Assessment of the Multi-Function Trawl Net system for Acoustic-Trawl Surveys of Coastal Pelagic Species in the California Current Ecosystem for the Integrated West Coast Pelagics Survey

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Executive Summary:

The NOAA Southwest Fisheries Science Center (SWFSC) conducts Coastal Pelagic Species (CPS) surveys (aka California Current Ecosystem Surveys) to collect data used to inform management of federally-managed fisheries. CPS surveys using the acoustic-trawl method (ATM) have been conducted since 2006 and data from these surveys are used in CPS stock assessments, with a different subset of data years used for each stock based on data and review history. These CPS surveys have almost always taken place during the summer and sometimes during the spring; spring CPS surveys have not happened since 2021. The survey data is used to estimate species-specific biomasses, age compositions, and weight-at-age data used in stock assessments.

In 2025, the SWFSC integrated their summer CPS survey with the Northwest Fisheries Science Center's Joint U.S.-Canada Integrated Ecosystem and Pacific Hake Survey, since both surveys used the ATM along the U.S. West Coast. The resulting Integrated West Coast Pelagics Survey, commonly referred to as the "Integrated Survey", completed its inaugural survey during summer 2025.

The Integrated Survey still uses the ATM to collect survey data. Methods and gear remain primarily the same as used on the CPS survey, with the exception of switching to a new Multi-Function Trawl (MFT) Net from the Nordic 264 net used during prior CPS surveys. The MFT was designed in collaboration with industry experts to be able to trawl in both the mid-water for hake and at the surface for CPS. The dual fishing modality of the MFT increases safety and efficiency with the goal of providing comparable biological data for the target species. The MFT was first tested during December 2023 then used operationally by the SWFSC for the duration of the 2024 summer CPS survey, the data from which has been incorporated into the 2025 Pacific sardine stock assessment update. The intent is to use the MFT as part of the ATM on the Integrated Survey for collecting survey data on CPS moving forward.

We analyzed available data from the Nordic 264 and MFT to evaluate whether there have been detectable effects on our survey results and survey-derived inputs for CPS stock assessments

over time and whether such changes may be due to the change in net type. For our analyses, we described the rationale for switching from the Nordic 264 to the MFT without paired trawling (Section A), and compared the two net systems to assess similarities and differences in their design (Section B) and performance (Section C). We then provided a summary of the methods and biomass estimation from the 2025 Integrated Survey (Section D). Next, we compared species-selectivity and length-selectivity between the two net types with data collected from ATM surveys between 2013 and 2025 (Section E). We also evaluated potential changes in length selectivity on inputs to the stock assessment by comparing simplified, survey-derived age composition and weight-at-age estimates from sample data between the two net types (Section F). An update on the status of trawl-related recommendations from the 2018 ATM survey review was also provided (Section G).

Compared to the Nordic 264, the MFT has a much larger mouth opening and overall area, fished deeper, and sampled a greater proportion of the water column. Performance of the MFT was more consistent with higher numbers of medium and large catches and fewer small catches than the Nordic 264 despite a shorter tow duration (30 vs 45 min). Mesh size of the codend was the same for both net types, but several design issues identified for the Nordic 264 in past reviews were considered and addressed in the design of the MFT.

The MFT performed well for the purposes of providing biological information to apportion backscatter attributed to CPS during the 2025 IWCPS. The MFT has now been used successfully in coastwide CPS surveys since 2024, with no other major differences in methods during the IWCPS compared to SWFSC-only CPS surveys conducted in the California Current Ecosystem (CCE) since 2015. Based on results of the 2025 survey, the CPS community in the CCE continue to be dominated by the central subpopulation of Northern Anchovy and Jack Mackerel. The point estimate for the ATM biomass of the northern subpopulation of Pacific Sardine increased slightly from 2024.

We identified no meaningful differences in observed species composition between surveys conducted with the two different net types. While data visualizations, descriptive statistics, and multivariate analyses of species catch and composition indicated a high degree of variability within and among survey years, there was no evidence of changes in species selectivity due to the change in net type. We did observe differences in estimated average species richness and beta diversity between net types, but these differences were attributed to underlying shifts in community composition over time.

Comparisons of length distributions by species and year revealed no meaningful differences in length selectivity for Northern Anchovy and Sardine. The MFT however, did capture the largest Pacific Mackerel collected in the ATM survey, and greater proportions of both large Pacific Mackerel and large Jack Mackerel. However, it is unclear if these observations could be attributed to net effects or underlying variability in demographics of the CPS community.

Comparisons of calculated age composition and weight-at-age values between Nordic 264 and MFT survey years for three assessed CPS indicated varying effects of possible differences in length-selectivity by species. While there were no consistent differences in calculated age composition and weight-at-age values by net for Sardine, greater sampled lengths and ages for Pacific Mackerel during MFT survey years translated into higher estimates of both weight-at-age and the proportional contribution of older ages (i.e., ages-4+). Furthermore, estimated weight-at-age for older age classes of Northern Anchovy (i.e., ages-2+) were consistently highest during MFT survey years; estimated age compositions for Northern Anchovy also exhibited the greatest variability during these years.

A check on the status of trawl-related recommendations from the 2018 ATM survey review revealed that most have either been accomplished or are in progress. Those in progress will likely require the dedication of sufficient time and resources directed toward research that would otherwise be dedicated to an operational survey.

In summary, the dynamics of the nets were similar, but the MFT can sample a larger portion of the water column and also waters below the propeller wash, which is likely advantageous for sampling CPS. The MFT also performed better by consistently catching larger volumes of samples in less time. Species- and length-compositions were similar, with observed differences likely reflective of changes in the community structure of CPS within the survey over the time period considered in these analyses. Therefore, we conclude that the data collected using the MFT likely provides better biological information for apportioning backscatter and estimating CPS biomass than the Nordic 264, net comparisons have limited value given the data variability makes it difficult to detect differences if they exist or whether observed differences were due to a net switch, and that the MFT will be used as the primary tool used to provide biological information in ATM surveys of CPS moving forward.

Table of Contents

Background:

The NOAA National Marine Fisheries Service (NOAA Fisheries or NMFS) conducts science, including collecting data through surveys, to inform sustainable management of the Pacific hake and coastal pelagic fisheries. This information is vital for tracking fish stocks and environmental changes that is incorporated into stock assessments and used to understand the long-term productivity of these West Coast fisheries. Before 2025, NOAA Fisheries relied on two separate fishery-independent surveys to gather this important survey data: The Coastal Pelagic Species (CPS) Survey, aka California Current Ecosystem Survey, conducted annually by the Southwest Fisheries Science Center (SWFSC), and the Joint U.S.-Canada Integrated Ecosystem and Pacific Hake Survey conducted biennially by the Northwest Fisheries Science Center (NWFSC) in collaboration with Fisheries and Oceans Canada. Both surveys used the acoustic-trawl method (ATM) during the summer to estimate fish biomass, distributions, and demographic data throughout most of the continental shelf habitat in the California Current Ecosystem, which are principal data inputs for stock assessments. However, they differed in their trawl sampling approach by time of day, depth, net design and configuration, and other aspects. Furthermore, the surveys were managed independently by their respective science centers, each having established its own data collection protocols and working relationships with corresponding fishing communities.

The SWFSC and NWFSC were charged to develop a robust fisheries-independent survey that integrates the CPS and hake surveys that supports sustainable fisheries for Pacific hake and coastal pelagics, collects ecosystem data, and maintains the survey schedule. Several emerging challenges and opportunities prompted NOAA's decision to integrate the two separate surveys, with the inaugural survey scheduled for 2025. First, NOAA ship schedules for major mid-life repairs starting in late 2025 would drastically impact the availability of days at sea for surveys. These repairs will be conducted on a rotating basis, with each vessel out of commission for 12–18+ months over the next several years. Consequently, only one of the two primary survey vessels—the hake survey ship (NOAA Ship *Bell M. Shimada*, hereafter *Shimada*) or the CPS survey ship (NOAA Ship *Reuben Lasker*, hereafter *Lasker*)—will be available at any given time. Second, it was recognized that a changing ocean environment necessitates more comprehensive data collection to effectively address shifts in ecosystem dynamics and their impacts on fisheries. This enhanced data will improve the responsiveness of fisheries management by allowing for better decision-making based on near-real-time ocean conditions. Third, short-term funding provided the necessary resources and unique opportunity to immediately design and execute the transition to an integrated survey platform.

In anticipation of a combined ATM survey of CPS and Pacific hake in 2025 (i.e., the inaugural Integrated West Coast Pelagics Survey, commonly referred to as the Integrated Survey or IWCPS), and in collaboration with experts from the commercial fishing industry, a multifunction trawl net (or MFT) was designed and fabricated that would replace the Nordic 264 trawl (used for CPS at the surface) and Aleutian Wing Trawl (used for hake at depth). Initial sea trials were conducted with the MFT aboard the *Lasker* in December 2023 to train the deck crew, assess net performance in surface and midwater modes, and identify modifications for optimizing performance in both modes. Based on the encouraging results from those trials, the first MFT was modified and improved, and ultimately three additional MFT nets were fabricated using the improved design (Shaughnessy, 2025).

During the first five days of the 2024 CPS survey aboard the *Lasker*, trawl operations were conducted to continue testing the configuration and performance of the MFT, refine trawl protocols, and finalize training of the crew. Based on the results of the MFT testing, the decision was made to switch from the Nordic 264 net to the MFT for the entirety of the survey. During summer 2024, 174 nighttime surface trawls were completed with the MFT, and biological data from specimens collected in those samples were used to apportion CPS backscatter and estimate their distributions and biomasses (Stierhoff et al., 2025). The 2024 biomass estimate was used in the 2024 Pacific sardine stock assessment update (Allen Akselrud et al., 2025). In 2025, a total of 104 nighttime surface trawls for CPS were completed with the MFT during the inaugural IWCPS aboard the *Shimada* for the same purpose. The SWFSC's intent is to use the MFT as part of any ATM survey for CPS moving forward.

Here we provide analyses comparing the net specifications and resulting data collected in support of a methodology review to evaluate the continued ability to use Integrated Survey data in CPS stock assessments, given the switch to the MFT. The information provided in this document is structured to address the following questions:

1. *Has the switch from a Nordic 264 to the new MFT net on the Integrated Survey resulted in important changes to the species- and length-selectivities?*
2. *If so, have these changes resulted in important changes in the survey-derived data inputs for the stock assessment (biomass, age composition, weight-at-age)?*

In this report, we provide the following information:

A. Results and recommendations from paired trawling tests in other systems and resource considerations as rationale for switching from the Nordic 264 to the MFT without paired trawling.
B. Specifications of both the Nordic 264 and MFT net systems, including dimensions of nets and doors, mesh sizes, and mesh-size transitions.
C. Performance of the Nordic 264 and MFT nets during fishing, including sampling depth and vertical and horizontal spread of the net mouth opening.
D. Methods and biomass estimation from the 2025 Integrated Survey.
E. Species- and length-selectivity comparisons between the Nordic 264 and MFT nets.
F. Statistical comparisons of length-selectivity between the Nordic 264 and MFT nets for effects on survey-derived age composition and weight-at-age estimates.
G. Status update on trawl-related recommendations from the 2018 ATM survey review.

All analyses were performed using R 4.5.1 (R Core Team, 2025).

A. Rationale for switching from the Nordic 264 to the MFT without paired trawling

A.1. Brief review of paired trawls for evaluating net changes in trawl-based surveys

Trawl sampling in ATM surveys is used to accurately estimate the species and size (i.e., length and weight) composition of acoustic backscatter data and provide other biological characteristics (e.g., length-at-age data for CPS) for target species. Lengths and weights of target species may be used to convert acoustic data into estimates of animal abundance or biomass (Simmonds and MacLennan, 2007; Thomas et al., 2024), whereas other biological data such as length-at-age are used to generate age-length keys and other inputs for stock assessment (Ailloud and Hoenig, 2019; Francis, 2016; Lorenzen, 2016).

Intraspecific and interspecific variations in fish behavior during trawling and capture can influence trawl samples and the resulting abundance estimates. More specifically, trawl design and sampling protocols can impact trawl performance such as the efficiency of capturing target species (a.k.a. trawl catchability or fishing power) and both the size and species selectivity of fish that enter and are retained in the trawl (Hilborn and Walters, 1992; Walker et al., 2017; Williams et al., 2015). Evaluations of trawl performance allow for calculations of bias and uncertainty in abundance (biomass) estimates (Kotwicki et al., 2018). Moreover, changes in trawl design or sampling methodology can be evaluated to identify and correct for any differences in trawl performance when combining the data into a single survey time series (De Robertis et al., 2017).

Catchability typically refers to the difference in abundance and size composition between the catch and the population that can be used to convert relative abundance estimates from surveys (catch-per-unit effort or CPUE) and establish biomass reference points (Fraser et al., 2007; Quinn and Deriso, 1999; Sparholt, 1990). Catchability (q)= C/EB where C equals catch, E refers to fishing effort, and B refers to the stock biomass (Arreguín-Sánchez, 1996). Catchability is a function of fish availability and gear efficiency (Heino et al., 2011; Zhou et al., 2014). Availability is the accessibility of fish to a given gear (e.g., trawl net) and depends on the horizontal and vertical distribution of fish in relation to the trawl at the time deployment (Walsh, 1996). Gear efficiency, which is the probability that fish in the path of a trawl will be caught and retained (Somerton, 1999), is determined by trawl design, deployment and performance of the gear and the size, morphology, behavior and other biological traits of fish (Fraser et al., 2007).

Bottom trawl surveys and other forms of quantitative trawl sampling that serve as the index for abundance estimates generate an estimated CPUE using the area-swept method (Alverson and Pereyra, 1969), which is calculated by multiplying the distance fished by the area of the trawl spread (Somerton and Weinberg, 2001; Weinberg and Kotwicki, 2008). This value is then used to generate absolute estimates of species and size composition in areas where acoustic backscatter was observed.

When a gear change occurs in a quantitative, bottom trawl survey, some form of relationship between the catch rates (CPUE) of the two gears can be estimated from paired trawl experiments (Walker et al., 2017). The results of such experiments are then used to quantify and correct for changes in catchability, gear efficiency, selectivity and other aspects that directly affect abundance estimates (Bethke et al., 1999; Reid et al., 2012). Paired trawls are also important when trawl sampling is used to directly validate the specific biological characteristics (e.g., age and length composition, sex ratios) of specific schools targeted by acoustics (e.g., PHEAT survey). Obtaining robust estimates of changes in catchability is challenging, because paired trawl experiments are difficult, costly, and often limited in time and space such that the results do not encompass the entire extent or variations of environmental conditions of the survey area (Kotwicki and Weinberg, 2005; Munro and Somerton, 2002).

A.2. Explanation of why paired trawls are not critical for the CPS Survey

The trawl sampling portion of the CPS survey is not designed to calculate swept area (or volume sampled) or CPUE, because trawl catches and catch rates are not used to generate the index of abundance for the assessment. Rather, abundance is estimated from acoustic backscatter, and the catch data from trawls are used to apportion the backscatter data to estimate biomass by species and size based on the relative abundance (% weight of catch) and length distributions of CPS and non-CPS in the catch. Thus, unlike traditional swept area surveys, the trawl nets used in the CPS survey provide relative, not absolute, estimates of species and size composition of CPS present in areas where acoustic backscatter was observed. Under these circumstances, nets that sample similar depth ranges and habitats and produce catches that are representative of the species and size composition of target species observed by echosigns should provide comparable biological information for apportioning backscatter from CPS and estimating their biomasses for stock assessment purposes (Simmonds and MacLennan, 2007).

Catchability as it relates to the CPS survey is largely dependent on two factors: (1) the ability of acoustics to "see" all the fish in the water column (assumed to be 100%); and 2) the coverage of the survey relative to the stock distribution (varies). Therefore, the catchability of the net does not play a critical role and is not required to be evaluated directly through paired trawling experiments. Rather, emphasis should be placed on comparing species and size compositions to determine whether there are differences in selectivity between the two net types. Biases in fish lengths and species composition in trawl catches due to species or size-specific differences in retention in the trawl can cause substantial errors in biomass estimates generated from acoustic surveys (Kotwicki et al., 2017; Wileman et al., 1996; Williams, 2013). It is therefore critical to understand and quantify the magnitude of selectivity as well as the potential influences on these variables associated with the conditions present during capture. For the CPS survey, this can be accomplished by comparing data from past trawl catches with the Nordic 264 (2013-2023) with recent catches using the MFT (2024-2025) to confirm that similar species, sizes, and composition are being sampled (see Section E. and Section F. below). Should any differences be detected that can be attributed to a net switch and are likely to have meaningful effects on survey results or survey-derived inputs to CPS stock assessments, the results can then be used to calibrate data from old or new net design as needed.

Relative selectivity ratios can be generated by comparing species proportions and proportions of fish across length bins for each target CPS (Walker et al., 2017). Comparing net specifications (e.g., mesh sizes, mesh size transitions) may help explain any observed changes in the length distributions. Comparisons of fishing performance (e.g., fishing depths, vertical and horizontal spread, trawl duration) are also useful to assess whether shifts in selectivity, availability, and representativeness occurred. Availability is the accessibility of fish to a specific net type and depends on the horizontal and vertical distribution of fish versus that of the trawl (Walsh, 1996). Trawl representativeness denotes that the trawl is representative of the echosigns observed in terms of species and length, and it is affected by trawl duration (Thomas et al., 2024). Therefore, comparisons of catch compositions by trawl duration of the two net systems can provide insights on whether the trawl results are representative of the acoustic data. A lack of trawl representativeness could be a source of important potential bias; sampling strategy of hauls can be as important as acoustic sampling strategy (Simmonds et al., 2009).

A.3. Agency/survey priorities and resource/time limitations

Initial scoping of a new net system able to trawl at any depth without changing nets or doors or requiring multiple net reels began in early 2023 (Shaughnessy, 2025). The timing of resource availability meant that the first MFT was constructed in late 2023 and was immediately tested in an initial gear trial for both surface and midwater trawls in December 2023 aboard the *Lasker*. The results of the initial trial were promising, as we were able to establish consistency in fishing performance (e.g., depths) and an initial protocol for deployment, fishing, and retrieval.

With only 6 months in between completion of initial gear trial and initiation of the summer 2024 CPS survey, there was just time to complete a few refinements to net specifications based on the trial and also build a second duplicate net. Both nets were delivered to the *Lasker* in time for the start of the summer 2024 CPS survey.

Further testing and training on the MFT was completed in the few days immediately prior to the start of Leg 1 of the 2024 CPS survey, which included multiple, daily, closed cod end trawls. Based on the results of these trials, all indications were that the MFT was fishing in a similar manner as the Nordic 264 (i.e., similar depth range, similar species compositions, similar length distributions of CPS). Moreover, the ship crew was able to demonstrate an ability to complete 2-3 surface trawls per night when fishing duration was reduced from 45 to 30 mins per trawl (see details below in Section C.).

There were no further sea days available in 2024 to conduct further gear trials or paired trawl comparisons without further impacting the ability to conduct the operational 2024 summer CPS survey. Additionally, the *Lasker* has a single net reel meaning any trawl comparisons would mean sequential trawling with quite a bit of time in between trawls due to the need to switch out nets. The scientific and industry experts on board were comfortable using the MFT system for the 2024 summer CPS survey based on their knowledge of both Nordic 264 and MFT operations and catches.

During the summer of 2024 and spring of 2025, the team also tested the MFT on the partner Fisheries and Oceans Canada (DFO) vessel and tested midwater trawling on the *Shimada* to prepare for the hake collection portion of the survey.

The next days at sea available were for the 2025 inaugural Integrated West Coast Pelagics Survey itself. The 24-hour operational high tempo of survey operations, and the need to include buffer days for weather, mechanical issues, and operational learning during a new survey meant there were not available days at sea to dedicate to paired trawling. While logistical constraints precluded ability to do paired trawling before operational switch to the MFT system, the science team was comfortable moving to the MFT based on trawls completed prior to this point with a plan to compare selectivity and performance of the MFT with the Nordic after the 2025 Integrated Survey.

A.4. Summary and Conclusions

- Based on the collective knowledge and experiences of fishery survey experts and our reviews of the literature, we concluded that direct empirical comparisons between the catches of the two nets (e.g., paired trawls) would require considerable time and financial resources. Performing a small number of paired trawls in 2024 or 2025 would be unlikely to provide enough information to detect meaningful differences between the two nets (i.e., whether any observed differences in length selectivity, species selectivity, or other survey results were due to the net switch).
- Considering the designed purpose of trawls in the ATM survey, agency and survey priorities, and stock assessment needs, we would generate more data on MFT to compare with Nordic by doing a complete switch than by investing limited portions of time to paired trawling experiments that result in a much smaller data set. This approach would also allow us to complete a full CPS survey for the assessment.
- Recognizing there is a potential for differences in data provided from these two nets, and therefore potential effects of changing nets on estimated biomass, distributions, and demographics of target species, the most efficient approach would be to compare available data from surveys using the Nordic 264 and the MFT to evaluate whether a change in the net type may have meaningful, detectable effects on species- and length-selectivity and survey-derived inputs for CPS stock assessments.
- Based on the purpose and use of trawl data for CPS biomass estimates, our analyses should focus on understanding whether the MFT is sampling the same portion of the water column (vertical and horizontal spread), same overall community (species composition), and the same length distributions of target species (length selectivity).
- We can accomplish this by completing as many MFT hauls as possible and then comparing the results with our extensive database on Nordic hauls to test whether our assumption that

the net switch has maintained survey continuity or whether it requires inter-survey calibrations (see ICES, 2020; Section 2.3.1).

- If deemed necessary, the SWFSC is open to future experiments and surveys designed to test for changes in net performance and quantify correction factors to maintain a consistent time series on fish abundance and demographics for use in CPS assessments. However, this would require dedication of sufficient time and resources that would most likely take away from operational survey days-at-sea which would result in some years having no survey estimate or possibly a much more uncertain survey estimate because sampling coverage was reduced.

B. Specifications of both the Nordic 264 and MFT net systems, including dimensions of nets and doors, mesh sizes, and mesh-size transitions

B.1. Net design and overall dimensions

Both the Nordic 264 and the MFT are kite-equipped, door-spread, rope trawls with a similar four panel design (Appendix 1, **Figs. A1 and A5**). The mouth opening of the Nordic 264 is approximately 15 m tall by 20 m wide, with an area of 336 m^2, and an overall length of 94.45 m. In comparison, the mouth opening of the MFT is approximately 18 m tall by 36 m wide, with an area of 648 m^2 and overall length of 124.1 m (**Table B1**). The headrope of the MFT is configured with mesh pockets to allow for the addition of up to ten A4 floats to adjust the fishing depth of the net.

Table B1. Nominal dimensions of the Nordic 264 and MFT trawl nets.

	Nordic 264	**MFT**
Height	15 m	18 m
Width	20 m	36 m
Overall length	94.45 m	124.1 m
Opening area	~336 m^2	~648 m^2
Codend mesh	8 mm	8 mm
Doors	Nets XL Lite 3m^2	Thyboron Type 22 VK 4m^2

B.2. Mesh configuration

From mouth to codend, the Nordic 264 is segmented by seven different mesh sizes with a marine mammal excluder device (MMED, Dotson et al., 2010) and a codend section with an 8 mm liner at the tail of the net (**Fig. B1**). In comparison, the MFT is segmented by eleven sections with decreasing mesh sizes with a separate, swappable codend section with an improved MMED and a 8 mm liner at the tail of the net (**Fig. B1**). The greater number of mesh sections along with the more gradual transition from large to small mesh sizes along the net allows for better water flow throughout the net, allowing fish to more easily enter the mouth of the net and not escape out of the side meshes, and reduces back flushing (sometimes called the “bucket effect”) as catch accumulates in the net (G. Shaughnessey, pers. Comm., **Fig. B1**).

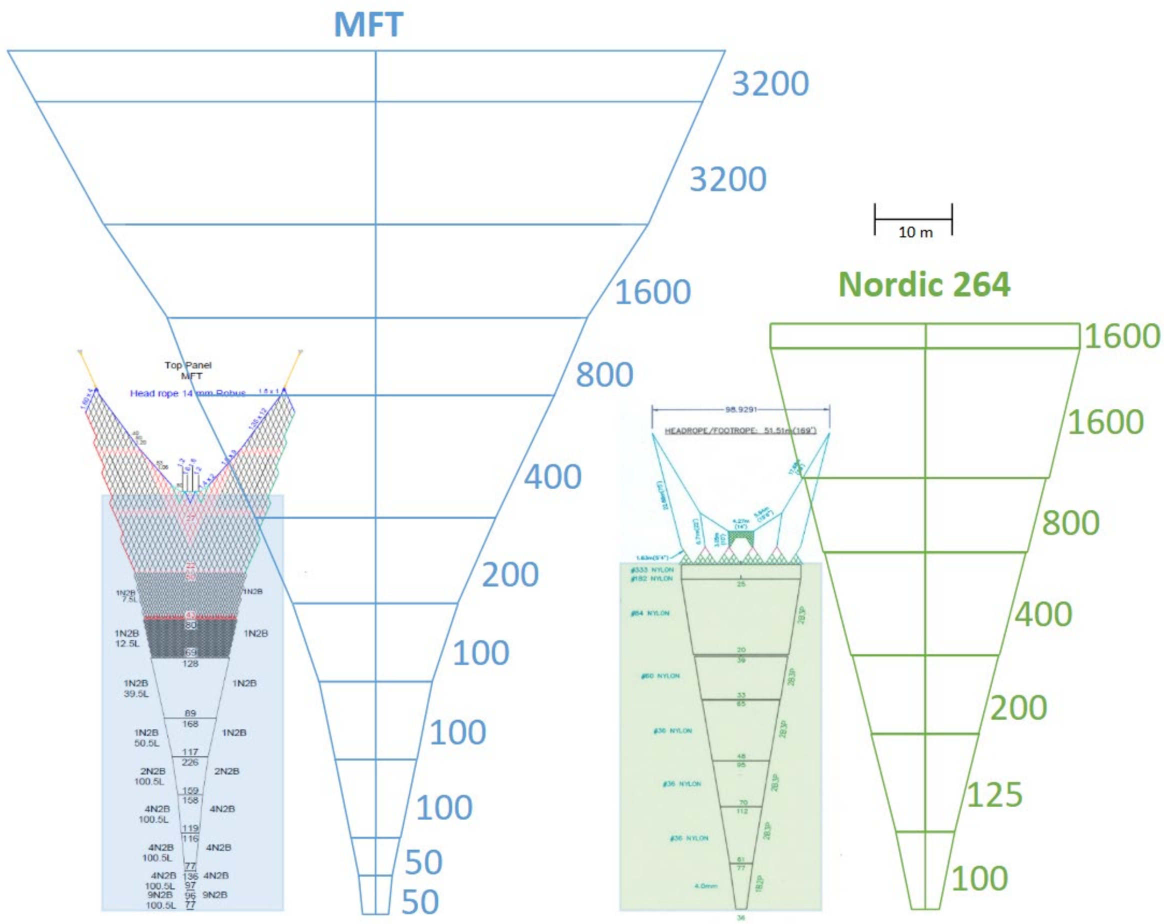


Figure B1. Schematic diagram illustrating the relative size differences and configuration of mesh panel sizes for the Nordic 264 and MFT. Numbers are the full mesh size (mm) of each panel (note, only the highlighted area of each net is drawn). Schematics courtesy of Sabrina Beyer (NWFSC).

B.3. Codend mesh sizes

A comparison between the codend mesh sizes was performed by making 50 measurements randomly throughout the codend sections of the Nordic 264 and MFT. The mean mesh size (+/- SD) for the Nordic 264 and MFT was 7.98 +/- 0.55 mm and 7.96 +/- 0.64 mm, respectively, and there was no statistical difference between the two (**Fig. B2**).

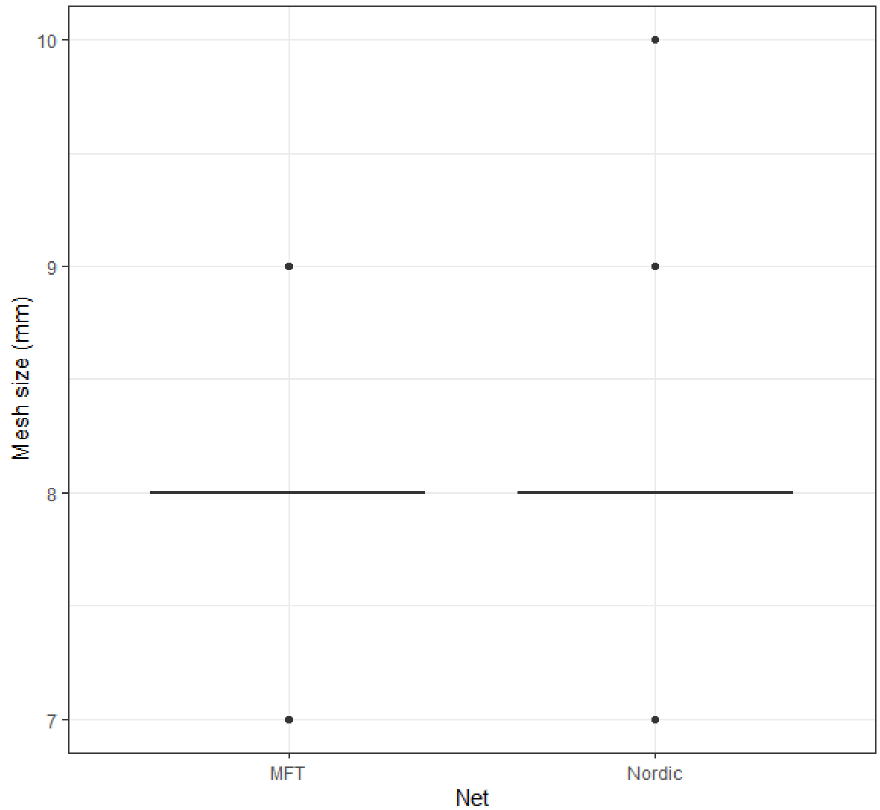


Fig. B2. Boxplot comparing codend mesh sizes between the Nordic 264 and MFT.

