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Reanalysis to standardize winter Shelikof Strait and summer Gulf of Alaska acoustic-trawl survey time series for walleye pollock (*Gadus chalcogrammus*)

D. W. McGowan, K. Williams, D. Jones, N. Lauffenburger, and M. Levine

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Executive Summary

Scientists from the Midwater Assessment and Conservation Engineering (MACE) Program of the Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering (RACE) Division conduct acoustic-trawl (AT) stock assessment surveys to estimate the abundance and distribution of walleye pollock (*Gadus chalcogrammus*; hereafter pollock) in the Gulf of Alaska (GOA). Annual surveys of pre-spawning pollock aggregations in the GOA have been conducted since 1981 during late winter at their main spawning grounds within Shelikof Strait. Biennial surveys conducted in summer since 2013 have covered the GOA continental shelf. Winter surveys conducted from 1992-2025 and summer surveys from 2013-2023 are currently included as inputs in the GOA pollock stock assessment. Throughout the history of both surveys, changes and upgrades in equipment and analysis approaches have occurred to better account for sampling biases and improve the accuracy and precision of survey estimates. Most of these improvements have yet to be incorporated into historical survey data products currently used in the GOA pollock stock assessment. To standardize the survey time series used in the GOA pollock stock assessment, observations from winter Shelikof Strait (2008-2025) and summer GOA (2013-2023) AT surveys were reanalyzed following the analytic approach currently used by the MACE program: correcting trawl catches using net selectivity functions, proportionally allocating backscatter to all organisms in the trawl catches from the geographically nearest haul, using species-specific target strength-to-length relationships for forage species, and weighting specimen data by local pollock abundance. The reanalyzed time series provides improved abundance and biomass estimates for GOA pollock in winter and summer, as well as improved estimates for Pacific ocean perch (*Sebastes alutus*), and Pacific capelin (*Mallotus catervarius*) in summer.

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Introduction

Scientists from the Midwater Assessment and Conservation Engineering (MACE) Program of the Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering (RACE) Division conduct acoustic-trawl (AT) stock assessment surveys to estimate the abundance and distribution of walleye pollock (*Gadus chalcogrammus*; hereafter pollock) in the Gulf of Alaska (GOA). Annual surveys of pre-spawning pollock aggregations in the GOA have been conducted during late winter at their main spawning grounds within Shelikof Strait (Fig. 1) since 1980 (note that no estimates were made in 1980 or 1987, and no surveys were conducted in 1982, 1999, and 2011; Levine and Jones 2025). AT surveys were conducted in Chiniak and Barnabas Troughs east of Kodiak Island during the summers of 2000-2006 to explore species spatial distribution relative to environmental conditions (Hollowed et al. 2007, Logerwell et al. 2007, 2010) and the effect of commercial fishing on pollock abundance (Wilson et al. 2003, Walline et al. 2012). Expanded summer AT surveys to estimate pollock distribution and abundance across the GOA were carried out by MACE in 2003, 2005, and biennially between 2011-2023. Surveys were abbreviated due to budget restrictions in 2003, and ship mechanical issues in 2005 and 2011 (Guttormsen and Yasenak 2007, Jones et al. 2015). Biennial surveys conducted from 2013-2023 (Jones et al. 2014, 2017, 2019, 2022, Levine et al. 2024, McGowan et al. 2025) have covered the continental shelf from the Islands of Four Mountains to Yakutat Trough as well as the Shelikof Strait, Shumagin Islands, Barnabas Trough, and Chiniak Trough regions (Fig. 1). In many summer surveys, additional bays and troughs along the GOA coastline have also been surveyed.

Estimates of the abundance and distribution of pollock by length and age are made in the winter Shelikof Strait AT survey (hereafter winter survey) and summer GOA AT survey (hereafter summer survey), and length-based estimates for Pacific ocean perch (POP; *Sebastes alutus*), Pacific capelin (*Mallotus catervarius*; hereafter capelin), and Pacific herring (*Clupea pallasii*, hereafter herring) are also made in the summer survey when they are abundant. Winter surveys conducted from 1992-2025 and summer surveys from 2013-2023 are currently included as inputs in the GOA pollock stock assessment (Monnahan et al. 2024).

Throughout the history of both surveys, changes in equipment and analysis approaches have occurred to better account for sampling biases and improve the accuracy and precision of survey estimates (Fig. 2).

Ships

Surveys were conducted on the NOAA Ship *Miller Freeman* through 2007, after which the noise-reduced NOAA Ship *Oscar Dyson* was used in all years, except winter 2019 when the noise-reduced NOAA Ship *Bell M. Shimada* was used (Fig. 2). The *Oscar Dyson* and *Shimada* are members of the same class of noise-reduced fisheries survey vessels, which are designed to minimize vessel-induced fish reactions associated with underwater radiated noise produced by the ship (De Robertis et al. 2010b). Results from surveys on prior to 2008 on the *Miller Freeman* have been scaled to be comparable to results from the *Oscar Dyson* surveys in the GOA pollock stock assessment (Monnahan et al. 2024), based on experimental measurements of vessel effects on survey results.

Trawls

The primary midwater trawl net used to sample acoustic targets has also changed throughout the survey period used in the GOA pollock stock assessment. A modified Northern Gold rope trawl (Nor'eastern Trawl Systems, Inc.) was used from 1992-1995 (a Diamond 1000 midwater trawl was also used for five hauls in 1993), and an Aleutian wing trawl (AWT; Nor'eastern Trawl Systems, Inc.) was used from 1996-winter 2019 (Fig. 2). These trawls were fitted with a 3.2 cm (1.25 in.) mesh codend liner prior to 2009, but to improve retention of juvenile pollock, the AWT was fitted with a finer 1.2 cm (0.5 in.) codend liner from 2009-2019. A Lummi Fisheries Supply LFS1421 (hereafter LFS) trawl has been used since summer 2019. This trawl was designed to further improve retention of juvenile pollock and other small fish (e.g., smelts, herring) and invertebrates (e.g., euphausiids, shrimp, squid) by reducing the mesh size in the section leading to the codend and adding a 0.3 cm (0.125 in.) codend liner (Williams and Kotwicki 2024). A gear comparison study between the AWT and LFS indicated the LFS trawl is more effective at retaining non-pollock organisms, while modest improvements in retention of age-0 and age-1 pollock were achieved by the LFS trawl (Williams and Kotwicki 2024).

Selectivity correction

To correct for species- and size-related differences in retention, a major source of uncertainty in trawl catch data, escapement of smaller fishes from the AWT and LFS trawls was estimated using recapture (or 'pocket') nets placed at several locations on the outside of the net to develop correction functions for each type of midwater net and season (Williams et al. 2011, Honkalehto et al. 2024). There were no recapture net data from the Northern Gold trawl or AWT trawl with a 3.2 cm codend liner. Recapture nets had a mesh size that matched the codend liner for the trawl to which it was attached. Net selectivity corrections to trawl species and size composition estimates have been incrementally implemented in winter surveys conducted since 2008 based on the survey vessel, how backscatter was allocated to species, and the type of midwater net used in the survey (Fig. 2).

Net selectivity corrections in the 2008-2019 winter surveys were estimated with recapture net data from the AWT with 1.2 cm liner. For the 2008-2017 surveys, a mean selectivity correction was applied using AWT recapture net data collected in 2008, 2013, and 2018, while corrections to the 2018-2019 surveys were applied based on AWT recapture net data from each year's survey only (Stienessen et al. 2019, Lauffenburger et al. 2019). Estimates for the 2008-2018 surveys only incorporated selectivity corrections for juvenile pollock escapement, but not for other species. The 2019 survey estimates reflect corrections for both juvenile pollock and eulachon escapement (see Appendix IV in Lauffenburger et al. 2019). Corrections for surveys 2020-present were estimated from LFS recapture net data. The 2020 survey was the first winter survey in which selectivity corrections were applied to all species (see Appendix IV in McCarthy et al. 2022). In winter 2021, additional recapture net data were collected for age-1 pollock due to their low abundance in 2020, and a revised selectivity curve for pollock was estimated (see Appendix IV in Honkalehto et al. 2024). Since 2021, selectivity corrections have been based on applying the 2020 selectivity curves for all species other than pollock, and the updated 2021 pollock selectivity curve for pollock.

Net selectivity corrections were first incorporated in summer survey estimates in 2019 using LFS recapture net data (Jones et al. 2022), and have been used in subsequent years for that survey's selectivity corrections.

Allocation of backscatter to trawl catches

Acoustic backscatter is assigned to strata based on the appearance and vertical distribution of the aggregations in the echogram. Prior to 2018, backscatter strata likely to contain pollock were associated with trawl(s) by analysts, based on geographic proximity as well as expert opinion as to the similarity of length compositions and backscatter characteristics (Fig. 2). Backscatter likely to contain pollock was allocated entirely to pollock caught in these trawls (the dominant species acoustically) in most cases. Since 2018, backscatter in a stratum has been associated with trawl catches from the nearest geographic haul that sampled that stratum and is proportionally allocated among all organisms in the trawl catch based on target strength (expected backscatter from each organism) and the selectivity-corrected species and size composition (Fig. 2, De Robertis et al. 2017b, Jones et al. 2022).

Re-scrutinizing of summer survey data

The summer surveys encounter relatively more acoustically-important fish species than the winter surveys. Backscatter stratum assignments from these surveys were reviewed and modified ('re-scrutinized') to include more mixed species aggregations excluded from the original survey analyses. These mixed aggregations can be handled in a more rigorous manner by proportional allocation of backscatter to all species in the trawl catch rather than only to the dominant species, thereby contributing more comprehensive estimates.

Specimen weighting

Prior to 2026, unweighted pollock specimens were used to compute weight-at-length, age-at-length, etc., though in surveys since 2019 (winter) and 2021 (summer) specimens used to compute maturity state have routinely been weighted by local pollock abundance estimated by the survey (Lauffenburger et al. 2019, Levine et al. 2024). Now, all pollock specimen data are weighted for local abundance (Appendix I) so that they more correctly represent the surveyed population. Weighting factors are computed for each specimen in the trawl catch based on catch sub-sampling, trawl selectivity, and total pollock abundance in the area assigned to that haul (nearest-haul stratum).

Reanalysis to standardize time series

In summary, to standardize the survey time series used in the GOA pollock stock assessment, winter Shelikof Strait (2008-2025) and summer (2013-2023) GOA pollock AT surveys were reanalyzed following the methods currently used by the MACE Program as described above: correcting trawl catches for net escapement using updated trawl selectivity functions; proportionally allocating backscatter to all organisms in the trawl catch from the geographically nearest haul; using species-specific target strength-to-length relationships for forage species; and using weighting factors for specimen data in both pollock abundance and maturity estimation. This report describes that process. The reanalyzed survey data is expected to provide improved abundance and biomass estimates for GOA pollock in winter and summer, along with improved estimates for POP, capelin, and herring in summer, using consistent methods.

Methods

The reanalysis of GOA AT survey data was limited to years in which the NOAA Ships *Oscar Dyson* and *Bell M. Shimada* were used for winter Shelikof Strait AT surveys (Fig. 2, 2008-2025) and when the full summer GOA AT survey domain was sampled biennially (2013-2023). Reanalysis of winter surveys from pre-2008 was considered but determined to be unfeasible due to a lack of recapture net data for the Northern Gold trawl or AWT fitted with a 3.2 cm codend mesh liner from the NOAA Ship *Miller Freeman* needed to estimate trawl net selectivity correction functions. For each survey estimate, this entailed at least one of the following steps (Tables 1, 2):

1) updating sets of species- and size-dependent selectivity correction functions for each midwater net type (AWT, LFS) and season (winter, summer) using all available recapture net data;
2) attributing backscatter to all organisms for which length data were collected in the selectivity-corrected trawl catch from the geographically nearest haul;
3) using species-specific target strength-to-length relationships for forage species (including capelin, herring, and eulachon *Thaleichthys pacificus*) in all years to convert backscatter to abundance; and
4) using pollock specimen data weighted for local abundance in all analyses (Appendix I), including weight-at-length, age-at-length, length at 50% maturity, age at 50% maturity, proportion-mature-at-age, and proportion of female pollock with spawning or spent maturity status.

Pollock abundance was estimated by combining acoustic and trawl catch information. The current analysis method had three principal steps. First, a correction was made for net selectivity of each midwater trawl (i.e., escapement from the midwater net, based on relationships derived from recapture nets; Williams et al. 2011; De Robertis et al. 2017, 2021). Next, backscatter was associated with the trawl catches from the nearest geographic haul locations within a stratum. Third, backscatter was converted to estimates of abundance-at-length using the selectivity-corrected catch (step 1) from the nearest haul (step 2) and the target strength of each organism given its species and size. Biomass was computed from abundance using the mean weight-at-length estimated from weighted pollock specimens measured in the winter and summer survey, and biomass was similarly estimated for POP, capelin, and herring using species-specific mean weight-at-length keys in the summer surveys. Abundance-at-age and biomass-at-age for pollock were estimated by converting abundance and biomass-at-length using age-length conversion keys that were based on weighted specimen data.

Net selectivity correction

To account for the size and species dependent loss of organisms though the meshes of the midwater trawl forward of the codend, or 'mesh selection,' length compositions were adjusted to that which would be expected from an unselective sampler. Species-specific selectivity relationships describing the probability of retaining a given sized individual were used for the most abundant species, and other species were pooled in broad taxonomic groups. Trawl selectivity S_l at length l of all species or species group caught was estimated by analyzing the catch of the codend and that of small recapture nets mounted on the outside of the trawl during the regular survey trawling operations using methods similar to those presented in Williams et al. (2011). Trawl selectivity corrections were estimated using recapture net data from the winters of 2013, 2018, 2019, 2020, and 2021 and summers of 2019 and 2021 (Table 3, Fig. 3). Recapture net data were pooled by midwater net type (AWT, LFS) and season (winter, summer); AWT data were pooled across seasons for species with limited observations (Table 3, Fig. 3). A generalized linear mixed effects model

(GLMM) was fitted with a logistic link function and binomial error where variation between tows in selectivity was modeled with random effects. S_l was then computed as:

$$S_l = \left(1 + e^{2\log 3(L_{50r} - l)/SR}\right)^{-1}, \quad \text{(Eq. 1)}$$

where L_{50r} is the length at which 50% of individuals were retained and *SR* is the selection range (i.e., range in length between 25% and 75% retention values).

