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Characterisation and CPUE indices for swordfish (Xiphias gladius) from the New Zealand surface longline fishery 1993 to 2023

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Tini a Tangaroa

Characterisation and CPUE indices for swordfish (*Xiphias gladius*) from the New Zealand surface longline fishery 1993 to 2023

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PLAIN LANGUAGE SUMMARY

Swordfish (*Xiphias gladius*) are a highly migratory species, widespread in the Pacific Ocean, with the New Zealand region only a small part of its range. This report describes the catch and effort data for swordfish in the New Zealand surface longline fishery and updates the catch-per-unit-effort (CPUE) indices using commercial catch effort and remote-sensed environmental variables. Data were analysed in four series: all vessels in the fishery from 1993–2023 and from 2004–2023, and a selected core fleet from 1999–2023 and from 2004–2023. The later time series incorporated operational changes in the fishery, including the recording of light sticks and bait type, when swordfish was introduced into the Quota Management System (QMS) in 2004. All models showed similar CPUE trends over time. CPUE gradually increased to a peak in 2012 and 2013, followed by a steady decline to 2019, with a slight recent increase to 2023. Average swordfish size across three data sources was 60 kg, and annual average size showed some increasing trend between 2005 and 2017, followed by decline to 2023 to sizes similar to those observed in 2005.

EXECUTIVE SUMMARY

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Swordfish (*Xiphias gladius*) are a highly migratory species, widespread in the Pacific Ocean, with the New Zealand region encompassing only a small part of the species' range. While several different stock structures have been proposed for swordfish, there is no clear evidence of subpopulations across the Pacific. Despite some degree of regional connectivity, swordfish are susceptible to local depletion and data from tagged individuals suggest foraging site fidelity in New Zealand waters.

This report provides a descriptive analysis of the catch and effort data for swordfish in the New Zealand surface longline fishery and updated catch-per-unit-effort (CPUE) indices using commercial catch effort and remote-sensed environmental variables. Data were analysed in four series: all vessels in the fishery from 1993–2023, and from 2004–2023; and a selected core fleet from 1999–2023, and from 2004–2023. The later time series incorporated operational changes in the fishery, including the recording of light sticks and bait type, when swordfish was introduced into the Quota Management System (QMS) in 2004. For each series, indices were developed using a delta-lognormal two-step hurdle models approach, with year-quarter or annual time steps.

All models showed similar CPUE trends over time which were comparable with previous iterations of this work. CPUE gradually increased in each time series, reaching a peak in 2012 and 2013, followed by a steady decline to 2019, with a slight increase thereafter to 2023. Variables that significantly influenced CPUE varied between models, but typically included *vessel*, *longitude**latitude*, *hooks per basket*, *night fraction* (the fraction of the set soak time during the hours of darkness), and *light stick rate*. *Season* was important in all annual models.

Trends in annual average swordfish size (kg) were similar between the commercial catch data, data held internally by Fisheries New Zealand (years 2020–2023), and the commercial catch sampling programme (years 2005–2023). Swordfish size showed an increased trend to 2017 (87 kg annual average), followed by decline to 2023 to sizes similar to those observed in 2005 (~50 kg). The overall average swordfish size in the commercial catch sampling was 60 kg, comparable to the most recent (2020–2023) commercial catch data (60 kg) and the Fisheries New Zealand data (59 kg), and larger than the historical (*tuna*) data (53 kg).

1. INTRODUCTION

Swordfish (*Xiphias gladius*) are a highly migratory species, found in all tropical and temperate oceans and large seas from approximately 50° N to 50° S, and are widespread in the western Pacific Ocean (Unwin et al. 2006). The New Zealand region encompasses only a small part of the species' range. While several different stock structures have been proposed for swordfish, there is no clear evidence of subpopulations across the Pacific (Lu et al. 2016, Moore 2021). Despite some degree of regional connectivity, swordfish are susceptible to local depletion (Ward et al. 2008) and data from tagged individuals suggest foraging site fidelity in New Zealand waters (Holdsworth et al. 2010, Holdsworth 2023).

Swordfish catches were first reported by Foreign Licensed Japanese longliners operating in New Zealand in the late 1970s. By the early 1990s, this fleet was largely replaced by a domestic fleet which grew rapidly in numbers through the 1990s and subsequently dominated effort and landings in the northern (north of 40º S) longline fishery (Anderson et al. 2013). Commercial catch of swordfish in New Zealand is mostly taken in the surface longline fishery, either as targeted catch, or taken incidentally predominately in bigeye tuna (*Thunnus obesus*) targeted fisheries, and to a lesser extent, in southern bluefin tuna (*T. maccoyii*) targeted fisheries (Griggs et al. 2024, Moore & Finucci 2024). Small amounts of catch (~5%) is also reported from mid-water trawl fisheries (Moore & Finucci 2024). Swordfish are caught throughout New Zealand waters and the adjacent high seas areas but most of the historical catch has come from north of 40ºS (Anderson et al. 2013). Swordfish catches vary considerably by season; they are greatest in the first and second quarters of the calendar year, lower in the third quarter, and lowest in the fourth quarter (Griggs & Richardson 2005, Finucci et al. 2021).

Swordfish was introduced into the New Zealand Quota Management System (QMS) in October 2004 under a single Quota Management Area (QMA) and with an annual Total Allowable Commercial Catch (TACC) of 885 tonnes (t). The TACC has remained unchanged. Before the introduction of the TACC, targeting of swordfish was prohibited, although retention of swordfish caught incidentally in other target fisheries was permitted. Since April 2025 swordfish can be legally discarded under the provisions of Schedule 72A of the Fisheries Act 1996 if it is likely to survive on return, the return takes places as soon as practicable, and if the swordfish is small (less than 1.25 m long from lower jaw to fork length). Most swordfish catch is landed (Griggs et al. 2024).

Swordfish have certain behavioural characteristics which can be taken advantage of by longline fishers to increase the likelihood of capture. One of these is their crepuscular diving behaviour. Swordfish move into surface waters at dusk and remain there during the hours of darkness, returning to deeper water (below 600 m and as deep as 900 m) at dawn and staying there during daylight hours (Carey & Robison, 1981). Larger fish were more often reported to make occasional excursions to the surface, which may be 'basking' behaviour observed off California (Holdsworth et al. 2010). Another is that catch rates of swordfish are known to be better when there is a bright moon (e.g., Bigelow et al. 1999). This influence of light on swordfish behaviour is recognised by fishers and catch rates can be increased by attaching luminescent light sticks at intervals along the longline. Although the use of light sticks in the New Zealand tuna longline fishery pre-dates the introduction of swordfish into the QMS (to attract some tuna species to the lines if not swordfish) this information was not recorded on catch-effort forms until 2003.

The first comprehensive analysis of New Zealand swordfish catch-per-unit-effort (CPUE) used Catch Effort Returns from the tuna longline fishery to generate standardised CPUE indices by year and quarter (Unwin et al. 2006). The study was later updated with a focus on the more fully developed domestic fishery (the years 1998 to 2007) and a core set of experienced vessels (Unwin et al. 2009). Subsequent analysis in 2012 and 2020 showed an increasing CPUE to 2012 and 2013, followed by steady declining CPUE thereafter (Anderson et al. 2013, Finucci et al. 2021). The initial CPUE increase was attributed to a change in operational procedures (e.g., use of light sticks) at the beginning of the fishery (Anderson et al. 2013), while the CPUE decline was determined to reflect wider South Pacific stock trends between the late 1990s and 2010 (Finucci et al. 2021).

Biological data for swordfish and other pelagic species was historically collected by observers aboard commercial vessels fishing in New Zealand waters. Observer coverage in the surface longline fleet has declined over time, with only 11% of days fished observed in 2021, further declining to 5.4% and 2.9% in 2022 and 2023, respectively (Kendrick 2025). Cameras were installed on all vessels in the fleet by 2024 but are not suitable for collecting information on biological parameters (Kendrick 2025). Some biological data (processed weights) on swordfish continues to be collected via sampling process sheds (Kendrick 2022, 2025).

1.1 Objectives

This report was prepared as an output from the Fisheries New Zealand project SWO2024-01 "Characterisation and CPUE analysis of the New Zealand commercial longline swordfish fishery" which had the following objectives:

Overall objective:

To characterise the commercial longline fishery for swordfish (*Xiphias gladius*) in New Zealand fisheries waters and analyse the CPUE data to contribute to the next WCPFC stock assessment of Southwest Pacific swordfish.

Specific objectives:

- Objective 1: Characterise the swordfish commercial longline fishery in NZ waters.
- Objective 2: Analyse swordfish length frequency distribution data available from market sampling.
- Objective 3: Carry out unstandardised and standardised CPUE analyses of swordfish catch and effort data from the commercial longline fishery in NZ waters.

2. METHODS

2.1 Data sources and fisheries characterisation

Set level catch-effort data from the New Zealand surface longline fishery are recorded with the Electronic Reporting (ERS) since 2018, and historically, on Tuna Longline Catch Effort Returns (TLCERs) and Catch, Effort and Landing Returns (CELRs), the latter which have not been used since 2015–16 (Griggs et al. 2024). Previous iterations of this work (Finucci et al. 2021) extracted groomed commercial surface longline data from the database *tuna*, which became static (i.e., is no longer updated) since 2021. Here, data extracts (landings, effort, and estimated catch files) were obtained from the Fisheries New Zealand Enterprise Data Warehouse between the period 1 January 1993 to 30 December 2023 (replog 16369). Bait type was also extracted under a separate replog (16400). Data were subjected to a set of error-checking procedures (e.g., removal of NA values, removal of data beyond the New Zealand EEZ). Corrections were also made to obvious latitude/longitude errors and to the timing of set or haul start/end where sets were not consistent with the remainder of sets on a trip. Four records from 2021 onwards were removed where high catches were deemed unplausible (245–870 swordfish in one set). Each set was assigned to a Fisheries Management Areas (FMA) based on its starting position. After grooming and removal of missing values for predictor variables, 87 432 records were available for the characterisation. The characterisation included longline data from all FMAs. This data is referred to as commercial catch data.

2.2 Swordfish catch numbers and weights data

In addition to the data request described in Section 2.1, groomed data from two additional sources were used to report on temporal changes in swordfish size (in weight). The first source was the groomed *tuna* database data, available from 1993 to 2019, which routinely went through extensive grooming procedures to check, and adjust where needed, the reporting of weights and numbers (Wei 2004). This data was important for making required adjustments to capture the use of different reporting forms over time (see Section 2.1). The second source was groomed data for the years 2020 to 2023; since the introduction of ERS data is being held internally by Fisheries New Zealand. Data from both sources has been submitted annually to the Western Central Pacific Fisheries Commission (WCPFC). Grooming processes used for the *tuna* database and the data held internally by Fisheries New Zealand are provided in Appendix A. The catch numbers and weights for swordfish from the groomed commercial catch data used for the characterisation and CPUE carrying on from the previous assessment (2020 onwards) were also reported. This data is referred to as groomed commercial catch data.

2.3 Environmental data

In addition to the operational data available from the catch-effort records, a set of independent environmental variables with potential for influencing swordfish distribution and local abundance were obtained for the analysis: estimated sea surface temperature (SST), SST anomaly, sea surface height (SSH), and current velocity variables at the start position and date of each set.

The SST estimates used were based on the Reynold's Optimum Interpolation Sea Surface Temperature Analysis (Reynolds et al. 2007, Banzon et al. 2016). This analysis is produced daily on a one-quarter degree grid and incorporates in situ and satellite SSTs in addition to SST values simulated from known sea ice cover. Before the analysis is computed, the satellite data are adjusted for biases using the method of Reynolds et al. (2007) and Banzon et al. (2016). The bias correction improves the large-scale accuracy of the Optimum Interpolation. The SST value for each set was determined by finding the nearest SST data point to the start position for the same day. The one-quarter degree SST grid provided a resolution of approximately 25 km. SST anomaly is essentially the difference between the estimated SST and the mean SST for the location and time of year.

The SSH values for the start of each set were determined using a web-based product (http://www.aviso.oceanobs.com/en/altimetry.html) which is the reference version of the Maps of Absolute Dynamic Topography (MADT) dataset. This is a spatially analysed combination of 10-day repeat measurements of sea surface height anomaly with the Mean Dynamic Topography (the part of mean SSH due to permanent currents, corresponding to the mean SSH minus the geoid). SSH is related to the integrated density of the water through the entire depth of the ocean - because less dense (warm, less salty) water stands taller than more dense (cold, saltier) water. The nature of ocean variability around New Zealand means that almost all the variability in SSH results from changes in temperature. Thus, highs in SSH correspond to areas with higher mean temperatures and vice versa.

The slopes in the sea surface due to variability in SSH result in currents that run along the lines of constant height (in the same way that winds flow along isobars in weather maps) which means that the estimates of SSH can also be used to supply estimates of the surface current field. In this study, the magnitude of the current at the start of each set was estimated from the SSH data.

The SSH and current velocity data have resolutions of about 20–30 km latitude, 30 km longitude, and 7 days. Estimates for these values at the start of each set were determined from the nearest data point to the set location, on the nearest day.

2.4 Commercial catch sampling

Swordfish sampled processed weights collected from tuna processing sheds were extracted from the NIWA-managed database *market*. Records were available from July 2005 to September 2023. Swordfish are processed at sea, preventing the collection of length or sex data in port sampling. However, swordfish are retained in a relatively whole state because of their high value, and individual processed weights of most of the catch are kept by fish processors that export. The sampled processed weights can then be converted to length frequencies to determine catch length composition. Processed swordfish weight (headed, gutted, and finned) was converted to fork length with the following equation: FL = 55.622 * PW^0.2895, using the regression formula by Davies & Griggs (2006). Sixteen records of swordfish measured to be 600 kg or more were deemed implausible and were removed. This data is referred to as catch sampling data.

Some shortfalls have been identified within this data collection, including underrepresentation from fish used for domestic consumption or exported as loins, chunks, or otherwise not whole, or where individual processed weights may not be available for poor-quality fish (e.g., skinny, badly bitten) that are filleted for the local market. Shark damage is identified as an issue for swordfish catch and processors have confirmed that data will include some bitten fish. However, previous analyses of the sampled processed weights have shown the data collection programme is effective and adequate to capture seasonal and spatial coverage of effort (Kendrick 2025). Although catch location is unknown, information on port of landing is available. Swordfish are selected for export based on condition, not size (T. Kendrick 2025, pers. communication).

2.5 CPUE analysis

The CPUE analysis for the New Zealand surface longline fishery for swordfish was updated using the four years of additional data available since the last analysis (Finucci et al. 2021). The CPUE models constructed were based on set-by-set operational data using either a year-quarter time step or year (i.e., annual) over the period 1 January 1993 to 30 December 2023 (Appendix Table B2). The response variable fitted in the analysis models was nominal CPUE (number of fish caught per 1000 hooks, rounded to the nearest whole number) (Appendix Table B2). The year-quarter or year term was ‘forced’ as the first ‘explanatory’ term in the CPUE model standardisations. The catch-effort data used was limited to that reported from within the New Zealand EEZ and within FMAs 1, 2, and 9 (Figure 1). This area accounted for 81.3% and 90.3% of the total estimated swordfish catch (in weight and numbers, respectively) between 1993 and 2023.

To remove any undue influence in the models from part-time vessels in the fishery, a core set of experienced vessels was identified, defined as vessels which had fished in at least half of the previous 24 years (1999–2023). This resulted in a set of 22 core vessels, which accounted for approximately 10% of all vessels, 37% of total effort (in number of hooks), and 50% of the total swordfish catch (in number of fish) for the 1999–2023 period. There was considerable overlap of vessels across years in the core dataset, ensuring that year-effects in models using this dataset would be properly linked (see Appendix Figure B1).

In addition to the independently derived environmental variables described above, a set of predictors with a potential influence on swordfish CPUE were selected or derived from the operational records for consideration in the CPUE model (Appendix Table B1). Time at start of set (*TSOS*) was adjusted to represent the nearest hour relative to midnight, a useful reference point with an essentially night-time fishery. Recent effort (*n10d50k*) was calculated for each set to quantify the level of local fishing effort. This was defined as the number of longline sets within a 50 km radius of the set (based on the start of set location) during the previous 10 days. Moon phase (the fraction of the illumination provided by a full moon) was calculated from an astronomical algorithm (Meeus 1991). A ratio of 25 hooks per basket (*hooks per basket*) and a ratio of 1000 or less light sticks per 1000 hooks (*light stick rate*) was set based on Fisheries New Zealand Highly Migratory Species Working Group (HMS WG) comments on the previous iteration of this work (Finucci et al. 2021). Additional grooming for this work removed the following records: sets exceeding the 99.9th quantile of the numbers per set, where individual swordfish weights >600 kg, sets that had numbers of hook outside of a range of 250–10 000 (Tremblay-Boyer 2021), vessels that fished in two or fewer year-quarters, or records with missing values for covariates. The final number of records used for each model is reported in Table 1.

Table 1: Additional data grooming steps and final numbers of records (sets) used in the catch-per-unit-effort analyses.

Step				Series
	All vessels long	All vessels short	Core vessels long	Core vessels short
Input data	74 640	74 640	74 640	74 640
Bound catch (in numbers) to 99.9th quantile	74 566	74 566	74 566	74 566
Remove sets where individual SWO weight is > 600 kg	74 563	74 563	74 563	74 563
Remove vessels that fished in 2 or fewer year-quarters	73 885	73 885	73 885	73 885
Select core vessels and/or years	-	37 813	28 247	23 691
Bound hooks per basket to 0–25	72 976	37 745	28 129	23 606
Bound number of hooks per set to 250–10 000	72 692	37 646	28 053	23 543
Bound light stick rate to 0–1000	-	35 749	-	21 772
Remove records with missing values for covariates	72 415	35 567	28 024	21 667

At the recommendation of the HMS WG, a preliminary analysis was undertaken to identify groups of vessels with the same exploitation pattern (e.g., gear configuration, fishing ground, catch), or 'métiers', to identify additional targeting behaviour beyond that reported under the declared target species field. This analysis used hierarchical clustering to identify different fishing strategies based on catch compositional data along with operational and environmental data. Data for two separate time periods, specifically 1993–2004 and 2004–2023, were analysed separately to account for the differences in data availability across the time series (e.g., the inclusion of information on light sticks in late 2003). Data were aggregated at the trip level to reduce issues associated with variability among sets within a trip. Only the main target species were retained when computing species composition, namely albacore tuna (*Thunnus alalunga*), bigeye tuna, Pacific bluefin tuna (*T. orientalis*), southern bluefin tuna, swordfish, and yellowfin tuna (*T. albacares*). Logbook records were only retained if the associated total trip catch was at least one individual across these species. The species composition for each trip was then calculated as the proportion of each species to the total catch of the main target species of the trip. Operational and environmental data were restricted to the mean values per trip of the following variables: longitude, latitude, month, number of hooks, hooks per basket, line length, percentage of squid bait (2004–2023 only), moon illumination, night fraction, and light stick rate (2004–2023 only). A hierarchical cluster analysis was then conducted to identify different fishing strategies. The cluster analysis was applied on scaled trip data using the 'agnes' function implemented in the *cluster* package in R (Maechler et al. 2025). Each fishing set was then assigned the fishing strategy of its fishing trip, for inclusion as a categorical variable in the CPUE standardisation.

As in previous iterations of this work (Unwin et al. 2009, Anderson et al. 2013, Finucci et al. 2021), generalised additive models (GAMs) were fitted to model covariates using the *mgcv* package in R (Wood et al. 2011) and implemented with restricted maximum likelihood (REML). Models were fitted using a delta lognormal stepwise approach, as this was shown to provide a better fit to the data than the negative binomial or quasi-Poisson error distributions used previously. First, presence-absence data were modelled using a binomial error distribution with a logit link function to estimate the probability of catching a swordfish. Positive catch data were modelled separately using a Gaussian error distribution to estimate the expected value of the swordfish catch (when positive). The final index was then calculated as the mean-standardised product of the two indices.

A separate model selection process was undertaken for the binomial and positive catch components of each index, as different variables can influence the presence or absence of swordfish in a catch compared to the number of swordfish in a catch (when catches are positive). For both components, predictors were introduced to the model in a forward stepwise approach and were accepted into the model when they explained at least 1% of the residual deviance. Continuous predictor variables were fitted as single thin plate regression splines (i.e., using the s() function in *mgcv*) or as tensor splines (i.e., using the te() function in *mgcv*; latitude-longitude interaction only). A *k* of 6 and 10 by 10 was used for all single term and tensor splines, respectively, unless evidence suggested greater flexibility was required (identified by evaluating the effective degrees of freedom against the *k* value). Associated variables (e.g., declared target vs. cluster number; longitude-latitude interaction vs. FMA) were not included in the same model, but modelled individually. In these instances, if both variables explained at least 1% of the residual deviance, the variable that explained the greatest amount of residual deviance was retained.

Separate CPUE standardisation models were constructed for the following data series:

- All vessel long series, 1993–2019, using a year-quarter time step
- All vessel short series, 2004–2019, using a year-quarter time step
- Core vessel long series, 1999–2019, using a year-quarter time step
- Core vessel short series, 2004–2019, using a year-quarter time step
- All vessel long series, 1993–2019, using a year (i.e., annual) time step
- All vessel short series, 2004–2019, using a year (i.e., annual) time step
- Core vessel long series, 1999–2019, using a year (i.e., annual) time step
- Core vessel short series, 2004–2019, using a year (i.e., annual) time step

The short series models covered the period since the introduction of swordfish into the QMS (2004) and this allowed information on light stick usage and bait type to be offered as covariate terms in the model standardisations (Appendix Table B2). For the best-fitting model in each time step, plots of the component indices (i.e., binomial and positive catch) and residuals were generated. Stepwise influence plots were also generated to examine the effect of iteratively adding a particular covariate to the model. Partial effects plots were constructed to examine the effect of different values of retained covariates. These were constructed by predicting from the best-fitting model whilst holding values for other covariates at a constant value (modes for factors, means for continuous variables).

