Evaluation of Alaska skate stock structure in the Bering Sea and Aleutian Islands

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EXECUTIVE SUMMARY

An evaluation of stock structure was first completed for the Bering Sea and Aleutian Islands (BSAI) Skate Stock Complex as a whole in September 2012. Here, we present an updated document focusing on the Alaska skate (*Arctoraja parmifera*), the dominant skate species in the BSAI Fishery Management Plan (FMP) area. We also comment on the morphologically similar leopard skate (*A. panthera*), a recently described species endemic to the Aleutian Islands (Orr et al. 2011). The purpose of this update is to highlight new species-specific information and address concerns that the current approach of managing skates in aggregate may mask localized depletions of other members of the Skate Stock Complex (Table 1).

The 2012 stock structure evaluation of the Skate Stock Complex concluded that the spatial management approach, with BSAI-wide harvest specifications and catch accounting, was appropriate due to 1) low exploitation rates relative to natural mortality for the complex as a whole and 2) seemingly stable biomass estimates for individual species within the complex.

This year's stock structure evaluation focuses specifically on the Alaska skate, while also noting trends in catch and biomass of other species in the Skate Stock Complex. Main conclusions of this evaluation include:

- Most of the skate bycatch in the BSAI FMP area is recorded as "Alaska skate" (81% of total skate catch on average between 2003 and 2025). In the Aleutian Islands, skates identified as Alaska skates may also include leopard skates.
- Alaska skate exploitation rates are generally low (average estimated $F = 0.05$ between 2000 and 2020). The exploitation rate of leopard skates is unknown but is probably low.
- Skate species composition differs among the eastern Bering Sea (EBS) shelf, EBS slope, and Aleutian Islands surveys, with the Alaska skate dominating the EBS shelf. The leopard skate is endemic to the Aleutian Islands. While Alaska skate occurs in the historical EBS slope survey data, it is generally found in shallower strata; the slope survey primarily catches skate species occurring in deeper waters.
- The 2026 biomass estimate for EBS Alaska skates is 24% below the reliable long-term mean.
- Survey biomass of Alaska skates is lower and more uncertain in the northern Bering Sea (NBS) than in the EBS. Relatively little fisheries bycatch occurs in the NBS.
- It is not possible to assess changes in the highly diverse skate populations constituting the other 15 species in the Skate Stock Complex on the EBS slope due to the lack of a slope survey.
- Total skate survey biomass has generally declined in the Aleutian Islands since the mid-2000s.
- Survey biomass of leopard skates has declined to low levels in the Aleutian Islands subarea; the 2026 biomass is 74% below the reliable long-term mean.
- Skates in Alaska waters, including the Alaska skate, have life history characteristics, including persistent utilization of discrete egg case nursery habitats and a relatively long generation time, that may make them more vulnerable to climate perturbations and fishing pressure.
- Genetics work suggests some level of stock structure in Alaska skates, likely due to egg case nursery site fidelity.

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- Genetic studies suggest the existence of a potential cryptic species (*Arctoraja* c.f. *parmifera*) found near Pervenets Canyon in the EBS.
- Conventional tagging data indicate that Alaska skates are capable of cross-shelf movements in the EBS, but there is no evidence of inter-basin movement between the Gulf of Alaska and Bering Sea.

Based on the results of this evaluation, we recommend:

1. Continuing to assess the Alaska skate separately from "Other Skates" in the EBS shelf area.
2. Continuing to consider skate egg case nursery areas Habitat Areas of Particular Concern to preserve genetic diversity of Alaska skates.
3. Exploration of a BSAI-wide Alaska skate assessment model.
4. Expanded research on leopard skates, including life history, risk evaluation, fishery catch, and the potential for single-species assessment.
5. Continued exploration of data-limited stock assessment methods.

Introduction

The last evaluation of BSAI skate stock structure was presented to the Plan Team in September 2012 on the Skate Stock Complex as a whole. Here, we present information specific to the Alaska skate (*Arctoraja parmifera*), with comments on other members of the complex (Table 1), including the morphologically similar leopard skate (*Arctoraja panthera*), in response to requests by the Scientific and Statistical Committee (SSC) at the December 2020, 2022, and 2023 North Pacific Fishery Management Council (NPFMC) meetings. We follow the Stock Structure template outlined in Spencer et al. (2010) (Table 2). An operational full assessment of the BSAI Skate Stock Complex is scheduled to occur in 2026.

The BSAI Skate Stock Complex includes 16 species (Table 1), of which the Alaska skate is the most dominant and least data-limited. In 2008, the SSC accepted two different approaches to generate BSAI harvest recommendations for Alaska skate and the other members of the complex (hereafter, "Other Skates"). Tier 3 and Tier 5 harvest specification rules are applied to Alaska skate and Other Skates, respectively, which are then combined to generate recommendations for the complex as a whole.

The skate species composition is markedly different between the eastern Bering Sea (EBS) and Aleutian Islands subareas of the BSAI FMP area, and it further varies by depth within the EBS. While the Alaska skate dominates the EBS continental shelf, the species compositions of the EBS slope and Aleutian Islands are diverse. We prepared this document in response to SSC concerns that the current management approach of managing skates in aggregate could mask localized depletions of less abundant members of the complex, particularly the leopard skate, which has experienced an apparent population decline since 2010. The leopard skate is endemic to the Aleutian Islands, where it overlaps with the Alaska skate (Figure 1). The two species are similar in appearance and have only been separated in survey catches since 2010; fisheries catches are still reported in aggregate.

Distribution

The Alaska skate has been observed at depths from 17-392 m throughout the EBS, Aleutian Islands, and Gulf of Alaska (GOA) (Figure 2; Stevenson et al. 2007). It has also been reported in the western Bering Sea, Sea of Okhotsk, and Sea of Japan (Antonenko et al. 2007; Dyldin & Orlov 2018), though some of these observations may have been mis-identified golden skates, *Bathyraja smirnovi* or Hokkaido skates, *B. simoterus* (Orr et al. 2011; Orlov and Volvenko 2022). In survey catches occurring in Alaska waters,

the Alaska skate is well-distributed over the EBS shelf and is observed with lower frequency in the Aleutian Islands and the western GOA (Figure 2).

The leopard skate was first described from the western Aleutian Islands (Stevenson et al. 2007; Orr et al. 2011), though it has also been observed, with lower frequency, in bottom trawl survey catches in the central and eastern Aleutian Islands (Figure 1).

Within Alaska waters, the Alaska skate is most commonly found in the eastern Bering Sea, dominating the skate biomass on the continental shelf (Figure 3) (Stevenson et al. 2007; Stevenson et al. 2008). Essential fish habitat (EFH) of the Alaska skate is broadly distributed over the EBS shelf, with geographic position, bottom temperature, and depth being the most important predictors of numerical abundance (Laman et al. 2022; Rooper et al. 2019). Habitat use differs by life stage, with immature Alaska skates (31-92 cm total length TL) primarily occurring in the shallower waters of the inner and middle shelf and adults (>92 cm TL) primarily located on the outer shelf (Hoff 2008). Eight egg case nursery areas have been identified in the EBS for the Alaska skate, occurring over diverse substrates (mud, sand, gravel, and boulder) along the outer shelf and upper slope near submarine canyons (Hoff 2016; Spies et al. 2021b). Newly hatched skates (<31 cm TL) appear to quickly depart egg case nursery areas, moving to the outer and middle shelf of the EBS, presumably to avoid predation by large predatory fishes (Hoff 2008; 2010; 2016).

Life History

Skates, like most elasmobranchs, possess life history traits that can make them vulnerable to overfishing, such as slow growth, delayed maturity, and low productivity (Hoenig and Gruber 1990; King and McFarlane 2003; Musick 1999). All skates are oviparous, wherein fertilization occurs internally and eggs are deposited in keratinized cases on the seafloor, where they continue to develop until hatching. The Alaska skate lays egg cases in pairs, with one embryo per case, in distinct and persistent nursery areas along the interface between the continental shelf and slope that are typically near the heads of underwater canyons (Hoff 2010; 2016). These areas have steady currents that may be important for oxygenating the egg cases, preventing accumulation of sediments, and sustaining metabolic processes, increasing the chance of survival to hatching (Hoff 2007). Egg case nursery areas are small in area (>2 km^2), with egg cases occurring in high densities (>1,000 cases/km^2) (Hoff 2007; 2010). In the Bering Sea, most egg case nursery areas are used predominantly by a single species, although some sites are shared by up to six skate species (Hoff 2010). Separate habitats are used for egg deposition and by post-emergent juveniles, with neonates moving from egg case nursery areas into the shallower waters of the outer shelf and the deeper waters of the middle shelf, essentially straddling the interface between the two domains (Hoff 2016). As of 2016, eight Alaska skate egg case nursery areas were identified in the eastern Bering Sea at depths from 145-316 m (Hoff 2016). Skate egg case nurseries have not been investigated in the Aleutian Islands; however, high densities of egg cases have been recorded during the Aleutian Islands bottom trawl survey (Figure 4). An Alaska skate egg case nursery has also been identified off the Gamov Peninsula in the Sea of Japan (Panchenko and Antonenko 2020).

The Alaska skate has a long incubation period of 3.5 years between egg case deposition and hatching, which appears to be temperature-dependent based on multi-species analyses (Hoff 2008; Wheeler et al. 2020). A small percentage (6.5%) of deposited egg cases are not viable (Hoff 2009). Egg case deposition occurs year-round but peaks during the summer (June-August) months (Hoff 2008; Matta 2015). Similarly, hatching occurs throughout the year but peaks in the fall and winter (October-February) (Hoff 2008). Size at hatching is estimated to be 21-23 cm TL (Hoff 2009; Matta and Gunderson 2007). The age (length) at 50% maturity is 9 years (92 cm TL) for males and 10 years (93 cm TL) for females (Matta and Gunderson 2007). The maximum observed size is 137 cm TL, and the maximum observed age is 26 years (Matta et al. 2017), though most individuals are under 120 cm TL (Matta 2006). Maternal size has weak

but significant effects on mature oocyte size and number (Matta 2015) as well as egg case size (Hoff 2007). Estimates of annual fecundity (21-37 egg cases/year) are imprecise and await validation (Matta 2015), but annual production is likely to under 100 egg cases per year (Hoff 2007). The estimate of natural mortality (*M*) used in the Alaska skate stock assessment model is 0.13 and was based on published relationships with other life history parameters (Tribuzio et al. 2023). Nothing is known about the life history of the leopard skate.

Fishery

There is no directed fishing for the Alaska skate or any other members of the Skate Stock Complex in the BSAI, though incidental catch can be retained (Tribuzio et al. 2023). Skate discard rates have varied over time and across sectors but are generally over 50% (Tribuzio et al. 2023). Survival of discarded skates in BSAI fisheries has not been studied, and mortality of incidentally caught skates is assumed to be 100% (Tribuzio et al. 2023). However, observations of skates with healed hook injuries (D. Stevenson, pers. comm.) and studies of incidental skate catch in other fisheries around the world suggest that discard mortality rates are variable, decreasing with fish length and increasing with tow duration and codend weight (Enever et al. 2009; Knotek et al. 2019; Mandelman et al. 2013).

Nearly all of the incidental BSAI skate catch occurs in the Bering Sea (Figure 5), primarily in the Pacific cod longline fishery, followed by the yellowfin sole bottom trawl fishery (Tribuzio et al. 2023). Within the Bering Sea, most of the total skate catch occurs in NMFS reporting areas 509, 513, 517, 521, and 524 (Figure 6).

Skate egg cases containing live embryos are also susceptible to longline and trawl gear, with Alaska skates being the most commonly encountered in EBS fisheries (Stevenson et al. 2019). The highest concentrations of skate egg case fishery catches occurred near known nursery areas, especially in Bering, Pribilof, and Pervenets Canyons (Stevenson et al. 2019). There are no total catch estimates for skate egg cases, only observer records, and the catch of skate egg cases is not included in the stock assessment.

Many skate species in the BSAI are morphologically similar, but following the development of field guides and additional observer training in the early 2000s, the rate of skates identified to the species level in commercial catches improved (Stevenson and Lewis 2010). The accuracy of skates that are identified to species is now over 99% (Stevenson 2018). However, much of the skate catch is still recorded as "unidentified skates" and must be apportioned to species with observer data using a process accepted by the BSAI Plan Team and SSC in 2018 and outlined in Ormseth (2018). The NMFS Alaska Regional Office's Catch Accounting System estimates total catch for five skate species: Alaska, Aleutian (*Bathyraja aleutica*), big (*Beringraja binoculata*), longnose (*Caliraja rhina*), and whiteblotched skates (*Bathyraja maculata*). The catches of all other species are combined. The Alaska skate comprises most of the skate incidental catch in the BSAI, accounting for 72-89% of the total skate catch between 2003 and 2025 (Figure 7). Most of the identified Alaska skates are caught in the middle and outer domains of the EBS shelf (Figure 8). In 2019 and 2020, small catches of Alaska skates were observed in the northern Bering Sea (NBS) (Figure 8), but the catch of Alaska skates north of 60°N has never exceeded 7% of the BSAI Alaska skate total annually.