B.4. Door systems

The Nordic 264 used NETS XL Lite 3 m^2 foam filled doors that weigh 523 kg (1153 lbs; Appendix 1, **Fig. A4**). The MFT used Thyboron Bluestream 22 VK 4 m^2 steel doors that weigh 840 kg (1851.9 lbs, Appendix 1, **Fig. A8**), and have adjustable attachment points and flaps to modulate the depth of the doors.

B.5. Net sensor suites

Both trawl systems use net sensors to examine net orientation while the net is fishing. During deployment, temperature depth readers (TDRs; RBRduet[3] T.D., RBR) are attached to the top and bottom of the mouth opening of the Nordic 264 and MFT to measure the headrope and footrope depths and to estimate the vertical opening of the net. Following retrieval of the nets, these sensors are removed and the data is downloaded. In addition to the TDRs, the MFT also has a suite of mensuration sensors that provide real-time data used to monitor and adjust the net depth while deployed, including: Simrad PX MultiSensors (Kongsberg) installed on the doors to provide measurements of door pitch, roll, depth, and spread; a Simrad PX TrawlEye attached forward of the codend which provides information about the volume of organisms entering the codend; and a Simrad ITI sensor attached to the footrope that provides footrope depth, absolute location relative to the ship, and net geometry (**Fig. 3**).

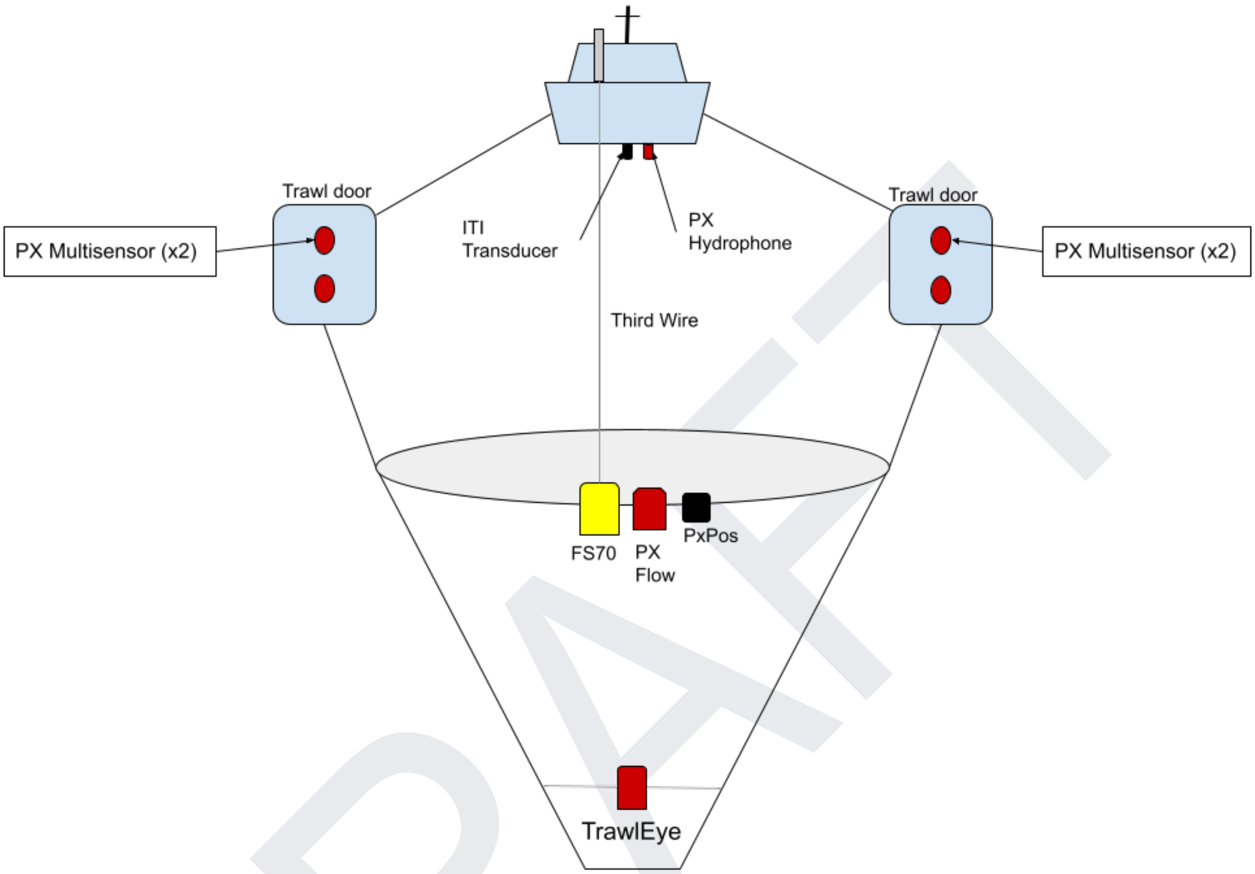


Figure 3. A schematic diagram of the net mensuration system present on both FSV *Bell M. Shimada* and *Reuben Lasker*.

B.6. Conclusion

In summary, the MFT was designed and built to provide equivalent data to the Nordic 264 by sampling similar portions of the water column and retaining similar sizes and proportions for target CPS species. The design of the MFT also addressed concerns from earlier reviews about potential losses of fish at the front of the codend that could potentially be mitigated by increasing the total length of the net and altering the mesh size near the codend (see Section 2.1.7 in the 2018 CIE Review report).

C. Performance of the Nordic 264 and MFT nets during fishing, including sampling depth and vertical and horizontal spread of the net mouth opening

Since 2006, the Nordic 264 surface trawl has been used at night to collect information about the species- and length-composition of the CPS community at the surface in areas where acoustic backscatter was observed along acoustic transects sampled during the daytime. In 2023, the MFT was designed and constructed to provide similar information for CPS, but also to allow the collection of hake in the midwater. Sea trials conducted in December 2023 indicated that, when configured in the surface mode, the MFT was capable of sampling at the surface similar to the Nordic 264, but also slightly deeper if desired to avoid sampling in the propeller wash of the vessel where the sampling of CPS may be negatively influenced. Based on the results of those gear trials, the decision was made to use the MFT in ATM surveys of CPS in 2024 and beyond.

Here we analyze data from temperature-depth recorders (or TDRs) attached to the net during trawl deployments to describe and compare the performance of the Nordic 264 and MFT nets as it pertains to the sampling of CPS that occur near the surface at night, specifically: sampling depths, net geometry (i.e., horizontal and vertical spread), and swept area (volume sampled).

Since spring 2021, data from TDRs (RBR Duet[3]) mounted on the kite and footrope of both nets continuously measure temperature and pressure throughout each net deployment. These data are then visually examined after each tow to assess the performance of the net during each tow, and then subsequently used to compute the vertical spread and fishing depths.

Prior to 2024, real-time information about net spread was unavailable or unreliable due to bubble interference in the propeller wash between the older net mensuration sensors deployed on the Nordic 264 net (Simrad ITI). In 2024 and 2025, real-time data from the net mensuration sensors (Simrad PxPos) mounted on the ships' keel and trawl doors provided real-time measurements of door depth and spread of the MFT via the Simrad TV80 software displays in the acoustics lab and wheelhouse, which aided the vessel operators and lead fishermen. However, due to the lack of comparable data from the Nordic 264, and the locations of the spread sensors forward of the net body on the MFT, it is difficult to accurately estimate net spread or area of the mouth opening of either net to enable comparisons between them. Therefore, only results from the analysis of TDR data, which were present on both nets, are presented here.

TDR data were analyzed from six ATM surveys of CPS conducted in the CCE, between spring 2021 and summer 2025, to describe the performance and geometry of each net as it relates to the collection of biological data used to apportion the backscatter attributed to CPS in ATM surveys. A total of 313 Nordic 264 hauls were conducted during four surveys between spring 2021 and summer 2023, and a total of 267 hauls were conducted during two surveys in the summers of 2024 and 2025. The analyses of net performance and geometry were performed on data collected during the time that the net was actively fishing, which was defined as the period between net equilibrium (i.e., when the target wire-out distance was achieved) and haul back. The target haul duration for the Nordic 264 was 45 minutes throughout. The target duration for the MFT was 45 minutes at the start of the summer 2024 survey, but was shortened to 30 minutes after six hauls to reduce the likelihood of unnecessarily large catches and increase the likelihood of achieving the goal of three trawls per night. The target duration for the MFT was 30 minutes for the entire summer 2025 survey.

C.1. Sampling depths

Sampling depths for each survey and net were visually examined by plotting the depth traces from the kite and footrope TDRs during each haul (**Fig. C1**). The sampling range for each net was then computed as the portion of the water column between the average depth of the kite and footrope TDRs. On average, the Nordic 264 sampled between 1.44 and 15.4 m depth, with an average sampling range of 13.9 m, while the MFT sampled between 7.28 and 27.8 m, with an average sampling range of 20.5 m. The MFT dynamics appeared to be more variable and prone to changes in vessel dynamics and the skill and training of the vessel operators and deck crew, and perhaps more variable in 2025 than 2024. However, the ability to intentionally fish below the surface to avoid the propeller wash was advantageous and specifically requested in the design specifications. In summary, the MFT fished deeper and sampled a greater portion of the upper water column than the Nordic 264.

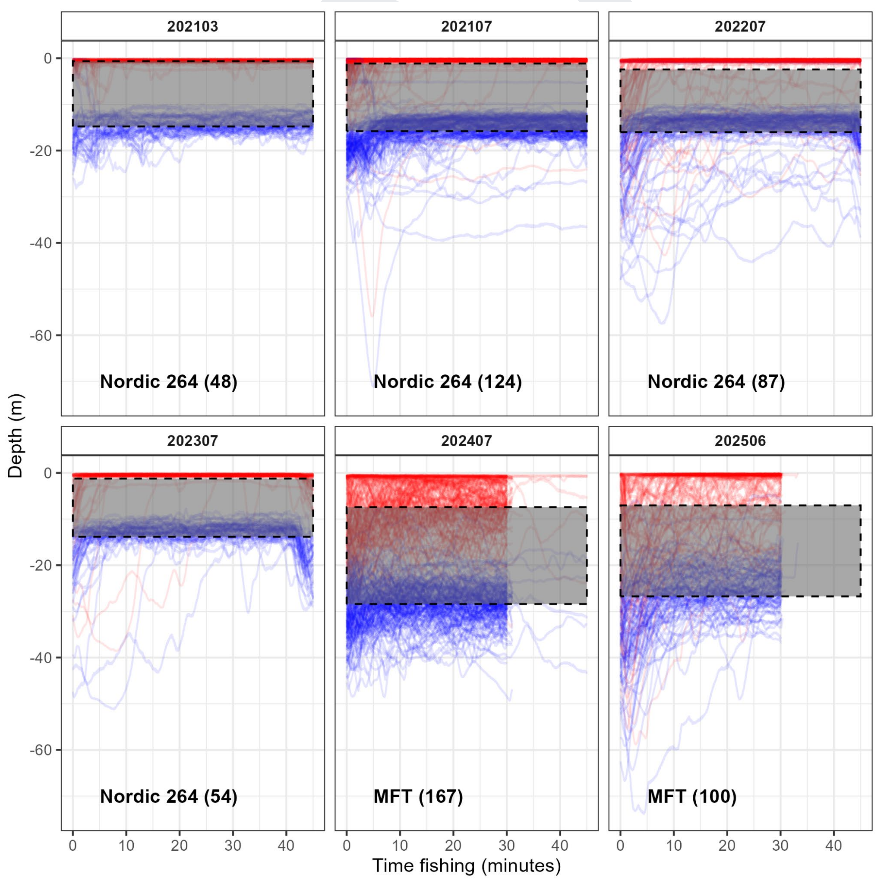


Fig. C1. Depth of the kite (red) and footrope (blue) temperature-depth recorders during the fishing period for each survey, net, and haul. Panel titles indicate the survey name, composed of the year and starting month (e.g., 202103 is March 2021). The gray shaded box indicates the area between the average kite and footrope depth for each survey. The number of hauls in each survey is in parentheses.

C.2. Net geometry

The area (A) of the mouth opening can be measured directly using a scanning sonar (e.g., FS70, Simrad-Kongsberg) mounted atop the net near the kite. However, deploying the sonar using the third-wire winch adds considerable time to the trawl evolution, complicates deployment and retrieval, and risks damaging the net when fishing either the Nordic 264 or MFT at or near the sea surface. Alternatively area may be estimated from the major axis (or width, $2a$) and minor axis (or height, $2b$) using the the equation: $A = \pi ab$, assuming the shape of the opening approximates an ellipse. Estimates of the minor axis were readily available from the TDRs mounted on the net. However, given the incomplete, inconsistent, or unreliable spread sensor data across years, estimates of horizontal spread for each net were instead derived from vertical spread and approximate estimates of the perimeter (P) of the mouth opening using the equation:

$$A \approx \sqrt{\frac{P^2}{2\pi^2} - b^2},$$

where P was 65.7 and 87.2 m for the Nordic 264 and MFT, respectively, and was computed from nominal height and width dimensions provided by the net manufacturers (Litz et al., 2008 S. Melly, pers. comm).

Mouth opening area for all hauls conducted with the Nordic 264 and MFT are shown in **Fig. C2**. Mouth opening area was greater but also more variable for the MFT than the Nordic 264. Across all years, the average area of the Nordic 264 and MFT were 280 and 520 m^2, respectively.

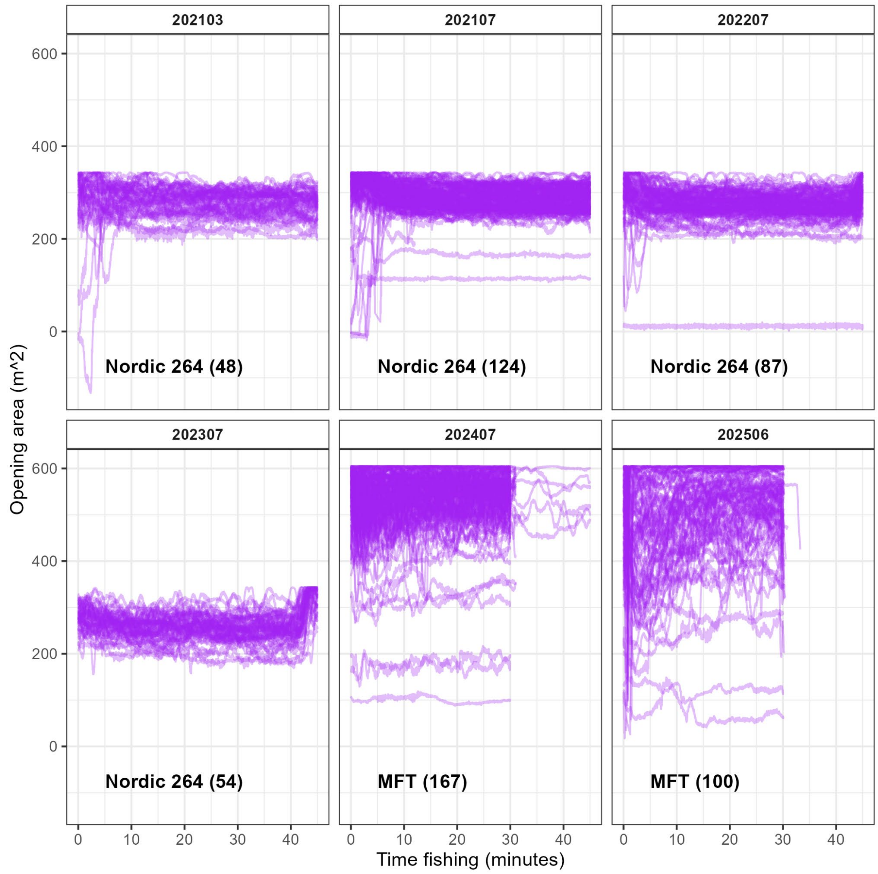


Fig. C2. Area estimates during the fishing period for each survey, net, and haul. Panel titles indicate the survey name, composed of the year and starting month (e.g., 202103 is March 2021).The number of hauls in each survey is in parentheses.

C.3. Sampling volume

Sampling volume (or swept area) was computed using estimates of the area of the mouth opening (measured by the TDRs at 2 Hz) and estimates of distance from the vessel speed over ground, then summed over the fishing period. The distribution of haul distances, opening areas, and total volumes sampled (m^3) for each survey, net, and haul are shown in **Fig. C3**. Despite the shorter tow duration used for the MFT in 2024 and 2025, the total volume sampled by the MFT was similar or greater than that of the Nordic. While catch-per-unit-effort (CPUE) is not quantified for trawls in ATM surveys, estimates of volume sampled do provide information that can be used to determine whether the two nets are sampling in a similar way and likely to provide comparable biological information for apportioning backscatter of CPS observed by the echosounders, despite potential differences related to changes in sampling such as an increase or decrease in haul duration.

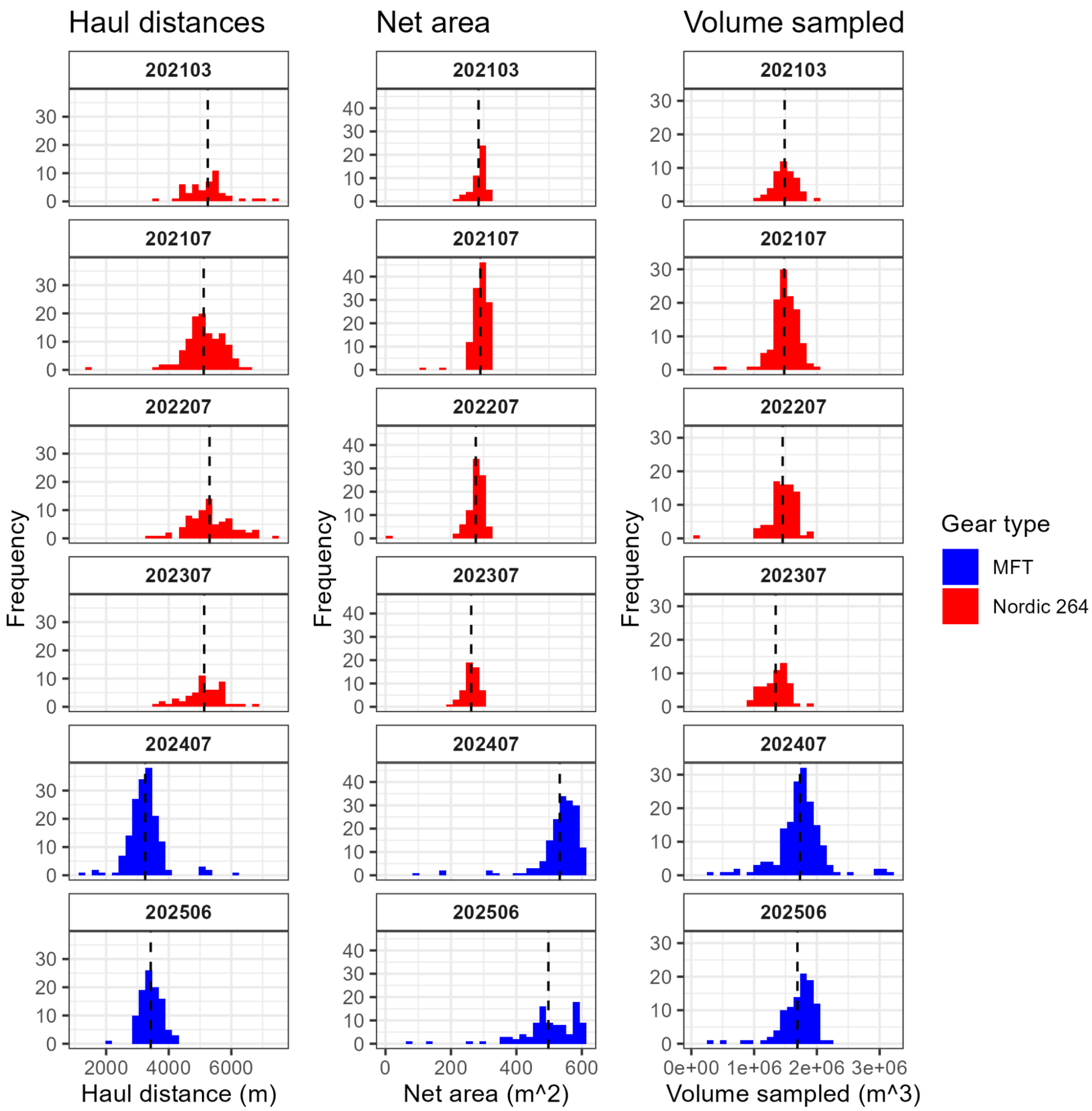


Fig. C3. Estimates of haul distances (m, left), opening area (m^2, middle), and volume sampled (m^3, right) during the fishing period for each survey, net, and haul. Dashed vertical lines indicate the mean across all hauls within a survey.

C.4. Catch volume

C.4.1. Summary statistics of overall catch weights

To examine catch volume, we summed species catch weights of individual trawls for the Nordic 264 and MFT nets and calculated the minimum, maximum, median, and average catch weights (kg) of both the entire catch and just the CPS catch for the years 2013 to 2025. We excluded aborted tows or tows less than 15 minutes due to poor trawl performance.

The largest catch volume and median and average catch volumes of both the whole catch and CPS only catch occurred using the MFT being towed at 30 minutes (**Table C1, Fig.C4**).

Table C1. Minimum, maximum, median, and average catch weights of the whole catch per haul and CPS only catch per haul for the Nordic 264 (2013 to 2023) and MFT nets (2024 to 2025) by tow duration. The Nordic 264 had 30 minute tow durations from 2013-2015 and 45 minute tow durations from 2016-2023. The MFT had 6 tows at 45 minutes at the beginning of 2024, then all subsequent tows were 30 minutes.

Catch	Net	Tow duration	Number trawls	Min. Catch (kg)	Max Catch (kg)	Median Catch (kg)	Average Catch (kg)
Whole catch	Nordic 264	30 min	393	0.003	2800.00	21.75	65.69
	Nordic 264	45 min	798	0.025	2795.85	33.36	137.03
	MFT	30 min	267	2.41	3655.54	168.00	348.25
	MFT	45 min	6	46.46	602.67	280.45	271.32
CPS catch	Nordic 264	30 min	214	0.0005	761.94	3.13	39.07
	Nordic 264	45 min	691	0.0025	2636.70	11.13	114.98
	MFT	30 min	225	0.001	3641.74	36.01	243.82
	MFT	45 min	6	0.052	229.82	17.37	58.05

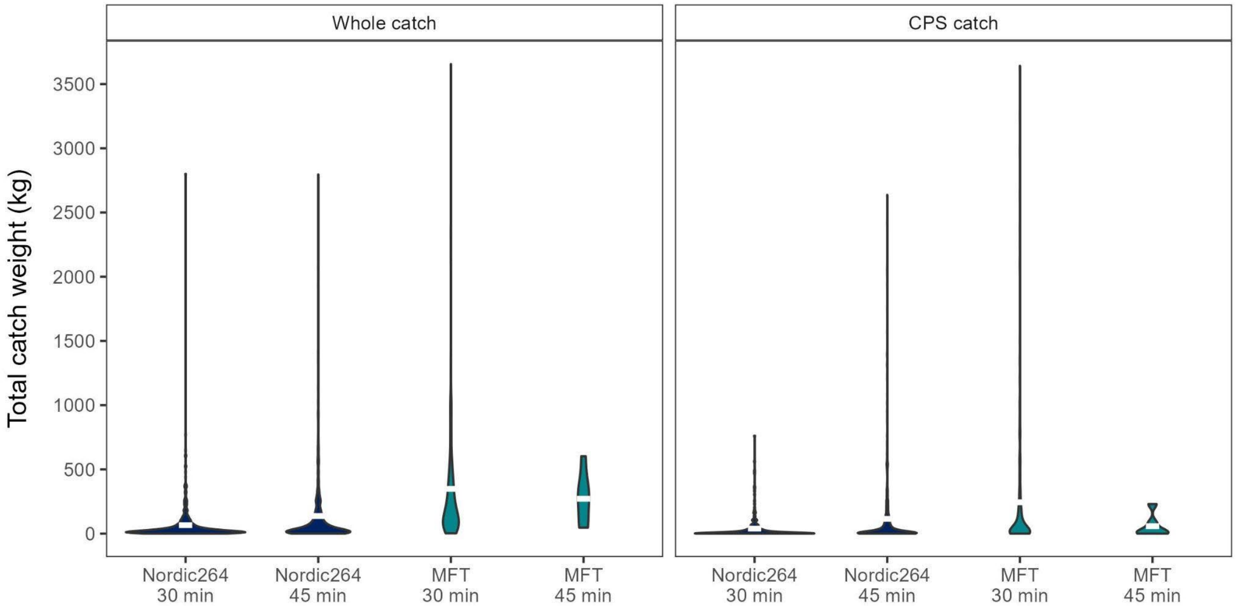


Figure C4. Violin plot of total catch weights and CPS catch weights of individual trawls using both the Nordic 264 and MFT nets with different tow durations.

C.4.2. Summary statistics of overall trawl performance with catch weights

To examine general performance of each net type in terms of catch volume, we examined the number and proportion of trawls with differing catch volumes. Four catch volume categories were examined: < 10 kg of catch ("water hauls"), 10-30 kg of catch ("small"), 30-150 kg of catch ("medium"), and > 150 kg of catch ("large"). These groupings were decided based on the sampling methodology of CPS on the SWFSC ATM survey (see Dorval et al., 2022). In short, catch is weighed using orange fish baskets, and the average weight that each basket holds is 30 kg. When the catch is more than five baskets (~150 kg), the catch is subsampled and is deemed a large catch. The weight of a medium catch was decided to be between one to five baskets.

The MFT had greater consistency with trawl performance with higher proportions of medium and large catches and very few "water hauls" or small catches compared to the Nordic 264 (**Table C2**).

Table C2. Number of hauls with very small catches ("water hauls", <10 kg), small catches (10-30 kg), medium catches (30-150 kg), and large catches (> 150 kg) for the Nordic 264 and MFT net with both 30 and 45 min tow durations. Also included is the total percentage of each size catch to the total number of hauls per net (n = 393 for Nordic 264 with 30 min tow durations encompassing the years 2013 to 2015, n = 798 for Nordic 264 with 45 min tow durations from 2016 to 2023, and n = 6 and n = 267 for the MFT encompassing the years 2024 to 2025 with 30 min and 45 min tow durations, respectively).

Net	Tow duration	# Water hauls	# Small catches	# Medium catches	# Large catches
Nordic 264	30 min	109 (27.7%)	128 (32.6%)	117 (29.8%)	39 (9.9%)
Nordic 264	45 min	200 (25.1%)	186 (23.3%)	243 (30.5%)	169 (21.2%)
MFT	30 min	4 (1.5%)	21 (7.9%)	96 (36.0%)	146 (54.7%)
MFT	45 min	0	0	2 (33.3%)	4 (66.7%)

D. Methods and biomass estimation from the 2025 Integrated Survey

D.1. Background and inputs to assessments

For each ATM survey in the California Current Ecosystem (CCE) conducted since 2015, the SWFSC produces a detailed report that presents information about the data collections, analytical methods, and biomass estimates for all CPS encountered in the survey area, including Pacific Sardine, Northern Anchovy, Pacific Mackerel, Jack Mackerel, Pacific Herring, and sometimes Round Herring. The biomass estimates and their CVs, and age compositions from these reports are the primary fishery-independent inputs to stock assessments for the northern subpopulation of Pacific Sardine, central subpopulation of Northern Anchovy, and Pacific Mackerel. Jack Mackerel are not actively managed and Pacific Herring are an ecosystem component species, but the ATM survey is the only monitoring program that provides information about their biomasses in U.S. waters. Details of the inaugural 2025 IWCPS, including differences from previous ATM surveys in the CCE, and preliminary biomass estimates are presented in the draft biomass report by Stierhoff et al. (In. prep.). All analyses and reporting was done in R using code and functions available in {*estimATM*} (Stierhoff et al., 2026) and {*atm*} (Stierhoff and Zwolinski, 2026). In this document, we highlight a few of those changes as they relate to the change in trawl nets from the Nordic 264 to the MFT beginning in summer 2024.

D.2. Methods

In summer 2024, after successful gear trials in December 2023 and additional gear trials at the beginning of the survey, the decision was made to use the MFT for surface trawling for CPS in 2024 and beyond. No other changes were made to the acoustic or trawl sampling methods compared to the Nordic 264, except for the decision to reduce the trawl duration from 45 to 30 minutes for the MFT after several large catches of CPS were encountered at the beginning of the summer 2024 survey.