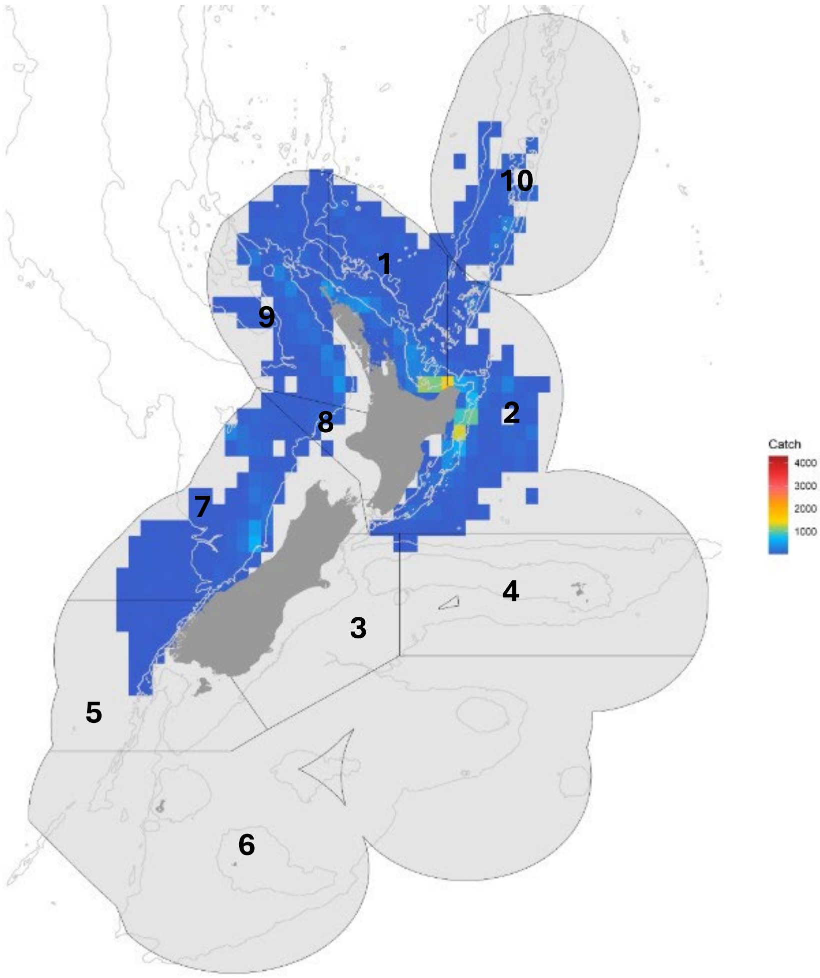

Figure 1: Total swordfish catch (number of 1000 fish) from the surface longline fishery in the New Zealand Exclusive Economic Zone between 1993 and 2023, aggregated at 0.5° resolution. Fisheries Management Areas (FMAs) are numbered and indicated by the grey lines. Each cell contains data from at least three permit holders.

3. RESULTS

3.1 Fishery characterisation

The spatial distribution of the tuna longline fishery and reported swordfish catches have changed over time (Figure 2, Figure 3). In the 1990s, areas of large swordfish catches were restricted to the northeastern area of the North Island (Bay of Plenty). The spatial extent of the surface longline fishery expanded in the late 1990s and early 2000s. Leading up to 2004 when swordfish was introduced into the QMS, the spatial extent of swordfish catches grew extensively around the North Island and extended far from the continental shelf and along the west coast of the South Island. After 2004, the spatial extent of swordfish catches contracted, reflective of contracted fishing effort, and were restricted to the north and northeast of the North Island, largely off Gisborne and in the Bay of Plenty. Between 2013 and 2017, swordfish catch was reported along the west coasts of the North and South Islands and off Wanganella Bank. In the most recent years (2018 onwards), areas of high swordfish catches were concentrated in discrete locations mostly along the continental shelf of the North Island (off Gisborne and the eastern Bay of Plenty), and off the west coast of the South Island (off Hokitika) (Figure 4, Figure 5). Swordfish has never been caught off the east or southwest coasts of the South Island (no catch below 44°S) (Figure 4).

Swordfish catch largely overlaps with bigeye tuna target fishing in FMAs 1 and 2, from North Cape to the Bay of Plenty and eastward to Gisborne (Figure 5). Effort for southern bluefin tuna also occurs off the eastern Bay of Plenty and along the east coast of the North Island, as well as off the west coast of the South Island.

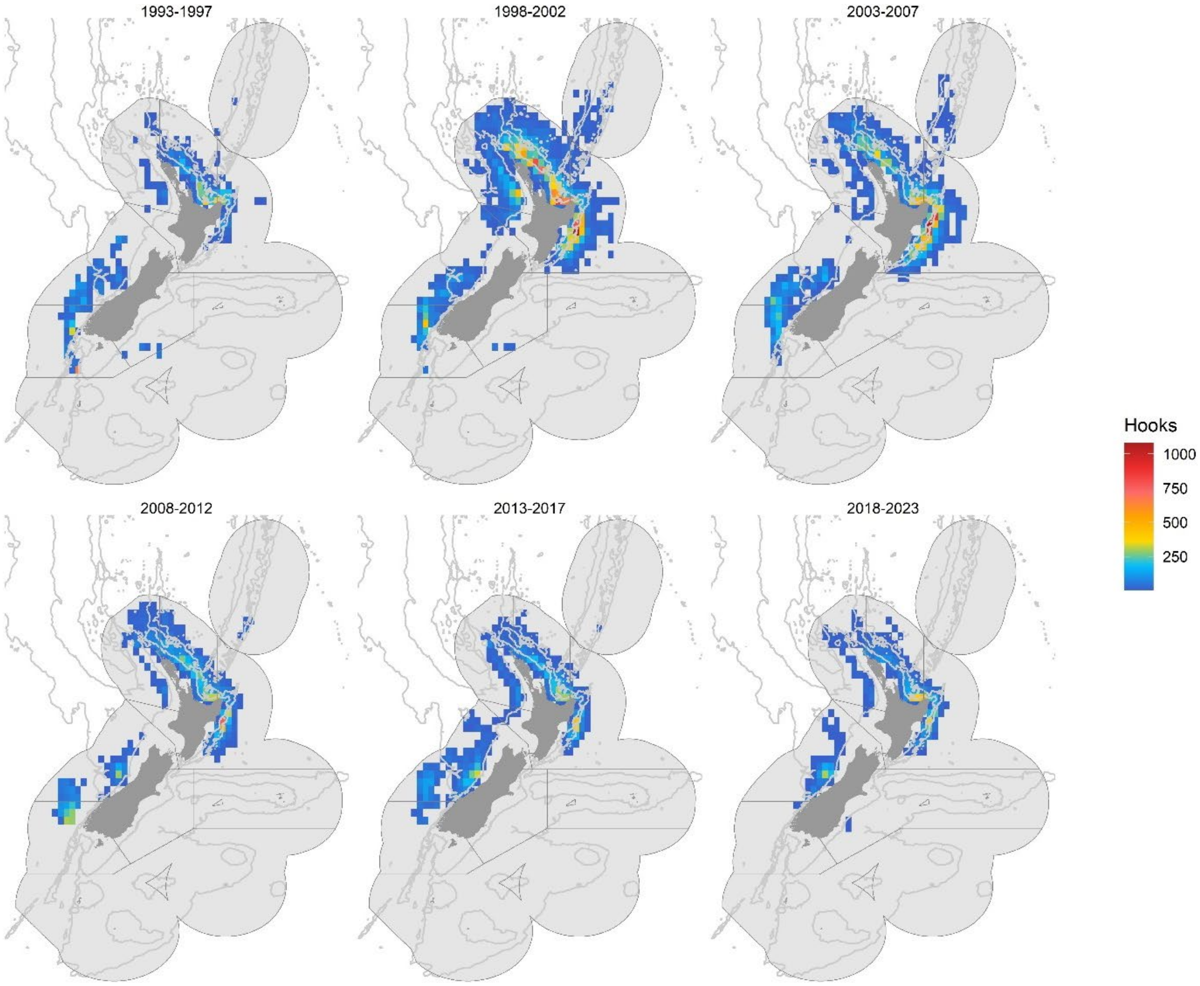

Figure 2: Surface longline effort (number of 1000 hooks) in the New Zealand Exclusive Economic Zone between 1993 and 2023, aggregated in five-year bins at 0.5° resolution. Each cell contains data from at least three permit holders.

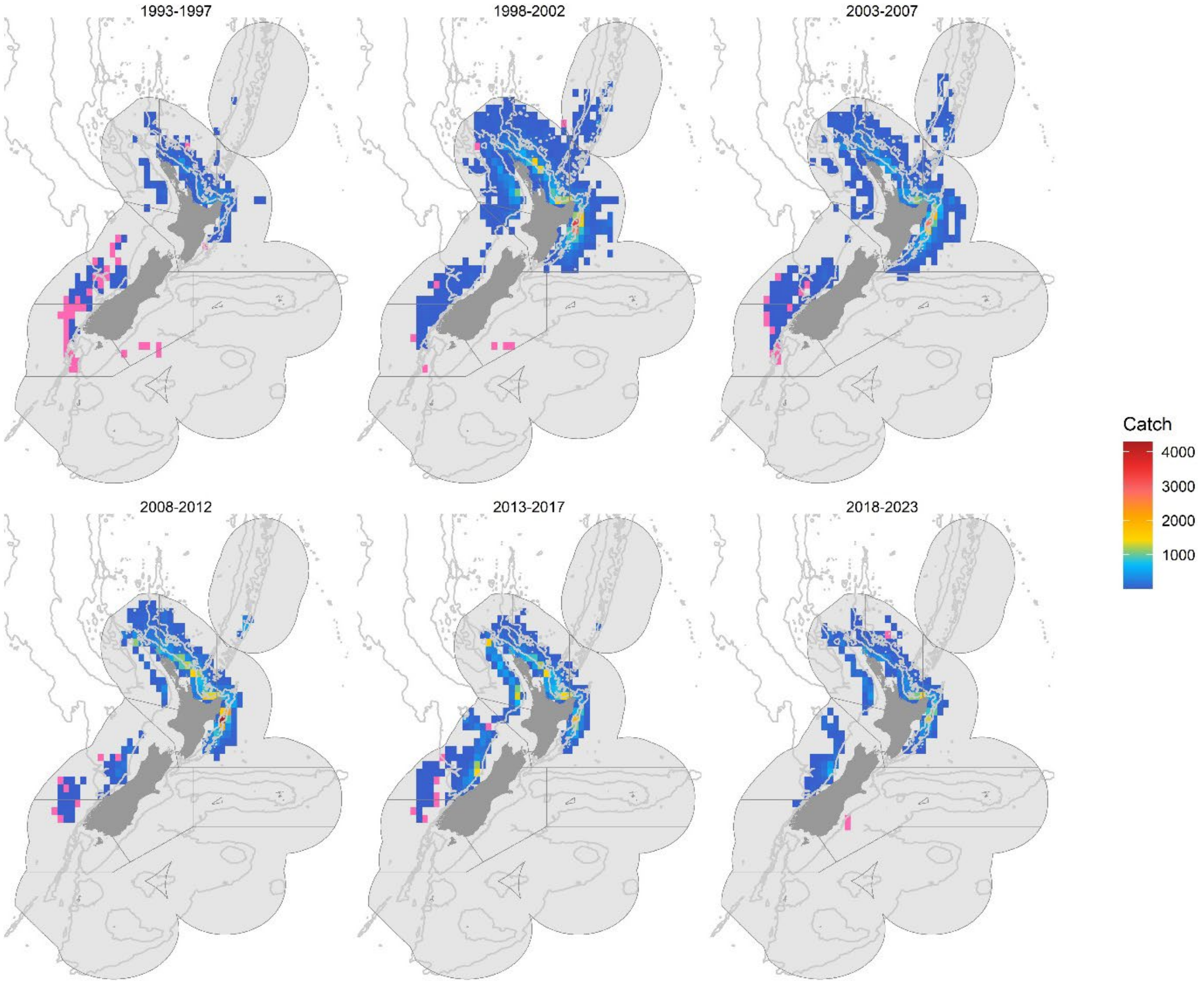

Figure 3: Swordfish catch (number of fish) from the surface longline fishery in the New Zealand Exclusive Economic Zone between 1993 and 2023, aggregated in five-year bins at 0.5° resolution. Pink represents locations where fishing occurs, but swordfish catch has never been reported. Each cell contains data from at least three permit holders.

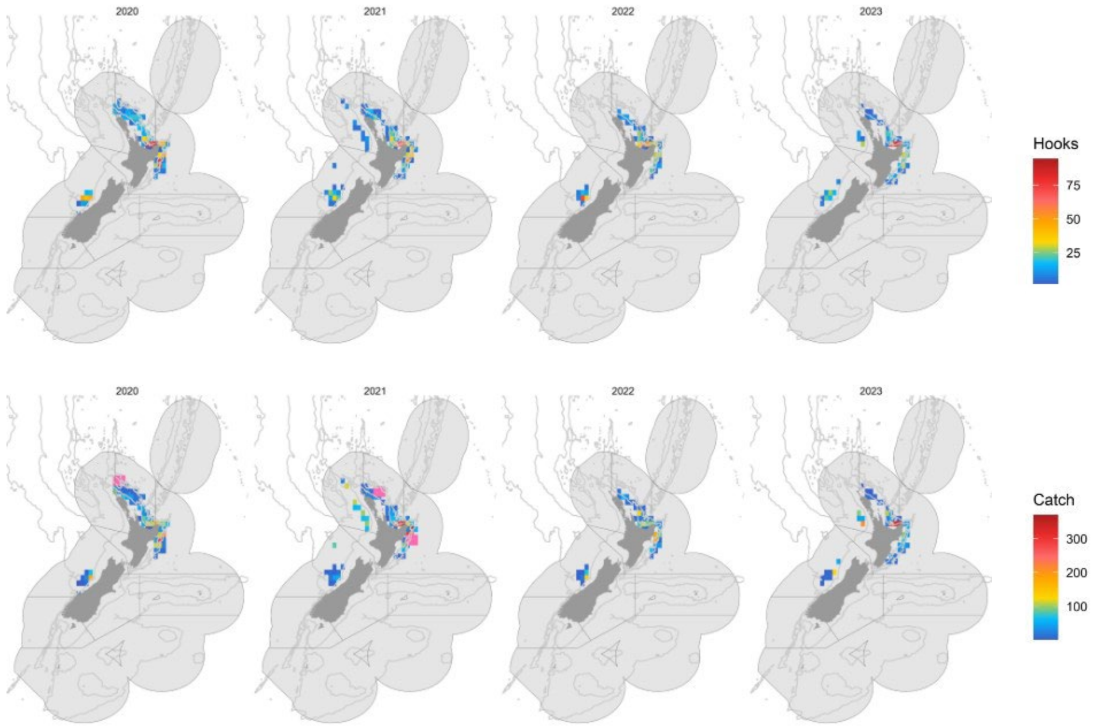

Figure 4: Annual surface longline effort (number of 1000 hooks, top panel) and swordfish catch (number of fish, bottom panel) from the surface longline fishery in the New Zealand Exclusive Economic Zone between 2020 and 2023, aggregated at 0.5° resolution. Pink represents locations where fishing occurs, but swordfish catch has never been reported. Each cell contains data from at least three permit holders.

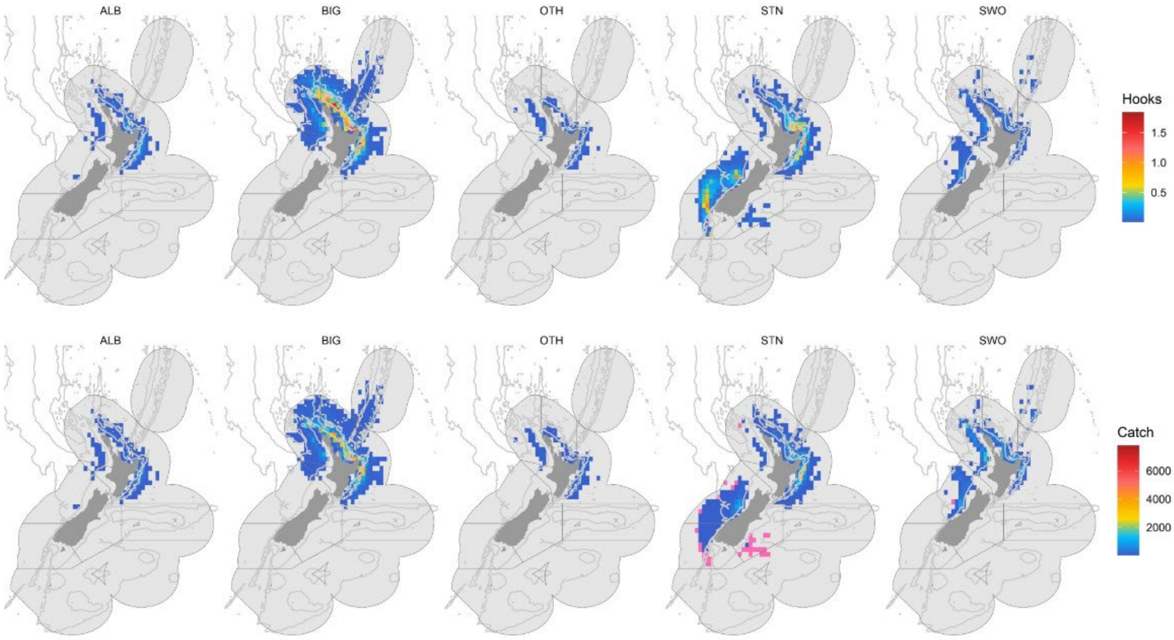

Figure 5: Total surface longline effort (number of 1000 hooks, top panel) and swordfish catch (number of fish, bottom panel) by target species from the surface longline fishery in the New Zealand Exclusive Economic Zone between 2020 and 2023, aggregated at 0.5° resolution (albacore, ALB; bigeye tuna, BIG; other target, OTH; southern bluefin tuna, STN; swordfish, SWO). Pink represents locations where fishing occurs, but swordfish catch has never been reported. Each cell contains data from at least three permit holders.

Swordfish catch (in number of fish) was predominately reported from FMA 1 and FMA 2 (Figure 6). Up until 2012, at least 80% of swordfish catch came from these two FMAs. Since then, a larger proportion of swordfish catch was reported from FMA 9 (~10–20%), with 35.8% in 2017 and 29.6% in 2021. There was also a greater increase in catch reported from FMA 7 from 2013, with a peak of 26.0% in 2016, and ~18% in 2019 and 2022. The proportion of catch from FMA 10 peaked in 2006 (at 17.6%) and has been negligible since.

The proportion of effort showed a similar pattern, with most effort occurring in FMA 1 and FMA 2, with upwards of 80% of effort in most years, and consistently since 2018 (Figure 6). Effort in FMA 7 peaked in 2014 and 2015 at 40.0% and 42.5%, respectively, and was about 28% in the following two years (2016, 2017). Since 2018, effort in FMA 7 has varied between 16.1% and 23.9%. In FMA 9, effort was highest from 1999 to 2003 (10–18%) and has been at or below 10% every year since, except for in 2023 where it accounted for 12.3%. There was a small (1.3%) amount of effort in FMA 8 in 2023.

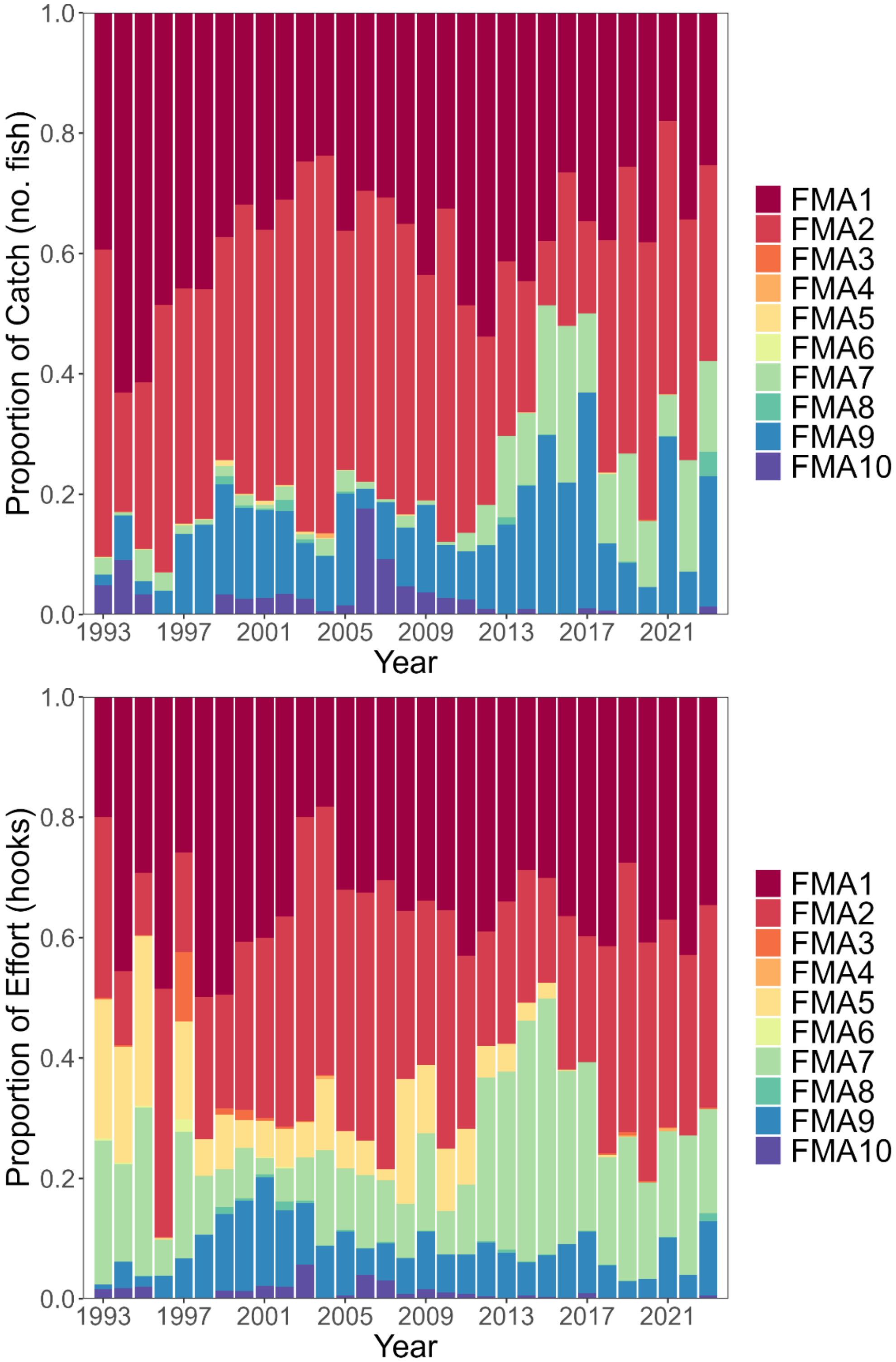

Figure 6: Proportion of swordfish catch (number of fish, top) and proportion of effort (hook numbers, bottom) by Fisheries Management Areas (FMAs) where swordfish was reported in the New Zealand surface longline fishery between 1993 and 2023.

3.2 FMAs 1, 2, and 9

In FMAs 1, 2, and 9 up until 2014, most (51–91%) swordfish catch was recorded in the bigeye tuna target fishery (Figure 7). The proportion of swordfish catch in the swordfish target fishery steadily increased since its QMS introduction in 2004 and peaked in 2015 at 62%. The decline of swordfish catch in the bigeye target fishery and the concurrent increase of swordfish in the swordfish target fishery at this time may have been due to declining port prices of southern bluefin tuna, resulting in an increase in vessels targeting swordfish. Since 2015, 22–50% of swordfish catch has been reported in the targeted fishery. There has been an increasing proportion of swordfish catch recorded in the southern bluefin tuna fishery since 2016, with up to 46% of swordfish catch recorded in this fishery in 2019. Small amounts (<5%) of swordfish catch has been recorded in other target fisheries (albacore tuna and Pacific bluefin tuna).

