Bottom trawl survey age and length composition input sample sizes for stocks assessed with statistical catch-at-age assessment models at the Alaska Fisheries Science Center

by

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# ABSTRACT

At the Alaska Fisheries Science Center (AFSC) a number of fish stocks are assessed using statistical catch-at-age models which integrate various sources of information to inform estimation of population dynamics that aid in the management of the fisheries that target these stocks. Two important sources of information are age and length composition data, from both fishery-independent (survey) and fishery-dependent sources. When used in statistical catch-at-age models, age and length composition data require determining *a priori* the ‘input sample size’ to weight the relative information content of the composition data against other data sources fit within the assessment model. We developed an R-package that uses bootstrap methods to estimate input sample size for age and length composition data from bottom trawl surveys conducted by the AFSC in the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska. Here we present annual input sample size estimates for length and age compositions (including sex-specific and sex combined compositions, and sub-regional compositions within the Gulf of Alaska) historically collected during Alaska bottom trawl surveys. These newly available input sample size estimates provide an objective method that follows the sampling design of the bottom trawl surveys to provide inputs for fishery stock assessments. We recommend that these input sample size estimates become a standard bottom trawl survey data product that are available to assessment authors for inclusion into AFSC fishery stock assessments.

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# INTRODUCTION

Under the North Pacific Fishery Management Council (NPFMC) Fishery Management Plan (FMP) for the Eastern Bering Sea, Aleutian Islands, and Gulf of Alaska, Tier 1–3 stocks use statistical catch-at-age assessment models to estimate population and management quantities (NPFMC 2020a, 2020b). While these models can vary in their specific implementation across stocks (i.e., due to differences in parameterization, error structures, or data availability), a critical and ubiquitous data component of this structure of assessment model is the age and length composition data. Age and length composition data are collected on both fishery-independent (e.g., bottom trawl or longline surveys) and fishery-dependent platforms, providing critical data to assessments in order to track population changes over time. The National Oceanic and Atmospheric Administration’s (NOAA) Alaska Fisheries Science Center (AFSC) operates fishery-independent bottom trawl surveys (Stauffer 2004) that span most of the continental shelf for federal waters off Alaska (i.e., the Bering Strait, the eastern Bering Sea (EBS), the Aleutian Islands (AI), and the Gulf of Alaska (GOA)) These surveys provide age and length composition data for 26 stocks (or stock complexes) assessed with statistical catch-at-age models.

At the AFSC, age and length frequency sampling from bottom trawl surveys is used in stock assessment models in a multitude of ways to inform estimates of population abundance that are subsequently used to set management quantities. The most common use of length frequency sampling is to derive estimates of the population abundance-at-length that are used in conjunction with an age-length key to estimate population estimates at age, which are then converted to age composition estimates (i.e., proportions-at-age) and fit in the model (e.g., Monnahan et al. 2021, Spencer and Ianelli 2022). Length frequency samples are also used in many assessments in a conditional-age-at-length framework (Rudd et al. 2021) that both fits the length compositions and enables estimation of growth internally to the assessment (e.g., McGilliard and Palsson 2017). In some cases, where age data is not available, length frequency samples which have been expanded to population abundance-at-length estimates are used directly as composition data within the assessment (e.g., McGilliard et al. 2019). Finally, recent developments have incorporated length frequency samples in a model-based framework to estimate length and age composition estimates (Thorson and Haltuch 2019, Ianelli et al. 2021, Thompson et al. 2021).

Predominantly, the multinomial likelihood is used to fit age and length composition data at the AFSC (e.g., Bryan and Palsson 2021), while recently the Dirichlet-Multinomial has also been explored (e.g., Barbeaux et al. 2022). A common requirement, regardless of the likelihood employed, is a pre-determination of the input sample size that is used to ‘weight’ each year’s age or length composition data. This weight subsequently influences the precision of the assessment model’s fit. Over the years, a variety of approaches have been used at AFSC to set the input sample size in stock assessments. These include selecting a constant value (e.g., Hulson et al. 2022), relating the input sample size to the number of hauls from which age or length composition data were collected (e.g., Spencer and Ianelli 2022), relating the input sample size to the nominal sample size (e.g., Hulson et al. 2021), or relating the input sample size to some combination of hauls and nominal sample size (e.g., Williams et al. 2022). Overall, there is no general or consensus method that is agreed upon at the AFSC to determine input sample size.

Stewart and Hamel (2014) introduced a method in which bootstrap techniques were used to resample age and length composition data that provides an estimate of the input sample size that can be used within assessment models. The primary advantage of this method is that it provides an objective framework from which estimates of input sample size are obtained that mimics the sampling design employed (i.e., design-based estimation), either on a fishery-independent survey or on fishery-dependent platforms. Here, we apply the methods of Stewart and Hamel (2014) to obtain historical estimates of input sample size for age and length composition data obtained by the AFSC bottom trawl surveys in the EBS, AI, and GOA for all stocks assessed at AFSC with statistical catch-at-age assessment models. The main objectives of this technical memorandum are to 1) document methods used by AFSC for expanding length and age collections to population abundance estimates (which are subsequently used as composition data in stock assessments), 2) present stock-specific results of historical input samples size from AFSC bottom trawl surveys for Tier 3 stocks, and 3) record methods for estimating input sample sizes of survey-based age and length compositions using a two-stage bootstrapping approach.

# MATERIALS AND METHODS

## Survey Data

Data collection for each AFSC groundfish survey is described in respective NOAA Technical Memorandum (EBS: Lauth et al. 2019, AI: von Szalay et al. 2017, GOA: von Szalay and Raring 2018). Length frequency protocols and a recent analysis of sex-specific length frequency data are further described in Hulson et al. (2023). To facilitate age estimation, individual fish are processed at sea; sex, length and weight are recorded, and sagittal otoliths are extracted and returned to the AFSC Age and Growth laboratory for age determination. Survey age sampling protocols are species-specific and follow 1 of 2 paradigms: 1) a stratified collection that is distributed over both the spatial grid of the survey area and the expected size range of the species; or 2) a small subsample (3-6 fish, species-dependent) collected randomly (i.e., no size stratification) per trawl. The protocol for some species has changed over the time series, which has followed a trend of transitioning from protocol 1) (stratified sample) to protocol 2) (random sample).

Species collected on each survey that are assessed with statistical catch-at-age models were selected to be included in this analysis (Tier 3 stock assessments, Table 1). Data from AFSC bottom trawl surveys conducted in the EBS shelf (1982 to present), EBS slope (2002, 2004, 2008, 2010, 2012, and 2016), AI (1991 to present), and GOA (1990 to present) that are employed in the stock assessment models for each respective area were used in this study to estimate input sample size with a bootstrap estimator. The bootstrap estimator is designed to be a standardized tool for generating input sample sizes and the input sample sizes generated with it are intended to be used to weight length and age composition data in future stock assessments.

## Expanding Length Frequency to Population Abundance-at-Length

Length frequency samples collected by the AFSC bottom trawl surveys are expanded by catch and stratum area using a design-based approach in order to obtain estimates of population abundance-at-length (this approach is also detailed in Hulson et al. 2023; we include the description here as well in order to provide a source for both the length and age expansions for reference). This is often referred to as the ‘first stage expansion’ and is a common method to obtain population abundance estimates at length from area-swept survey data (Miller and Skalski, 2006). Population abundance-at-length is computed for three sex categories at the stratum level: males, females, and unsexed; these estimates are then summed across strata to obtain the population abundance-at-length for the management-scale region (i.e., EBS, AI, or GOA). However, these estimates can also be summed to any sub-region level.

