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Acoustic surveys of Cook Strait and east coast South Island hoki during winter 2025 from fishing vessel *Rakaia*

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PLAIN LANGUAGE SUMMARY

Aggregations of spawning hoki were surveyed in Cook Strait, and off the east coast South Island (ECSI), in Pegasus Canyon and Conway Trough. The surveys were carried out from 23 July to 4 September 2025 using the fishing vessel *Rakaia*.

A calibrated scientific echosounder was used to complete the surveys. Six acoustic surveys, or snapshots, of the main Cook Strait spawning grounds were completed between 23 July and 24 August 2025. Six snapshots of Pegasus Canyon were completed from 13 August to 4 September, and two snapshots of Conway Trough on 14 and 25 August 2025.

Hoki schools were found in the main Cook Strait Canyon, in the deepwater southeast of the main Cook Strait Canyon, Terawhiti Sill, Nicholson Canyon, and in Pegasus Canyon and Conway Trough.

The estimated average abundance of hoki for Cook Strait in 2025 was 124 000 t. This was more than double the estimate from the previous survey in 2023 (58 000 t).

The average abundance estimate of hoki for Pegasus Canyon in 2025 was 145 000 t, which was higher than that from the 2023 survey (102 000 t), and the highest estimate in the time series of acoustic surveys of spawning hoki for Pegasus Canyon.

The average abundance of hoki for Conway Trough in 2025 was 38 000 t. This was higher than the estimate from the 2023 survey, and the highest estimate in the time series of acoustic surveys of spawning hoki for Conway Trough.

The importance of ECSI spawning areas in Pegasus Canyon and Conway Trough appears to have increased relative to Cook Strait in recent surveys.

EXECUTIVE SUMMARY

Escobar-Flores, P.C. [1]; Ballara, S.L.[1]; O'Driscoll, R.L.[1] (2026). Acoustic surveys of Cook Strait and east coast South Island hoki during winter 2025 from fishing vessel *Rakaia*.

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Acoustic surveys of spawning hoki in Cook Strait and off the east coast South Island (ECSI), in Pegasus Canyon and Conway Trough, were carried out using the fishing vessel (FV) *Rakaia* from 23 July to 4 September 2025. This was the first acoustic survey conducted from FV *Rakaia,* and the 24th acoustic survey in Cook Strait, the 8th of Pegasus Canyon, and the 7th of Conway Trough.

Six acoustic snapshots of the main Cook Strait spawning grounds were completed between 13 July and 24 August 2025. Seven mark-identification tows and three commercial tows were carried out in Cook Strait during the acoustic survey. In three trips to the ECSI: six snapshots of Pegasus Canyon were completed from 12 August to 4 September; and two of Conway Trough on 14 and 25 August 2025. Nine mark-identification tows were carried out off the ECSI (seven in Pegasus Canyon and two in Conway Trough).

The acoustic abundance index of hoki for Cook Strait in 2025 was 124 000 t, which was more than double the equivalent index from the 2023 survey (58 000 t). The weighting of the abundance estimate (expressed as a coefficient of variation, CV), which includes uncertainty associated with survey timing, sampling precision, acoustic detectability, mark identification, calibration, and target strength, was 31%. Hoki abundance in Cook Strait from individual snapshots ranged from 92 000 t (on 24–25 July) to 161 000 t (on 14–15 August). Most of the hoki backscatter was concentrated in Cook Strait Canyon in snapshots 1 and 3–6, and in the Cook Strait Canyon extension stratum (stratum 5A) in snapshot 2.

The acoustic abundance index of hoki for Pegasus Canyon in 2025 was 145 000 t, which was the highest in the time series. Hoki abundance estimates from Pegasus Canyon varied substantially between snapshots from 50 000 t (on 12–13 August) to 229 000 t (on 26–27 August). Following the same approach used for calculating the Cook Strait total survey uncertainty, the weightings of the abundance estimate for Pegasus Canyon for the 2025 survey was 39%. The acoustic abundance index of hoki for Conway Trough in 2025 was 38 000 t, which was the highest in the time series.

For the second consecutive acoustic survey, the acoustic abundance index for Pegasus Canyon in 2025 was higher than that for Cook Strait. Although the abundance index of Conway Trough in 2025 was the highest in the time series, as a percentage of the estimate from Pegasus Canyon it was similar to that from surveys in 2019, 2021, and 2023 (27%).

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1 INTRODUCTION

Hoki (*Macruronus novaezelandiae*) is Aotearoa New Zealand's largest fishery, with a total allowable commercial catch (TACC) of 110 000 t from 1 October 2021. Although managed within a single quota management area (QMA), hoki are assessed as two stocks, western and eastern. Juveniles from both stocks are thought to mix on the Chatham Rise and then recruit to their respective stocks as they approach sexual maturity. Spawning occurs in winter (June to September), with the major spawning areas on the west coast of the South Island (WCSI) for the western stock, and in Cook Strait and Pegasus Canyon for the eastern stock.

On the spawning grounds, hoki typically form large midwater aggregations. This occurrence of readily identifiable single species aggregations that are often clear of the seabed allows for abundance estimation using acoustic techniques. Such surveys of spawning hoki have been conducted regularly since a 1984 pilot survey on the WCSI spawning grounds (Coombs & Cordue 1995). The results of acoustic surveys of spawning hoki in Cook Strait have been important inputs into hoki stock assessments for over 30 years (O'Driscoll 2002a, Fisheries New Zealand 2025).

Acoustic surveys of Cook Strait were carried out on research vessel (RV) *Kaharoa* annually from 1991–2008 (except in 2000, 2004, and 2007). From 2007–2015, fishing industry vessels also surveyed Cook Strait during the spawning season using the same protocols as for the research vessel surveys (O'Driscoll & Macaulay 2009, 2010, O'Driscoll 2012, O'Driscoll et al. 2015a, 2016). Surveys were biennial between 2009 and 2015. With no suitable industry vessel available to carry out the acoustic survey in 2017, acoustic data collection was carried out from the NIWA coastal RV *Ikatere* (O'Driscoll & Escobar-Flores 2018). Use of that vessel meant that no mark identification trawling could be completed. The three most recent Cook Strait hoki acoustic surveys in 2019, 2021, and 2023 again used RV *Kaharoa* for acoustic data collection and mark identification trawling (O'Driscoll & Escobar-Flores 2020, Escobar-Flores & O'Driscoll 2022, Escobar-Flores et al. 2024).

In addition to Cook Strait, spawning also occurs on the east coast of the South Island (ECSI) in an area centred on Pegasus Canyon (Livingston 1990). Annual catches from the ECSI spawning fishery doubled from around 5000 t in 2011–12 to 2017–18 to around 10 000 t from 2018–19 to 2022–23, increasing further to over 15 000 t in 2023–24, and the catch from this fishery is now greater than that from Cook Strait (Ballara et al. 2025). The first two acoustic surveys of Pegasus Canyon were carried out from a commercial vessel in 2002 (O'Driscoll 2003) and 2003 (O'Driscoll et al. 2004). These surveys produced acoustic biomass estimates 35% and 43% of the equivalent estimates from Cook Strait in 2002 and 2003, respectively. Acoustic snapshots of Pegasus Canyon were also completed during the 2006, 2008, 2019, 2021, and 2023 research surveys on RV *Kaharoa* (O'Driscoll 2007, 2009, O'Driscoll & Escobar-Flores 2020, Escobar-Flores & O'Driscoll 2022, Escobar-Flores et al. 2024) and during the 2013 survey from *Thomas Harrison* (O'Driscoll et al. 2015b). The 2023 acoustic survey of Pegasus Canyon was the first to produce higher acoustic biomass estimates than those from Cook Strait, with biomass 178% of the equivalent estimates from Cook Strait (Escobar-Flores et al. 2024).

Because of the importance of the hoki fishery, the hoki stock assessment is regularly updated with new information from a range of data collection and research programmes. Acoustic surveys of the Cook Strait (Figure 1) and ECSI hoki spawning grounds (Figure 2) are planned to be conducted biennially to update the biomass indices for the eastern spawning stock. Although the acoustic results from Cook Strait have not always been influential on the stock assessment model results, the surveys are considered necessary to monitor the abundance of the eastern spawning stock independently of the Chatham Rise, where both eastern and western hoki stocks mix together.

The survey in 2023 produced the highest average biomass estimate of the ECSI time series (103 000 t), but with a high inter-snapshot variability in the biomass estimates (approximately one order of magnitude). The high inter-snapshot variability could be related to fish availability and detectability (Escobar-Flores & O'Driscoll 2022). The biomass estimates of Pegasus Canyon in 2023 peaked in the last trip to the ECSI in late August (Escobar-Flores et al. 2024), suggesting that the survey did not cover the entire plateau-interval that describes the build-up and decline of biomass in the spawning area for a transient fish population (Coombs & Cordue 1995). Thus, Escobar-Flores et al. (2024) recommended that future ECSI surveys extend their length into mid-September.

The 2025 survey was the 24th in the time series of acoustic estimates of abundance of hoki in Cook Strait and the 8th of the ECSI. The survey was carried out from 23 July to 4 September 2025 using FV *Rakaia* (Santy Maria Fishing Limited.). This was the first time that the FV *Rakaia* was used to conduct the survey.

This report fulfils the final reporting requirement of Seafood New Zealand research project SNZ25303. The overall objective was to estimate the spawning biomass of hoki in Cook Strait and off the east coast of the South Island, at Pegasus Canyon and Conway Trough, using acoustic surveys.

The specific objectives of the project were:

1. To continue the time series of relative abundance indices of spawning hoki in Cook Strait using acoustic surveys, with a target coefficient of variation (CV) of the estimate of 30%.
2. To provide a relative abundance index of hoki in Pegasus Canyon using acoustic surveys, with a target CV of the estimate of 30%.

2 METHODS

2.1 Survey design

Acoustic estimates for spawning hoki in Cook Strait are obtained from area-based surveys. Hoki have a long spawning season, from June to September, and turnover of fish on the grounds means that not all spawning fish are present at any one time. The survey was designed to accommodate this behaviour by using sub-surveys (or "snapshots") spread through the spawning season. Each snapshot consists of a series of randomly spaced transects (following the design of Jolly & Hampton (1990)) in strata covering the known distribution of spawning hoki. Estimates of spawning biomass are calculated for each of the snapshots and averaged to estimate the "mean plateau height" (average biomass during the main spawning season). Under various assumptions about the timing and length of the spawning season (Cordue et al. 1992, Coombs & Cordue 1995), estimates of mean plateau height form a valid relative abundance time series. To ensure consistency with the existing time series, future surveys retain the same survey area and methodology.

An aggregation-based survey design is not appropriate for the hoki stocks. Although much of the hoki spawning biomass is concentrated in Cook Strait Canyon, a variable proportion of the biomass occurs in other areas. This proportion varies between years and at short time scales, including between snapshots (e.g., Escobar-Flores et al. 2024).

Based on an analysis of previous surveys, O'Driscoll (2004) found that the optimal survey design for Cook Strait was a relatively long survey (more than 26 days) centred around 7 August with at least six snapshots. This number ensured that interannual variation in the timing of the season and any systematic trends in the spawning biomass through the season were appropriately observed. Increasing the number of snapshots reduced bias and increased precision, but there was little advantage in having a survey with more than six snapshots if they were spread over a long time period. The survey design, survey operation, and data analysis methods are described for hoki acoustic surveys in Coombs & Cordue (1995) and O'Driscoll (2002b).

In 2025, the acoustic survey included the areas of Cook Strait, Pegasus Canyon, and Conway Trough. Because of the proximity of the Cook Strait spawning grounds to Nelson and Wellington, short (2–5 day) trips from Nelson (port of FV *Rakaia* during the survey) to Cook Strait and to Wellington to disembark scientific personnel were planned for periods of good weather conditions. The eastern spawning grounds are located 370–440 km from Nelson or 180–250 km from Wellington (see Figure 2).

The stratum boundaries and areas in Cook Strait (Figure 1, Table 1) were the same as those for previous surveys, with six main strata (strata 1, 2, 3, 5A, 5B, and 6) covering the areas with depth greater than 200 m (180 m in stratum 2). The acoustic survey area in Cook Strait included grounds which are not often commercially fished by the fleet (i.e., strata 1, 3, 5B, and 6).

The stratum boundaries and areas in Pegasus Canyon and Conway Trough (Table 1 and Figure 2) were the same as those for previous surveys (e.g., 2006, 2008, 2013, 2019, 2021, and 2023) and are based on the 2003 survey from an industry vessel (O'Driscoll et al. 2004). As in Cook Strait, the strata included areas with depth greater than 200 m. Pegasus Canyon was subdivided into two strata because the highest densities of hoki were in the southern part of the Canyon (PCB) in 2002 and 2003 (O'Driscoll 2003, O'Driscoll et al. 2004).

2.2 Vessels and equipment

The survey in 2025 was carried out on FV *Rakaia,* a 32 m stern trawler with a beam of 10 m, and displacement of 498 t. The echosounder onboard the vessel consisted of a Simrad EK60 general-purpose transceiver (GPT) connected to the hull-mounted Simrad ES38B 38 kHz transducer. The echosounder acquisition software was the Simrad EK80 version 24.1.0. The calibration was conducted following the standard protocols described in Demer et al. (2015). The calibration was of excellent quality and indicated that the echosounder was functioning correctly. A calibration report is provided as Appendix 1.

2.3 Acoustic data collection

To collect high quality acoustic data in poor weather, the transducer must be below the bubble layer produced by surface waves and turbulence (Jech et al. 2021). Cook Strait acoustic surveys from RV *Kaharoa* before 2008 used towed acoustic systems to increase the range of weather conditions in which acoustic data of suitable quality could be collected (e.g., O'Driscoll 2009). The use of towed acoustic systems was discontinued in 2008 due to financial constraints, with later surveys carried out using hull-mounted systems, limiting the range of weather conditions in which quality data could be acquired. The size and relatively shallow draft (~4 m) of FV *Rakaia,* comparable to RV *Kaharoa* (28 m length and 3.6 m draft), restricted the range of weather conditions for acquiring high quality data to periods of less than 25 knots of wind and 2 m swell. In 2025, acoustic snapshots were all conducted within the specified weather conditions.