For the 2025 IWCPS, and like most years, the survey area spanned the continental shelf along the west coast of the U.S. between Mexico and Canada. A total of 81 days at sea (DAS) were allocated for this survey. The survey progressed from south to north, beginning in San Diego, CA on 3 June and ending near Cape Flattery, WA on September 13. Acoustic transects in the Southern CA Bight (SCB) were oriented perpendicular to shore and spaced 20 nmi apart, and between Pt. Conception and Cape Flattery were oriented E-W and spaced 15 nmi apart. Acoustic sampling was conducted along each transect between sunrise and sunset. The MFT was used to conduct both midwater trawling during daytime and sub-surface trawling at nighttime, to characterize the species- and size- composition of hake and CPS, respectively.

Due to significant losses in DAS related to personnel and mechanical issues, and the need to complete the survey with the DAS remaining, several acoustic transects were randomly dropped between Pt. Conception and Cape Mendocino, and every other transect was dropped between Brookings, OR and Cape Flattery, resulting in 30-nmi transect spacing for the latter. However, these changes to the survey are unrelated to the integration of the hake and CPS surveys nor the change in nets, but are rather adaptations to losses in survey effort that do not deviate from the typical ATM survey.

D.3. Preliminary results

We estimated the abundances, biomasses, spatial distributions, and demographics of CPS, specifically the northern and southern subpopulations of Pacific Sardine, the central and northern subpopulations of Northern Anchovy, Pacific Mackerel, Jack Mackerel, and Pacific Herring for the core and nearshore survey regions in which they were sampled. While Japanese Sardine (*S. melanosticta*) were likely present in the survey area (Longo et al., 2025), they are visually indistinguishable from Pacific Sardine and genetic analyses had not been completed, so all sardine are considered to be Pacific Sardine for the purpose of estimating biomass. These results are preliminary and subject to change.

The estimated biomass of the central subpopulation of Northern Anchovy was 1,238,571 t ($CI_{95\%}$ = 554,511 - 1,638,504 t, CV = 21%, **Fig. D1a**). In the core region, the biomass was 1,124,464 t ($CI_{95\%}$ = 495,095 - 1,444,839 t, CV = 23%), and in the nearshore region the biomass was 114,107 t ($CI_{95\%}$ = 59,416 - 193,665 t, CV = 31%), or 9.2% of the total biomass. The central subpopulation ranged from approximately San Diego to Fort Bragg, and the distribution of L_S ranged from 6 to 16 cm with a mode at 12 cm in both regions. The estimated biomass of the central subpopulation of Northern Anchovy, which has comprised the majority of CPS biomass since 2015, increased 80% from the 689,785 t estimated in summer 2024 (Stierhoff et al., 2025).

The estimated biomass of the northern subpopulation of Pacific Sardine was 90,430 t ($CI_{95\%}$ = 23,577 - 213,454 t, CV = 48%, **Fig. D1a**). In the core region, the biomass was 45,850 t ($CI_{95\%}$ = 215 - 153,954 t, CV = 92%) and in the nearshore region the biomass was 44,581 t ($CI_{95\%}$ = 23,362 - 59,500 t, CV = 23%), or 49.3% of the total biomass. The northern subpopulation was observed between Pt. Conception and Newport, but was most abundant in the core region near Fort Bragg and, in the nearshore region, was most abundant along the Big Sur coast and between Fort Bragg and Cape Mendocino. The distribution of L_S ranged from 13 to 24 cm with a mode at 20 cm in the core region and at 18 cm in the nearshore region.

The estimated biomass of the southern subpopulation of Pacific Sardine in the surveyed area was 17,519 t ($CI_{95\%}$ = 7,844 - 29,922 t, CV = 28%, **Fig. D1a**). In the core region, the biomass was 985 t ($CI_{95\%}$ = 1.1 - 2,703 t, CV = 78%), and in the nearshore region the biomass was 16,534 t ($CI_{95\%}$ = 7,842 - 27,219 t, CV = 29%), or 94% of the total biomass. The southern subpopulation in the survey area was observed predominantly in the nearshore area of the SCB, but was most abundant near San Diego, Long Beach, and Santa Barbara. The distribution of L_S ranged from 10 to 24 cm with a mode at 19 cm in the core region and a mode at 16 cm in the nearshore region.

The estimated biomass of Pacific Mackerel was 9,259 t ($CI_{95\%}$ = 3,745 - 14,758 t, CV = 23%, **Fig. D1a**). In the core region, the biomass was 4,429 t ($CI_{95\%}$ = 1,213 - 8,234 t, CV = 41%), and in the nearshore region the biomass was 4,830 t ($CI_{95\%}$ = 2,533 - 6,524 t, CV = 24%), or 52% of the total biomass. Pacific Mackerel were sparsely distributed in the core and nearshore regions throughout the survey area. The distribution of fork lengths (L_F) ranged from 14 to 43 cm with modes at 27 and 42 cm in the core region and at 23, 27, and 41 cm in the nearshore region.

Even though they are not actively managed stocks, Jack Mackerel (867,960 t; $CI_{95\%}$ = 542,838 - 1,279,494 t, CV = 20%) and Pacific Herring (118,479 t; $CI_{95\%}$ = 50,555 - 220,551 t, CV = 28%) comprised a considerable amount of the CPS biomass in the survey area. The northern subpopulation of the Northern Anchovy were relatively scarce.

The total estimated biomass of eight populations or subpopulations of six coastal pelagic species within the survey area was 2,346,391 t (**Fig. D1b**). Of this, 53% (1,238,571 t) was from the central subpopulation of Northern Anchovy (*Engraulis mordax*) and 37% (867,960 t) was from Jack Mackerel (*Trachurus symmetricus*). Proportions of other subpopulations, in decreasing order, were: northern subpopulation of Pacific Sardine (*Sardinops sagax*; 3.9%), Pacific Herring (*Clupea pallasii*; 5%), southern subpopulation of Pacific Sardine (1%), Pacific Mackerel (*Scomber japonicus* ;0.4%), and northern subpopulation of Northern Anchovy (0.18%).

<u>D.4. Conclusions</u>

The MFT performed well for the purposes of providing biological information to apportion backscatter attributed to CPS during the 2025 survey. The MFT has now been used successfully in coastwide CPS surveys since 2024, with no meaningful differences in methods during the IWCPS compared to SWFSC-only surveys conducted in the CCE since 2015. The CPS community in the CCE continue to be dominated by the central subpopulation of Northern Anchovy and Jack Mackerel (**Fig. D1**).

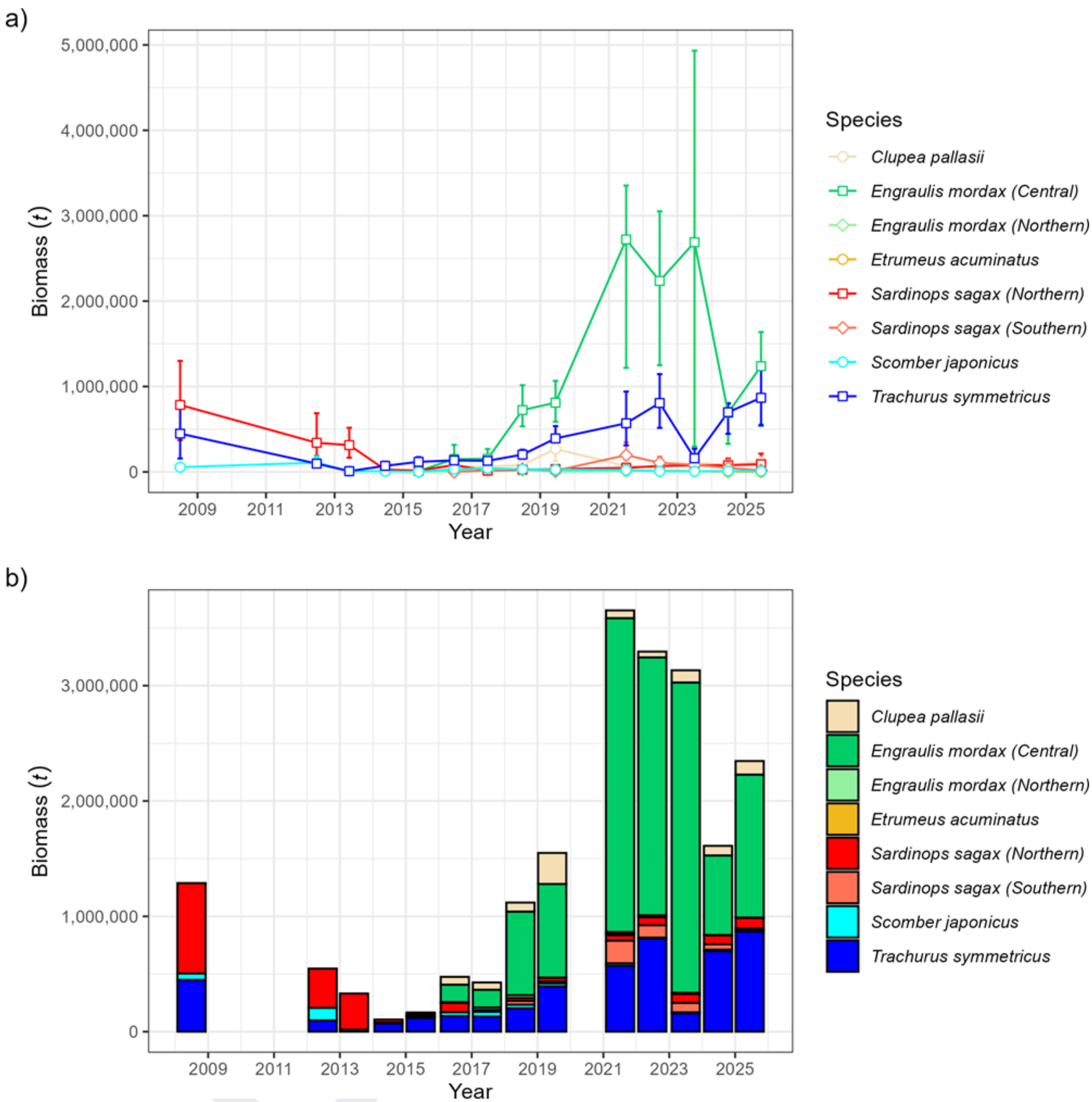


Figure D1. a) Estimated and b) cumulative estimated biomasses (t) of the eight most abundant CPS populations or subpopulations of six species in the CCE during summer since 2008. Surveys typically span the area between Cape Flattery and San Diego, but in some years also include Vancouver Island, Canada (2015-2019, 2024) and portions of Baja CA (2021-2022, 2024). Data from the 2025 survey are preliminary.

E. Species- and length-selectivity comparisons between the Nordic 264 and MFT nets

E.1. Defining the dataset

Trawl catch data were obtained for CPS summer survey years 2013-2025 (excluding 2020, due to a pandemic-related cancellation; **Figures E1**, **E2**). We chose 2013 as the starting survey year, because it was the first year that the whole coast was covered by one vessel [see Table 3 and Figures A4-A6 in Dorval et al., (2022) for survey-specific details]. Spring surveys were excluded here, because of the seasonal timing difference and the smaller geographic extent. Data were filtered to include only catches of focal species: Northern Anchovy, Pacific Sardine, Pacific Mackerel, Jack Mackerel, and Pacific Herring. We focused on these to prioritize species routinely encountered during CPS surveys, pass the acoustic filter for CPS-like attributes, and underwent standardized catch weight measurements across the time series. Japanese Sardine (*S. melanosticta*) have also been recently observed off the U.S. West Coast (Longo et al. 2025), are phenotypically similar to Pacific Sardine, and have not been separated out from Pacific Sardine in recent assessments (e.g., Allen Akselrud et al., 2025). We therefore included both Japanese Sardine and Pacific Sardine biological data in an aggregate 'Sardine' species category for all subsequent analyses of length, age, and weight data (**Sections E, F**).

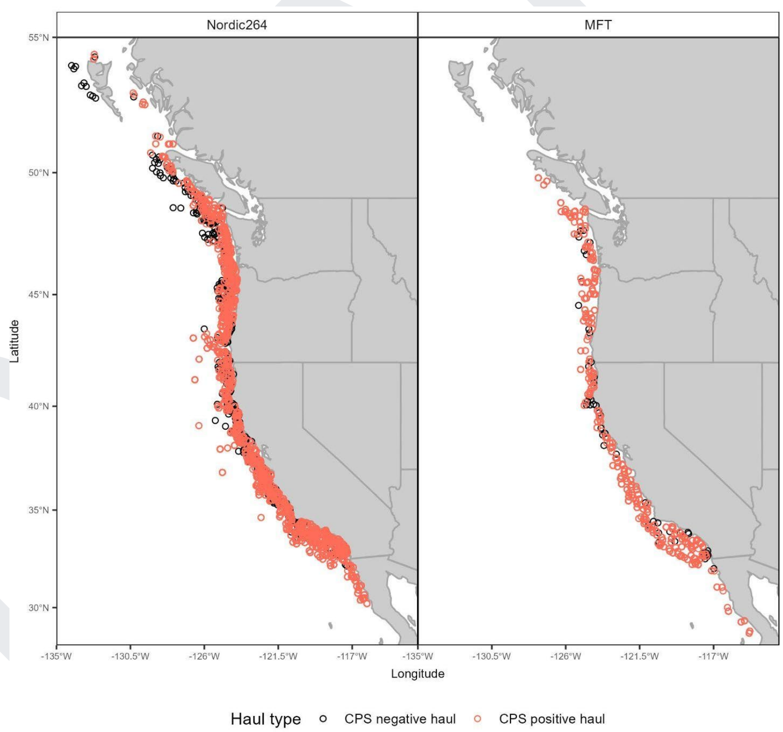


Figure E1. Map of trawling locations during the SWFSC summer trawl surveys pooled from 2013-2023 using the Nordic 264 net and from 2024-2025 using the MFT net. Black circles represent individual trawls where no coastal pelagic species (CPS; i.e., Sardine, Northern Anchovy, Pacific Mackerel, Jack Mackerel, Pacific Herring) were caught, and orange circles represent individual trawls where at least one of the CPS were caught.

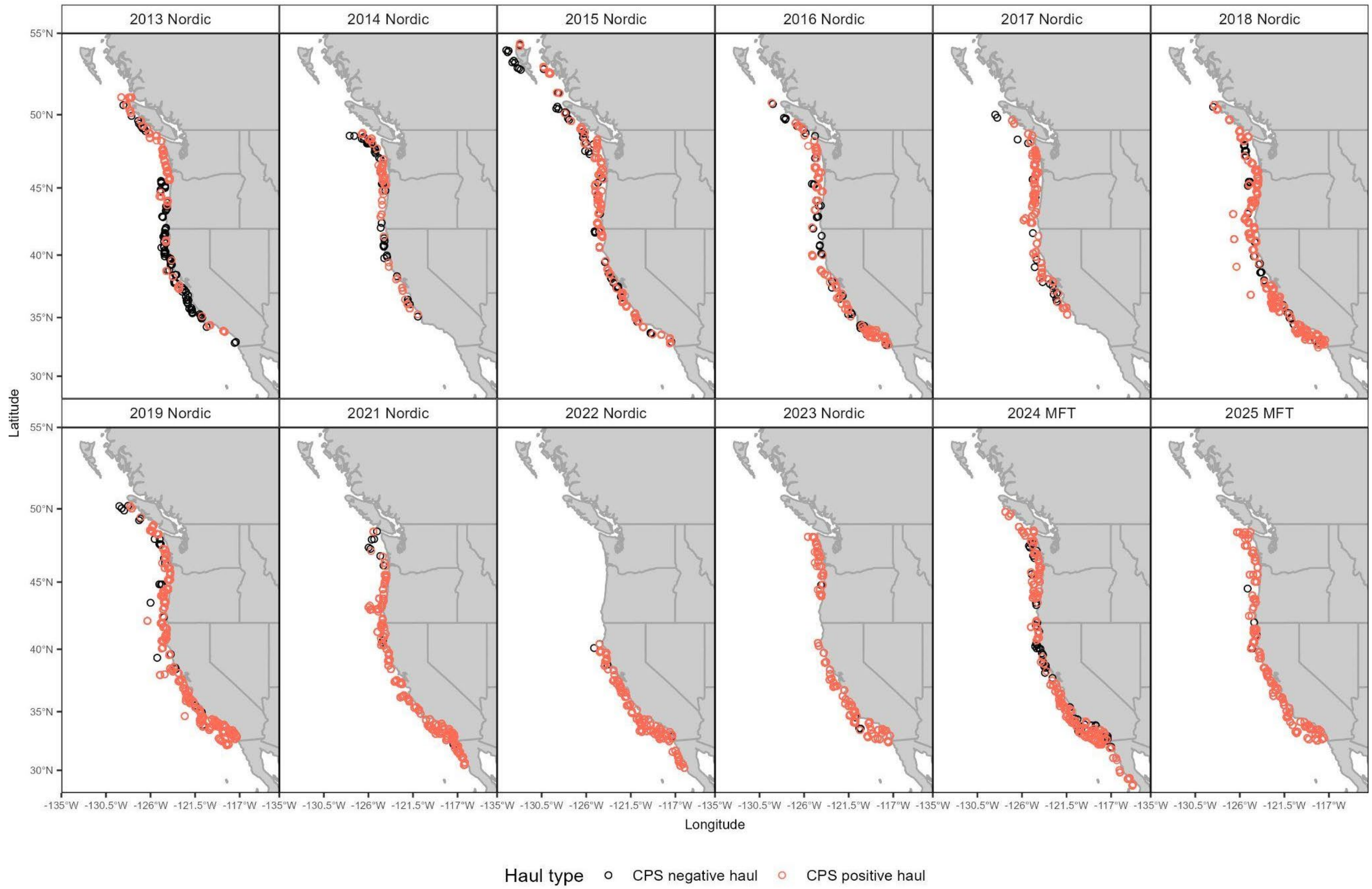


Figure E2. Map of trawling locations by year during the SWFSC summer trawl surveys from 2013-2023 using the Nordic 264 net and from 2024-2025 using the MFT net. Black circles represent individual trawls where no coastal pelagic species (CPS; i.e., Sardine, Northern Anchovy, Pacific Mackerel, Jack Mackerel, Pacific Herring) were caught, and orange circles represent individual trawls where at least one of the CPS were caught.

E.2. Species-selectivity comparisons

E.2.1 Analysis overview

We compared species-selectivity between net types by analyzing species composition data collected from ATM surveys between 2013 and 2025. Analyses featured the same five focal species as before (i.e., Northern Anchovy, Sardine, Pacific Mackerel, Jack Mackerel, and Pacific Herring), and included visualizations of survey cluster catch compositions by year and net type, calculation of descriptive multivariate statistics, K-means clustering, and non-metric multidimensional scaling.

E.2.2. Additional data processing

Prior to conducting species-selectivity comparisons, we aggregated haul-level catches by cluster to match the use of trawl data in apportioning estimates of biomass from acoustics (e.g., Stierhoff et al., 2025). Hauls conducted within 12 hours of one another were grouped into the same cluster; these clusters represented the base sampling units for all subsequent analyses. Cluster-level catch data were only retained for analysis if catch for at least one of the focal species was greater than zero.

E.2.3. Catch composition visualizations

Exploratory visualizations of catch proportions among clusters, survey years, and net types were conducted using stacked bar plots and spatially-explicit pie charts (i.e., located at the central location of hauls comprising each cluster). These visualizations were intended to provide intuitive representations of patterns in catch proportions along the spatial extent of CPS surveys and across survey years without corresponding formal quantitative analyses, data transformations, or additional data filtering.

The catch proportions for Northern Anchovy, Sardine, Pacific Mackerel, Jack Mackerel, and Pacific Herring exhibited a high degree of variability across clusters and years in addition to several overarching trends (**Figs. E3-E5**). Specifically, catches of Sardine were more prevalent and higher in 2013 and 2014 relative to subsequent years, Pacific Mackerel were more prevalent in 2016, 2017, and 2018, and Northern Anchovy increasingly dominated trawl catches from 2013 to 2025. Jack Mackerel and Pacific Herring both showed sporadic pulses of relative dominance across years. Observed temporal fluctuations in catch proportions, including among years with the same net type, likely reflect changes in the underlying community over time. Catch proportions also generally followed a latitudinal trend, in which Northern Anchovy dominated catches across the southern extent of the survey (e.g., off southern and central California), Jack Mackerel were dominant across northern California, Oregon, and sometimes Washington, and Pacific Herring dominated catches off Washington and north (**Fig. E4**). Sardine and Pacific Mackerel sporadically dominated sample catches throughout the survey extent. Aside from more pronounced contributions of Northern Anchovy and Jack Mackerel to catch in the MFT net survey years of 2024 and 2025, there were no obvious differences in observed catch proportions between surveys conducted with the Nordic 264 and MFT nets. This indicates there is no clear evidence for meaningful differences in species selectivity between net types that would be expected to have major impacts on the survey results or survey-related inputs to assessments..

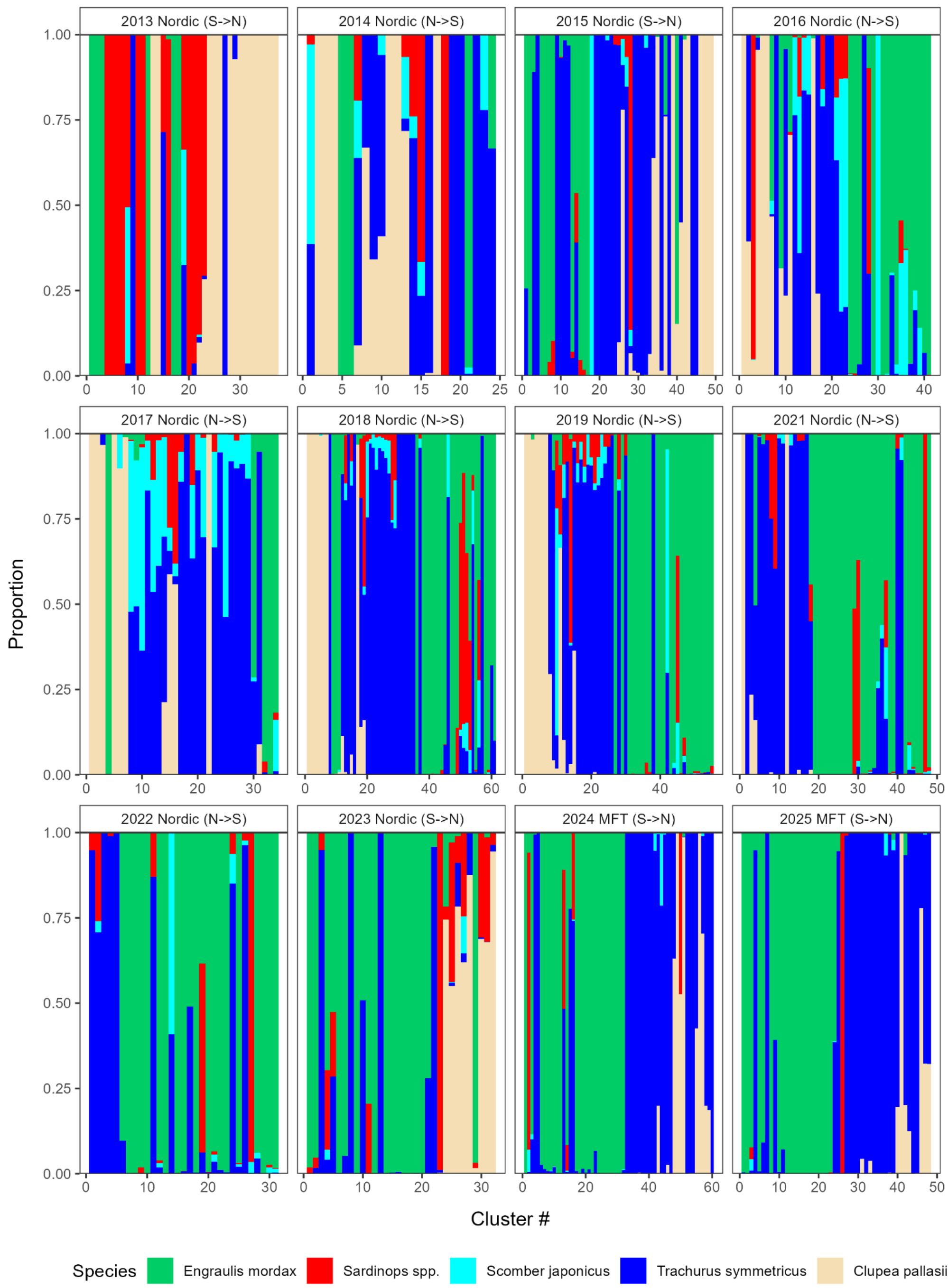


Figure E3. Trawl species catch proportions for each sampling year, aggregated by cluster. Cluster numbers are ordered sequentially by the order in which component trawls were conducted during each survey year. Facets are labeled by sampling year, net, and the direction of the survey (either south to north or north to south).

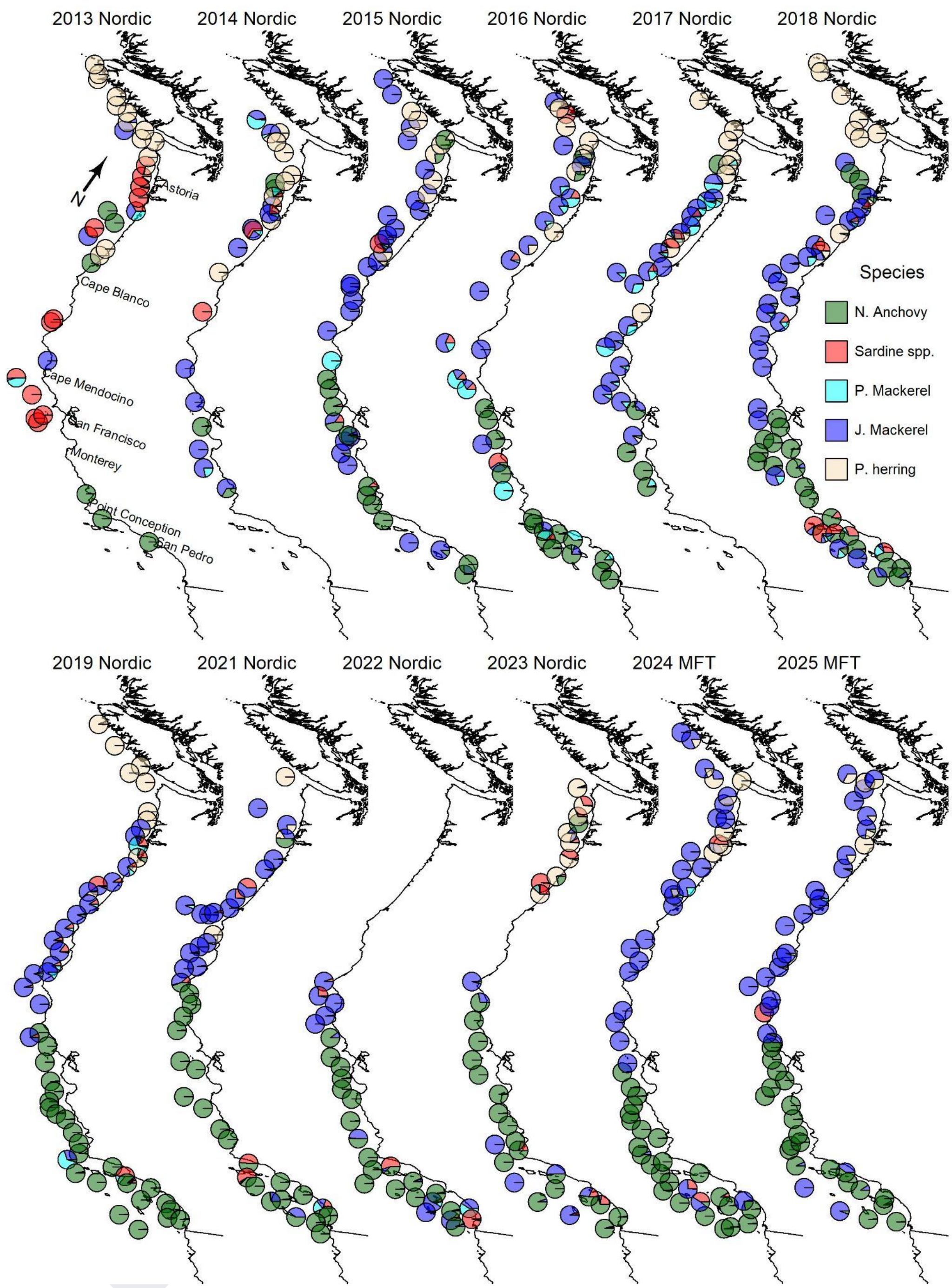


Figure E4. Species catch proportions within spatially referenced trawl clusters for each sampling year. Facets are labeled by sampling year and net. For legibility, trawl clusters outside the core survey area (e.g. north of Vancouver Island, off the coast of Baja California) were excluded.