Swordfish catch (in numbers of fish) peaked in the early 2000s, and again between 2012 and 2015, followed by a steady decline thereafter to catches comparable to the late 1990s (Figure 8). Some increase in swordfish catch was observed in 2021. Effort for swordfish peaked in 2002, followed by a steep initial decline to 2005, and continued gradual decline thereafter. Swordfish effort at the end of the timeseries (2022–2023) was comparable, and slightly lower than effort at the beginning of the time series (1993). The catch rate for swordfish (number of fish per thousand hooks) gradually increased over time, peaked between 2012 and 2015, and declined thereafter. A sharp noticeable increase in swordfish catch rate was observed in 2021.

Annual swordfish catch has always been highest in the first half of the calendar year (Quarters 1 and 2) (Figure 9). The number of swordfish caught was generally highest in Quarter 2 (with a maximum of 5742 fish in 2001) until 2011 when the number of fish caught became higher in Quarter 1 (maximum of 5949 fish in 2013). Reported swordfish catch has always been lowest in Quarter 3 and Quarter 4, with 351 and 50 swordfish, respectively, reported in 2023.

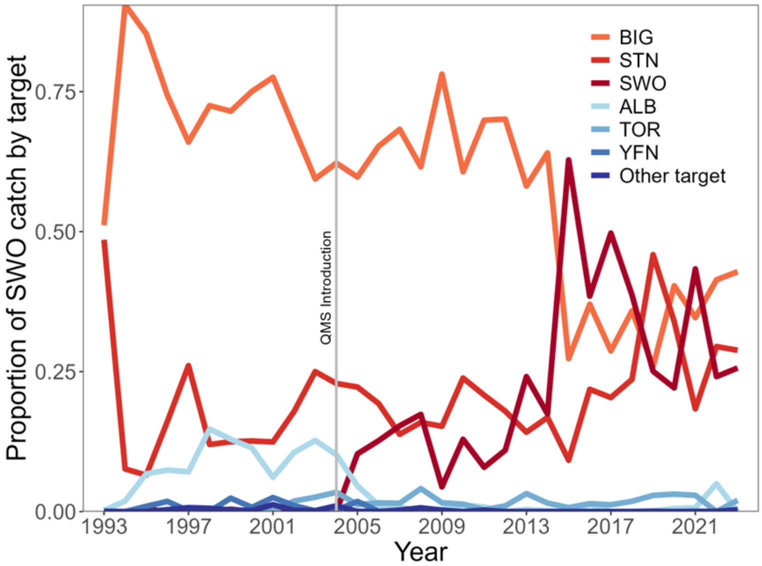

Figure 7: Proportion of swordfish catch reported by target species in the New Zealand surface longline fishery between 1993 and 2023 for Fisheries Management Areas (FMAs) 1, 2, and 9 (bigeye tuna, BIG; southern bluefin tuna, STN; swordfish, SWO; albacore, ALB; Pacific bluefin tuna, TOR; yellowfin tuna, YFN). Swordfish introduction into the Quota Management System (QMS) in 2004 is indicated by the grey line.

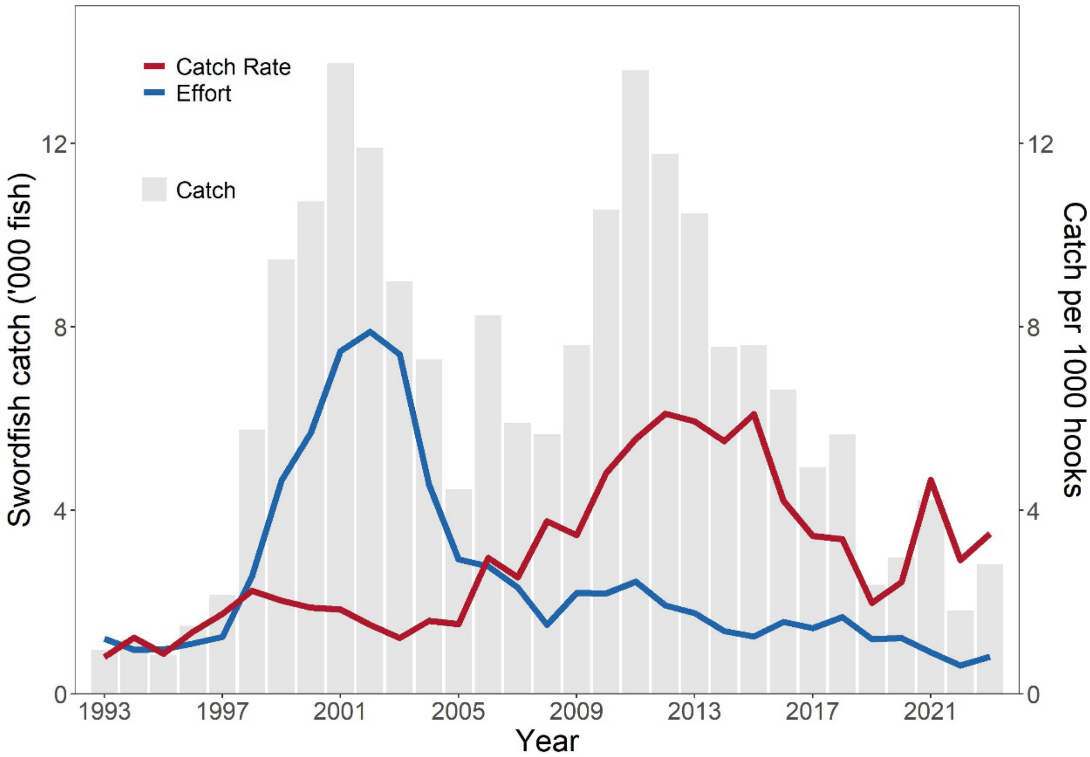

Figure 8: Annual swordfish catch (thousands of swordfish, grey bars), effort (thousands of hooks, solid blue line), and catch rate (number of swordfish per thousand hooks, red line) in the New Zealand surface longline fishery between 1993 and 2023 for Fisheries Management Areas (FMAs) 1, 2, and 9.

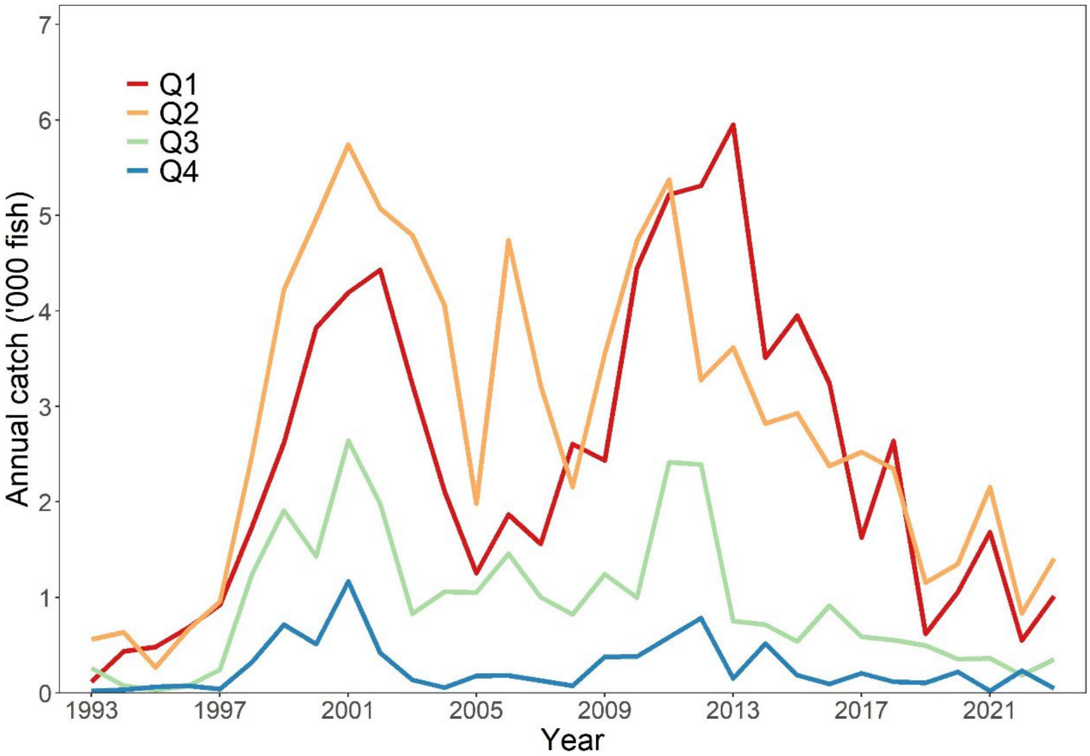

Figure 9: Annual catch (thousands of swordfish) by quarter-year (Q1: January–March, Q2: April–June, Q3: July–September, Q4: October–December) between 1993 and 2023 for Fisheries Management Areas (FMAs) 1, 2, and 9.

3.3 Commercial catch sampling

A total of 102 848 swordfish were sampled for processed weight between 2005 and 2023. Most swordfish were measured in Quarter 2 (n=42 788, 41.6%) or Quarter 1 (n=40 572, 39.4%), followed by Quarter 3 (n=15 705, 15.3%) and Quarter 4 (n=3783, 3.7%). Swordfish weighed from 1.25 to 595.5 kg, which converted to fork lengths (FL) of 59 to 353 cm.

Annual sampling peaked in 2011 with 12 520 swordfish measured, and has steadily declined over time, with between 1400 and 3000 swordfish measured annually since 2019 (Figure 10). In 2006, and again between 2014 and 2017, there was a considerable number of small fish (100–150 cm estimated FL) measured, and the mean and median size of swordfish during these times were ~160–170 cm estimated FL. Estimated swordfish size increased thereafter, and peaked in 2017 with a mean size of 196 cm estimated FL. The size of swordfish has since slowly declined, and in the most recent years of the time series, the mean estimated swordfish size (165–169 cm estimated FL) is comparable to sizes at the beginning of the time series. Swordfish size was comparable across quarters (169–173 cm estimated FL); on average, swordfish were slightly larger in quarter 3 (mean=173 cm estimated FL) and slightly smaller in quarter 1 (mean=169 cm estimated FL).

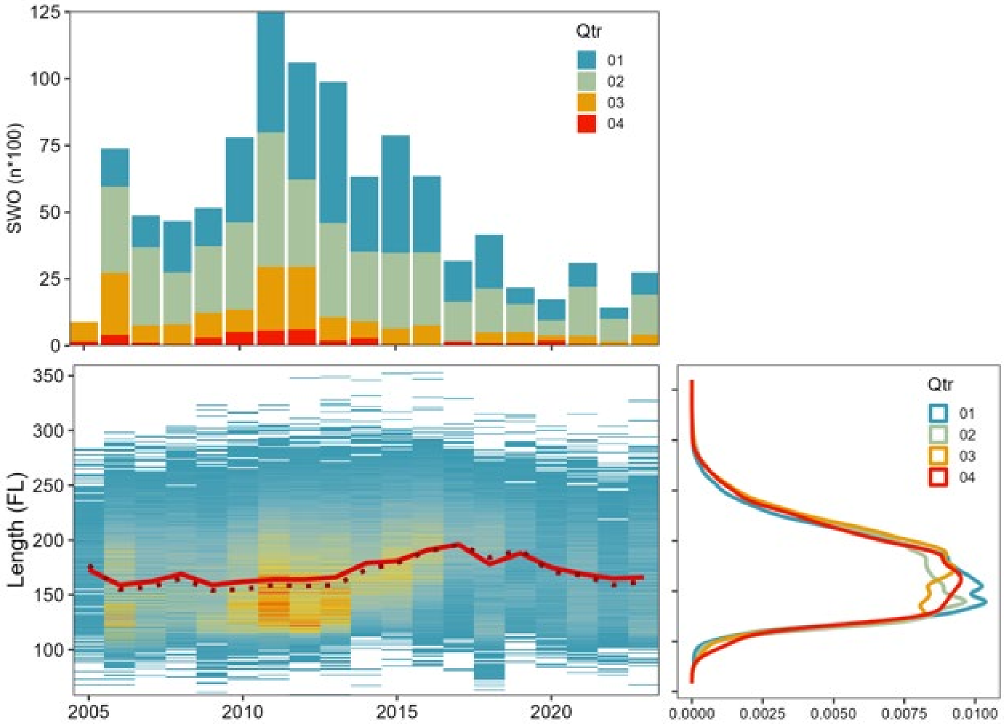

Figure 10: Annual number of swordfish (hundreds of fish) by quarter-year sampled for processed weight between 2005 and 2023 (top panel); annual size frequency of sampled swordfish (converted to fork length, FL) with annual mean (solid red line) and median (dotted red line) swordfish size (bottom left panel); and overall density distribution of swordfish sampled size by quarter-year (Q1: January–March, Q2: April–June, Q3: July–September, Q4: October–December) (bottom right panel).

3.4 Swordfish size

Across the different data sources, recent (since 2020) commercial catch size data used for the characterisation and CPUE analysis was generally comparable to the historical groomed commercial catch data in the *tuna* database (Figure 11, Appendix Table C1). Across all areas, average annual swordfish size has shown some declining trend from 1993 to the late 2010s and was the lowest in 2010 and 2011 (41 kg). Average size has since increased to around 60 kg by 2019 and has remained between 57 and 63 kg since. The groomed commercial catch data held by Fisheries New Zealand was comparable to the characterisation-CPUE data in years 2020 to 2023, with an annual average size between 52 and 59 kg.

Average swordfish size (in weight) varied by FMA, with swordfish in northern New Zealand (FMAs 1, 2, 9, and 10) generally smaller (~50 kg) than swordfish caught further south (100 kg or more, in FMAs 5 and 7) (Figure 12). Since 2020, average annual size of swordfish was smallest in FMA 1 (36–47 kg), followed by FMA 2 (44–55 kg), and FMA 9 (55–63 kg). Average annual size of swordfish was between 80 and 99 kg in FMA 7 since 2020.

The commercial catch data and the historical groomed commercial catch data (*tuna* database) and the catch sampling (from processed weights) showed similar trends in annual average swordfish size (kg) in overlapping years (Figure 13). The catch sampling showed an increasing trend to 2017 (87 kg annual average), followed by a decline to 2023 to sizes similar to those observed in 2005 (~50 kg). The overall average swordfish size in the catch sampling was 60 kg, comparable to the most recent (2020–2023) commercial catch data (60 kg) and the groomed commercial catch data (59 kg), and larger than the historical commercial catch (*tuna*) data (53 kg).

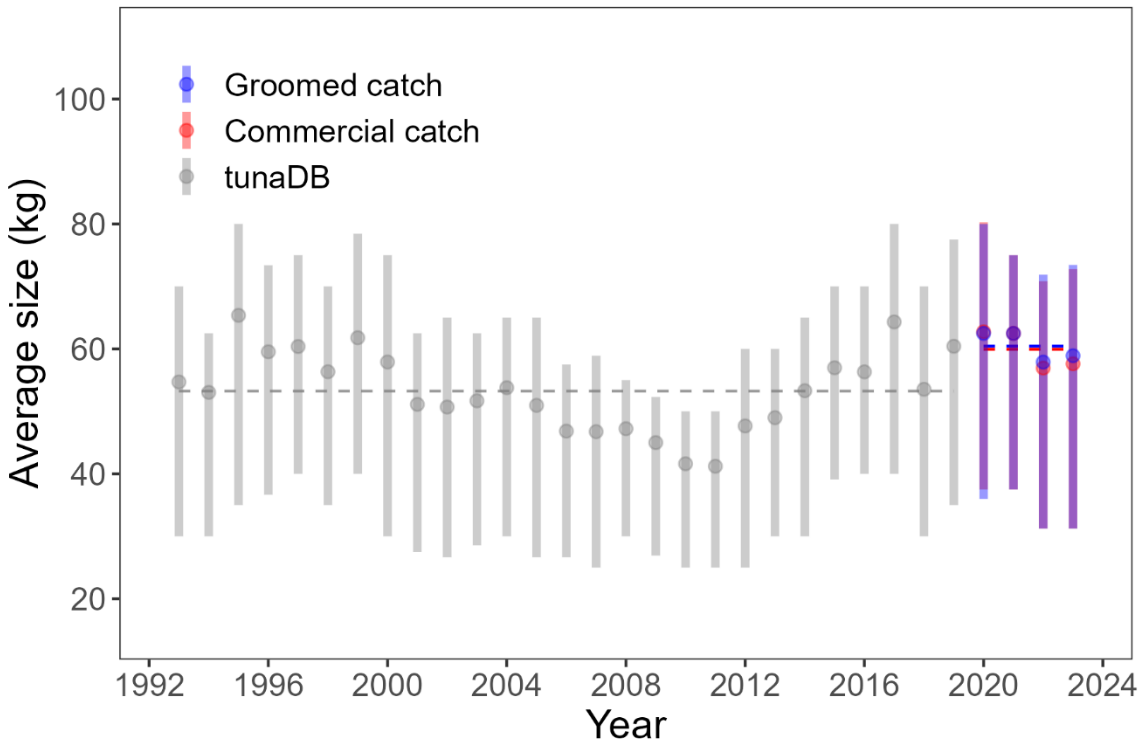

Figure 11: Annual average swordfish size (kg) between 1993 and 2023 for records held in the *tuna* database (tunaDB, 1993–2019, grey), commercial catch data used in the characterisation and CPUE analysis (Commercial catch, 2020–2023, red), and groomed commercial catch data from Fisheries New Zealand (Groomed catch, 2020–2023, blue). Dot represents the annual mean size, vertical bands are the interquartile range (25th, 75th), and the dotted horizontal line represents the overall average size for each data source (53 kg in grey, 60 kg in red, 59 kg in blue).

Figure 12: Annual average swordfish size (kg) by Fisheries Management Area (FMA) between 1993 and 2023 and for records held in the *tuna* database (1993–2019, blue), commercial catch data used in the characterisation and CPUE analysis (2020–2023, red), and groomed commercial catch data from Fisheries New Zealand (2020–2023, dark red dots).

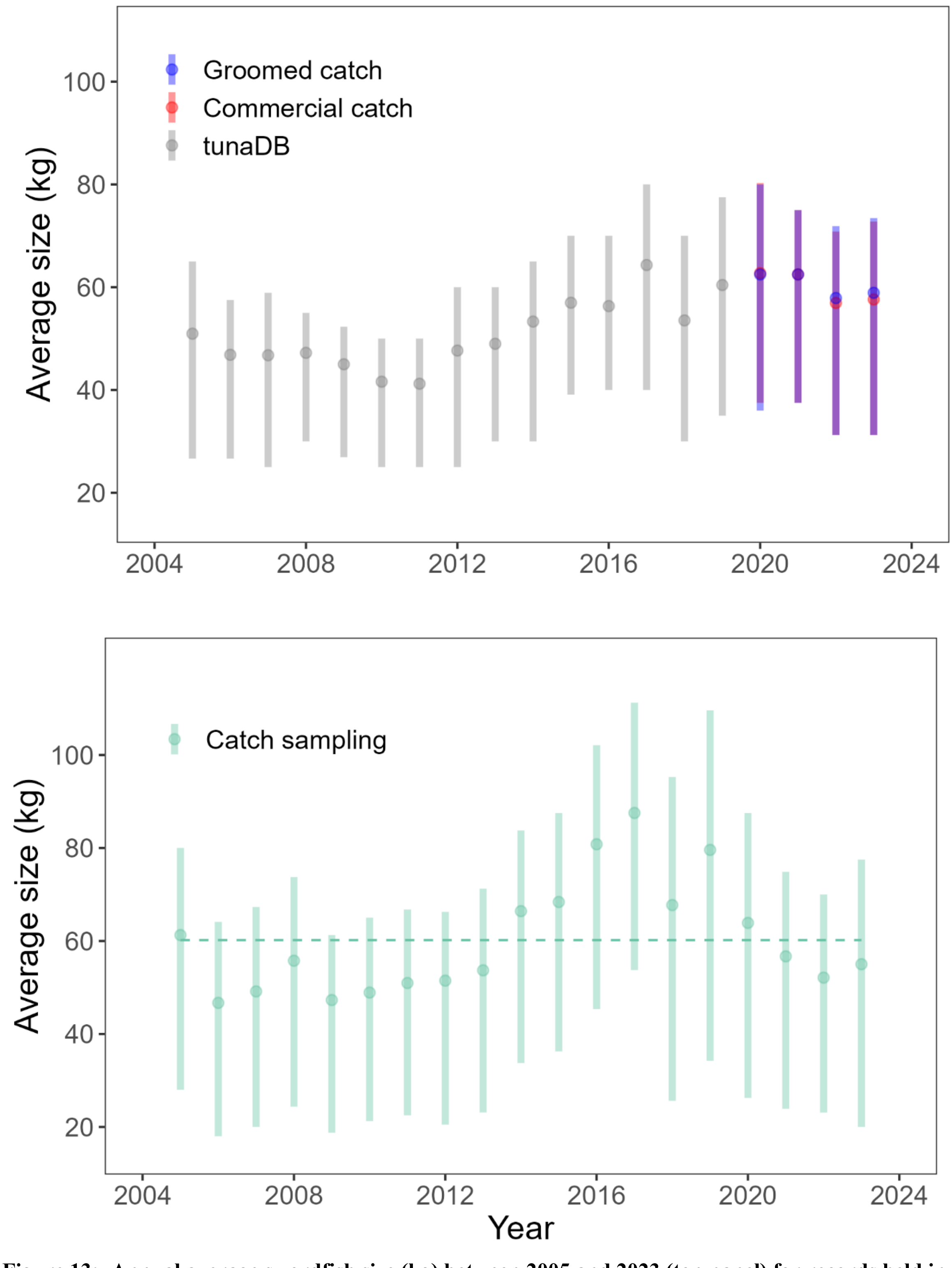

Figure 13: Annual average swordfish size (kg) between 2005 and 2023 (top panel) for records held in the *tuna* database (tunaDB, 2005–2019, grey), commercial catch data used in the characterisation and CPUE analysis (Commercial catch, 2020–2023, red), and groomed commercial catch data from Fisheries New Zealand (Groomed catch, 2020–2023, blue), and (bottom panel) records from the catch sampling data (Catch sampling). Dot represents the annual mean size, vertical bands are the interquartile range (25th, 75th), and the dotted horizontal line represents the overall average size (60 kg) for the commercial catch sampling.

3.5 CPUE analysis

Predictor variables

Changes over time in recorded and derived operational variables, as well as independently estimated environmental variables associated with the longline sets used in the CPUE analysis are shown in Figure 14.

The percentage of sets where no swordfish catch was recorded declined from about 50% in 1993 to less than 10% in 2012. This may indicate an increase in effective targeting of swordfish over time, an increase in reporting swordfish catch, or an increase in abundance during this time. From 2012, zero swordfish catch sets increased, and since 2018, between 25- and 35% of sets have reported no swordfish.

There have been several changes in the fishery over time. Light sticks have been used in nearly every set in most years since reporting of use was introduced in 2003; some decline (to 87–90%) was observed between 2013 and 2017. The percentage of squid bait gradually increased to nearly 100% to 2017 but has declined in more recent years, most likely due to increasing costs. The mean annual number of hooks per basket has gradually declined and has been less than 12.5 in most years since 2007. Soak time has remained consistently at or just below 0.60 since a peak in 2004 and recent effort (number of sets within 50 km during the previous 10 days) has gradually declined since 2010, to 2 or less since 2021. Recent trends in latitude (~37°S) and longitude (between 176.5° and 177.5°E) indicated more effort in recent years (2019 onwards) in the Bay of Plenty.

