Fisheries New Zealand
Tini a Tangaroa

Trawl survey for middle depth fish species off the west coast South Island, July–August 2024 (TAN2407)

New Zealand Fisheries Assessment Report 2025/41

J.A. Devine,
S.L. Ballara,
A.M. Wieczorek

ISSN 1179-5352 (online)
ISBN 978-1-991380-91-3 (online)

September 2025

Te Kāwanatanga o Aotearoa
New Zealand Government

Disclaimer

This document is published by Fisheries New Zealand, a business unit of the Ministry for Primary Industries (MPI). The information in this publication is not government policy. While every effort has been made to ensure the information is accurate, the Ministry for Primary Industries does not accept any responsibility or liability for error of fact, omission, interpretation, or opinion that may be present, nor for the consequence of any decisions based on this information. Any view or opinion expressed does not necessarily represent the view of Fisheries New Zealand or the Ministry for Primary Industries.

Requests for further copies should be directed to:

Fisheries Science Editor
Fisheries New Zealand
Ministry for Primary Industries
PO Box 2526
Wellington 6140
NEW ZEALAND

Email: Fisheries-Science.Editor@mpi.govt.nz
Telephone: 0800 00 83 33

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications
http://fs.fish.govt.nz go to Document library/Research reports

Please cite this report as:

Devine, J.A.; Ballara, S.L.; Wieczorek, A.M. (2025). Trawl survey for middle depth fish species off the west coast South Island, July–August 2024 (TAN2407). *New Zealand Fisheries Assessment Report 2025/41.* 93 p.

TABLE OF CONTENTS

PLAIN LANGUAGE SUMMARY

A combined trawl-acoustic survey was carried out off the west coast South Island (WCSI) from 21 July to 13 August 2024. It was the 7th trawl survey, targeting primarily hake and ling, and the 12th acoustic survey for hoki.

Estimated ling biomass in 2024 was the lowest of the trawl time series (which started in 2000), while hake biomass has increased since 2016. A total of 242 species or species groups were caught.

The acoustic estimate of hoki biomass was the second lowest of the time series (which started in 1988) but showed an increase since the previous acoustic survey in 2018.

Bottom temperatures have been warming since 2012, mainly in the northern strata. Hake, ling, and hoki appear to have shifted deeper and into cooler water.

EXECUTIVE SUMMARY

Devine, J.A.[1]; Ballara, S.L.; Wieczorek, A.M. (2025). Trawl survey for middle depth fish species off the west coast South Island, July–August 2024 (TAN2407).

***New Zealand Fisheries Assessment Report 2025/41.* 93 p.**

A combined trawl-acoustic survey was carried out off the west coast South Island (WCSI) from 21 July to 13 August 2024. This was the seventh in a time series of trawl estimates for middle depth species from the WCSI, with previous surveys in 2000, 2012, 2013, 2016, 2018, and 2021, and the 12th acoustic survey for hoki (*Macruronus novaezelandiae*), comparable to hoki acoustic surveys in 1988–2000, 2012, 2013, and 2018. Species monitored by the trawl survey include important commercial species such as hake (*Merluccius australis*) and ling (*Genypterus blacodes*), as well as a wide range of non-commercial fish and invertebrate species.

A total of 64 successful trawl survey tows were completed in 13 strata, two of which were phase-two stations for hake, and seven were in the deepwater exploratory strata added to the survey design in 2021. One acoustic snapshot was achieved for the northern acoustic strata, while two were achieved for the southern strata (Hokitika Canyon and south). Six target identification tows were completed in the southern hoki acoustic strata.

The estimate of hake biomass from strata consistently sampled since 2012 (200–800 m) increased in the last three surveys but was still lower than the level observed in 2012. The 2024 hake biomass estimate for the core 300–650 m survey area, sampled since 2000, was the lowest observed in the series. Estimated ling biomass in 2024 was the lowest observed in the series. Trawl estimates of hoki, giant stargazer, dark ghost shark, lookdown dory, spiny dogfish, sea perch and silver warehou biomass also declined in 2024, and for dark ghost shark, spiny dogfish, and sea perch were the lowest of the time series.

Hoki biomass estimated from the acoustic component of the survey was the second lowest of the time series but was 10% higher than that from the previous acoustic survey in 2018. Hoki abundance was highest in the inner Hokitika Canyon and in stratum 4, and lowest in the northernmost strata and outer Hokitika Canyon. Abundance in Hokitika Canyon was the lowest observed since 1992.

Bottom temperatures have been warming since 2012, after an initial cooling period, and the effect has been greater in the northern bottom trawl strata compared to the southern strata. The effect on catch rates of bottom temperature and depth of capture was investigated for hake, ling, and hoki using data from consistently sampled strata. While the analysis was not comprehensive, indications were that the species distributions had shifted deeper and into cooler water, suggesting that changes are occurring and should be investigated further.

[1] All authors: National Institute of Water and Atmospheric Research (NIWA), New Zealand.

1. INTRODUCTION

The west coast South Island (WCSI) contains the main fishery for spawning hoki, but it is also a key fishery area for hake and ling, and a number of other middle depth species. The WCSI hake fishery (HAK 7) is the largest hake fishery in New Zealand while the WCSI ling fishery (LIN 7) is the third largest (behind LIN 5 and LIN 6). The ling fishery is certified as sustainable by the Marine Stewardship Council, but the HAK 7 fishery was withdrawn from certification in 2019.

A series of acoustic surveys targeting hoki were carried out on the WCSI from 1988–2000 (reviewed by O'Driscoll 2002). However, the abundance indices were uncertain 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 measure 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 survey 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 and concluded that trawl estimates from the northern area did not appear to be providing reliable indices of hoki abundance. 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.

Three further WCSI trawl surveys have been carried out in 2016, 2018, and 2021 with a focus on hake and ling, and included deeper strata (800–1000 m) (Devine et al. 2022, O'Driscoll & Ballara 2018, 2019). The deeper strata added in 2016 improved the survey coverage for ribaldo, shovelnose dogfish, and other deepwater shark species, and also revealed that there was a large amount of hake deeper than 800 m, with between 20% and 38% of the estimated total hake biomass coming from the new deep strata (O'Driscoll & Ballara 2018, 2019). The 2021 survey also included two additional exploratory strata, extending the survey between 1000 and 1050 m in the southwest and between 650 and 800 m in the northwest, in which hake were caught (Devine et al. 2022).

In addition to supporting the stock assessments for these two Tier 1 deepwater fisheries, the trawl survey also provides information on a number of bycatch species including lookdown dory, sea perch, javelinfish, dark ghost shark, ribaldo, and several deepwater shark species. 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 (e.g., length, weight, sex, reproductive condition, and, in some cases, age). Trawl estimates provide data that could be used in the future to develop species-based, size-based, and trophodynamic ecosystem indicators.

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. 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, application of trawl survey indices for the entire WCSI (or FMA 7) relies on the assumption that a constant proportion of the stock resides within the northern trawlable area. Concerns exist over the representativeness of the survey for hake, including use of the deepwater strata, because the survey does not monitor in or south of Hokitika Canyon (Fisheries New Zealand 2024).

There was no acoustic survey component to the 2016 or 2021 surveys. In 2018, NIWA received MBIE funding to add 4 days to the 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 hoki on the WCSI consistent with those obtained in 1998–2013 (O'Driscoll & Ballara 2018). This 2018 acoustic index has been incorporated in the hoki stock assessment since 2020 (Fisheries New Zealand 2020). The acoustic objective was reincorporated in 2024.

1.1 Project objectives

This is one of five trawl surveys contracted under project MID2021–02, which includes the 2022 and 2024 Sub-Antarctic surveys (Overall Objective 1), 2024 and 2026 Chatham Rise surveys (Overall Objective 2), and the 2024 West Coast South Island survey (Overall Objective 3). Stock assessments of hake, ling, and hoki are based, in part, on the relative abundance indices from these regularly occurring trawl survey time series.

This report is the final reporting requirement for Fisheries New Zealand Research Project MID2021–02. The overall aim of Objective 3 is to continue a time series of relative abundance indices for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) off the west coast South Island (June/July 2024). The specific objectives were as follows:

1. To estimate relative abundance indices for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) off the west coast South Island with a target coefficient of variation (CV) of the estimate of 30%.

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

3. To collect acoustic and related data during the trawl survey.

4. To collect and preserve specimens of unidentified organisms taken during the trawl survey for later identification ashore.

5. To carry out an acoustic snapshot comparable to hoki acoustic surveys in 1988–2000, 2012, 2013, and 2018.

6. Broader objectives: To collect data to increase New Zealand's understanding of the wider marine ecosystem and support an ecosystem approach to fisheries management.

2. METHODS

2.1 Objective 1: Trawl survey

2.1.1 Survey design

A key aspect of the survey design was to ensure consistency with trawl surveys completed in 2000, 2012, 2013, 2016, 2018, and 2021. This required the survey to be carried out from RV *Tangaroa* using the same trawl gear used for previous surveys. To allow comparability with results from the previous surveys, the trawl survey component also needed to be carried out in July–August, the period when commercial catches and catch rates are highest (O'Driscoll et al. 2015b). The trawl estimate is based on a stratified random trawl survey design (after Francis 1984).

Survey timing

The 2024 survey was carried out during 21 July – 13 August, which was approximately the same period as in previous surveys in 2000 (25 July to 31 August), 2012 (22 July to 14 August), 2013 (1–18 August), 2016 (2–20 August), 2018 (24 July to 16 August), and 2021 (2–20 August). The survey period aligned with the timing of highest historic commercial catches and catch rates (O'Driscoll et al. 2015b). With the exception of jack mackerel, most of the catch of other deepwater species off the WCSI is taken in the June to September period of the hoki fishery, with little catch outside this period.

Stratum definitions

The trawl survey area in 2012, 2013, 2016, 2018, and 2021 (Table 1, Figure 1) 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). Changes were made to the survey area in 2012 to improve coverage of other key species, particularly hake and ling, including:

- 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 2016 survey (Table 1, Figure 1) and, based on suggestions by the Deepwater Working Group (DWWG_2021_103, 2 July 2021), two exploratory strata (4G, 1000–1050 m depth and 1&2D, 650–800 m) were added to the 2021 survey to better determine the distribution of hake.

The 2024 survey covered the same 11 strata and two exploratory deepwater strata that were surveyed in 2021 (Table 1, Figure 1).

Table 1: Stratum depth ranges, areas, and numbers of planned and completed stations for the 2024 west coast South Island trawl survey. Trawl station locations are shown in Figure 1 with station details in Appendix 2.

				Completed stations		
Stratum number	Depth range (m)	Area (km^2)	Phase 1 allocation	Phase 1	Phase 2	Total
1&2S	200–300	1 450	3	3	–	3
1&2A	300–430	1 214	12	11	–	11
1&2B	430–500	1 028	8	8	–	8
1&2C	500–650	3 148	5	5	–	5
1&2D	650–800	3 569	4	4	–	4
4S	200–300	1 600	3	3	–	3
4A	300–430	786	7	8	–	8
4B	430–500	592	3	3	–	3
4C	500–650	1 455	3	3	–	3
4D	650–800	1 655	5	5	2	7
4E	800–900	1 192	3	3	–	3
4F	900–1 000	2 097	3	3	–	3
4G	1 000–1 050	2 242	4	3	–	3
Total		22 028	63	62	2	64

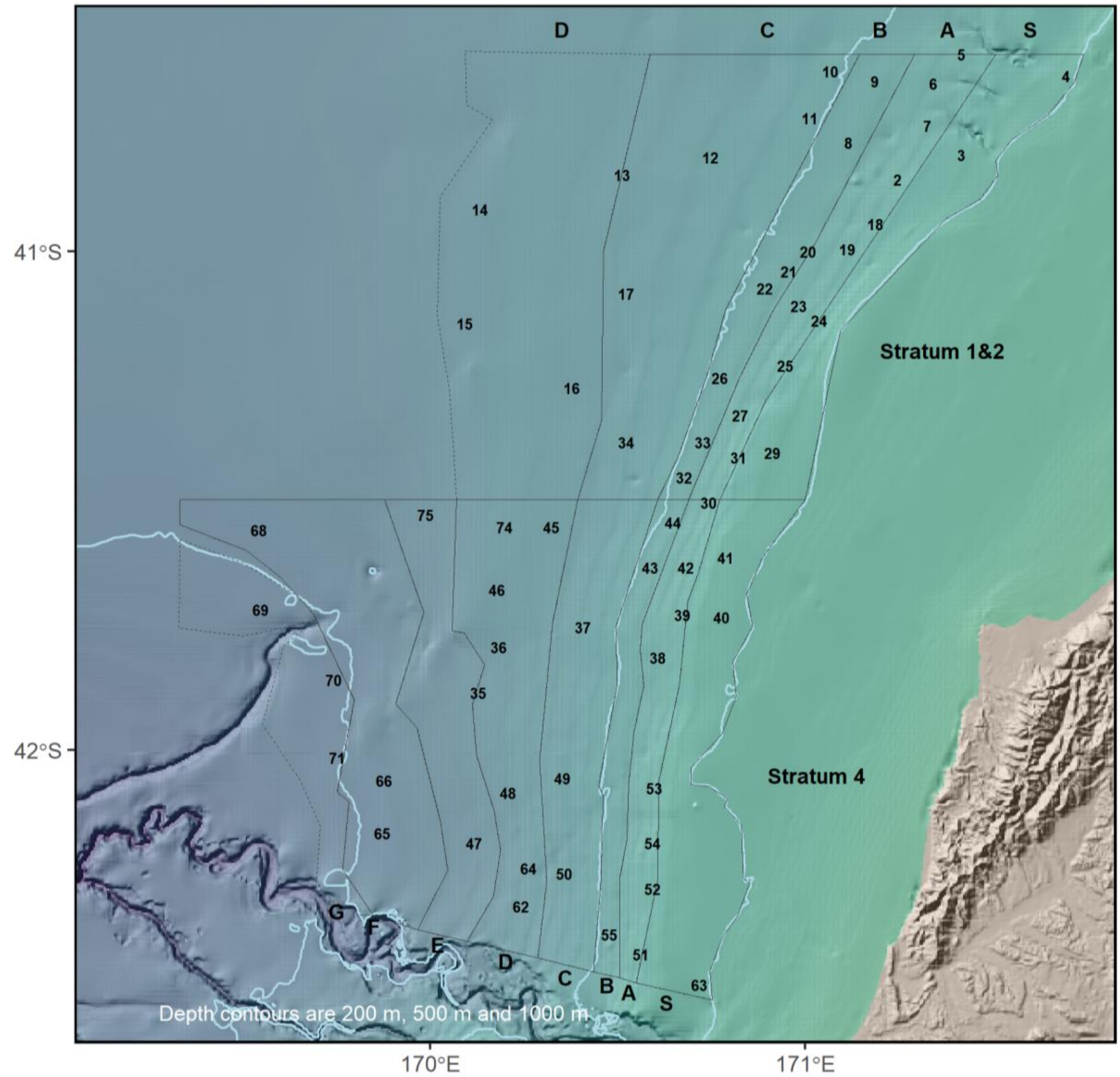


Figure 1: Trawl survey area stratum boundaries and positions of tows conducted during the 2024 survey. For estimation of biomass, experimental strata (4G and 1&2D). Station details are given in Appendix 2.

Number of stations

A total of 63 phase-one stations were planned, based on a statistical analysis of catch rate data from the 2012, 2013, 2016, 2018, and 2021 surveys using the *allocate* programme (Francis 2006) (Table 1). A minimum of 3 and a maximum of 12 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, as in previous years, we believed that the Fisheries New Zealand stated target CV of 30% would not provide sufficient certainty for ongoing monitoring and assessment. Four tows were arbitrarily assigned to each of the deep exploratory strata, outside the statistical allocation process. This will be done until this survey provides enough data to include the deep exploratory strata in the allocation process in the future. Hoki were included in the allocation process because the Deepwater Working Group has considered using these trawl indices in the hoki assessment for the WCSI north sub-fishery. In previous surveys, there was no allowance for phase-two stations. If phase-two stations were needed to reduce the CVs of hake or ling and if time permitted, phase-two stations would be allocated but at the cost of reducing stations in the exploratory strata.

This allocation gave a similar number of phase-one stations to that achieved in 2018 and 2021 for all strata except the deep exploratory strata. In 2021, total CVs were 18% for ling and 20% for hake (Devine et al. 2022).

Table 2: Estimated number of stations required to achieve a target CV (in parentheses) for hake (HAK), ling (LIN), hoki (HOK), giant stargazer (GIZ), sea perch (SPE), lookdown dory (LDO), dark ghost shark (GSH), silver warehou (SWA), and spiny dogfish (SPD) are given by stratum. Four tows were arbitrarily assigned to each of the deep exploratory strata, outside of the statistical allocation process.

	Number of tows									
Stratum	HAK (20%)	LIN (20%)	HOK (25%)	SWA (30%)	GIZ (25%)	SPD (30%)	SPE (25%)	LDO (25%)	GSH (25%)	Max
1&2S	3	3	3	3	3	3	3	3	3	3
1&2A	3	12	4	3	3	3	3	3	5	12
1&2B	3	3	8	3	3	3	3	3	3	8
1&2C	5	3	4	3	3	3	3	3	3	5
1&2D										4
4S	3	3	3	3	3	3	3	3	3	3
4A	3	7	5	3	3	7	3	3	4	7
4B	3	3	3	3	3	3	3	3	3	3
4C	3	3	3	3	3	3	3	3	3	3
4D	5	3	3	3	3	3	3	3	3	5
4E	3	3	3	3	3	3	3	3	3	3
4F	3	3	3	3	3	3	3	3	3	3
4G										4
Total	37	46	42	33	33	37	33	33	36	63

2.1.2 Vessel and trawling equipment

RV *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.

2.1.3 Trawling procedure

Random trawling followed the standardised procedures described by Hurst et al. (1992). Station positions were generated randomly before the voyage using the Random Stations Generation Program (Version 1.6) developed by NIWA (Doonan & Rasmussen 2017). A minimum distance of 3 n. miles between tows was used. If a station was found to be on foul ground, a search was made for suitable ground within a 3 n. mile radius 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 which, at this time of year, was between 0758 h and 1730 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 were covered.

Measurements of doorspread and headline height (from a Simrad TV80 Trawl Eye net monitoring system) and vessel speed (GPS speed over the ground, cross checked against distance travelled during the tow) were recorded every five minutes during each tow and average values were 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).

2.1.4 Estimation of biomass

Doorspread biomass was estimated by the swept area method of Francis (1981, 1989) using the formula given by Vignaux (1994) as implemented in the analysis programme *SurvCalc* (Francis 2009). Relative 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. Lacking information on these factors, all were set at one for the analysis, with 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.

2.1.5 Species distribution

Catch rates were calculated for the key species with *SurvCalc.* Catch rates and distributions were mapped for the survey series for the main species.

2.2 Objective 2: Biological data collection

2.2.1 Biological sampling

Biological sampling procedures followed standardised procedures outlined by Hurst et al. (1992). All items in the catch were sorted into species and weighed on Marel motion-compensating electronic scales which are accurate to 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 (Objective 4).

Table 3: Details of biological sampling for key species during the survey.

Species	Length	Weight	Sex	Stage	Gonad weight	Liver weight	Gutted weight	No. otolith per tow
Hake	200	All	All	All	All	–	–	All*
Ling	200	20	20	20	20	–	–	20
Silver warehou	200	20	20	20	–	–	–	20 (fish > 25 cm)
Lookdown dory	200	20	20	20	–	–	–	20
Ribaldo	200	20	20	20	–	–	–	20
Alfonsino	200	20	20	20	–	–	–	20
Gemfish	200	20	20	20	–	–	–	20
Sea perch†	200	20	20	20	–	–	–	20
Hoki	200	20	20	20	20	20	20	0

* Up to a maximum of 200 fish per station.
† Expected to be mainly the deeper living bigeye seaperch, *Helicolenus barathri*.

An approximately random sample of up to 200 individuals of each commercial and some common non-commercial species were measured from each successful tow. More detailed biological data were collected on a subset of species, including fish weight, sex, gonad stage, and gonad weight (Table 3). A description of the macroscopic gonad stages used for teleosts and elasmobranchs is given in Appendix 1. Data on liver condition of hoki were collected by recording gutted and liver weights at sea, from up to 20 hoki per station. Otoliths were collected from all hake caught, up to a maximum of 200 fish per tow. Otoliths were collected from subsamples of other species except hoki; sufficient hoki otoliths are collected from the WCSI commercial fishery that is taking place at the same time as the survey (Table 3). The otoliths were cleaned, dried, and stored in suitably labelled envelopes at sea for further processing ashore. Individuals of species were weighed using motion-compensated scales.

Trawl data were entered in real time using the electronic data capture system onboard the *Tangaroa* and were error-checked at sea. Final error checking was done on land prior to loading of data into the *trawl* database.

2.2.2 Estimation of length and age frequencies

Scaled population length frequencies were calculated for the key species with *SurvCalc*. Length-weight parameters used in *SurvCalc* were calculated using length-weight data collected from the relevant species from this survey (Table 4, Appendix 7).

Hake and ling otoliths were prepared and aged using validated ageing methods (hake, Horn 1997; ling, Horn 2021). Otoliths were selected based on 1-cm length classes, roughly in proportion to their occurrence in the scaled length frequency, with the constraint that at least one otolith per length class (where available) was selected. All otoliths from the extreme right-hand tail of the scaled length frequency distribution were fully sampled (i.e., the last 2% of the length frequency distribution) and clear juvenile length modes were under-sampled by taking only 2–3 otoliths per length class. This sampling procedure was thought to be more likely to provide a sample with a mean weighted CV better than that from proportional sampling, particularly for the older age classes. The target mean-weighted CV for ageing for both species was 30%.

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).

Table 4: Length-weight regression parameters used to scale length frequencies for species for which the survey was optimised. Where data source is given as 'All WCSI *Tangaroa* surveys', parameters were estimated from combined data from the 2000, 2012, 2013, 2016, 2018, 2021 and 2024 surveys.

		Regression parameters					
Common name	Code	*a*	*b*	r^2	*n*	Length range (cm)	Data source
Hake	HAK	0.002109	3.285539	97.69	657	30.7–115.6	TAN2407
Ling	LIN	0.000895	3.370826	98.58	434	33.2–154	TAN2407
Hoki	HOK	0.004343	2.927529	97.79	506	32.3–110.2	TAN2407
Dark ghost shark	GSH	0.002134	3.250052	97.99	176	27.9-76.3	TAN2407
Giant stargazer	GIZ	0.004407	3.343893	95.33	163	31.2–79.9	TAN2407
Lookdown dory	LDO	0.023386	2.960251	98.71	576	10.9–57.7	TAN2407
Sea perch	SPE	0.014062	3.000215	97.56	795	9.5–48.5	TAN2407
Silver warehou	SWA	0.005148	3.332548	97.97	2 586	21.6–58.8	All WCSI *Tangaroa* surveys
Spiny dogfish	SPD	0.000480	3.516412	88.38	1 289	43–96.5	All WCSI *Tangaroa* surveys

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

2.3 Objective 3: Other data collection

Acoustic data were recorded during the normal trawl survey operations on the hull-mounted multifrequency echosounder system on RV *Tangaroa*. This consisted of five synchronised Simrad EK80 echosounders (18, 38, 70, 120, and 200 kHz) operated as detailed in Table 5, which were calibrated both before and after the survey following standard procedures outlined in Demer et al. (2015) (Appendix 3).

Recordings were made during trawls and when steaming between stations (day and night). Acoustic data provided information on the amount of backscatter that was not available to the bottom trawl, either through being off the bottom, or over areas of foul ground, and aided in interpretation of trawl survey results. In the future, acoustic estimates of mesopelagic fish may also be important when developing a trophic ecosystem model (e.g., O'Driscoll et al. 2011).

Table 5: EK80 settings used during acoustic data collection.

Frequency (kHz)	18	38	70	120	200
Transducer model	ES18-11	ES38B	ES70-7C	ES120-7C	ES200-7C
Transmit power (W)	1 000	2 000	750	250	150
Mode	CW	CW	CW	CW	CW
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Sample interval (ms)	0.256	0.256	0.256	0.256	0.256

Data on temperature and salinity were collected as part of routine trawl survey operations using a calibrated Seabird SM-37 Microcat conductivity-temperature-depth (CTD) profiler mounted on the headline of the trawl. Data were collected at 6-second intervals throughout the trawl, which provided vertical hydrographic profiles from the surface to about 7.0 m above the seabed (i.e., the height of the headline). These data provided information about the oceanographic environment over the survey area, which can be related to trawl survey results, and measurements of sound speed for calibration of the acoustic systems.

2.4 Objective 4: Collection of specimens

All catch was taken under NIWA's special permit No. 841 (valid until 30 September 2027). NIWA has approved biosecurity holding facilities for biological materials that cannot be imported under the fisheries provision to the Biosecurity Act 2012.

2.5 Objective 5: Acoustic survey

2.5.1 Survey Design

The survey design was similar to that used for the combined trawl and acoustic survey of the WCSI in 2013 and 2018 (O'Driscoll et al. 2015a, O'Driscoll & Ballara 2019). Acoustic transects for hoki were conducted at night in the trawl survey area and an additional four days were used to survey the area of Hokitika Canyon and further south (Strata 5A, 5B, 6, and 7, Figure 2), where hoki are also abundant. The aim was to complete at least one snapshot of the acoustic survey area (Figure 2), comparable to hoki acoustic surveys in 1988–2000, 2012, 2013, and 2018.

The proposed and completed acoustic transects for this survey are shown in Table 6. The allocation of proposed transects was based on previous acoustic surveys (O'Driscoll 2002). Transects were run at 6–10 knots using the RV Tangaroa hull-mounted EK80 system (dependent on weather and sea conditions). Placement of transects within strata was randomly generated and carried out at right angles to the depth contours.

Table 6: Proposed and completed transect allocation for the 2024 WCSI acoustic survey by stratum. Stratum locations are shown in Figure 2.

		Proposed			Completed	
Stratum	Area (km^2)	Snapshot 1	Snapshot 2	Snapshot 3	Snapshot 1	Snapshot 2
1&2	5 390	4	3–5	3–5	4	4
4	4 488	8	7–9	7–9	8	8
5A	254	7	6–8	6–8	7	7
5B	529	3	3–4	3–4	3	4
6	2 165	9	8–10	8–10	9	9
7	565	4	3–5	3–5	4	4
Total	13 391	35	30–41	30–41	35	36

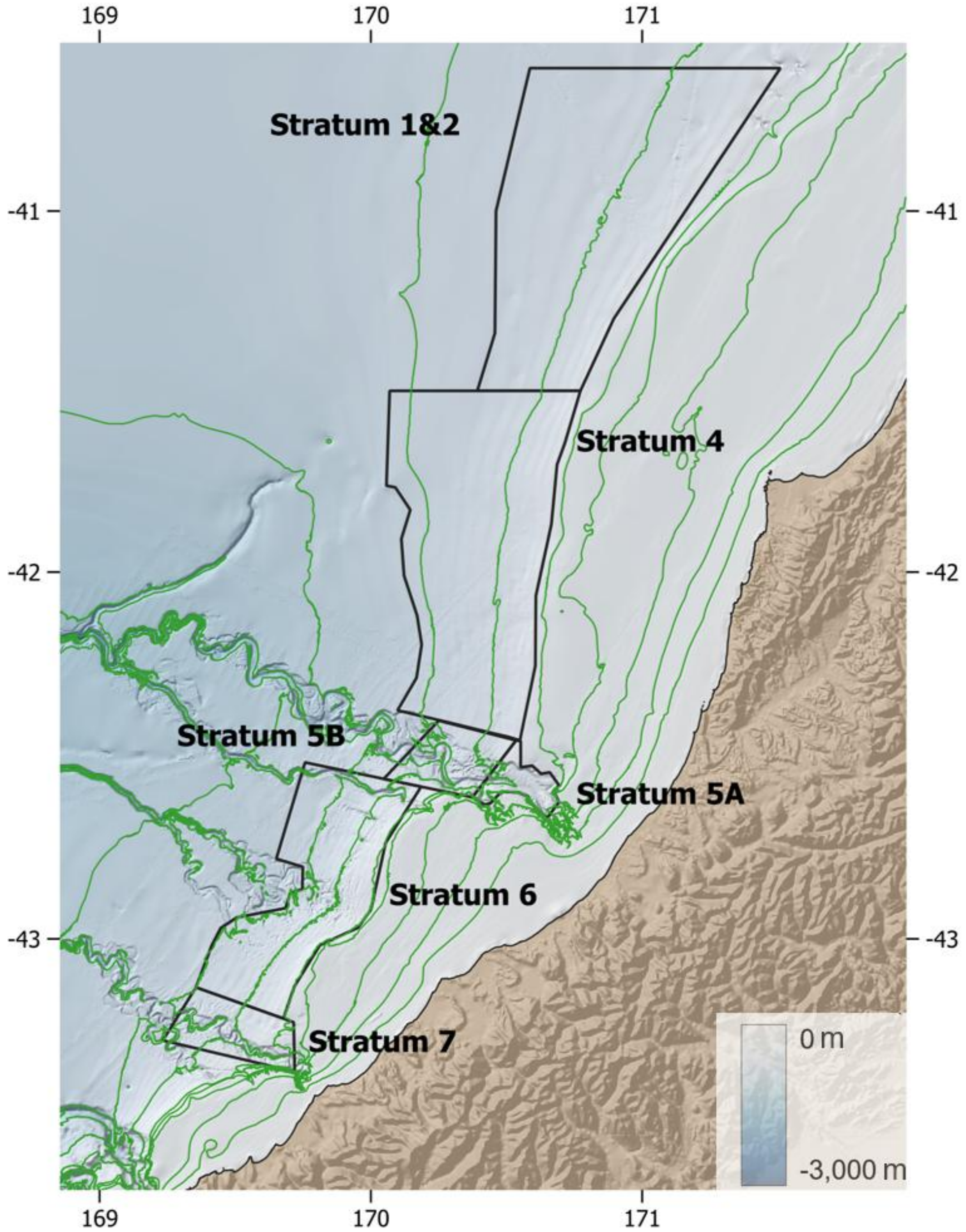


Figure 2: Proposed stratum boundaries for the 2024 WCSI acoustic survey. Stratum areas are given in Table 6.

2.5.2 Acoustic data analysis

Acoustic data collected during the survey were analysed using standard echo-integration methods (MacLennan & Simmonds 1992), as implemented in NIWA's Echo Sounder Package (ESP3) software (Ladroit et al. 2020).

Hoki abundance in 2018 and 2024 was estimated using the 'revised' method described by O'Driscoll et al. (2015a) and summarised in Table 7. 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:

$$\mathrm{TS} = 24.5 \log 10(\mathrm{TL}) - 83.9 \quad (1)$$

Table 7: Summary of 'revised' acoustic method used to estimate hoki abundance from the 2018 and 2024 WCSI acoustic

Parameter	'Revised'
Sound absorption	8.88 dB km-1 (Table A3.2)
Hoki TS used to estimate abundance	Dunford et al. (2015)
Hoki length-weight	Francis (2003)
Hoki length distribution	2024 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 2
Stratum areas	Table 6
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)

2.5.3 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 below.

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 currently) than on 38 kHz, possibly because the swimbladders of the small pelagic species involved resonate at these lower frequencies (Bull 2000). 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. Mark classification was generally easier at night when pelagic layers migrated towards the surface, and hoki aggregations moved up off the bottom allowing more separation of mark types. Random trawl survey tows in the northern area were useful for mark identification of daytime bottom fuzz marks and were used extensively in decomposition of species mix. Separating different mark types was not always straightforward and was subjective; however, mark classification was carried out by a senior acoustician who has consistently classified hoki marks from this survey.

2.5.4 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 m^2 of area). Acoustic density was derived two ways: (i) average acoustic density over each transect and substratum was calculated; and (ii) 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.

2.5.5 Species decomposition

Ideally, all species could be distinguished acoustically and classified separately, so all backscatter from hoki marks came from hoki, and there were no hoki present in other marks. In reality, species mixes occur. The approaches to resolve species mix in hoki acoustic surveys varied 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 (1):

$$p_i = \frac{c_i \sigma_i}{\sum_{i=1}^{n} c_i \sigma_i} \qquad (2)$$

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 were 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) and best available target strength-length relationships as listed in Table 8.

Table 8: Mean fish size and derived target strength (TS) for species used in species decomposition. Smooth skate, sea perch and other bottom-dwelling species were also an important part of the catch (see Table 13) but were not included in the species decomposition as it was assumed that these species were in the acoustic "deadzone" close to the bottom. Minor species were considered as a group ('Other'), and an average TS was assigned.

	Mean length+	Mean weight+	TS+	TS-length relationship*	
Species name	(cm)	(kg)	(dB kg^{-1})	*a*	*b*
Hoki	71	1.0	-39.8	24.5	83.9
Ling	99	3.6	-29.6	20	68
Hake	72	2.8	-33.2	27.1	83.5
Silver warehou	50	2.4	-46.0	20	80
Spiny dogfish	67	1.5	-43.3	20	80
Javelinfish	33	0.1	-43.8	20	73.5
Bollon's rattail	40	0.3	-38.2	20	70
Lookdown dory	30	0.8	-34.0	20	64
Silver dory	18	0.1	-38.7	20	64
Dark ghost shark	45	1.2	-45.3	20	80
Ribaldo	45	0.7	-32.2	21.7	66.7
Alfonsino	20	0.2	-41.7	20	68
Pale ghost shark	60	1.2	-44.6	20	80
School shark	100	7.9	-38.5	20	80
Leafscale gulper shark	124	12.7	-38.1	20	80
Shovelnose dogfish	84	2.6	-41.1	20	80
Gemfish	54	1.4	-34.6	20	70
Other	–	–	-35.2	–	–

* TS = *a* $\log_{10}$ (length) – *b*. Best estimates from *in situ* measurements, swimbladder modelling, or related species.
+ Values of mean length, weight, and TS were estimated by substratum, but averages across all strata are summarised here.

Hoki TS in species decomposition in 2024 was estimated using Equation 1. The TS-TL relationship of Coombs & Cordue (1995) (equation 3) 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 1) 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).

$$\mathrm{TS} = 22.32 \log10(\mathrm{TL}) - 79.84 \quad (3)$$

2.5.6 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) using:

1. the length frequency distribution of the commercial catch from the year of the survey;

2. the generic length-weight regression of Francis (2003) to determine mean hoki weight (w in kilograms)

$$w = (4.79 * 10^{-6})L^{2.89} \quad (4)$$

3. the most recent TS-length relationship for New Zealand hoki (Equation 1).

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 6) were used to estimate abundance. Stratum estimates were combined to produce snapshot estimates, and the snapshots were averaged to obtain the abundance index for 2024.

2.5.7 Coefficient of variation estimation

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, O'Driscoll et al. 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, and
- acoustic calibration.

The method has two main steps. First, a probability distribution was created for each of the variables of interest. Then 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 9. This model was then 'sampled' at dates equivalent to the mid dates of each snapshot (Table 10). 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 was estimated by resampling with replacement (bootstrapping) from the observations (tows) within a substratum. 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 8). 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. Weightings were calculated for abundance estimates from the northern (strata 1&2 and 4) and southern (strata 5A, 5B, 6, and 7) areas. The CV for the total area is not the simple sum of squares because errors in the northern and southern areas are not independent.

Table 9: Values of parameters and their distributions used in Monte Carlo uncertainty simulations to estimate weighting (CV) of WCSI acoustic survey abundance indices

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	id_{mix}	Lognormal	0 (0.3) +
Mark identification – 'hoki' strataq	id_{hoki}	Lognormal	0 (0.08)
Calibration (1988–90)	$cal_{88\text{-}90}$	Uniform	0.75–1.25
Calibration (1991–99)	$cal_{91\text{-}99}$	Uniform	0.88–1.12
Calibration (post 2000)	$cal_{00\text{-}01}$	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 standard deviation (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).

Table 10: Summary of acoustic snapshots and mark identification tows in 2024 WCSI survey. North area includes strata 1&2 and 4. South area includes strata 5A, 5B, 6, and 7.

Snapshot	Area	Transect start time	Transect end time	No. of transects	No. of trawls
1	North	28 Jul 22:27	3 Aug 00:01	44	42
	South	3 Aug 17:34	6 Aug 01:08	23	3
2	South	6 Aug 01:20	08 Aug 06:59	23	3
Total				90	48

2.6 Objective 6: Broader outcomes

The current level of biological sampling on the WCSI surveys is among the most comprehensive of any New Zealand survey (O'Driscoll et al. 2015b). All items in the catch were sorted and weighed, and random samples of most fish species were measured and sex determined.

Of the types of ecosystem information suggested by Fisheries New Zealand, this survey routinely collected the following:

- detailed information on non-Quota Management fish species;
- specimens of unidentified organisms for identification by experts and retention for the invertebrate collection (Objective 4);
- acoustic data collected within and between trawl tows;
- physical data (temperature and salinity) at depth; and
- unusual or rare specimens for Te Papa.

As requested by the Deepwater Working Group, the number of otoliths collected from silver warehou was increased from 10 fish to 20 fish per tow for a future stock assessment, and for gemfish, particularly at the tails of the length distribution.

Biological sampling and retention of unidentifiable (at sea) or unique organisms was outlined in Section 2.2.1. Additional sampling was conducted for shark reproductive status, cephalopods, and mesopelagic species for DNA barcoding.

Only a subset of species is included in Fisheries Assessment Reports (FARs) from each survey. All information from all species will be made more widely available through a searchable web-based portal (https://tsip-uat.niwa.co.nz/). This web-based portal is made possible by the development of R code to produce consistent, standardised outputs with embedded metadata from trawl surveys and is intended to make quality-assured information from trawl surveys much more widely available to Fisheries New Zealand, stakeholders, and other scientists.

