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Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2018 (TAN1807)

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A trawl survey of the west coast South Island (WCSI) was carried out from 26 July to 8 August 2018. This was the fifth in a time-series of trawl estimates for middle depth species from the WCSI, with previous surveys in 2000, 2012, 2013, and 2016. Species monitored by the trawl survey include important commercial species such as hake and ling, as well as a wide range of non-commercial fish and invertebrate species. Hoki was not a target species for the 2018 trawl survey.

NIWA received Ministry of Business Innovation and Employment (MBIE) funding to add four days to the 2018 WCSI trawl survey for testing of a new acoustic-optical system (AOS). An outcome of having additional time and staff onboard for this testing was to produce an acoustic abundance estimate of spawning hoki on the WCSI. Two acoustic snapshots were carried out from 26 July to 14 August. This is the eleventh in a series of acoustic surveys of WCSI hoki spawning areas, with previous surveys in 1988–2013.

A total of 57 successful random trawl survey tows were completed in 11 strata north of Hokitika Canyon. Trawl abundance estimates and sampling CVs (in parentheses as a percentage) were estimated for three different areas: 'core' (2000 survey area from 300–650 m); 'all' (2012–13 survey area from 200–800 m); and 'deep' (2016 survey area from 200–1000 m). Estimates for 'all' in 2018 were 1686 t (18 %) for ling and 559 t (18 %) for hake. The trawl estimate of ling abundance in 2018 was very similar to that from the most recent survey in 2016. The estimate for hake increased by 57% from 2016, but was still lower than the levels observed in 2012 and 2013. Hake were also caught in the deeper 800–1000 m strata, and the 2018 estimate for 'deep' of 899 t (14%) was 61% higher than that for 'all'. Although the random trawl survey is not thought to be a good index of hoki abundance, the trawl estimate in 2018 was only a third of what it was in 2016, and less than 10% of that in 2012. The abundance of gemfish has continued to increase from 2016. Species like lookdown dory and ghost shark were also up from 2016, but very few alfonsino, silver warehou, or spiny dogfish were caught on this survey. Spiny dogfish in particular have shown a very large decline since 2012.

A broad size range of ling was caught, with fish between 40 and 140 cm, with most fish ages 3–18. There were two length modes of hake, at 40–60 cm and 70–90 cm, corresponding to hake of ages 2–3 and 6–8 respectively. Gonad staging suggested that both hake and ling were close to spawning during the survey, with some running ripe females caught. A high proportion of the hoki were 3-year old fish (2015 year-class) about 60 cm long, with other length modes at about 50 cm and 70–75 cm corresponding to ages 2 (2016 year-class) and 4 (2014 year-class) respectively. Most smaller hoki were in pre-spawning or spawning condition, but a few large spent female hoki were caught in deeper water (greater than 650 m). There were three distinct length modes in the gemfish length frequency corresponding to recent year-classes.

As well as supporting the stock assessments for hake and ling, the trawl survey provides information on a number of bycatch species. A total of 195 species or species groups were caught, and 28 187 fish or squid of 103 different species were measured during the 2018 survey. Otoliths were collected from ling, hake, silver warehou, sea perch, lookdown dory, alfonsino, gemfish, and ribaldo. Female maturity measurements were made on 172 sharks and skates across 17 species.

The two acoustic snapshots both covered the entire acoustic survey area, with 9 targeted tows to identify acoustic marks and collect biological samples. Acoustic estimates of hoki abundance were calculated using the same ('revised') methods as previous surveys in the time series, and gave a 2018 survey abundance index averaged over the two snapshots of 123 000 t. This was about half the equivalent acoustic index from

2013 (233 000 t) and the lowest estimate in the time-series, going back to 1988. The 2018 acoustic survey weighting (expressed as a coefficient of variation, CV), which includes uncertainty associated with survey timing, sampling precision, mark identification, calibration, and target strength was 46%. Spawning hoki aggregations were detected in the inner Hokitika Canyon with weaker aggregations also observed on the slope south of Hokitika Canyon and in Cook Canyon. Only about 36% of the estimated hoki abundance was from hoki schools, where marks were assumed to contain 100% hoki. Remaining abundance came from mixed species ‘fuzz’ marks. Unlike in previous acoustic surveys, no hoki aggregations were detected in the northern area and only about 20% of the hoki from the WCSI in 2018 was from the area north of the Hokitika Canyon.

1. INTRODUCTION

The west coast South Island (WCSI) is known as the main fishery for spawning hoki, but it is also a key fishery for a number of other middle depth species including hake and ling. Hake on the WCSI (HAK 7) is the largest hake fishery in New Zealand, with a current TACC (in 2017–18) of 5064 t. Ling on the WCSI (LIN 7) has a current TACC of 3080 t. Both the hake and ling fisheries are certified as sustainable by the Marine Stewardship Council.

A series of acoustic surveys targeting hoki were carried out on the WCSI from 1988–2000 (reviewed by O'Driscoll 2002). There was uncertainty over the abundance indices from the 1997 and 2000 surveys because of the species mix in the northern strata. Following a review of results from the 2000 survey, Francis & O'Driscoll (2004) proposed a combined trawl and acoustic survey as a practical approach to measuring hoki abundance more consistently. The trawl component of a combined survey would also provide relative abundance estimates for other species in the northern area, including ling, hake, silver warehou, and lookdown dory (O'Driscoll et al. 2004).

Two WCSI surveys using the new combined trawl and acoustic design were carried out in 2012 (O'Driscoll et al. 2014) and 2013 (O'Driscoll et al. 2015a). These surveys were designed so that trawl surveys results were comparable to the random trawl component from the 2000 WCSI survey. O'Driscoll et al. (2015b) reviewed the trawl and acoustic components of the WCSI survey to inform future survey design. This report concluded that trawl estimates from the northern area did not appear to be providing reliable indices of hoki abundance. Hoki trawl indices were highly variable from 2000–13 and were not consistent with changes in WCSI acoustic indices over the same period, estimated hoki abundance from trawl surveys in the Sub-Antarctic, or western spawning stock biomass estimated from the hoki stock assessment model. However, the trawl survey component provides fisheries-independent estimates of abundance for hake, ling, and associated middle depth species. Trawl estimates of hake and ling abundance were of high quality, with relatively good precision (CV less than 20%), consistent abundance estimates and length and age frequencies between surveys, and appropriate spatial and depth distribution.

A further WCSI trawl survey was carried out in 2016 with a focus on hake and ling (O'Driscoll & Ballara 2018). The 2016 survey also included deeper strata (4E and 4F in 800–1000 m). These deeper strata improved the survey coverage for ribaldo, shovelnose dogfish, and other deepwater shark species, and also revealed that there was a significant amount of hake deeper than 800 m, with 29% of the estimated total hake biomass in 2016 coming from the new deep strata (O'Driscoll & Ballara 2018).

The main objective of the 2018 voyage was to continue the time series of relative abundance indices of hake and ling on the WCSI. In addition to supporting the stock assessments for hake and ling, the trawl survey also provides information on a number of bycatch species including lookdown dory, sea perch, javelinfish, dark ghost shark, ribaldo, and deepwater sharks. For most of these species, the trawl survey provides the only fisheries-independent estimate of abundance on the WCSI, as well as providing biological data (length, sex, reproductive condition, age, etc.). Trawl estimates also provide data that could be used in the future to develop species-based, size-based, and trophodynamic ecosystem indicators (e.g., Tuck et al. 2009).

NIWA have developed a dual-frequency Acoustic Optical System (AOS), and received Ministry of Business Innovation and Employment (MBIE) funding to add 4 days to the 2018 WCSI trawl survey for testing of this technology An outcome of having additional time and staff onboard for this testing was to produce an acoustic abundance estimate of hoki on the WCSI consistent with those obtained in 1988–2013. This will help inform management of the NZ western hoki stock.

1.1 Project objectives

This report is the final reporting requirement for Fisheries New Zealand Research Project MID2018/02. The overall objective of this project is to estimate relative abundance indices for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) off the west coast South Island. The specific objectives were as follows:

1. To continue the time series of relative abundance indices of hake and ling on the west coast South Island with a target coefficient of variation (CV) of the estimate of 30%.

2. To collect data for determining the age and size structure of hake, ling and other middle depth species.

3. To collect data to underpin the development of assessment and monitoring capabilities for biodiversity and ecosystems.

4. To survey the area of Hokitika Canyon and further south, including completion of an acoustic snapshot of the acoustic survey area comparable to hoki acoustic surveys in 1988–2000, 2012, and 2013 to test a multi-frequency Acoustic Optical System.

2. METHODS

2.1 Survey design

A key aspect of the survey design was to ensure consistency with trawl surveys in 2000, 2012, 2013, and 2016. This required the survey to be carried out from *Tangaroa* using the same trawl gear used for previous surveys. The 2018 survey was carried out from 24 July – 16 August, which was over approximately the same time period as random trawling in previous surveys in 2000 (25 July to 31 August), 2012 (22 July to 14 August), 2013 (1–18 August), and 2016 (2–20 August).

The trawl estimate was based on a stratified random trawl survey design (after Francis 1984). The trawl survey area in 2018 had the same 11 northern strata surveyed in 2016 (Table 1, Figure 1). This survey area was based on the same strata used in 2000, retaining the sub-stratification of Strata 1&2, and 4 used in the 2000 survey (Cordue 2002). There were four changes to the survey area in 2012 to improve coverage of other key species, particularly hake and ling. These were:

- Stratum 1&2 was extended further north from 40.8°S to 40.6°S to better cover the distribution of hoki and ling catches;
- Stratum 4D (650–800 m) was added to fully sample the offshore distribution of hoki, hake, and ribaldo in that area;
- Stratum 1&2S and 4S (200–300 m) were added to improve trawl indices for silver warehou, barracouta, frostfish, and gemfish.

Two deeper strata (4E and 4F) were added to the survey area in 2016.

A total of 54 phase 1 stations was planned, based on a statistical analysis of catch rate data from the 2012–16 surveys using the *allocate* programme (Francis 2006). A minimum of 3 stations per stratum was used, with target sampling CVs of 20% for hake and ling, 25% for hoki, giant stargazer, sea perch, lookdown dory, and dark ghost shark, and 30% for silver warehou and spiny dogfish (Table 2). The allocation was run with a target CV of 20% for hake and ling because we believed that the MPI stated target of 30% would not provide sufficient certainty for ongoing monitoring and assessment (Alistair Dunn, MPI, pers. comm.). Four tows were arbitrarily assigned to each of the deep strata, outside of the statistical allocation process.

This allocation gave a similar number of phase 1 stations to that achieved in 2016, when 58 stations were completed in 11 strata. In 2016, total CVs were 13% for ling and 13% for hake (O'Driscoll & Ballara 2018). Two days were allocated for phase 2 and/or bad weather.

The voyage also aimed to test NIWA's new dual frequency towed acoustic-optical system (AOS) as a tool to estimate abundance of New Zealand commercial fish species. Dual frequency acoustic systems have been used to improve species discrimination on schools containing an assemblage of species (Ryan & Kloser 2016) and are now required by MPI for research surveys of orange roughy. NIWA has strategically invested in the development of its own dual-frequency AOS over the past three years. This incorporates the latest Simrad EK80 broadband acoustic technology with 38 and 120 kHz transducers. The system has been tank tested, but requires extensive trials at sea to determine its operating ranges, signal-to-noise ratio, reliability, and suitability for use in surveys of New Zealand deepwater species. NIWA received MBIE funding to add 4 days to the WCSI trawl survey for testing of this technology.

The acoustic survey design followed that used for the combined trawl and acoustic survey of the WCSI in 2013 (O'Driscoll et al. 2015a). The trawl survey component was carried out north of Hokitika Canyon only. Random bottom trawls were carried out during daylight hours when a greater proportion of fish are near the bottom and catch rates are typically higher. During the night, AOS trials and acoustic transects to estimate hoki abundance were carried out in the northern area. The 4 MBIE-funded days were then used to survey the area of Hokitika Canyon and further south (Strata 5A, 5B, 6, and 7 in Figure 1) where hoki are also abundant. The aim was to complete at least one snapshot of the acoustic survey area, comparable to hoki acoustic surveys in 1988–2000, 2012, and 2013.

2.2 Vessel and equipment

R.V. *Tangaroa* is a purpose-built research stern trawler of 70 m overall length, a beam of 14 m, 3000 kW (4000 hp) of power, and a gross tonnage of 2282 t. The survey used the same eight-seam hoki trawl (see Hurst et al. 1992 for net plan) that was used on previous surveys in the series. This net has 100 m sweeps, 50 m bridles, 12 m backstrops, 58.8 m groundrope, 45 m headline, and 60 mm codend mesh. The trawl doors were Super Vee type with an area of 6.1 m^2.

Acoustic data were collected with the multifrequency (18, 38, 70, 120, and 200 kHz) Simrad EK60 system on *Tangaroa*. The *Tangaroa* hull echosounders were calibrated on the preceding voyage (TAN1806) as part of another (non-MPI) project. The calibration report is given in Appendix 2.

2.3 Trawling procedure and biological sampling

Random trawling followed the standardised procedures described by Hurst et al. (1992). Station positions were selected randomly before the voyage using the Random Stations Generation Program (Version 1.6) developed by NIWA. A minimum distance between tows of 3 n. miles was used. If a station was found to be on foul ground, a search was made for suitable ground within 3 n. miles of the station position. If no suitable ground could be found, the station was abandoned and another random position was substituted. Random bottom tows were only carried out during daylight hours, with all random tows carried out between 0800 h and 1748 h NZST. At each station the trawl was towed for 3 n. miles at a speed over the ground of 3.5 knots. If foul ground was encountered, or the trawl hauled early due to reducing daylight or strong marks on the net monitor, the tow was included as valid only if at least 2 n. miles was covered.

Targeted trawling was carried out for mark identification in support of the acoustic survey, and to collect biological data south of Hokitika Canyon. Target trawling was carried out both day and night.

Measurements of doorspread (from a SCANMAR system), headline height (from a Furuno CN22 net monitor), and vessel speed (GPS speed over the ground, cross checked against distance travelled during the tow) were recorded every 5 min during each tow and average values calculated. Towing speed and gear configuration for random tows were maintained as constant as possible during the survey, following the guidelines given by Hurst et al. (1992). Acoustic recordings were made for all tows using the multi-frequency hull-mounted transducers.

From each tow, all items in the catch were sorted into species and weighed on Marel motion-compensating electronic scales which resolved to about 0.1 kg. Where possible, finfish, squid, and crustaceans were identified to species and other benthic fauna were identified to species, genus, or family. Unidentified organisms were collected and frozen at sea for subsequent identification ashore.

An approximately random sample of up to 200 individuals of each commercial, and some common non-commercial, species from every successful tow was measured and sex determined. More detailed biological data were also collected on a subset of species and included fish weight, sex, gonad stage, gonad weight, and occasional observations on stomach fullness, contents, and prey condition. Otoliths were taken from hake and ling for age determination. Otoliths were also taken from silver warehou, sea perch, lookdown dory, alfonsino, gemfish, and ribaldo for future aging work. A description of the macroscopic gonad stages used for teleosts and elasmobranchs is given in Appendix 3. Liver and gutted weights were recorded from up to 20 hoki per tow to determine condition indices. Measurements were made on the reproductive condition of female deepwater sharks.

2.4 Acoustic data collection

Acoustic transect locations were randomly generated, and were carried out at right angles to the depth contours (i.e., from shallow to deep or vice versa). The minimum distance between transect midpoints varied between strata, and was calculated as follows:

$$m = 0.5 * L/n \tag{1}$$

where m is minimum distance, L is length of stratum, and n is the number of transects.

Transects were run at speeds of 6–10 knots (depending on the weather and sea conditions). Acoustic transects were mainly run in the northern strata during the night (with random tows during the day), but the area from Hokitika Canyon south was acoustically surveyed day and night. Acoustic data collection was interrupted (generally between transects) for mark identification tows.

Acoustic data were also collected during trawling and while steaming between trawl stations (both day and night) throughout the survey.

2.5 Other data collection

Temperature and salinity data were collected using a calibrated Seabird SM-37 Microcat CTD datalogger mounted on the headline of the trawl. Data were collected at 5 s intervals throughout the trawl, providing vertical profiles. Surface values were read off the vertical profile at the beginning of each tow at a depth of about 5 m, which corresponded to the depth of the hull temperature sensor used in previous surveys. Bottom values were from about 7.0 m above the seabed (i.e., the height of the trawl headline).

2.6 Trawl data analysis

Doorspread biomass was estimated by the swept area method of Francis (1981, 1989) as implemented in the analysis programme *SurvCalc* (Francis 2009). Total survey abundance was estimated for all species in the catch. The catchability coefficient (an estimate of the proportion of fish in the path of the net which is caught) is the product of vulnerability, vertical availability, and areal availability. These factors were set at 1 for the analysis, the assumptions being that fish were randomly distributed over the bottom, that no fish were present above the height of the headline, and that all fish within the path of the trawl doors were caught. Only data from random trawl tows where the gear performance was satisfactory (codes 1 or 2) were included for estimating abundance. Scaled length frequencies were calculated for the key species with *SurvCalc*, using length-weight data from this survey (Table 3).

Hake and ling otoliths were prepared and aged using validated ageing methods (hake, Horn (1997); ling, Horn (1993)). All available hake and ling otoliths were aged. Numbers-at-age were calculated from observed length frequencies from successful random tows and age-length keys using custom NIWA catch-at-age software (Bull & Dunn 2002).

2.7 Acoustic data analysis

Acoustic data collected during the survey were analysed using standard echo-integration methods (Simmonds & MacLennan 2005), as implemented in NIWA's Echo Sounder Package (ESP3) software (Ladroit 2017).

Hoki abundance in 2018 was estimated using the 'revised' method described by O'Driscoll et al. (2015a) and summarised in Table 4. An updated WCSI time-series and priors based on this method was produced by O'Driscoll et al. (2016) and accepted by the Deepwater Fishery Assessment Working Group before the 2016 hoki assessment. The 'revised' method updated WCSI acoustic abundance indices from 1988–2013 for changes in sound absorption, more accurately estimated stratum areas, and used the target strength to total length (TS-TL) relationship of Dunford et al. (2015), derived from New Zealand only data:

$$TS = 24.5 \log_{10}(TL) - 83.9 \qquad (2)$$

2.7.1 Mark identification

Echograms were visually examined, and the bottom determined by a combination of an in-built bottom tracking algorithm and manual editing. Regions corresponding to various acoustic mark types were then identified. Marks were classified subjectively based on their appearance on the echogram (shape, structure, depth, relative strength on multiple frequencies), and using information from mark identification tows. The classification procedure was described in detail by O'Driscoll et al. (2014) and is summarised here.

Hoki form large, dense, single-species aggregations during spawning which are readily identifiable acoustically. Mark classification initially involved distinguishing hoki schools from other non-hoki marks and layers. Schools classified as hoki were between 200 and 750 m water depth, forming elongated schools in midwater, but sometimes making contact with the bottom. Hoki schools were usually of moderate to high density (echo amplitude), with single target echoes sometimes visible around the margins. Other, non-hoki, pelagic marks were usually layers rather than schools, often with a wavy, undulating appearance. Non-hoki layers were typically shallower than hoki schools and were more homogeneous, with no obvious single targets. Non-hoki pelagic layers tended to be much stronger on lower frequencies (12 kHz in surveys up to 2000 and 18 kHz now) than on 38 kHz, possibly because the swimbladders of the small pelagic species involved resonate at these lower frequencies. Tows on hoki school marks typically produced clean catches (over 90 % by weight) of hoki, and bycatch of commercial vessels during the hoki spawning fishery is also low. Other pelagic layers typically contain mesopelagic fish species and jack mackerel.

Mark identification is much more difficult away from hoki school marks. A common mark type on the WCSI is a bottom-oriented, low density layer, which may extend up to 50 m above the bottom during the day. These 'hoki bottom fuzz' marks consisted of a variety of species including hoki. Similarly, 'hoki pelagic fuzz' marks are low-density midwater marks containing hoki and other species and are more commonly observed at night.

2.7.2 Integration

Backscatter at 38 kHz from marks (regions) identified as hoki schools and hoki fuzz were integrated separately to produce estimates of acoustic density, expressed as the mean area backscattering coefficient (m^2 of backscatter per km^2 of area). Acoustic density was output in two ways. First, average acoustic density over each transect and substratum was calculated. These values were used in abundance estimation (see Section 2.7.4). Second, acoustic backscatter was integrated over 10-ping bins to produce a series of acoustic densities for each transect (typically 30–100 values per transect). These data had a high spatial resolution, with each value (10 pings) corresponding to about 100 m along a transect, and were used to produce plots showing the spatial distribution of acoustic density.

For hoki surveys before 2003, the standard procedure (Coombs & Cordue 1995, O'Driscoll 2002) was to use an estimate of sound absorption of 8.0 dB km^{-1}, calculated using the formula of Fisher & Simmons (1977), which was based on laboratory measurements of artificial seawater. Doonan et al. (2003) reviewed the absorption of sound in seawater focusing on the frequencies and water properties used in fisheries acoustics in New Zealand and published a new formula based on a statistical reanalysis of existing data. This new formula was adopted for acoustic surveys of New Zealand deepwater fish species. O'Driscoll et al. (2015a, 2016) updated the time series of acoustic estimates for the WCSI using the updated sound absorption. Acoustic integration of data from 2018 was carried out using the estimated sound absorption of 8.88 dB km^{-1} from the survey (see Appendix 4).

2.7.3 Species decomposition

Ideally, all species could be distinguished acoustically and classified separately, so that all backscatter from hoki marks came from hoki, and there were no hoki present in other marks. In reality, species mixes occur. There are a number of approaches to deal with the problem of species mix in hoki acoustic surveys in the past and these were described in detail by O'Driscoll et al. (2014).

The method of species decomposition used in the analysis of the 2018 survey attempted to emulate what was done in 2000 (Cordue 2002, O'Driscoll et al. 2004). All backscatter from the area south of Hokitika Canyon (strata 5A, 5B, 6, and 7) and from hoki school marks in the northern area (strata 1&2 and 4) was assumed to be 100% hoki. The proportion of hoki in fuzz marks in strata 1&2 and 4 was estimated using the "standard method" of species decomposition which partitions acoustic backscatter in each tow based on the composition of the catch and acoustic TS according to equation (3):

$$p_i = \frac{c_i \sigma_i}{\sum_{i=1}^{n} c_i \sigma_i} \qquad (3)$$

The proportion of backscatter contributed by each species i (p_i) in a tow is proportional to the product of its catch rate (c_i) and its mean TS (σ_i) as a proportion of the summed acoustic contribution of all species $i = 1 \ldots n$ in the catch. All catch rates (c_i) were expressed as kg km^{-2} and mean target strengths (σ_i) were expressed per kilogram, instead of per fish. This was done for simplicity since fish in trawl catches were weighed rather than counted. When estimating average acoustic proportion of hoki by substratum, all tows were assigned equal weighting, regardless of catch. The mean TS per kilogram of species in each tow was estimated from the mean lengths of fish in the catch using estimated length-weight parameters (determined from the subsample of fish weighed during each survey) (see Table 3) and the best available target strength-length relationships (Table 5).

Hoki TS in species decomposition in 2018 was estimated using equation (2). The TS-TL relationship of Coombs & Cordue (1995) (equation 4) was used to estimate hoki TS in species decomposition in surveys from 1988–2000 (Cordue 2002) and this could not be easily recalculated without detailed re-analysis of research and commercial trawl data. The new TS-TL relationship (equation 2) gives similar estimates of hoki TS to that of Coombs & Cordue (1995), and therefore the effect on decomposition is small (O'Driscoll et al. 2016).

$$TS = 22.32 \log_{10}(TL) - 79.84 \qquad (4)$$

2.7.4 Abundance estimation

Transect acoustic density estimates were converted to hoki biomass using a ratio, *r*, of mean weight to mean backscattering cross section (linear equivalent of target strength, TS) for hoki.

The method of calculating *r* was based on that of O'Driscoll (2002), as revised by O'Driscoll et al. (2015a):

1. using the length frequency distribution of the commercial catch from the year of the survey;
2. using the generic length-weight regression of Francis (2003) to determine mean hoki weight (w in kilograms)

$$w = (4.79 * 10^{-6})\, L^{2.89} \qquad (5)$$

3. using the latest TS-TL relationship for hoki (equation 2).

A single ratio was estimated and applied to all substrata.

Abundance estimates and variances were obtained for each substratum in each snapshot using the formulae of Jolly & Hampton (1990), as described by Coombs & Cordue (1995). During a re-analysis of the 2000 WCSI survey, O'Driscoll et al. (2004) re-calculated stratum areas for the WCSI based on recorded depth cut-offs for stratum boundaries. Stratum areas differed slightly from those used by Cordue (2002) and O'Driscoll (2002), which were based on less detailed boundaries. The updated stratum areas (Table 1) were used to estimate abundance. Stratum estimates were combined to produce snapshot estimates, and the snapshots were averaged to obtain the abundance index for 2018.

2.7.5 Acoustic survey weighting for stock assessment

The sampling precision will greatly underestimate the overall survey variability, which also includes uncertainty in TS, calibration, and mark identification (Rose et al. 2000). The model weightings (expressed as proportional coefficient of variation or CV) used in the hoki stock assessment model are calculated for individual surveys using a Monte Carlo procedure which incorporates these additional uncertainties (O'Driscoll 2002, 2004).

The simulation method used to combine uncertainties and estimate an overall weighting (CV) for each acoustic survey of the WCSI was described in detail by O'Driscoll (2002, 2004), and is summarised below.

Five sources of variance were considered:

- plateau model assumptions about timing and duration of spawning and residence time
- sampling precision
- mark identification
- fish weight and target strength
- acoustic calibration

The method has two main steps. First, a probability distribution was created for each of the variables of interest. Second, random samples from each of the probability distributions were selected and combined multiplicatively in Monte Carlo simulations of the process of acoustic abundance estimation.

In each simulation an abundance model was constructed by randomly selecting values for each variable from the distributions in Table 6. This model was then 'sampled' at dates equivalent to the mid dates of each snapshot (Table 7). The precision of sampling was determined by the snapshot CV, and the abundance adjusted for variability in detectability. The simulated abundance estimate in each snapshot was then split, based on the proportion of acoustic backscatter in 'hoki school' and 'hoki fuzz' marks, and mark identification uncertainties applied to each part. Uncertainty in mix marks in surveys since 2000 is estimated by resampling with replacement (bootstrapping) from the observations (tows). A reduced error component (again based on an assumed distribution) was then added to account for potential variability in trawl catchability and relative TS (Table 6). The abundance estimates were recombined and calibration and TS uncertainties applied in turn. The same random value for calibration and TS was applied to all snapshots in each simulated 'survey'. Abundance estimates from all snapshot estimates from the simulated survey were averaged to produce an abundance index. This whole process was repeated 1000 times (1000 simulated surveys) and the distribution of the 1000 abundance indices was output. The overall CV was the standard deviation of the 1000 abundance (mean biomass) indices divided by their mean. Separate weightings were calculated for abundance estimates from the northern (strata 1&2 and 4) and southern (strata 5A, 5B, 6, and 7) areas.

3. RESULTS

3.1 Data collection

All survey objectives were completed. Weather conditions were generally very good, with wind speeds less than 20 knots. No survey time was lost due to bad weather. About 3 hours was lost on 27 July due to a leaking pipe in the engine room. This was fixed by the ship's engineers.

All 54 planned phase 1 trawl survey tows were successfully completed in 11 strata (Figure 2, Table 1). Individual station details from all tows, including the catch of hoki, hake and ling are listed in Appendix 1. One further tow (station 37) was unsuccessful as the trawl came fast. No phase 2 tows were required for hake and ling as CVs for these species were both less than 20% after phase 1 (13.9% for hake, 18.3% for ling). Three phase 2 tows were carried out for gemfish in stratum 4S which reduced the CV from 50.8% to 33.1%.

Two full acoustic snapshots of both the northern and southern areas were carried out (Table 7, Figure 3). The generally good weather allowed acoustic data to be collected using the multi-frequency *Tangaroa* EK60 hull system. A total of 330 acoustic data files were recorded during the survey, constituting 55.7 GB of data. Nine trawls were made to identify targets and collect biological samples in support of the acoustic survey work (Appendix 1, Figure 3). On two of the mark identification tows (stations 76 and 77) the acoustic-optical system (AOS) was mounted on the headline. Tow length in mark identification trawls ranged from 0.2 to 3.1 n. miles at an average speed of 3.6 knots.

3.2 Gear performance

Gear parameters by depth for valid trawl survey tows are summarised in Table 8. The headline height was obtained for all successful tows, and doorspread readings collected for all but three of the valid tows. The missing doorspread values were estimated from data collected in the same depth range on this voyage. Measured gear parameters in 2018 were within the range of those obtained on the valid tows from the 2000–16 surveys where the same gear was used (Table 9), although headline height was slightly lower on average than in 2012–16. Mean doorspread distances and headline heights for the

2018 survey were also consistent with those from recent *Tangaroa* hoki and middle depths time series surveys on the Chatham Rise (e.g., Stevens et al. in press) and Sub-Antarctic (O'Driscoll et al. 2018).

3.3 Catch

A total catch of 38.5 t was recorded from all trawl stations (including mark identification trawls) (Table 10). From the 195 species or species groups caught, 100 were teleosts, 26 elasmobranchs, 13 squids or octopuses, 17 crustaceans, and 19 echinoderms, the remainder comprising assorted benthic and pelagic animals (Appendix 5). Hoki accounted for 25.2%, ling 19.5%, giant stargazer 8.8%, barracouta 8.8%, hake 5.4%, and gemfish 5.2% of the total catch from all trawls (Table 10).

3.4 Trawl abundance estimates

Abundance estimates and the trawl survey catch for core, all, and deep strata are given in Table 11. Abundance estimates and CVs (in parentheses) for 'all' strata were 1686 t (18%) for ling and 559 t (18%) for hake. The core strata abundance estimate of 1682 t for ling was similar to the total estimate, and no ling were caught in the deep (800–1000 m) strata. The estimate for hake from the core strata was 229 t, and the estimate including the deep strata of 899 t (14%) was 61% higher than that the 'all' estimate (Table 11). Target CVs were met for ling and hake (both target 20%), giant stargazer, sea perch, lookdown dory, dark ghost shark, hoki (all target 25%), and silver warehou (target 30%), but exceeded for spiny dogfish (also target 30%). Gemfish were very abundant and had a relatively high CV (50.8%) after phase 1, so three phase 2 tows were carried out in stratum 4S, which reduced the gemfish CV for all strata to 33.1%.

Abundance estimates by stratum are given in Table 12. No hake or ling were caught in the 200–300 m shallow strata 4S and 1&2S (Table 12, Figure 4). Stratum 1&2A accounted for 49% of the ling abundance in 2018, lower than in 2012–16 when this stratum contributed 60–70% of the ling abundance (Figure 4). Hake were most abundant in strata deeper than 650 m (4D, 4E, and 4F) (Figure 4). The shallow strata between 200–300 m accounted for most of the abundance of giant stargazer, barracouta, northern spiny dogfish and tarakihi, and were also important for school shark and gemfish (Table 12). The deep strata 4E and 4F (800–1000 m) had higher abundance estimates for smooth skin dogfish, Plunket's shark, and longnose velvet dogfish (Table 12, Figure 5). The deep strata also accounted for 24% of the total (deep) abundance for ribaldo, and 39% for shovelnosed dogfish (Table 12).

Trawl estimates from 2018 were compared to previous surveys in the WCSI time series in Table 13 and Figure 6. The 'all' area trawl estimate of hake abundance in 2018 (559 t) was 57% higher than that in 2016 (355 t), but was still lower than the levels observed in 2012 and 2013. The ling estimate (1686 t) was very similar to that in 2016 (1661 t). Although the random trawl survey is not thought to be a good index of hoki abundance, the trawl estimate in 2018 was only a third of what it was in 2016, and less than 10% of that in 2012. The abundance of gemfish has continued to increase from 2016. Species like lookdown dory and ghost shark were also up from 2016, but very few alfonsino, silver warehou, or spiny dogfish were caught on this survey. Spiny dogfish in particular have shown a very large decline since 2012 (Table 13, Figure 6).

3.5 Species distribution

Catch rates of key species are plotted in Figure 7. As noted in Section 3.4, hake mainly occurred deeper than 650 m, with highest catch rates between 700 and 900 m in stratum 4D and 4E (Figure 7). Ling catch rates were highest between 300–430 m (Figure 7). Hoki catch rates were highest in 430–500 m. The highest catch rates of giant stargazer, barracouta, tarakihi, school shark, and silver dory were in shallow strata less than 300 m (Figure 7). Northern spiny dogfish and gemfish were widespread from 200–500 m depth, with the two largest catches of gemfish in the northern part of stratum 4S (Figure 7). Ribaldo and shovelnose dogfish had highest catch rates deeper than 650 m.

3.6 Biological data

A total of 28 187 fish and squid of 103 different species were measured (Table 14). Of these, 11 316 fish were also individually weighed (Table 14). Additional data on fish condition (liver and gutted weight) were recorded from 802 hoki. Pairs of otoliths were removed from 478 ling, 632 hake, 141 silver warehou, 568 bigeye sea perch, 430 lookdown dory, 28 alfonsino, 481 gemfish, and 149 ribaldo.

Population scaled length frequencies, calculated using length-weight data in Table 3, are presented for key species in Figure 8 and compared to previous surveys in 2000, 2012, 2013, and 2016. A broad size range of ling was caught, with fish between 40 and 140 cm (Figure 8). Most ling were ages 3 to 18 years (Figure 9). There were two length modes of hake, at 40–60 cm and 70–90 cm (Figure 8), which correspond to ages 2–3 and 6–8 respectively (Figure 10). A high proportion of the hoki were 3-year old fish (2015 year-class) about 60 cm long, with other length modes at about 50 cm and 70–75 cm corresponding to ages 2 (2016 year-class) and 4 (2014 year-class) respectively (Figure 8). The modal length of silver warehou in 2018 of about 50 cm was similar to that in previous surveys (Figure 8). The increase in gemfish abundance in 2018 (see Figure 6) was comprised of three length modes (Figure 8), likely to be ages 2–4 years, and reflects good recent recruitment. Most other key species had similar length frequencies to previous surveys (Figure 8). There were modes of small lookdown dory and silver dory which may indicate strong year-classes (Figure 8).

Gonad staging of fish and elasmobranchs showed that many species were in spawning condition during the survey (Table 15). Fish in active spawning stages (gonad stages 4–6) accounted for 43% of ling females, and 23% of hake females. Most female hake were immature (stage 1) or maturing (gonad stage 3) (Table 15), but note that about one third of the female hake were younger than the age at maturity (see Figure 10). Hoki were also actively spawning throughout the survey period, with 50% of female hoki maturing (stage 3), 23% spawning (stages 4–6) and 11% spent (stage 7) in research catches. A high proportion of hoki caught in deeper strata (greater than 500 m) were spent females. Other species of teleosts with more than 200 observations and over 50% of fish in maturing and spawning condition (gonad stages 3–6) included giant stargazer, silver dory, barracouta, Bollons' rattail and Oliver's rattail. Many female lookdown dory and tarakihi were spent (stage 7) or resting (stage 2). For elasmobranchs, 64% of the spiny dogfish females had pups (stage 5).

Measurements of female maturity were made from 172 specimens of female sharks and skates across 17 species. These data included counts and size measurements of vitellogenic (yolky) eggs, pups, and uterus and oviducal gland sizes, and were collected to help verify the maturity stage allocation. Egg and pup counts are also necessary to provide a basis to assess fecundity and therefore vulnerability of many of these poorly-known species. A gravid Plunket's shark caught on this survey, is only the third record for a gravid female of this species from the New Zealand and Australian region, and only the second pup count recorded. We also recorded the first vitellogenic egg count for the velvet dogfish, *Zameus squamulosus*, for which there were only two fish previously staged.

A total of 240 kg of samples were inventoried and preserved (by freezing). Unusual or unidentified organisms were retained to confirm identification or for on-going molecular studies. DNA samples (n = 70) and selected whole specimens were collected to provide material for quantifying the occurrence of two poorly described shovelnose dogfish; *Deania quadrispinosa*, and *Deania hystricosa*, which may be confused with the more common *Deania calcea*. DNA fin clips (n = 50) from barracouta were taken for Stellenbosch University, to contribute to a population genetics study of this species across New Zealand, Australia and South Africa. Samples were also collected from 117 gravid and non-gravid female sharks across a range of species to allow assessment of the prevalence of multiple paternity amongst litters of pups/embryos, and the occurrence of sperm storage as part of the reproductive strategy of different species. Stomachs were taken from 14 rattail species for an ongoing feeding study.

3.7 Acoustic survey data

Spawning hoki aggregations were detected in the inner Hokitika Canyon (stratum 5A) with weaker aggregations also observed in strata 5B, 6, and 7 (e.g., Figure 11). Unlike in previous acoustic surveys, no hoki aggregations were detected in the northern area (strata 1&2 and 4), with only low density "fuzz" marks observed (e.g., Figure 11). Mesopelagic marks, which do not usually contain hoki, were common. Mesopelagic marks were usually in layers, often with a wavy, undulating appearance. These were typically shallower and/or deeper than hoki schools, with less "structure" in the mark, and with no obvious single targets.

Eight of the 9 mark identification tows were targeted at fuzz marks, with one tow on a hoki school in stratum 6. Catches are summarised in Table 16. The tow on the hoki school caught 93% hoki by weight. Tows targeted on bottom fuzz marks with the bottom trawl caught an average of 34% hoki by weight (range 6–56%). Tows targeted on pelagic fuzz marks with the bottom trawl caught an average of 37% hoki by weight, but two of these tows had total catches less than 10 kg suggesting that they had missed the targeted mark. The other two trawls on pelagic fuzz caught 59% and 73% hoki by weight (Table 16).

Random trawl survey tows in the northern area were also useful for mark identification and were used extensively in decomposition of species mix (see Section 3.9).

3.8 Distribution of hoki backscatter

Expanding symbol plots show the spatial distribution of hoki backscatter along each transect during the two snapshots of the WCSI (Figure 12). Maps show unpartitioned backscatter from hoki schools and hoki fuzz marks separately. Dense hoki schools were present in Hokitika Canyon (stratum 5A) in both snapshots, with lower density schools also detected in the southern area (strata 6 and 7). As noted in Section 3.7, no hoki schools were detected in the northern area.

Hoki fuzz marks were widespread in all strata throughout the survey period, with highest (unpartitioned) densities in strata 5B and 6 (Figure 12). Few hoki marks (schools or fuzz) were seen shallower than 300 m or deeper than 600 m.

The acoustic survey area appeared to encompass all of the commercial fishing effort during the survey period; most commercial fishing targeting hoki occurred from 300–600 m depth (Figure 13). There was more commercial fishing south of Hokitika Canyon in 2018 compared to 2012, when there were very few tows in strata 6 and 7 (O'Driscoll et al. 2014). The acoustic survey was within the period of highest commercial catches (Figure 14).

3.9 Species decomposition

The 2 targeted tows on fuzz marks and the 39 successful random bottom tows in the northern acoustic survey area (i.e., excluding the 16 tows in strata 1&2S, 4S, 4E, and 4F) were used to partition acoustic backscatter. On average hoki made up between 4% (stratum 12A) and 72% (stratum 4B) of the trawl catch by substratum. Using the 'revised' methods (TS from Table 5 and equal weighting of tows), hoki contributed 2–48% of the backscatter from mixed species marks in the northern substrata (Table 17), and these values were used to scale integrated acoustic backscatter from fuzz marks when estimating hoki abundance in the northern area. In the southern area all backscatter was assumed to be hoki (see Section 2.7.3).

3.10 Acoustic abundance estimates

Estimates of hoki abundance were based on a single ratio, *r*, of mean weight to mean backscattering cross section calculated from the length frequency for the commercial fishery. The hoki length frequency from the 2018 WCSI fishery based on scientific observer data and land-based sampling is shown in Figure 15. The mean length of hoki was 79.4 cm (Table 18). Mean weight (obtained by transforming the scaled length frequency distribution in Figure 15 by equation (5) and then calculating the mean of the transformed distribution) was 1.60 kg. The estimated ratios, *r*, for 2018 based on the latest TS-TL relationship (equation 2) was 8279 kg m^{-2} (Table 18).

Hoki abundance estimates by snapshot and strata are given in Table 19. Estimates of hoki abundance were 140 000 t (CV 14%) in the first snapshot and 106 000 t (29%) in the second snapshot. The average abundance estimate over the two snapshots was 123 000 t. About 20% of the hoki abundance was in the northern area (strata 1&2 and 4), 44% in Hokitika Canyon (strata 5A and 5B), and 36% from south of Hokitika Canyon (strata 6 and 7). The average proportion of the abundance from hoki schools ranged from 0% in strata 1&2 and 4 to 84% in stratum 5A (Table 20). On average, across both snapshots, only 36% of the hoki abundance was from hoki schools (Table 20).

The acoustic time-series, based on the same 'revised' methodology used by O'Driscoll et al. (2016), is updated in Table 21. The 2018 acoustic estimate was about half (53%) of the equivalent estimate from 2013, and the lowest in the time-series which goes back to 1988.

3.11 Acoustic weighting for stock assessment

The overall survey weighting estimated from the Monte Carlo simulation model for the 2018 WCSI estimate was 0.46 (Table 22). The greatest contribution to the uncertainty came from species composition of the fuzz marks (Table 22).

3.12 Acoustic optical system

There were 13 deployments of NIWA's new dual frequency broadband acoustic optical system (AOS) (Figure 16). After resolving issues due to acoustic interference from the net monitor, we were able to collect high quality acoustic data at 38 and 120 kHz with the AOS mounted in the hoki trawl towed in midwater (e.g., Figure 17). The AOS was calibrated down to 800 m depth on 31 July and 6 August.

3.13 Hydrological data

The water column was weakly stratified with surface temperatures ranging between 13.3 and 14.3°C (Figure 18) and bottom temperatures between 5.9 and 13.6°C (Figure 19). Surface temperatures were slightly higher than those in 2016 when surface temperatures were between 13.0 and 13.9°C (O'Driscoll & Ballara 2018). Bottom temperatures were very similar to those in other years, with an average temperature at typical hoki depths (about 500 m) of about 9°C.

4. DISCUSSION

The WCSI survey has evolved: from a hoki acoustic survey in 1988–2007, with limited target trawling for mark identification (e.g., Cordue & Ballara 1998); to a design incorporating random bottom trawling to inform species mix in 2000 (Cordue 2002); to a combined acoustic and trawl survey design in 2012 and 2013 (O'Driscoll et al. 2014, 2015a); and now (since 2016), to a random trawl survey only, where hoki are no longer a target. The 2018 survey was successfully completed and was the fifth in a time-series of trawl estimates for ling and hake from the WCSI. In addition to supporting the stock assessments for these two Tier 1 deepwater fisheries, the trawl survey provides information on a number of bycatch species.

NIWA received MBIE funding to add four days to the 2018 WCSI trawl survey for testing of a new AOS. An outcome of having additional time and staff onboard for this testing was to produce an acoustic abundance estimate of spawning hoki on the WCSI. Good weather conditions meant that two acoustic snapshots were carried out. This is the eleventh in a series of acoustic surveys of WCSI hoki spawning areas, with previous surveys in 1988–2013.

The timing of WCSI trawl surveys in 2000 and 2012–13 was driven by the need to obtain a concurrent acoustic index of spawning hoki. To allow comparability with results from the 2000–16 surveys, the random trawl component of the 2018 survey was carried out from 26 July – 8 August. O'Driscoll et al. (2015b) explored the timing of the trawl survey component with respect to hoki, hake and ling based on an analysis of commercial fishing catch and effort in FMA7 over the period June-September in all years from 2000 to 2011. They concluded that there are strong reasons why the survey needs to be in July-August for hoki, and no clear reasons to indicate more appropriate timing for hake and ling. Research trawl catches in 2018 showed that some ling (43% of females) and hake (23% of females) were actively spawning during the survey, but estimated CVs less than 20% for all five WCSI surveys (see Table 13) do not suggest that there are particular issues with these species being aggregated at the time of the survey.

Data from commercial fisheries and the 2012–18 trawl surveys suggests that the 2012 survey area (referred to as 'all' in this report) appears to have an appropriate spatial and depth distribution in the northern area for ling, as well as for silver warehou, silver dory, alfonsino, smooth skate, sea perch, gemfish, javelinfish, lookdown dory, and dark ghost shark (O'Driscoll et al. 2015b, O'Driscoll & Ballara 2018, Figure 7). Coverage of species with a more inshore distribution (giant stargazer, spiny dogfish, barracouta, school shark, northern spiny dogfish, jack mackerel, frostfish, arrow squid, and tarakihi) was improved by the inclusion of shallower strata (1&2S and 4S) from 2012, but densities of these nine species are still likely to be considerable inshore of 200 m. The addition of deeper strata 4E and 4F from 800–1000 m since 2016 has improved the survey coverage for shovelnose dogfish, ribaldo, and other deepwater species (notably deepwater sharks) (see Figure 7), and also revealed that there is a significant amount of hake deeper than 800 m, with 38% of the estimated total ('deep') hake biomass in 2018 coming from the deep strata (see Figure 4).

The trawl survey is restricted to the region north of Hokitika Canyon, but commercial catches show that the distribution of hake and ling extends into the Hokitika Canyon and along the shelf to the south (O'Driscoll et al. 2015b). The southern region is characterised by canyons with a steeply sloping shelf. The rough bottom topography means that much of the area is unsuitable for bottom trawling and therefore cannot be easily incorporated in a random trawl survey. As a consequence, use of trawl survey estimates from the northern area only as indices for the entire WCSI (or FMA7) relies on the assumption that a constant proportion of the stock resides within the northern trawlable area.

The estimate of hake biomass ('all' area) increased by 57% from 2016, but was still lower than the levels observed in 2012 and 2013 (see Table 13). The 'core' area estimate of hake abundance in 2018 is less than 30% of that in 2000 (see Figure 6). The stock assessment for hake on the west coast South Island (HAK 7) was accepted for the first time in 2013 after incorporation of the 2000 and 2012 trawl survey series provided a 'reliable' abundance index. A new stock assessment for HAK 7 was carried out in 2017 using fisheries and research data up to the end of the 2015–16 fishing year (Horn 2017). The biomass in the three trawl surveys from 2000–13 decreased, which was in conflict with the trend in commercial CPUE, which increased from a low in 2008–09 to 2011–12 and then has remained stable. The Deepwater Working Group could not identify a base case model because but both sets of relative abundance indices were considered to be equally plausible. Consequently, estimates of biomass were produced for two models: a 'survey' model that included all the research survey biomass estimates and catch-at-age data, but excluded the CPUE; and a 'CPUE' model that included the CPUE series but excluded all the survey data. The trends of the two models diverged from around 2010 when stock status in both was estimated to be about 25–30% of B_0. The survey model indicated that biomass subsequently remained around this level owing to continued generally poor recruitment and relatively high exploitation rates, with estimated 2016 biomass from the survey model of 26% B_0. The CPUE model suggested a steady stock recovery as a consequence of recruitment of several average year classes and relatively low exploitation rates, with estimated 2016 biomass from the CPUE model of 50% B_0 (Horn 2017).

Estimated ling biomass in 2018 was very similar to that in 2016 (see Table 13). The stock assessment for ling on the west coast South Island (LIN 7) was updated in 2017 (Fisheries New Zealand 2018). There is little contrast in the trawl survey biomass indices to allow for estimation of the magnitude of the biomass, but it is highly probable that biomass in 2017 was greater than 40% B_0 and it could be much higher.

O'Driscoll et al. (2015b) concluded that trawl estimates from the northern area did not appear to be providing reliable indices of hoki abundance. Hoki estimates have been highly variable between trawl surveys (see Table 13). There was a six-fold increase in estimated hoki abundance in the core trawl strata between 2000 and 2012, a halving in 2013, and further large reductions in 2016 (by 45%) and 2018 (by another 68%). Although the amount of variability in northern trawl estimates on the WCSI is not consistent with changes in WCSI acoustic indices over the same period, estimated hoki abundance from trawl surveys in the Sub-Antarctic, or western spawning stock biomass estimated from the hoki stock assessment model, recent large declines in catch rates are of concern.

The acoustic survey provided a relative estimate of spawning hoki abundance on the WCSI, the first since 2013. The survey timing and spatial coverage were appropriate. The survey period was within the period of peak commercial catches (see Figure 14), gonad stage information showed hoki were actively spawning (see Table 15), and the survey area encompassed most of the commercial catch and effort (see Figure 13). The acoustic survey estimated that hoki abundance on the WCSI in 2018 was about half that in 2013, and the lowest in the time-series which began in 1988 (see Table 21). This decline is not consistent with current estimates of western hoki stock status; the 2018 base case suggests that biomass has been stable at about 62% B_0 for the last 6 years (Fisheries New Zealand 2018).

Species decomposition remains a major source of uncertainty in acoustic estimates of hoki on the WCSI, especially in 2018 when only a low proportion of the hoki (36%) were in dense schools where species identification is relatively certain. The standard decomposition method (Equation 3) assumes that all species which contribute to the backscatter are caught in the net, all species have equal catchability, and TS-length relationships (see Table 5) are known. None of these assumptions are likely to be fully met (O'Driscoll et al. 2014). Before 2000, there was the further problem that there was little or no research trawl data to carry out species decomposition and commercial data were used to derive estimates of P(hoki) (Cordue 2002). This uncertainty is now reflected in the revised CVs used for model weighting, which assign lower weights (higher CVs) to surveys before 2000 (see Table 21).

The 'revised' analysis methods also assume that hoki contribute 100% of the backscatter from all hoki marks (schools and fuzz) outside the northern area. This is not consistent with catch composition from the six mark identification trawls on fuzz marks in strata 6 and 7 in 2018 which only caught an (unweighted) average of 30% hoki by weight (see Table 17). O'Driscoll et al. (2015a) suggested that the assumption of 100% hoki in marks in the southern area does not have a major impact on estimated hoki abundance. However, if there are future WCSI acoustic surveys, consideration should be given to further increasing the level of mark identification trawling in the southern areas.

A notable observation was the very large increase in abundance of gemfish in the survey area (see Figure 6). Very few gemfish were caught in surveys from 2000–13, but small gemfish were widespread from 200–430 m depth in 2016 (O'Driscoll & Ballara 2018). In 2018, the abundance further increased (by a factor of 5.5) due to growth of the two year-classes observed in 2016, and also the recruitment of a further year-class (see Figure 8). Commercial landings of gemfish on the WCSI (SKI 7) were over 1000 t annually from 1983–84 to 1988–89, but then declined. The TACC was reduced to 300 t in 1997–98 and gemfish catches in the past 10 years were 144–301 t (Fisheries New Zealand 2018). The assessment of the southern gemfish stock (SKI 3&7) is being updated in 2019.

Other middle depth species were also monitored by this survey. None of the other stocks of species potentially monitored by the WCSI surveys are currently formally assessed (Fisheries New Zealand 2018). However, for most Tier 2 species, the trawl survey provides the only fisheries-independent estimate of abundance on the WCSI, as well as providing biological data (length, sex, reproductive condition, age, etc.). It is difficult to assess the "quality" of trawl estimates for many of these species based on surveys in 2000–18, as there are often no alternative indices of abundance (either from stock assessment or reliable CPUE indices). However, the relatively good precision (CVs) of survey estimates, consistency of abundance estimates and length frequency distributions between surveys, and appropriate spatial and depth distribution, suggest that the WCSI survey provides potential for monitoring species including lookdown dory, sea perch, silver warehou, javelinfish, dark ghost shark, and ribaldo. There have been notable declines in abundance of spiny dogfish and silver warehou since 2012 (see Figure 8).

Understanding change in the marine ecosystem is becoming increasingly important to provide context for fisheries management and decision making about sustainable fishing. Indicators are important for monitoring different types of change, and more than one type of indicator is required, particularly within the context of climate change. The level of biological sampling on the 2018 WCSI survey was among the most comprehensive of any New Zealand survey. As noted in Section 2.3, all items in the catch are sorted and weighed, and large numbers of individuals were measured and weighed (see Table 14). In the future this high level of sampling will allow development of ecosystem indicators. Ecosystem indicators derived from trawl survey data have been developed elsewhere, and used successfully to identify the effects of fishing on fish communities (review by Tuck et al. 2009). The most commonly used indicators were based on measures of diversity or fish size (mean size or size spectra), but indicators incorporating trophic level were also considered. Routine data collection of catch weight by species by tow means that species-based indicators could be estimated for the core survey area in 2000–18, but size-based indicators could only be calculated for 2012–18, when a much wider range of species was measured.

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7. TABLES

Table 1: Stratum depth boundaries, areas, and acoustic transect and random trawl allocations for the 2018 WCSI survey. Stratum locations are shown in Figure 1. Curly bracket ({) indicates the same transects crossed several trawl strata. Boundaries of strata 5B and 7 were defined by geographical positions rather than depth.

				Acoustic transects		Random trawls	
Stratum	Stratum code	Depth (m)	Area (km^2)	Snap 1	Snap 2	Planned	Actual
1&2S	12S	200–300	1 450	0	0	3	3
1&2A	12A	300–430	1 214	{4	{4	8	8
1&2B	12B	430–500	1 028	{4	{4	7	7
1&2C	12C	500–650	3 148	{4	{4	5	5
4S	4S	200–300	1 600	0	0	4	7
4A	4A	300–430	786	{8	{7	6	6
4B	4B	430–500	592	{8	{7	3	3
4C	4C	500–650	1 455	{8	{7	3	3
4D	4D	650–800	1 655	{8	0	7	7
4E	4E	800–900	1 192	0	0	4	4
4F	4F	900–1000	2 097	0	0	4	4
5A	5A	300–300	254	7	7	0	0
5B	5B	position–position	529	3	3	0	0
6	6	250–850 (north of 42.85°S) 250–750 (south of 42.85°S)	2 165	9	8	0	0
7	7	position–position	565	4	4	0	0
	Total		19 730	35	33	54	57

Table 2: Numbers of stations required to achieve a target CV of 20% for hake (HAK) and ling (LIN), 25% for hoki (HOK), giant stargazer (GIZ), sea perch (SPE), lookdown dory (LDO), and dark ghost shark (GSH), and 30% for silver warehou (SWA) and spiny dogfish (SPD) are given by species. Four tows were arbitrarily assigned to each of the deep strata, outside of the statistical allocation process. –, not applicable.