Catch totals of the leopard skate are unknown, as this species is not identified to species by observers. Leopard skates caught as bycatch in western Aleutian Islands fisheries are recorded as "Alaska skates" or "unidentified skates". Fisheries catches of skates in the Aleutian Islands, where the leopard skate is endemic, are generally low, averaging 1,141 t annually from 2003-2025, or about 5% of the total BSAI skate catch (Figure 5; Figure 8). In the Aleutian Islands, catch to survey biomass ratios of all skate species combined ranged from 0.02-0.06 (mean = 0.04) between 2004 and 2024.

Length distributions of Alaska skates caught in target fisheries differ between gear types and FMP subareas (Figure 9). Only length compositions from EBS fisheries are used in the Tier 3 Alaska skate model.

Survey

There are several sources of survey information for skates in the BSAI FMP area: the EBS shelf, NBS, EBS slope, and Aleutian Islands bottom trawl surveys, all of which occur during the summer months. Skates are also caught in the AFSC longline survey, but Aleutian, Bering, and Alaska skates are grouped together in longline survey catch reports. Only data from the EBS shelf bottom trawl survey are used in the Alaska skate Tier 3 model.

Survey biomass estimates for the Alaska skate in the EBS have been considered generally reliable since 1999 (Stevenson and Hoff 2009). Within the Bering Sea, most of the Alaska skate biomass is located on the EBS shelf. Estimated biomass on the EBS shelf was approximately 300,000 metric tons (t) in the early 2000s, reaching a maximum of just over 531,000 t in 2016, and has since declined to about 307,000 t in the most recent (2026) survey, which is 24% below the long-term mean (Figure 10). Estimated biomass in the NBS has ranged from approximately 47,000 to 95,000 t in years with observations, or 9.9-17.9% of total Bering Sea biomass, though coefficients of variation in the NBS have generally been higher and more variable from year to year than those in the EBS (Figure 10). Though the Alaska skate is dominant on the EBS shelf, other common species include the Aleutian skate, Bering skate (*Bathyraja interrupta*), whiteblotched skate, mud skate (*B. taranetzi*), and big skate (Figure 11). Coincident with declines in Alaska skates on the EBS shelf, there have been slight increases over the past 10-15 years in Aleutian, Bering, and big skates (Figure 11).

There are fewer years with trawl survey data from the EBS slope, which has not been surveyed since 2016; therefore it is difficult to assess trends in biomass. However, the species composition on the EBS slope is more diverse than on the EBS shelf (Figure 12). The most common species observed on the EBS slope include Alaska, Aleutian, Bering, Commander (*Bathyraja lindbergi*), whiteblotched, whitebrow (*B. minispinosa*), mud, and roughtail (*B. trachura*) skates (Figure 12).

The Aleutian Islands area also supports a more diverse range of skate species than the EBS shelf (Figure 13). The most common species in the Aleutian Islands include Alaska, Aleutian, whiteblotched, leopard, mud, and big skates (Figure 13). Identification of skates in this region has also been reliable since 1999 (Orr et al. 2014), although identification issues with some morphologically similar species pairs (mud/butterfly and Alaska/leopard skates) likely still exist. Total skate biomass declined in the Aleutian Islands from a high of around 54,000 t in 2006 to around 20,000 t in 2024 but rebounded in 2026 to around 27,000 t (Figure 3). Prior to 2010, the estimated biomass of Alaska skates was between 10,000 and 14,000 t, but at least part of this biomass was likely misidentified leopard skates (Figure 14). Survey catches of leopard skates and Alaska skates in the Aleutian Islands have been variable over time and patchily distributed (Figure 1; Figure 14). However, biomass of leopard skates has declined 89% since 2010, when reliable identification of this species began; the 2026 biomass estimate is 74% below the reliable long-term mean, with a slight increase between 2024 and 2026 (Figure 14). Alaska skates are similarly 63% below the long-term mean biomass level (Figure 14). Whiteblotched, mud, and Aleutian skates have also experienced decreasing trends from highs in the mid-2000s, though biomass estimates for whiteblotched and mud skates increased between 2024 and 2026 (Figure 13). It should be noted that biomass estimates of skates in the Aleutian Islands are more uncertain than those in the EBS, with coefficients of variation ranging from 0.09 to 0.23 annually between 1991 and 2022 (Tribuzio et al. 2023).

Trawl surveys have moderate capture efficiency confidence scores for the Alaska skate in the EBS (Stevenson et al. 2016). Trawl experiments have determined that capture probability of skates is length-dependent, ranging from around 0.6 for small skates to 0.8 for large skates (Kotwicki and Weinberg 2005). Capture probabilities of skates in the Aleutian Islands and on the EBS slope, which have more complex bottom habitats and different sampling gear than the EBS shelf, are unknown.

Length compositions of Alaska skates differ by survey area (Figure 15). While the full length distribution of Alaska skates appears to be well-observed in the EBS shelf survey, bimodal distributions are sometimes observed in other areas, particularly the EBS slope and Aleutian Islands in some years (Figure 15). Length observations of leopard skates are limited, particularly as survey catches have become more infrequent in recent years but have sometimes followed a bimodal distribution (Figure 16).

Management

Beginning in 2011, BSAI skates were split from the Other Species category within the BSAI Fishery Management Plan (FMP) and managed as a species complex (Table 1). Since 2009, separate models have been used to generate harvest specifications for Alaska skates (Tier 3) and "Other Skates" (Tier 5). The Tier 3 and Tier 5 recommendations are combined to generate a single BSAI-wide ABC and OFL for the complex.

Six egg nursery sites, four of which are utilized by the Alaska skate, were designated by the NPFMC as Habitat Areas of Particular Concern (HAPC) in 2015 by FMP Amendment 104 (https://media.fisheries.noaa.gov/dam-migration/hapc-ak-akr.pdf). While there are no fishing restrictions within the HAPCs, the importance of these areas as Essential Fish Habitat for the Alaska skate is recognized and recommended as a monitoring priority.

Application of Stock Structure Template

To address stock structure concerns, we utilize the existing framework for defining spatial management units introduced by Spencer et al. (2010) (Table 2). In the following sections, we elaborate on the available information used to respond to specific factors and criteria for defining Alaska skate stock structure.

Harvest and trends

Fishing mortality

The Alaska skate is assessed as Tier 3, and therefore exploitation rates (F) can be estimated with reasonable confidence. Exploitation rates were highest in the 1970s and early 1980s but have remained relatively stable and low since the early 1990s, with an average value of 0.05 between 2020 and 2020 (Figure 17; Tribuzio et al. 2023). From 2013-2022, the average ratio of F to F_{ABC} for the Alaska skate was 0.58, but annual F:F_{ABC} values have been variable during that time period, ranging from 0.44 to 0.84. For the BSAI Skate Stock Complex as a whole, catch has never exceeded ABC.

Because exploitation rates have been consistently under the maximum permissible rate for Alaska skates, conservation concerns related to the effects of fishing mortality are low at the FMP level. Furthermore, the total Alaska skate catch (EBS and Aleutian Islands) is used in the Tier 3 assessment model, resulting in a more conservative F.

Spatial concentration of fishery relative to abundance

Spatial patterns in skate catches have been somewhat variable from year to year (Figure 6; Figure 8). Because skates are taken as bycatch, this may be in part due to changes in behavior of target fisheries; the spatial extent of Alaska skate catch also varies by gear (Tribuzio et al. 2023). Pelagic trawl and longline catches have tended to occur in the outer domain of the EBS, with some longline catches also occurring in the NBS (Tribuzio et al. 2023). Bycatch of Alaska skates in the non-pelagic trawl fishery occurs more frequently in the middle and inner domains of the EBS and in the Aleutian Islands (Tribuzio et al. 2023).

Survey catches show that Alaska skates are well-distributed over the EBS shelf (Figure 2). Fishery catches of Alaska skates in some years are more highly concentrated in the outer domain of the EBS shelf (Figure 8), where adults are generally more abundant (Hoff 2008). Limited fishery catches occur in the Aleutian Islands (Figure 8), though how much of this catch is actually leopard skates is unknown, because leopard skates are not identified to species.

Population trends

In the EBS, Alaska skate survey biomass has declined from historical peaks; the 2026 estimate is 24% below the long-term mean (Figure 10). Alaska skate survey biomass in the Aleutian Islands has also declined from historical peaks, but these peaks were all pre-2010, when there was high potential for conflation of Alaska skates with leopard skates (Figure 14). The 2026 biomass estimate of Alaska skates in the Aleutian Islands is 63% below the reliable long-term mean (Figure 14).

Barriers and phenotypic characters

Generation time

Generation time is related to lifespan and reproductive output and is relevant to the amount of time it would take to rebuild an overfished stock to an unfished state (Restrepo et al. 1998; Spies et al. 2025). Generation times over 10 years suggest longer population recovery times following over-harvesting (Spencer et al. 2010). While skates attain moderate maximum ages, they tend to mature late relative to their lifespans. The maximum observed age for the Alaska skate is 26 years (Matta et al. 2017). The age at 50% maturity is 9 and 10 years for males and females, respectively (Matta et al. 2007). Annual fecundity is not well-estimated but is thought to be under 40 egg cases per female per year (Matta et al. 2015). Skates have far lower fecundities than teleosts, but higher egg survival rates. Natural mortality is lower than that of most teleosts (M = 0.13; Tribuzio et al. 2023).

Generation time can be defined in a number of different ways (Tanner 1978), but here we follow methods outlined in Restrepo et al. (1998), where mean generation time (G) is

$$G = \frac{\sum_{a=1}^{A} a E_a N_a}{\sum_{a=1}^{A} E_a N_a}$$

where a is age, A is the maximum age expected in an unfished population, E_a is the mean fecundity-at-age, and N_a is the average number of females at age per recruit in an unfished population. Because fecundity of Alaska skates is highly uncertain, we replaced E_a with a vector of the product of the proportion of mature females at each age a times body weight at a (Restrepo et al. 1998; Spencer and Gharrett 2010).

Mean generation time of Alaska skates was estimated as 18.7 years.

Physical limitations

Alaska skates exhibit ontogenetic migration across the EBS shelf (Hoff 2010; 2016), suggesting that physical barriers do not prohibit movements within the EBS basin. The limited tagging data available

suggest no inter-basin movement between the EBS and GOA (Figure 18), with the caveats that tag recovery is fishery dependent and recovery rates are influenced by fishing effort. It is unknown if island passes or strong oceanographic currents act as physical barriers to movement between the EBS and GOA basins or along the Aleutian Island chain.

Growth differences

Spatial variation in growth of Alaska skates has not been examined. Age estimates are limited to a few years for this species and are only available from the EBS shelf.

Age/size structure

Alaska skate age composition data are limited to a few years of collection, and the most recent age data are from 2015. Length compositions differ somewhat by area, with bimodal distributions sometimes observed in the Aleutian Islands and EBS slope surveys (Figure 15). The bimodal distributions observed in the EBS slope may be explained by the presence of skate egg case nursery areas in the shallower waters of the EBS slope area.

Spawning time differences

Alaska skate reproduction occurs year-round, with observed peaks in egg deposition and hatching occurring in the summer (June-August) and fall-winter (October-February), respectively, within the Bering Canyon nursery site (Hoff 2008). It is unknown whether deposition timing differs among other egg case nursery sites, though adult females have been observed in a reproductive state (with large vitellogenic ovarian follicles or uteri containing egg cases) throughout the year (Matta 2015). There is no reproductive information available for Alaska skates from the Aleutian Islands.

Maturity-at age/length differences

There are no known regional differences in maturity-at-age or maturity-at-length for the Alaska skate.

Morphometrics and Meristics

A study that examined Alaska skate embryos from Pervenets Canyon that had two different haplotypes found no morphological differences; however, the number of morphological characteristics that could be examined was limited due to the small size of the embryos (Spies et al. 2021a).

Behavior and movement

Spawning site fidelity

Alaska skates have internal fertilization, and mating sites are unknown. However, female Alaska skates use discrete nursery habitats near undersea canyons along the upper continental slope and outer shelf of the EBS for egg case deposition (Hoff 2010; 2016). To date, eight sites have been identified as egg case nursery areas, including in Pervenets Canyon, Zhemchug Canyon, Pribilof Canyon, and Bering Canyon (Hoff 2016). Egg cases are highly concentrated (~16,000-800,000 eggs per km^2) and temperatures are relatively constant (3.7-4.6°C) in nursery areas (Hoff 2010). Fisheries trawl data suggest that these sites are persistent over time, indicating possible spawning site fidelity, with large catches of egg cases occurring in the same location >10 years (Hoff 2010). Spies et al. (2021b) found higher relatedness between embryos taken within the same nursery area than among embryos from different nursery areas, further suggesting site fidelity.