NIWA also mentors and develops students through university programs and internships. As such, one AUT doctoral student working on population genetics of arrow squids and one NIWA Te Kūwaha intern joined the survey.

3. RESULTS

3.1 Objective 1: Trawl survey

3.1.1 Trawl data collection

Weather conditions during the voyage were generally good; although several weather systems passed through the survey area, with winds of 30 to 40 knots, which delayed survey operations for several hours on three separate days (Figure 3), for a total loss of approximately 24 hours trawling time. Some of the lost time was able to be compensated for by completing more than four tows on 6 separate days.

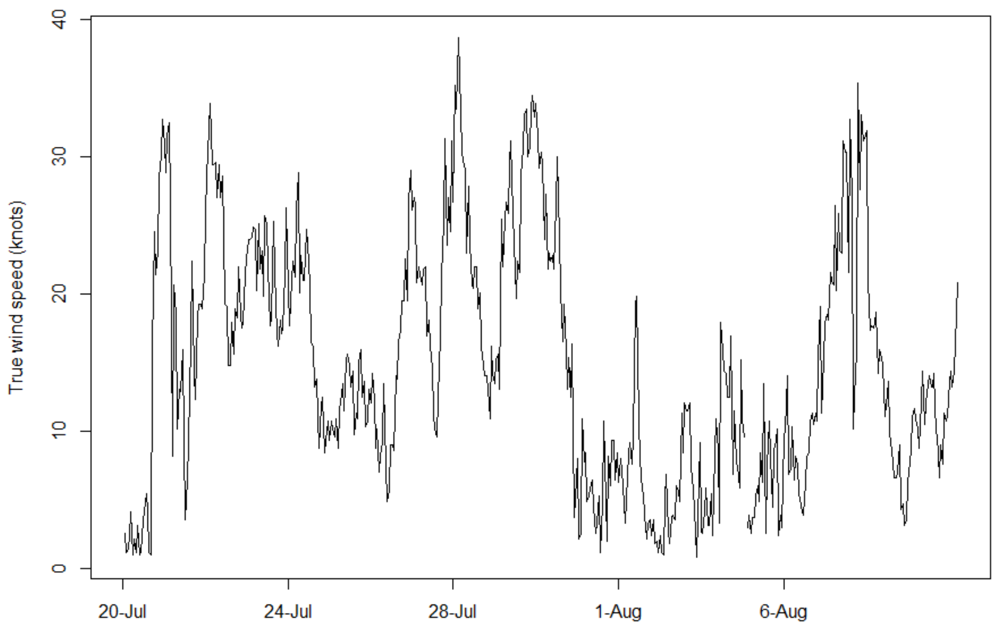


Figure 3: Mean hourly wind speed (knots) during the 2024 WCSI survey. Wind data was taken from the Tangaroa automatic weather station and was corrected for vessel speed.

A total of 64 successful trawl survey tows were completed in 13 strata, two of which were phase-two stations for hake, and seven were in the deepwater exploratory strata added to the survey design in 2021 (Table 1, Figure 1). This included 62 of the 63 phase-one stations; a station in stratum 4G, the deep exploratory stratum, had to be dropped because of time constraints imposed by poor weather conditions. The decision was made to conduct the phase-two stations for hake before completing all survey stations because time constraints would not have permitted the vessel returning to stratum 4D.

One tow, station 28, was a foul shot and had to be repeated (station 29, Figure 1) as the trawl winches malfunctioned and caused the doors to cross. A station in stratum 1&2A had crossed the stratum boundary into stratum 4A and slightly more than half of the tow length was in the southern stratum, therefore that station was allocated to stratum 4A for the biomass estimation.

Individual station details from all tows, including the catch of hoki, ling, and hake are listed in Appendix 2.

Gear performance

Gear parameters by depth for valid trawl survey tows are summarised in Table 11. Headline height and doorspread readings were obtained for all valid tows. Measured gear parameters in 2024 were within the range of those obtained on valid tows from the 2000–21 surveys, where the same gear was used (Table 12), although headline height was slightly lower on average than in 2012–16. Mean doorspread distances and headline heights for the 2024 survey were also consistent with those from recent *Tangaroa* hoki and middle depths time-series surveys on the Chatham Rise (Stevens et al. 2024) and Sub-Antarctic (Stevens et al. 2022).

Table 11: Survey tow and gear parameters (recorded values only) for valid tows on the 2024 trawl survey (includes exploratory tows from strata 1&2D and 4G). Values are number of tows (*n*), and the mean, standard deviation (s.d.), and range of observations for each parameter.

	Depth range (m)	*n*	Mean	s.d.	Range
Tow length (n. miles)	All tows 200–1 050	64	3.0	0.40	2.1–3.8
Tow speed (knots)	All tows 200–1 050	64	3.5	0.08	3.0–3.6
Headline height (m)	200–300	6	6.9	0.45	6.4–7.5
	300–650	38	6.7	0.27	6.3–7.2
	650–800	11	6.9	0.26	6.6–7.6
	800–1 000	6	6.8	0.15	6.5–6.9
	All tows 200–1 050	64	6.8	0.29	6.3–7.6
Doorspread (m)	200–300	6	109.6	7.48	100.3–118.8
	300–650	38	121.8	7.37	104.0–133.9
	650–800	11	123.8	7.10	117.2–137.8
	800–1 000	6	126.8	4.86	120.7–132.9
	All tows 200–1 050	64	121.7	8.06	100.3–137.8

Table 12: Comparison of doorspread and headline height measurements from valid trawl survey tows from the *Tangaroa* WCSI time series (excludes exploratory tows from strata 1&2D or 4G in 2021 and 2024). 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
2021	60	123.1	7.12	103.4	136.2	6.7	0.25
2024	57	121.3	8.36	100.3	137.8	6.8	0.30

3.1.2 Catch composition

A total catch of 30 525.7 kg was recorded from the trawl survey component. From the 242 species or species groups caught during the trawl survey, 124 were teleosts, 28 elasmobranchs, 5 holocephalans, 15 cephalopods, 23 echinoderms, and 23 crustaceans; the remainder comprised assorted benthic and pelagic animals (Appendix 4).

Hoki accounted for 28.3%, ling 9.3%, hake 9.8%, gemfish 11.8%, giant stargazer 4.2%, lookdown dory 3.4%, and silver warehou 2.0% of the total catch from all trawl survey tows (Table 13). No spiny dogfish were caught. Other species for which the survey was optimised (Table 2) made up less than 1% of the total catch.

An additional 2929.8 kg was caught in acoustic identification trawl tows and 16.6 kg in mesopelagic midwater trawl tows (details in Sections 3.5 and 3.6).

Table 13: Total catch of the top 50 species by weight from all tows during the 2024 WCSI trawl survey.

Species	Common name	Scientific name	Catch (kg)
HOK	Hoki	*Macruronus novaezelandiae*	8 653.5
RSO	Gemfish	*Rexea solandri*	3 594.3
HAK	Hake	*Merluccius australis*	2 985.6
LIN	Ling	*Genypterus blacodes*	2 824.3
GIZ	Giant stargazer	*Kathetostoma giganteum*	1 285.5
LDO	Lookdown dory	*Cyttus traversi*	1 047.7
SND	Shovelnose dogfish	*Deania calcea*	958.7
SSK	Smooth skate	*Dipturus innominatus*	715.7
SWA	Silver warehou	*Seriolella punctata*	615.9
NMP	Tarakihi	*Nemadactylus macropterus*	560.6
BAR	Barracouta	*Thyrsites atun*	558.6
WHX	White rattail	*Trachyrincus aphyodes*	504.1
CSQ	Leafscale gulper shark	*Centrophorus squamosus*	484.4
CYO	Smooth skin dogfish	*Centroscymnus owstoni*	381.1
NSD	Northern spiny dogfish	*Squalus griffini*	305.0
RIB	Ribaldo	*Mora moro*	272.8
HBA	Bigeye sea perch	*Helicolenus barathri*	272.7
CBO	Bollon's rattail	*Coelorinchus bollonsi*	229.6
SQU	Arrow squid	*Nototodarus sloanii & N. gouldi*	224.4
SRH	Silver roughy	*Hoplostethus mediterraneus*	218.0
YBO	Yellow boarfish	*Pentaceros decacanthus*	204.4
JAV	Javelinfish	*Lepidorhynchus denticulatus*	202.7
SCH	School shark	*Galeorhinus galeus*	181.6
SOR	Spiky oreo	*Neocyttus rhomboidalis*	162.9
GSH	Dark ghost shark	*Hydrolagus novaezealandiae*	162.0
BSL	Black slickhead	*Xenodermichthys copei*	147.7
FRO	Frostfish	*Lepidopus caudatus*	137.9
SWO	Broadbill swordfish	*Xiphias gladius*	130.0
OPE	Orange perch	*Lepidoperca aurantia*	122.7
GSP	Pale ghost shark	*Hydrolagus bemisi*	118.6
HAP	Hāpuku	*Polyprion oxygeneios*	118.5
NOS	NZ southern arrow squid	*Nototodarus sloanii*	116.5
SSH	Slender smooth-hound	*Gollum attenuatus*	94.8
CAR	Carpet shark	*Cephaloscyllium isabella*	82.2
ORH	Orange roughy	*Hoplostethus atlanticus*	81.7
MRQ	Slender clubhook squid	*Onykia robsoni* & *O.* sp. A	81.4
SCO	Swollenhead conger	*Bassanago bulbiceps*	77.9
PLS	Plunket's shark	*Proscymnodon plunketi*	70.3
RBY	Rubyfish	*Plagiogeneion rubiginosum*	67.5
BEE	Basketwork eel	*Diastobranchus capensis*	65.2
SSM	Smallscaled brown slickhead	*Alepocephalus antipodianus*	62.3
SBI	Bigscaled brown slickhead	*Alepocephalus australis*	61.8
JDO	John dory	*Zeus faber*	61.0
EUC	Eucla cod	*Euclichthys polynemus*	57.5

Species	Common name	Scientific name	Catch (kg)
NOG	NZ northern arrow squid	*Nototodarus gouldi*	53.4
CYP	Longnose velvet dogfish	*Centroscymnus crepidater*	46.0
COL	Oliver's rattail	*Coelorinchus oliverianus*	45.3
SDO	Silver dory	*Cyttus novaezealandiae*	43.9
FHD	Deepsea flathead	*Hoplichthys haswelli*	39.0
RCH	Pacific spookfish	*Rhinochimaera pacifica*	37.9
Total			29 627.1

3.1.3 Species distribution and catch rates

The time series of catch distributions for hake, ling, and hoki are shown in Figure 4. Time series for other species that the survey is optimised for are shown in Appendix 5. Results from all species are found on the trawl portal (https://tsip-uat.niwa.co.nz/search).

Hake mainly occurred deeper than 500 m, with highest catch rates in 650–800 m in stratum 1&2D and 4D, where the two largest catches were taken in 2024 (Figure 4). Catch rates have typically been highest in the southern strata (4) except in 2021; catches were notably lower in the northern strata (1&2) in 2024 (Figure 4). Hake catches were highest in stratum 4C in 2000, 2012, and 2013, but have been noticeably lower after 2013.

Ling catch rates were highest between 300–430 m, strata 1&2A and 4A (Figure 4, Table 1). Ling were predominantly in strata 4A in the 2021 survey but appeared to be again shifting southward in 2024.

Hoki catch rates were highest in 430–500 m in the north (stratum 1&2B) but were deeper (500–650 m) in the south (stratum 4C, Figure 4). Historically, hoki were mainly caught in the 430–650 m depth range with a very small amount of catch taken at most deeper stations.

The highest catch rates of giant stargazer were in the shallow southern strata (200–300 m, stratum 4S) (Appendix 5), which was similar to the 2018 survey but different to the 2021 survey when they were more widespread (Appendix 5). Dark ghost shark were mainly caught in the north in 300–650 m (strata 1&2A–C) in 2021, but were again more widespread in the south in 2024 (Appendix 5). Lookdown dory were caught in 300–800 m throughout the survey area (strata A–D; Appendix 5). Sea perch (combined species) were mainly distributed deeper than 300 m in the northern strata (strata 1&2A–D) but were also in shallower southern strata in lower amounts. Silver warehou were caught in small amounts to 1000 m depth, with highest catch rates in 300–430 m (strata 1&2A, 4A). Spiny dogfish were not caught at any stations in 2024 (Appendix 5).

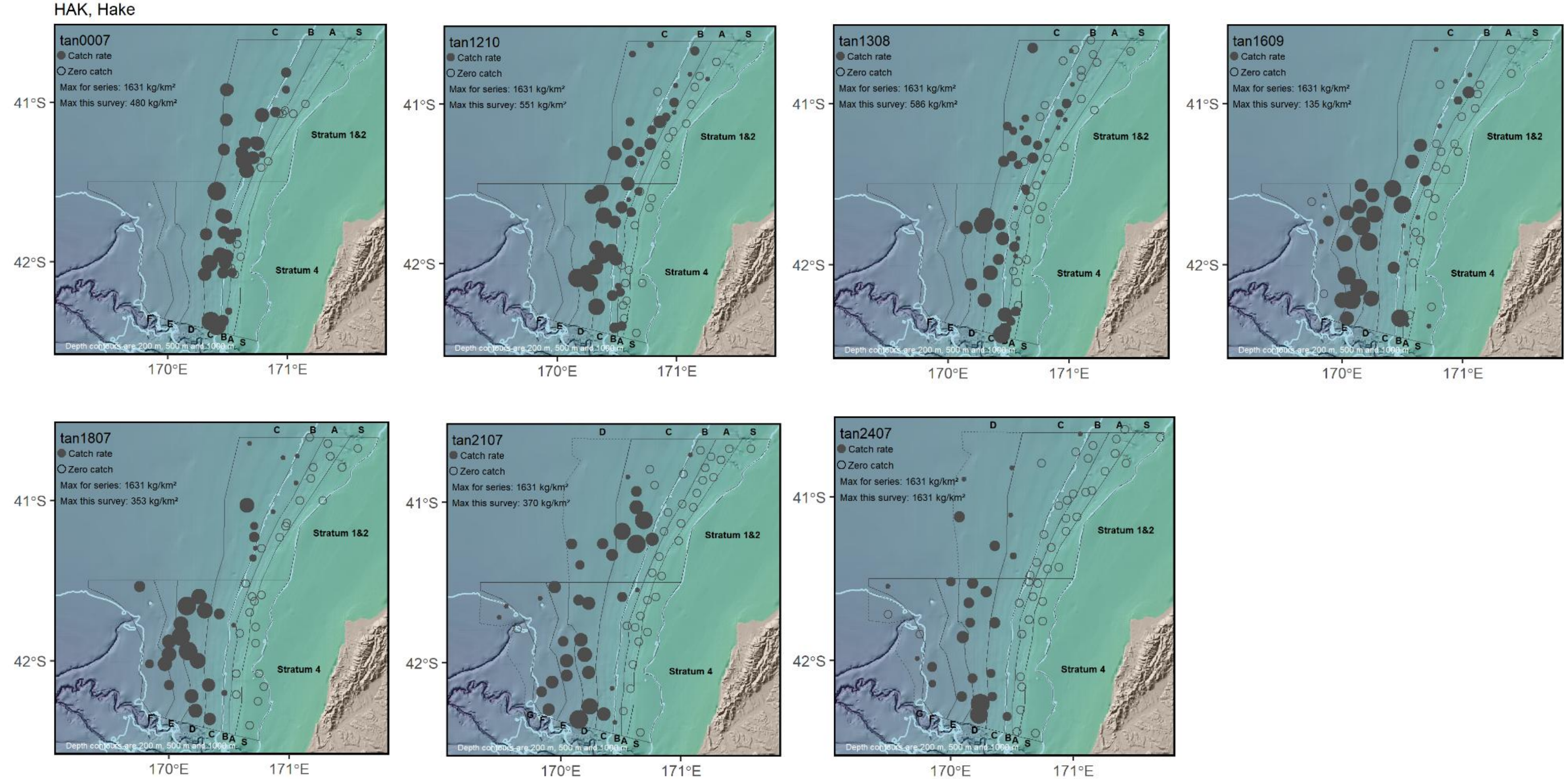


Figure 4: **Distribution and catch rates of hake, ling, and hoki for the WCSI trawl survey time series. Exploratory strata are indicated by dashed lines. Circle area is proportional to catch rate. Open circles indicate zero catches. 'Max for series' is the maximum catch rate for all WCSI surveys, 'Max this survey' is the maximum catch rate for the given survey.**

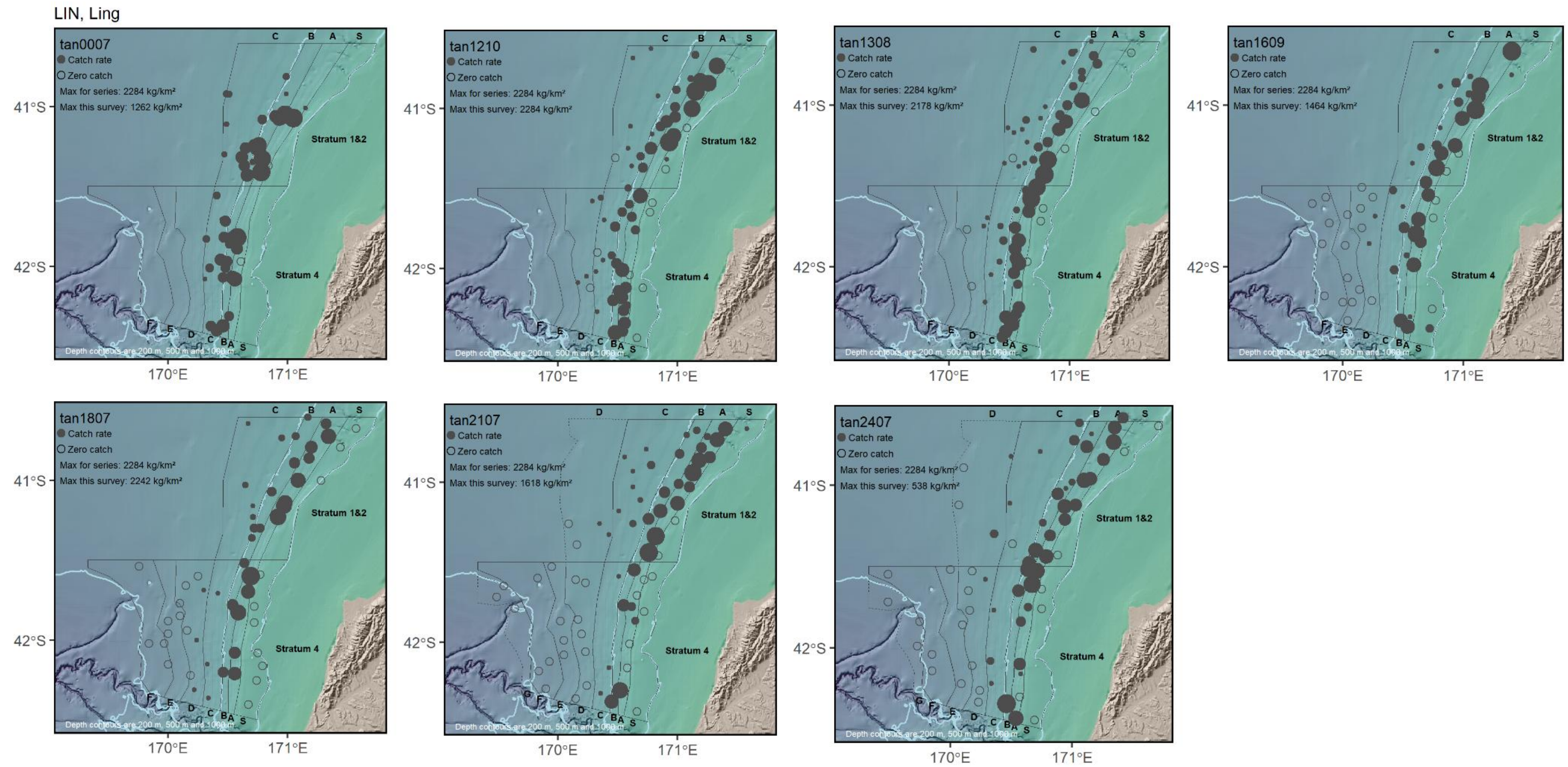


Figure 4: **(continued).**

HOK, Hoki

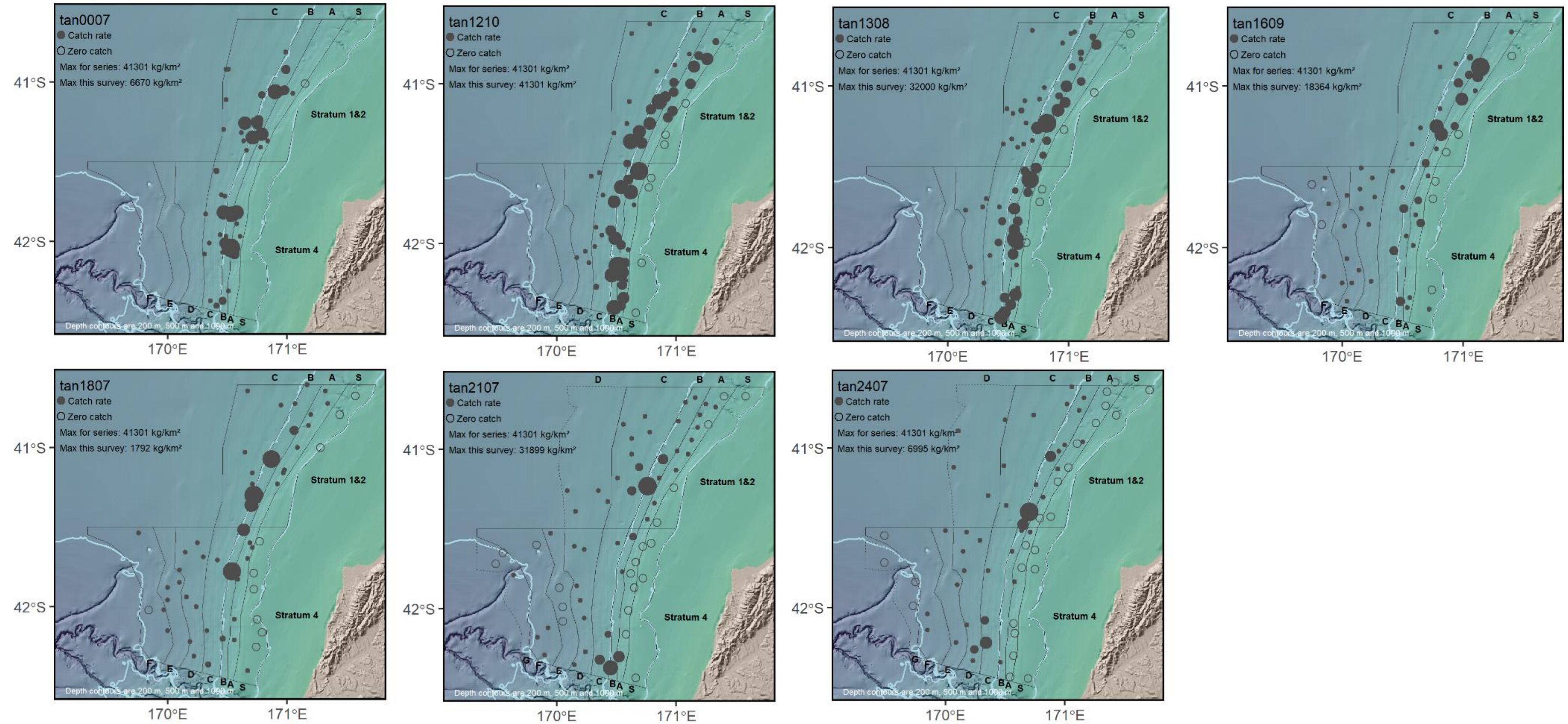


Figure 4: (continued).

3.1.4 Relative biomass estimates

Trawl survey catch and biomass estimates for species for which the survey was optimised in the core (300–650 m), all (200–800 m), deep plus (200–1000 m), and ex strata (deep strata plus exploratory strata) are given in Table 14. Note that 'core' refers to strata sampled in 2000, and 'all' refers to strata that have been consistently sampled since 2012. All other species can be found on the portal (https://tsip-uat.niwa.co.nz/search).

The biomass estimate for hake in all strata was 891 t (CV 45%), substantially higher than the core strata estimate, while the deep plus strata estimate was 22% greater than that from all consistently sampled strata (Table 14). The two phase-two tows reduced the CV for hake from 54.8% to 45.2% in the 200–800 m strata. However, a catch of 1.26 t of hake at the first phase-two station meant that the CV was not reduced as much as hoped for.

The estimated biomass for ling in the all strata was 612 t (CV 16%) (Table 14). Very few ling were caught in the deep (800–1000 m) strata, which meant that the core strata biomass estimate of ling was very similar to the consistently sampled strata estimate.

Target CVs were met for ling (target 20%), big-eye sea perch (*Helicolenus barathri*), lookdown dory, dark ghost shark (all target 25%), and silver warehou (target 30%), but exceeded for hake (target 20%), hoki (target 25%), and giant stargazer (target 25%). For the first time, no spiny dogfish were caught on this survey.

Biomass estimates for the species for which the survey was optimised by stratum are given in Table 15. No hake or ling were caught in the 200–300 m shallow strata 4S and 1&2S (Table 15, Figure 5). Stratum 1&2A accounted for 28% of the ling biomass in 2024, which was a decrease from 2021 (57%) and the lowest observed biomass in this stratum since 2012, when this stratum contributed 49–70% of the total ling biomass. In the northern strata, ling were caught in the exploratory deep strata 1&2D, in slightly greater amounts than in 2021 (Figure 5). Hake were again abundant in strata deeper than 500 m but were less abundant in 1&2C and more abundant in the southern strata (4D) than in 2021 (Figure 5). The shallow strata of 200–300 m accounted for most of the biomass of giant stargazer, gemfish, barracouta, tarakihi, and school shark, but giant stargazer, gemfish, and school shark biomass was higher in deeper strata than previous surveys (Figure 5, https://tsip-uat.niwa.co.nz/search). Silver warehou, lookdown dory, dark ghost shark, and bigeye sea perch (*Helicolenus barathri*) biomass was higher in the northern strata (Figure 5). The deep exploratory strata 1&2D and 4G had higher biomass estimates for white rattail, ribaldo, and shovelnose dogfish than other strata (https://tsip-uat.niwa.co.nz/search). These deep exploratory strata accounted for 16% of the hake and lookdown dory biomass, 34% of shovelnose dogfish, and 28% of bigeye sea perch biomass.

Trawl survey biomass estimates from 2024 for species for which the survey was optimised were compared with previous survey estimates in the WCSI time series in Table 16 and Figure 6. Hake biomass estimated in the all area has been increasing since the 2016 survey but was still lower than the levels observed in 2012. Ling biomass has steadily declined and the 2024 estimate was the lowest in the time series. Although the survey is not thought to be a good index of hoki biomass, the trawl biomass estimate declined in 2024; the 2021 estimate was the highest observed since 2013. Giant stargazer, dark ghost shark, lookdown dory, spiny dogfish, sea perch and silver warehou biomass declined in 2024, and for dark ghost shark, spiny dogfish, and sea perch, to the lowest estimated biomass of the time series.

Table 14: Catch and relative biomass estimates with coefficient of variation (CV in parentheses) for species for which the survey was optimised (Table 2), ranked by biomass, for valid trawl tows in: Core strata (300–650 m); All strata consistently sampled since 2012 (200–800 m); Deep + strata (200–1000 m); Ex + strata (deep strata plus exploratory tows in 2024). –, zero catch or biomass.

Species	Common	Catch (kg)				Biomass (t)			
code	name	Core	All	Deep +	Ex +	Core	All	Deep +	Ex +
HAK	Hake	211.8	2 517.6	2 827.4	2 985.6	139.4 (26.1)	891.3 (45.2)	1 089.5 (37.4)	1 300.5 (32.2)
LIN	Ling	2 799.8	2 800.3	2 800.3	2 824.3	611.7 (16.0)	611.9 (16.0)	611.9 (16.0)	643.1 (16.0)
HOK	Hoki	7 700.3	8 469.0	8 496.8	8 653.5	2 749.1 (38.0)	2 996.3 (35.1)	3 013.7 (34.9)	3 213.8 (32.9)
GIZ	Giant stargazer	481.0	1 285.5	1 285.5	1 285.5	96.7 (19.5)	813.1 (29.8)	813.1 (29.8)	813.1 (29.8)
LDO	Lookdown dory	932.4	997.3	1 000.4	1 047.7	304.3 (12.0)	326.6 (11.6)	328.3 (11.5)	388.9 (11.4)
SWA	Silver warehou	595.1	609.6	611.6	615.9	115.6 (23.2)	122.1 (22.1)	123.0 (21.9)	128.6 (21.4)
HBA	Bigeye sea perch	214.8	246.5	249.6	272.7	65.2 (11.6)	75.9 (10.1)	77.6 (10.1)	107.9 (10.5)
GSH	Dark ghost shark	154.7	162.0	162.0	162.0	29.9 (23.0)	35.7 (22.5)	35.7 (22.5)	35.7 (22.5)
HPC	Sea perch	15.2	26.8	26.8	26.8	2.6 (63.1)	11.5 (60.9)	11.5 (60.9)	11.5 (60.9)
SPD	Spiny dogfish	–	–	–	–	–	–	–	–

Table 15: Relative biomass (t) and coefficient of variation (% CV) for species for which the 2024 survey was optimised (Table 2), by stratum. Anything with less than 0.1 t total not shown. See Table 1 for stratum codes and Table 14 for species common names. Value of * indicates biomass less than 0.1 t; –, indicates zero biomass.

Species	Core strata							All strata				Deep strata			Ex strata		
code	1&2A	1&2B	1&2C	4A	4B	4C	Total	1&2S	4S	4D	Total	4E	4F	Total	1&2D	4G	Total
HAK	–	–	22.3	–	9.8	107.2	139.4	–	–	751.8	891.3	128.5	69.7	1 089.5	206.8	4.2	1 300.5
			(67.3)		(100.0)	(29.6)	(26.1)			(53.4)	(45.2)	(39.0)	(56.4)	(37.4)	(46.6)	(100.0)	(32.2)
LIN	173.5	82.3	67.8	103.6	167.7	16.7	611.7	–	–	0.2	611.9	–	–	611.9	31.3	–	643.1
	(11.0)	(28.5)	(49.8)	(35.9)	(46.2)	(81.4)	(16.0)			(100.0)	(16.0)			(16.0)	(98.9)		(16.0)
HOK	3.2	1 223.9	364.1	0.8	107.4	1 049.7	2 749.1	–	–	247.2	2 996.3	12.0	5.3	3 013.7	200.1	–	3 213.8
	(62.3)	(71.4)	(29.9)	(97.7)	(53.4)	(53.2)	(38.0)			(54.4)	(35.1)	(53.6)	(50.3)	(34.9)	(41.3)		(32.9)
GIZ	29.9	3.6	–	29.7	29.6	3.9	96.7	38.8	677.6	–	813.1	–	–	813.1	–	–	813.1
	(28.0)	(44.3)		(25.0)	(49.1)	(100.0)	(19.5)	(34.0)	(35.5)		(29.8)			(29.8)			(29.8)
LDO	13.3	101.3	99.4	7.4	23.2	59.6	304.3	–	–	22.4	326.6	1.7	–	328.3	60.6	–	388.9
	(59.2)	(16.6)	(29.6)	(58.6)	(27.6)	(14.2)	(12.0)			(43.2)	(11.6)	(100.0)		(11.5)	(37.9)		(11.4)
SWA	58.5	8.5	12.1	24.9	4.9	6.7	115.6	0.6	1.8	4.1 (42.4)	122.1	0.9	–	123.0	5.6	–	128.6
	(40.4)	(36.2)	(30.6)	(38.0)	(40.1)	(100.0)	(23.2)	(100.0)	(100.0)		(22.1)	(100.0)		(21.9)	(100.0)		(21.4)
HBA	7.6	18.1	24.4	1.8	9.9	3.4	65.2	–	*	10.6	75.9	1.7	–	77.6	30.4	–	107.9
	(24.9)	(15.7)	(23.8)	(30.7)	(33.3)	(14.6)	(11.6)			(12.7)	(10.1)	(100.0)		(10.1)	(26.8)		(10.5)
GSH	12.4	10.3	4.2	2.7	0.3	–	29.9	2.5	3.3	–	35.7	–	–	35.7	–	–	35.7
	(29.8)	(33.1)	(100.0)	(75.2)	(100.0)		(23.0)	(100.0)	(100.0)		(22.5)			(22.5)			(22.5)
SPD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

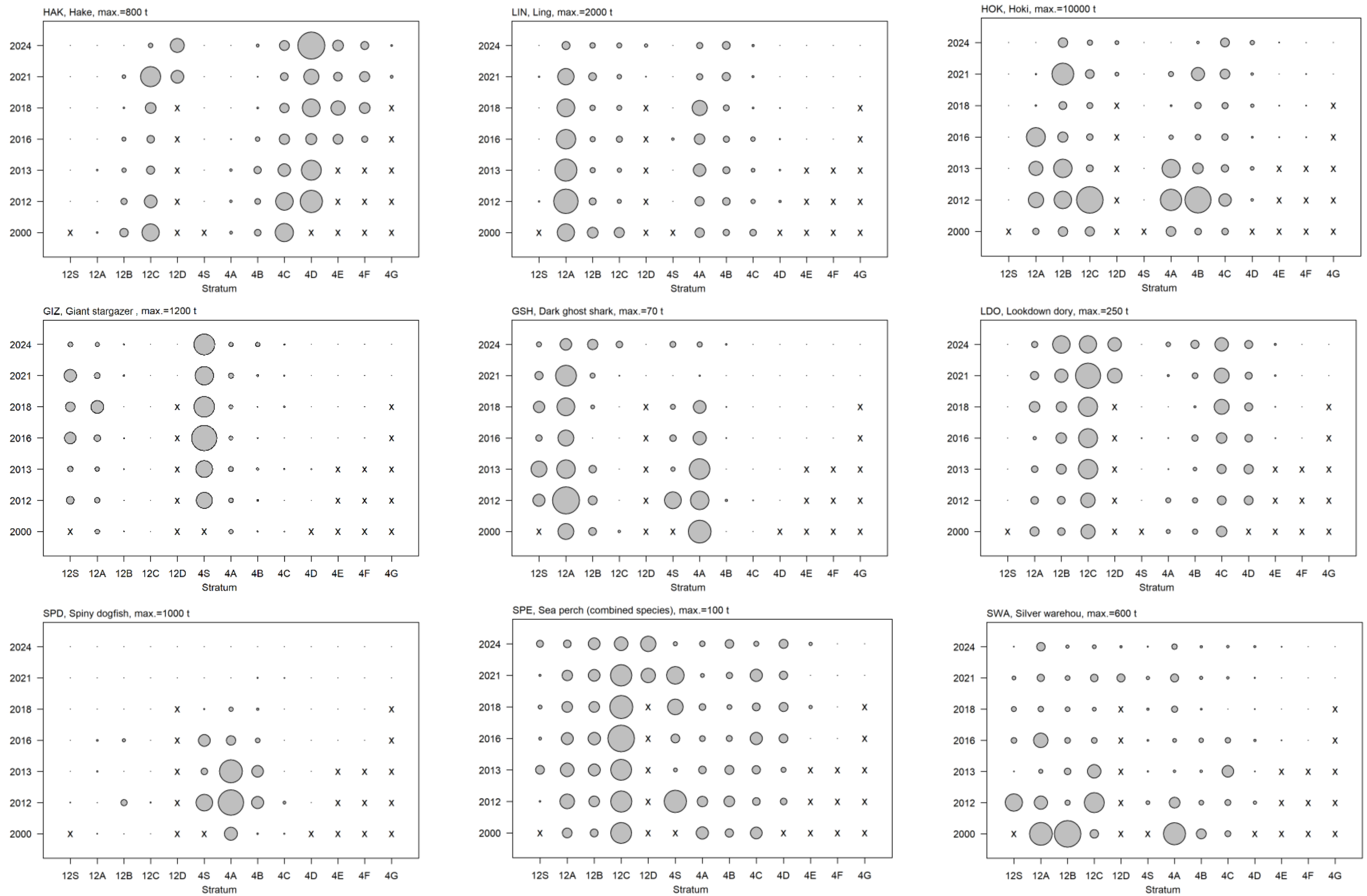


Figure 5: Relative biomass estimates by stratum and survey year for species for which the survey was optimised (Table 2) for the WCSI trawl survey time series. See Appendix 9 for species changes or combined groups. × indicates stratum not surveyed in that year.

Table 16: Relative biomass estimates, coefficients of variation comparisons for species for which the 2024 survey was optimised (Table 2) from all WCSI trawl surveys from: the Core strata (300–650 m); All strata consistently sampled since 2012 (200–800 m); Deep + strata (200–1000 m); and Deep plus ex strata including exploratory tows. The 2000 survey biomass estimates were re-calculated using 2012–13 stratum areas. See Appendix 9 for species code changes or combinations. Value of * indicates biomass less than 0.1 t; -, zero biomass.