The mean day length associated with set deployment has shown some variability across the time series but has declined slightly from nearly 0.60 to 0.56–0.57. Mean time at which sets are deployed has shifted from one hour after midnight, to one to two hours before midnight. Moon fullness (fraction of the illumination provided by a full moon) has generally been around 0.54 since 2016, while night fraction (the fraction of the set soak time during the hours of darkness) showed an increasing trend to the late 2010s and has been variable between 0.35 and 0.40 since. Distance from the nearest hill was highly variable across most years, but has remained consistent around 12 nmi since 2019, while depth of fishing (depth at location of fishing event) has shown a declining trend since the early 2000s and is around or below 1600 m in most recent years.

No trend was observed with currents (speed, eastward, or northward direction). However, sea surface height (SSH), a measure of thermal energy of the entire water column at the start position of the set, has been steadily increasing across the time series, from less than 0 to over 0.15 in 2023, suggesting a slight shift of effort into warmer bodies of water. Sea surface temperature (SST) has shown some variability but a relatively stable trend, with fishing occurring at temperatures between 18 and 19°C, while sea surface temperature anomaly suggests some increasing trend over time, to more fishing effort occurring in warmer than average waters (by 0.5–1°C).

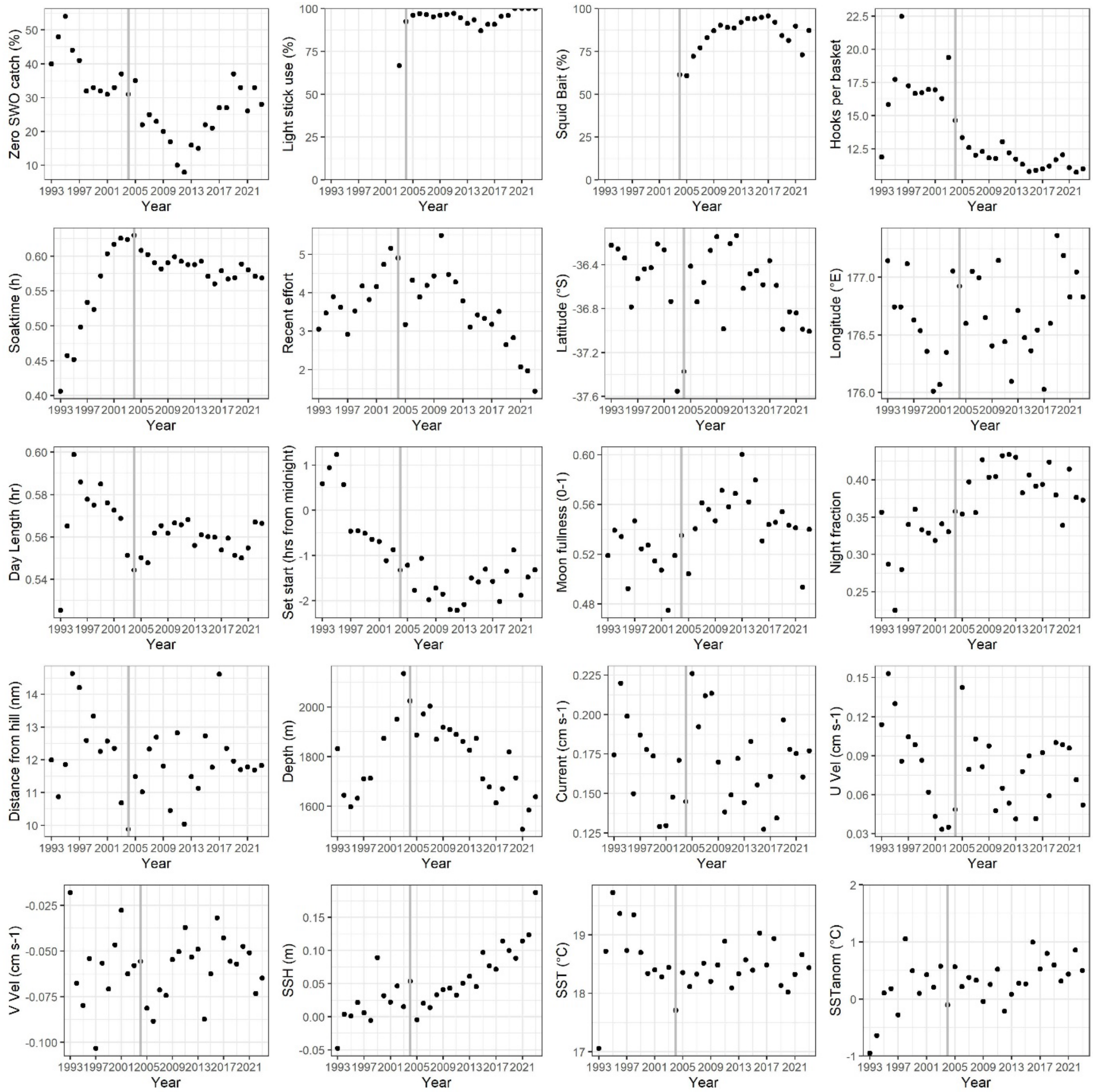

Figure 14: Changes in recorded and derived operational variables and independently estimated environmental variables associated with the longline sets used in the catch-per-unit-effort analyses. Annual means are plotted, with the exception of zero swordfish catch (first panel). Swordfish introduction into the Quota Management System (QMS) in 2004 is indicated by the grey vertical line.

Métier analysis

The métier analysis identified four grouping of catch composition targeting behaviour for each of the long and short time series. For the long time series, Cluster 1 was characterised by relatively high catches of albacore tuna and low catches of all other species. Cluster 2 was again characterised by high albacore tuna catches, from fishing events that took place later in the year and further to the north-west and more offshore than Cluster 1 (Table 2, Figure 15). Cluster 3 was characterised by relatively high swordfish catches and greater nighttime setting, from fishing trips that took place earlier in the year relative to the other clusters. Cluster 4 was characterised by high southern bluefin tuna catches and from fishing events that took place in winter (Table 2, Figure 15).

For the short time series, Cluster 1 was characterised by relatively high catches of southern bluefin tuna from fishing events in winter. Cluster 2 was characterised by high albacore tuna catches. Cluster 3 was characterised by relatively high swordfish catches and greater nighttime setting, light stick usage, and a high percentage of squid bait from fishing trips that took place along the shelf of the east and west coasts of the North Island and earlier in the year relative to the other clusters (Table 2, Figure 15). Cluster 4 was characterised by high bigeye tuna catches relative to other clusters, with fishing taking place later in the year relative to other clusters (Table 2, Figure 15).

Table 2: Mean operational and environmental variables and the number of catch records (in numbers of fish) by identified métier. ALB = albacore tuna, BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish, TOR = Pacific bluefin tuna, YFN = yellowfin tuna.

Series	Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Long series	Longitude	178.09	174.73	175.55	177.52
(1993–2023)	Latitude	-38.11	-34.81	-35.79	-36.96
	Month	4.5	8.0	3.8	7.1
	Hooks	1050	1153	919	863
	Hooks per basket	14.4	14.6	12.6	11.5
	Line length	26.6	34.4	25.4	20.7
	Moon illumination	0.52	0.52	0.57	0.54
	Night fraction	0.36	0.33	0.44	0.30
	ALB	0.87	0.84	0.40	0.27
	BIG	0.02	0.07	0.13	0.02
	STN	0.03	0.01	0.02	0.65
	SWO	0.07	0.05	0.37	0.06
	TOR	<0.01	<0.01	0.01	<0.01
	YFN	<0.01	0.01	0.07	<0.01
Short series	Longitude	177.67	178.32	176.00	174.56
(2004–2023)	Latitude	-37.11	-38.26	-36.18	-34.43
	Month	6.9	4.8	3.8	8.2
	Hooks	909	1096	850	1016
	Hooks per basket	12.1	12.7	10.9	13.2
	Line length	20.8	22.9	22.5	22.2
	Moon illumination	0.53	0.53	0.58	0.54
	Night fraction	0.30	0.37	0.50	0.34
	Light stick rate	144.4	223.4	429.4	193.4
	% squid bait	91.7	76.4	90.1	73.3
	ALB	0.34	0.83	0.40	0.71
	BIG	0.01	0.02	0.11	0.15
	STN	0.57	0.04	0.05	0.02
	SWO	0.07	0.10	0.41	0.11
	TOR	<0.01	<0.01	0.01	<0.01
	YFN	<0.01	<0.01	0.03	0.01

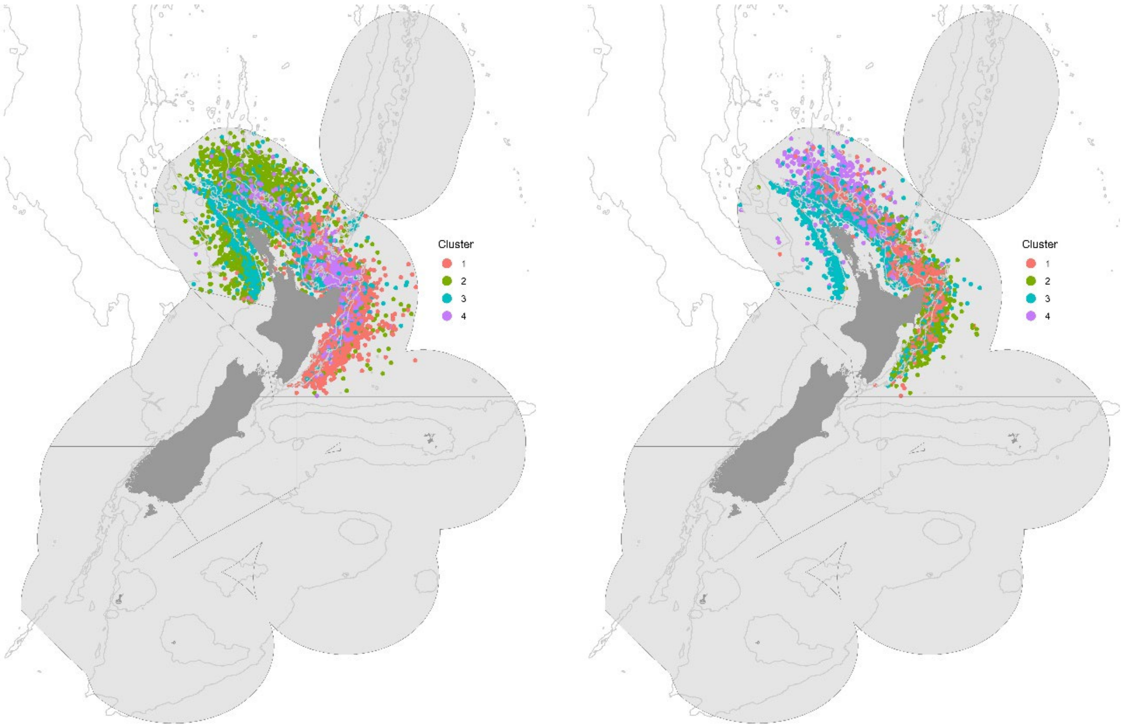

Figure 15: Location of fishing events allocated to each identified cluster from the métier analysis for the long time series (1993–2023, left panel) and short time series (2004–2023, right panel). Each dot represents an average event location.

CPUE standardisations – year-quarter indices

After data grooming, a total of 270 and 135 unique vessels were included in the all-vessels series 1993–2023 (long) and 2004–2023 (short) time series, respectively. A total of 22 vessels were retained for the core series model for both the long and short series.

Among the different year-quarter indices, models retained similar variables and, within each component (i.e., binomial and positive catch), the percentage of deviance explained was largely comparable, ranging from 13.4–20.2% for the binomial component, and 44.2–48.8% for the positive catch component (Table 3). Both the all-vessels and core-vessels series showed very similar trends between themselves, and to the indices from the previous study (Finucci et al. 2021), with strong seasonal fluctuations and increasing CPUE until 2012 and 2013, a declining trend to 2019, and a slight increase thereafter (Figure 16).

For the all-vessels long series, the binomial model explained 15.2% of the residual deviance, and, in addition to the *Year-quarter* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, *vessel*, and *night fraction*. The positive catch model explained 44.2% of the residual deviance, and, in addition to *Year-quarter*, included terms for the interaction between *longitude* and *latitude*, *vessel*, *hooks per basket*, *SST*, *declared target species*, and *night fraction*.

For the core-vessels long series (1999–2023), the binomial model explained 18.4% of the residual deviance, and, in addition to the *Year-quarter* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, *vessel*, and *night fraction*. The positive catch component explained 48.7% of the residual deviance, and, in addition to the *Year-quarter* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, as well as *vessel*, *hooks per basket*, *SST*, *declared target species*, and *night fraction*, consistent with the all-vessels long series.

For the all-vessels short series, the binomial model explained 19.5% of the residual deviance, and, in addition to the *Year-quarter* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, as well as *vessel*, *night fraction*, and *light stick rate*. The positive catch component explained 46.9% of the residual deviance and included terms for the interaction between *longitude* and *latitude* at the start of the set, *vessel*, *hooks per basket*, *SST*, *declared target species*, *night fraction*, and *light stick rate*, in addition to the *Year-quarter* term.

Of the models fitted with a year-quarter time step, the core-vessels short series showed the greatest explanatory power. Here, the binomial model explained 20.2% of the residual deviance, and, in addition to the *Year-quarter* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, *night fraction*, and *light stick rate*. The positive catch component explained 48.8% of the residual deviance, and, in addition to the *Year-quarter* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, as well as *vessel*, *hooks per basket*, *SST*, *cluster*, *night fraction*, and *light stick rate*.

The combined index showed similar trends to those observed from other indices, with increasing CPUE until 2012 and 2013, a subsequent decline to 2019, and a slight increase thereafter (Appendix Figure D1). Residuals of the two components showed a good fit to the data (Appendix Figure D2) and were a substantial improvement from the previous analysis. *Night fraction* and *light stick rate* showed a positive association on the probability that a set captured a swordfish (Appendix Figure D3). The impact of sequentially adding each predictor variables for the binomial component of models are shown in Appendix Figure D4 and Appendix Figure D5. For the positive catch component, *night fraction*, *light stick rate*, and *SST* had a positive influence on CPUE, while hooks per basket negatively influenced CPUE (Appendix Figure D6).

Final indices for the year-quarter models are reported in Appendix Table D1.

Table 3: **Variables retained by each model (all-vessels series and core-vessels series) and each time series (1993–2023 and 2004–2023 for the all-vessels series, 1999–2023 and 2004–2023 for the core-vessels series) and the percentage of deviance explained with the addition of each variable for the Year-quarter indices.**

1993–2023 (all vessels long)

Binomial component		**Positive catch component**	
Variable	**% deviance explained**	**Variable**	**% deviance explained**
Year-quarter	9.1	Year-quarter	28.0
Longitude*Latitude	10.5	Longitude*Latitude	32.7
Vessel	12.5	Vessel	38.5
Night fraction	15.2	Hooks per basket	39.5
		SST	40.5
		Target species	41.5
		Night fraction	44.2

1999–2023 (core vessels long)

Binomial component		**Positive catch component**	
Variable	**% deviance explained**	**Variable**	**% deviance explained**
Year-quarter	13.0	Year-quarter	30.5
Longitude*Latitude	14.5	Longitude*Latitude	37.3
Vessel	15.5	Vessel	41.7
Night fraction	18.4	Hooks per basket	43.2
		SST	44.7
		Target species	45.8
		Night fraction	48.7

2003–2024 (all vessels short)

Binomial component		**Positive catch component**	
Variable	**% deviance explained**	**Variable**	**% deviance explained**
Year-quarter	12.0	Year-quarter	25.6
Longitude*Latitude	13.8	Longitude*Latitude	31.7
Vessel	15.5	Vessel	38.3
Night fraction	18.3	Hooks per basket	39.6
Light stick rate	19.5	SST	40.9
		Target species	42.3
		Night fraction	45.0
		Light stick rate	46.9

2003–2024 (core vessels short)

Binomial component		**Positive catch component**	
Variable	**% deviance explained**	**Variable**	**% deviance explained**
Year-quarter	14.5	Year-quarter	26.1
Longitude*Latitude	16.0	Longitude*Latitude	34.9
Night fraction	18.8	Vessel	40.1
Light stick rate	20.2	Hooks per basket	41.4
		SST	42.9
		Cluster	44.4
		Night fraction	47.0
		Light stick rate	48.8

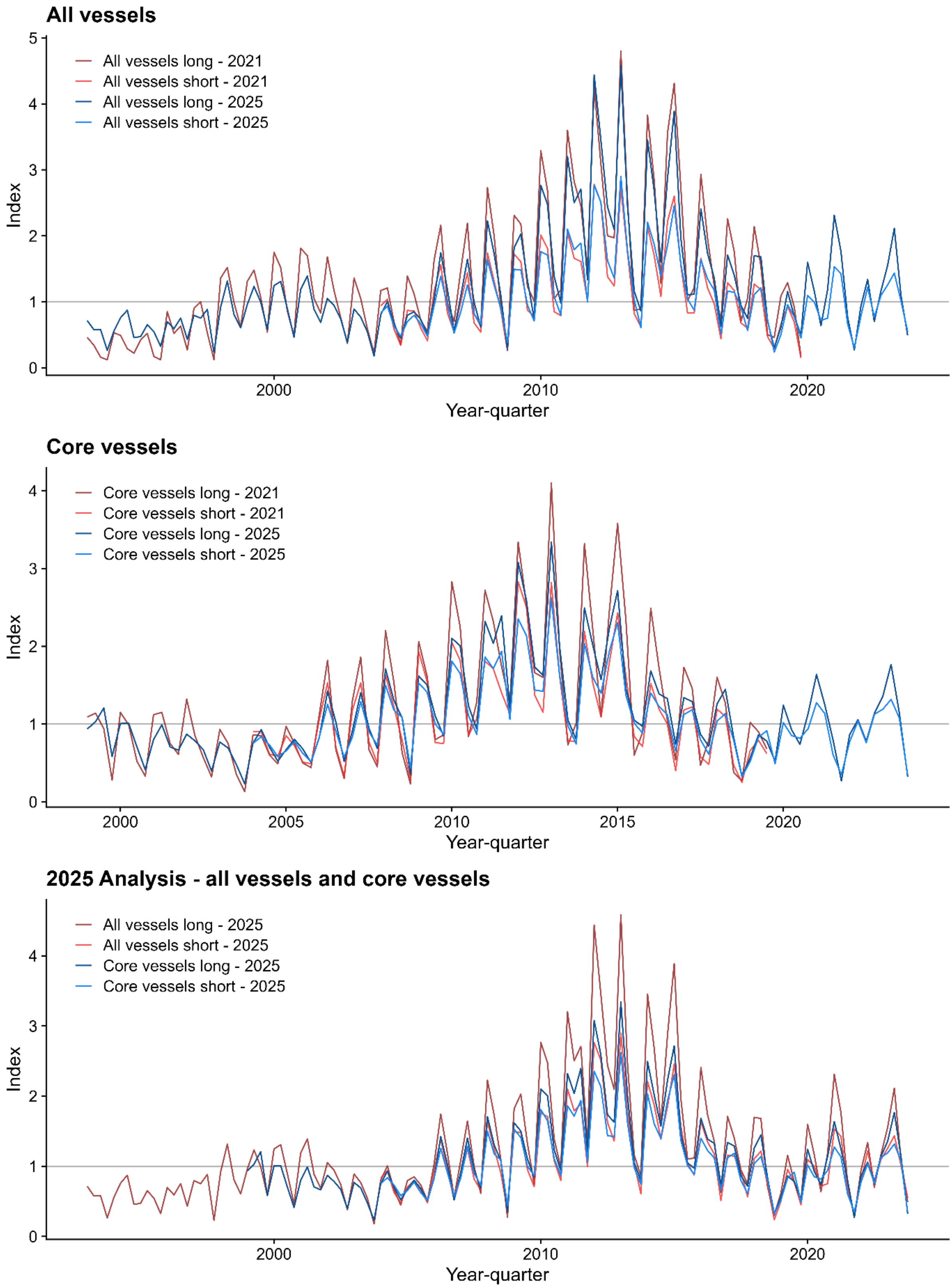

Figure 16: Comparison of year-quarter catch-per-unit-effort (CPUE) indices for the all-vessels series (top panel), core-vessels series (middle panel), and all-vessels series combined (bottom panel) for each of the time series (1993–2023 and 2004–2023 for the all-vessels series and 1999–2023 and 2004–2023 for the core-vessels series). All series are scaled to their geometric mean. The horizontal grey line shows the level of no change (Index = 1) as a reference.

Annual (Year) CPUE series

Among the different annual indices, models retained similar variables and, within each component (i.e., binomial and positive catch), models fits were largely comparable, ranging from 13.0–19.1% for the binomial component, and 42.8–46.8% for the positive catch component (Table 4). Both the all-vessels and core-vessels- series showed very similar trends, with increasing CPUE until 2012 and 2013, followed by a decline to 2019, and a slight increase thereafter (Figure 17).

For the all-vessels long series, the binomial model explained 14.2% of the residual deviance, and, in addition to the *Year* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, *season*, *vessel*, and *night fraction*. The positive catch component explained 42.8% of the residual deviance, and, in addition to these terms, included additional terms for *hooks per basket*, *SST*, and *target species*.

For the core-vessels long series, the binomial model explained 17.7% of the residual deviance, and, in addition to the *Year* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, *season*, *vessel*, *SST*, and *night fraction*. The positive catch component explained 46.0% of the residual deviance, and, in addition to the *Year* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, *season*, *vessel*, *hooks per basket*, *SST*, *declared target species*, and *night fraction*.

For the all-vessels short series, the binomial model explained 18.9% of the residual deviance, and, in addition to the *Year* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, *season*, *vessel*, *cluster*, *night fraction*, and *light stick rate*. The positive catch component explained 46.0% of the residual deviance and included terms for the interaction between *longitude* and *latitude* at the start of the set, *season*, *vessel*, *hooks per basket*, *SST*, *declared target species*, *night fraction*, and *light stick rate*, in addition to the *Year* term.

Of the models fitted with an annual time step, the core-vessels short series showed the greatest explanatory power. Here, the binomial model explained 19.1% of the residual deviance, and, in addition to the *Year* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, *season*, *cluster*, *night fraction*, and *light stick rate*. The positive catch component explained 46.8% of the residual deviance, and, in addition to the *Year* term, included terms for the interaction between *longitude* and *latitude* at the start of the set, as well as *season*, *vessel*, *hooks per basket*, *SST*, *cluster*, *night fraction*, and *light stick rate*.

The combined index showed similar trends to those observed from other indices, with increasing CPUE until 2012 and 2013, a subsequent decline to 2019, and a slight increase thereafter (Appendix Figure D7). Residuals of the two components showed a good fit to the data (Appendix Figure D8). The impact of sequentially adding each predictor variables for the binomial component of models are shown in Appendix Figure D9 and Appendix Figure D10. Swordfish occurrence in catches was highest during seasons 1 and 2, and in Clusters 3 and 4 (Appendix Figure D11). As observed in the year-quarter models, n*ight fraction* and *light stick rate* showed a positive association on the probability that a set captured a swordfish (Appendix Figure D12). For the positive catch component, seasons 1 and 2, Cluster 3, *night fraction*, *light stick rate*, and *SST* had a positive influence on CPUE, while *hooks per basket* negatively influenced CPUE (Appendix Figure D12).