Mark-recapture data

Alaska skates were tagged with conventional spaghetti tags during EBS summer bottom trawl surveys in 2000, 2008, and 2009. Over 3,000 skates were tagged and released, and to date, 32 tags have been

recovered. Of these, 27 had location coordinates recorded at the time of recapture. Preliminary analysis indicates that the distance between tagging and recovery ranged from 27 to 804 km and times at liberty ranged from 9 days to over 10 years (Figure 18). The skate that was recaptured the furthest distance from tagging was at liberty for 271 days, from 12 June 2008 to 11 March 2009. This skate was 46 cm TL (immature) at the time of tagging. Sex was not recorded at the time of tagging, and the length was not recorded at the time of recovery. The skate that was at liberty the longest was recovered on 4 March 2019, approximately 322 km from the site of its tagging, which occurred on 7 June 2008. This individual was 100 cm TL (likely mature) but unsexed at the time of tagging, and length was not recorded at recapture. No movement was observed between the EBS and GOA, but some individuals moved from the inner domain of the EBS shelf where they were tagged to the outer domain when they were recaptured (Figure 18). Two Alaska skates that were tagged just north of Unimak Island moved north within the middle domain of the EBS shelf, but no individuals were observed moving between the EBS and Aleutian Islands subareas (Figure 18).

Natural tags

To the best of our knowledge, no studies have investigated natural tags (e.g., vertebral chemistry or parasites) in Alaska skates.

Genetics

Several genetic studies have been conducted to determine lineage of *Bathyraja* (*Arctoraja*) species and evaluate the population structure of Alaska skates. The Alaska skate was formerly known as *Bathyraja parmifera*, but Orr et al. (2011) and Spies et al. (2011) included the species in the subgenus *Arctoraja*, which many authors (e.g., Naylor et al. 2012; Dyldin and Orlov 2018; Kurbanov and Vinogradskaya 2023) now consider to be a valid genus. Beginning in 2010, the leopard skate was separated from the Alaska skate based on morphological and molecular evidence (Orr et al. 2011; Spies et al. 2011). More recent work using restriction-site-associated DNA sequencing (RAD-seq) has indicated that *A. parmifera* and *A. panthera* are paraphyletic with incomplete lineage sorting (Skalley 2024). The leopard skate is endemic to the Aleutian Islands, where it overlaps with the Alaska skate (Figure 1), but is differentiated physically by its color pattern, thorn and vertebra counts, and other morphological characteristics (Orr et al. 2011). Furthermore, studies have suggested the possible existence of another cryptic species, *A*. cf. *parmifera*, on the EBS shelf that is genetically but not phenotypically discernable from *Arctoraja parmifera* (Orr et al. 2011; Spies et al. 2011; Spies et al. 2021a).

Distinct egg case nursery areas may enhance genetic diversity of the Alaska skate if females return to natal sites, which is suggested by within-nursery relatedness (Spies et al. 2021b) and persistence of nursery areas over time (Hoff 2010).

More genetic analysis of Aleutian Islands and Bering Sea Alaska skates is warranted. Previous work indicated large genetic differences between embryos taken in the EBS and adults taken throughout the EBS and Aleutian Islands (Spies et al. 2021b).

Factors and criteria specific to genetics of the Alaska skate are:

Inbreeding coefficient

A study that sampled embryos from five egg case nursery areas in the EBS and adults in the central and eastern Aleutian Islands and near EBS nursery areas found no significant evidence of Alaska skate inbreeding based on single nucleotide polymorphisms (SNPs) obtained through RAD sequencing (Spies et al. 2021b). While none of the inbreeding coefficients (F_{IS}) in that study were considered significant, all nursery areas except Pervenets Canyon had positive F_{IS} scores (Spies et al. 2021b). Positive F_{IS} scores indicate lower heterozygosity and that individuals in a population are more closely related than expected given random mating. Overall, this supports spawning site fidelity.

Effective population size

Effective population sizes (N_e) estimated for Alaska skates have generally been low, ranging from 890 in the Bering/Pribilof Canyon nursery areas to 1,257 in a nursery area between Pribilof and Zhemchug Canyons (Spies et al. 2021b). Values of N_e under 1,000 are considered relatively low, but it should be noted that estimating N_e is difficult, and it can be biased (Marandel et al. 2019; Waples 2016). There is no documented extinction risk at $N_e \sim 1{,}000$, but estimates in the range of several hundred are potentially problematic (Lande 1998).

Isolation by distance

A test for isolation-by-distance was not significant, indicating that genetic differences could not be explained by geographic distance (Spies et al. 2021b).

Dispersal distance

Genetic studies have not evaluated dispersal distance. Other studies suggest broad dispersal following hatching. Alaska skate egg case nursery sites are located near the heads of submarine canyons along the interface between the continental shelf and slope of the EBS (Hoff 2010; Hoff 2016). However, Alaska skates are capable of directed swimming at hatching and appear to quickly leave egg case nursery areas for shallower waters on the middle to outer continental shelf of the EBS (Hoff 2010; 2016). It is speculated that juveniles use these habitats for continued development (Hoff 2016).

Pairwise genetic differences

Significant pairwise genetic differences (measured as F_{ST}) were detected among Alaska skate embryos from different nursery sites in the EBS, suggesting that skates originating from different nursery areas are genetically distinct and that there is some level of population structure in Alaska skates (Spies et al. 2021b).

Summary and Implications

This stock structure evaluation reports on the potential stock structure of the Alaska skate, while incorporating information on the morphologically similar leopard skate. Estimated biomass of both species is currently below the long-term means. The Alaska skate exhibits significant stock structure due to spawning-site fidelity, with significant genetic differences and low effective population sizes. There is no evidence of movement between the EBS and Aleutian Islands or Gulf of Alaska, though tagging data are limited. Furthermore, there is genetic evidence for a cryptic species, *A* cf. *parmifera*, near Pervenets Canyon that appears to be morphologically indistinct from the Alaska skate. Regional biological differences have not been studied in the Alaska skate. Given the likely high degree of mixing of adults on the EBS shelf where fishing occurs, the impact of fishing is likely reduced on any one specific spawning site (i.e., egg case nursery). However, we recommend continuing to consider skate egg case nursery areas Habitat Areas of Particular Concern to preserve genetic diversity of Alaska skates.

The leopard skate, which is morphologically similar to the Alaska skate and overlaps with it in the Aleutian Islands, has experienced an apparent population decrease of 89% since 2010. Leopard skates are identified to species in survey data but not in fishery catch records, which is why we consider its status in this stock structure evaluation.

While fishing pressure is lower in the Aleutian Islands, the total skate biomass there has declined since 2010. The skate species composition in the Aleutian Islands is more diverse, experiences less frequent monitoring, and has unknown biological parameters and spawning sites. Given the lack of information specific to the Aleutian Islands and the leopard skate in particular, the risks of fishing impacting the structure of the stocks are unknown.

Recommendations

Relative to many of the other assessed stocks in the BSAI, skates are data-poor due to their nontarget status and morphological similarities, which makes species identification difficult and sometimes impractical. However, survey trends in the Aleutian Islands suggest cause for concern, with apparent declines observed for several species including the endemic leopard skate. We make several recommendations to improve monitoring and assessment:

1) Improve identification of skate bycatch in the Aleutian Islands subarea. Currently, Alaska skates and leopard skates are grouped in commercial catch records, and the proportion of the bycatch that is leopard skates is unknown.
2) Investigate potential causes of the leopard skate biomass decline.
3) Determine whether leopard skates and Alaska skates differ in their demographic rates.
4) Further investigate whether individuals from the Pervenets Canyon egg case nursery site represent a species that is genetically distinct from the Alaska skate. Whether this was a known species can be evaluated by comparing existing genetic data to newly published genetic data on other skates in the Bering Sea. Development of an at-sea genetic test would allow for the collection of an adult specimen for examination.
5) Monitor skate egg case relative abundance and catch.
6) Continue to explore data-limited assessment methods that may be more appropriate for non-target species and stock complexes.

Research Priorities

Recommendations for research to improve the stock assessment include:

- Genetically identify skate bycatch in the Aleutian Islands to estimate the proportions of Alaska and leopard skates. This could include development of an at-sea genetic test to identify leopard vs. Alaska skates and further define their species boundaries.
- Collect demographic and biological information from skates in the Aleutian Islands to identify potential egg case nursery areas and describe life history parameters.
- Collect new age and maturity data for EBS Alaska skates to update parameter estimates in the Tier 3 model.
- Conduct genetic and morphometric analysis of adult putative Alaska skates from the Pervenets Canyon region to confirm whether there is a separate species in the EBS.
- Conduct a broader genetics study on adult Alaska skate to determine the relative contributions of each egg case nursery area to the stock, particularly between the Aleutian Islands and EBS, preferably with samples from nursery areas in each region.
- Consider if egg case biomass or catch can be incorporated into the Tier 3 assessment.
- Investigate methods to assess the status of the skate community along the EBS slope.

Acknowledgments

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Tables and Figures

Table 1. Common and scientific names for species represented in the Bering Sea and Aleutian Islands Skate Complex.

		Common Name	***Scientific Name***
Primary Species			
	1	Alaska skate	*Arctoraja parmifera*
Other Skates			
	2	Big skate	*Beringraja binoculata*
	3	Longnose skate	*Caliraja rhina*
	4	Aleutian skate	*Bathyraja aleutica*
	5	Bering skate	*Bathyraja interrupta*
	6	Commander skate	*Bathyraja lindbergi*
	7	Whiteblotched skate	*Bathyraja maculata*
	8	Butterfly skate	*Bathyraja mariposa*
	9	Whitebrow skate	*Bathyraja minispinosa*
	10	Mud skate	*Bathyraja taranetzi*
	11	Roughtail skate	*Bathyraja trachura*
	12	Okhotsk skate	*Bathyraja violacea*
	13	Roughshoulder skate	*Amblyraja badia*
	14	Deepsea skate	*Bathyraja abyssicola*
	15	Leopard skate	*Arctoraja panthera*
	16	Pacific white skate	*Bathyraja spinosissima*

Table 2. Summary of available data on stock structure evaluation of the Alaska skate (*Arctoraja parmifera*). Adapted from the template of Spencer et al. (2010).

Factor and criterion	Justification	Findings
Harvest and trends		
Fishing mortality (5-year average percent of F_{ABC} or F_{OFL})	If this value is low, then conservation concern is low	Exploitation rates of Alaska skate in recent years have been variable but below F_{ABC} (10 year average $F:F_{ABC}$ = 0.58)
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	Differing population trends reflect demographic independence that could be caused by different productivities, adaptive selection, differing fishing pressure, or better recruitment conditions	Alaska skates are well-distributed in survey catches across the EBS shelf, but fishery catches have tended to be more highly concentrated in the outer domain (may disproportionately impact adults). Some spatial differences in fishery catch among years and target fisheries
Population trends (Different areas show different trend directions)	If this value is low, then conservation concern is low	Declines from historical highs in the EBS and Aleutian Islands. Biomass estimates from 2026 surveys are 24% below long-term mean in EBS and 63% long-term mean in Aleutian Islands
Barriers and phenotypic characters		
Generation time (e.g., >10 years)	If generation time is long, the population recovery from overharvest will be increased.	Generation time is over 10 years (18.7 years), suggesting longer time until recovery if overfished
Physical limitations (Clear physical inhibitors to movement)	Sessile organism; physical barriers to dispersal such as strong oceanographic currents or fjord stocks	No apparent limitations within EBS
Growth differences (Significantly different LAA, WAA, or LW parameters)	Temporally stable differences in growth could be a result of either short term genetic selection from fishing, local environmental influences, or longer-term adaptive genetic change.	Unknown
Age/size-structure (Significantly different size/age compositions)	Differing recruitment by area could manifest in different age/size compositions. This could be caused by different spawning times, local conditions, or a phenotypic response to genetic adaptation.	Some differences in length compositions among areas (sometimes bimodal in Aleutian Islands and EBS slope)
Spawning time differences (Significantly different mean time of spawning)	Differences in spawning time could be a result of local environmental conditions but indicate isolated spawning stocks.	Some level of egg case deposition occurs throughout the year with peak in summer. Unknown whether individual nursery sites differ in peak deposition timing
Maturity-at-age/length differences	Differences in size or age at maturity could impact production rates	Unknown

Table 2. Continued.