Species	Core							All						Deep +				Deep plus ex	
code	2000	2012	2013	2016	2018	2021	2024	2012	2013	2016	2018	2021	2024	2016	2018	2021	2024	2021	2024
HAK	803.1	582.8	330.9	221.5	229.2	506.6	139.4	1 102.6	747.1	354.7	559.2	747.3	891.3	502.4	899.4	939.4	1 089.5	1 123.8	1 300.5
	(13.4)	(12.8)	(17.4)	(23.9)	(32.6)	(33.9)	(26.2)	(13.0)	(21.3)	(16.1)	(17.6)	(24.6)	(45.2)	(12.6)	(13.9)	(19.9)	(37.4)	(16.8)	(32.2)
LIN	1 860.9	2 168.8	2 000.4	1 635.4	1 682.4	1 230.7	611.7	2 194.1	2 008.6	1 661.0	1 686.5	1 237.4	611.9	1 661.0	1 686.5	1 237.4	611.9	1 240.0	643.1
	(17.3)	(14.8)	(18.4)	(12.7)	(18.3)	(17.7)	(16.0)	(14.7)	(18.3)	(12.5)	(18.3)	(17.7)	(16.0)	(12.5)	(18.3)	(17.7)	(16.0)	(17.6)	(16.0)
HOK	5 384.7	32 494.7	14 183.9	7 733.6	2 484.2	10 961.6	2 749.1	32 601.8	14 356.5	7 797.4	2 636.4	11 069.8	2 996.3	7 829.9	2 661.1	11 083.1	3 013.7	11 289.4	3 213.8
	(20.6)	(24.2)	(26.9)	(35.7)	(14.2)	(52.9)	(38.0)	(24.1)	(26.5)	(35.4)	(13.6)	(52.4)	(35.1)	(35.3)	(13.5)	(52.3)	(34.9)	(51.3)	(32.9)
GIZ	73.9	97.4	92.2	107.0	295.2	120.9	96.7	608.1	592.0	1 326.8	1 118.9	917.7	813.1	1 326.8	1 118.9	917.7	813.1	917.7	813.1
	(27.3)	(22.6)	(21.8)	(19.9)	(54.7)	(17.6)	(19.5)	(24.8)	(21.4)	(19.2)	(20.5)	(21.7)	(29.8)	(19.2)	(20.5)	(21.7)	(29.8)	(21.7)	(29.8)
GSH	76.8	106.3	75.3	39.4	46.3	42.4	29.9	146.2	100.5	47.6	60.5	48.9	35.7	47.6	60.5	48.9	35.7	48.9	35.7
	(32.5)	(16.9)	(21.4)	(16.6)	(18.0)	(24.9)	(23.0)	(15.1)	(20.2)	(15.3)	(14.2)	(22.9)	(22.5)	(15.3)	(14.2)	(22.9)	(22.5)	(22.9)	(22.5)
LDO	169.1	154.6	205.4	209.9	270.6	374.3	304.3	181.4	236.1	229.7	292.4	391.0	326.6	230.1	292.8	392.1	328.3	463.3	388.9
	(14.4)	(11.9)	(11.1)	(12.2)	(21.7)	(15.6)	(12.0)	(10.6)	(11.6)	(11.4)	(20.2)	(15.0)	(11.6)	(11.3)	(20.2)	(14.9)	(11.5)	(16.2)	(11.4)
SPD	233.4	1 095.1	866.7	172.7	35.5	4.4	–	1 452.7	927.5	357.8	38.5	4.4	–	357.8	38.5	4.4	–	4.4	–
	(53.6)	(24.7)	(29.0)	(16.8)	(39.8)	(73.0)		(22.6)	(27.2)	(43.3)	(37.1)	(73.0)		(43.3)	(37.1)	(73.0)		(73.0)	
SPE	123.3	136.1	126.2	157.6	114.9	117.3	67.7	205.5	142.2	179.3	158.9	166.3	87.4	179.4	160.5	166.4	89.1	193.3	119.5
	(6.8)	(15.9)	(9.2)	(18.6)	(16.8)	(9.7)	(11.5)	(26.9)	(9.8)	(17.2)	(16.7)	(23.7)	(11.9)	(17.2)	(16.5)	(23.7)	(11.9)	(21.0)	(11.2)
SWA	1 506.5	617.3	313.5	271.2	90.5	176.3	115.6	876.8	317.5	305.8	117.7	199.4	122.1	306.4	117.7	199.9	123.0	252.2	128.6
	(24.6)	(32.2)	(22.7)	(36.5)	(20.6)	(12.1)	(23.2)	(26.5)	(22.4)	(33.4)	(22.4)	(12.4)	(22.1)	(33.3)	(22.4)	(12.4)	(21.9)	(15.5)	(21.4)

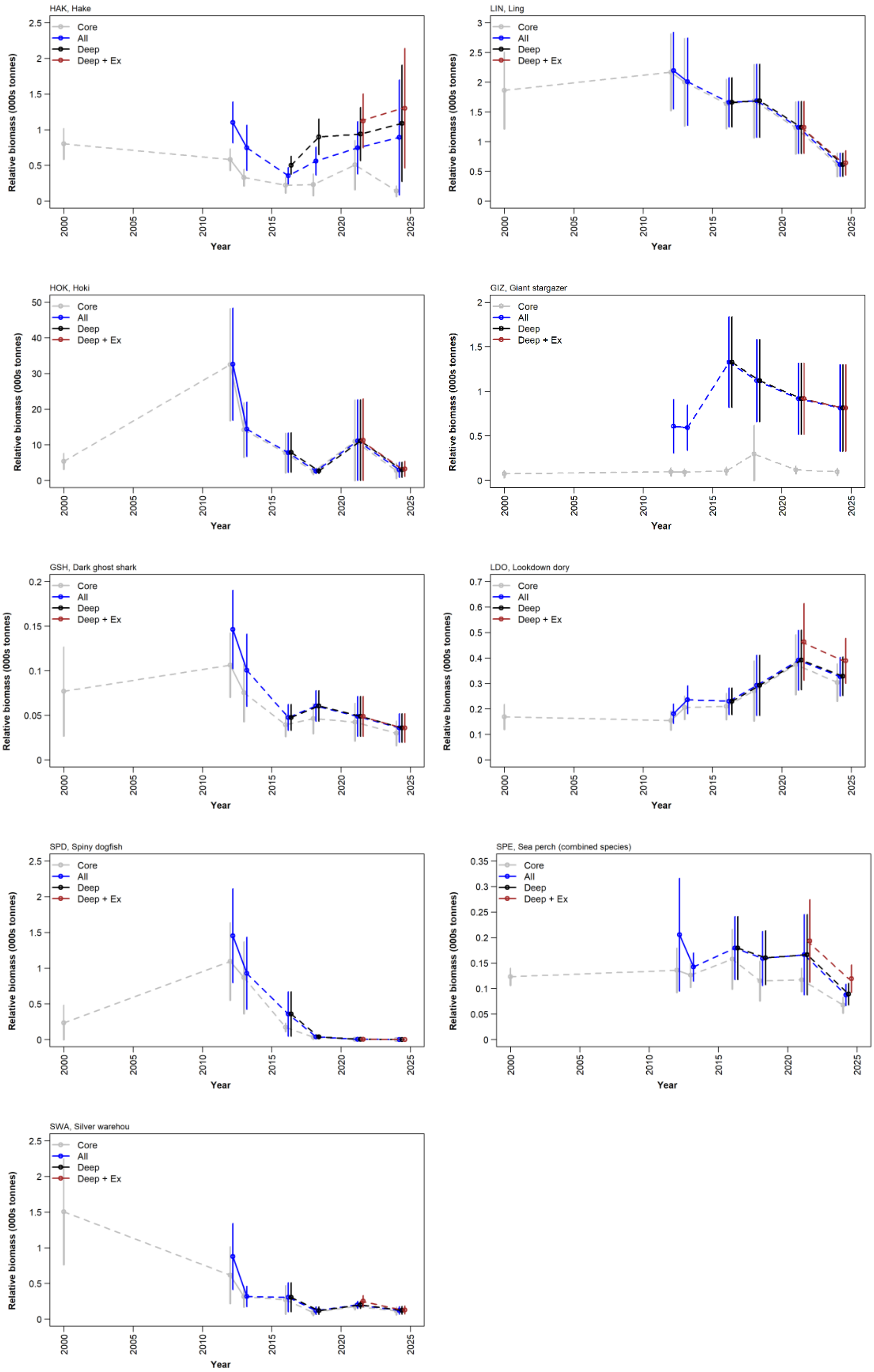


Figure 6: Relative biomass estimates (thousands of tonnes) for species for which the survey was optimised. Grey lines show fish from core (300–650 m) strata, blue lines indicate all strata consistently sampled since 2012 (200–800 m), black solid lines are deep + (200–1000 m) strata, and red lines include the deep exploratory strata. Error bars show ± 2 standard errors.

3.2 Objective 2: Biological data collection

3.2.1 Biological sampling

A random sample of all quota, commercially important, and selected non-commercial species were measured from all survey tows, including target identification tows during the hoki acoustic survey component, and the midwater sampling for mesopelagic species (Table 17). This resulted in a total of 25 268 fish, squid, and scampi of 144 different species. Of these, 10 055 were also individually weighed and 7326 were assessed for maturity stage. Additional data on fish condition (liver and gutted weight) were recorded from 563 hoki. Pairs of otoliths were removed from 678 hake, 423 ling, 716 bigeye seaperch (*Helicolenus barathri*), 651 gemfish, 545 lookdown dory, 179 silver warehou, 204 ribaldo, 67 sea perch (*H. percoides*), 9 alfonsino, and 179 silver warehou.

Table 17: Numbers of fish for which length, sex, and biological data were collected for species for which the 2024 survey was optimised. Numbers of samples refers to the number of stations where measurements were recorded.

		Length frequency data				Length-weight data	
Common name	Species code	Males	Number measured Females	†Total	Number of samples	No. of fish	No. of samples
Hake	HAK	341	339	680	27	680	27
Ling	LIN	279	217	496	41	449	40
Giant stargazer	GIZ	171	143	314	36	169	32
Dark ghost shark	GSH	137	110	247	26	184	23
Bigeye sea perch	HBA	1 171	778	2 053	55	763	49
Hoki	HOK	1 162	1 692	2 857	46	563	43
Sea perch	HPC	65	58	124	8	103	8
Lookdown dory	LDO	547	801	1358	44	593	39
Silver warehou	SWA	98	162	260	42	190	40

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

3.2.2 Reproductive status

Gonad staging of fish and elasmobranchs showed that many species were either in or approaching spawning condition (gonad stages 4–6) during the survey or resting (gonad stage 2, Appendix 6). Fish in active spawning stages (gonad stages 4–6) accounted for 70% of male hake, but only 16% of the females; most females were stage 3 (maturing) (Table 18). Only about one third of the ling sampled were in spawning condition; most were immature or resting (Table 18). Hoki were actively spawning throughout the survey period, with 49% of female hoki maturing (stage 3), 25% spawning (stages 4–6), and 6% spent (stage 7), while 81% of males were in spawning condition.

Table 18: Gonad reproductive stage observations for the hake, ling, and hoki from the 2024 WCSI survey. Gonad stages are defined in Appendix 1. –, indicates that no fish at that stage were observed.

				Reproductive stage							
Species code	Common name	Sex	Staging method	1	2	3	4	5	6	7	Total
HAK	Hake	Female	MD	31	12	229	22	10	21	14	339
		Male		51	17	35	60	128	49	–	340
LIN	Ling	Female	MD	28	78	40	56	12	–	–	214
		Male		34	86	59	85	14	–	–	278
HOK	Hoki	Female	MD	77	256	833	294	46	80	102	1 688
		Male		31	81	101	729	190	25	2	1 159

Reproductive stage information was collected from 1118 elasmobranch specimens across 28 species (Appendix 6). Additional data were collected from selected mature elasmobranch females and included counts and size measurements of vitellogenic (yolky) eggs, pups, and uterus and oviducal gland sizes to help verify the maturity stage allocation (see Section 3.6).

3.2.3 Length and age frequencies

The length distribution of hake in 2024 was broad but lacked the distinct mode of smaller hake (under 50 cm) seen in the previous three surveys (Figure 7). Male hake rarely exceeded 90 cm in length while larger female hake, up to about 120 cm, were present in all years. The mode of smaller (under 60 cm) hake observed in 2021 was most likely responsible for the large numbers of 70–90 cm fish present in 2024. The progression of these fish was more apparent in the age frequencies, where there were a high number of small hake aged 2 in 2021 and aged 5 in 2024 (Figure 8). While there were few male hake larger than 90 cm caught in 2024, these individuals were from a broader range of ages than observed in 2021.

While a broad size range of ling was again caught in 2024, there was a noticeable truncation of the male length frequency and fewer males and females than in previous years (Figure 9). Ling otoliths from this survey were not contracted to be aged until after this report was written.

Most of the hoki were larger than 60 cm, with no distinct modes. A small mode of fish of 30–40 cm was present, most likely corresponding to age 1 fish (Figure 10). There were few hoki between 40–60 cm (age 2) in the catch.

The time series of length frequency distributions for the other six species for which this survey was optimised are in Appendix 7.

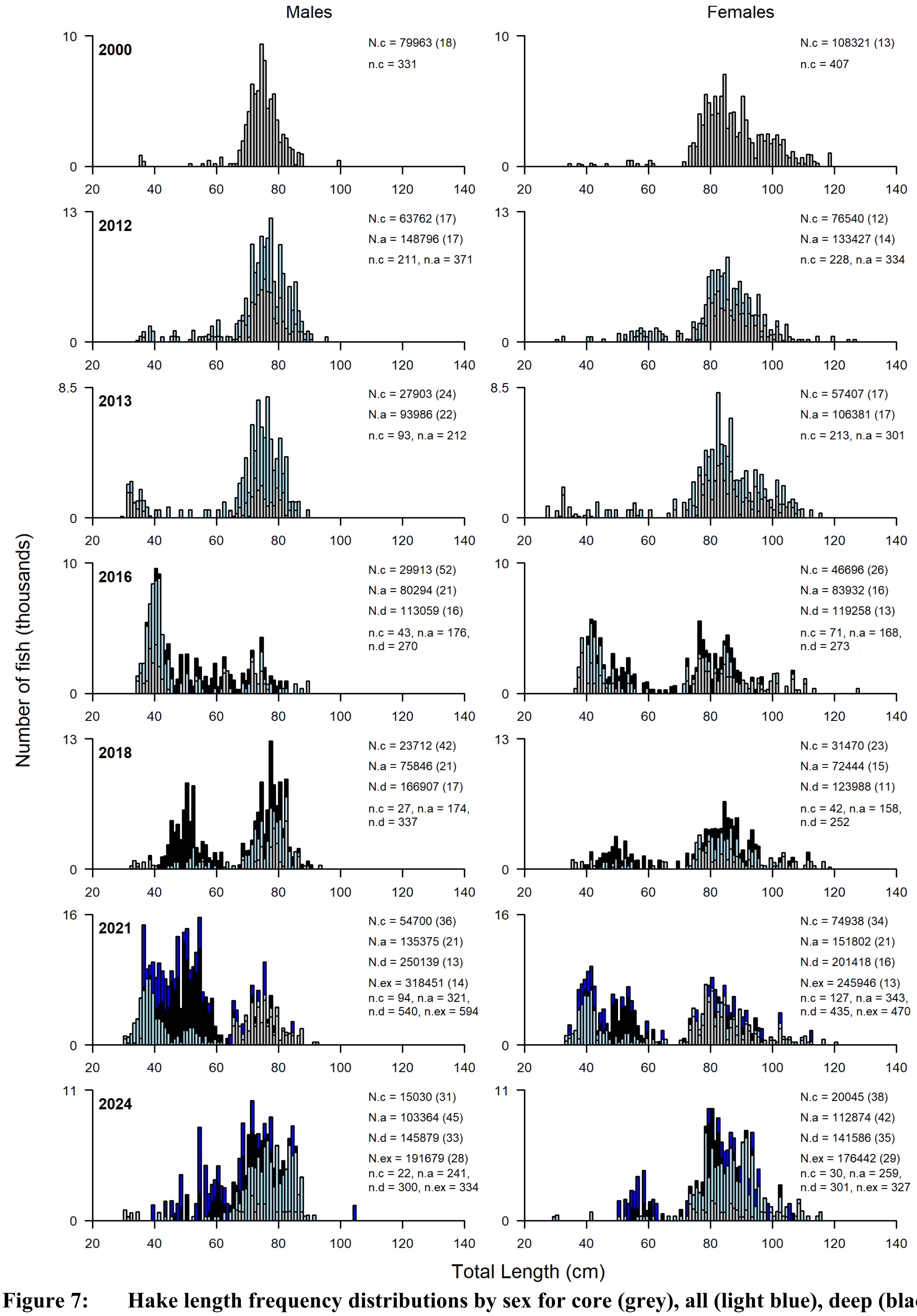


Figure 7: Hake length frequency distributions by sex for core (grey), all (light blue), deep (black), and deep exploratory (dark blue) strata for the WCSI trawl survey time series. N.c, estimated scaled total number of fish for core strata; N.a, estimated scaled total number of fish for all strata; N.d, estimated scaled total number of fish for deep strata; N.ex, estimated scaled total number of fish for deep exploratory strata; n.c, number of fish measured in core strata; n.a, number of fish measured for all strata; n.d, number of fish measured for deep strata; n.ex, number of fish measured for exploratory strata; and CV, the coefficient of variation (in parentheses).

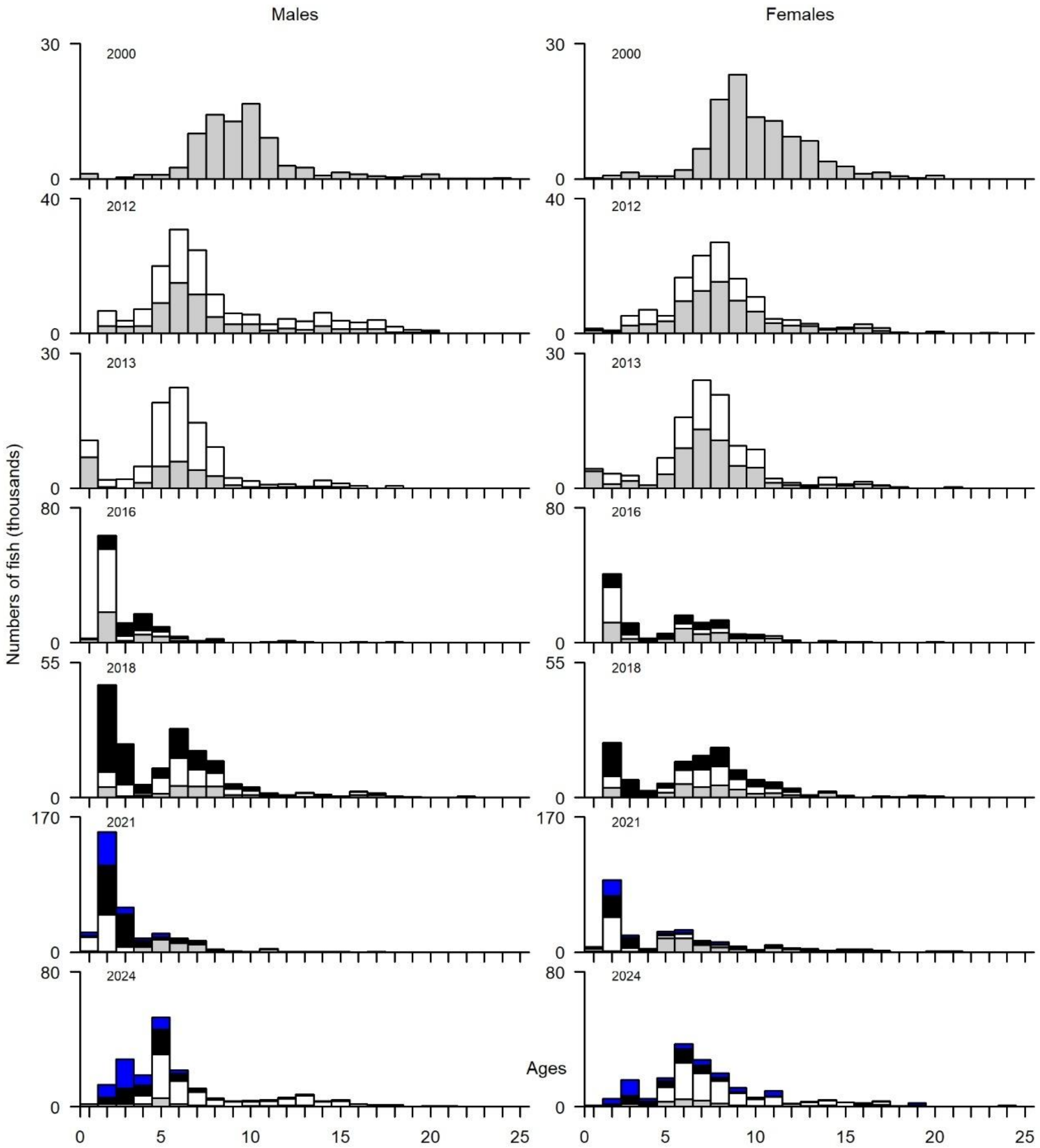


Figure 8: Scaled age frequency distribution for hake for core (grey), all (white), and deep (black), and deep exploratory (dark blue) strata from the WCSI trawl survey time series.

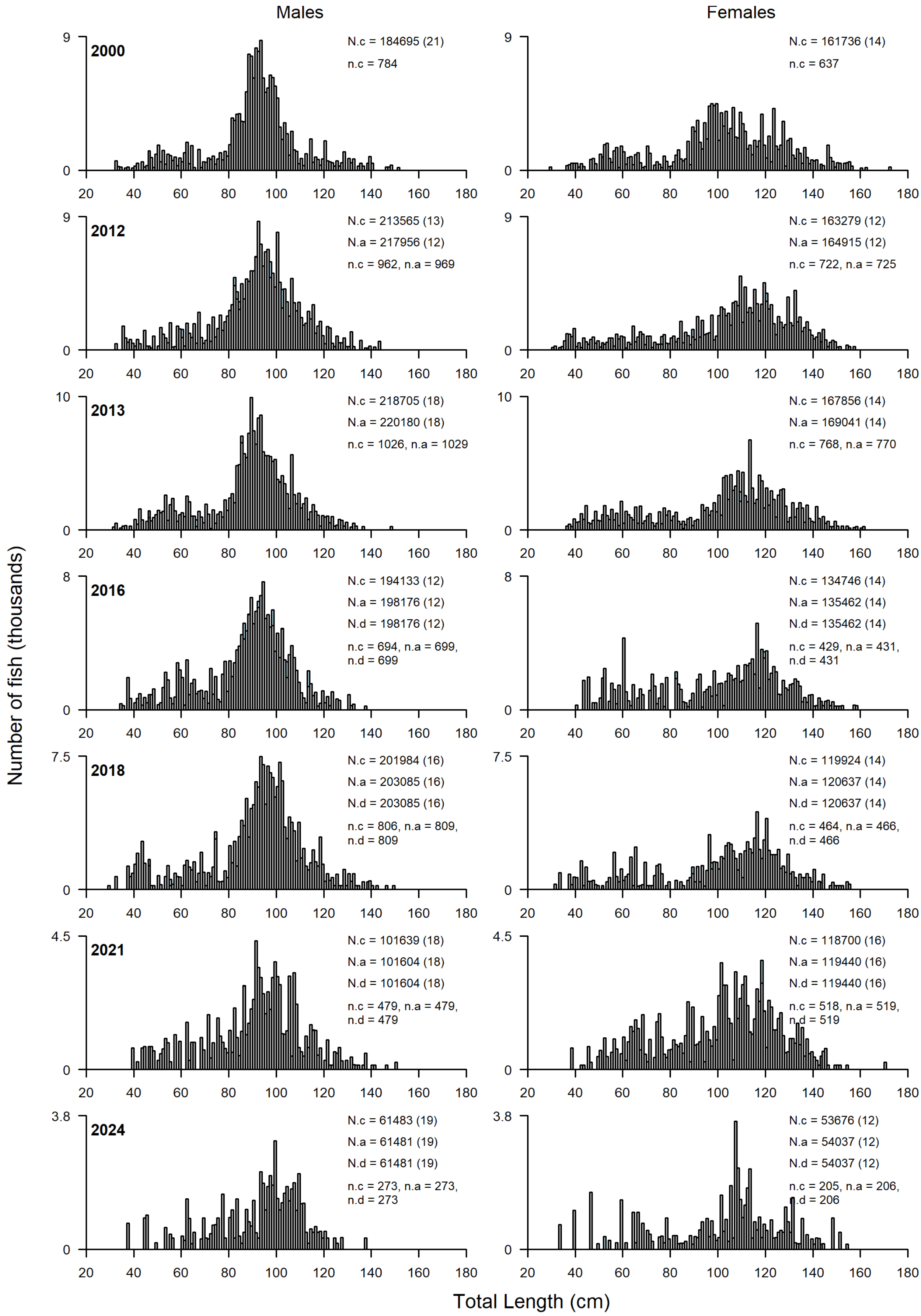


Figure 9: Ling length frequency distributions by sex for core (grey), all (light blue), deep (black), and deep exploratory (dark blue) strata for the WCSI trawl survey time series. See Figure 7 legend for an explanation of the figure.

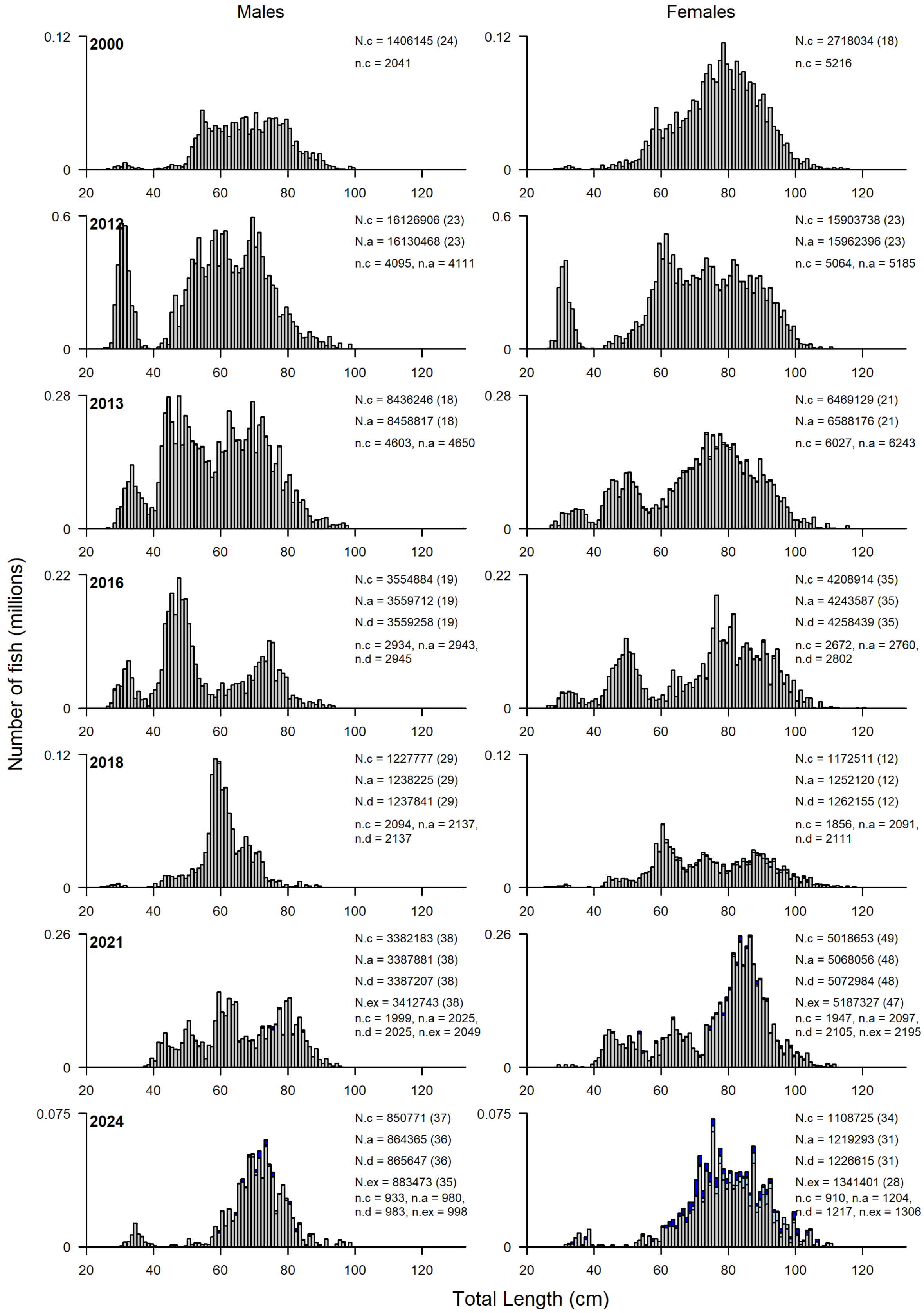


Figure 10: Hoki length frequency distributions by sex for core (grey), all (light blue), deep (black), and deep exploratory (dark blue) strata for the WCSI trawl survey time series. See Figure 7 legend for an explanation of the figure.

3.3 Objective 3: Other data collection

Over 221 GB of acoustic data were collected with the multi-frequency (18, 38, 70, 120, and 200 kHz) hull-mounted EK80 systems, which included the acoustic survey and data collected continuously outside of the acoustic strata. Details on the results of the acoustic survey are in Section 3.5.

Sea temperature and conductivity (salinity) were measured using the Seabird Microcat CTD mounted on the trawl headline for 71 bottom tows (including acoustic identification tows) and for 3 midwater mesopelagic tows using an RBR-duet on the midwater trawl headline. Surface temperatures ranged from 13.4 °C to 14.5 °C (mean 14.1 °C) and bottom temperatures ranged from 5.5 °C to 14.0 °C (mean 9.9 °C) (Figure 11).

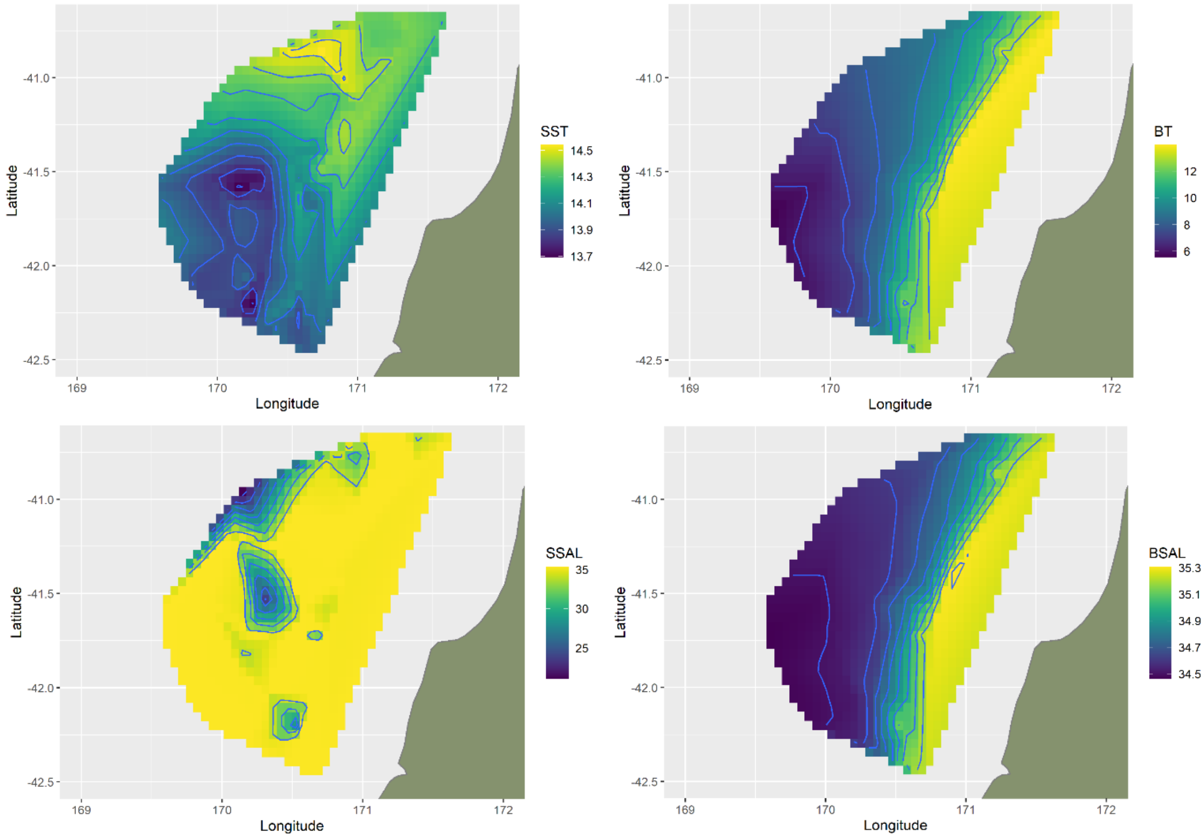


Figure 11: Sea surface and bottom temperature (SST, BT) and salinity (SSAL, BSAL) for the 2024 WCSI bottom trawl survey area. Data were interpolated between stations.

Average bottom temperatures in the northern shallow strata (200–500 m) declined between 1.0–1.6 °C from 2012 until 2018, after which, they began warming again (Table 19). Deeper waters in the northern strata (greater than 500 m) began warming sooner (2018) but had less of an overall temperature change. The shallowest northern strata (1&2S, 200–300 m) in 2024 was 0.5 °C warmer than bottom temperatures in the same strata in 2012, while stratum 1&2B (430–500 m) was cooler in 2024 than in 2012 (~0.7 °C).

The southern strata experienced different conditions, where bottom temperatures cooled in the 200–300 m strata until 2016 and then began warming (Table 19). Temperature warmed over 0.5 °C between 2012 and 2013 in the 300–650 m strata before cooling and then warming again. Bottom temperatures at depths greater than 300 m have generally warmed in the southern strata since 2018, and temperatures at depths greater than 500 m in 2024 were still cooler than in 2012.

When comparing bottom temperatures by depth for the entire survey area (e.g., a more general trend), the cooling that occurred in 2016 and 2018 was readily apparent at all depths (Figure 12). Bottom temperature in 2024 at depths greater than 550 m is warmer than at any time during the survey time series, but for depths between 300 and 430 m, temperatures were still noticeably cooler than in 2012 but only for the northern stratum (Figure 12).

Table 19: Average bottom temperature by stratum and survey year.

								Northern strata
Survey year	1&2S	1&2A	1&2B	1&2C	1&2D			
2012	13.63	12.29	10.98	9.05	–	–	–	–
2013	13.43	11.84	10.80	9.10	–	–	–	–
2016	12.90	11.80	10.48	9.26	–	–	–	–
2018	12.67	10.69	9.59	8.80	–	–	–	–
2021	13.50	11.67	9.88	8.84	7.62	–	–	–
2024	14.13	11.68	10.25	9.14	7.95	–	–	–
								Southern strata
	4S	4A	4B	4C	4D	4E	4F	4G
2012	13.55	11.57	10.40	8.96	8.02	–	–	–
2013	13.53	12.23	10.75	9.03	7.84	–	–	–
2016	12.65	11.56	9.63	8.60	7.34	6.35	5.93	–
2018	13.16	11.27	9.35	8.40	7.10	6.40	6.10	–
2021	13.23	11.79	9.53	8.80	7.57	6.72	6.15	–
2024	13.27	11.88	10.23	8.60	7.46	6.67	6.07	5.73

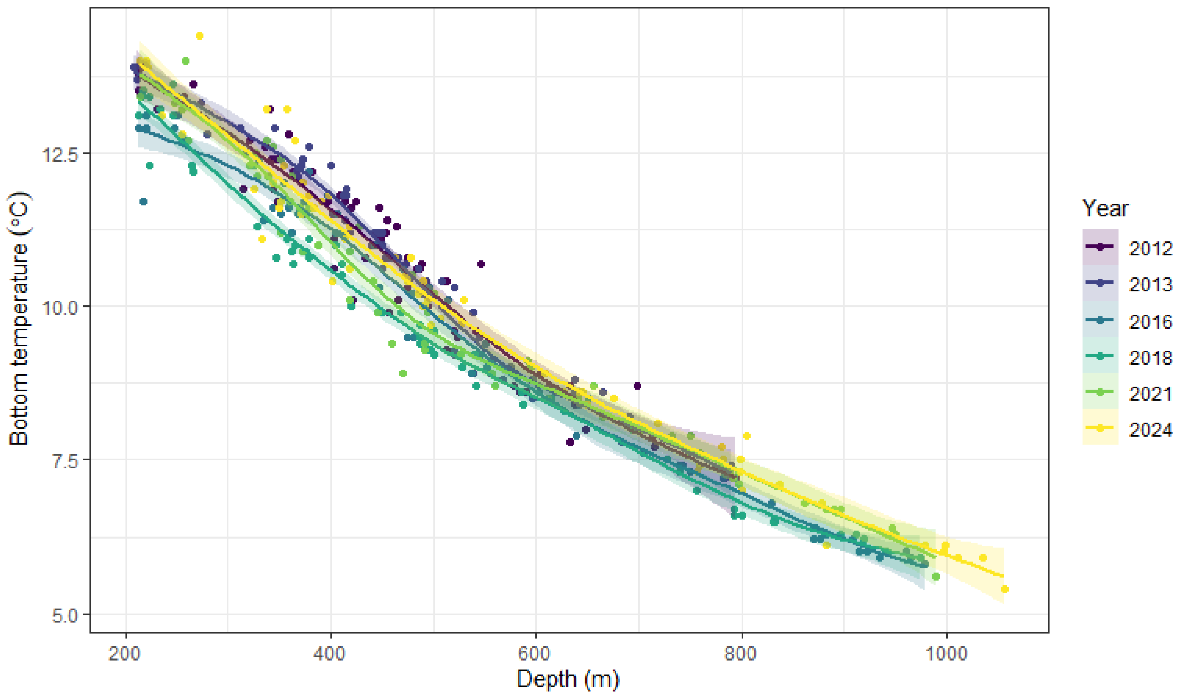


Figure 12: Bottom temperature by depth and survey year as recorded at bottom trawl stations on the WCSI survey.