In the first step of this process, we compute the overall population numbers in year-*y* within stratum-*st* () with

where is the area of stratum-*st* (in km2), and is the average catch per unit effort of numbers captured across the hauls within a stratum-*st* for year-*y*, given by

where is the number of hauls conducted in stratum-*st* in year-*y*, is the catch per unit effort (i.e., numbers caught divided by effort) within a haul-*h*, is the catch (in numbers) in haul-*h* for stratum-*st* in year-*y*, and is the effort in haul-*h* for stratum-*st* in year-*y*. Effort is computed as the net width multiplied by the time on bottom (i.e., the area swept by the haul in km2). Next, the ratio of catch per unit effort among hauls () is computed by

. We then compute the sex-specific ratio of the total number of lengths sampled within a haul by length bin () with

where is the length frequency sampled, in numbers, by sex-*sx*, length-*l*, stratum-*st*, and year-*y*. In some cases there are hauls that have catch for a species but no length frequency data were collected. In this case, variant (2) of equation (4) is applied in order to account for the unknown length frequency in these hauls. Otherwise, if length frequency samples are obtained, case (1) is applied. Finally, we estimate the sex-specific population abundance-at-length within strata-*st* with

and to obtain the sex-specific estimates of population abundance-at-length in a management area one would simply sum across strata.

## Expanding Specimen Collections to Population Abundance-at-Age

In the second stage expansion the sex-specific estimates of population abundance-at-length are used to estimate sex-specific population abundance-at-age. The annual specimen data that is collected during the survey, which includes observations of age-at-length, are first populated into sex-specific numbers-at-age and length (). Next, the sex-specific numbers-at-age and length are converted to sex-specific proportions of age-at-length (i.e., age-length key) with

The proportions of age-at-length are then expanded to population abundance-at-age with

where is the population abundance-at-length from (5) summed across strata. For specimen age data with observations of sex (either female or male), the sex-specific specimen age data are used. However, for specimen age data without observations of sex, the specimen age data is pooled across all sexes and the unsexed population abundance-at-length is then applied to the pooled specimen data to estimate unsexed population abundance-at-age.

Two general categories of special cases for several stock assessments were also included in our analysis: 1) spatially-explicit assessments, and 2) assessments for species complexes. For the majority of stocks assessed at AFSC, population abundance-at-age estimates are computed at the management area scale (e.g., the entire GOA, AI, or EBS), however, we note that there are two flatfish stock assessments that are spatially-explicit in the GOA (McGilliard and Palsson 2017, Bryan and Palsson 2021). While in the preceding equations we do not include a subscript for sub-region, population abundance-at-age can be estimated by sub-region through summing the population abundance-at-length in equation (5) across selected strata within the region that correspond to the sub-region and applying equations (6) and (7) to specimen age data that are subsetted to the sub-region. We have developed functions to estimate population abundance-at-age by sub-region, and by a combination of sub-regions within the GOA to allow for this flexibility in estimating population abundance-at-age. There are a handful of assessments conducted at AFSC that evaluate stocks at a complex level, where several species are included together in an assessment. In addition, there are two stock complexes managed by AFSC in which the species are combined and assessed within the same statistical catch-at-age model: blackspotted and rougheye rockfish in the GOA and AI (Spencer et al. 2020, Sullivan et al. 2021). Between the two management regions there are subtle differences in how the population abundance-at-age is estimated from the survey specimen age data; we have developed functions that allow for these differences and estimate population abundance-at-age for these two stock complexes. In a similar case, while not assessed as a complex, over the historical bottom trawl survey in the GOA several species codes have been used for dusky rockfish. We have also developed a custom function that estimates population abundance-at-length and -age for this case.

## Bootstrap Framework for Estimating Age and Length Composition Input Sample Size

To estimate the historical input sample sizes for age and length compositions of stocks assessed at AFSC, we developed a bootstrap framework based on the methodology outlined in Stewart and Hamel (2014). The bootstrap framework is composed of a suite of nested resampling (with replacement) protocols. Functions to run the sampling protocols were developed in a compartmentalized manner to provide for substantial flexibility in exploring desired resampling protocols. The order of operations (Figure 1) has the following schedule, with steps 1-3 being optional switches:

1. Resample hauls from the set of hauls with associated catch per unit effort (in numbers)
2. Within the resampled hauls from step 1, resample the observed length frequency data
3. Within the resampled hauls from step 1, resample the observed specimen age data
4. From the resampled length frequency data in step 2, calculate sex-specific population abundance-at-length, using equations (1) - (5)
5. From the resampled specimen age data in step 3 and the sex-specific population abundance-at-length in step 4, calculate sex-specific population abundance-at-age, using equations (6) - (7)

The bootstrap framework then repeated steps 1-5 iteratively, providing iterated sex-specific population abundance-at-length and -age that was then compared to the historical sex-specific population abundance-at-length and -age as observed by the bottom trawl surveys. We ran the bootstrap-simulation for 500 iterations, which was a level at which the variability in population abundance-at-length results had stabilized. The bootstrap-simulation was developed in R (R Core Team 2022) and is available via GitHub as an R package (<https://github.com/BenWilliams-NOAA/surveyISS>).

## Computing Effective and Input Sample Size

Effective sample size (ESS), as introduced by McAllister and Ianelli (1997), is a statistic that can evaluate the level of intra-haul correlation in composition samples that are collected on a survey (whether from age or length frequency collections). It is also a statistic that can evaluate the amount of uncertainty in an estimated composition compared to an observed composition. Effective sample size is given by

where is the estimated proportion for category-*c* (which can be either age or length or any other arbitrary category across which proportions are computed) and is the observed proportion. A higher ESS indicates less uncertainty in the composition estimates, while a lower ESS indicates more uncertainty.

In this bootstrap-simulation, we used effective sample size to calculate uncertainty in length compositions for each simulation replicate, where the underlying age and length compositions (Eqs. 1-7) derived from the historical bottom trawl surveys were treated as the observed proportions in equation (8). For each iteration of the bootstrapped survey data, we computed a sex-specific estimated proportion () that was then compared to the underlying historical sex-specific age and length composition (the effective sample size for the total age and length composition, or the sum of sex-specific population abundance-at-age and length, was also computed). Thus, for each iteration of the simulation, we computed an effective sample size that quantifies the amount of uncertainty that resulted from that iteration of sub-sampling sexed length frequency data. This resulted in distributions of effective sample size for each species, each sex, and each sub-region of interest.

Input sample size (ISS) is defined as a metric of uncertainty used in data-weighting procedures for stock assessment models. An input sample size is usually assigned to annual length and age compositions in the model fitting process, but there are a variety of methods for calculation – many of which are closely related to the information content of the data product in question (see Introduction for list). To summarize uncertainty across bootstrap replicates of ESS, we calculated ISS as the harmonic mean of effective sample size across bootstrap iterations

where is the annual input sample size, is the effective sample size for iteration-*i*, and *I* is the total number of iterations for which the bootstrap procedure is run. The harmonic mean has been shown to reduce bias in recovering the true sample size in simulations for a multinomial distribution. Due to this reduction in bias the harmonic mean has also been recommended to determine the ISS that is used in stock assessment models to fit compositional data (Stewart and Hamel 2014). Herein, when we use the term ‘effective sample size’ or ‘ESS’ we are referring to the effective sample sizes that were computed for each iteration of the bootstrap-simulation from equation (8), when we use the term ‘input sample size’ or ‘ISS’ we are referring to the harmonic mean of the iterated effective sample sizes from equation (9).

# RESULTS

Average age and length composition nominal sample sizes (i.e., number of length samples collected on deck or number of otoliths aged in the laboratory rounded to the nearest 10s for age and 100s for length) for the bottom trawl surveys evaluated are shown in Tables 2 - 3. Across the surveys, average sex-specific length frequency? nominal sample size ranged from 300--35, 600 samples per year, where the total length frequency? nominal sample size (for all sexes combined) ranged from 700--82,500 per year. The most frequently sampled species for length frequency within in eastern Bering Sea shelf survey were walleye pollock, yellowfin sole, northern rock sole, and arrowtooth flounder, and while arrowtooth flounder, kamchatka flounder, and Pacific ocean perch were the most frequently sampled in the eastern Bering Sea slope survey (Table 2). The most frequently sampled species for length frequency within the Aleutian Islands bottom trawl survey were Pacific ocean perch, walleye pollock, and arrowtooth flounder and in the Gulf of Alaska bottom trawl survey were arrowtooth flounder, walleye pollock, flathead flounder, and Pacific ocean perch (Table 3). Across the surveys, average sex-specific otolith nominal sample sizes ranged from 130--850 per year, while the total otolith nominal sample size (for all sexes combined) ranged from 290-- 1,550 per year. It was commonly the case that the most frequently sampled species in each survey for otoliths were the most frequently sampled species for length frequency, exceptions being… .