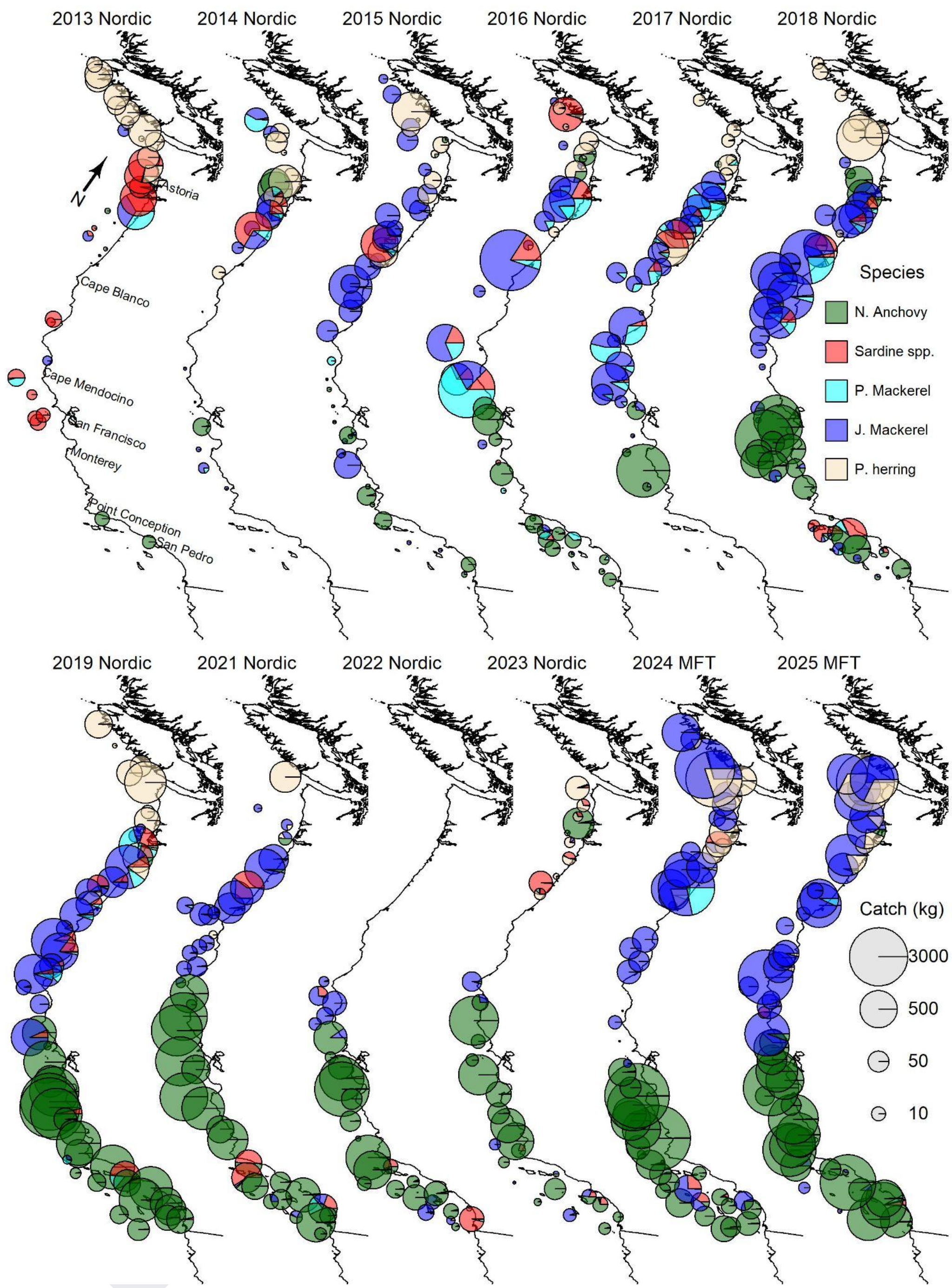


Figure E5. Species catch proportions within spatially referenced trawl clusters for each sampling year, in which pie chart size reflects total catch weight by cluster. Facets are labeled by sampling year and net. For legibility, trawl clusters outside the core survey area (e.g. north of Vancouver Island, off the coast of Baja California) were excluded.

E.2.4. Descriptive multivariate statistics

We calculated numerous descriptive statistics to inform multivariate analyses and evaluate catch composition among years and net types. Across the entire dataset, we calculated the skewness of catches for each species and the coefficient of variation (CV) across catch row (sampling units) and column (species) sums. High values for skewness (e.g., absolute values greater than one) and coefficient of variation (>100%) can indicate a need for data transformation. We also calculated average species richness, beta diversity (Whittaker, 1972), and average Pielou's J (Pielou, 1969; measure of species evenness, 1966) among clusters for the entire dataset and by both year and net type. Beta diversity represents diversity within a set of sample units in which values less than one both indicate low diversity (i.e., most samples contain similar communities) and facilitate straightforward ordination methods. Pielou's J represents species evenness in which values close to 0 indicate highly uneven communities (i.e., one or two species dominate abundance within each sample) and values close to 1 indicate high evenness. We note that the upper end of possible values for species richness and beta diversity are determined by the number of species analyzed (five in this case), while evenness has a fixed scale. Calculation of descriptive statistics followed recommended practices for the analysis of ecological communities (McCune and Grace, 2002).

There was a high degree of positive skewness in catches for all five focal CPS, with values of 5.32, 10.77, 15.35, 6.58, and 10.94 for Northern Anchovy, Sardine, Pacific Mackerel, Jack Mackerel, and Pacific Herring. Furthermore, calculated coefficients of variation were high across both row and column sums (i.e., 218 and 105%, respectively), indicating a need for data transformations.

Overall average species richness was 2.38 (**Table E1**). Annual average species richness varied between 1.51 and 2.74 among years and peaked between 2016 and 2023. While average species richness for samples collected with the MFT net as a whole (2.14) was lower than that for samples collected by the Nordic 264 net (2.44), annual average richness values for MFT net years (i.e., 2024, 2025) fell within the range of average richness values calculated for some survey years that utilized the Nordic 264 net (i.e., 2013, 2014, 2015).

Overall beta diversity was 1.10, reflecting moderately low species diversity among clusters (**Table E1**). Annual beta diversity varied between 0.46 and 2.30, with the lowest diversity (fewest number of distinct communities) occurring between 2016 and 2023. Beta diversity for MFT net samples was higher than that for Nordic 264 net samples (1.34 and 1.04, respectively), but diversity values for MFT net years again fell within the range of diversity values for a subset of survey years utilizing the Nordic 264 net.

Overall average species evenness was 0.31, reflecting relatively unbalanced communities in which catches of one or two species dominate within cluster samples (**Table E1**). Annual average species evenness values varied between 0.22 and 0.48, with no obvious annual pattern. Average species evenness for MFT net samples was lower than that for Nordic 264 net samples (0.24 and 0.32, respectively). Although average evenness for MFT net years represented two of the three lowest annual values, annual values were generally lower during 2021-2025 relative to the previous survey years.

While estimated differences in average species richness and beta diversity between the nets could indicate a difference in species selectivity, there is also a high degree of annual variability between 2013 and 2025 which makes it challenging to discern whether there are differences post-2023 and whether those are attributed to the net, community shifts, or both.

Table E1. Summary of descriptive statistics ($\underline{D_0}$ = average species richness, β_w = beta diversity, $\underline{J}$ = average evenness) for the five-species complex. Skewness values are excluded here (but provided in the text), because they are reported on a per-species basis.

Statistic	Overall	By year												By net type	
		2013	2014	2015	2016	2017	2018	2019	2021	2022	2023	2024	2025	Nordic 264	MFT
$\underline{D_0}$	2.38	1.51	2.25	2.20	2.49	2.74	2.51	2.64	2.67	2.74	2.59	2.23	2.02	2.44	2.14
β_w	1.10	2.30	1.22	1.27	1.01	0.83	0.99	0.90	0.88	0.46	0.93	1.24	1.47	1.05	1.34
$\underline{J}$	0.31	0.33	0.43	0.26	0.44	0.48	0.33	0.28	0.25	0.22	0.35	0.23	0.25	0.32	0.24

E.2.5. Data transformations

Catch data were transformed to improve the quality of inference from subsequent multivariate analyses. Catch data for rare species, indicated by occurrence in less than 5% of sampling clusters, are usually removed; no species were sufficiently rare to warrant exclusion. Catch data were then monotonically log-transformed in response to high calculated skewness and CV values. The log transformation included corrections to account for the prevalence of zero catch values in the dataset; this correction preserved the original order of magnitudes and returned zero values for raw catch values of zero (McCune and Grace, 2002). Post-transformation, recalculated row and column CVs were just 53% and 38%, suggesting no need for additional data standardization or relativization. Application of data transformations again followed recommended practices for the analysis of ecological communities (McCune and Grace, 2002).

E.2.6. K-means cluster analysis

K-means cluster analysis was conducted to identify the best supported number of clusters in the transformed catch data and visualize any differences in relative cluster assignments among years and between net types. Briefly, K-means cluster analysis was conducted for predetermined cluster numbers one through ten using the Hartigan and Wong (1979) algorithm. The total within-cluster sum of squares was then plotted against the number of predetermined clusters to select a best supported number of clusters (i.e., using an elbow plot). We then identified any differences in the relative number of assignments to each K-means cluster among years and between net types to detect possible differences in sampled catch compositions.

Examination of the number of K-means clusters relative to the total within-cluster sum-of-squares showed no clear ‘elbow’ that would indicate a best supported cluster number (**Fig. E6**).

Therefore, we selected a two-cluster structure for subsequent evaluations, primarily for the convenience of displaying results using two-dimensional plots. Plots of transformed catches for Northern Anchovy and Sardine, colored by their corresponding assignment to varying numbers of K-means clusters, indicated that the K-means clustering was assigning samples to clusters in part based on the relative dominance of either Northern Anchovy or Sardine (**Fig. E7**). Proportional sample assignments to K-means clusters by survey year show a general trend over time that partially corresponds to the increasing dominance of Northern Anchovy in catches from 2013 to 2025 (**Figs. E3, E8**). Proportional sample assignments to K-means cluster by net type show only a slight difference that is not readily explained by trends in the relative dominance of Northern Anchovy alone (**Fig. E8**). These results support previous analyses (i.e., descriptive statistics, visualizations) in showing temporal variation in cluster assignment but no meaningful differences between net types that would be expected to affect survey results or survey-related inputs to stock assessments.

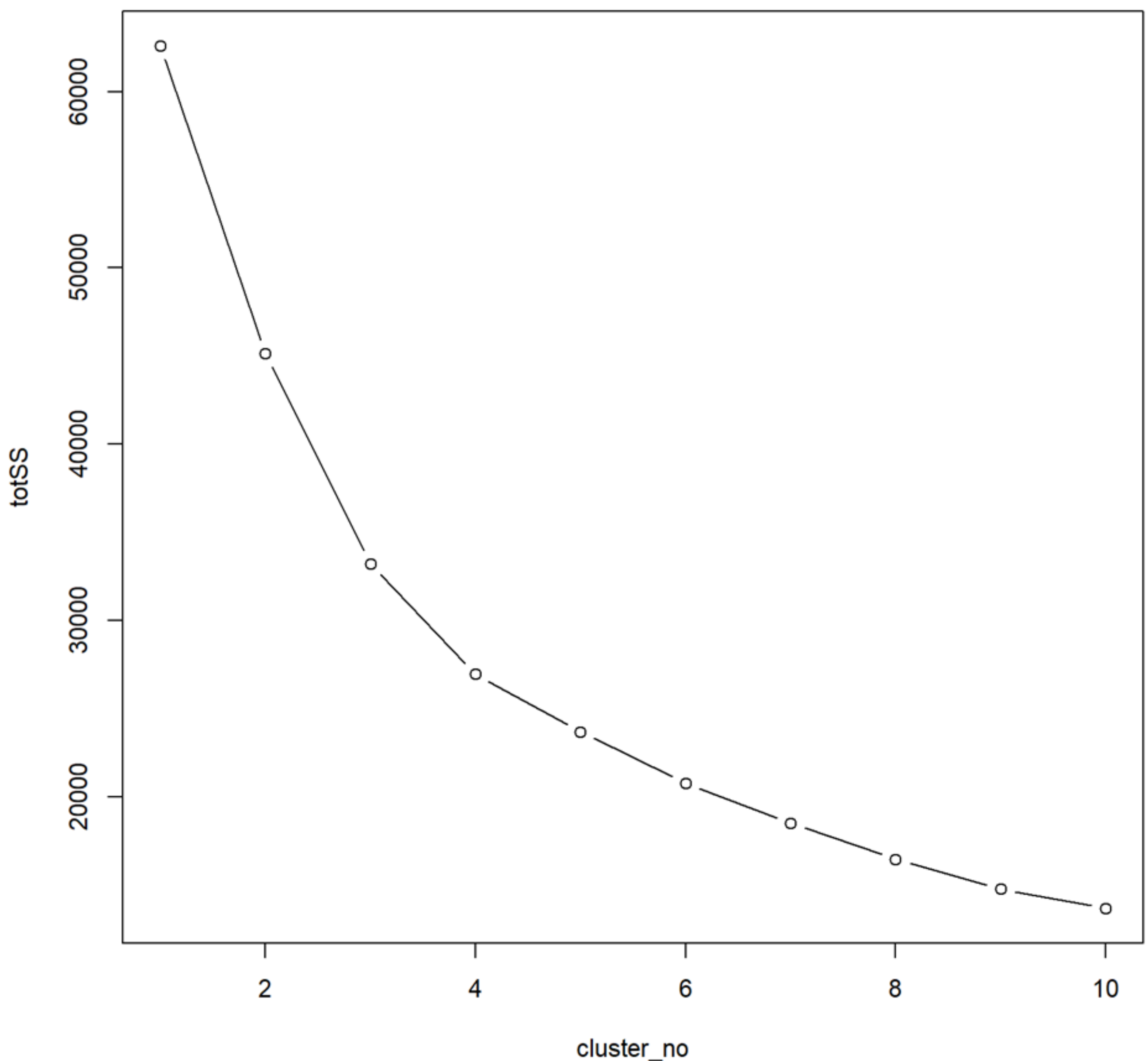


Figure E6. Comparison of the number of K-means clusters against total within-cluster sum-of-squares.

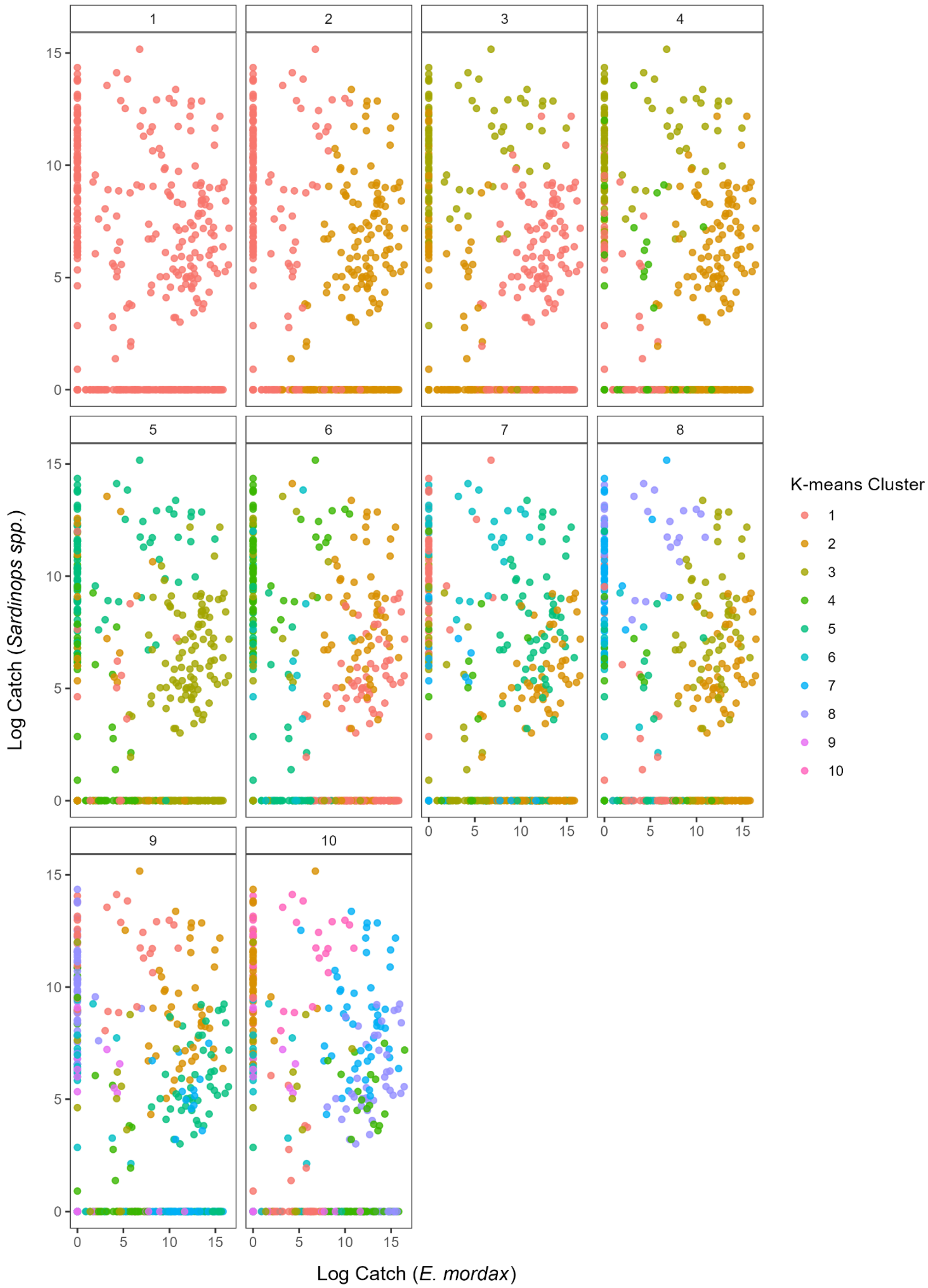


Figure E7. Comparison of log-transformed catch values (with corrections) for two prevalent CPS species as a function of K-means cluster identity for assessed CPS. Facets represent the number of fitted K-means clusters.

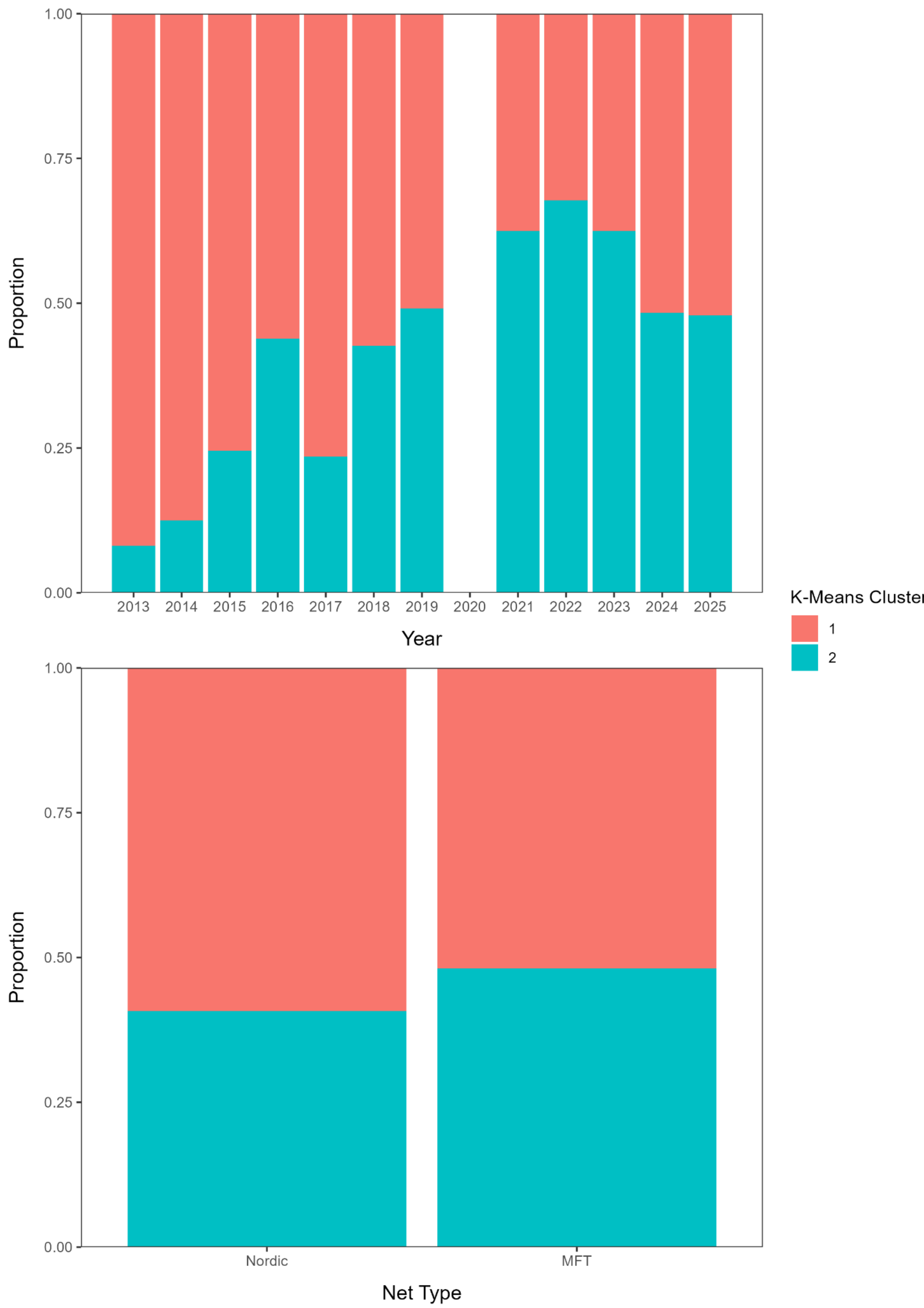


Figure E8. Proportion of sampling cluster assignments to two possible K-means clusters as a function of survey year (top) and net type (bottom).

E.2.7. Non-metric multidimensional scaling (NMDS)

Non-metric multidimensional scaling was conducted to determine the best supported number of ordination dimensions and analyze differences in community structure among years and between net types. We elected to use NMDS over other ordination techniques, because it performs well with nonnormal data, including a prevalence of zero catch values. We used the Bray-Curtis dissimilarity index to calculate distance matrices for NMDS based on recommendations in (McCune and Grace, 2002). We conducted NMDS for a number of dimensions ranging from one to six and evaluated the corresponding stress to select the best supported number of dimensions (i.e., using a scree plot). Finally, we plotted the NMDS axis scores for each sampling cluster and applied various color groupings to visualize any differences in catch compositions among years and between net types.

Comparison of the number of NMDS dimensions to model stress exhibited no clear “elbow” that would indicate a best supported number of ordination dimensions (**Fig. E9**). Similar to the logic for K-means clustering, we therefore selected a two-dimensional structure for plotting convenience. Plots of NMDS axis scores as a function of survey year showed high variability in catch composition within years and no obvious patterns over time (**Fig. E10**). Axis scores for samples collected by the MFT net generally fell within the range of scores for samples collected by the Nordic 264 net (**Fig. E10**). Finally, clear horseshoe patterns of sampling clusters in ordination space, despite the application of data transformations and NMDS, reflect the highly heterogeneous nature of the catch composition data. These results underscore previous findings reported above in highlighting the high degree of variability in catch composition both within and among survey years that provides no clear support for differences in species-selectivity between net types.

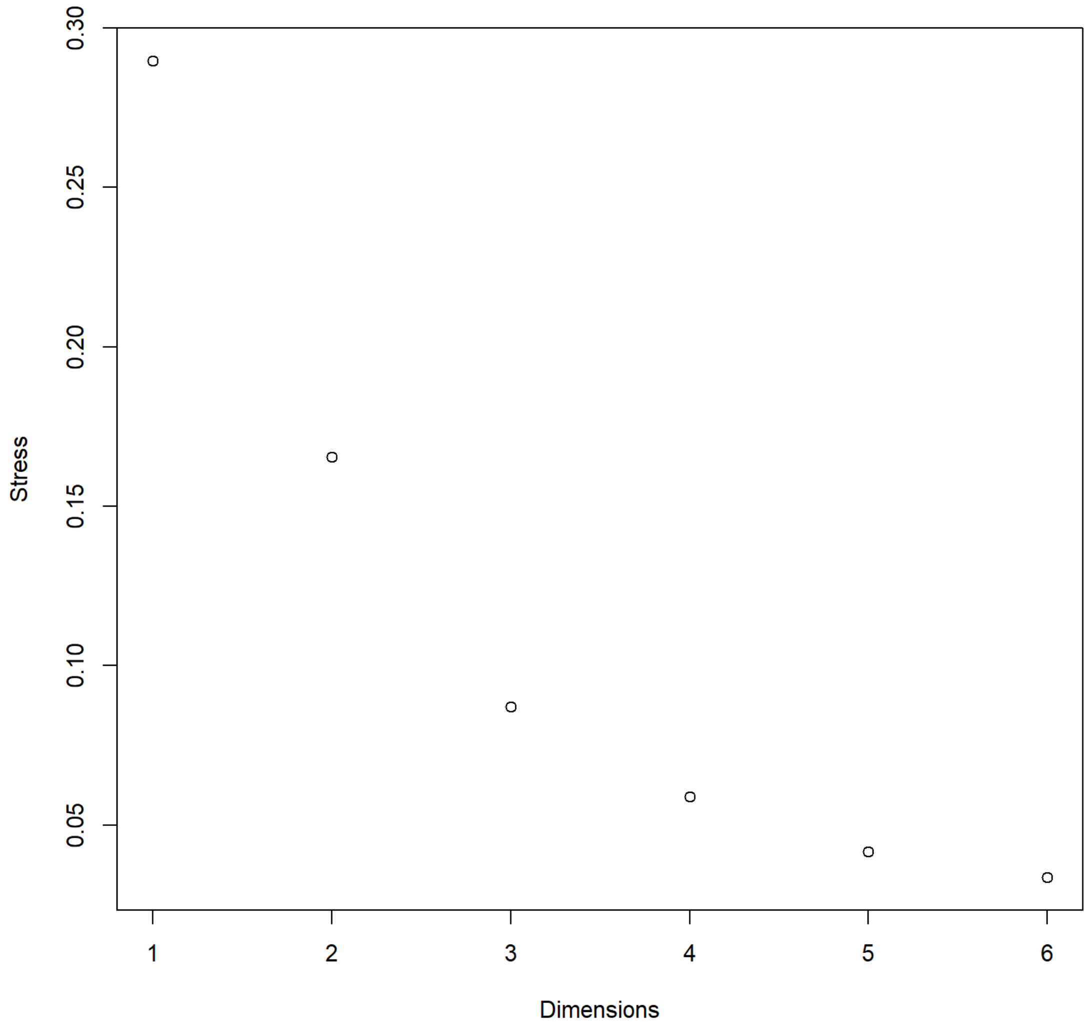
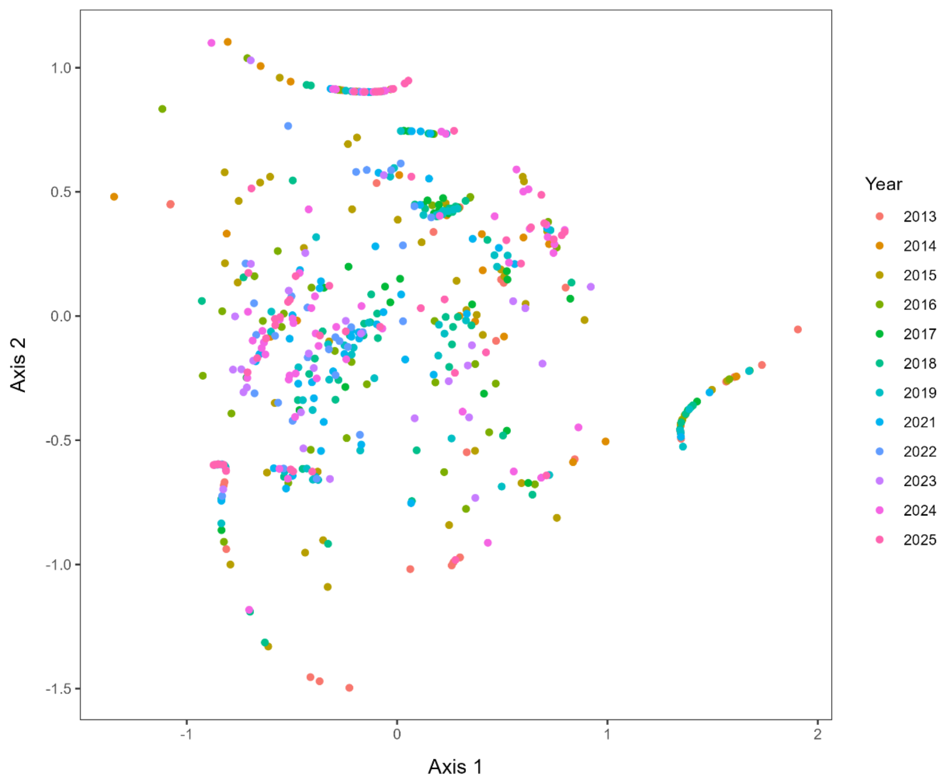


Figure E9. Comparison of the number of NMDS dimensions against stress.