3.4 Objective 4: Collection of specimens

A further 81 lots of unusual or unidentified organisms were retained for identification ashore, 56 invertebrates to be identified, should a contract become available or should experts donate their time and experience, and 23 fish specimens and 2 lots of wood (with associated organisms; 24.5 kg in total) for Te Papa Tongarewa.

3.5 Objective 5: Acoustic survey

One snapshot of the northern strata (1&2 and 4) was achieved, while two snapshots were conducted for the southern strata (Hokitika Canyon and southwards).

3.5.1 Acoustic survey data

Spawning hoki aggregations (Figure 13) were detected in the inner Hokitika Canyon (stratum 5A) and strata 6 and 7. As in 2018, and unlike in years preceding, no hoki aggregations were detected in stratum 1&2, and for the first time no hoki aggregations were observed in stratum 5B. Lower density marks consisting of hoki and a variety of other species were observed in all strata, either as a bottom-oriented “fuzz” layer or in midwater (Figure 14). Mesopelagic marks, which usually did not contain hoki, were common. Mesopelagic marks were usually in layers, often with a wavy, undulating appearance. These were typically shallower than hoki schools, and more homogeneous, with no obvious single targets. Mesopelagic layers tended to be stronger on 18 kHz than on 38 kHz suggesting that the organisms were small fish with gas-bladders.

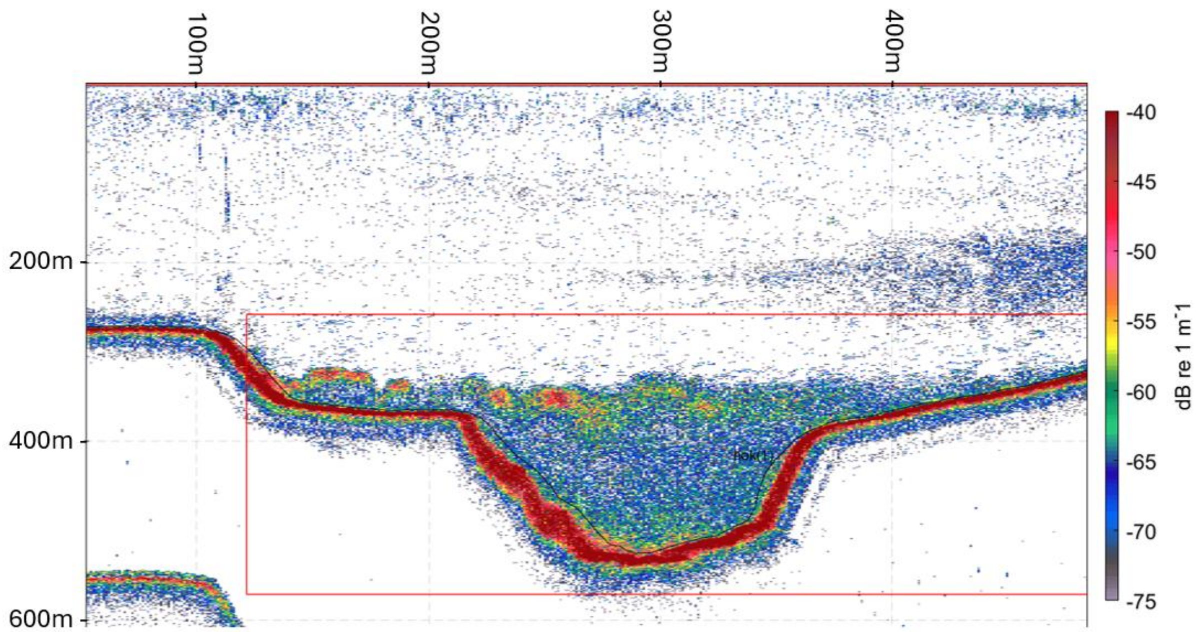


Figure 13: Example echogram showing hoki school marks in stratum 7. Approximate boundaries of marks are shown by red box.

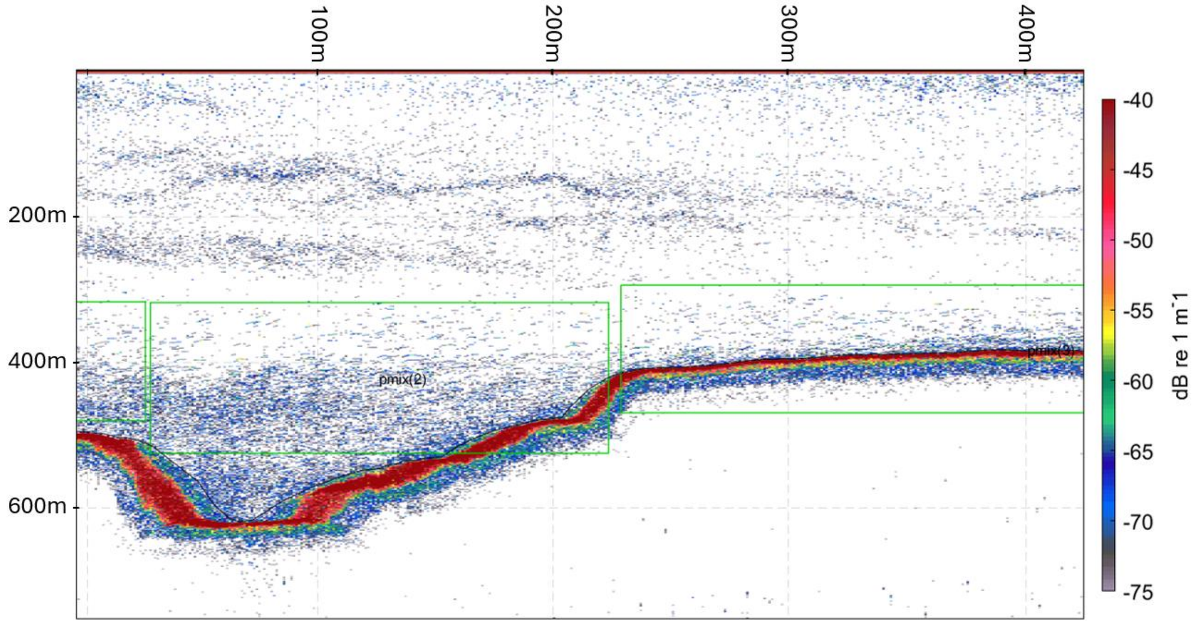


Figure 14: Example echogram showing hoki fuzz marks in stratum 7. Approximate boundaries of marks are shown by green boxes.

3.5.2 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 15). Maps show unpartitioned backscatter from hoki schools and hoki fuzz marks separately. Dense hoki schools were present in Hokitika Canyon (stratum 5A) and the eastern side of stratum 7 in both snapshots. In the northern area, which was only sampled in the first snapshot, no hoki schools were observed in stratum 1&2 (Figure 15). Hoki fuzz marks were widespread in all strata throughout the survey period, with highest (unpartitioned) densities in strata 5A, 6, and 7 (Figure 15).

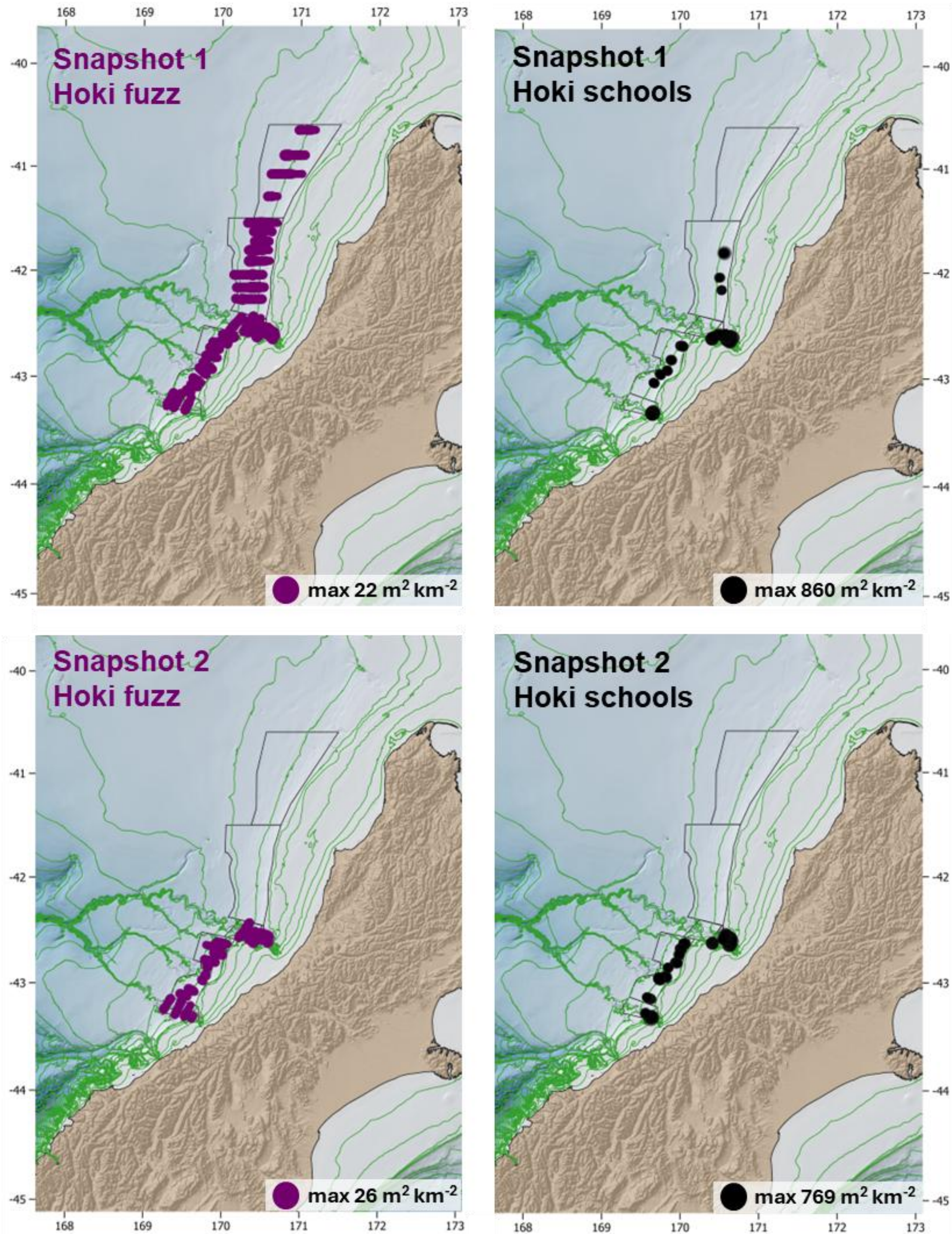


Figure 15: Spatial distribution of acoustic backscatter from hoki schools and hoki fuzz marks plotted in 10 ping (~100 m) bins for the three snapshots of the WCSI. Symbol size is proportional to the log of the acoustic backscatter (S_a scaled to m^2 km^{-2}).

3.5.3 Species decomposition

The 42 successful random bottom tows in the acoustic survey area of snapshot 1 were used to partition acoustic backscatter. On average hoki made up between 1% (stratum 1&2A) and 70% (stratum 4C) of the trawl catch by substratum. Species decomposition was based on catch rates in random tows and best estimates of acoustic TS (see Table 8). Using hoki TS from equation (1) and weighting by the square root of the tow catch rate, hoki contributed 0.5–47% of the backscatter from mixed species marks in the northern strata (Table 20). These values were used to scale integrated acoustic backscatter from fuzz marks when estimating hoki abundance in the northern strata. In the southern strata, all backscatter was assumed to be hoki.

Table 20: Estimates of the proportion of acoustic backscatter from hoki (P(hoki)) in mixed species marks by substratum for snapshot 1 of northern strata (1&2 and 4). Average percentage of hoki by weight in the catch is also given under equal weighting of all tows ('unweighted') and after weighting by the square root of the catch rate ('weighted').

		Mean % hoki in catch		
Stratum	No. of tows	Unweighted	Weighted	P(hoki)
1&2A	12	1	1	0.005
1&2B	8	34	56	0.250
1&2C	5	38	38	0.201
4A	7	0	0	0.000
4B	3	23	23	0.116
4C	3	63	70	0.470
4D	4	8	8	0.000

3.5.4 Acoustic abundance estimates

The estimates of hoki abundance were based on a single ratio, *r*, of mean weight to mean backscattering cross section from the commercial trawl data. The mean length of hoki was 74.9 cm (Table 21). Mean weight (obtained by transforming the scaled length frequency distribution by Equation 4 and then calculating the mean of the transformed distribution) was 1.35 kg. The estimated ratios, *r*, for 2024, based on the latest TS-TL relationship (Equation 1), was 8054 kg m^{-2} (Table 21).

Table 21: Estimates of the ratio *r* for converting hoki acoustic backscatter to biomass using acoustic TS derived from commercial trawl length frequency data using the TS-length relationships of Dunford et al. (2015), estimated acoustic abundance indices and CV, where CV was estimated using model weighting (see Table 24).

Year	Mean length (cm)	Mean weight (kg)	Mean TS (dB)	*r* (kg m^{-2})	Abundance ('000 t)	CV
1988	81.1	1.66	-40.0	8 272	266	0.60
1989	81.6	1.67	-36.9	8 263	165	0.38
1990	81.9	1.69	-36.9	8 279	169	0.40
1991	80.5	1.63	-37.0	8 261	227	0.73
1992	79.3	1.54	-37.2	8 175	229	0.49
1993	78.2	1.49	-37.4	8 128	380	0.38
1997	74.1	1.31	-37.9	8 016	445	0.60
2000	80.3	1.59	-37.1	8 211	263	0.28
2012	75.4	1.37	-37.7	8 070	283	0.34
2013	79.1	1.56	-37.2	8 209	233	0.35
2018	79.4	1.60	-37.1	8 279	123	0.46
2024	74.9	1.35	-37.8	8 054	138	0.53

Table 22: Hoki acoustic abundance (thousand tonnes) estimates from the 2024 WCSI by snapshot and stratum.

	Stratum							
Snapshot	12	4	5A	5B	6	7	Total	CV (%)
1	12	30	34	13	26	25	141	18
2	–	–	29	10	31	23	92	24
Mean	12	30	31	11	29	24	138	

Hoki abundance estimates by snapshot and strata are given in Table 22 and plotted in Figure 16. Estimates of hoki abundance were 141 000 t (CV 18%) in the first snapshot and 92 000 t (CV 24%) in the second snapshot (Table 22). The average abundance estimate over the two snapshots was

138 000 t. About 31% of hoki abundance was in the northern area (strata 1&2 and 4), 30% in Hokitika Canyon (strata 5A and 5B), and 38% from south of the Hokitika Canyon (strata 6 and 7). Acoustic biomass in the northern area in 2024 was 10% higher than in 2018, but 7–8% lower than in 2012 and 2013. In the southern area, acoustic biomass was the lowest in 2024 in strata 5A and 5B since 1992, and in stratum 6 since surveying began (Figure 16). On average, across both snapshots, only 45% of the hoki abundance was from hoki schools (Table 23).

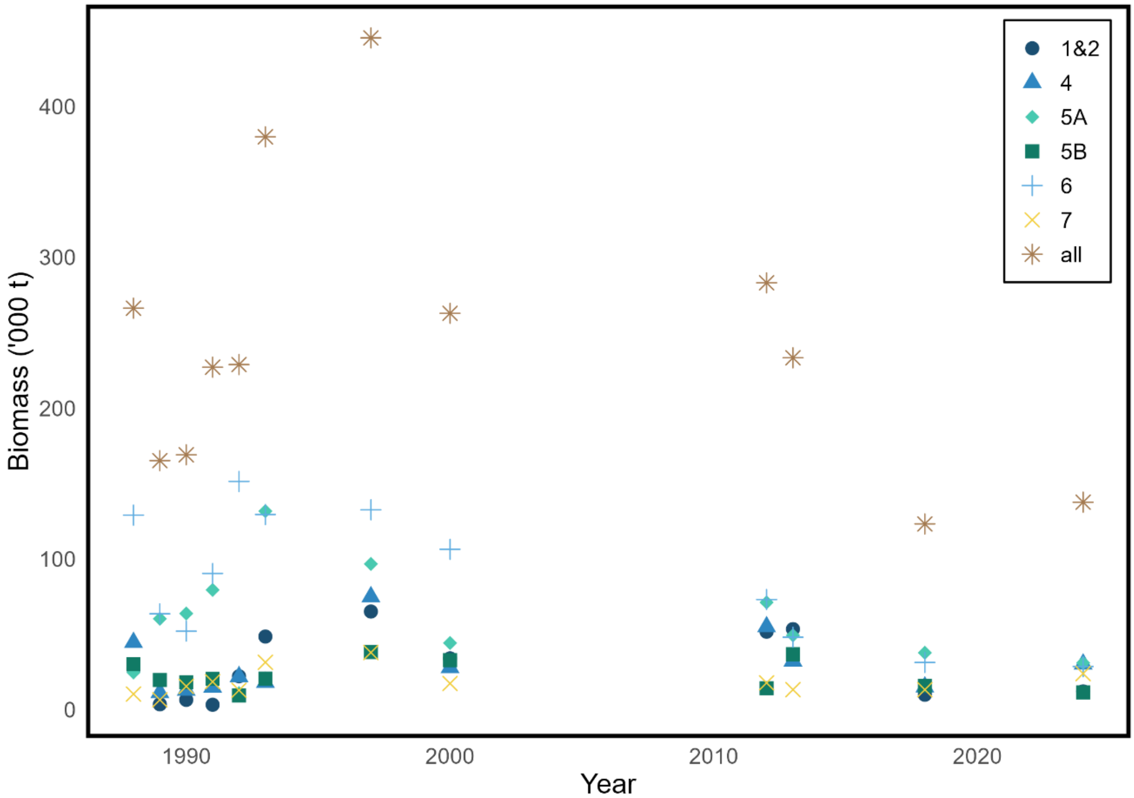


Figure 16: Time-series of hoki acoustic abundance indices by stratum on the WCSI survey.

Table 23: Percentage of the hoki abundance estimate contained in hoki school marks in each snapshot and stratum. Percentages were calculated in relation to abundance estimates in Table 22.

	Stratum						
Snapshot	1&2	4	5A	5B	6	7	Total
1	0	10	84	0	17	59	36
2	–	–	81	0	40	66	55
Mean	0	10	83	0	29	63	45

The estimated acoustic abundance time-series, based on the same 'revised' methodology used by O'Driscoll et al. (2016), indicated that the 2024 estimate was slightly higher than in 2018 but overall, still considerably lower than any estimates preceding 2018 (e.g., 59% that of the 2013 survey) (Table 21).

3.5.5 Acoustic weighting for stock assessment

The overall survey weighting estimated from the Monte Carlo simulation model for the 2024 WCSI estimate was 0.53 (Table 24). The greatest contribution to the uncertainty was from the species composition of the fuzz marks (Table 24). The overall survey weighting in 2018 and 2024 was lower (higher CV) than for surveys in 2000, 2012, and 2013 because recent surveys only had 1–2 snapshots compared to 3–5 in the earlier surveys and there was a lower proportion of hoki in schools in recent surveys.

Table 24: Results of Monte Carlo simulations to determine model weighting for the 2024 WCSI acoustic survey. 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	0.207	0.056	
+ Sampling	0.281	0.177	
+ Mark identification	0.822	0.383	
+ Calibration	0.824	0.386	
+ TS	0.825	0.393	
Total	0.825	0.393	0.526

3.6 Objective 6: Broader outcomes

A total of 578 sample lots were inventoried and preserved. Many of the sample lots were collected by Connor Wallace, a visiting AUT researcher (147 sample lots – cephalopod tissue samples and whole specimens). In addition to sample lots mentioned in section 3.4, 7 sample lots of whole cephalopods were collected for Fisheries New Zealand (Alexander Arkhipkin) for a study investigating acoustic reflection properties, and 200 sample lots of mesopelagic organisms and basketwork eels were collected for DNA barcoding. Samples were also collected for pale toadfish diet work, understanding of trophic dynamics of several rattail species, improved species identification of several deepwater shrimp species, and to increase knowledge of poorly understood deepwater skate and shark reproduction.

Uncommon elasmobranch species encountered included a velvet dogfish (*Zameus squamulosus*) and a small number of the longsnout dogfish (*Deania quadrispinosa*), which were saved along with a selection of shovelnose dogfish (*D. calcea*) to confirm identification of these closely related species. Maturity stage data was collected from a total of 909 individuals, including shovelnose dogfish (n=314), dark ghost shark (*Hydrolagus novaezealandiae*) (n=184) and northern spiny dogfish (*Squalus griffini*) (n=189). Additional reproductive measurements were collected across a range of species including counts of vitellogenic egg counts, embryo counts and oviducal gland measurements from 10 different species of sharks and skates, including the slender smoothhound (*Gollum attenuatus*), leafscale gulper shark (*Centrophorus squamosus*), and shovelnose dogfish. These data contribute to understanding fecundity and vulnerability of these vulnerable species. Tissue samples from leafscale gulper sharks and Portuguese dogfish were also retained for genetic information.

4. DISCUSSION AND CONCLUSIONS

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 to a random trawl survey only, where hoki are no longer a target. The 2024 survey was the seventh in a time series of trawl survey estimates for ling and hake from the WCSI and provided an additional acoustic survey for hoki, the first since 2018. In addition to supporting the stock assessments for two Tier 1 deepwater fisheries species, the trawl survey provides information on a wide variety of bycatch species.

Data from commercial fisheries and the trawl surveys since 2012 suggests that the current survey area appears to have an appropriate spatial and depth distribution in the northern area for ling, as well as for silver warehou, giant stargazer, dark ghost shark, and, with the recent extension of the survey area to 800 m, hake, hoki, lookdown dory, and sea perch (O'Driscoll et al. 2015b). The southern strata had been appropriate for most of the species for which the survey was optimized but added additional information for hake. The deep exploratory strata for hake (1&2D and 4G) seems to be particularly important for smaller fish (under 70 cm), however, this survey is conducted to obtain relative biomass of adult hake and is not currently designed to provide recruitment indices. There is likely little to gain by extending the survey any deeper. The survey area appears to have an appropriate spatial and depth distribution for larger hake without these areas, as indicated by O'Driscoll et al. (2015b).

The addition of deeper strata in 2016 and again in 2021 has improved the survey coverage for deeper-living species, such as shovelnose dogfish, ribaldo, and deepwater sharks. These deeper strata have allowed an opportunity to collect detailed reproductive information from these elasmobranch species.

Commercial catches indicate that the distribution of hake, hoki, 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 and rough bottom topography, which means that much of the area is unsuitable for bottom trawling and therefore cannot be easily incorporated into a random trawl survey (O'Driscoll & Ballara 2019). As a consequence, use of trawl survey estimates from only the northern area as indices for the entire WCSI (or FMA 7) relies on the assumption that a constant proportion of the stock resides within the trawlable northern area.

The estimate of hake biomass ('all' area) increased in the last three surveys but was still lower than the level observed in 2012. The 'core' area estimate of hake abundance in 2024 was the lowest observed in the series and was the result of very little hake caught in the northern trawl survey stratum (1&2C). Ling biomass declined to the lowest observed in the series and hoki biomass has also declined. None of the other stocks of species potentially monitored by the WCSI surveys are currently formally assessed (Fisheries New Zealand 2024). However, for most Tier 2 species, the trawl survey provides the only fisheries-independent estimate of abundance off the WCSI, as well as providing biological data (e.g., length, sex, reproductive condition, age). Giant stargazer, dark ghost shark, lookdown dory, spiny dogfish, sea perch and silver warehou biomass declined in 2024, and for dark ghost shark, spiny dogfish, and sea perch, to the lowest estimated biomass of the time series. It is difficult to assess the 'quality' of trawl estimates for many of these species based on surveys in 2000–24 because 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 other species including the surveys for which it has been optimised.

Hoki biomass estimated from the acoustic component of the survey was the second lowest of the time series but showed an increase since the 2018 survey. Hoki abundance was highest in the inner Hokitika Canyon and in stratum 4, and lowest in stratum 1&2 and in the outer Hokitika Canyon (stratum 5B). Despite having low biomass in the northernmost strata, this estimate was still 10% higher than in 2018. Abundance in Hokitika Canyon was the lowest observed since 1992.

Bottom temperatures have been warming after an initial cooling period, and the effect has been greater in the northern bottom trawl strata (stratum 1&2) compared to the southern (stratum 4). The effect on catch rates of bottom temperature and depth of capture was preliminarily investigated for hake, ling, and hoki using data from consistently sampled strata (Figure 17, methods described in Appendix 10). Predicted trends indicated a notably different trend in 2024 for the three species, compared to earlier survey years and might possibly be linked to the observed changes in biomass for hake, hoki, and ling (Figure 17). This analysis is not comprehensive but does indicate that changes have occurred and should be investigated further.

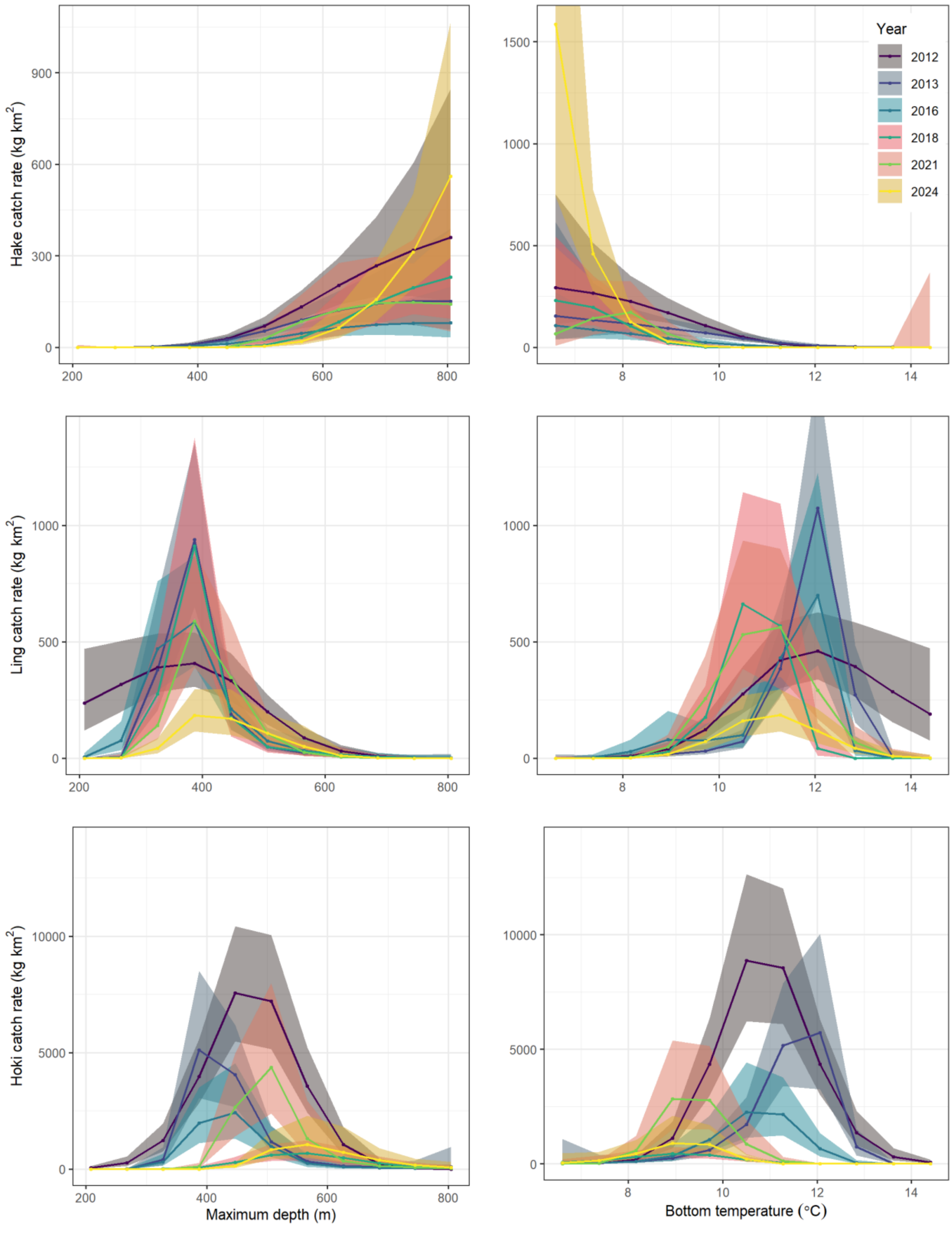


Figure 17: Trend in hake (top), ling (middle), and hoki (bottom) GAM predicted catch rates with depth (left) and bottom temperature (right) for each survey year. Data were from consistently sampled strata since 2012. See Appendix 10 for description of models.

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 WCSI survey is among the most comprehensive of any New Zealand survey. As noted in Section 3.2.1, all items in the catch are sorted and weighed and large numbers of individuals were measured and weighed (Table 17). 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 2000–24, but size-based indicators could only be calculated for 2012–24, when a much wider range of species was measured. Information on all species are available on the trawl portal (https://tsip-uat.niwa.co.nz/search).

5. FUTURE RESEARCH

The survey biomass estimates for hake and ling are used in stock assessments, but, particularly for ling, the lack of contrast creates issues for the assessment models. Currently, the survey is not used as an index of recruitment for hake or ling; recruitment is hard to monitor for a survey that occurs with 3- to 5-year gaps. Tracking of cohorts in the length or age frequencies is difficult because of the frequency of the surveys. For example, hake that appears at age 5 in 2018 is not seen again until age 8 in 2021, when it is part of the broad mode of older-aged fish. The data supplied by the west coast South Island survey could be more useful for stock assessment modelling if the survey was run more frequently or at consistent intervals, such as every other year.

The survey estimates rely on the assumption that a constant proportion of the stock resides within the northern trawlable area, but it appears that fish movement, spatially and temporally, occurs. In some years, hake are more present further north than in other years. Commercial catches also indicate that the distribution of hake and ling extends into the Hokitika Canyon and along the shelf to the south. The survey could provide better data (and has been shown to in previous surveys) if an acoustic component was routinely included for Hokitika Canyon, where the seabed is too rough for a bottom trawl survey.

6. ACKNOWLEDGEMENTS

This work was funded by Fisheries New Zealand under Project MID2021-02. Thank you to Gretchen Skea (Fisheries New Zealand) for guiding and reviewing this project, and to the Fisheries New Zealand Deepwater Working Group for useful suggestions and contributions. Thanks to the officers and crew of the *Tangaroa* and to the scientific staff for making this a successful voyage, to Keren Spong and Colin Sutton (NIWA) for processing and reading the otoliths, and to Richard O'Driscoll and Darren Stevens (NIWA) and Marianne Vignaux (Fisheries New Zealand) for reviewing and editing this report.

7. REFERENCES

Bull, B. (2000). An acoustic study of the vertical distribution of hoki on the Chatham Rise. *New Zealand Fisheries Assessment Report 2000/5*. 59 p.

Bull, B.; Dunn, A. (2002). Catch-at-age user manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. (Unpublished report held by NIWA library, Wellington.)

Coombs, R.F.; Cordue, P.L. (1995). Evolution of a stock assessment tool: acoustic surveys of spawning hoki (*Macruronus novaezelandiae*) off the west coast of South Island, New Zealand, 1985–91. *New Zealand Journal of Marine and Freshwater Research 29*: 175–194.

Cordue, P.L. (2002). An analysis of an acoustic survey of spawning hoki off the west coast South Island during winter 2000. *New Zealand Fisheries Assessment Report 2002/26*. 51 p.

Cordue, P.L.; Ballara, S.L. (1998). Acoustic surveys of spawning hoki off the west coast South Island and in Cook Strait during winter 1997. *New Zealand Fisheries Assessment Research Document 98/24*. 31 p.

Demer, D.A.; Berger, L.; Bernasconi, M.; Bethke, E.; Boswell, K.; Chu, D.; Domokos, R. et al. (2015). Calibration of acoustic instruments. *ICES Cooperative Research Report No. 326*, 133 p. DOI: http://dx.doi.org/10.25607/OBP-185.

Devine, J.A.; Stevens, D.W.; Ballara, S.L. (2022). Trawl survey of middle depth fish species off the west coast South Island, July–August 2021 (TAN2107). *New Zealand Fisheries Assessment Report 2022/53*. 131 p.

Doonan, I.J.; Rasmussen, S. (2017). Random Station User Manual, RandomStation v1.00-2017-05-26 (rev. 171). 47 p. National Institute of Water and Atmospheric Research.

Dunford, A.J.; O'Driscoll, R.L.; Oeffner, J. (2015). Improvements in estimating an acoustic target strength length relationship for hoki (*Macruronus novaezelandiae*). *Fisheries Research 162*:12–19.

Fisheries New Zealand (2020). Fisheries Assessment Plenary, May 2020: stock assessments and stock status. Compiled by the Fisheries Science and Information Group, Fisheries New Zealand, Wellington, New Zealand. 1746 p.

Fisheries New Zealand (2024). Fisheries Assessment Plenary, May 2024: stock assessments and stock status. Compiled by the Fisheries Science Team, Fisheries New Zealand, Wellington, New Zealand. 1941 p.

Francis, R.I.C.C. (1981). Stratified random trawl surveys of deep-water demersal fish stocks around New Zealand. *Fisheries Research Division Occasional Publication 32*. 28 p.

Francis, R.I.C.C. (1984). An adaptive strategy for stratified random trawl surveys. *New Zealand Journal of Marine and Freshwater Research 18:* 59–71.

Francis, R.I.C.C. (1989). A standard approach to biomass estimation from bottom trawl surveys. *New Zealand Fisheries Assessment Research Document 89/3*. 3 p.

Francis, R.I.C.C. (2003). Analyses supporting the 2002 stock assessment of hoki. *New Zealand Fisheries Assessment Report 2003/5*. 34 p.

Francis, R.I.C.C. (2006). Optimum allocation of stations to strata in trawl surveys. *New Zealand Fisheries Assessment Report 2006/23*. 50 p.

Francis, R.I.C.C. (2009). SurvCalc User Manual. 39 p. (Unpublished report held by NIWA, Wellington.)

Francis, R.I.C.C.; O'Driscoll, R.L. (2004). Proposed design for a 2004 west coast South Island hoki survey combining acoustic and trawl data. *New Zealand Fisheries Assessment Report 2004/3*. 28 p.

Horn, P.L. (1997). An ageing methodology, growth parameters and estimates of mortality for hake (*Merluccius australis*) from around the South Island, New Zealand. *Marine and Freshwater Research 48:* 201–209.

Horn, P.L. (2021). Age determination protocol for ling (*Genypterus blacodes*). *New Zealand Fisheries Assessment Report 2021/31*. 19 p.

Hurst, R.J.; Bagley, N.; Chatterton, T.; Hanchet, S.; Schofield, K.; Vignaux, M. (1992). Standardisation of hoki/middle depth time series trawl surveys. MAF Fisheries Greta Point Internal Report No. 194. 89 p. (Unpublished report held by NIWA library, Wellington.)

Johnson, N.L.; Kemp, A.W.; Kotz, S. (2005). Univariate discrete distributions. Third edition. Wiley.

Jolly, G.M.; Hampton, I. (1990). A stratified random transect design for acoustic surveys of fish stocks. *Canadian Journal of Fisheries and Aquatic Sciences 47*: 1282–1291.

Ladroit, Y.; Escobar-Flores, P.C.; Schimel, A.C.G.; O'Driscoll, R.L. (2020). ESP3: An opensource software for the quantitative processing of hydro-acoustic data. SoftwareX, 12: 100581

MacLennan, D.N.; Simmonds, E.J. (1992). Fisheries Acoustics. Chapman & Hall, London. *Fish and Fisheries Series 5*. 325 p.

O'Driscoll, R.L. (2002). Review of acoustic data inputs for the 2002 hoki stock assessment. *New Zealand Fisheries Assessment Report 2002/36*. 66 p.

O'Driscoll, R.L.; Bagley, N.W.; Ballara, S.L.; Ladroit, Y. (2015a). Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2013 (TAN1308). *New Zealand Fisheries Assessment Report 2015/20*. 104 p.

O'Driscoll, R.L.; Bagley, N.W.; Ballara, S.L.; Oeffner, J. (2014). Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2012 (TAN1210). *New Zealand Fisheries Assessment Report 2014/09*. 102 p.

O'Driscoll, R.L.; Bagley, N.W.; Dunn, A. (2004). Further analysis of an acoustic survey of spawning hoki off the west coast South Island in winter 2000. *New Zealand Fisheries Assessment Report 2004/2*. 53 p.

O'Driscoll, R.L.; Ballara, S.L. (2018). Trawl survey of middle depth fish abundance on the west coast South Island, August 2016 (TAN1609). *New Zealand Fisheries Assessment Report 2018/47*. 76 p.

O'Driscoll, R.L.; Ballara, S.L. (2019). Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2018 (TAN1807). *New Zealand Fisheries Assessment Report 2019/19*. 120 p.

O'Driscoll, R.L.; Ballara, S.L.; Bagley, N.W. (2015b). Review of performance of west coast South Island trawl/acoustic survey of deepwater stocks. (Final Research Report for Ministry for Primary Industries Research Project SEA2014/10 held by Fisheries New Zealand.) 86 p.

O'Driscoll, R.L.; Hurst, R.J.; Dunn, M.R.; Gauthier, S.; Ballara, S.L. (2011). Trends in relative mesopelagic biomass using time series of acoustic backscatter data from trawl surveys. *New Zealand Aquatic Environment and Biodiversity Report 2011/76*. 99 p.