	Number of tows									
Stratum	HAK	LIN	HOK	SWA	GIZ	SPD	SPE	LDO	GSH	ALL
1&2A	3	8	4	3	3	3	3	3	4	8
1&2B	3	3	7	3	3	3	3	3	3	7
1&2C	4	3	4	5	3	3	3	3	3	5
1&2S	3	3	3	3	3	3	3	3	3	3
4A	3	3	5	3	3	6	3	3	3	6
4B	3	3	3	3	3	3	3	3	3	3
4C	3	3	3	3	3	3	3	3	3	3
4D	7	3	3	3	3	3	3	3	3	7
4S	3	3	3	3	4	3	3	3	3	4
4E	–	–	–	–	–	–	–	–	–	4
4F	–	–	–	–	–	–	–	–	–	4
Total	32	32	35	29	28	30	27	27	28	54

Table 3: Length-weight regression parameters* used to scale length frequencies for the top key species. Where data source is given as '5 WCSI surveys' length-weight parameters were estimated from combined data from TAN0007, TAN1210, TAN1308, TAN1609, and TAN1807.

		Regression parameters					
Common name	Code	*a*	*b*	r^2	*n*	Length range (cm)	Data sourrce
Alfonsino	BYS	0.010897	3.202853	93.72	746	18.8–42.8	5 WCSI surveys
Arrow squid	SQU	0.088170	2.652793	98.03	401	8.6–43.1	TAN1807
Australasian slender cod	HAS	0.002980	3.175718	97.02	26	29.2–44.8	5 WCSI surveys
Banded bellowsfish	BBE	0.001691	3.557696	93.96	13	18.8–25.6	5 WCSI surveys
Banded rattail	CFA	0.001766	3.259089	85.71	87	19.2–35.0	5 WCSI surveys
Barracouta	BAR	0.016141	2.722201	87.05	849	49.8–106.0	5 WCSI surveys
Basketwork eel	BEE	0.000351	3.289194	96.30	54	60.4–124.1	5 WCSI surveys
Baxter's lantern dogfish	ETB	0.001071	3.385652	95.11	22	50.2–80.0	5 WCSI surveys
Bigeye cardinalfish	EPL	0.034700	2.687622	86.41	250	14.3–23.3	5 WCSI surveys
Bigeye sea perch	HBA	0.007526	3.216895	98.51	734	11.6–47.3	TAN1807
Bigscaled brown slickhead	SBI	0.001294	3.500308	86.67	27	34.6–51.5	5 WCSI surveys
Black slickhead	BSL	0.003306	3.282782	97.56	158	20.0–42.1	TAN1807
Bollons' rattail	CBO	0.000774	3.512397	97.93	303	20.1–66.6	TAN1807
Cape scorpionfish	TRS	0.006042	3.332224	98.85	22	18.4–43.7	5 WCSI surveys
Capro dory	CDO	0.136551	2.092776	55.87	37	8.2–11.2	5 WCSI surveys
Carpet shark	CAR	0.039931	2.577816	65.86	103	50.7–88.8	5 WCSI surveys
Common roughy	RHY	0.062725	2.649598	85.80	42	17.7–26.0	5 WCSI surveys
Common warehou	WAR	0.026521	2.931808	87.87	40	49.9–63.3	5 WCSI surveys
Cucumber fish	CUC	0.012497	2.951838	84.97	372	14.6–25.1	5 WCSI surveys
Dark banded rattail	CDX	0.000686	3.526235	85.41	14	21.0–30.8	5 WCSI surveys
Dark ghost shark	GSH	0.001666	3.310410	97.74	218	34.8–73.2	TAN1807
Deepsea flathead	FHD	0.001001	3.479027	96.82	51	29.2–51.3	5 WCSI surveys
Eucla cod	EUC	0.000990	3.535681	96.34	221	16.8–31.4	TAN1807
Four-rayed rattail	CSU	0.004610	2.729948	79.70	202	17.7–37.3	5 WCSI surveys
Frostfish	FRO	0.000820	3.006079	95.46	134	72.7–165.3	TAN1807
Gemfish	RSO	0.005260	3.050627	98.65	564	31.7–95.2	TAN1807
Giant stargazer	GIZ	0.003326	3.407583	97.82	272	14.4–79.0	TAN1807
Hairy conger	HCO	0.001087	3.144077	85.95	20	69.9–98.5	5 WCSI surveys
Hake	HAK	0.001916	3.310195	99.00	588	32.3–118.0	TAN1807
Hapuku	HAP	0.001565	3.506222	98.54	76	53.6–134.2	5 WCSI surveys
Hoki	HOK	0.004787	2.894484	98.41	745	25.1–113.0	TAN1807
Jack mackerel	JMD	0.017051	2.900032	95.99	69	28.7–55.3	5 WCSI surveys
Javelinfish	JAV	0.000928	3.250221	98.07	470	19.5–60.1	TAN1807
John dory	JDO	0.019367	2.976991	90.69	97	35.0–55.4	TAN1807
Johnson's cod	HJO	0.002980	3.175718	97.02	26	29.2–44.8	5 WCSI surveys
Leafscale gulper shark	CSQ	0.000360	3.601420	87.87	104	89.0–145.0	5 WCSI surveys
Ling	LIN	0.001221	3.308853	99.43	496	29.3–155.3	TAN1807
Longnose velvet dogfish	CYP	0.002729	3.111932	99.07	135	32.2–97.6	5 WCSI surveys
Lookdown dory	LDO	0.022051	3.000201	99.25	438	10.9–53.2	TAN1807
Lucifer dogfish	ETL	0.000771	3.396523	93.04	163	30.0–50.9	5 WCSI surveys
Mahia rattail	CMA	0.000910	3.414583	96.98	42	30.4–63.6	5 WCSI surveys
Northern spiny dogfish	NSD	0.003269	3.065469	96.02	209	41.1–88.2	TAN1807
Notable rattail	CIN	0.001658	3.075378	86.72	20	18.5–31.0	5 WCSI surveys
Oliver's rattail	COL	0.000981	3.283629	95.74	171	15.6–41.1	TAN1807
Orange perch	OPE	0.024540	2.918501	97.43	79	17.6–34.1	TAN1807
Orange roughy	ORH	0.065582	2.793752	98.62	110	6.4–42.4	TAN1807
Pale ghost shark	GSP	0.005170	3.022036	97.91	171	30.2–88.4	5 WCSI surveys
Plunket's shark	PLS	0.004009	3.114436	96.86	39	61.1–144.4	5 WCSI surveys
Portugese dogfish	CYL	0.000686	3.521696	84.92	45	85.7–121.0	5 WCSI surveys
Red cod	RCO	0.009666	2.984309	99.04	646	15.4–69.6	5 WCSI surveys
Redbait	RBT	0.001880	3.580719	99.56	216	14.0–39.3	TAN1807
Ribaldo	RIB	0.004979	3.198264	98.87	152	17.3–67.9	TAN1807
Rig	SPO	0.000037	4.040013	96.00	13	79.9–114.7	5 WCSI surveys
Rough skate	RSK	0.060165	2.713196	97.77	41	29.5–64.1	5 WCSI surveys
Rudderfish	RUD	0.026643	2.828314	95.47	14	61.8–113.3	5 WCSI surveys
Scaly gurnard	SCG	0.004742	3.421392	96.80	15	9.6–17.9	5 WCSI surveys
Scampi	SCI	0.684617	2.822982	91.20	123	3.3–6.1	5 WCSI surveys
School shark	SCH	0.008421	2.870580	97.77	80	64.6–147.7	TAN1807
Sea perch	HBA	0.007526	3.216895	98.51	734	11.6–47.3	TAN1807
Seal shark	BSH	0.001437	3.286226	97.71	62	38.5–139.2	5 WCSI surveys

Serrulate rattail	CSE	0.000528	3.540431	89.77	58	23.8–43.2	5 WCSI surveys
Shovelnose dogfish	SND	0.000291	3.558377	96.01	144	60.6–117.9	TAN1807
Silver dory	SDO	0.019178	2.954000	96.34	207	13.7–26.6	TAN1807
Silver roughy	SRH	0.015047	3.135028	89.09	546	8.4–16.7	5 WCSI surveys
Silver warehou	SWA	0.009909	3.166754	97.14	180	29.2–57.4	TAN1807
Silverside	SSI	0.056337	2.111346	53.10	11	14.1–17.9	5 WCSI surveys
Slender mackerel	JMM	0.024874	2.771876	60.26	26	49.4–57.7	5 WCSI surveys
Slender smooth-hound	SSH	0.001579	3.111712	96.60	254	40.3–107.5	5 WCSI surveys
Small banded rattail	CCX	0.001106	3.265012	94.29	74	17.7–32.4	TAN1807
Smooth skate	SSK	0.018874	2.998459	99.31	252	38.1–155.0	5 WCSI surveys
Smooth skin dogfish	CYO	0.000301	3.667902	95.27	90	73.2–124.3	TAN1807
Southern Ray's bream	SRB	0.008266	3.209247	92.48	127	34.9–46.8	5 WCSI surveys
Spiky oreo	SOR	0.030702	2.902818	97.20	300	11.4–33.9	TAN1807
Spineback	SBK	0.000649	3.233341	93.95	15	45.8–72.2	5 WCSI surveys
Spiny dogfish	SPD	0.000074	3.943166	91.46	79	57.9–96.5	TAN1807
Spotted gurnard	JGU	0.006785	3.198633	98.53	63	15.6–53.1	5 WCSI surveys
Swollenhead conger	SCO	0.002728	2.937679	63.85	78	79.2–102.1	5 WCSI surveys
Tarakihi	NMP	0.017869	2.987920	93.57	220	29.7–48.9	TAN1807
Two saddle rattail	CBI	0.000903	3.443974	97.62	158	22.9–56.6	5 WCSI surveys
White rattail	WHX	0.000607	3.573884	98.36	128	36.5–97.0	TAN1807
White warehou	WWA	0.016162	3.094055	97.90	62	28.5–69.2	5 WCSI surveys
Widenosed chimaera	RCH	0.002849	2.907787	87.73	17	103.5–142.9	5 WCSI surveys
Yellow boarfish	YBO	0.037307	2.848742	97.16	153	10.3–24.1	TAN1807

*W = aL^b where W is weight (g) and L is length (cm); r^2 is the correlation coefficient, *n* is the number of samples.

Table 4: Summary of 'revised' acoustic method used to estimate hoki abundance from the 2018 WCSI acoustic survey.

Parameter	'Revised'
Sound absorption	8.88 dB km^{-1} (Appendix 4)
Hoki TS used to estimate abundance	Dunford et al. (2015)
Hoki length-weight	Francis (2003)
Hoki length distribution	2018 commercial fishery (all strata)
Species decomposition of hoki schools	None (assumed 100% hoki)
Species decomposition of mixed marks	Northern strata only
Hoki TS used in species decomposition	Dunford et al. (2015); Coombs & Cordue (1995) for 1988–2000
Tow weighting for species decomposition	Equal weighting
Survey area	Figure 1 excluding substrata 1&2S, 4S, 4D, 4E, 4F
Stratum areas	Table 1
Survey weighting	Error in mix marks based on bootstrapping tow data from 2000 on
Abundance estimate	One (entire area)
Backward comparability	Comparable to 'revised' WCSI indices of O'Driscoll et al. (2015a) adjusted for change in hoki TS by O'Driscoll et al. (2016)

Table 5: Mean fish size and derived target strength (TS) for species used in species decomposition. Other species were considered as a group ("Other"), and an average TS was assigned.

Species name	Mean length$^+$ (cm)	Mean weight$^+$ (kg)	TS$^+$ (dB kg^{-1})	TS-length relationship* *a*	*b*
Hoki	68	0.9	-38.6	24.5	83.9
Ling	98	3.1	-33.6	20	68
Hake	71	3.3	-37.5	27.1	83.5
Silver warehou	47	2.3	-49.7	20	80
Spiny dogfish	75	1.8	-45.1	20	80
Javelinfish	30	0.1	-32.1	20	73.5
Bigeyed rattail	43	0.4	-33.5	20	70
Lookdown dory	24	0.4	-31.2	20	64
Silver dory	19	0.1	-29.1	20	64
Dark ghost shark	53	1.0	-44.8	20	80
Ribaldo	45	0.7	-30.0	21.7	66.7
Alfonsino	22	0.2	-34.7	20	68
Pale ghost shark	62	1.2	-45.1	20	80
School shark	101	6.1	-47.2	20	80
Deepwater spiny dogfish	130	18.7	-50.0	20	80
Shovelnosed dogfish	85	2.7	-45.2	20	80
Other	–	–	-34.7	–	–

* TS = *a* $\log_{10}$ (length) – *b*. Best estimates from *in situ* measurements, swimbladder modelling, or related species (Gavin Macaulay, pers. comm.).

$^+$ Values of mean length, weight, and TS were estimated by substratum, but averages across all strata are summarised here.

Table 6: Values of parameters and their distributions used in Monte Carlo uncertainty simulations to estimate weighting (CV) of WCSI acoustic survey abundance indices (see Section 2.7.5).

Term	Notation	Distribution*	Value
Mean arrival date	$\bar{d}$	Uniform	197–212
Mean residence time	$\bar{r}$	Uniform	27–47
Individual arrival date	d_i	Normal	$\bar{d}$ (5)
Individual residence time	r_i	Normal	$\bar{r}$ (10)
Sampling	s	Normal	1.0 (snapshot c.v)
Mark identification – "mix" strata (1988–97)	id_{mix}	Lognormal	-0.2 (0.5)$^+$
Mark identification – "mix" strata (2000–18)	id_{mix}	Lognormal	0 (0.3)$^+$
Mark identification – "hoki" strata	id_{hoki}	Lognormal	0 (0.08)
Calibration (1988–90)	$\text{cal}_{88\text{-}90}$	Uniform	0.75–1.25
Calibration (1991–99)	$\text{cal}_{91\text{-}99}$	Uniform	0.88–1.12
Calibration (post 2000)	$\text{cal}_{00\text{-}01}$	Uniform	0.95–1.05
Target strength	TS	Uniform	0.88–1.12

*For uniform distributions the values are ranges; for normal distributions values are means with s.d. in parentheses; for lognormal distributions values are the mean and s.d. of $\log_{10}$(variable). Plateau model variables (mean and individual arrival dates, mean and individual residence times) are in days. All other variables are relative (scaled to one).

$^+$ Uncertainty in mixed marks since 2000 was estimated by bootstrapping from observed trawl catches in each survey and then applying a reduced error component to account for potential variability in trawl catchability and relative TS.

Table 7: Summary of acoustic snapshots and mark identification trawls in 2018 WCSI survey. South area includes strata 5A, 5B, 6, and 7. North area includes strata 1&2 and 4.

Snapshot	Area	Start time	End time	No. of transects	No. of trawls
1	North	26 Jul 18:43	4 Aug 22:25	12	0
	South	6 Aug 19:44	10 Aug 06:11	23	3
2	South	10 Aug 09:36	12 Aug 10:08	22	4
	North	12 Aug 11:59	14 Aug 06:57	11	2
Total				**68**	**9**

Table 8: Survey tow and gear parameters (recorded values only) for valid tows on the 2018 trawl survey (i.e., excluding mark identification tows). Values are number of tows (*n*), and the mean, standard deviation (s.d.), and range of observations for each parameter.

	n	Mean	s.d	Range
Tow parameters				
Tow length (n. miles)	57	2.95	0.19	2.11–3.19
Tow speed (knots)	57	3.5	0.02	3.4–3.6
Gear parameters (m)				
200–300 m				
Headline height	10	6.8	0.29	6.2–7.1
Doorspread	9	108.7	3.46	103.2–113.0
300–650 m				
Headline height	31	6.7	0.29	6.0–7.3
Doorspread	29	122.3	5.65	111.0–129.2
650–800 m				
Headline height	8	6.7	0.32	6.0–7.1
Doorspread	8	124.0	3.57	117.7–128.0
800–1000 m				
Headline height	8	6.9	0.32	6.4–7.4
Doorspread	8	123.0	3.77	116.8–127.0
All tows 200–1000 m				
Headline height	57	6.8	0.30	6.0–7.4
Doorspread	54	120.4	7.11	103.2–129.2

Table 9: Comparison of doorspread and headline measurements from valid trawl survey tows from the *Tangaroa* WCSI time-series. Values are the mean and standard deviation (s.d.). The number of tows with measurements (*n*) and the range of observations are also given for doorspread.

	Doorspread (m)					Headline height (m)	
Survey	*n*	Mean	s.d.	min	max	mean	s.d.
2000	42	123.9	6.91	106.4	138.0	6.7	0.28
2012	60	119.2	8.04	101.3	135.1	7.0	0.32
2013	64	123.9	8.50	108.5	138.3	7.0	0.23
2016	58	119.8	7.69	99.5	133.0	7.1	0.40
2018	54	120.4	7.11	103.2	129.2	6.8	0.30

Table 10: Total catch of the top 50 species from all tows during the 2018 WCSI survey.

Code	Common name	Scientific name	Catch (kg)
HOK	Hoki	*Macruronus novaezelandiae*	9 682.8
LIN	Ling	*Genypterus blacodes*	7 510.0
GIZ	Giant stargazer	*Kathetostoma giganteum*	3 388.0
BAR	Barracouta	*Thyrsites atun*	3 382.1
HAK	Hake	*Merluccius australis*	2 078.6
RSO	Gemfish	*Rexea solandri*	2 010.8
SSK	Smooth skate	*Dipturus innominatus*	892.5
NMP	Tarakihi	*Nemadactylus macropterus*	803.9
LDO	Lookdown dory	*Cyttus traversi*	667.1
CYO	Smooth skin dogfish	*Centroscymnus owstoni*	447.4
SCH	School shark	*Galeorhinus galeus*	444.6
SWA	Silver warehou	*Seriolella punctata*	422.0
WHX	White rattail	*Trachyrincus aphyodes*	414.7
CSQ	Leafscale gulper shark	*Centrophorus squamosus*	414.2
SND	Shovelnose spiny dogfish	*Deania calcea*	382.5
JAV	Javelin fish	*Lepidorhynchus denticulatus*	372.6
CBO	Bollons' rattail	*Coelorinchus bollonsi*	336.4
HBA	Bigeye sea perch	*Helicolenus barathri*	317.0
NSD	Northern spiny dogfish	*Squalus griffini*	311.2
SQU	Arrow squid	*Nototodarus sloanii* & *N. gouldi*	277.1
FRO	Frostfish	*Lepidopus caudatus*	257.7
SRH	Silver roughy	*Hoplostethus mediterraneus*	246.0
GSH	Ghost shark	*Hydrolagus novaezealandiae*	232.2
SPD	Spiny dogfish	*Squalus acanthias*	212.8
RIB	Ribaldo	*Mora moro*	206.2
JDO	John dory	*Zeus faber*	184.3
HAP	Hapuku	*Polyprion oxygeneios*	178.7
OPE	Orange perch	*Lepidoperca aurantia*	169.0
CAR	Carpet shark	*Cephaloscyllium isabellum*	142.8
YBO	Yellow boarfish	*Pentaceros decacanthus*	139.7
RBT	Redbait	*Emmelichthys nitidus*	124.6
SOR	Spiky oreo	*Neocyttus rhomboidalis*	112.2
SDO	Silver dory	*Cyttus novaezealandiae*	104.9
HPC	Sea perch	*Helicolenus percoides*	97.1
EUC	Eucla cod	*Euclichthys polynemus*	95.6
ORH	Orange roughy	*Hoplostethus atlanticus*	92.2
PLS	Plunket's shark	*Proscymnodon plunketi*	82.6
SSH	Slender smooth-hound	*Gollum attenuatus*	65.2
BEE	Basketwork eel	*Diastobranchus capensis*	57.0
BSL	Black slickhead	*Xenodermichthys* spp.	54.9
SCO	Swollenhead conger	*Bassanago bulbiceps*	51.6
GSP	Pale ghost shark	*Hydrolagus bemisi*	50.4
ERA	Electric ray	*Torpedo fairchildi*	50.0
CYP	Longnose velvet dogfish	*Centroscymnus crepidater*	45.4
COL	Olivers rattail	*Coelorinchus oliverianus*	40.4
MRQ	Warty squid	*Onykia robsoni*	39.0
JMD	Greenback jack mackerel	*Trachurus declivis*	37.9
RUD	Rudderfish	*Centrolophus niger*	36.6
CUC	Cucumber fish	*Paraulopus nigripinnis*	36.3
CYL	Portugese dogfish	*Centroscymnus coelolepis*	34.9
Total			38 470.1

Table 11: Catch and total abundance estimates with coefficient of variation (CV in parentheses) of species ranked by abundance, for valid trawl tows in core strata (300–650 m), all strata (200–800 m), and deep strata (200–1000 m) in 2018. Species arranged in descending order of abundance. Value of 0 indicates catch less than 0.5 kg or biomass less than 0.5 t; -, zero catch or biomass.

		Catch (kg)			Biomass (t)		
Common name	Code	Core	All	Deep	Core total	All total	Deep total
Hoki	HOK	7 563	8 003	8 050	2 484 (14.2)	2 636 (13.6)	2 661 (13.5)
Ling	LIN	7 374	7 386	7 386	1 682 (18.3)	1 686 (18.3)	1 686 (18.3)
Barracouta	BAR	6	3 342	3 342	1 (58.1)	1 583 (32.0)	1 583 (32.0)
Giant stargazer	GIZ	1 360	3 298	3 298	295 (54.7)	1 119 (20.5)	1 119 (20.5)
Hake	HAK	285	1 244	1 910	229 (32.6)	559 (17.6)	899 (13.9)
Gemfish	RSO	741	1 987	1 987	171 (14.2)	702 (33.1)	702 (33.1)
Tarakihi	NMP	24	773	773	5 (35.8)	353 (15.8)	353 (15.8)
Lookdown dory	LDO	577	640	640	271 (21.7)	292 (20.2)	293 (20.2)
Smooth skate	SSK	731	834	834	177 (24.1)	225 (22.3)	225 (22.3)
White rattail	WHX	-	113	395	-	39 (25.7)	202 (18.8)
Smooth skin dogfish	CYO	8	147	412	5 (100.0)	53 (52.9)	201 (21.9)
Shovelnose dogfish	SND	69	222	361	61 (64.7)	114 (36.4)	188 (24.0)
Bollons’ rattail	CBO	291	294	294	176 (19.0)	177 (18.9)	177 (18.9)
Leafscale gulper shark	CSQ	38	337	398	30 (71.5)	134 (24.4)	166 (22.1)
School shark	SCH	242	441	441	53 (21.9)	144 (9.8)	144 (9.8)
Bigeye sea perch	HBA	253	285	289	114 (16.9)	125 (15.4)	127 (15.2)
Silver warehou	SWA	375	417	417	91 (20.6)	118 (22.4)	118 (22.4)
Javelinfish	JAV	320	358	361	98 (17.0)	112 (15.1)	113 (14.9)
Ribaldo	RIB	41	162	201	29 (21.1)	71 (14.3)	93 (12.7)
Northern spiny dogfish	NSD	224	303	303	50 (19.0)	90 (16.5)	90 (16.5)
Redbait	RBT	117	125	125	84 (40.9)	88 (39.4)	88 (39.4)
Silver roughy	SRH	227	238	238	82 (21.8)	86 (21.0)	86 (21.0)
Arrow squid	SQU	175	244	244	43 (16.0)	83 (15.0)	83 (15.0)
John dory	JDO	-	180	180	-	77 (25.0)	77 (25.0)
Frostfish	FRO	218	256	256	50 (37.5)	70 (30.1)	70 (30.1)
Orange perch	OPE	4	169	169	1 (53.2)	62 (50.0)	62 (50.0)
Dark ghost shark	GSH	212	232	232	46 (18.0)	61 (14.2)	61 (14.2)
Orange roughy	ORH	-	1	90	-	0 (100.0)	55 (29.0)
Carpet shark	CAR	28	143	143	6 (48.7)	49 (26.3)	49 (26.3)
Spiky oreo	SOR	1	77	112	0 (100.0)	28 (30.1)	46 (20.7)
Hapuku	HAP	156	179	179	35 (38.0)	43 (30.8)	43 (30.8)
Yellow boarfish	YBO	139	139	139	38 (30.9)	39 (30.6)	39 (30.6)
Plunket's shark	PLS	26	43	50	30 (88.0)	35 (75.3)	38 (69.9)
Spiny dogfish	SPD	159	167	167	36 (39.8)	38 (37.1)	38 (37.1)
Silver dory	SDO	53	104	104	11 (47.6)	35 (23.1)	35 (23.1)
Sea perch	HPC	4	88	88	1 (67.9)	33 (54.0)	33 (54.0)
Basketwork eel	BEE	-	0	47	-	0 (100.0)	31 (24.4)
Pale ghost shark	GSP	19	33	49	18 (19.7)	23 (16.7)	31 (16.5)
Swollenhead conger	SCO	27	49	49	21 (33.3)	29 (26.8)	29 (26.5)
Black slickhead	BSL	-	28	54	-	10 (23.2)	24 (17.4)
Portugese dogfish	CYL	-	-	35	-	-	24 (39.2)
Eucla cod	EUC	96	96	96	24 (25.8)	24 (25.8)	24 (25.8)
Jack mackerel	JMD	1	38	38	0 (100.0)	22 (50.6)	22 (50.6)
Warty squid	MRQ	-	17	36	-	6 (29.5)	18 (20.6)
Longnose velvet dogfish	CYP	-	11	31	-	4 (41.5)	17 (43.6)
Hairy conger	HCO	14	28	29	11 (40.2)	16 (32.2)	17 (31.2)
Slender smooth-hound	SSH	65	65	65	16 (24.3)	16 (24.3)	16 (24.3)
Cucumber fish	CUC	9	36	36	2 (36.1)	15 (23.6)	15 (23.6)
Electric ray	ERA	46	50	50	10 (65.4)	15 (54.8)	15 (54.8)
Oliver's rattail	COL	14	34	34	8 (29.5)	14 (24.3)	14 (24.3)
White warehou	WWA	6	34	34	4 (100.0)	14 (44.6)	14 (44.6)
Baxter's lantern dogfish	ETB	-	2	20	-	1 (100.0)	13 (30.2)
Rig	SPO	26	33	33	6 (56.8)	13 (39.7)	13 (39.7)
Widenosed chimaera	RCH	-	-	18	-	-	12 (17.3)
Bigscaled brown slickhead	SBI	-	-	15	-	-	12 (58.0)
Dealfish	DEA	12	16	16	11 (100.0)	12 (89.8)	12 (89.8)
Four-rayed rattail	CSU	-	1	16	-	0 (89.2)	9 (18.3)
Seal shark	BSH	10	12	14	6 (22.9)	7 (21.6)	8 (21.6)
Banded rattail	CFA	8	8	8	8 (38.7)	8 (38.5)	8 (38.5)

Table 11: continued.

		Catch (kg)			Biomass (t)		
Common name	Code	Core	All	Deep	Core total	All total	Deep total
Mahia rattail	CMA	-	7	18	-	2 (56.8)	8 (22.3)
Kingfish	KIN	-	10	10	-	8 (100.0)	8 (100.0)
Slender mackerel	JMM	4	18	18	1 (100.0)	7 (51.0)	7 (51.0)
Octopoteuthis spp.	OPO	-	-	10	-	-	7 (100.0)
Porcupine fish	POP	-	18	18	-	7 (77.7)	7 (77.7)
Serrulate rattail	CSE	-	1	10	-	0 (56.1)	6 (15.3)
Deepsea flathead	FHD	23	23	23	6 (19.4)	6 (19.4)	6 (19.4)
Red cod	RCO	30	30	30	6 (36.6)	6 (36.6)	6 (36.6)
Rudderfish	RUD	29	29	29	6 (66.8)	6 (66.8)	6 (66.8)
Common warehou	WAR	-	15	15	-	6 (64.9)	6 (64.9)
Bigeye cardinalfish	EPL	4	8	8	3 (20.8)	5 (19.0)	5 (19.0)
Rough skate	RSK	12	18	18	2 (69.2)	5 (50.6)	5 (50.6)
Pale toadfish	TOP	6	6	6	5 (70.7)	5 (70.7)	5 (70.7)
Velvet dogfish	ZAS	-	-	6	-	-	5 (58.5)
Small banded rattail	CCX	14	14	14	4 (42.4)	4 (42.4)	4 (42.4)
Capro dory	CDO	14	15	15	4 (18.6)	4 (18.4)	4 (18.4)
Lucifer dogfish	ETL	6	7	7	4 (31.6)	4 (28.7)	4 (28.7)
Spotted gurnard	JGU	10	13	13	2 (38.2)	4 (43.5)	4 (43.5)
Common roughy	RHY	-	11	11	-	4 (54.3)	4 (54.3)
Cape scorpionfish	TRS	-	-	8	-	-	4 (47.8)
Australasian slender cod	HAS	-	2	8	-	1 (40.5)	4 (21.2)
Alfonsino	BYS	8	8	8	3 (57.8)	3 (57.8)	3 (57.8)
Spineback	SBK	2	3	5	2 (83.8)	2 (71.5)	3 (49.1)
Humpback rattail (slender rattail)	CBA	-	-	7	-	-	3 (35.2)
Violet squid	HAA	4	4	4	3 (100.0)	3 (100.0)	3 (100.0)
Violet squid	HMI	-	6	7	-	2 (54.5)	3 (47.9)
Omega prawn	LHO	0	1	5	0 (100.0)	0 (28.2)	3 (23.4)
Two saddle rattail	CBI	8	8	8	2 (38.9)	2 (38.9)	2 (38.9)
Southern Ray’s bream	SRB	3	3	3	2 (81.7)	2 (81.7)	2 (81.7)
Smooth deepsea anemones	ACS	2	2	3	1 (79.0)	1 (79.0)	2 (65.7)
Rope-like sea pen	FQU	2	2	2	2 (81.6)	2 (81.6)	2 (81.6)
Hagfish	HAG	3	3	3	2 (85.8)	2 (85.8)	2 (85.8)
Geometric star	PSI	4	4	4	2 (31.7)	2 (31.0)	2 (31.0)
Large red scaly squid	PSQ	-	5	5	-	2 (66.6)	2 (66.6)
Todarodes filippovae	TSQ	-	2	3	-	1 (100.0)	2 (70.8)
Banded bellowsfish	BBE	2	2	2	1 (57.5)	1 (51.7)	1 (51.7)
Dark banded rattail	CDX	2	2	2	1 (41.7)	1 (41.7)	1 (41.7)
Notable rattail	CIN	0	1	2	0 (100.0)	0 (33.6)	1 (24.8)
Scaly gurnard	SCG	-	1	1	-	1 (42.4)	1 (42.4)
Scampi	SCI	1	1	1	1 (36.1)	1 (36.1)	1 (36.1)
New Zealand catshark	AEX	-	-	1	-	-	1 (75.3)
Scabbardfish	BEN	1	1	1	1 (38.8)	1 (38.8)	1 (38.8)
Benthoctopus spp.	BNO	-	1	1	-	0 (100.0)	1 (76.0)
Brisingida (Order)	BRG	-	-	1	-	-	1 (61.2)
Smooth deepsea skate	BTA	1	1	1	1 (87.9)	1 (87.9)	1 (87.9)
Viper fish	CHA	-	1	1	-	0 (32.4)	1 (31.9)
Sun star	CJA	1	1	1	1 (29.7)	1 (28.6)	1 (28.6)
Dipsacaster magnificus	DMG	1	1	1	1 (60.9)	1 (57.2)	1 (57.2)
Echinothuriidae (family)	ECT	-	0	1	-	0 (70.8)	1 (59.1)
Blue mackerel	EMA	-	2	2	-	1 (100.0)	1 (100.0)
Deepsea anemone	HMT	1	1	1	1 (69.8)	1 (69.8)	1 (69.8)
Floppy tubular sponge	HYA	-	3	3	-	1 (100.0)	1 (100.0)
Umbrella octopus	OPI	-	3	3	-	1 (66.8)	1 (66.8)
Lighthouse fish	PHO	0	1	2	0 (100.0)	0 (48.2)	1 (40.5)
Sergia potens	SEP	-	0	1	-	0 (53.8)	1 (26.3)
Spinyfin	SFN	-	2	2	-	1 (64.6)	1 (64.6)
Smallscaled brown slickhead	SSM	-	-	2	-	-	1 (100.0)
Violet squid	VSQ	-	3	3	-	1 (72.4)	1 (61.7)
Rat-tail star	ZOR	0	1	1	0 (100.0)	0 (60.7)	1 (41.1)

Table 12: Estimated trawl abundance (t) and coefficient of variation (% CV) of species by stratum arranged in descending order of total abundance. See Table 1 for stratum codes and Table 11 for species common names. Value of 0 indicates biomass less than 0.5 t; -, zero biomass.

														Stratum
Species	012A	012B	012C	004A	004B	004C	Core (total)	012S	004S	004D	All (total)	004E	004F	Total
HOK	42 (35.6)	838 (29.5)	479 (23.1)	58 (42.2)	554 (38.9)	514 (11.0)	2 484 (14.2)	-	0 (100.0)	152 (44.4)	2 636 (13.6)	15 (30.2)	9 (40.5)	2 661 (13.5)
LIN	824 (20.8)	85 (24.6)	70 (21.5)	597 (42.6)	96 (21.5)	11 (48.1)	1 682 (18.3)	-	-	4 (52.8)	1 686 (18.3)	-	-	1 686 (18.3)
BAR	1 (100.0)	-	-	1 (67.2)	-	-	1 (58.1)	485 (85.1)	1 097 (26.8)	-	1 583 (32.0)	-	-	1 583 (32.0)
GIZ	258 (62.3)	0 (64.6)	-	29 (32.6)	1 (100.0)	6 (100.0)	295 (54.7)	153 (59.1)	671 (20.3)	0 (100.0)	1 119 (20.5)	-	-	1 119 (20.5)
HAK	-	4 (72.2)	124 (58.5)	-	5 (59.6)	96 (17.5)	229 (32.6)	-	-	330 (19.3)	559 (17.6)	215 (29.4)	125 (36.4)	899 (13.9)
RSO	72 (23.0)	26 (30.2)	8 (82.0)	47 (26.0)	18 (43.9)	-	171 (14.2)	67 (38.5)	464 (49.6)	-	702 (33.1)	-	-	702 (33.1)
NMP	-	-	-	5 (35.8)	-	-	5 (35.8)	107 (20.2)	241 (21.3)	-	353 (15.8)	-	-	353 (15.8)
LDO	38 (49.0)	36 (28.6)	120 (40.6)	-	2 (42.9)	74 (33.4)	271 (21.7)	-	-	22 (26.4)	292 (20.2)	0 (100.0)	-	293 (20.2)
SSK	47 (43.5)	54 (28.8)	23 (100.0)	49 (50.4)	4 (100.0)	-	177 (24.1)	16 (100.0)	18 (84.2)	15 (100.0)	225 (22.3)	-	-	225 (22.3)
WHX	-	-	-	-	-	-	-	-	-	39 (25.7)	39 (25.7)	71 (7.4)	92 (39.5)	202 (18.8)
CYO	-	-	-	-	-	5 (100.0)	5 (100.0)	-	-	48 (57.8)	53 (52.9)	72 (26.3)	76 (37.2)	201 (21.9)
SND	-	-	55 (71.0)	-	-	6 (100.0)	61 (64.7)	-	-	53 (24.1)	114 (36.4)	41 (21.7)	33 (47.1)	188 (24.0)
CBO	4 (67.9)	24 (24.2)	142 (23.0)	-	1 (70.4)	4 (50.9)	176 (19.0)	-	-	1 (100.0)	177 (18.9)	-	-	177 (18.9)
CSQ	-	-	17 (100.0)	-	-	13 (100.0)	30 (71.5)	-	-	104 (23.7)	134 (24.4)	20 (58.0)	12 (100.0)	166 (22.1)
SCH	33 (20.3)	-	-	21 (46.5)	-	-	53 (21.9)	28 (18.2)	64 (10.0)	-	144 (9.8)	-	-	144 (9.8)
HBA	15 (16.3)	15 (39.6)	68 (26.3)	5 (46.9)	3 (46.8)	8 (27.2)	114 (16.9)	0 (71.7)	-	11 (14.7)	125 (15.4)	2 (43.3)	-	127 (15.2)
SWA	26 (37.6)	19 (50.3)	13 (49.6)	30 (36.6)	3 (40.4)	-	91 (20.6)	21 (84.6)	5 (84.8)	1 (100.0)	118 (22.4)	-	-	118 (22.4)
JAV	24 (27.8)	12 (39.4)	21 (34.1)	9 (49.8)	24 (47.9)	9 (41.5)	98 (17.0)	-	-	14 (15.4)	112 (15.1)	1 (66.8)	-	113 (14.9)
RIB	-	1 (62.1)	10 (30.7)	-	0 (100.0)	18 (29.3)	29 (21.1)	-	-	42 (19.2)	71 (14.3)	11 (20.1)	11 (49.7)	93 (12.7)
NSD	17 (32.2)	4 (44.4)	2 (100.0)	26 (28.0)	1 (53.3)	-	50 (19.0)	19 (8.2)	21 (52.5)	-	90 (16.5)	-	-	90 (16.5)
RBT	2 (39.3)	5 (29.6)	71 (48.2)	0 (44.9)	3 (13.6)	2 (64.0)	84 (40.9)	1 (87.0)	2 (46.8)	1 (49.1)	88 (39.4)	-	-	88 (39.4)
SRH	26 (47.9)	11 (35.9)	28 (37.8)	1 (87.0)	1 (45.9)	16 (40.1)	82 (21.8)	-	0 (100.0)	4 (46.2)	86 (21.0)	0 (100.0)	-	86 (21.0)
SQU	14 (17.7)	2 (42.1)	-	14 (30.1)	8 (54.4)	5 (27.8)	43 (16.0)	24 (41.1)	15 (17.4)	-	83 (15.0)	-	-	83 (15.0)
JDO	-	-	-	-	-	-	-	16 (58.0)	61 (27.7)	-	77 (25.0)	-	-	77 (25.0)
FRO	37 (47.6)	-	-	7 (33.3)	5 (100.0)	-	50 (37.5)	9 (35.9)	11 (81.3)	-	70 (30.1)	-	-	70 (30.1)
OPE	0 (74.7)	-	-	1 (65.7)	-	-	1 (53.2)	-	61 (50.7)	-	62 (50.0)	-	-	62 (50.0)
GSH	29 (23.6)	2 (92.2)	-	15 (28.8)	0 (100.0)	-	46 (18.0)	12 (13.9)	2 (57.8)	-	61 (14.2)	-	-	61 (14.2)
ORH	-	-	-	-	-	-	-	-	-	0 (100.0)	0 (100.0)	19 (35.7)	36 (40.3)	55 (29.0)
CAR	2 (100.0)	-	-	4 (53.0)	-	-	6 (48.7)	-	43 (29.3)	-	49 (26.3)	-	-	49 (26.3)
SOR	-	-	-	-	-	0 (100.0)	0 (100.0)	-	-	27 (30.5)	28 (30.1)	11 (30.0)	8 (44.3)	46 (20.7)
HAP	22 (48.6)	-	-	12 (60.7)	-	-	35 (38.0)	-	9 (28.7)	-	43 (30.8)	-	-	43 (30.8)
YBO	12 (50.9)	15 (35.4)	9 (90.6)	0 (65.7)	1 (29.8)	0 (100.0)	38 (30.9)	0 (100.0)	-	-	39 (30.6)	-	-	39 (30.6)
PLS	-	-	26 (100.0)	-	-	4 (100.0)	30 (88.0)	-	-	6 (88.8)	35 (75.3)	3 (100.0)	-	38 (69.9)
SPD	-	-	-	27 (47.0)	9 (73.3)	-	36 (39.8)	-	3 (64.7)	-	38 (37.1)	-	-	38 (37.1)
SDO	2 (88.5)	-	-	9 (54.9)	-	-	11 (47.6)	9 (27.0)	15 (37.6)	-	35 (23.1)	-	-	35 (23.1)
HPC	-	-	-	1 (67.9)	-	-	1 (67.9)	2 (100.0)	31 (58.1)	-	33 (54.0)	-	-	33 (54.0)
BEE	-	-	-	-	-	-	-	-	-	0 (100.0)	0 (100.0)	7 (54.8)	24 (27.4)	31 (24.4)
GSP	-	-	17 (20.0)	-	-	0 (100.0)	18 (19.7)	-	-	5 (29.9)	23 (16.7)	5 (56.0)	3 (61.0)	31 (16.5)
SCO	-	-	11 (54.0)	-	-	11 (38.5)	21 (33.3)	-	-	7 (40.7)	29 (26.8)	0 (100.0)	0 (100.0)	29 (26.5)
BSL	-	-	-	-	-	-	-	-	-	10 (23.2)	10 (23.2)	7 (30.5)	7 (38.3)	24 (17.4)

Table 12: continued

														Stratum
Species	012A	012B	012C	004A	004B	004C	Core (total)	012S	004S	004D	All (total)	004E	004F	Total
CYL	-	-	-	-	-	-	-	-	-	-	-	4 (100.0)	19 (42.4)	24 (39.2)
EUC	14 (29.1)	5 (62.1)	3 (96.8)	1 (61.1)	1 (95.5)	0 (50.0)	24 (25.8)	-	-	-	24 (25.8)	-	-	24 (25.8)
JMD	0 (100.0)	-	-	-	-	-	0 (100.0)	14 (71.9)	7 (54.9)	-	22 (50.6)	-	-	22 (50.6)
MRQ	-	-	-	-	-	-	-	-	-	6 (29.5)	6 (29.5)	3 (44.9)	8 (34.0)	18 (20.6)
CYP	-	-	-	-	-	-	-	-	-	4 (41.5)	4 (41.5)	2 (45.7)	11 (65.7)	17 (43.6)
HCO	-	-	6 (75.8)	-	-	5 (2.0)	11 (40.2)	-	-	5 (52.4)	16 (32.2)	0 (60.8)	0 (100.0)	17 (31.2)
SSH	11 (28.4)	3 (49.9)	2 (100.0)	0 (100.0)	-	-	16 (24.3)	-	-	-	16 (24.3)	-	-	16 (24.3)
CUC	1 (48.4)	-	-	1 (41.9)	-	-	2 (36.1)	4 (55.5)	9 (29.3)	-	15 (23.6)	-	-	15 (23.6)
ERA	8 (78.3)	1 (100.0)	-	1 (100.0)	-	-	10 (65.4)	5 (100.0)	-	-	15 (54.8)	-	-	15 (54.8)
COL	0 (100.0)	1 (47.3)	3 (50.4)	0 (100.0)	0 (100.0)	3 (48.1)	8 (29.5)	-	-	7 (39.3)	14 (24.3)	-	-	14 (24.3)
WWA	-	-	-	-	-	4 (100.0)	4 (100.0)	-	-	10 (47.1)	14 (44.6)	-	-	14 (44.6)
ETB	-	-	-	-	-	-	-	-	-	1 (100.0)	1 (100.0)	2 (67.3)	10 (35.6)	13 (30.2)
SPO	6 (56.8)	-	-	-	-	-	6 (56.8)	7 (55.4)	-	-	13 (39.7)	-	-	13 (39.7)
RCH	-	-	-	-	-	-	-	-	-	-	-	3 (61.9)	8 (5.5)	12 (17.3)
SBI	-	-	-	-	-	-	-	-	-	-	-	-	12 (58.0)	12 (58.0)
DEA	-	-	11 (100.0)	-	-	-	11 (100.0)	-	-	1 (100.0)	12 (89.8)	-	-	12 (89.8)
CSU	-	-	-	-	-	-	-	-	-	0 (89.2)	0 (89.2)	4 (20.7)	5 (27.9)	9 (18.3)
BSH	-	1 (80.3)	2 (59.7)	-	-	4 (16.6)	6 (22.9)	-	-	1 (65.6)	7 (21.6)	1 (100.0)	-	8 (21.6)
CFA	-	0 (75.6)	7 (40.5)	-	-	0 (100.0)	8 (38.7)	-	-	0 (100.0)	8 (38.5)	-	-	8 (38.5)
CMA	-	-	-	-	-	-	-	-	-	2 (56.8)	2 (56.8)	4 (21.4)	1 (54.2)	8 (22.3)
KIN	-	-	-	-	-	-	-	8 (100.0)	-	-	8 (100.0)	-	-	8 (100.0)
JMM	-	-	-	1 (100.0)	-	-	1 (100.0)	1 (100.0)	5 (66.4)	-	7 (51.0)	-	-	7 (51.0)
OPO	-	-	-	-	-	-	-	-	-	-	-	-	7 (100.0)	7 (100.0)
POP	-	-	-	-	-	-	-	-	7 (77.7)	-	7 (77.7)	-	-	7 (77.7)
CSE	-	-	-	-	-	-	-	-	-	0 (56.1)	0 (56.1)	1 (32.3)	5 (18.0)	6 (15.3)
FHD	1 (47.1)	3 (25.1)	1 (61.3)	0 (100.0)	1 (57.1)	-	6 (19.4)	-	-	-	6 (19.4)	-	-	6 (19.4)
RCO	1 (50.1)	0 (93.9)	-	5 (48.3)	0 (82.1)	-	6 (36.6)	-	-	-	6 (36.6)	-	-	6 (36.6)
RUD	6 (66.8)	-	-	-	-	-	6 (66.8)	-	-	-	6 (66.8)	-	-	6 (66.8)
WAR	-	-	-	-	-	-	-	-	6 (64.9)	-	6 (64.9)	-	-	6 (64.9)
EPL	-	0 (100.0)	2 (37.5)	-	-	2 (17.0)	3 (20.8)	-	-	1 (43.2)	5 (19.0)	-	-	5 (19.0)
RSK	-	-	-	2 (69.2)	-	-	2 (69.2)	1 (100.0)	2 (100.0)	-	5 (50.6)	-	-	5 (50.6)
TOP	-	-	2 (100.0)	-	-	3 (100.0)	5 (70.7)	-	-	-	5 (70.7)	-	-	5 (70.7)
ZAS	-	-	-	-	-	-	-	-	-	-	-	-	5 (58.5)	5 (58.5)
CCX	1 (54.6)	1 (49.6)	0 (100.0)	0 (51.8)	1 (100.0)	0 (100.0)	4 (42.4)	-	-	-	4 (42.4)	-	-	4 (42.4)
CDO	2 (27.7)	0 (23.1)	0 (63.1)	1 (31.2)	0 (76.2)	0 (57.2)	4 (18.6)	-	0 (100.0)	-	4 (18.4)	-	-	4 (18.4)
ETL	-	0 (90.1)	1 (51.6)	-	-	3 (40.3)	4 (31.6)	-	-	0 (53.1)	4 (28.7)	-	-	4 (28.7)
JGU	2 (38.2)	-	-	-	-	-	2 (38.2)	2 (100.0)	0 (82.5)	-	4 (43.5)	-	-	4 (43.5)
RHY	-	-	-	-	-	-	-	-	4 (54.3)	-	4 (54.3)	-	-	4 (54.3)
TRS	-	-	-	-	-	-	-	-	-	-	-	2 (69.5)	2 (57.8)	4 (47.8)
HAS	-	-	-	-	-	-	-	-	-	1 (40.5)	1 (40.5)	2 (14.2)	2 (50.0)	4 (21.2)
BYS	-	1 (63.2)	2 (100.0)	-	1 (77.4)	-	3 (57.8)	-	-	-	3 (57.8)	-	-	3 (57.8)
SBK	-	-	1 (100.0)	-	-	0 (100.0)	2 (83.8)	-	-	0 (100.0)	2 (71.5)	1 (36.3)	0 (100.0)	3 (49.1)

Table 12: continued.

														Stratum
Species	012A	012B	012C	004A	004B	004C	Core (total)	012S	004S	004D	All (total)	004E	004F	Total
CBA	-	-	-	-	-	-	-	-	-	-	-	3 (36.6)	0 (100.0)	3 (35.2)
HAA	-	-	3 (100.0)	-	-	-	3 (100.0)	-	-	-	3 (100.0)	-	-	3 (100.0)
HMI	-	-	-	-	-	-	-	-	-	2 (54.5)	2 (54.5)	1 (100.0)	-	3 (47.9)
LHO	-	-	-	-	-	0 (100.0)	0 (100.0)	-	-	0 (16.8)	0 (28.2)	1 (36.9)	1 (35.9)	3 (23.4)
CBI	1 (43.3)	-	-	1 (61.4)	-	-	2 (38.9)	-	-	-	2 (38.9)	-	-	2 (38.9)
SRB	-	0 (100.0)	1 (100.0)	-	-	-	2 (81.7)	-	-	-	2 (81.7)	-	-	2 (81.7)
ACS	-	-	1 (100.0)	-	-	0 (100.0)	1 (79.0)	-	-	-	1 (79.0)	0 (100.0)	-	2 (65.7)
FQU	0 (49.3)	0 (100.0)	1 (86.7)	-	-	-	2 (81.6)	-	-	-	2 (81.6)	-	-	2 (81.6)
HAG	-	-	2 (100.0)	-	0 (100.0)	-	2 (85.8)	-	-	-	2 (85.8)	-	-	2 (85.8)
PSI	0 (41.0)	0 (32.5)	1 (53.2)	0 (73.4)	-	-	2 (31.7)	-	-	0 (100.0)	2 (31.0)	-	-	2 (31.0)
PSQ	-	-	-	-	-	-	-	-	-	2 (66.6)	2 (66.6)	-	-	2 (66.6)
TSQ	-	-	-	-	-	-	-	-	-	1 (100.0)	1 (100.0)	-	1 (100.0)	2 (70.8)
BBE	-	0 (80.2)	1 (72.0)	-	0 (100.0)	-	1 (57.5)	0 (100.0)	-	0 (100.0)	1 (51.7)	-	-	1 (51.7)
CDX	-	0 (52.1)	1 (51.1)	-	0 (100.0)	0 (100.0)	1 (41.7)	-	-	-	1 (41.7)	-	-	1 (41.7)
CIN	-	-	-	-	-	0 (100.0)	0 (100.0)	-	-	0 (30.3)	0 (33.6)	0 (19.8)	0 (49.7)	1 (24.8)
SCG	-	-	-	-	-	-	-	1 (49.9)	0 (47.1)	-	1 (42.4)	-	-	1 (42.4)
SCI	0 (66.2)	0 (64.6)	0 (47.3)	-	-	0 (100.0)	1 (36.1)	-	-	-	1 (36.1)	-	-	1 (36.1)
AEX	-	-	-	-	-	-	-	-	-	-	-	-	1 (75.3)	1 (75.3)
BEN	0 (100.0)	0 (70.3)	0 (100.0)	-	-	0 (52.9)	1 (38.8)	-	-	-	1 (38.8)	-	-	1 (38.8)
BNO	-	-	-	-	-	-	-	-	-	0 (100.0)	0 (100.0)	-	1 (100.0)	1 (76.0)
BRG	-	-	-	-	-	-	-	-	-	-	-	0 (82.6)	1 (83.1)	1 (61.2)
BTA	0 (100.0)	-	0 (100.0)	-	-	-	1 (87.9)	-	-	-	1 (87.9)	-	-	1 (87.9)
CHA	-	-	-	-	-	-	-	-	-	0 (32.4)	0 (32.4)	0 (57.7)	0 (62.9)	1 (31.9)
CJA	-	0 (50.4)	0 (66.0)	-	0 (100.0)	0 (1.0)	1 (29.7)	-	-	0 (100.0)	1 (28.6)	-	-	1 (28.6)
DMG	-	-	0 (66.4)	-	-	0 (100.0)	1 (60.9)	-	-	0 (100.0)	1 (57.2)	-	-	1 (57.2)
ECT	-	-	-	-	-	-	-	-	-	0 (70.8)	0 (70.8)	0 (64.5)	0 (100.0)	1 (59.1)
EMA	-	-	-	-	-	-	-	-	1 (100.0)	-	1 (100.0)	-	-	1 (100.0)
HMT	-	0 (64.6)	-	-	-	0 (100.0)	1 (69.8)	-	-	-	1 (69.8)	-	-	1 (69.8)
HYA	-	-	-	-	-	-	-	-	-	1 (100.0)	1 (100.0)	-	-	1 (100.0)
OPI	-	-	-	-	-	-	-	-	-	1 (66.8)	1 (66.8)	-	-	1 (66.8)
PHO	-	-	0 (100.0)	-	-	-	0 (100.0)	-	-	0 (53.8)	0 (48.2)	0 (37.8)	0 (100.0)	1 (40.5)
SEP	-	-	-	-	-	-	-	-	-	0 (53.8)	0 (53.8)	0 (40.2)	0 (41.2)	1 (26.3)
SFN	-	-	-	-	-	-	-	-	-	1 (64.6)	1 (64.6)	-	-	1 (64.6)
SSM	-	-	-	-	-	-	-	-	-	-	-	-	1 (100.0)	1 (100.0)
VSQ	-	-	-	-	-	-	-	-	-	1 (72.4)	1 (72.4)	0 (100.0)	0 (100.0)	1 (61.7)
ZOR	-	-	0 (100.0)	-	-	-	0 (100.0)	-	-	0 (52.0)	0 (60.7)	0 (100.0)	0 (57.7)	1 (41.1)

Table 13: Trawl abundance estimates, coefficients of variation comparisons for the core strata (300–650 m), all strata (200–800 m), and deep strata (200–1000 m) from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. The 2000 survey abundance estimates were re-calculated using 2012–13 stratum areas. See Appendix 6 for species changes. Species arranged in descending order of abundance in 2018 survey. Value of 0 indicates biomass less than 0.5 t; -, zero biomass.