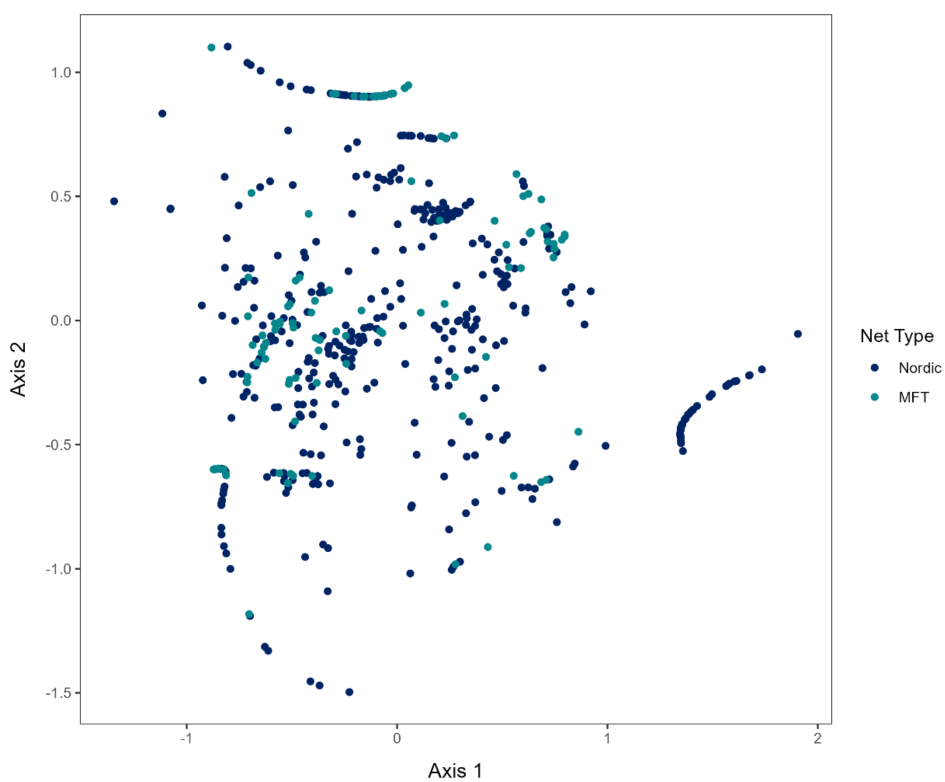


Figure E10. Two-dimensional NMDS axis scores for each sampling cluster, colored by survey year (top) and net type (bottom).

E.3. Length-selectivity comparisons

To examine potential differences in length selectivity between the Nordic 264 and MFT nets, we generated CPS length distributions for each net (**Fig. E10**) and annually for each species (**Figs. E11-E15**). For each species, the minimum and maximum lengths were presented for each net (**Table E2**). Length distributions were presented as ridgeline plots generated using the geom_density_ridges function, which estimates data densities using kernel density estimation, in the R package *ggridges*, vers. 0.5.7 (Wilke, 2025).

To get a general idea on catch proportions by length class for the focal CPS, species were put into three length groups using wide length bins to generally represent small, medium, and large sized fish. The width of the length bins varied per species and was based on length ranges. For Sardine, small fish were considered < 150 mm SL, medium fish were considered to be between 150 to 220 mm SL, and large fish were considered > 220 mm SL. For Northern Anchovy, bin sizes were < 100 mm SL, 100 to 140 mm SL, and >140 mm SL for small, medium, and large fish, respectively. For Pacific Mackerel, bin sizes were < 175 mm FL, 175 to 325 mm FL, and >325 mm FL for small, medium, and large fish, respectively. For Jack Mackerel, bin sizes were < 200 mm FL, 200 to 400 mm FL, and >400 mm FL for small, medium, and large fish, respectively. For Pacific Herring, bin sizes were < 125 mm FL, 125 to 200 mm FL, and >200 mm FL for small, medium, and large fish, respectively. Proportions of each length bin caught by both the Nordic 264 and MFT nets were then generated (**Fig. E16**).

Table E2. Number of fish measured and minimum and maximum sizes of Sardine, Northern Anchovy, Pacific Mackerel, Jack Mackerel, and Pacific Herring for both the Nordic 264 and MFT nets from 2013-2025. Sizes are in standard length (mm) for Sardine and Northern Anchovy and fork length (mm) for Pacific Mackerel, Jack Mackerel, and Pacific Herring.

Net	Nordic 264			MFT		
Species	n	Min. Size	Max Size	n	Min. Size	Max Size
Sardine	7,016	25	292	561	60	256
Northern Anchovy	19,597	22	178	7,492	35	163
Pacific Mackerel	4,174	53	382	232	47	431
Jack Mackerel	10,958	15	595	4,035	18	551
Pacific Herring	5,060	55	247	1,497	79	250

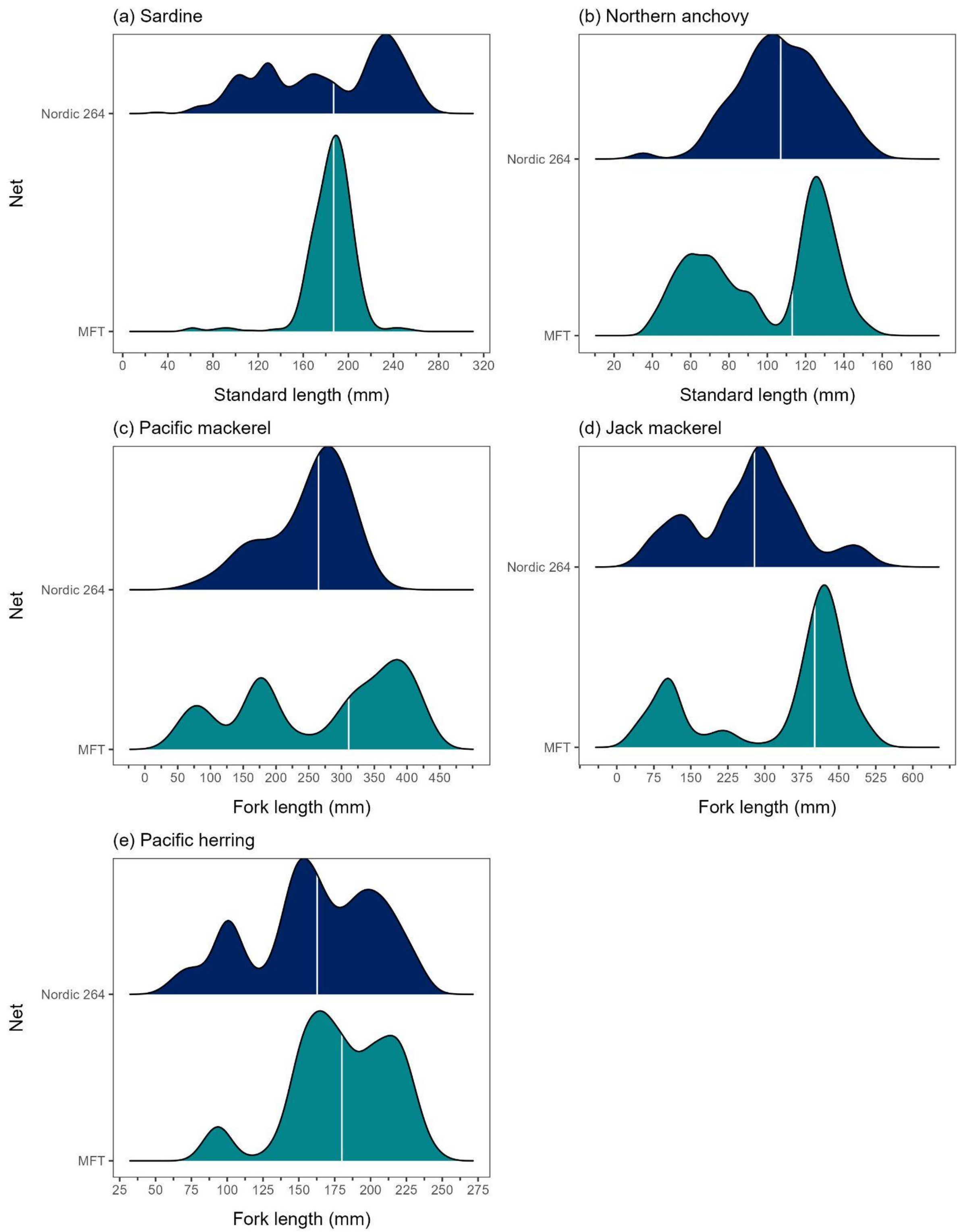


Figure E10. Length distributions, represented by density curves, pooled by year of (a) Sardine, (b) Northern Anchovy, (c) Pacific Mackerel, (d) Jack Mackerel, and (e) Pacific Herring by Nordic 264 and MFT nets. The white vertical line represents the median.

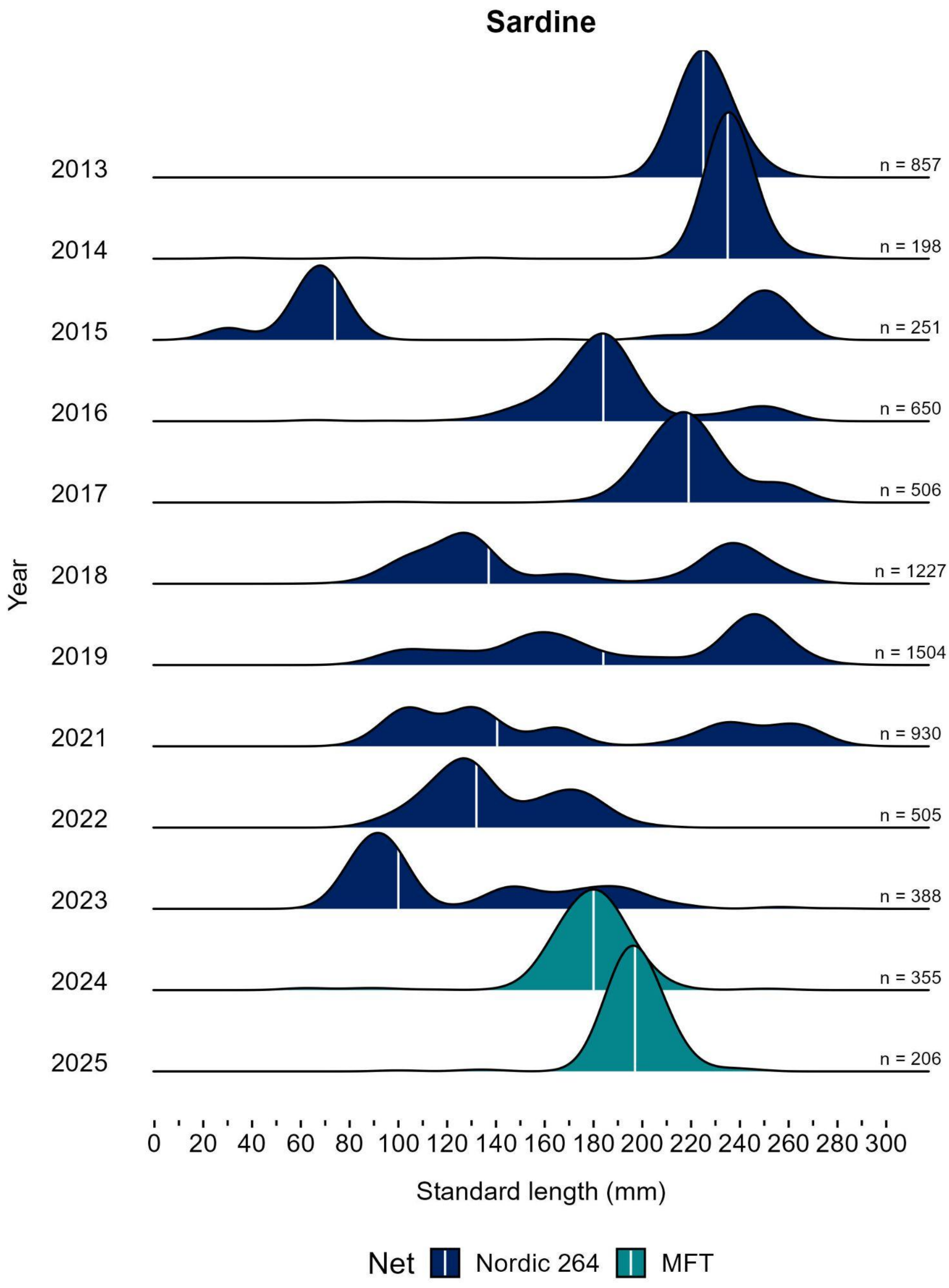


Figure E11. Annual length distributions, represented by density curves, of Sardine by Nordic 264 and MFT nets. The white vertical line represents the median and the sample size for each year is included on the righthand side.

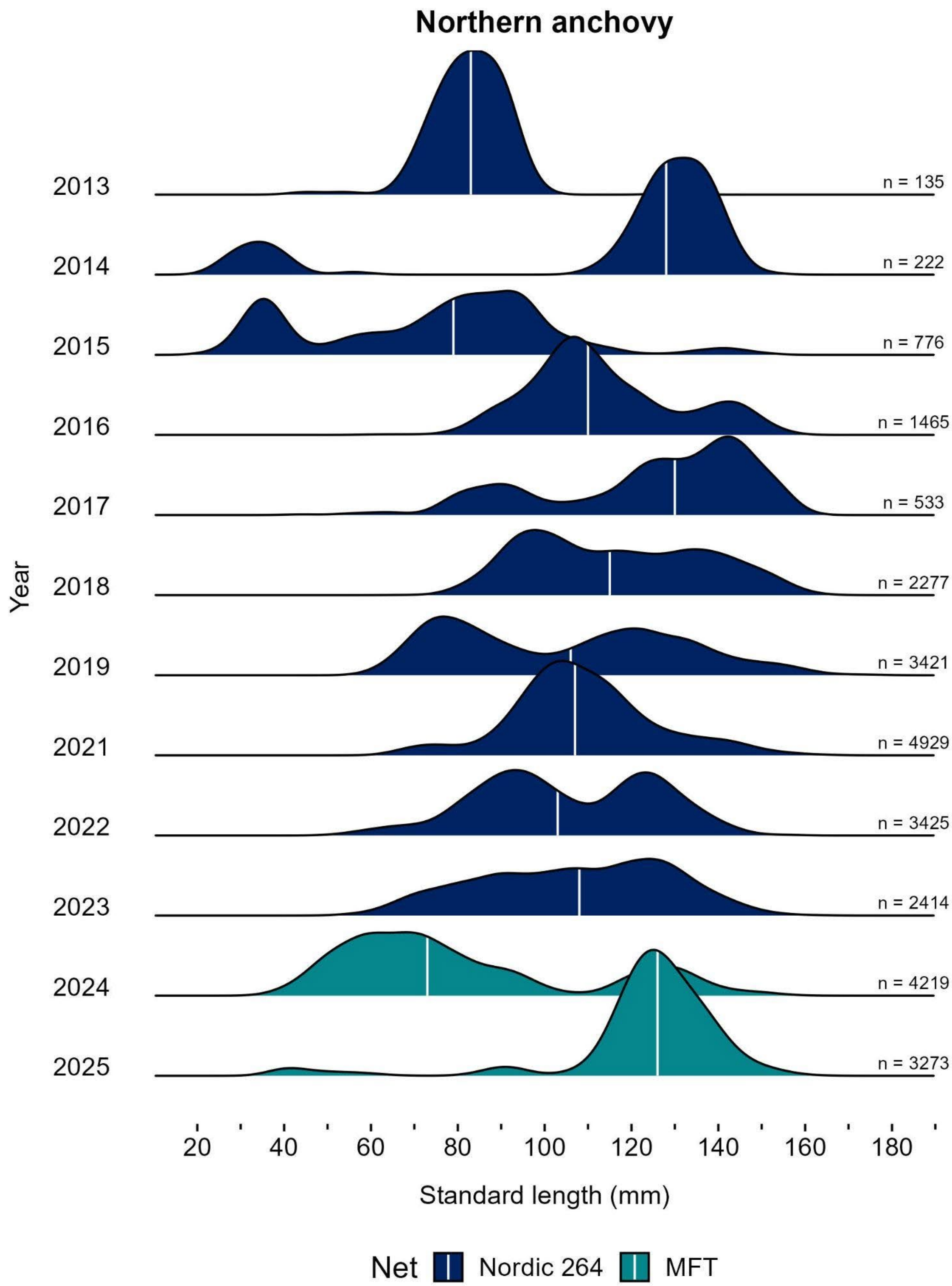


Figure E12. Annual length distributions, represented by density curves, of Northern Anchovy by Nordic 264 and MFT nets. The white vertical line represents the median and the sample size for each year is included on the righthand side.

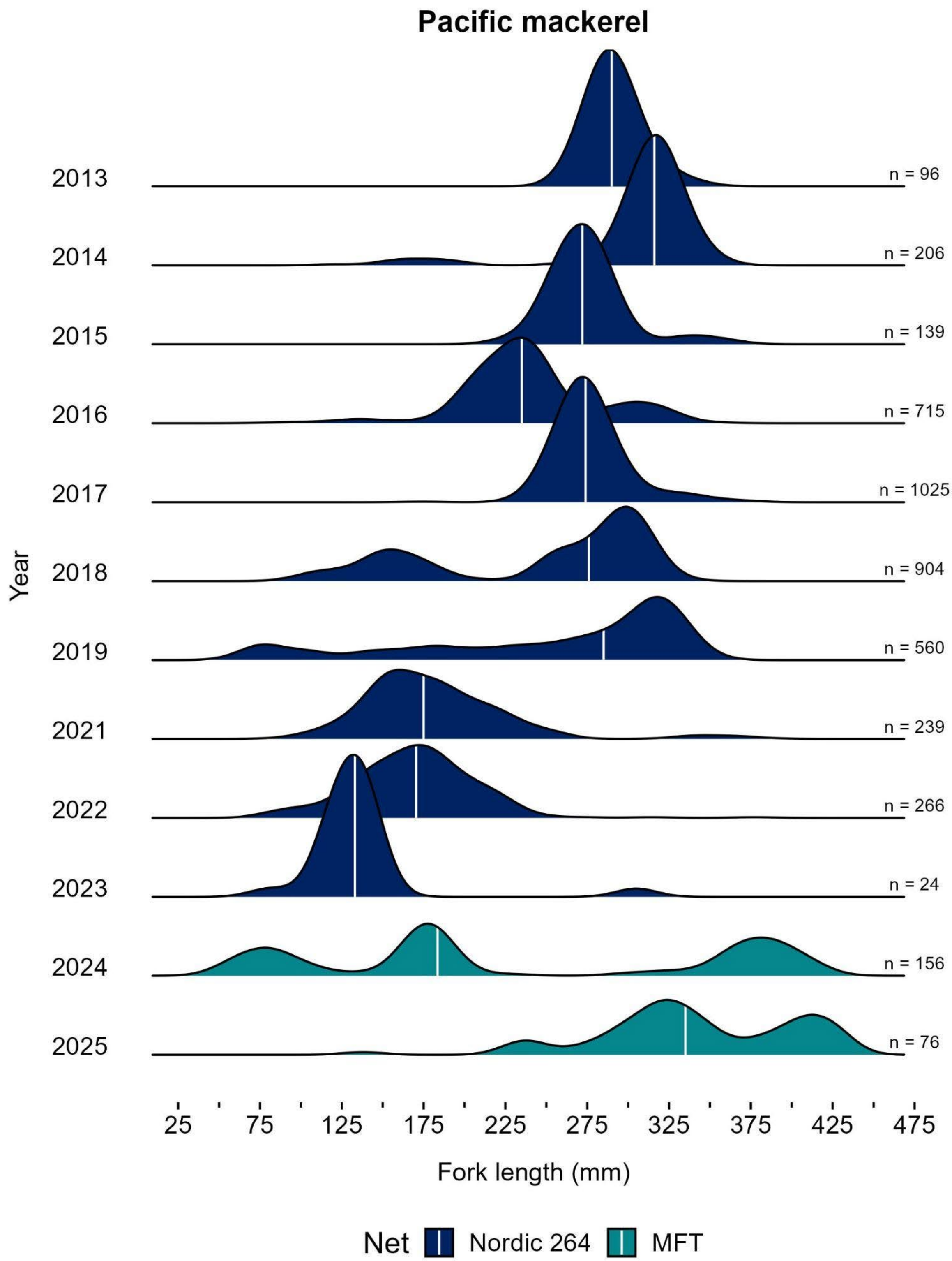


Figure E13. Annual length distributions, represented by density curves, of Pacific Mackerel by Nordic 264 and MFT nets. The white vertical line represents the median and the sample size for each year is included on the righthand side.

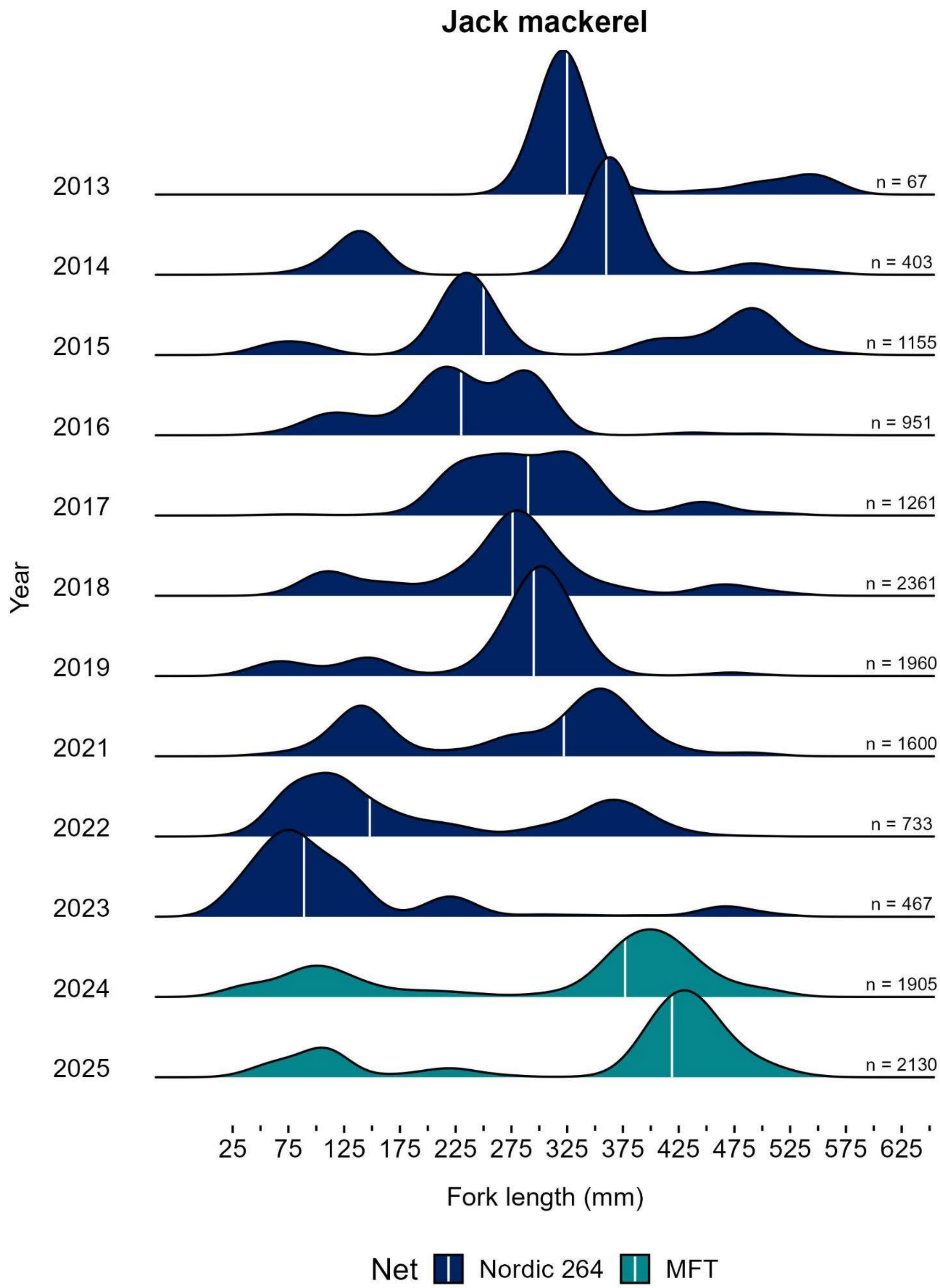


Figure E14. Annual length distributions, represented by density curves, of Jack Mackerel by Nordic 264 and MFT nets. The white vertical line represents the median and the sample size for each year is included on the righthand side.

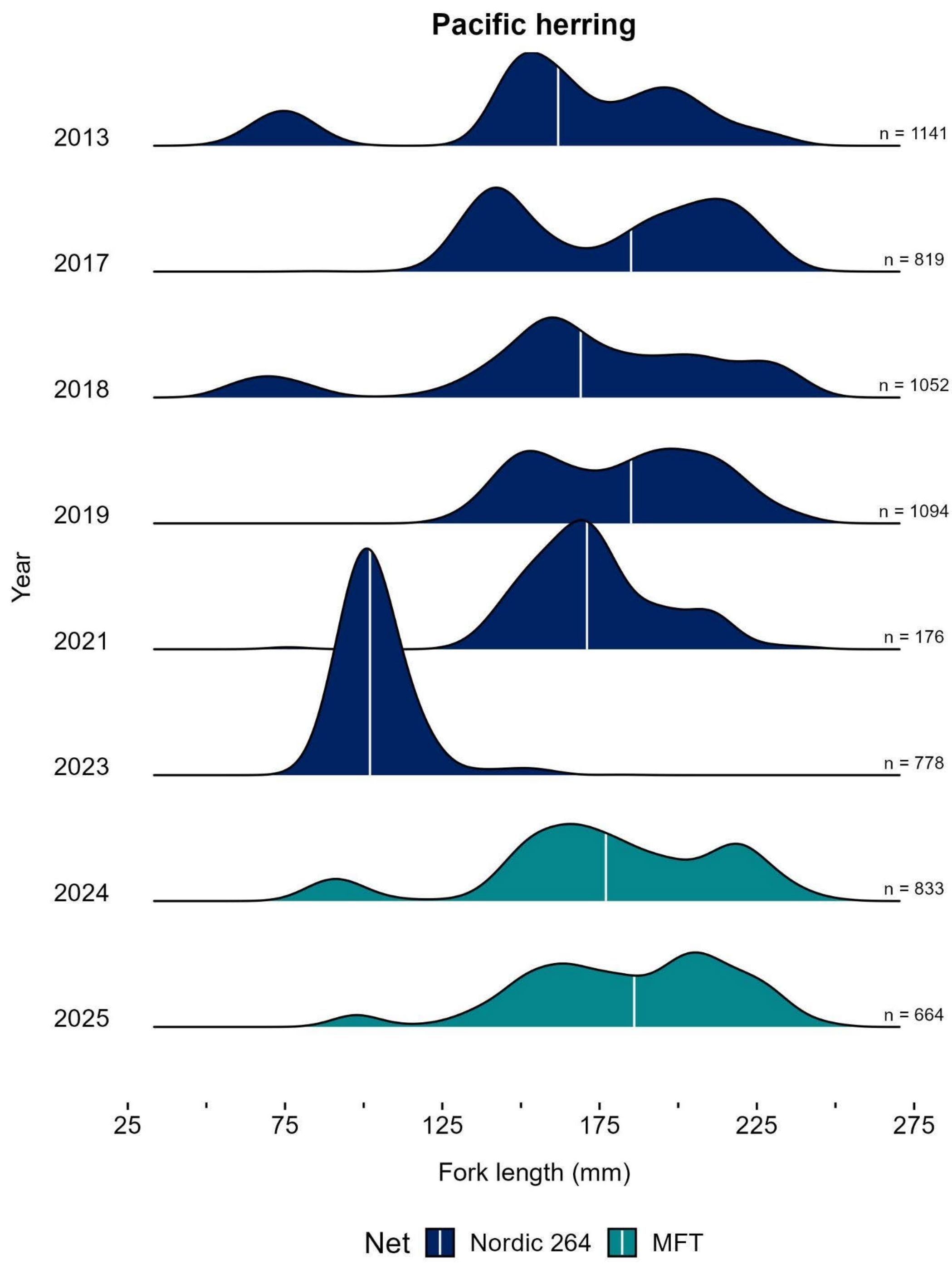


Figure E15. Annual length distributions, represented by density curves, of Pacific Herring by Nordic 264 and MFT nets. The white vertical line represents the median and the sample size for each year is included on the righthand side. Although Pacific Herring were collected during 2014 to 2016 surveys, length frequencies instead of individual measurements were taken for Pacific Herring during these years and thus could not be plotted as densities. No Pacific Herring were collected in 2022, because the ship did not sample north of Cape Mendocino, CA (see **Fig. E2**).