Transects were conducted at speeds of 7–9 knots. The aim was to complete each Cook Strait snapshot within 48 hours (preferable, 72 hours maximum). All transects in the main Cook Strait Canyon (strata 5A and 2) and Pegasus Canyon (strata PCA and PCB) were run without breaks because of fish movement related to tides in these areas.

2.4 Mark identification trawling

Midwater trawling was carried out for mark identification and commercial fishing operations. Both activities enabled the collection of hoki length frequency and biological data. All mark identification tows were carried out using FV *Rakaia*'s midwater trawl, which has 150 m bridles, 24 m vertical opening, and a 60 mm codend. Vee-type trawl doors with a surface area of 5 m^2 were used.

For each tow, all items in the catch were sorted by species and weighed on Marel motion-compensating electronic scales accurate to about 0.1 kg. Where possible, fish, squid, and crustaceans were identified to species level, and other benthic fauna to family. A random sample of up to 200 hoki and 100 individuals of each other species from every tow were measured for length. In most tows, the sex and macroscopic gonad stage of all hoki in the length sample were also recorded. More detailed biological data were collected on a subsample of up to 20 hoki per trawl and included fish length, weight, sex, gonad stage (as per Appendix 2), gonad weight, and removal of otoliths.

Estimated hoki length frequencies were constructed for each stratum by using data from all trawl tows, weighted by the hoki catch in the trawl, within that stratum.

2.5 Environmental data collection

An RBR temperature data logger (serial no. 60418) was mounted on the headline of the net to collect temperature and depth during all midwater trawls. These data were then used to estimate the acoustic absorption coefficient using the formula of Doonan et al. (2003).

2.6 Acoustic data analysis

Acoustic data collected during the survey were analysed using standard echo-integration methods (Simmonds & MacLennan 2005), implemented in NIWA's ESP3 software package (Ladroit et al. 2020) version 1.80.0. Echograms were visually examined and the location of the bottom in each ping determined by a combination of an in-built bottom-echo identification algorithm and manual editing. Regions corresponding to various acoustic mark types were then identified. Marks were classified subjectively from experience, based on characteristics such as shape, structure, depth, and echo strength (O'Driscoll 2002c). Backscatter from marks identified as hoki was then integrated to produce an estimate of acoustic density, expressed as the mean area backscattering coefficient (s_a, m^2 m^{-2}, MacLennan et al. (2002)).

Acoustic density was output two ways. First, average acoustic density per transect was calculated. These values were used for abundance estimation (see Section 2.7). Second, acoustic backscatter was integrated into 10-ping bins (approximately 100 m) to produce a set of acoustic densities for each transect. There were typically 30–100 density values per transect and they were used to display the spatial distribution of acoustic density along each transect.

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 (2002b), 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):

$$w = (4.79\times10^{-6})\ TL^{2.89} \quad (1)$$

where TL is total fish length in centimetres; and

3. the most recent TS-length relationship for New Zealand hoki (Dunford et al. 2015):

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

2.7 Abundance estimation

Abundance estimates and variances were obtained for each stratum using the formulae of Jolly & Hampton (1990), as described by Coombs & Cordue (1995). Stratum estimates were combined to produce snapshot estimates which were averaged to obtain the abundance index for 2025.

The sampling precision of the abundance index was calculated in two ways, as described by Cordue & Ballara (2001). The first method was to average the variances from each snapshot. This method potentially underestimated the sampling variance, as it accounted for only the observation error in each snapshot. The imprecision introduced by the inherent variability of the abundance in the survey area during the main spawning season was ignored. The second method assumed that the snapshot abundance estimates were independent and identically distributed random variables. The sample variance of the snapshot means divided by the number of snapshots was therefore an unbiased estimator of the variance of the index (the mean of the snapshots).

2.8 Survey weighting for stock assessment

The sampling precision greatly underestimates the overall survey variability, which also includes uncertainty in TS, calibration, and mark identification (Rose et al. 2000). These additional uncertainties were calculated for individual Cook Strait and Pegasus Canyon surveys using a Monte Carlo simulation method (O'Driscoll 2004) and were used as model weightings (expressed as coefficient of variation or CV) in the hoki stock assessment model.

The simulation method by O'Driscoll (2004) combined six sources of variance:

- plateau model assumptions about timing, duration of spawning, and residence time,
- sampling precision,
- detectability,
- 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. Second, random samples from each of the probability distributions were selected and combined multiplicatively in Monte Carlo simulations of the process of acoustic abundance estimation.

In each Cook Strait simulation, a biomass model was constructed by randomly selecting values for each variable from the distributions in Table 2. This model was then 'sampled' at dates equivalent to the mid-dates of each snapshot. The precision of sampling was determined by the snapshot CV and the biomass adjusted for variability in detectability. The simulated biomass estimate in each snapshot was then split, based on the proportion of acoustic backscatter in 'school' and 'fuzz' mark types (see Section 3.3.1 for a list of mark categories), and mark identification uncertainties were applied to each part. The biomass estimates were recombined and calibration and TS uncertainties were 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.

A similar approach was used to estimate the weighting of the six snapshots in the Pegasus Canyon acoustic time series. The methods were the same as for Cook Strait but with a later assumed mean arrival date (see Escobar-Flores et al. (2024)).

3 RESULTS

3.1 2025 commercial fishery

3.1.1 Cook Strait

A total catch of 11 213 t was taken by the commercial fishery from Cook Strait between 1 June and 30 September 2025, with most hoki caught between late June and mid-September (Figure 3). The acoustic survey was carried out within the period of high catches, but it did not cover the peak catch around 5 September. Almost all of the commercial effort in 2025 was concentrated in Cook Strait Canyon (strata

2 and 5A), but hoki were also caught in the deepwater (stratum 5B), in Nicholson Canyon (stratum 3), and to a lesser degree in the Narrows Basin (stratum 1) (Figure 4).

The hoki length frequency distribution from the 2025 commercial fishery in Cook Strait (based on scientific observer data and land-based sampling for Fisheries New Zealand projects MID2024-01 and HOK2023-02) is shown in Figure 5. The mean length of hoki was 78.9 cm. Mean weight and mean backscattering cross-section (obtained by transforming the scaled length frequency distribution in Figure 5 by equations (1) and (2) and then calculating the means of the transformed distributions) were 1.53 kg and 0.000187 m^2 (equivalent to –37.3 dB). The *r* ratio was 8180 kg m^{-2}.

Actively spawning (ripe and running ripe) female hoki were recorded in the commercial catch throughout the period of observer and land-based sampling from 30 June to 14 September (Figure 6). The proportion of spawning females was consistently high from early-July until mid-August and was highest around 28 August and 2 September driven by the observer and market data, respectively. The proportion of spent females increased from mid-to-late August (Figure 6).

3.1.2 East coast South Island

A total catch of 14 523 t of hoki was taken from the ECSI (as defined by Ballara et al. 2025) between 1 June and 29 September 2025, a substantial increase from the catch in 2023 (5724 t). Hoki were taken from Pegasus Canyon and from outside the acoustic survey area (east of Pegasus Canyon and along the slope to the north and south) (Figure 4). There was very little effort in Conway Trough. High catches were taken from ECSI in mid-July and from mid-August to late-September. The acoustic survey was carried out within the second and main period of high catches from mid-August until early September, which included the peak of the catches around 30 August–4 September (Figure 3).

The hoki length frequency distribution from the 2025 commercial fishery off the ECSI (based on scientific observer and land-based sampling data) had a strong mode around 63 cm (Figure 5); the mean length of 71.1 cm was around 8 cm shorter than the mean length from Cook Strait in 2025. Mean weight and mean backscattering cross-section were 1.16 kg and 0.000148 m^2 (equivalent to –38.3 dB). The *r* ratio was 7886 kg m^{-2}.

Actively spawning (ripe and running ripe) female hoki were recorded in the commercial catch in early to mid-August mainly driven by the market sampling, and from late-August to mid-to-late September (Figure 6). A relatively low proportion of fish were recorded as actively spawning between these two periods, while the proportion of fish recorded as maturing increased. The proportion of hoki actively spawning and spent from late-August to mid-September varied substantially with no clear peaks (Figure 7).

3.2 Data collection

3.2.1 Acoustic data

Six acoustic snapshots of the main Cook Strait spawning grounds were carried out on six separate trips from 17 July to 24 August 2025 (Table 3). Three trips to the ECSI were completed between 13 August and 4 September. During both the first and second trips (12–14 and 25–27 August, respectively) two snapshots of Pegasus Canyon and one of Conway Trough were completed. On the third trip (3–4 September) two snapshots of Pegasus Canyon were completed (Table 4).

The weather conditions encountered in Cook Strait during the survey were challenging with an average hourly wind speed of 19.4 knots during the survey period (Figure 8). However, relatively brief windows of good weather between 17 July to 24 August 2025 were used to conduct the survey. The weather conditions in the ECSI area were generally better with an average hourly wind speed of 8.1 knots during the survey period. Although there were reasonable windows of good weather in the ECSI in August, from late August the weather became more unstable, with stronger winds and more limited opportunities to conduct acoustic surveys (Figure 8).

Acoustic surveys using hull-mounted systems are limited to less than 25 knots of wind and less than 2 m of swell to ensure that data is of sufficient quality for biomass estimation. Although the aim of the survey was to conduct snapshots at regular intervals throughout the survey period, in practice the timing of the acoustic snapshots was determined by the occurrence of brief windows of good weather. As in previous surveys, a higher priority was given to the completion of snapshots than to mark identification fishing (see Section 3.2.2).

The fishing vessel *Rakaia* was used for the first time in 2025 to conduct the acoustic survey of spawning hoki in Cook Strait and the ECSI. During the survey, it was observed that, even when sea conditions were reasonably good, the vessel experienced noticeable pitch movement (i.e., an up-and-down rotation of the bow and stern around the transverse axis). This suggested that the motion was due to the vessel's inherent handling characteristics rather than adverse weather or rough seas. During acoustic data collection, vessel speed was limited to 7.0–7.5 knots to maintain data quality, as higher speeds were found to degrade the overall quality of acoustic data.

3.2.2 Trawl data

Poor weather reduced the number of mark identification tows that could be carried out, as the collection of acoustic data was prioritised. In 2025, 19 hoki midwater tows were carried out for mark identification: 10 in Cook Strait (including three commercial tows that were sampled); 7 in Pegasus Canyon; and 2 in Conway Trough (Figure 9). Further details on mark identification tows are in Section 3.3.2.

A total of 4029 fish from 17 species were measured during this survey. Otoliths and detailed biological data (including individual fish weights and gonad stage) were collected from 545 hoki (Cook Strait = 196, and ECSI = 349). The species list from the survey mark-identification tows is provided in Appendix 3.

3.2.3 Environmental data

Temperature profiles were obtained in conjunction with mark identification midwater tows. Average temperature profiles in Cook Strait and off east coast South Island are shown in Figure 10.

The average water temperature from seven profiles (six mark identification tows and one commercial tow) in Cook Strait between 4.5 m (estimated transducer depth) and 500 m depth was 10.8 ºC (s.d. ± 1.3). No salinity data were collected in 2025 therefore the average salinity (34.8 PSU) from the previous survey carried out from RV *Kaharoa* (KAH2304) was used to calculate sound absorption. The average sound absorption in 2025 was 8.99 dB km^{-1} (s.d. ± 0.06). This was higher than the average sound absorption estimated in Cook Strait in 2023 and slightly higher than values from surveys in the last ten years (range 8.84–8.97 dB km^{-1}). This was due to the warmer water temperatures recorded in 2025.

Ten temperature profiles (all from mark identification tows) were obtained off the ECSI. The average temperature was 10.1 ºC (s.d. ± 0.4). The average salinity (34.7 PSU) from the previous survey carried out from RV *Kaharoa* (KAH2304) was used to calculate sound absorption. The calculated sound absorption was 9.07 dB km^{-1} (s.d. ± 0.2), which was within the range of previous surveys for this area (range 9.06–9.20 dB km^{-1}).

3.3 Mark identification

3.3.1 Acoustic mark types

Marks were similar to those observed in previous surveys from 2001 to 2023. Example echograms of some of these mark types are shown in Figures 11–15. Further examples are provided by O'Driscoll (2002a, 2003, 2007, 2009, 2012), O'Driscoll & Dunford (2008), O'Driscoll & Macaulay (2009, 2010), O'Driscoll et al. (2015a, 2016), O'Driscoll & Escobar-Flores (2018, 2020), Escobar-Flores & O'Driscoll (2022), and Escobar-Flores et al. (2024).

Hoki schools ('HOK')
Hoki school marks are characterised by relatively high acoustic return, clearly defined edges, typically occurring at 200–500 m water depth, and often in midwater over canyon features. The densest hoki school marks were observed in the Cook Strait and Pegasus Canyon (Figure 11), but were also observed in the Cook Strait Canyon extension (stratum 5A), Nicholson Canyon (stratum 3), Terawhiti Sill (stratum 6), and Conway Trough (stratum CT). Eleven research tows were carried out on hoki school marks in 2025 across different strata, see Table 5.

Hoki bottom fuzz ('BMIX')
Hoki bottom fuzz marks are diffuse, low-density layers adjoining the seabed and extending to more than 50 m above it. These are usually in water depths shallower than 300 m. This mark type was commonly observed in the Narrows Basin (stratum 1, e.g., Figure 12) and Terawhiti Sill in Cook Strait. One research tow was carried out on hoki bottom fuzz marks in 2025 in the Narrows Basin (station 4).