These trawl selectivity estimates were then applied to the codend catch composition to correct the sample for escapement from the trawl as:

$$C_{i,l} = \frac{1}{S_l}, \quad \text{(Eq. 2)}$$

where $C_{i,l}$ is the sample correction scalar for organism *i* of length *l* given the species-specific selectivity *S*. *C* is used in abundance computations to estimate the mean target strength in a given haul, which is directly used to compute abundance (Appendix II).

Selectivity curves for the most abundant taxa were estimated using the generalized linear mixed model (GLMM; Table 3), where each haul used to estimate overall selectivity was treated as a random factor. Variance was estimated by multivariate normal resampling of selectivity parameters using the parameter estimates and variance-covariance matrix (n = 1,000). For some less abundant species, the catch data were too sparse for this approach. In these cases, data were combined across all hauls and a model was fit to a general linear model (GLM) logistic regression. Variance for this approach was estimated by bootstrap (random sub-sampling with replacement) of the input data by haul (n = 1,000). The criteria for deciding which of these approaches was used was based on whether a selectivity group had at least ten hauls in which at least 20 individuals were encountered in the combined recapture nets. A simpler model estimating the ratio of biomass retained in the codend without length dependence was used for euphausiids because of their similar sizes, and reliable length estimates of retained individuals were not available, particularly from the codend where they were often damaged.

Selectivity curve estimates and their uncertainty are presented by midwater trawl type and season in Table 3 and Fig. 3. For the GLMM, some hauls with strong outlier estimates of selectivity were further excluded. For all curves, a minimum retention of 0.25% was enforced to prevent overlarge extrapolation errors with model values approaching 0%.

Re-scrutinizing acoustic data

The grouping of similar acoustic backscatter into strata from the original analysis for each of the summer surveys was revisited to identify strata assigned to mixed-species aggregations that were previously excluded from survey estimates. Under the current analysis approach, acoustic backscatter is assigned to strata based on the appearance and vertical distribution of the aggregations in the echogram. Strata containing backscatter not considered to be from pollock, POP, capelin, or herring—for example, the near-surface mixture of unidentifiable backscatter, backscatter with frequency response indicative of euphausiids or myctophids (De Robertis et al. 2010a), or near-bottom backscatter 'haystack' morphology indicative of some rockfishes that could not be sampled by the trawl, were excluded from further analyses. The backscatter at a given location is associated with the species and size composition of the geographically-

nearest haul within that stratum (see De Robertis et al. 2017, 2021 for details). For example, juvenile pollock can be found in shallow, dense schools with a diffuse layer of adult pollock at deeper depths in the same area. In this case, the backscatter dominated by aggregations of juveniles would be assigned to a shallow stratum (A) and the backscatter dominated by adult layers would be assigned to a deep stratum (B). Hauls that sampled the shallow layer would be assigned to stratum A, and hauls that sampled the deeper layer would be assigned to stratum B. Backscatter is proportionally apportioned by species and size within an acoustic stratum using the selectivity-corrected catch composition from the geographically-nearest trawl in that stratum and converted to abundance.

Historically, acoustic strata associated with mixed aggregations of pelagic fish in which age-1+ pollock was not the dominant species may have been excluded from further analyses, but the current approach allows for such strata to be included as backscatter is proportionally apportioned to all species in the trawl catch. Such strata and their associated hauls were reanalyzed for all summer surveys and included in abundance estimation if they were comprised of age-1+ pollock, POP, capelin, and/or herring.

Accounting for catch from age-0 pollock in summer 2017

The summer 2017 survey presented a somewhat special case: large numbers of age-0 pollock were observed in images from a stereo camera system mounted inside the trawl approximately 20 m forward of the codend (CamTrawl; Williams et al. 2010), and appeared more frequently in trawl catches as the survey progressed and the fish grew large enough to be retained in the AWT's 1.2 cm mesh codend liner (Fig. 2). Age-0 pollock were often co-located with larger age-1+ pollock, with such mixed aggregations occurring in approximately 22% of the entire GOA survey area. Given their abundance and relatively high scattering strength, age-0 pollock likely contributed substantially to the observed backscatter at 38 kHz, yet their scattering could not be readily distinguished from that of larger pollock at the five frequencies used in this survey (18, 38, 70, 120, and 200 kHz; De Robertis et al. 2010a). For 12 trawls collected earlier in the survey, no age-0 pollock were captured in the codend due to their small size, however, they were still observed in the CamTrawl images in sufficient numbers to be acoustically-important ($n > 10$). The number of age-0 pollock that had entered the trawl opening catch for these hauls was inferred from the image counts which were scaled by the ratio of the trawl opening and the trawl section where the images were taken (Jones et al. 2019). The length measurements for these hauls were taken from the age-0 pollock captured in an 'index' pocket net attached near the CamTrawl, unless the number captured in the pocket net was insufficient ($n < 10$). In those cases, length data was pooled from pocket net catches from the nearest five hauls. For the remainder of the trawls with age-0 pollock ($n = 21$), sufficient retention in the codend along with length measurements allowed for the selectivity functions for the AWT derived from the 2019 trawl comparison work to be used to make the standard selectivity correction. The estimated age-0 catch and length data were then combined with all remaining catch data and used to account for the acoustic contribution from age-0 pollock in the regular analysis process described below.

Abundance calculations

A series of target strength (TS, dB re 1 m^2)-to-length relationships from the literature (Table 4) were used along with size and species distributions from selectivity-corrected trawl catches to estimate the proportion of the observed acoustic scattering attributable to each of the species captured in the trawls (Appendix II). For species for which the TS-length relationship was derived using a different length measurement type than the one used for measuring the trawl catch specimens, an appropriate length conversion was applied (e.g., total length to fork length). Species-specific TS-length relationships from the literature were used for

pollock, capelin, eulachon, herring, and for any species whose contribution to the total backscatter used in survey estimates was > 5%. Otherwise, species were assigned to one of five group TS-length relationships: fishes with swim bladders, fishes without swim bladders, jellyfish, squid, and pelagic crustaceans (Table 4). Observed backscatter could only be apportioned among species using the for whom length measurements were collected. In the 2008-2010 winter surveys, length measurements were limited to pollock and eulachon due to the survey sampling protocol at the time (Table 5), so neither selectivity corrections nor backscatter apportionment were possible for other species. These other species accounted for only < 3.4% of numbers of fish (Table 6) and < 3.1% of weight (not shown) from combined trawl catches in any of those years, so the impact of this on reanalysis results from those years was likely small. Starting in 2012, length measurements were collected more consistently for other species— including POP, capelin, and herring— allowing for more complete selectivity correction and backscatter apportionment.

Backscatter was converted to estimates of abundance-at-length using the selectivity-corrected catch from the nearest haul and TS for each organism given its species and size. Biomass was derived from abundance-at-length using length-weight keys (average weight-at-length for 1 cm intervals). For pollock, the keys were based on weighted specimens (Appendix I), but for all other species, unweighted specimens were used. In the summer 2013 survey, there were an insufficient number of length-weight measurements collected for capelin (n = 12) to create a length-weight key. Instead, capelin length-weight measurements (n = 400) collected by a separate AT survey (McGowan et al. 2019) conducted during the same period over the shelf east of Kodiak Island between Barnabas and Amatuli Troughs (Fig. 1) were used. The McGowan et al. (2019) survey used a midwater trawl fitted with the same 1.2 cm codend mesh liner survey as used in the AWT at the time (Fig. 2), and capelin length frequency distributions are similar for catches by both trawls from this time period (*cf.* Fig. 8 in McGowan et al. 2020).

Abundance-at-age and biomass-at-age for pollock were similarly computed by multiplying the abundance and biomass-at-length by proportion-at-age for each 1 cm length (age-length keys; Appendix II), based on weighted specimens for pollock and unweighted specimens for all other species (Appendix I). Samples from outside the winter Shelikof Strait survey area (e.g., from shelf near Chirikof Island and/or Marmot Bay that may have been sampled during the same cruise and erroneously included; Fig. 1) were removed from the age-length keys used in the 2016-2019 and 2021 winter surveys (Table 1).

Pollock female maturity-at-length, maturity-at-age, as well as other maturity metrics including proportion-at-maturity stage and proportion of females in spawning/spent maturity states were computed for pollock in winter surveys using weighted specimens (Appendix I).

Comparison metrics

All survey data products from the winter and summer AT surveys used in the GOA pollock stock assessment and fishery evaluation report (Monnahan et al. 2024; hereafter SAFE) were compared to updated estimates from the reanalyzed survey data (hereafter reanalysis). For the winter surveys, these include abundance estimates for age-1, age-2, and age-3+ pollock, biomass estimates for age-1 and age-2 combined and age-3+ pollock, proportional numbers by age, estimates of the length and age 50% of pollock are mature (L50 and A50, respectively), and the proportion of mature female pollock by age. For the summer surveys, these include biomass estimates for age-1+ pollock and pollock numbers by age. Additionally, biomass estimates for POP, capelin, and herring published in cruise reports for the summer surveys are compared to reanalysis estimates. It should be noted that SAFE estimates in some years were

from preliminary survey data products at the time they were delivered to the stock assessment author and may not always reflect subsequent QA/QC or later updates.

Results and Discussion

Winter Shelikof Strait pre-spawning pollock survey 2008-2025

There were relatively small differences between reanalysis and SAFE estimates of age-3+ pollock abundance and biomass for winter surveys in Shelikof Strait. The reanalysis estimates are generally lower because of the cumulative impact of changes in allocation of backscatter to smaller sizes and non-pollock species. Reanalysis estimates for age-3+ pollock abundance were lower on average by 3.0 ± 5.3% (± 1 standard deviation, SD) from 2008-2025, and within 5.3% in all years except 2008 and 2013 when reanalysis estimates were lower by 18.4% and 13.1%, respectively (Table 7, Fig. 4A). Similarly, reanalysis estimates for age-3+ pollock biomass (directly used in the GOA pollock stock assessment) were on average 3.5 ± 6.2% lower than SAFE estimates, and within 5.5% in all years except 2008 and 2013 when biomass declined by 22.1% and 15.8%, respectively (Table 8, Fig. 4C). The relatively high proportional decreases in 2008 occurred in a year when biomass was lowest among all years that were analyzed, and the absolute decrease of approximately 57.7 million age-3+ fish weighing 30,713 t is similar to differences in other years in this time series (Fig. 4A, C). The large relative decrease in age-3+ abundance and biomass in 2013 (Fig. 4A,C) was due to an increase of nearly 2 billion age-1 pollock (Fig. 4B, D) from the record 2012 year class (Monnahan et al. 2024) in the reanalysis results, likely as a principal result of updated trawl selectivity corrections. In contrast, age-3+ biomass was less impacted in other years (Fig. 4C) in which selectivity-related changes in age-1 abundance were of similar magnitude to 2013—increases of 1.6 and 2.3 billion fish in 2018 and 2019 (Table 7, Figs. 4B and 5)—because the age-3+ biomass was dominated by larger fish (e.g., age-6 and age-7 fish from the 2012 year class in those years; McCarthy et al. 2018, Lauffenburger et al. 2019).

The updated trawl selectivity corrections had a more pronounced effect on reanalysis estimates for juvenile pollock. Age-1 pollock numbers from the reanalysis increased on average by 26.8 ± 35.7%, with increases > 83% in three years, although the high proportional differences occurred in years when absolute age-1 abundance was relatively low (2012, 2015) or near the time series average (2018) (Table 7, Fig. 4B). Reanalysis estimates for age-2 pollock numbers were lower on average by 11.7 ± 18.5% than SAFE estimates, with the highest proportional differences occurring in years of very low (2016, 2021) or average (2008) age-2 abundance (Table 7, Fig. 4B). Age-1 and age-2 combined biomass estimates from the reanalysis were on average similar but highly variable (0.4 ± 23.9% lower than SAFE estimates).

Decreases in reanalysis abundance-at-age estimates for age-2+ pollock resulted from more backscatter being apportioned to age-1 pollock (Fig. 5), likely due to using updated selectivity corrections for the AWT between 2008-2019. Among the five years with the most pronounced increases in the proportion of age-1 abundance (2008-09, 2012, and 2018-19), corresponding declines in other age classes were most pronounced for age-2 pollock in four of the five years and for age-6 pollock in 2018 (Fig. 5). More pronounced changes in proportion of age-1 versus age-2+ abundance were expected for years in which the AWT was used. The updated selectivity correction's L_{50r} value for age-1+ pollock (14.47 cm FL, Table 3) increased from earlier estimates used for the SAFE estimates (11.52 cm, Stienessen et al. 2019; 13.71 cm, Lauffenburger et al. 2019), resulting in higher estimated net escapement by age-1 fish and thus an increase

in age-1 abundance (Table 7, Figs. 4-5). In contrast, the updated L_{50r} for the LFS (11.38 cm FL, Table 3) decreased from the original estimate (13.73 cm, McCarthy et al. 2022), indicating lower escapement, but had a minimal impact on the only year affected (2020) because there were very few age-1 and age-2 fish observed that year (Table 7, Figs. 4-5).

Estimates of 50% pollock maturity at length (L50) remained relatively similar between SAFE and reanalysis estimates (Fig. 6). In only three years reanalysis estimates were statistically lower than SAFE estimates (2012, 2015, 2021). Similarly, estimates of 50% maturity at age (A50) for SAFE estimates were within 95% confidence intervals of the reanalysis estimates in all years except 2012 (higher) and 2017 (lower). Some variation in maturity estimates was expected given the number of changes implemented to the 2008-2021 surveys (Table 1), yet weighting specimen data does not appear to have had a pronounced effect on maturity estimates. Decreases in reanalysis estimates for A50 in 2012 (Fig. 6) and the proportion of mature age-2 to age-4 fish in 2012 and 2022 (Fig. 7) correspond with the weighting of specimen data (Fig. A1.2), but in all other years there were minimal differences between weighted and unweighted maturity estimates.

There were differences between SAFE and reanalysis estimates in the proportion of mature pollock by age, mostly among age-3 to age-5 fish (Fig. 7). Reanalysis estimates for the proportion of mature age-4 were lower than SAFE estimates in 11 of 17 years, most notably in 2010 and 2013, and higher only in 2021. Age-3 and age-5 reanalysis estimates were lower in five (notably in 2015, 2017, and 2022) and four years (notably in 2008, 2013, 2020), respectively, while age-5 and age-6 reanalysis estimates were higher more frequently in three years, particularly in 2015 and 2021 for both age classes. With the exception of 2008, in which reanalysis estimates were lower for age-4 to age-8 fish, few years had differences in the proportion of mature pollock across multiple age classes.