Final indices for the annual models are reported in Appendix Table D2.

Table 4: Variables retained by each model (all-vessels series and core-vessels series) and each time series (1993–2023 and 2004–2023 for the all-vessels series, 1999–2023 and 2004–2023 for the core-vessels series) and the percentage of deviance explained with the addition of each variable for the Annual indices.

1993–2023 (all vessels long)

Binomial component

Variable	% deviance explained
Year	3.5
Longitude*Latitude	6.6
Season	9.0
Vessel	11.2
Night fraction	14.2

Positive catch component

Variable	% deviance explained
Year	18.1
Longitude*Latitude	26.6
Season	30.8
Vessel	36.5
Hooks per basket	37.6
SST	38.6
Target species	40.0
Night fraction	42.8

1999–2023 (core vessels long)

Binomial component

Variable	% deviance explained
Year	3.8
Longitude*Latitude	8.5
Season	12.4
Vessel	13.5
SST	14.5
Night fraction	17.7

Positive catch component

Variable	% deviance explained
Year	18.2
Longitude*Latitude	30.2
Season	34.8
Vessel	39.2
Hooks per basket	40.7
SST	42.3
Target species	43.7
Night fraction	46.7

2003–2024 (all vessels short)

Binomial component

Variable	% deviance explained
Year	3.8
Longitude*Latitude	8.7
Season	12.2
Vessel	13.9
Cluster	15.2
Night fraction	17.8
Light stick rate	18.9

Positive catch component

Variable	% deviance explained
Year	13.6
Longitude*Latitude	26.7
Season	31.7
Vessel	37.6
Hooks per basket	38.6
SST	40.0
Target species	41.8
Night fraction	44.0
Light stick rate	46.0

2003–2024 (core vessels short)

Binomial component

Variable	% deviance explained
Year	4.3
Longitude*Latitude	9.8
Season	14.1
Cluster	15.4
Night fraction	17.8
Light stick rate	19.1

Positive catch component

Variable	% deviance explained
Year	13.2
Longitude*Latitude	27.8
Season	32.5
Vessel	37.6
Hooks per basket	38.9
SST	40.5
Cluster	42.2
Night fraction	44.8
Light stick rate	46.8

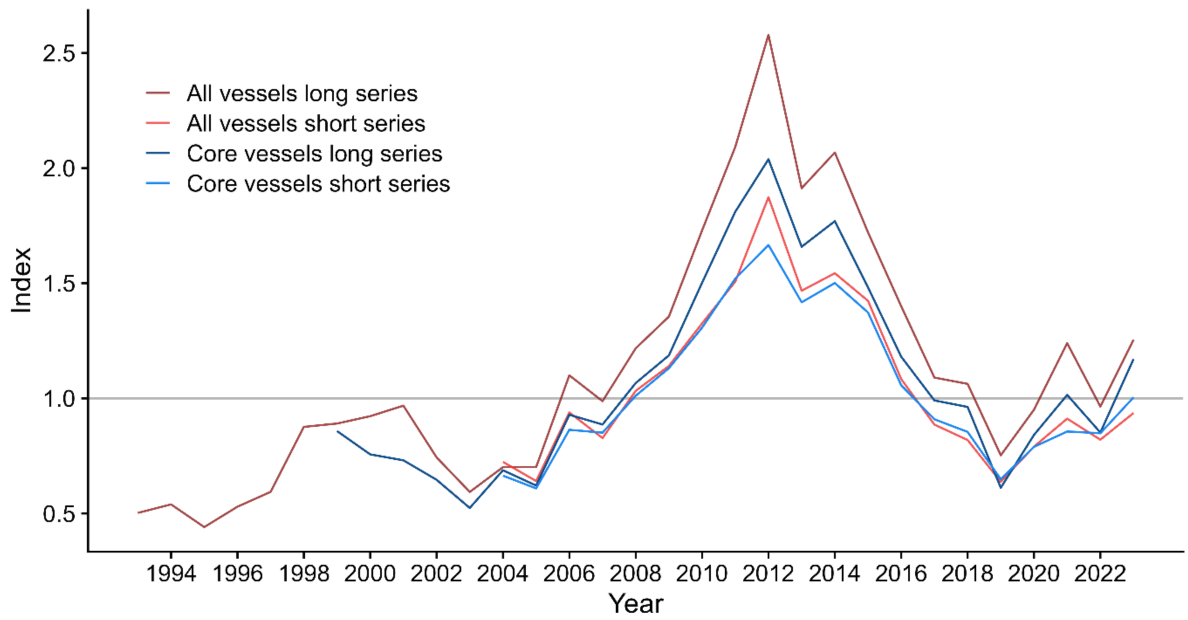

Figure 17: Comparison of annual catch-per-unit-effort (CPUE) indices for the all-vessels series (top panel), core-vessels series (middle panel), and all-vessels series combined (bottom panel) for each of the time series (1993–2023 and 2004–2023 for the all-vessels series and 1999–2023 and 2004–2023 for the core-vessels series). All series are scaled to their geometric mean. The horizontal grey line shows the level of no change (Index = 1) as a reference.

4. DISCUSSION

The surface longline fishery (for all species) within the New Zealand Exclusive Economic Zone (EEZ) has seen a large reduction in effort in the past few decades, from 25.8 million hooks set per year in 1980–1982 to 2.1 million hooks in 2014–2018 (Francis & Finucci 2019) and approximately 6 million hooks in 2019–2023. Most effort is now restricted to along the continental shelf-break, especially around northern New Zealand. Some increasing effort (and swordfish catch) was reported from along the west coast of the South Island and Challenger Plateau in FMA 7, particularly between 2013 and 2017, however, most effort in recent years has been largely restricted to the eastern Bay of Plenty and off the northeast coast of the North Island.

There has been some change in average swordfish size over time, with an increase in size from 2005 to 2017, followed by a gradual decline. This trend was observed in both the commercial catch data and the commercial catch sampling programme. The overall average swordfish size in the commercial catch sampling was 60 kg, comparable to the most recent (2020–2023) commercial catch data (60 kg) and the Fisheries New Zealand data (59 kg), and larger than the historical (*tuna*) data (53 kg). It is unknown where swordfish sampled in the catch sampling programme were caught, though there is sampling of pelagic species (including tunas and swordfish) from the fishery operating throughout the New Zealand EEZ, and data on port of landing is available (Kendrick 2025). Sampling of swordfish from areas where larger fish tend to be recorded (i.e., FMA 7) should be explored.

In all four CPUE models, the year-quarter predictor explained most (25–30%) of the residual deviance, followed by the longitude-latitude predictor, indicating time of year and location as the most important factors in explaining swordfish catch. Operational variables including night fraction, the number of light sticks, and hooks per basket were also important predictors of swordfish catch. Sea surface temperature was found to be a more important predictor in this analysis than in the previous analysis (Finucci et al. 2021) and was selected by all model iterations. No other environmental oceanographic variable was found to be an important predictor. Elsewhere, dynamic ocean structures (e.g., Lagrangian coherent structures) were found to play important roles in swordfish bycatch (Scales et al. 2018), and the El Niño Ocean Index (ONI) and the Pacific Decadal Oscillation were important in explaining swordfish CPUE in the Eastern Pacific Ocean (Félix-Salazar et al. 2024). The ONI was presented to the models here. Swordfish catch rates in the Atlantic were also best explained by operational predictors (e.g., year, vessel, position) (Coelho et al. 2022, Mourato et al. 2022). Information on swordfish migration patterns around New Zealand is limited, restricted to one study conducted in 2006 from individuals caught on surface longline vessels operating northeast of New Zealand (Holdworth et al. 2010). The New Zealand Gamefish Tagging Programme (NZGTP) is a cooperative gamefish tagging programme that collects release and recapture data on a range of pelagic species (Holdsworth & Curtis 2025). An annual average of 40 swordfish were tagged with conventional tags and released between 2014–15 and 2023–24, and seven swordfish were recaptured during that time (Holdsworth & Curtis 2025). Improved information on swordfish movement may better inform future models.

The all-vessel short series developed in the previous iteration of this work was used to provide an index of swordfish abundance in the 2021 Western and Central Pacific Fisheries Commission (WCPFC) stock assessment of southwest Pacific swordfish (Ducharme-Barth et al. 2021). Of the CPUE indices used (which also included those from Australia, the European Union, Japan, and Chinese Taipei), the New Zealand CPUE index was found to be the most influential for the diagnostic case model. Use of this index led to higher estimates of spawning potential and more optimistic levels of depletion, likely due to the model attempting to fit the increasing trend seen in the New Zealand index from 2004 to the early 2010s (Ducharme-Barth et al. 2021). The short series was selected for use in the assessment due to concerns over potential catchability changes brought on by the introduction of a swordfish catch quota in 2004. Subsequently, we recommend continuing to use the short series developed here in the scheduled 2025 southwest Pacific swordfish stock assessment. Given the lack of difference between the long and short series in overlapping years potentially the long series could be used in a sensitivity analysis.

For the first time in the time series of swordfish characterisations, this study included an analysis of fishing strategies to identify groups of vessels with the same exploitation pattern (e.g., gear configuration, fishing ground, catch), commonly known as métiers. Both the long and short series analyses identified four distinct groups (clusters), that were differentiated primarily based on catch composition, location of setting, time of setting (both diurnal time and month), and, for the short series, light stick usage. Further refinement of this approach may yield additional targeting patterns.

The New Zealand longline fishery has exhibited a number of changes since the 1990s, including introduction of tunas, billfish, and pelagic sharks into the QMS and, for some species, Schedule 6 of the Fisheries Act (fish may be returned to the waters if it is likely to survive on return), reduction in effort, cessation of foreign chartered surface longline vessels in 2015, and changes in observer coverage (see Francis & Finucci 2019). Many of these changes are likely to have influenced the fishery CPUE reported here.

For future iterations of this work, the utility of the long CPUE series (both all-vessels and core vessels) should be carefully considered. While the short series have been used to provide an index of abundance to the southwest Pacific swordfish stock assessment (e.g., Ducharme-Barth et al. 2021), to our knowledge, the long series are not used in any formal way. We suggest that further development of the short series models, including more detailed data grooming and exploration, would be more worthwhile than generating additional time series of indices. Future analysis (e.g., size data modelling) should explore the drivers in changes in average swordfish size, which may reflect changes in fishing location or increased swordfish recruitment.

5. FULFILMENT OF BROADER OUTCOMES

As required under Government Procurement rules[1], Fisheries New Zealand considered broader outcomes (secondary benefits such as environmental, social, economic or cultural benefits) that would be generated by this project. The following broader outcomes were delivered:

Building capacity and capability in the research sector
The team working on the project brought together a diverse range of skill sets and experience levels and building capacity in fisheries science and spatial management.

6. ACKNOWLEDGEMENTS

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[1] https://www.procurement.govt.nz/procurement/principles-charter-and-rules/government-procurement-rules/planning-your-procurement/broader-outcomes/

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APPENDIX A

Table A1: Grooming processes used for the *tuna* database and the data held internally by Fisheries New Zealand.

tunaDB_rule_code	tunaDB_rule_desc	still used after ERS	new rule since ERS	new rule desc
GAP	If a record has parent key which can not be found in its parent table, then move the record into reject table.	yes		
DUPLICATE	If two or more records have the same primary key, move those having lower version number or having same version number but higher record number into reject table.	yes		
ORPHAN	If a record has null parent key then the record is regarded as an orphan record.	yes		
ADOPT	If an orphan record has the same vessel as that of a parent record and its event date is between start event date and end event date of the parent record, then this parent record is regarded as the parent of the orphan record.	yes		
PSEUDO	For each vessel in the orphan records which can not be adopted, create a pseudo trip which has minimum fishing date in a month as trip start date and maximum fishing date in the same month as trip end date, and uses number greater than 2000000000 as trip_key.	yes		
STAT	Set stat area to null if stat area is not a valid stat area, by valid we mean the stat areas in the General Statistical Areas.	yes		
POSERR	For a trip having more than or equal to 5 fishing positions (sets), firstly calculate average travelling speed and average travelling distances between each adjacent fishing positions. If both differences between a positions adjacent distances and its average travelling distances are more than 3 degrees, this position is thought to be wrong. If only one erroneous position found then use the middle position between the adjacent ones as correct position, otherwise mark the position as POSCHK1 in the memo field.	yes		
LAT	Set latitude to null if not between -25 to -60 degrees if stat area is valid.	yes		
LON	Set longitude to null if not between 160E to 170W degrees if stat area is valid.	yes		
			CHGHEM	If the latitude is positive multiply it by -1
POSCHK1	For those position errors found in rule POSERR but can not be fixed.	yes		
POSCHK2	If a position is not inside its stat area, flag the position as questionable but does nothing to fix.	yes		
CENTROID	Set latitude and longitude to that of centroid of stat area if latitude or longitude is null.	yes		
FMA	if FMA is NI or SI then set the FMA to null, if stat area is available then set latitude and longitude to that of centroid of the stat area, otherwise set to null.	no		
VSLDUM	Use master vessel table (t_vessel_tuna in vessel database) to fill vessel type and/or nationality fields for nulls or unknown value U and DUM.	no		

VSLONE	If there is only one value for vessel type of a vessel except U, then set that known vessel type to all the U vessel type.This rule also applys to vessel nationality, set the known nationality to DUM value.	no		
VSLD	For vessels having vessel_nation as NZL but vessel_type not D, set vessel_type to D.	changed slightly		All vessels should be 'D'
			VSLNZL	All vessel nationalities should be 'NZL'
VSLC	For vessels having vessel_nation not as NZL and DUM but vessel_type as D, set vessel_type to C.	no		
VSLNEW	For new vessel keys not found in master vessel table, update the master vessel table. This rule code is recorded in t_vessel_tuna.memo field.	no		
VSLCHG	For discrepancy of vessel type or nationality for the same vessel between that in master vessel table and in tuna trip table, treat it as normal change, and insert a new record in the master vessel table with its memo field marked with this rule code.	no		
SETEND	If datetime_set_end is before datetime_set_start, set it to null.	yes		
HAULSTART	If datetime_haul_start is before datetime_set_end or datetime_set_start, set it to null.	yes		
HAULEND	If datetime_haul_end is before datetime_haul_start, set it to null.	yes		
SST	Set sea surface temperature to null if its not between 10 to 30 degrees.	yes		
SPNUL	Set species code to UNI if species code is null.	yes		
SPUNI1	Re-assign species code to UNI if the species code is within the following list:AGR,BBA,BCO,BEN,BUT,CDL,DIS,DOS,ESQ,FBA,FRO,GSC,HAK,LEA,LIN, MAC,MDO,MIX,MOK,OFF,ORH,OTH,PIF,PMA,POP,RBY,RCO,RDO,REP,RSN,R UB,SEO,SKA,SKI,SLR,SPE,SQU,SSK,STA,SWA,TAR.	yes		
SPUNI2	Re-assign species code to UNI if the species code is within the following list: BMA,EMA,KAH,SNA,TRE and for all longline catch effort records and for landing/CELR effort and catch records where method is not PS (Purse Seining).	yes		
SPSHA	Reassign species code to SHA if the species code is within the following list:BSH,GSH,HHS,SEV,SOP,SPD.	yes		
SPOFH	Reassign species code to OFH if the species code is OIL.	yes		
SPPOS	Reassign species code to POS if the species code is POR.	yes		
SPDAS	Reassign species code to DAS if the species code is RAY.	yes		
SPSHF	Reassign species code to SHF if the species code is SFN.	yes		
GWCAL	If green weight is null use bin number X bin weight to get the green weight.	no		
MTHSLL	Set method to SLL if fishing method for longline effort is null.	yes		
PSSET7	For method PS if number of sets per day > 7, set number of sets to null.	no		
LONSET2	For method SLL/BLL if number of sets per day > 2, set number of sets to null.	no		

50HK4000	For method SLL/BLL, set number of hooks to null if number of hooks per set is not between 50 and 4000 for non-PHI vessels, for PHI vessels the limit is between 50 and 4600.	yes
NUMWGT	If total catch number per trip per species > 1000 or if no green weight is available and average catch number per species per record >100, set the catch number to catch weight except ALB and YFN species.	yes
NUMWGT2	If the average catch weight fails the lower limit (2kg or more) of the following rules and it is between 0.7 to 1.3 (the difference of estimated catch number and green weight is close to <= 30%), then set the estimated catch number to weight.	yes
1PS160	For method PS and vessel overall length <= 50m if estimated catch weight per set > 160t or < 1t, set the catch to null.	yes
1PS350	For method PS and vessel overall length > 50m if estimated catch weight per set > 350t or < 1t, set the catch to null.	yes
ALB300	For method T/PL and species ALB if catch number per day > 300, set catch number to weight.	yes
ALB2000	For method T/PL and species ALB if catch number per trip > 2000, set catch number to weight.	no
ALB10	For method T/PL and species ALB if green weight per trip > 10t, set green weight to null.	yes
2ALB20	For method T/PL and species ALB if average catch weight <2 kg or > 20 kg, firstly apply rule NUMWGT2, if not applicable then set the catch number to null.	yes
10STN225	For method T/PL and species STN if average catch weight < 10 kg or > 225 kg, firstly apply rule NUMWGT2, if not applicable then set the catch number to null.	yes
25NTUTOR350	For method T/PL and species in (NTU, TOR) if average catch weight < 25 kg or > 350 kg, firstly apply rule NUMWGT2, if not applicable then set the catch number to null.	yes
1YFN70	For method T/PL and species YFN if average catch weight < 1.2 kg or > 70 kg, set the catch number to null.	yes
2ALB45	For method in (HL, SLL, BLL,DL,TL) and species ALB if average catch weight < 2 kg or > 45 kg, firstly apply rule NUMWGT2, if not applicable then set the catch number to null; for TLCER form set catch to null.	yes
15BIG210	For method in (HL, SLL, BLL,DL,TL) and species BIG if average catch weight < 15 kg or > 210 kg, firstly apply rule NUMWGT2, if not applicable then set the catch number to null; for TLCER form set catch to null.	yes
25NTUTOR350L	For method in (HL, SLL, BLL,DL,TL) and species in (NTU,TOR) if average catch weight < 25 kg or > 350 kg, firstly apply rule NUMWGT2, if not applicable then set the catch number to null; for TLCER form set catch to null.	yes
10STN250	For method in (HL, SLL, BLL,DL,TL) and species STN if average catch weight < 10 kg or > 250 kg, firstly apply rule NUMWGT2, if not applicable then set the catch number to null; for TLCER form set catch to null.	yes
7SWO650	For method in (HL, SLL, BLL,DL,TL) and species SWO if average catch weight < 7 kg or > 650 kg, firstly apply rule NUMWGT2, if not applicable then set the catch number to null; for TLCER form set catch to null.	yes

10YFN200	For method in (HL, SLL, BLL,DL,TL) and species YFN if average catch weight < 10 kg or > 200 kg, firstly apply rule NUMWGT2, if not applicable then set the catch number to null; for TLCER form set catch to null.	yes		
SKJ3	For method PS and species SKJ if the ratio of green weight over estimated catch weight > 3 set the catch to null.	yes		
SETNO	For method PS,set no_sets to 1 in the following conditions: 1.the values in no_sets column per day per vessel are null; 2. the values in no_sets column per day per vessel are sequential numbers; 3. the values in no_sets column per day per vessel are all the same as the number of fishing efforts	no		
			BWSFlip	If number of fish is larger than weight, swap the two around

APPENDIX B

Table B1: Predictors used in the swordfish catch-per-unit-effort (CPUE) models.

Variable	Description
Catch-per-unit-effort (CPUE)	Number of fish per 1000 hooks (rounded to the nearest whole number).
Categorical predictor variables	
*Year-quarter (*Year-quarter*)	Calendar year and quarter, Jan–Mar = 1, etc.; all-data model, 108 levels, core-data model, 83 levels, late-series model, 63 levels.
or	
*Year	Calendar year only, core data (21 levels).
Fisheries Management Area (*FMA*)	FMA 1, FMA 2, FMA 9; 3 levels.
Target species (*target*)	Albacore (ALB), bigeye (BIG), southern bluefin (STN), swordfish (SWO), other (OTHER); 5 levels.
Cluster	Métier cluster number (not included in same model as target species).
Time at start of set (*TSOS*)	Nearest hour relative to midnight (-11 to +12), 24 levels.
Vessel (*Vessel*)	Coded vessel registration number (all-data model, 270 and 142 levels; core-data models, 15 levels).
Season	Seasonal 3-monthly quarters evenly defined between January 1st to December 31st (offered to "Year" index CPUE model only, 4 levels)
Continuous predictor variables	
Latitude (*start latitude*)	Latitude (in decimal degrees) at start of set.
Longitude (*start longitude*)	Longitude (in decimal degrees) at start of set.
Latitude*Longitude	Spatial interaction term
Recent effort (*n10d50k*)	Number of sets within 50 km during the previous 10 days.
Soak-time (*soak time*)	Hours from start of set to start of haul.
Hooks per basket (*hooks per basket*)	The number of hooks per basket (i.e. between floats)
Moon phase (*moonbright*)	The fraction of the illumination provided by a full moon (0–1).
Day length (*daylength*)	Length of day (sunrise to sunset, hours).
Night fraction (*night fraction*)	Fraction of the set (soaktime) during the hours of darkness.
Sea surface temperature (*SST*)	Estimated from remotely sensed data – see text (°C).
SST anomaly (*SSTanom*)	Estimated from remotely sensed data – see text (°C).
Sea surface height (*SSH*)	Estimated from remotely sensed data – see text (metres).
Current speed (*CRNTspd*)	Derived from SSH – see text (cm.s-1).
Light stick rate (*light stick rate*)	Number of light sticks per 1000 hooks (late-series model only).
Squid bait % (*Bait_Squid_pct*)	Percentage of hooks baited with squid (late-series model only).
Distance from nearest hill (*nm.hill*)	Distance (nm) from the nearest underwater hill.
Depth	Depth (m) at location of fishing event.
ONI	Oceanic Niño Index, used as a metric for the El Niño Southern Oscillation Index

* Predictive CPUE index term always 'forced' as first model 'explanatory' term. Note: Year-quarter was not offered in the annual (Year) model.

