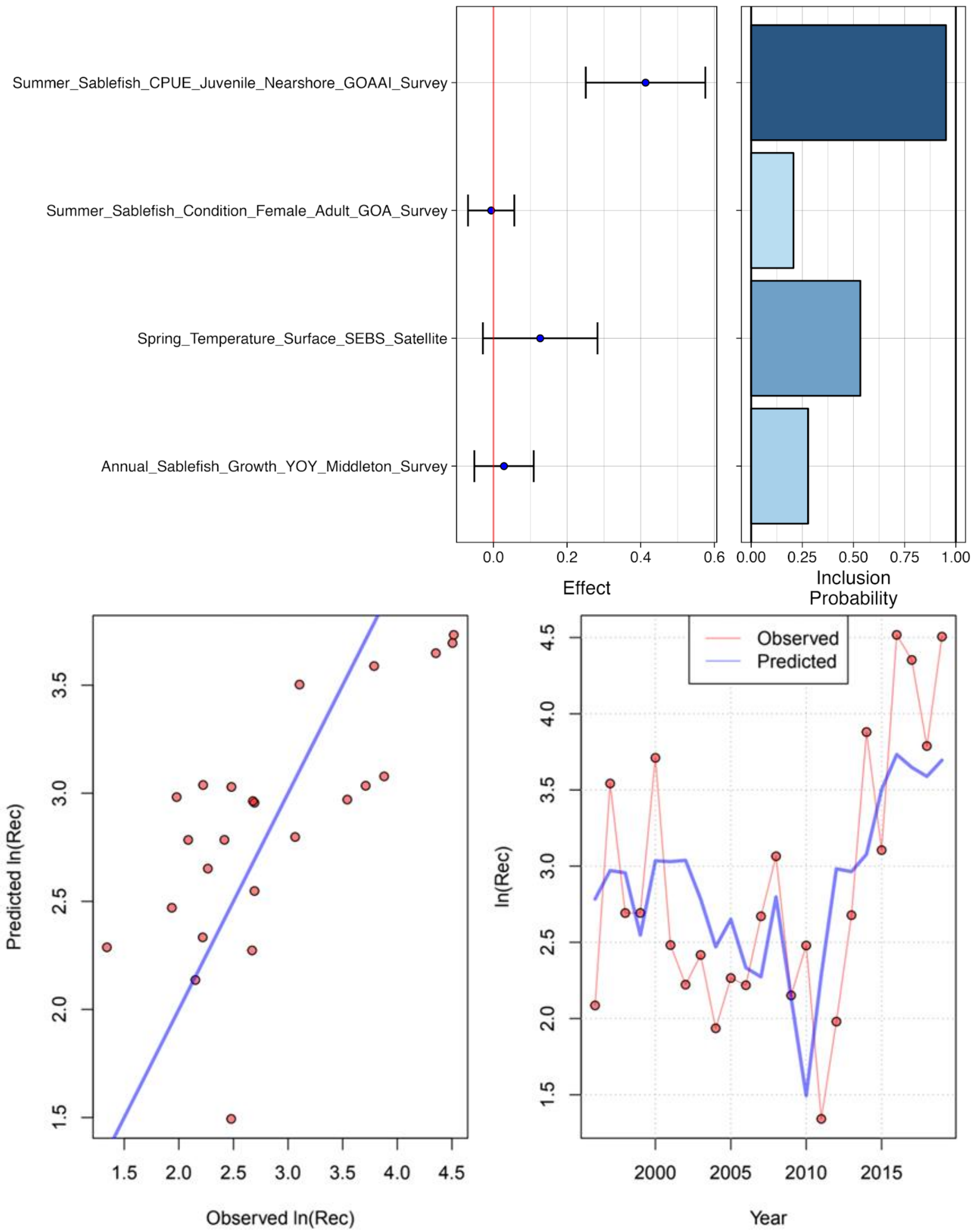

Figure 3D.6: Bayesian adaptive sampling output showing the mean relationship and uncertainty (± 1 SD) with log-transformed estimated sablefish recruitment from the operational stock assessment model: the estimated effect (top left) and the marginal inclusion probabilities (top right) for each predictor variable of the subsetted covariate ecosystem indicator dataset. Output also includes model predicted fit (1:1 line, bottom left) and average fit across the abbreviated recruitment time series (1996-2019, bottom right).