Hoki pelagic fuzz ('PMIX')
Hoki pelagic fuzz marks are characterised by low acoustic returns, a relatively constant depth within the 200–600 m range, they are typically over deep waters (500–1000 m), and often have single target echoes within the layers. As in previous years these marks were common in the Cook Strait Canyon extension (stratum 5A), the deep water between Cook Canyon and Wairarapa Canyon (stratum 5B), and Conway Trough (e.g., Figure 13). Two research tows were carried out on hoki pelagic fuzz marks in 2025 in the Deep Water (stratum 5B) and Conway Trough (stratum CT) (stations 5 and 14, respectively).

Bottom non-hoki ('B')
Bottom non-hoki marks are bottom-referenced layers or schools typically denser and shallower (less than 200 m depth) than hoki bottom fuzz layers. Bottom non-hoki marks were observed on transects in the deep water between Cook Canyon and Wairarapa Canyon (stratum 5B). Previous research tows on this mark type had catches dominated by ling. No research tows were carried out on bottom non-hoki marks in 2025.

Jack mackerel ('JMA')
Jack mackerel (*Trachurus declivis*) form strong pelagic marks consisting of small schools and strong single targets at depths of 50 to 200 m. As in previous surveys, jack mackerel marks were observed in the Narrows Basin (e.g., Figure 14), Nicholson Canyon, Terawhiti Sill, Cook Strait Canyon extension, and in the deep water between Cook Strait Canyon and Wairarapa Canyons. No research tows were carried out on jack mackerel marks in 2025.

Mesopelagic layers ('MESO')
Mesopelagic layers are strong marks usually occurring between the surface and 300 m depth and exhibit strong diurnal vertical migration patterns. Mesopelagic layers were widespread throughout the survey areas (e.g., Figure 15). Targeted trawling on this mark type in the main Cook Strait Canyon (station 6) and Nicholson Canyon (station 7) yielded small catches (less than 15 kg), dominated by weight and number by pearlside (*Maurolicus australis*). A small number of hoki were caught in station 6, however these were most likely caught at the beginning of the tow when the net dropped below the target depth of the mark identification tow.

Spiny dogfish (‘SPD’)
Spiny dogfish (*Squalus acanthias*) marks are characteristically surface-referenced marks, similar to jack mackerel marks, consisting of small schools and single targets at depths of 100–200 m that are usually above hoki school marks. Midwater spiny dogfish marks were not observed in Cook Strait Canyon during the 2025 survey.

3.3.2 Mark identification trawling

Mark identification tows were carried out on four of the seven mark types (Table 5). None were targeted at jack mackerel, spiny dogfish, or bottom non-hoki marks. Mark identification tows targeted on some of these mark types in previous years have typically caught less than 10% hoki (e.g., O’Driscoll & Escobar-Flores (2020)).

Mark identification tows carried out in Cook Strait targeted mainly hoki school marks (n = 6), three of which were commercial tows (stations 2, 3, and 11, Table 5). The proportion of hoki in these tows was high (83–99% of the catch in weight). Because of survey time constraints, only one tow was carried out on both bottom and pelagic mix marks (stations 4 and 5, respectively), which consisted of 30 and 94% hoki (Table 5). The proportions of hoki in trawls targeted at hoki pelagic and bottom fuzz were within the ranges caught from this mark type in previous surveys (Figure 16). Important bycatch species in Cook Strait included spiny dogfish (*Squalus acanthias*), ling (*Genypterus blacodes*), rattails (mainly Bollons’s rattail *Coelorinchus bollonsi*), silver warehou (*Seriolella punctata*), gemfish (*Rexea solandri*), lucifer dogfish (*Etmopterus lucifer*), and mesopelagic species (Table 5).

Two tows (stations 6 and 7) were carried out mesopelagic marks in strata 2 and 3, respectively. Although a few hoki were caught in station 6, this was due to the net dropping below target depth at the beginning of the tow, however mesopelagic fish (e.g., pearlside *Maurolicus australis*) dominated the catch by weight and number.

Mark identification tows carried out in the ECSI survey area mostly targeted hoki schools (Pegasus Canyon A, n = 3; Pegasus Canyon B, n = 4, and Conway Trough, n = 1). The proportion of hoki in trawls targeted at hoki schools in Pegasus Canyon and Conway Trough was high (90–100%, Table 5). Bycatch species in Pegasus Canyon and Conway Trough was similar to those in Cook Strait and included species such as spiny dogfish, ling, silver warehou, rattails, and mesopelagic fish (Table 5).

A single mark identification tow targeted at pelagic fuzz in Conway Trough (station 14) had a proportion of hoki within the range caught from this mark type in previous surveys (Figure 16). No mark identification trawls targeted bottom fuzz marks in the east coast South Island.

3.4 Processing of acoustic backscatter data

Acoustic backscatter from regions corresponding to hoki schools, hoki bottom fuzz, and hoki pelagic fuzz were integrated to obtain acoustic density estimates. This approach was consistent with the analysis of acoustic data from previous surveys. Although hoki fuzz marks are known to contain a proportion of other species, all backscatter from these marks was assumed to be from hoki (O’Driscoll 2002b). No species decomposition of acoustic backscatter in mixed layers was attempted because of the limited mark identification trawling. If there was a change in the proportion of hoki in fuzz marks over time (as suggested by O’Driscoll (2006) for bottom fuzz marks), this approach will lead to a bias in the relative abundance estimates. However, the Monte Carlo estimation of survey uncertainty will include some of this potential bias because the lognormal distribution of uncertainty associated with species mix is very broad (see Table 2, Appendix 4).

3.5 Distribution of hoki backscatter

Expanding symbol plots show the spatial distribution of hoki backscatter along each transect during the six snapshots of Cook Strait (Figure 17) and Pegasus Canyon (Figure 18), and two snapshots of Conway Trough (Figure 19).

Overall, the distribution of hoki in Cook Strait was similar to that observed on previous research and industry surveys (e.g., O'Driscoll et al. (2015a), Escobar-Flores & O'Driscoll (2022), Escobar-Flores et al. (2024). The main hoki school marks were observed in the Cook Strait Canyon, with a higher average proportion of backscatter than in 2023, but still lower than the average since 2009 (2025 = 60%, 2023 = 43%, and 2009–2023 average = 66%) (Table 6). Strata 5B and 5A also had the second and third highest proportion of backscatter of the survey (15 and 16%, respectively), both higher than the average between 2009–2023 (9 and 10%, respectively).

In Cook Strait, hoki were mostly aggregated towards the eastern half of the Cook Strait Canyon (stratum 2) in snapshots 1, 3, 4 and 6, and towards the western half of the Cook Strait Canyon in snapshot 5 (Figure 17). Lower acoustic densities were observed in Cook Strait Canyon in snapshot 2, when hoki marks of moderate densities were observed in stratum 5A. Moderate density hoki schools were also observed at Terawhiti Sill in snapshots 1 and 3. Acoustic densities in the Narrows Basin (stratum 1) and Nicholson Canyon were low, about half of those in 2023, with most of the backscatter from these areas from bottom and pelagic fuzz marks, respectively.

The distribution of backscatter on the east coast South Island was also consistent with previous surveys. Hoki schools were detected in south (PCB) and north (PCA) Pegasus Canyon during all snapshots (Figure 18). As the survey progressed, these schools intensified and were densest in snapshots 3–6. Highest hoki densities were in PCB. Lower acoustic densities were observed in stratum PCA where backscatter was associated with hoki schools and pelagic fuzz marks (particularly towards the outer end of the stratum).

Consistent with previous surveys, densities of acoustic backscatter were much lower in Conway Trough than in Pegasus Canyon and Cook Strait (Figure 19). The acoustic densities were highest in the shallower southern end of the Trough, where hoki schools were detected in snapshot 2. Lower density hoki pelagic fuzz marks were spread north along the trough in both snapshots.

3.6 Hoki size and maturity

The length frequency distributions of hoki in Cook Strait varied between strata in 2025 (Table 7). The largest hoki were caught in the Nicholson Canyon stratum (stratum 3, mean length of 79.0 cm), with the smallest in the Narrows Basin (mean length = 34.8 cm). The overall mean length from mark identification and commercial tows combined carried in Cook Strait was 78.0 cm, which was larger than the average size of hoki in the most recent Cook Strait acoustic survey (2021 = 52.4 cm, and 2023 = 53.9 cm). The difference in size is explained by the inclusion of commercial tows which targeted spawning aggregation of adult hoki (hoki schools) in strata 2 and 3 (n = 3). Typically, spawning aggregations of adult hoki are not targeted by tows carried out by the survey. The mean length from survey tows was similar to the mean length in the Cook Strait commercial catch (78.9 cm, see Figure 5).

While male hoki dominated the catch of the mark identification trawl tows in Terawhiti Sill (stratum 6), females dominated the catch elsewhere in Cook Strait, with the highest proportion of females recorded in the Nicholson Canyon and the Deep Water strata (strata 3 and 5A) (Table 7).

There were several modes on the unsexed length frequency distribution from the 2025 Cook Strait survey. The main unsexed length modes were centred on 68–75 cm and 76–81 cm. The main mode for males was centred around 70–73 cm. There was no clear dominant length mode for females in the survey data (Figure 20). Only a small number of age 1 fish (less than 40 cm) from the 2024 year-class were caught by research tows.

The hoki catch in Pegasus Canyon and Conway Trough were dominated by females and males, respectively (Table 7). The mean length of all hoki was slightly higher in outer Pegasus Canyon (PCA, 76.5 cm) than in the inner stratum (PCB, 73.1 cm) (Figure 21). The overall mean length in Pegasus Canyon (73.8 cm) was smaller than in Cook Strait (78.0 cm) (Table 7, Figure 21) but higher than the mean length from the commercial fishery for the ECSI in 2025 (71.1 cm, Figure 5).

A subsample of 546 hoki from Cook Strait and ECSI was weighed during the 2025 survey. The derived length-weight relationship ($R^2 = 0.97$) from these fish was:

$$w = (2.931\times10^{-6})\, L^{3.0113} \qquad (3)$$

were *w* was in kg. This relationship gave a weight about 3.3% higher for a hoki of 75 cm than from the generic relationship of Francis (2003).

The *r* value calculated using the hoki length frequencies from research tows, length-weight relationship estimated from the survey (equation 3), and the TS-length relationship of Dunford et al. (2015) (equation 2) was 8506 kg m^{-2} for Cook Strait and 8274 kg m^{-2} for Pegasus Canyon. The Cook Strait *r* value was higher than that obtained from the commercial fishery in 2025 using the standard approach (Section 3.1.1, r = 8180 kg m^{-2}) because the average weight of hoki obtained from the survey L-W relationship was higher than that from obtained from the L-W relationship from Francis (2003). Ideally, hoki TS values should be stratum- and snapshot-specific, based on length frequencies from research tows during the acoustic survey. In practice, this level of research fishing was not practicable, and *r* calculated from commercial tows (which provided extensive sampling of the main spawning marks) was used to estimate biomass. The length frequency of hoki caught in the commercial fishery may not have represented the length frequency of the underlying spawning population due to gear selectivity or targeting of fish of certain size or at certain depth ranges. However, the variation in length in the commercial catch was likely to give a realistic idea of the level of interannual variability in fish size (O'Driscoll 2002b).

The *r* value for Pegasus Canyon, calculated from length frequency data research tows and the length-weight relationship in equation (3), was also higher than that obtained from commercial data for the ECSI (Section 3.1.2, r = 7886 kg m^{-2}). As for Cook Strait, this was because the average hoki weight obtained from the survey L-W relationship and the average length of the hoki from the survey tows were greater than that of hoki caught commercially. The value of *r* was calculated from commercial data when estimating hoki biomass off the ECSI.

The number of mark identification trawl tows carried out during each snapshot was small and temporal patterns in hoki gonad stages (

Table 8) were confounded by the spatial distribution of tows. In Cook Strait, 72% of hoki sampled during the acoustic survey were in spawning condition (stages 3–7). Sixty-one percent of males and 70% of females were ripe or running ripe (stages 3–5), and 6% of females and 2% males were partially spent or spent (stages 6–7). In Pegasus Canyon, 97% of hoki sampled were in spawning condition, 97% of males and 98% of females were ripe or running ripe, and 15% of males and 8% females were partially spent or spent. In Conway Trough, 88% of hoki sampled also were in spawning condition; 81% of males and 88% females were ripe or running ripe, and 1% of males and 3% of females were partially spent or spent.

3.7 Hoki abundance estimates

3.7.1 Cook Strait

Hoki abundance during the survey varied between snapshots (Figure 22). Hoki abundance peaked in snapshot 5 at 161 000 t carried out on 14 August 2025, and it was lowest in snapshot 2 (24 July) with an estimate of 92 000 t (Table 9). The largest changes in abundance occurred between snapshots 1 and 2 when the biomass dropped by 49 000 t (30%), and between snapshots 4 and 5, when biomass increased by over 56 000 t (53%). Differences between individual snapshots were probably due to sampling variability (transect location and fish behaviour) as well as changes in abundance and availability. High variability in abundance between snapshots is often observed in Cook Strait (e.g., in 2002, 2006, 2011, 2013, 2015, 2017, and 2021, Figure 23). Sampling precision (CV) of individual snapshots ranged between 12 and 51% (Table 9).

The hoki abundance index for Cook Strait in 2025, averaged over all snapshots, was 124 000 t (Table 9). This estimate represented more than a two-fold increase (113%) of the estimate from the previous survey in 2023 (58 000 t), which was the lowest of the time series. The estimate from 2025 was still lower than the estimate from 2021 (159 000 t), and it was comparable to estimates from surveys carried out in the mid-to-late 90s and early 2000s (

Table 10). Averaging over all snapshots, 60% of the hoki biomass was in stratum 2, 16% in stratum 5B, 15% in stratum 5A, 4% in stratum 1, 3% in stratum 3, and 2% in stratum 6 (Table 6). The relative importance of strata 5A and 5B to the overall biomass was lower in 2025 than in 2023, however it was higher than the average contribution of these strata in previous surveys over the last 20 years (10 and 11%, respectively). The contribution of strata outside Cook Strait Canyon was likely to have been overestimated because much of the biomass was from hoki fuzz marks and these are known to contain other species (Table 5).