		Core area abundance (t)					All area abundance (t)				Deep area abundance (t)	
Common name	Code	2000	2012	2013	2016	2018	2012	2013	2016	2018	2016	2018
Hoki	HOK	5 385 (20.6)	32 495 (24.2)	14 184 (26.9)	7 734 (35.7)	2 484 (14.2)	32 602 (24.1)	14 356 (26.5)	7 797 (35.4)	2 636 (13.6)	7 830 (35.3)	2 661 (13.5)
Ling	LIN	1 861 (17.3)	2 169 (14.8)	2 000 (18.4)	1 635 (12.7)	1 682 (18.3)	2 194 (14.7)	2 009 (18.3)	1 661 (12.5)	1 686 (18.3)	1 661 (12.5)	1 686 (18.3)
Barracouta	BAR	4 (72.7)	12 (42.8)	5 (52.1)	9 (33.9)	1 (58.1)	417 (34.8)	1 617 (36.8)	2 328 (30.1)	1 583 (32.0)	2 328 (30.1)	1 583 (32.0)
Giant stargazer	GIZ	74 (27.3)	97 (22.6)	92 (21.8)	107 (19.9)	295 (54.7)	608 (24.8)	592 (21.4)	1 327 (19.2)	1 119 (20.5)	1 327 (19.2)	1 119 (20.5)
Hake	HAK	803 (13.4)	583 (12.8)	331 (17.4)	221 (23.9)	229 (32.6)	1 103 (13.0)	747 (21.3)	355 (16.1)	559 (17.6)	502 (12.6)	899 (13.9)
Gemfish	RSO	29 (39.4)	14 (32.2)	10 (46.8)	71 (15.6)	171 (14.2)	14 (32.2)	11 (43.0)	127 (22.5)	702 (33.1)	127 (22.5)	702 (33.1)
Tarakihi	NMP	22 (32.2)	21 (41.7)	24 (48.5)	24 (36.9)	5 (35.8)	267 (23.0)	311 (22.8)	241 (23.8)	353 (15.8)	241 (23.8)	353 (15.8)
Lookdown dory	LDO	169 (14.4)	155 (11.9)	205 (11.1)	210 (12.2)	271 (21.7)	181 (10.6)	236 (11.6)	230 (11.4)	292 (20.2)	230 (11.3)	293 (20.2)
Smooth skate	SSK	186 (28.0)	167 (29.5)	228 (19.6)	190 (54.0)	177 (24.1)	239 (30.4)	272 (23.1)	238 (45.5)	225 (22.3)	238 (45.5)	225 (22.3)
White rattail	WHX	-	-	3 (100.0)	-	-	17 (100.0)	19 (71.3)	38 (40.4)	39 (25.7)	164 (13.0)	202 (18.8)
Smooth skin dogfish	CYO	-	-	-	-	5 (100.0)	19 (73.4)	20 (100.0)	110 (32.3)	53 (52.9)	244 (18.1)	201 (21.9)
Shovelnose dogfish	SND	153 (29.5)	68 (70.6)	49 (24.8)	68 (71.4)	61 (64.7)	146 (44.4)	95 (28.0)	151 (32.8)	114 (36.4)	189 (26.5)	188 (24.0)
Bollons' rattail	CBO	192 (11.3)	93 (10.8)	118 (8.9)	157 (14.6)	176 (19.0)	105 (11.1)	126 (9.3)	161 (14.4)	177 (18.9)	161 (14.4)	177 (18.9)
Leafscale gulper shark	CSQ	83 (46.2)	67 (45.6)	31 (52.0)	-	30 (71.5)	125 (35.0)	67 (43.2)	142 (26.5)	134 (24.4)	180 (23.0)	166 (22.1)
School shark	SCH	123 (6.7)	136 (15.9)	126 (9.2)	158 (18.6)	115 (16.8)	205 (26.9)	142 (9.8)	179 (17.2)	158 (16.6)	179 (17.2)	160 (16.4)
Silver warehou	SWA	98 (69.8)	186 (24.8)	159 (24.8)	68 (18.7)	53 (21.9)	323 (15.8)	252 (18.3)	193 (12.7)	144 (9.8)	193 (12.7)	144 (9.8)
Javelinfish	JAV	1 507 (24.6)	617 (32.2)	313 (22.7)	271 (36.5)	91 (20.6)	877 (26.5)	317 (22.4)	306 (33.4)	118 (22.4)	306 (33.3)	118 (22.4)
Ribaldo	RIB	198 (17.4)	166 (11.3)	122 (13.1)	112 (22.9)	98 (17.0)	195 (10.9)	141 (11.5)	124 (20.7)	112 (15.1)	124 (20.7)	113 (14.9)
Northern spiny dogfish	NSD	104 (26.3)	43 (25.3)	16 (29.9)	15 (44.3)	29 (21.1)	140 (21.6)	57 (25.7)	55 (17.2)	71 (14.3)	69 (14.3)	93 (12.7)
Redbait	RBT	96 (23.1)	49 (20.4)	48 (29.5)	33 (20.4)	50 (19.0)	269 (28.7)	131 (22.7)	132 (25.6)	90 (16.5)	132 (25.6)	90 (16.5)
Silver roughy	SRH	3 (29.2)	13 (32.2)	13 (17.3)	55 (19.6)	84 (40.9)	16 (27.3)	14 (16.9)	58 (18.8)	88 (39.4)	58 (18.8)	88 (39.4)
Arrow squid	SQU	23 (18.0)	101 (23.3)	123 (14.8)	92 (22.8)	82 (21.8)	106 (22.3)	127 (14.3)	93 (22.6)	86 (21.0)	93 (22.6)	86 (21.0)
John dory	JDO	18 (22.6)	95 (18.3)	28 (9.9)	55 (17.1)	43 (16.0)	137 (14.9)	52 (17.6)	131 (22.8)	83 (15.0)	131 (22.8)	83 (15.0)
Frostfish	FRO	-	-	-	-	-	43 (41.2)	46 (46.9)	38 (34.0)	77 (25.0)	38 (34.0)	77 (25.0)
Orange perch	OPE	31 (27.3)	30 (51.9)	9 (30.5)	602 (96.0)	50 (37.5)	38 (46.1)	26 (35.3)	729 (80.7)	70 (30.1)	729 (80.7)	70 (30.1)
Dark ghost shark	GSH	17 (99.4)	15 (66.1)	5 (100.0)	2 (40.5)	1 (53.2)	49 (45.2)	81 (93.1)	3 (37.8)	62 (50.0)	3 (37.8)	62 (50.0)
Orange roughy	ORH	77 (32.5)	106 (16.9)	75 (21.4)	39 (16.6)	46 (18.0)	146 (15.1)	101 (20.2)	48 (15.3)	61 (14.2)	48 (15.3)	61 (14.2)
Carpet shark	CAR	-	-	-	-	-	-	-	2 (47.7)	0 (100.0)	46 (13.5)	55 (29.0)
Spiky oreo	SOR	11 (46.0)	28 (22.4)	16 (38.2)	7 (28.6)	6 (48.7)	89 (39.3)	36 (32.7)	23 (52.0)	49 (26.3)	23 (52.0)	49 (26.3)
Hapuku	HAP	-	-	-	1 (100.0)	0 (100.0)	12 (72.1)	9 (74.8)	25 (28.2)	28 (30.1)	38 (20.7)	46 (20.7)
Yellow boarfish	YBO	36 (46.6)	35 (39.3)	16 (56.0)	12 (81.2)	35 (38.0)	99 (29.0)	61 (49.8)	17 (58.8)	43 (30.8)	17 (58.8)	43 (30.8)
Plunket's shark	PLS	4 (47.3)	15 (39.7)	22 (21.6)	22 (29.4)	38 (30.9)	15 (39.6)	22 (21.5)	22 (29.4)	39 (30.6)	22 (29.4)	39 (30.6)
Spiny dogfish	SPD	6 (70.6)	3 (71.3)	-	-	30 (88.0)	23 (54.4)	13 (100.0)	25 (33.5)	35 (75.3)	35 (31.4)	38 (69.9)
Silver dory	SDO	233 (53.6)	1 095 (24.7)	867 (29.0)	173 (16.8)	36 (39.8)	1 453 (22.6)	928 (27.2)	358 (43.3)	38 (37.1)	358 (43.3)	38 (37.1)
Sea perch	SPE	113 (62.0)	259 (46.5)	304 (77.9)	85 (43.1)	11 (47.6)	677 (44.2)	602 (45.9)	398 (62.1)	35 (23.1)	398 (62.1)	35 (23.1)
Basketwork eel	BEE	-	-	-	-	-	0 (100.0)	-	1 (100.0)	0 (100.0)	22 (35.1)	31 (24.4)
Pale ghost shark	GSP	23 (28.2)	32 (28.2)	20 (18.5)	16 (47.1)	18 (19.7)	40 (25.4)	29 (18.4)	21 (37.9)	23 (16.7)	26 (31.7)	31 (16.5)
Swollenhead conger	SCO	57 (19.2)	51 (31.6)	14 (30.9)	39 (41.6)	21 (33.3)	56 (29.1)	17 (27.9)	46 (37.0)	29 (26.8)	46 (36.6)	29 (26.5)
Black slickhead	BSL	1 (70.1)	6 (70.5)	0 (100.0)	-	-	28 (32.6)	13 (51.6)	14 (21.8)	10 (23.2)	20 (17.9)	24 (17.4)
Portugese dogfish	CYL	-	-	-	-	-	-	-	-	-	79 (36.4)	24 (39.2)

Table 13: continued.

		Core area abundance (t)					All area abundance (t)				Deep area abundance (t)	
Common name	Code	2000	2012	2013	2016	2018	2012	2013	2016	2018	2016	2018
Eucla cod	EUC	0 (73.0)	7 (27.7)	10 (23.0)	19 (12.5)	24 (25.8)	7 (27.7)	10 (23.0)	19 (12.5)	24 (25.8)	19 (12.5)	24 (25.8)
Jack mackerel	JMD	-	-	-	1 (78.1)	0 (100.0)	3 (73.4)	9 (100.0)	10 (56.1)	22 (50.6)	10 (56.1)	22 (50.6)
Warty squid	MRQ	1 (100.0)	-	-	-	-	-	-	1 (100.0)	6 (29.5)	7 (30.8)	18 (20.6)
Longnose velvet dogfish	CYP	-	-	0 (100.0)	0 (100.0)	-	5 (56.9)	10 (65.1)	9 (33.5)	4 (41.5)	25 (16.3)	17 (43.6)
Hairy conger	HCO	24 (24.3)	4 (40.1)	16 (22.3)	17 (49.3)	11 (40.2)	19 (45.7)	22 (19.2)	19 (44.5)	16 (32.2)	20 (42.6)	17 (31.2)
Slender smooth-hound	SSH	34 (21.1)	40 (34.2)	36 (26.3)	15 (46.0)	16 (24.3)	40 (34.2)	36 (26.3)	15 (46.0)	16 (24.3)	15 (46.0)	16 (24.3)
Cucumber fish	CUC	0 (100.0)	2 (30.1)	2 (33.8)	3 (26.7)	2 (36.1)	51 (60.6)	83 (34.7)	33 (46.7)	15 (23.6)	33 (46.7)	15 (23.6)
Electric ray	ERA	7 (58.3)	6 (90.4)	21 (75.6)	8 (100.0)	10 (65.4)	6 (90.4)	21 (75.6)	8 (100.0)	15 (54.8)	9 (88.2)	15 (54.8)
Oliver's rattail	COL	13 (29.1)	12 (34.5)	7 (35.2)	5 (39.6)	8 (29.5)	41 (34.8)	21 (35.8)	13 (29.3)	14 (24.3)	13 (29.3)	14 (24.3)
White warehou	WWA	12 (50.9)	26 (60.4)	23 (27.9)	18 (40.7)	4 (100.0)	65 (34.2)	26 (26.9)	20 (38.2)	14 (44.6)	20 (38.2)	14 (44.6)
Baxter's lantern dogfish	ETB	-	-	-	-	-	-	-	1 (100.0)	1 (100.0)	5 (45.4)	13 (30.2)
Rig	SPO	-	0 (100.0)	1 (100.0)	1 (100.0)	6 (56.8)	3 (90.6)	6 (45.9)	3 (80.1)	13 (39.7)	3 (80.1)	13 (39.7)
Widenosed chimaera	RCH	-	-	-	-	-	-	-	-	-	16 (29.3)	12 (17.3)
Bigscaled brown slickhead	SBI	-	-	-	-	-	-	-	-	-	15 (27.7)	12 (58.0)
Dealfish	DEA	1 (100.0)	5 (100.0)	-	3 (100.0)	11 (100.0)	5 (100.0)	-	3 (100.0)	12 (89.8)	3 (100.0)	12 (89.8)
Four-rayed rattail	CSU	-	-	-	-	-	-	-	0 (100.0)	0 (89.2)	8 (18.3)	9 (18.3)
Seal shark	BSH	10 (68.9)	3 (36.1)	3 (34.3)	1 (51.7)	6 (22.9)	4 (32.2)	3 (28.2)	1 (33.0)	7 (21.6)	2 (34.4)	8 (21.6)
Banded rattail	CFA	1 (29.2)	3 (27.4)	1 (24.8)	2 (26.8)	8 (38.7)	4 (25.6)	1 (24.1)	2 (26.3)	8 (38.5)	2 (26.3)	8 (38.5)
Mahia rattail	CMA	-	-	-	-	-	1 (33.9)	1 (63.0)	6 (22.3)	2 (56.8)	9 (18.7)	8 (22.3)
Kingfish	KIN	-	-	-	-	-	-	-	5 (100.0)	8 (100.0)	5 (100.0)	8 (100.0)
Slender mackerel	JMM	7 (60.6)	3 (43.8)	-	0 (100.0)	1 (100.0)	6 (50.2)	1 (100.0)	3 (61.5)	7 (51.0)	3 (61.5)	7 (51.0)
Octopoteuthis spp.	OPO	-	3 (100.0)	-	-	-	3 (100.0)	-	-	-	-	7 (100.0)
Porcupine fish	POP	-	-	-	-	-	4 (100.0)	7 (100.0)	8 (60.7)	7 (77.7)	8 (60.7)	7 (77.7)
Serrulate rattail	CSE	-	-	-	-	-	-	0 (100.0)	0 (100.0)	0 (56.1)	5 (10.6)	6 (15.3)
Deepsea flathead	FHD	5 (17.7)	7 (18.5)	6 (19.2)	5 (22.7)	6 (19.4)	7 (18.5)	6 (19.1)	5 (22.7)	6 (19.4)	5 (22.7)	6 (19.4)
Red cod	RCO	12 (31.8)	22 (17.5)	62 (34.9)	29 (18.5)	6 (36.6)	22 (17.5)	62 (34.9)	31 (18.4)	6 (36.6)	31 (18.4)	6 (36.6)
Rudderfish	RUD	8 (67.9)	6 (49.6)	15 (59.2)	12 (85.4)	6 (66.8)	6 (49.6)	15 (59.2)	12 (85.4)	6 (66.8)	14 (74.5)	6 (66.8)
Common warehou	WAR	-	-	-	2 (100.0)	-	33 (88.7)	-	335 (96.0)	6 (64.9)	335 (96.0)	6 (64.9)
Bigeye cardinalfish	EPL	8 (32.8)	4 (29.7)	5 (27.0)	4 (48.0)	3 (20.8)	7 (22.8)	7 (26.0)	4 (42.4)	5 (19.0)	4 (41.5)	5 (19.0)
Rough skate	RSK	2 (70.5)	8 (31.9)	4 (42.9)	1 (78.7)	2 (69.2)	12 (39.1)	8 (39.8)	4 (48.2)	5 (50.6)	4 (48.2)	5 (50.6)
Pale toadfish	TOP	1 (73.9)	1 (100.0)	1 (53.6)	1 (100.0)	5 (70.7)	2 (60.0)	1 (53.6)	1 (100.0)	5 (70.7)	3 (60.9)	5 (70.7)
Velvet dogfish	ZAS	-	-	-	-	-	-	-	-	-	1 (100.0)	5 (58.5)
Small banded rattail	CCX	2 (33.7)	3 (27.4)	3 (19.5)	1 (29.1)	4 (42.4)	3 (27.4)	3 (19.5)	1 (29.1)	4 (42.4)	1 (29.1)	4 (42.4)
Capro dory	CDO	1 (33.6)	10 (40.5)	2 (23.2)	3 (19.0)	4 (18.6)	11 (38.4)	3 (22.6)	3 (17.8)	4 (18.4)	3 (17.8)	4 (18.4)
Lucifer dogfish	ETL	7 (16.3)	5 (15.3)	5 (36.0)	3 (17.5)	4 (31.6)	6 (13.9)	6 (29.1)	4 (16.2)	4 (28.7)	4 (16.2)	4 (28.7)
Spotted gurnard	JGU	-	1 (79.2)	0 (69.0)	3 (67.6)	2 (38.2)	1 (79.2)	0 (42.1)	7 (66.7)	4 (43.5)	7 (66.7)	4 (43.5)
Common roughy	RHY	0 (100.0)	1 (92.4)	0 (100.0)	0 (100.0)	-	1 (76.9)	6 (98.5)	0 (100.0)	4 (54.3)	0 (100.0)	4 (54.3)
Cape scorpionfish	TRS	-	-	-	-	-	-	1 (100.0)	0 (100.0)	-	7 (22.9)	4 (47.8)
Johnson's cod	HJO	-	-	-	-	-	-	-	1 (32.7)	1 (40.5)	2 (29.3)	4 (21.2)
Alfonsino	BYS	14 (41.0)	262 (58.8)	120 (26.2)	31 (38.4)	3 (57.8)	262 (58.8)	120 (26.2)	31 (38.4)	3 (57.8)	31 (38.4)	3 (57.8)

Table 13: continued.

		Core area abundance (t)					All area abundance (t)				Deep area abundance (t)	
Common name	Code	2000	2012	2013	2016	2018	2012	2013	2016	2018	2016	2018
Spineback	SBK	2 (50.9)	1 (47.1)	1 (51.9)	0 (100.0)	2 (83.8)	3 (42.4)	2 (42.5)	1 (45.6)	2 (71.5)	2 (31.3)	3 (49.1)
Humpback rattail	CBA	-	-	-	-	-	-	0 (100.0)	0 (85.9)	-	2 (64.5)	3 (35.2)
Violet squid	HAA	-	-	-	-	3 (100.0)	0 (100.0)	-	-	3 (100.0)	-	3 (100.0)
Violet squid	HMI	-	3 (64.6)	-	-	-	3 (57.9)	-	-	2 (54.5)	-	3 (47.9)
Omega prawn	LHO	-	-	-	-	0 (100.0)	-	0 (61.2)	0 (30.5)	0 (28.2)	1 (13.5)	3 (23.4)
Two saddle rattail	CBI	1 (68.4)	14 (20.5)	7 (29.0)	3 (26.8)	2 (38.9)	14 (20.5)	7 (28.3)	3 (26.8)	2 (38.9)	3 (26.8)	2 (38.9)
Southern Ray’s bream	SRB	-	15 (41.1)	9 (41.0)	10 (44.9)	2 (81.7)	16 (37.9)	9 (38.7)	10 (44.9)	2 (81.7)	10 (44.9)	2 (81.7)
Smooth deepsea anemones	ACS	-	0 (100.0)	0 (100.0)	-	1 (79.0)	1 (54.2)	0 (100.0)	-	1 (79.0)	-	2 (65.7)
Rope-like sea pen	FQU	-	-	0 (100.0)	-	2 (81.6)	-	0 (100.0)	-	2 (81.6)	-	2 (81.6)
Hagfish	HAG	3 (53.9)	1 (59.7)	0 (72.4)	-	2 (85.8)	1 (59.7)	0 (72.4)	-	2 (85.8)	-	2 (85.8)
Geometric star	PSI	-	1 (24.3)	1 (20.5)	0 (28.8)	2 (31.7)	1 (23.1)	1 (20.4)	0 (28.8)	2 (31.0)	0 (28.8)	2 (31.0)
Large red scaly squid	PSQ	-	-	-	2 (100.0)	-	-	-	2 (100.0)	2 (66.6)	3 (87.8)	2 (66.6)
Todarodes filippovae	TSQ	-	-	0 (100.0)	0 (100.0)	-	-	2 (60.4)	0 (100.0)	1 (100.0)	14 (92.0)	2 (70.8)
Banded bellowsfish	BBE	4 (28.8)	1 (39.9)	1 (25.5)	2 (18.7)	1 (57.5)	2 (31.4)	2 (25.0)	2 (18.4)	1 (51.7)	2 (18.4)	1 (51.7)
Dark banded rattail	CDX	-	1 (30.6)	1 (24.1)	0 (100.0)	1 (41.7)	1 (30.6)	1 (24.1)	0 (100.0)	1 (41.7)	0 (100.0)	1 (41.7)
Notable rattail	CIN	0 (100.0)	-	0 (100.0)	-	0 (100.0)	0 (66.8)	0 (28.2)	0 (47.2)	0 (33.6)	0 (21.4)	1 (24.8)
Scaly gurnard	SCG	-	-	-	-	-	1 (66.0)	1 (72.9)	1 (56.1)	1 (42.4)	1 (56.1)	1 (42.4)
Scampi	SCI	0 (33.8)	1 (21.8)	1 (20.2)	1 (34.0)	1 (36.1)	1 (21.8)	1 (20.2)	1 (32.5)	1 (36.1)	1 (32.5)	1 (36.1)
Catshark	APR	-	-	-	-	-	-	-	-	-	1 (100.0)	1 (75.3)
Scabbardfish	BEN	0 (86.5)	0 (52.5)	0 (77.1)	1 (42.7)	1 (38.8)	0 (52.5)	0 (77.1)	1 (39.3)	1 (38.8)	1 (39.3)	1 (38.8)
Benthoctopus spp.	BNO	-	-	-	-	-	-	-	-	0 (100.0)	-	1 (76.0)
Brisingida (Order)	BRG	-	-	-	-	-	-	-	-	-	0 (29.5)	1 (61.2)
Smooth deepsea skate	BTA	0 (100.0)	2 (44.4)	1 (57.0)	1 (100.0)	1 (87.9)	2 (44.4)	1 (57.0)	1 (100.0)	1 (87.9)	1 (100.0)	1 (87.9)
Viper fish	CHA	0 (100.0)	0 (100.0)	0 (100.0)	-	-	0 (58.6)	1 (85.3)	0 (64.6)	0 (32.4)	0 (20.0)	1 (31.9)
Sun star	CJA	-	0 (37.8)	0 (42.8)	0 (100.0)	1 (29.7)	0 (37.8)	0 (42.8)	0 (100.0)	1 (28.6)	0 (100.0)	1 (28.6)
Dipsacaster magnificus	DMG	-	0 (100.0)	0 (47.8)	-	1 (60.9)	0 (84.6)	0 (47.8)	-	1 (57.2)	0 (56.9)	1 (57.2)
Echinothuriidae (family)	ECT	-	-	-	0 (100.0)	-	-	-	0 (100.0)	0 (70.8)	0 (100.0)	1 (59.1)
Blue mackerel	EMA	-	-	-	-	-	-	-	-	1 (100.0)	-	1 (100.0)
Deepsea anemone	HMT	-	0 (41.4)	0 (77.7)	-	1 (69.8)	0 (41.4)	0 (77.7)	-	1 (69.8)	-	1 (69.8)
Floppy tubular sponge	HYA	-	-	-	-	-	-	-	0 (100.0)	1 (100.0)	0 (83.6)	1 (100.0)
Umbrella octopus	OPI	0 (93.5)	5 (50.8)	-	-	-	8 (36.5)	-	0 (100.0)	1 (66.8)	1 (74.0)	1 (66.8)
Lighthouse fish	PHO	0 (100.0)	0 (100.0)	0 (100.0)	-	0 (100.0)	0 (70.8)	0 (58.5)	0 (39.9)	0 (48.2)	1 (27.1)	1 (40.5)
Sergia potens	SEP	-	-	-	-	-	-	0 (61.2)	-	0 (53.8)	-	1 (26.3)
Spinyfin	SFN	-	-	-	-	-	-	1 (100.0)	0 (100.0)	1 (64.6)	2 (42.4)	1 (64.6)
Smallscaled brown slickhead	SSM	-	-	-	-	-	-	-	-	-	11 (21.1)	1 (100.0)
Violet squid	VSQ	0 (100.0)	-	-	-	-	-	0 (100.0)	3 (49.1)	1 (72.4)	3 (48.2)	1 (61.7)
Rat-tail star	ZOR	-	-	-	-	0 (100.0)	-	-	0 (100.0)	0 (60.7)	0 (71.1)	1 (41.1)

Table 14: Numbers of fish for which length, sex, and biological data were collected. Species arranged in alphabetical order of common name.

	Length frequency data				Length-weight data	
	No. of fish measured			No. of	No. of	No. of
Species	Male	Female	Total †	samples	fish	samples
Alfonsino	16	13	29	6	29	6
Arrow squid	248	227	558	39	489	38
Australasian slender cod	12	17	29	12	26	11
Banded bellowsfish	2	4	6	3	2	2
Banded rattail	47	16	63	8	63	8
Barracouta	431	505	936	13	209	13
Basketwork eel	32	28	61	10	48	9
Baxter's lantern dogfish	6	7	13	8	13	8
Bigeye cardinalfish	32	42	75	12	75	12
Bigeye sea perch	1 083	1 083	2 228	51	648	44
Bigscaled brown slickhead	1	16	17	2	17	2
Black javelinfish	1	-	1	1	1	1
Black slickhead	55	101	163	15	159	14
Blackspot rattail	1	3	4	3	4	3
Blue mackerel	1	-	1	1	1	1
Bollons’ rattail	381	251	633	26	361	24
Cape scorpionfish	4	4	9	5	9	5
Capro dory	10	24	538	12	20	1
Carpet shark	44	8	52	11	52	11
Common roughy	24	17	42	4	42	4
Common warehou	2	2	4	2	4	2
Cubehead	-	1	1	1	1	1
Cucumber fish	308	179	490	17	224	15
Dark banded rattail	7	7	14	7	14	7
Dark ghost shark	120	125	245	22	219	22
Deepsea cardinalfish	-	1	2	2	2	2
Deepsea flathead	17	29	46	14	33	11
Electric ray	4	4	8	6	8	6
Eucla cod	67	563	644	15	223	10
Four-rayed rattail	172	164	351	11	193	10
Frostfish	50	139	191	17	135	17
Gemfish	764	482	1 248	39	569	37
Giant stargazer	526	330	858	28	279	27
Hairy conger	8	17	25	13	23	11
Hake	356	278	634	37	633	37
Hapuku	9	7	16	12	16	12
Hoki	2 379	2 606	4 993	55	842	53
Humpback rattail (slender rattail)	-	8	8	5	8	5
Jack mackerel	22	20	45	8	45	8
Javelinfish	559	1 564	2 162	49	552	35
John dory	27	70	97	9	97	9
Kingfish	-	-	1	1	1	1
Leafscale gulper shark	3	25	28	13	28	13
Lighthouse fish	1	-	4	1	4	1
Ling	820	480	1 301	40	509	38
Longnose velvet dogfish	23	22	45	14	45	14
Lookdown dory	540	622	1 191	38	466	34
Lucifer dogfish	26	27	53	16	49	15
Mahia rattail	8	27	35	12	34	12
New Zealand catshark	2	-	2	2	2	2
Northern spiny dogfish	121	90	211	29	210	29
Notable rattail	6	18	28	13	28	13
Numbfish	1	-	1	1	1	1

†Total is sometimes greater than the sum of male and female fish because the sex of some fish was not recorded.

Table 14: continued.

	Length frequency data				Length-weight data	
	No. of fish measured			No. of	No. of	No. of
Species	Male	Female	Total †	samples	fish	samples
Oliver's rattail	481	226	716	23	221	18
Orange perch	121	117	240	9	79	9
Orange roughy	52	61	114	10	110	9
Pale ghost shark	18	16	34	18	33	17
Plunket's shark	4	6	10	7	10	7
Portugese dogfish	6	-	6	4	6	4
Red cod	27	9	41	13	41	13
Redbait	81	124	314	35	219	35
Ribaldo	28	132	161	31	152	28
Rig	1	5	6	4	6	4
Rough skate	3	3	6	4	6	4
Rudderfish	-	3	3	3	3	3
Scabbardfish	1	1	6	4	2	2
Scaly gurnard	1	4	17	4	5	3
Scampi	6	3	9	7	9	7
School shark	42	39	81	20	81	20
Sea perch	155	141	304	9	103	8
Seal shark	11	12	23	12	23	12
Serrulate rattail	5	47	52	13	51	13
Shovelnose dogfish	103	55	158	20	156	20
Silver dory	395	344	746	15	212	12
Silver roughy	800	963	1 867	31	331	19
Silver warehou	72	110	182	35	181	34
Silverside	5	2	11	4	10	3
Slender mackerel	7	4	11	6	11	6
Slender smooth-hound	12	20	32	13	32	13
Small-headed cod	-	2	2	2	1	1
Small banded rattail	107	206	319	15	93	9
Smallscaled brown slickhead	-	1	1	1	1	1
Smooth deepsea skate	1	1	2	2	2	2
Smooth oreo	-	1	1	1	1	1
Smooth skate	28	24	52	23	49	23
Smooth skin dogfish	67	29	96	14	96	14
Snubnosed eel	-	1	1	1	1	1
Softnose skate (longtail skate)	1	-	1	1	1	1
Southern Ray's bream	2	2	4	3	4	3
Spiky oreo	239	198	439	15	304	15
Spineback	2	10	12	6	10	5
Spiny dogfish	28	81	109	13	104	12
Spinyfin	1	1	2	2	2	2
Spotted gurnard	14	15	29	10	29	10
Swollenhead conger	22	16	38	14	37	13
Tarakihi	303	322	626	15	220	15
Two saddle rattail	6	13	19	7	19	7
Velvet dogfish	-	2	2	2	2	2
White rattail	54	80	134	16	133	16
White warehou	5	2	7	5	7	5
Widenosed chimaera	5	1	6	6	6	6
Witch	1	2	3	3	3	3
Yellow boarfish	410	261	692	17	153	12
Total	13 112	13 991	28 187	1 339	11 136	1 229

†Total is sometimes greater than the sum of male and female fish because the sex of some fish was not recorded.

Table 15: Species gonad stage observations* by each reproductive stage. Gonad stages are defined in Appendix 3. –, indicates no relevant stage. Species arranged in alphabetical order of research codes.

Code	Common name	Sex	Method	1	2	3	4	5	6	7	Total
AEX	New Zealand catshark	Female	MD	-	-	-	-	-	-	-	-
		Male		1	1	-	-	-	-	-	2
BAR	Barracouta	Female	MD	-	7	463	8	1	23	2	504
		Male		-	-	10	263	52	106	-	431
BBE	Banded bellowsfish	Female	MD	-	-	1	-	-	-	-	1
		Male		-	1	-	-	-	-	-	1
BEE	Basketwork eel	Female	MD	-	11	7	-	-	-	-	18
		Male		-	10	4	3	-	-	-	17
BEN	Scabbardfish	Female	MD	-	-	-	-	-	-	-	-
		Male		1	-	-	-	-	-	-	1
BER	Numbfish	Female	MD	-	-	-	-	-	-	-	-
		Male		-	1	-	-	-	-	-	1
BJA	Black javelinfish	Female	MD	-	-	-	-	-	-	-	-
		Male		-	-	-	1	-	-	-	1
BSH	Seal shark	Female	SS	12	-	-	-	-	-	-	12
		Male		11	-	-	-	-	-	-	11
BSL	Black slickhead	Female	MD	15	1	67	6	5	-	1	95
		Male		20	1	9	15	10	-	-	55
BTA	Smooth deepsea skate	Female	SS	-	-	1	-	-	-	-	1
		Male		-	-	1	-	-	-	-	1
BYS	Alfonsino	Female	MD	8	5	-	-	-	-	-	13
		Male		11	4	1	-	-	-	-	16
CAR	Carpet shark	Female	SS	-	-	4	-	-	-	-	4
		Male		-	-	44	-	-	-	-	44
CBA	Humpback rattail (slender rattail)	Female	MD	2	5	1	-	-	-	-	8
		Male		-	-	-	-	-	-	-	-
CBI	Two saddle rattail	Female	MD	-	2	6	3	-	-	1	12
		Male		-	1	5	-	-	-	-	6
CBO	Bollons' rattail	Female	MD	40	37	54	87	1	9	10	238
		Male		8	76	224	-	-	-	-	308
CCX	Small banded rattail	Female	MD	5	28	14	8	-	-	-	55
		Male		6	17	14	-	-	-	-	37
CDX	Dark banded rattail	Female	MD	5	2	-	-	-	-	-	7
		Male		2	4	-	-	-	-	-	6
CFA	Banded rattail	Female	MD	1	1	-	5	-	1	-	8
		Male		-	17	10	-	-	-	-	27
CIN	Notable rattail	Female	MD	3	7	3	3	1	-	-	17
		Male		1	5	-	-	-	-	-	6
CMA	Mahia rattail	Female	MD	3	3	17	4	-	-	-	27
		Male		1	4	2	-	-	-	-	7
COL	Oliver's rattail	Female	MD	7	6	40	41	3	-	-	97
		Male		9	132	6	1	-	-	-	148
CSE	Serrulate rattail	Female	MD	3	39	-	-	1	-	-	43
		Male		1	2	-	-	-	-	-	3
CSQ	Leafscale gulper shark	Female	SS	-	2	19	-	-	4	-	25
		Male		-	-	3	-	-	-	-	3
CSU	Four-rayed rattail	Female	MD	11	48	7	9	10	-	-	85
		Male		3	61	25	1	-	-	-	90
CUB	Cubehead	Female	MD	-	-	1	-	-	-	-	1
		Male		-	-	-	-	-	-	-	-
CUC	Cucumber fish	Female	MD	-	2	29	50	-	1	-	82
		Male		-	2	76	28	1	-	-	107
CYL	Portugese dogfish	Female	MD	-	-	-	-	-	-	-	-
		Male		-	-	6	-	-	-	-	6
CYO	Smooth skin dogfish	Female	SS	-	9	12	1	3	4	-	29
		Male		1	1	65	-	-	-	-	67
CYP	Longnose velvet dogfish	Female	SS	15	3	3	-	-	1	-	22
		Male		15	-	8	-	-	-	-	23
EMA	Blue mackerel	Female	MD	-	-	-	-	-	-	-	-
		Male		-	1	-	-	-	-	-	1

Table 15: continued.

Code	Common name	Sex	Method	1	2	3	4	5	6	7	Total
EPL	Bigeye cardinalfish	Female	MD	10	8	8	15	-	-	-	41
		Male		2	16	12	2	-	-	-	32
EPT	Deepsea cardinalfish	Female	MD	1	-	-	-	-	-	-	1
		Male		-	-	-	-	-	-	-	-
ERA	Electric ray	Female	MD	1	1	1	-	-	-	-	3
		Male		-	-	4	-	-	-	-	4
ETB	Baxter's lantern dogfish	Female	SS	1	3	2	-	-	1	-	7
		Male		1	1	4	-	-	-	-	6
ETL	Lucifer dogfish	Female	SS	1	15	6	-	-	5	-	27
		Male		-	10	16	-	-	-	-	26
EUC	Eucla cod	Female	MD	19	32	11	410	-	-	-	472
		Male		13	22	15	1	-	-	-	51
FHD	Deepsea flathead	Female	MD	-	2	19	2	-	5	-	28
		Male		-	2	14	1	-	-	-	17
FRO	Frostfish	Female	MD	5	86	32	-	-	4	6	133
		Male		3	12	10	17	2	2	1	47
GIZ	Giant stargazer	Female	MD	14	26	203	23	25	3	32	326
		Male		6	4	8	135	350	20	2	525
GSH	Dark ghost shark	Female	SS	30	35	44	3	-	1	-	113
		Male		33	13	60	-	-	-	-	106
GSP	Pale ghost shark	Female	SS	6	7	3	-	-	-	-	16
		Male		6	3	9	-	-	-	-	18
HAK	Hake	Female	MD	70	1	125	16	18	30	17	277
		Male		124	13	2	9	181	22	4	355
HAP	Hapuku	Female	MD	-	2	5	-	-	-	-	7
		Male		3	1	2	3	-	-	-	9
HAS	Australasian slender cod	Female	MD	3	14	-	-	-	-	-	17
		Male		6	5	-	1	-	-	-	12
HBA	Bigeye sea perch	Female	MD	175	68	21	1	1	-	3	269
		Male		184	38	15	30	-	15	4	286
HCO	Hairy conger	Female	MD	-	-	7	6	-	-	-	13
		Male		-	2	3	-	1	2	-	8
HOK	Hoki	Female	MD	209	210	1 311	377	31	181	284	2 603
		Male		173	40	210	993	613	290	59	2 378
HPC	Sea perch	Female	MD	9	11	14	14	24	-	-	72
		Male		3	7	29	9	1	26	2	77
JAV	Javelinfish	Female	MD	64	267	3	-	-	-	1	335
		Male		27	29	-	-	-	-	-	56
JDO	John dory	Female	MD	-	1	36	-	-	27	6	70
		Male		-	5	12	-	-	3	7	27
JGU	Spotted gurnard	Female	MD	3	8	2	-	-	-	2	15
		Male		6	8	-	-	-	-	-	14
JMD	Jack mackerel	Female	MD	-	17	-	-	-	-	-	17
		Male		-	11	6	-	-	-	-	17
JMM	Slender mackerel	Female	MD	-	1	3	-	-	-	-	4
		Male		-	1	5	1	-	-	-	7
LDO	Lookdown dory	Female	MD	175	90	1	-	-	3	93	362
		Male		127	62	17	10	2	1	4	223
LIN	Ling	Female	MD	92	66	103	162	11	25	6	465
		Male		59	50	62	314	279	29	4	797
LSK	Softnose skate (longtail skate)	Female	MD	-	-	-	-	-	-	-	-
		Male		-	-	1	-	-	-	-	1
NMP	Tarakihi	Female	MD	5	104	-	-	-	-	212	321
		Male		5	83	1	8	1	1	203	302
NSD	Northern spiny dogfish	Female	SS	65	14	1	-	-	-	-	80
		Male		37	7	75	-	-	-	-	119
OPE	Orange perch	Female	MD	6	66	-	1	-	1	1	75
		Male		4	53	9	-	-	2	3	71
ORH	Orange roughy	Female	MD	8	34	3	-	-	-	15	60
		Male		26	12	2	1	-	5	3	49

Table 15: continued.

Code	Common name	Sex	Method	1	2	3	4	5	6	7	Total
PLS	Plunket's shark	Female	SS	3	2	-	-	1	-	-	6
		Male		3	-	1	-	-	-	-	4
RBT	Redbait	Female	MD	1	3	37	6	-	65	8	120
		Male		-	-	24	13	2	24	17	80
RCH	Widenosed chimaera	Female	SS	-	-	-	-	-	1	-	1
		Male		-	2	3	-	-	-	-	5
RCO	Red cod	Female	MD	1	-	4	2	-	-	2	9
		Male		1	2	4	16	1	2	-	26
RHY	Common roughy	Female	MD	-	2	13	-	-	-	1	16
		Male		2	7	10	-	-	1	4	24
RIB	Ribaldo	Female	MD	36	36	5	2	-	3	50	132
		Male		4	4	5	6	2	1	1	23
RSK	Rough skate	Female	MD	-	-	-	-	-	1	-	1
		Male		-	2	1	-	-	-	-	3
RSO	Gemfish	Female	MD	78	361	34	-	-	2	-	475
		Male		207	248	54	105	10	50	67	741
RUD	Rudderfish	Female	MD	-	-	3	-	-	-	-	3
		Male		-	-	-	-	-	-	-	-
SBI	Bigscaled brown slickhead	Female	MD	-	-	2	-	-	-	5	7
		Male		-	-	-	1	-	-	-	1
SBK	Spineback	Female	MD	-	1	5	-	-	-	1	7
		Male		-	1	1	-	-	-	-	2
SCG	Scaly gurnard	Female	MD	1	-	1	2	-	-	-	4
		Male		-	1	-	-	-	-	-	1
SCH	School shark	Female	SS	21	1	-	-	-	-	-	22
		Male		26	11	5	-	-	-	-	42
SCO	Swollenhead conger	Female	MD	-	-	10	2	-	-	1	13
		Male		-	-	2	13	5	1	-	21
SDO	Silver dory	Female	MD	1	-	135	1	-	-	-	137
		Male		3	28	58	18	-	-	-	107
SFN	Spinyfin	Female	MD	-	-	1	-	-	-	-	1
		Male		-	-	1	-	-	-	-	1
SMC	Small-headed cod	Female	MD	-	1	-	-	1	-	-	2
		Male		-	-	-	-	-	-	-	-
SND	Shovelnose dogfish	Female	SS	10	31	4	-	3	4	-	52
		Male		17	15	71	-	-	-	-	103
SNE	Snubnosed eel	Female	MD	-	1	-	-	-	-	-	1
		Male		-	-	-	-	-	-	-	-
SOR	Spiky oreo	Female	MD	138	10	2	-	-	1	-	151
		Male		171	23	-	-	-	-	-	194
SPD	Spiny dogfish	Female	SS	1	2	5	10	35	2	-	55
		Male		-	1	25	-	-	-	-	26
SPO	Rig	Female	MD	-	-	1	-	1	1	-	3
		Male		-	-	1	-	-	-	-	1
SRB	Southern Ray’s bream	Female	MD	1	-	1	-	-	-	-	2
		Male		-	1	1	-	-	-	-	2
SRH	Silver roughy	Female	MD	41	100	1	-	-	-	-	142
		Male		38	56	3	-	-	-	-	97
SSH	Slender smooth-hound	Female	MD	-	3	1	4	11	1	-	20
		Male		1	-	11	-	-	-	-	12
SSI	Silverside	Female	MD	-	-	2	-	-	-	-	2
		Male		-	-	3	1	-	-	-	4
SSK	Smooth skate	Female	SS	10	4	1	1	-	1	-	17
		Male		13	5	10	-	-	-	-	28
SSM	Smallscaled brown slickhead	Female	MD	-	-	1	-	-	-	-	1
		Male		-	-	-	-	-	-	-	-
SSO	Smooth oreo	Female	MD	1	-	-	-	-	-	-	1
		Male		-	-	-	-	-	-	-	-
SWA	Silver warehou	Female	MD	-	-	109	1	-	-	-	110
		Male		-	-	11	43	18	-	-	72

Table 15: continued.

Code	Common name	Sex	Method	1	2	3	4	5	6	7	Total
TRS	Cape scorpionfish	Female	MD	1	2	1	-	-	-	-	4
		Male		2	2	-	-	-	-	-	4
VNI	Blackspot rattail	Female	MD	-	-	1	1	1	-	-	3
		Male		-	1	-	-	-	-	-	1
WAR	Common warehou	Female	MD	-	-	2	-	-	-	-	2
		Male		-	-	-	2	-	-	-	2
WHX	White rattail	Female	MD	9	18	5	1	12	4	30	79
		Male		4	9	22	1	1	5	11	53
WIT	Witch	Female	MD	-	-	1	1	-	-	-	2
		Male		-	1	-	-	-	-	-	1
WWA	White warehou	Female	MD	-	-	2	-	-	-	-	2
		Male		-	-	-	4	1	-	-	5
YBO	Yellow boarfish	Female	MD	22	29	-	-	-	-	-	51
		Male		40	23	-	-	-	-	-	63
ZAS	Velvet dogfish	Female	MD	-	-	1	-	-	1	-	2
		Male		-	-	-	-	-	-	-	-

Table 16: Summary and catch information from mark identification tows during the 2018 WCSI survey. Mark type: HOK = hoki school; PMIX = hoki pelagic fuzz; BMIX = hoki bottom fuzz.

				Catch (kg)						
Station	Trawl	Stratum	Mark type	Hoki	Hake	Spiny dogfish	Ling	Silver warehou	Other	% Hoki
69	Bottom	6	PMIX	1	5	0	0	0	2	15
70	Bottom	6	PMIX	381	0	10	19	3	93	73
71	Bottom*	7	PMIX	0	0	0	0	0	3	0
72	Bottom	6	PMIX	227	7	6	83	0	44	59
73	Bottom	6	HOK	805	10	17	11	0	9	93
74	Bottom	6	BMIX	13	38	0	0	0	122	6
75	Bottom	6	BMIX	24	33	0	2	0	17	25
76	Bottom$^+$	4C	BMIX	138	60	12	3	0	22	56
77	Bottom$^+$	4C	BMIX	42	16	0	0	2	5	49

* Net was flown above the bottom and did not contact the seabed.
$^+$ Tow with acoustic-optical system (AOS) attached.

Table 17: Estimates of the proportion of acoustic backscatter from hoki (P(hoki)) in mixed species marks by substratum for all snapshots combined. Average percentage of hoki by weight in the catch is also given with equal weighting of all tows ('unweighted') and weighted by the square root of the catch rate ('weighted'). South area includes strata 6 and 7. In the 'revised' analysis method, P(hoki) from the south area was assumed to be 1 and stratum 4D was excluded (see Table 4).

		Mean % hoki in catch		
Stratum	No. of tows	Unweighted	Weighted	P(hoki)
1&2A	8	4	3	0.02
1&2B	7	64	68	0.39
1&2C	5	35	36	0.17
4A	6	5	6	0.03
4B	3	72	73	0.48
4C	5	58	60	0.33
4D	7	14	15	–
South	6	30	45	1.00

Table 18: Estimates of the ratio *r* for converting hoki acoustic backscatter to biomass using acoustic TS derived from commercial length frequency data (see Figure 15) using the TS-length relationship of Dunford et al. (2015). Values for 1988–2003 from O'Driscoll et al. (2016).

Year	Mean length (cm)	Mean weight (kg)	Mean TS (dB)	*r* (kg m^{-2})
1988	81.1	1.66	-37.0	8 272
1989	81.6	1.67	-36.9	8 263
1990	81.9	1.69	-36.9	8 279
1991	80.5	1.63	-37.0	8 261
1992	79.3	1.54	-37.2	8 175
1993	78.2	1.49	-37.4	8 128
1997	74.1	1.31	-37.9	8 016
2000	80.3	1.59	-37.1	8 211
2012	75.4	1.37	-37.7	8 070
2013	79.1	1.56	-37.2	8 209
2018	79.4	1.60	-37.1	8 279

Table 19: Hoki acoustic abundance estimates from the 2018 WCSI by snapshot and stratum.

	Abundance ('000 t)							
Snapshot	12	4	5A	5B	6	7	Total	CV (%)
1	11	18	36	19	35	21	140	14
2	8	13	39	13	28	5	106	29
Mean	10	15	38	16	31	13	123	

Table 20: Percentage of the hoki abundance estimate from hoki school marks in each snapshot and stratum. Percentages were calculated in relation to abundance estimates in Table 19.

	% hoki in schools						
Snapshot	12	4	5A	5B	6	7	Total
1	0	0	80	20	5	30	29
2	0	0	89	0	22	88	43
Mean	0	0	84	10	13	59	36

Table 21: Acoustic abundance indices for WCSI. Values for 1988–2003 from O'Driscoll et al. (2016).

Year	Abundance ('000 t)	CV
1988	266	0.60
1989	165	0.38
1990	169	0.40
1991	227	0.73
1992	229	0.49
1993	380	0.38
1997	445	0.60
2000	263	0.28
2012	283	0.34
2013	233	0.35
2018	123	0.46

Table 22: Results of Monte Carlo simulations to determine model weighting for the 2018 WCSI acoustic survey (see Section 2.7.5 for details). The CV for the survey is given in a stepwise cumulative fashion to allow the contribution of each component of the abundance estimation process to be assessed. 'Timing' refers to uncertainties associated with the timing of snapshots relative to the plateau height model and includes uncertainties associated with assumptions about fish arrival date and residence time. CV for the total area is not the simple sum of squares as errors are not independent.

	North	South	Total
Timing	0.084	0.093	
+ Sampling	0.235	0.208	
+ Mark identification	0.611	0.414	
+ Calibration	0.611	0.414	
+ TS	0.612	0.424	
Total	0.612	0.424	0.462

8. FIGURES

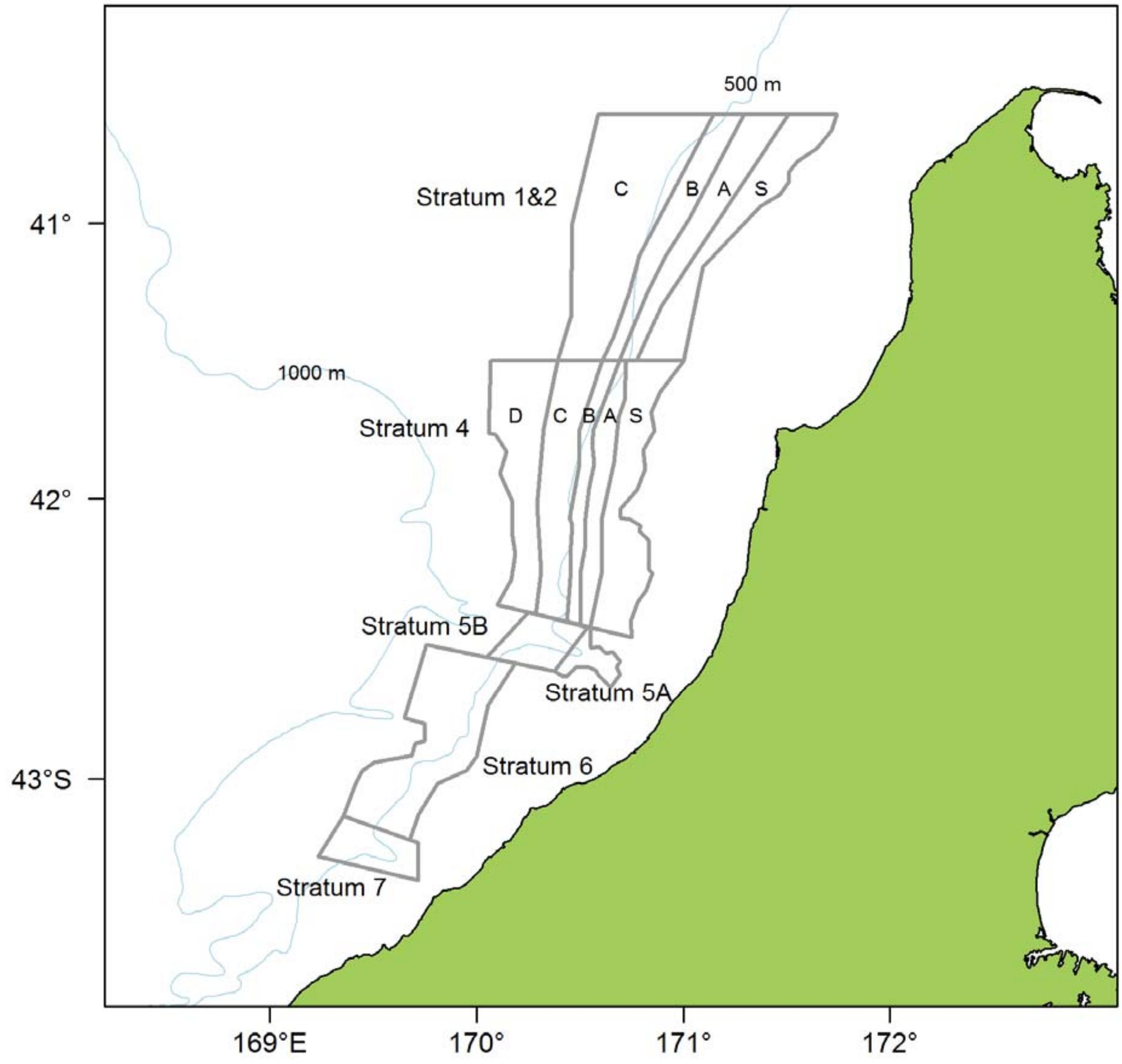


Figure 1: Stratum boundaries for the 2018 survey of the WCSI. Stratum areas are given in Table 1.

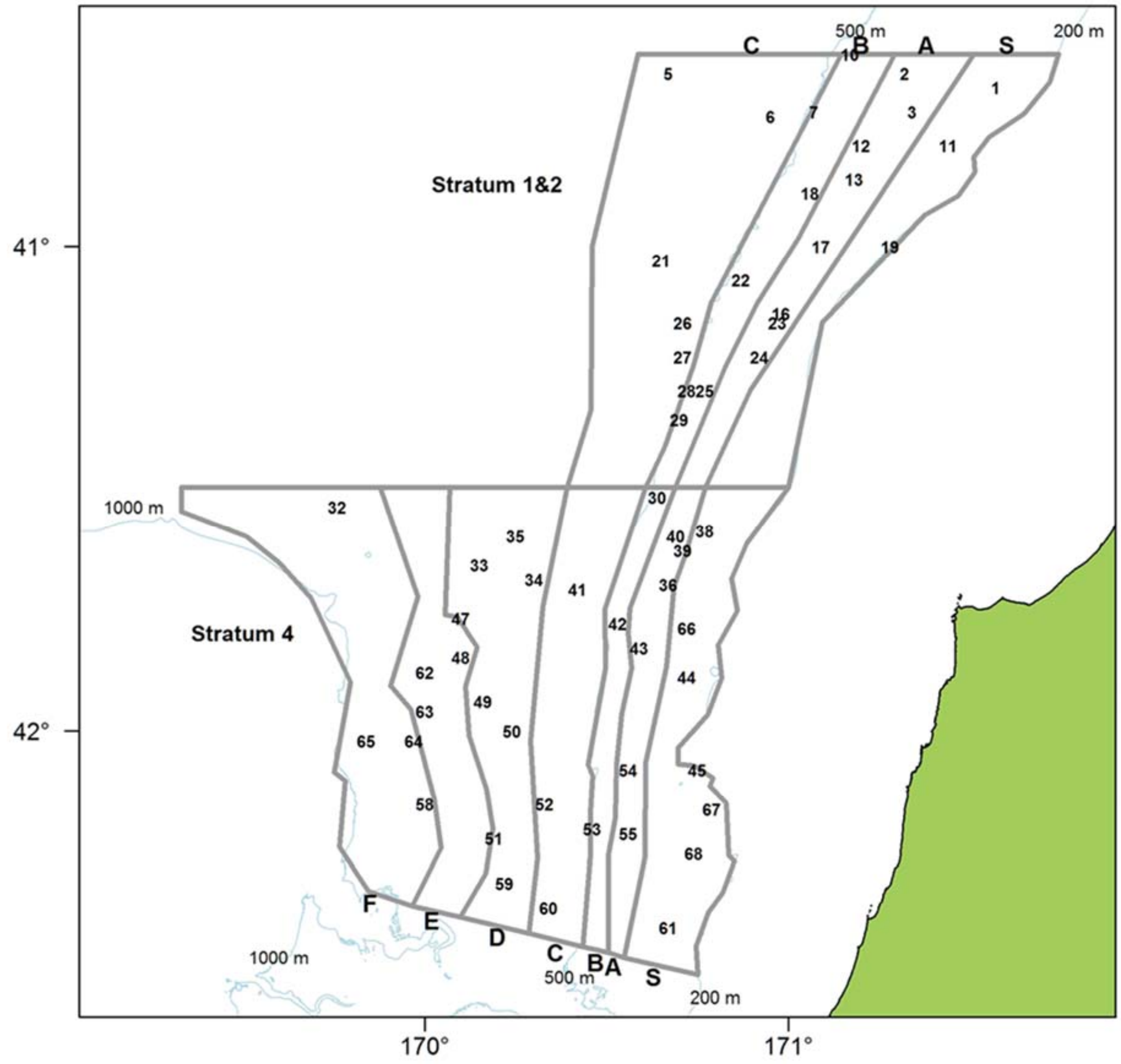


Figure 2: Trawl station positions for the random trawl survey of the WCSI. Labels show station numbers. Station details are given in Appendix 1.