Summer GOA pollock survey 2013-2023

There were relatively small differences between reanalysis and SAFE estimates for age-1+ pollock biomass from summer surveys in the GOA. Reanalysis estimates for age-1+ pollock biomass were lower on average by 0.8 ± 2.5% (± 1 standard deviation, SD) from 2013-2023, and within 4.9% in all years (Table 8, Fig. 8). As in winter, this pattern is probably due to the cumulative impact of changes in allocation of backscatter to smaller sizes and non-pollock species. There was also little change in pollock numbers by age, with only minimal changes in the 2017 summer survey for age-1 and age-5 abundance (Fig. 9), likely due to incorporating the corrected species and size composition data from the CamTrawl analysis. The lack of differences between reanalysis and SAFE abundance and biomass estimates for pollock in most years is somewhat surprising given the number of reanalysis steps implemented for the 2013-2019 surveys (Table 2). Apportioning backscatter to multiple species from the nearest haul was expected to have a more pronounced impact on pollock estimates given the large proportion of total backscatter associated with other species ranging from 15.7% in 2015 to 59.5% in 2017 (Table 6) but ultimately this had a minimal impact. However, in 2017, the backscatter contribution of 'Other species' (54.3% total s_A) was mainly from unusually abundant age-0 pollock discussed earlier, which had been accounted for in the SAFE results (Jones et al. 2019) as well as the reanalysis. Re-scrutinizing acoustic data in these surveys likely had a small impact on age-1+ pollock estimates relative to estimates for other species, as it primarily entailed adding strata with backscatter associated with capelin and herring that had been previously excluded from the original analyses.

In contrast to pollock, there were more pronounced differences between the reanalysis and originally published abundance and biomass estimates for POP, capelin, and herring from several summer surveys.

POP abundance and biomass increased by 6.5% in 2013 and decreased by 25.1% and 24.0%, respectively, in 2015 (Table 9, Fig. 10A, C). In other years, POP abundance and biomass from the reanalysis were within 1% of published estimates. Capelin abundance declined by 25.2% in 2013 (Table 9, Fig. 10B), primarily due to the exclusion of a large aggregation that was not directly sampled during the survey but was classified as capelin during the original analysis (Jones et al. 2014). Capelin biomass declined by 70.7% in 2013 (Table 9, Fig. 10D), due to the combined effects of excluding the unsampled aggregation and using a more robust length-weight relationship based on 400 versus 12 samples provided by a local AT survey using similar trawl gear (McGowan et al. 2019). Capelin reanalysis estimates from 2021 and 2023 were nearly identical to published estimates, with only minimal changes due to weighting specimen data. Herring biomass was only previously estimated in 2019 and 2021 and were within 0.6% of reanalysis estimates (Table 9). In other years, capelin and herring were not estimated in the original analysis due to their densities being too low to be isolated in monospecific strata, or because they were only encountered in mixed-species aggregations dominated by pollock or another species. These low-density and mixed-species situations were handled more correctly in the reanalysis.

Understanding impacts and limitations of the reanalysis

The primary objectives of the reanalysis were to standardize analysis methods for AT survey data products used in the GOA pollock stock assessment over as much of the time series as possible, and to provide more accurate estimates of pollock abundance and maturity, and abundance of POP, capelin, and herring. The reanalysis estimates for pollock, POP, and capelin are likely to be more reliable than SAFE and original survey estimates because the methods used are more rigorous. For example, it is more correct to allocate backscatter to all species in the catch rather than only the most common acoustically-important species, and specimen weighting ensures that specimens from the areas of relatively high abundance more strongly influence survey-wide maturity estimates than those from areas of relatively low abundance. While the overall methodological approach is more robust, the individual reanalysis updates did not always lead to notable changes from SAFE estimates for pollock or survey estimates for other species.

In winter surveys, the updated net selectivity correction functions had an impact on reanalysis estimates in some years prior to 2020, primarily by shifting backscatter assignment from age-3+ pollock to age-1 and-2 fish (Fig. 5), but there were minimal differences in reanalysis abundance and biomass estimates for pollock due to specimen weighting (Fig. A1.1). Similarly, apportioning backscatter to all species in the trawl catch from the nearest haul had a negligible effect on pollock estimates when there were few juvenile pollock and/or small, non-pollock species mixed with adult pollock in trawl catches (Table 6, Figs. 5, 9). Selectivity corrections only impact the relative composition of a trawl catch when it is comprised of species or sizes with differing retention probabilities (Fig. 3; Williams et al. 2011, Williams and Kotwicki 2024). The proportion of total backscatter apportioned to age-1+ pollock in winter surveys averaged 98.8 ± 1.0% (± 1 SD) between 2008-2019 while the AWT was used as the primary midwater trawl (Table 6); indicating other non-pollock species had minimal impact on differences between SAFE and reanalysis estimates for adult pollock in winter. After the winter survey switched to the LFS trawl in 2020 to more efficiently retain non-pollock fish and macroinvertebrate species (Williams and Kotwicki 2024) to which some backscatter was apportioned, the proportion of total backscatter apportioned to age-1+ pollock declined to a mean of 96.3 ± 1.7%. Despite more backscatter being apportioned to non-pollock retained in LFS catches (Table 6), it had no impact on the 2020-2025 reanalysis estimates as the SAFE estimates already included multispecies proportional allocation as part of the original survey analyses (Table 1).

The methodological changes of the reanalysis may be more important in mixed-species situations. Proportionally allocating backscatter to all species in the trawl catch from the nearest haul had a more pronounced impact on estimates for non-pollock species from the summer survey, while having a minimal effect on pollock. Primarily, this was because the reanalysis allowed the inclusion of backscatter associated with multispecies aggregations that were not dominated by age-1+ pollock (e.g., strata comprised of forage species and/or age-0 pollock), which had previously been excluded. While there were minimal differences between pollock SAFE and reanalysis biomass (Table 8, Fig. 8) and proportion of abundance at age (Fig. 9) estimates in summer surveys, improved accounting for non-pollock species has the potential to impact pollock estimates. Greater interannual variation is evident in the proportion of total backscatter apportioned to pollock in all summer surveys (67.4 ± 14.4%) and to other species in winter since 2020, such as increases in total backscatter for POP in 2024 and 2025, and capelin in 2025 (Table 6).

The apportionment of backscatter to non-pollock species provides useful information on some non-targeted species (i.e., POP, capelin). The reanalysis resulted in abundance estimates for capelin in years of very low density that improved monitoring abundance trends for a key forage species in the GOA (McGowan et al. 2026). Reanalysis estimates for capelin from 2015 and 2017 provide a baseline for the population's collapse during the Northeast Pacific marine heatwave in 2014-2016 (Arimitsu et al. 2021). Reanalysis estimates also more accurately apportioned backscatter associated with pollock/POP mixed aggregations at the shelf break. Abundance estimates for non-pollock species should still be interpreted cautiously, as the summer survey is principally designed for midwater pollock, in terms of area covered and trawl sampling gear. In particular with herring, it is difficult to accurately survey the highly patchy, discrete dense aggregations characteristic for herring over the GOA shelf in summer. In addition, very dense schools suspected of being comprised of herring are often not effectively sampled by a trawl during the pollock AT surveys due to the difficulty of catching these mobile targets without a directional sonar. Given the difficulty of sampling such targets and the high likelihood that they are not pollock, herring acoustic targets are not consistently sampled and their associated backscatter are often excluded from analysis altogether.

Key requirements for applying updated net selectivity corrections to catch data and apportioning backscatter to all species is that in most cases it can only be done when there is at least some retention in the codend, and when there are associated length measurements for all species (Eq. 1, Appendix II). This is challenging for historical surveys when the AWT was less effective at retaining small fish and macroinvertebrates as compared to the LFS trawl (Williams and Kotwicki 2024). The winter survey did not consistently measure individual lengths for most non-pollock species prior to the late-2010s (Table 5), and this limits the ability to correct catch data for net escapement or allocate backscatter to non-pollock species.

CamTrawl data in the summer 2017 survey provided a way to supplement trawl catch in addressing the challenging issue of highly abundant age-0 pollock co-occurring with age-1+ pollock. Early in the survey, age-0 pollock were too small to be retained by the AWT fitted with a 1.2 cm mesh codend liner and therefore could not be accounted for using selectivity correction functions, yet CamTrawl image data showed age-0s in the net co-occurring with larger pollock that were retained in the codend (Jones et al. 2019). Using only the trawl catch to apportion backscatter in these circumstances would overestimate abundance and biomass of age-1+ pollock biomass. A combination of camera-based and trawl catch composition in conjunction with net selectivity corrections was used in this case, which led to an improved accounting of age-0 pollock in the summer 2017 survey. This is not possible for earlier surveys as CamTrawl data of sufficient quality were not available.

Reanalysis of winter survey data prior to 2008 is not recommended. Winter surveys prior to 2009 used trawls fitted with the coarser 3.2 cm codend mesh liner (Fig. 2) and thus had decreased retention of small organisms. In addition, lengths were generally not recorded for non-pollock species, and neither recapture net data nor CamTrawl data were available, meaning it would be difficult to adjust apportionment of backscatter in these older surveys for the effects of mesh selection or the contribution of acoustically-important components of the catch not retained in the codend. Results from the 2008 survey were included in the reanalysis because some of the required data were available, and it was deemed beneficial on balance to reanalyze the entire series of winter surveys conducted by the *Oscar Dyson* to the extent possible. Due to insufficient data and the substantial effort required, no correction for the 3.2 vs. 1.2 cm codend liner was developed or applied for this survey.

Summary

The reanalysis of winter and summer GOA AT survey data provides standardized time series for all survey products used as inputs in the GOA pollock stock assessment, following the current analysis approach for MACE AT surveys. These estimates are a notable improvement, providing the best available information for tracking pollock abundance trends and changes in maturity in the GOA. In the winter survey, the reanalysis indicates that improved estimation of net selectivity is the most significant update: in surveys where smaller age-1 and age-2 pollock are present, updated estimates are lower for age-3+ pollock as an increased proportion of the pollock backscatter is now attributed to age-1 and/or age-2 pollock. In the summer, the most significant change in the reanalysis was the apportionment of backscatter to all species present in the trawl catch: while this had little impact on pollock estimates, it improved estimates for POP and capelin. Abundance estimates for herring are considered less reliable than those for other species estimated in this report, given the challenges of consistently sampling them in a survey designed for midwater pollock, and should be interpreted with particular caution.

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Tables

Table 1. Updates completed as part of the reanalysis of winter Shelikof Strait acoustic-trawl surveys in 2008-2025.

Year	Apply updated selectivity set	Switch to nearest haul & multispp.	Species-specific TS relationships for capelin & herring	Exclude Marmot & Chirikof samples from age-length key	Specimen weighting
2008	X	X	X		X
2009	X		X		X
2010	X	X	X		X
2012	X	X	X		X
2013	X	X	X		X
2014	X	X	X		X
2015	X	X	X		X
2016	X	X	X	X	X
2017	X		X	X	X
2018	X		X	X	X
2019	X		X	X	X
2020	X		X		X
2021			X	X	X
2022					X
2023					X
2024					X
2025					X

Table 2. Updates completed as part of the reanalysis of summer GOA acoustic-trawl surveys in 2013-2023.

Year	Apply updated selectivity set	Switch to nearest haul & multispp.	Species-specific TS relationships for capelin & herring	Acoustic data re-scrutinized	Specimen weighting
2013 *	X	X	X	X	X
2015	X	X	X	X	X
2017 **	X	X	X	X	X
2019	X		X	X	X
2021			X	X	X
2023					X

* External length-weight measurements from McGowan et al. (2019) used to estimate length-weight relationship for capelin.

** Species- and size-composition of trawl data corrected based on CamTrawl analysis of age-0 pollock too small to be retained in codend in conjunction with net selectivity functions for age-0 pollock retained in codend.

Table 3. Selectivity curve estimates of length at 50% retention (L_{50r}) and selection range (*SR*) from either the generalized linear mixed effects model (GLMM) or cumulative GLM (Cum. GLM) for species and groups of species by midwater trawl type and season. Surveys used in estimating the selectivity are listed. All values are in cm. * indicates some values may be negative.

Selectivity group	Trawl	Season	Survey data used	Model used	Length at 50% retention (L_{50r})	L_{50r} 95% resample range*	Selection Range (*SR*)	*SR* 95% resample range*	Length range
Age-1+ pollock	LFS	Winter	DY2102	GLMM	11.38	10.44-11.98	6.22	4.26-11.21	11-60
	LFS	Summer	DY1906	GLMM	9.14	5.94-11.29	8.14	6.37-11.31	6-54
	AWT	Winter	DY1303 DY1803 SH1904 DY2003	GLMM	14.47	13.67-15.50	4.80	4.01-5.84	8-73
	AWT	Summer	DY1906	GLMM	6.06	-2.18-11.14	12.62	9.53-19.08	12-57
Age-0 pollock	LFS	Summer	DY1906	Cum. GLM	6.44	5.48-7.56	2.25	1.57-3.24	2-8
Pacific capelin	LFS	Winter	DY2001 DY2003	Cum. GLM	13.08	12.08-15.21	3.69	2.85-5.89	3-13
	LFS	Summer	DY1906	GLMM	11.39	9.85-15.01	3.23	2.20-6.13	5-14
	AWT	All	DY1906	Cum. GLM	16.32	6.73-25.28	5.38	-8.94-18.57	6-14
Eulachon	LFS	Winter	DY2001 DY2002 DY2003	GLMM	13.38	11.82-15.47	5.11	3.70-8.03	4-25
	LFS	Summer	DY1906	Cum. GLM	7.64	-93.98-55.58	11.12	-51.51-140.31	10-20
	AWT	Winter	DY1303 DY1803 DY1904 DY2003	GLMM	14.34	13.30-15.43	6.41	5.28-7.99	7-24
	AWT	Summer	DY1906	Cum. GLM	14.65	8.01-428.50	15.9	-34.28-511.77	8-18
Fish larvae	LFS	Winter	DY2003	Cum. GLM	13.06	-74.74-55.08	6.78	-89.99-47.08	4-9
	LFS	Summer	DY1906	Cum. GLM	6.36	5.91-18.91	2.43	2.00-11.97	2-7

Selectivity group	Trawl	Season	Survey data used	Model used	Length at 50% retention (L_{50r})	L_{50r} 95% resample range*	Selection Range (*SR*)	*SR* 95% resample range*	Length range
Gelatinous zooplankton	LFS	All	DY1906	Cum. GLM	15.12	10.28-18.65	11.68	5.01-16.31	1-62
	AWT	All	DY1906	Cum. GLM	11.50	9.15-14.18	5.14	2.51-7.94	1-47
Generic fish	LFS	Winter	DY2001 DY2002 DY2003	Cum. GLM	11.51	9.65-15.11	3.79	2.53-7.48	2-67
	LFS	Summer	DY1906	Cum. GLM	9.96	7.85-14.83	5.00	3.10-8.82	2-86
Pacific herring	LFS	Winter	DY2001 DY2003	Cum. GLM	11.81	11.20-16.33	3.38	1.83-11.78	7-23
	LFS	Summer	DY2104	Cum. GLM	0.39	-181.50-184.33	15.34	-132.09-160.58	12-30
	AWT	All	DY1303 DY1906	Cum. GLM	17.47	0.52-18.64	5.06	-5.02-5.92	7-24
Myctophids	LFS	All	DY1906 DY2002 DY2003	GLMM	7.26	6.46-10.54	1.16	0.56-6.47	5-21
Non-krill crustaceans	LFS	All	DY1906 DY2002 DY2003	GLMM	8.39	-7.54-19.95	1.74	-11.58-10.30	5-11
Squid	LFS	All	DY1906 DY2001 DY2002 DY2003	Cum. GLM	6.69	5.46-9.27	2.26	1.60-3.34	1-32

Table 4. Target strength (TS)-to-size relationships from the literature used to allocate 38 kHz acoustic backscatter to species in this report. The symbols in the equations are as follows: *r* is the bell radius in cm and *L* is length in cm for all groups except pelagic crustaceans, in which case *L* is in m.