The average proportion of the biomass from hoki schools in 2025 was 83% (Table 11), which was the highest in the time series of acoustic surveys (range of proportions of hoki in schools from previous surveys in 1991–2023 was 30–78%). All hoki observed in stratum 2 in 2025 were in schools, which was higher than in 2019 (82%), 2021 (95%), and 2023 (86%). Hoki schools were also regularly observed in strata 5A, 5B, 3, and stratum 6 (snapshots 1–4). Due to the high proportion of hoki biomass concentrated in hoki schools, changes in the biomass of hoki schools drove changes in abundance over the survey period (Figure 22). The biomass from hoki fuzz marks varied between 7000 and 37 000 t between snapshots. Their contribution to the overall biomass fluctuated between 7 and 20%, being lowest in snapshot 4 and highest in snapshot 3.

The average of the snapshot variance was 8%. The variance of the abundance estimates from the six snapshots (sampling CV) was 12% (Table 9 The similarity of these two estimates suggests that the variation in biomass estimates among individual snapshots was largely explained by sampling variability. The overall survey weighting estimated from the Monte Carlo simulation model for Cook Strait was 31% (Table 12). As in previous Cook Strait surveys (O'Driscoll 2004), timing (including uncertainties about plateau timing and residence time), sampling error, and mark identification, were the major sources of uncertainty (Table 12). The overall CV associated with the 2025 survey was lower than that in 2021 and 2023 (41 and 38%, respectively), and the lowest for any survey since 2013 (

Table 10). Uncertainties due to calibration, detectability, and TS contributed relatively little to the overall CV. However, incorrect choice of TS and calibration coefficients have the potential to introduce bias in estimates, which is not reflected in the CV in Table 12.

3.7.2 East coast South Island

The average abundance index of hoki from Pegasus Canyon in 2025 was 145 000 t (Table 13). This was the highest estimate in the time series (Table 14 and Figure 24) and 42 000 t higher than the previous highest biomass estimated in 2023 (Table 14). The average abundance index of hoki of Conway Trough was 38 000 t, also the highest in the time series and an increase of 10 000 t with respect to the previous estimate from 2023 (Table 14).

Estimates of hoki abundance in Pegasus Canyon varied substantially during the survey period and between snapshots completed within 24 hours and ranged from 50 000 t to 229 000 t (Table 13). The lowest index of abundance was the estimate from snapshot 1, carried out on the first trip to the ECSI on 14 August (Table 4). The second snapshot carried out on the first trip to the ECSI produced an estimate of 97 000 t, which was nearly twice the biomass of snapshot 1. On the second trip, the estimates from two snapshots were higher than those on the first trip and were less variable (the estimate from snapshot 3 was 62% of that on snapshot 4). The biomass estimate from snapshot 4 was the highest index of hoki abundance of the ECSI survey in 2025. The estimates from the individual snapshots completed on the third trip were again variable, but less than for the first and second trips, with the estimate from snapshot 6 being 30 000 t higher than the estimate of abundance from snapshot 5. The strong spatio-temporal variability (or availability) of hoki in Pegasus Canyon observed in 2025 was consistent with the observations from the 2021 and 2023 surveys (Escobar-Flores & O'Driscoll 2022, Escobar-Flores et al. 2024).

Sampling precision (CV) of individual snapshots of Pegasus Canyon ranged between 15 and 51% (Table 13). The average of the snapshot variance was 12% and the variance of the abundance estimates from the seven snapshots (sampling CV) was 18%. The overall survey weighting estimated from the Monte Carlo simulation model for Pegasus Canyon in 2025 was 32% (Table 12). The major sources of uncertainty were timing (including uncertainties about plateau timing and residence time), and sampling error. Uncertainties due to calibration, detectability, and TS contributed relatively little to the overall CV.

The distribution of biomass between PCA and PCB changed between snapshots but, overall, it was relatively well spread with no clear pattern. Higher estimates of abundances of hoki were obtained in PCA in snapshots 1–3 and 6, and higher estimates were obtained in PCB in snapshots 4 and 5 (Table 13). Typically, the highest acoustic densities were found in PCB (Figure 18), but the larger area of PCA resulted in higher biomass in this stratum for most snapshots.

On average, 92% of the hoki biomass in Pegasus Canyon came from hoki schools, with a higher proportion of schooling hoki in stratum PCB (Table 15). The overall proportion of hoki in schools was the highest in the time series, with previous surveys in 2002–23 showing proportions between 33% and 86% (O'Driscoll 2007, 2009, O'Driscoll & Escobar-Flores 2020, Escobar-Flores & O'Driscoll 2022, Escobar-Flores et al. 2024).

Hoki schools were detected in both snapshots of Conway Trough accounting for 46% (snapshot 1) and 90% (snapshot 2) of the abundance of hoki in their respective snapshots (Table 15). Hoki schools had only previously been observed in Conway Trough in 2008 (O'Driscoll 2009) and in 2023 (Escobar-Flores et al. 2024). The percentage of hoki in schools in 2025 was higher than in 2002–23, where between 8 and 32% of hoki were in schools in Conway Trough (O'Driscoll 2007, 2009, Escobar-Flores et al. 2024).

In 2025, the estimates of hoki abundance in both Pegasus Canyon and Conway Trough, as a percentage of the equivalent estimate from Cook Strait, was lower than in 2023, when the Cook Strait biomass was the lowest in the time series, but higher than in all previous years (Table 16). The abundance in Conway Trough as a percentage of the equivalent estimate from Pegasus Canyon was 26%. This was consistent with the previous three surveys (Table 17).

4 DISCUSSION

The 2025 acoustic survey of spawning hoki was carried out from fishing vessel *Rakaia* (Santy Maria Fishing Limited) between 23 July and 4 September 2025 and covered the areas of Cook Strait and the ECSI. Six acoustic snapshots were completed in Cook Strait and Pegasus Canyon, and two in Conway Trough; all of which were of good quality for estimating the abundance of spawning hoki.

Weather during the Cook Strait 2025 survey was variable with periods of good weather interleaved with northerly and southerly fronts hitting the survey area, which influenced the timing of the snapshots and limited the mark identification trawling activities. The last snapshot of Cook Strait (snapshot number 6) was carried out on 23–24 August, which was the last window of good weather during the survey period. On the ECSI, weather conditions during the survey period were more stable than in Cook Strait during most of August, however these became more unstable during late August and early September. Towed echosounder systems (last used in Cook Strait in 2008) expand the range of weather conditions in which acoustic data of suitable quality can be collected and would provide more flexibility in the timing of the snapshots during the survey period.

The 2025 survey was the first Cook Strait survey carried out from the FV *Rakaia.* The echosounder system of *Rakaia* was the same as that installed on RV *Kaharoa* when it was used to carry out the last survey of spawning hoki in 2023. Although the overall quality of the acoustic data collected by FV *Rakaia* was good (i.e., less than 10% bad transmits), the quality of the data was lower than that collected by RV *Kaharoa* in 2023, having twice as many bad transmits (*Rakaia* 6% vs RV *Kaharoa* 3%).

The hoki abundance index from Cook Strait in 2025 (124 000 t) was more than double the equivalent index from the 2023 survey (58 000 t), but it was still lower than the estimate from the 2021 survey (159 000 t). The estimate from the 2025 survey was similar to estimates from surveys conducted between 1999 and 2003 (

Table 10). The estimates of abundance from single snapshots suggested that abundance of hoki increased from mid-to-late July until mid-August, when it peaked on snapshot 5. Snapshot 6 was completed ten days after the biomass peaked, suggested that there was a decreasing trend in biomass towards the end of August.

Commercial catches and gonad staging data showed that the timing of the 2025 survey was appropriate and that it is likely that the survey did not miss the fish. Commercial catch data showed a period of high and consistent catches from 20 July and 5 September (Figure 3); the acoustic survey of spawning hoki was carried out within this period of high catches. Market and observer combined gonad staging data from Cook Strait (Figure 6) showed that female hoki were actively spawning (i.e., over 20%) consistently from about 20 July and that the proportion of actively spawning hoki increased through late July and August and it was highest from 24 August and 4 September. This was consistent with the increasing trends in estimates of abundance from the survey, however the survey did not extend until the end of August-early September period, where the proportion of spawning female hoki was highest.

The abundance estimate for Pegasus Canyon from the 2025 survey was the highest in the time series (145 000 t). This estimate represented a 41% increase from the 2023 estimate that was previously the highest in the time series (103 000 t) (Escobar-Flores et al. 2024). As in previous surveys, estimates of hoki abundance from snapshots completed within 24 hours were highly variable. However, the inter-snapshot variability decreased closer to the peak of biomass estimates (and possible peak of the spawning) towards the end of the survey period (Tables 13 and 14). Whether the high variability could be due to temporal or spatial variability, changes in fish detectability (e.g., fish closer to the bottom), availability (e.g., fish movement in and out of the canyon, possibly related to currents or tides), or to the random nature of sampling (e.g., location of transects) is still relatively unknown; a longer survey period and more survey effort would be needed to continue to improve our understanding of the hoki dynamics in the ECSI during the spawning season.

Two snapshots of Conway Trough were completed in 2025, which yielded the highest estimate of hoki abundance (38 000 t) in the time series. For the second consecutive survey, hoki schools were observed in Conway Trough. Hoki schools were also previously detected in Conway Trough in 2008 (O'Driscoll 2009). The percentage of hoki found in schools in the Conway Trough in 2025 (68%) was the highest in the time series, compared with a range of 8–35% recorded in surveys from 2002 to 2023 (O'Driscoll 2007, 2009, Escobar-Flores et al. 2024). Although the 2025 survey produced the highest estimate of hoki biomass in the time series for the Conway Trough, and hoki schools accounted for an important contribution of the estimate, the estimate of abundance relative to that from Pegasus Canyon (26% in 2025) remained consistent, similar to the proportions observed in the previous three surveys (27%) (O'Driscoll & Escobar-Flores 2020, Escobar-Flores & O'Driscoll 2022, Escobar-Flores et al. 2024).

The last three ECSI surveys have produced highly variable estimates of hoki biomass between snapshots, along with relatively high average biomass estimates (see Table 13 and Table 14). Although both the sampling effort (number of snapshots) and the duration of the survey (6–7 weeks in 2021 when two vessels, RV *Kaharoa* and fishing vessel *San Granit*, were used) have increased since the 2019 survey, there is still limited information regarding the timing of the spawning in Pegasus Canyon. Based on the biomass estimates from the last three surveys, the timing of the peak spawning period, assumed to occur when the highest single-snapshot biomass estimate is recorded, shows substantial variability. In 2021, the highest estimate of hoki biomass occurred on 11 August, with lower estimates recorded both before and after this date. In 2023 and 2025, the highest biomass estimates were obtained later in the season, on 28 August and 26 August, respectively. While the 2023 survey tracked an increase in biomass over the duration of the survey, no snapshot was conducted after the peak estimate was recorded. In contrast, the 2025 survey appeared to capture the full peak-spawning period, showing both an increase leading up to, and a decrease following, the 26 August peak. The high variability in both biomass estimates and the inferred timing of spawning highlights the need for longer survey periods (e.g., mid-July to mid-September) and increased survey effort on the ECSI spawning grounds.

In 2025, the Deepwater Working Group agreed to adopt new L-W relationship parameters for the hoki stock assessment (045 DWWG 2025-03-26 DWWG Hoki Assessment – biological parameters). These new L-W parameters replaced those from Francis (2003) (equation 1), which had been used in hoki stock assessments up to 2025. Applying the updated L-W parameters (i.e., a = 0.00416 and b = 2.94) to estimate hoki biomass from the 2025 acoustic surveys resulted in an increase of approximately 8% in biomass estimates.

Because the acoustic survey time series provides relative estimates of abundance, the impact of this change in L-W relationship on the relative biomass trend is unlikely to be significant. However, for consistency across hoki fisheries research projects, the updated L-W parameters should be used when generating biomass estimates from acoustic surveys. Updating the full time series of hoki abundance indices was outside the scope of project SNZ2025303. We recommend that the entire time series of abundance indices for all years and areas (i.e., Cook Strait, ECSI, and the west coast South Island) be recalculated using the newly adopted L–W relationship parameters for the next stock assessment.

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7 TABLES

Table 1: Stratum boundaries, areas, and transect allocations in the 2025 acoustic survey of spawning hoki on board FV *Rakaia* in Cook Strait and off the east coast South Island (ECSI). Stratum locations are shown in Figure 1 Error! Reference source not found.**and Figure 2.**

Area	Stratum	Name	Boundary	Area (km^2)	No. of transects
Cook Strait	1	Narrows Basin	200–200 m	330	4
	2	Cook Strait Canyon	180–180 m	220	9
	3	Nicholson Canyon	200–200 m	55	4
	5A	Cook Strait Canyon extension	boundary to 200 m	90	3
	5B	Deep water	boundary to 200 m	215	3
	6	Terawhiti Sill	200–200 m	65	4
ECSI	CT	Conway Trough	200–200 m	171	6
	PCA	North Pegasus Canyon	boundary to 200 m	270	6
	PCB	South Pegasus Canyon	200–200 m	63	4

Table 2: Values of parameters and their distributions used in the Monte Carlo uncertainty simulations to determine stock assessment model weighting for Cook Strait and Pegasus Cayon biomass uncertainties (from O'Driscoll 2004).

			Survey area	
Term	Notation	Distribution	Cook Strait Values*	Pegasus Canyon Values*
Mean arrival date	$\bar{d}$	Uniform	1 July–9 August	1 August–1 September
Mean residence time	$\bar{r}$	Uniform	24–47 days	24–47 days
Individual arrival date	d_i	Normal	$\bar{d}$ (5 days)	$\bar{d}$ (5 days)
Individual residence time	r_i	Normal	$\bar{r}$ (10 days)	$\bar{r}$ (10 days)
Sampling	s	Normal	1.0 (snapshot CV)	1.0 (snapshot CV)
Detectability	D	Uniform	0.85–0.97	0.85–0.97
Mark identification – 'fuzz' marks	Id_{fuzz}	Lognormal	0.78 (0.72)	0.78 (0.72)
Mark identification – 'school' marks	Id_{school}	Lognormal	0.10 (0.16)	0.10 (0.16)
Calibration	cal	Uniform	cal ± 0.2 dB	cal ± 0.2 dB
Target strength†	TS	Uniform	TS ± 0.5 dB	TS ± 0.5 dB

* For uniform distribution, values are ranges; for normal distributions, values are means with standard deviations (in parentheses); for lognormal distributions, values are the mean and standard deviation (in parentheses) of $\log_e$(variable).