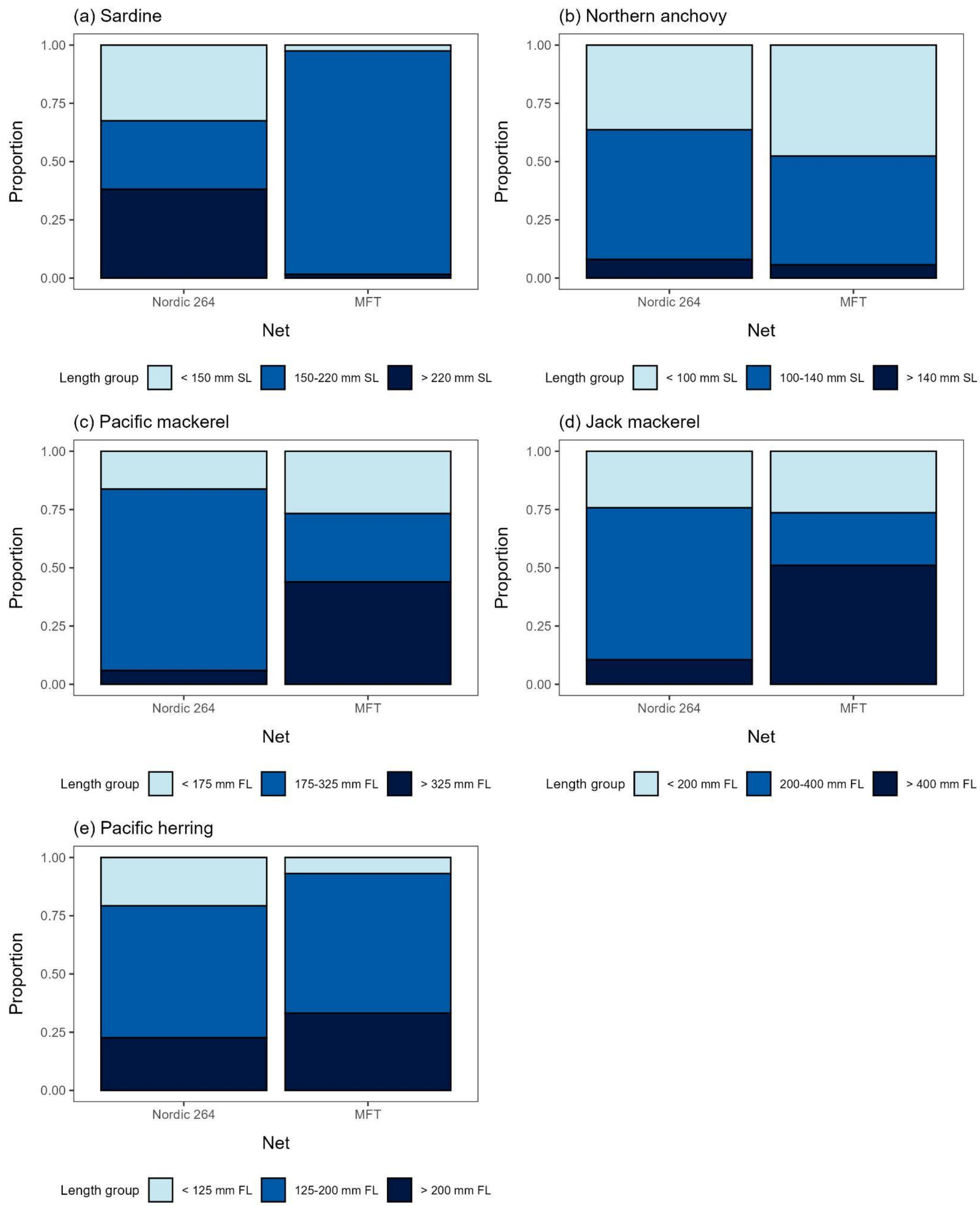


Figure E16. Catch proportion of each length group for (a) Sardine, (b) Northern Anchovy, (c) Pacific Mackerel, (d) Jack Mackerel, and (e) Pacific Herring by Nordic 264 and MFT nets. Lengths were grouped in wide bins to generally represent small, medium, and large sized fish.

Length ranges and distributions of specimens collected using the MFT fell within the ranges of specimens collected using the Nordic 264 for all target CPS (**Figs. E10-E15**).

The maximum size of Sardine collected using the MFT was smaller than the maximum size collected using the Nordic 264 (**Table E2**), but Sardine larger than 250 mm SL have been uncommon since 2022 (**Fig. E11**).

The maximum size of Northern Anchovy collected using the MFT was also smaller than the maximum size collected using the Nordic 264 (**Table E2**), but Northern Anchovy larger than 160 mm SL are rare (**Fig. E12**).

The MFT did collect larger Pacific Mackerel than the Nordic 264 (**Table E2**). From 2013 - 2023, the Nordic 264 did not catch a Pacific Mackerel above 400 mm. Pacific Mackerel have been systematically measured starting in 2008, and since then, the Nordic 264 has only ever caught one Pacific Mackerel above 400 mm out of 2209 trawls (occurred in 2012, Zwolinski et al., 2014). After switching to the MFT in 2024, we have collected 29 Pacific Mackerel above 400 mm over two surveys and 278 trawls. Large-sized Pacific Mackerel are also being caught in greater proportion using the MFT compared to the Nordic 264 (**Figs. E13, E16**).

The maximum size of Jack mackerel collected using the MFT was smaller than the maximum size collected using the Nordic 264 (**Table E2**), but Jack Mackerel larger than 550 mm FL have been uncommon since 2015 (**Fig. E14**). Large-sized Jack Mackerel were collected in greater proportions using the MFT compared to the Nordic 264 (**Figs. E14, E16**).

Pacific Herring had similar length range and distributions across nets (**Table E2, Figs. E10, E15**).

For all other species besides Pacific Mackerel, differences in catch proportions of length groups (**Fig. E16**) is likely driven by annual variability in what fish were available to be collected. This is best observed in the annual length distributions of each fish species (**Figs. E11-E15**), which show high annual variability in the lengths collected using the same net (Nordic 264) over 10 years.Therefore, it is not possible to determine the degree to which annual variations in length distributions are due to actual changes in length selectivity (i.e., a net change effect), annual variations in fish availability, or other factors.

F. Statistical comparisons of length-selectivity between the Nordic 264 and MFT nets for effects on survey-derived age composition and weight-at-age estimates.

F.1. Comparing simplified, survey-derived age composition and weight-at-age estimates using sample data collected by the Nordic 264 and MFT nets

F.1.1. Methods overview

We developed an approximate, simplified version of the acoustic-trawl methodology (ATM) calculations involved in processing survey-based acoustics and trawl sampling data (Stierhoff et al., In. prep.) into final estimates of age composition and weight-at-age (WAA), with the intent of evaluating effects of possible differences in net selectivity on inputs to the assessment. The simplified calculations, below, were derived from those conducted for previous summer ATM surveys and CPS assessments (e.g., Kuriyama et al., 2024; Stierhoff et al., 2025). The workflow only accounts for the three currently assessed CPS species: Pacific Sardine ('Sardine'), Pacific Mackerel, and Northern Anchovy. Analyses only included length, weight, and age data for the northern subunit of 'Sardine' (i.e., defined annually by latitude to match habitat assignments) and the central stock of Northern Anchovy (i.e., defined by a constant latitude); these cut-offs were applied throughout these analyses to ensure consistency with their application in previous assessments.

The simplified ATM calculations also ignore any confounding spatial structure (i.e., all annual samples are pooled into a single cluster) and avoid stochasticity in annual age-length keys (ALK) by using a single 'pooled' ALK for each species. These calculations were applied to species- and survey-specific length and weight data collected in the 'core' area (i.e., using either the Nordic 264 or MFT net) during summer ATM surveys to identify any departures in estimated age composition and WAA for MFT survey years from the range of variability observed for Nordic 264 survey years.

F.1.2. Simplified ATM calculations

The simplified ATM calculations require the following inputs: single values for both the nautical area scattering coefficient (i.e., strength of the acoustic biomass signal, or s_A) and survey region area (A), and fish sample sizes (N), lengths (L), and weights (W) for Sardine, Pacific Mackerel, and Northern Anchovy. The following calculations were then conducted sequentially:

- Calculate the length frequencies for each species *sp* within 1 cm length bins ($\vec{Lfreq}_{sp}$), such that the 1 cm length bin contains the following lengths: [0.5, 1.5)
- Calculate the nautical area scatter coefficient associated with CPS ($s_{A,CPS}$)
  - We assumed $s_{A,CPS} = S_A$
- Calculate the acoustic proportion for each species *sp* (i.e., the fraction of the acoustic signal assigned to each species, or P_{sp}) using only the sample lengths and weights
  - Calculate target strength for each individual *i* ($TS_{sp,i}$) using established species-specific relationships (see below)
  - Calculate the arithmetic counterpart of average target strength for each species:

  - $\underline{\sigma}_{sp} = \frac{\sum_{i=1}^{N_{sp}} 10^{TS_{sp,i}/10}}{N_{sp}}$
- Calculate the average weight for each species:
  - $\underline{w_{sp}} = \frac{\sum_{i}^{N_{sp}} W_{sp,i}}{N_{sp}}$
- Calculate P_{sp}
  - $P_{sp} = \frac{N_{sp} * \underline{w_{sp}} * \underline{\sigma}_{sp}}{\sum_{sp=1}^{3} N_{sp} * \underline{w_{sp}} * \underline{\sigma}_{sp}}$

- Calculate the nautical area scattering coefficient associated with each species ($s_{A,sp}$):
  - $s_{A,sp} = s_{A,CPS} * P_{sp}$
- Calculate the biomass density (kg nmi^{-2}) for each species ($\rho_{w,sp}$):
  - $\rho_{w,sp} = \frac{s_{A,sp}}{4 * \pi * \underline{\sigma}_{sp}}$
- Calculate the numerical density (# nmi-2) for each species ($\rho_{n,sp}$):
  - $\rho_{n,sp} = \frac{\rho_{w,sp}}{\underline{w}_{sp}}$
- Calculate abundance-at-length vector for each species (***AAL$_{sp}$***)
  - $\boldsymbol{AAL_{sp}} = \rho_{n,sp} * A * \boldsymbol{Lfreq_{sp}}$
- Calculate abundance-at-age vector for each species (***AAA$_{sp}$***)
  - Applied a 'pooled' ALK to ***AAL$_{sp}$***
- Calculate biomass-at-length vector for each species (***BAL$_{sp}$***)
  - Calculate expected weight for each length bin (***w$_{sp}$***) using species-specific fork-/standard-length to total length and total length to weight relationships
  - Calculate ***BAL$_{sp}$***
    - $\boldsymbol{BAL_{sp}} = \boldsymbol{Lfreq_{sp}} * \mathbf{w}_{\boldsymbol{sp}}$
- Calculate biomass-at-age vector for each species (***BAA$_{sp}$***)
  - Applied a 'pooled' ALK to ***BAL$_{sp}$***
- Calculate total species-specific biomass (*Bio$_{sp}$*)
  - $Bio_{sp} = \rho_{w,sp} * A$
- Calculate species-specific weight-at-age vector (***WAA$_{sp}$***)
  - $\boldsymbol{WAA_{sp}} = \boldsymbol{BAA_{sp}} * \boldsymbol{AAA_{sp}}$
  - Note: Collapsed ages-3+ for Northern Anchovy into a single age-class to match the age class definitions used in the most recent benchmark assessment (Kuriyama et al., 2022)
- Calculate species-specific age compositions (***AC$_{sp}$***)
  - $\boldsymbol{AC_{sp}} = \frac{\boldsymbol{AAA_{sp}}}{\sum_{a=1}^{MaxAge_{sp}} \boldsymbol{AAA_{sp}}}$
  - Note: Again collapsed ages-3+ for Northern Anchovy into a single age class

This approach deviates somewhat from standard calculations that provide inputs to stock assessments. Namely, these simplified calculations assume there is no spatial structure (e.g., no 100-m transects, no trawl clusters, etc.), and as such perform a single set of calculations on the single scattering coefficient s_A, single spatial region, and single set of species-specific samples. Additionally, this structure assumes that the sampled fish with corresponding measurements of length and weight comprise all of the trawl catch (i.e., there is no need to deal with unsampled catch weights). This structure also assumes that only the three assessed CPS species comprise catches and acoustic biomass. Finally, this method utilizes a single 'pooled' ALK calculated externally (see below) instead of estimating a new ALK for each sampling scenario.

The simplified calculations required the use of several species-specific life history relationships, including conversions of standard length and/or fork length to total length, total length to weight, and total length to target strength. We specified each of these to exactly match those used in current ATM calculations. We also estimated species-specific ALKs using accepted best practices (i.e., GAM modeling) and including all assessment-ready age and length samples collected by either the Nordic 264 or MFT nets during summer ATM surveys from 2013 onwards to maintain consistency with previous species composition- and length-selectivity analyses. For Northern Anchovy, only samples from 2015 onwards were included to match survey data utilized in the recent benchmark assessment. The following years of data were used for each species' ALK: 2013-2019 and 2021-2024 for Pacific Mackerel, 2013-2019 and 2021-2024 for Sardine, and 2015-2019 and 2021-2024 for Northern Anchovy. These 'pooled' ALKs were used to convert abundance-at-length and biomass-at-length to abundance-at-age and biomass-at-age.

The following estimated values are saved and summarized for each set of calculations:

- Species-specific WAA, for the following age ranges:
  - Northern Anchovy: ages 0-3+
  - Pacific Mackerel: ages 0-8+
  - Sardine: ages 0-8+
- Species-specific age compositions, for the same age ranges

F.1.3. Estimation scenarios using empirical survey data

We used length and weight observations for Pacific Mackerel, Sardine, and Northern Anchovy to calculate corresponding estimates of age composition and WAA; ages were not required due to the use of an ALK. First, we conducted simplified ATM calculations in which trawl-collected observations from all summer Nordic 264-based surveys, starting with either 2013 or the first year of data in the recent benchmark assessment (if after 2013), were supplied for Pacific Mackerel, Sardine, and Northern Anchovy. The following survey years therefore were included for each species: 2013-2019 and 2021-2023 for Pacific Mackerel, 2013-2019 and 2021-2023 for Sardine, and 2015-2019 and 2021-2023 for Northern Anchovy. The resulting estimates of age composition and WAA represent expected averages during survey years utilizing the Nordic 264 net.

Next, we evaluated scenarios in which trawl-based length and weight data from a single Nordic 264 survey were provided for a focal species and observations from all Nordic 264 survey years were provided for the remaining species. For each scenario, we only retained calculated age compositions and WAA for the focal species with a single year of data; estimates for the nonfocal species were equal to the already estimated average values (above). These scenarios were intended to capture interannual variability in assessment inputs resulting from sampling distributions collected by the Nordic 264 net, and again included all Nordic 264-based survey years starting in 2013.

Finally, we evaluated scenarios in which we supplied data from survey years that used the MFT net. Specifically, we conducted simulations in which only trawl-based observations from a single MFT survey year were provided for a focal species and observations from all Nordic 264 surveys were again provided for the remaining two species. Results from these scenarios were intended to identify whether calculated age composition and WAA values for MFT survey years (i.e., 2024, 2025) fell outside of the range of values calculated for Nordic 264 survey years. In essence, we attempted to identify any impact of potential differences in length selectivity between the net types on assessment inputs.

For all scenarios, we assumed s_A=200 and A=1000 nmi^2 for the sake of convenience; in the context of these evaluations, these parameters only serve to proportionally scale estimates of total biomass. Despite calculating acoustic proportions and biomass as part of the simplified workflow, we did not attempt to evaluate effects of length-selectivity on these estimates. We made this decision in response to the difficulty in disentangling interactions among acoustics and trawl data and varying possible length selectivity patterns among CPS species. More specifically, biomass estimates rely on trawl data to partition acoustic signals of abundance, and the relative contribution of any single species is necessarily dependent on the catches of all other CPS. In contrast, calculations of species-specific age composition and WAA rely only on species-specific measurements (i.e., are insensitive to both acoustic data and biological data for other species).

F.1.4. Results

The 'pooled' ALKs for Pacific Mackerel, Sardine, and Northern Anchovy, used to convert abundance- and biomass-at-length to abundance- and biomass-at-age, are provided in **Figures F1-F3**. Sampled ages and lengths used to generate the species-specific 'pooled' ALKs are summarized in **Fig. F4**. Summaries of length data used to generate species- and survey year-specific estimates of age composition and WAA, with corresponding sample sizes, are provided in **Fig. F5**.

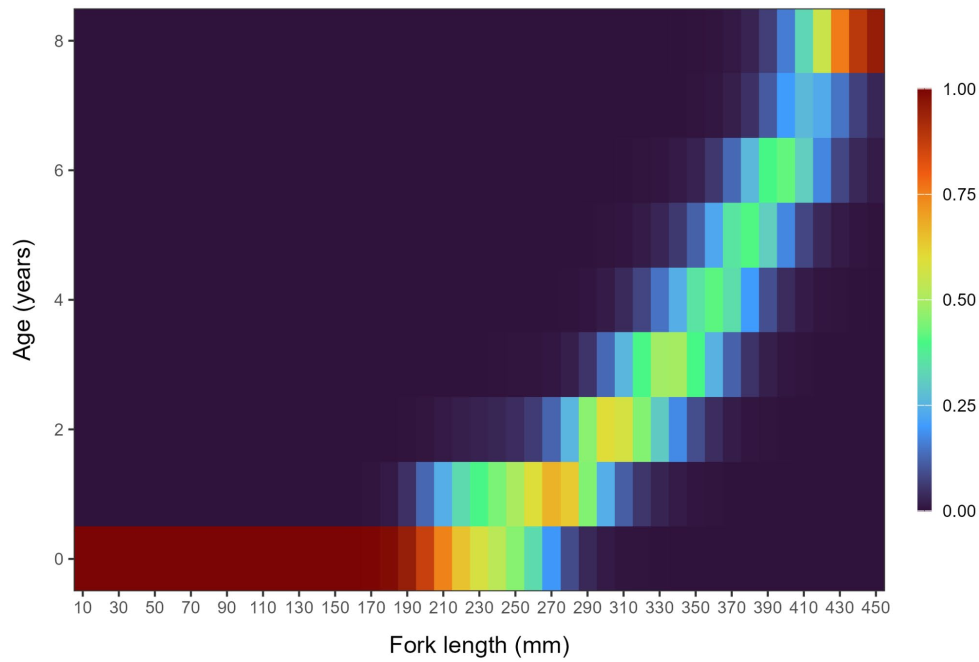


Figure F1. 'Pooled' ALK for Pacific Mackerel, in which colored values indicate the probability of assigning to an age given a specified fork length.

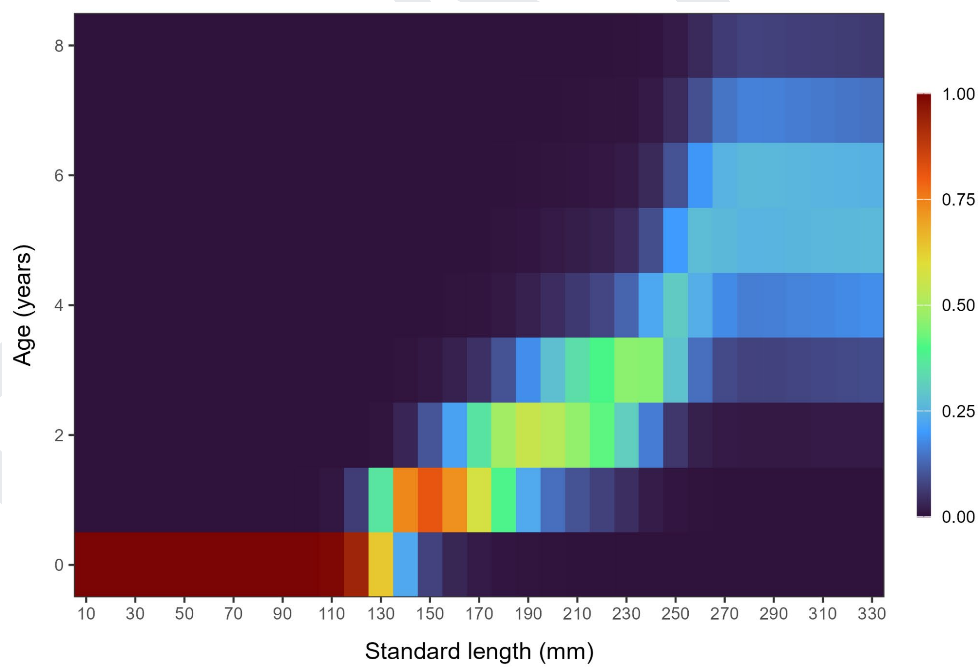


Figure F2. 'Pooled' ALK for Sardine, in which colored values indicate the probability of assigning to an age given a specified standard length.

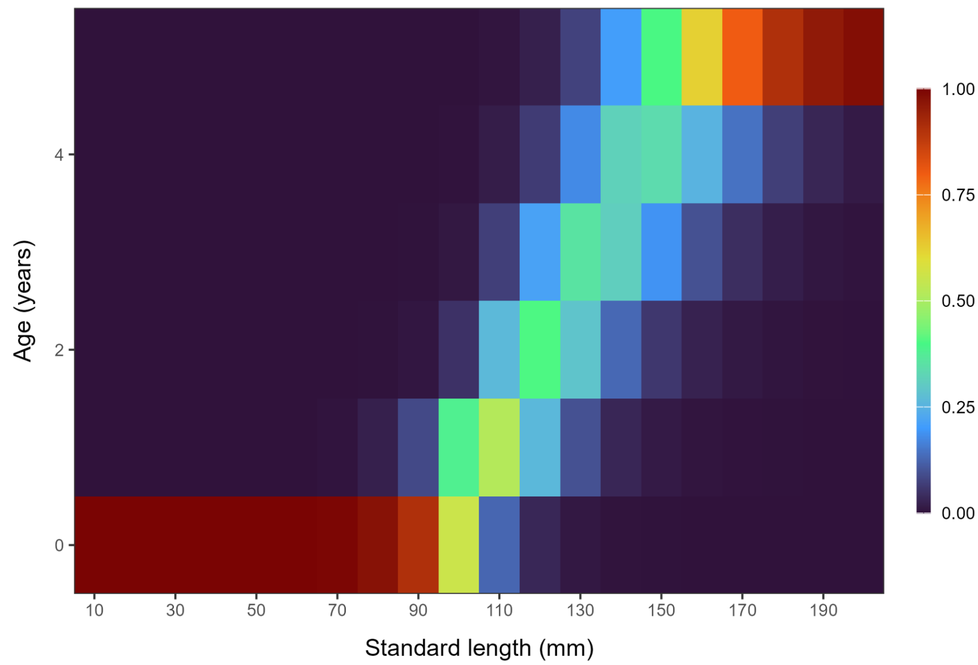


Figure F3. 'Pooled' ALK for Northern Anchovy, in which colored values indicate the probability of assigning to an age given a specified standard length.

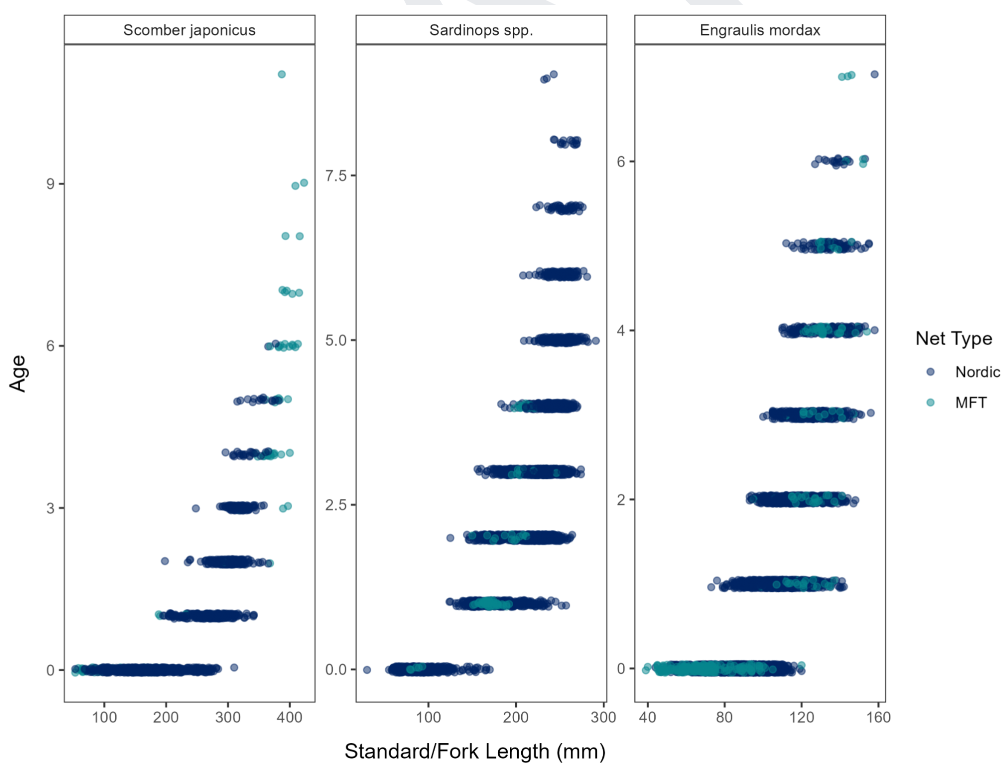


Figure F4. Sampled lengths and ages by species and net type, used to generate 'pooled' species-specific ALKs. Northern Anchovy and Sardine are measured using standard length and Pacific Mackerel using fork length. A small amount of vertical jitter was added to facilitate interpretation.

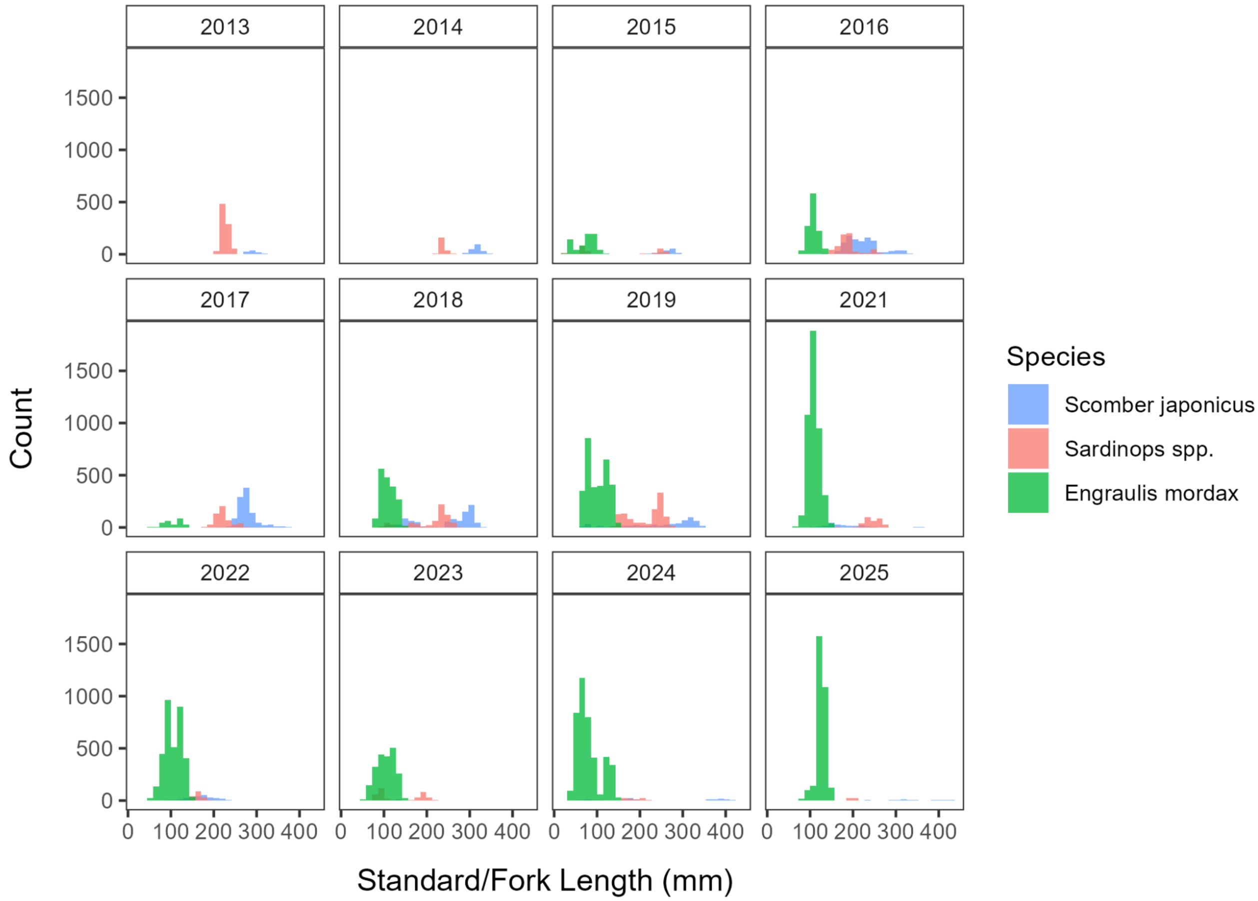


Figure F5. Distributions of sampled length data applied in calculations of age composition and WAA for Northern Anchovy, Sardine, and Pacific Mackerel. Northern Anchovy and Sardine are measured using standard length and Pacific Mackerel using fork length.