Group	TS (dB re 1 m^2)	Length type	TS derived for which species	Reference
Walleye pollock	$TS = 20 \log_{10} L - 66$	*L* = fork length	*Gadus chalcogrammus*	Foote and Traynor 1988, Traynor 1996
Pacific capelin	$TS = 20 \log_{10} L - 70.3$	*L* = total length	*Mallotus catervarius*	Guttormsen and Wilson 2009
Pacific herring[1]	$TS = 20 \log_{10} L\text{-}2.3 \log_{10}(1 + depth/10) - 65.4$	*L* = fork length	*Clupea harengus*	Ona 2003
Eulachon	$TS = 20 \log_{10} L - 84.5$	*L* = total length	*Thaleichthys pacificus*	Gauthier and Horne 2004
Fish with swim bladders	$TS = 20 \log_{10} L - 67.4$	*L* = total length	Physoclist fishes	Foote 1987
Fish without swim bladders	$TS = 20 \log_{10} L - 83.2$	*L* = total length	*Pleurogrammus monopterygius*	Gauthier and Horne 2004
Jellyfish	$TS = 10 \log_{10}(\pi r^2) - 86.8$	*r* = bell radius	*Chrysaora melanaster*	De Robertis and Taylor 2014
Squid	$TS = 20 \log_{10} L - 75.4$	*L* = mantle length	*Todarodes pacificus*	Kang et al. 2005
Pelagic crustaceans[2]	$TS = A * (\log_{10}(BkL)/(BkL))^c + D((kL)^6) + E((kL)^5) + F((kL)^4) + G((kL)^3) + H((kL)^2) + I(kL) + J + 20 \log_{10}(L/L_0)$	*L* = total length	*Euphausia superba*	Demer and Conti 2005

[1] *depth* (m) is fixed at 75 m.

[2] A = -930.429983; B = 3.21027896; C = 1.74003785; D = $1.36133896 \times 10^{-8}$; E = $-2.26958555 \times 10^{-6}$
F= $1.50291244 \times 10^{-4}$; G = $-4.86306872 \times 10^{-3}$; H = 0.0738748423; I = -0.408004891; J = -73.9078690; and L_0 = 0.03835
If L < 0.015 m, TS = -105 dB; and if L > 0.065 m, TS = -73 dB.
k = 2πfc, where f = 38,000 (frequency in Hz) and c = 1470 (sound speed in m s^{-1}).

Table 5. Summary of length measurement counts for key species and all other species combined ('Other spp.,' excludes large sharks and skates) from winter and summer surveys. Catch compositions are not corrected for selectivity and reflect combined catch from AWT and PNE trawls in 2008-2019 and LFS and PNE trawls in 2020-2025. Note, '-' indicates no fish were caught during that survey.

Year	Pollock	Eulachon	POP	Capelin	Herring	Other spp.
Winter						
2008	3,479	893	0	0	0	0
2009	3,962	780	-	0	0	0
2010	4,948	722	-	0	-	0
2012	4,013	497	8	4	0	11
2013	5,951	1,000	-	25	39	3
2014	7,952	1,252	233	1	1	378
2015	8,955	251	0	89	57	489
2016	8,405	320	1	-	22	231
2017	5,797	514	21	1	147	186
2018	5,521	473	-	11	18	218
2019	7,595	717	-	16	7	380
2020	5,962	633	1	102	49	971
2021	8,814	820	237	38	67	824
2022	6,752	648	2	55	10	1,312
2023	4,535	368	93	6	1	1,401
2024	5,597	455	48	5	-	1,115
2025	6,006	454	76	337	94	980
Summer						
2013	15,641	820	970	1,988	237	767
2015	30,119	306	2,784	240	650	2,378
2017	17,030	514	1,144	420	626	5,351
2019	20,709	453	1,138	760	1,485	5,946
2021	11,890	616	1,731	373	313	2,495
2023	13,723	379	1,328	936	561	4,219

Table 6. Percentage of numbers of fish for raw (N_{raw}) and selectivity-corrected (N_{cor}) catch composition and percentage of backscatter in the survey (s_A) from reanalyzed winter and summer survey data for key species and all other species ('Other spp.', excludes large sharks and skates). Catch compositions reflect combined catch from AWT/ LFS and PNE trawls.

	Age-1+ pollock			Eulachon			POP			Capelin			Herring			Other spp.		
Year	N_{raw}	N_{cor}	s_A	N_{raw}	N_{cor}	s_A	N_{raw}	N_{cor}	s_A	N_{raw}	N_{cor}	s_A	N_{raw}	N_{cor}	s_A	N_{raw}	N_{cor}	s_A
Winter																		
2008	31.8	48.5	97.0	66.2	51.5	3.0	<0.1	-	-	0.1	-	-	<0.1	-	-	1.9	-	-
2009	56.9	53.1	98.6	39.7	46.9	1.4	-	-	-	0.1	-	-	<0.1	-	-	3.3	-	-
2010	27.8	18.6	98.0	70.6	81.4	2.0	-	-	-	<0.1	-	-	-	-	-	1.6	-	-
2012	66.9	51.0	99.5	30.1	48.4	0.4	<0.1	<0.1	<0.1	<0.1	0.6	<0.1	<0.1	-	-	2.9	<0.1	<0.1
2013	80.7	86.7	99.7	18.0	10.5	0.1	-	-	-	0.2	1.9	0.1	0.1	0.9	0.1	1.1	<0.1	<0.1
2014	58.7	58.5	99.0	39.4	41.0	0.9	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.7	0.5	0.1
2015	55.6	48.5	98.0	33.7	41.1	0.5	-	-	-	0.1	2.9	0.2	0.1	0.8	0.1	10.5	6.6	1.2
2016	83.0	73.5	99.8	14.0	25.5	0.2	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1	2.9	1.0	<0.1
2017	48.1	32.8	97.8	45.4	57.3	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.7	7.3	1.9	5.8	2.6	<0.1
2018	60.9	60.6	99.6	36.1	37.7	0.3	-	-	-	<0.1	0.5	<0.1	0.1	0.1	<0.1	2.8	1.1	0.1
2019	75.1	86.0	99.8	18.7	11.2	0.1	-	-	-	0.1	0.4	0.1	<0.1	<0.1	<0.1	6.1	2.3	0.1
2020	35.9	14.4	96.3	47.0	28.7	0.6	<0.1	<0.1	<0.1	0.8	3.0	0.4	0.1	0.1	<0.1	16.2	53.7	2.7
2021	52.1	42.0	97.5	40.9	18.0	0.8	0.4	<0.1	<0.1	0.0	0.1	<0.1	0.6	0.9	0.1	5.9	38.9	1.5
2022	57.4	28.1	98.5	23.1	14.7	0.4	<0.1	<0.1	<0.1	0.1	0.6	<0.1	<0.1	<0.1	<0.1	19.4	56.6	1.1
2023	19.7	4.8	96.2	31.4	9.5	0.4	1.1	0.3	0.3	0.2	0.5	0.1	<0.1	<0.1	<0.1	47.7	84.9	3.1
2024	34.2	14.4	95.7	31.0	19.1	0.3	0.2	0.1	1.6	0.0	<0.1	<0.1	-	-	-	34.7	66.4	2.3
2025	35.2	11.1	93.5	13.8	5.5	0.4	1.0	0.2	1.5	12.0	34.4	2.6	1.0	1.3	0.3	36.9	47.4	1.7
Summer																		
2013	85.4	78.2	68.1	1.3	1.8	0.1	6.1	3.1	7.4	2.6	15.0	22.5	0.2	0.1	<0.1	4.3	1.8	1.8
2015	15.4	50.0	84.3	1.0	6.6	<0.1	3.1	10.1	8.3	0.3	18.8	0.6	2.9	9.1	5.4	77.4	5.4	1.4
2017	2.3	28.7	40.5	0.3	7.5	0.1	0.3	3.9	3.0	0.1	16.3	0.7	0.4	4.5	1.4	96.6	39.1	54.3
2019	18.3	1.2	70.6	1.1	0.1	0.2	0.4	<0.1	6.2	7.2	1.5	3.2	4.5	0.3	12.3	68.5	96.9	7.5
2021	32.0	12.9	69.2	13.0	5.8	0.7	3.3	1.1	16.0	5.7	11.9	2.1	2.3	0.8	6.2	43.6	67.6	5.8
2023	15.5	4.3	71.4	12.3	3.3	0.3	1.5	0.3	6.8	29.9	74.6	18.1	1.2	0.0	0.4	39.5	17.5	3.0

Table 7. Abundance estimates of pollock currently used in the GOA pollock stock assessment ('SAFE') and the updated reanalysis ('Reanalysis') for winter and summer surveys. Abundance estimates from summer surveys are not available from SAFE.

	SAFE				Reanalysis				Difference (%)			
Year	Age-1	Age-2	Age-3+	Total	Age-1	Age-2	Age-3+	Total	Age-1	Age-2	Age-3+	Total
Winter												
2008	1,778.2	359.2	314.5	2,451.9	2,622.6	227.3	256.8	3,106.7	47.5	-36.7	-18.4	26.7
2009	814.1	1,127.2	284.2	2,225.5	1,133.8	1,045.5	278.9	2,458.2	39.3	-7.2	-1.9	10.5
2010	270.5	299.1	769.1	1,338.7	243.2	289.8	772.3	1,305.2	-10.1	-3.1	0.4	-2.5
2012	193.8	842.3	295.9	1,332.0	354.8	831.7	280.3	1,466.8	83.1	-1.3	-5.3	10.1
2013	9,178.4	117.1	1,037.1	10,332.6	11,047.5	116.3	901.3	12,065.2	20.4	-0.7	-13.1	16.8
2014	1,590.8	3,492.9	645.2	5,728.9	1,915.4	3,442.1	618.8	5,976.3	20.4	-1.5	-4.1	4.3
2015	19.8	103.9	2,104.0	2,227.8	37.1	86.3	2,041.3	2,164.7	87.3	-17.0	-3.0	-2.8
2016	0.0	1.8	1,635.1	1,636.9	0.0	1.1	1,619.6	1,620.7	0.0	-39.1	-0.9	-1.0
2017	744.7	0.0	2,879.5	3,624.2	1,047.7	0.0	2,797.2	3,844.8	40.7	0.0	-2.9	6.1
2018	1,819.6	142.6	2,114.4	4,076.5	3,442.2	133.1	2,016.4	5,591.7	89.2	-6.7	-4.6	37.2
2019	7,361.2	1,671.7	1,631.5	10,664.4	9,708.7	1,295.0	1,588.8	12,592.5	31.9	-22.5	-2.6	18.1
2020	17.1	80.0	881.1	978.2	12.7	79.4	890.0	982.1	-25.8	-0.8	1.0	0.4
2021	7,730.1	36.7	597.9	8,364.7	7,771.8	15.0	618.5	8,405.3	0.5	-59.0	3.4	0.5
2022	11.1	193.3	462.2	666.6	11.1	193.2	463.7	667.9	0.3	-0.1	0.3	0.2
2023	0.1	1.4	286.7	288.1	0.1	1.4	285.9	287.4	-0.3	0.7	-0.3	-0.3
2024	0.3	7.7	359.7	367.7	0.3	7.6	359.8	367.7	0.0	-1.3	< 0.1	0.0
2025	562.7	0.7	339.7	903.2	562.7	0.8	339.6	903.2	0.0	8.7	< 0.1	0.0
Summer												
2013	-	-	-	-	8,142.7	82.4	712.5	8,937.7	-	-	-	-
2015	-	-	-	-	6.2	158.0	3,654.8	3,819.0	-	-	-	-
2017	-	-	-	-	497.6	0.3	1,895.6	2,393.5	-	-	-	-
2019	-	-	-	-	2,874.4	1,346.2	420.5	4,641.2	-	-	-	-
2021	-	-	-	-	3,626.2	135.5	549.5	4,311.2	-	-	-	-
2023	-	-	-	-	570.7	129.1	1,075.1	1,775.0	-	-	-	-

Table 8. Biomass estimates of pollock currently used in the GOA pollock stock assessment ('SAFE') and the updated reanalysis ('Reanalysis') for winter and summer surveys. Biomass estimates by age from summer surveys are not available from SAFE.