† Uncertainty associated with TS arose from variation in fish size and from differences in the slope of alternative TS-length relationships. Potential bias due to differences in the intercept of alternative TS-length models was ignored because it will not affect the relative values of acoustic indices (see O'Driscoll 2004 for details).

Table 3: Summary of snapshots carried out during the 2025 Cook Strait hoki acoustic survey. Times are NZST.

Snapshot	Start time	End time	No. of transects	No. of tows	No. mark identification tows	No. mark commercial tows
1	23 Jul 01:22	24 Jul 06:31	28	3	1	2
2	24 Jul 17:01	25 Jul 20:04	28	0	0	0
3	30 Jul 06:29	31 Jul 05:38	28	0	0	0
4	05 Aug 06:10	06 Aug 12:50	28	4	4	0
5	14 Aug 16:23	16 Aug 00:39	28	2	1	1
6	23 Aug 16:46	24 Aug 18:10	28	1	1	0

Table 4: Summary of snapshots carried out during the 2025 acoustic survey of Pegasus Canyon and Conway Trough. Times are NZST.

Area	Snapshot	Start time	End time	No. of transects	No. mark identification tows
Pegasus Canyon	1	12 Aug 23:49	13 Aug 08:05	10	1
	2	13 Aug 11:59	14 Aug 20:19	10	1
	3	25 Aug 18:04	26 Aug 01:46	10	0
	4	26 Aug 06:01	27 Aug 12:33	10	2
	5	03 Sep 18:16	04 Sep 02:05	10	0
	6	04 Sep 03:51	04 Sep 10:54	10	3
Conway Trough	1	14 Aug 03:27	14 Aug 07:38	6	0
	2	25 Aug 05:20	25 Aug 09:38	6	2

Table 5: Summary of catch information from mark identification and commercial tows completed during the 2025 hoki acoustic survey in Cook Strait (CKST) and the east coast of the South Island (Pegasus Canyon (PCA, PCB) and Conway Trough (CT)). Acoustic mark type refers to the categories described by O'Driscoll (2002b): HOK = hoki school; PMIX = hoki pelagic fuzz; BMIX = hoki bottom fuzz. Tow types refer to the aim of the tow: mark identification (ID) or commercial fishing (CO).

						Catch (kg)									
Stn. #	Area	Snap.	Tow type	Strat.	Acoustic mark type	Hoki	Bollons' rattail	Gemfish	Silver warehou	Ling	Lucifer dogfish	Spiny dogfish	Pearlside	Other species	% Hoki
1	CKST	1	ID	6	HOK	168.3						2.7	0.1	31.6	83
2	CKST	1	CO	2	HOK	10 133.7	2.2				6.9	79.0	0.1	17.8	99
3	CKST	1	CO	5A	HOK	6 325.1	0.6	4.5	4.9		0.7	33.1		1.8	99
4	CKST	4	ID	1	BMIX	35.4		15.4		10.1		3.5		54.7	30
5	CKST	4	ID	5B	PMIX	70.3							0.1	4.3	94
6	CKST	4	ID	3	MESO	2.5						1.0	3.3	4.0	23
7	CKST	4	ID	2	MESO								11.4	2.1	0
8	ECSI	1	ID	PCB	HOK	11 797.6	1.1			41.7		28.9		0.1	99
9	ECSI	1	ID	PCA	HOK	476.9	8.3	1.1			0.6	19.0	0.1	25.2	90
10	CKST	5	ID	3	HOK	448	1.0	1.5		1.6	15.0	6.1		0.7	95
11	CKST	5	CO	2	HOK	16 918.4			5.4	36.8		184.0		2.0	99
12	CKST	6	ID	5A	HOK	204.9		0.2				15.5	0.1	1.8	92
13	ECSI	2	ID	CT	HOK	204.2	0.7						0.1	0.2	100
14	ECSI	2	ID	CT	PMIX	31.5	0.5					1.4	0.1	16.1	64
15	ECSI	4	ID	PCB	HOK	7 560.0	3.0		28.0	14.4	0.5	628.0		0.1	92
16	ECSI	4	ID	PCB	HOK	14 028.0			39.0	21.5		63.8		0.3	99
17	ECSI	6	ID	PCB	HOK	12 450.0			3.9	29.3		23.0		0	100
18	ECSI	6	ID	PCA	HOK	875.0				29.2				0	97
19	ECSI	6	ID	PCA	HOK	12 900.0	17.0		9.4	50.1		8.1	0.1	0	99

Table 6: Spatial distribution of acoustic backscatter (%) in Cook Strait across survey strata and surveys.

	Stratum					
Year	1	2	3	5A	5B	6
1991–2003	23	42	4	10	14	8
2005	10	54	6	13	14	3
2006	13	55	4	12	15	1
2008	13	57	3	11	14	3
2009	8	69	2	10	9	2
2011	12	68	2	7	8	3
2013	9	77	1	6	4	3
2015	8	75	2	7	6	2
2017	15	62	3	8	11	2
2019	14	61	5	7	9	3
2021	5	69	5	8	11	2
2023	8	43	6	17	25	1
2025	4	60	3	15	16	2

Table 7: Mean length of hoki caught during the 2025 acoustic survey by stratum. Length frequency distributions are shown in Figure 20 and Figure 21. CT = Conway Trough, PCA = Pegasus Canyon north, and PCB = Pegasus Canyon south.

Stratum	Number of hoki measured	Number of mark identification trawls	Mean length unsexed (cm)	Mean length female (cm)	Mean length males (cm)	% female hoki
1	124	1	34.8	39.8	28.3	56.5
2	544	4	78.9	83.8	73.4	60.8
3	224	2	79.0	82.7	42.1	89.7
5A	219	1	48.6	57.8	35.2	59.4
5B	51	1	74.2	75.9	68.6	76.5
6	140	1	67.7	79.4	63.7	25.7
CT	286	2	60.2	61.5	59.5	35.3
PCA	599	3	76.5	79.6	72.0	69.1
PCB	848	4	73.1	78.3	70.2	43.0

Table 8: Gonad stages of hoki caught in during the 2025 acoustic survey. Data are arranged by area and snapshot; CKST = Cook Strait, CT = Conway Trough, and PC = Pegasus Canyon. Gonad stages are defined in Appendix 2.

			Male stages							Female stages						
Area	Snapshot	Date	1	2	3	4	5	6	7	1	5	149	29	3	3	1
CKST	1	23 Jul	0	22	13	97	156	0	0	0	34	106	40	9	1	9
CKST	2	25 Jul	0	2	0	0	3	0	0	52	25	32	2	0	0	0
CKST	4	5 Aug	15	51	4	3	11	0	0	0	5	85	60	15	3	8
CKST	5	16 Aug	0	0	4	11	11	2	1	42	6	52	4	0	7	19
CKST	6	24 Aug	25	52	1	3	1	2	5	29	11	29	13	11	3	5
CT	2	25 Aug	23	12	7	22	119	1	1	2	8	163	17	1	1	4
PC	1	13 Aug	2	0	14	63	147	1	0	0	2	138	134	35	8	7
PC	4	27 Aug	0	5	5	17	63	10	2	0	9	130	56	20	6	38
PC	6	4 Sep	0	13	31	10	201	44	40	1	5	149	29	3	3	1

Table 9: Hoki acoustic abundance estimates from the 2025 Cook Strait survey by snapshot and stratum. Sampling CV calculated as the mean of individual snapshots CVs.

	Stratum biomass ('000 t)						Total	Snapshot
Snapshot	1	2	3	5A	5B	6	('000 t)	CV
1	7	82	3	23	13	4	133	51
2	7	17	8	37	22	1	92	23
3	4	83	3	17	28	5	141	21
4	5	65	2	12	19	2	105	31
5	2	119	3	13	23	1	161	12
6	5	85	2	10	14	1	116	27
Mean	5	75	3	19	20	2	124	12

Table 10: Acoustic indices of hoki abundance for Cook Strait 1988–2025. All indices were re-calculated by O'Driscoll & Escobar-Flores (2018) using an acoustic TS derived from commercial length frequency data in each survey year and the most recent hoki TS-length relationship of Dunford et al. (2015). The 2025 estimate is the mean of snapshots 1–6. CV was estimated using Monte Carlo simulations (see Table 12).

Year	No of accepted snapshots	Biomass ('000 t)	CV	% biomass in schools
1991	4	88	0.41	52
1993	4	283	0.52	43
1994	3	278	0.91	30
1995	4	194	0.61	41
1996	5	92	0.57	60
1997	6	141	0.40	46
1998	5	80	0.44	38
1999	6	114	0.36	48
2001	11	102	0.30	57
2002	9	145	0.35	68
2003	9	104	0.34	56
2005	9	59	0.32	62
2006	7	60	0.34	57
2007†	4	104	0.46	63
2008	7	82	0.30	61
2009†	5	166	0.39	74
2011†	6	141	0.35	66
2013†	7	168	0.30	78
2015†	5	204	0.33	73
2017	6	102	0.36	54
2019	7	91	0.36	53
2021	6	159	0.41	72
2023	6	58	0.38	50
2025†	6	124	0.31	83

† Surveys from industry vessels.

Table 11: Percentage of the hoki abundance estimate from hoki school marks in each snapshot and stratum for Cook Strait in 2025. Percentages were calculated in relation to abundance estimates in Table 9.

	Stratum biomass ('000 t)						Total
Snapshot	1	2	3	5A	5B	6	('000 t)
1	0	98	0	97	0	98	80
2	0	100	100	93	100	64	89
3	0	100	100	58	7	96	74
4	0	100	100	100	100	5	93
5	0	100	53	67	0	0	81
6	0	100	9	71	16	0	81
Mean	0	100	60	81	37	44	83

Table 12: Results of Monte Carlo simulations to determine model weighting for the 2025 acoustic surveys in Cook Strait and Pegasus Canyon. 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.

	Cook Strait	Pegasus Canyon
Timing	0.245	0.269
+ Sampling	0.270	0.302
+ Detectability	0.271	0.304
+ Mark identification	0.295	0.312
+ Calibration	0.298	0.314
+ TS	0.307	0.319
Total	0.307	0.319

Table 13: Hoki acoustic abundance estimates from the 2025 east coast South Island survey by snapshot and stratum. Average sampling CV calculated as the mean of individual snapshots CVs.

		Stratum biomass ('000 t)		Total	Snapshot
Area	Snapshot	PCA	PCB	('000 t)	CV
Pegasus Canyon	1	27	23	50	51
	2	50	47	97	15
	3	83	57	141	18
	4	107	122	229	24
	5	78	83	161	28
	6	114	79	192	35
	Mean	76	68	145	12
		CT			
Conway Trough	1	26		26	26
	2	50		50	53
	Mean	38		38	36

Table 14: Hoki acoustic biomass estimates for previous ECSI hoki acoustic surveys by snapshot and stratum for 2002–23. Percentage of the biomass from hoki school marks is also given. These values have been revised from those in the original documents to use the most recent TS-length relationship for hoki (Dunford et al. 2015). Average sampling CV calculated as the mean of individual snapshots CVs.

Year	Snapshot	Start date	End date	Biomass ('000 t)	Snapshot CV	% biomass in schools
2002	1	3 Sep	3 Sep	50	31	73
Pegasus Canyon	2	3 Sep	5 Sep	57	29	61
	3	5 Sep	6 Sep	47	21	88
	4	7 Sep	8 Sep	84	50	93
	5	8 Sep	9 Sep	54	40	87
	6	9 Sep	9 Sep	99	55	95
	7	10 Sep	11 Sep	26	15	46
	Mean			60	19	78
Conway Trough	1	7 Sep	10 Sep	14	21	27
2003						
Pegasus Canyon	1	30 Jul	31 Jul	32	18	72
	2	18 Aug	18 Aug	61	31	71
	3	22 Aug	23 Aug	62	33	64
	4	11 Sep	12 Sep	26	12	26
	Mean			45	16	58
Conway Trough	1	18 Aug	18 Aug	26	14	15
2006						
Pegasus Canyon	1	29 Jul	29 Jul	12	22	14
	2	23 Aug	23 Aug	19	41	56
	3	23 Aug	24 Aug	21	26	45
	Mean			17	19	38
Conway Trough	1	30 Jul	30 Jul	24	12	8
2008						
Pegasus Canyon	1	14 Aug	15 Aug	20	9	25
	2	15 Aug	16 Aug	20	21	41
	Mean			20	11	33
Conway Trough	1	14 Aug	14 Aug	20	32	14
	2	16 Aug	16 Aug	25	12	11
	Mean			23	10	13
2013						
Pegasus Canyon	1	20 Aug	20 Aug	64	28	80
2019						
Pegasus Canyon	1	15 Aug	16 Aug	60	33	67
	2	16 Aug	16 Aug	51	25	60
	Mean			55	21	64
Conway Trough	1	17 Aug	17 Aug	15	8	0

Table 14: continued.