O'Driscoll, R.L.; Ladroit, Y.; Dunford, A.J.: MacGibbon, D.J. (2016). Acoustic survey of spawning hoki in Cook Strait during winter 2015 and update of acoustic q priors for hoki stock assessment modelling. *New Zealand Fisheries Assessment Report 2016/44*. 55 p.

Rose, G.; Gauthier, S.; Lawson, G. (2000). Acoustic surveys in the full monte: simulating uncertainty. *Aquatic Living Resources 13*: 367–372.

Stevens, D.W.; Ballara, S.L.; Maurice, A.; Escobar-Flores, P.C.; Yeoman, J. (2024). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2024 (TAN2401). *New Zealand Fisheries Assessment Report 2024/77*. 118 p.

Tuck I.; Cole, R.; Devine, J. (2009). Ecosystem indicators for New Zealand fisheries. *New Zealand Aquatic Environment and Biodiversity Report 42*. 188 p.

Vignaux, M. (1994). Documentation of Trawl survey Analysis Program. MAF Fisheries Greta Point Internal Report No. 225. 44 p. (Unpublished report held by NIWA library, Wellington.)

Appendix 1 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)

Research	Gonad stage	Males	Females
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 2 Station details

* indicates tow was not considered suitable for abundance estimation. # indicates midwater tow.

Station	Date	Start time (NZST)	Stratum	Start latitude (° ') S	Start longitude (° ') E	Max. depth (m)	Distance towed (n. mile)	Catch hoki (kg)	Catch hake (kg)	Catch ling (kg)
1*	2024-07-22	0807	–	40 52.29	173 42.64	–	1.68	–	–	–
2	2024-07-23	0932	1&2A	40 50.33	171 15.60	357	3.00	–	–	76.6
3	2024-07-23	1300	1&2S	40 47.48	171 26.08	272	3.02	–	–	–
4	2024-07-23	1628	1&2S	40 37.56	171 42.52	214	3.05	–	–	–
5	2024-07-24	0748	1&2A	40 34.75	171 25.33	378	3.08	–	–	52.8
6	2024-07-24	0947	1&2A	40 38.39	171 20.97	399	2.96	–	–	103.4
7	2024-07-24	1137	1&2A	40 43.60	171 20.14	372	3.00	–	–	167.2
8	2024-07-24	1415	1&2B	40 45.32	171 07.40	478	3.01	8.4	–	77.0
9	2024-07-24	1642	1&2B	40 40.52	171 09.56	473	3.02	1.2	–	14.9
10	2024-07-25	0739	1&2C	40 36.82	171 03.34	527	2.98	29.3	0.2	25.6
11	2024-07-25	0945	1&2C	40 43.47	171 01.30	530	3.03	89.6	–	41.3
12	2024-07-25	1239	1&2C	40 47.37	170 44.23	609	2.93	66.0	–	11.5
13	2024-07-25	1537	1&2D	40 49.18	170 29.98	676	2.99	85.7	8.7	0.2
14	2024-07-26	0740	1&2D	40 53.45	170 06.61	780	3.09	10.4	9.6	–
15	2024-07-26	1021	1&2D	41 07.37	170 04.30	799	2.91	18.6	77.5	–
16	2024-07-26	1345	1&2D	41 18.21	170 21.43	718	3.01	42.0	58.4	23.8
17	2024-07-26	1618	1&2C	41 06.36	170 29.32	650	3.00	164.2	7.4	0.4
18	2024-07-27	0727	1&2A	40 57.62	171 09.11	344	2.21	1.0	–	70.3
19	2024-07-27	0912	1&2A	40 58.12	171 06.19	383	3.02	–-	–	143.1
20	2024-07-27	1124	1&2B	40 58.51	170 59.88	462	3.02	0.7	–	18.2
21	2024-07-27	1325	1&2B	41 01.17	170 56.94	475	2.49	2.2	–	12.2
22	2024-07-27	1532	1&2B	41 02.99	170 52.58	490	3.05	812.9	–	70.7
23	2024-07-28	0727	1&2A	41 08.05	170 56.30	413	3.04	8.5	–	131.1
24	2024-07-28	0918	1&2A	41 07.04	171 02.03	333	3.00	–	–	73.7
25	2024-07-28	1118	1&2A	41 12.44	170 56.10	350	3.06	–	–	75.9
26	2024-07-28	1355	1&2B	41 13.93	170 45.81	506	3.01	90.6	–	21.9
27	2024-07-28	1604	1&2A	41 18.41	170 49.07	418	3.05	10.6	–	61.4
28*	2024-07-29	0723	1&2S	41 27.12	170 51.75	215	0.32	–	–	–
29	2024-07-29	1552	1&2S	41 25.61	170 52.54	220	3.06	–	–	–
30	2024-07-30	0727	4A	41 31.85	170 42.88	402	3.11	5.4	–	177.6
31	2024-07-30	0922	1&2A	41 26.38	170 47.21	352	3.04	–	–	118.0

Station	Date	Start time (NZST)	Stratum	Start latitude (° ‘) S	Start longitude (° ‘) E	Max. depth (m)	Distance towed (n. mile)	Catch hoki (kg)	Catch hake (kg)	Catch ling (kg)
32	2024-07-30	1150	1&2B	41 29.00	170 38.89	498	3.03	861.8	–	99.8
33	2024-07-30	1353	1&2B	41 24.26	170 41.87	491	2.22	3 675.6	–	99.3
34	2024-07-30	1645	1&2C	41 21.54	170 30.67	627	3.03	57.6	17.5	–
35	2024-07-31	0936	4E	41 51.31	170 06.22	837	3.02	15.4	141.1	–
36	2024-07-31	1305	4D	41 46.06	170 09.67	799	3.00	64.5	49.6	–
37	2024-07-31	1625	4C	41 46.37	170 21.65	642	3.03	91.7	84.5	0.4
38	2024-08-01	0730	4A	41 50.22	170 34.75	418	3.01	0.1	–	35.5
39	2024-08-01	0920	4A	41 45.25	170 38.57	338	3.00	–	–	22.5
40	2024-08-01	1129	4S	41 45.35	170 45.18	222	3.02	–	–	–
41	2024-08-01	1315	4S	41 38.22	170 44.99	256	3.05	–	–	–
42	2024-08-01	1517	4A	41 36.67	170 40.20	391	3.05	–	–	232.9
43	2024-08-01	1707	4B	41 39.17	170 33.74	486	2.15	31.2	–	49.0
44	2024-08-02	0923	4B	41 31.43	170 38.43	490	3.16	71.5	–	142.7
45	2024-08-02	1240	4D	41 34.59	170 17.25	733	3.06	16.4	75.1	0.5
46	2024-08-02	1530	4D	41 39.26	170 09.02	805	3.23	17.3	71.7	–
47	2024-08-03	0730	4E	42 12.99	170 05.64	878	3.76	4.4	63.7	–
48	2024-08-03	0954	4D	42 06.78	170 11.00	800	3.04	20.4	42.0	–
49	2024-08-03	1242	4C	42 04.78	170 19.55	642	3.09	399.1	31.7	20.1
50	2024-08-03	1529	4C	42 13.45	170 20.30	645	3.06	981.7	38.6	2.6
51	2024-08-04	0752	4A	42 25.77	170 32.30	354	3.06	–	–	132.2
52	2024-08-04	0940	4A	42 18.08	170 34.08	325	3.02	–	–	–
53	2024-08-04	1152	4A	42 06.18	170 34.28	371	3.07	–	–	66.5
54	2024-08-04	1359	4A	42 09.75	170 34.53	365	3.01	–	–	7.1
55	2024-08-04	1610	4B	42 20.35	170 27.54	494	3.03	239.4	31.9	344.4
56*	2024-08-05	0927	6	43 02.99	169 40.28	522	2.06	126.9	36.3	67.8
57*	2024-08-05	1705	6	43 08.57	169 34.86	486	0.64	1 430.5	–	–
58*	2024-08-05	2119	7	43 14.86	169 33.86	394	1.01	412.3	–	3.9
59*	2024-08-06	1456	6	42 57.97	169 51.48	362	0.52	0.1	–	–
60*	2024-08-06	2036	6	42 48.70	169 57.46	377	0.64	198.7	–	–
61*	2024-08-07	0550	6	42 38.47	169 48.28	800	2.07	8.4	54.2	–
62	2024-08-07	1005	4D	42 19.93	170 13.95	760	2.98	183.3	734.9	–
63	2024-08-07	1457	4S	42 26.22	170 41.12	235	3.03	–	–	–
64	2024-08-08	0925	4D	42 15.80	170 14.11	757	3.03	456.5	1 260.9	–
65	2024-08-08	1343	4F	42 08.36	169 51.19	999	3.05	2.9	23.3	–
66	2024-08-08	1704	4F	42 02.20	169 50.89	979	2.64	2.3	42.9	–
67#	2024-08-09	0320	4G	41 35.11	169 25.29	820	1.43	–	–	–
68	2024-08-09	0726	4F	41 32.96	169 29.52	997	3.08	–	0.8	–

Station	Date	Start time (NZST)	Stratum	Start latitude (° ‘) S	Start longitude (° ‘) E	Max. depth (m)	Distance towed (n. mile)	Catch hoki (kg)	Catch hake (kg)	Catch ling (kg)
69	2024-08-09	1045	4G	41 43.01	169 29.40	1 056	3.02	–	–	–
70	2024-08-09	1408	4G	41 50.69	169 44.84	1 035	3.08	–	–	–
71	2024-08-09	1635	4G	41 59.13	169 43.94	1 010	3.05	–	4.0	–
72#	2024-08-09	2002	4G	41 54.18	169 44.00	801	1.46	–	–	–
73#	2024-08-10	0253	4F	41 35.90	169 50.67	810	3.33	–	–	–
74	2024-08-10	0807	4D	41 31.53	170 10.54	782	3.03	10.3	71.6	–
75	2024-08-10	1052	4E	41 31.33	169 59.71	883	2.96	2.8	38.0	–
76*	2024-08-11	1220	–	40 40.30	173 26.47	–	–	–	–	–
77*	2024-08-11	1747	–	40 41.01	173 28.22	50	–	–	–	–

Appendix 3: Calibration report RV *Tangaroa* hull mounted EK60/EK80 echosounder system

The echosounders on RV *Tangaroa* were calibrated on 22 July 2024 in Tasman Bay West of Greville Harbour (40˚ 52.16’ S, 173˚ 42.64’ E), at the start of the west coast South Island trawl survey (TAN2407). The calibration was conducted broadly as per the procedures in Demer et al. (2015). The echosounder configuration consisted of three EK60 (38, 120, and 200 kHz) and two EK80 (18 and 70 kHz) systems. All systems were calibrated in continuous wave (CW) using 1.024 ms. The transceiver settings used during the calibration are shown in Table A3.1.

A weighted line was passed under the keel to facilitate setting up the three lines and calibration sphere. Long (3.8 m) fibreglass calibration poles were used to help keep the calibration lines clear of the hull. The sphere and associated lines were immersed in a soap solution prior to entering the water. A lead weight was deployed about 6 m below the sphere to steady the arrangement of lines.

The weather during the calibration was good with 4 knots of south-westerly wind and 1 m swell. Initially the calibration was attempted with the vessel drifting (‘unclutched’), however as the vessel was drifting at speed of about 1 knot, the decision to anchor was made.

The calibration started at 08:30 NZST on 22 July, and the sphere was first located in the 38 kHz beam at 09:20 on 22 July. The 38 kHz sounder calibration was carried out first. At the start of the calibration the sphere was positioned toward the forward starboard side of the beam of the 38 kHz transducer. It appeared that the line on the port side got caught at the anode on the ship’s hull which is why it was difficult to collect readings from the port and especially port aft side of the beam. With some adjusting of the line lengths and rod positions it was eventually possible to ensure on-axis calibrations and good coverage of the 38 kHz beam pattern, as well as the 18 kHz beam pattern due to its proximity. With some further adjustments in rod positioning, it was possible to also collect readings for the 70, 120 and 200 kHz transducers which are located further to the aft towards the port side of the vessel which is why there was not much coverage for the port and especially port aft quadrant.

The calibration data were recorded using EK80 software in raw file format: TAN24070-D20240721-T2033003raw. These data are stored in the NIWA *acoustics* database. The EK60/EK80 transceiver settings in effect during the calibration are given in Table A3.1.

A temperature/salinity/depth profile was taken using a Seabird SBE37SM-RS232 (V2 2.8.0.119 SERIAL No. 03715257) conductivity, temperature, and depth probe (CTD). 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}.

Analysis

The data in the. raw EK80 files were extracted using the software ESP3 (Ladroit et al. 2020). 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} the maximum sphere echo power measurement. A value for $S_{a,corr}$ is calculated for all valid sphere echoes and the mean over all sphere echoes is used to determine the final $S_{a,corr}$.

Results
The results from the CTD cast are given in Table A3.2, along with estimates of the sphere target strength, sound speed, and acoustic absorption for 18, 38, 70, 120, and 200 kHz.

The calibration parameters resulting from the CW calibrations are given in Table A3.3 and compared with results from previous calibrations (up to 2015). Excluding calibrations carried out in Antarctica, the results from calibrations at 38 kHz have been relatively consistent (usually within 0.5 dB). Calibrations in Antarctic have also been consistent.

The estimated beam patterns, as well as the coverage of the beam by the calibration sphere, are given in Figures A3.1–A3.10. The symmetrical nature of the beam patterns and the centering near zero indicates that the transducers and transceivers were all operating correctly.

The root mean square (RMS) of the difference between the Simrad beam model and the sphere echoes out to the 3 dB beamwidth was 0.13 dB for 18 kHz, 0.12 for 38 kHz, 0.18 dB for 70 kHz, 0.16 dB for 120 kHz, and 0.20 dB at 200 kHz (Table A3.3), indicating excellent quality calibrations for 18 – 120 kHz and good quality calibration for 200 kHz (<0.4 dB is acceptable, 0.2–0.3 dB good, and <0.2 dB excellent). On-axis estimates were derived from 280 sphere echoes at 18 kHz, 132 echoes at 38 kHz, 51 echoes at 70 kHz, 55 echoes at 120 kHz, and 122 echoes at 200 kHz (Figures A3.1, A3.3, A3.5, A3.7, A3.9).

Results of the broadband calibrations showed a change of beamwidth with frequency that matched the theoretical curves (Figures A3.2, A3.4, A3.6, A3.8, A3.10).

References

Demer, D.A.; Berger, L.; Bernasconi, M.; Bethke, E.; Boswell, K.; Chu, D.; Domokos, R.; et al. (2015). Calibration of acoustic instruments. *ICES Cooperative Research Report No. 326*. 133 p.

Doonan, I.; Coombs, R.; McClatchie, S. (2003). The absorption of sound in seawater in relation to estimation of deep-water fish biomass. *ICES Journal of Marine Science 60*: 1047–1055.

Fofonoff, P.; Millard, R., Jr (1983). Algorithms for computation of fundamental properties of seawater. *UNESCO Technical Papers in Marine Science 44*. 53 p.

Francois, R.E.; Garrison, G.R. (1982). Sound absorption based on ocean measurements. Part II: Boric acid contribution and equation for total absorption. *Journal of the Acoustical Society of America 72*: 1879–1890.

Ladroit, Y.; Escobar-Flores, P.C.; Schimel, A.C.G.; O'Driscoll, R.L. (2020). ESP3: An opensource software for the quantitative processing of hydro-acoustic data. *SoftwareX*, 12: 100581

MacLennan, D.N. (1981). The theory of solid spheres as sonar calibration targets. *Scottish Fisheries Research 22*. 17 p.

Table A3.1: EK60/EK80 transceiver settings and other relevant parameters in effect during the calibration.

Parameter					
Frequency (kHz)	18	38	70	120	200
GPT model	–	0090720580ea	--	009072058148	00907205da23
GPT/WBT serial number	400065	650	145607	668	692
GPT/WBT software version	2.54	70413.0	2.54	70413.0	70413.0
EK80 software version	21.15.1	21.15.1	21.15.1	21.15.1	21.15.1
Transducer model	ES18-11	ES38B	ES70-7C	ES120-7C	ES200-7C
Transducer serial number	2080	31378	158	477	364
Sphere type/size	tungsten carbide/38.1 mm diameter (same for all frequencie				
Transducer draft setting (m)	0.0	0.0	0.0	0.0	0.0
Transmit power (W)	1000	2000	750*	250*	150*
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Transducer peak gain by pulse length (dB)	22.4	25.5	27.0	27.0	26.0
Sa correction (dB)	0.00	0.00	0.00	0.00	0.00
Bandwidth (Hz)	0	0	0	0	0
Sample interval (ms) by pulse length (dB)	0.256	0.256	0.256	0.256	0.256
Two-way (equivalent) beam angle (dB)	–17.0	–20.7	–20.7	–20.7	–20.7
Angle sensitivity (dB) along/athwartship	15.50/15.50	23.0/23.0	23.0/23.0	23.0/23.0	23.0/23.0
3 dB beamwidth (º) along/athwartship	11.0/11.0	7.0/7.0	7.0/7.0	7.0/7.0	7.0/7.0
Angle offset (º) along/athwartship	0.0/0.0	0.0/0.0	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 A3.2: 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 (NZST, start)	22 July 2024 17:45
Position	40˚ 52.16' S, 173˚ 42.64' E
Mean sphere range (m)	12.0 (18 kHz), 14.4 (38), 13.7 (70), 13.9 (120), 14.0 (200)
Mean temperature (ºC)	13.2
Mean salinity (psu)	35.0
Sound speed (m/s)	1 498.48
Water density (kg/m^3)	1 027.45
Sound absorption (dB/km)	2.23 (18 kHz)
	9.27 (38 kHz)
	22.89 (70 kHz)
	38.19 (120 kHz)
	58.60 (200 kHz)
Sphere target strength (dB re 1m^2)	-42.63 (18 kHz)
	-42.41 (38 kHz)
	-41.42 (70 kHz)
	-39.52 (120 kHz)
	-39.08 (200 kHz)

Table A3.3: Estimated calibration coefficients for all calibrations of *Tangaroa* hull EK80 (continuous wave, CW)/EK60 echosounders since 2015. Transducer peak gain was estimated from mean sphere TS. * The 38 kHz transducer was changed in October 2015. The Jan 2021, Jan 2019, and Feb 2015 calibrations were in Antarctica. Calibrations of the 18 and 70 kHz echosounders in 2021 and 2019 are from EK80 systems.

		Jul 2024	2023 ANT	Aug 2022	Jan 2021	Aug 2019	Jan 2019	Jul 2018	Aug 2016	Feb 2016	Feb 2015
18 kHz											
	Transducer peak gain (dB)	23.53	N/A	23.36	N/A	22.92	23.43	N/A	22.80	22.85	23.21
	Sa correction (dB)	-0.113	N/A	-0.168	N/A	-0.76	-0.76	N/A	-0.71	-0.73	-0.76
	Beamwidth (º) along/athwartship	9.7/9.9	N/A	10.45/10.34	N/A	9.7/9.7	9.7/9.7	N/A	10.6/10.9	10.5/11.3	10.7/11.2
	Beam offset (º) along/athwartship	0.07/0.09	N/A	-0.009/0.033	N/A	-0.04/0.14	-0.04/0.14	N/A	0.00/0.00	0.00/0.00	0.00/0.00
	RMS deviation (dB)	0.13	N/A	0.13	N/A	0.12	0.12	N/A	0.10	0.14	0.12
38 kHz*											
	Transducer peak gain (dB)	26.66	26.29	26.43	26.29	26.31	26.32	26.37	26.23	26.21	25.69
	Sa correction (dB)	-0.59	-0.54	-0.60	-0.54	-0.59	-0.56	-0.55	-0.62	-0.58	-0.54
	Beamwidth (º) along/athwartship	6.9/6.8	6.7/6.5	6.7/6.8	6.7/6.5	6.8/6.8	6.6/6.6	6.7/6.8	7.0/7.1	6.9/7.2	6.8/6.9
	Beam offset (º) along/athwartship	0.04/-0.12	0.13/0.20	0.05/-0.12	0.13/0.20	0.06/-0.12	0.11/-0.14	0.06/-0.08	0.00/0.00	0.14/-0.19	0.00/0.00
	RMS deviation (dB)	0.07	0.20	0.12	0.20	0.08	0.14	0.12	0.11	0.14	0.12
70 kHz											
	Transducer peak gain (dB)	27.88	N/A	27.14	N/A	26.36	26.27	N/A	26.33	26.28	26.55
	Sa correction (dB)	-0.03	N/A	-0.16	N/A	-0.33	-0.32	N/A	-0.31	-0.38	-0.35
	Beamwidth (º) along/athwartship	6.3/6.2	N/A	7.1/ 7.2	N/A	6.8/6.8	6.4/6.5	N/A	6.4/6.6	6.2/6.5	6.6/6.7
	Beam offset (º) along/athwartship	0.04/0.19	N/A	-0.23/-0.04	N/A	0.00/0.00	0.02/0.06	N/A	0.00/0.00	0.13/-0.04	0.04/-0.02
	RMS deviation (dB)	0.08	N/A	0.18	N/A	0.06	0.16	N/A	0.13	0.18	0.10

Table A3.3: Continued.

		Jul 2024	2023 ANT	Aug 2022	Jan 2021	Aug 2019	Jan 2019	Jul 2018	Aug 2016	Feb 2016	Feb 2015
120 kHz											
	Transducer peak gain (dB)	25.9	26.01	25.89	26.01	26.71	26.29	26.20	26.19	26.15	26.92
	Sa correction (dB)	-0.32	-0.26	-0.38	-0.26	-0.38	-0.37	-0.45	-0.33	-0.29	-0.33
	Beamwidth (º) along/athwartship	6.4/5.9	6.4/6.4	6.6/6.8	6.4/6.4	6.5/6.4	6.4/6.6	6.7/6.8	6.3/6.5	6.1/6.2	6.4/6.5
	Beam offset (º) along/athwartship	0.03/0.51	0.00/-0.13	-0.09/0.03	0.00/-0.13	-0.10/0.04	-0.01/-0.01	-0.02/0.00	0.00/0.00	-0.00/0.00	-0.00/0.00
	RMS deviation (dB)	0.15	0.23	0.16	0.23	0.17	0.18	0.20	0.17	0.18	0.16
200 kHz											
	Transducer peak gain (dB)	24.96	25.06	25.11	24.67	25.09	24.98	25.15	24.92	25.10	24.90
	Sa correction (dB)	-0.23	-0.32	-0.25	-0.32	-0.33	-0.20	-0.29	-0.17	-0.22	-0.27
	Beamwidth (º) along/athwartship	6.0/6.3	6.2/6.4	6.7/6.8	6.2/6.4	6.8/6.6	6.3/6.4	6.5/6.5	6.4/6.3	6.2/6.2	6.6/6.9
	Beam offset (º) along/athwartship	0.33/0.02	0.22/-0.27	-0.08/-0.16	0.22/-0.27	-0.24/-0.08	0.18/-0.08	-0.03/-0.1	0.00/0.00	0.00/0.00	0.00/0.00
	RMS deviation (dB)	0.20	0.26	0.21	0.26	0.20	0.19	0.25	0.19	0.18	0.20

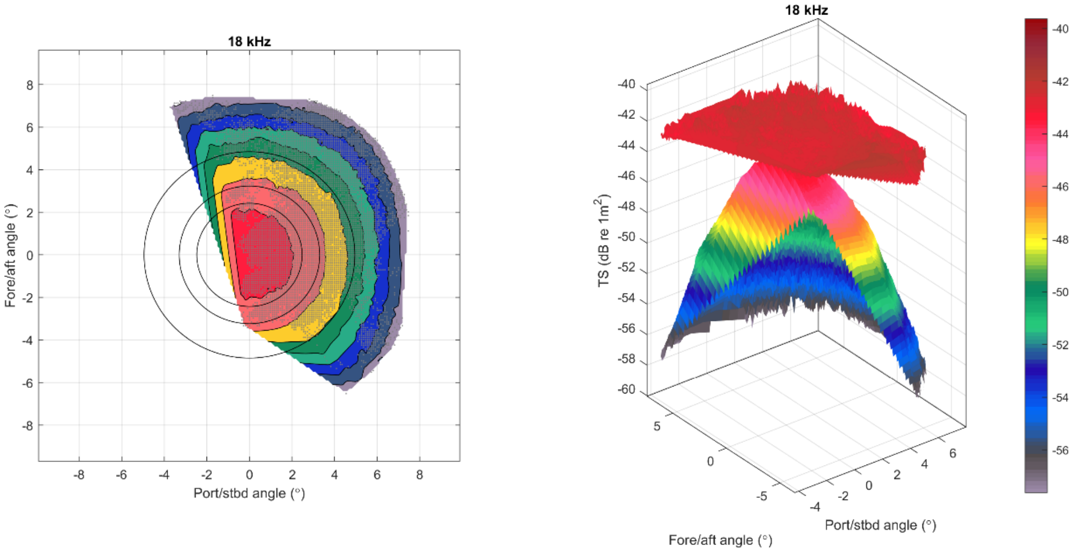


Figure A3.1: The 18 kHz estimated beam pattern from the sphere echo strength and position shown in two- (left) and three-dimensional (right) coordinate planes. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.

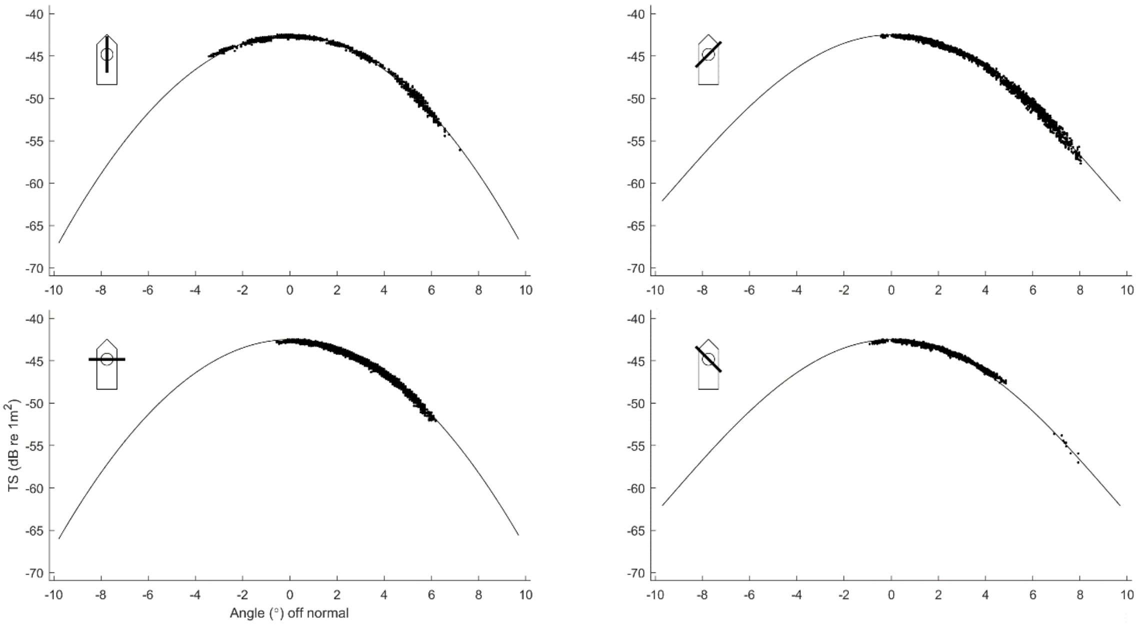


Figure A3.2: Beam pattern results from the 18 kHz analysis. The solid line is the ideal beam pattern fit to the sphere echoes for four slices through the beam.

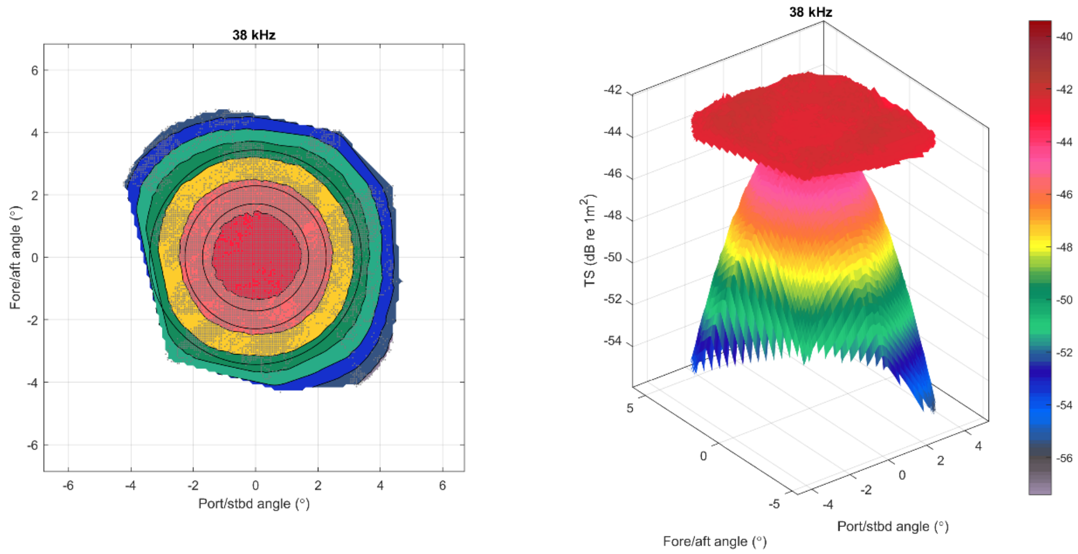


Figure A3.3: The 38 kHz estimated beam pattern from the sphere echo strength and position shown in two- (left) and three-dimensional (right) coordinate planes. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.

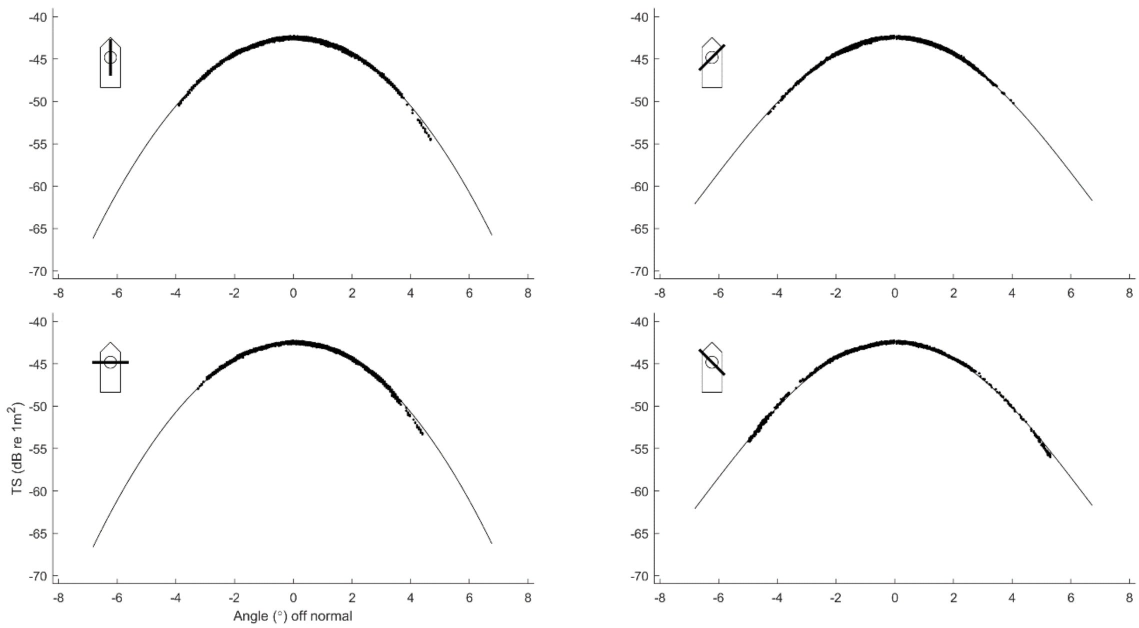


Figure A3.4: Beam pattern results from the 38 kHz analysis. The solid line is the ideal beam pattern fit to the sphere echoes for four slices through the beam.

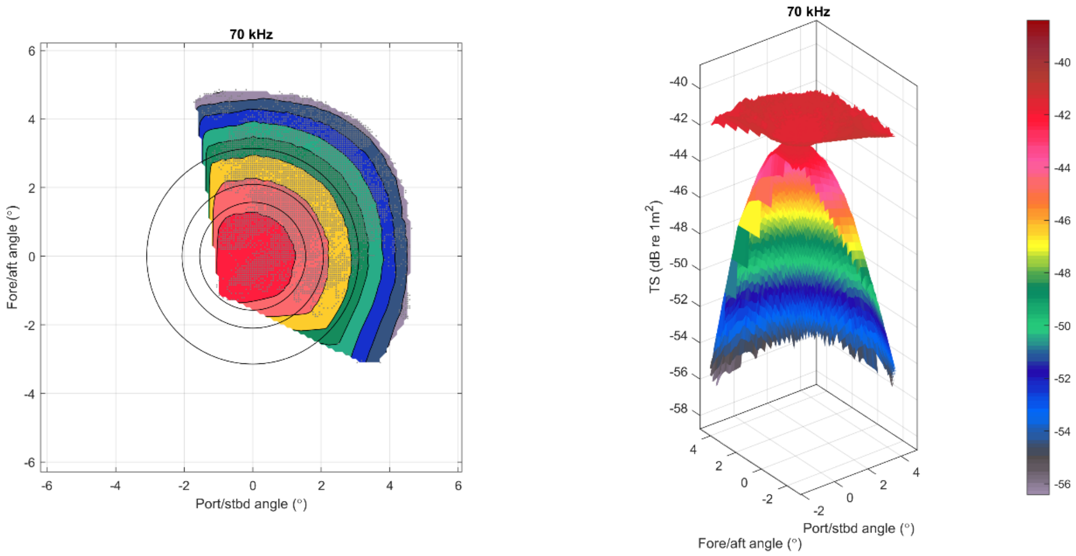


Figure A3.5: The 70 kHz estimated beam pattern from the sphere echo strength and position shown in two- (left) and three-dimensional (right) coordinate planes. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.

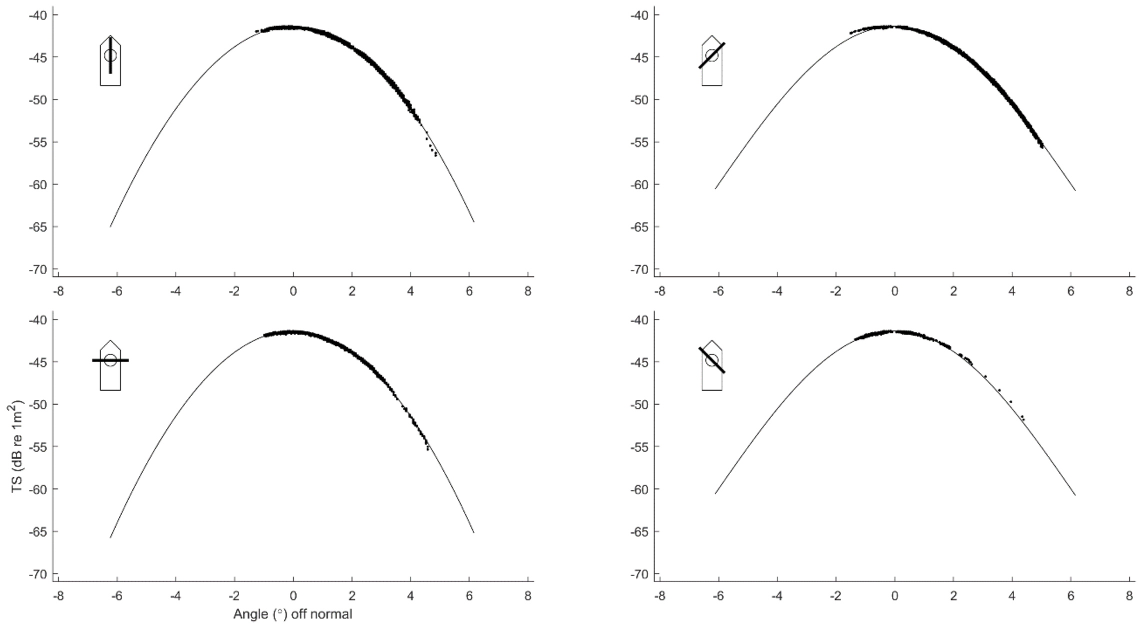


Figure A3.6: Beam pattern results from the 70 kHz analysis. The solid line is the ideal beam pattern fit to the sphere echoes for four slices through the beam.

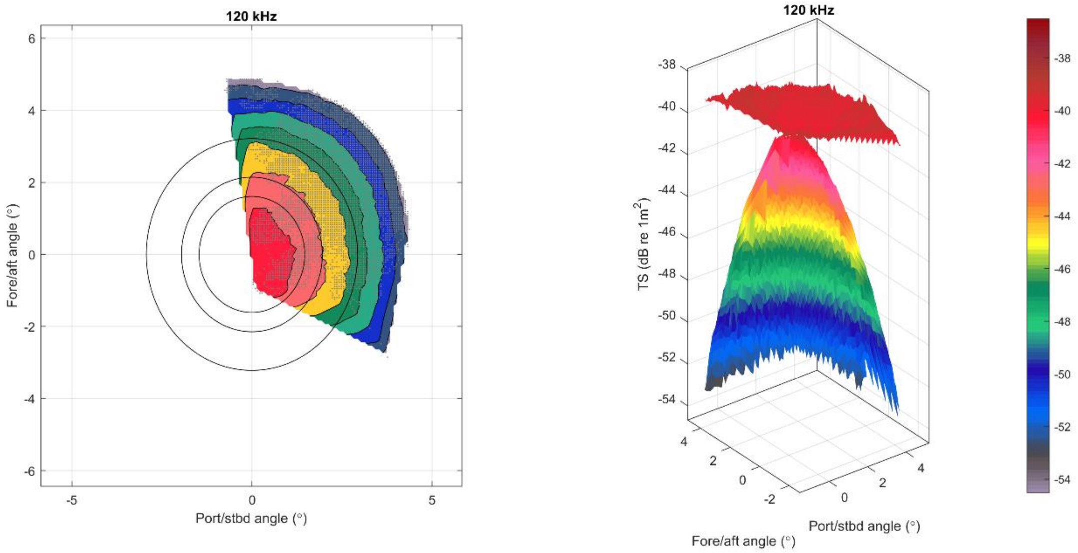


Figure A3.7: The 120 kHz estimated beam pattern from the sphere echo strength and position shown in two- (left) and three-dimensional (right) coordinate planes. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.