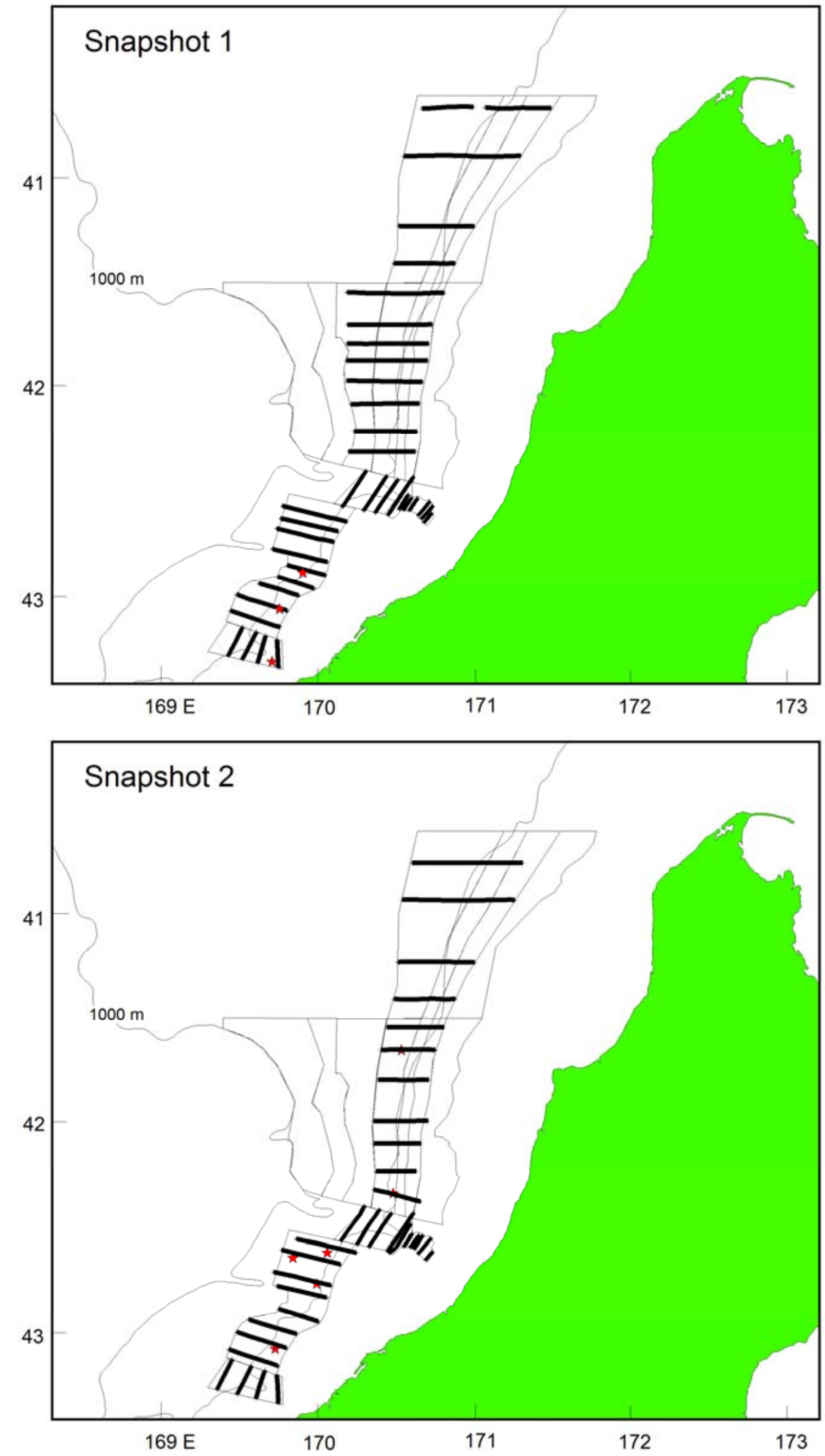


Figure 3: Location of acoustic transects during acoustic snapshots 1 and 2. Red stars show location of mark identification trawls.

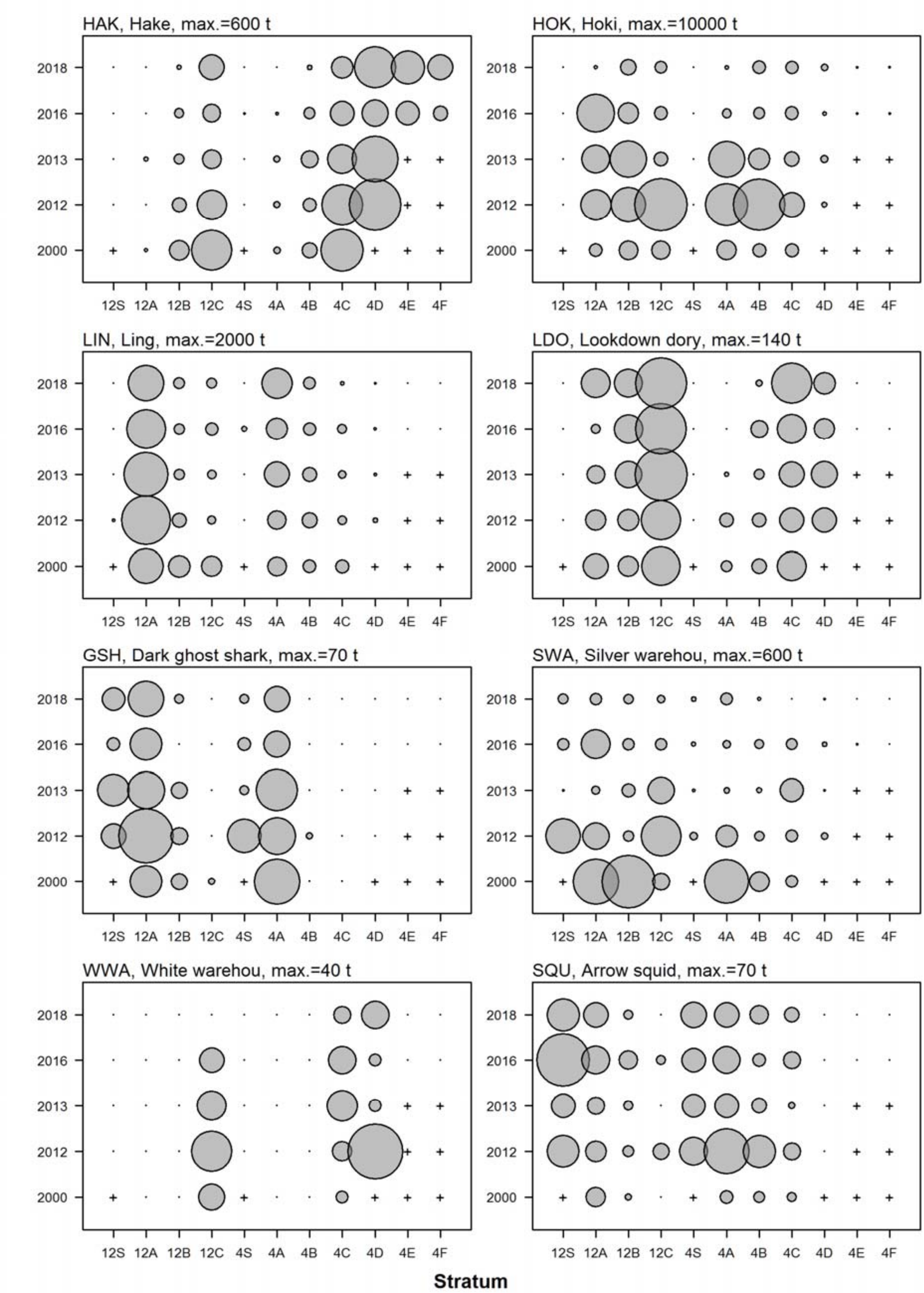


Figure 4: Relative biomass estimates by strata for 8 commercially important middle depth species sampled by annual trawl surveys of the WCSI, in 2000, 2012, 2013, 2016 and 2018. + indicates stratum not surveyed in that year.

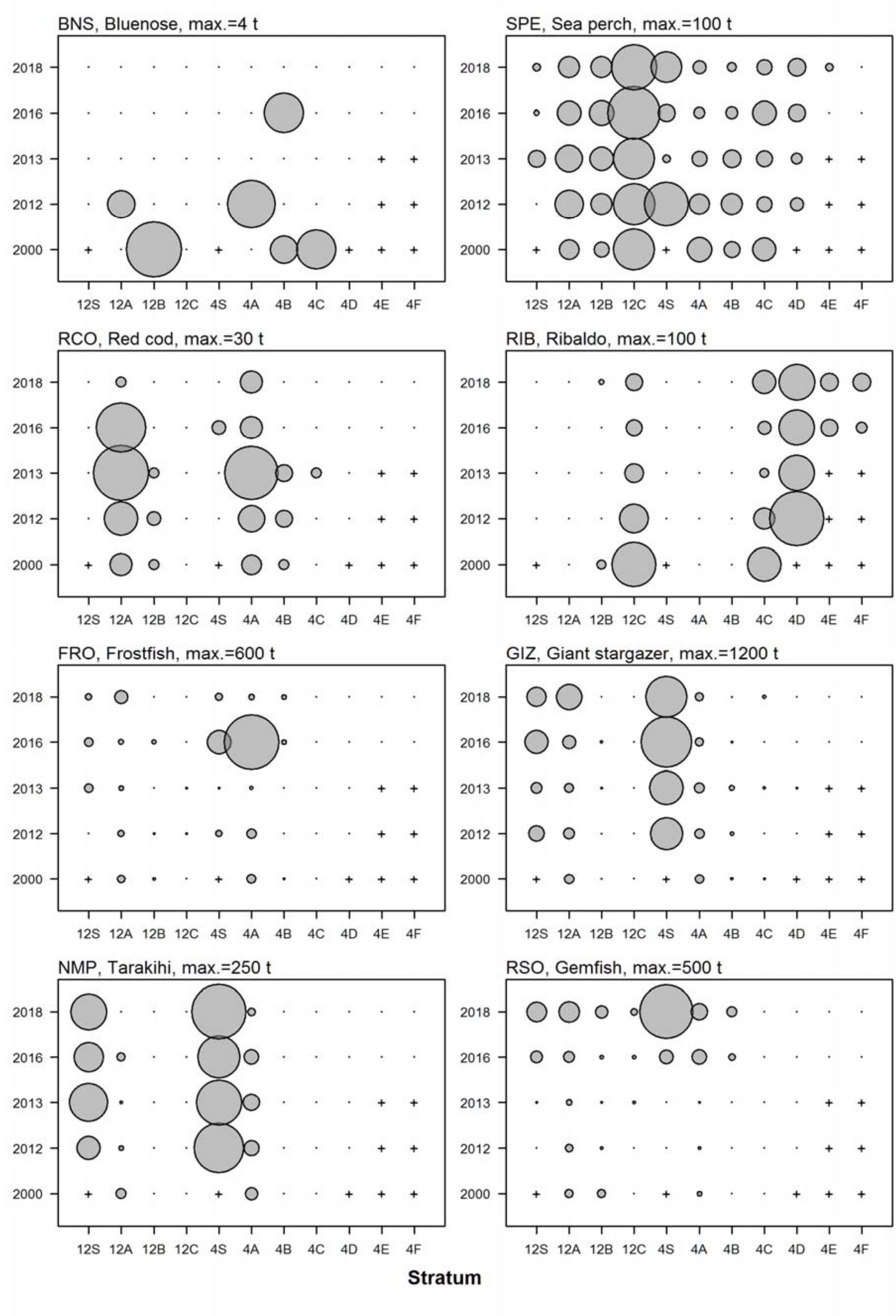


Figure 4: continued.

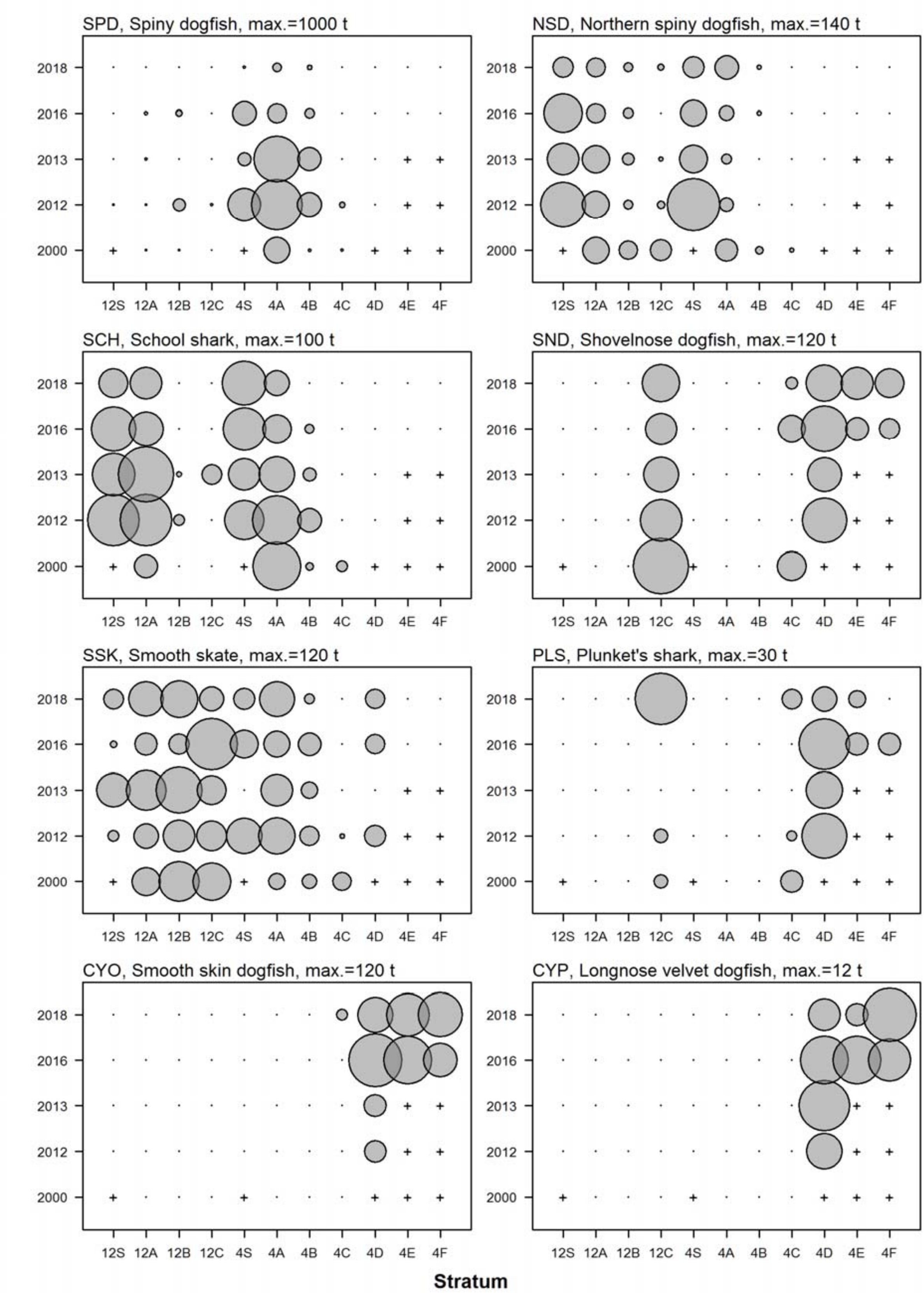


Figure 5: Relative biomass estimates by strata for 8 elasmobranch bycatch species sampled by annual trawl surveys of the WCSI, in 2000, 2012, 2013, 2016 and 2018. + indicates stratum not surveyed in that year.

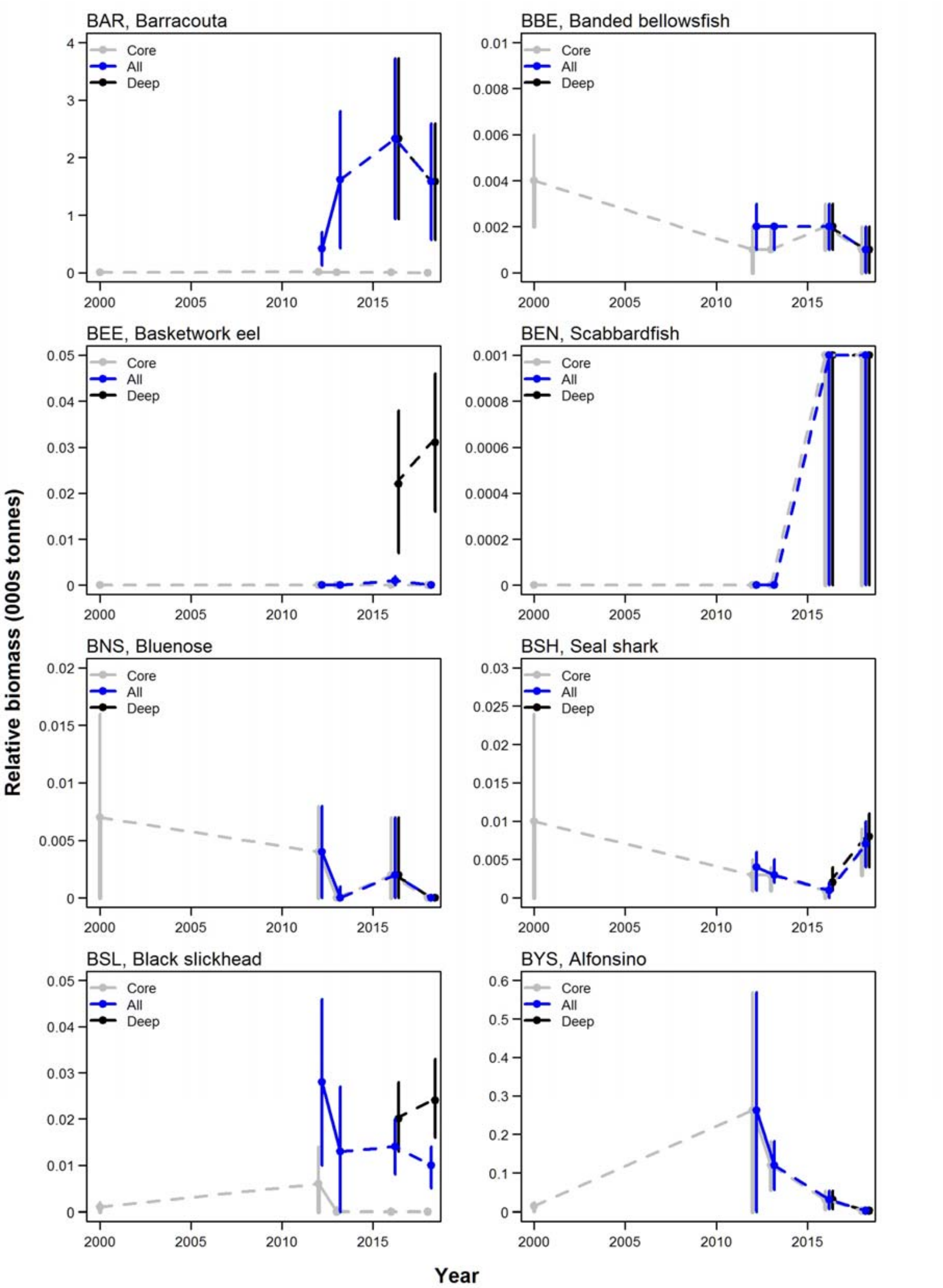
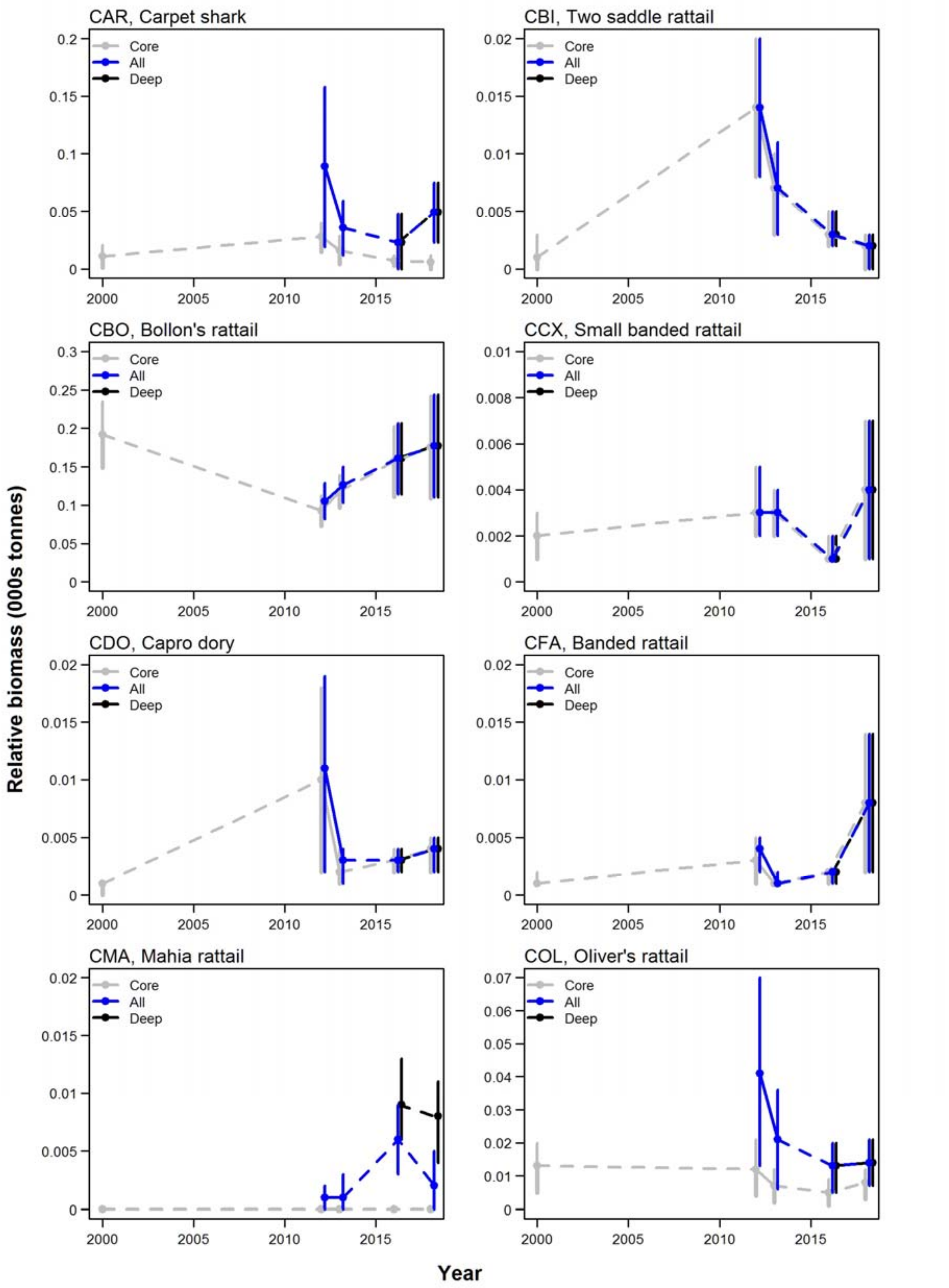


Figure 6: Relative biomass estimates (thousands of tonnes) of selected species sorted alphabetically by research code sampled by trawl surveys of the WCSI, 2000, 2012, 2013, 2016, and 2018. Grey lines show fish from core (300–650 m) strata, blue lines show fish from all strata (200–800 m), and black solid lines show fish from deep (200–1000 m) strata. Error bars show ± 2 standard errors.



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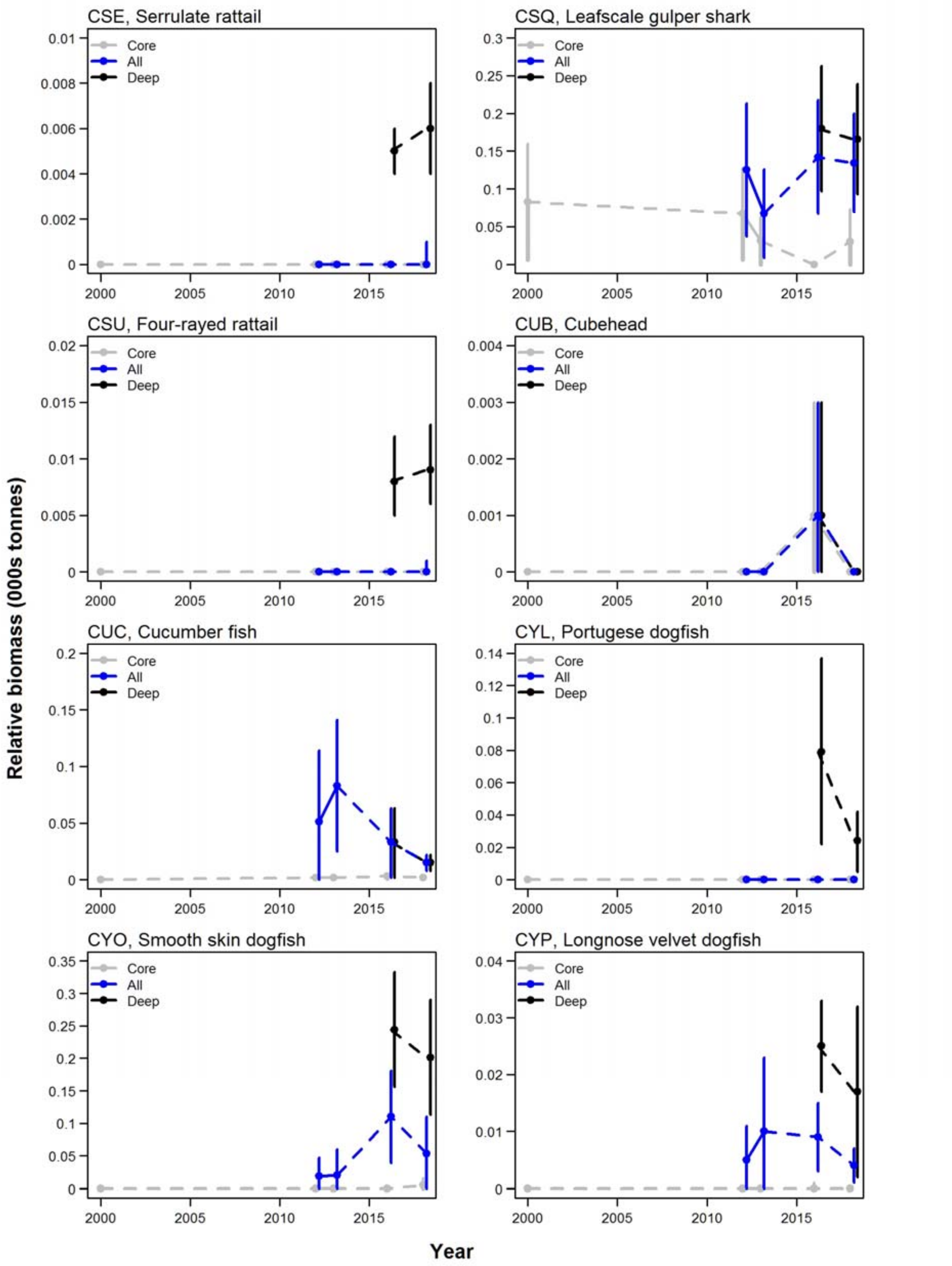

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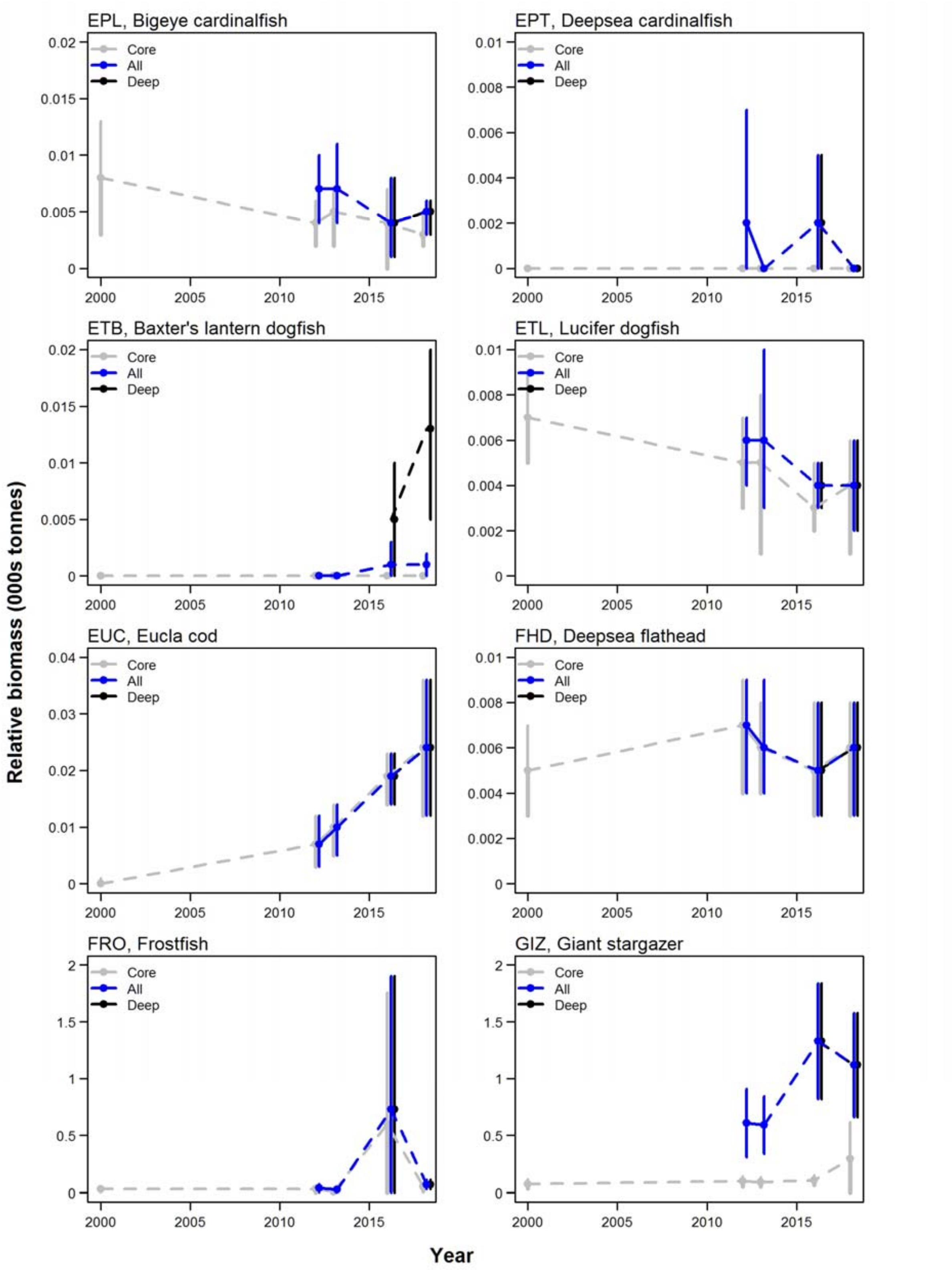

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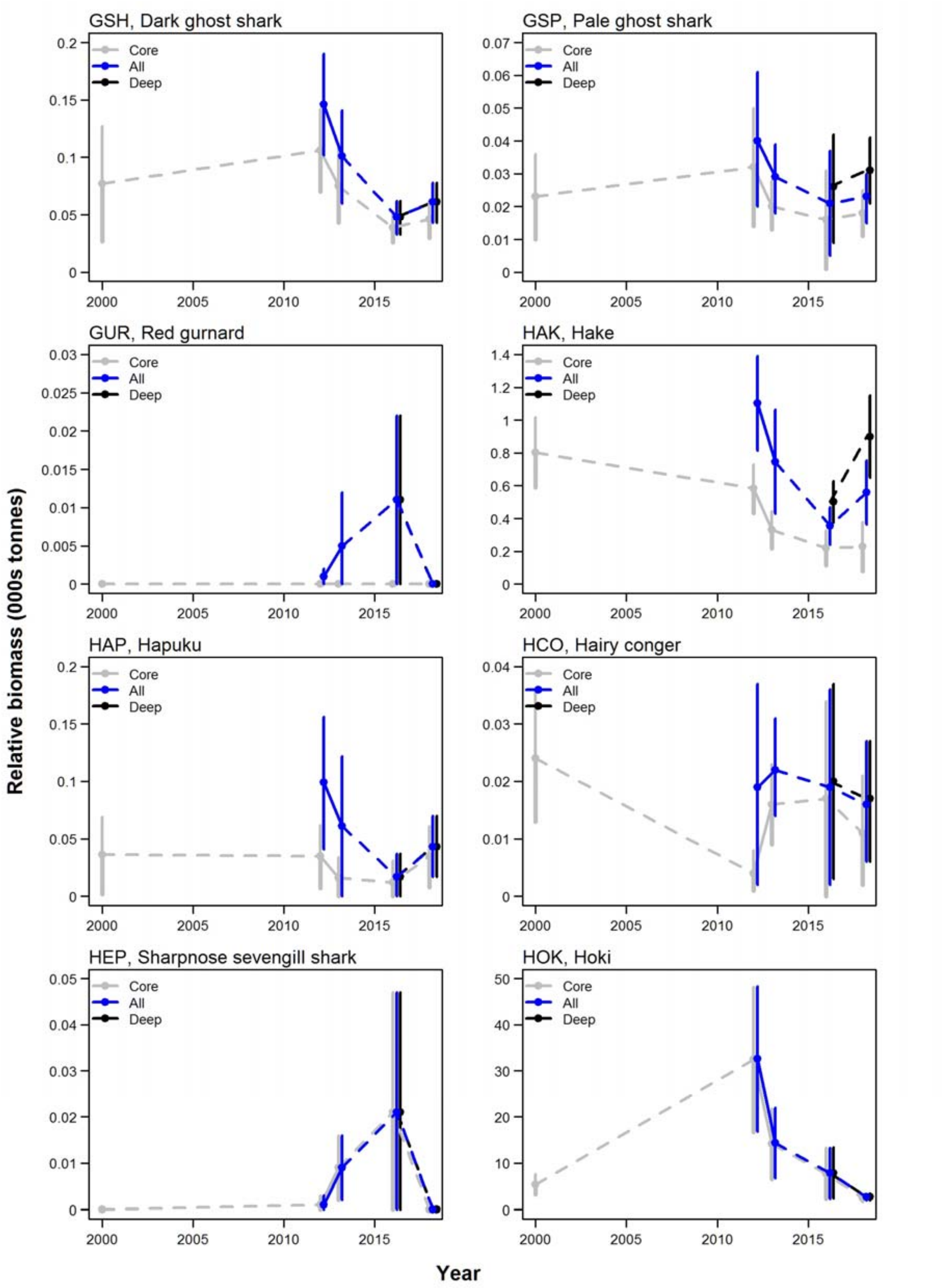

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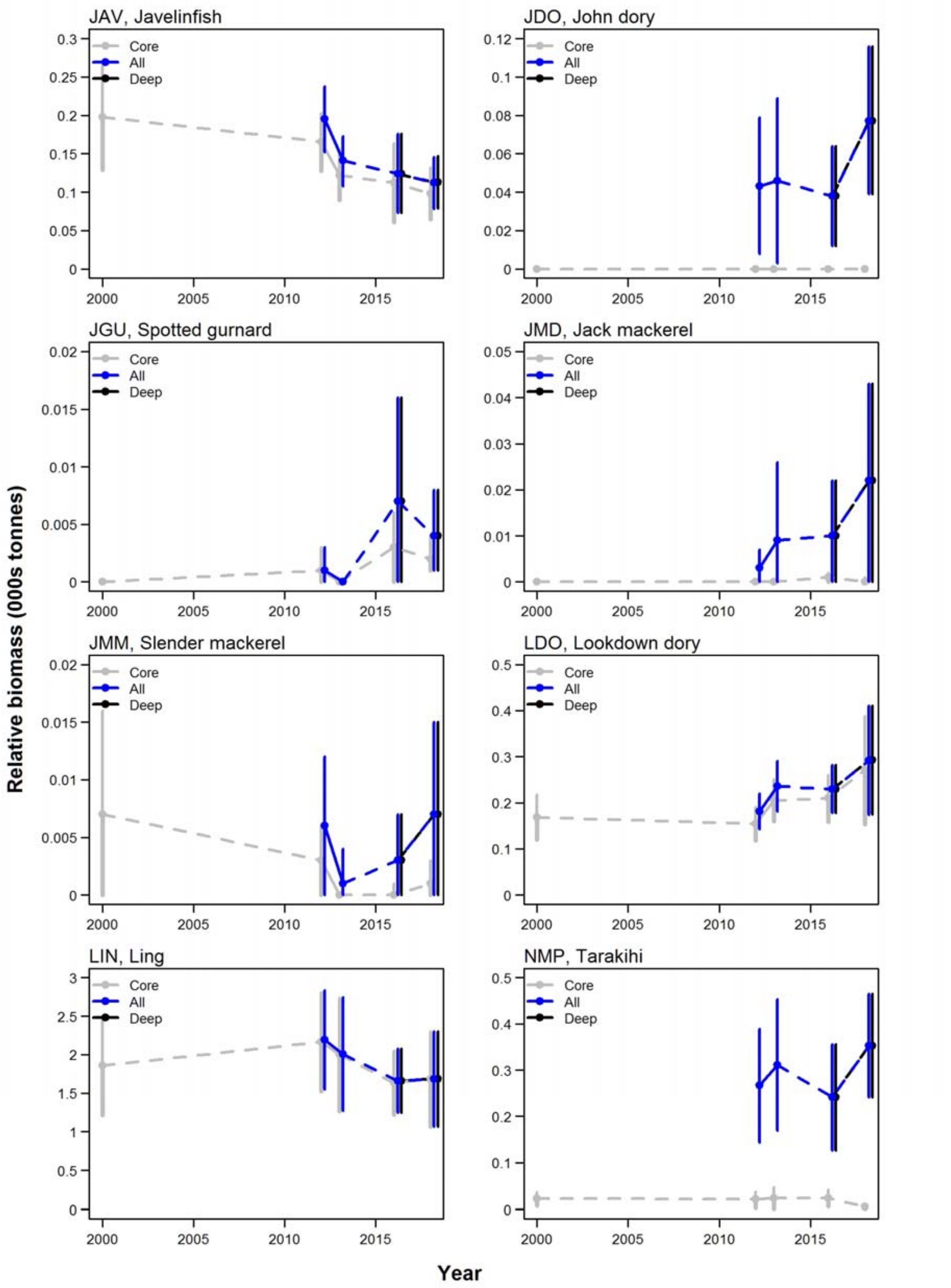

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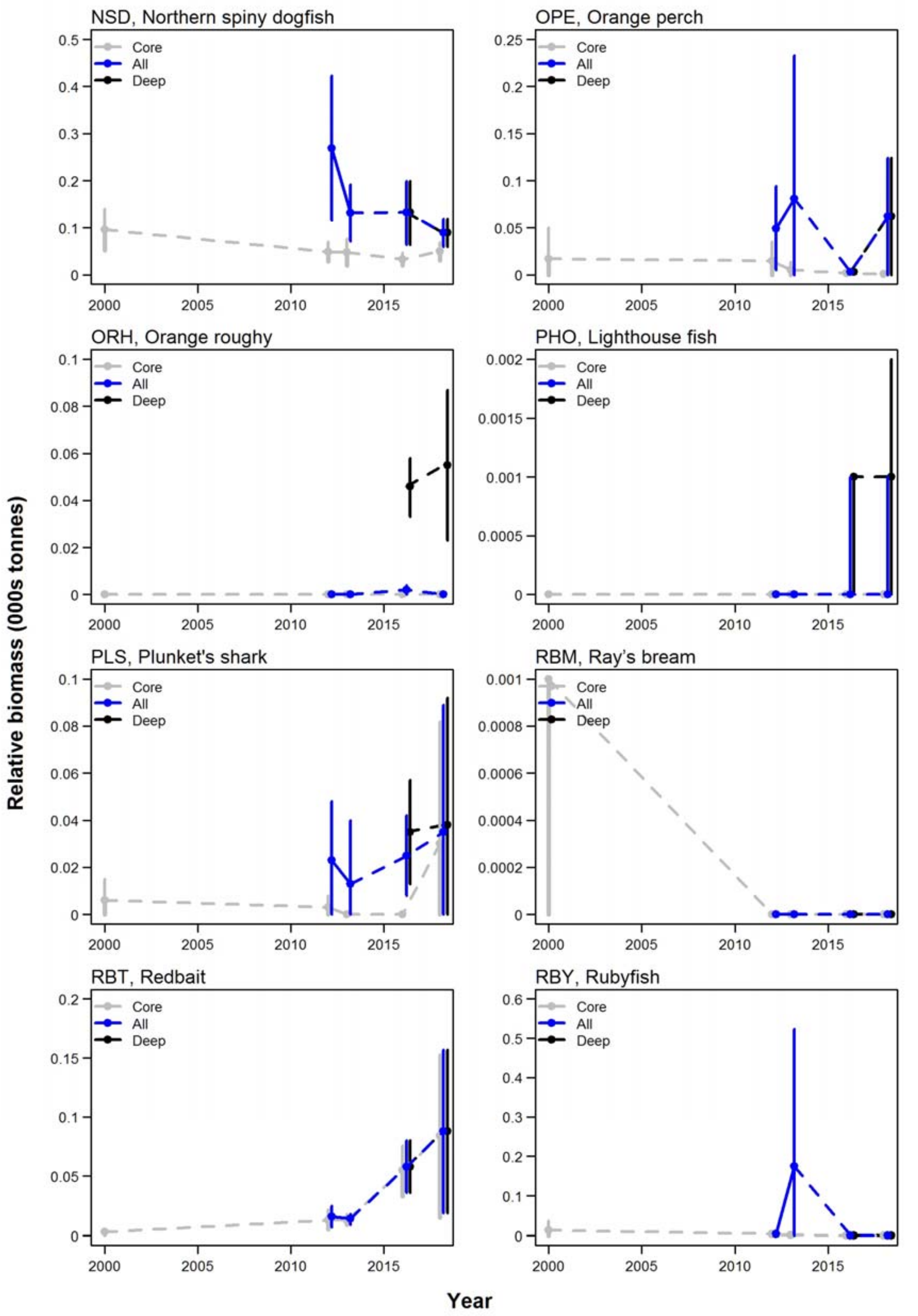

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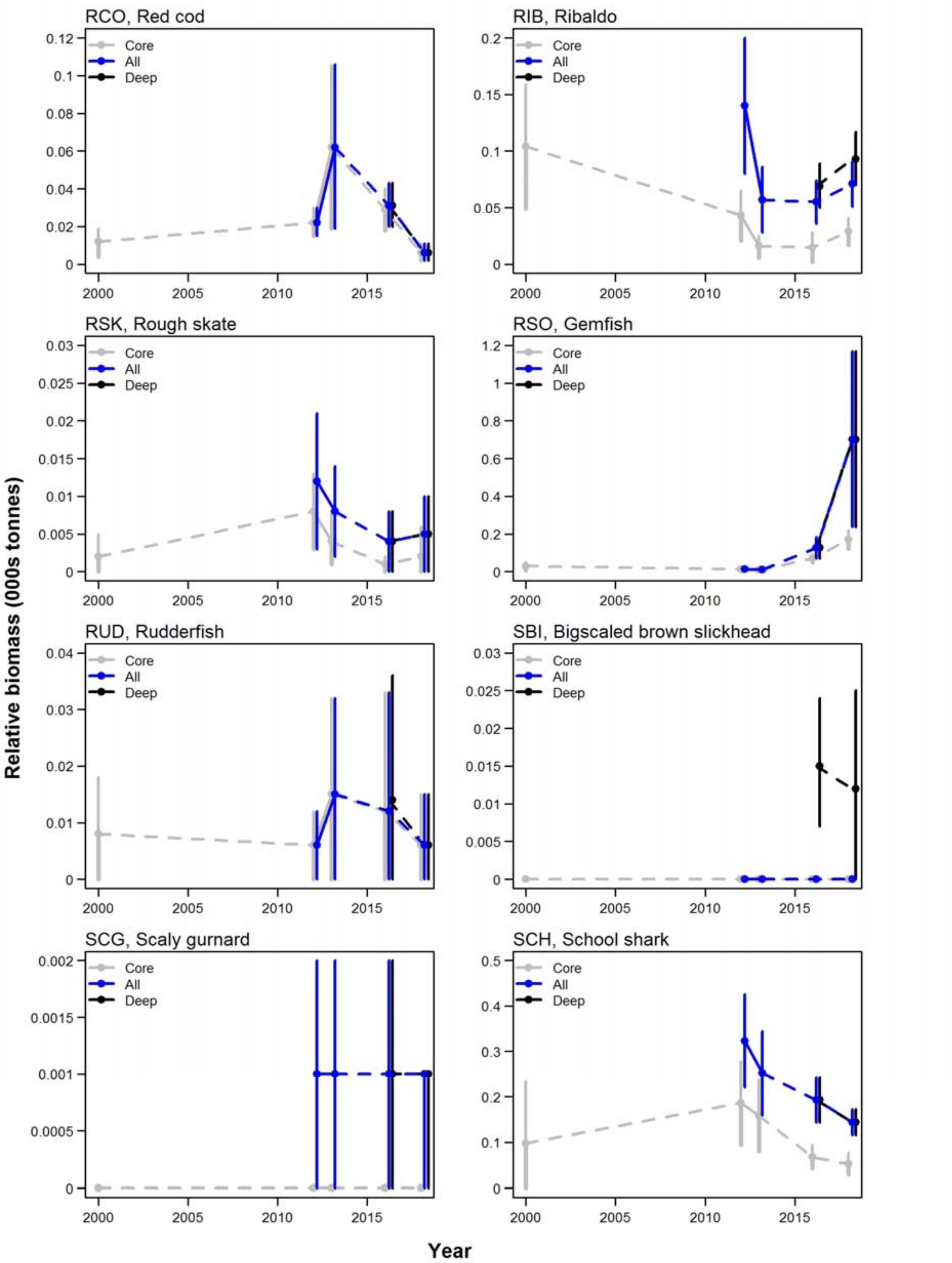

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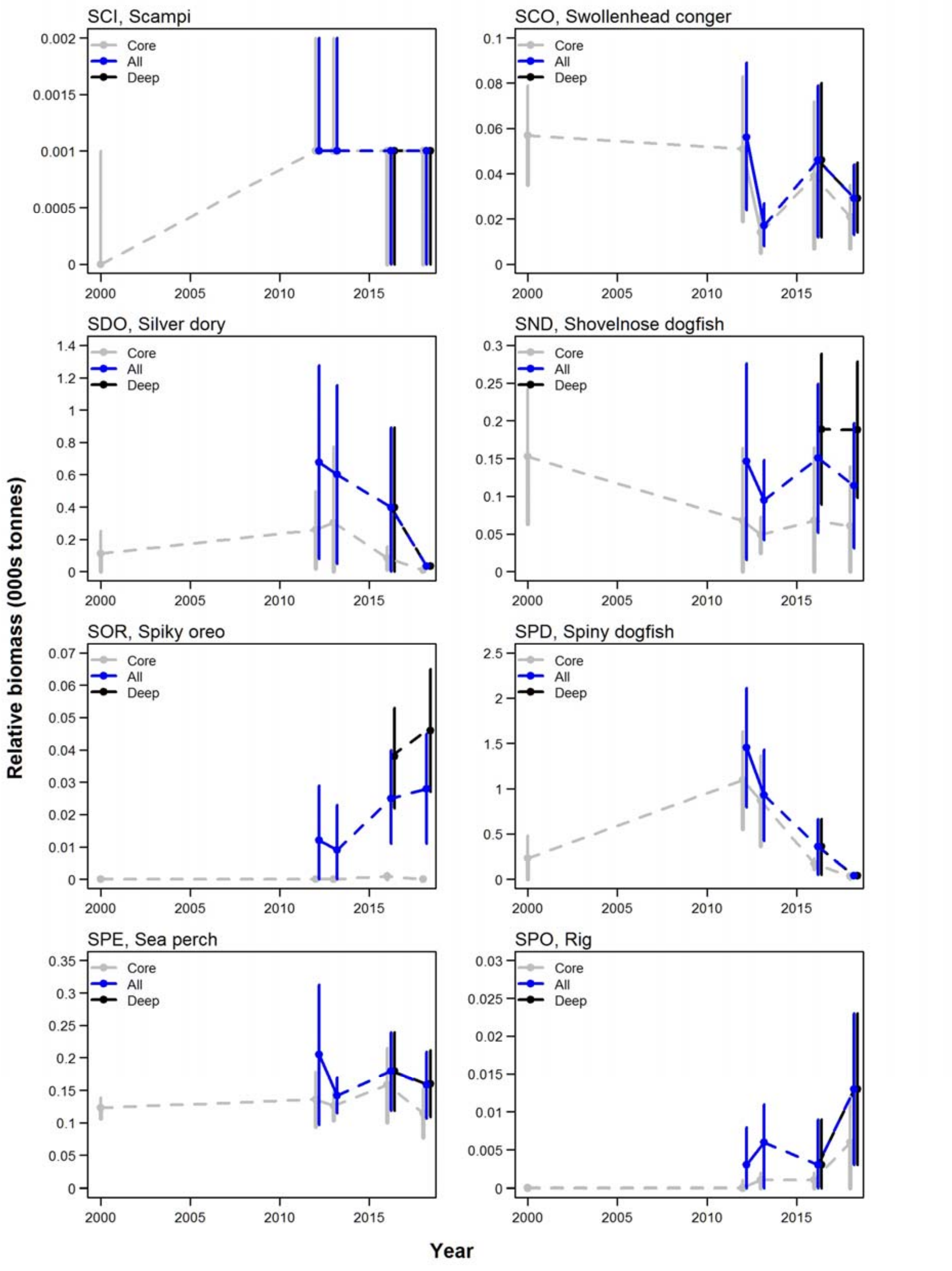

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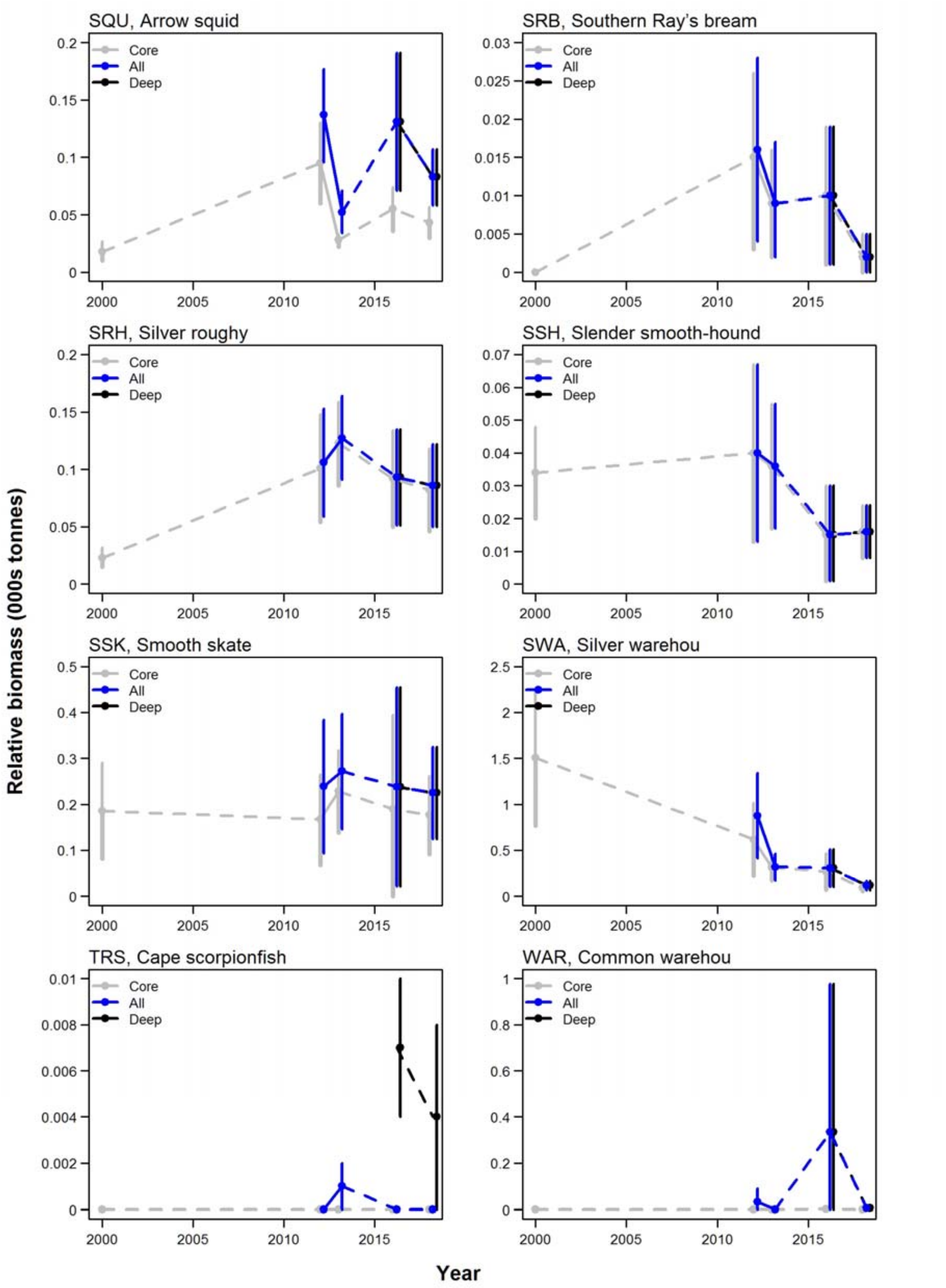

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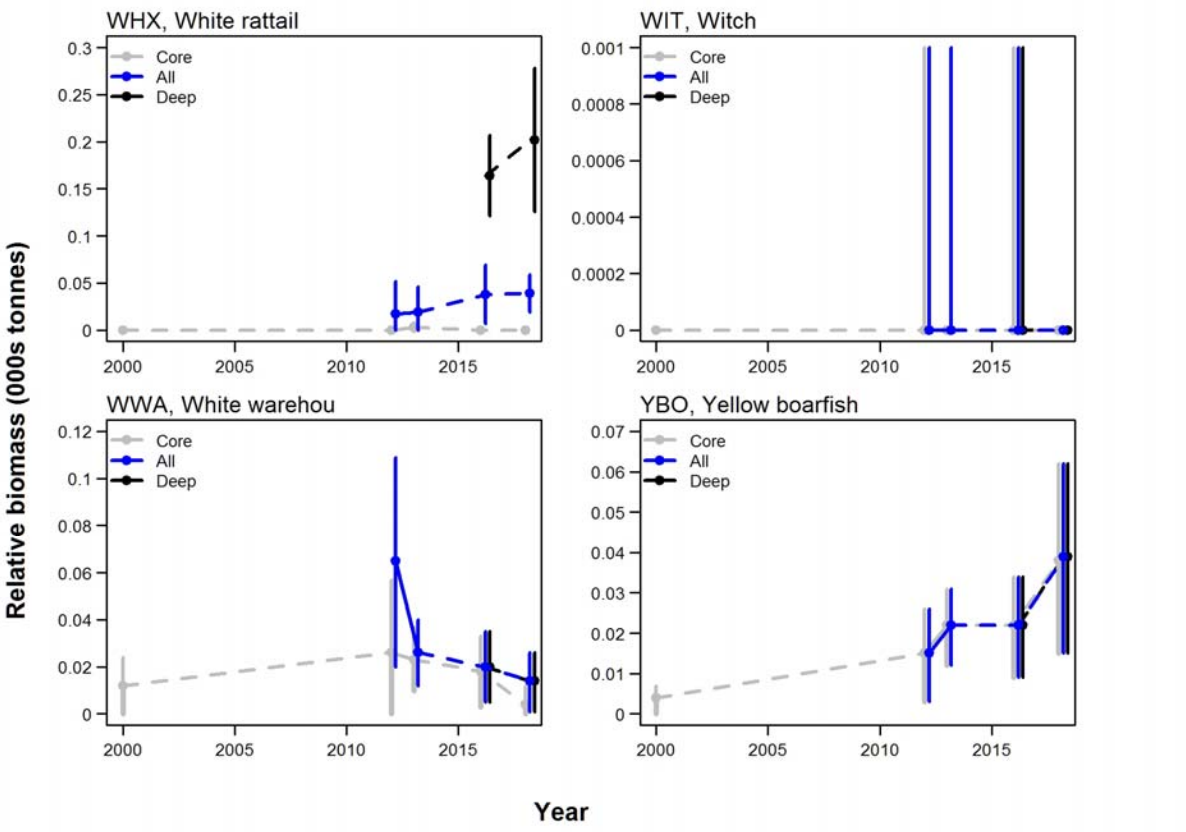


Figure 6: continued.