The age and length composition ISS output of the surveyISS package is structured by year, species (using the AFSC survey species code), sex, and region (an example of the output is shown in Table 4). Using walleye pollock total (combined sex) age composition as an example, ISS is produced by year for each survey the stock is sampled from (Figure 2). Sex specific yellowfin sole age composition ISS from the EBS shelf survey is shown in Figure 3. For all species sampled in each survey, the range and median of total and sex-specific length composition ISS across survey years is shown in Figure 4, and age composition ISS is shown in Figure 5. Sub-regional ISS for age and length composition can also be estimated within the GOA survey (Figures 6 and 7). These results show that the length composition ISS ranged from the hundreds to thousands and were larger than the age composition ISS. Additionally, the sex-specific ISS for either length or age composition were smaller than the ISS for the total age compositions. For both the age and length compositions ISS, the magnitude was species-specific, and was closely related to the overall sampling intensity for age and length observations on the surveys.

For both age and length compositions (including sex-specific composition data), the ISS was smaller than the nominal sample sizes (Figure 8, shown for age compositions) and there was a generally increasing trend between nominal sample size and input sample size with gadids being the exception. Comparing the age composition ISS to the number of hauls from which age samples were obtained did not result in a strong relationship for the flatfish and gadids sampled in the AFSC surveys, but there was an increasing trend for the rockfish species (Figure 9). There was an increasing trend between age composition ISS per sampled haul and the number of samples per sampled haul for most of the species sampled; this trend was most striking for the flatfish species (Figure 10). The ISS for age compositions sampled during AFSC surveys was 2.6 per sampled haul for flatfish, 1.7 per sampled haul for gadids, and 1.5 per sampled haul for rockfish. This translated to 0.36 ISS per age sample for flatfish, 0.22 ISS per age sample for gadids, and 0.26 ISS per age sample for rockfish.

# DISCUSSION

Here we have presented an application of the method outlined in Stewart and Hamel (2014) to produce annual age and length composition ISS for fishery stocks assessed by AFSC with statistical catch-at-age models. We present results for the bottom trawl surveys conducted in the EBS shelf, slope, AI and GOA by AFSC with the hope that this will motivate the adoption of a standardized approach akin to ours for setting initial composition weights in future assessments. This application produces total (combined sex) and sex-specific ISS, as well as sub-region ISS within the GOA bottom trawl survey. We found that the magnitude of age and length compositions ISS can vary across stocks and years, but in general age composition ISS ranged from the tens to hundreds (with an average age ISS of around 100 across all years and species) and length composition ISSs ranged from the hundreds to thousands (with an average length ISS of around 1,000 across all years and species). This is not surprising, given that the magnitude of sampling for length frequency is much larger than sampling for ages. We also found that the sex-specific ISS is smaller than the total (combined sex) ISS, which again, is not surprising given the relatively smaller sampling intensity for sex-specific samples. We will note from this result that care and intentionality should be taken when developing and implementing sex-specific assessments given this increase in uncertainty in composition data.

At the AFSC, as noted previously, there are a myriad of approaches employed to set ISS for age and length composition data used in assessments. There is no generally agreed upon approach, however, a common approach that has been implemented is to set ISS as some function of the number of hauls. This follows from a result of Pennington et al. (2000) who found the age composition ISS to be one per sampled haul. Herein we find that the average age composition ISS per haul by species group (gadid, flatish, and rockfish) to be larger than one per sampled haul. We also find that there is no clear relationship between the number of sampled hauls and the magnitude of ISS, particularly for gadids and flatfish. There was, however, a stronger trend for rockfish. It is unclear as to the consequence of ISS misspecification in AFSC assessments that use the number of sampled hauls as a proxy for ISS, as ISS misspecification can lead to biased model results (Stewart and Monnahan 2017, Xu et al. 2020). We note that the results of the analysis conducted here do not strongly support the approach of using hauls as a proxy due to the large uncertainty and lack of correspondence when comparing ISS to the number of sampled hauls. The results of this analysis showed an increasing trend between the age composition ISS per haul and the number of ages sampled per haul, however, we support the approach of increasing the number of hauls sampled from rather than reducing the number of hauls in order to increase sampling on any given haul (e.g., Siskey et al. 2023).

A strength of the methodology presented by Stewart and Hamel (2014) is that it provides an objective method that produces estimates of ISS that follow from the sampling design employed (i.e., design-based estimator). As such, this approach has been adopted in a number of assessments, both internationally and domestically. For example, this bootstrap approach has been applied to weight compositional data within the Pacific halibut stock assessment performed by the International Pacific Halibut Commission (Stewart and Allan 2022). If adopted for assessments conducted at AFSC, this approach would provide an objective and unifying method to set ISS when weighting compositional data. Further analysis to be developed and conducted includes constructing methods that apply the bootstrap approach to fishery-dependent age and length composition used in AFSC assessments. We recommend that the surveyISS package be adopted and further developed by assessment and survey programs at AFSC so that bootstrap derived ISS is a standard data product available to scientists conducting assessments with statistical catch-at-age models at AFSC.

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Table 1. -- Species assessed at the Alaska Fisheries Science Center that were evaluated in the bootstrap analysis for bottom trawl survey length and age composition input sample size (AI - Aleutian Islands, EBS - Eastern Bering Sea, GOA - Gulf of Alaska)

| Species | Scientific name | Survey evaluated |
| --- | --- | --- |
| Alaska plaice | *Pleuronectes quadrituberculatus* | EBS shelf |
| arrowtooth flounder | *Atheresthes stomias* | AI, EBS shelf, EBS slope, GOA |
| Atka mackerel | *Pleurogrammus monopterygius* | AI |
| Dover sole | *Microstomus pacificus* | GOA |
| Dusky rockfish | *Sebastes ciliatus* | GOA |
| flathead sole | *Hippoglossoides elassodon* | EBS shelf, GOA |
| Greenland turbot | *Reinhardtius hippoglossoides* | EBS shelf, EBS slope |
| Kamchatka flounder | *Atheresthes evermanni* | AI, EBS shelf, EBS slope |
| northern rock sole | *Lepidopsetta polyxystra* | EBS shelf, GOA |
| northern rockfish | *Sebastes polyspinis* | AI, GOA |
| Pacific cod | *Gadus macrocephalus* | AI, EBS shelf, GOA |
| Pacific ocean perch | *Sebastes alutus* | AI, EBS slope, GOA |
| REBS rockfish complex | *Sebastes aleutianus* | AI, GOA |
| rex sole | *Glyptocephalus* | GOA |
| sablefish | *Anoplopoma fimbria* | GOA |
| southern rock sole | *Lepidopsetta billineta* | GOA |
| walleye pollock | *Gadus chalcogrammus* | AI, EBS shelf, GOA |
| yellowfin sole | *Limanda aspera* | EBS shelf |

Table 2. -- Average age (a) and length (l) frequency samples for Female (F), Male (M), and Total (T, all sexes combined) collections from the Eastern Bering Sea shelf and slope bottom trawl surveys.