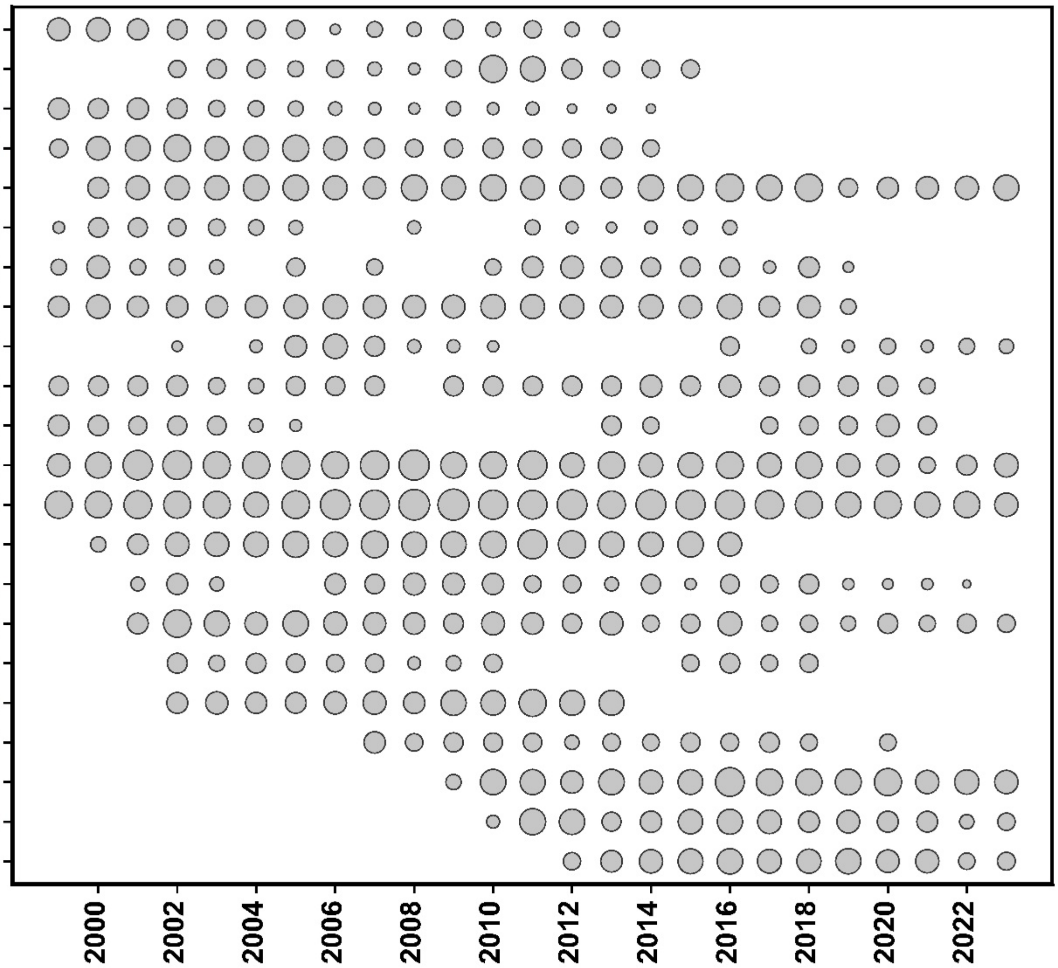

Figure B1: Bubble plot with the relative annual effort (number of sets) by each vessel selected in the core fleet between 1999–2023. The area of the circles is proportional to the number of sets. Each line represents a different vessel on y-axis.

APPENDIX C

Table C1: Annual average swordfish size (kg) by data source. tunaDB = tuna database; EDW = Enterprise Data Warehouse; FNZ = data held by Fisheries New Zealand; commercial catch sampling programme.

Year	tunaDB	EDW	FNZ	Commercial catch sampling
1993	54.7			
1994	53.0			
1995	65.4			
1996	59.5			
1997	60.4			
1998	56.3			
1999	61.8			
2000	57.9			
2001	51.1			
2002	50.7			
2003	51.7			
2004	53.8			
2005	51.0			61.3
2006	46.8			46.7
2007	46.8			49.1
2008	47.2			55.7
2009	45.0			47.3
2010	41.6			48.9
2011	41.2			51.0
2012	47.7			51.5
2013	49.0			53.7
2014	53.3			66.4
2015	57.0			68.4
2016	56.3			80.8
2017	64.3			87.5
2018	53.5			67.7
2019	60.4			79.6
2020		62.7	62.5	63.9
2021		62.5	87.2	56.7
2022		56.9	80.3	52.1
2023		57.6	58.9	55.0

APPENDIX D

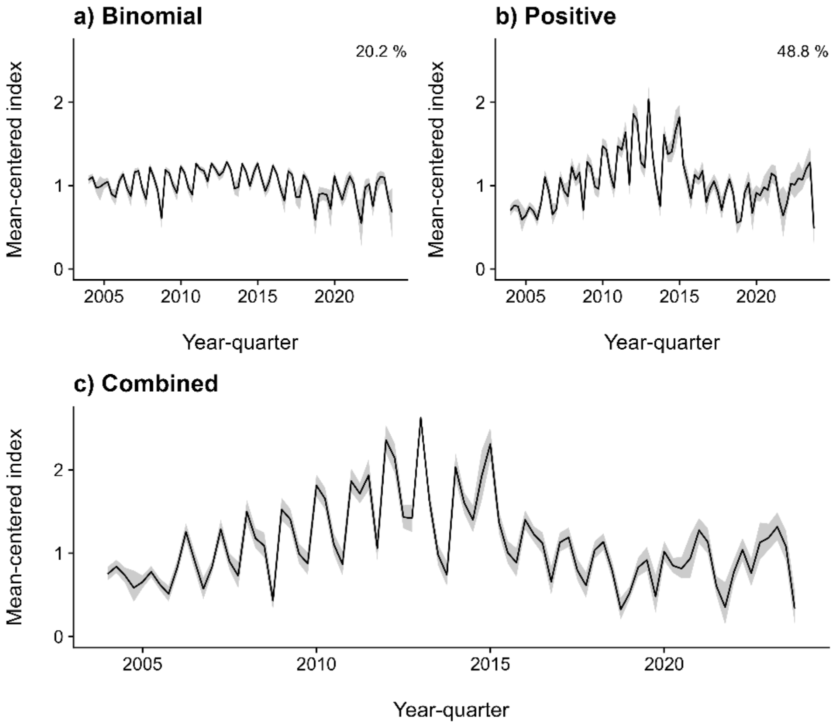

Figure D1: Mean-centred standardised CPUE indices for the binomial component (top left), positive catch component (top right) and combined index (bottom) for the core vessels short (i.e., 2004–2023) standardisation model with a year-quarter time step. Shaded regions represent 95% confidence intervals.

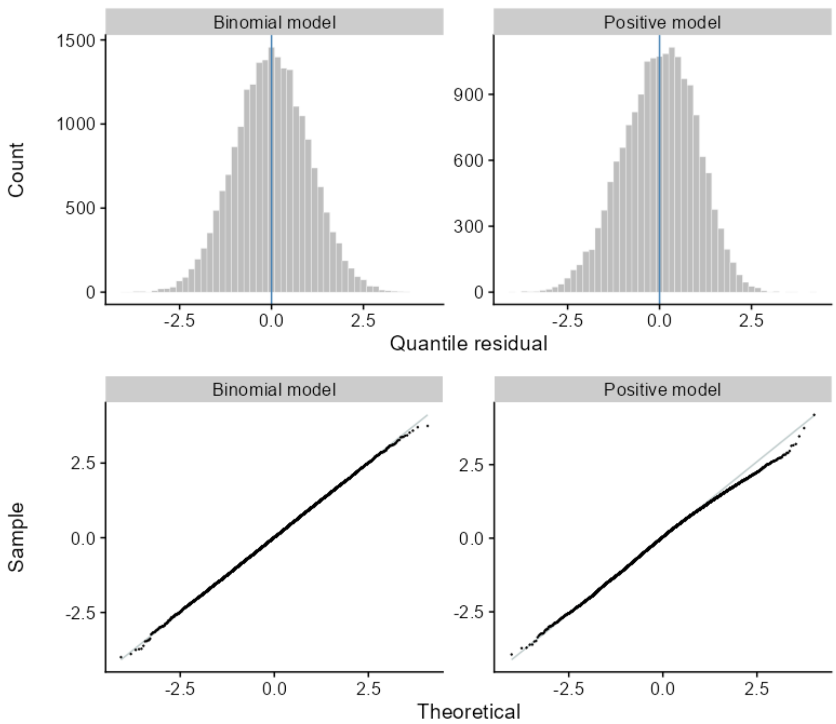

Figure D2: Residuals for the binomial (left) and positive catch (right) components of the core vessels short (i.e., 2004–2023) standardisation model with a year-quarter time step.

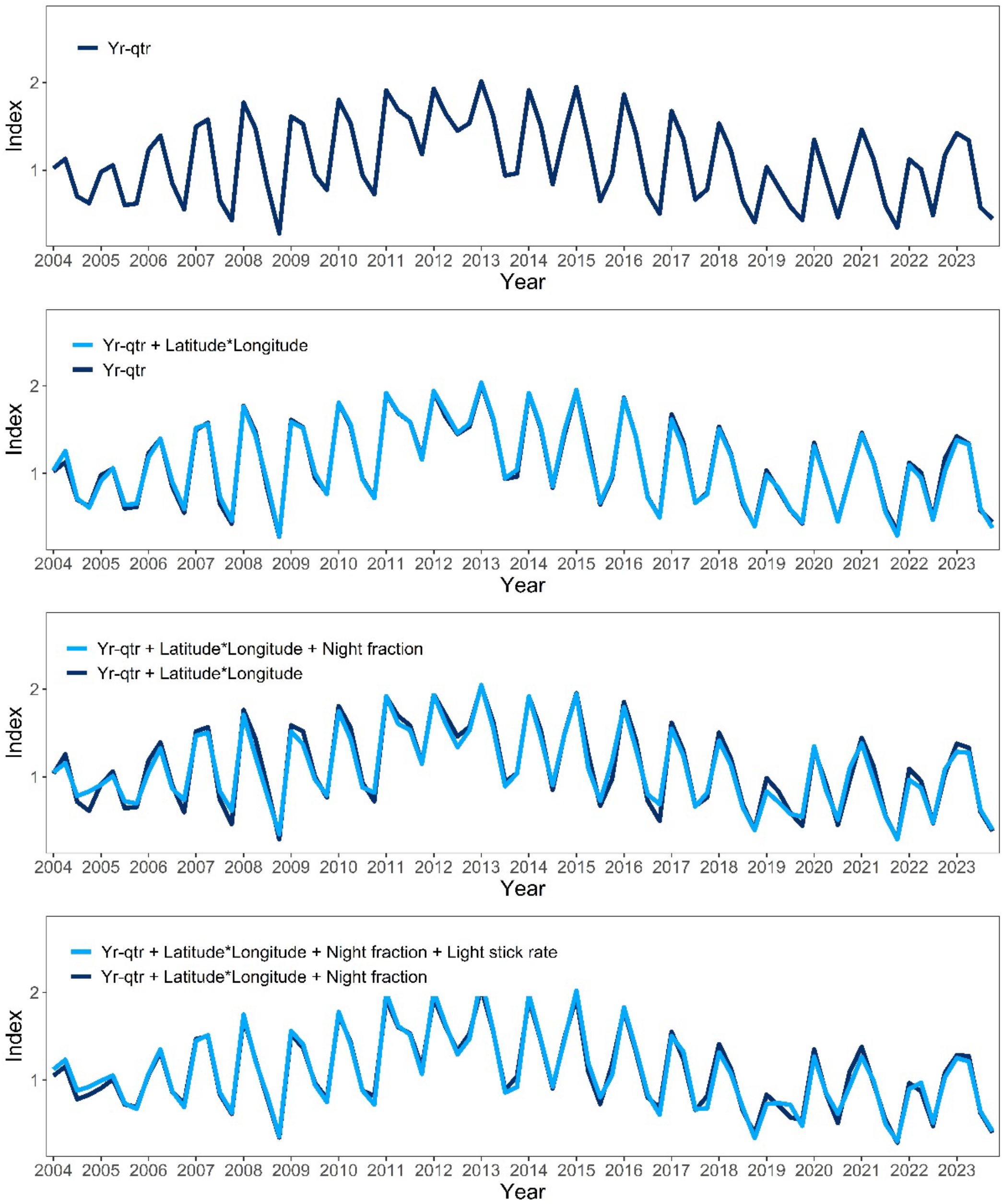

Figure D3: Stepwise influence plots showing the impact of sequentially adding predictor variables for the binomial component of the core vessels short (i.e., 2004–2023) standardisation model with a year-quarter time step.

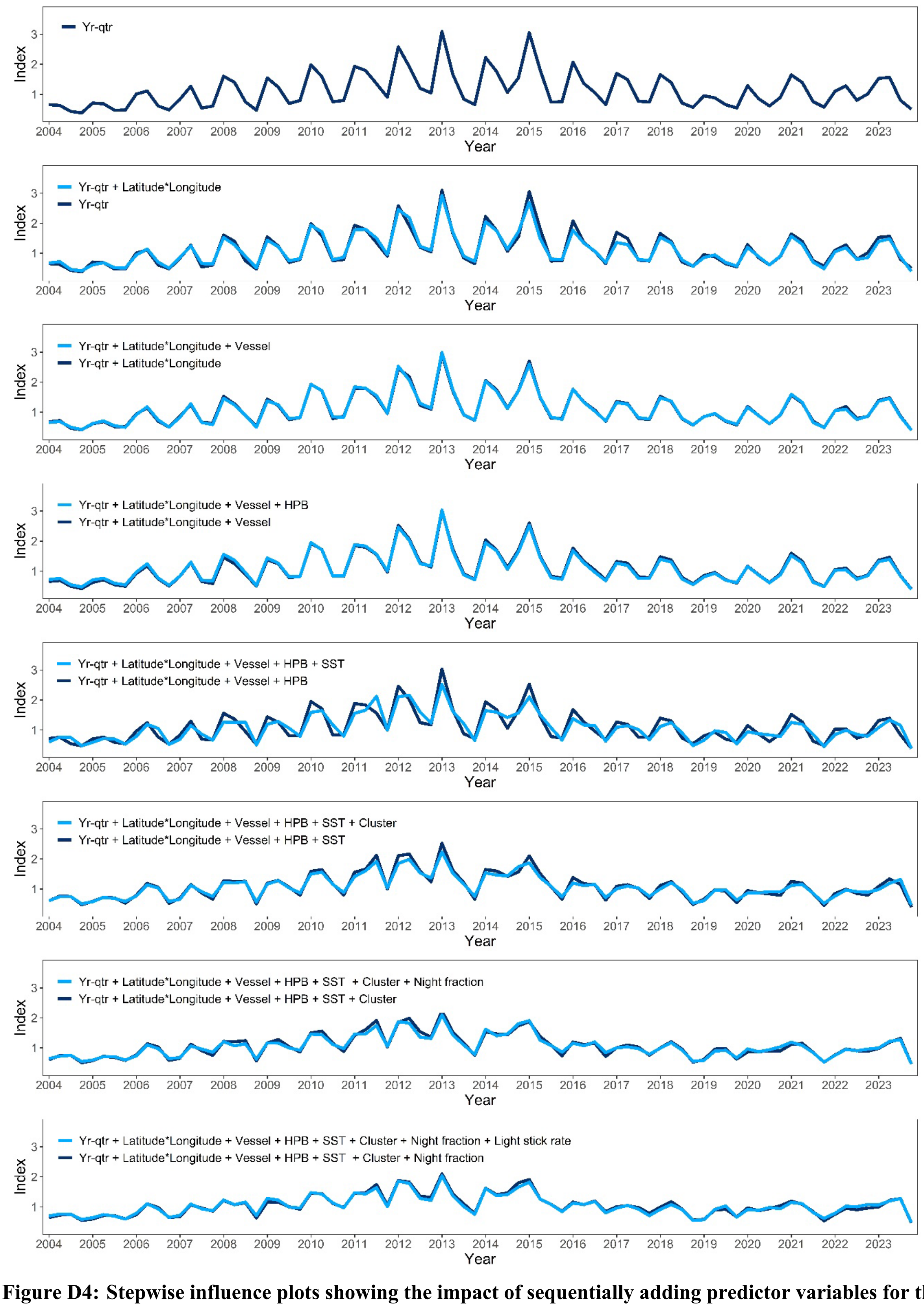

Figure D4: Stepwise influence plots showing the impact of sequentially adding predictor variables for the binomial component of the core vessels short (i.e., 2004–2023) standardisation model with a year-quarter time step.

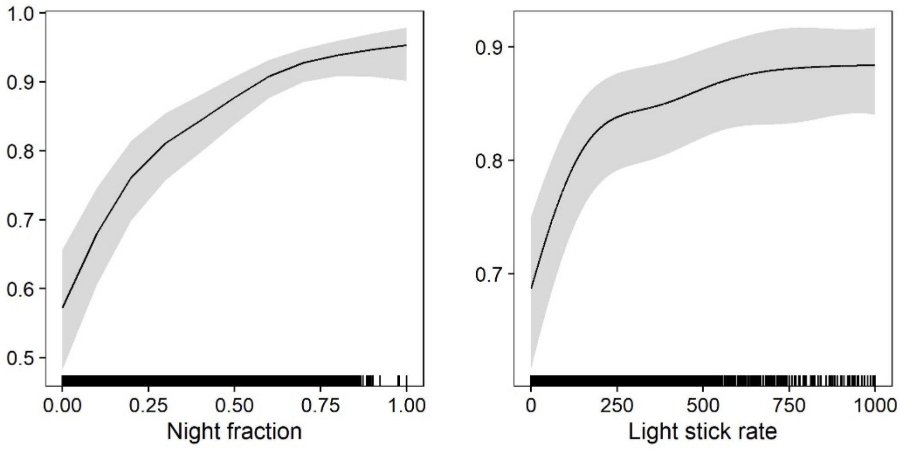

Figure D5: Effects of retained variables for the binomial component for the core vessels short (i.e., 2004–2023) standardisation model with a year-quarter time step. Plots show the partial effects of the respective variable on the probability of capturing a swordfish and their standard error (grey shading).

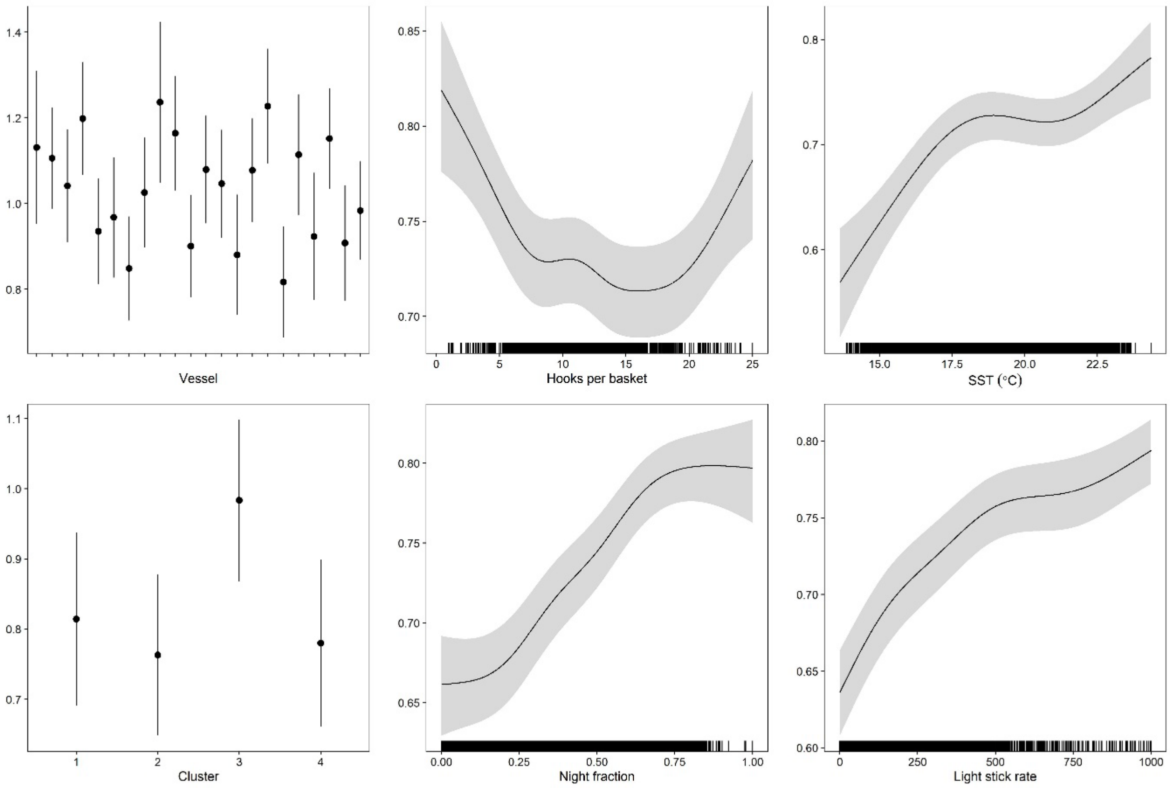

Figure D6: Effects of retained variables for the positive catch component for the core vessels short (i.e., 2004–2023) standardisation model with a year-quarter time step. Plots show the partial effects of the respective variable on CPUE and their standard error (grey shading).

Table D1: Model indices for the year-quarter models. Lower bound is the 2.5th quantile, upper bound in 97.5th quantile.