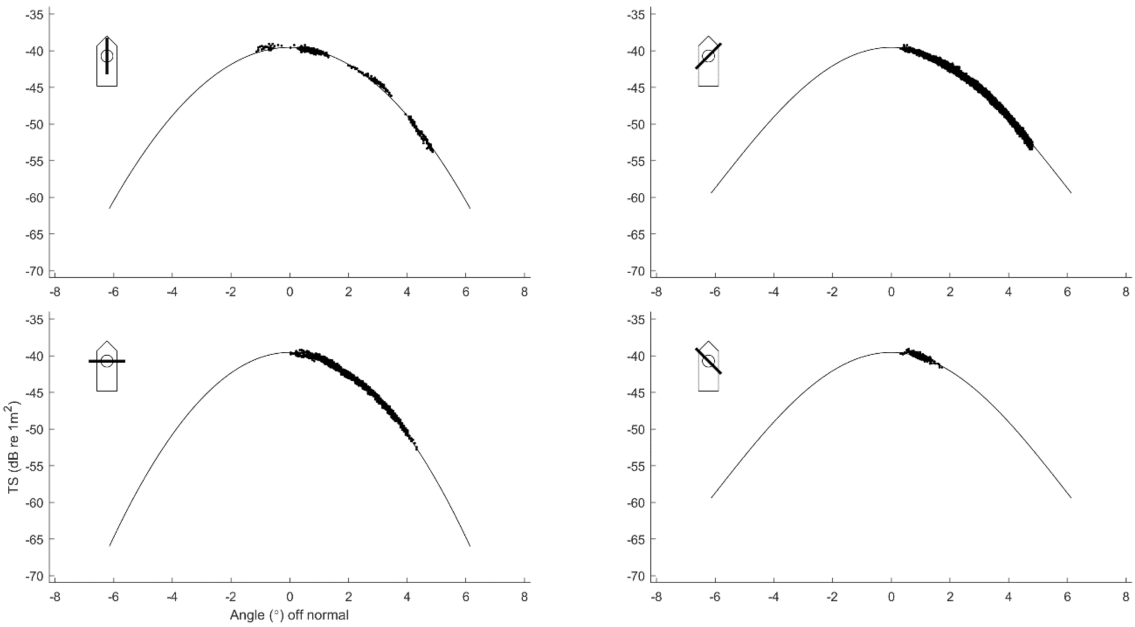


Figure A3.8: Beam pattern results from the 120 kHz analysis. The solid line is the ideal beam pattern fit to the sphere echoes for four slices through the beam.

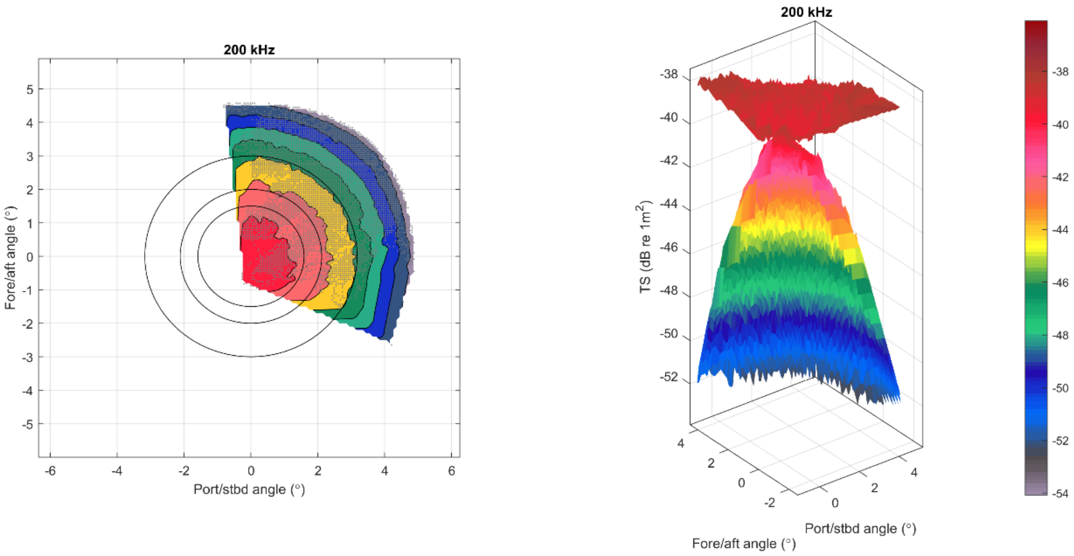


Figure A3.9: The 200 kHz estimated beam pattern from the sphere echo strength and position shown in two- (left) and three-dimensional (right) coordinate planes. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.

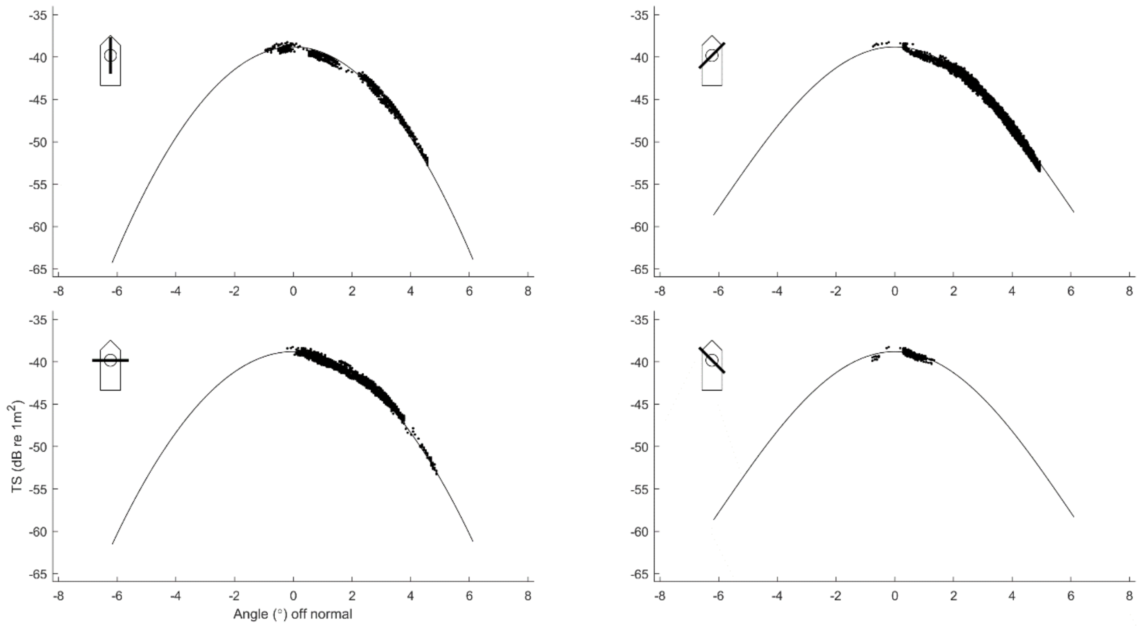


Figure A3.10: Beam pattern results from the 200 kHz analysis. The solid line is the ideal beam pattern fit to the sphere echoes for four slices through the beam.

Appendix 4: Species list with occurrence

Scientific and common names of species caught from bottom and midwater tows (TAN2407). The occurrence (Occ.) of each species (number of tows caught) in all 130 core and deep tows is also shown (i.e., encompasses 200–1000 m). Note that species codes are continually updated on the database following this and other surveys.

Scientific name	Common name	Code	Occ.
Porifera	unspecified sponge	ONG	2
Spirophorida (spiral sponges)			
Tetillidae			
Tetilla australe	bristle ball sponge	TTL	1
T. leptoderma	furry oval sponge	TLD	1
Hexactinellida (glass sponges)			
Lyssacinosida (glass horn sponges)			
Euplectellidae			
Euplectella regalis	basket-weave horn sponge	ERE	1
Hyalascus sp.	floppy tubular sponge	HYA	4
Poecilosclerida (bright sponges)			
Hymedesmiidae			
Phorbas spp.	grey fibrous massive sponge	PHB	2
Cnidaria			
Scyphozoa	unspecified jellyfish	JFI	10
Periphyllidae			
Periphylla periphylla	helmet jellyfish	PPE	2
Anthozoa			
Octocorallia			
Alcyonacea (soft corals)			
Keratoisididae (bamboo corals)			
Acanella spp.	bushy bamboo coral	ACN	1
Pennatulacea (sea pens)	unspecified sea pens	PTU/SPN	12
Hexacorallia			
Actinaria (anemones)	unspecified anemone	ANT	1
Actinostolidae (smooth deepsea anemones)		ACS	2
Hormathiidae (warty deepsea anemones)		HMT	4
Scleractinia (stony corals)			
Caryophyllidae			
Desmophyllum dianthus	crested cup coral	DDI	1
Stephanocyathus platypus	solitary bowl coral	STP	2
Zoantharia (zoanthids)			
Epizoanthidae			
Epizoanthus sp.		EPZ	2
Hydrozoa (hydroids)			
Siphonophorae	unspecified siphonophore	ZSP	2
Tunicata			
Thaliacea			
Pyrosomida (pyrosomes)			
Pyrosomatidae			
Pyrosoma atlanticum		PYR	1
Salpida (salps)	unspecified salp	SAL	4
Salpidae			
Thetys vagina		ZVA	19
Mollusca			
Bivalvia (bivalves)			
Gastropoda (gastropods)	unspecified gastropod	GAS	1
Ranellidae (tritons)			

Scientific name	Common name	Code	Occ.
Fusitriton magellanicus		FMA	1
Pterapoda (pterapods)			
Cymbuliidae			
Cymbulia peronii		CPE	3
Nudibranchia (nudibranchs)	unspecified nudibranch	NUD	1
Cephalopoda			
Teuthoidea (squids)	unidentified squid	SQX	4
Spirulida			
Spirulidae			
Spirula spirula	ram's horn squid	SPQ	1
Sepiida			
Sepiolidae (bobtail squids)			
Stoloteuthis maoria	bobtail squid	IRM	1
Oegopsida			
Lycoteuthidae			
Lycoteuthis lorigera	crowned firefly squid	LSQ	1
Enoploteuthidae			
Enoploteuthis sp.	squid	ESQ	4
Octopoteuthidae			
Taningia danae & *T. fimbria*	squid	TDQ	1
Pholidoteuthidae			
Pholidoteuthis spp.	large red scaly squids	PSQ	4
Histioteuthidae (violet squids)			
Histioteuthis miranda	violet squid	HMI	7
Histioteuthis spp.	violet squid	VSQ	6
Ommastrephidae			
Nototodarus gouldi	NZ northern arrow squid	NOG	18
N. sloanii	NZ southern arrow squid	NOS	25
N. sloanii & *N. gouldi*	arrow squid	SQU	41
Todarodes filippovae	Todarodes squid	TSQ	5
Cranchiidae	unspecified cranchiid	CHQ	4
Teuthowenia pellucida	squid	TPE	2
Onychoteuthidae			
Onykia robsoni & *O.* sp. A	warty squid	MRQ	12
Octopodiformes			
Cirrata (cirrate octopus)			
Opisthoteuthidae			
Opisthoteuthis spp.	umbrella octopus	OPI	3
Polychaeta (polychaete worms)	unspecified polychaete	POL	1
Onuphidae			
Hyalinoecia tubicola	quill worm	HTU	2
Crustacea			
Cirripedia (barnacles)			
Thoracica			
Scalpellomorpha			
Scalpellidae	unspecified stalked barnacle	SBN	15
Malacostraca			
Eucarida			
Euphausiacea	unspecified euphausiid	EUP	3
Decapoda			
Dendrobranchiata/Pleocyemata	unspecified natant decapod	NAT	2
Dendrobranchiata			
Aristeidae			
Aristaeomorpha foliacea	royal red prawn	AFO	1
Aristaeopsis edwardsiana	scarlet prawn	PED	4
Aristeus sp.	prawn	ARI	2
Austropenaeus nitidus	prawn	ANI	1

Scientific name	Common name	Code	Occ.
Penaeidae			
Funchalia spp.	Funchalia prawn	FUN	3
Sergestidae			
Eusergestes antarcticus	prawn	SAC	3
Sergia potens	prawn	SEP	7
Solenoceridae			
Haliporoides sibogae	jackknife prawn	HSI	7
Pleocyemata			
Caridea			
Oplophoridae			
Acanthephyra spp.	Sub-Antarctic ruby prawn	ACA	4
Notostomus auriculatus	scarlet prawn	NAU	1
Oplophorus spp.	deepwater prawn	OPP	7
Pandalidae			
Plesionika martia	golden prawn	PLM	2
Pasiphaeidae			
Pasiphaea barnardi	deepwater prawn	PBA	3
Pasiphaea spp.	prawn	PAS	1
Nematocarcinidae			
Lipkius holthuisi	omega prawn	LHO	11
Achelata			
Phyllosoma	unspecified phyllosoma	PHY	1
Astacidea			
Nephropidae (clawed lobsters)			
Metanephrops challengeri	scampi	SCI	12
Achelata			
Scyllaridae (slipper lobsters)			
Ibacus alticrenatus	prawn killer	PRK	8
Polychelida			
Polychelidae			
Polycheles spp.	deepsea blind lobster	PLY	1
Anomura			
Chirostyloidea			
Chirostylidae			
Uroptychus spp.		URP	4
Galatheoidea			
Munididae	unspecified munidid squat lobster	MNI	2
Lithodidae (king crabs)	unspecified king crab	KIC	1
Paguroidea (hermit crabs)			
Parapaguridae (Parapagurid hermit crabs)			
Sympagurus dimorphus	hermit crab	SDM	1
Brachyura (true crabs)			
Goneplacidae			
Pycnoplax victoriensis	two-spined crab	CVI	2
Inachidae			
Platymaia maoria	Dell's spider crab	PTM	2
Mysidacea	unspecified mysid	MYS	1
Amphipoda			
Pelagic amphipod	unspecified pelagic amphipod	APP	2
Hyperiidea			
Phronimidae			
Phronima sedentaria	barrel shrimp	ZBS	2
Echinodermata			
Asteroidea (starfish)			
Asteriidae			
Sclerasterias mollis	cross-fish	SMO	2
Astropectinidae			
Dipsacaster magnificus	magnificent sea-star	DMG	9

Scientific name	Common name	Code	Occ.
Plutonaster knoxi	abyssal star	PKN	7
Proserpinaster neozelanicus	starfish	PNE	14
Psilaster acuminatus	geometric star	PSI	16
Benthopectinidae			
Benthopecten spp.	starfish	BES	2
Brisingida	unspecified brisingid	BRG	7
Echinasteridae			
Henricia compacta	starfish	HEC	1
Goniasteridae			
Lithosoma novaezelandiae	rock star	LNV	1
Mediaster sladeni	starfish	MSL	7
Pillsburiaster aoteanus	starfish	PAO	2
Solasteridae			
Crossaster multispinus	sun star	CJA	5
Solaster torulatus	chubby sun-star	SOT	2
Zoroasteridae			
Zoroaster spp.	rat-tail star	ZOR	1
Ophiuroidea (basket & brittle stars)			
Ophiurida (brittle stars)			
Ophiodermatidae			
Bathypectinura heros	deepsea brittle star	BHE	1
Ophiuridae			
Ophiomusium lymani	deepsea brittle star	OLY	1
Echinoidea (sea urchins)			
Echinothuriidae/Phormosomatidae	unspecified Tam O'Shanter urchin	TAM	24
Aulodonta			
Pedinidae			
Caenopedina porphyrogigas	giant purple pedinid	CAL	3
Irregularia			
Spatangoida (heart urchins)			
Spatangidae			
Spatangus multispinus	purple-heart urchin	SPT	4
Holothuroidea	unspecified holothurian	HTH	2
Aspidochirotida			
Synallactidae			
Bathyplotes sp.	sea cucumber	BAM	3
Elasipodida			
Laetmogonidae			
Pannychia moseleyi	sea cucumber	PAM	2
Pelagothuridae			
Enypniastes eximia	sea cucumber	EEX	7
Agnatha (jawless fishes)			
Myxinidae: hagfishes			
Eptatretus cirrhatus	hagfish	HAG	3
Chondrichthyes (cartilaginous fishes)			
Chimaeridae: chimaeras, ghost sharks			
Hydrolagus bemisi	pale ghost shark	GSP	26
H. homonycteris	black ghost shark	HYB	1
H. novaezealandiae	dark ghost shark	GSH	27
Rhinochimaeridae: longnosed chimaeras			
Harriotta raleighana	longnose spookfish	LCH	3
Rhinochimaera pacifica	Pacific spookfish	RCH	6
Scyliorhinidae: cat sharks			
Apristurus exsanguis	New Zealand catshark	AEX	3
Cephaloscyllium isabella	carpet shark	CAR	12
Pseudotriakidae: false cat sharks			
Gollum attenuatus	slender smooth-hound	SSH	23

Scientific name	Common name	Code	Occ.
Triakidae: smoothhounds			
Galeorhinus galeus	school shark	SCH	10
Mustelus lenticulatus	rig	SPO	6
Hexanchidae: cow sharks			
Heptranchias perlo	sharpnose sevengill shark	HEP	2
Hexanchus griseus	sixgill shark	HEX	1
Squalidae: dogfishes			
Squalus acanthias	spiny dogfish	SPD	3
S. griffini	northern spiny dogfish	NSD	33
Centrophoridae: gulper sharks			
Centrophorus squamosus	leafscale gulper shark	CSQ	14
Deania quadrispinosa	longsnout dogfish	DEQ	3
D. spp.	shovelnose spiny dogfish	SND	24
Etmopteridae: lantern sharks			
Etmopterus granulosus	Baxter's dogfish	ETB	7
E. lucifer	lucifer dogfish	ETL	16
Somniosidae: sleeper sharks			
Centroselachus crepidater	longnose velvet dogfish	CYP	18
Centroscymnus coelolepis	Portuguese dogfish	CYL	4
C. owstoni	Owston’s dogfish	CYO	15
Proscymnodon plunketi	Plunket's shark	PLS	10
Zameus squamulosus	velvet dogfish	ZAS	1
Oxynotidae: rough sharks			
Oxynotus bruniensis	prickly dogfish	PDG	3
Dalatiidae: kitefin sharks			
Dalatias licha	seal shark	BSH	13
Torpedinidae: electric rays			
Tetronarce nobiliana	electric ray	ERA	3
Rajidae: skates			
Dipturus innominatus	smooth skate	SSK	25
Zearaja nasuta	rough skate	RSK	4
Arhynchobatidae: softnose skates			
Arhynchobatis asperrimus	longtail skate	LSK	3
Bathyraja shuntovi	longnosed deepsea skate	PSK	2
Brochiraja asperula	smooth deepsea skate	BTA	1
B. spinifera	prickly deepsea skate	BTS	1
Dasyatidae: stingrays			
Bathytoshia brevicaudata	short-tailed black ray	BRA	1
Osteichthyes (bony fishes)			
Notocanthidae: spiny eels			
Notacanthus chemnitzi	giant spineback	NOC	1
N. sexspinis	spineback	SBK	11
Anguilliformes	unspecified eel	EEL	2
Synaphobranchidae: cutthroat eels			
Diastobranchus capensis	basketwork eel	BEE	13
Synaphobranchus affinis	grey cutthroat eel	SAF	1
Nemichthyidae: snipe eels			
Avocettina paucipora	fewpore snipe eel	APA	1
Congridae: conger eels			
Bassanago bulbiceps	swollenhead conger	SCO	22
B. hirsutus	hairy conger	HCO	18
Serrivomeridae: sawtooth eels			
Serrivomer samoensis	common sawtooth eel	SSA	1
Argentinidae: silversides			
Argentina elongata	silverside	SSI	17
Platytroctidae: tubeshoulders	unspecified tubeshoulder	SID	2
Persparsia kopua	common tubeshoulder	PER	4
Alepocephalidae: slickheads			

Scientific name	Common name	Code	Occ.
Alepocephalus antipodianus	smallscaled brown slickhead	SSM	6
A. australis	bigscaled brown slickhead	SBI	6
Rouleina guentheri	bordello slickhead	RGN	1
Xenodermichthys copei	black slickhead	BSL	22
Gonostomatidae: bristlemouths			
Cyclothone spp.	bristlemouth	CYC	3
Sigmops elongatum	black lightfish	GEL	5
Sternoptychidae: hatchetfishes			
Argyropelecus gigas	giant hatchetfish	AGI	5
A. hemigymnus	common hatchetfish	AHE	1
A. olfersii	Olfer's hatchetfish	AOL	1
Maurolicus australis	pearlside	MMU	5
Polyipnus spp.	hatchetfish	PYP	1
Phosichthyidae: lighthouse fishes			
Phosichthys argenteus	lighthouse fish	PHO	16
Vinciguerria spp.	lighthouse fish	VIN	2
Stomiidae (dragonfishes)			
Stomiinae: scaly dragonfishes			
Stomias boa	scaly dragonfish	SBB	8
Astronesthinae: snaggletooths			
Neonesthes microcephalus	smallhead snaggletooth	NMI	2
Chauliodontinae: viperfishes			
Chauliodus sloani	viperfish	CHA	13
Malacosteinae: loosejaws			
Malacosteus australis	southern loosejaw	MAU	2
Melanostomiinae: barbeled dragonfishes			
Melanostomias niger	black dragonfish	MNG	2
Paraulopidae: cucumberfishes			
Paraulopus nigripinnis	cucumberfish	CUC	28
P. okamurai	magpie cucumberfish	POK	1
Alepisauridae: lancetfishes			
Alepisaurus ferox	longsnout lancetfish	LAT	1
Neoscopelidae: blackchins			
Neoscopelus macrolepidotus	largescale blackchin	NML	3
Myctophidae: lanternfishes			
Ceratoscopelus warmingi	Warming's lanternfish	CWA	1
Diaphus danae	Dana lanternfish	DDA	1
D. hudsoni	Hudson's lanternfish	DHU	3
D. meadi	Mead's lanternfish	DMI	1
D. metopoclampus	Spothead lanternfish	DME	2
D. ostenfeldi	Ostenfeld's lanternfish	DOE	2
Electrona paucirastra	Belted lanternfish	EPA	1
E. risso	Risso's lanternfish	ERI	3
Gymnoscopelus bolini	Bolin's lanternfish	GYB	1
Lampadena notialis	Notal lanternfish	LNT	1
Lampanyctus ater	dusky lanternfish	LAR	3
L. australis	austral lanternfish	LAU	8
L. intricarius	intricate lanternfish	LIT	3
L. pusillus	pygmy lanternfish	LPU	3
L. macdonaldi	MacDonald's lanternfish	LMD	1
L. spp.	unspecified *Lampanyctus* species	LPA	1
Lampanyctodes hectoris	Hector's lanternfish	LHE	5
Lampichthys procerus	Blackhead lanternfish	LPR	1
Lobianchia spp.	unspecified *Lobianchia* species	LBC	1
Trachipteridae: dealfishes			
Trachipterus trachypterus	dealfish	DEA	1
Ophidiidae: cuskeels			
Brotulotaenia nigra	blue cusk eel	BCR	1
Genypterus blacodes	ling	LIN	41

Scientific name	Common name	Code	Occ.
Euclichthyidae: eucla cods			
Euclichthys polynemus	eucla cod	EUC	33
Macrouridae: rattails			
Bathygadus cottoides	codheaded rattail	BAC	1
Coelorinchus biclinozonalis	two saddle rattail	CBI	6
C. bollonsi	Bollons' rattail	CBO	33
C. fasciatus	banded rattail	CFA	11
C. innotabilis	notable rattail	CIN	12
C. matamua	Mahia rattail	CMA	17
C. maurofasciatus	darkbanded rattail	CDX	9
C. oliverianus	Oliver's rattail	COL	39
C. parvifasciatus	small banded rattail	CCX	25
Coryphaenoides dossenus	humpback rattail	CBA	3
C. serrulatus	serrulate rattail	CSE	13
C. subserrulatus	four-rayed rattail	CSU	10
Gadomus aoteanus	filamentous rattail	GAO	2
Kuronezumia bubonis	bulbous rattail	NBU	2
Lepidorhynchus denticulatus	javelinfish	JAV	52
Lucigadus nigromaculatus	blackspot rattail	VNI	3
Trachonurus gagates	velvet rattail	TRX	2
Trachyrincidae: rough rattails			
Trachyrincus aphyodes	white rattail	WHX	17
T. longirostris	unicorn rattail	WHR	2
Moridae: morid cods			
Halargyreus sp.	Australasian slender cod	HAS	11
Lepidion microcephalus	small-headed cod	SMC	1
Mora moro	ribaldo	RIB	28
Pseudophycis bachus	red cod	RCO	6
Tripterophycis gilchristi	grenadier cod	GRC	2
Melanonidae: pelagic cods			
Melanonus zugmayeri	largetooth pelagic cod	MEZ	3
Merlucciidae: hakes			
Lyconus pinnatus	fangtooth hake	LYC	1
Macruronus novaezelandiae	hoki	HOK	46
Merluccius australis	hake	HAK	27
Chaunacidae: coffinfishes			
Chaunax russatus	pink frogmouth	CHX	2
Melanocetidae: black seadevils			
Melanocetus johnsonii	humpback anglerfish	MEJ	1
Ceratiidae: seadevils			
Ceratias spp.	seadevils	CER	1
Melamphaidae: bigscalefishes	unspecified bigscalefish	MPH	1
Poromitra atlantica	common bigscalefish	CBS	1
Diretmidae: spinyfins			
Diretmichthys parini	spinyfin	SFN	2
Diretmus argenteus	discfish	DIS	1
Trachichthyidae: roughies, slimeheads			
Hoplostethus atlanticus	orange roughy	ORH	12
H. mediterraneus	silver roughy	SRH	41
Paratrachichthys trailli	common roughy	RHY	3
Berycidae: alfonsinos			
Beryx decadactylus	longfinned beryx	BYD	2
B. splendens	alfonsino	BYS	5
Cyttidae: cyttid dories			
Cyttus novaezealandiae	silver dory	SDO	9
C. traversi	lookdown dory	LDO	44
Zeniontidae: armoureye dories			
Capromimus abbreviatus	capro dory	CDO	44
Zeidae: dories			

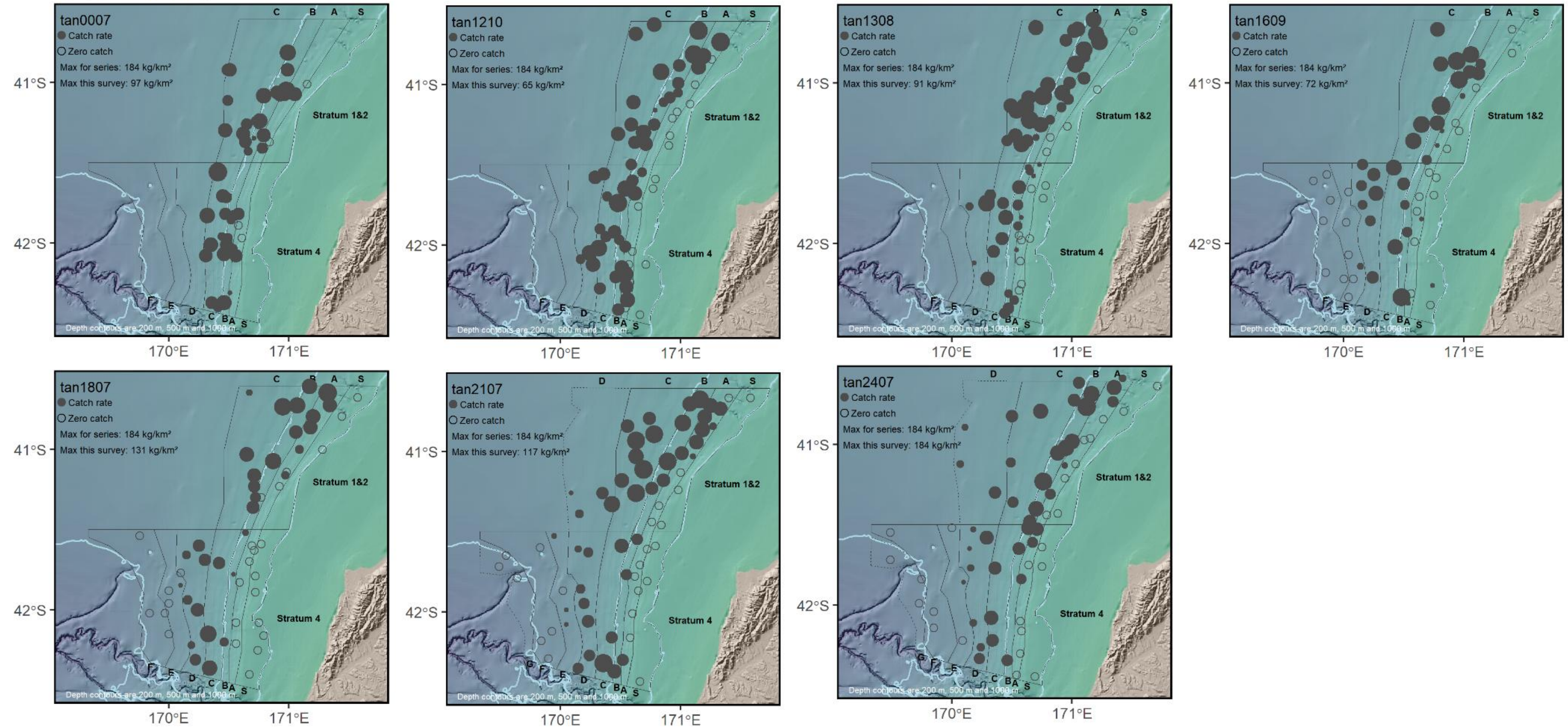
Scientific name	Common name	Code	Occ.
Zenopsis nebulosa	mirror dory	MDO	2
Zeus faber	John dory	JDO	6
Oreosomatidae: oreos	unspecified oreo	OEO	1
Allocyttus verrucosus	warty oreo	WOE	1
Neocyttus rhomboidalis	spiky oreo	SOR	17
Macrorhamphosidae: snipefishes			
Centriscops humerosus	banded bellowsfish	BBE	13
Sebastidae: seaperches			
Helicolenus barathri	bigeye sea perch	HBA	55
H. percoides	sea perch	HPC	8
Trachyscorpia eschmeyeri	Cape scorpionfish	TRS	5
Triglidae: gurnards			
Chelidonichthys kumu	red gurnard	GUR	1
Lepidotrigla brachyoptera	scaly gurnard	SCG	2
Pterygotrigla andertoni	spotted gurnard	JGU	16
Hoplichthyidae: ghostflatheads			
Hoplichthys cf. *haswelli*	deepsea flathead	FHD	25
Psychrolutidae: toadfishes			
Ambophthalmos angustus	pale toadfish	TOP	4
Polyprionidae: wreckfishes			
Polyprion oxygeneios	hāpuku	HAP	6
Serranidae: sea perches, gropers			
Lepidoperca aurantia	orange perch	OPE	12
Callanthiidae: splendid perches			
Callanthias allporti	southern splendid perch	SDP	1
Epigonidae: deepwater cardinalfishes			
Epigonus lenimen	bigeye cardinalfish	EPL	15
E. telescopus	deepsea cardinalfish	EPT	5
Howellidae: pelagic basslets			
Howella brodiei	pelagic cardinalfish	HOW	2
Carangidae: trevallies, kingfishes			
Trachurus declivis	greenback jack mackerel	JMD	3
Emmelichthyidae: bonnetmouths, rovers			
Emmelichthys nitidus	redbait	RBT	27
Plagiogeneion rubiginosum	rubyfish	RBY	5
Sparidae: seabreams, porgies			
Chrysophrys auratus	snapper	SNA	1
Sparidae: seabreams, porgies			
Pentaceros decacanthus	yellow boarfish	YBO	28
Cheilodactylidae: tarakihi, morwongs			
Nemadactylus macropterus	tarakihi	NMP	19
Latridae: trumpeters			
Latris lineata	trumpeter	TRU	1
Percophidae: opalfishes			
Hemerocoetes spp.	opalfish	OPA	1
Uranoscopidae: armourhead stargazers			
Kathetostoma giganteum	giant stargazer	GIZ	36
Gempylidae: snake mackerels			
Rexea solandri	gemfish	RSO	46
Thyrsites atun	barracouta	BAR	7
Trichiuridae: cutlassfishes			
Benthodesmus spp.	scabbardfish	BEN	7
Lepidopus caudatus	frostfish	FRO	23
Xiphiidae: swordfishes			
Xiphias gladius	swordfish	SWO	1
Centrolophidae: raftfishes, medusafishes			
Centrolophus niger	rudderfish	RUD	3
Hyperoglyphe antarctica	bluenose	BNS	1
Schedophilus huttoni	slender ragfish	SUH	2

Scientific name	Common name	Code	Occ.
Seriolella caerulea	white warehou	WWA	5
S. punctata	silver warehou	SWA	43
Tubbia tasmanica	Tasmanian ruffe	TUB	1
Rhombosoleidae: southern righteye flounders			
Azygopus pinnifasciatus	spotted flounder	SDF	1
Diodontidae: porcupinefishes			
Allomycterus pilatus	porcupine fish	POP	2

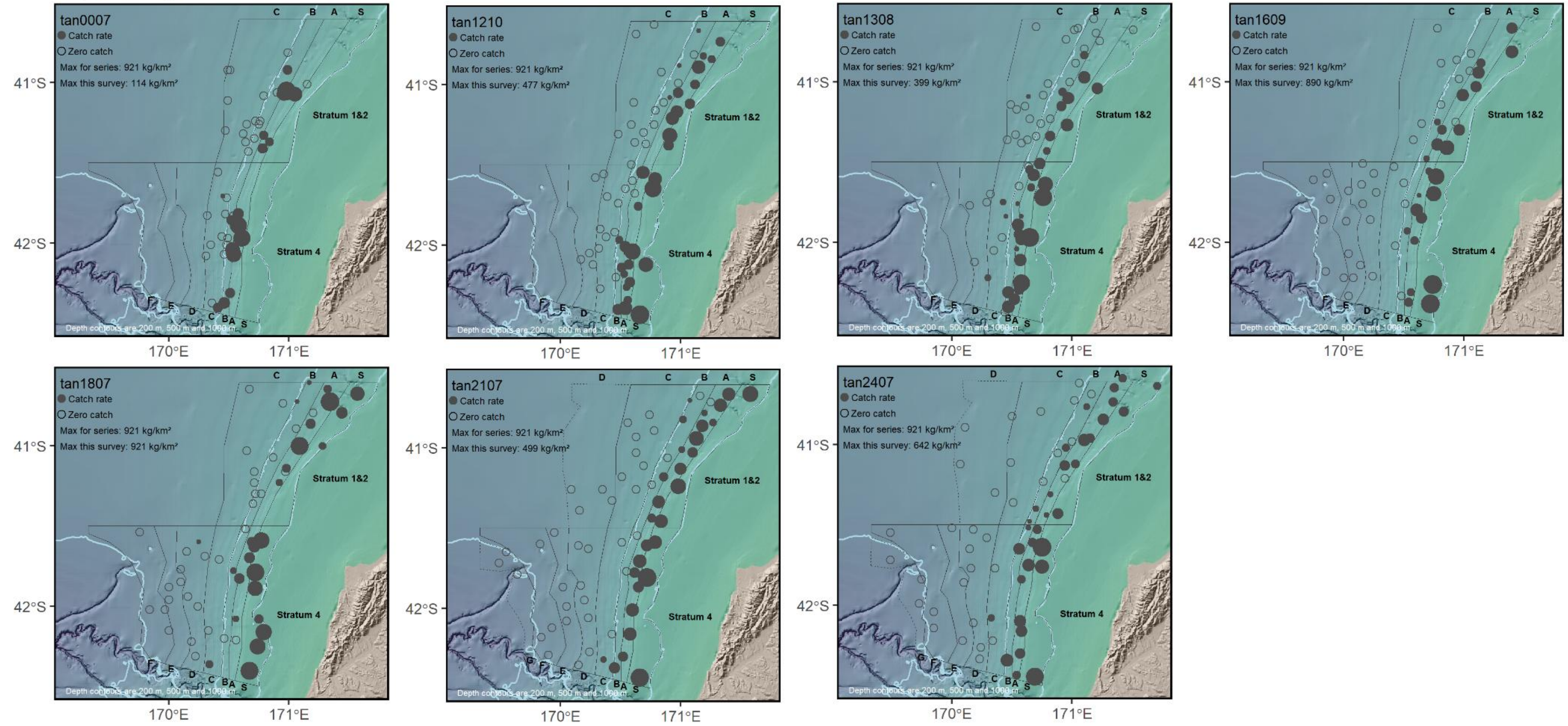
Appendix 5: Species distribution and catch rate maps

Time series of distribution and catch rates of species for which the WCSI 2024 trawl survey was optimised, sorted alphabetically by research code. Exploratory strata are indicated by dashed lines. Circle area is proportional to catch rate. Open circles indicate zero catches. 'Max for series' is the maximum catch rate for all WCSI surveys in the time series, 'Max this survey' is the maximum catch rate for the featured survey. See Appendix 9 for species code changes or combined groups.