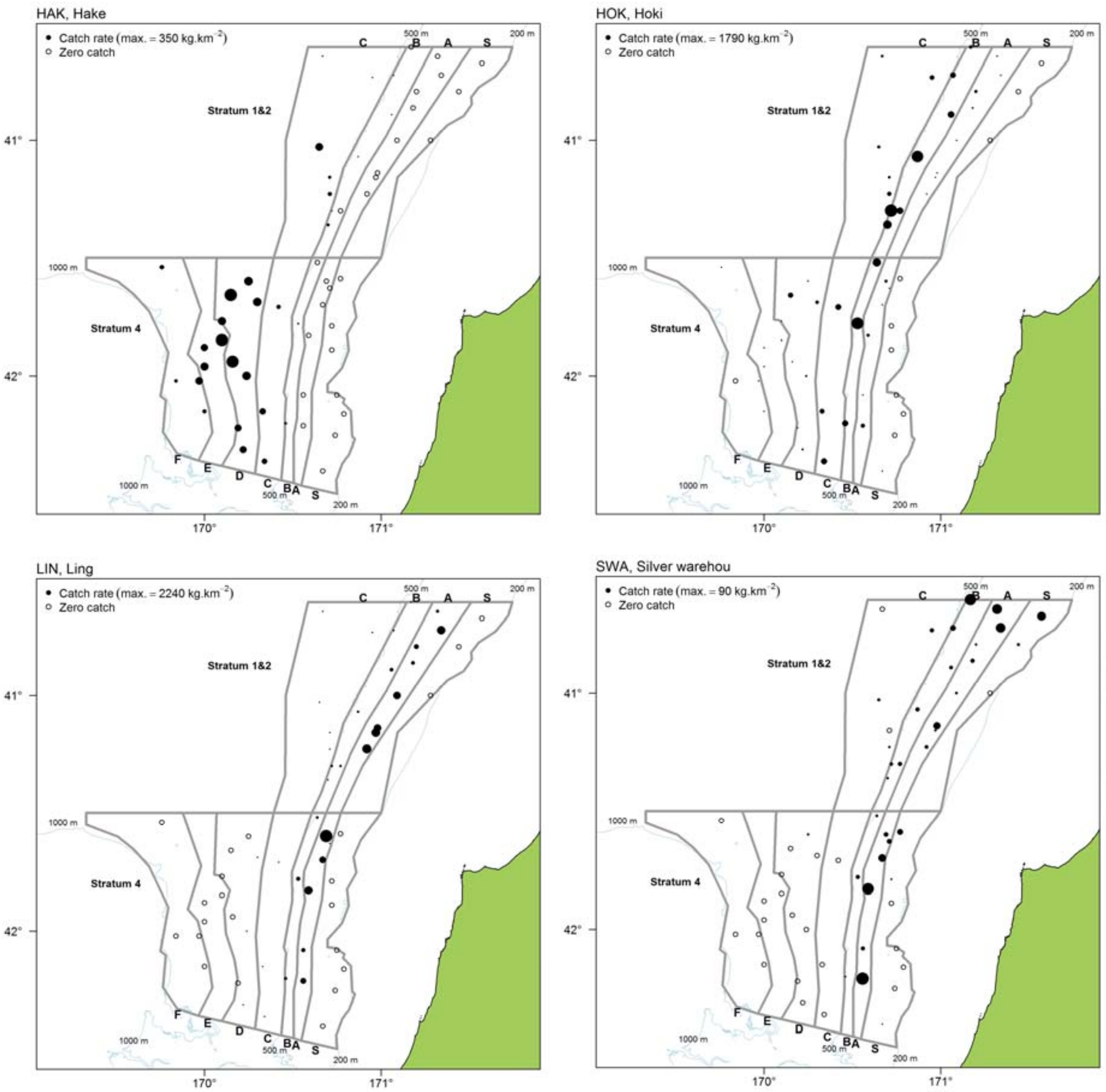


Figure 7: Distribution and catch rates of ling (LIN), hoki (HOK), hake (HAK), and silver warehou (SWA) on the WCSI 2018 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.

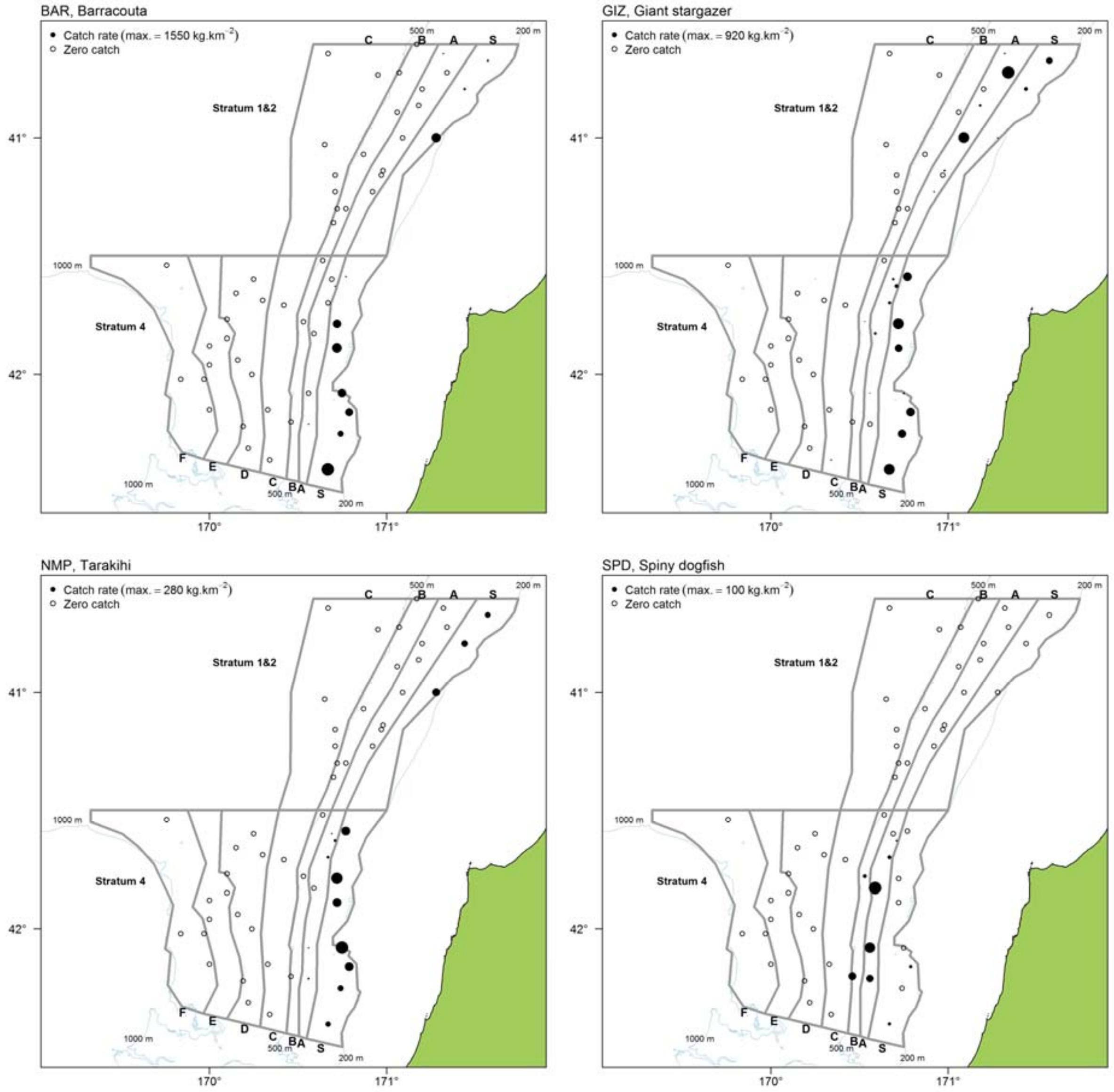
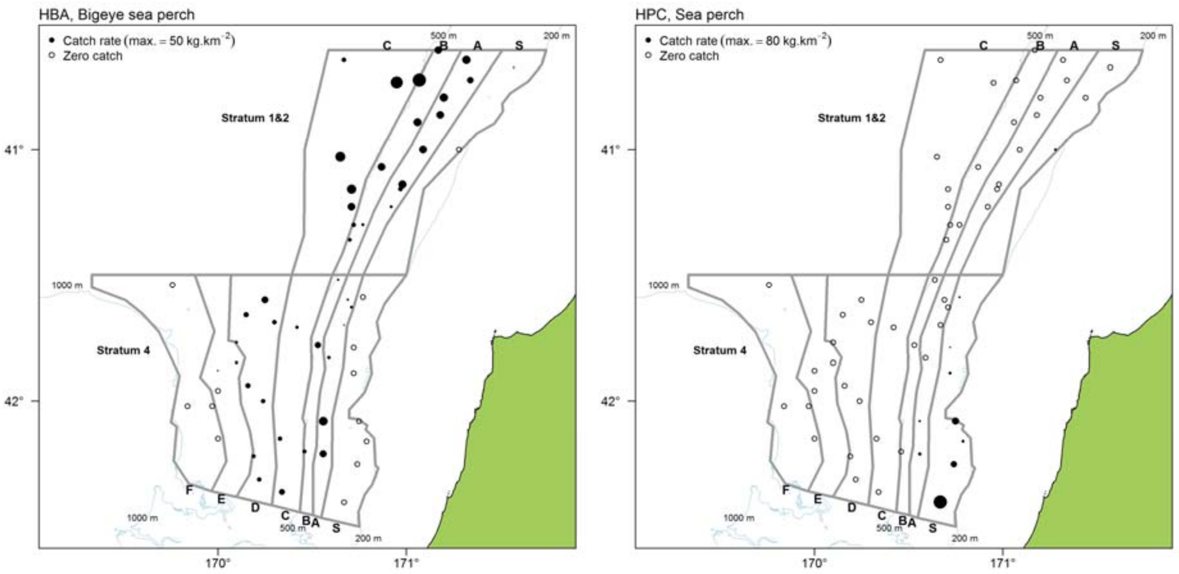
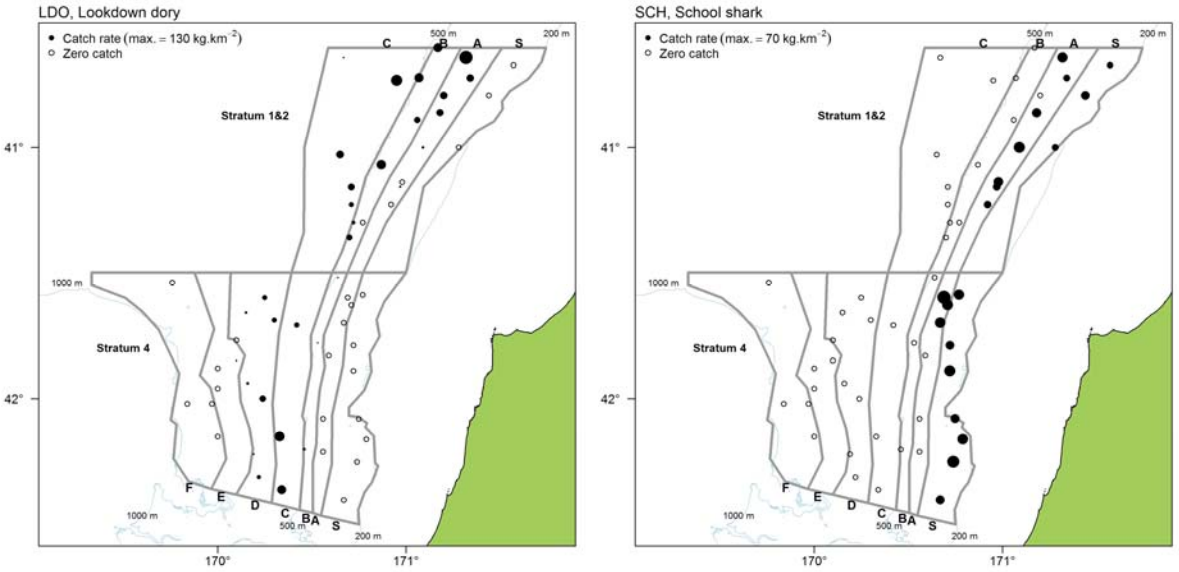


Figure 7 continued: Distribution and catch rates of barracouta (BAR), spiny dogfish (SPD), giant stargazer (GIZ), and tarakihi (NMP) on the WCSI 2018 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.



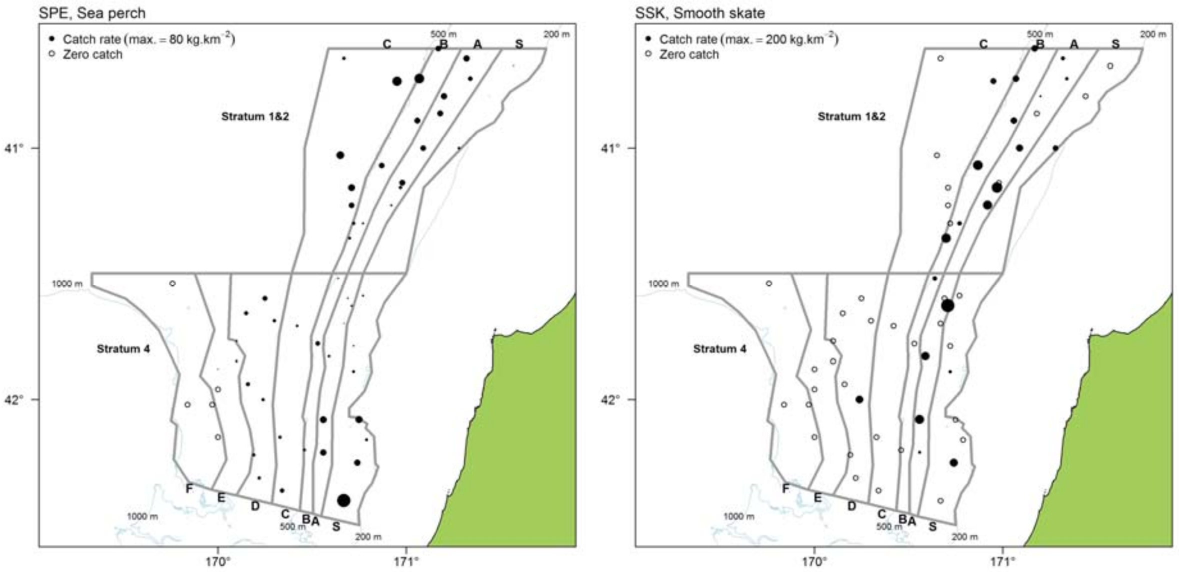
HBA, Bigeye sea perch

HPC, Sea perch



LDO, Lookdown dory

SCH, School shark



SPE, Sea perch

SSK, Smooth skate

Figure 7 continued: Distribution and catch rates of smooth skate (SSK), school shark (SCH), lookdown dory (LDO) and sea perch (HBA and HPC combined) on the WCSI 2018 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.

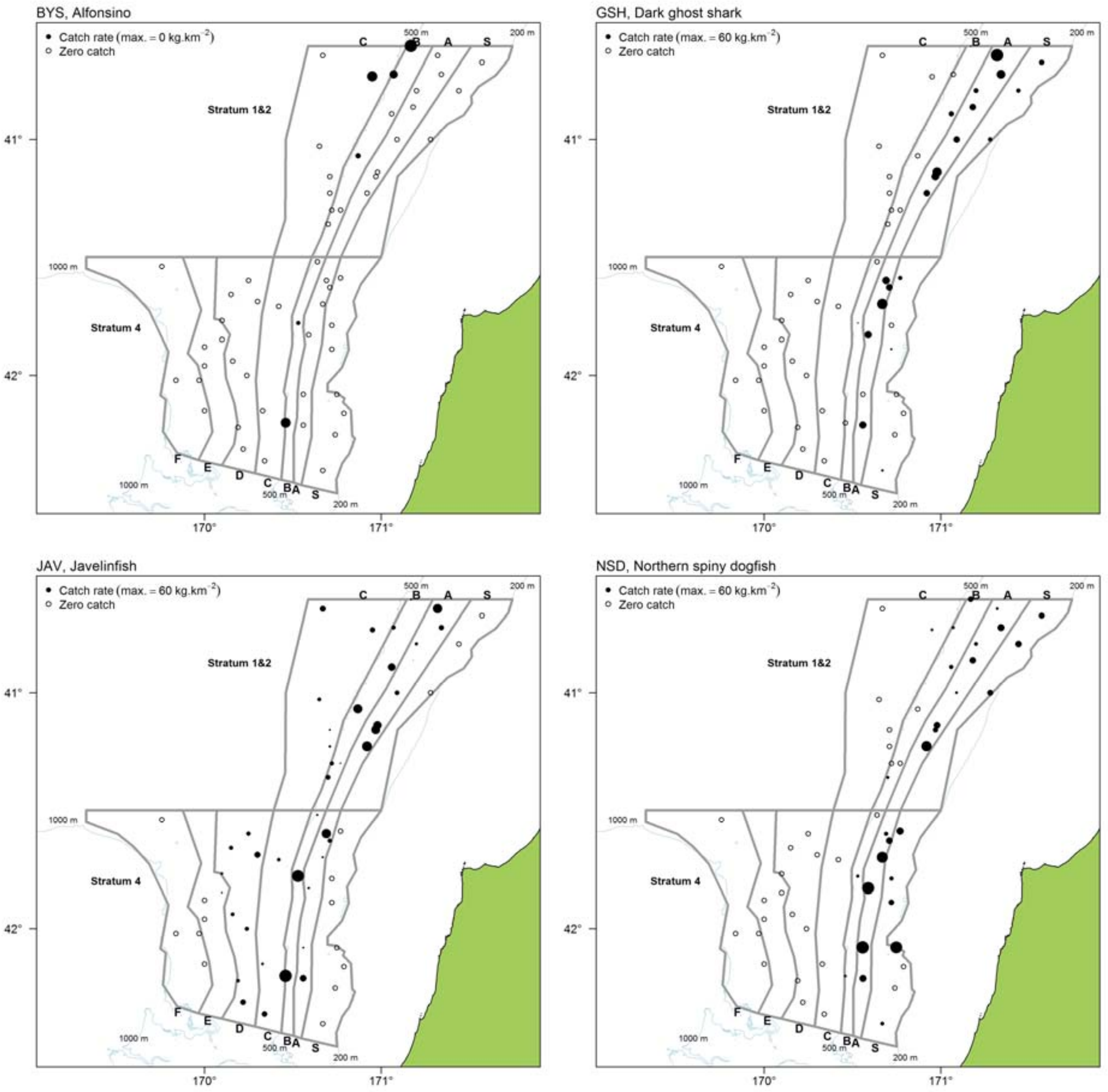
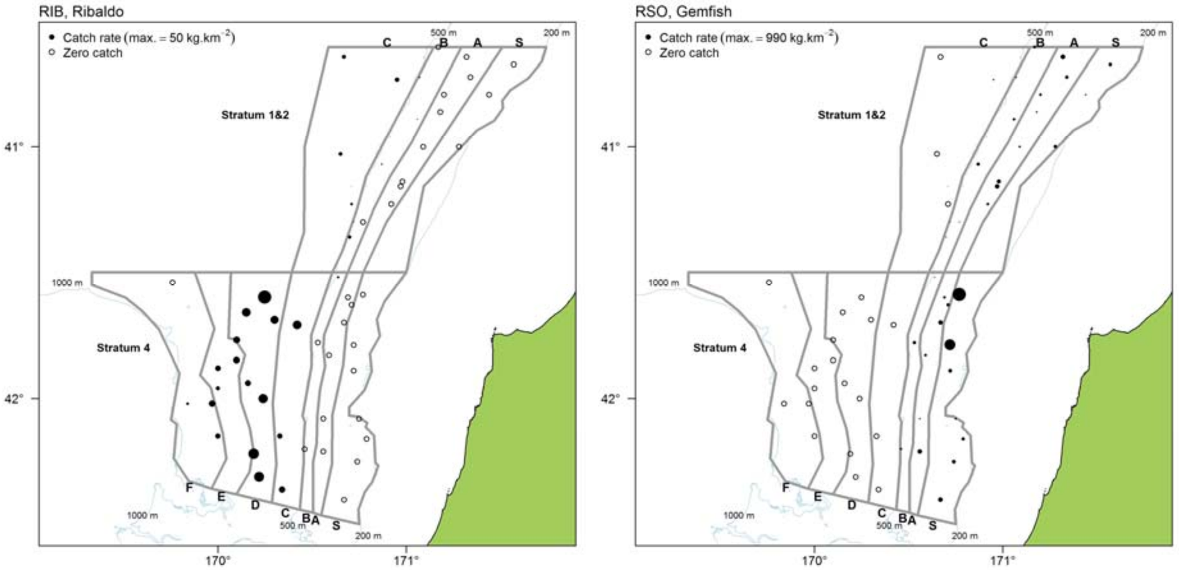


Figure 7 continued: Distribution and catch rates of javelinfish (JAV), northern spiny dogfish (NSD), alfonsino (BYS), and dark ghost shark (GSH) on the WCSI 2018 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.



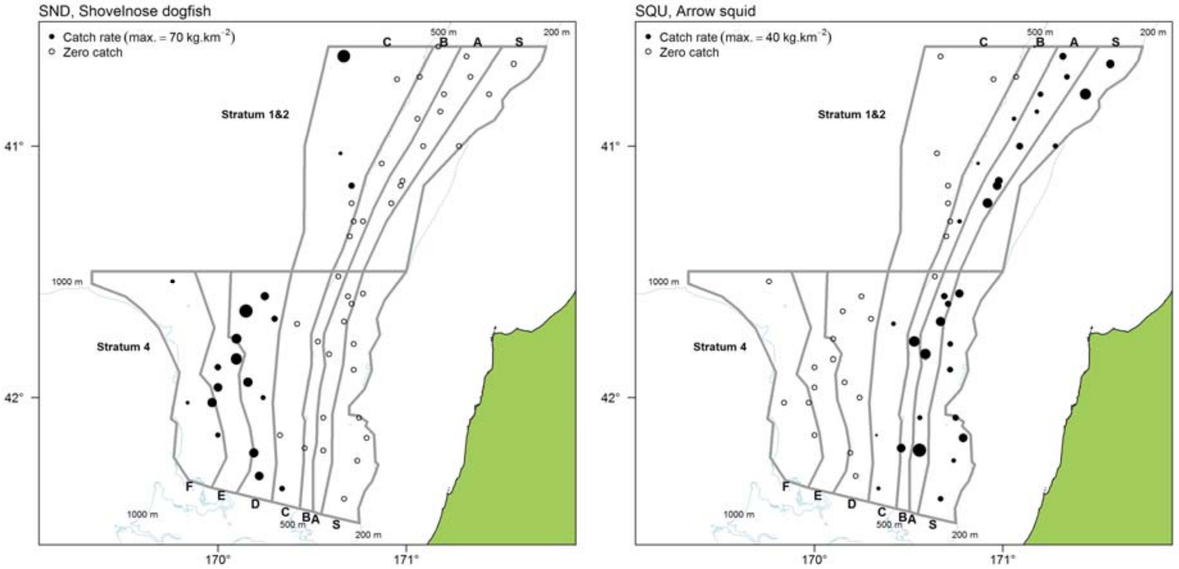


Figure 7 continued: Distribution and catch rates of shovelnose dogfish (SND), arrow squid (SQU), ribaldo (RIB), and gemfish (RSO) on the WCSI 2018 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.

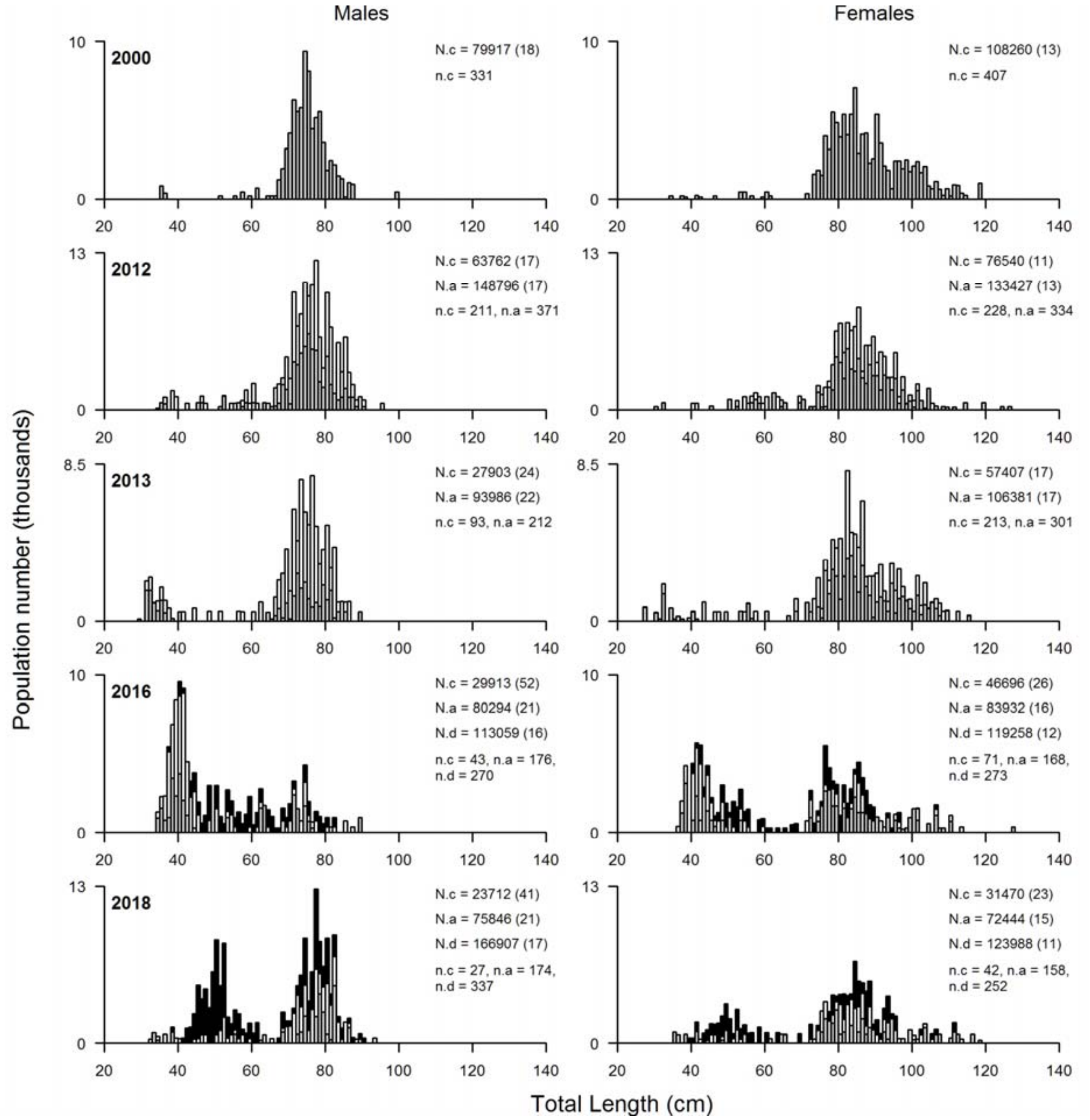


Figure 8: Length frequency distributions by sex of hake (HAK) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

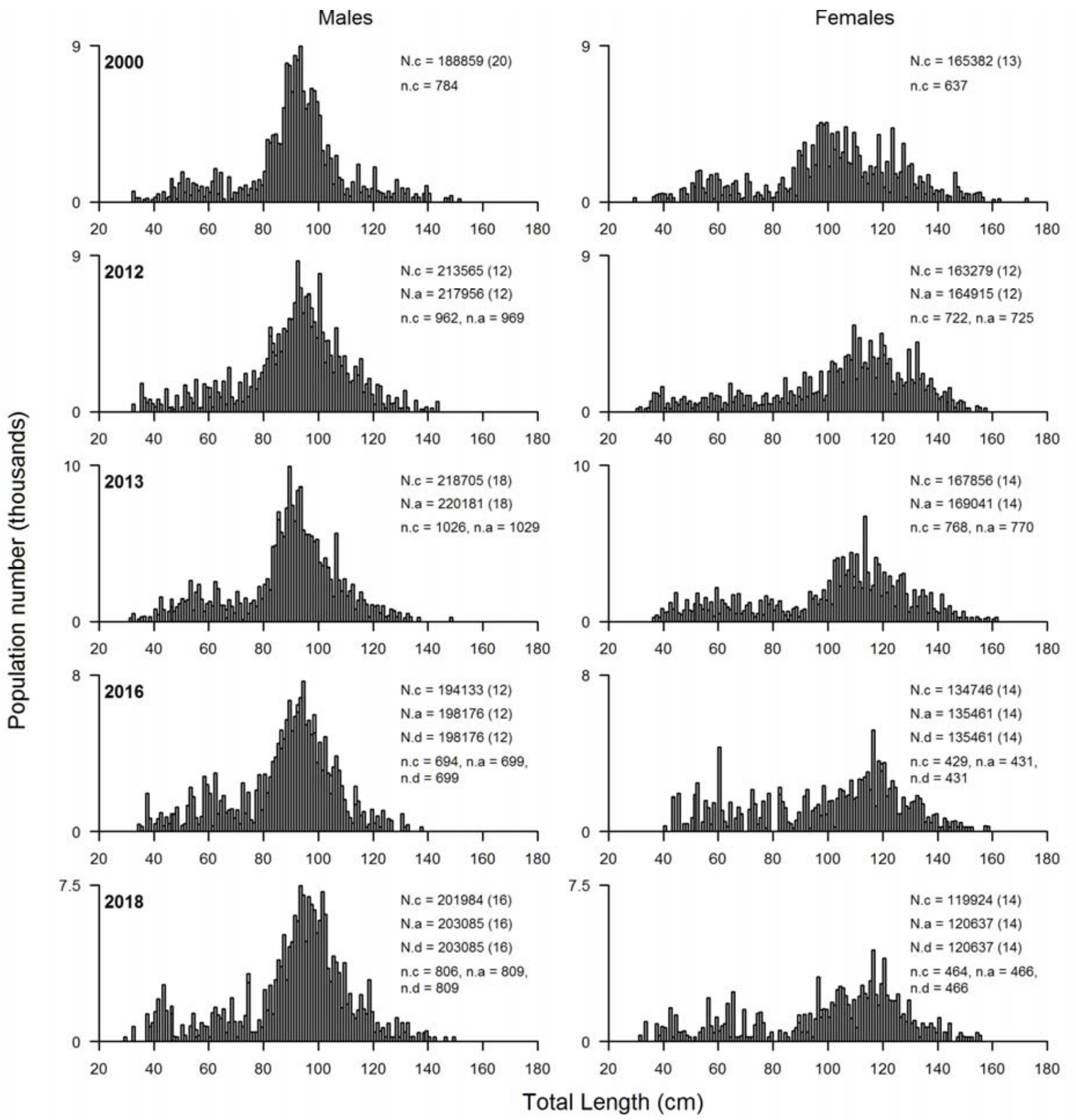


Figure 8: continued. Length frequency distributions by sex of ling (LIN) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

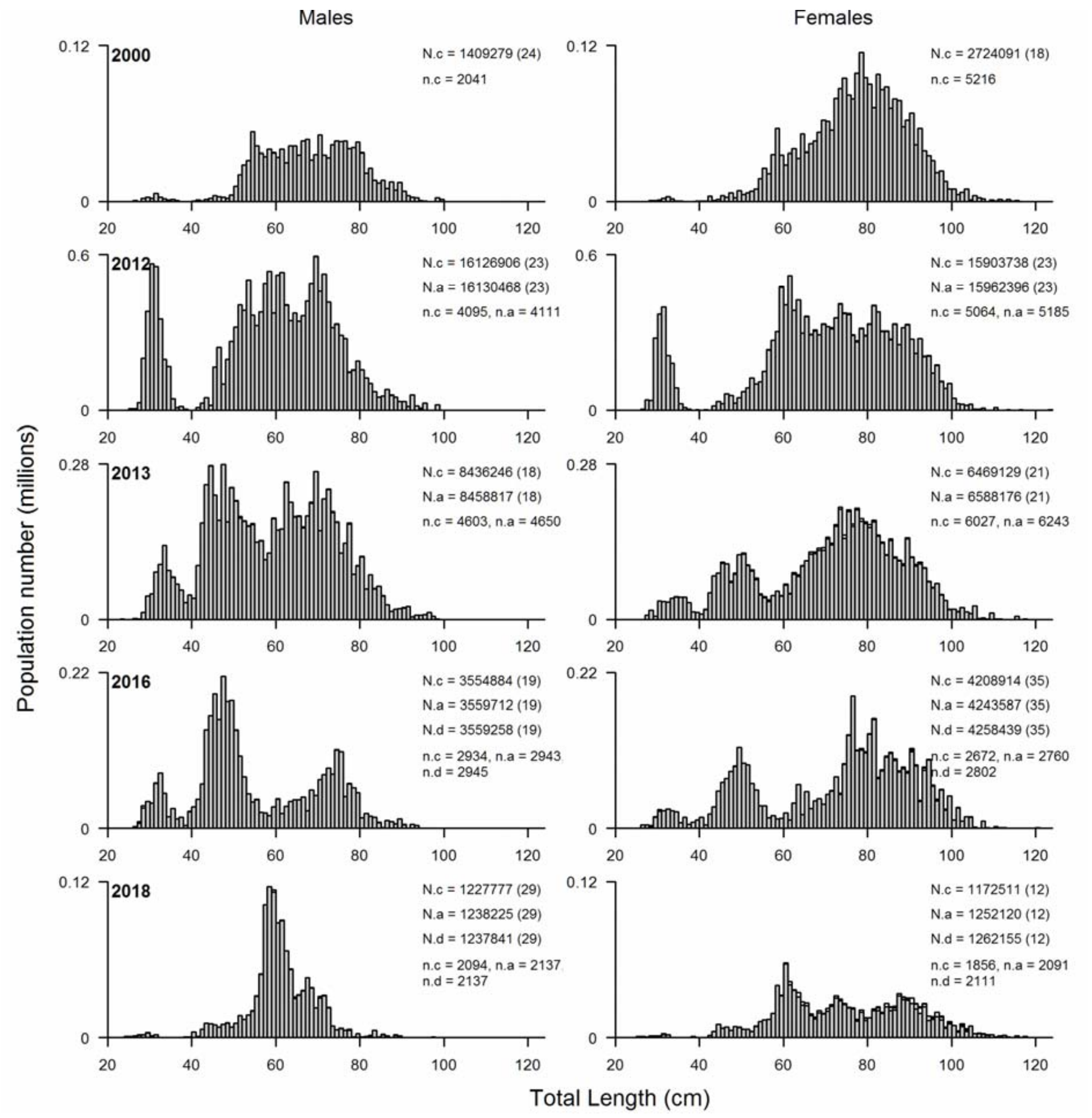


Figure 8: continued. Length frequency distributions by sex of hoki (HOK) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

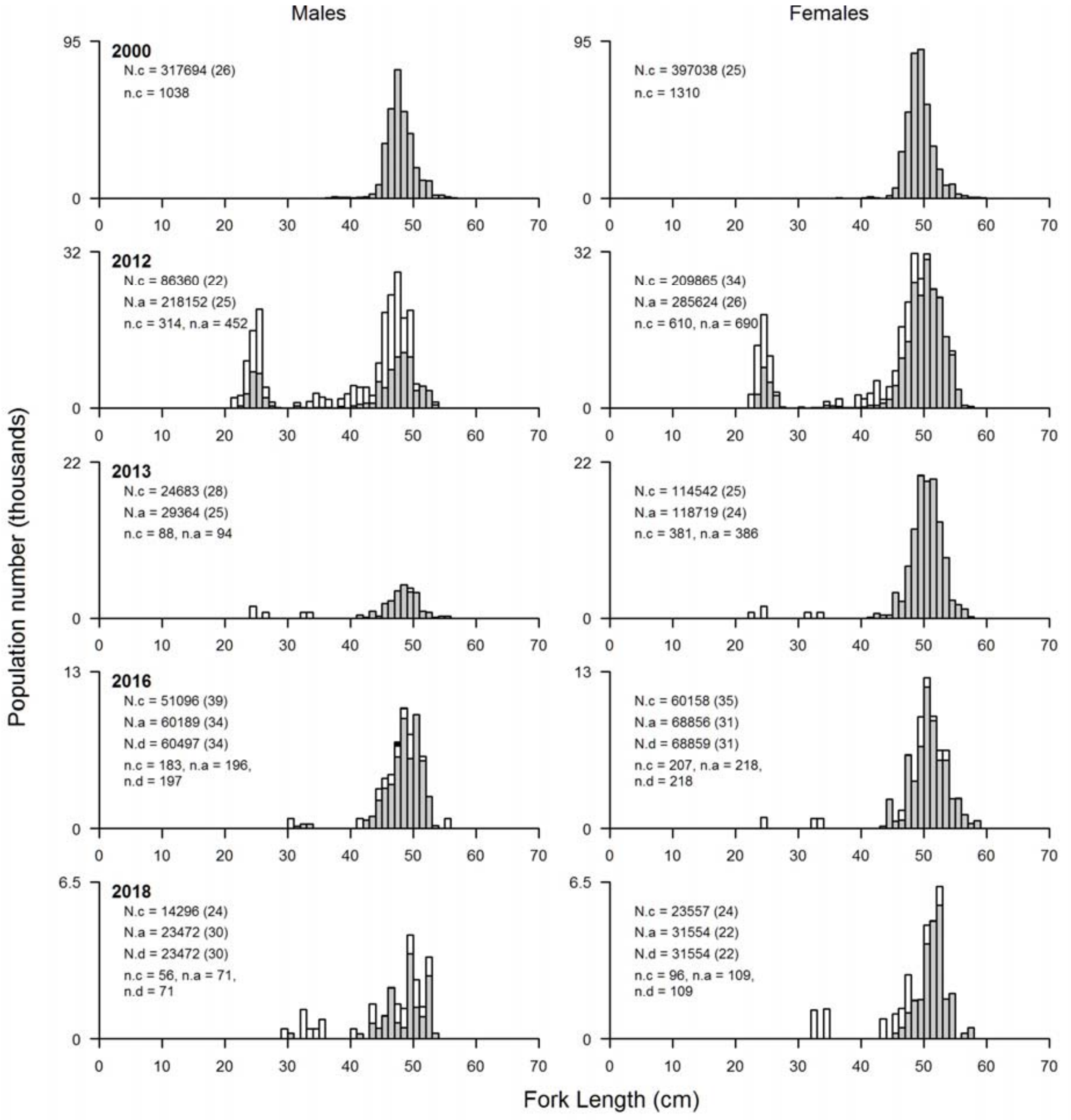


Figure 8: continued. Length frequency distributions by sex of silver warehou (SWA) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

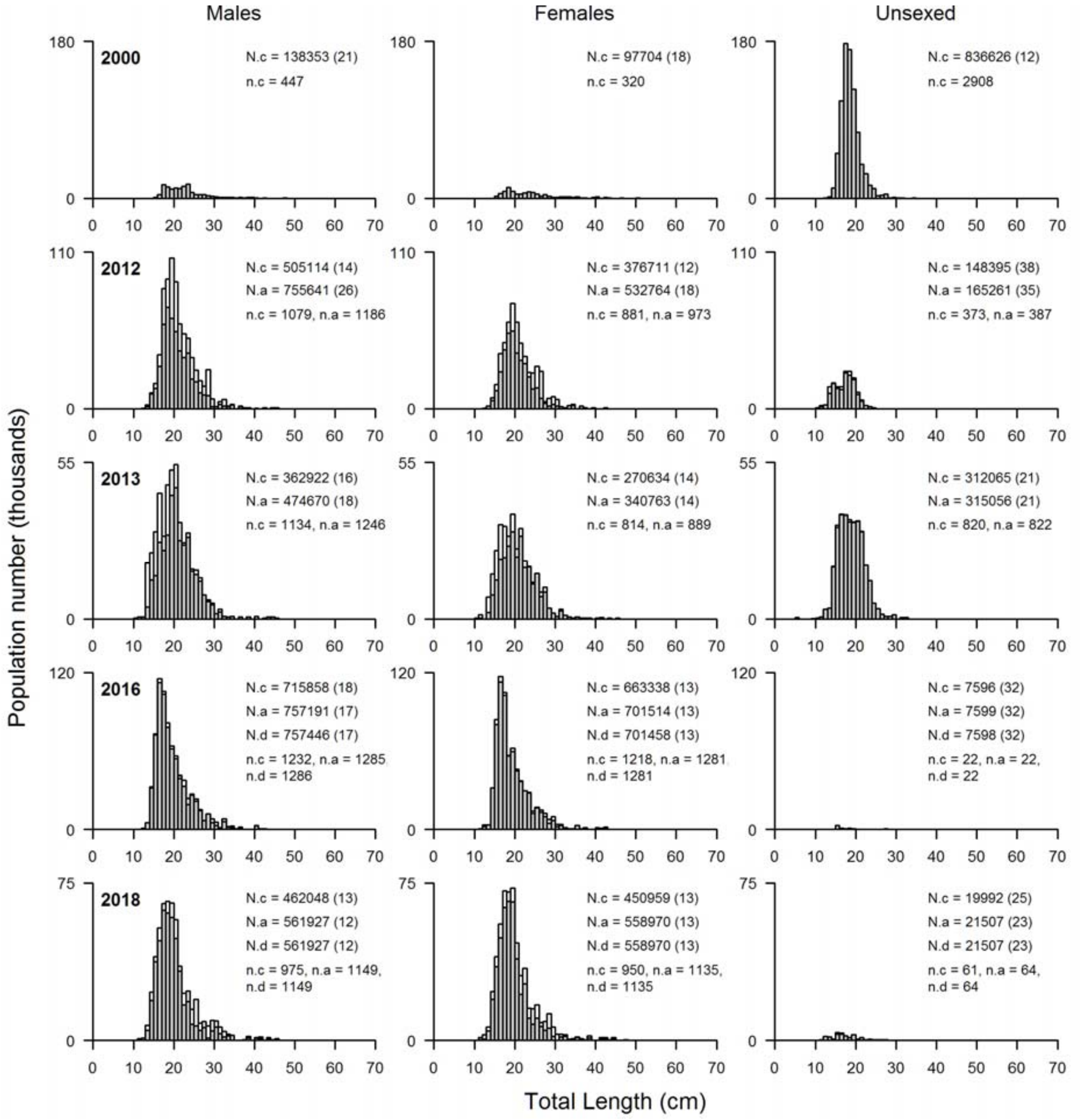


Figure 8: continued. Length frequency distributions by sex of sea perch (SPE) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

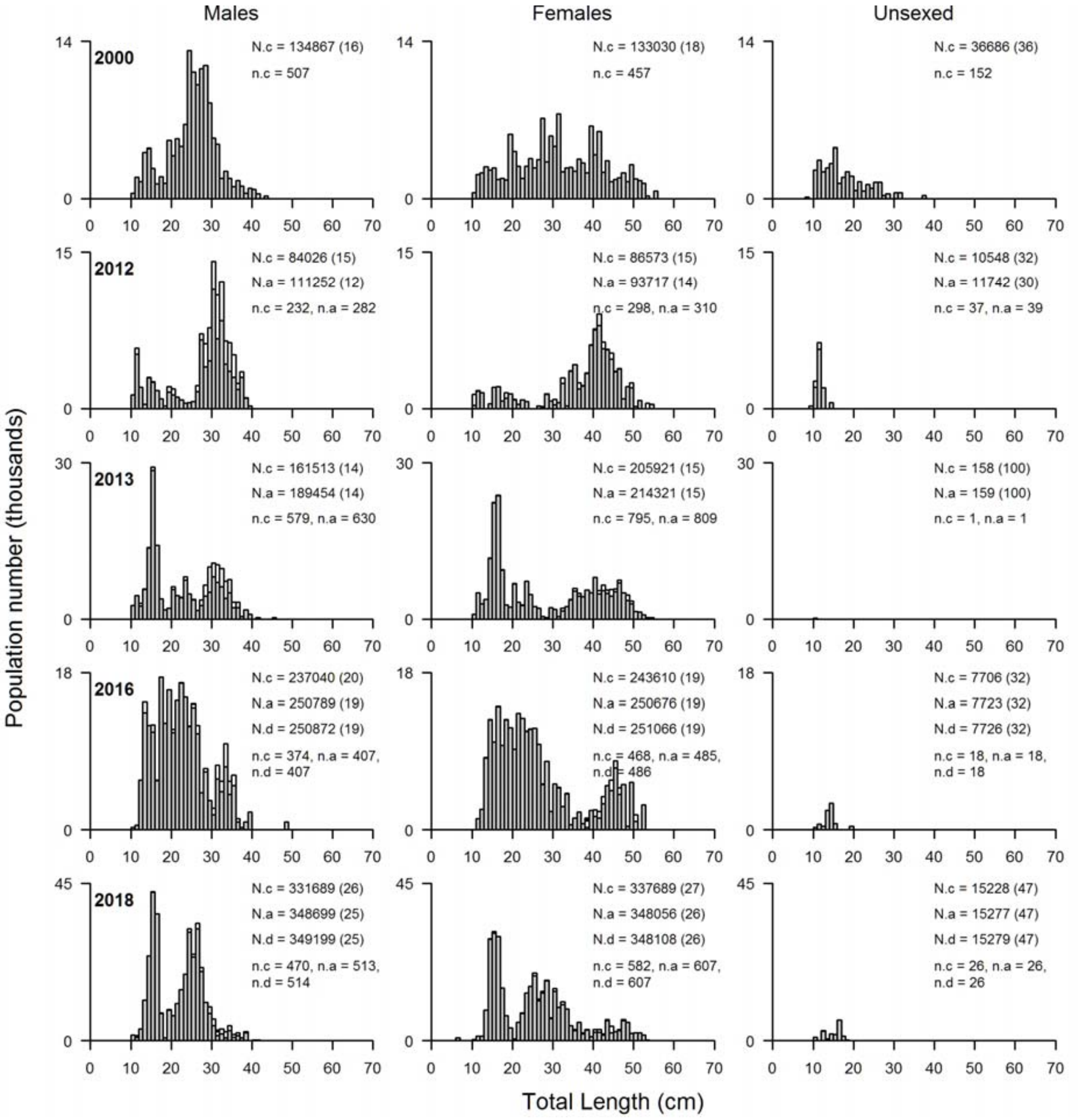


Figure 8: continued. Length frequency distributions by sex of lookdown dory (LDO) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

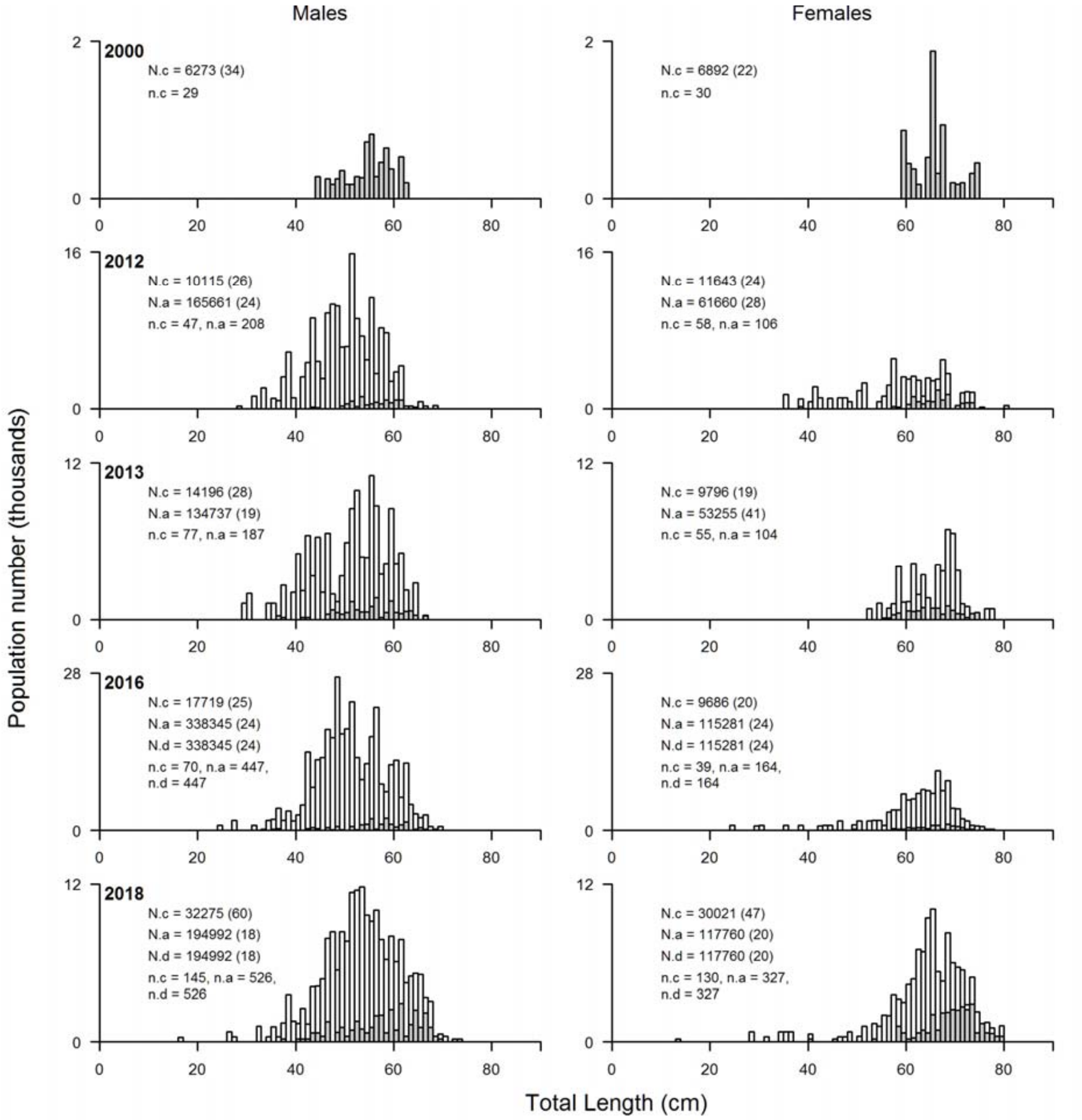


Figure 8: continued. Length frequency distributions by sex of giant stargazer (GIZ) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