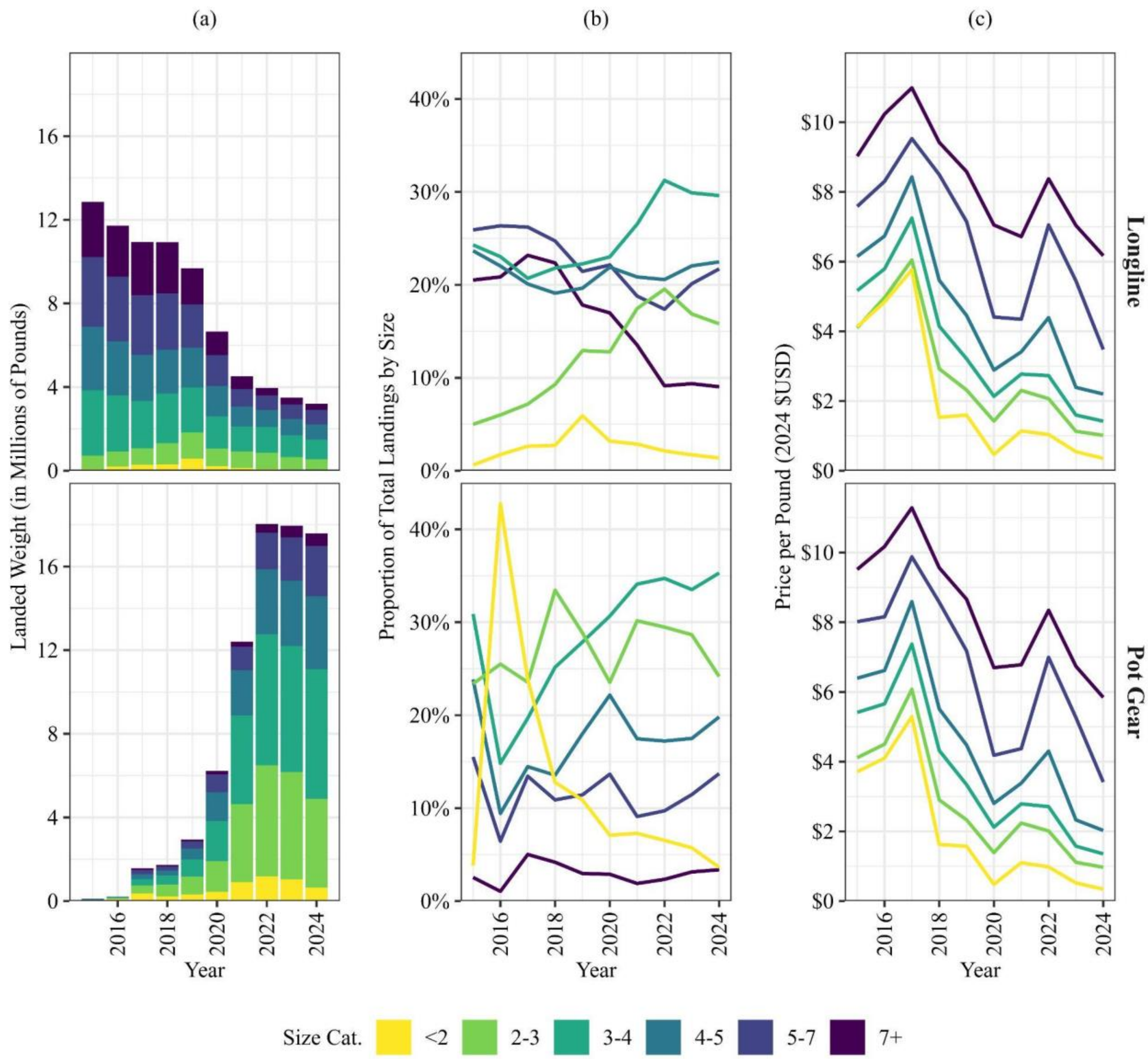

Figure 3D.7: (a) Total sablefish landings by gear type and size class; (b) Percent of total sablefish landings by gear type differentiated by size class and; (c) Average price per-pound differentiated by size class. Note: The information above considers data between January through October for sablefish sold for human consumption from catcher-vessels (no size reporting submitted by catcher-processors) in the fixed gear fishery (limited size information from the trawl fishery) that contain size information. All prices are adjusted to 2024 dollars using the BLS CPI to account for inflation.