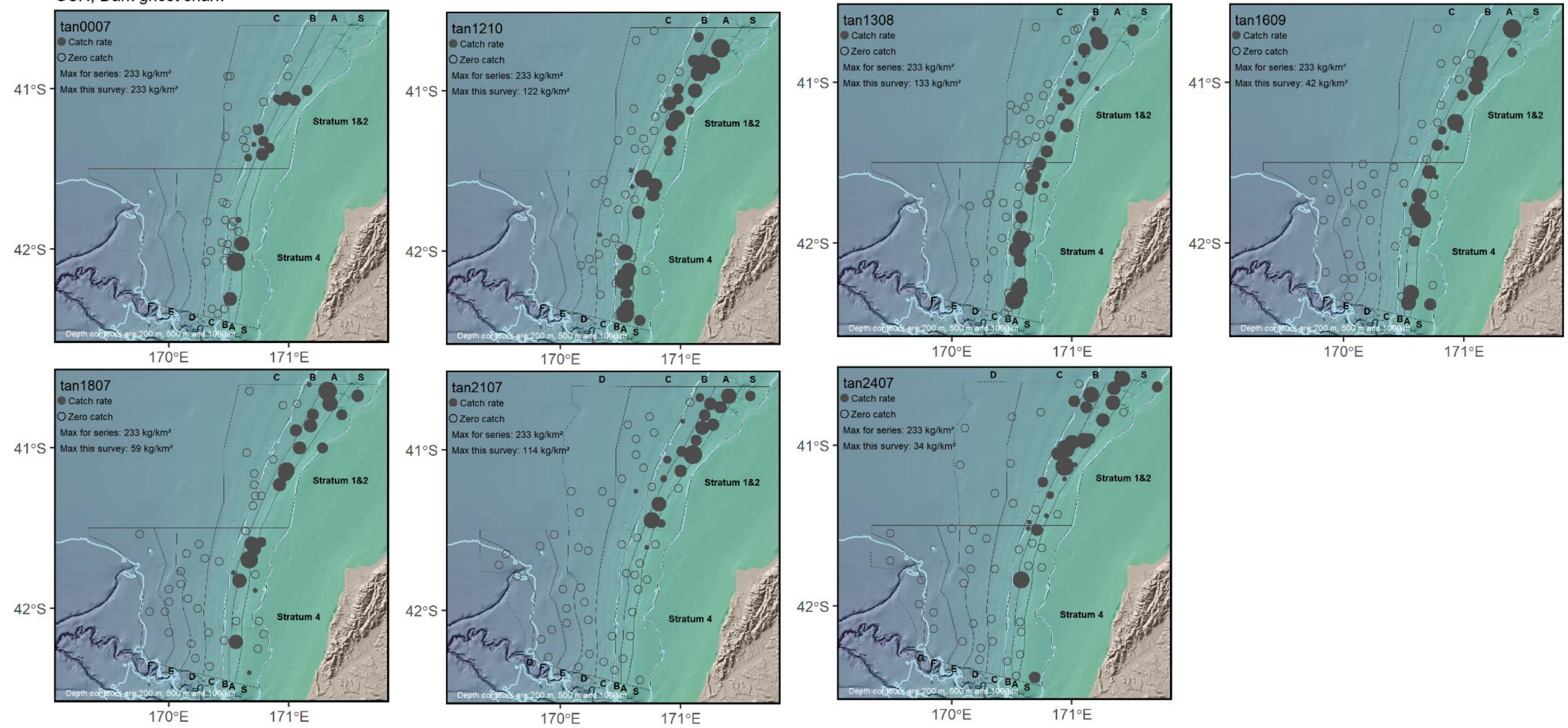
LDO, Lookdown dory



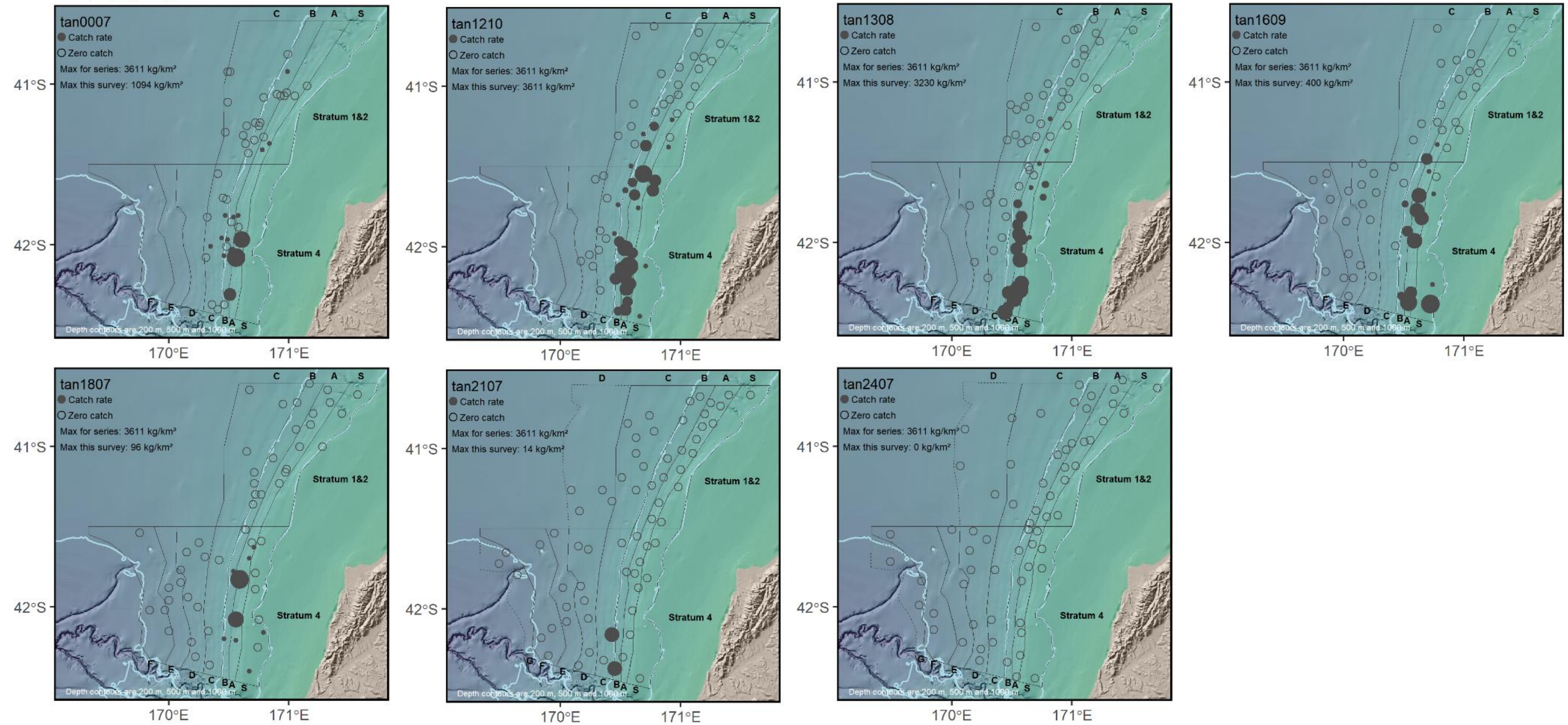
GIZ, Giant stargazer



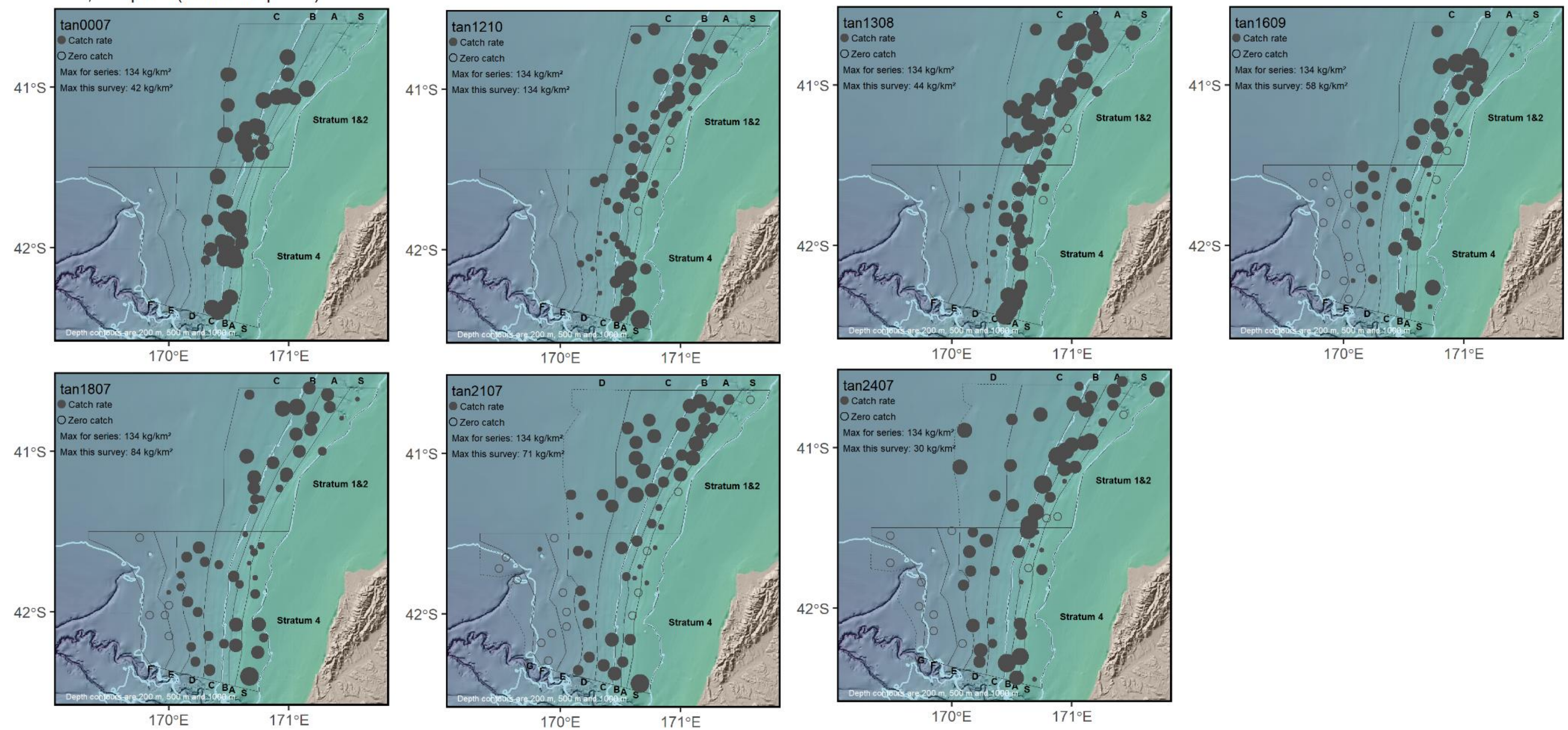
GSH, Dark ghost shark



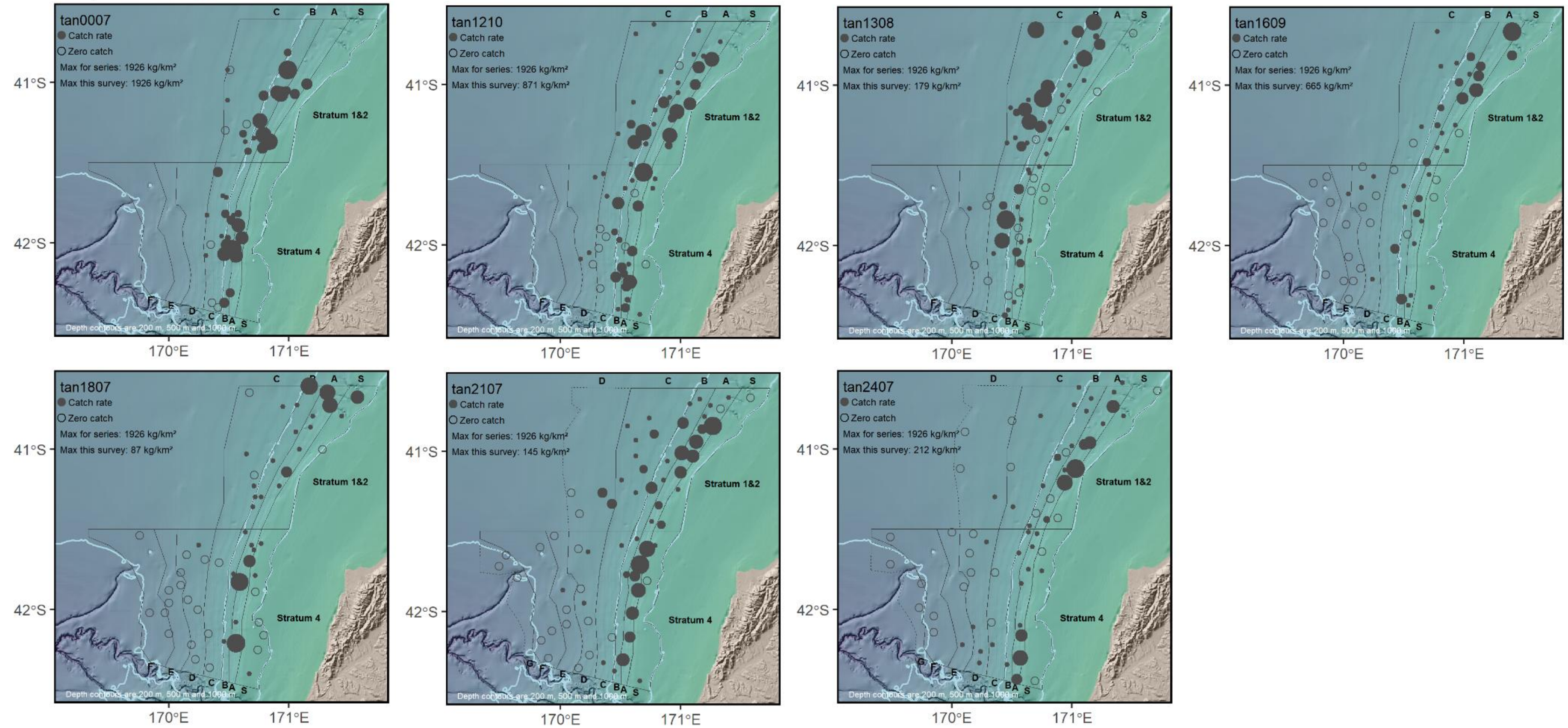
SPD, Spiny dogfish



SPE, Sea perch (combined species)



SWA, Silver warehou



Appendix 6: Reproductive status

Gonad stage observations by each reproductive stage for species for which the 2024 survey was optimised. Gonad stages are defined in Appendix 1. –, indicates no relevant stage. Species arranged in alphabetical order of research codes.

Species code	Common name	Sex	Staging method	Reproductive stage 1	2	3	4	5	6	7	Total
GIZ	Giant stargazer	Female	MD	–	16	51	1	5	1	1	75
		Male		–	–	–	36	27	–	–	63
GSH	Dark ghost shark	Female	SS	48	25	32	3	–	–	–	108
		Male		92	6	38	–	–	–	–	136
HBA	Bigeye sea perch	Female	MD	193	95	27	3	–	–	2	320
	(*H. barathri*)	Male		242	65	50	43	–	5	1	406
HPC	Sea perch	Female	MD	5	3	13	8	2	–	–	31
	(*H. percoides*)	Male		7	4	8	16	–	1	–	36
LDO	Lookdown dory	Female	MD	61	157	3	1	1	11	114	348
		Male		61	147	14	5	8	–	6	241
SWA	Silver warehou	Female	MD	–	1	138	12	3	–	–	154
		Male		–	1	1	63	29	–	–	94

Appendix 7: Length-weight regression parameters

Length-weight regression parameters used to scale length frequencies for the most frequently encountered species, arranged alphabetically by common name. Where data source is given as ‘All WCSI *Tangaroa* surveys’, parameters were estimated from combined data from the 2000, 2012, 2013, 2016, 2018, 2021 and 2024 surveys. Where data source is given as ‘All surveys’, length-weight parameters were estimated from combined data from all surveys in the database, including from other areas, because there were < 100 fish with length-weight data from the WCSI Tangaroa surveys combined.

		Regression parameters					
Common name	Code	*a*	*b*	r^2	*n*	Length range (cm)	Data source
Alfonsino	BYS	0.010593	3.213282	93.09	693	18.4-42.8	All WCSI *Tangaroa* surveys
Arrow squid	SQU	0.038697	2.908422	98.02	137	10.4-40.2	TAN2407
Banded bellowsfish	BBE	0.003443	3.3272	92.41	5 549	5.6-30.6	All surveys in database
Banded rattail	CFA	0.001673	3.276434	81.83	127	19.2-34.1	All WCSI *Tangaroa* surveys
Barracouta	BAR	0.014010	2.758224	86.12	1 010	49.8-106	All WCSI *Tangaroa* surveys
Basketwork eel	BEE	0.000310	3.307108	95.82	148	52-129.6	All WCSI *Tangaroa* surveys
Bigscaled brown slickhead	SBI	0.001322	3.501715	94.66	119	24.8-51.9	All WCSI *Tangaroa* surveys
Black slickhead	BSL	0.003198	3.266386	93.53	173	19.5-44.6	TAN2407
Bollon's rattail	CBO	0.000826	3.512652	96.56	163	26.6-59.5	TAN2407
Capro dory	CDO	0.074996	2.372637	83.36	100	5.2-11.2	All WCSI *Tangaroa* surveys
Carpet shark	CAR	0.034590	2.616650	63.59	137	50.7-88.8	All WCSI *Tangaroa* surveys
Cucumber fish	CUC	0.018868	2.809289	85.90	566	12.9-26.6	All WCSI *Tangaroa* surveys
Deepsea flathead	FHD	0.000576	3.626271	95.89	120	26.4-51.5	All WCSI *Tangaroa* surveys
Eucla cod	EUC	0.005123	3.028099	92.04	273	17.3–32.1	TAN2407
Four-rayed rattail	CSU	0.024856	2.234046	70.13	445	17.4–37.3	All WCSI *Tangaroa* surveys
Frostfish	FRO	0.000303	3.232743	97.36	103	52.2–138.2	TAN2407
Gemfish	RSO	0.004338	3.101811	99.26	658	23–102.2	TAN2407
Hairy conger	HCO	0.000050	3.845058	97.73	1 969	29.5–109.8	All surveys in database
Hake	HAK	0.002109	3.285539	97.69	657	30.7–115.6	TAN2407
Hāpuku	HAP	0.001116	3.585008	98.03	107	53.6–134.2	All WCSI *Tangaroa* surveys
Jack mackerel (*T. declivis*)	JMD	0.018505	2.869656	98.38	173	20.5–56.2	All WCSI *Tangaroa* surveys
Javelinfish	JAV	0.000935	3.253670	98.11	311	16.3–57.7	TAN2407
John dory	JDO	0.014167	3.064558	86.99	224	35–55.4	All WCSI *Tangaroa* surveys
Johnson's cod	HJO	0.002024	3.278028	97.95	15 595	11.7–70.2	All surveys in database
Leafscale gulper shark	CSQ	0.000332	3.619662	91.57	165	87.2–145	All WCSI *Tangaroa* surveys
Longnose velvet dogfish	CYP	0.002583	3.125832	98.92	223	31.6–97.6	All WCSI *Tangaroa* surveys
Lucifer dogfish	ETL	0.000634	3.451295	92.45	205	30–50.9	All WCSI *Tangaroa* surveys
Mahia rattail	CMA	0.000592	3.530338	95.97	123	28.2–66.2	All WCSI *Tangaroa* surveys
Northern spiny dogfish	NSD	0.002221	3.171631	96.94	188	28.6–90.1	TAN2407
Oliver's rattail	COL	0.001662	3.144319	93.19	198	17–40.4	TAN2407
Orange perch	OPE	0.029505	2.871203	95.49	451	15.6–35.3	All WCSI *Tangaroa* surveys
Orange roughy	ORH	0.061515	2.802545	97.66	477	6.4–42.4	All WCSI *Tangaroa* surveys
Pale ghost shark	GSP	0.005986	2.987244	97.76	284	30.2–88.4	All WCSI *Tangaroa* surveys
Ray’s bream	RBM	0.006457	3.276666	92.63	128	34.9–49.4	All WCSI *Tangaroa* surveys
Red cod	RCO	0.009701	2.983370	99.05	654	15.1–69.6	All WCSI *Tangaroa* surveys
Redbait	RBT	0.001668	3.611973	98.77	789	14–39.7	All WCSI *Tangaroa* surveys
Ribaldo	RIB	0.005643	3.149863	98.85	208	20.4–74.6	TAN2407
Rubyfish	RBY	0.056888	2.710806	92.02	117	29.3–52.5	All WCSI *Tangaroa* surveys
Scampi	SCI	0.877344	2.678655	88.55	164	2.9–6.3	All WCSI *Tangaroa* surveys
School shark	SCH	0.007353	2.906517	95.89	611	64.6–154.4	All WCSI *Tangaroa* surveys
Seal shark	BSH	0.001622	3.261002	99.17	1 289	35.7–153.8	All surveys in database
Serrulate rattail	CSE	0.002815	3.078761	86.29	178	25.4–45.5	All WCSI *Tangaroa* surveys
Shovelnose dogfish	SND	0.000544	3.428301	96.65	299	56.6–114.8	TAN2407
Silver dory	SDO	0.012354	3.105105	95.23	861	10.3–26.6	All WCSI *Tangaroa* surveys
Silver roughy	SRH	0.046261	2.710360	86.14	791	5.6–17.5	All WCSI *Tangaroa* surveys
Silverside	SSI	0.011200	2.836988	90.38	9 761	11.8–35.3	All surveys in database
Slender smooth-hound	SSH	0.001451	3.130923	96.39	338	40.3–107.5	All WCSI *Tangaroa* surveys

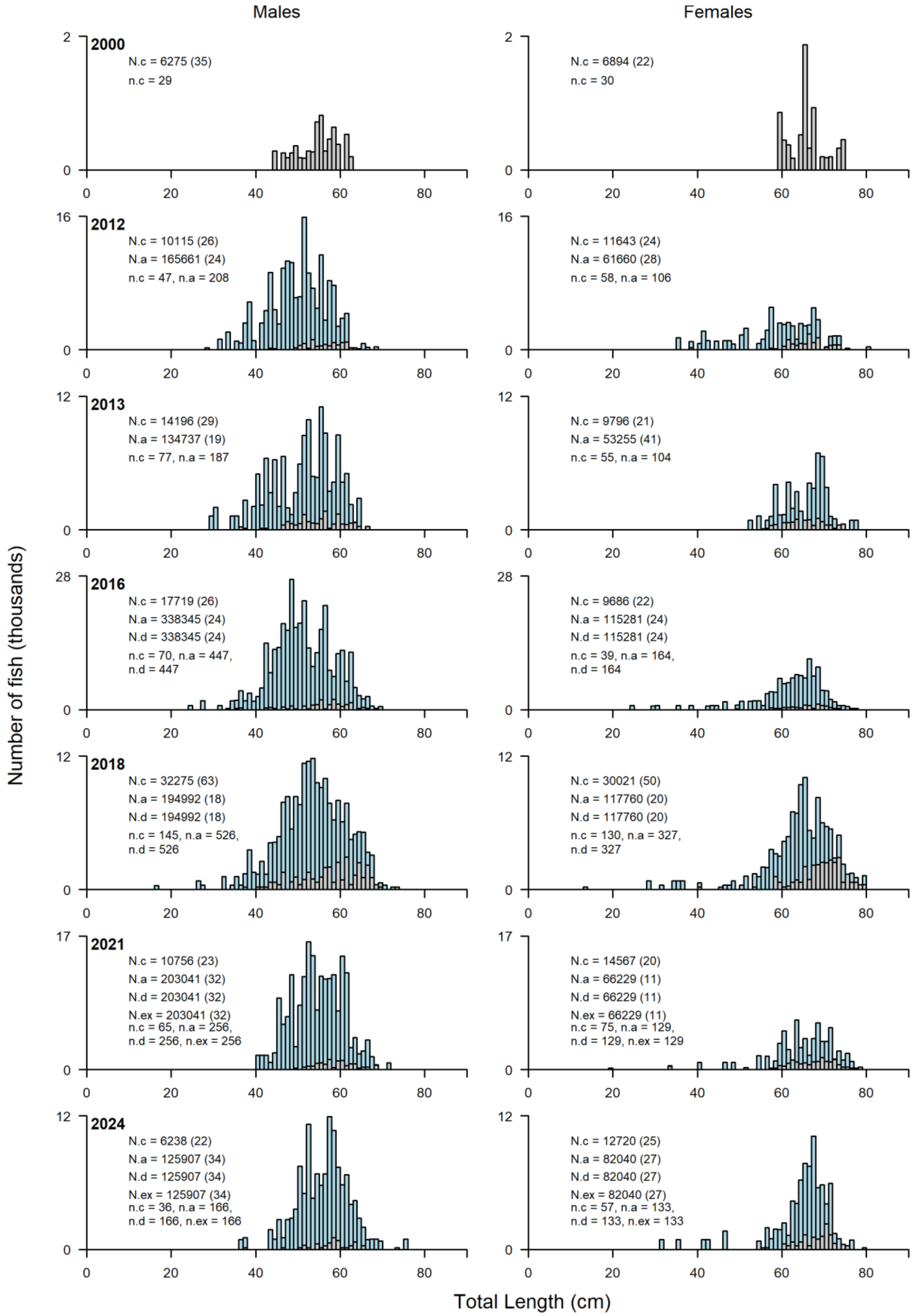
		Regression parameters					
Common name	Code	*a*	*b*	r^2	*n*	Length range (cm)	Data source
Small banded rattail	CCX	0.000960	3.334058	89.03	159	17.2–32.4	All WCSI *Tangaroa* surveys
Smooth skate	SSK	0.020006	2.984789	99.21	318	36.5–155	All WCSI *Tangaroa* surveys
Smooth skin dogfish	CYO	0.002300	3.231900	96.11	379	27.9–119.4	All WCSI *Tangaroa* surveys
Spiky oreo	SOR	0.022531	2.965136	96.87	227	12.3–32.2	TAN2407
Spineback	SBK	0.001043	3.107491	88.02	7 368	23.5–81.8	All WCSI *Tangaroa* surveys
Spotted gurnard	JGU	0.010937	3.055555	98.19	177	13.9–53.1	All WCSI *Tangaroa* surveys
Swollenhead conger	SCO	0.000303	3.426469	83.14	114	69.7–102.1	All WCSI *Tangaroa* surveys
Tarakihi	NMP	0.032160	2.834047	91.41	235	26–49.8	TAN2407
Thin tongue cardinalfish	EPM	0.015271	2.972475	96.38	329	14.3–66.4	All WCSI *Tangaroa* surveys
Two saddle rattail	CBI	0.000885	3.449297	97.65	168	22.9–56.6	All WCSI *Tangaroa* surveys
White rattail	WHX	0.000474	3.631735	97.85	146	43.4–100.9	TAN2407
Yellow boarfish	YBO	0.046721	2.791145	96.65	177	9.6–30.8	TAN2407

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

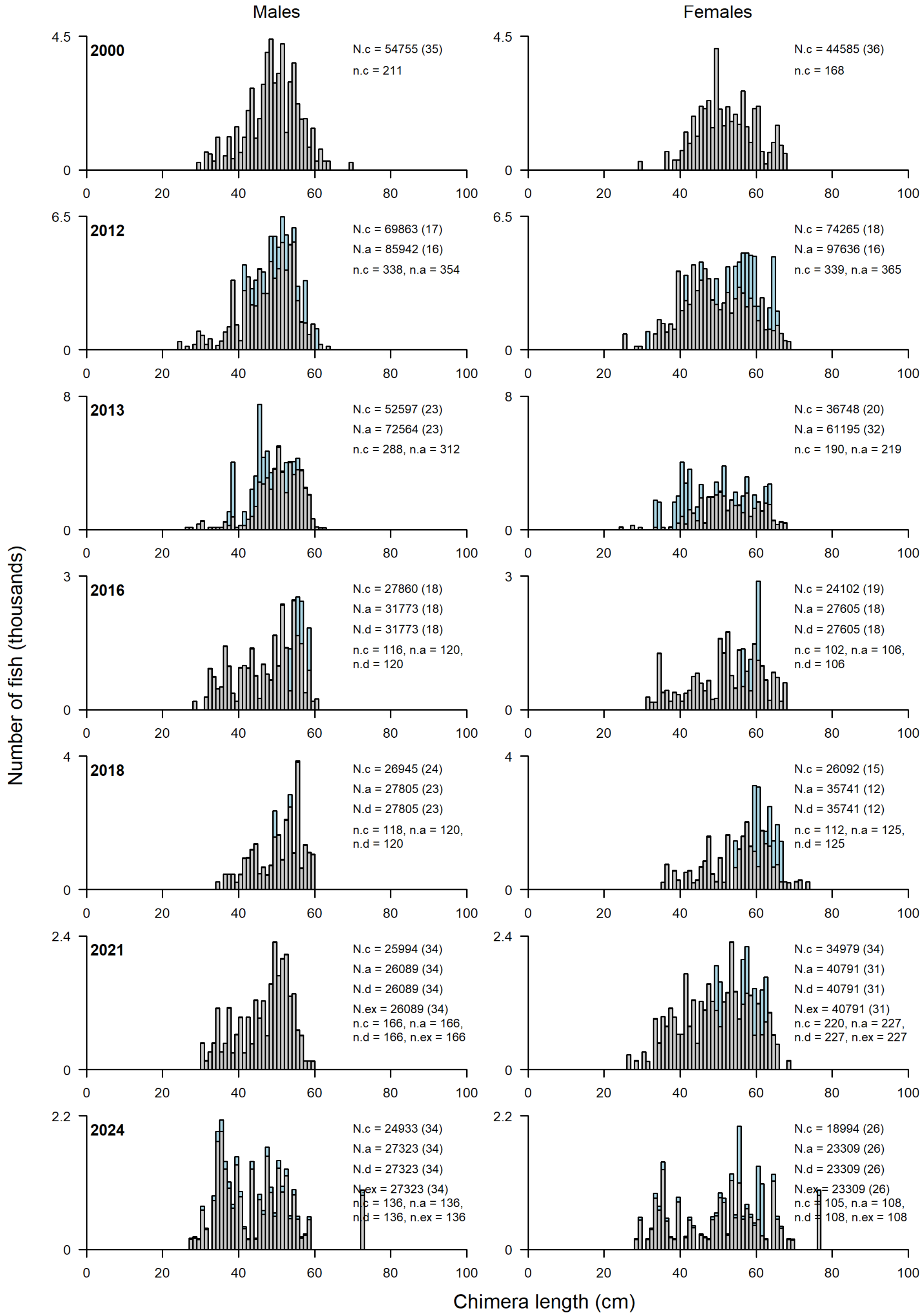
Appendix 8: Length frequency distributions

Key to subsequent figures

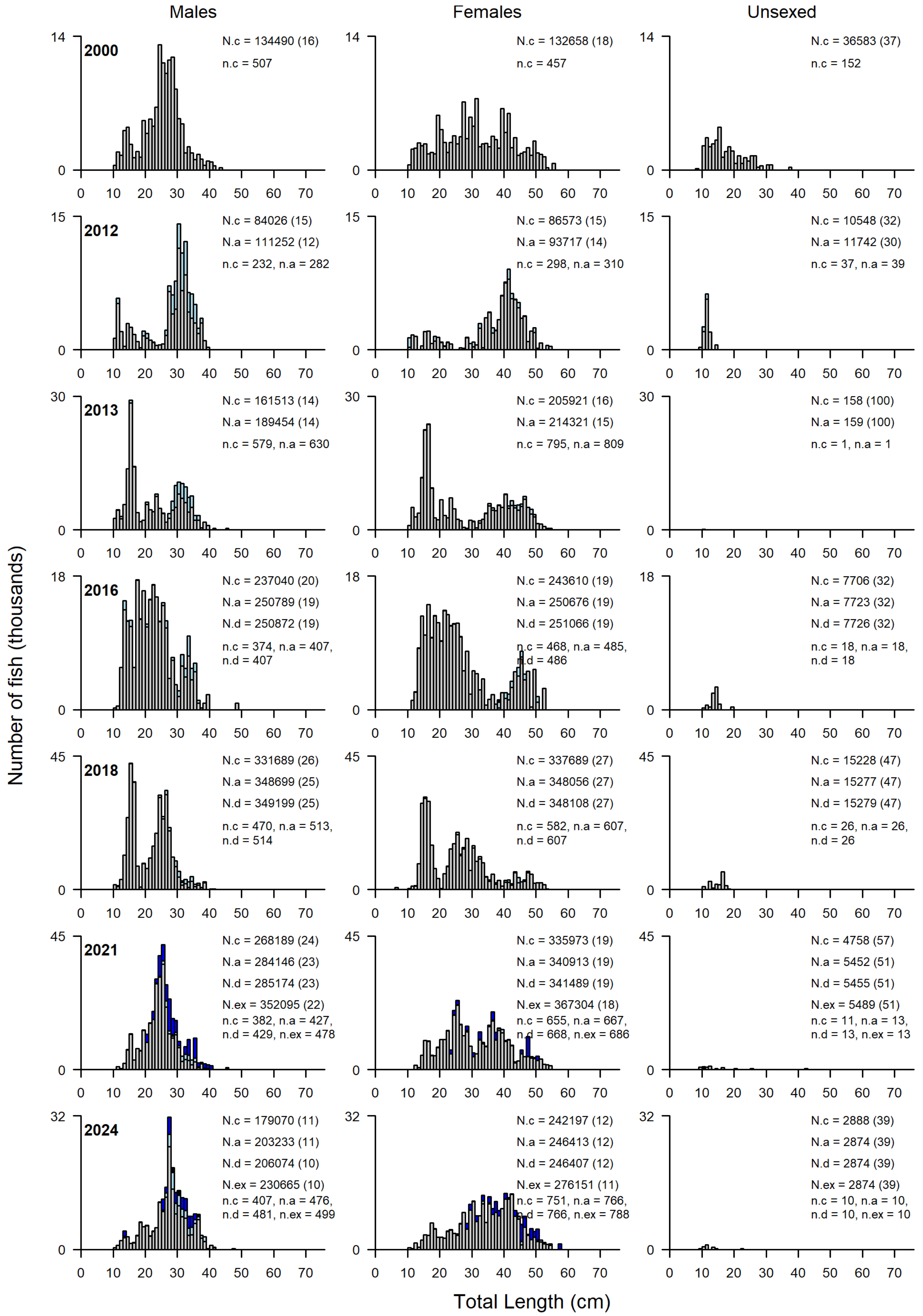
Length frequency distributions by sex for species for which the trawl survey was optimised for core (grey), all (light blue), deep (black), and deep exploratory (blue) strata from the WCSI trawl survey time series. N.ex, estimated scaled total number of fish for deep exploratory strata; N.d, estimated 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.ex, estimated scaled total number of fish for exploratory strata; n.ex, number of fish measured for exploratory 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). See Appendix 9 for species code changes.