Estimated age composition values for Pacific Mackerel primarily followed a trend of decreasing proportional contributions to abundance with increasing age, with a high degree of annual variability (**Fig. F6**). There were noticeable differences in the contributions of older ages (i.e., ages 5 and older) between Nordic 264 and MFT years, with greater estimated contributions of older ages during MFT years. It is possible that these differences were based solely on annual variability in what fish are available to be collected, but the magnitude and consistency of the differences suggest this may be unlikely. Estimated WAA generally displayed an increasing, asymptotic pattern for Nordic 264 survey years (**Fig. F6**). Some annual WAA estimates exhibited asymptotic behavior at ages as low as 1; for these years, few or no older ages in the dataset resulted in all older ages being assigned to WAA values of younger fish. MFT survey years yielded more linear WAA relationships, with higher WAA estimates for ages-5+ than any Nordic 264 year.

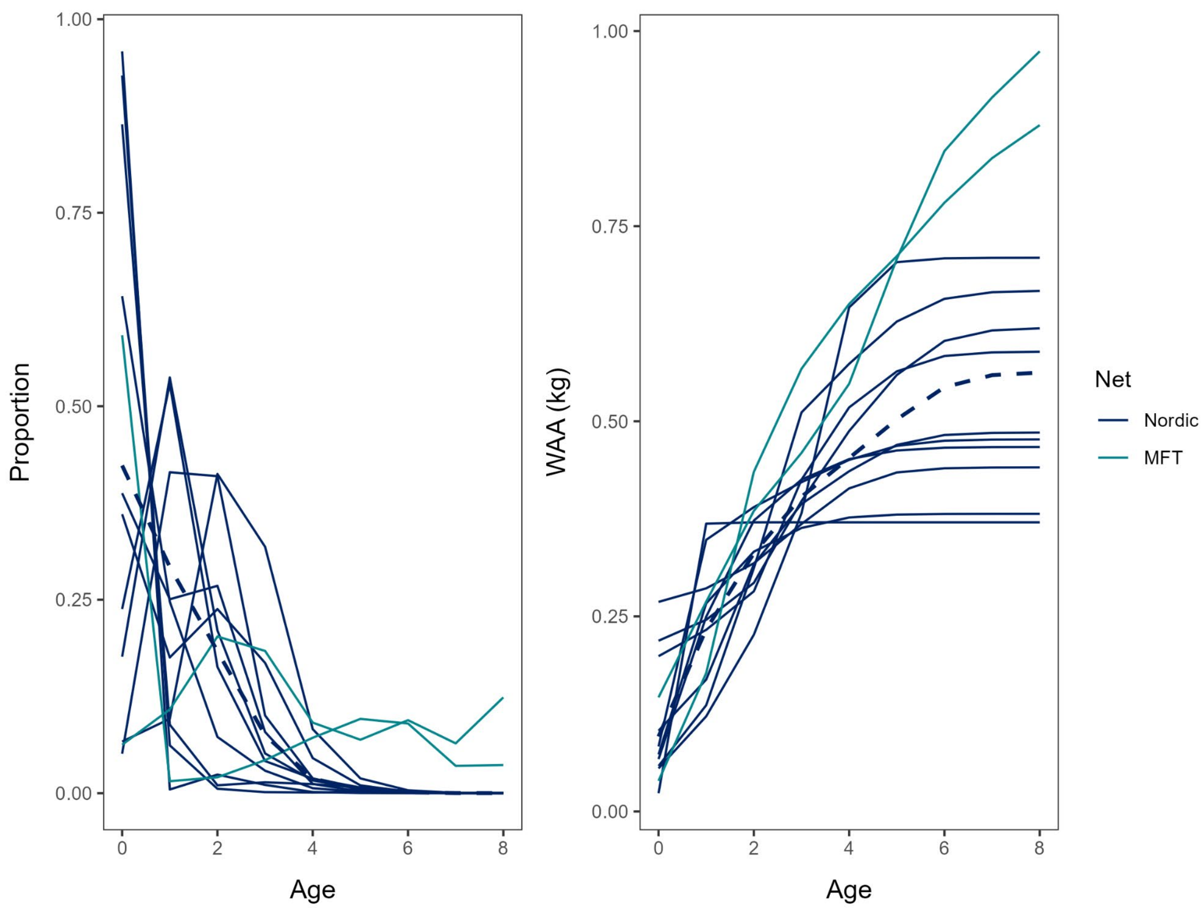


Figure F6. Estimated age compositions (left) and WAA (right) using the simplified workflow for Pacific Mackerel. Solid lines represent estimates for survey year-specific datasets and the dashed lines represent estimates for pooled length, age, and weight data across all Nordic 264 survey years.

Annual age composition estimates for the northern subunit of Sardine from Nordic 264 years generally exhibited either a dome-shaped pattern, in which ages 1-3 were estimated to be numerically dominant, or a right-skewed pattern in which age 0 fish were dominant (**Fig. F7**). There was again a high degree of variability among years, with ages 0, 1, 2, and 3 contributing the most to abundance in at least one survey year. Age 2 fish were numerically dominant for both MFT survey years, and the contributions of older fish (i.e., ages 4 and older) were lower in these years relative to most Nordic 264 years. Estimated WAA values again had a positive, asymptotic pattern with a moderate degree of variability (**Fig. F7**). Corresponding to fewer observed older fish, WAA estimates for ages 4-8 for MFT survey years were lower than corresponding estimates for all but two Nordic 264 years. These results suggest little evidence for differences in Sardine lengths, weights, and ages sampled by the two net types.

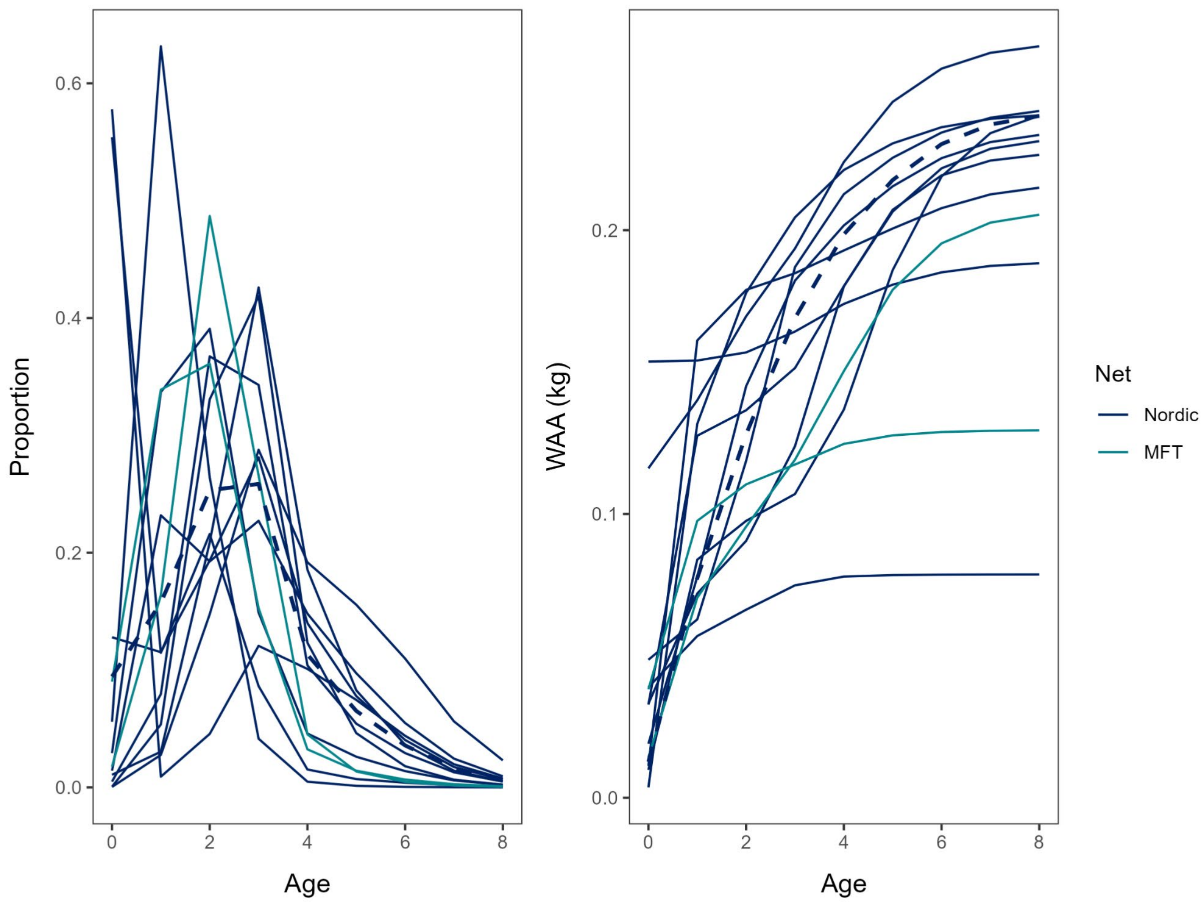


Figure F7. Estimated age compositions (left) and WAA (right) using the simplified workflow for Sardine. Solid lines represent estimates for survey year-specific datasets and the dashed lines represent estimates for pooled length, age, and weight data across all Nordic 264 survey years.

Age composition estimates for the central stock of Northern Anchovy generally showed a pattern of decreasing proportional contributions to abundance from age 0 to 2, followed by either small increases or decreases in the contribution of age-3+ fish (**Fig. F8**). The continued substantial contribution of age-3+ fish is likely explained by meaningful contributions of age-4 and older fish to this age-3+ category. There was a moderate degree of variability in patterns among years despite high sample sizes relative to other CPS. One of the MFT-based years (2025) produced the lowest estimated contribution of age-0 fish and highest contributions of age-2 and 3 fish among survey years, due to a preponderance of large sampled fish, while 2024 had comparable age composition estimates to Nordic 264 years (**Fig. F5**). Estimated WAA showed an approximately linear or weakly asymptotic pattern of increasing WAA with age (**Fig. F8**). The absence of strong asymptotic patterns is likely explained by the aggregation of all age 3 and older fish into a single age 3+ group. The two highest estimated WAA for ages 2 and 3 occurred during the MFT surveys, but estimated WAA for ages 0 and 1 varied widely between 2024 and 2025. These results reveal differences in estimated WAA of older Northern Anchovy during MFT survey years as well as a marked departure in estimated age composition in 2025 relative to other survey years; these differences could stem from annual variability in fish availability. We also note that Northern Anchovy has the shortest time series of estimated assessment inputs among assessed CPS, and therefore has fewer Nordic 264 survey years to compare against MFT survey years.

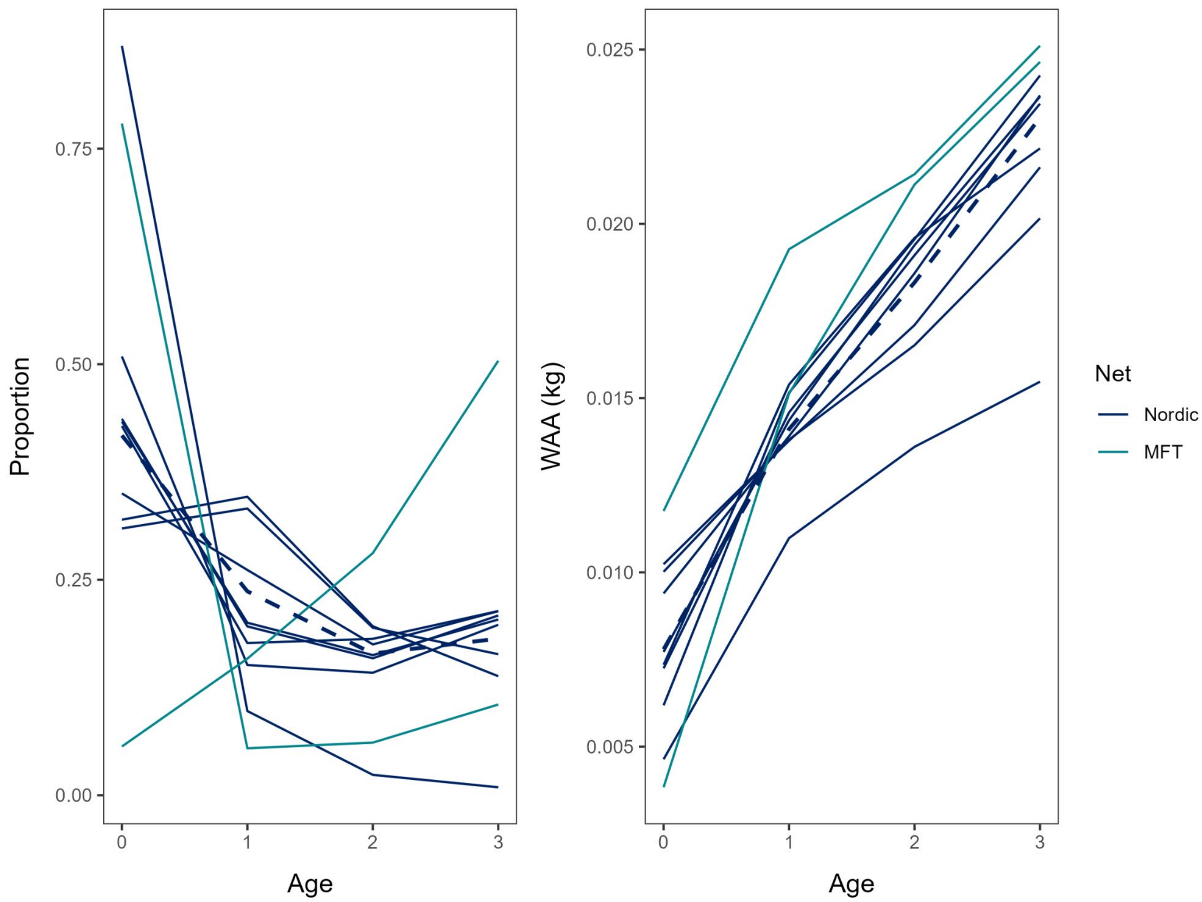


Figure F8. Estimated age compositions (left) and WAA (right) using the simplified workflow for Northern Anchovy. Solid lines represent estimates for survey year-specific datasets and the dashed lines represent estimates for pooled length, age, and weight data across all Nordic 264 survey years.

For comparison purposes, we also present available estimates of age composition and WAA for Pacific Mackerel, Pacific Sardine, and Northern Anchovy from their corresponding most recent benchmark assessments, for the years 2013-onwards (**Figs. F9-F11**). The magnitude and trends in estimates from the most recent assessments were generally similar to those generated from the simplified workflow, supporting the validity of this workflow for comparing Nordic 264 and MFT survey years. These similarities occur despite the recent inclusion of nearshore data provided by purse seine nets in past assessments; nearshore data were excluded in our calculations to focus on differences between the Nordic 264 and MFT nets.

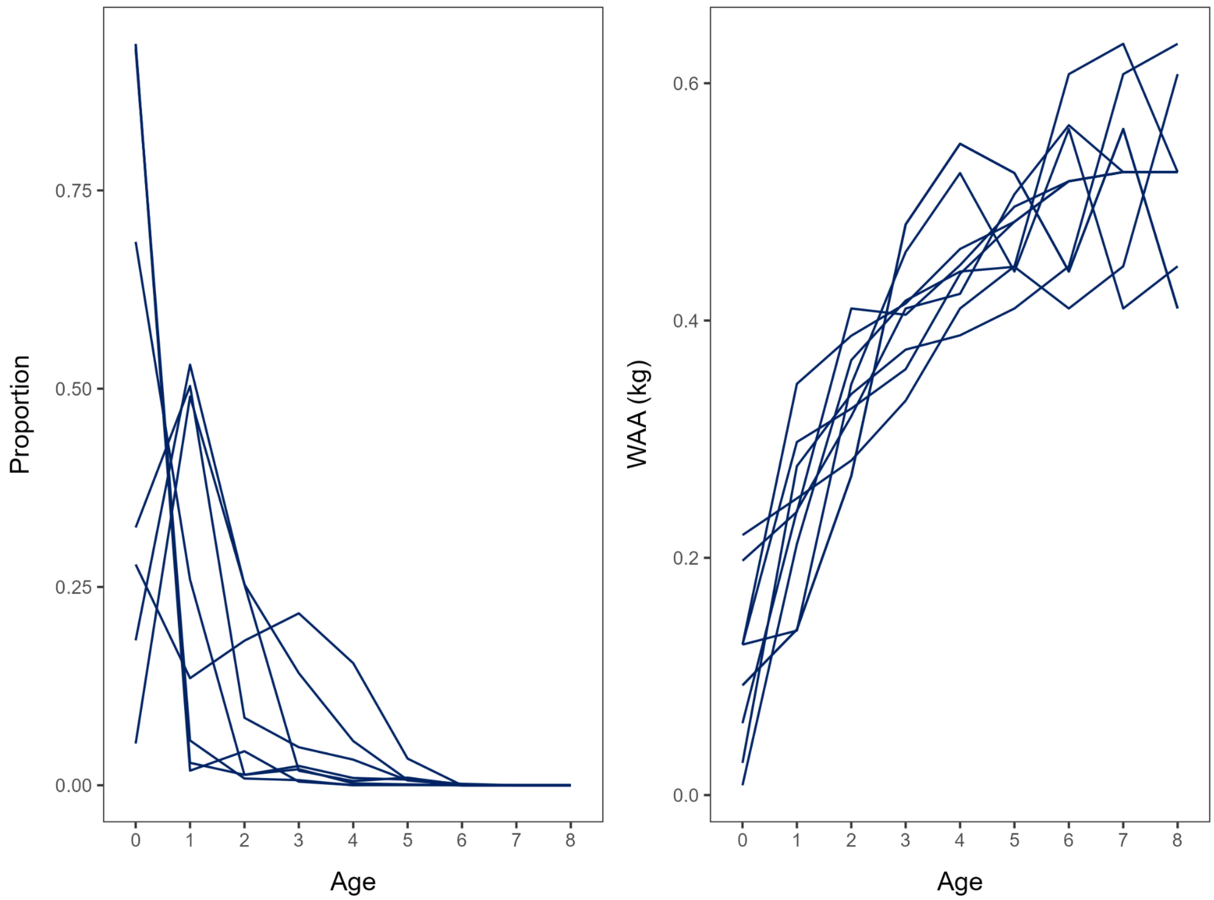


Figure F9. Estimated age compositions (left) and WAA (right) in the most recent Pacific Mackerel benchmark assessment from 2013-onwards (i.e., 2013-2019, 2021).

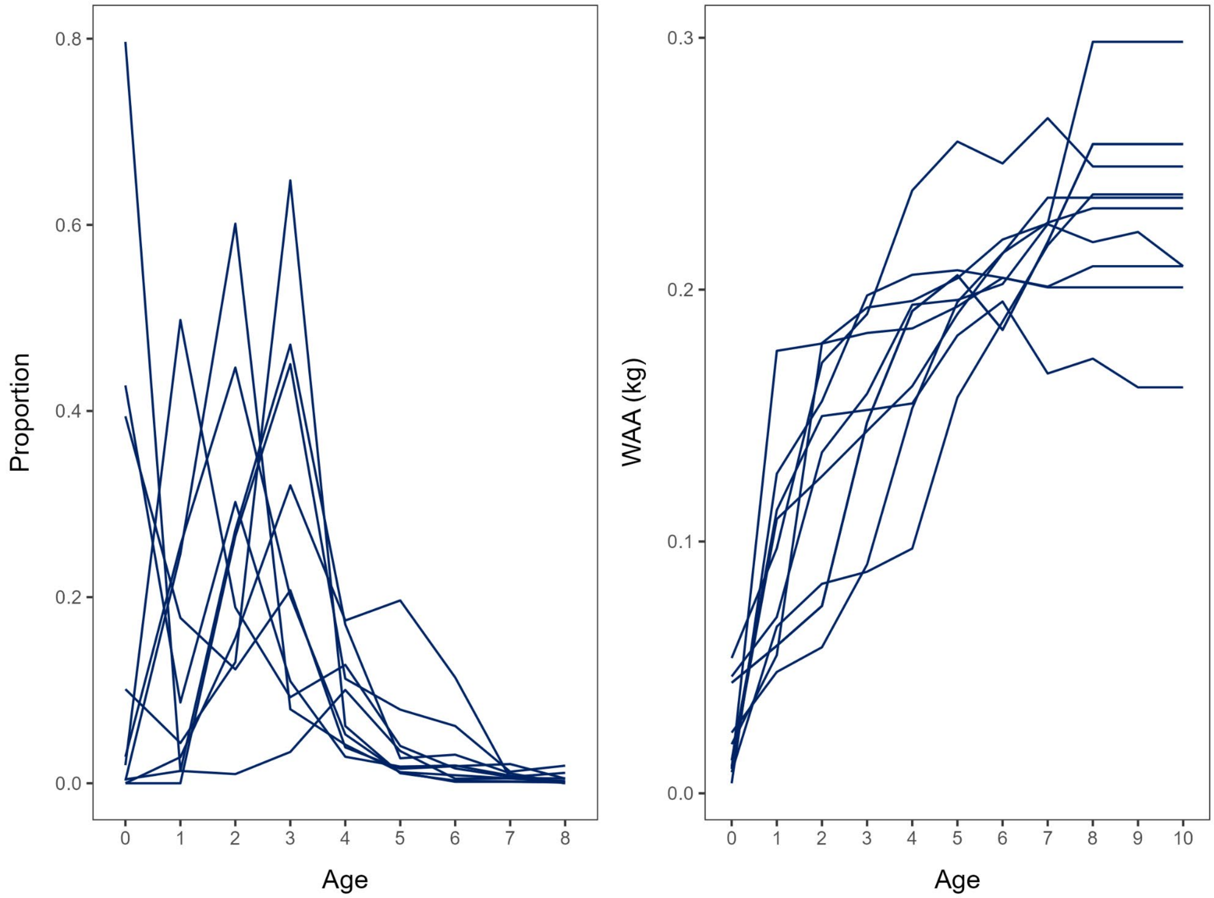


Figure F10. Estimated age compositions (left) and WAA (right) in the most recent Pacific Sardine benchmark assessment from 2013-onwards (i.e., 2013-2019, 2021-2023).

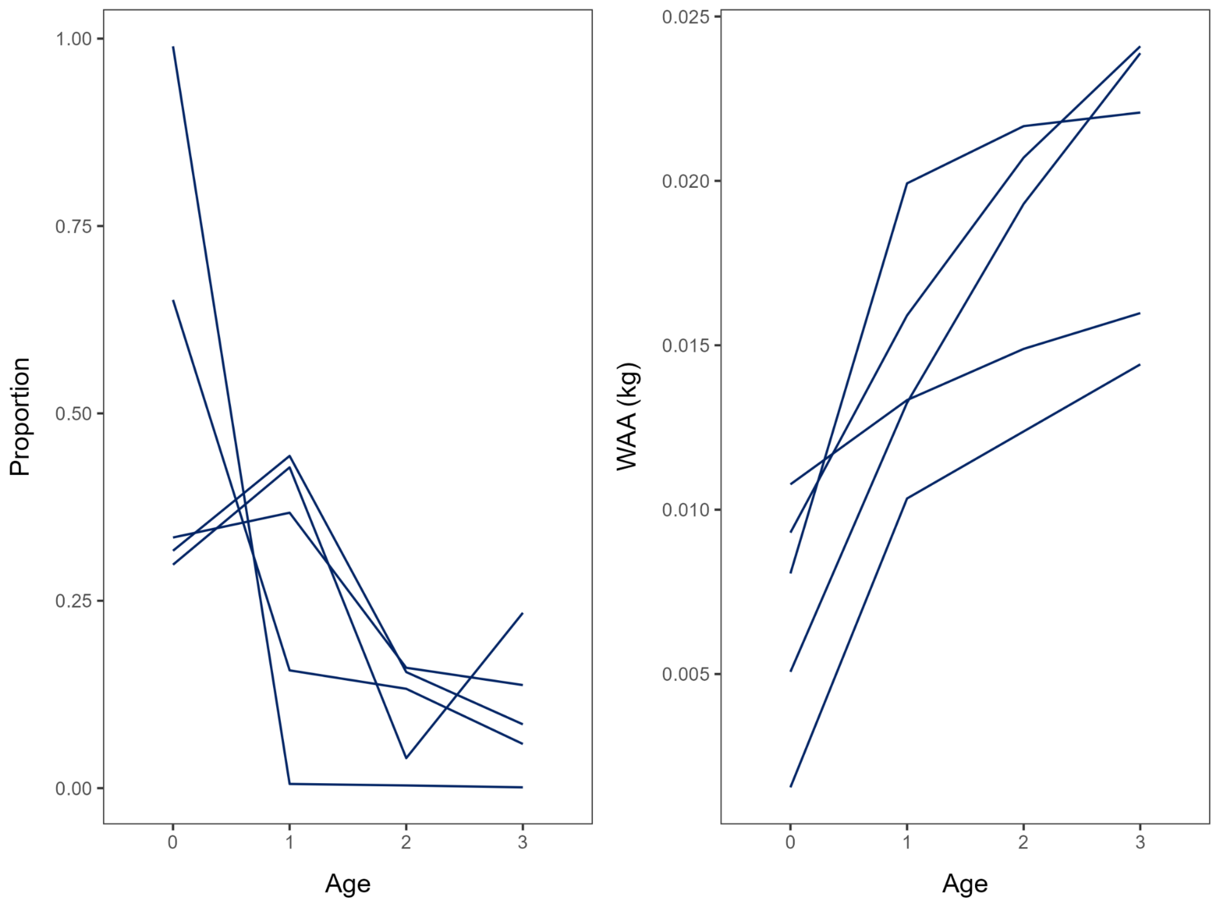


Figure F11. Estimated age compositions (left) and WAA (right) in the most recent Northern Anchovy benchmark assessment from 2013-onwards (i.e., 2015-2019).

G. Status update on trawl-related recommendations from the 2018 ATM survey review

In 2018, a Pacific Fishery Management Council methodology review examined the use of the acoustic-trawl method as it related to biomass estimation for use in stock assessments of CPS. In the panel summary report, the panel made prioritized recommendations for future research and data collections. Here we provide an update to those recommendations that relate to the trawl sampling aspect of the ATM surveys used to estimate CPS biomass.

G.1. High priority

G.1.1. Net mensuration (#4)

Recommendation: Use net monitoring devices to monitor the trawl during all hauls. The optimal instrumentation is trawl sonar, which monitors the variable geometry of the trawl opening, and the distribution of fish within and outside the trawl opening.

Response: Addressed.

A suite of Kongsberg net mensuration sensors is now regularly being utilized on MFT trawls that allow for real-time monitoring of trawl performance, including sensors to measure door spread, height, and geometry; headrope and footrope depths; a miniature echosounder that can be positioned anywhere along the net; and a flow sensor. An FS70 trawl sonar has also been deployed during gear trials to verify net characteristics, but is not regularly used during the survey due to risk of complications and net entanglements during deployments.

G.1.2. Trawl efficiency (#9)

Recommendation: Test efficiency (and suitability) of the existing trawl. This can be done either by comparing acoustic density measures with swept volume densities of the trawl or comparing swept volume densities with similar measures from larger trawls and other gear types.

Response: Partially addressed.

Preliminary analysis was done using data from the 2024 CPS Survey to compare nighttime CPS backscatter with the catch size of CPS in the concurrent MFT trawl, however no correlation was found (unpublished data). Additional analyses can be done to include more years and trawls or to utilize narrowband CW echosounder data as opposed to the wideband FM data used thus far.

G.1.3. Verify if acoustic CPS are the same as trawl CPS (#10)

Recommendation: Develop methods to verify that daytime sound scatterers are the species and sizes caught in nighttime trawls; i.e. verify that efficient day time sampling of the acoustic record gives similar results as present night time sampling strategy. Such approaches could include alternative day-time sampling strategies (e.g. curved trawling trajectories) and/or different trawl gear, purse seining by day (either using research or industry vessels), or alternative sampling techniques such as drop cameras.

Response: Addressed.

In 2023, after conversations with Icelandic fishermen skilled in curved tows, we conducted such tows during nighttime fishing operations when weather conditions permitted. Anecdotally, there was no advantage to curved tows, and in 2024 we resumed traditional upswell or downswell tows after switching from the Nordic 264 to the MFT.

In 2024, through a collaboration with industry, the F/V *Lisa Marie* conducted thirteen nighttime purse seine sets in close proximity to eighteen trawl locations sampled by FSV Lasker. In general, the species composition and length distributions in catches from nighttime seine samples were similar to those from the trawls. One notable exception was two nearshore locations where purse seines collected Pacific Sardine but none were captured in the trawls. Alternatively, several of the offshore purse seine samples contained no CPS but had nearby trawls containing Jack and Pacific Mackerels (Stierhoff et al., 2025).

<u>*G.2. Medium priority*</u>

G.2.1. Compare catches from different trawl depths (#1)

Recommendation: Conduct night trawls at different depths in the same area, with the headrope at the surface, at 15 m, and at 30 m depth, for example to compare estimates of species and length composition.

Response: Partially addressed or addressed.

During the 2024 and 2025 surveys, nighttime surface trawls with the MFT occurred at varying depths (**Figure C.1**). While not an intentional study, these data could be analyzed to compare species and length compositions from trawls in similar areas and times but at different depths. It should be noted, however, that trawls during the ATM surveys are never conducted in the exact same location, and the depths would not be substantially different given the door opening dimensions and operational fishing depths (~0-15-m variability; **Figure C.1**). Finally, it would be difficult to fish the MFT at such specific depths given the observed variability in depths in 2024 and 2025.