Year	Snapshot	Start date	End date	Biomass ('000 t)	Snapshot CV	% biomass in schools
2021						
Pegasus Canyon	1	28 Jul	29 Jul	40	21	48
	2	11 Aug	11 Aug	187	48	96
	3	11 Aug	12 Aug	63	29	89
	4	22 Aug	23 Aug	106	21	95
	5	23 Aug	23 Aug	282	44	97
	6	29 Aug	30 Aug	57	40	78
	7	7 Sep	7 Sep	55	28	83
	8	11 Sep	11 Sep	28	19	67
	Mean			102	19	82
Conway Trough	1	12 Aug	12 Aug	32	11	0
	2	12 Aug	12 Aug	28	10	0
	3	12 Aug	12 Aug	36	6	0
	4	12 Aug	13 Aug	32	7	0
	5	22 Aug	22 Aug	12	30	0
	Mean			28	5	0
2023						
Pegasus Canyon	1	30 Jul	30 Jul	62	10	64
	2	30 Jul	31 Jul	50	27	78
	3	31 Jul	31 Jul	60	30	93
	4	12 Aug	12 Aug	128	21	100
	5	12 Aug	13 Aug	73	25	82
	6	28 Aug	28 Aug	113	44	93
	7	28 Aug	29 Aug	238	37	95
	Mean			103	15	86
Conway Trough	1	31 Jul	01 Aug	27	13	25
	2	13 Aug	13 Aug	29	24	38
	Mean			28	14	32

Table 15: Percentage of the hoki abundance estimate from hoki school marks in each snapshot and strata for the east coast South Island in 2025. Percentages were calculated in relation to abundance estimates in Table 13.

		Percentage of biomass in schools		
Area	Snapshot	PCA	PCB	Total
Pegasus Canyon	1	100	100	100
	2	67	93	80
	3	84	100	90
	4	94	100	97
	5	84	100	92
	6	92	100	95
	Mean	87	99	92
		CT		
Conway Trough	1	46		
	2	90		
	Mean	68		

Table 16: Acoustic indices of hoki abundance for Pegasus Canyon 2002–25. All biomass values were estimated using the TS-length relationships of Dunford et al. (2015). % PC ref CS indicates the abundance in Pegasus Canyon as a percentage of the equivalent estimate from Cook Strait. Values for previous surveys by snapshot and stratum are given in Table 14. CV was estimated using Monte Carlo simulations (see Table 12).

Year	No of snapshots	Biomass (‘000 t)	CV	% PC ref CS
2002†	7	60	0.33	41
2003†	4	45	0.47	43
2006	3	17	0.63	28
2008	2	20	1.07	24
2013†	1	64	0.74	38
2019	2	55	0.92	60
2021*	8	102	0.30	64
2023	7	103	0.53	178
2025†	6	145	0.32	117

† Surveys from industry vessels.
* Survey from industry and research vessels.

Table 17: Acoustic indices of hoki abundance for Conway Trough 2002–25. All biomass values were estimated using the TS-length relationships of Dunford et al. (2015). % Cook Strait indicates the abundance in Conway Trough as a percentage of the equivalent estimate from Cook Strait. % Pegasus Canyon indicates the abundance in Conway Trough as a percentage of the equivalent estimate from Pegasus Canyon. Values for previous surveys by snapshot and stratum are given in Table 14.

Year	No of snapshots	Biomass (‘000 t)	% Cook Strait	% Pegasus Canyon
2002†	1	14	10	23
2003†	1	26	25	58
2006	1	24	40	141
2008	2	23	28	115
2013	0	–	–	–
2019	1	15	16	27
2021	5	28	18	27
2023	2	28	49	27
2025†	2	38	31	26

† Surveys from industry vessels.

8 FIGURES

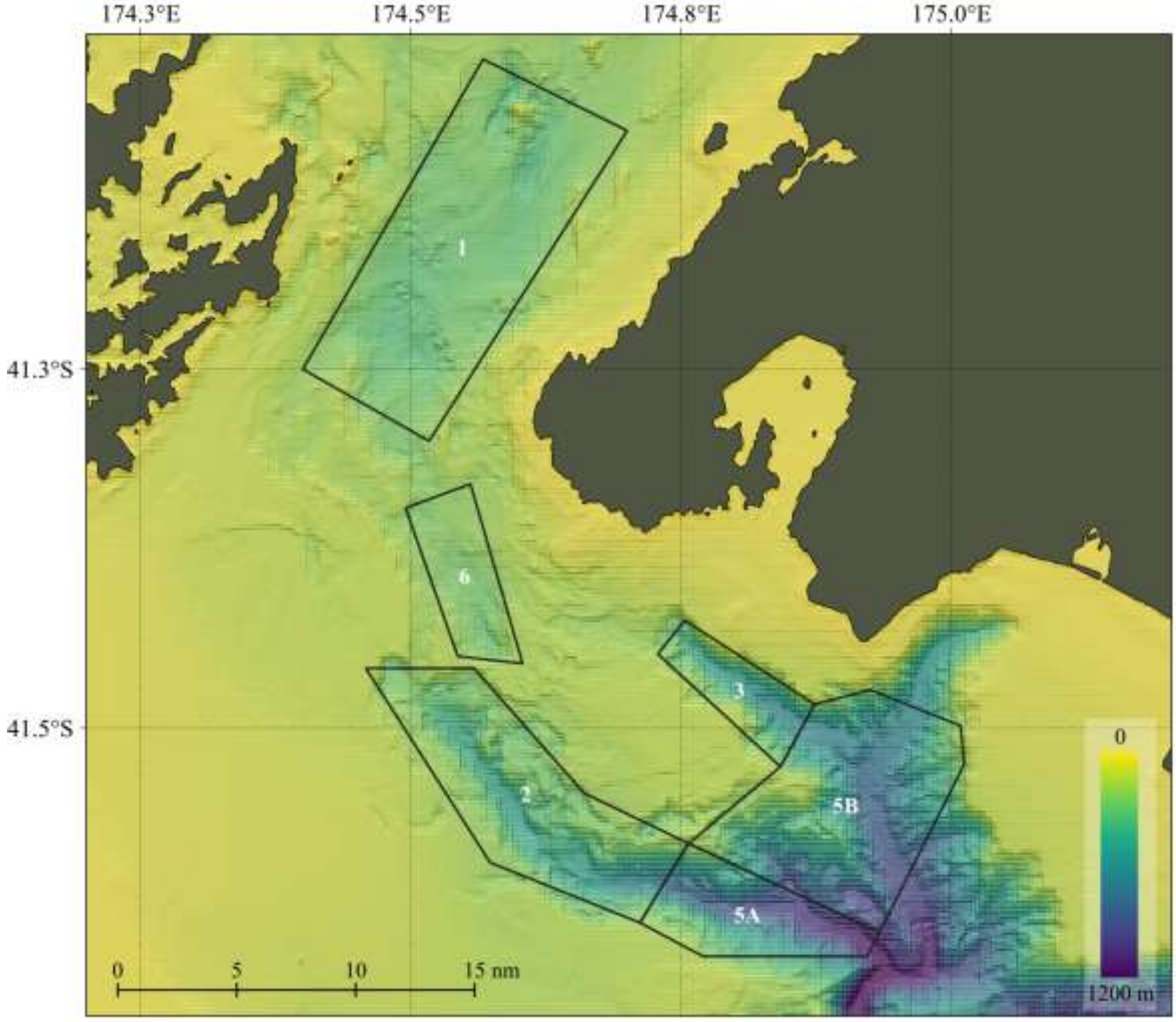

Figure 1: Stratum boundaries for the 2025 acoustic survey of spawning hoki in Cook Strait. The stratum names and estimated areas are: 1, Narrows Basin (330 km^2); 2, Cook Strait Canyon (220 km^2); 3, Nicholson Canyon (55 km^2); 5A, Cook Strait Canyon extension (90 km^2); 5B, Deepwater outside Nicholson Canyon and Wairarapa Canyon (215 km^2); and 6, Terawhiti Sill (65 km^2).

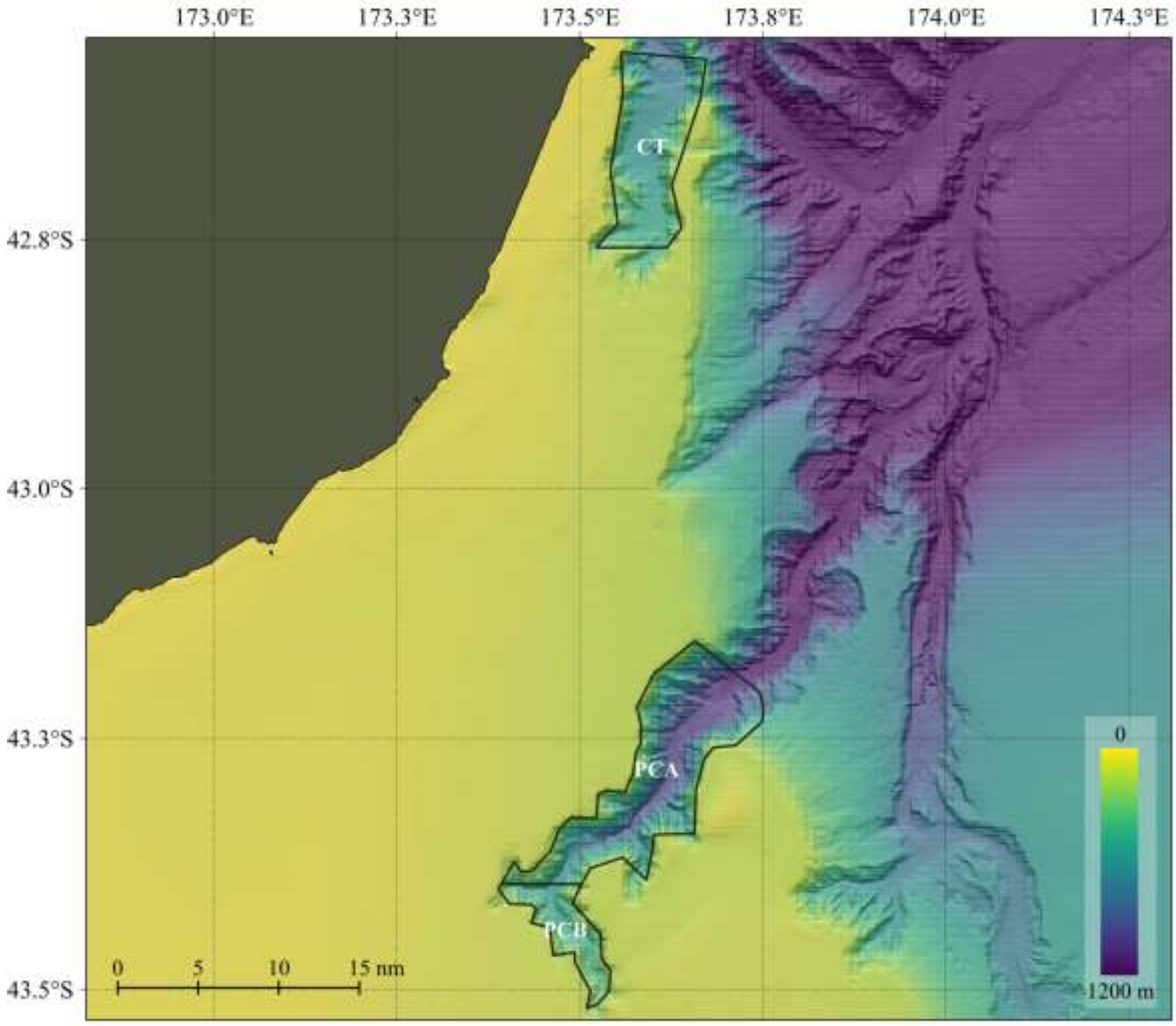

Figure 2: Stratum boundaries for the 2025 East Coast South Island hoki survey. The stratum names and estimated areas are: CT, Conway Trough (171 km^2); PCA, North Pegasus Canyon (270 km^2); PCB, South Pegasus Canyon (63 km^2).

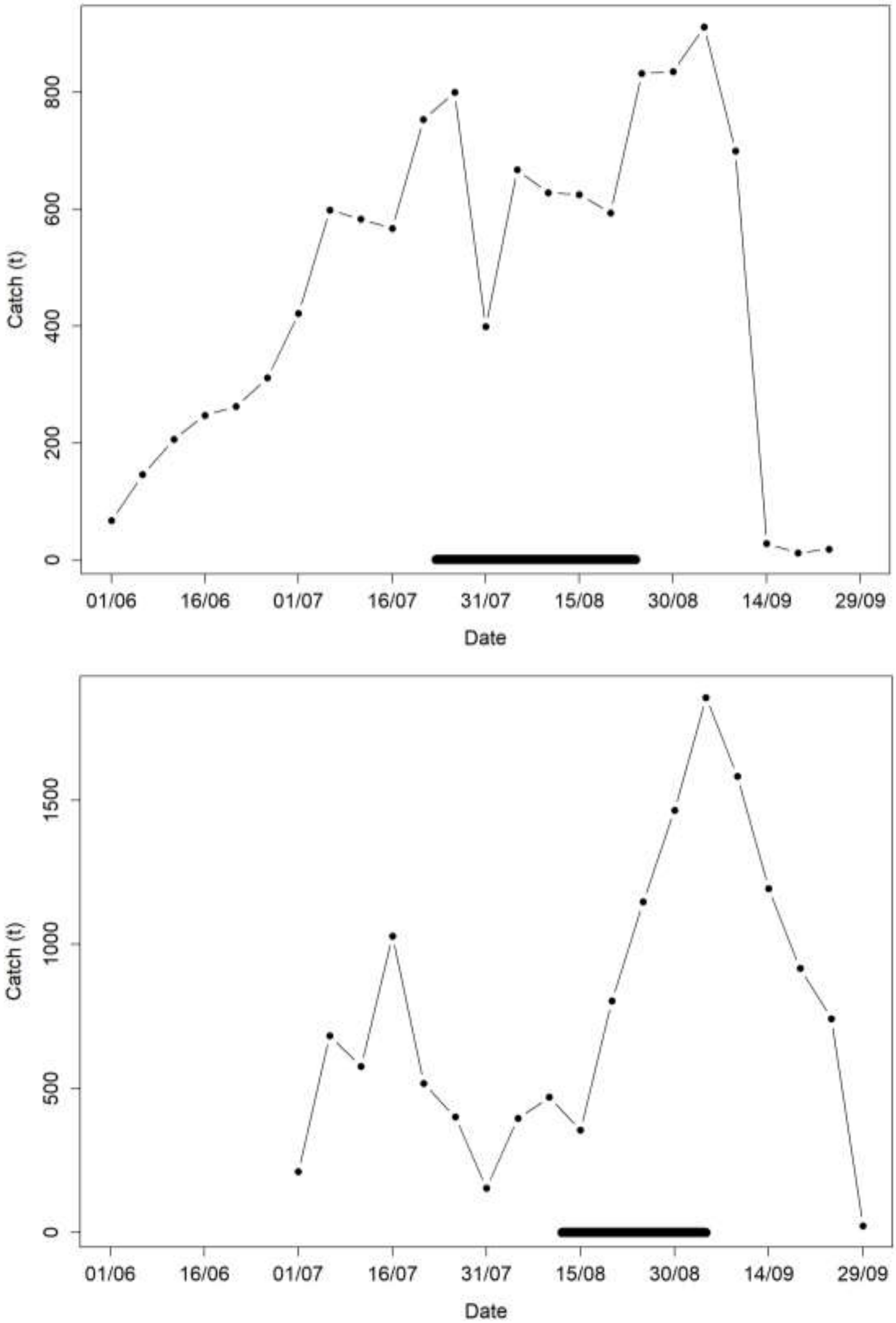

Figure 3: Timing of acoustic surveys in 2025 (bold bar along the x-axes) in relation to the commercial hoki catch from Cook Strait (upper panel) and ECSI (lower panel), presented as sums of 5-day periods.