Year-quarter	Series	Component	Index	Lower bound	Upper bound
1999_01	Core vessels long	Combined	0.936	0.793	1.069
1999_02	Core vessels long	Combined	1.029	0.881	1.187
1999_03	Core vessels long	Combined	1.207	1.013	1.419
1999_04	Core vessels long	Combined	0.583	0.476	0.706
2000_01	Core vessels long	Combined	1.006	0.897	1.122
2000_02	Core vessels long	Combined	1.010	0.897	1.133
2000_03	Core vessels long	Combined	0.705	0.599	0.833
2000_04	Core vessels long	Combined	0.413	0.324	0.525
2001_01	Core vessels long	Combined	0.800	0.708	0.897
2001_02	Core vessels long	Combined	0.990	0.887	1.101
2001_03	Core vessels long	Combined	0.706	0.623	0.800
2001_04	Core vessels long	Combined	0.664	0.561	0.783
2002_01	Core vessels long	Combined	0.870	0.784	0.959
2002_02	Core vessels long	Combined	0.784	0.714	0.855
2002_03	Core vessels long	Combined	0.670	0.586	0.767
2002_04	Core vessels long	Combined	0.395	0.316	0.489
2003_01	Core vessels long	Combined	0.768	0.687	0.855
2003_02	Core vessels long	Combined	0.692	0.629	0.757
2003_03	Core vessels long	Combined	0.477	0.387	0.572
2003_04	Core vessels long	Combined	0.231	0.164	0.315
2004_01	Core vessels long	Combined	0.755	0.671	0.840
2004_02	Core vessels long	Combined	0.928	0.849	1.022
2004_03	Core vessels long	Combined	0.700	0.603	0.801
2004_04	Core vessels long	Combined	0.522	0.363	0.715
2005_01	Core vessels long	Combined	0.672	0.593	0.755
2005_02	Core vessels long	Combined	0.802	0.726	0.878
2005_03	Core vessels long	Combined	0.681	0.598	0.771
2005_04	Core vessels long	Combined	0.506	0.409	0.616
2006_01	Core vessels long	Combined	0.826	0.737	0.919
2006_02	Core vessels long	Combined	1.422	1.308	1.544
2006_03	Core vessels long	Combined	1.026	0.907	1.153
2006_04	Core vessels long	Combined	0.520	0.406	0.657
2007_01	Core vessels long	Combined	0.914	0.830	1.004
2007_02	Core vessels long	Combined	1.400	1.283	1.535
2007_03	Core vessels long	Combined	0.944	0.844	1.044
2007_04	Core vessels long	Combined	0.688	0.538	0.845
2008_01	Core vessels long	Combined	1.706	1.551	1.881
2008_02	Core vessels long	Combined	1.306	1.169	1.450
2008_03	Core vessels long	Combined	1.079	0.935	1.232
2008_04	Core vessels long	Combined	0.352	0.256	0.454
2009_01	Core vessels long	Combined	1.618	1.460	1.790
2009_02	Core vessels long	Combined	1.502	1.366	1.646

Year-quarter	Series	Component	Index	Lower bound	Upper bound
2009_03	Core vessels long	Combined	1.101	0.972	1.241
2009_04	Core vessels long	Combined	0.846	0.711	0.980
2010_01	Core vessels long	Combined	2.102	1.922	2.285
2010_02	Core vessels long	Combined	2.007	1.851	2.182
2010_03	Core vessels long	Combined	1.237	1.086	1.379
2010_04	Core vessels long	Combined	0.935	0.784	1.094
2011_01	Core vessels long	Combined	2.322	2.139	2.520
2011_02	Core vessels long	Combined	2.038	1.887	2.204
2011_03	Core vessels long	Combined	2.393	2.189	2.627
2011_04	Core vessels long	Combined	1.206	1.030	1.389
2012_01	Core vessels long	Combined	3.077	2.829	3.340
2012_02	Core vessels long	Combined	2.589	2.370	2.809
2012_03	Core vessels long	Combined	1.733	1.568	1.912
2012_04	Core vessels long	Combined	1.630	1.431	1.833
2013_01	Core vessels long	Combined	3.341	3.042	3.663
2013_02	Core vessels long	Combined	1.997	1.846	2.161
2013_03	Core vessels long	Combined	1.052	0.938	1.195
2013_04	Core vessels long	Combined	0.801	0.639	0.976
2014_01	Core vessels long	Combined	2.494	2.283	2.736
2014_02	Core vessels long	Combined	2.016	1.858	2.191
2014_03	Core vessels long	Combined	1.572	1.409	1.751
2014_04	Core vessels long	Combined	2.228	1.894	2.582
2015_01	Core vessels long	Combined	2.716	2.482	2.984
2015_02	Core vessels long	Combined	1.457	1.317	1.608
2015_03	Core vessels long	Combined	1.048	0.927	1.194
2015_04	Core vessels long	Combined	0.972	0.793	1.175
2016_01	Core vessels long	Combined	1.685	1.537	1.841
2016_02	Core vessels long	Combined	1.388	1.285	1.494
2016_03	Core vessels long	Combined	1.327	1.195	1.476
2016_04	Core vessels long	Combined	0.743	0.578	0.951
2017_01	Core vessels long	Combined	1.340	1.206	1.480
2017_02	Core vessels long	Combined	1.288	1.174	1.410
2017_03	Core vessels long	Combined	0.869	0.735	0.995
2017_04	Core vessels long	Combined	0.714	0.548	0.900
2018_01	Core vessels long	Combined	1.259	1.137	1.392
2018_02	Core vessels long	Combined	1.446	1.316	1.578
2018_03	Core vessels long	Combined	0.829	0.717	0.954
2018_04	Core vessels long	Combined	0.327	0.216	0.464
2019_01	Core vessels long	Combined	0.565	0.486	0.656
2019_02	Core vessels long	Combined	0.862	0.746	0.984
2019_03	Core vessels long	Combined	0.781	0.642	0.927
2019_04	Core vessels long	Combined	0.519	0.287	0.825
2020_01	Core vessels long	Combined	1.241	1.097	1.401
2020_02	Core vessels long	Combined	0.925	0.824	1.036
2020_03	Core vessels long	Combined	0.738	0.611	0.865

Year-quarter	Series	Component	Index	Lower bound	Upper bound
2020_04	Core vessels long	Combined	1.141	0.862	1.432
2021_01	Core vessels long	Combined	1.636	1.443	1.848
2021_02	Core vessels long	Combined	1.248	1.077	1.431
2021_03	Core vessels long	Combined	0.794	0.640	0.954
2021_04	Core vessels long	Combined	0.270	0.100	0.550
2022_01	Core vessels long	Combined	0.863	0.715	1.024
2022_02	Core vessels long	Combined	1.056	0.898	1.222
2022_03	Core vessels long	Combined	0.779	0.609	0.967
2022_04	Core vessels long	Combined	1.141	0.925	1.377
2023_01	Core vessels long	Combined	1.355	1.181	1.546
2023_02	Core vessels long	Combined	1.766	1.570	1.987
2023_03	Core vessels long	Combined	1.140	0.934	1.354
2023_04	Core vessels long	Combined	0.324	0.144	0.559
2004_01	Core vessels short	Combined	0.751	0.676	0.832
2004_02	Core vessels short	Combined	0.837	0.766	0.911
2004_03	Core vessels short	Combined	0.730	0.643	0.829
2004_04	Core vessels short	Combined	0.581	0.424	0.776
2005_01	Core vessels short	Combined	0.655	0.576	0.742
2005_02	Core vessels short	Combined	0.775	0.706	0.842
2005_03	Core vessels short	Combined	0.624	0.556	0.700
2005_04	Core vessels short	Combined	0.514	0.418	0.625
2006_01	Core vessels short	Combined	0.833	0.750	0.920
2006_02	Core vessels short	Combined	1.253	1.154	1.348
2006_03	Core vessels short	Combined	0.908	0.806	1.025
2006_04	Core vessels short	Combined	0.575	0.455	0.715
2007_01	Core vessels short	Combined	0.834	0.757	0.910
2007_02	Core vessels short	Combined	1.286	1.183	1.388
2007_03	Core vessels short	Combined	0.898	0.802	1.002
2007_04	Core vessels short	Combined	0.730	0.594	0.893
2008_01	Core vessels short	Combined	1.499	1.366	1.635
2008_02	Core vessels short	Combined	1.179	1.060	1.303
2008_03	Core vessels short	Combined	1.088	0.944	1.230
2008_04	Core vessels short	Combined	0.437	0.326	0.577
2009_01	Core vessels short	Combined	1.527	1.401	1.668
2009_02	Core vessels short	Combined	1.411	1.289	1.538
2009_03	Core vessels short	Combined	0.997	0.884	1.117
2009_04	Core vessels short	Combined	0.871	0.751	1.006
2010_01	Core vessels short	Combined	1.808	1.664	1.947
2010_02	Core vessels short	Combined	1.649	1.519	1.781
2010_03	Core vessels short	Combined	1.109	0.990	1.254
2010_04	Core vessels short	Combined	0.868	0.725	1.018
2011_01	Core vessels short	Combined	1.863	1.722	2.010
2011_02	Core vessels short	Combined	1.715	1.589	1.841
2011_03	Core vessels short	Combined	1.936	1.765	2.134
2011_04	Core vessels short	Combined	1.060	0.903	1.229

Year-quarter	Series	Component	Index	Lower bound	Upper bound
2012_01	Core vessels short	Combined	2.353	2.181	2.543
2012_02	Core vessels short	Combined	2.137	1.968	2.329
2012_03	Core vessels short	Combined	1.438	1.306	1.582
2012_04	Core vessels short	Combined	1.421	1.263	1.593
2013_01	Core vessels short	Combined	2.620	2.420	2.836
2013_02	Core vessels short	Combined	1.624	1.512	1.749
2013_03	Core vessels short	Combined	0.979	0.869	1.104
2013_04	Core vessels short	Combined	0.744	0.609	0.914
2014_01	Core vessels short	Combined	2.034	1.882	2.206
2014_02	Core vessels short	Combined	1.603	1.478	1.737
2014_03	Core vessels short	Combined	1.398	1.238	1.583
2014_04	Core vessels short	Combined	1.935	1.651	2.261
2015_01	Core vessels short	Combined	2.306	2.122	2.496
2015_02	Core vessels short	Combined	1.369	1.232	1.503
2015_03	Core vessels short	Combined	1.010	0.886	1.156
2015_04	Core vessels short	Combined	0.885	0.729	1.060
2016_01	Core vessels short	Combined	1.399	1.288	1.513
2016_02	Core vessels short	Combined	1.225	1.128	1.323
2016_03	Core vessels short	Combined	1.119	0.990	1.268
2016_04	Core vessels short	Combined	0.657	0.499	0.836
2017_01	Core vessels short	Combined	1.122	1.021	1.231
2017_02	Core vessels short	Combined	1.184	1.089	1.287
2017_03	Core vessels short	Combined	0.797	0.673	0.929
2017_04	Core vessels short	Combined	0.612	0.477	0.767
2018_01	Core vessels short	Combined	1.036	0.933	1.143
2018_02	Core vessels short	Combined	1.136	1.039	1.243
2018_03	Core vessels short	Combined	0.793	0.692	0.898
2018_04	Core vessels short	Combined	0.321	0.210	0.462
2019_01	Core vessels short	Combined	0.519	0.444	0.600
2019_02	Core vessels short	Combined	0.831	0.719	0.951
2019_03	Core vessels short	Combined	0.914	0.776	1.049
2019_04	Core vessels short	Combined	0.488	0.283	0.742
2020_01	Core vessels short	Combined	1.017	0.898	1.142
2020_02	Core vessels short	Combined	0.851	0.764	0.940
2020_03	Core vessels short	Combined	0.816	0.693	0.946
2020_04	Core vessels short	Combined	0.942	0.711	1.213
2021_01	Core vessels short	Combined	1.275	1.121	1.440
2021_02	Core vessels short	Combined	1.133	0.991	1.283
2021_03	Core vessels short	Combined	0.603	0.494	0.719
2021_04	Core vessels short	Combined	0.349	0.149	0.636
2022_01	Core vessels short	Combined	0.771	0.641	0.904
2022_02	Core vessels short	Combined	1.037	0.897	1.191
2022_03	Core vessels short	Combined	0.761	0.595	0.970
2022_04	Core vessels short	Combined	1.126	0.916	1.364
2023_01	Core vessels short	Combined	1.190	1.036	1.339

Year-quarter	Series	Component	Index	Lower bound	Upper bound
2023_02	Core vessels short	Combined	1.317	1.168	1.470
2023_03	Core vessels short	Combined	1.076	0.895	1.277
2023_04	Core vessels short	Combined	0.341	0.151	0.601
1993_01	All vessels long	Combined	0.715	0.511	0.938
1993_02	All vessels long	Combined	0.576	0.393	0.754
1993_03	All vessels long	Combined	0.578	0.200	1.046
1993_04	All vessels long	Combined	0.264	0.131	0.448
1994_01	All vessels long	Combined	0.557	0.375	0.726
1994_02	All vessels long	Combined	0.759	0.530	0.996
1994_03	All vessels long	Combined	0.872	0.661	1.129
1994_04	All vessels long	Combined	0.456	0.250	0.728
1995_01	All vessels long	Combined	0.472	0.320	0.632
1995_02	All vessels long	Combined	0.651	0.453	0.843
1995_03	All vessels long	Combined	0.545	0.250	0.995
1995_04	All vessels long	Combined	0.326	0.195	0.478
1996_01	All vessels long	Combined	0.697	0.548	0.845
1996_02	All vessels long	Combined	0.591	0.443	0.751
1996_03	All vessels long	Combined	0.752	0.449	1.142
1996_04	All vessels long	Combined	0.432	0.249	0.651
1997_01	All vessels long	Combined	0.794	0.597	0.985
1997_02	All vessels long	Combined	0.752	0.520	0.994
1997_03	All vessels long	Combined	0.883	0.590	1.202
1997_04	All vessels long	Combined	0.229	0.127	0.369
1998_01	All vessels long	Combined	0.920	0.727	1.127
1998_02	All vessels long	Combined	1.314	1.121	1.554
1998_03	All vessels long	Combined	0.808	0.608	0.990
1998_04	All vessels long	Combined	0.605	0.460	0.742
1999_01	All vessels long	Combined	0.960	0.772	1.163
1999_02	All vessels long	Combined	1.232	1.047	1.460
1999_03	All vessels long	Combined	0.998	0.811	1.176
1999_04	All vessels long	Combined	0.583	0.468	0.691
2000_01	All vessels long	Combined	1.246	1.046	1.531
2000_02	All vessels long	Combined	1.308	1.155	1.506
2000_03	All vessels long	Combined	0.895	0.765	1.019
2000_04	All vessels long	Combined	0.463	0.365	0.561
2001_01	All vessels long	Combined	1.188	1.035	1.391
2001_02	All vessels long	Combined	1.390	1.218	1.628
2001_03	All vessels long	Combined	0.886	0.764	1.009
2001_04	All vessels long	Combined	0.687	0.596	0.778
2002_01	All vessels long	Combined	1.051	0.936	1.200
2002_02	All vessels long	Combined	0.943	0.826	1.080
2002_03	All vessels long	Combined	0.741	0.637	0.838
2002_04	All vessels long	Combined	0.382	0.280	0.482
2003_01	All vessels long	Combined	0.890	0.804	0.990
2003_02	All vessels long	Combined	0.767	0.617	0.919

Year-quarter	Series	Component	Index	Lower bound	Upper bound
2003_03	All vessels long	Combined	0.544	0.432	0.651
2003_04	All vessels long	Combined	0.179	0.122	0.248
2004_01	All vessels long	Combined	0.804	0.692	0.923
2004_02	All vessels long	Combined	1.004	0.900	1.136
2004_03	All vessels long	Combined	0.662	0.527	0.784
2004_04	All vessels long	Combined	0.447	0.289	0.628
2005_01	All vessels long	Combined	0.795	0.679	0.912
2005_02	All vessels long	Combined	0.849	0.743	0.952
2005_03	All vessels long	Combined	0.734	0.606	0.843
2005_04	All vessels long	Combined	0.506	0.386	0.625
2006_01	All vessels long	Combined	1.030	0.905	1.190
2006_02	All vessels long	Combined	1.744	1.514	2.050
2006_03	All vessels long	Combined	1.187	1.043	1.331
2006_04	All vessels long	Combined	0.555	0.421	0.703
2007_01	All vessels long	Combined	1.087	0.927	1.292
2007_02	All vessels long	Combined	1.644	1.402	1.956
2007_03	All vessels long	Combined	0.994	0.851	1.123
2007_04	All vessels long	Combined	0.613	0.442	0.784
2008_01	All vessels long	Combined	2.226	1.778	2.901
2008_02	All vessels long	Combined	1.730	1.478	2.068
2008_03	All vessels long	Combined	1.099	0.899	1.299
2008_04	All vessels long	Combined	0.274	0.177	0.397
2009_01	All vessels long	Combined	1.819	1.543	2.169
2009_02	All vessels long	Combined	2.028	1.739	2.423
2009_03	All vessels long	Combined	1.322	1.160	1.524
2009_04	All vessels long	Combined	0.744	0.568	0.923
2010_01	All vessels long	Combined	2.767	2.210	3.556
2010_02	All vessels long	Combined	2.478	2.104	2.981
2010_03	All vessels long	Combined	1.389	1.220	1.581
2010_04	All vessels long	Combined	0.981	0.807	1.161
2011_01	All vessels long	Combined	3.202	2.464	4.314
2011_02	All vessels long	Combined	2.503	2.115	3.016
2011_03	All vessels long	Combined	2.708	2.283	3.273
2011_04	All vessels long	Combined	1.332	1.134	1.565
2012_01	All vessels long	Combined	4.438	3.364	6.048
2012_02	All vessels long	Combined	3.457	2.821	4.364
2012_03	All vessels long	Combined	2.439	2.024	2.961
2012_04	All vessels long	Combined	2.098	1.704	2.585
2013_01	All vessels long	Combined	4.583	3.439	6.419
2013_02	All vessels long	Combined	2.452	2.050	2.987
2013_03	All vessels long	Combined	1.162	0.981	1.327
2013_04	All vessels long	Combined	0.861	0.661	1.067
2014_01	All vessels long	Combined	3.454	2.637	4.773
2014_02	All vessels long	Combined	2.682	2.209	3.355
2014_03	All vessels long	Combined	1.605	1.378	1.850

Year-quarter	Series	Component	Index	Lower bound	Upper bound
2014_04	All vessels long	Combined	2.877	2.243	3.804
2015_01	All vessels long	Combined	3.888	2.940	5.345
2015_02	All vessels long	Combined	1.959	1.713	2.264
2015_03	All vessels long	Combined	1.107	0.911	1.299
2015_04	All vessels long	Combined	1.114	0.870	1.406
2016_01	All vessels long	Combined	2.409	1.872	3.210
2016_02	All vessels long	Combined	1.734	1.506	2.057
2016_03	All vessels long	Combined	1.359	1.163	1.544
2016_04	All vessels long	Combined	0.626	0.456	0.812
2017_01	All vessels long	Combined	1.710	1.404	2.138
2017_02	All vessels long	Combined	1.402	1.232	1.615
2017_03	All vessels long	Combined	0.948	0.749	1.152
2017_04	All vessels long	Combined	0.749	0.593	0.922
2018_01	All vessels long	Combined	1.697	1.402	2.068
2018_02	All vessels long	Combined	1.681	1.488	1.930
2018_03	All vessels long	Combined	0.706	0.553	0.851
2018_04	All vessels long	Combined	0.302	0.208	0.414
2019_01	All vessels long	Combined	0.616	0.496	0.722
2019_02	All vessels long	Combined	1.155	0.998	1.314
2019_03	All vessels long	Combined	0.779	0.604	0.942
2019_04	All vessels long	Combined	0.496	0.316	0.711
2020_01	All vessels long	Combined	1.598	1.317	1.977
2020_02	All vessels long	Combined	1.162	1.004	1.330
2020_03	All vessels long	Combined	0.637	0.481	0.785
2020_04	All vessels long	Combined	1.185	0.949	1.453
2021_01	All vessels long	Combined	2.312	1.906	2.832
2021_02	All vessels long	Combined	1.764	1.539	2.023
2021_03	All vessels long	Combined	0.765	0.563	0.954
2021_04	All vessels long	Combined	0.268	0.136	0.439
2022_01	All vessels long	Combined	0.940	0.753	1.132
2022_02	All vessels long	Combined	1.339	1.138	1.562
2022_03	All vessels long	Combined	0.701	0.488	0.907
2022_04	All vessels long	Combined	1.165	0.908	1.451
2023_01	All vessels long	Combined	1.553	1.324	1.839
2023_02	All vessels long	Combined	2.113	1.794	2.519
2023_03	All vessels long	Combined	1.093	0.868	1.312
2023_04	All vessels long	Combined	0.489	0.308	0.716
2004_01	All vessels short	Combined	0.833	0.758	0.922
2004_02	All vessels short	Combined	0.934	0.594	1.152
2004_03	All vessels short	Combined	0.625	0.085	1.004
2004_04	All vessels short	Combined	0.479	0.179	0.739
2005_01	All vessels short	Combined	0.702	0.463	0.875
2005_02	All vessels short	Combined	0.794	0.453	1.034
2005_03	All vessels short	Combined	0.667	0.398	0.881
2005_04	All vessels short	Combined	0.479	0.227	0.697

Year-quarter	Series	Component	Index	Lower bound	Upper bound
2006_01	All vessels short	Combined	0.939	0.734	1.116
2006_02	All vessels short	Combined	1.387	1.108	1.628
2006_03	All vessels short	Combined	0.941	0.326	1.320
2006_04	All vessels short	Combined	0.525	0.130	0.886
2007_01	All vessels short	Combined	0.847	0.582	1.044
2007_02	All vessels short	Combined	1.255	0.833	1.561
2007_03	All vessels short	Combined	0.817	0.448	1.098
2007_04	All vessels short	Combined	0.658	0.290	0.977
2008_01	All vessels short	Combined	1.635	1.399	1.900
2008_02	All vessels short	Combined	1.252	0.475	1.709
2008_03	All vessels short	Combined	0.906	0.061	1.514
2008_04	All vessels short	Combined	0.383	0.099	0.742
2009_01	All vessels short	Combined	1.492	1.234	1.752
2009_02	All vessels short	Combined	1.484	1.103	1.784
2009_03	All vessels short	Combined	0.950	0.497	1.293
2009_04	All vessels short	Combined	0.710	0.270	1.092
2010_01	All vessels short	Combined	1.760	0.681	2.265
2010_02	All vessels short	Combined	1.708	1.341	2.036
2010_03	All vessels short	Combined	1.079	0.687	1.371
2010_04	All vessels short	Combined	0.799	0.468	1.064
2011_01	All vessels short	Combined	2.102	1.824	2.401
2011_02	All vessels short	Combined	1.789	1.627	1.979
2011_03	All vessels short	Combined	1.890	1.712	2.106
2011_04	All vessels short	Combined	0.994	0.840	1.162
2012_01	All vessels short	Combined	2.762	2.469	3.107
2012_02	All vessels short	Combined	2.511	2.267	2.819
2012_03	All vessels short	Combined	1.624	1.474	1.806
2012_04	All vessels short	Combined	1.360	1.202	1.550
2013_01	All vessels short	Combined	2.899	2.557	3.297
2013_02	All vessels short	Combined	1.768	1.602	1.955
2013_03	All vessels short	Combined	1.035	0.893	1.192
2013_04	All vessels short	Combined	0.609	0.496	0.743
2014_01	All vessels short	Combined	2.208	1.962	2.511
2014_02	All vessels short	Combined	1.871	1.689	2.070
2014_03	All vessels short	Combined	1.388	1.159	1.628
2014_04	All vessels short	Combined	1.855	1.570	2.191
2015_01	All vessels short	Combined	2.455	2.179	2.803
2015_02	All vessels short	Combined	1.569	1.408	1.759
2015_03	All vessels short	Combined	1.040	0.884	1.201
2015_04	All vessels short	Combined	0.873	0.731	1.036
2016_01	All vessels short	Combined	1.635	1.460	1.855
2016_02	All vessels short	Combined	1.347	1.223	1.494
2016_03	All vessels short	Combined	1.175	1.033	1.313
2016_04	All vessels short	Combined	0.513	0.384	0.676
2017_01	All vessels short	Combined	1.159	1.040	1.304

Year-quarter	Series	Component	Index	Lower bound	Upper bound
2017_02	All vessels short	Combined	1.146	1.004	1.288
2017_03	All vessels short	Combined	0.919	0.749	1.093
2017_04	All vessels short	Combined	0.564	0.460	0.675
2018_01	All vessels short	Combined	1.108	0.996	1.254
2018_02	All vessels short	Combined	1.214	1.095	1.345
2018_03	All vessels short	Combined	0.725	0.611	0.839
2018_04	All vessels short	Combined	0.237	0.164	0.328
2019_01	All vessels short	Combined	0.503	0.408	0.597
2019_02	All vessels short	Combined	0.954	0.830	1.073
2019_03	All vessels short	Combined	0.772	0.611	0.922
2019_04	All vessels short	Combined	0.452	0.300	0.616
2020_01	All vessels short	Combined	1.097	0.971	1.237
2020_02	All vessels short	Combined	0.997	0.876	1.119
2020_03	All vessels short	Combined	0.719	0.580	0.851
2020_04	All vessels short	Combined	0.751	0.619	0.889
2021_01	All vessels short	Combined	1.531	1.331	1.742
2021_02	All vessels short	Combined	1.427	1.245	1.620
2021_03	All vessels short	Combined	0.664	0.515	0.812
2021_04	All vessels short	Combined	0.303	0.163	0.490
2022_01	All vessels short	Combined	0.787	0.663	0.917
2022_02	All vessels short	Combined	1.219	1.058	1.395
2022_03	All vessels short	Combined	0.769	0.578	0.953
2022_04	All vessels short	Combined	1.096	0.883	1.330
2023_01	All vessels short	Combined	1.256	1.079	1.445
2023_02	All vessels short	Combined	1.436	1.273	1.617
2023_03	All vessels short	Combined	1.013	0.854	1.180
2023_04	All vessels short	Combined	0.549	0.380	0.750

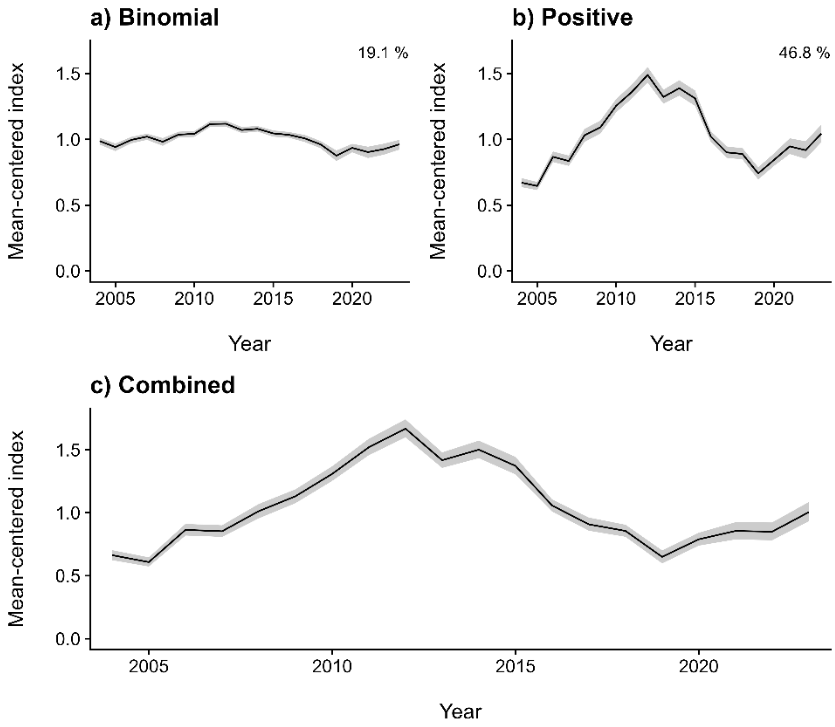

Figure D7: Mean-centred standardised CPUE indices for the binomial component (top left), positive catch component (top right) and combined index (bottom) for the core vessels short (i.e., 2004–2023) standardisation model with annual time step. Shaded regions represent 95% confidence intervals.