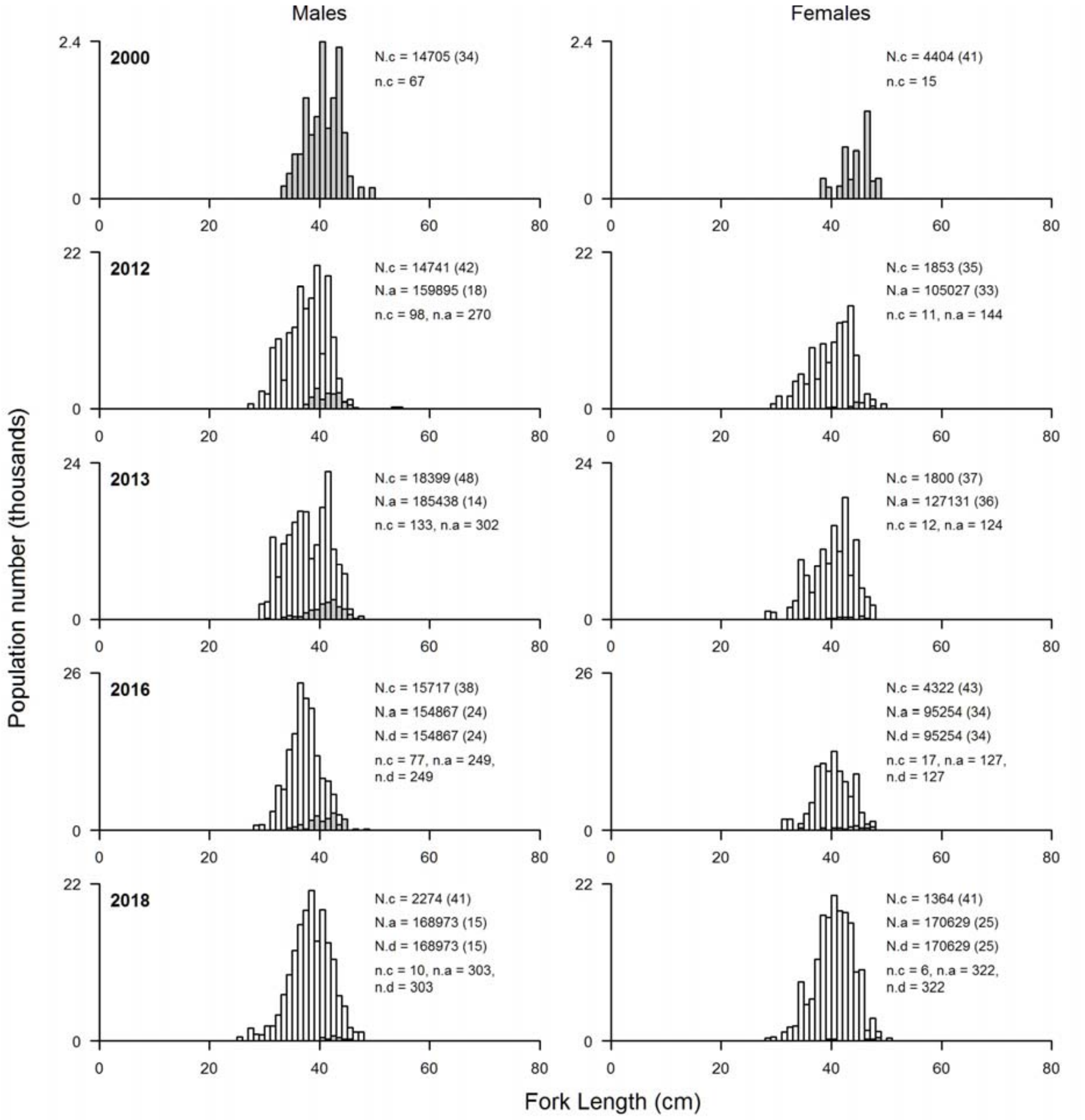


Figure 8: continued. Length frequency distributions by sex of tarakihi (NMP) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

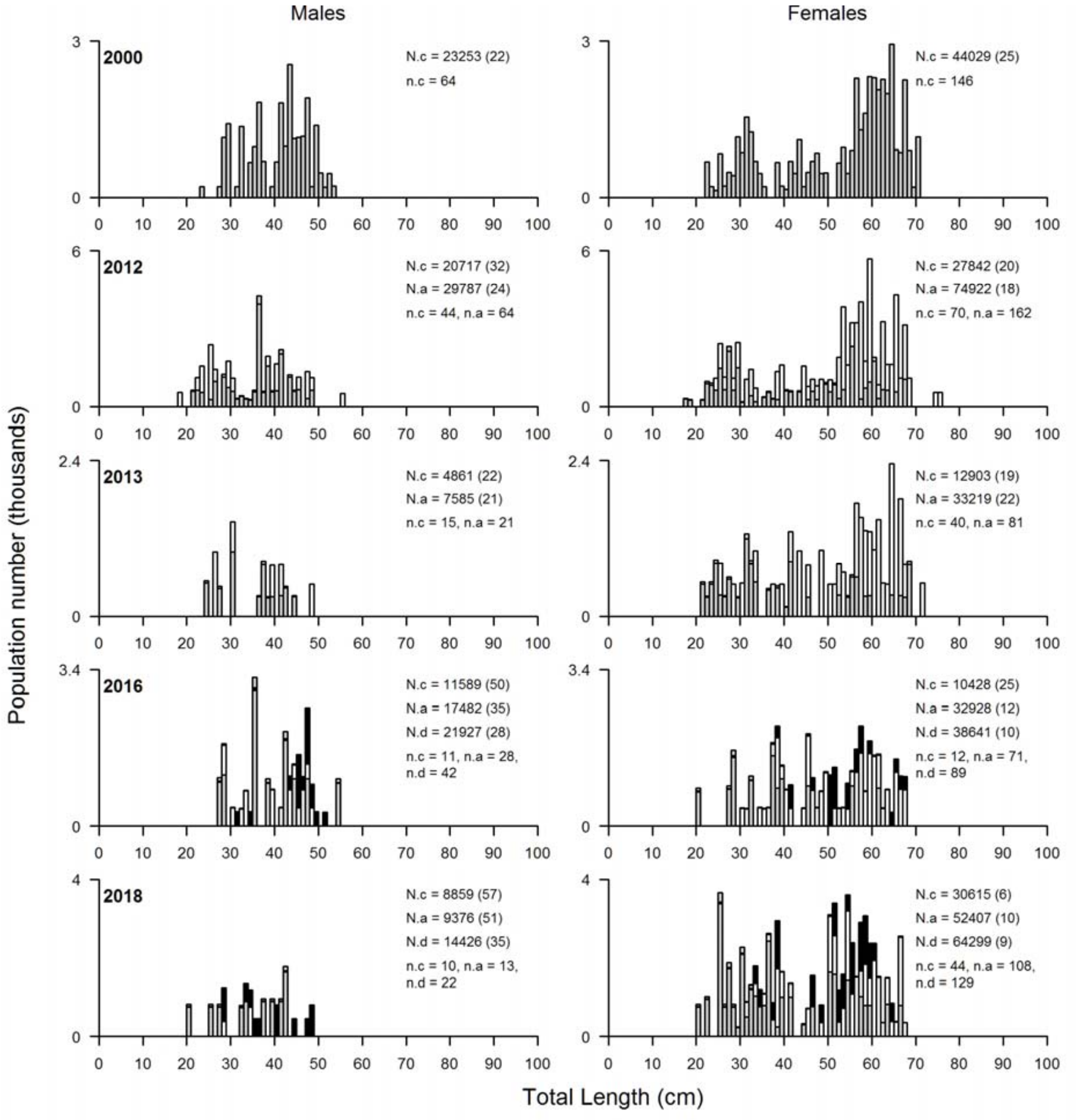


Figure 8: continued. Length frequency distributions by sex of ribaldo (RIB) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, and 2016 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

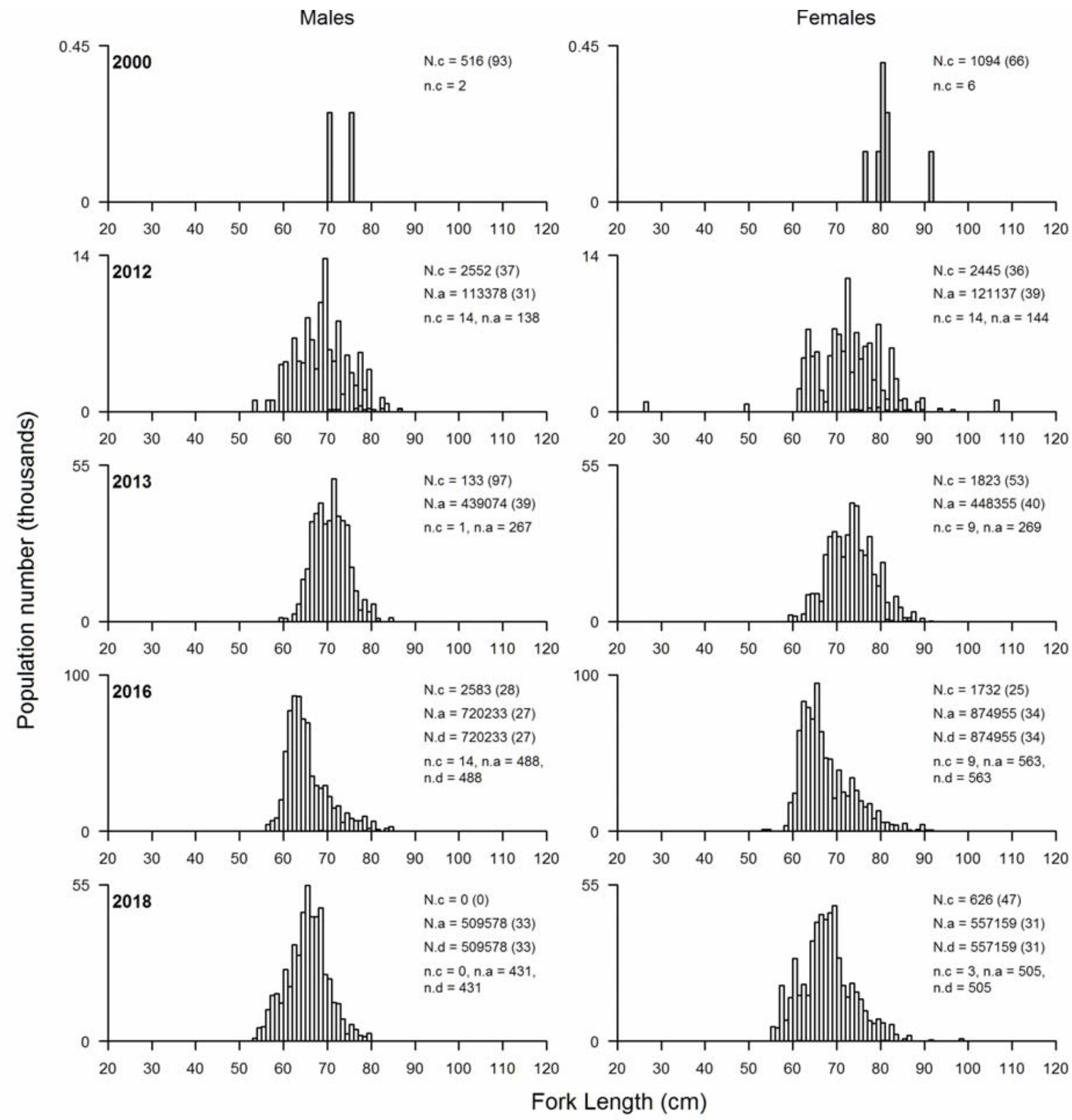


Figure 8: continued. Length frequency distributions by sex of barracouta (BAR) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, and 2016 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

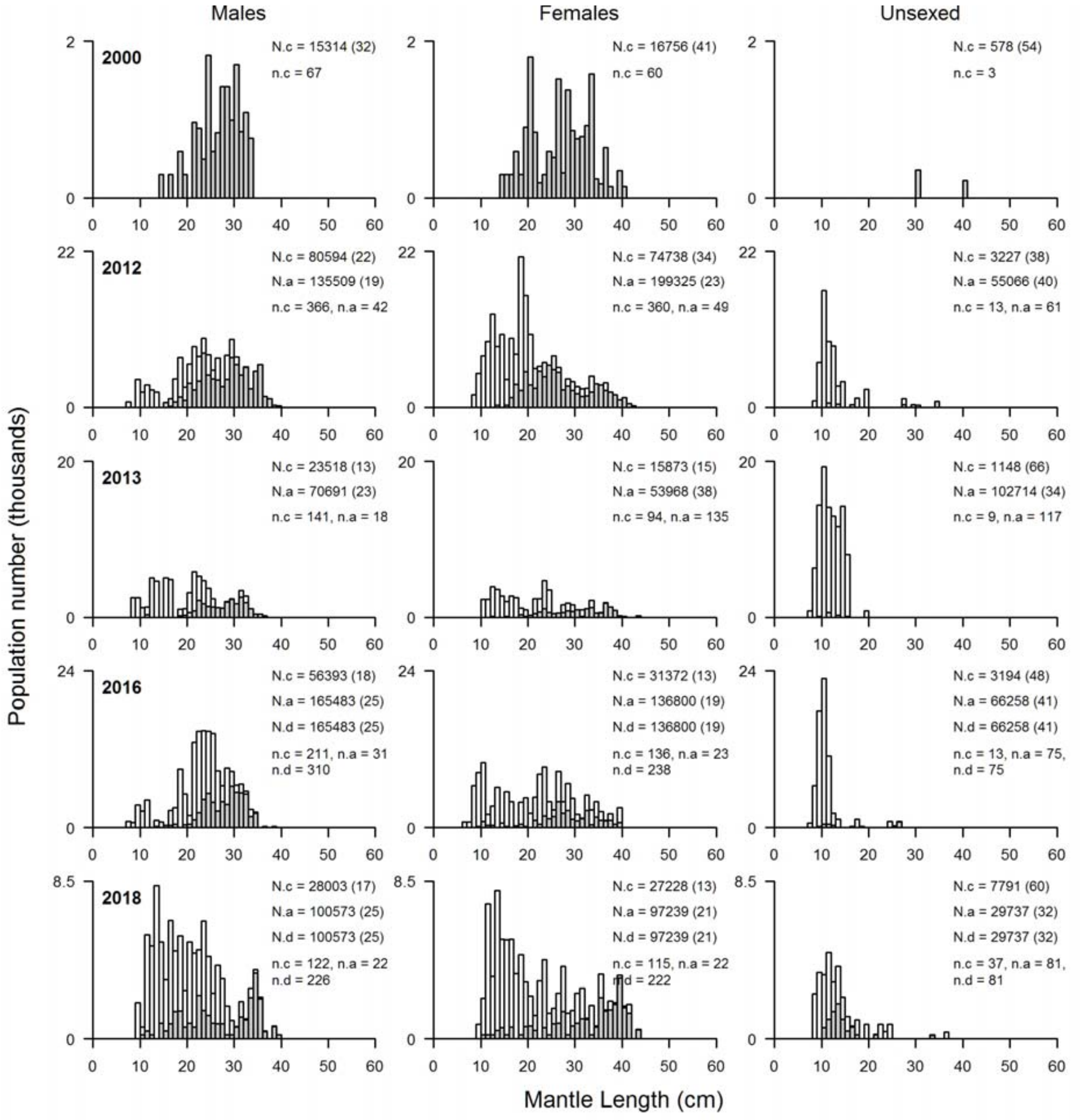


Figure 8: continued. Length frequency distributions by sex of arrow squid (SQU) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

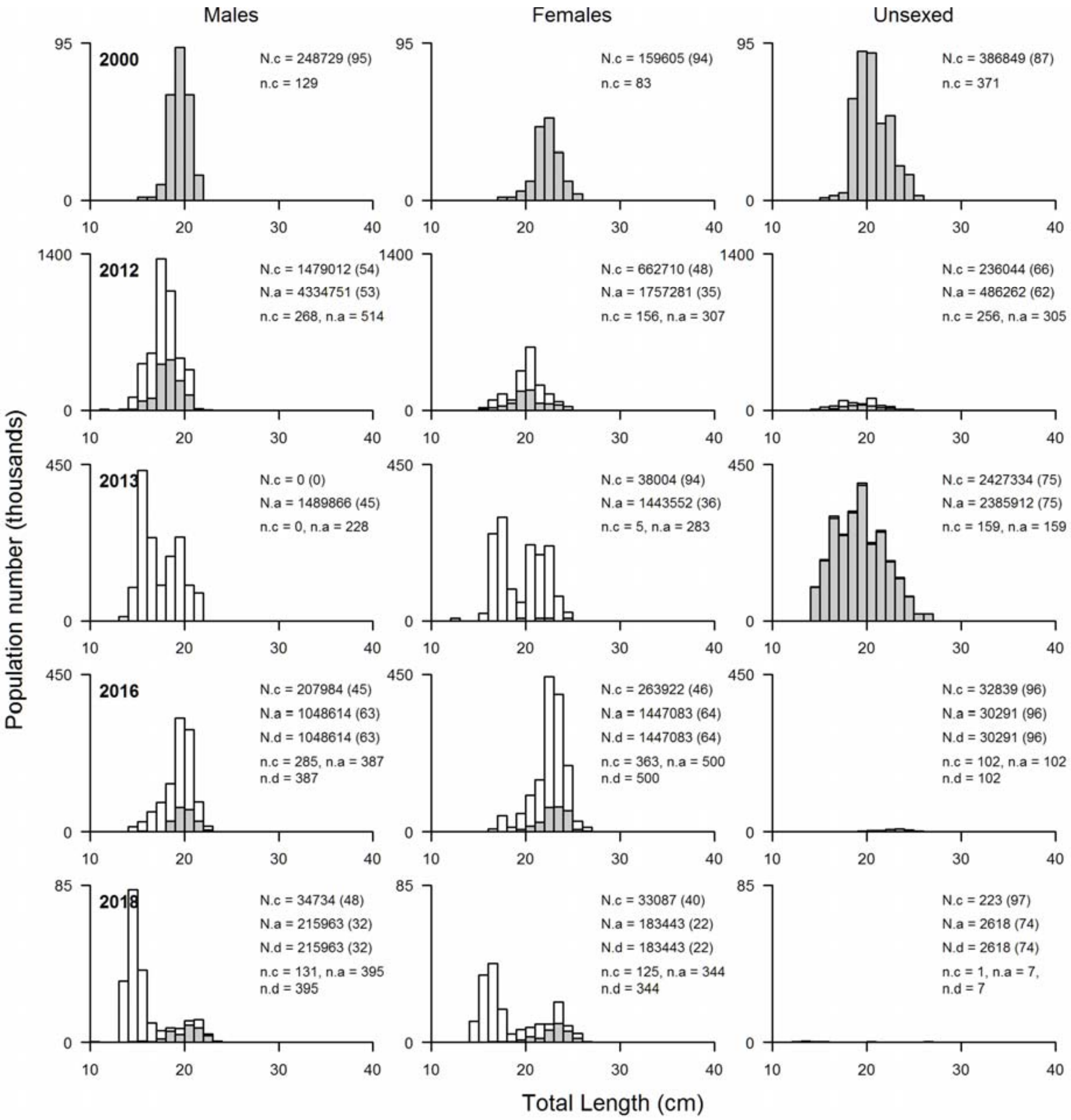


Figure 8: continued. Length frequency distributions by sex of silver dory (SDO) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

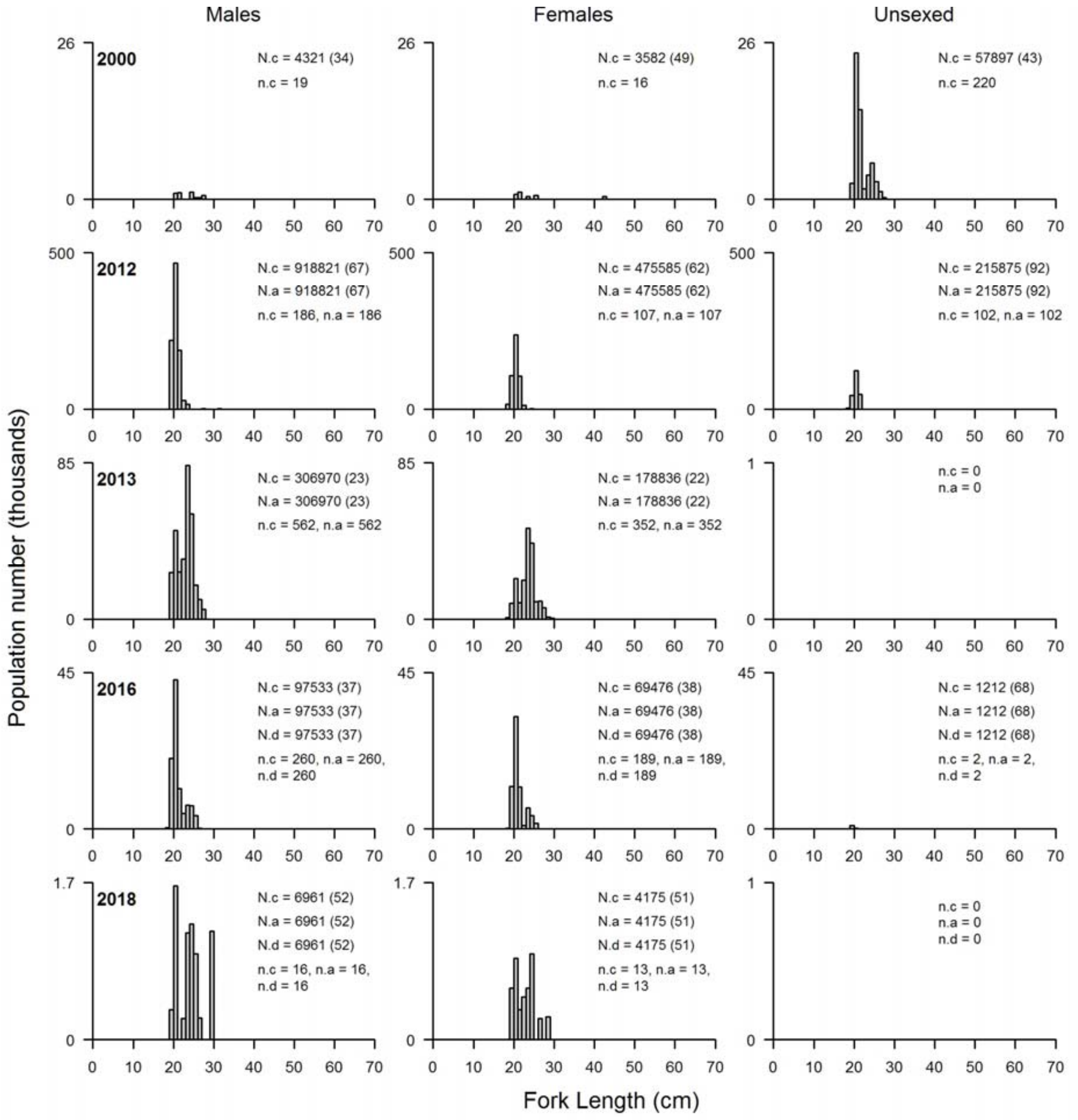


Figure 8: continued. Length frequency distributions by sex of alfonsino (BYS) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

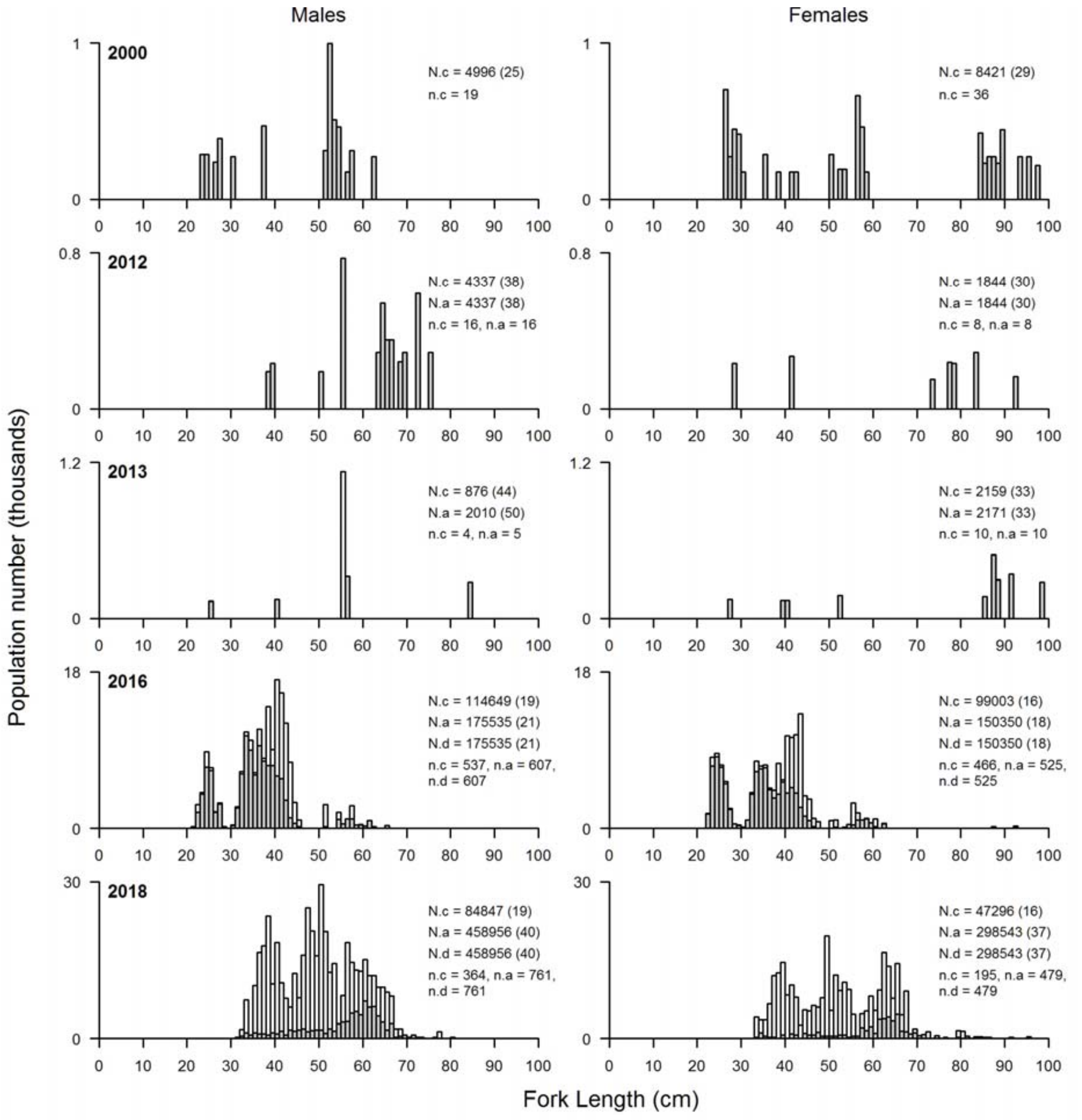


Figure 8: continued. Length frequency distributions by sex of gemfish (RSO) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

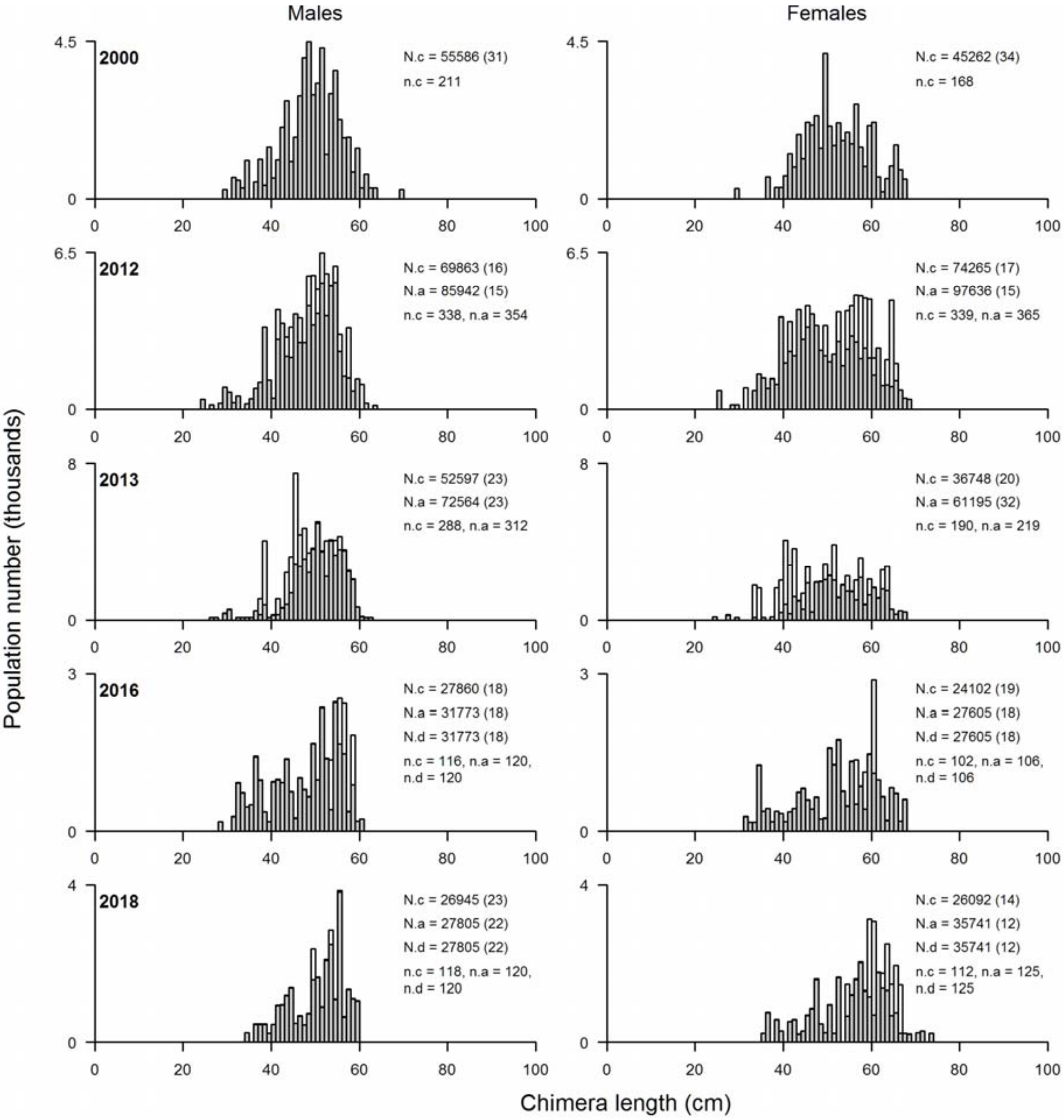


Figure 8: continued. Length frequency distributions by sex of dark ghost shark (GSH) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

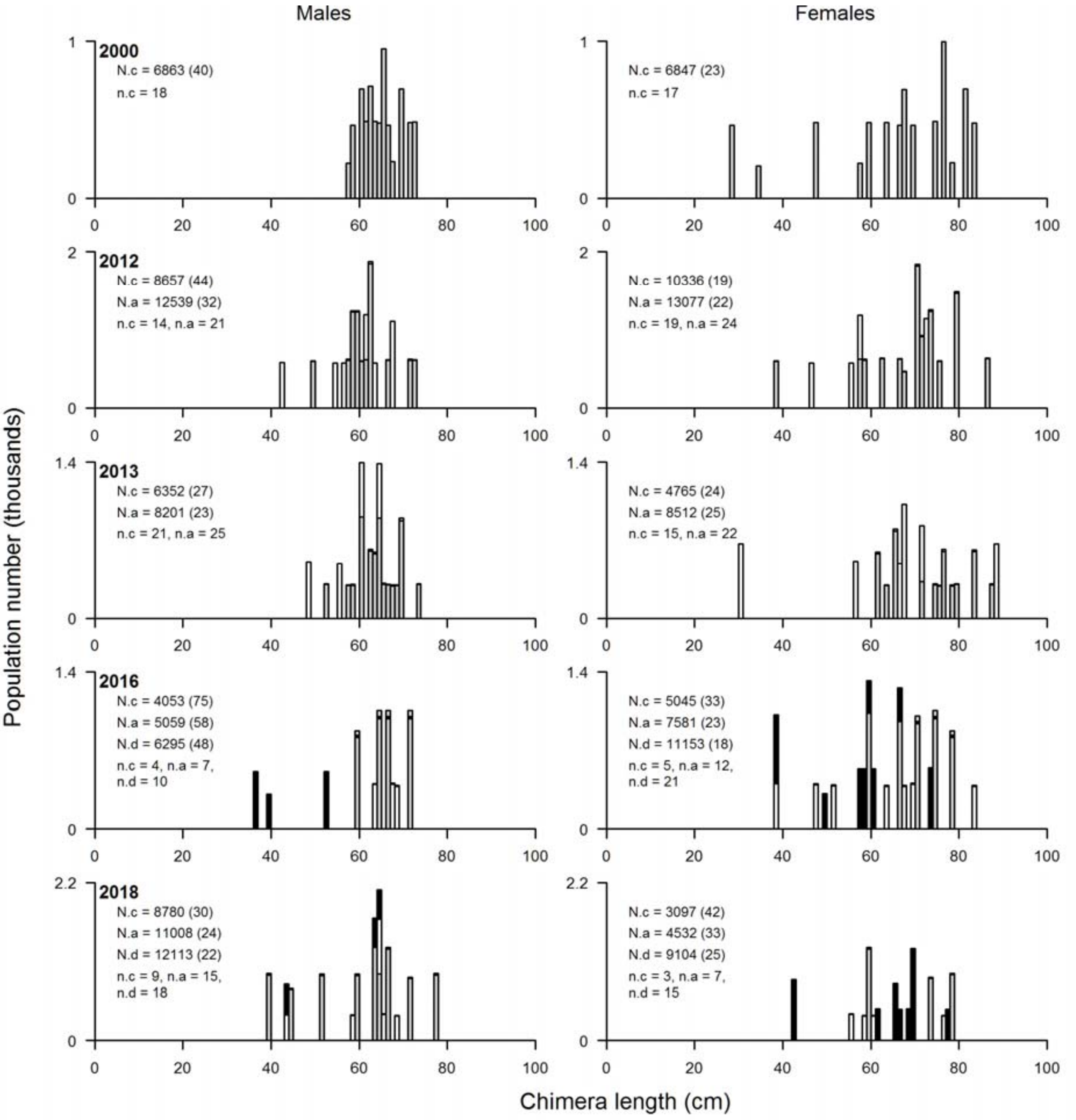


Figure 8: continued. Length frequency distributions by sex of pale ghost shark (GSP) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

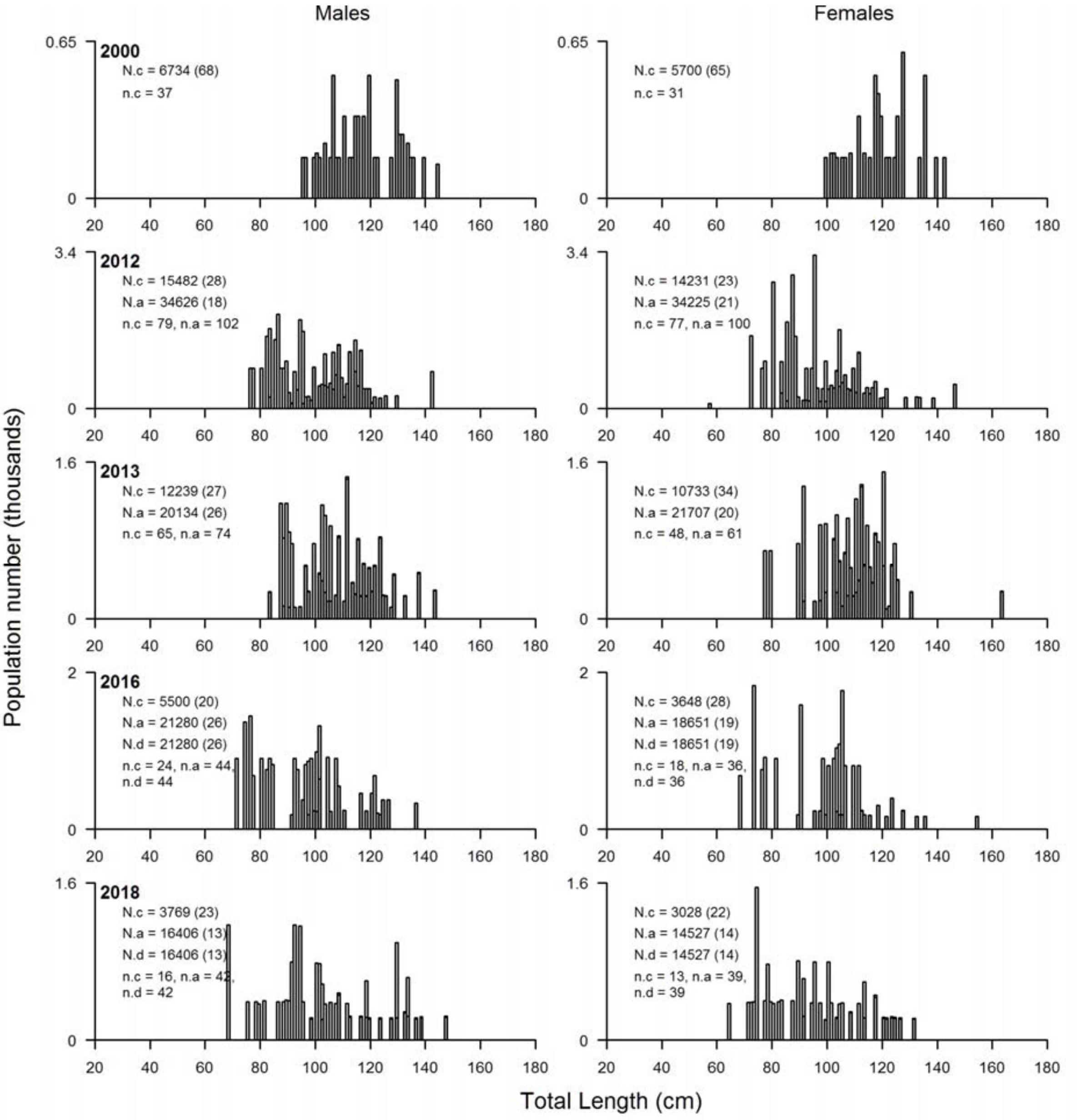


Figure 8: continued. Length frequency distributions by sex of school shark (SCH) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

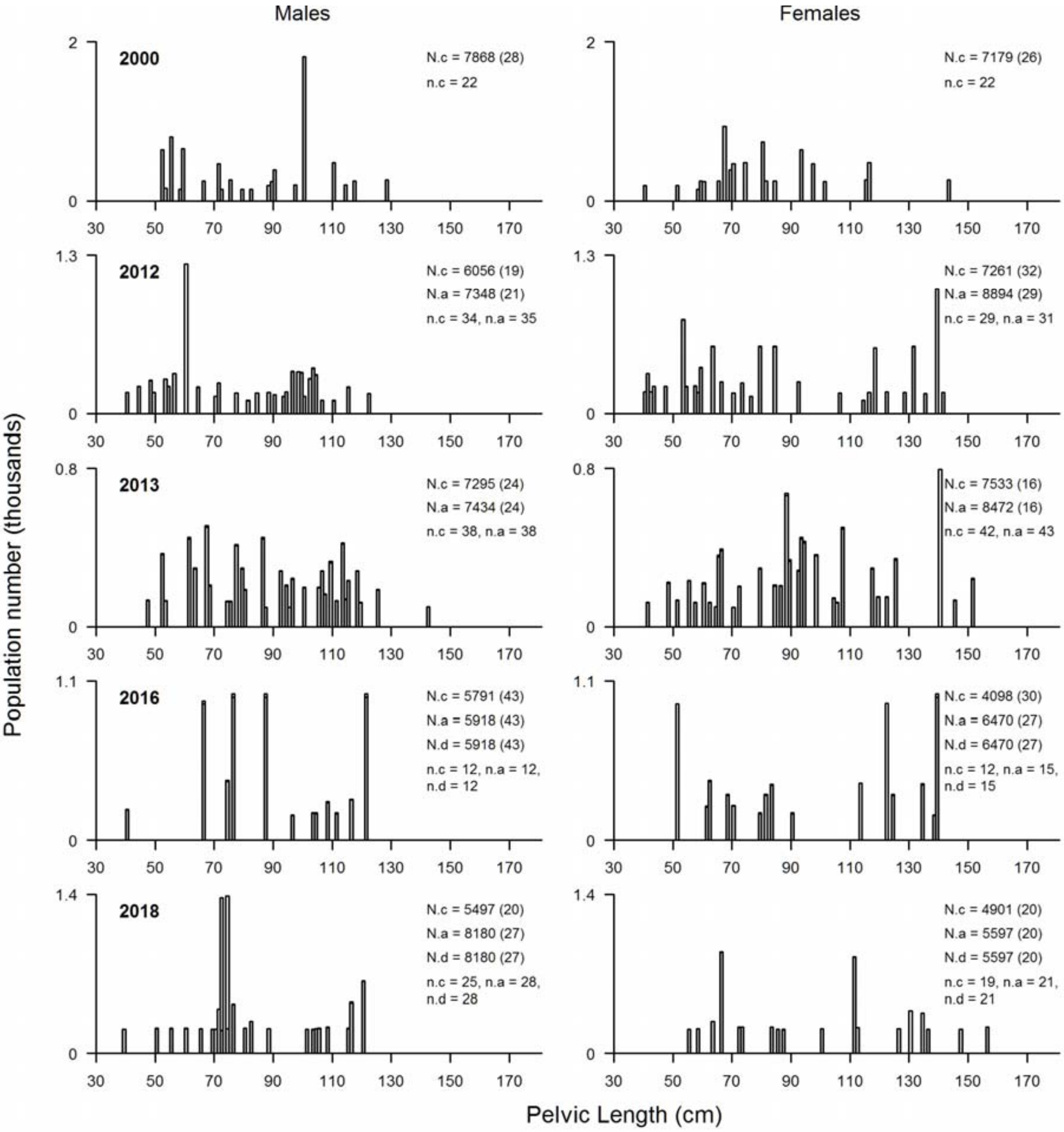


Figure 8: continued. Length frequency distributions by sex of smooth skate (SSK) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

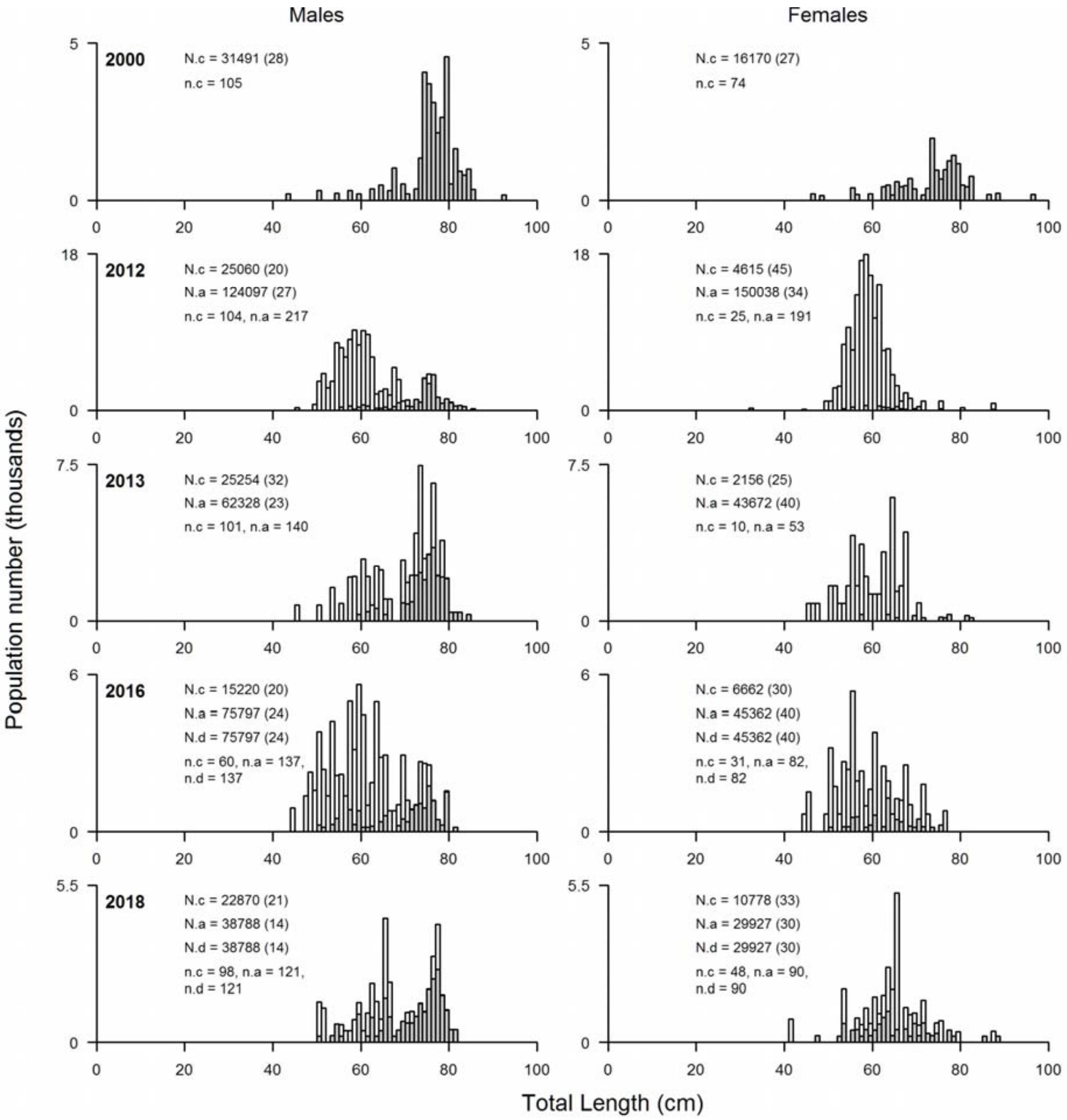


Figure 8: continued. Length frequency distributions by sex of northern spiny dogfish (NSD) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

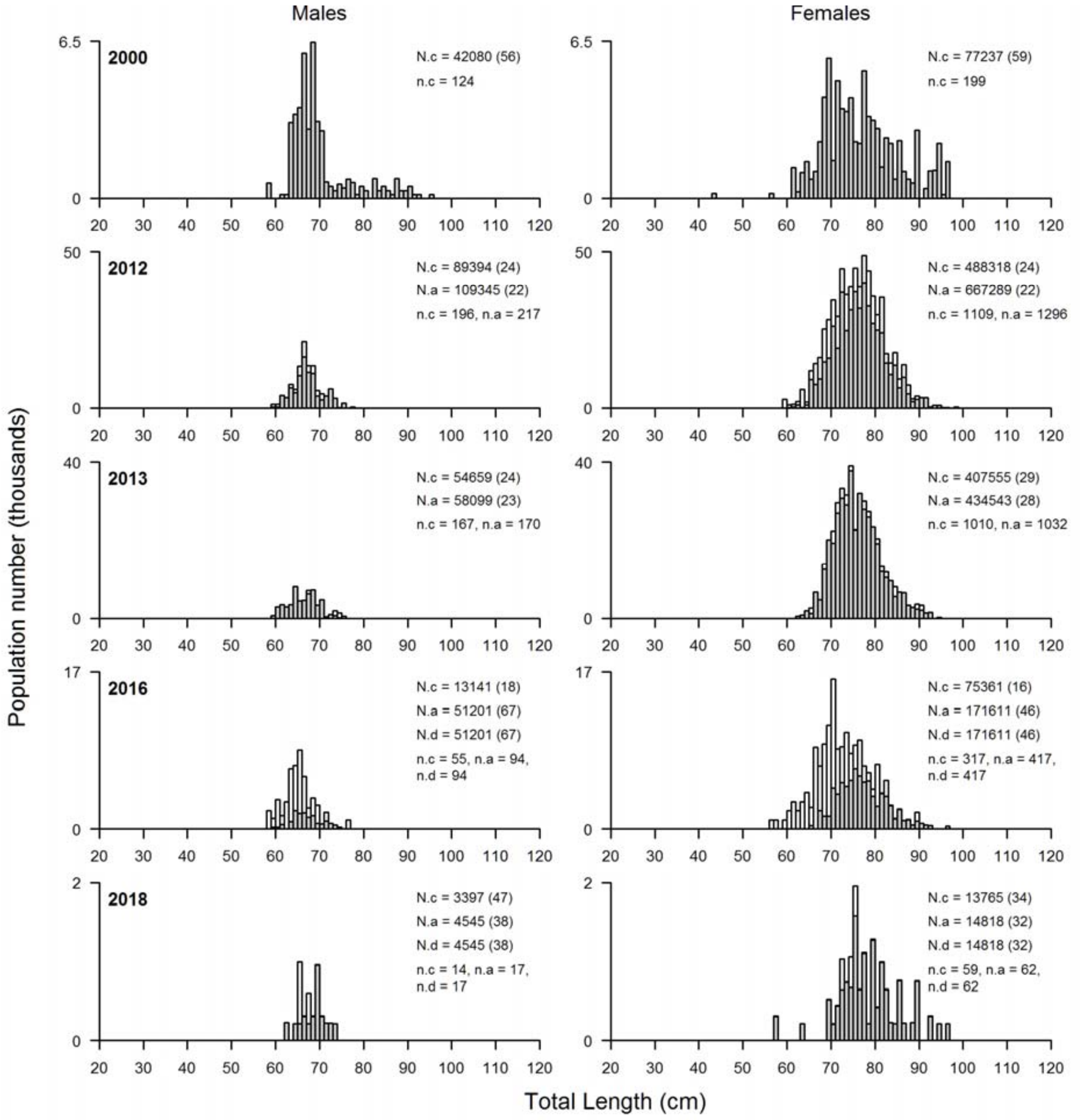


Figure 8: continued. Length frequency distributions by sex of spiny dogfish (SPD) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

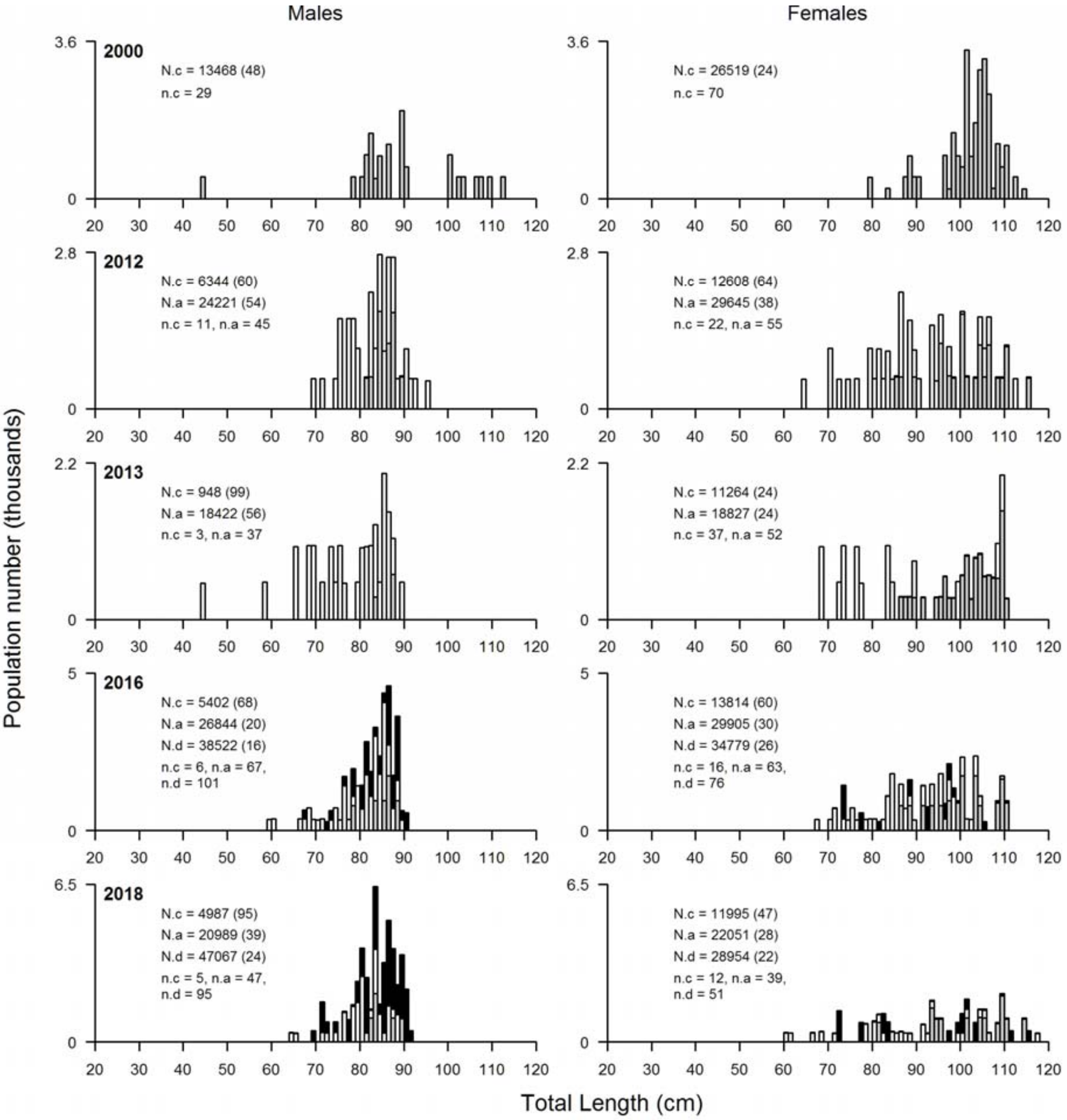


Figure 8: continued. Length frequency distributions by sex of shovelnose dogfish (SND) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

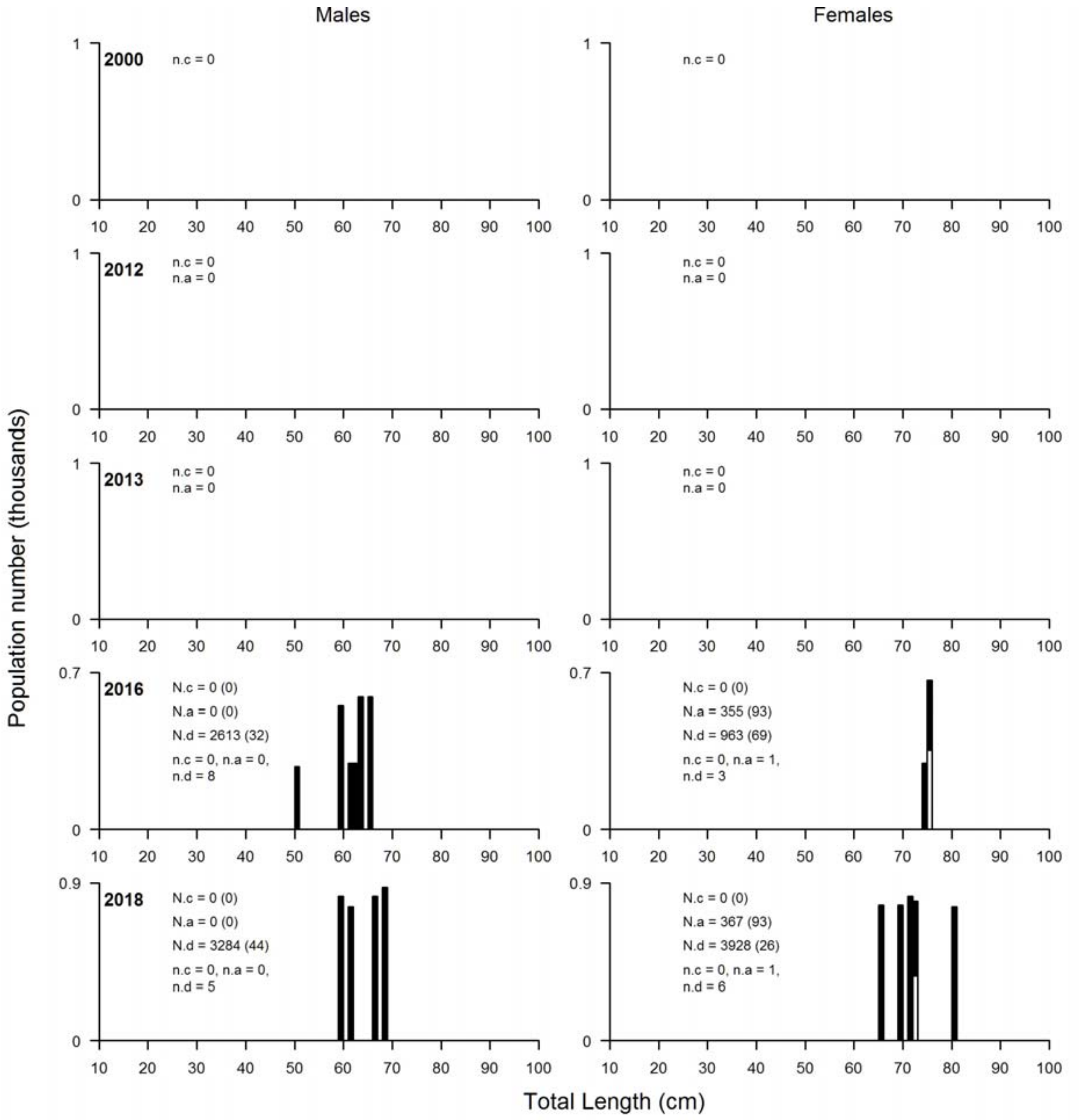


Figure 8: continued. Length frequency distributions by sex of Baxter's lantern dogfish (ETB) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. Baxter's lantern dogfish was not measured in the 2000, 2012, and 2013 surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