| Stock | Survey | F (a) | M (a) | T (a) | F (l) | M (l) | T (l) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Alaska plaice | Shelf | 250 | 160 | 410 | 5,200 | 5,100 | 10,800 |
| arrowtooth flounder | Shelf | 330 | 140 | 470 | 6,700 | 2,800 | 9,800 |
| flathead sole | Shelf | 310 | 250 | 560 | 8,100 | 8,000 | 17,200 |
| Greenland turbot | Shelf | 150 | 130 | 290 | 300 | 300 | 700 |
| Kamchatka flounder | Shelf | 260 | 220 | 480 | 900 | 900 | 1,800 |
| northern rock sole | Shelf | 260 | 190 | 460 | 14,100 | 14,300 | 29,100 |
| Pacific cod | Shelf | 540 | 520 | 1,060 | 6,000 | 6,200 | 13,300 |
| walleye pollock | Shelf | 740 | 680 | 1,530 | 28,700 | 29,400 | 82,500 |
| yellowfin sole | Shelf | 430 | 320 | 750 | 17,300 | 11,000 | 29,800 |
| arrowtooth flounder | Slope | 390 | 150 | 540 | 4,600 | 1,100 | 5,800 |
| Greenland turbot | Slope | 240 | 250 | 490 | 600 | 1,000 | 1,600 |
| Kamchatka flounder | Slope | 370 | 300 | 660 | 1,300 | 1,900 | 3,300 |
| Pacific ocean perch | Slope | 210 | 190 | 400 | 1,400 | 1,800 | 3,200 |

Table 3. -- Average age (a) and length (l) frequency samples for Female (F), Male (M), and Total (T, all sexes combined) collections from the Aleutian Islands (AI) and Gulf of Alaska (GOA) bottom trawl surveys.

| Stock | Survey | F (a) | M (a) | T (a) | F (l) | M (l) | T (l) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| arrowtooth flounder | AI | 560 | 360 | 920 | 35,600 | 17,100 | 54,100 |
| Dover sole | AI | 210 | 190 | 390 | 2,500 | 3,200 | 6,100 |
| Dusky rockfish | AI | 230 | 200 | 430 | 1,000 | 900 | 2,000 |
| flathead sole | AI | 290 | 240 | 540 | 10,800 | 9,800 | 21,300 |
| northern rockfish | AI | 240 | 210 | 450 | 2,000 | 1,800 | 3,900 |
| Pacific cod | AI | 320 | 300 | 620 | 5,300 | 5,200 | 10,900 |
| Pacific ocean perch | AI | 550 | 550 | 1,100 | 9,000 | 10,200 | 20,500 |
| REBS rockfish complex | AI | 280 | 280 | 560 | 1,600 | 1,700 | 3,400 |
| walleye pollock | AI | 710 | 600 | 1,330 | 13,700 | 11,400 | 28,200 |
| arrowtooth flounder | GOA | 290 | 240 | 520 | 6,300 | 3,900 | 10,600 |
| Atka mackerel | GOA | 320 | 290 | 610 | 4,600 | 4,300 | 9,100 |
| Kamchatka flounder | GOA | 260 | 250 | 510 | 1,100 | 1,600 | 2,700 |
| northern rockfish | GOA | 300 | 240 | 540 | 5,600 | 3,600 | 9,300 |
| Pacific cod | GOA | 390 | 390 | 790 | 3,300 | 3,500 | 7,100 |
| Pacific ocean perch | GOA | 550 | 550 | 1,100 | 9,800 | 13,200 | 23,500 |
| REBS rockfish complex | GOA | 230 | 230 | 460 | 900 | 900 | 2,100 |
| walleye pollock | GOA | 850 | 700 | 1,550 | 7,800 | 6,300 | 14,500 |

Table 4. -- Example output for age (a) and length (l) input sample size from the surveyISS package.

| Year | Species Code | Comp Type | ISS (a) | ISS (l) | Survey |
| --- | --- | --- | --- | --- | --- |
| 1990 | 10110 | female | 94 | 2633 | goa |
| 1990 | 10110 | male | 35 | 1625 | goa |
| 1990 | 10110 | total | 106 | 3532 | goa |
| 1990 | 10130 | female | 34 | 1101 | goa |
| 1990 | 10130 | male | 28 | 923 | goa |
| 1990 | 10130 | total | 68 | 1725 | goa |
| 1990 | 10180 | female | 42 | 536 | goa |
| 1990 | 10180 | male | 23 | 236 | goa |
| 1990 | 10180 | total | 64 | 615 | goa |
| 1990 | 21720 | female | 85 | 483 | goa |
| 1990 | 21720 | male | 63 | 416 | goa |
| 1990 | 21720 | total | 106 | 601 | goa |
| 1990 | 21740 | female | 100 | 657 | goa |
| 1990 | 21740 | male | 74 | 441 | goa |
| ⁝ | ⁝ | ⁝ | ⁝ | ⁝ | ⁝ |



Figure 1. -- Bootstrap flow chart, the steps refer to the order of operations.

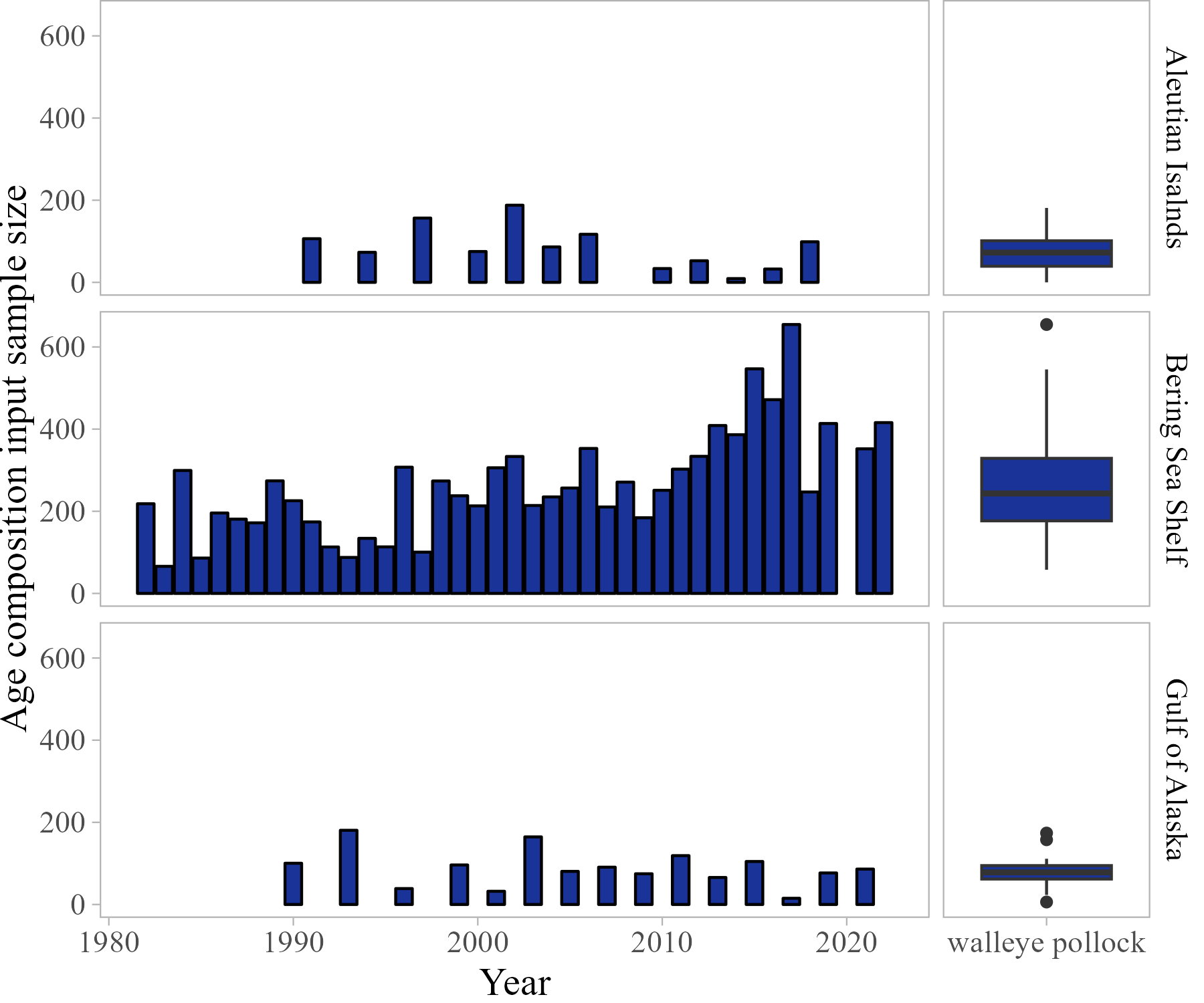


Figure 2. Walleye pollock total age composition input sample size by year and survey.