G.1.2. Compare cluster approach for low sample sizes (#3)

Recommendation: Compare the area (e.g. over several transects) and the current cluster approach to convert backscatter data to biomass when sample sizes for a particular species are insufficient.

Response: Addressed.

In the biomass reports, the length distribution of each species in each cluster is reported alongside the proportion of the abundance that it represents in each cluster. These plots allow for a descriptive analysis of the influence of each cluster in the biomass estimates. Furthermore, the lower percentage of small and "water" hauls since switching to the MFT in 2024 suggests that the occurrence of small sample sizes has been mitigated by the MFT net (Section C.4.2, this report).

G.3. Lower priority

G.3.1 Assess behavior at codend using ADCP (#1)

Recommendation: Study fish behavior in front of the codend and trawl opening and measure flow inside/outside the trawl using a high frequency Acoustic Doppler Current Profiler (ADCP). This will allow an evaluation of the frequency with which fish escape. Such work is needed because the codend is relatively short with a small mesh liner, and has probably insufficient filtering capacity at 4 knots. This might "block" the entrance of the codend and lead to an increased flow of water through the meshes in front of the codend where some fish will probably escape.

Response: Partially addressed.

Compared to the Nordic 264, the MFT has a longer total length and more gradual mesh taper throughout the net forward of the codend, which should improve water flow and minimize the escapement of fish through the net meshes caused by the "bucket effect". This water flow could be assessed with the flow sensor (Simrad PX Flow; Kongsberg), however this sensor is typically deployed at the mouth of the net and those data have not been analyzed. Directed research could be conducted to reposition the sensor and assess flow rates at various points along the net.

To partially assess the "bucket effect," a net camera system was deployed near the Marine Mammal Excluder Device (MMED) during several cruises using the Nordic 264 and also during initial development of the MFT and sea trials, allowing for observations of fish behavior and escapement. Changes to the MMED and MFT were applied based on these observations, with anecdotal improvements observed in video recordings throughout the 2024 and 2025 surveys. No changes to the Nordic 264 were made based on observations from the cameras.

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Appendix

Appendix 1: Schematic diagrams of Nordic 264 and multifunction trawl (MFT) nets

<u>*Nordic 264*</u>

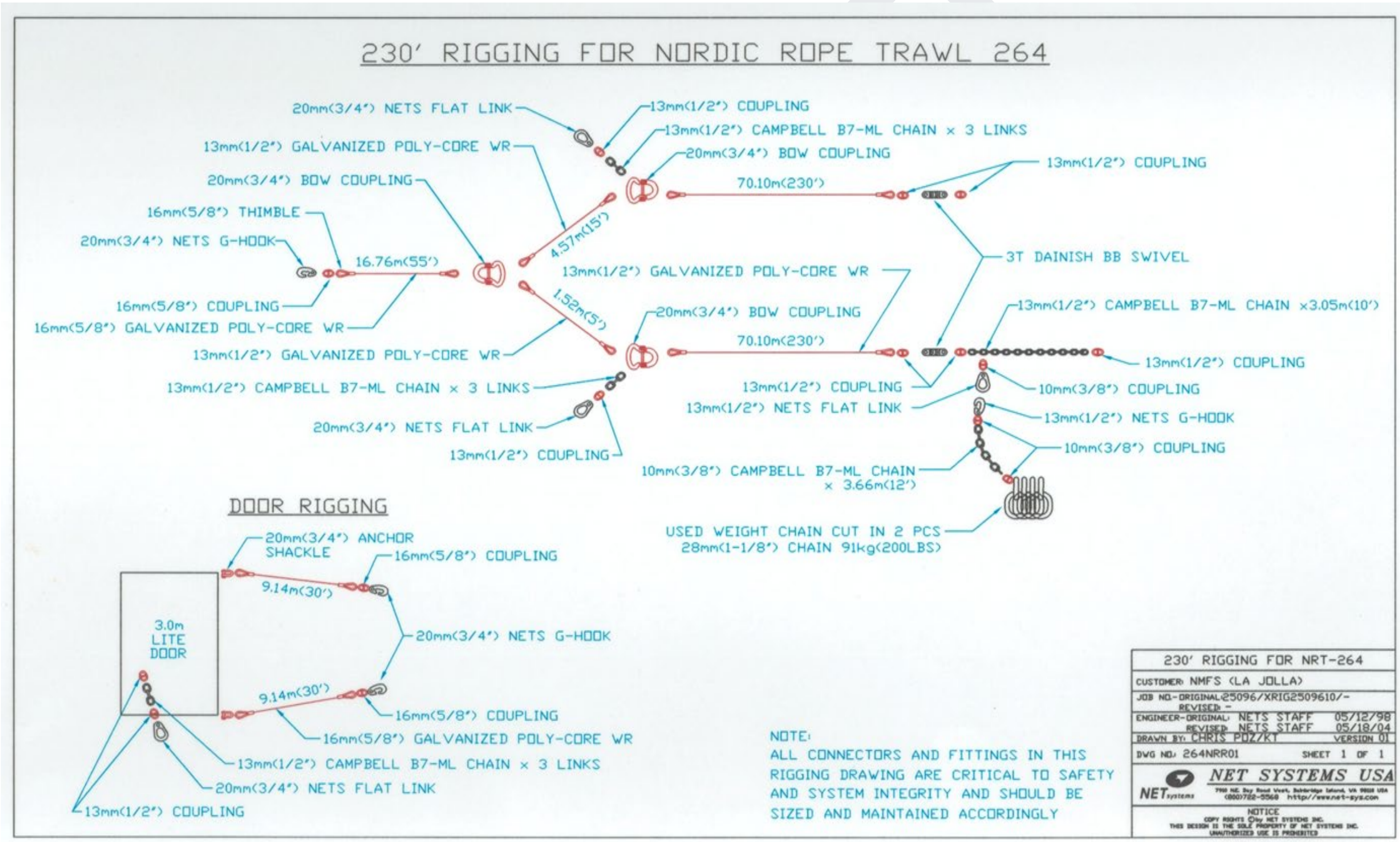

Fig. A2: : Rigging and door connection schematics for the Nordic 264.

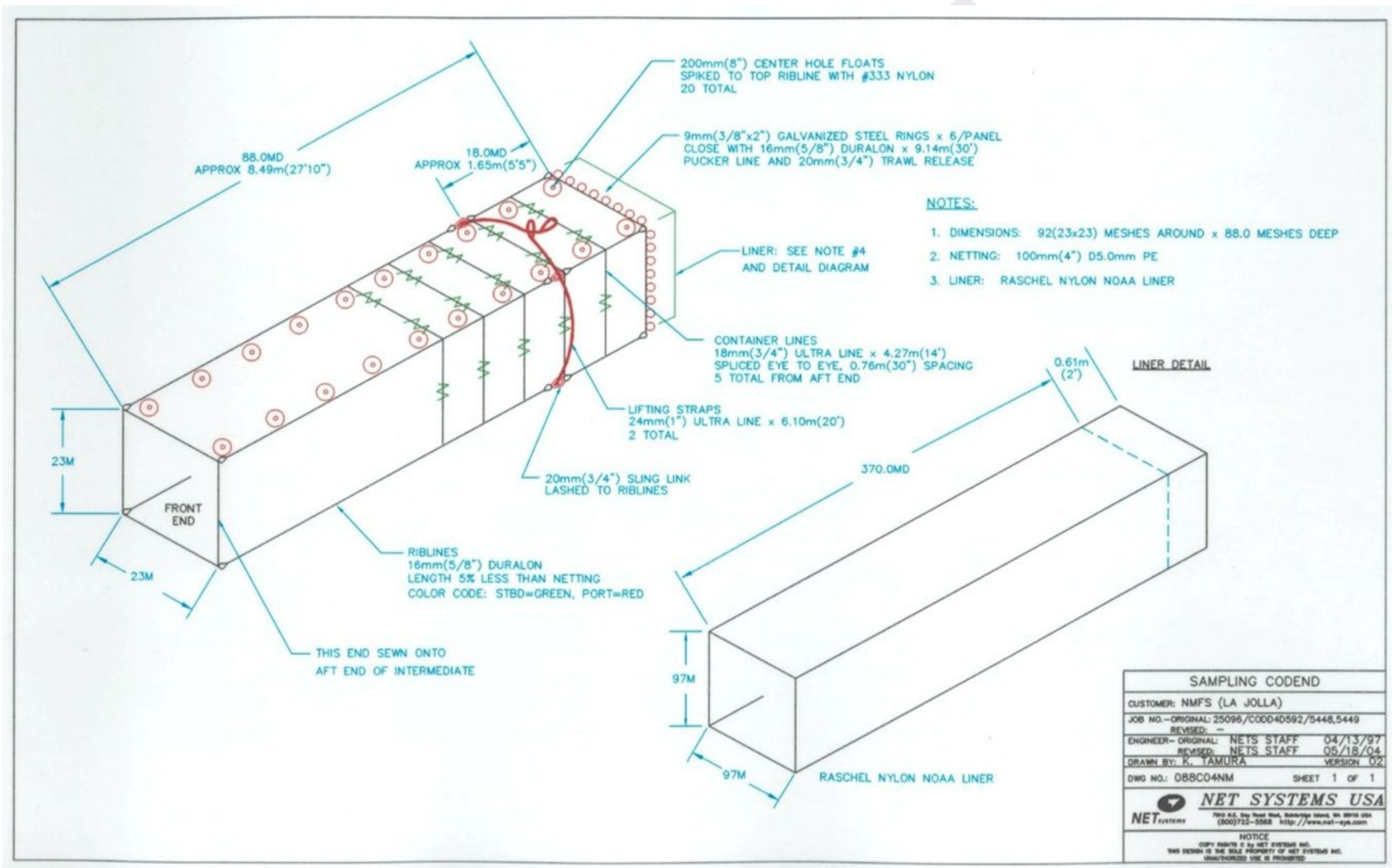

Fig. A3: Codend schematics for the Nordic 264.

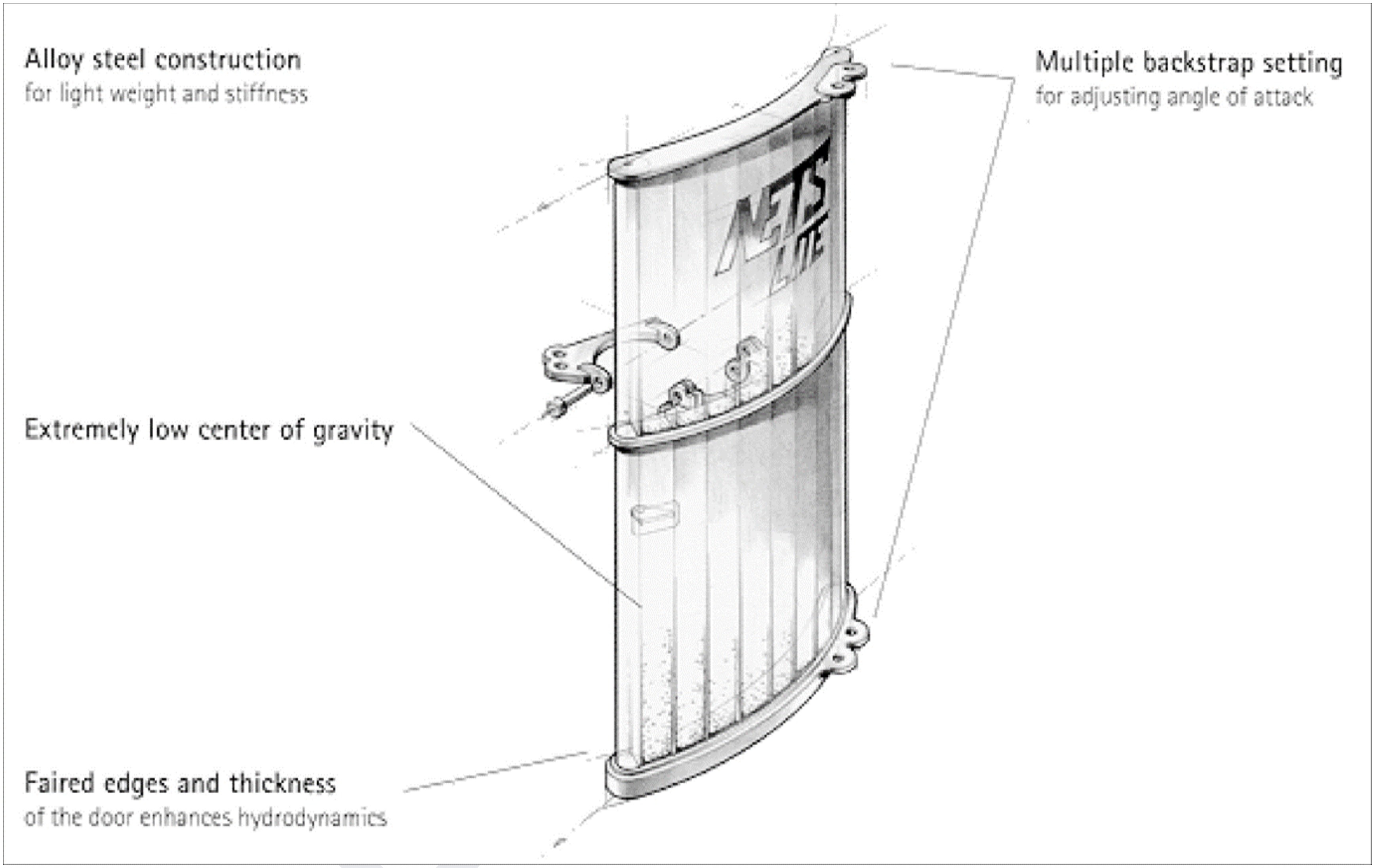

Fig. A4: Net Lite door diagram for the Nordic 264.

MFT

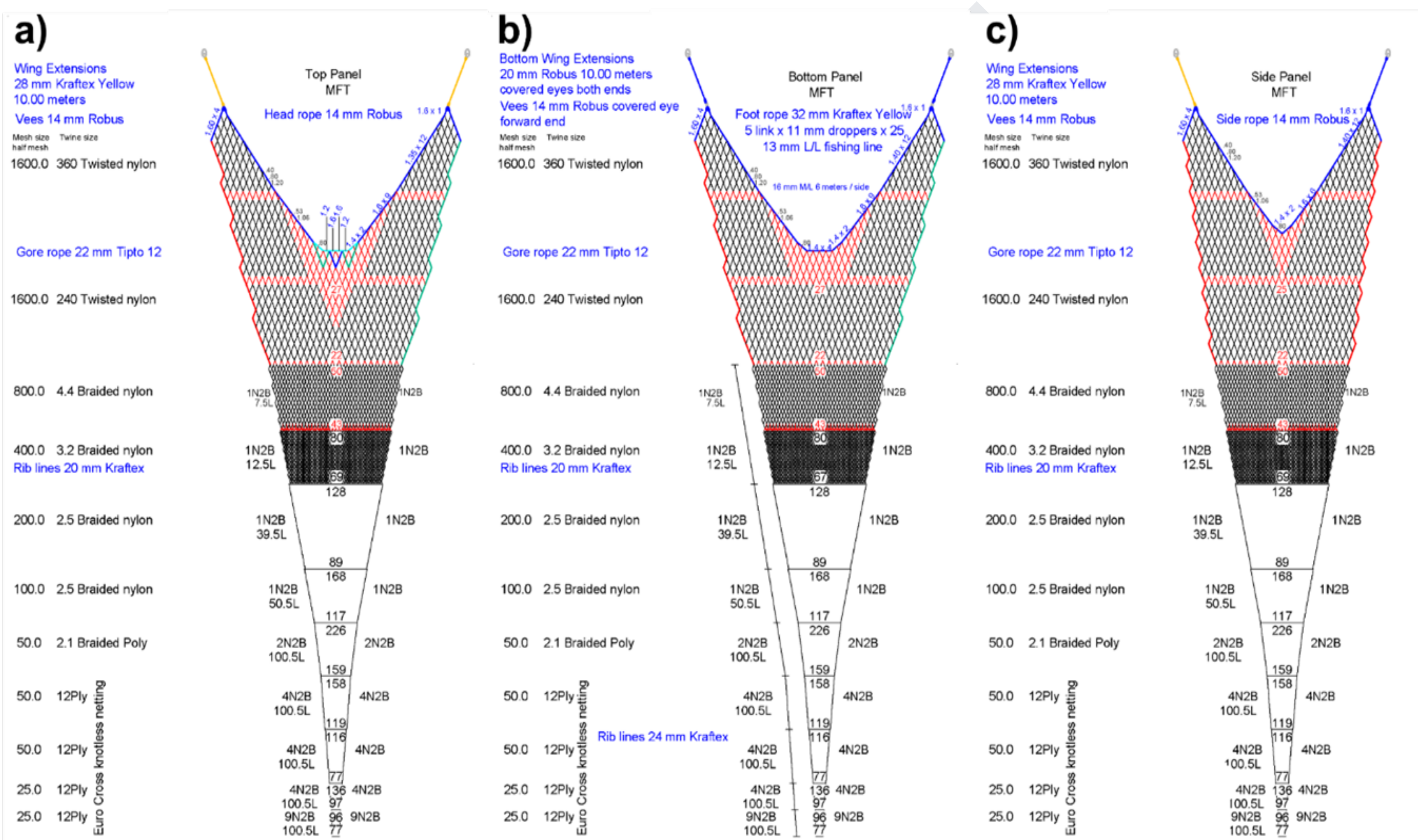

Fig. A5: Schematic diagrams of the a) top panel, b) bottom panel, and c) side panels of the MFT. Designed length 124.1m (406.8').

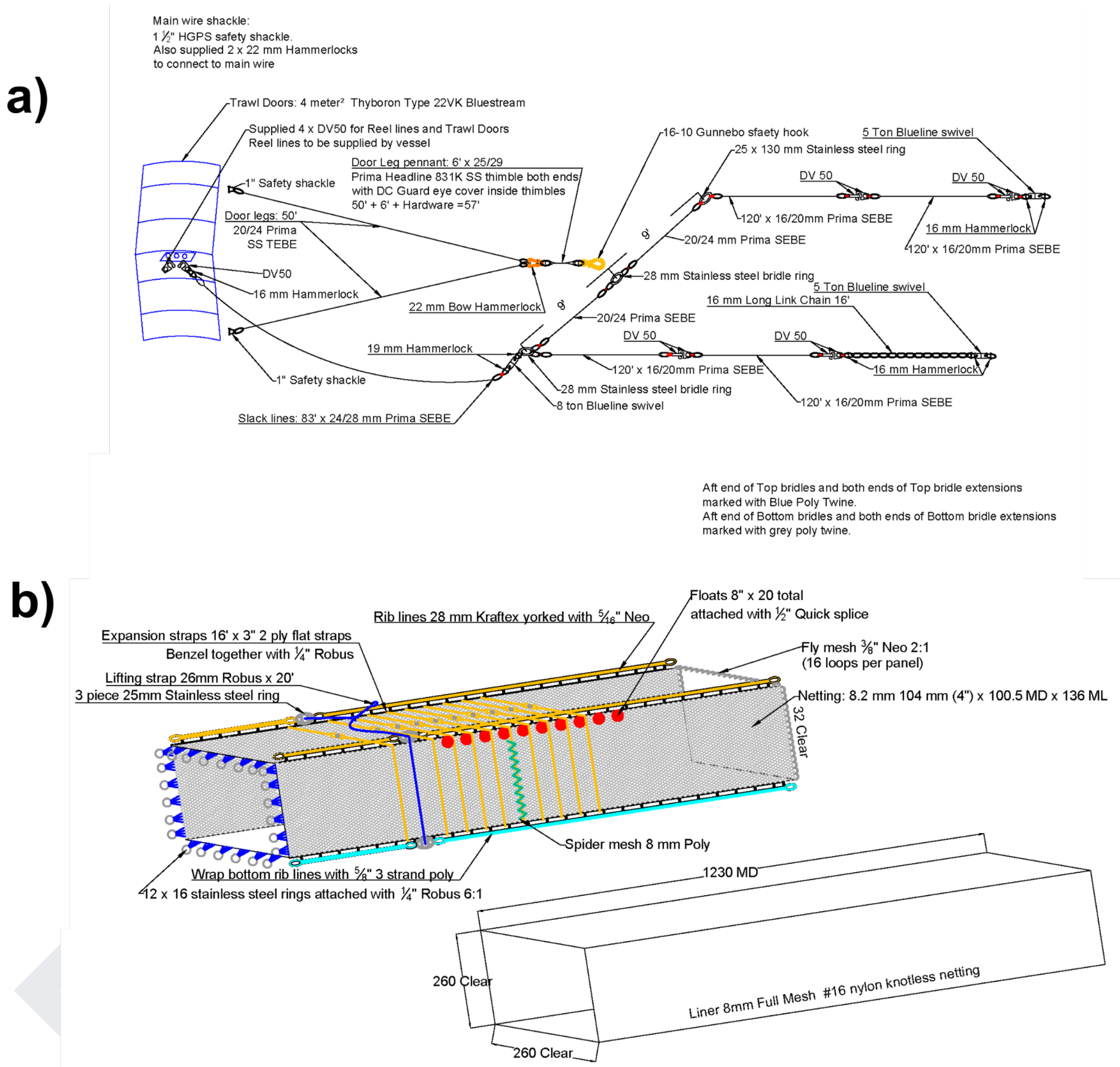

Fig. A6: Schematic diagrams of the a) rigging and door connections and b) codend for the MFT.

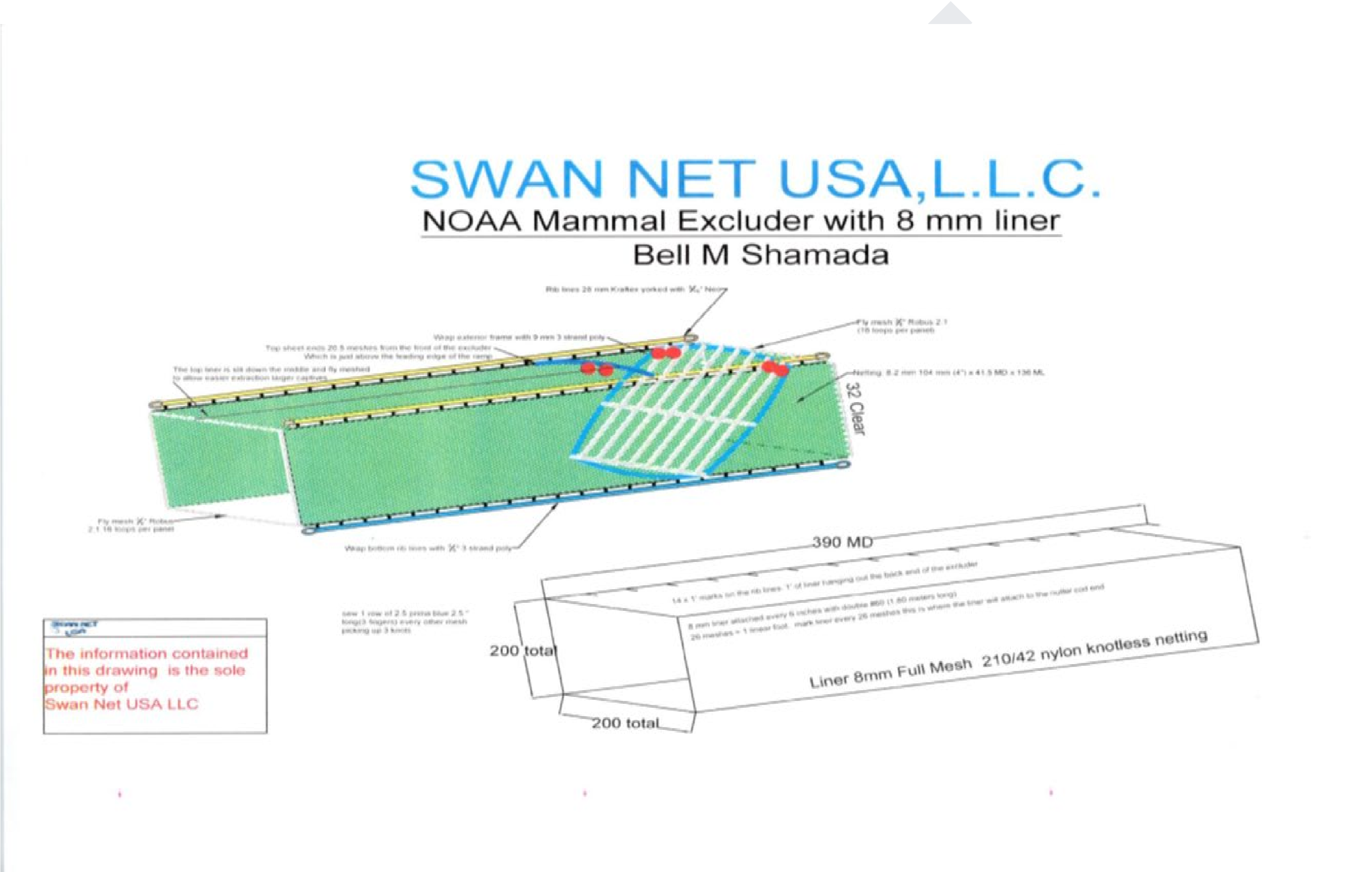

Fig. A7: Schematic drawings of the codend with improved marine mammal excluder device (MMED) for the MFT.

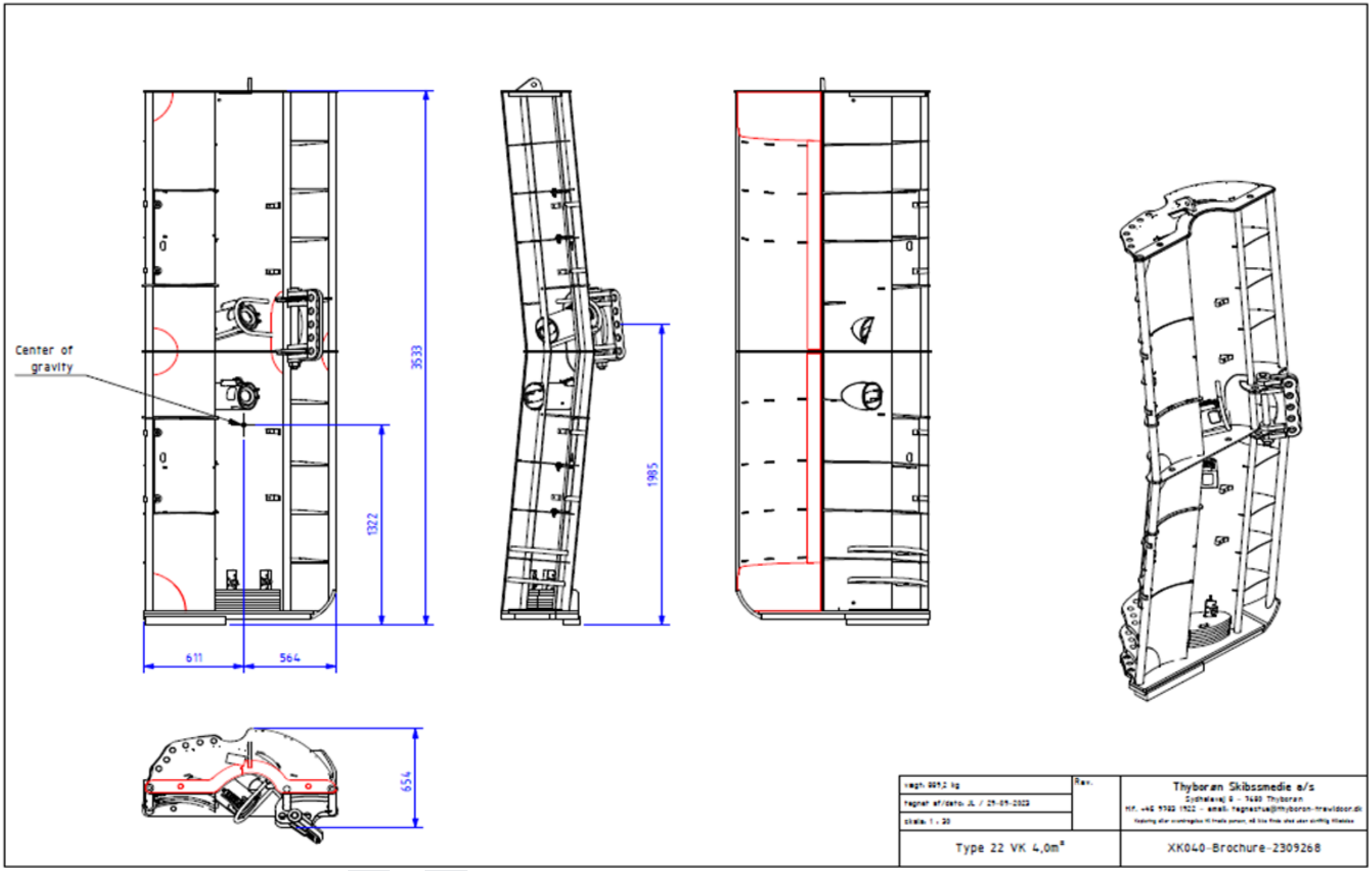

Fig. A8: Schematics of the Thyboron 22 VK 4m2 doors for the MFT.