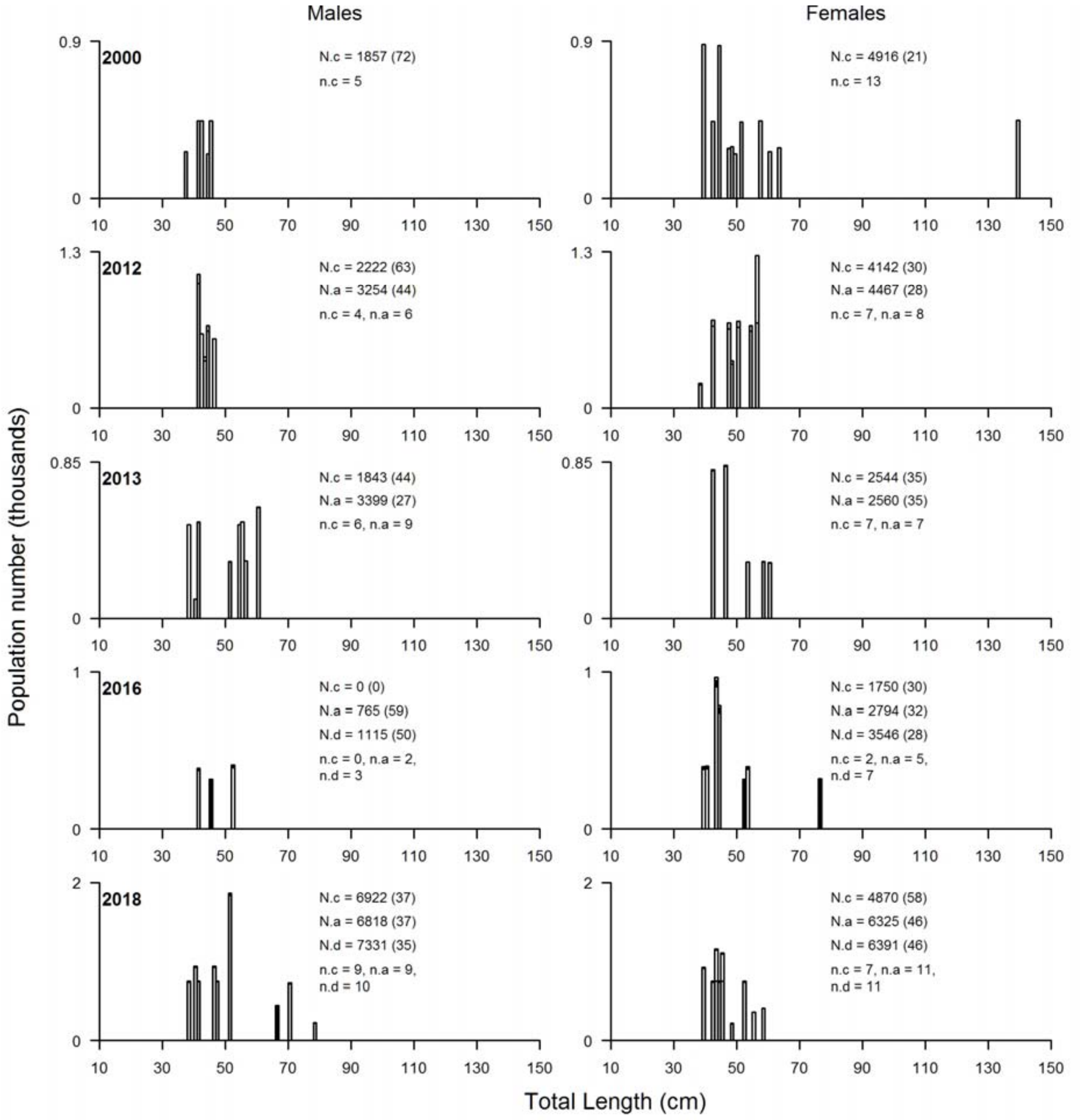


Figure 8: continued. Length frequency distributions by sex of seal shark (BSH) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

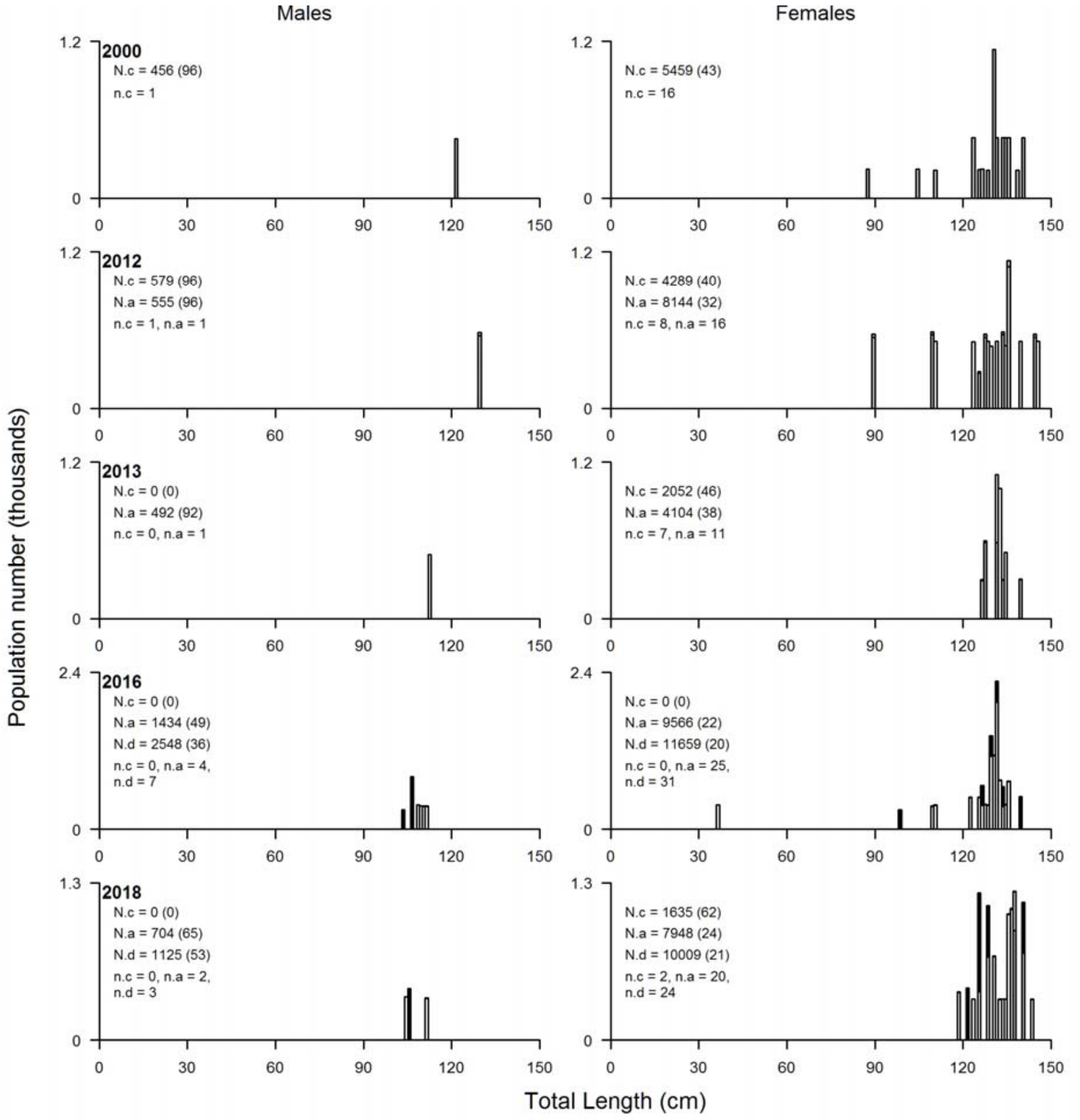


Figure 8: continued. Length frequency distributions by sex of leafscale gulper shark (CSQ) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

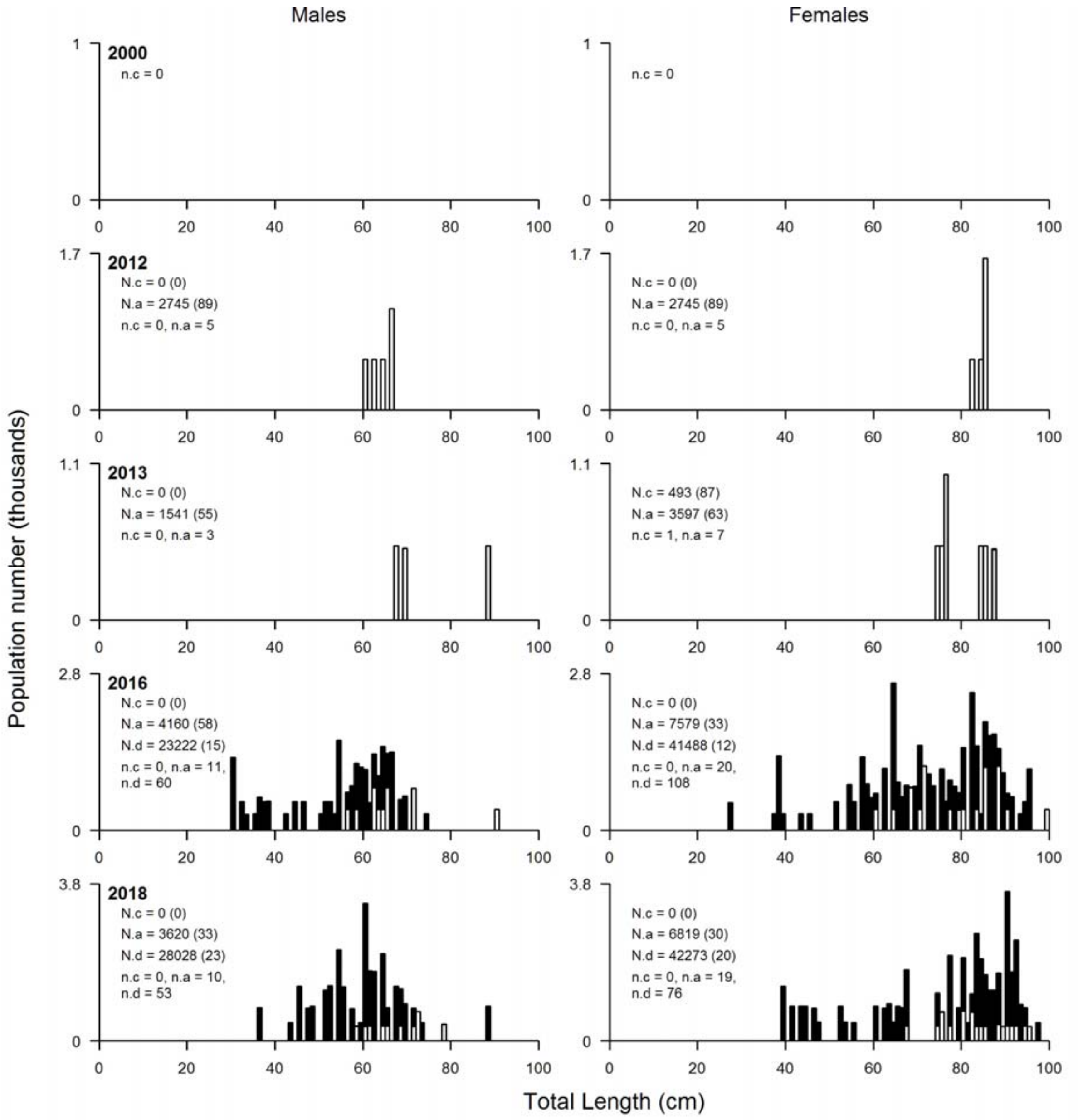


Figure 8: continued. Length frequency distributions by sex of white rattail (WHX) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. White rattail was not measured in the 2000 survey. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

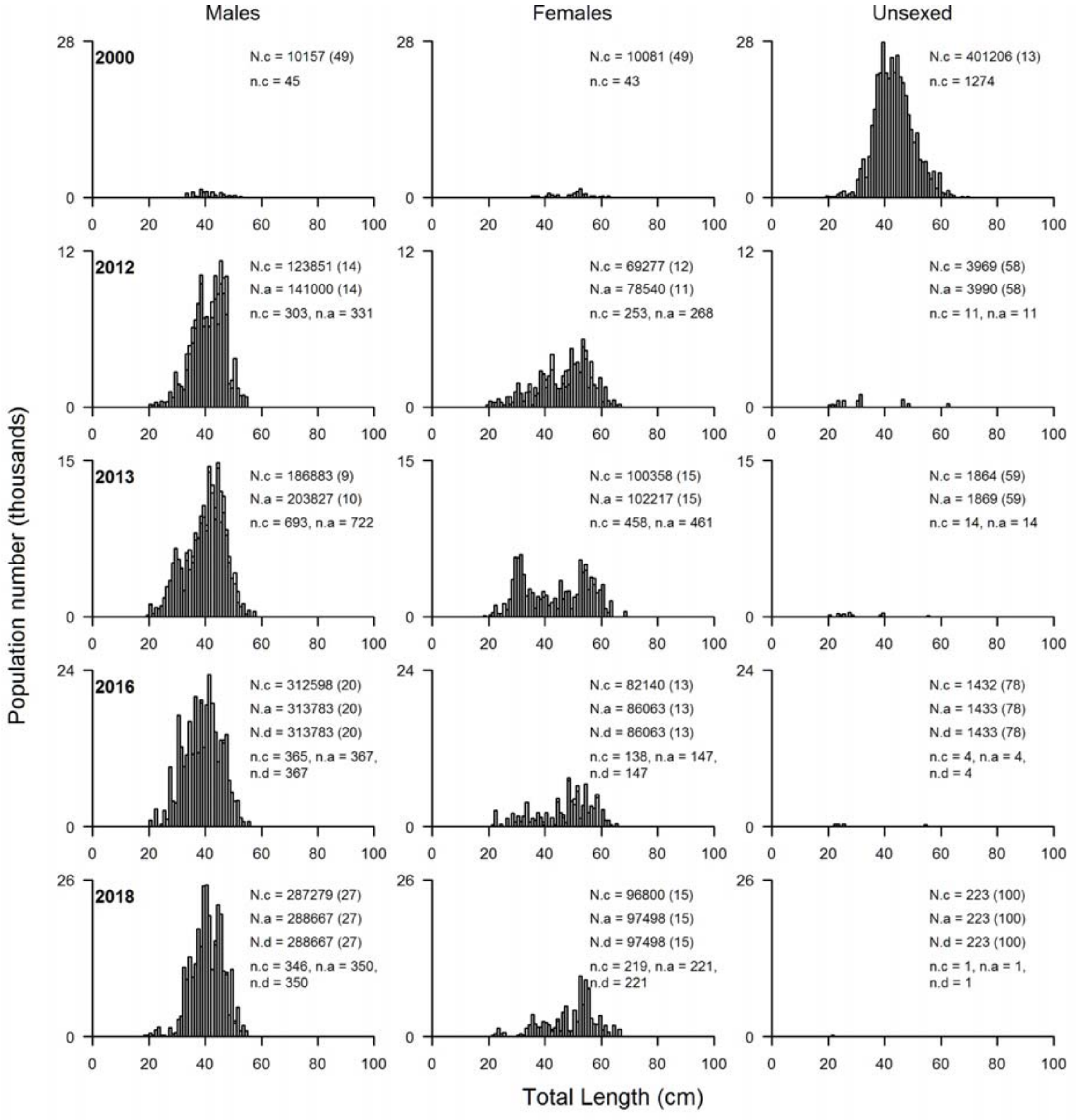


Figure 8: continued. Length frequency distributions by sex of Bollons' rattail (CBO) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

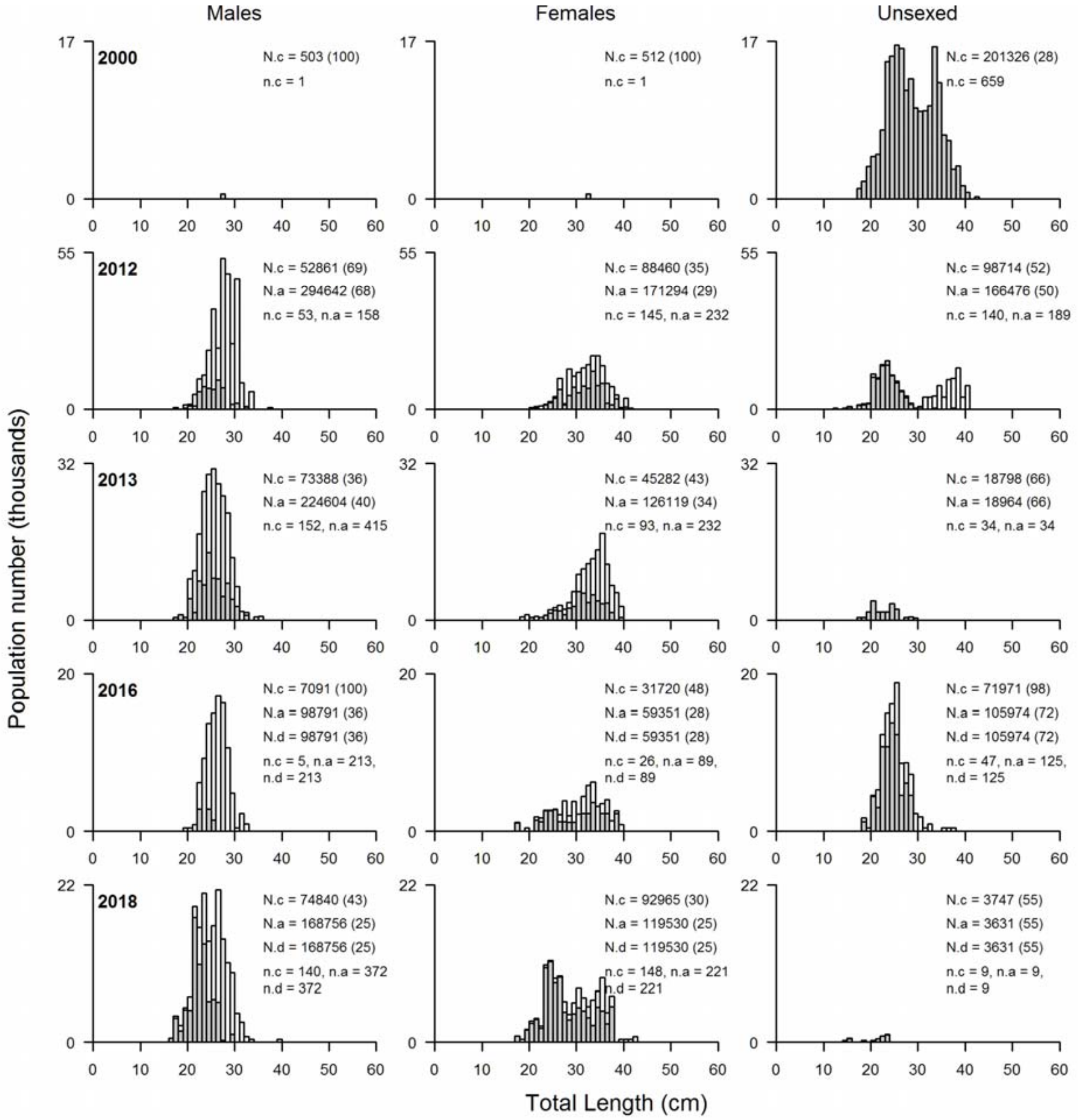


Figure 8: continued. Length frequency distributions by sex of Oliver's rattail (COL) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

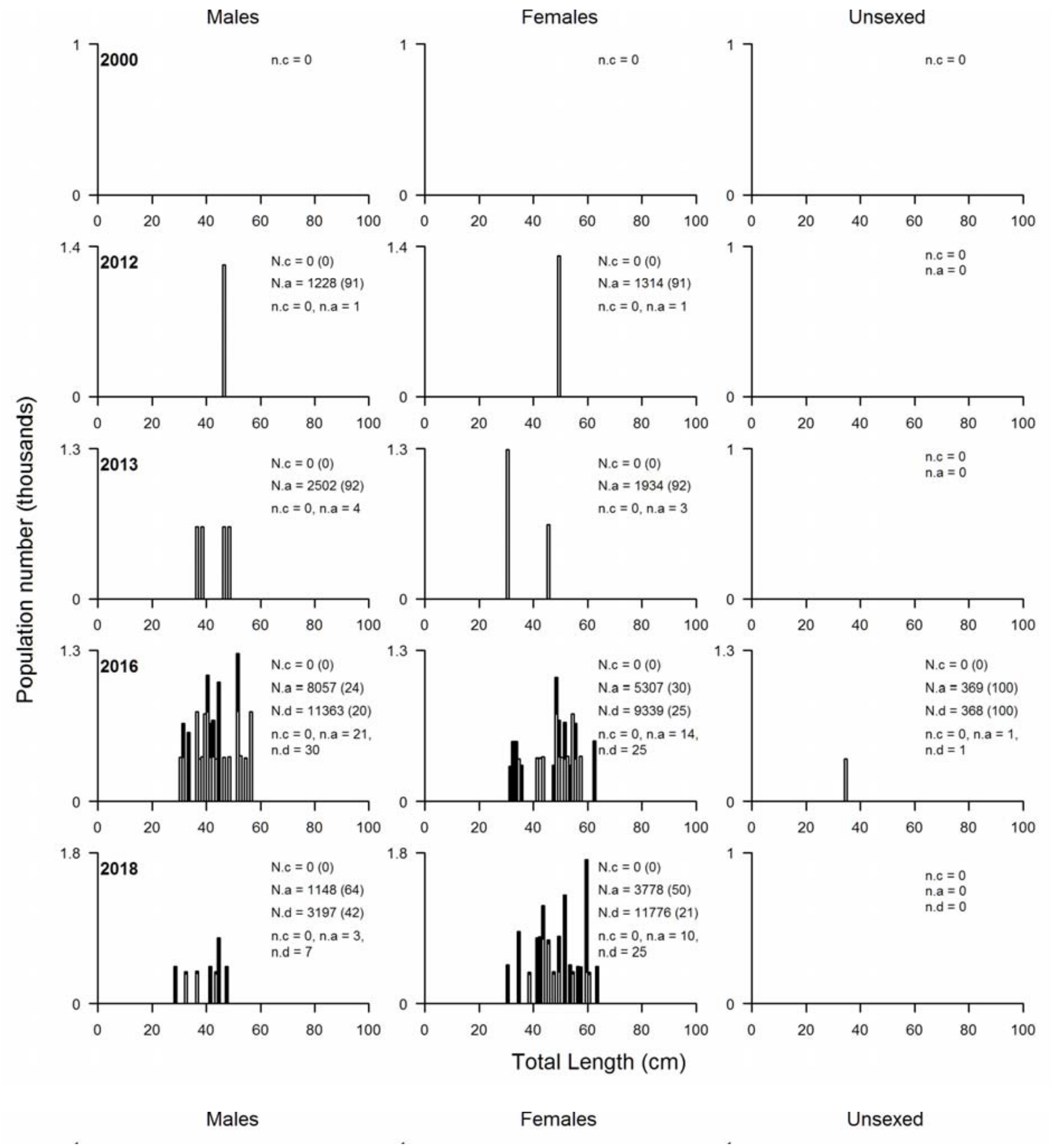


Figure 8: continued. Length frequency distributions by sex of Mahia rattail (CMA) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. Mahia rattail were not measured in the 2000 survey. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

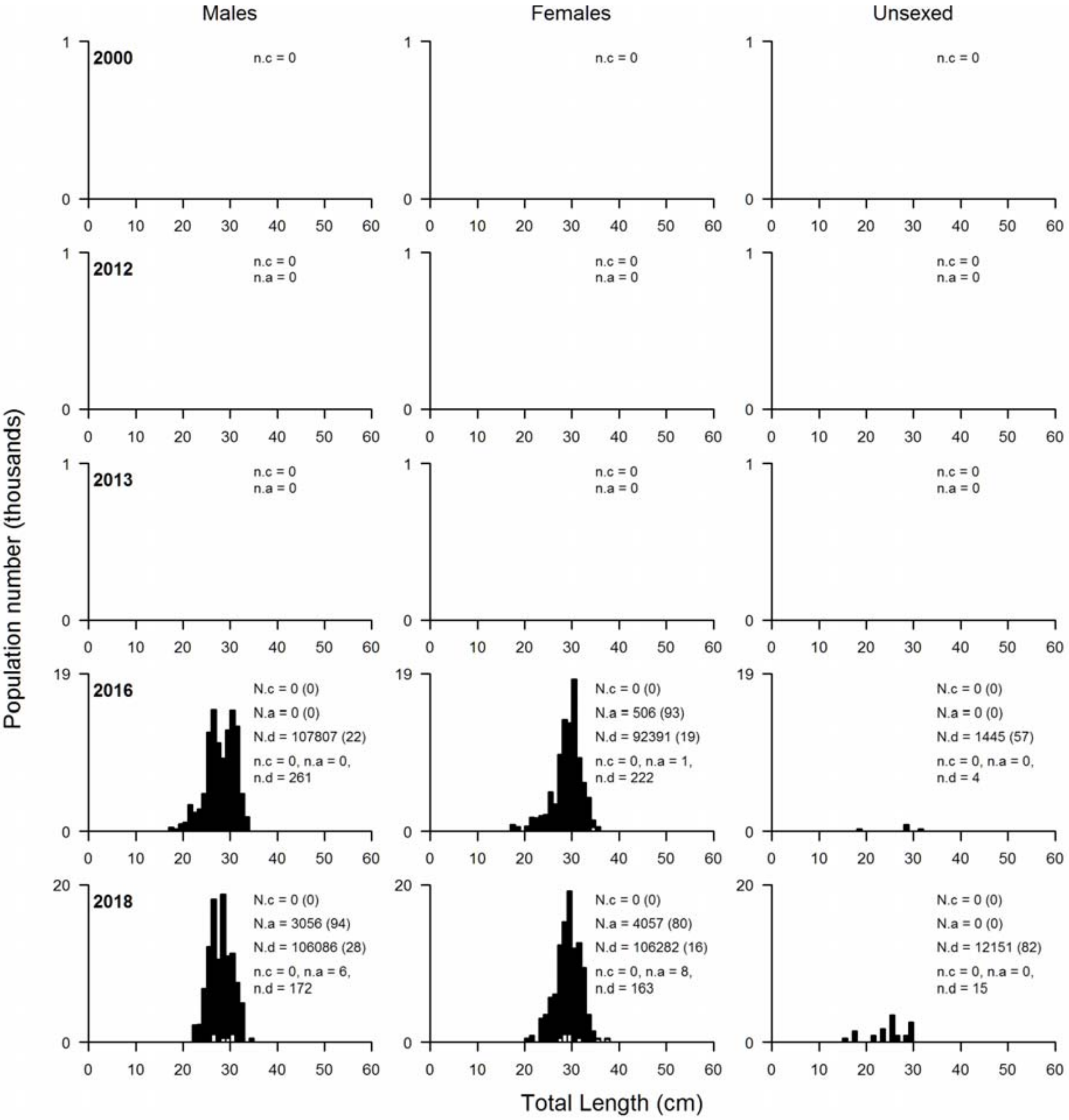


Figure 8: continued. Length frequency distributions by sex of and four rayed rattail (CSU) for core (grey), all (white), and deep (black) strata from the 2000, 2012, 2013, 2016, and 2018 WCSI trawl surveys. Four rayed rattail were not measured in the 2000, 2012, and 2013 surveys. N.d, estimated scaled total number of fish for deep strata; N.a, estimated scaled total number of fish for all strata; N.c, estimated scaled total number of fish for core strata; n.d, number of fish measured for deep strata; n.a, number of fish measured for all strata; n.c, number of fish measured in core strata; and CV, the coefficient of variation (in parentheses).

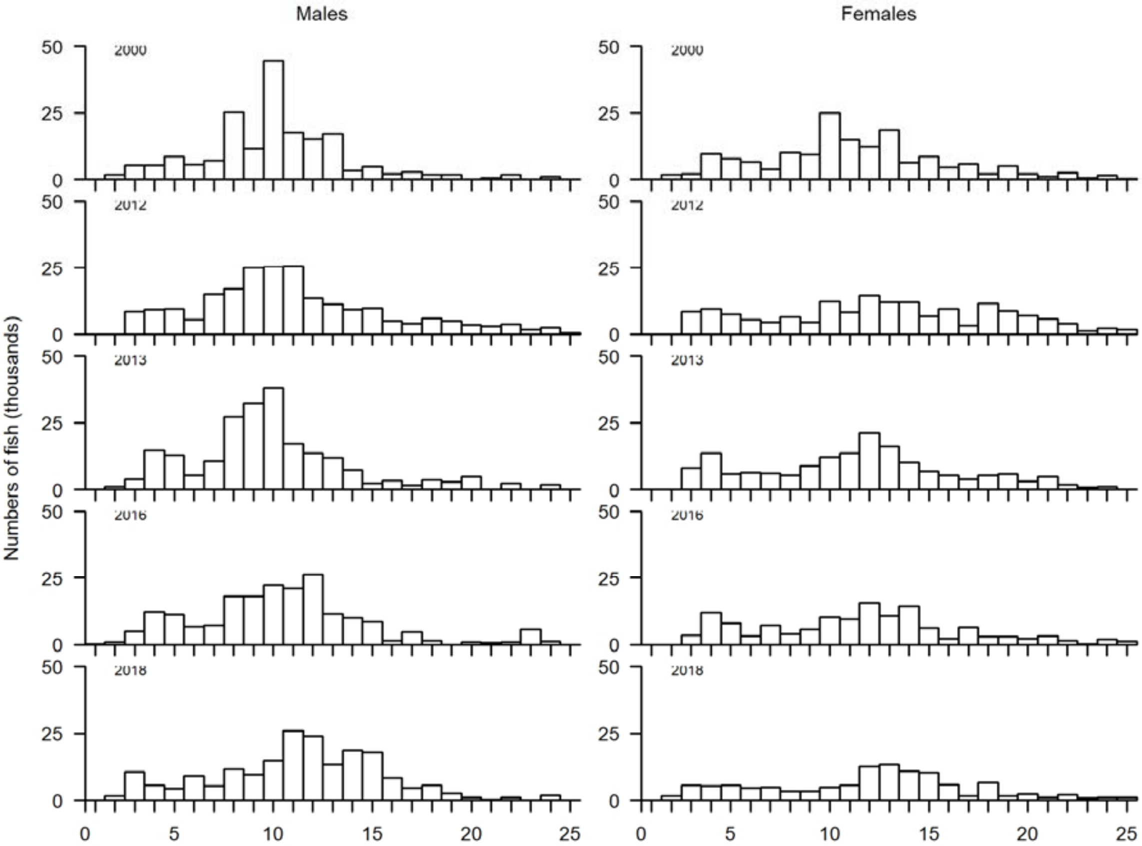


Figure 9: Scaled age frequency for ling in core strata from the WCSI trawl surveys in 2000 (TAN0007), 2012 (TAN1210), 2013 (TAN1308), 2016 (TAN1609), and 2018 (TAN1807).

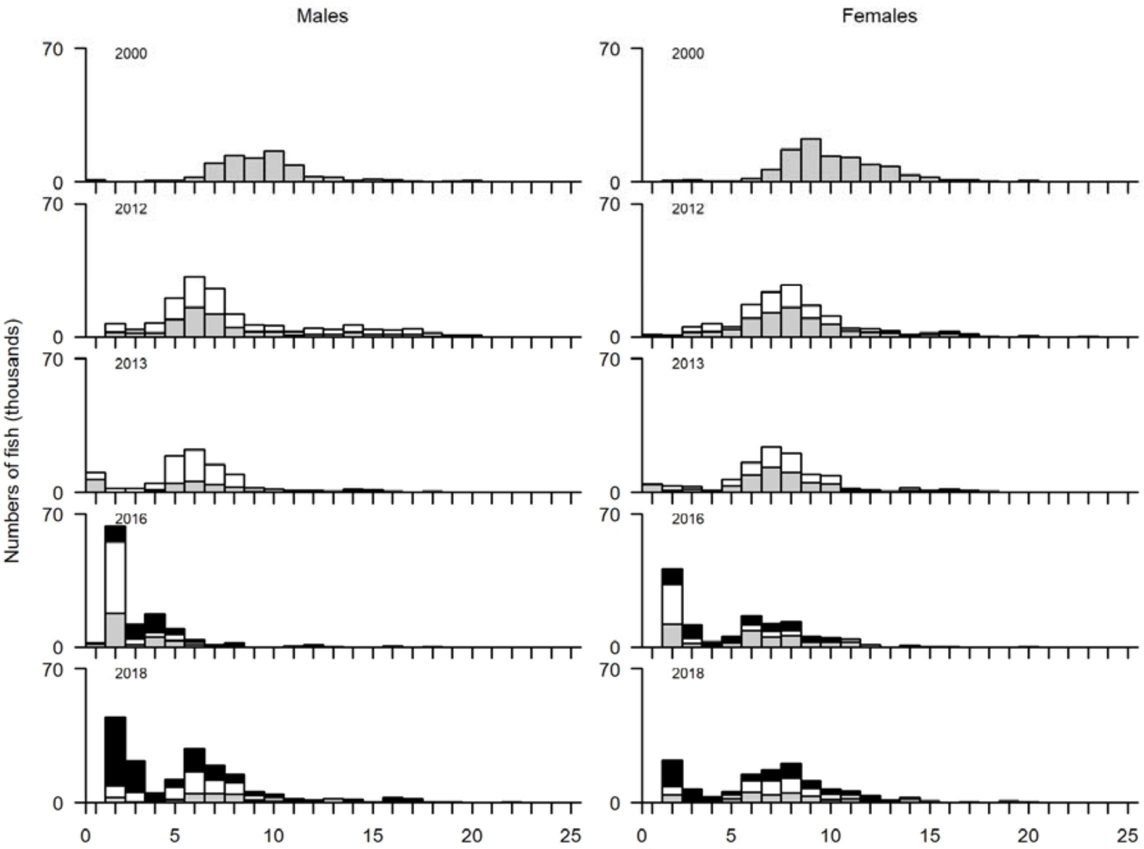


Figure 10: Scaled age frequency for hake for core (grey), all (white), and deep (black) strata from the WCSI trawl surveys in 2000 (TAN0007), 2012 (TAN1210), 2013 (TAN1308), 2016 (TAN1609), and 2018 (TAN1807).

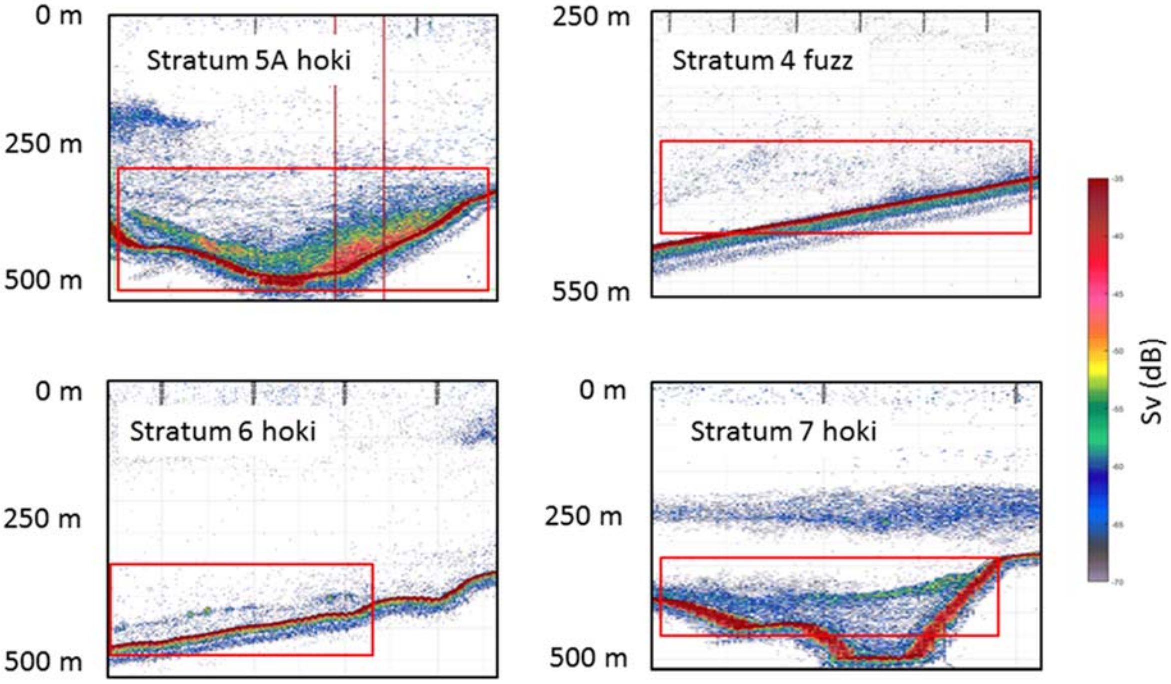


Figure 11: Examples of echograms showing hoki marks (outlined by red boxes) by strata: stratum 5A at 20:30 on 6 Aug; stratum 6 at 19:00 on 9 Aug; stratum 4 at 18:00 on 7 Aug; stratum 7 at 04:00 on 10 Aug.

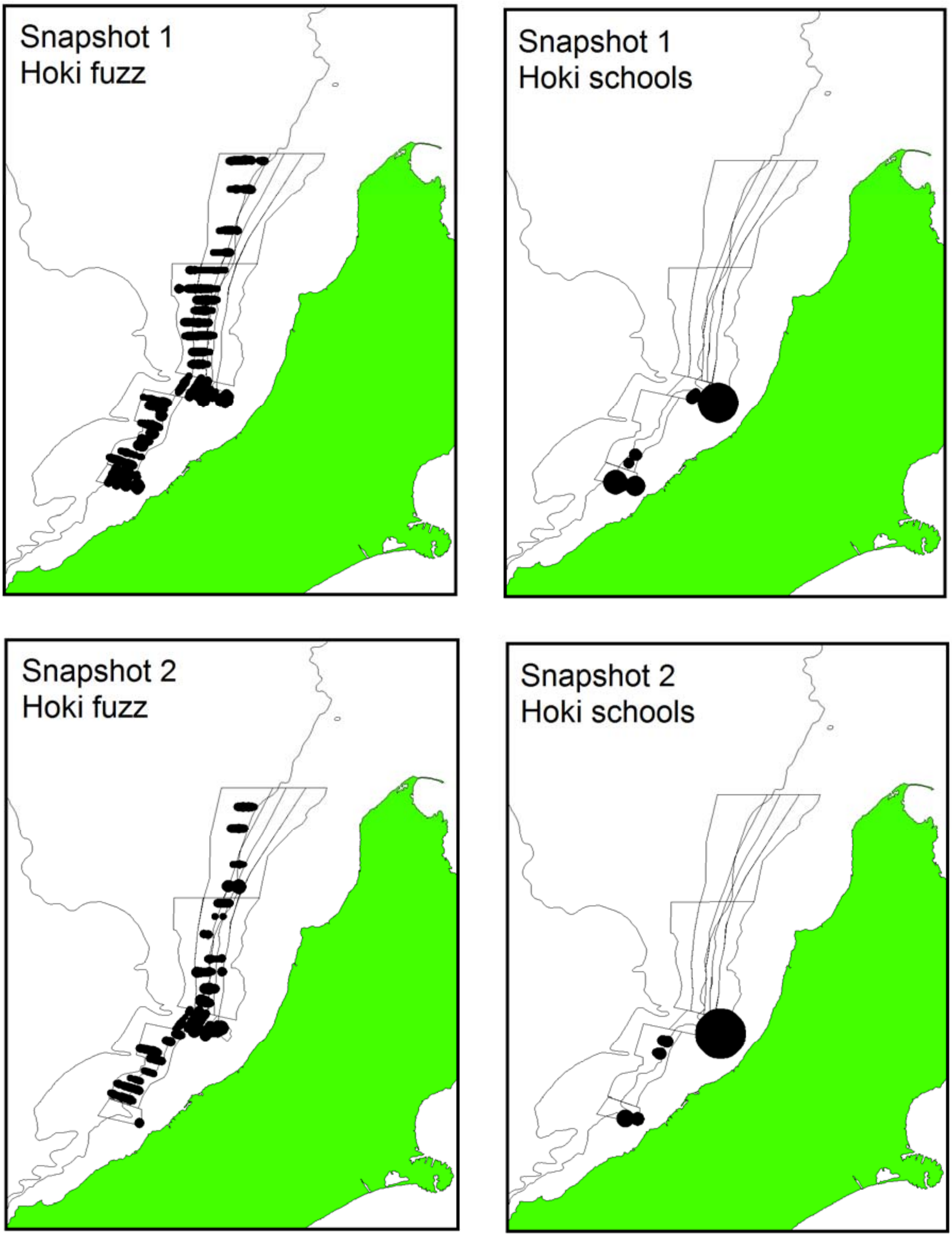


Figure 12: Spatial distribution of acoustic backscatter from hoki schools and hoki fuzz marks plotted in 10 ping (approximately 100 m) bins for the two snapshots of the WCSI. Symbol size is proportional to the log of the acoustic backscatter.

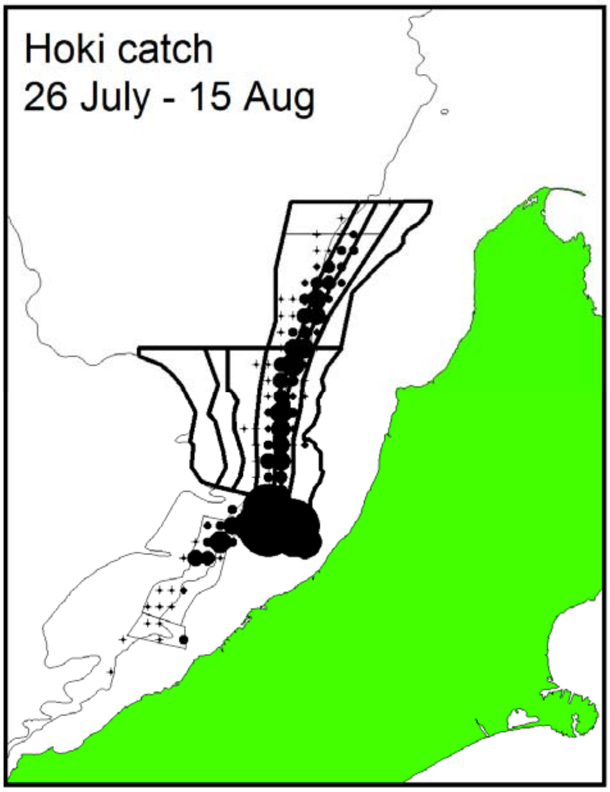


Figure 13: Spatial distribution of commercial catch (tonnes) from hoki target tows during the 2018 survey period. Data are aggregated by decimal degree. Symbol size is proportional to the square root of catch with the largest circle equal to 2700 t. Bold lines show trawl survey strata.

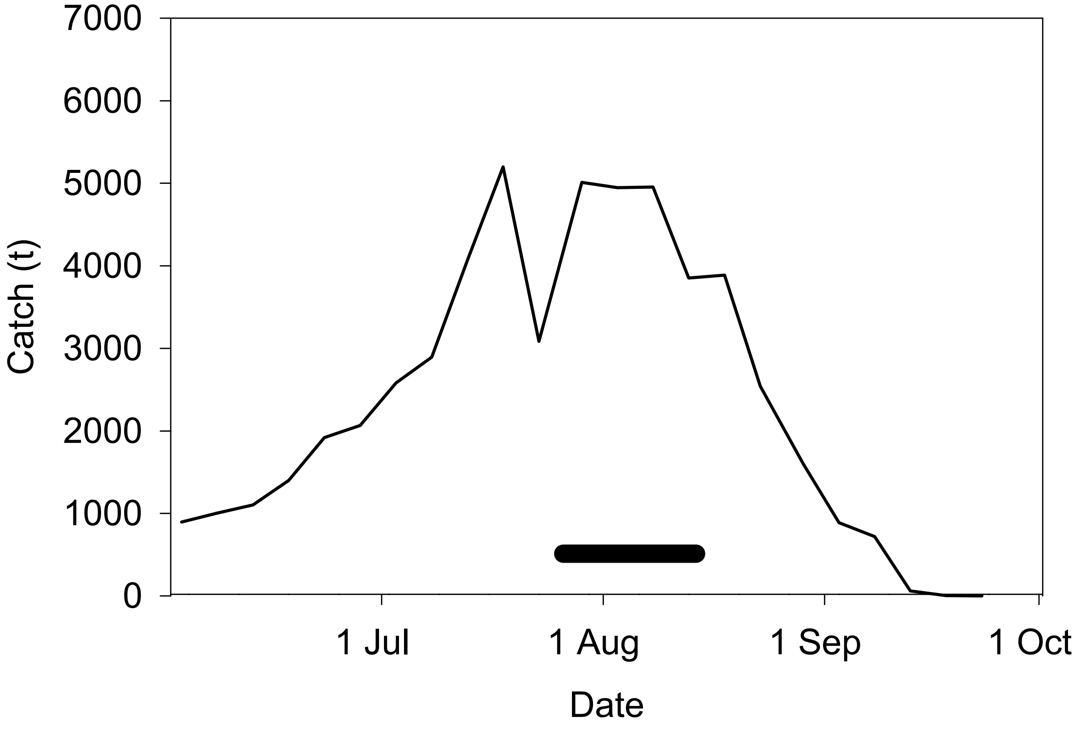


Figure 14: Timing of acoustic survey in 2018 (thick black line) in relation to the commercial hoki catch from the WCSI in 5-day periods.

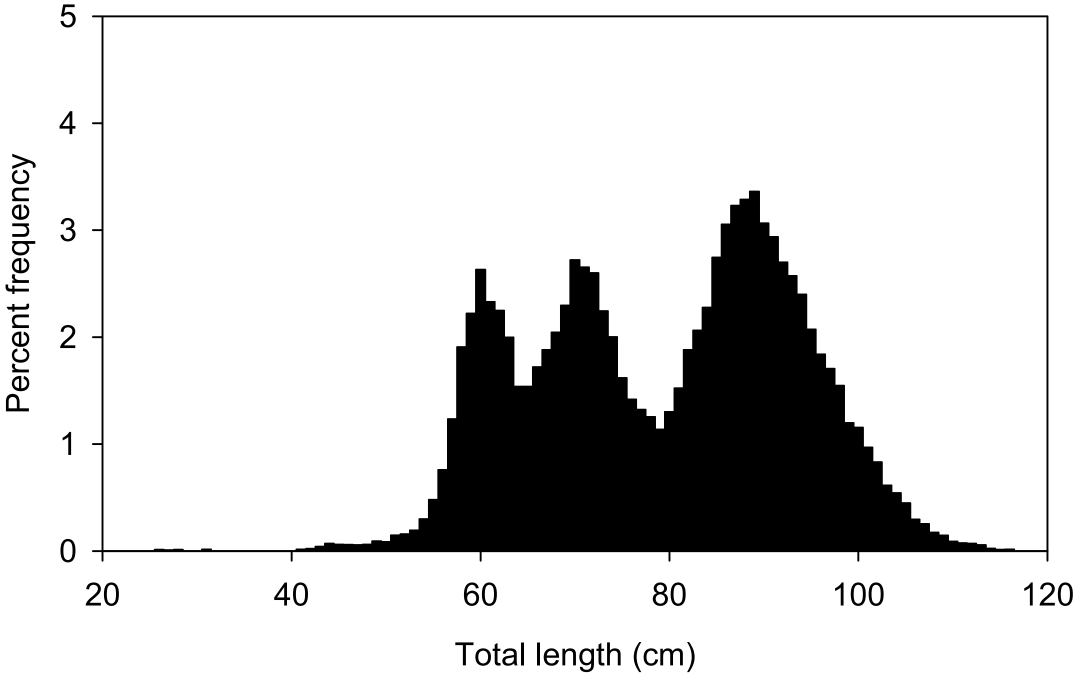


Figure 15: Scaled unsexed length frequencies of hoki caught in the commercial fishery on the WCSI in 2018 based on at-sea observer and land-based sampling. Data were used to estimate the ratio, *r*, of mean weight to mean backscattering cross-section (see Table 18).

Figure 16: NIWA AOS mounted in the hoki trawl being deployed from *Tangaroa* (Photo by Richard O'Driscoll, NIWA).

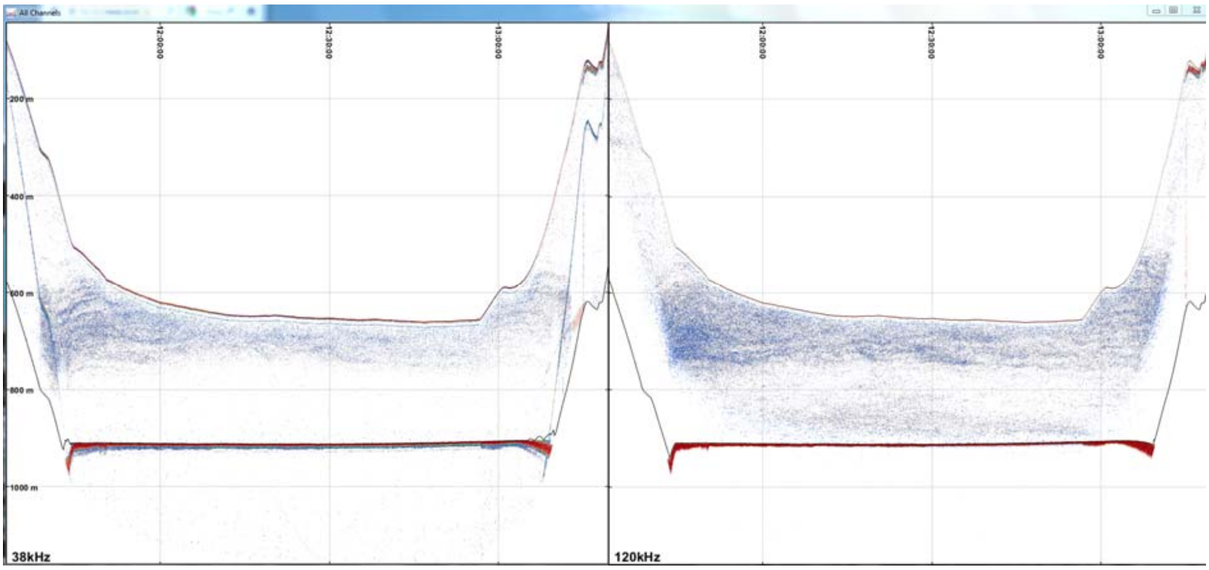


Figure 17: Examples of AOS echograms at 38 kHz (left panel) and 120 kHz (right panel). AOS is deployed at about 650 m depth over a seabed depth of 950 m. Both frequencies show clean (noise-free) data to over 300 m range.

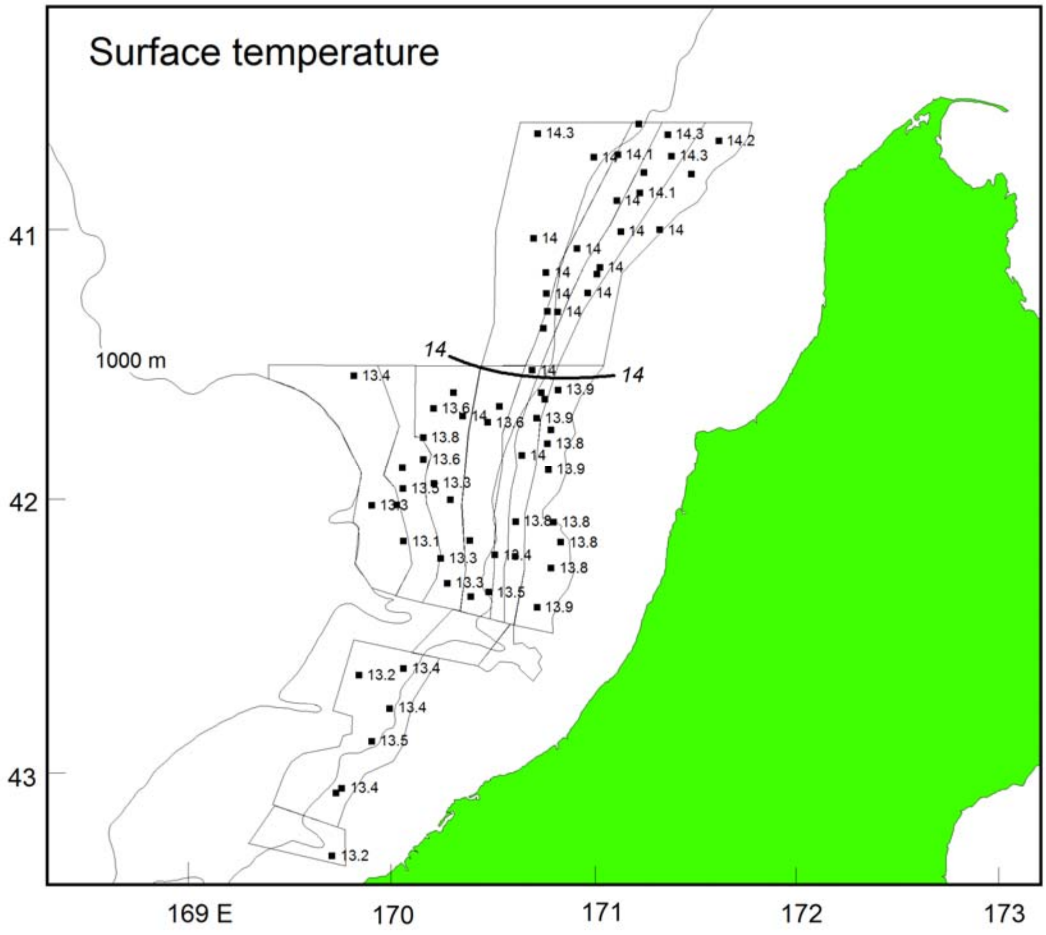


Figure 18: Surface water temperatures (°C) during the 2018 WCSI survey. Squares indicate bottom trawl tow positions. Contours show isotherms estimated by eye.