Factor and criterion	Justification	Findings
Barriers and phenotypic characters		
Morphometrics (Field identifiable characters)	Identifiable physical attributes may indicate underlying genotypic variation or adaptive selection. Mixed stocks w/ different reproductive timing would need to be field identified to quantify abundance and catch	No apparent differences
Meristics (Minimally overlapping differences in counts)	Differences in counts such as gillrakers suggest different environments during early life stages.	No apparent differences
Behavior & movement		
Spawning site fidelity (Spawning individuals occur in same location consistently)	Primary indicator of limited dispersal or homing	Genetic and nursery area studies indicate possible site fidelity
Mark-recapture data (Tagging data may show limited movement)	If tag returns indicate large movements and spawning of fish among spawning grounds, this would suggest panmixia	Limited tagging data show movements of 27-804 km in the EBS. Cross-shelf movements were observed but there was no evidence of inter-basin movement
Natural tags (Acquired tags may show movement smaller than management areas)	Otolith microchemistry and parasites can indicate natal origins, showing amount of dispersal	Unknown
Genetics		
Inbreeding coefficient (F_{IS})	Indicator of stability of population	Positive values (indicating decreased heterozygosity) but none are significant
Effective population size (N_e)	Estimate of number of breeding adults in an idealized population that would lose heterozygosity (due to inbreeding or genetic drift) at a rate equal to the observed population)	Relatively low (N_e = 890-1,257)
Isolation by distance (Significant regression)	Indicator of limited dispersal within a continuous population	Not significant (genetic differences cannot be explained by geographic distance)
Dispersal distance (<<Management areas)	Genetic data can be used to corroborate or refute movement from tagging data. If conflicting, resolution between sources is needed.	Not formally evaluated by genetics; surveys and special studies indicate rapid dispersal from egg case nursery areas after hatching
Pairwise genetic differences (Significant differences between geographically distinct collections)	Indicates reproductive isolation.	Significant pairwise differences (F_{ST}) found among nursery sites

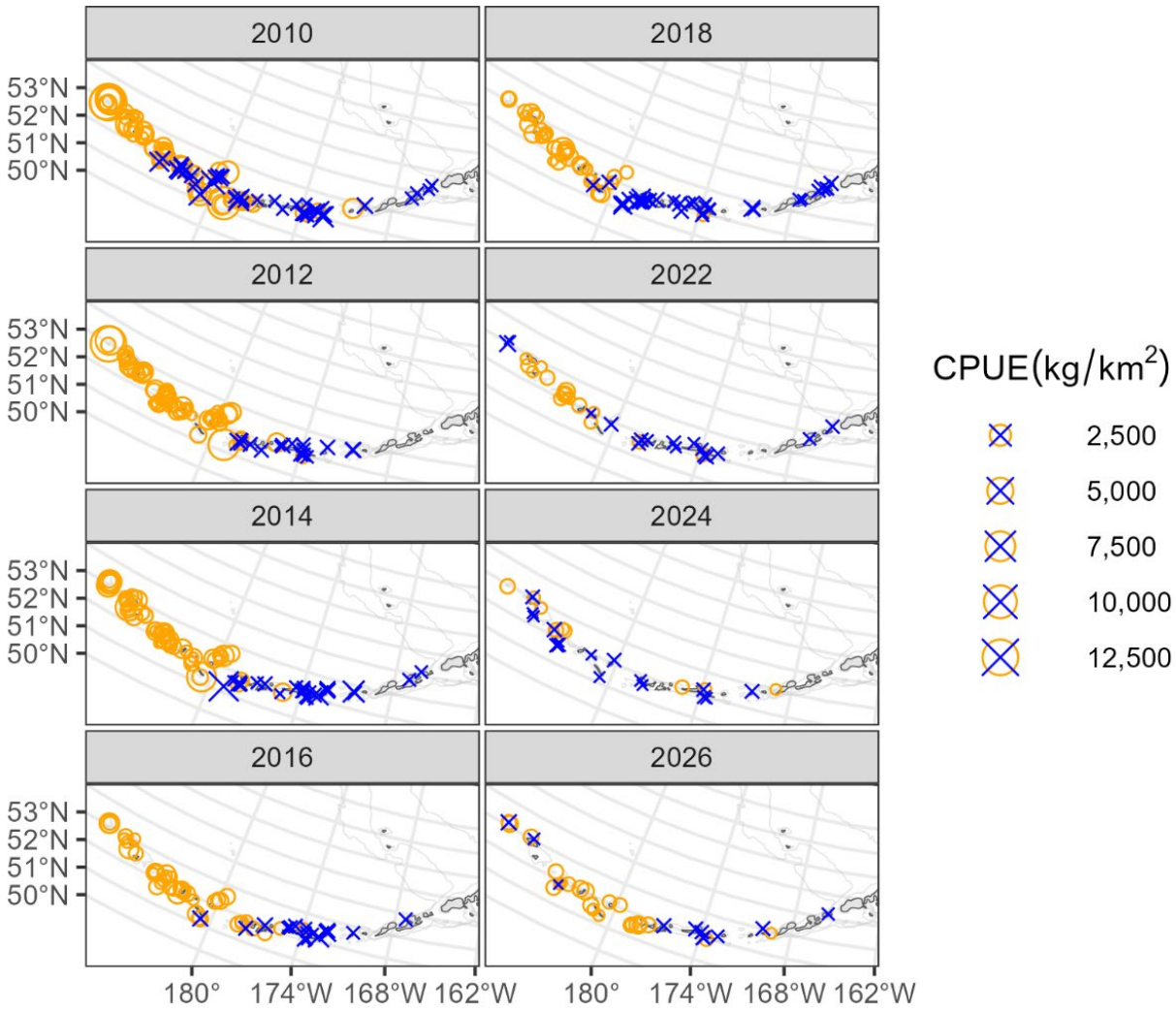


Figure 1. Catches of Alaska skates (blue crosses) and leopard skates (orange circles) in the AFSC Aleutian Islands bottom trawl surveys since 2010.

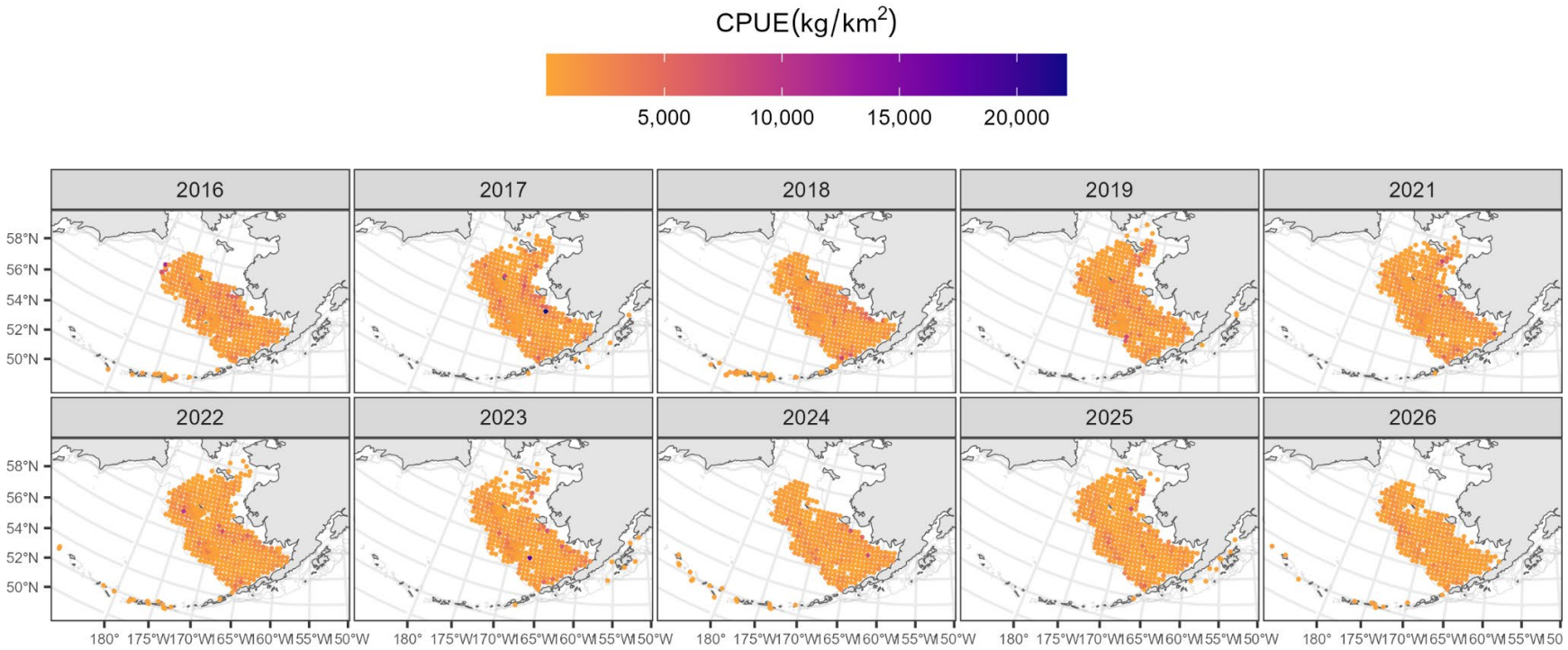


Figure 2. Catches of Alaska skates (*Arctoraja parmifera*) in all AFSC bottom trawl surveys (eastern Bering Sea shelf, eastern Bering Sea slope, Aleutian Islands, Northern Bering Sea, and Gulf of Alaska) since 2016.

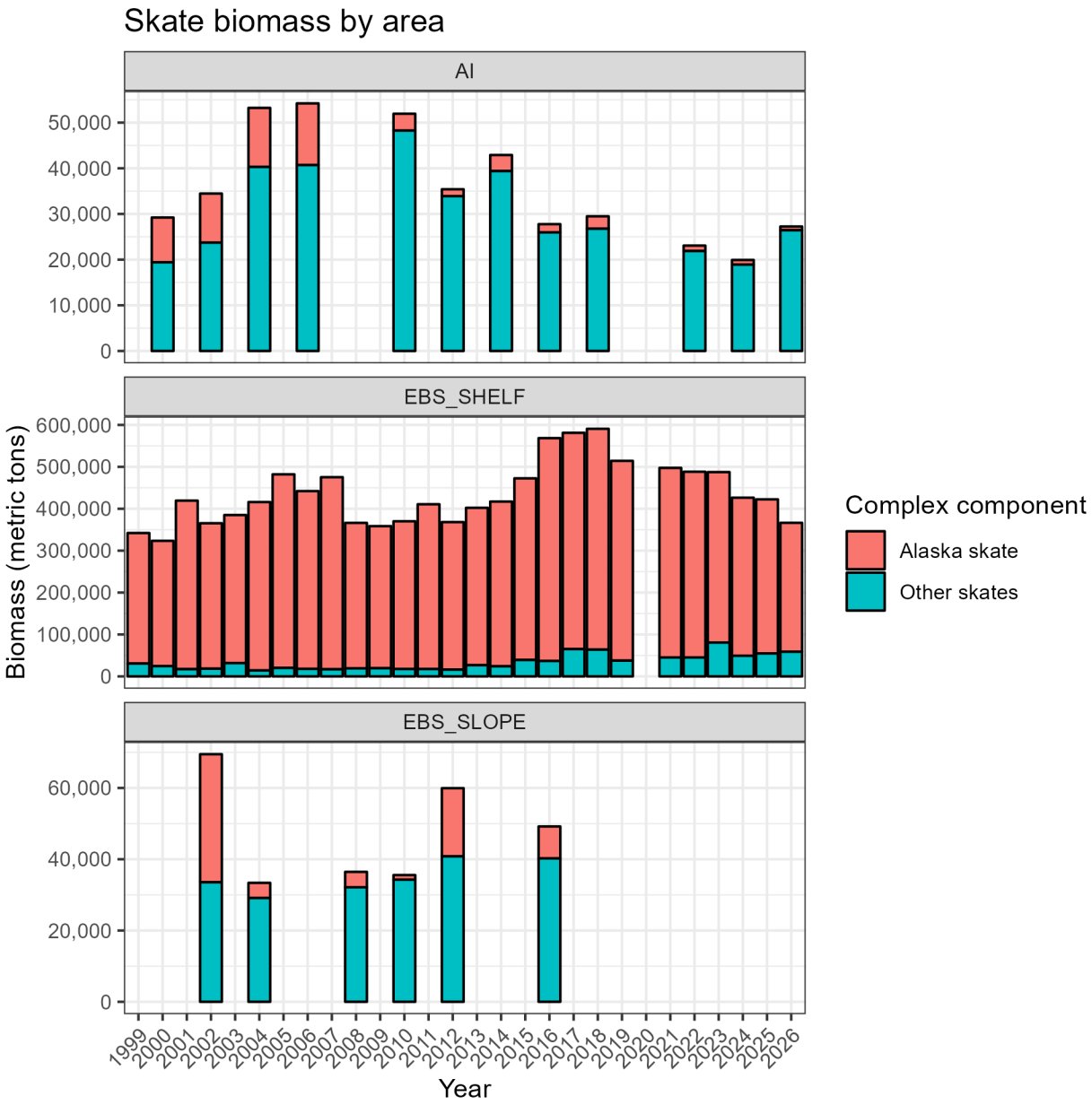


Figure 3. Trawl survey biomass estimates for Alaska skates and all Other Skates combined, for the Aleutian Islands (top), eastern Bering Sea shelf (middle), and EBS slope (bottom).