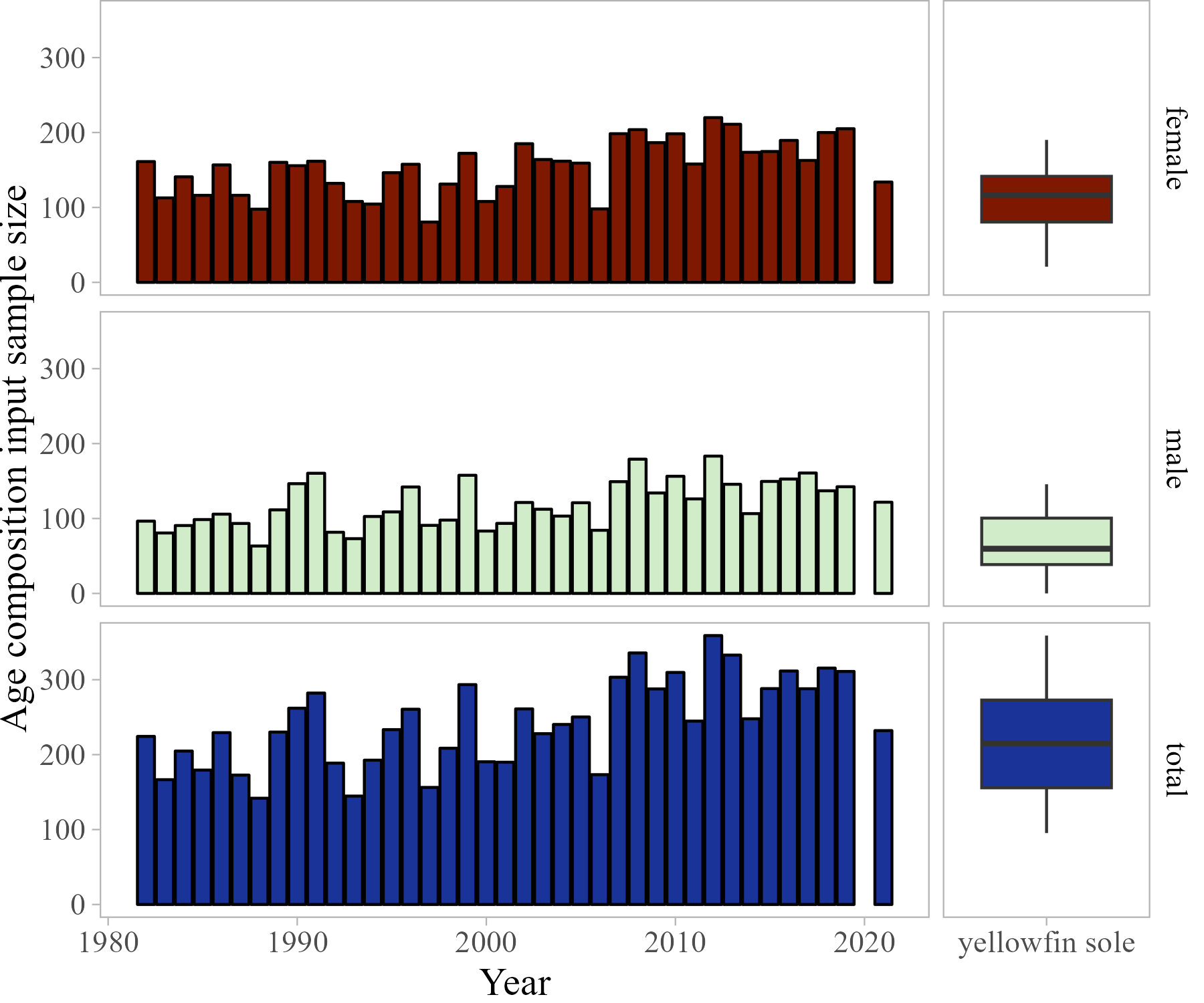


Figure 3. Eastern Bering Sea Yellowfin sole sex-specific age composition annual input sample size.

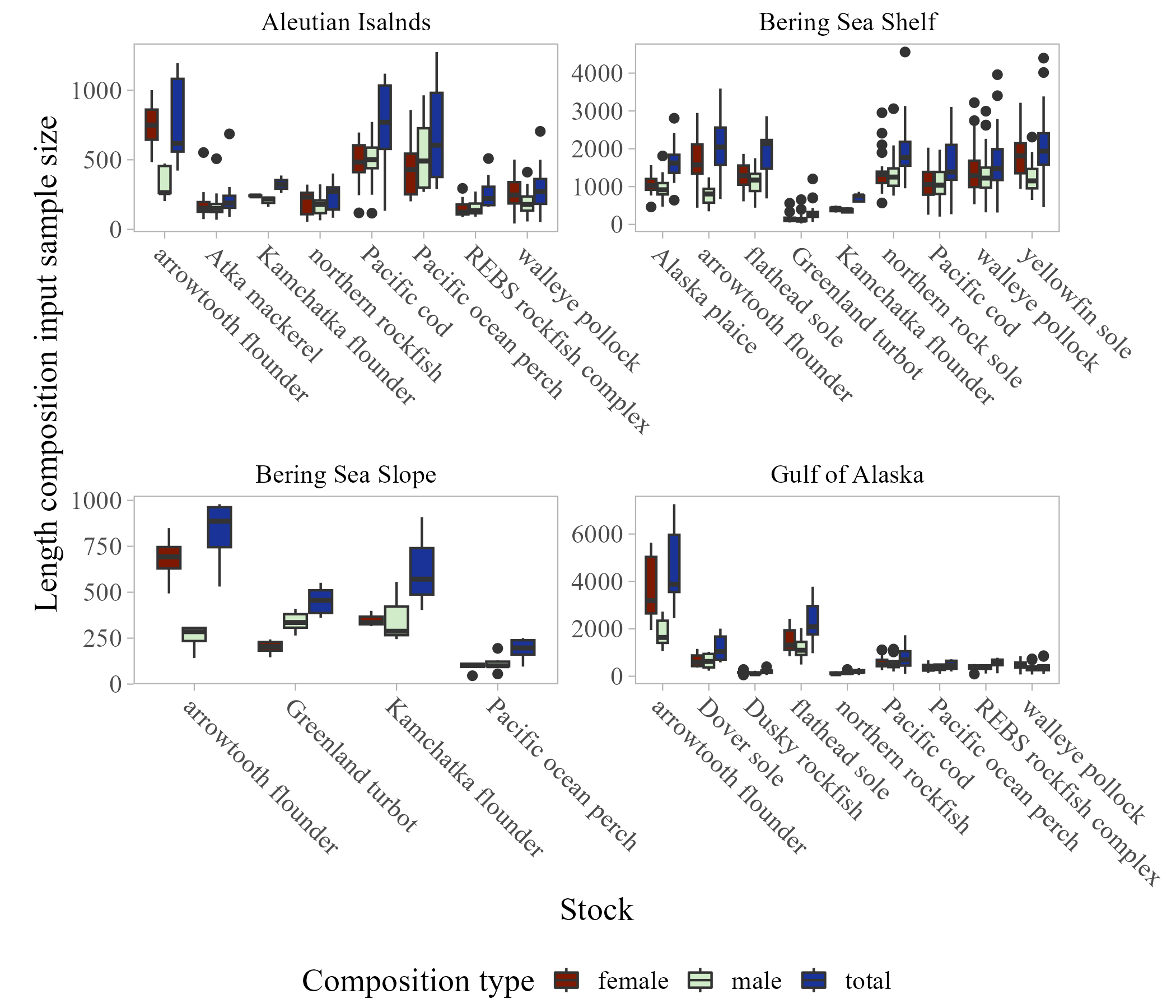


Figure 4. -- Length composition input sample size by species and survey.