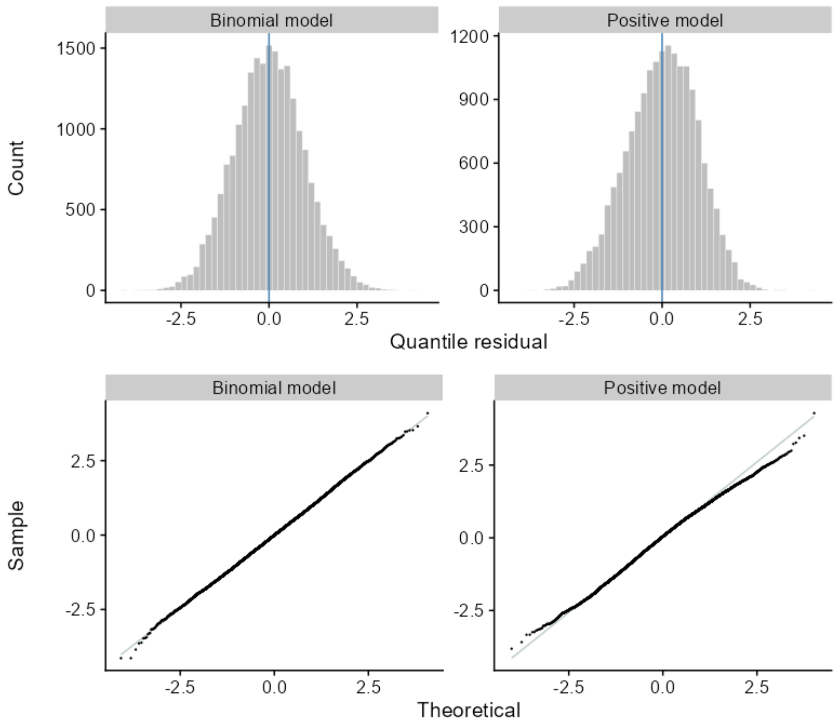

Figure D8: Residuals for the binomial (left) and positive catch (right) components of the core vessels short (i.e., 2004–2023) standardisation model with an annual time step.

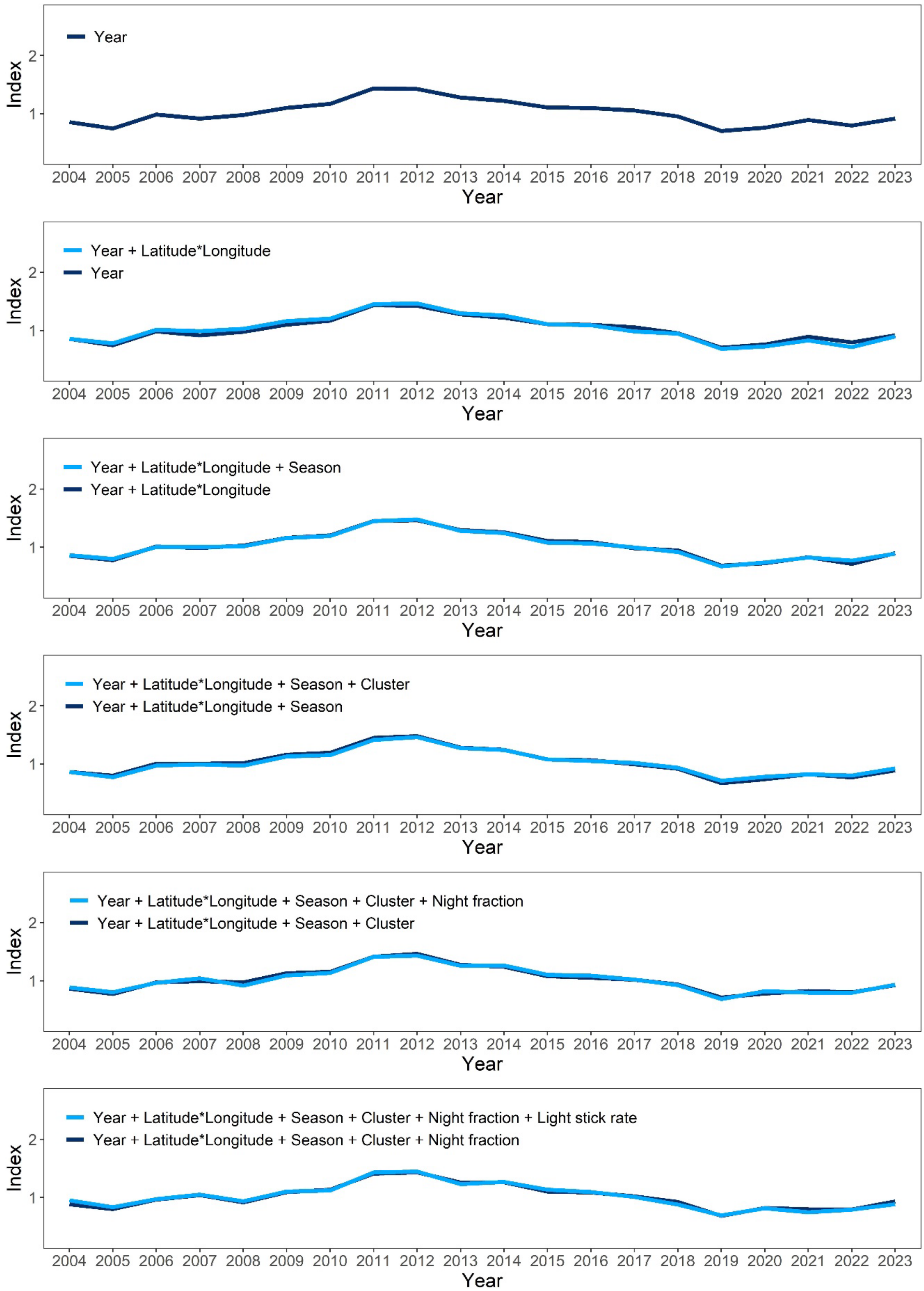

Figure D9: Stepwise influence plots showing the impact of sequentially adding predictor variables for the binomial component of the core vessels short (i.e., 2004–2023) standardisation model with an annual time step.

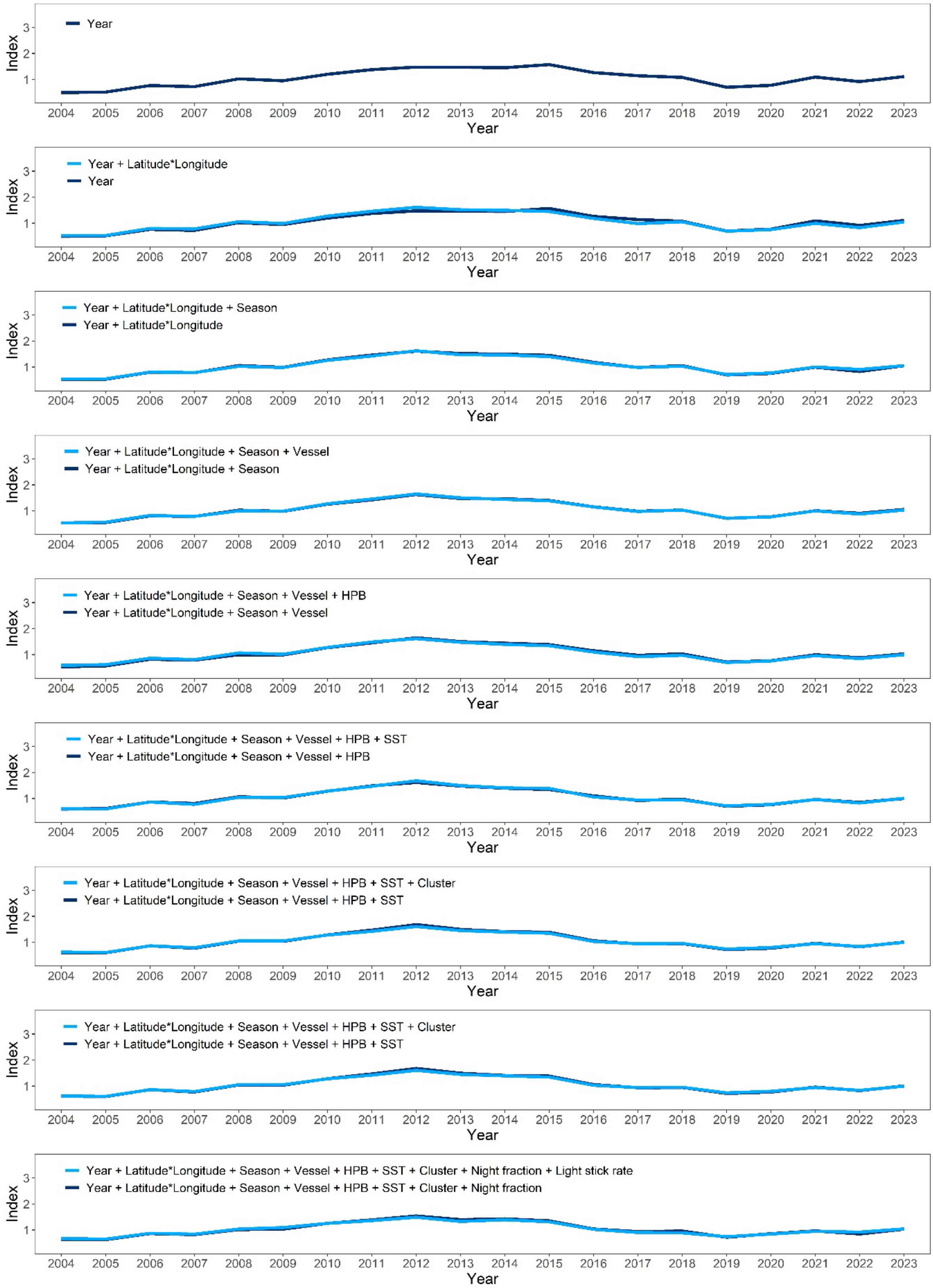

Figure D10: Stepwise influence plots showing the impact of sequentially adding predictor variables for the positive catch component of the core vessels short (i.e., 2004–2023) standardisation model with an annual time step.

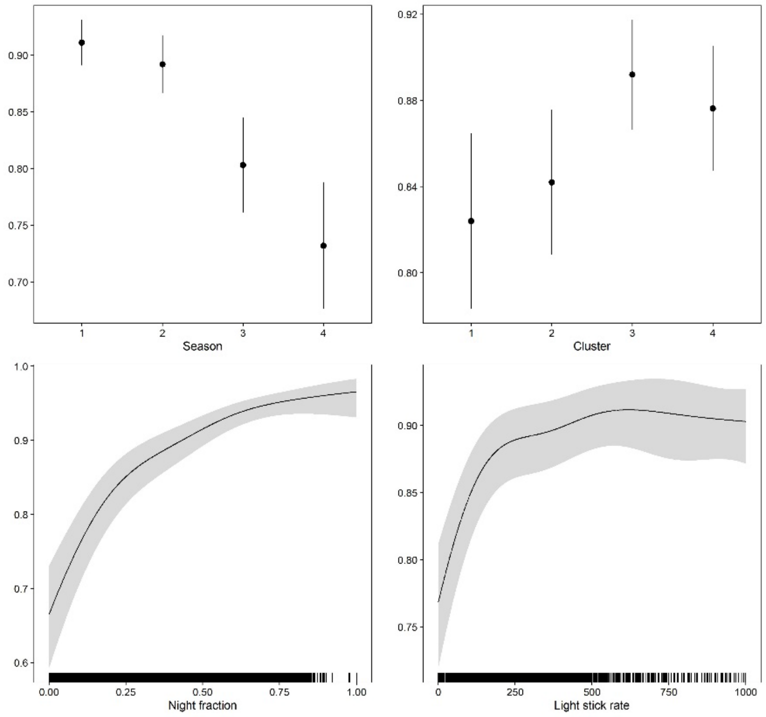

Figure D11: Effects of retained variables for the binomial component for the core vessels short (i.e., 2004–2023) standardisation model with an annual time step. Plots show the partial effects of the respective variable on the probability of capturing a swordfish and their standard error (grey shading).

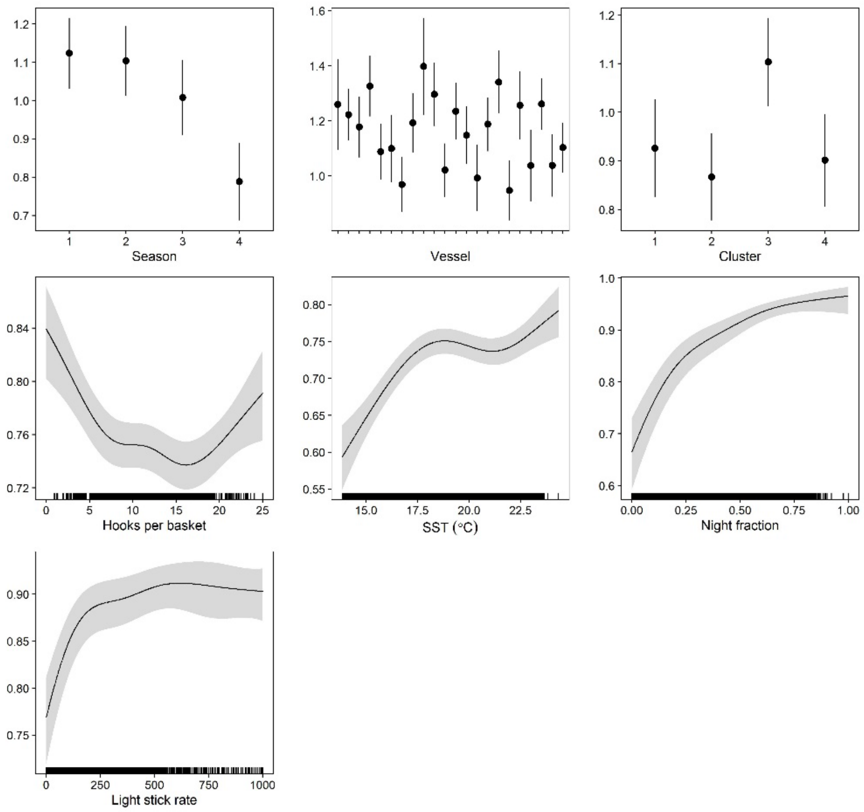

Figure D12: Effects of retained variables for the positive catch component for the core vessels short (i.e., 2004–2023) standardisation model with an annual time step. Plots show the partial effects of the respective variable on CPUE and their standard error (grey shading).

Table D2: Model indices for the annual models. Lower bound is the 2.5th quantile, upper bound is the 97.5th quantile.

Year	Series	Component	Index	Lower bound	Upper bound
1999	Core vessels long	Combined	0.858	0.797	0.927
2000	Core vessels long	Combined	0.757	0.703	0.814
2001	Core vessels long	Combined	0.731	0.688	0.774
2002	Core vessels long	Combined	0.646	0.611	0.684
2003	Core vessels long	Combined	0.524	0.489	0.560
2004	Core vessels long	Combined	0.688	0.648	0.731
2005	Core vessels long	Combined	0.621	0.586	0.659
2006	Core vessels long	Combined	0.929	0.882	0.979
2007	Core vessels long	Combined	0.886	0.841	0.933
2008	Core vessels long	Combined	1.066	1.010	1.125
2009	Core vessels long	Combined	1.187	1.127	1.250
2010	Core vessels long	Combined	1.502	1.431	1.578
2011	Core vessels long	Combined	1.810	1.729	1.895
2012	Core vessels long	Combined	2.038	1.939	2.145
2013	Core vessels long	Combined	1.658	1.584	1.736
2014	Core vessels long	Combined	1.769	1.688	1.862
2015	Core vessels long	Combined	1.482	1.404	1.560
2016	Core vessels long	Combined	1.181	1.126	1.238
2017	Core vessels long	Combined	0.991	0.931	1.048
2018	Core vessels long	Combined	0.963	0.907	1.021
2019	Core vessels long	Combined	0.612	0.554	0.667
2020	Core vessels long	Combined	0.841	0.784	0.904
2021	Core vessels long	Combined	1.015	0.931	1.107
2022	Core vessels long	Combined	0.852	0.770	0.931
2023	Core vessels long	Combined	1.171	1.084	1.265
2004	Core vessels short	Combined	0.664	0.625	0.703
2005	Core vessels short	Combined	0.609	0.574	0.642
2006	Core vessels short	Combined	0.863	0.821	0.908
2007	Core vessels short	Combined	0.851	0.805	0.896
2008	Core vessels short	Combined	1.011	0.957	1.071
2009	Core vessels short	Combined	1.131	1.079	1.184
2010	Core vessels short	Combined	1.307	1.245	1.367
2011	Core vessels short	Combined	1.520	1.456	1.589
2012	Core vessels short	Combined	1.666	1.596	1.742
2013	Core vessels short	Combined	1.417	1.353	1.484
2014	Core vessels short	Combined	1.501	1.430	1.573
2015	Core vessels short	Combined	1.373	1.305	1.446
2016	Core vessels short	Combined	1.057	1.011	1.108
2017	Core vessels short	Combined	0.909	0.859	0.958
2018	Core vessels short	Combined	0.854	0.804	0.899
2019	Core vessels short	Combined	0.649	0.600	0.698
2020	Core vessels short	Combined	0.789	0.741	0.841

Year	Series	Component	Index	Lower bound	Upper bound
2021	Core vessels short	Combined	0.856	0.789	0.925
2022	Core vessels short	Combined	0.849	0.776	0.925
2023	Core vessels short	Combined	1.004	0.930	1.078
1993	All vessels long	Combined	0.503	0.394	0.612
1994	All vessels long	Combined	0.540	0.391	0.685
1995	All vessels long	Combined	0.441	0.325	0.564
1996	All vessels long	Combined	0.530	0.413	0.628
1997	All vessels long	Combined	0.594	0.456	0.712
1998	All vessels long	Combined	0.876	0.694	1.038
1999	All vessels long	Combined	0.891	0.830	0.966
2000	All vessels long	Combined	0.923	0.793	1.069
2001	All vessels long	Combined	0.968	0.866	1.083
2002	All vessels long	Combined	0.744	0.639	0.857
2003	All vessels long	Combined	0.594	0.471	0.690
2004	All vessels long	Combined	0.701	0.561	0.812
2005	All vessels long	Combined	0.701	0.590	0.789
2006	All vessels long	Combined	1.100	0.948	1.266
2007	All vessels long	Combined	0.988	0.838	1.160
2008	All vessels long	Combined	1.217	1.055	1.387
2009	All vessels long	Combined	1.355	1.185	1.576
2010	All vessels long	Combined	1.729	1.517	2.033
2011	All vessels long	Combined	2.092	1.809	2.537
2012	All vessels long	Combined	2.579	2.187	3.142
2013	All vessels long	Combined	1.913	1.688	2.210
2014	All vessels long	Combined	2.068	1.811	2.435
2015	All vessels long	Combined	1.721	1.514	1.959
2016	All vessels long	Combined	1.400	1.248	1.621
2017	All vessels long	Combined	1.090	0.899	1.273
2018	All vessels long	Combined	1.063	0.870	1.239
2019	All vessels long	Combined	0.753	0.583	0.890
2020	All vessels long	Combined	0.951	0.771	1.119
2021	All vessels long	Combined	1.240	1.074	1.399
2022	All vessels long	Combined	0.965	0.803	1.109
2023	All vessels long	Combined	1.255	1.088	1.431
2004	All vessels short	Combined	0.724	0.663	0.808
2005	All vessels short	Combined	0.641	0.435	0.788
2006	All vessels short	Combined	0.939	0.462	1.252
2007	All vessels short	Combined	0.828	0.419	1.074
2008	All vessels short	Combined	1.033	0.554	1.371
2009	All vessels short	Combined	1.141	0.849	1.388
2010	All vessels short	Combined	1.326	0.943	1.608
2011	All vessels short	Combined	1.507	1.159	1.791
2012	All vessels short	Combined	1.874	1.653	2.158
2013	All vessels short	Combined	1.468	1.025	1.793
2014	All vessels short	Combined	1.544	1.157	1.840

Year	Series	Component	Index	Lower bound	Upper bound
2015	All vessels short	Combined	1.424	1.054	1.703
2016	All vessels short	Combined	1.084	0.703	1.357
2017	All vessels short	Combined	0.886	0.511	1.154
2018	All vessels short	Combined	0.819	0.555	1.017
2019	All vessels short	Combined	0.637	0.390	0.842
2020	All vessels short	Combined	0.790	0.457	1.036
2021	All vessels short	Combined	0.912	0.386	1.315
2022	All vessels short	Combined	0.821	0.272	1.232
2023	All vessels short	Combined	0.936	0.559	1.245