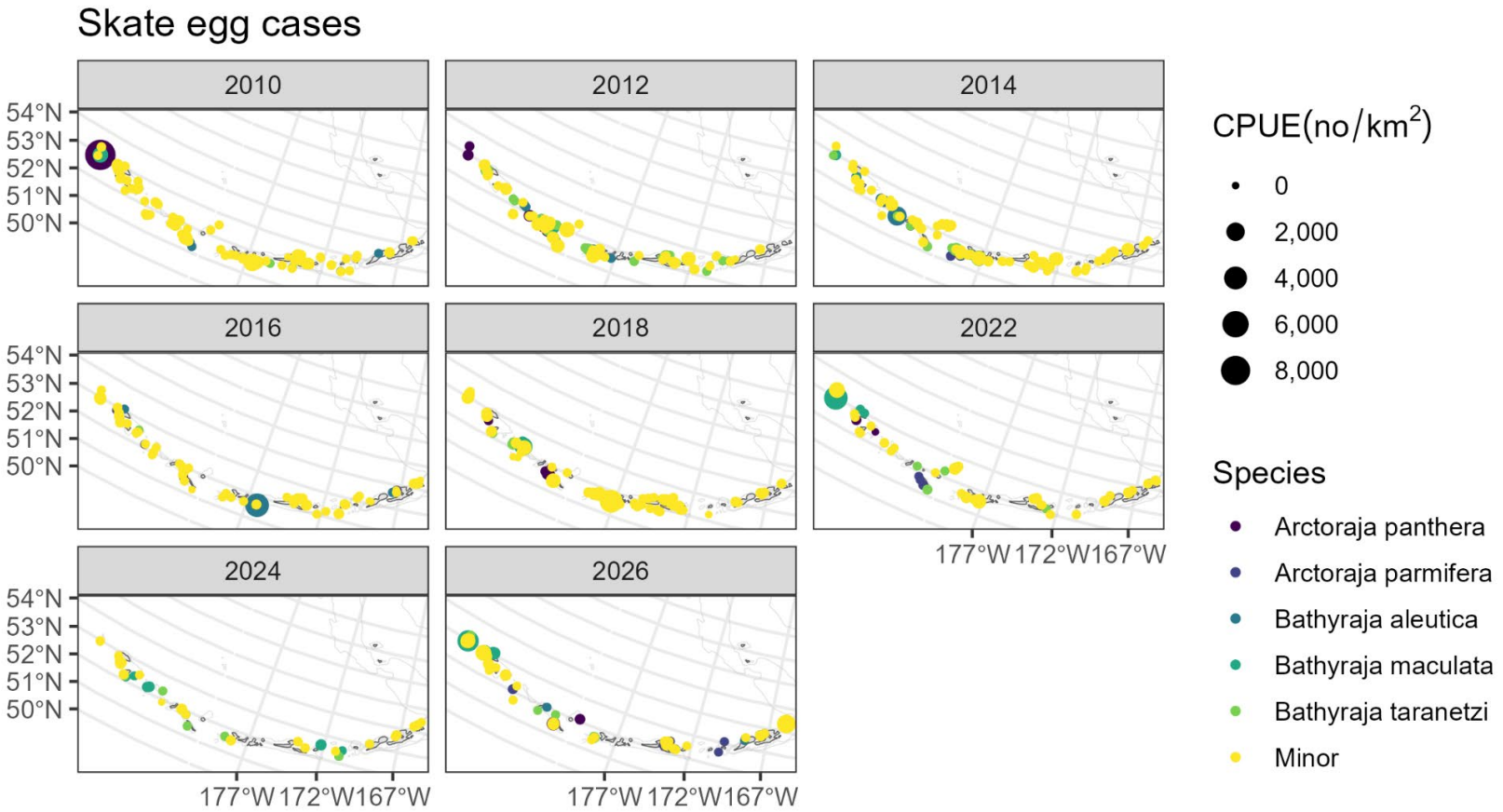


Figure 4. Catches of egg cases in the Aleutian Islands summer bottom trawl survey since 2010 for all major skate species (leopard skate *Arctoraja panthera*, Alaska skate *A. parmifera*, Aleutian skate *Bathyraja aleutica*, whiteblotched skate *B. maculata*, and mud skate *B. taranetzi*). Minor species include *B. abyssicola, B interrupta, B. mariposa, B. minispinosa, Caliraja rhina*, and unidentified skate egg cases.



Figure 5. Total skate catch, in metric tons, in the BSAI Fishery Management Plan subareas (AI = Aleutian Islands, BS = Bering Sea). Data are from the NMFS AKRO Catch Accounting System.

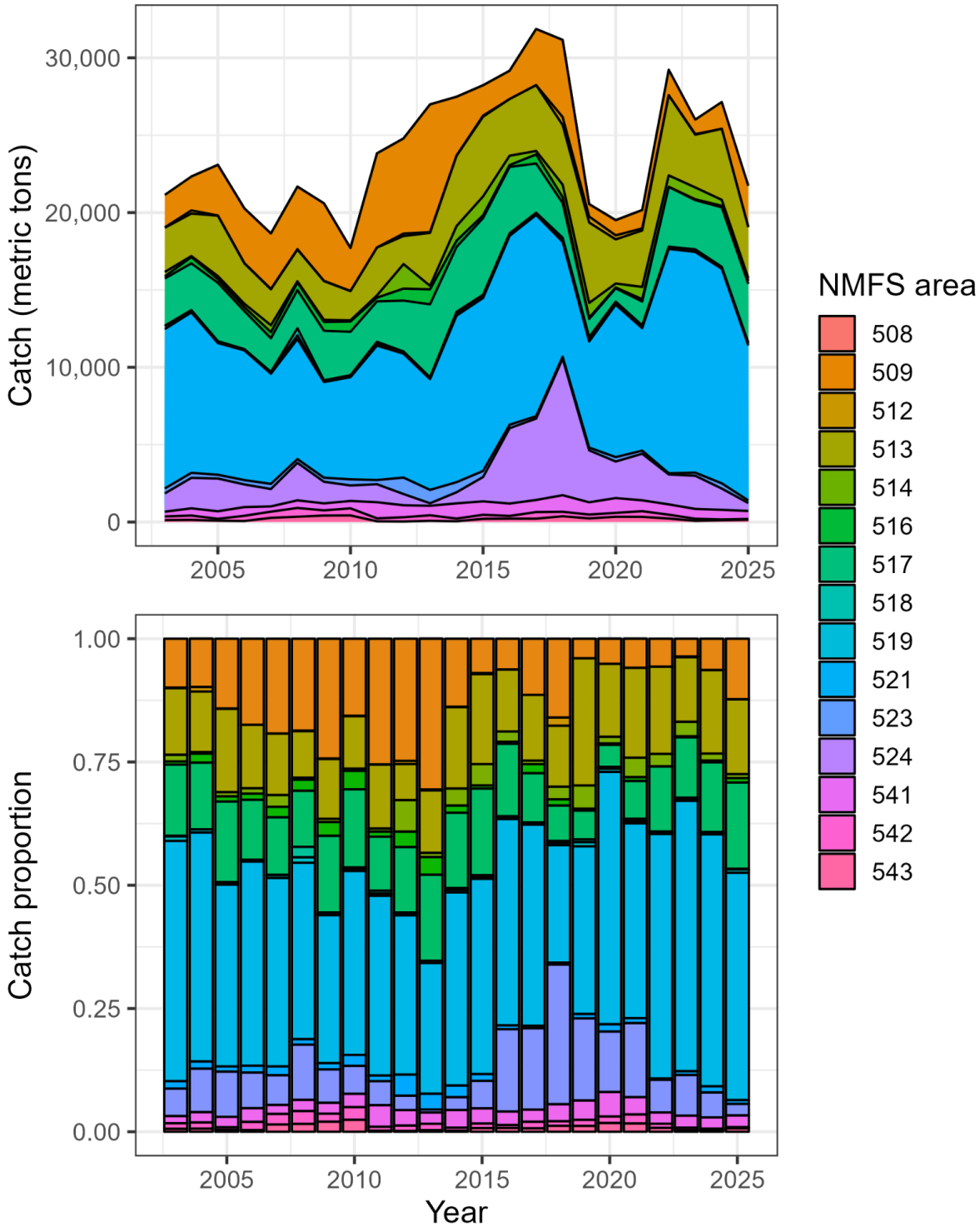


Figure 6. Bering Sea/Aleutian Islands Skate Stock Complex catch in total metric tons (top panel) and percentage by NMFS reporting area (bottom panel). Areas 541, 542, and 543 are in the Aleutian Islands; all other areas are in the Bering Sea. Data are from the NMFS AKRO Catch Accounting System.

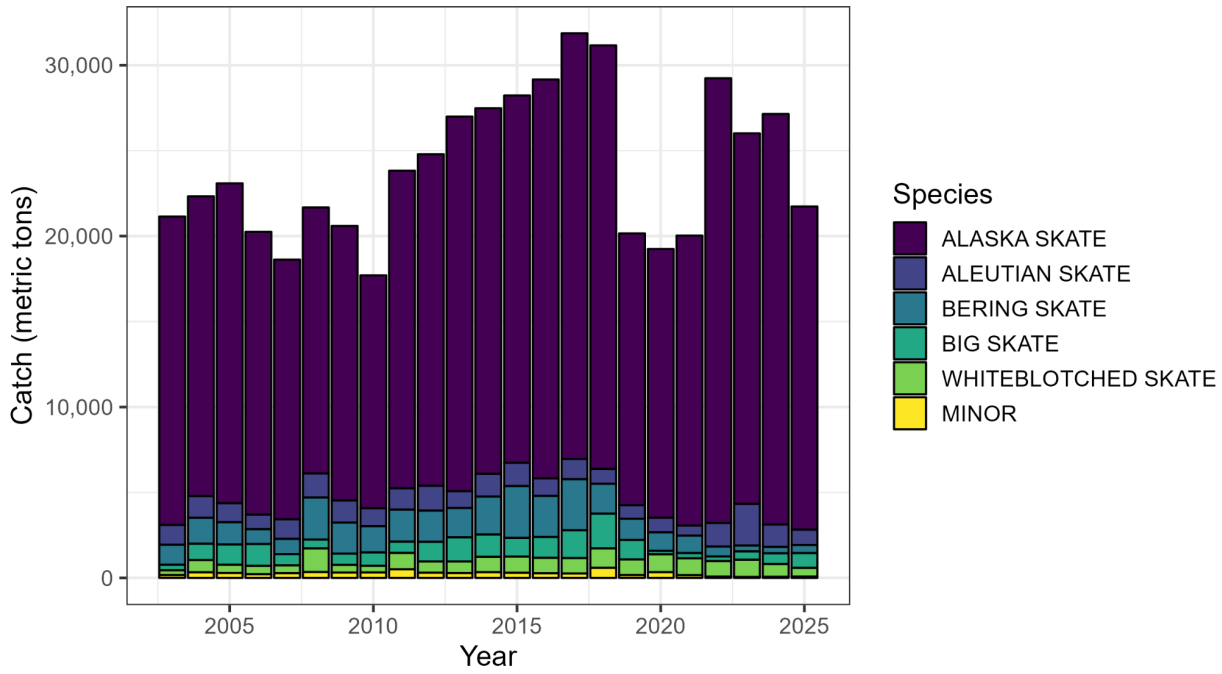


Figure 7. Bering Sea/Aleutian Islands Skate Stock Complex catch time series, partitioned to species using methods outlined in Ormseth (2018) using data from the NMFS AKRO Catch Accounting System and the North Pacific Observer Program.

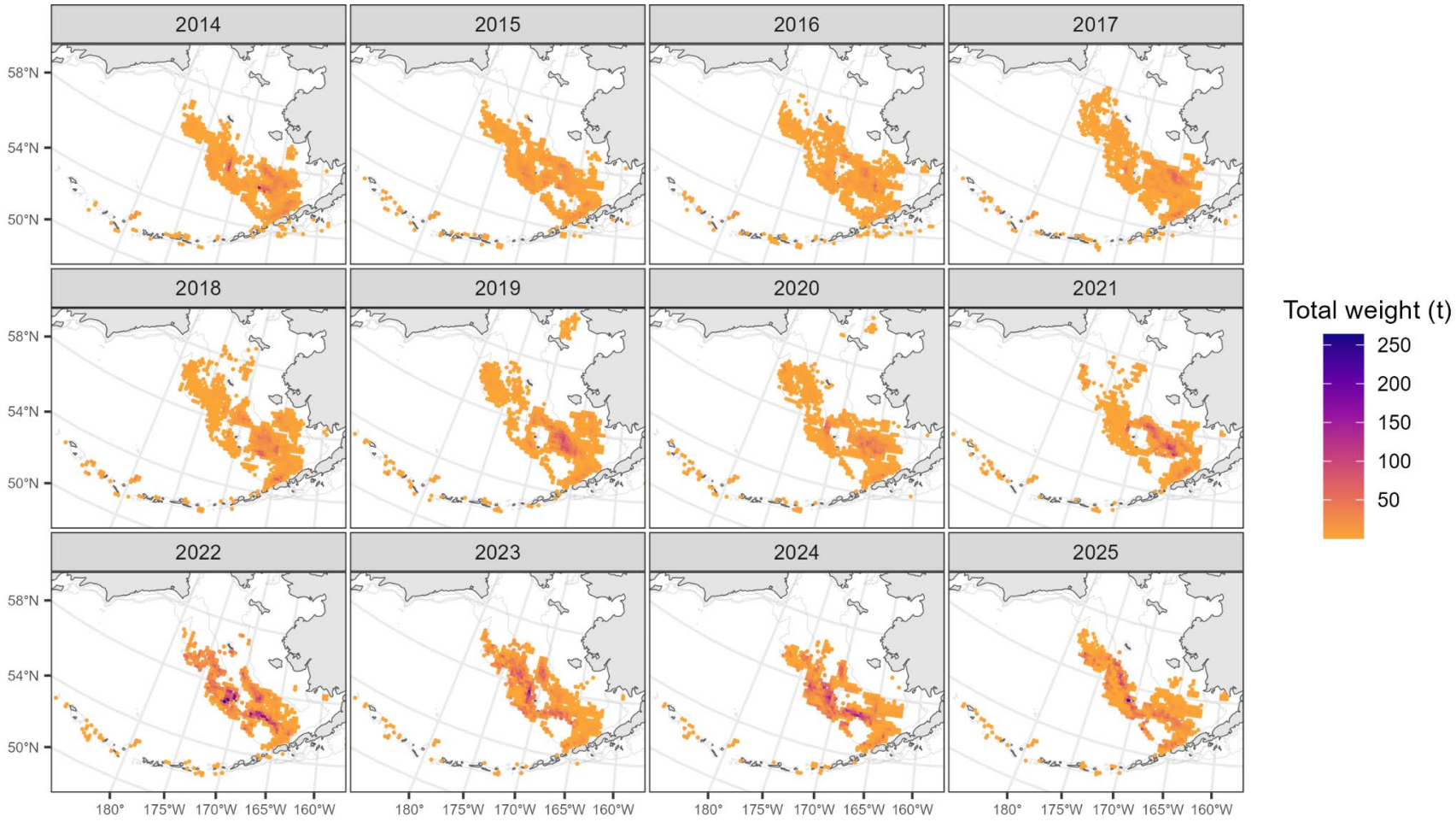


Figure 8. Fishery bycatch in metric tons of skates identified by observers as Alaska skates (*Arctoraja parmifera*). Data are nonconfidential and aggregated to 400 km^2 grid cells, and were obtained from https://www.fisheries.noaa.gov/resource/map/spatial-data-collected-groundfish-observers-alaska on 10 June 2026.