	SAFE			Reanalysis			Difference (%)		
Year	Age-1+2	Age-3+	Total	Age-1+2	Age-3+	Total	Age-1+2	Age-3+	Total
Winter									
2008	58,827.8	139,094.5	197,922.3	57,894.4	108,377.9	166,272.3	-1.6	-22.1	-16.0
2009	96,609.8	160,812.6	257,422.4	92,313.3	156,258.7	248,572.0	-4.4	-2.8	-3.4
2010	26,258.9	395,316.3	421,575.2	25,110.0	387,177.8	412,287.7	-4.4	-2.1	-2.2
2012	69,247.8	264,812.9	334,060.6	69,403.5	257,674.8	327,078.3	0.2	-2.7	-2.1
2013	91,797.1	716,040.5	807,837.7	112,127.8	602,737.6	714,865.4	22.1	-15.8	-11.5
2014	218,003.0	609,334.6	827,337.6	219,127.6	589,922.7	809,050.3	0.5	-3.2	-2.2
2015	10,191.2	837,778.3	847,969.6	8,328.0	836,000.1	844,328.1	-18.3	-0.2	-0.4
2016	474.2	666,528.6	667,002.8	134.4	665,205.0	665,339.4	-71.7	-0.2	-0.2
2017	7,947.3	1,457,281.6	1,465,228.9	10,729.2	1,411,296.5	1,422,025.7	35.0	-3.2	-2.9
2018	27,404.0	1,293,463.5	1,320,867.4	39,117.8	1,222,376.6	1,261,494.4	42.7	-5.5	-4.5
2019	164,061.0	1,117,022.3	1,281,083.3	156,524.4	1,087,654.3	1,244,178.7	-4.6	-2.6	-2.9
2020	6,044.7	450,667.9	456,712.6	5,825.7	451,269.7	457,095.4	-3.6	0.1	0.1
2021	76,305.2	450,668.5	526,973.8	71,766.3	451,232.8	522,999.1	-5.9	0.1	-0.8
2022	10,027.0	355,384.5	365,411.5	10,040.0	359,544.3	369,584.3	0.1	1.2	1.1
2023	265.5	258,563.3	258,828.8	268.1	260,953.4	261,221.5	1.0	0.9	0.9
2024	994.6	288,978.3	289,972.9	1,006.1	287,231.6	288,237.7	1.2	-0.6	-0.6
2025	7,451.0	319,753.2	327,204.2	7,827.8	315,596.0	323,423.8	5.1	-1.3	-1.2
Summer									
2013	-	-	884,048.5	236,638.7	603,767.0	840,405.7	-	-	-4.9
2015	-	-	1,606,171.3	35,509.4	1,528,534.6	1,564,044.0	-	-	-2.6
2017	-	-	1,318,396.4	17,315.3	1,295,709.3	1,313,024.5	-	-	-0.4
2019	-	-	580,542.9	293,447.9	297,296.6	590,744.5	-	-	1.8
2021	-	-	431,147.7	122,601.1	308,182.6	430,783.8	-	-	-0.1
2023	-	-	740,416.9	82,710.4	667,195.1	749,905.5	-	-	1.3

Table 9. Abundance and biomass estimates of Pacific ocean perch (POP), capelin, and herring for summer surveys in 2013-2023 published in each survey's cruise report ('Published') and from reanalyzed survey data ('Reanalysis'). 'NA' indicates years when no estimate was reported for that species.

	Abundance (millions of fish)			Biomass (t)		
Year	Published	Reanalysis	Difference (%)	Published	Reanalysis	Difference (%)
POP						
2013	332.2	353.9	6.5	243,536.0	259,331.6	6.5
2015	599.8	449.0	-25.1	438,545.0	333,260.3	-24.0
2017	305.9	304.2	-0.5	172,388.2	171,201.7	-0.7
2019	218.0	218.2	0.1	144,045.1	144,121.6	0.1
2021	386.0	386.0	0	277,941.5	277,920.1	<0.1
2023	190.7	190.7	0	137,891.6	137,891.6	0
Capelin						
2013	53,692.4	40,161.3	-25.2	493,106.0	144,642.8	-70.7
2015	24.6	1,171.3	4654.6	NA	4,023.2	-
2017	17.7	1,520.0	8490.6	NA	6,843.9	-
2019	5,291.8	5,283.3	-0.2	16,525.3	16,808.7	1.7
2021	1,563.7	1,563.3	<0.1	8,592.7	8,589.1	<0.1
2023	21,057.3	21,057.4	<0.1	71,712.3	71,713.0	<0.1
Herring						
2013	NA	27.8	-	NA	1,316.4	-
2015	6.4	1,220.7	18915.6	NA	96,754.4	-
2017	NA	824.1	-	NA	30,656.8	-
2019	1,771.4	1,773.7	0.1	135,504.2	136,307.4	0.6
2021	458.8	460.2	0.3	59,241.9	59,415.6	0.3
2023	NA	NA	-	NA	NA	-

Figures

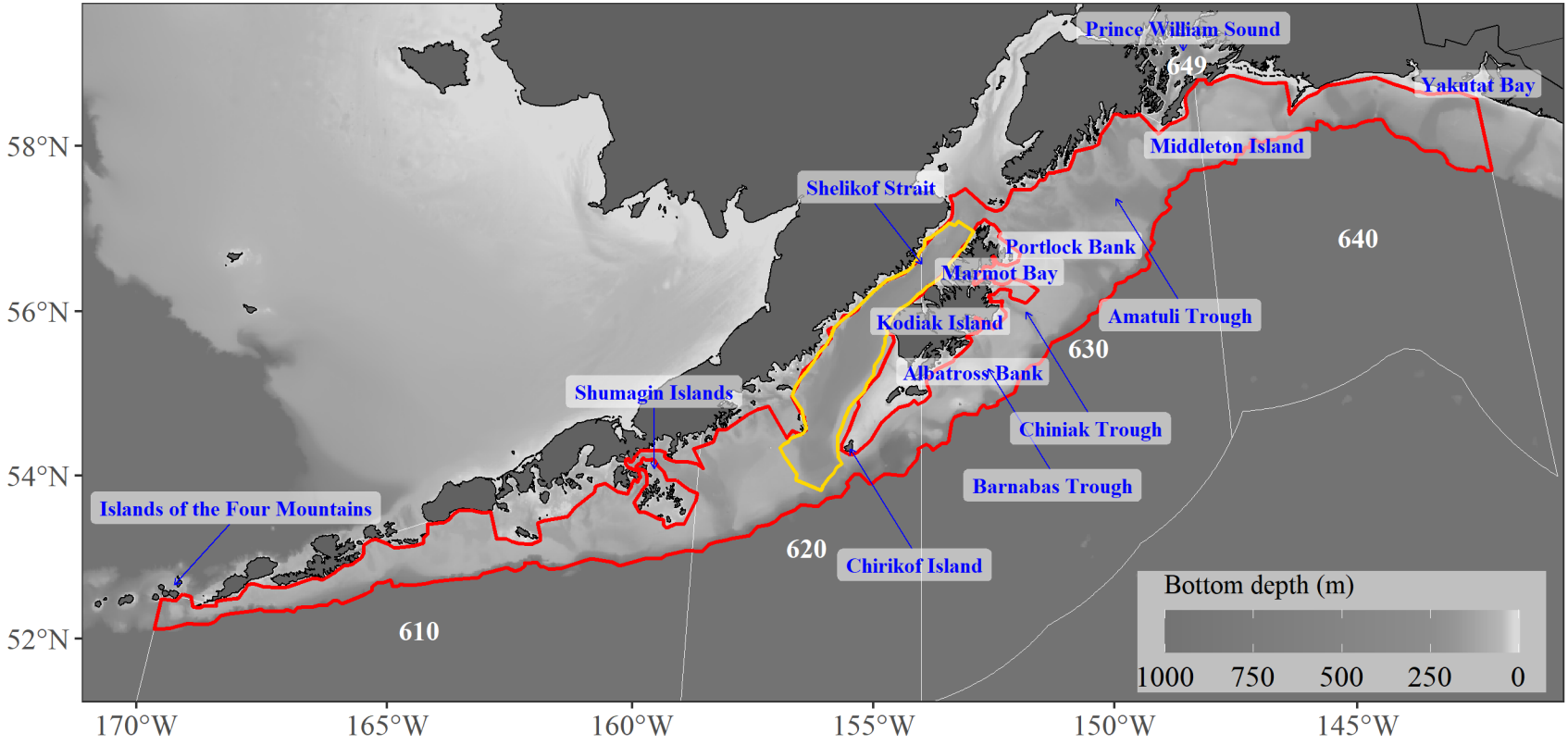

Figure 1. Survey areas for winter Shelikof Strait (red) and summer Gulf of Alaska (yellow) acoustic-trawl surveys.

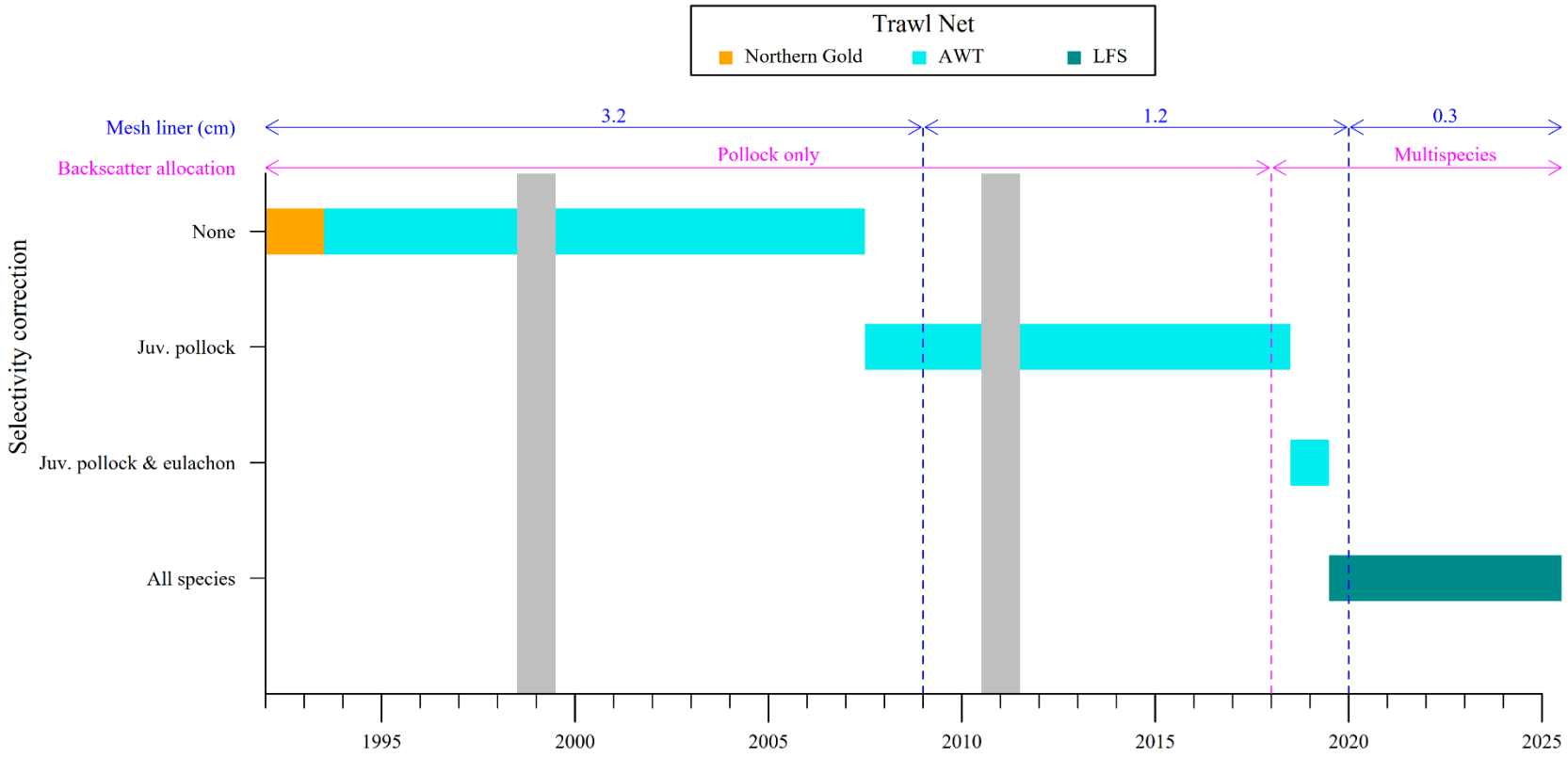

Figure 2. Historical survey gear and analysis approach for the winter Shelikof Strait acoustic-trawl survey from 1992-2025. Shown are the primary midwater trawl net (the Diamond 1000 trawl was used for 5 hauls in 1993) and codend liner mesh size used to sample acoustic targets; the allocation of backscatter to species in the trawl catch; trawl selectivity corrections to catch data for juvenile pollock, eulachon, and all other species. Surveys were completed on the NOAA Ships *Miller Freeman* (1992-2007), *Oscar Dyson* (2008-2018, 2020-present), and *Bell M. Shimada* (2019). Note, no surveys were conducted in 1999 or 2011.

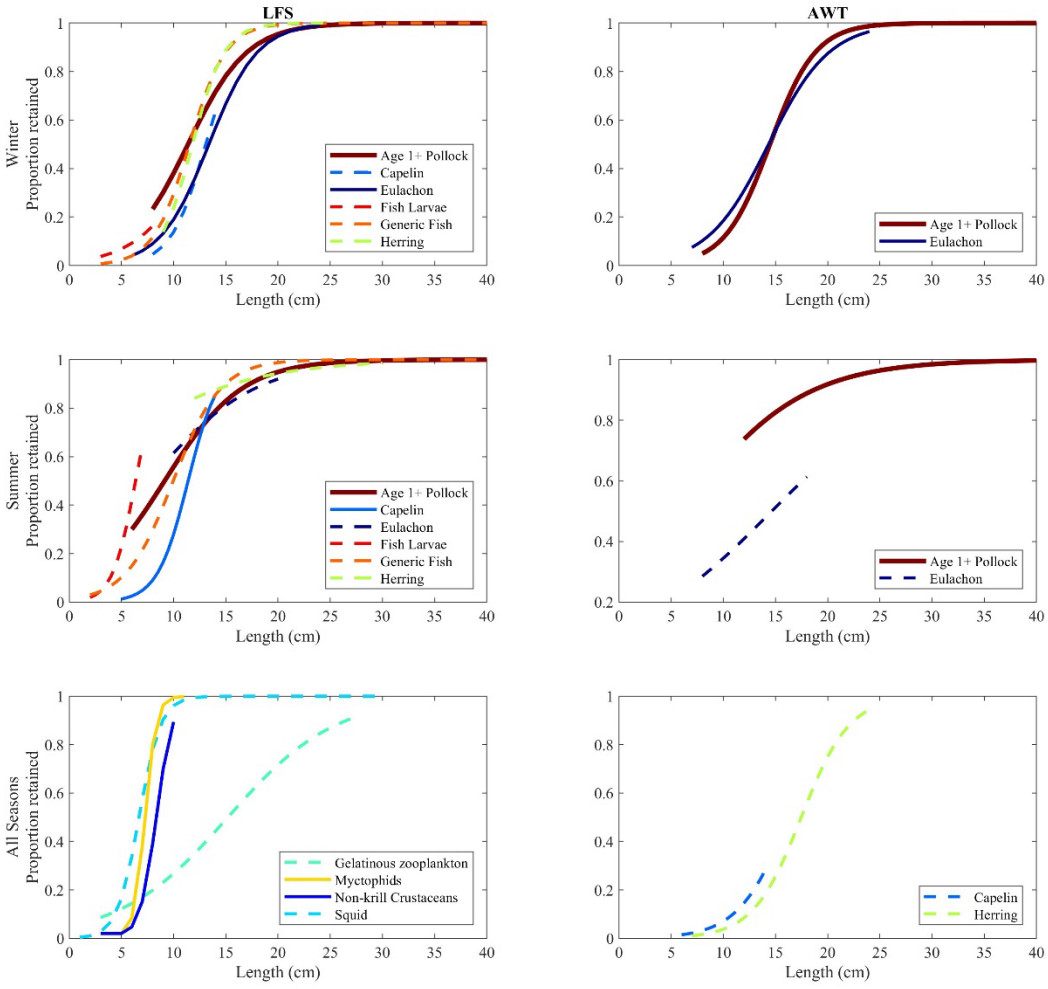

Figure 3. Selectivity functions estimated for the GOA acoustic-trawl surveys using recapture nets by midwater trawl type (LFS, AWT) and season. Selection function values are only plotted for length ranges encountered for each species or selectivity group. Recapture net data was pooled across seasons ('All Season') when sample sizes were too low.