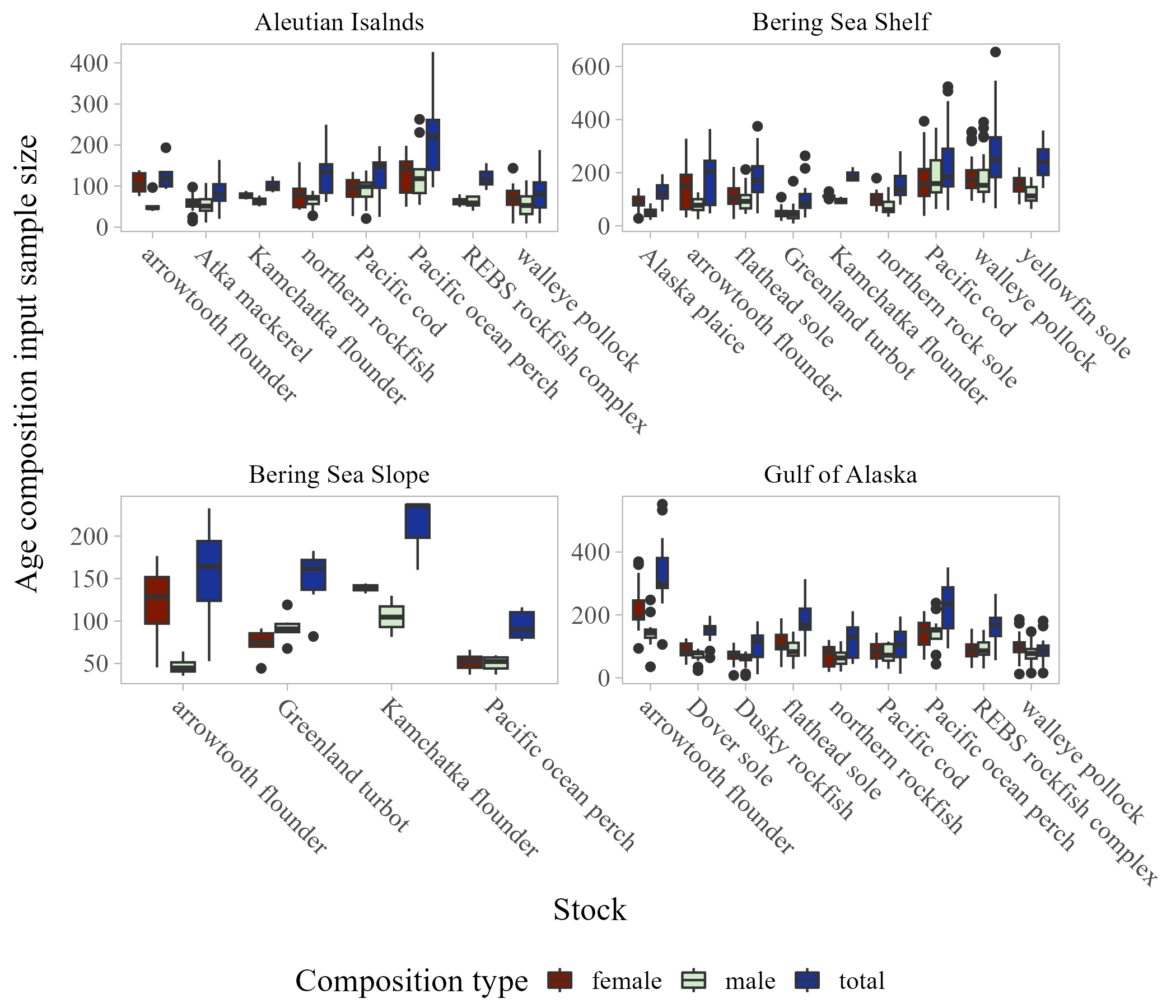


Figure 5. -- Age composition input sample size by species and survey.

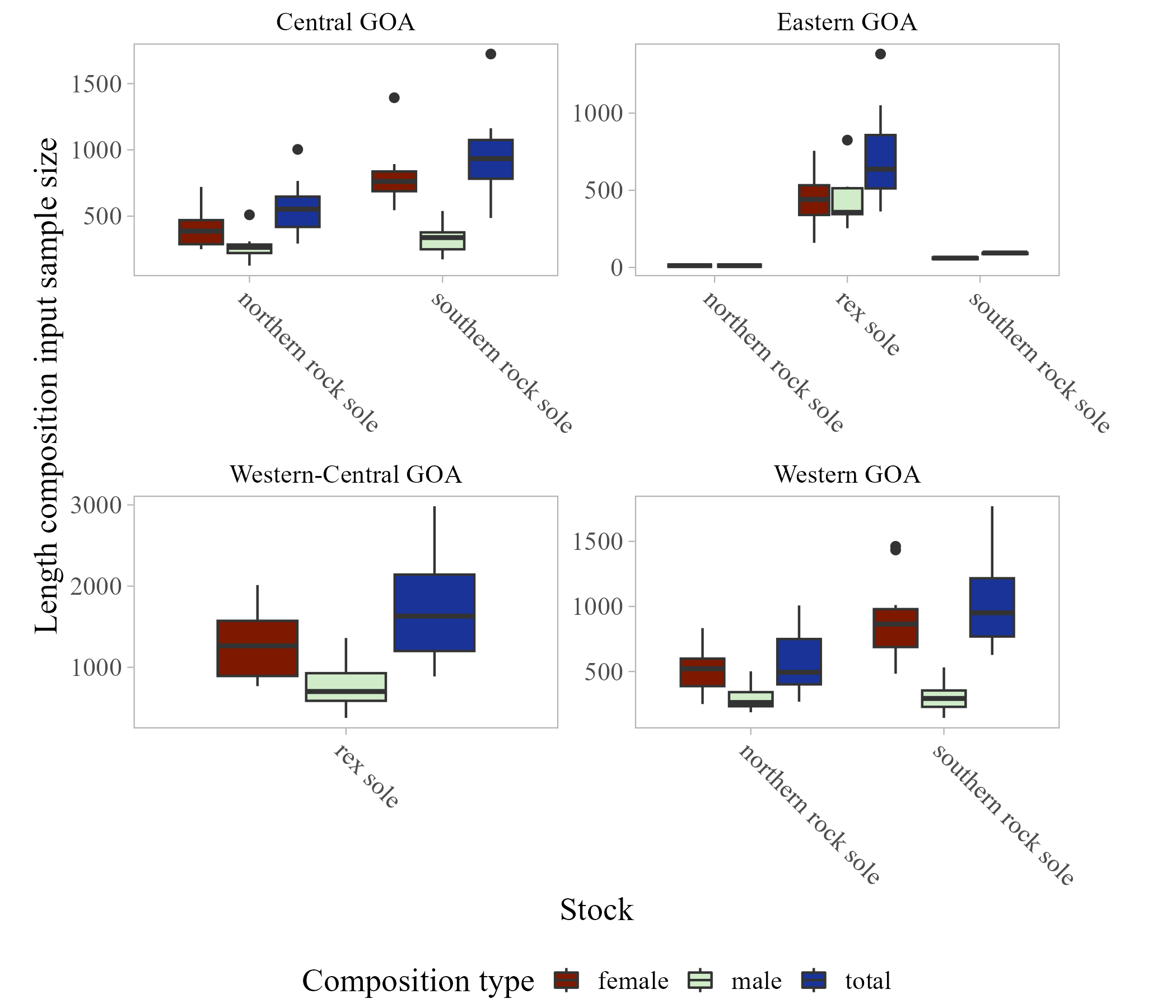


Figure 6. -- Sub-region length composition input sample size by species within the Gulf of Alaska survey.