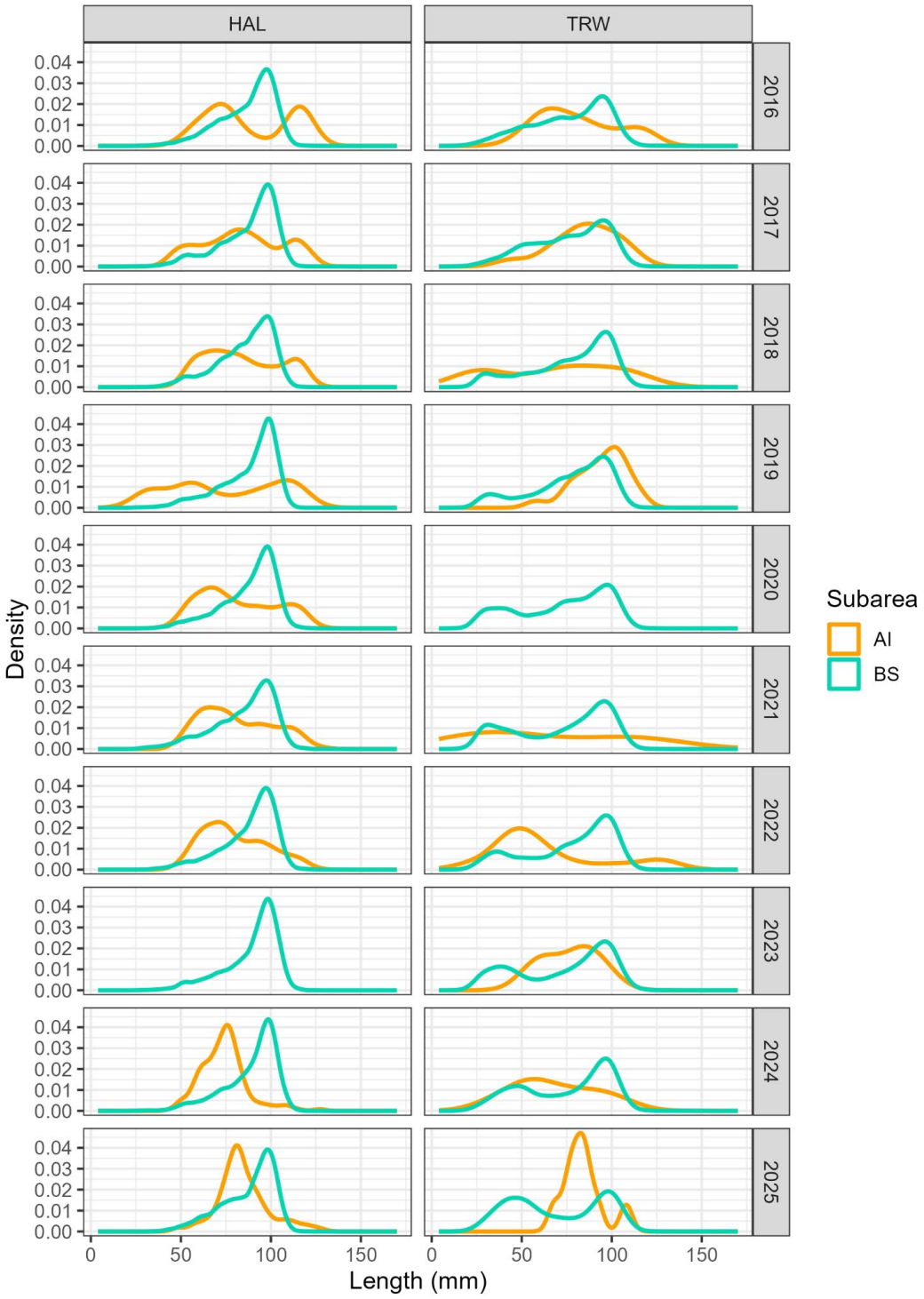


Figure 9. Fishery length compositions of Alaska skates caught from the Aleutian Islands (AI) and Bering Sea (BS) in target fisheries using hook-and-line (HAL) and trawl (TWL) gear.

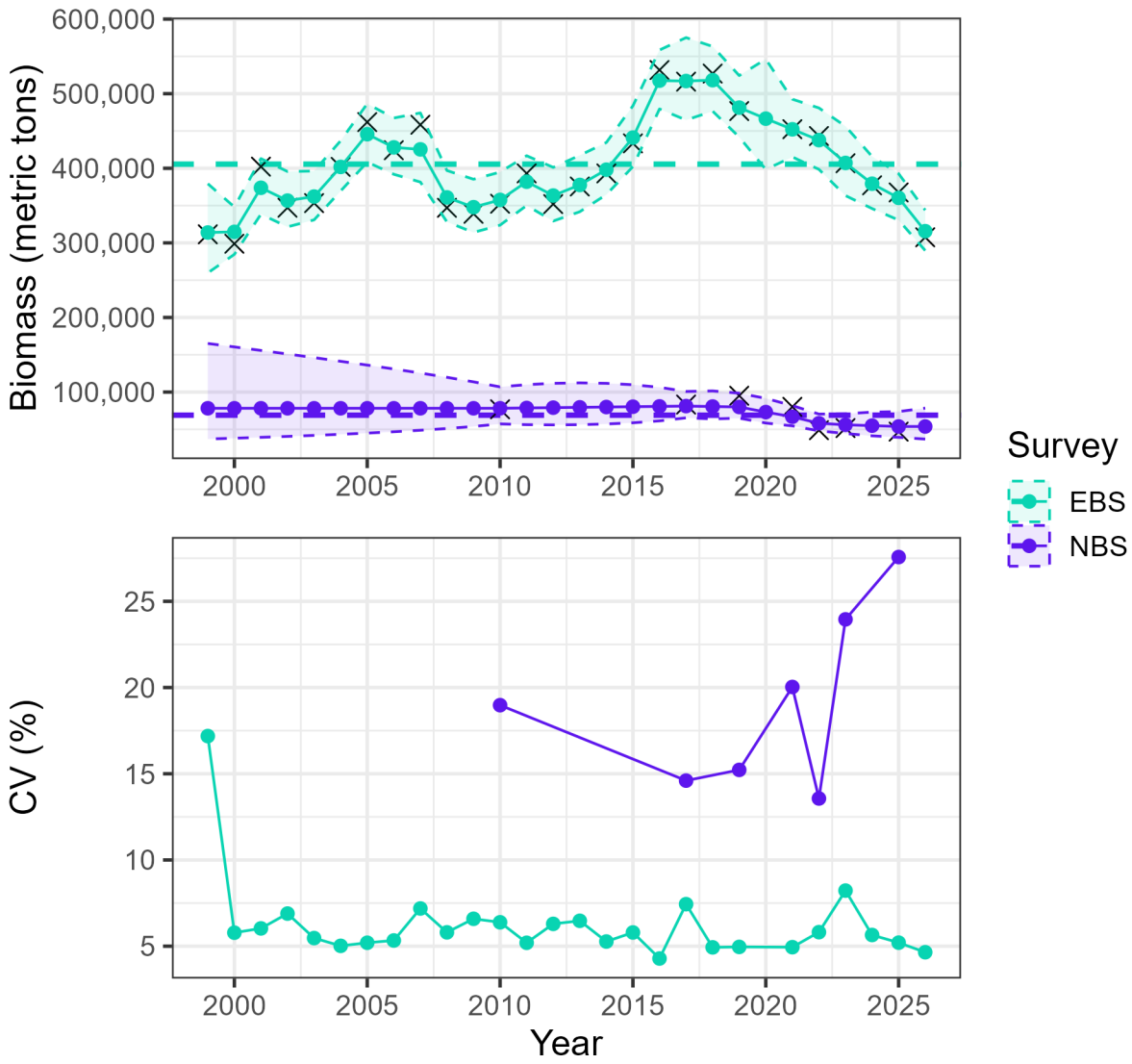


Figure 10. Alaska skate biomass estimates (top) and coefficients of variation, CV (bottom) from Alaska Fisheries Science Center summer bottom trawl surveys in the eastern Bering Sea (EBS) and northern Bering Sea (NBS). In top panel, colored points represent random effects model (REMA) biomass estimates, black ✕'s represent design-based estimates (i.e., years with observations), and horizontal dashed lines represent the long-term mean biomass of Alaska skates in each area. Biomass estimates are shown with shaded 95% confidence intervals. The bottom panel demonstrates differences in the CV (i.e., uncertainty) between the two surveys.

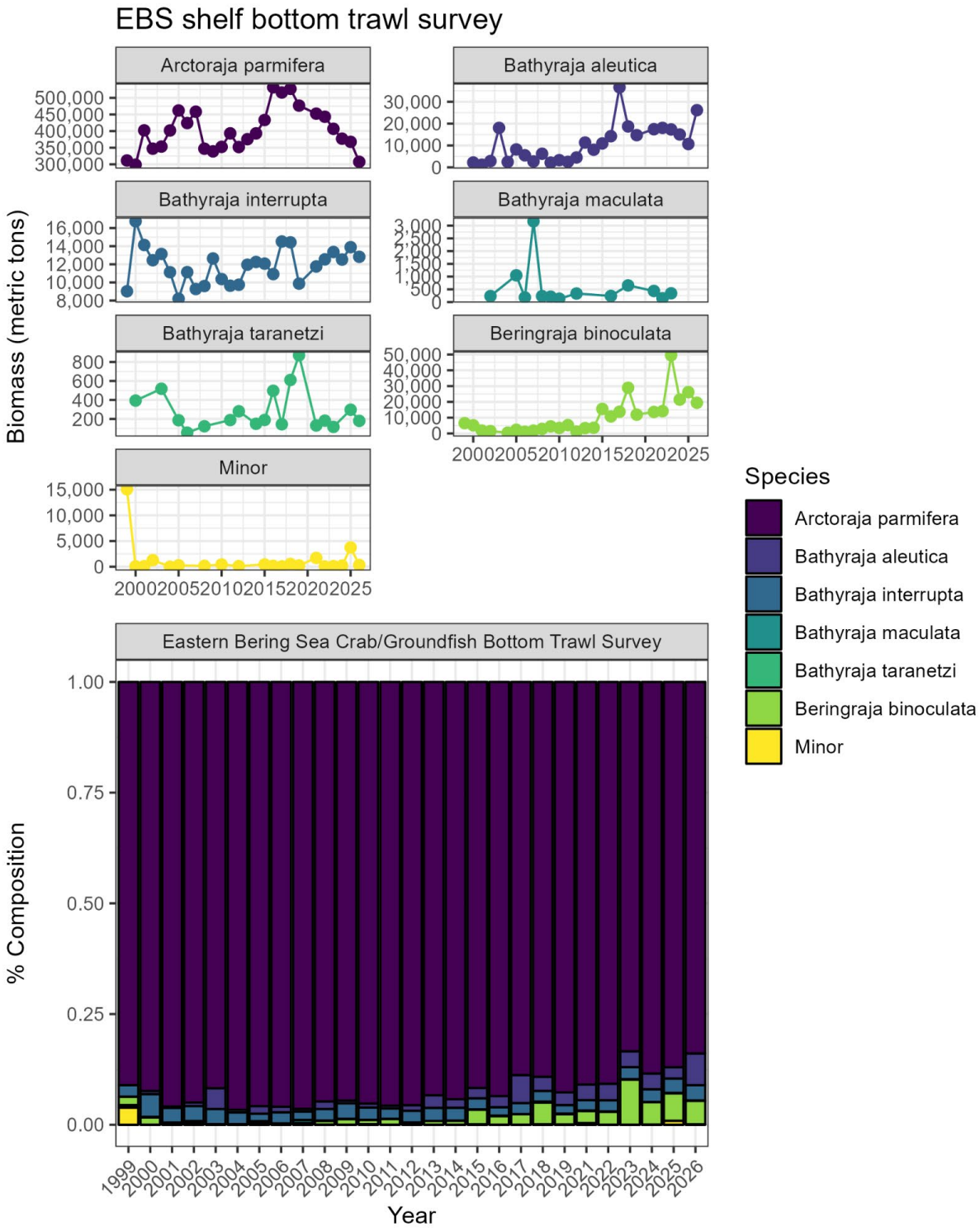


Figure 11. Biomass estimates for major skate species on the eastern Bering Sea shelf. Top panel shows biomass trends for individual species, bottom panel shows percentage composition by species.