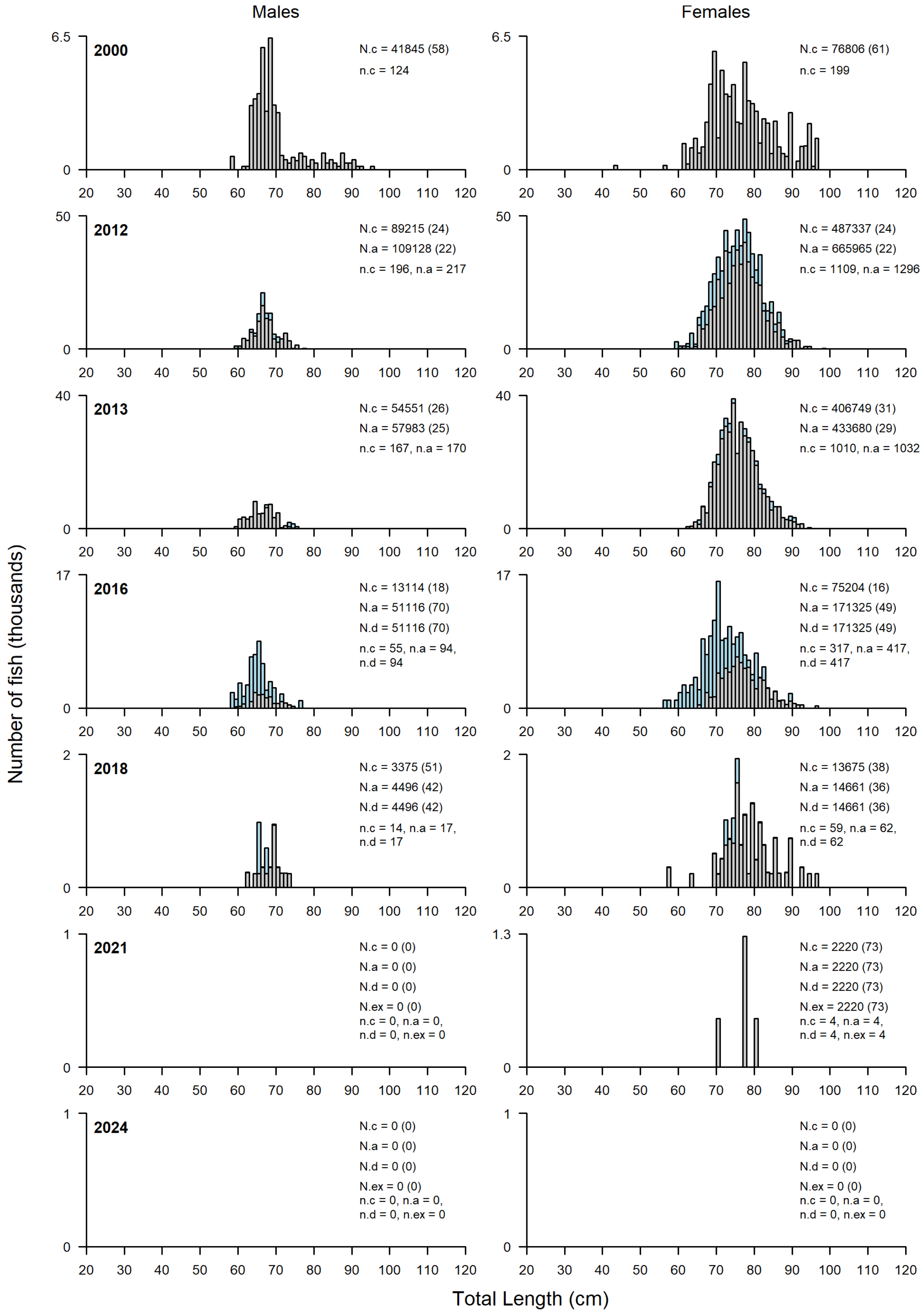
GIZ, Giant stargazer



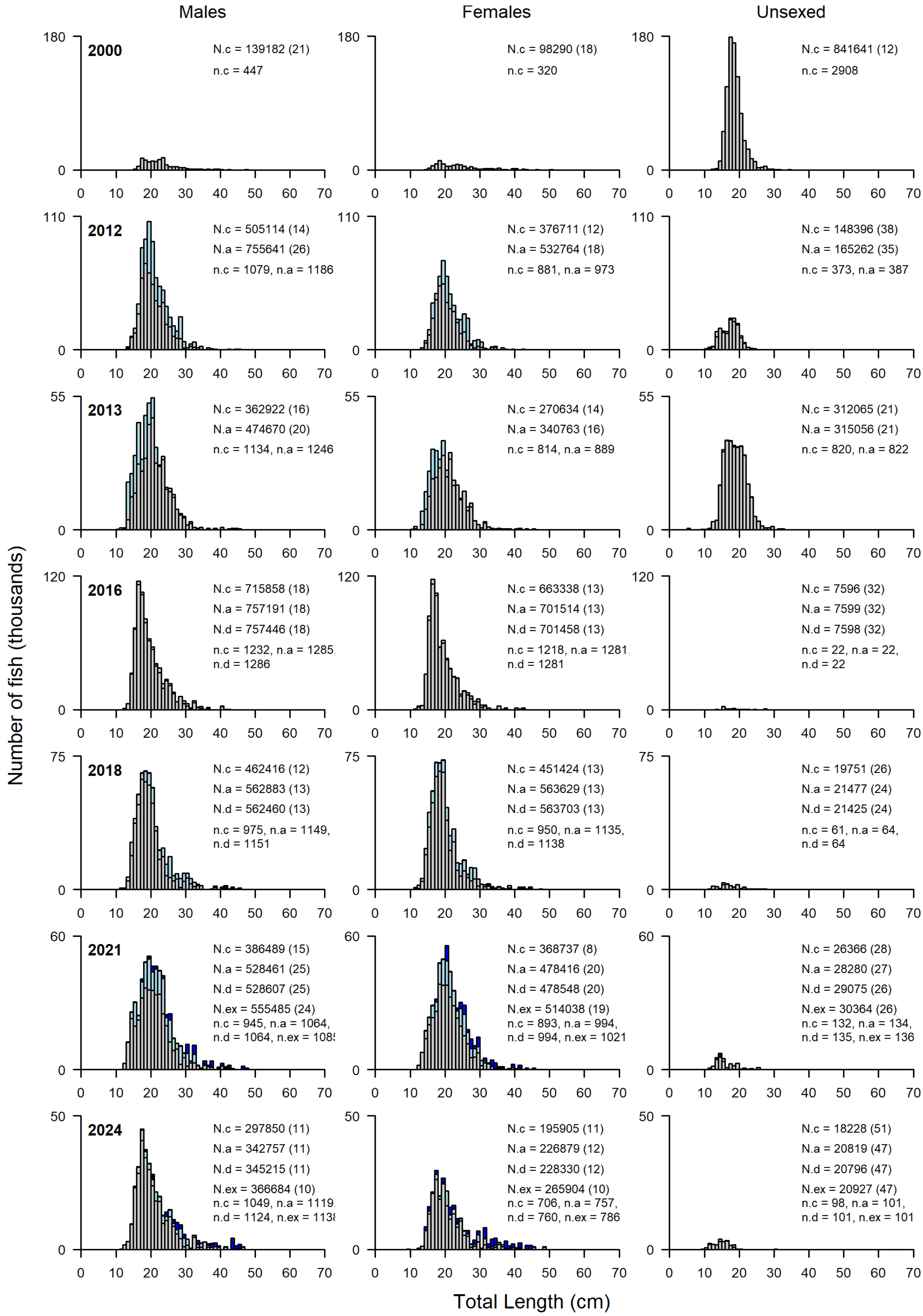
GSH, Dark ghost shark



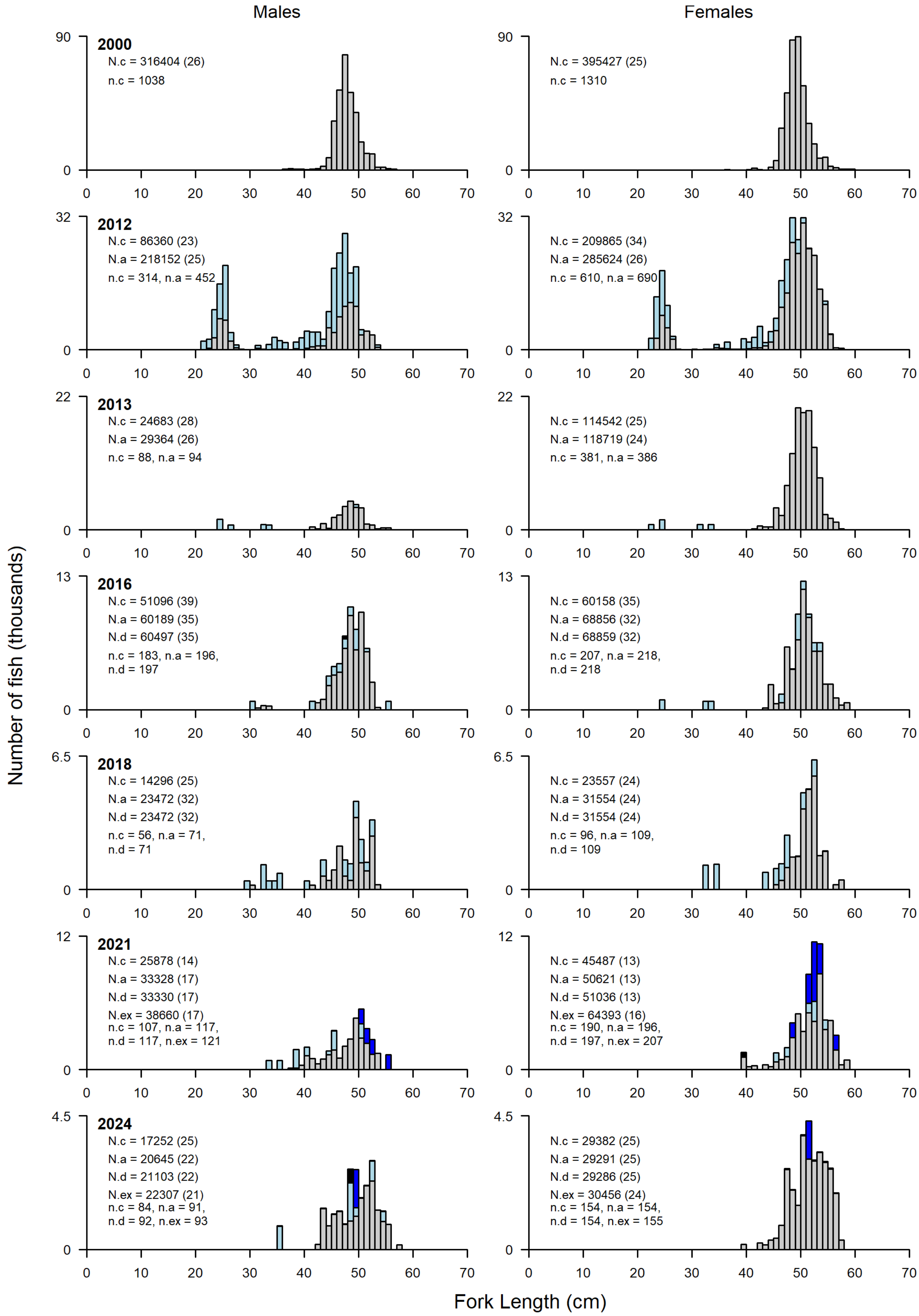
LDO, Lookdown dory



SPD, Spiny dogfish



SPE, Sea perch (combined species)



SWA, Silver warehou

Appendix 9: Species code changes and species groups used for biomass estimates

Species codes in the database for previous surveys were changed due to changes in taxonomic definitions.

Species name	Species code	Notes
Giant stargazer	GIZ	Coded as STA in 2000; Coded as GIZ from 2012 survey; Recoded 2000 as GIZ.
Sea perch	SPE	Coded as SPE in 2000, 2012, 2013, 2016 SPE was split to 2 species in 2018: HBA and HPC, which were then re-combined as SPE to compare with data from earlier years.

Appendix 10: Effect of bottom temperature and depth on catch rates of hake, ling, and hoki

To determine the trend over time in catch rates of hake hoki, and ling and the effect of bottom temperature or depth of capture, generalised additive models (GAMs) were used. Because depth and bottom temperature were strongly collinear (correlation = 0.97), GAMs could not include both terms. Survey year was included as an ordered factor and because catch rates were zero–inflated, the Tweedie distribution and log link were used. GAMs were structured to include the interaction between survey year and bottom temperature (or depth) as

$$Catch\,rate \sim Year + te(BT) + te(BT, by = Year)$$

where the number of knots was restricted to avoid issues with running out of degrees of freedom for estimation to three for the temperature smooth and five for each of the interactions. Ordered–factor–smooth interactions were used because we were interested in the difference between the reference category (e.g., the 2012 survey year) and the following survey years. Data were included only from strata that were consistently sampled since 2012 (e.g., omitting strata 1&2D, 4E, 4F, and 4G).

All models estimated Tweedie parameters were between 1 and 2, which indicated that a compound Poisson–gamma distribution was used (Johnson et al. 2005) (Table A10.1). All models fit the data reasonably well, with depth explaining slightly more of the trend in catch rates over time for hoki and ling, but not for hake (Table A10.1). Catch rates for most species and model formulations, were significantly different in 2012 than other survey years, with the exception of hake (Table A10.2).

Table A10.1: Model fits information for GAMs fitting trends in catch rates of hake, ling, and hoki, including the effect of depth or bottom temperature.

	Hake		Ling		Hoki	
	Depth	Bottom temp	Depth	Bottom temp	Depth	Bottom temp
Tweedie parameter	1.539	1.538	1.616	1.635	1.765	1.765
Deviance explained (%)	68.5	69.3	67.4	60.2	67.2	62.4
AIC	1909	1901	3184	3251	4075	4123

Table A10.2: Significance (p–values) of the interaction terms, indicating whether the depth (or bottom temperature) and year interaction trend differences were significantly different when compared with the reference year, 2012. Bolded values indicate non–significant differences between survey year and 2012. Non-significant differences indicate that the trend in 2012 is stronger than the trend estimated in e.g. 2013.

	Hake		Ling		Hoki	
Survey year	Depth	Bottom temp	Depth	Bottom temp	Depth	Bottom temp
2012	–	–	–	–	–	–
2013	**0.3070**	**0.0922**	< 0.0001	< 0.0001	< 0.0001	< 0.0001
2016	**0.3683**	**0.4630**	< 0.0001	< 0.0001	< 0.0001	0.0040
2018	0.0090	0.0024	< 0.0001	< 0.0001	< 0.0001	< 0.0001
2021	0.0650	0.0130	< 0.0001	< 0.0001	< 0.0001	< 0.0001
2024	< 0.0001	< 0.0001	0.0002	0.0063	< 0.0001	< 0.0001

The trends in hake catch rates at depth and bottom temperature were similar in 2012, 2013, and 2016. Note that this does not indicate that the catch rates estimated for a given depth or temperature were similar, just that the trend with depth (or temperature) was of a similar pattern. That can be seen in the estimated differenced smooth trends, where the differenced trend for 2013 and 2016 surveys were linear with wide confidence intervals, indicating that the trend in 2012 was stronger, and the difference is not so large as to (with confidence) be an identifiably different trend (Figure A10.1). The estimated trend for these years for depth indicate a gentle increase in catch rates beginning at 500 m, while the trend in temperature is a gentle decline (Figure 17). This differs from e.g., the hoki trend with bottom temperature for 2018, where the difference trend was linear but with tight confidence intervals (Figure A10.6), was significantly different than 2012 (Table A10.2), and had a different peak in catch rates for a given temperature (Figure 17).

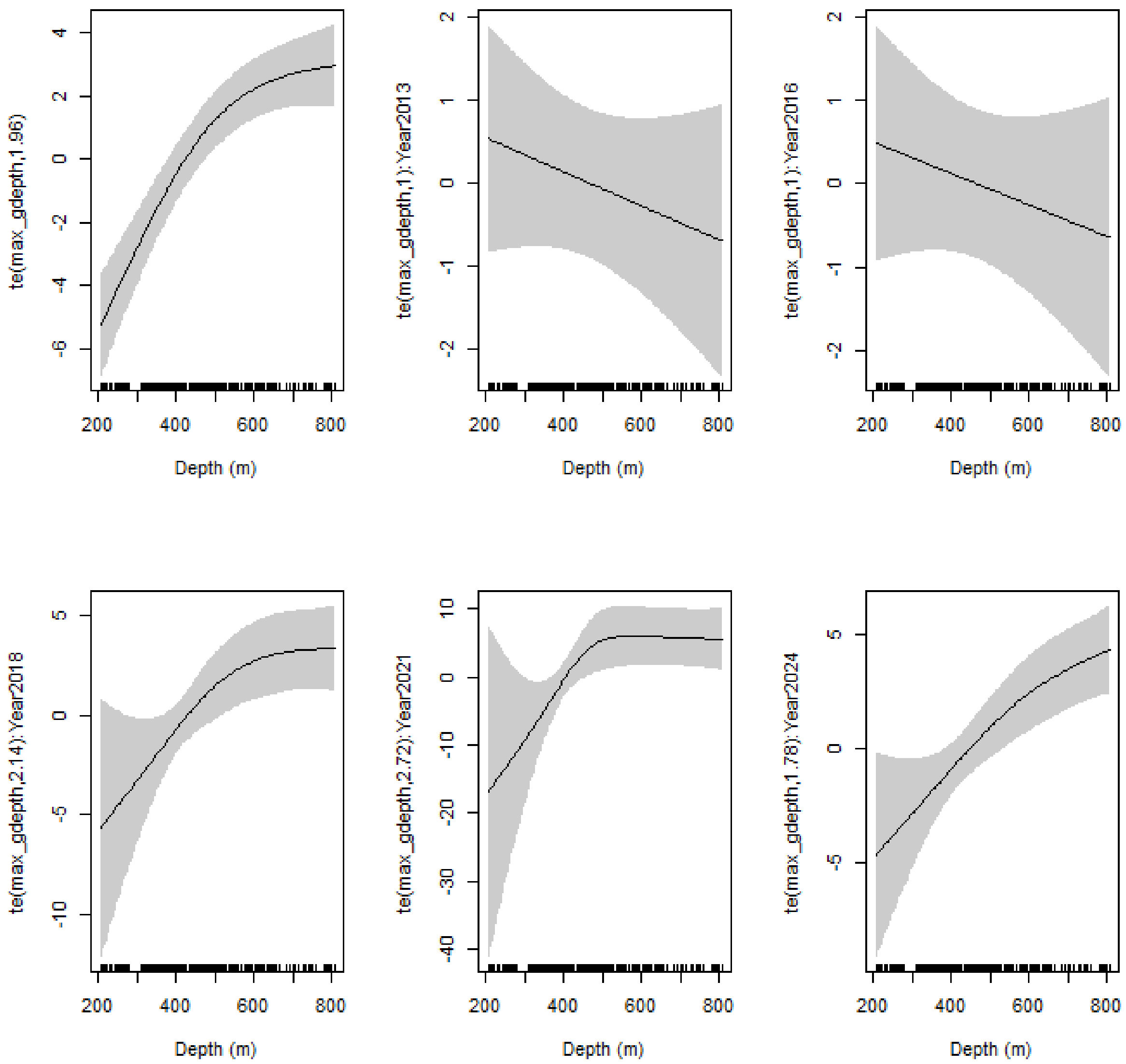


Figure A10.1: Estimated smooth trend for the 2012 survey year (top left) and difference smooths reflecting estimated difference between 2012 and each of the remaining survey years for the relationship describing hake catch rates over time and depth. Shaded intervals are confidence bands for the smooths that also include the uncertainty about the overall mean. If the estimate trend is linear with wide confidence intervals (e.g., 2013 and 2016, top row), this indicates that the trend in 2012 was stronger, and the difference was not so large as to be an identifiably different trend.

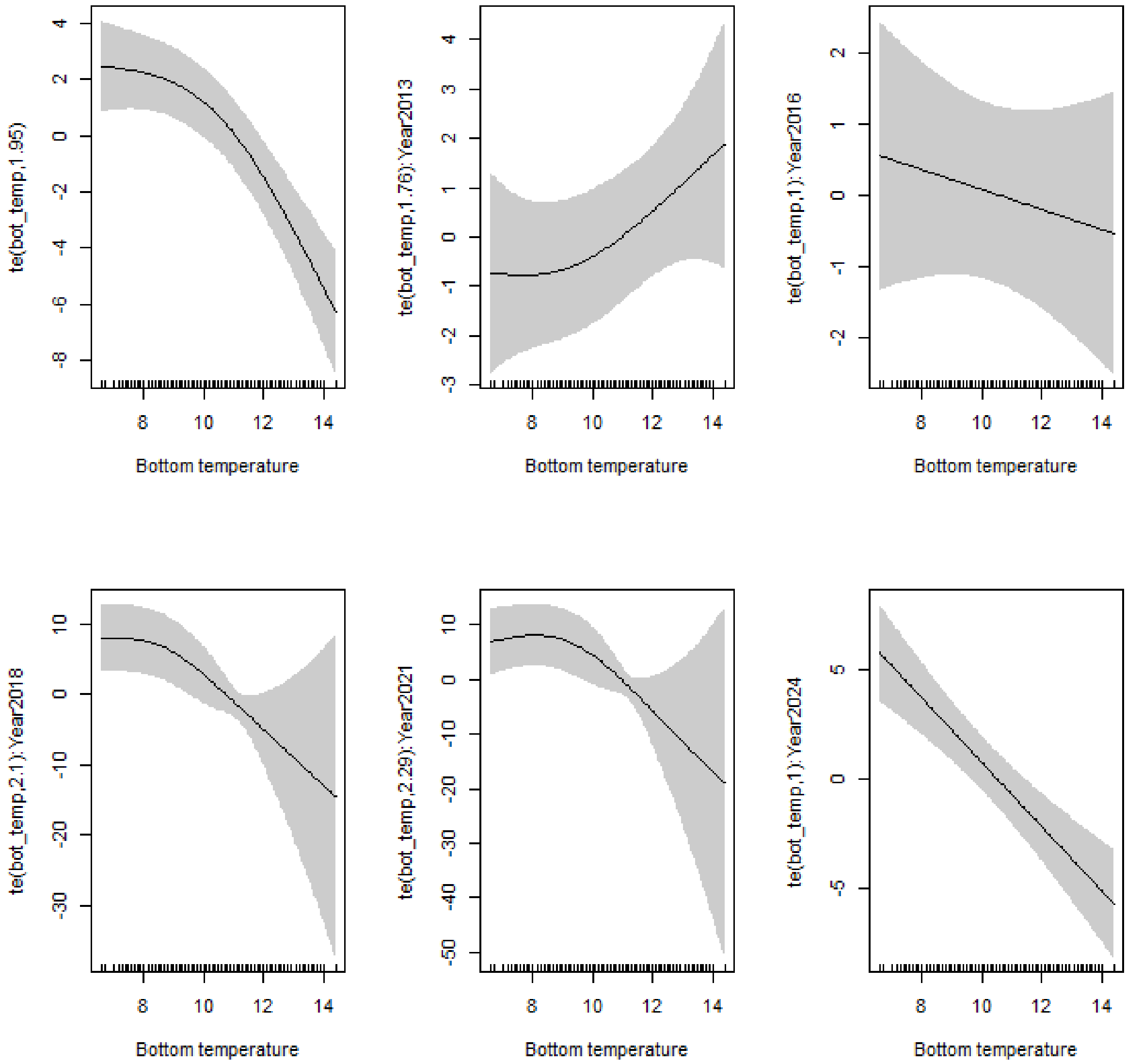


Figure A10.2: Estimated smooth trend for the 2012 survey year (top left) and difference smooths reflecting estimated difference between 2012 and each of the remaining survey years for the relationship describing hake catch rates over time and bottom temperature. Shaded intervals are confidence bands for the smooths that also include the uncertainty about the overall mean.

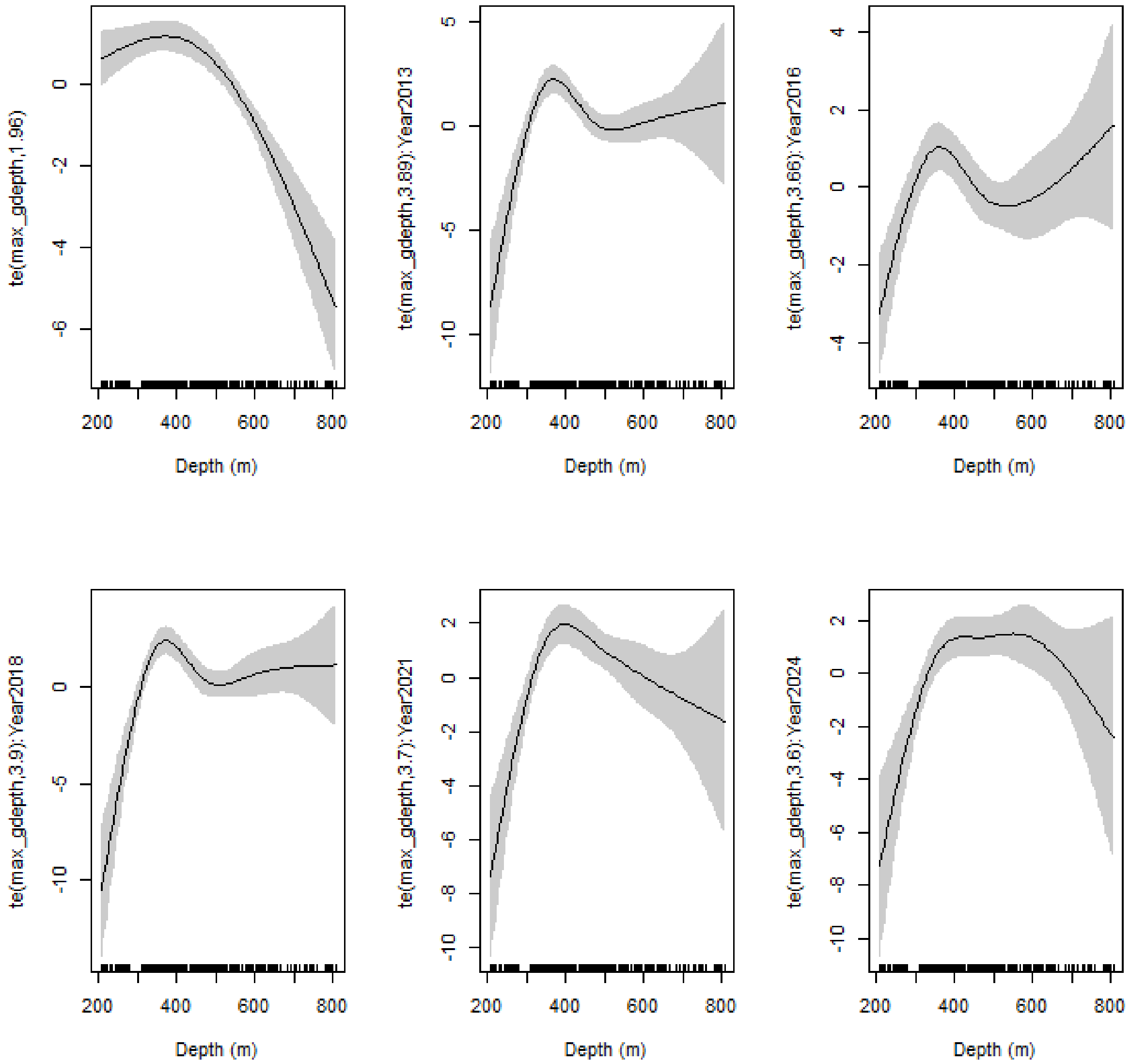


Figure A10.3: Estimated smooth trend for the 2012 survey year (top left) and difference smooths reflecting estimated difference between 2012 and each of the remaining survey years for the relationship describing ling catch rates over time and depth. Shaded intervals are confidence bands for the smooths that also include the uncertainty about the overall mean.

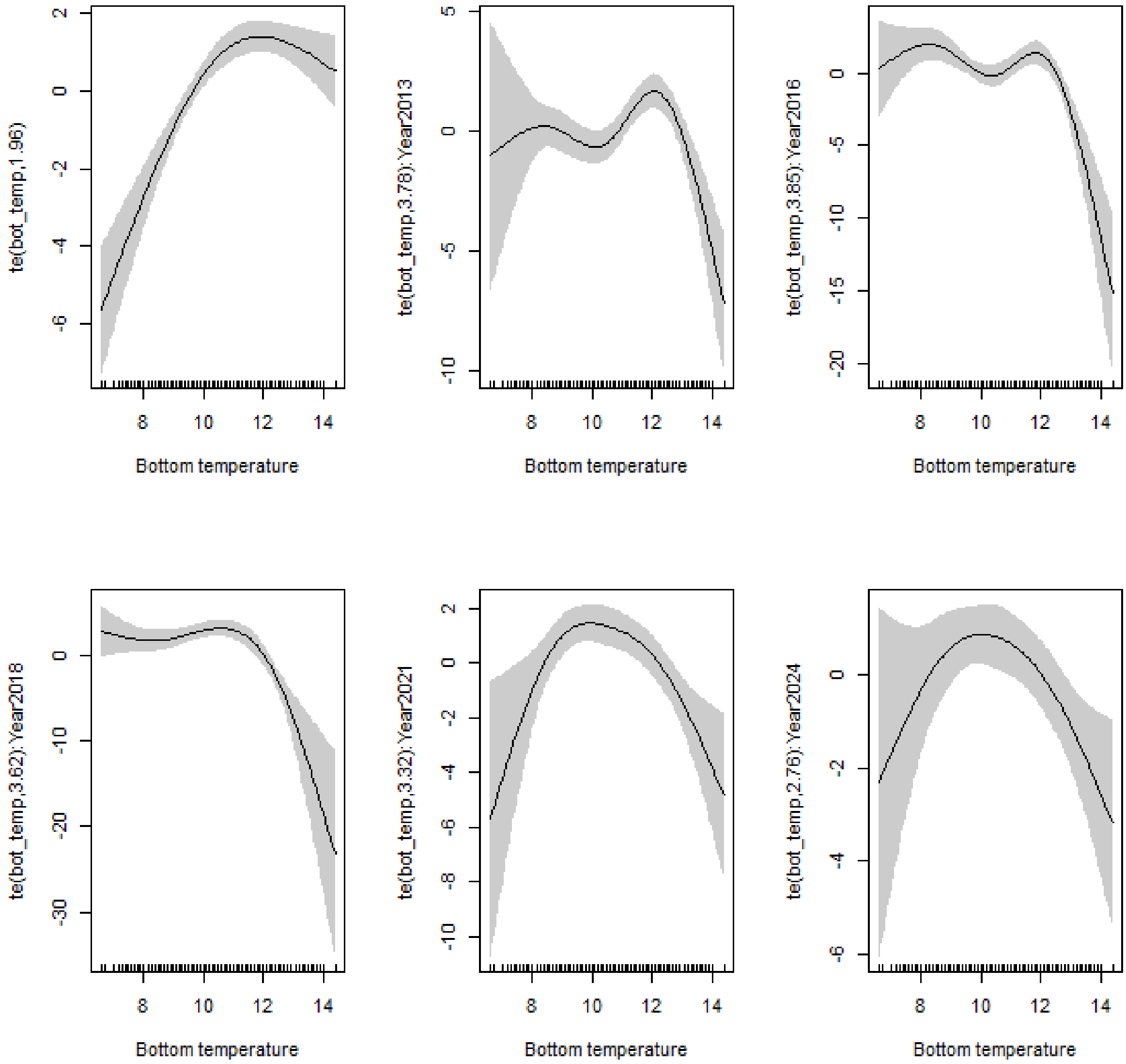


Figure A10.4: Estimated smooth trend for the 2012 survey year (top left) and difference smooths reflecting estimated difference between 2012 and each of the remaining survey years for the relationship describing ling catch rates over time and bottom temperature. Shaded intervals are confidence bands for the smooths that also include the uncertainty about the overall mean.

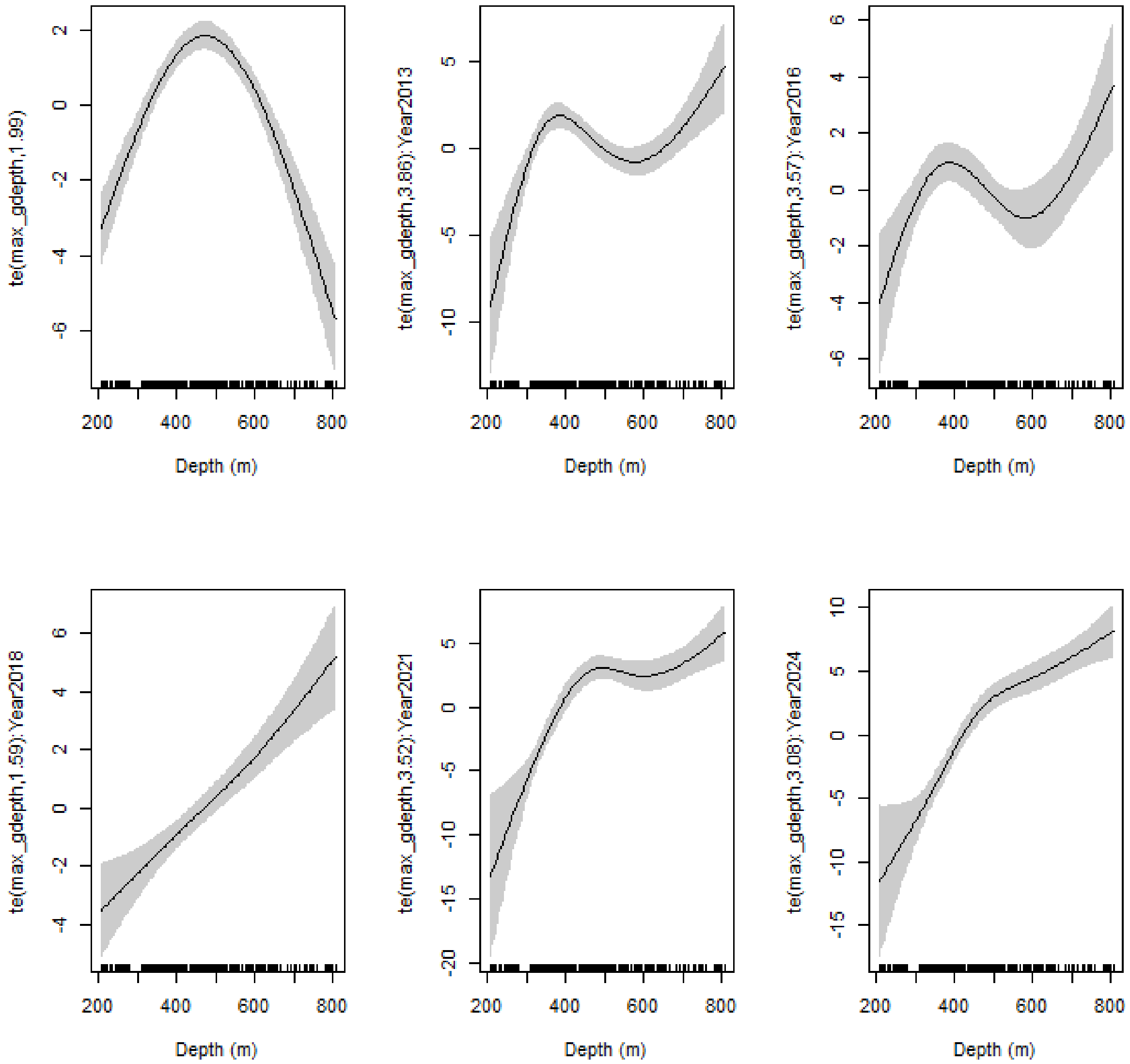


Figure A10.5: Estimated smooth trend for the 2012 survey year (top left) and difference smooths reflecting estimated difference between 2012 and each of the remaining survey years for the relationship describing hoki catch rates over time and depth. Shaded intervals are confidence bands for the smooths that also include the uncertainty about the overall mean.

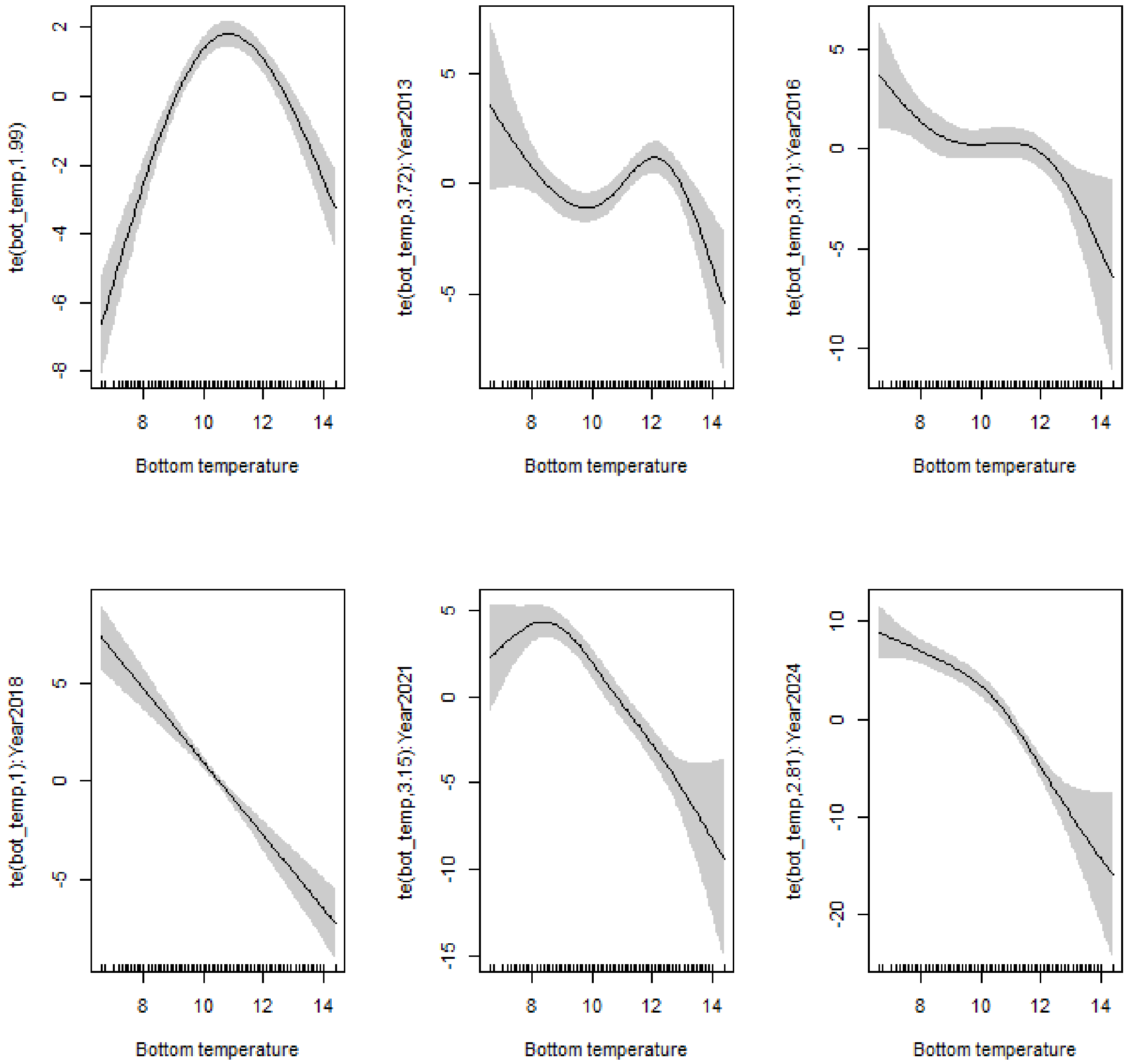


Figure A10.6: Estimated smooth trend for the 2012 survey year (top left) and difference smooths reflecting estimated difference between 2012 and each of the remaining survey years for the relationship describing hoki catch rates over time and bottom temperature. Shaded intervals are confidence bands for the smooths that also include the uncertainty about the overall mean. The strongly linear trend (with tight confidence interval) in 2018 was significantly different from the trend estimates in 2012.