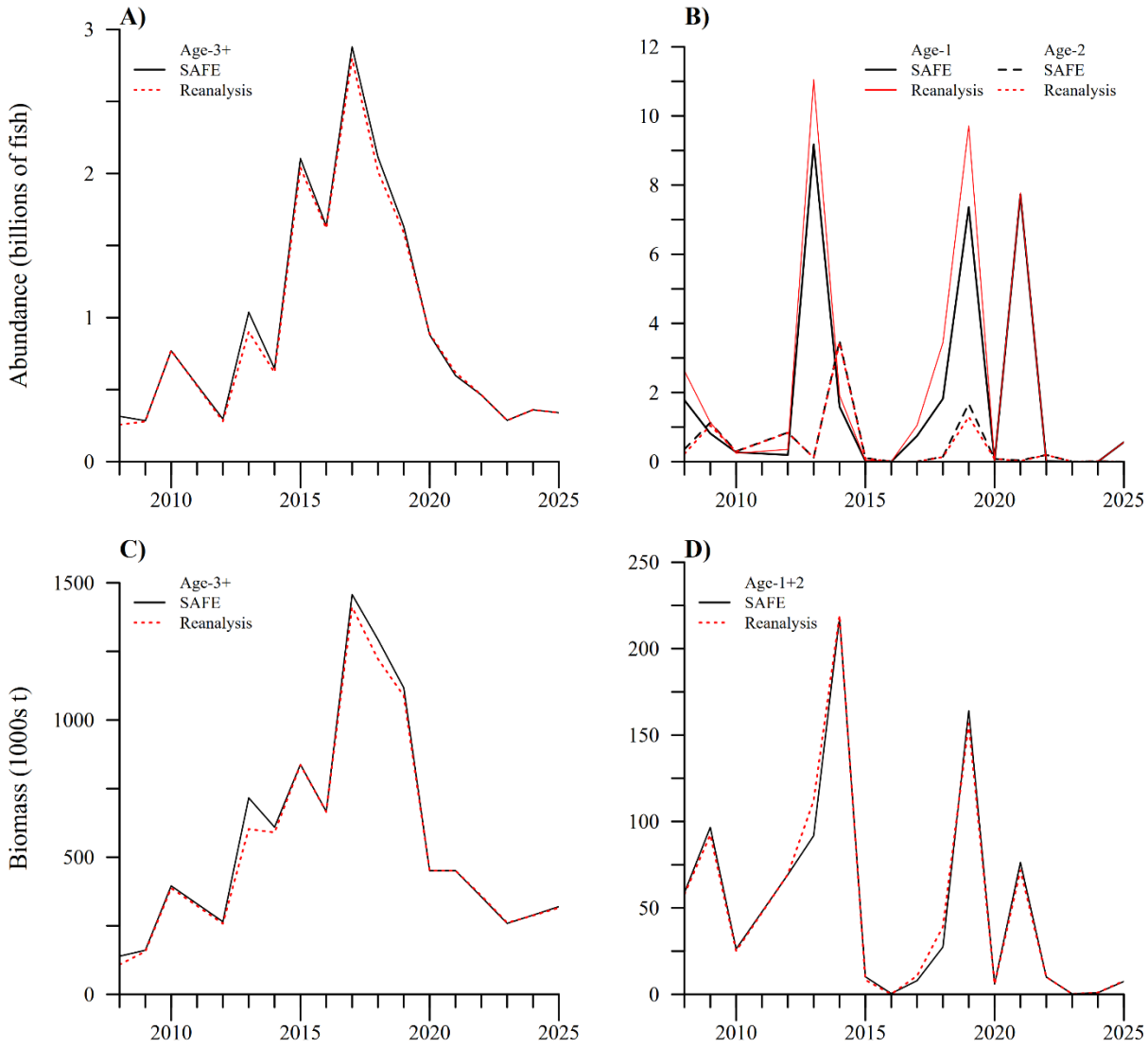

Figure 4. Abundance and biomass estimates for pollock in winter surveys from 2008-2025. Plots on left show abundance A) and biomass C) time series for age-3+ pollock, from reanalyzed survey data ('reanalysis') and estimates currently used in the GOA pollock stock assessment ('SAFE'). Plots on right show B) age-1 and age-2 pollock abundance and D) age-1 + age-2 pollock combined biomass. Note, no survey was conducted in 2011.

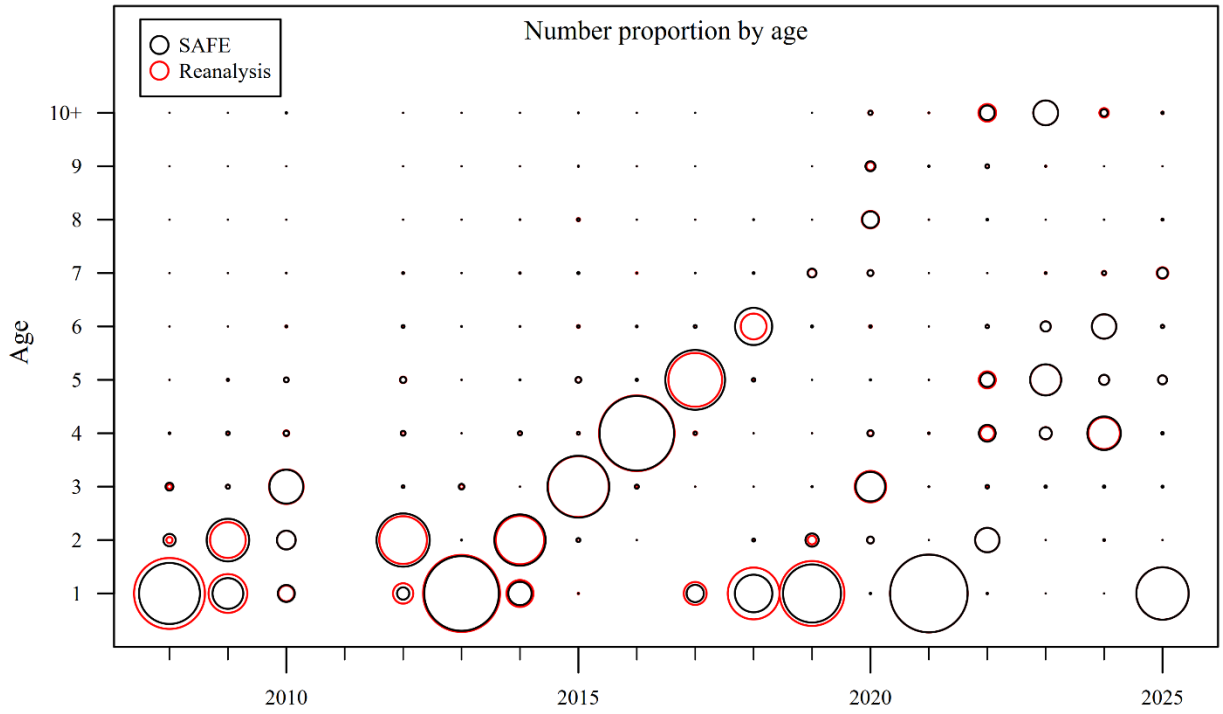

Figure 5. Pollock numbers by age for winter surveys in 2008-2025 from reanalyzed survey data ('Reanalysis') and estimates currently used in the GOA pollock stock assessment ('SAFE'). Bubble sizes are scaled within years. Note, no winter survey was conducted in 2011.

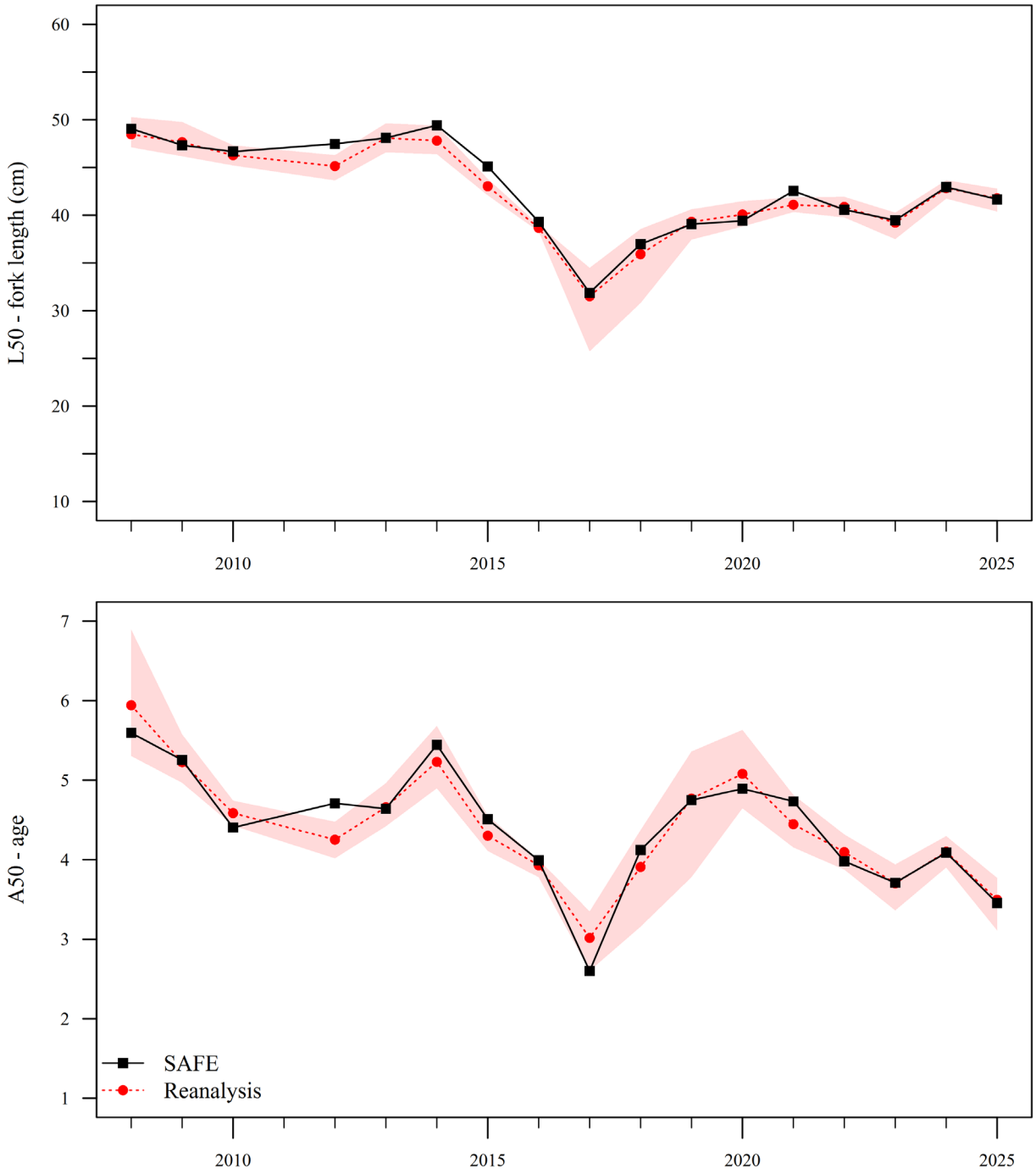

Figure 6. Time series of pollock length at 50% mature (L50 - top) and age at 50% mature (A50 - bottom) estimates from winter surveys in 2008-2025 from weighted maturity estimates from the reanalyzed survey data ('Reanalysis') and estimates currently used in the GOA pollock stock assessment ('SAFE'). Reanalysis estimates include 95% confidence intervals (shaded area).