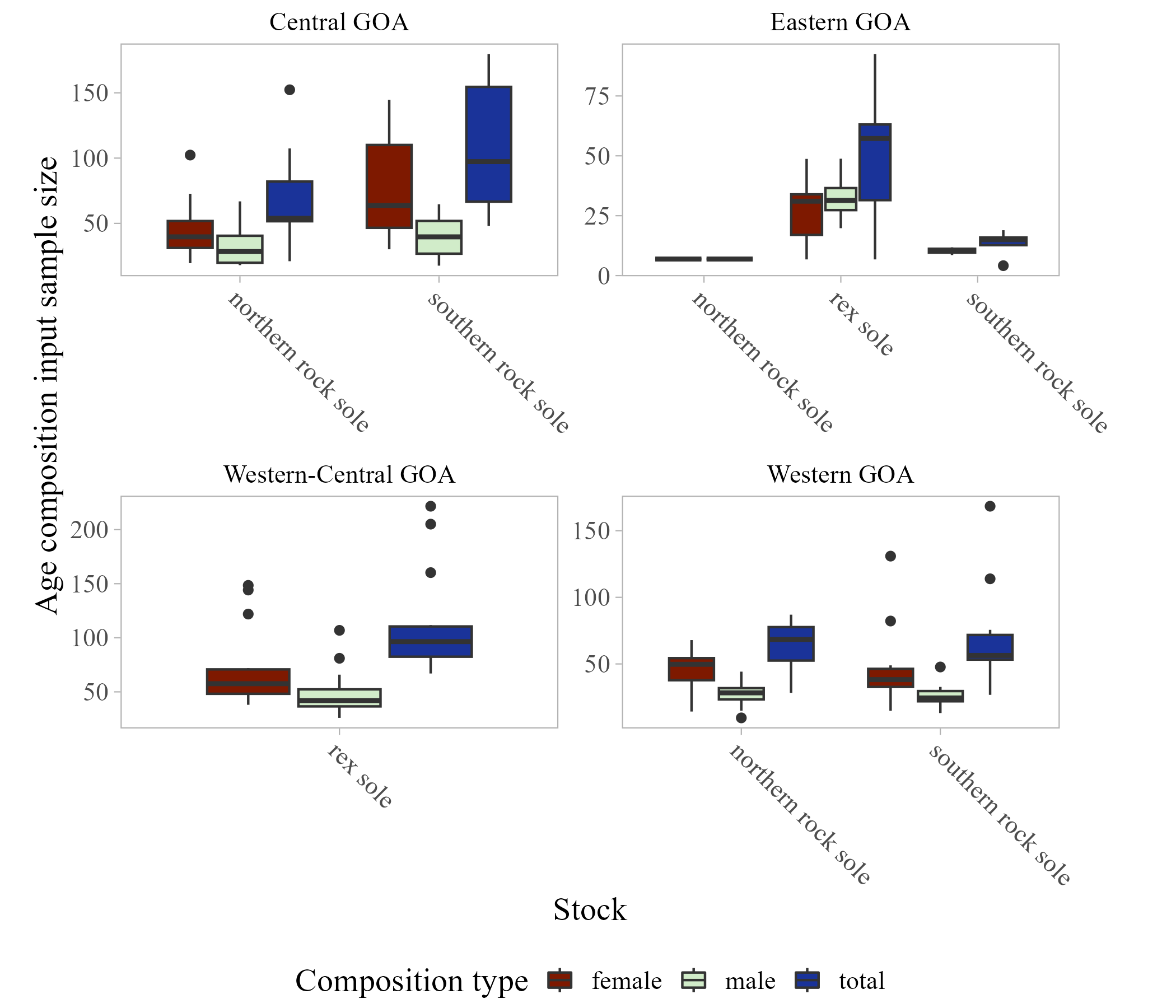


Figure 7. -- Sub-region age composition input sample size by species within the Gulf of Alaska survey.

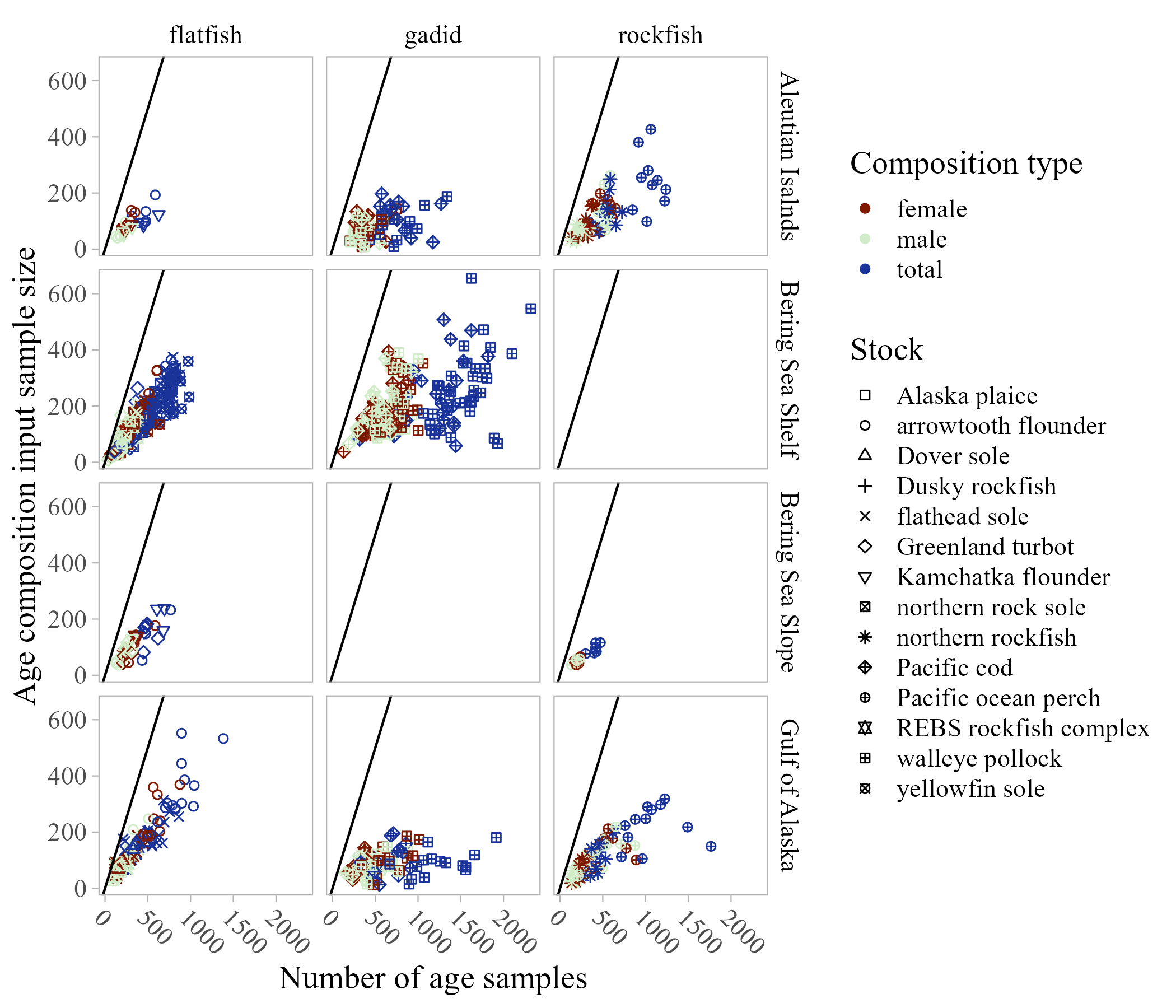


Figure 8. -- Number of fish aged and age composition input sample size by species group and survey (1-1 line shown in black for reference).