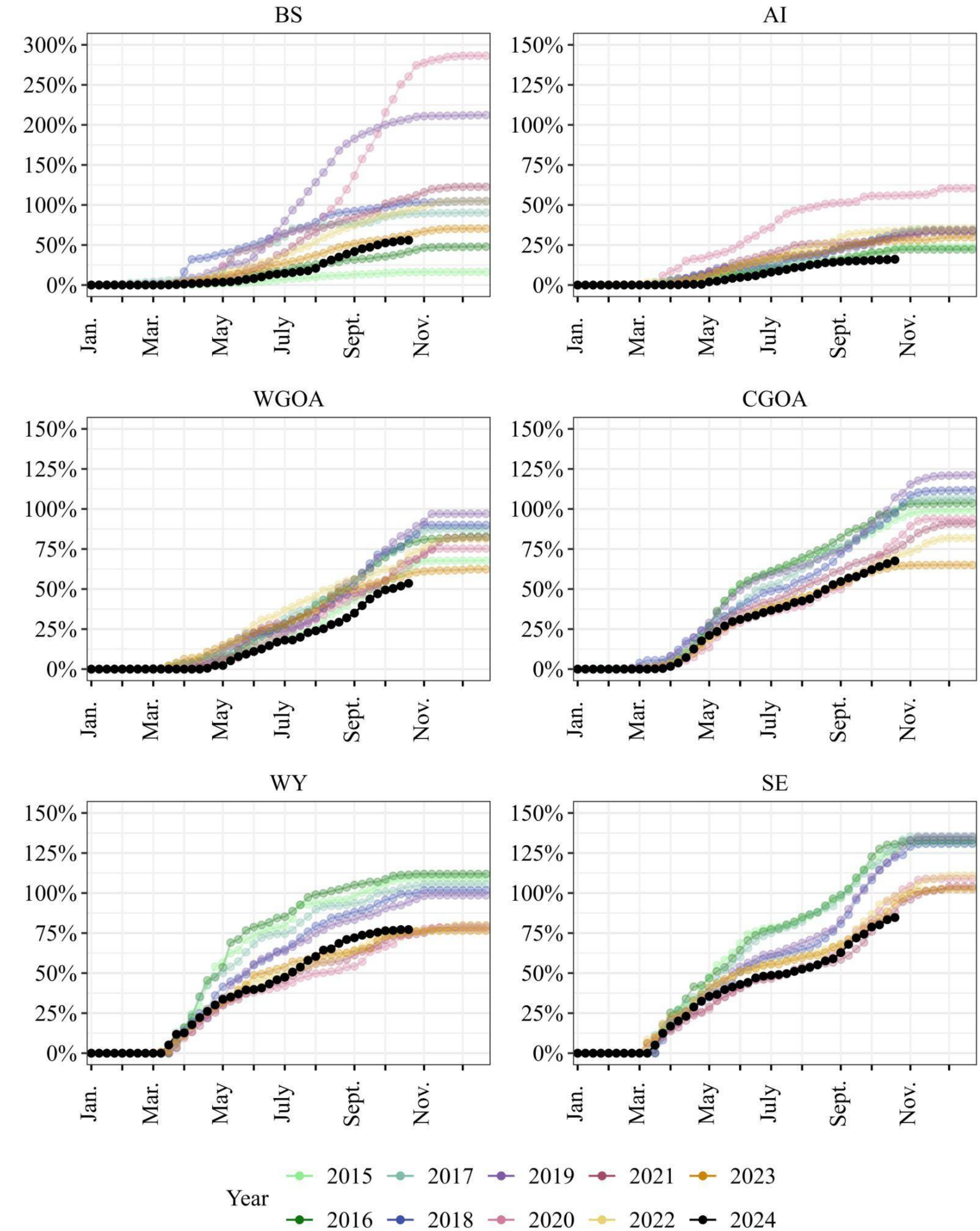

Figure 3D.8: Cumulative Utilization of TAC by year differentiated by subarea. Note: BS (Bering Sea); AI (Aleutian Islands); WGOA (Western GOA); CGOA (Central GOA); WY (West Yakutat); SE (Southeast). Data on landings used within the TAC utilization calculation includes catch and discards. Also, the y-axis is the same for each subarea, making comparisons easier, except for the Bering Sea.