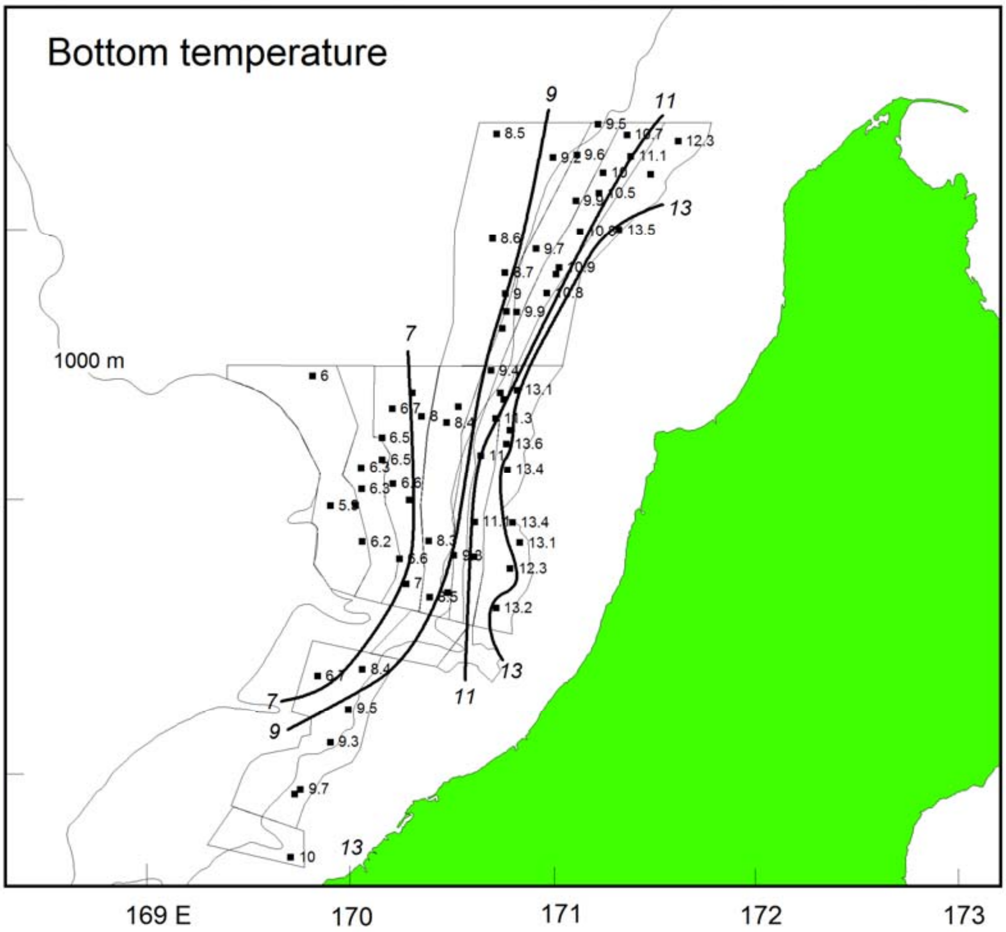


Figure 19: Bottom water temperatures (°C) during the 2018 WCSI survey. Squares indicate bottom trawl tow positions. Contours show isotherms estimated by eye.

APPENDIX 1: Station details and catch of hoki, ling, and hake.

Station	Date	Stratum code	Start latitude (° ‘ S)	Start longitude (° ‘ E)	Max. depth (m)	Distance towed (n. mile)	Catch hoki (kg)	Catch ling (kg)	Catch hake (kg)
1	26-Jul-18	012S	40 40.06	171 34.40	265	3.10	0	0	0
2	26-Jul-18	012A	40 38.68	171 19.13	410	2.88	20.2	98.8	0
3	26-Jul-18	012A	40 43.45	171 20.27	358	3.16	14.9	667.0	0
4*	27-Jul-18	AOS	40 39.86	170 34.40	350	5.00	0	0	0
5	27-Jul-18	012C	40 38.46	170 40.32	652	3.02	59.9	12.7	4.7
6	27-Jul-18	012C	40 43.73	170 57.03	540	3.19	187.1	24.8	0.4
7	27-Jul-18	012B	40 43.16	171 04.22	500	2.88	222.9	31	0.5
8*	28-Jul-18	AOS	40 36.43	171 08.18	200	2.02	-	-	-
9*	28-Jul-18	AOS	40 35.74	171 04.50		1.48	-	-	-
10	28-Jul-18	012B	40 36.26	171 10.44	487	2.99	94.3	25.7	0
11	28-Jul-18	012S	40 47.41	171 26.18	266	2.95	0	0	0
12	28-Jul-18	012A	40 47.13	171 11.95	420	2.98	83.1	252.2	0
13	28-Jul-18	012A	40 51.66	171 10.77	410	2.38	20.8	110.7	0
14*	28-Jul-18	AOS	40 51.59	171 00.37	204	2.04	-	-	-
15*	29-Jul-18	AOS	41 10.13	170 57.47	320	4.75	-	-	-
16	29-Jul-18	012A	41 08.29	170 58.86	376	3.02	14.7	540.4	0
17	29-Jul-18	012A	41 00.26	171 05.17	378	3.04	3.3	535.0	0
18	29-Jul-18	012B	40 53.39	171 03.88	451	3.00	342.1	130.7	0.8
19	29-Jul-18	012S	40 59.80	171 16.66	217	2.11	0	0	0
20*	29-Jul-18	AOS	41 13.26	170 59.25	438	29.55	-	-	-
21	30-Jul-18	012C	41 01.73	170 39.14	586	2.15	56.9	14.7	65.1
22	30-Jul-18	012B	41 04.05	170 52.00	487	2.97	1 094.4	64.1	0.6
23	30-Jul-18	012A	41 09.68	170 57.93	364	2.98	15.4	652.1	0
24	30-Jul-18	012A	41 13.90	170 55.17	347	2.96	13.6	830.5	0
25	30-Jul-18	012B	41 18.16	170 46.27	469	2.97	328.3	53.5	0
26	31-Jul-18	012C	41 09.34	170 42.73	542	2.99	64.0	4.2	16.7
27	31-Jul-18	012C	41 14.05	170 42.84	528	3.00	161.6	18.5	27.9
28	31-Jul-18	012B	41 17.99	170 43.25	500	2.97	1 263.8	60.9	2.6
29	31-Jul-18	012B	41 21.71	170 42.01	496	2.89	588.5	28.1	13.5
30	31-Jul-18	004B	41 31.11	170 38.69	487	2.98	525.2	78.3	0
31*	31-Jul-18	AOS	41 32.04	169 41.47	945	2.01	-	-	-
32	1-Aug-18	004F	41 32.36	169 45.48	940	3.00	4.0	0	35.4
33	1-Aug-18	004D	41 39.57	170 09.14	793	3.01	218.6	0	243.3
34	1-Aug-18	004D	41 41.27	170 17.94	694	3.02	99.9	6.1	120.7
35	1-Aug-18	004D	41 36.12	170 15.15	740	3.00	20.0	0	113.0
36	2-Aug-18	004A	41 41.71	170 39.99	329	2.98	14.3	413.9	0
37*	2-Aug-18	004S	41 44.36	170 44.20	228	1.18	0	5.9	0
38	2-Aug-18	004S	41 35.46	170 46.46	246	2.96	0	0	0
39	2-Aug-18	004A	41 37.52	170 42.49	326	3.01	2.8	18.1	0
40	2-Aug-18	004A	41 36.02	170 41.38	362	2.99	62.2	1 384.2	0
41	3-Aug-18	004C	41 42.67	170 25.41	587	2.99	251.0	8.0	31.5
42	3-Aug-18	004B	41 47.09	170 32.10	467	3.01	1 097.2	153.6	5.2
43	3-Aug-18	004A	41 50.04	170 35.65	404	3.03	80.8	618.2	0
44	3-Aug-18	004S	41 53.18	170 43.45	224	2.93	0	0	0
45	3-Aug-18	004S	42 04.98	170 45.09	216	3.02	0	0	0
46*	4-Aug-18	AOS	41 49.38	169 54.62	710	12.09	-	-	-
47	4-Aug-18	004E	41 46.03	170 06.16	832	3.02	11.6	0	94.2
48	4-Aug-18	004E	41 50.94	170 06.22	831	3.00	15.6	0	238.4
49	4-Aug-18	004D	41 56.32	170 09.37	793	2.98	12.7	0	233.1
50	4-Aug-18	004D	41 59.91	170 14.18	728	3.00	31.7	3.3	115.8
51	5-Aug-18	004D	42 12.95	170 11.38	800	2.99	21.5	0	70.8
52	5-Aug-18	004C	42 09.06	170 20.08	627	3.04	193.5	0.2	57.7
53	5-Aug-18	004B	42 12.23	170 27.47	498	3.06	283.9	99.2	11.5
54	5-Aug-18	004A	42 04.78	170 33.77	378	2.93	1.2	146.1	0
55	5-Aug-18	004A	42 12.54	170 33.56	365	3.03	116.3	291.4	0

56*	5-Aug-18	AOS	42 11.59	170 00.59		4.67	-	-	-
57*	6-Aug-18	AOS	42 13.10	170 00.49		1.84	-	-	-
58	6-Aug-18	004F	42 09.19	170 00.15	920	2.96	5.4	0	23.4
59	6-Aug-18	004D	42 18.58	170 13.26	757	2.76	34.5	2.1	61.8
60	6-Aug-18	004C	42 21.51	170 20.35	615	2.95	284.6	7.5	46.6
61	6-Aug-18	004S	42 23.92	170 40.08	234	3.01	0.9	0	0
62	7-Aug-18	004E	41 52.76	169 59.96	896	3.06	3.9	0	74.5
63	7-Aug-18	004E	41 57.47	170 00.05	897	2.97	5.0	0	95.4
64	7-Aug-18	004F	42 01.05	169 58.19	911	3.05	2.4	0	85.2
65	7-Aug-18	004F	42 01.20	169 50.70	974	3.02	0	0	19.4
66	8-Aug-18	004S	41 47.38	170 43.21	246	3.00	0	0	0
67	8-Aug-18	004S	42 09.40	170 47.18	213	2.99	0	0	0
68	8-Aug-18	004S	42 15.20	170 44.27	223	3.00	0	0	0
69*	9-Aug-18	0006	42 53.77	169 50.72	557	0.15	1.2	0	4.6
70*	9-Aug-18	0006	43 04.24	169 41.79	456	1.84	381.1	19.1	0
71*	10-Aug-18	0007	43 19.23	169 38.88	420	1.61	0	0	0
72*	10-Aug-18	0006	43 05.23	169 40.10	470	1.72	227.2	83.3	7.0
73*	11-Aug-18	0006	42 46.48	169 56.14	464	0.35	805.1	11.3	10.3
74*	11-Aug-18	0006	42 38.98	169 46.95	802	2.96	12.7	0	38.3
75*	11-Aug-18	0006	42 37.55	170 00.15	553	0.96	24.3	1.8	33.2
76*	12-Aug-18	AOS	42 20.50	170 25.74	526	2.03	138.4	2.8	59.8
77*	13-Aug-18	AOS	41 39.18	170 28.80	593	3.06	42.3	0	15.7
78*	14-Aug-18	AOS	40 39.54	171 43.69	25	0.28	-	-	-

* Indicates stations not suitable for biomass estimation
- Indicates tow with codend open, so no catch recorded

APPENDIX 2: Calibration Report for Tangaroa EK60 echosounders

Yoann Ladroit, 4 July 2018

The, 38, 120, and 200 kHz EK60 echosounders on *Tangaroa* were calibrated on the 4 July 2018, in Palliser Bay (41° 28.4' S, 175° 03.1' E), at the start of the QUOI experimental voyage (TAN1806). The 18 and 70 kHz EK60 echosounders were not calibrated as these were configured with EK80 WBTs. The calibration was conducted broadly as per the procedures in Demer et al. (2015).

The calibration data were recorded using the EK80 software version 1.12.2, in 4 .raw files (tan1806-D20180704-T023903.raw, tan1806-D20180704-T025841.raw, tan1806-D20180704-T031815.raw, tan1806-D20180704-T033753.raw). The EK60 GPT transceiver settings in effect during the calibration are given in Table A2.1.

Wind was around 10 knots from the NW, and sea state was good with very little swell (less than 1 m). The vessel was declutched and left to drift freely at about 0.5 knots to the SE.

A 38.1 mm tungsten carbide sphere was deployed at 14:30 NZST and first observed in the beam around 15:00. It was first set in the middle of the 38 kHz beam and left there to record on-axis echoes for about 10 minutes. It was then moved around the whole beam to obtain good coverage. Complete coverage was obtained around 16:00 NZST, and the sphere was retrieved.

A temperature/salinity/depth profile was taken using a Seabird SBE21 conductivity, temperature, and depth probe (CTD). Salinity was observed to be low (33.8 PSU at surface, 34.2 PSU at 30 m), presumably because of the proximity to Lake Ferry, and heavy rain from previous days.

Estimates of acoustic absorption were calculated using the formulae in Doonan et al. (2003). The formula from Francois & Garrison (1982) was used at 200 kHz. Estimates of seawater sound speed and density were calculated using the formulae of Fofonoff & Millard (1983). The sphere target strength was calculated as per equations 6 to 9 in MacLennan (1981), using longitudinal and transverse sphere sound velocities of 6853 and 4171 m s^{-1} respectively and a sphere density of 14 900 kg m^{-3}.

The data in the .raw EK80 files were extracted using ESP3 (Ladroit 2017). The amplitude of the sphere echoes was obtained by filtering on range, and choosing the sample with the highest amplitude. Instances where the sphere echo was disturbed by fish echoes were discarded. The alongship and athwartship beam widths and offsets were calculated by fitting the sphere echo amplitudes to the Simrad theoretical beam pattern:

$$compensation = 6.0206\left(\left(\frac{2\theta_{fa}}{BW_{fa}}\right)^2 + \left(\frac{2\theta_{ps}}{BW_{ps}}\right)^2 - 0.18\left(\frac{2\theta_{fa}}{BW_{fa}}\right)^2\left(\frac{2\theta_{ps}}{BW_{ps}}\right)^2\right),$$

where θ_{ps} is the port/starboard echo angle, θ_{fa} the fore/aft echo angle, BW_{ps} the port/starboard beamwidth, BW_{fa} the fore/aft beamwidth, and *compensation* the value, in dB, to add to an uncompensated echo to yield the compensated echo value. The fitting was done using an unconstrained nonlinear optimisation (as implemented by the Matlab fminsearch function). The S_a correction was calculated from:

$$Sa, corr = 5\log 10\left(\frac{\sum P_i}{4P_{\max}}\right),$$

where P_i is sphere echo power measurements and P_{max} maximum sphere echo power measurement. A value for $Sa,corr$ is calculated for all valid sphere echoes and the mean over all sphere echoes is used to determine the final $Sa,corr$.

Results

The results from the CTD cast are given in Table A2.2, along with estimates of the sphere target strength, sound speed, and acoustic absorption for 38, 120, and 200 kHz.

The calibration parameters resulting from the calibration are given in Table A2.3, and compared with results from previous calibrations. Results for all frequencies have been relatively consistent (usually within 0.5 dB) across all calibrations, with higher frequencies being more variable over time. The new 38 kHz transducer has slightly higher estimated gain than the previous one.

The estimated beam patterns, as well as the coverage of the beam by the calibration sphere, are given in Figures A2.1–A2.6. The symmetrical nature of the beam patterns and the centering near zero indicates that the transducers and EK60 transceivers were all operating correctly. The new 38 kHz transducer (fitted in October 2015) had slightly higher G_0 than that recorded in February and July 2016 (see Table A2.3).

The root mean square (RMS) of the difference between the Simrad beam model and the sphere echoes out to the 3 dB beamwidth was 0.12 for 38 kHz, 0.20 dB for 120 kHz, and 0.25 dB at 200 kHz (Table A2.3), indicating good or excellent quality calibrations on all three frequencies (0.3–0.4 dB is acceptable, 0.2–0.3 dB good, and <0.2 dB excellent).

Table A2.1. EK60 transceiver settings and other relevant parameters in effect during the calibration. These were set to default in the EK80 software.

Frequency (kHz)	38	120	200
GPT model	0090720580ea	009072058148	00907205da23
GPT serial number	650	668	692
GPT software version	050112	050112	050112
ER60 software version	2.4.3	2.4.3	2.4.3
Transducer model	ES38B	ES120-7C	ES200-7C
Transducer serial number	31378	477	364
Sphere type	WC38.1mm	WC38.1mm	WC38.1mm
Transducer draft setting (m)	0.0	0.0	0.0
Transmit power (W)	2000	250*	150*
Pulse length (ms)	1.024	1.024	1.024
Transducer peak gain (dB)	25.50	25.50	27.00
Sa correction (dB)	0.00	0.00	0.00
Bandwidth (Hz)	2425	3026	3088
Sample interval (m)	0.191	0.191	0.191
Two-way beam angle (dB)	–20.6	–21.0	–20.7
Absorption coefficient (dB/km)	9.8	37.4	52.7
Speed of sound (m/s)	1494	1494	1494
Angle sensitivity (dB) along/athwartship	21.90/21.90	23.0/23.0	23.0/23.0
3 dB beamwidth (°) along/athwartship	7.0/7.0	6.5/6.6	6.8/6.9
Angle offset (°) along/athwartship	0.0/0.0	0.0/0.0	0.0/0.0

* Maximum transmit power of 70, 120, and 200 kHz echosounders was reduced when ER60 software was upgraded in April 2013. Previously transmit power was 1000 W, 500 W, and 300 W respectively.

Table A2.2. CTD cast details and derived water properties. The values for sound speed, salinity and absorption are the mean over water depths 6 to 30 m.

Parameter	
Date/time (UTC, start)	04 July 2018 02:30
Position	41˚ 28.73’ S, 175˚ 03.34’ E
Mean sphere range (m)	26.0 (38), 23.9 (120), 24.0 (200)
Mean temperature (ºC)	10.5
Mean salinity (psu)	34.0
Sound speed (m/s)	1490.8
Water density (kg/m^3)	1026.7
Sound absorption (dB/km)	9.24 (38 kHz)
	37.30 (120 kHz)
	54.17 (200 kHz)
Sphere target strength (dB re 1m^2)	–42.39 (38 kHz)
	–39.48 (120 kHz)
	–39.22 (200 kHz)

Table A2.3. Estimated calibration coefficients for recent calibrations of *Tangaroa* hull EK60 echosounders. Transducer peak gain was estimated from mean sphere TS. * The 38 kHz transducer was changed in October 2015. The Feb 2015 calibration was in Antarctica.

		July 2018	Aug 2016	Feb 2016	Feb 2015	Jul 2013	Jul 2012	Feb 2012
18 kHz								
	Transducer peak gain (dB)	N/A	22.80	22.85	23.21	22.99	22.97	22.81
	Sa correction (dB)	N/A	-0.71	-0.73	-0.76	-0.78	-0.84	-0.69
	Beamwidth (º) along/athwartship	N/A	10.6/10.9	10.5/11.3	10.7/11.2	10.6/10.7	10.7/11.2	10.7/10.9
	Beam offset (º) along/athwartship	N/A	0.00/0.00	0.00/0.00	0.00/0.00	0.00/-0.00	0.00/-0.00	0.00/-0/.00
	RMS deviation (dB)	N/A	0.10	0.14	0.12	0.08	0.09	0.14
38 kHz*								
	Transducer peak gain (dB)	26.37	26.23	26.21	25.69	25.42	25.62	25.75
	Sa correction (dB)	-0.55	-0.62	-0.58	-0.54	-0.55	-0.61	-0.57
	Beamwidth (º) along/athwartship	6.7/6.8	7.0/7.1	6.9/7.2	6.8/6.9	6.8/6.9	6.8/6.9	6.8/6.8
	Beam offset (º) along/athwartship	0.06/-0.08	0.00/0.00	0.14/-0.19	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00
	RMS deviation (dB)	0.12	0.11	0.14	0.12	0.09	0.10	0.14
70 kHz								
	Transducer peak gain (dB)	N/A	26.33	26.28	26.55	26.43	26.04	26.78
	Sa correction (dB)	N/A	-0.31	-0.38	-0.35	-0.37	-0.31	-0.35
	Beamwidth (º) along/athwartship	N/A	6.4/6.6	6.2/6.5	6.6/6.7	6.6/6.3	6.6/6.6	6.3/6.1
	Beam offset (º) along/athwartship	N/A	0.00/0.00	0.13/-0.04	0.04/-0.02	0.00/0.00	0.00/0.00	0.00/0.00
	RMS deviation (dB)	N/A	0.13	0.18	0.10	0.10	0.10	0.21
120 kHz								
	Transducer peak gain (dB)	26.20	26.19	26.15	26.92	26.22	26.11	26.80
	Sa correction (dB)	-0.45	-0.33	-0.29	-0.33	-0.39	-0.34	-0.38
	Beamwidth (º) along/athwartship	67/6.8	6.3/6.5	6.1/6.2	6.4/6.5	6.5/6.4	6.5/6.6	6.0/6.0
	Beam offset (º) along/athwartship	-0.02/0.00	0.00/0.00	-0.00/0.00	-0.00/0.00	0.00/0.00	-0.00/-0.00	0.00/0.00
	RMS deviation (dB)	0.20	0.17	0.18	0.16	0.15	0.17	0.19
200 kHz								
	Transducer peak gain (dB)	25.15	24.92	25.10	24.90	25.27	25.31	25.16
	Sa correction (dB)	-0.29	-0.17	-0.22	-0.27	-0.31	-0.24	-0.21
	Beamwidth (º) along/athwartship	6.5/6.5	6.4/6.3	6.2/6.2	6.6/6.9	6.4/6.3	6.8/6.5	6.2/6.2
	Beam offset (º) along/athwartship	-0.03/-0.1	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	-0.27/-0.10	0.08/-0.08
	RMS deviation (dB)	0.25	0.19	0.18	0.20	0.20	0.21	0.18

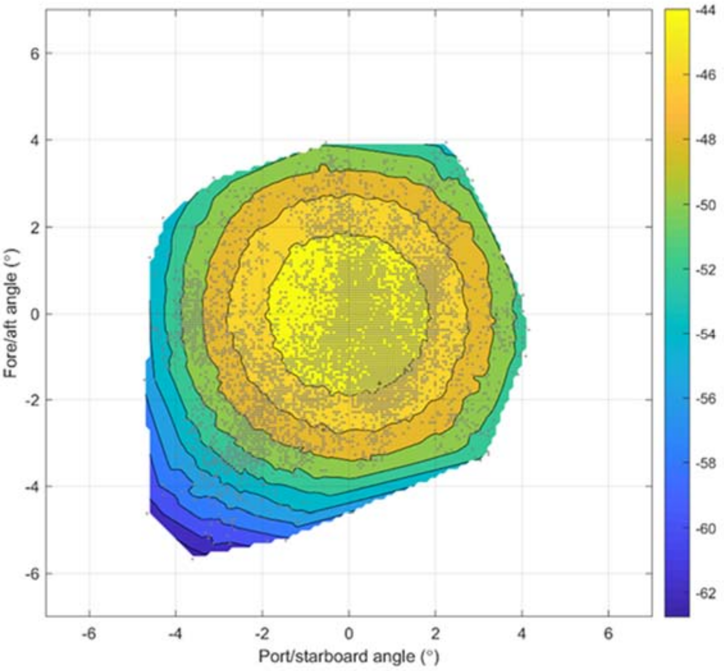


Figure A2.1. The 38 kHz estimated beam pattern from the sphere echo strength and position. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.

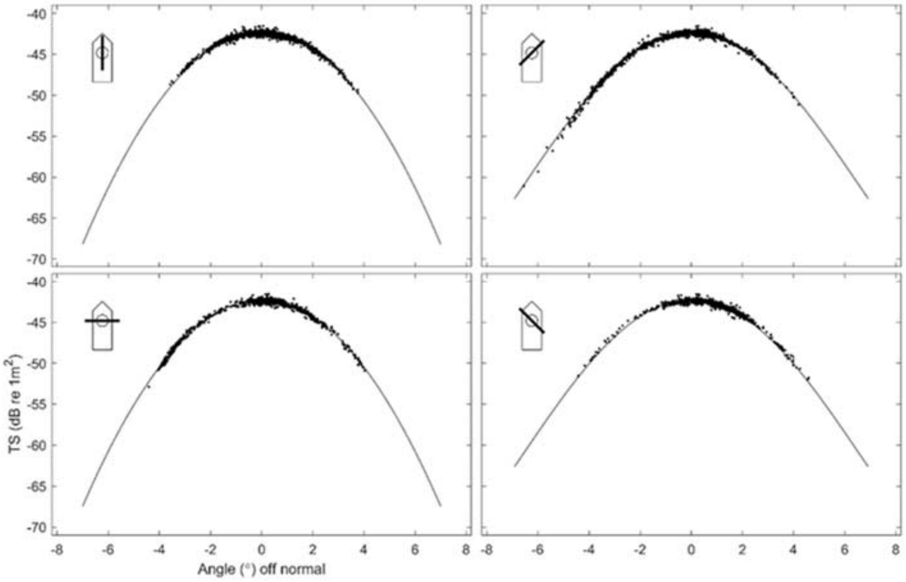


Figure A2.2. Beam pattern results from the 38 kHz analysis. The solid line is the ideal beam pattern fit to the sphere echoes for four slices through the beam.

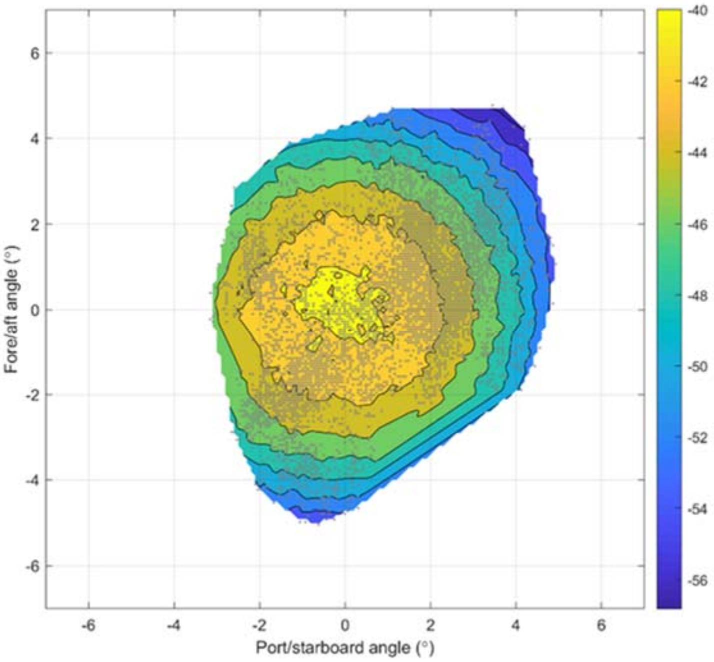
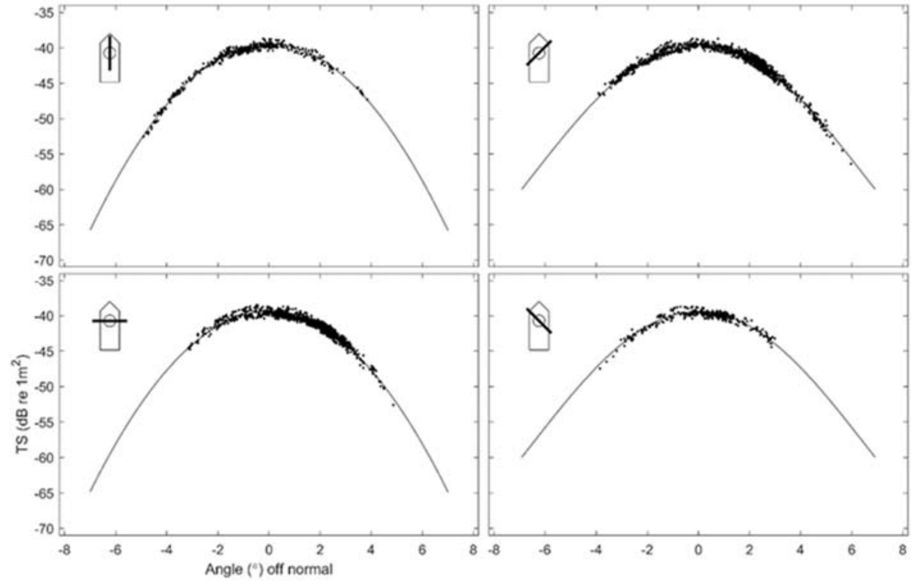


Figure A2.3. The 120 kHz estimated beam pattern from the sphere echo strength and position. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.



FigureA2.4. Beam pattern results from the 120 kHz analysis. The solid line is the ideal beam pattern fit to the sphere echoes for four slices through the beam.

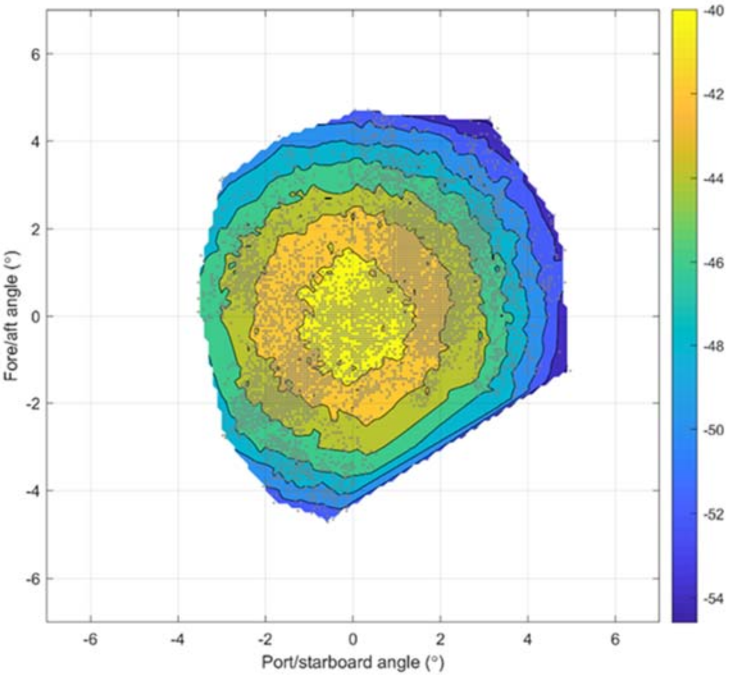


Figure A2.5. The 200 kHz estimated beam pattern from the sphere echo strength and position. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.

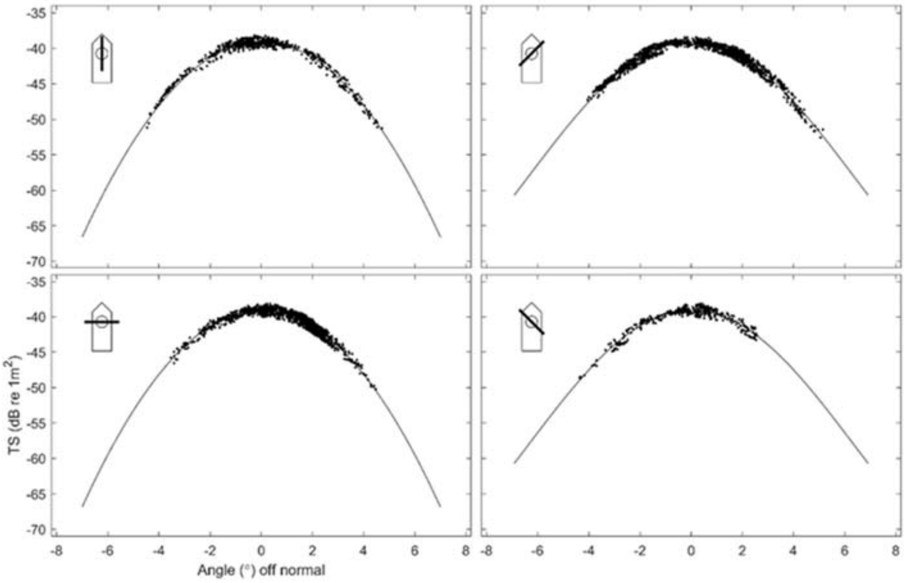


Figure A2.6. Beam pattern results from the 200 kHz analysis. The solid line is the ideal beam pattern fit to the sphere echoes for four slices through the beam.

APPENDIX 3: Description of gonad staging for teleosts and elasmobranchs

Teleosts (Middle Depths method, MD)

Research gonad stage		Males	Females
1	Immature	Testes small and translucent, threadlike or narrow membranes.	Ovaries small and translucent. No developing oocytes.
2	Resting	Testes thin and flabby; white or transparent.	Ovaries are developed, but no developing eggs are visible.
3	Ripening	Testes firm and well developed, but no milt is present.	Ovaries contain visible developing eggs, but no hyaline eggs present.
4	Ripe	Testes large, well developed; milt is present and flows when testis is cut, but not when body is squeezed.	Some or all eggs are hyaline, but eggs are not extruded when body is squeezed.
5	Running-ripe	Testis is large, well formed; milt flows easily under pressure on the body.	Eggs flow freely from the ovary when it is cut or the body is pressed.
6	Partially spent	Testis somewhat flabby and may be slightly bloodshot, but milt still flows freely under pressure on the body.	Ovary partially deflated, often bloodshot. Some hyaline and ovulated eggs present and flowing from a cut ovary or when the body is squeezed.
7	Spent	Testis is flabby and bloodshot. No milt in most of testis, but there may be some remaining near the lumen. Milt not easily expressed even when present.	Ovary bloodshot; ovary wall may appear thick and white. Some residual ovulated eggs may still remain but will not flow when body is squeezed.

Elasmobranchs (Generalised shark and skate stage method, SS)

1	Immature	Claspers shorter than pelvic fins, soft and uncalcified, unable or difficult to splay open Testes small.	Ovaries small and undeveloped. Oocytes not visible, or small (pin-head sized) and translucent, whitish.
2	Maturing	Claspers longer than pelvic fins, soft and uncalcified, unable or difficult to splay open or rotate forwards.	Some oocytes enlarged, up to about pea-sized or larger, and white to cream.
3	Mature	Claspers longer than pelvic fins, hard and calcified, able to splay open and rotate forwards to expose clasper spine.	Some oocytes large (greater than pea-sized) and yolky (bright yellow).
4	Gravid I	-	Uteri contain eggs or egg cases but no embryos are visible.
5	Gravid II	-	Uteri contain visible embryos. Not applicable to egg laying sharks and skates
6	Post-partum	-	Uteri flaccid and vascularised Indicating recent birth.

APPENDIX 4: Calculation of sound absorption coefficients

CTD data were collected on 47 tows within the 2018 acoustic survey area. Plots of average temperature, salinity, and sound absorption as a function of depth are given in Figure A4.1. Average sound absorption was estimated using the formula of Doonan et al. (2003). An absorption estimate of 8.88 dB km^{-1} from the absorption profile over the upper 400 m (Figure A4.1c) was used when estimating hoki abundance (see Section 2.7.2).

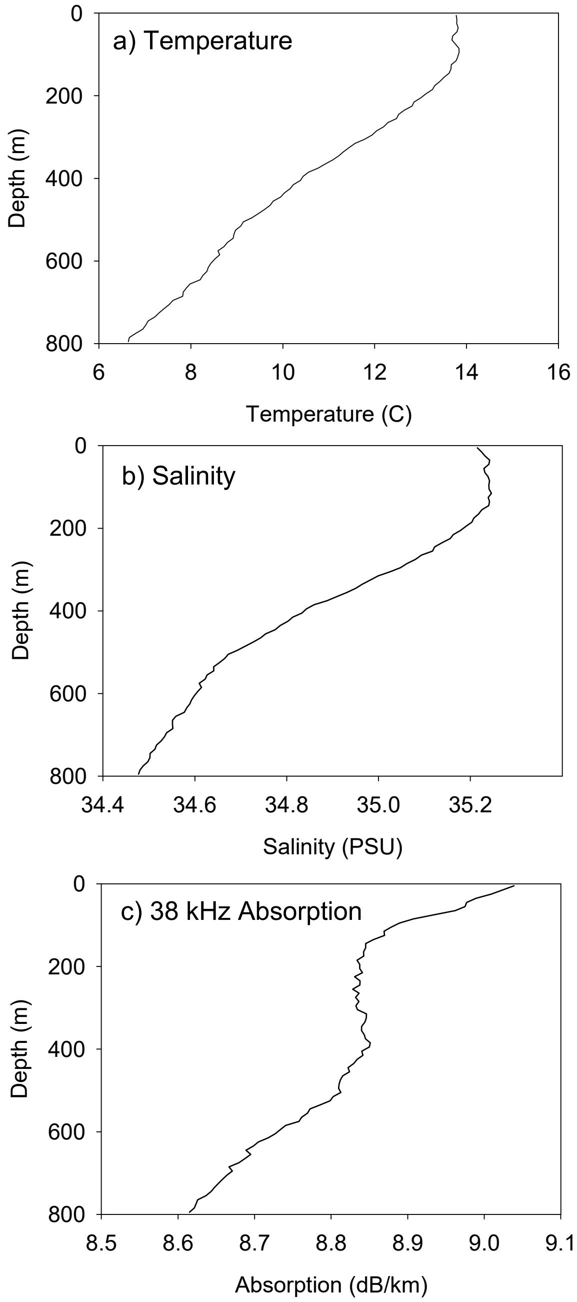


Figure A4.1: Profiles of average temperature, salinity, and sound absorption at 38 kHz from the 47 CTD deployments carried out in the 2018 WCSI acoustic survey area.

APPENDIX 5: Species list

Scientific and common names, species codes and occurrence (Occ.) of fish, squid, and other organisms from all trawl tows. Note species codes, particularly invertebrates are continually updated on the database following identification ashore.

Scientific name	Common name	Species code	Occ.
Porifera	unspecified sponges	ONG	3
Hexactinellida			
Euplectellidae			
Euplectella regalis	basket-weave horn sponge	ERE	1
Rossellidae			
Hyalascus sp.	Floppy tubular sponge	HYA	1
Cnidaria			
Scyphozoa	unspecified jellyfish	JFI	2
Anthozoa			
Actiniidae			
Bolocera spp	deepsea anenome	BOC	1
Actinostolidae	deepsea anenome	ACS	3
Hormathiidae	warty deepsea anenome	HMT	3
Corallimorphidae	coral-like anenome	CLM	1
Pennatulacea			
Anthoptilum grandiflorum	flower sea pen	AGF	3
Funiculina quadrangularis	rope-like sea pen	FQU	6
Kophobelemnon stelliferum	club sea pen	KST	2
Hexacorallia			
Zoanthidea			
Epizoanthus sp.	zoanthid anenome	EPZ	2
Alcyonacea			
Isididae			
Keratoisis spp.	bamboo coral	BOO	2
Scleractinia			
Caryophyliidae			
Stephanocyatus platypus	solitary bowl coral	STP	3
Flabellidae	flabellum coral	COF	1
Thaliacea			
Salpidae	unspecified salp	SAL	1
Pyrosoma atlanticum		PYR	3
Mollusca			
Nudibranchia	unidentified sea slug	NUD	2
Gastropoda			
Ranellidae			
Fusitron magellanicus		FMA	1
Cephalopoda			
Teuthoidea: squids			
Histioteuthidae			
Histioteuthis spp.	violet squid	VSQ	5
Histioteuthis atlantica	violet squid	HAA	1
H. macrohista	violet squid	HMC	1
H. miranda	violet squid	HMI	4
Lycoteuthidae			
Lycoteiuthis lorigera	crowned firefly squid	LSQ	1
Octopoteuthidae			
Octopoteuthis spp.	octopoteuthis squid	OPO	1
Ommastrephidae			
Nototodarus sloanii & *N.gouldi*	arrow squid	SQU	40
Todarodes fillippovae	todarodes squid	TSQ	2

Onychoteuthidae			
Onykia robsoni	warty squid	MRQ	12
Pholidoteuthidae			
Pholidoteuthis massyae	large red scaly squid	PSQ	3
Octopodidae	unspecified octopus	OCP	1
Enteroctopodidae			
Benthoctopus spp.		BNO	3
Opisthoteuthididae			
Opisthoteuthis spp.	umbrella octopus	OPI	2
Arthropoda			
Crustacea			
Malacostraca			
Campylonotidae			
Campylonotus rathbunae	sabre prawn	CAM	1
Nematocarcinidae			
Lipkius holthuisi	omega prawn	LHO	17
Oplophoridae			
Acanthephyra spp.	Subantarctic ruby prawn	ACA	2
Oplophorus spp.	deepwater prawn	OPP	2
Pasiphaeidae			
Pasiphaea spp.	pasiphaeid prawn	PAS	2
P. barnardi.		PBA	4
Sergestidae			
Sergia potens		SEP	10
Sergestes spp.	sergestid prawn	SER	1
Solenoceridae			
Haliporoides sibogae	jack-knife prawn	HSI	14
Brachyura			
Inachinidae			
Platymaia maoria	Dell's spider crab	PTM	1
Majidae			
Leptomithrax garricki	Garrick's masking crab	GMC	1
Nephropidae			
Metanephrops challengeri	scampi	SCI	8
Paguridae			
Pagurus novaezelandiae	hermit crab	PGN	1
Sympagurus dimorphis	hermit crab	SDM	1
Scyllaridae			
Ibacus alticrenatus	prawn killer	PRK	13
Hexanauplia			
Cirripedia	barnacle	BRN	1
Thoracica			
Scapellidae	stalked barnacle	SBN	9
Echinodermata			
Ophiuroidea Brittle stars			
Ophiodermatidae			
Bathypectinura heros		BHE	1
Asteroidea Sea stars			
Asteriidae			
Sclerasterias mollis	cross-fish	SMO	3
Astropectinidae			
Dipsacaster magnificus	magnificent sea-star	DMG	4
Plutonaster knoxi	abyssal star	PKN	6
Psilaster acuminatus	geometric star	PSI	15
Echinasteridae			
Henricia compacta		HEC	1
Brisingidae	armless stars	BRG	4
Goniasteridae			

Lithosoma novaezelandiae	rock star	LNV	2
Mediaster sladeni	Sladen’s star	MSL	2
Pillsburiaster aoteanus		PAO	2
Solasteridae			
Crossaster multispinus	sun star	CJA	10
Solaster torulatus	chubby sun-star	SOT	2
Zoroasteridae			
Zoroaster spp.	rat-tail star	ZOR	7
Echinoidea			
Echinothuriidae, Phormosomatidae	unspecified Tam O’Shanter urchin	TAM	10
Echinothuriidae,		ECT	6
Spatangidae,			
Spatangus multispinus.	purple heart urchin	SPT	4
Holothuroidea	unspecified holothurian	HTH	1
Laetmogonidae			
Laetmogone spp.	sea cucumber	LAG	1
Synallactidae			
Stichopus mollis	sea cucumber	SCC	1
Myxini			
Myxinidae: hagfishes			
Eptatretus cirrhatus	hagfish	HAG	2
Chondrichthyes			
Triakidae: smoothhounds			
Galeorhinus galeus	school shark	SCH	21
Mustelus lenticilatus	rig	SPO	5
Centrophoridae: gulper sharks			
Centrophorus squamosus	deepwater spiny dogfish	CSQ	13
Deania calcea	shovelnose dogfish	SND	20
Somniosidae: sleeper sharks			
Centroscymnus crepidater	longnose velvet dogfish	CYP	14
C. owstoni	smooth skin dogfish	CYO	14
C. coelolepis	Portugese dogfish	CYL	4
Proscymnodon plunketi	Plunket's shark	PLS	7
Zameus squamulosus	velvet dogfish	ZAS	2
Etmopteridae: lanternsharks			
Etmopterus lucifer	lucifer dogfish	ETL	16
E. baxteri	Baxter’s lantern dogfish	ETB	8
Dalatiidae: kitefin sharks			
Scymnorhinus licha	seal shark	BSH	12
Squalidae: dogfishes			
Squalus acanthias	spiny dogfish	SPD	13
Squalus griffini	northern spiny dogfish	NSD	30
Proscylliidae: finback cat sharks			
Gollum attenuatus	slender smoothhound	SSH	13
Scyliorhinidae: cat sharks			
Apristurus exanguis	New Zealand catshark	AEX	2
Cephaloscyllium isabellum	carpet shark	CAR	11
Torpedinidae: torpedo electric rays			
Torpedo fairchildi	electric ray	ERA	6
Narkidae: numbfishes			
Typhlonarke spp	numbfish	BER	1
Rajidae: skates			
Brochiraja asperula	smooth deepsea skate	BTA	2
Arhynchobatis asperrimus	softnose skate	LSK	1
Dipturus innominata	smooth skate	SSK	23
Zearaja nasuta	rough skate	RSK	5
Chimaeridae: chimaeras, ghost sharks			
Hydrolagus bemisi	pale ghost shark	GSP	18

H. novaezelandiae	dark ghost shark	GSH	23
Rhinochimaeridae: longnosed chimaeras			
Rhinochimaera pacifica	widenose chimaera	RCH	6
Osteichthyes			
Notacanthidae: spiny eels			
Notocanthus sexspinis	spineback	SBK	8
Synaphobranchidae: cutthroat eels			
Diastobranchus capensis	basketwork eel	BEE	10
Simenchelys parasitica	snubnosed eel	SNE	1
Nemichthyidae: snipe eels			
Avocettina paucipora	fewspore snipe eel	APA	1
Congridae: conger eels			
Bassanago bulbiceps	swollenheaded conger	SCO	16
B. hirsutus	hairy conger	HCO	15
Nettastomatidae:duckbill eels			
Nettastoma parviceps	duckbill eel	NET	1
Argentinidae: silversides			
Argentina elongata	silverside	SSI	14
Alepocephalidae: slickheads			
Alepocephalus antipodianus	smallscaled brown slickhead	SSM	1
A. australis	bigscaled brown slickhead	SBI	2
Xenodermichthys copei	black slickhead	BSL	15
Gonostomatidae: bristlemouths			
Gonostoma bathyphilum	deepsea lightfish	GBT	1
Chauliodontidae: viperfishes			
Chauliodus sloani	viperfish	CHA	9
Stomiinae: scaly dragonfishes			
Stomias boa	scaly dragonfish	SBB	7
Paraulopidae: cucumber fishes			
Paraulopus nigripinnis	cucumber fish	CUC	23
Sternoptychidae: hatchetfishes			
Argyropelecus gigas	giant hatchetfish	AGI	1
Gonostomatidae: bristlemouths			
Diplophos rebainsi	Rebain’s portholefish	DRB	2
Phosichthyidae: lighthouse fishes			
Phosichthys argenteus	lighthouse fish	PHO	8
Sternoptycthidae: hatchetfishes			
Sternoptyx psudodiaphana	false oblique hatchetfish	SPU	1
Myctophidae: lanternfishes			
Diaphus danae	Dana lanternfish	DDA	5
Lampanyctus australis	Austral lanternfish	LAU	5
Symbolophorus boops	Bogue lanternfish	SBP	1
Trachipteridae: dealfishes			
Trachipterus trachypterus	dealfish	DEA	2
Ophidiidae: cusk eels			
Genypterus blacodes	ling	LIN	41
Moridae: morid cods			
Halargyreus sp.	Australasian slender cod	HAS	12
Lepidion microcephalus	small-headed cod	SMC	2
Mora moro	ribaldo	RIB	31
Pseudophycis bachus	red cod	RCO	14
Tripterophycis gilchristi	grenadier cod	GRC	3
Euclichthyidae: eucla cods			
Euclichthys polynemus	eucla cod	EUC	25
Merlucciidae: hakes			
Macruronus novaezelandiae	hoki	HOK	55
Merluccius australis	hake	HAK	37
Macrouridae: rattails, grenadiers			
Coelorinchus biclinozonalis	two saddle rattail	CBI	7

C. bollonsi	Bollons’ rattail	CBO	27
C. fasciatus	banded rattail	CFA	9
C. innotabilis	notable rattail	CIN	14
C. matamua	Mahia rattail	CMA	12
C. maurofasciatus	dark banded rattail	CDX	8
C. oliverianus	Oliver's rattail	COL	27
C. parvifasciatus	small-banded rattail	CCX	24
Coryphaenoides dossenus	humpback rattail	CBA	5
C. serrulatus	serrulate rattail	CSE	13
C. subserrulatus	four rayed rattail	CSU	11
Lepidorhynchus denticulatus	javelinfish	JAV	49
Lucigadus nigromaculatus	blackspot rattail	VNI	5
Mesobius antipodium	black javelinfish	BJA	1
Trachyrincus aphyodes	white rattail	WHX	16
Ceratiidae: sea devils			
Ceratias spp.	seadevil	CER	1
Cryptopsaras couesii	seadevil	SDE	1
Trachichthyidae: roughies			
Hoplostethus atlanticus	orange roughy	ORH	10
H. mediterraneus	silver roughy	SRH	42
Paratrachichthys trailli	common roughy	RHY	4
Diretmidae: discfishes			
Diretmichthys parini	spinyfin	SFN	2
Berycidae: alfonsinos			
Beryx splendens	alfonsino	BYS	6
Macrorhamphosidae: snipefishes			
Centriscops humerosus	banded bellowsfish	BBE	7
Scorpaenidae: scorpionfishes			
Helicolenus barathri	bigeye sea perch	HBA	52
H. percoides	sea perch	HPC	11
Trachyscorpia eschmeyeri	cape scorpionfish	TRS	5
Oreosomatidae: oreos			
Neocyttus rhomboidalis	spiky oreo	SOR	15
Pseudocyttus maculatus	smooth oreo	SSO	1
Oreosoma atlanticum	ox-eye oreo	OXO	1
Zeidae: dories			
Capromimus abbreviatus	capro dory	CDO	29
Cyttus novaezealandiae	silver dory	SDO	18
C. traversi	lookdown dory	LDO	38
Zeus faber	john dory	JDO	10
Congiopodidae: pigfishes			
Congiopodus leucopaecilus	pigfish	PIG	1
Triglidae: searobins gurnards			
Lepidotrigla brachyoptera	scaly gurnard	SCG	6
Pterygotrigla picta	spotted gurnard	JGU	10
Hoplichthyidae: ghostflatheads			
Hoplichthys haswelli	deepsea flathead	FHD	20
Psychrolutidae: toadfishes			
Ambophthalmos angustus	pale toadfish	TOP	2
Neophrynichthys latus	dark toadfish	TOD	1
Polyprionidae: wreckfishes			
Polyprion oxygeneios	hapuku	HAP	12
Serranidae: sea basses			
Callanthias allporti	southern splendid perch	SDP	1
Lepidoperca aurantia	orange perch	OPE	10
Apogonidae: cardinalfishes			
Epigonus denticulatus	white cardinalfish	EPD	1
E. lenimen	bigeye cardinalfish	EPL	14
E. telescopus	black cardinalfish	EPT	2
Emmelichthyidae: rovers			

Emmelichthys nitidus	redbait	RBT	35
Carangidae: jacks, pompanos			
Seriola lalandi	kingfish	KIN	1
Trachurus declivis	greenback jack mackerel	JMD	8
T. murphyi	slender jack mackerel	JMM	7
Bramidae: pomfrets			
Brama australis	southern Ray's bream	SRB	3
Pentacerotidae: armorheads			
Pentaceros decacanthus	yellow boarfish	YBO	24
Cheilodactylidae: morwongs			
Nemadactylus macropterus	tarakihi	NMP	16
Percophidae: opalfishes			
Hemerocoetes spp.	opalfish	OPA	1
Uranoscopidae: armourhead stargazers			
Kathetostoma giganteum	giant stargazer	GIZ	29
Gempylidae: snake mackerels			
Rexea solandri	gemfish	RSO	40
Thyrsites atun	barracouta	BAR	14
Trichiuridae: cutlassfishes			
Benthodesmus spp.	scabbard fish	BEN	9
Lepidopus caudatus	frostfish	FRO	18
Scombridae: mackerels and tunas			
Scomber australasicus	blue mackerel	EMA	1
Centrolophidae: raftfishes, medusafishes			
Centrolophus niger	rudderfish	RUD	3
Seriolella caerulea	white warehou	WWA	5
S. punctata	silver warehou	SWA	35
S. brama	common warehou	WAR	2
Tubbia tasmanica	Tasmanian ruffe	TUB	1
Nomeidae: eyebrowfishes, driftfishes			
Cubiceps spp.	cubehead	CUB	1
Bothidae: lefteyed flounders			
Arnoglossus scapha	witch	WIT	5
Diodontidae: porcupinefishes			
Allomycterus pilatus	porcupine fish	POP	2

APPENDIX 6: Species code changes

Species name	Species code	Notes
Giant stargazer	GIZ	Coded as STA in 2000; Coded as GIZ from 2012 survey; Recoded 2000 as GIZ
Gemfish	RSO	Coded as SKI in 2000; Coded as RSO from 2012 survey; Recoded 2000 as RSO
Tarakihi	NMP	Coded as TAR in 2000; Coded as NMP from 2012 survey; Recoded 2000 as NMP
Catfish	APR	Coded as APR in 2000, 2012, 2013, 2016 APR split to 6 species AEX, AAM, AGK, AML, APN, ASI AEX caught in 2018 and recoded as APR
Johnson's cod	HJO	Coded as HJO in 2000, 2012, 2013, 2016 HJO split to 2 species HAS and HJC HAS caught in 2018 and recoded as HJO
Sea perch	SPE	Coded as SPE in 2000, 2012, 2013, 2016 SPE split to 2 species HBA and HPC HBA and HPC recoded as SPE in 2018