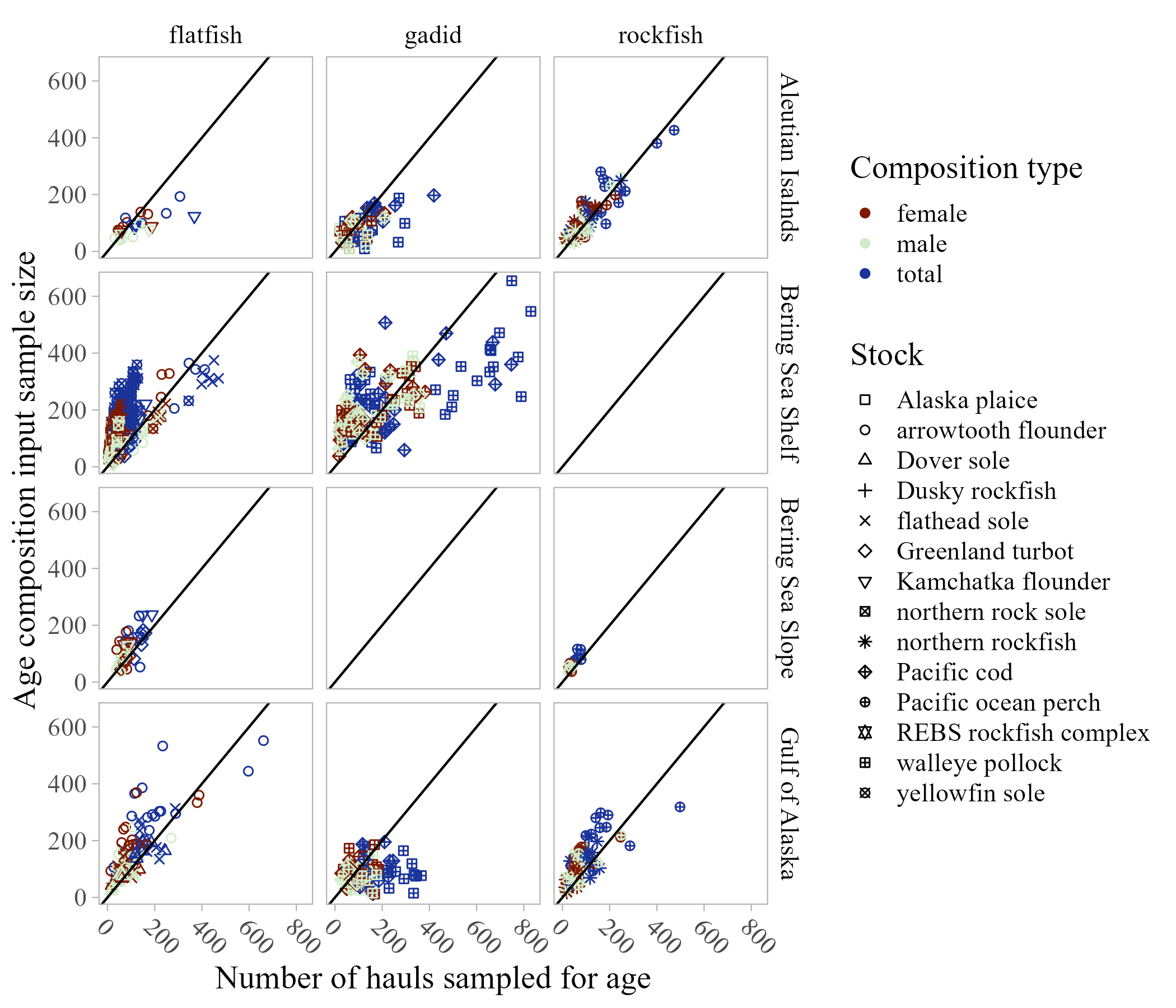


Figure 9. -- Number of sampled hauls compared to age composition input sample size by species group and survey (1-1 line shown in black for reference).

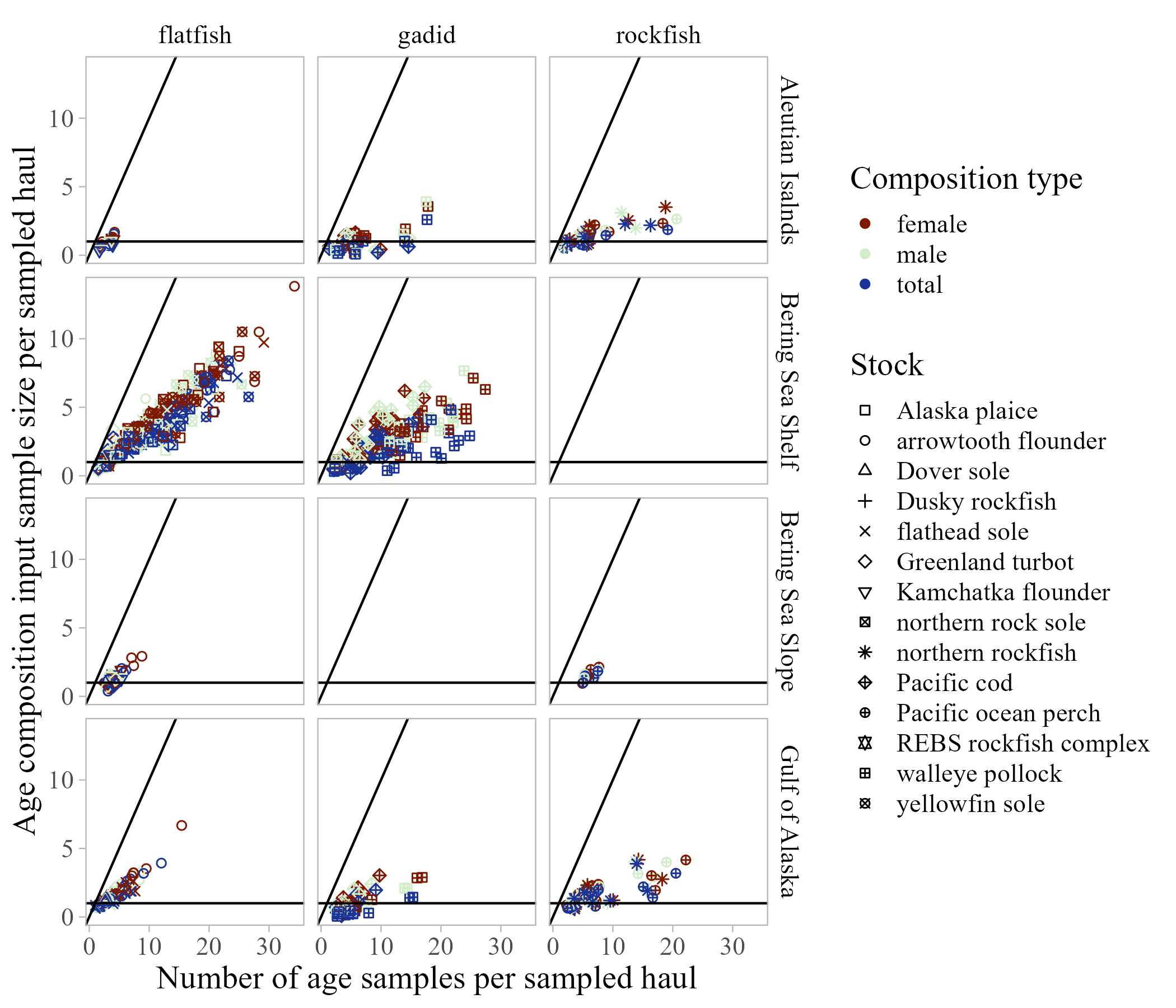


Figure 10. -- Number of age samples compared to age composition input sample size per sampled haul by species group and survey (1-1 line and the slope = 1 line (when all samples are identical in each haul) shown in black for reference).