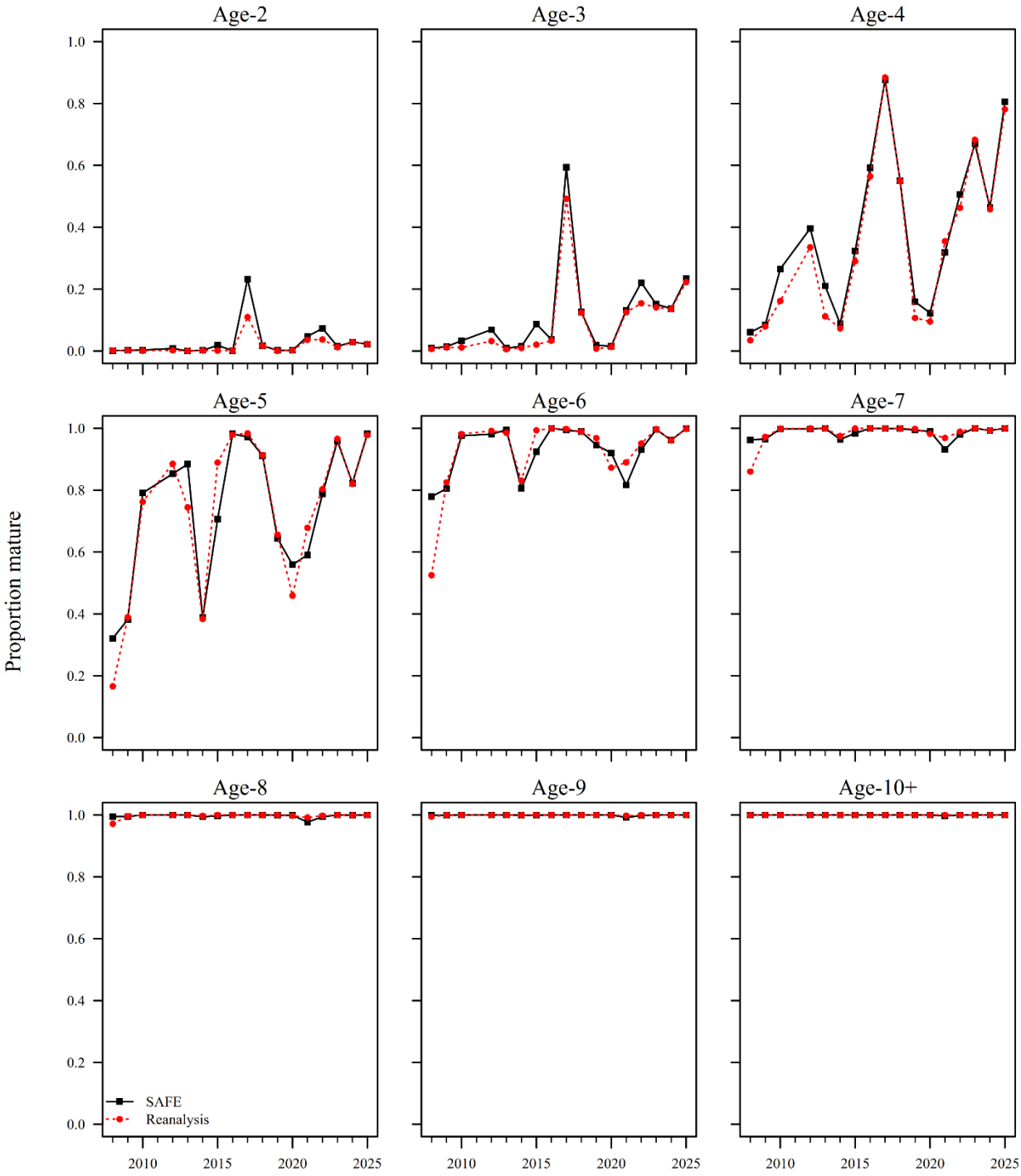

Figure 7. Proportion of mature female pollock by age based on maturity stage collected during winter surveys in 2008-2025 from the reanalyzed survey data ('Reanalysis') and estimates currently used in the GOA pollock stock assessment ('SAFE').

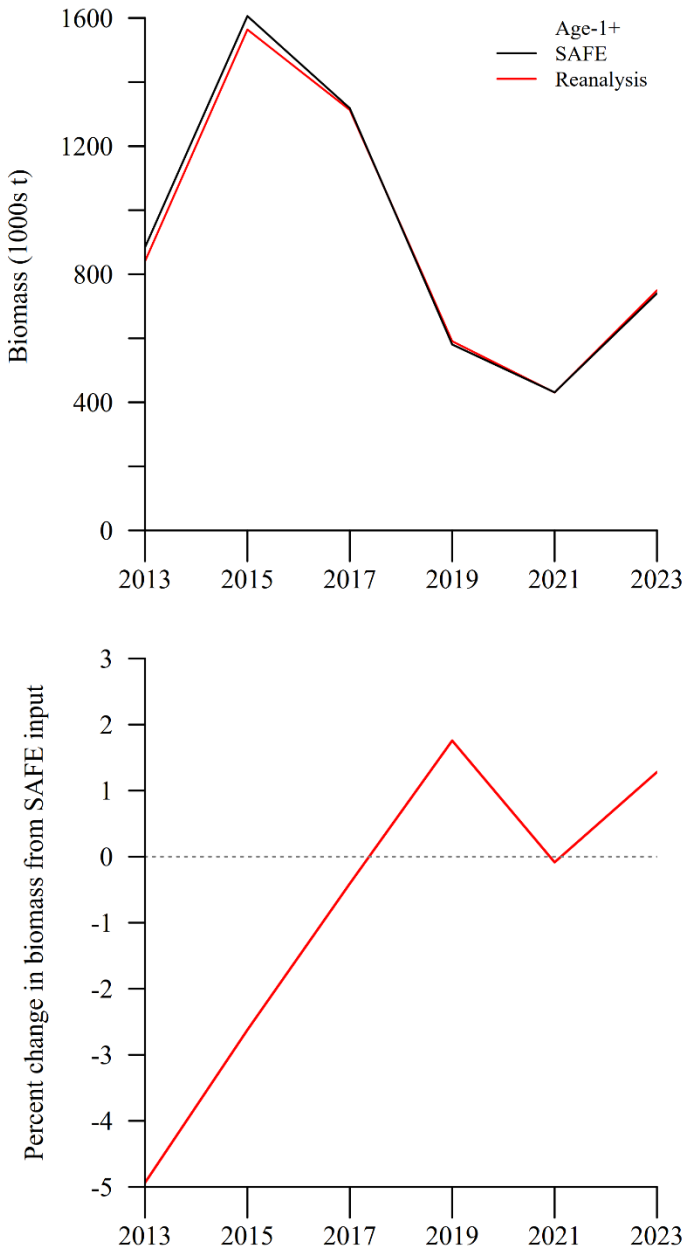

Figure 8. Abundance and biomass estimates for pollock in summer surveys from 2013-2023 (odd years only). The upper plot shows biomass time series for age-1+ pollock from reanalyzed survey data ('Reanalysis') and estimates currently used in the GOA pollock stock assessment ('SAFE'). The lower plot shows differences (%) in age-1+ pollock biomass estimates between the reanalysis and SAFE. Positive (negative) percent values indicate reanalysis estimates increased (decreased) from SAFE values.



Figure 9. Pollock numbers by age for summer surveys in 2013-2023 (odd years only) from reanalyzed survey data ('Reanalysis') and estimates currently used in the GOA pollock stock assessment ('SAFE'). Bubble sizes are scaled within years.

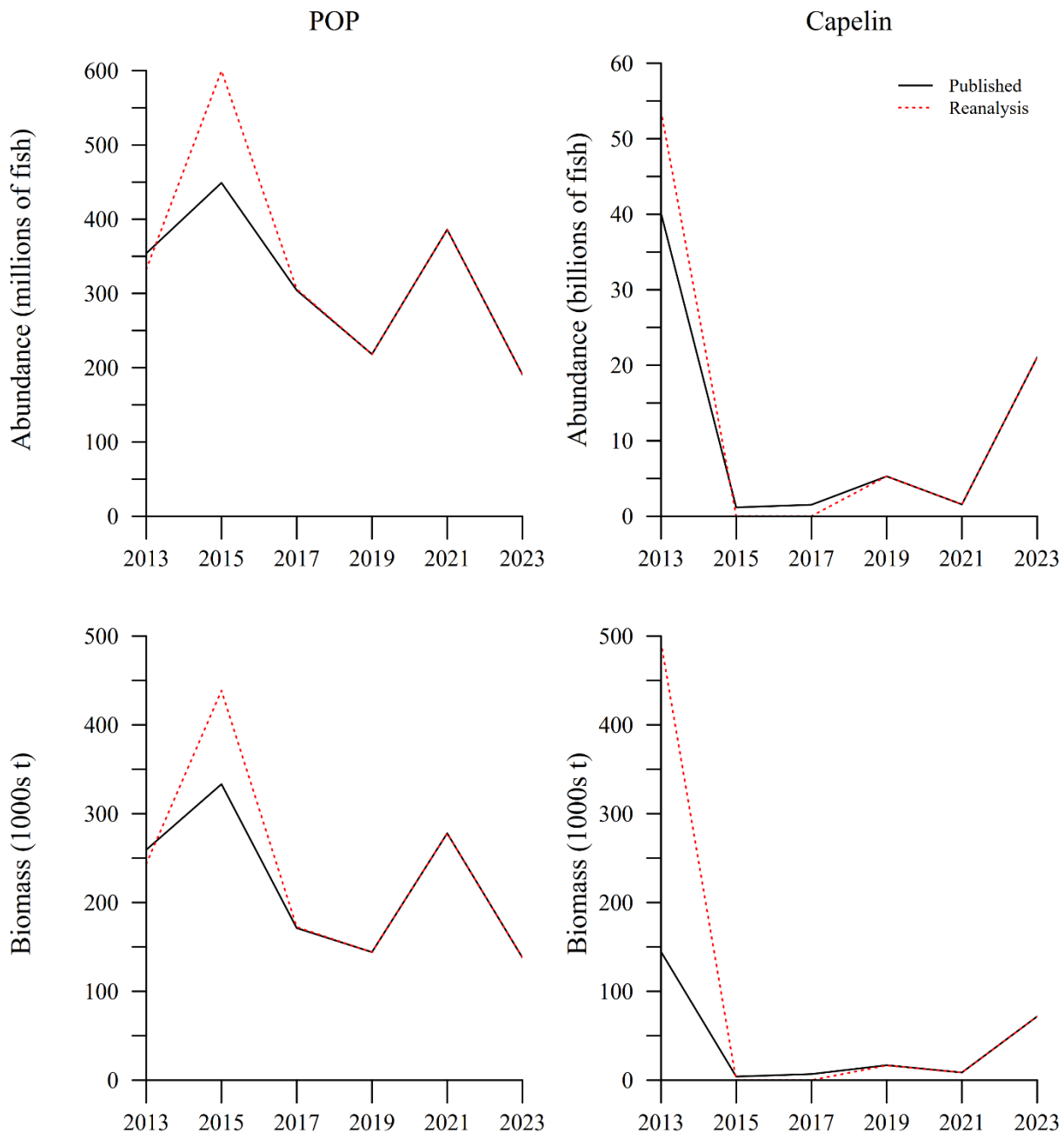

Figure 10. Abundance (top) and biomass (bottom) estimates for Pacific ocean perch (POP, left) and capelin (right) in summer surveys from 2013-2023 (odd years only) from reanalyzed survey data ('Reanalysis') and estimates published in each survey's cruise report ('Published'). Note, capelin biomass estimates were not produced in historical published analyses for 2015 and 2017 due to exceptionally low abundance, and published survey estimates in 2021 and 2023 match those from the reanalysis.

Appendix I. Specimen Weighting

Pollock specimen data collected from catches was used to compute length-weight and age-length keys, with the following occurring after the age structures were processed and made available for analysis. A weighting factor was computed for each specimen to express how it represented the total surveyed population in subsequent computations. The weighting factor is based on catch sub-sampling, trawl selectivity, and the total pollock abundance in the area that was represented by the particular haul location (e.g., the nearest-haul stratum).

This process consisted of two scalars; the first scalar is the proportion of all the fish entering the mouth of the trawl that each specimen represents (*P*), which accounts for catch subsampling for specimens by age subcategory and also for length-dependent retention by the trawl, or trawl selectivity (*S*). *P* is computed as:

$$P_{i,a} = \frac{\left(R_a * {}^{1}/_{S_l}\right)}{N}\,, \qquad \text{(Eq. } ii\text{)}$$

where *i* is the individual fish which has a length of *l*, *R* is the sampling expansion (1 / sampling fraction) for size subcategory *a* (number caught in codend/number sampled), and *N* is the total number that entered the trawl mouth (total codend catch adjusted for escapement). The number sampled is dependent on what measurement is being weighted; if age data is being weighted, only fish sampled for age structures are counted. It is assumed that the sampled fish are a random representation of all fish within the subcategory.

The second weighting component is the local abundance as estimated by the survey, computed as the total number of pollock estimated in the nearest-haul stratum (*A*) associated with a particular trawl sample *h*. The total weight factor (*W*) for an individual specimen *i* is the product for the two scalars, or

$$W_{i,h} = P_{i,h} * A_h\ . \qquad \text{(Eq. } ii\text{)}$$

Finally, the weight factors are scaled to the number of specimen samples as

$$\widehat{W}_{i,h} = \frac{W_{i,h}}{\left(\sum_{i,h} W_{i,h}\right)} \times n\,, \qquad \text{(Eq. } iii\text{)}$$

where n is the total number sampled for a given quantity in the entire survey. While this adjustment does not affect the maturity-at-length and maturity-at-age model coefficient point estimates, it does influence the variance estimates. $\widehat{W}$ is then inserted as a weighing factor in the equations used for estimating the length-weight key, the age-length key, and the parameters of the maturity at length and maturity at age models.

Length-weight keys

Biomass was computed from abundance using the weighted mean weight-at-length at from all pollock specimens ($\bar{G}_l$), as

$$\bar{G}_l = \frac{\sum_i \left(G_{l.i} * \widehat{W}_i\right)}{\sum_i \left(\widehat{W}_i\right)}\,, \qquad \text{(Eq. } iv\text{)}$$

where *G* is the individual organism weight for individual *i* at 1-cm interval *l*, where at least five individuals at length *l* were sampled. When < 5 fish occurred within a 1-cm length interval, weight at a given length interval was estimated from a weighted linear regression of the natural logs of the length and organism weight data and corrected for a small bias due to back-transformation (Miller 1984, De Robertis and Williams 2008).

Age-length keys

Age-length keys were used to estimate proportion-at-age and applied to the survey estimates of numbers-at-length and biomass-at-length to estimate numbers and biomass at age. This computation also used weighting factors and was computed as follows:

$$Q_{a,l} = \frac{\sum_{a,l} \widehat{W}_{a,l}}{\sum_{l} \widehat{W}_{l}}\,, \qquad \text{(Eq. } v\text{)}$$

where $Q_{a,l}$ is the proportion of all specimens at length *l* that are of age *a*, $\widehat{W}_{a,l}$ is the weighting factor for an individual specimen of age *a* and length *l*. For estimates at lengths where no otolith specimens were collected, the proportion-at-age was estimated using a Gaussian-model approach based on historical age-at-length data (2000-2014).

Maturity computations

Maturity-at- length and maturity-at-age for female pollock were estimated using weighting factors by providing these as a separate input to the generalized linear model (GLM) used to fit maturity state as a function of length or age. Specifically, the GLM model fitting functions (using the R statistical software or Python language equivalent) accept a weighting input of the same length as the maturity observations, which then adjust the impact each data point has on the final function parameter fit.