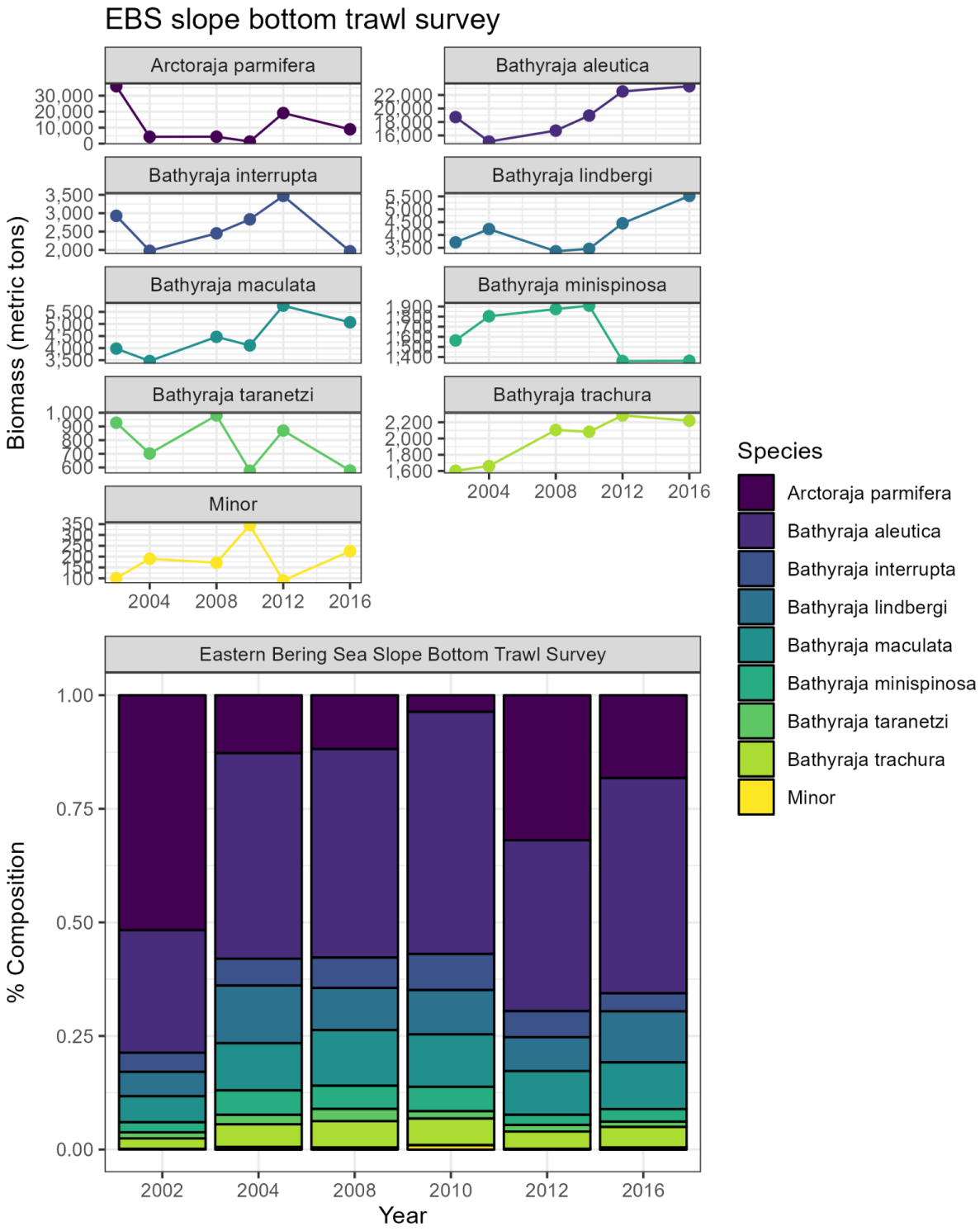


Figure 12. Biomass estimates for major skate species on the eastern Bering Sea slope. Top panel shows biomass trends for individual species, bottom panel shows percentage composition by species.

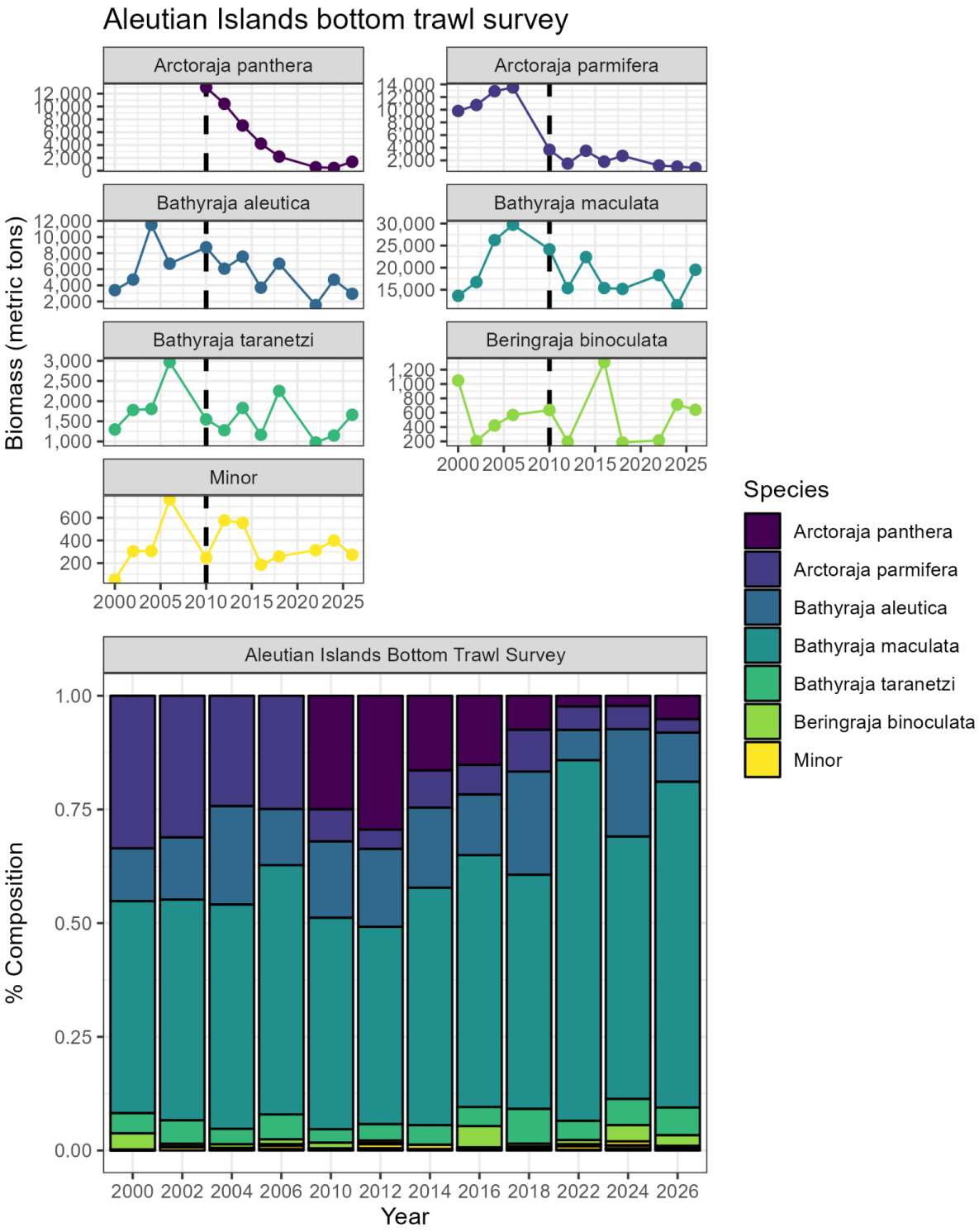


Figure 13. Biomass estimates for major skate species around the Aleutian Islands. Top panel shows biomass trends for individual species, bottom panel shows percentage composition by species. Vertical dashed line indicates 2010, when leopard skate (*Arctoraja panthera*) started being identified in survey catches consistently. Percentages of "Alaska skate" (*A. parmifera*) in the bottom panel prior to 2010 likely include leopard skates and are overestimated.

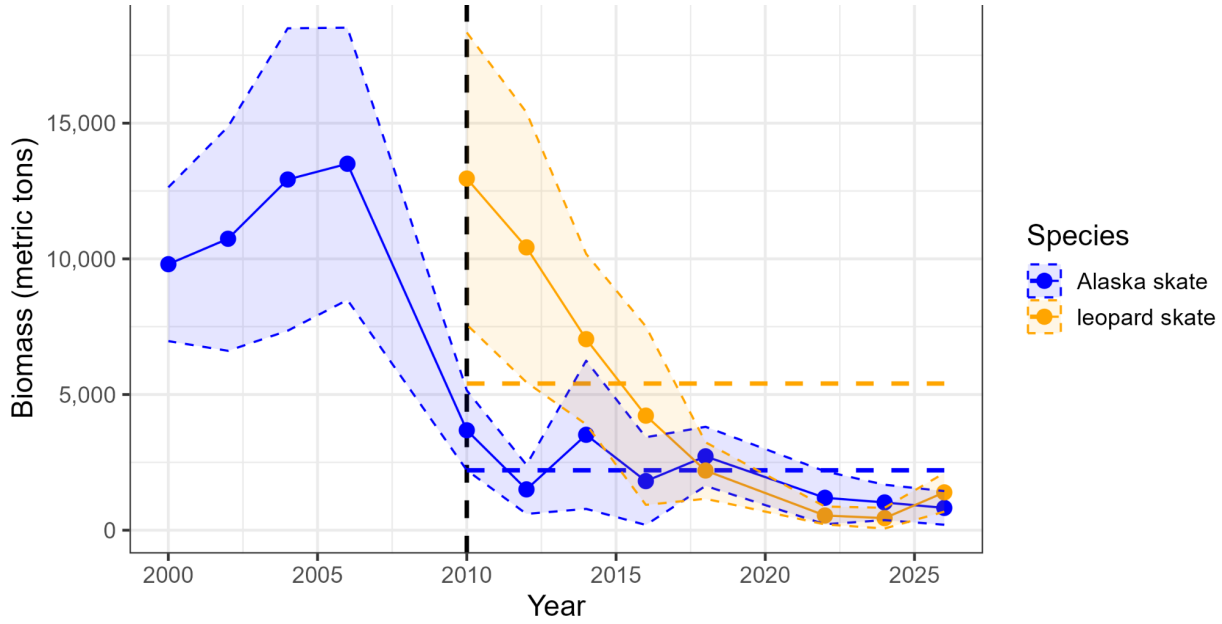


Figure 14. Biomass estimates (with 95% confidence intervals) of Alaska skate (*Arctoraja parmifera*) and leopard skate (*A. panthera*) in the Aleutian Islands summer bottom trawl surveys. The black vertical dashed line indicates 2010, when leopard skates started being identified in survey catches consistently. The dashed horizontal lines represent the long-term (2010-2024) means with reliable species identification for Alaska and leopard skates.