Figure 3D.9: Revenue share by sector and gear type differentiated by region. Note: The sum of each line by year within each subplot equals 1 (or 100%) representing the full sablefish revenue in each area. Pot gear includes slinky pots. In GOA, the revenue share for POT gear is not shown before 2017 due to confidentiality.

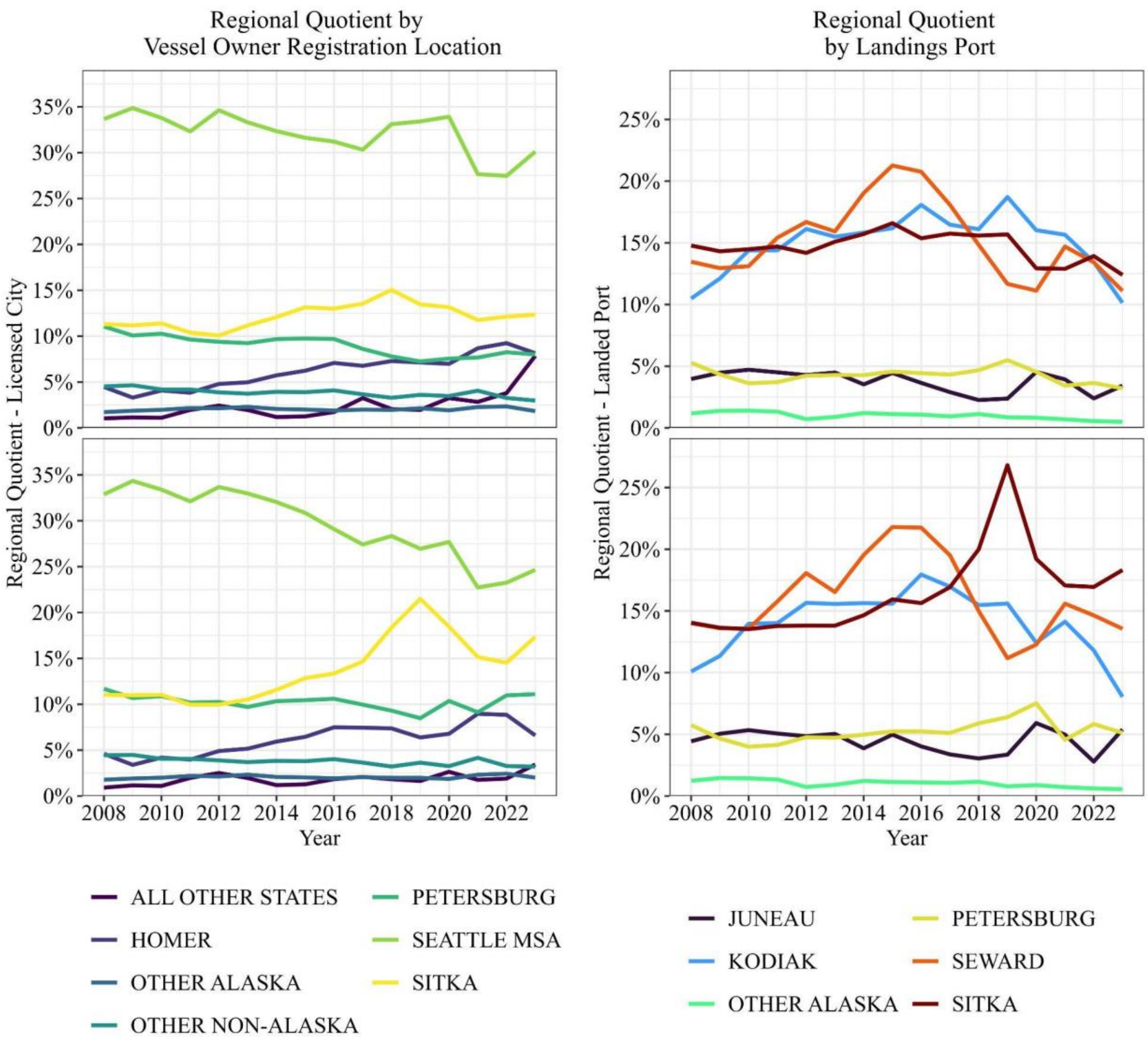

Figure 3D.10: Regional quotient by vessel owner residence and by port of landings. Note: The vessel owner residence column (1) shows locations that have an average regional quotient greater than 5% between 2008 and 2023 and the landings port column (2) shows the locations with an average regional quotient greater than 2.5% between 2008 and 2023.