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Figure 4: Distribution of recorded start positions of commercial tows targeting hoki aggregated in a 5-by-5 n.mile hexagonal grid in Cook Strait (upper panel) and ECSI (lower panel) from 1 June to 30 September 2025. Acoustic survey strata boundaries are shown in black. Note that data were not checked for positional errors.

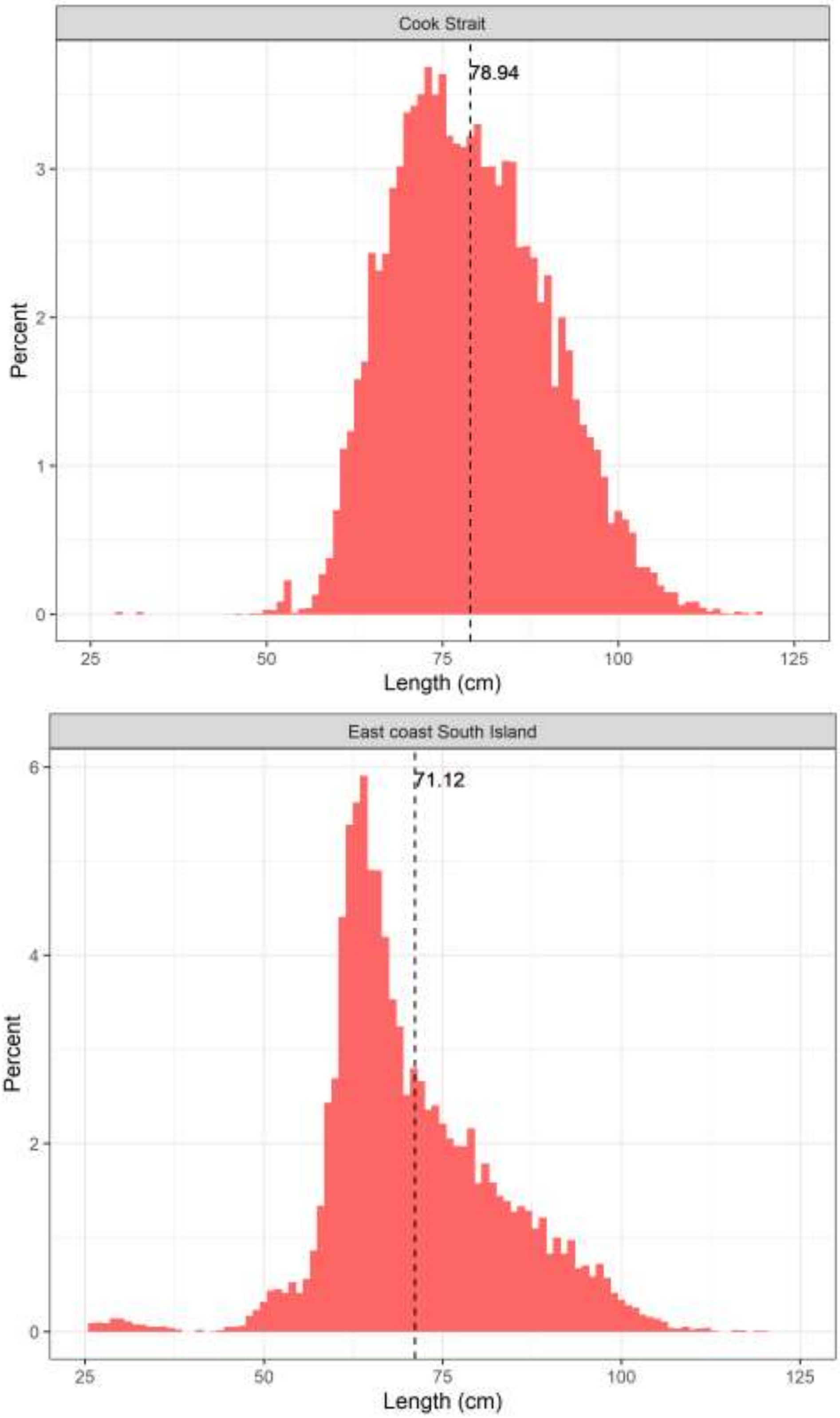
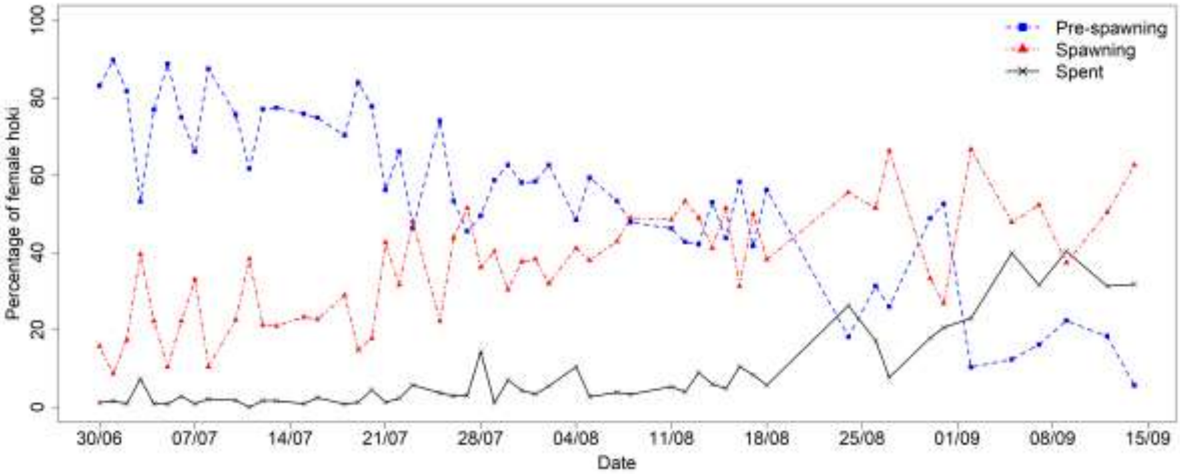
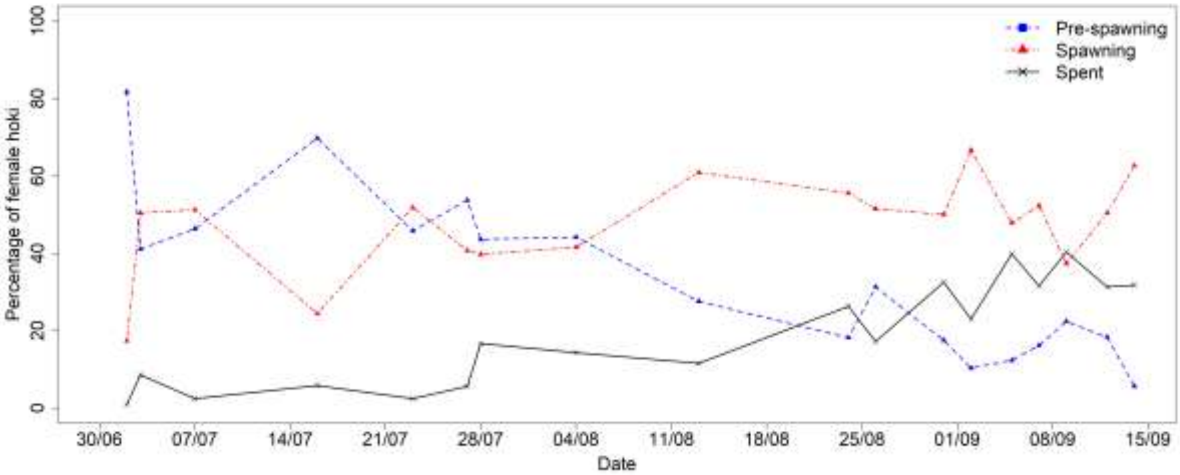


Figure 5: Scaled (by catch) unsexed length frequency distribution of hoki caught in the commercial fishery in Cook Strait (upper panel) and ECSI (lower panel) in 2025 obtained from at-sea observer sampling (both areas) and land-based sampling (Cook Strait and ECSI). Data were used to estimate the ratios, *r*, of mean weight to mean backscattering cross-section. The mean length is shown with the vertical dotted line and number.

Cook Strait – market and observer combined



Cook Strait – market only



Cook Strait – observer only

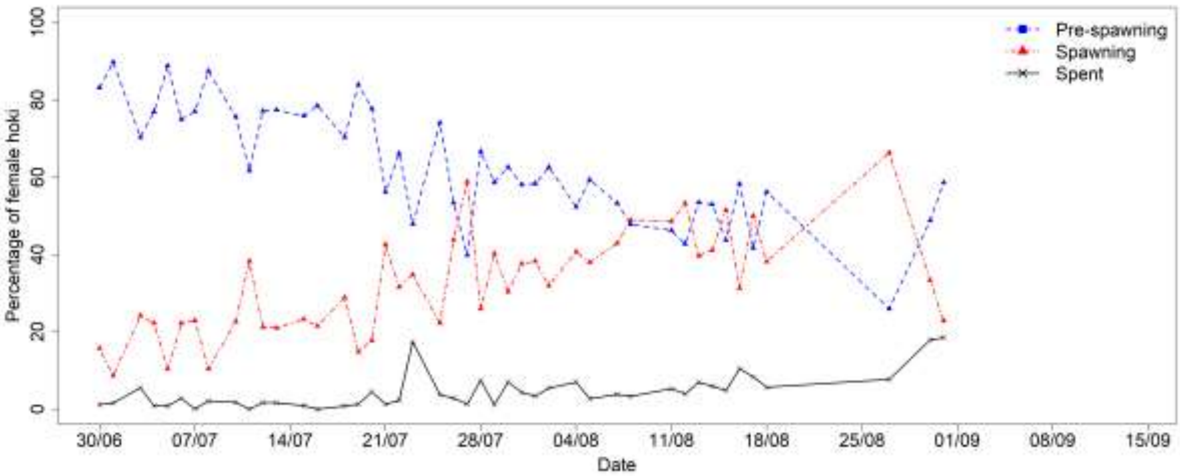
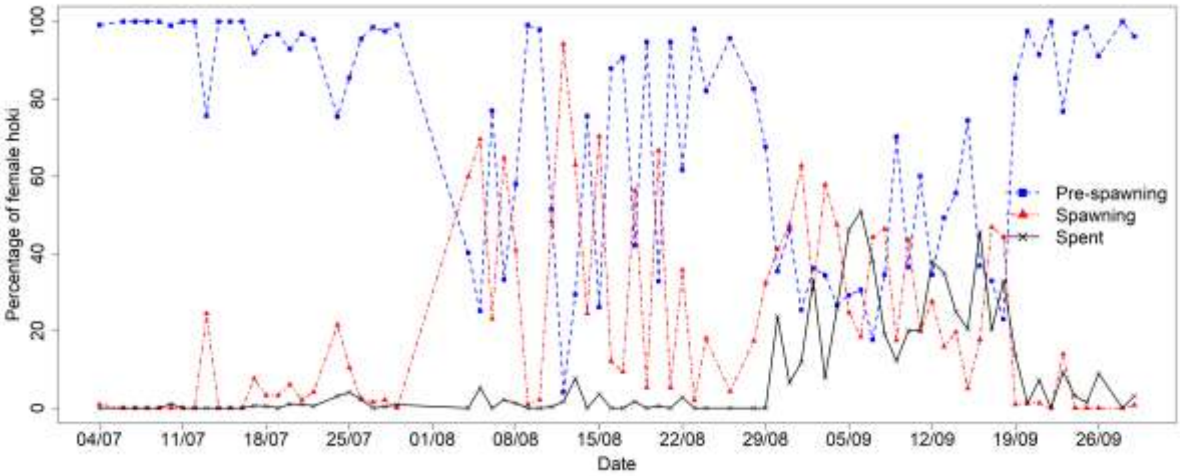
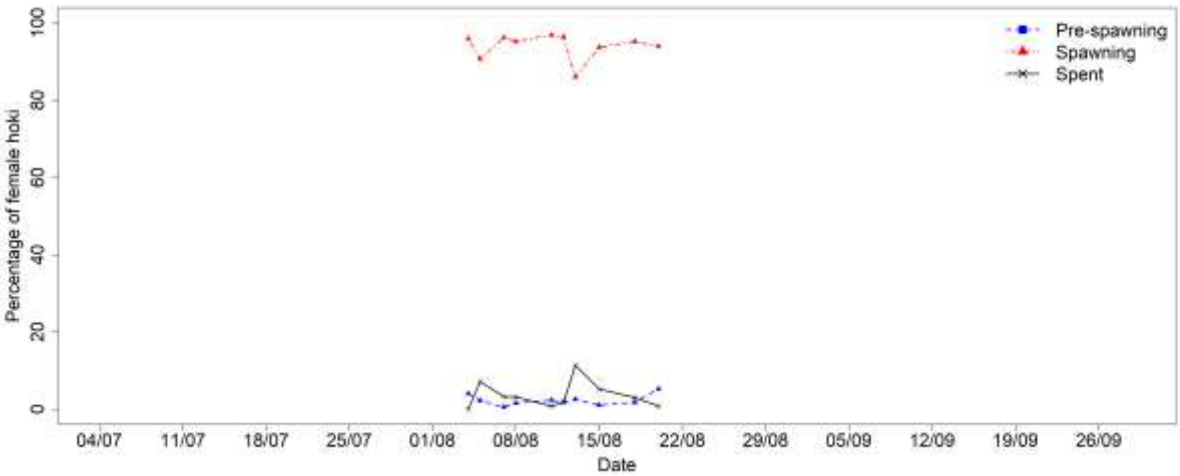


Figure 6: Proportion of female hoki in different maturity states from combined at-sea observer data and land-based sampling of commercial landings from Cook Strait in 2025. Research gonad stages were pre-spawning = gonad stages 1–3 and 6 (observer stages 1 and 2); spawning = gonad stages 4 and 5 (observer stages 3 and 4); post-spawning = gonad stage 7 (observer stage 5) (Appendix 2).