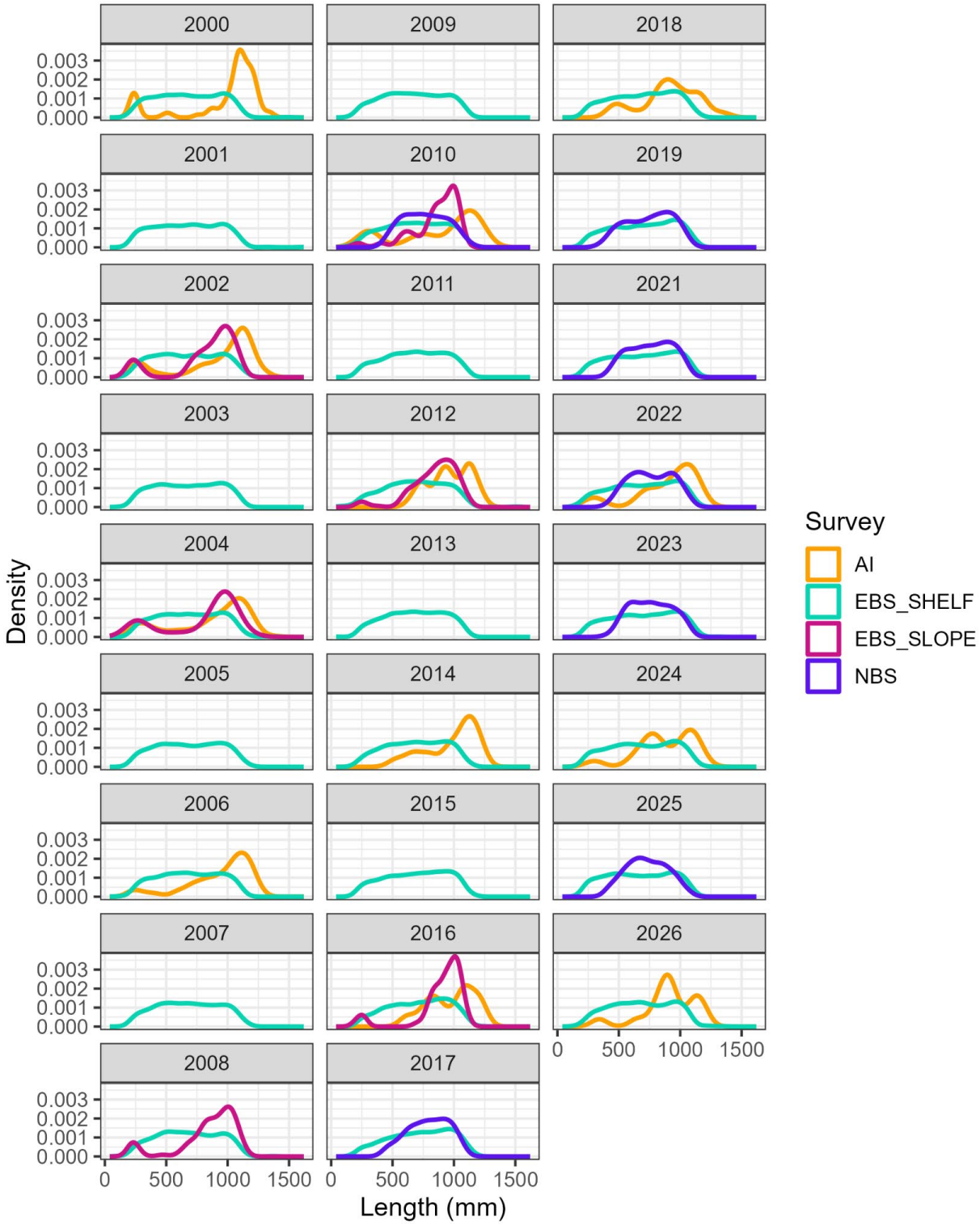


Figure 15. Survey length compositions of Alaska skate by area and year. Note that Aleutian Islands data prior to 2010 may include misidentified leopard skates.

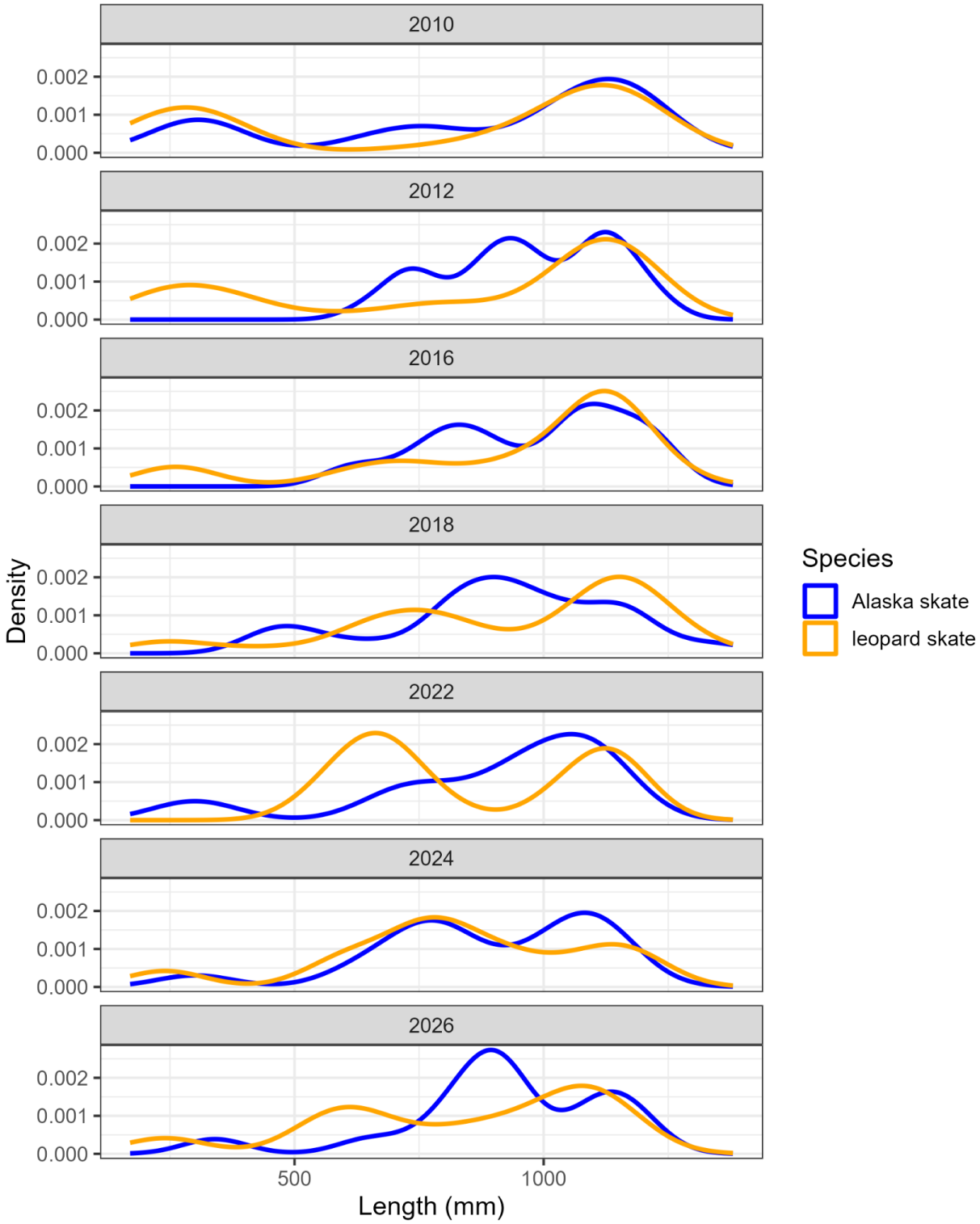


Figure 16. Alaska skate (*Arctoraja parmifera*) and leopard skate (*A. panthera*) length compositions from the Aleutian Islands bottom trawl survey. No leopard skate length data are available from the 2014 survey.

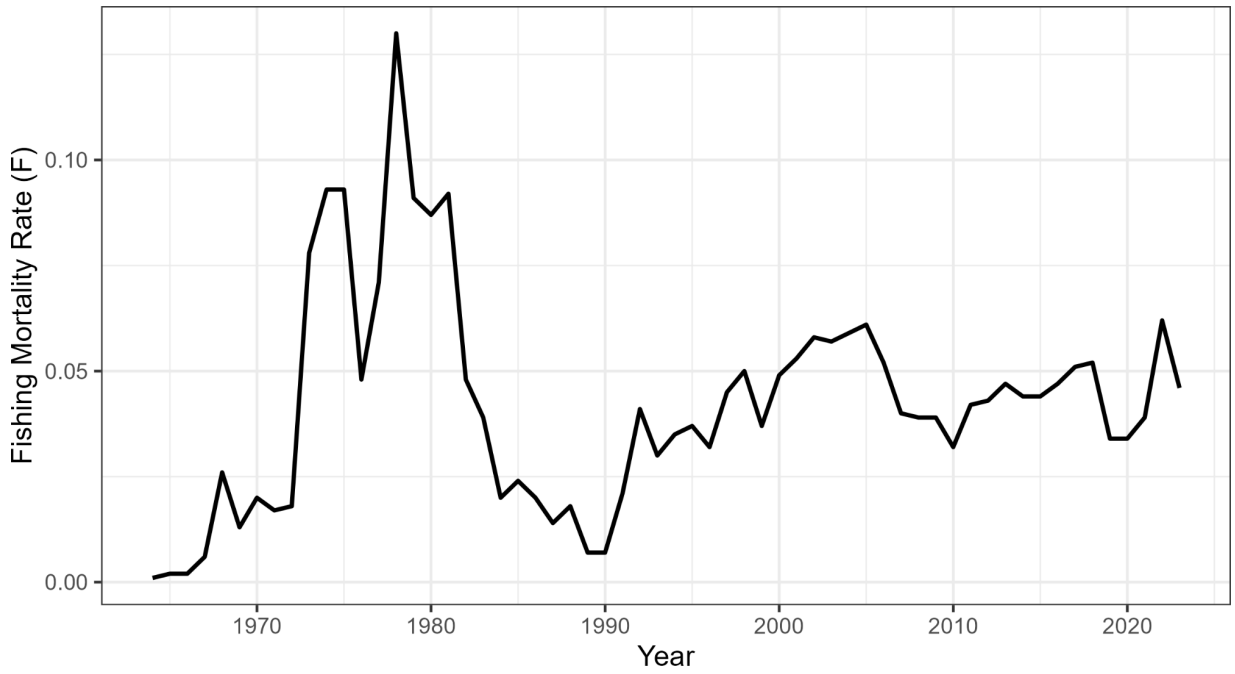


Figure 17. Time series of total fishing mortality rate for BSAI Alaska skate. From Tribuzio et al. (2023).

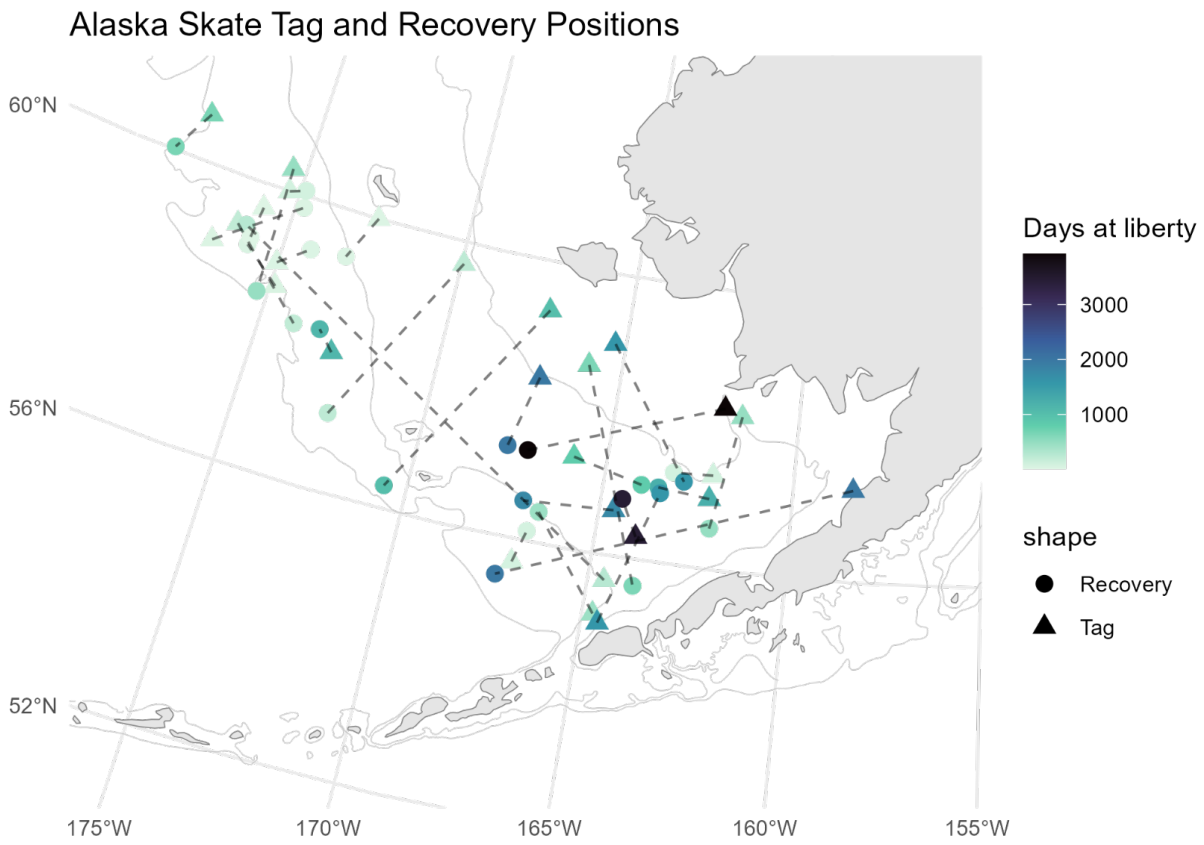


Figure 18. Tag-recapture locations of Alaska skates.