Additional maturity stage metrics, such as sex-specific proportion by maturity stage, were also computed using weighting factors as

$$M_{s,x} = \frac{\sum_{s} \widehat{W}_{s,x}}{\sum \widehat{W}_{x}}\,, \qquad \text{(Eq. } vi\text{)}$$

where $M_{s,x}$ is the proportion at stage *s* and sex *x*. The proportion of females in a spawning or spent condition was similarly computed where instead of a particular stage, the 'Spawning' and 'Spent' stages were combined for female fish only. For computing these values, the specimen data are limited to only individuals > 40 cm, with the weights computed separately to accommodate this specific size cutoff.

This weighting method is general and could be applied to any acoustic-trawl (AT) survey, and/or to biomass and abundance estimates of any species.

Impact on biomass and maturity estimates

To examine the impact of using weighted length-weight and age-length keys on biomass estimates, an additional analysis was conducted which was identical to the updated analysis presented in the main report with the exception of the length-weight and age-length keys. This comparison analysis (referred to as the

'unweighted' analysis here) used length-weight and age-length keys that were not created using weighting factors, while the updated analysis presented in the main report (referred to as the 'weighted' analysis here) relied on keys created using weighting factors. The use of weighted keys had a very minimal impact on total survey estimates in both the summer Gulf of Alaska AT survey (hereafter summer survey) time series (mean change in total biomass -0.07%, range -2.28-0.99%, n = 6 surveys) and the winter Shelikof Strait AT survey (hereafter winter survey) time series (mean change in total biomass 0.06%, range -1.32-1.17%, n = 17 surveys). This impact was slightly more apparent in younger age classes but had a minimal effect on total biomass in all cases (Fig. A1).

A similar comparison was conducted for maturity-at-age and maturity-at-length. In both cases, the impact of using weighting factors as an input to the generalized linear models fitting maturity state was again minimal. In the winter survey time series, the length at 50% maturity was generally slightly lower when weighting factors were included (mean -0.88 cm fork length shorter, range -3.78-0.46 cm; Fig. A2). The age at 50% maturity was slightly younger when weighting factors were included (mean -0.17 years younger, range -1.11-0.35 years; Fig. A2). However, in nearly all years, 95% confidence intervals on estimates overlap between estimates from weighted and unweighted specimen data, and absolute differences between estimates are minor (Fig. A2).

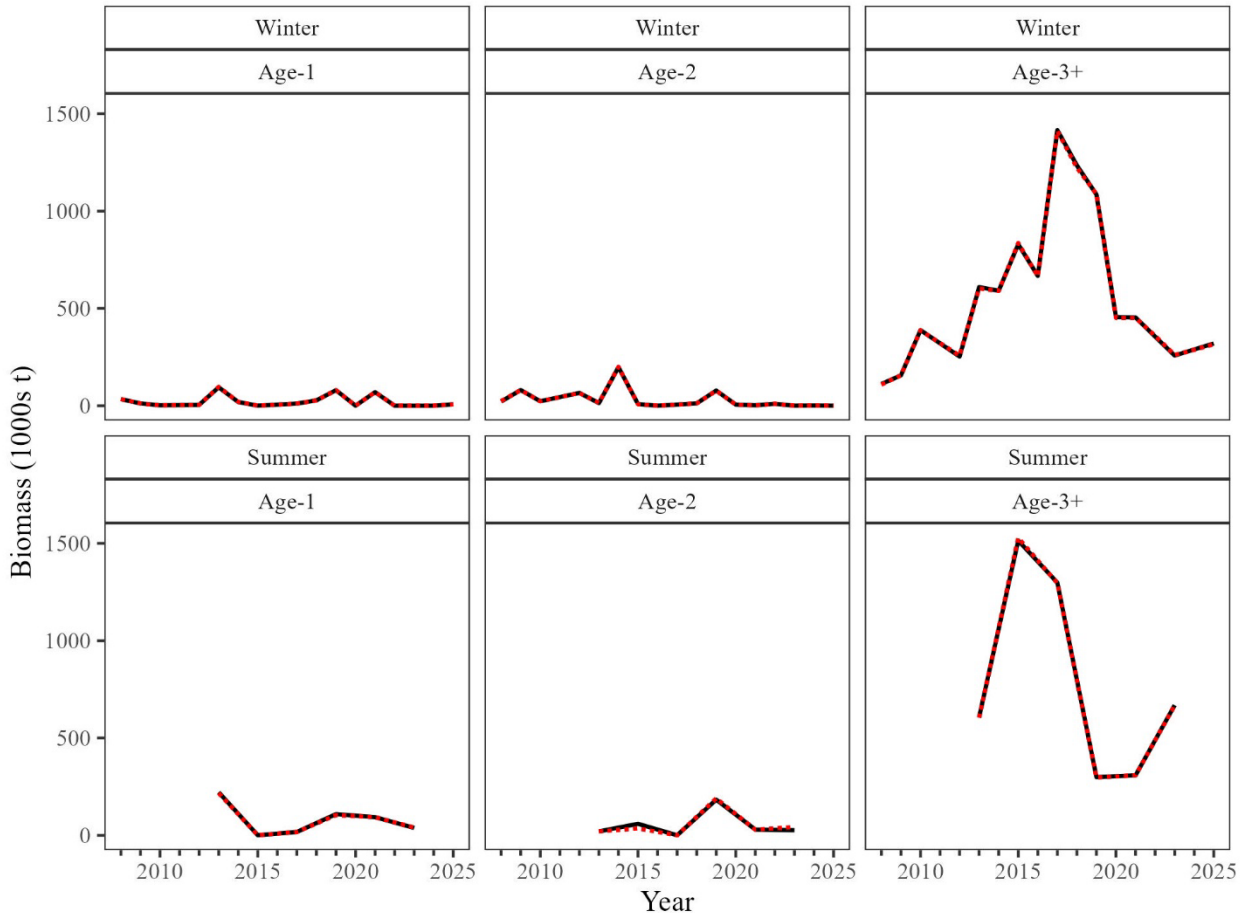

Figure A1.1. Time series of biomass estimates in the winter Shelikof Strait acoustic-trawl survey and the summer Gulf of Alaska acoustic-trawl survey generated using length-weight and age-length keys generated using weighting factors (red dashed line) and age-length keys generated without using weighting factors (black solid line). Estimates were generated for three pollock age classes: age-1, age-2, and a combined age-3+ class.

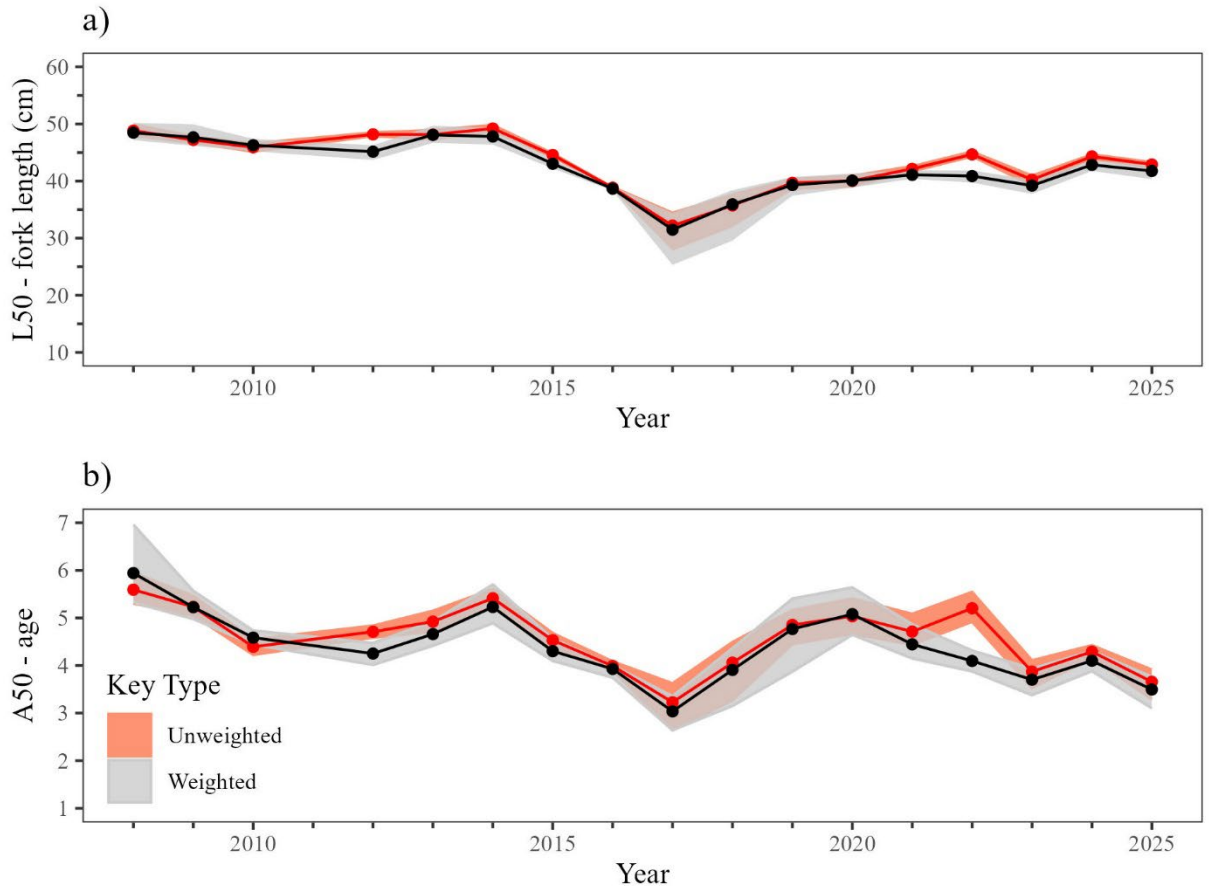

Figure A1.2. Time series of a) L50 and b) A50 estimates from the winter Shelikof Strait acoustic-trawl survey estimated using weighting factors in modeling maturity state ('Weighted') and without using weighting factors ('Unweighted'). Shaded area indicates 95% confidence intervals.

Appendix II. Abundance Calculations

The abundance of target species was calculated by combining the echosounder measurements with size and species distributions from trawl catches and TS-length relationships from the literature (see De Robertis et al. 2017b for details). The echosounder measures volume backscattering strength, which is integrated vertically to produce the nautical area scattering coefficient, s_A (units of m^2 nmi^{-2}; MacLennan et al. 2002). The backscatter from an individual fish of species s at length l is referred to as its backscattering cross-section, $\sigma_{bs_{s,l}}$ (m^2), or in logarithmic terms as its target strength, $TS_{s,l}$ (dB re 1 m^2):

$$TS_{s,l} = 10\log_{10}\left(\sigma_{bs_{s,l}}\right) . \qquad \text{(Eq. } i\text{)}$$

The numbers of individuals of species s in length class l ($N_{s,l}$) captured in the nearest haul h were used to compute the proportion of acoustic backscatter associated with each species and length. First, the number of individuals in the catch were converted to a proportion ($P_{s.l,h}$):

$$P_{s,l,h} = \frac{N_{s,l,h}}{\sum_{s,l} N_{s,l,h}} , \quad \text{where} \sum_{s,l} P_{s,l,h} = 1 . \qquad \text{(Eq. } ii\text{)}$$

In analyses where trawl selectivity was considered, the selectivity-corrected numbers $N_{s_{corr},l,h}$ were used in place of $N_{s,l,h}$ in Eq. ii. This correction corrects the catch for trawl escapement. The corrected catch is that expected for an unselective sampling device. Refer to the main text for a description of the selectivity corrections applied.

The mean backscattering cross-section (an areal measure of acoustic scattering in m^2; MacLennan et al 2002) of species s of length class l is:

$$\sigma_{bs_{s,l}} = 10^{\left(0.1 \cdot TS_{s,l}\right)} , \qquad \text{(Eq. } iii\text{)}$$

where TS is the target strength (dB re 1 m^2) of species *s* at size *l* (Table 1).

The proportion of backscatter from species s of length class l in haul h ($PB_{s,l,h}$) is computed from the proportion of individuals of species s and length class l estimated from haul h ($P_{s,l,h}$) and their backscattering cross-section:

$$PB_{s,l,h} = \frac{P_{s,l,h} \cdot \sigma_{bs_{s,l}}}{\sum_{s,l}\left(P_{s,l,h} \cdot \sigma_{bs_{s,l}}\right)} . \qquad \text{(Eq. } iv\text{)}$$

The measured nautical area scattering coefficient (s_A) at interval i was allocated to species s and length l as follows:

$$s_{A_{s,l,i}} = s_{A_i} \cdot PB_{s,l,h} , \qquad \text{(Eq. } v\text{)}$$

where haul h is the nearest haul within a stratum assigned to represent the species composition in a given 0.5 nmi along-track interval i. The nearest geographic haul was determined by using the great-circle distance to find the nearest trawl location (defined as the location where the net is at depth and begins to

catch fish) out of the pool of hauls assigned to the same stratum (see above for details) closest to the start of interval i.

The abundance of species of length l in an area encompassing a series of transect intervals i was estimated from the area represented by that interval (A_i, nmi^2), the mean areal backscatter attributed to species s in given length/size class l ($s_{A_{s,l,i}}$, m^2 nmi^{-2}), and mean backscattering cross-section of species s at that size ($\sigma_{bs_{s,l}}$ m^2) as follows:

$$\text{Numbers-at-length } l\text{: } N_{s,l} = \sum_i \left(\frac{s_{A_{s,l,i}}}{4\pi\sigma_{bs_{s,l,i}}} \times A_i \right) \qquad \text{(Eq. } vi\text{)}$$

$$\text{Biomass-at-length } l\text{: } B_{s,l} = \sum_i \left(W_{s,l} \times N_{s,l,i} \right) \ , \qquad \text{(Eq. } vii\text{)}$$

where $W_{s,l}$ is the mean weight-at-length for species s in each 1-cm length l derived from length-weight regressions. In the case of pollock, when five or more individuals were measured within a length interval, the mean weight-at-length was used. Otherwise (i.e., for length classes of pollock with < 5 weight measurements, or other species), weight-at-length was estimated using a linear regression of the natural log-transformed length-weight data (De Robertis and Williams 2008).

The abundance-at-age was computed from $Q_{s,l,j}$, the proportion of j-aged individuals of species s in length class l, and the abundance of that species and age class in each surveyed interval follows:

$$\text{Numbers-at-age } j\text{: } N_{s,j} = \sum_i \left(Q_{s,l,j} \times N_{s,l} \right) \qquad \text{(Eq. } viii\text{)}$$

$$\text{Biomass-at-age } j\text{: } B_{s,j} = \sum_i \left(Q_{s,l,j} \times B_{s,l} \right) \ . \qquad \text{(Eq. } ix\text{)}$$