ECSI – market and observer combined



ECSI – market only



ECSI – observer only

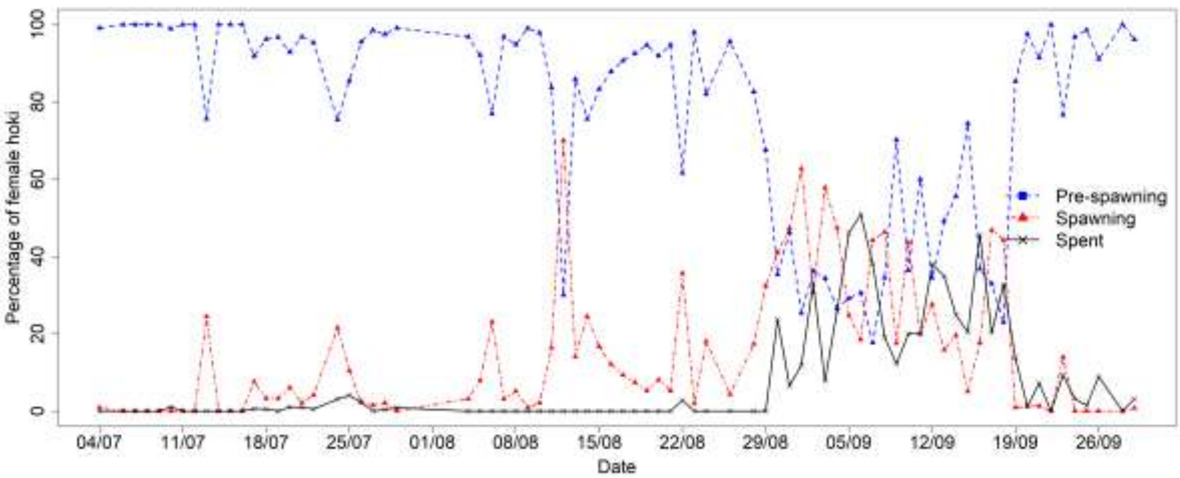


Figure 7: Proportion of female hoki in different maturity states from combined at-sea observer data and land-based sampling of commercial landings from ECSI in 2025. Research gonad stages were pre-spawning = gonad stages 1–3 and 6 (observer stages 1 and 2); spawning = gonad stages 4 and 5 (observer stages 3 and 4); post-spawning = gonad stage 7 (observer stage 5) (Appendix 2).

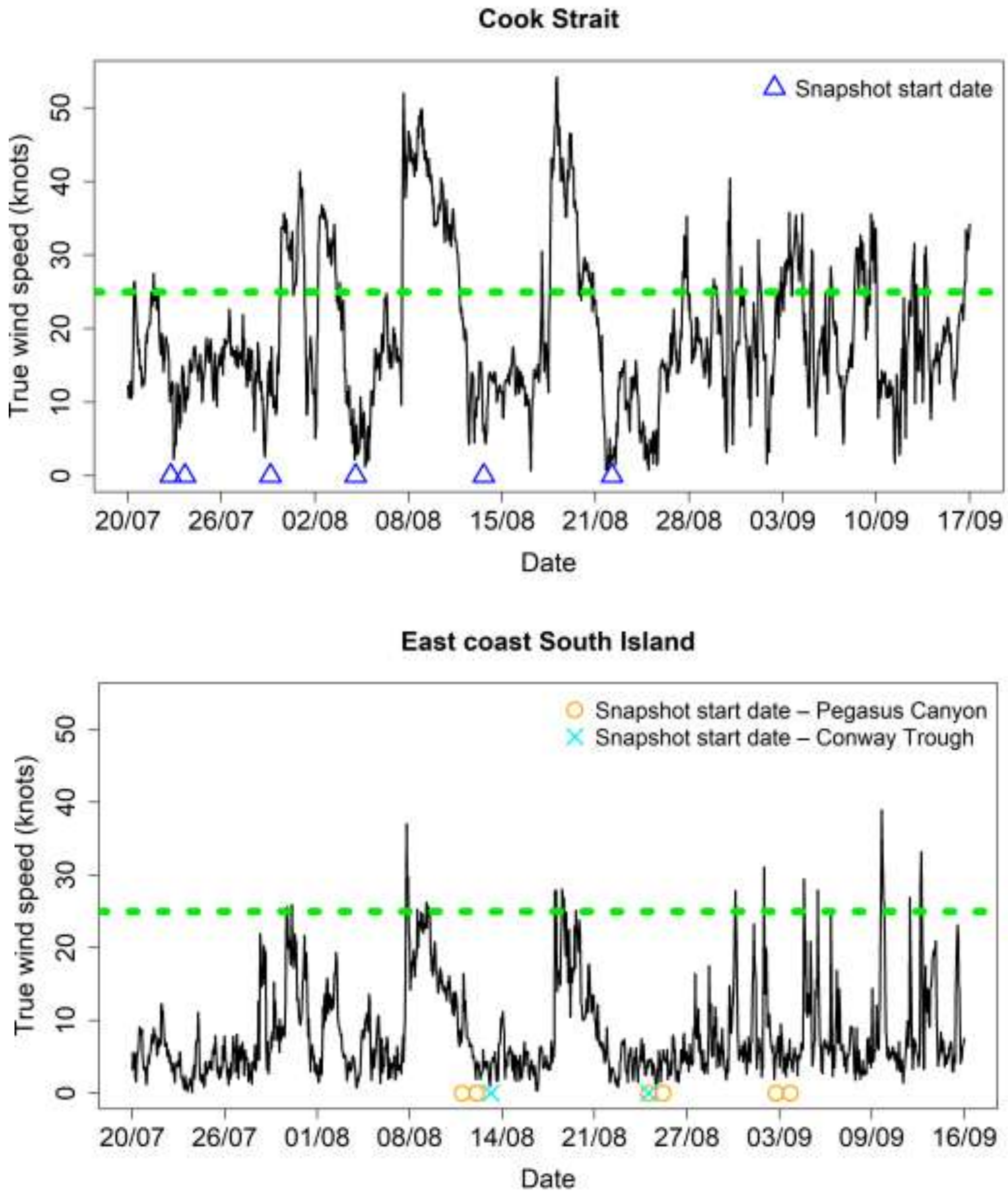


Figure 8: Hourly wind speeds (in knots) at Baring Head (top panel) and at Kaikoura (bottom panel) during the Cook Strait and east coast South Island acoustic survey of hoki. Symbols indicate the start dates of snapshots in Cook Strait, Pegasus Canyon, and Conway Trough. Green dashed-line at 25 knots is considered the maximum threshold for collection of acoustic data with hull-mounted transducers. Wind data were extracted from the National Climate Database (https://cliflo.niwa.co.nz/).

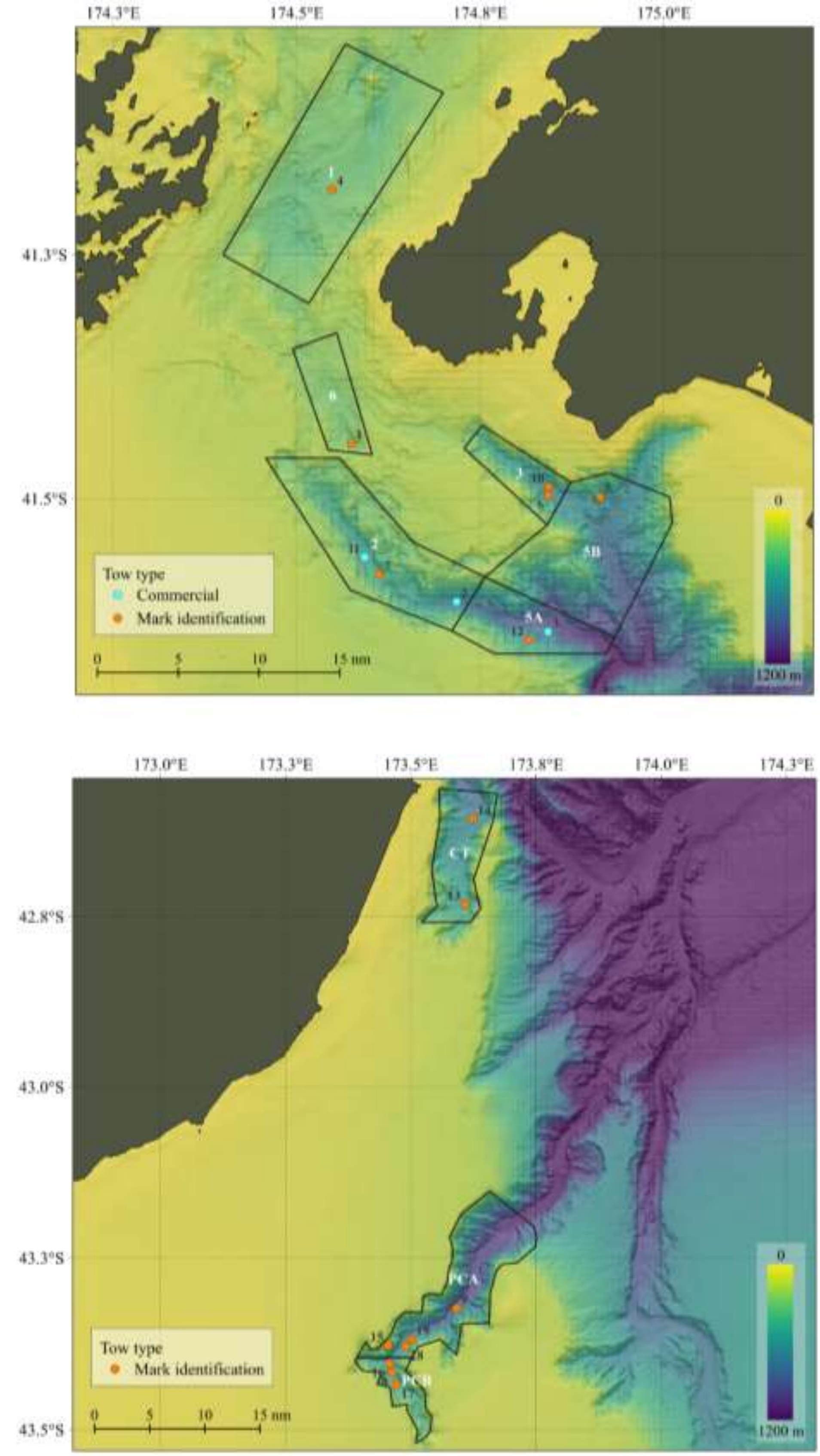


Figure 9: Location of mark identification trawls carried out in Cook Strait and ECSI during the 2025 hoki acoustic survey. Station numbers and strata names are indicated, with catch details in Table 5.

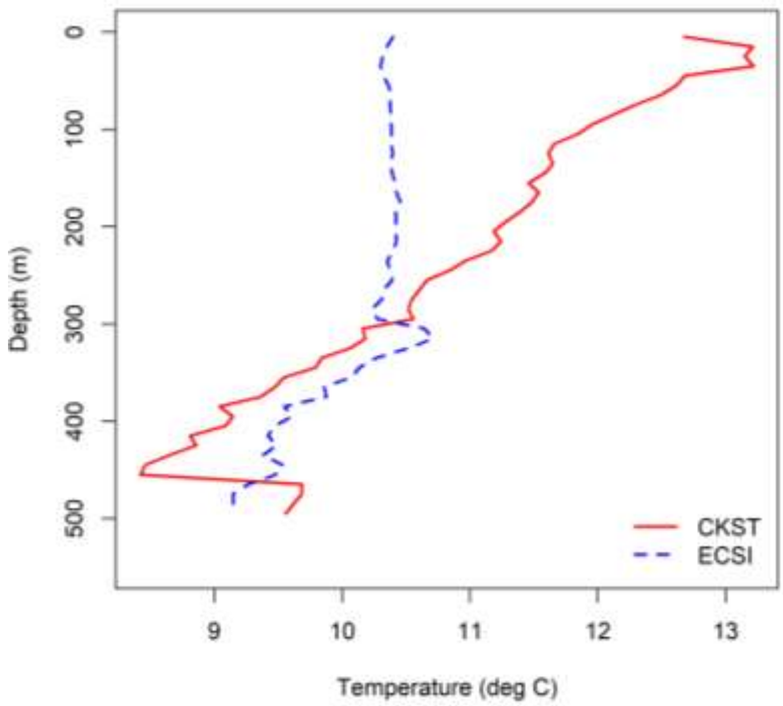


Figure 10: Average temperature profiles from data collected on a RBR data logger attached to the trawl when conducting mark identification (n = 7) and commercial tows (n = 3) in Cook Strait (CKST) and east coast South Island (ECSI, n = 9).

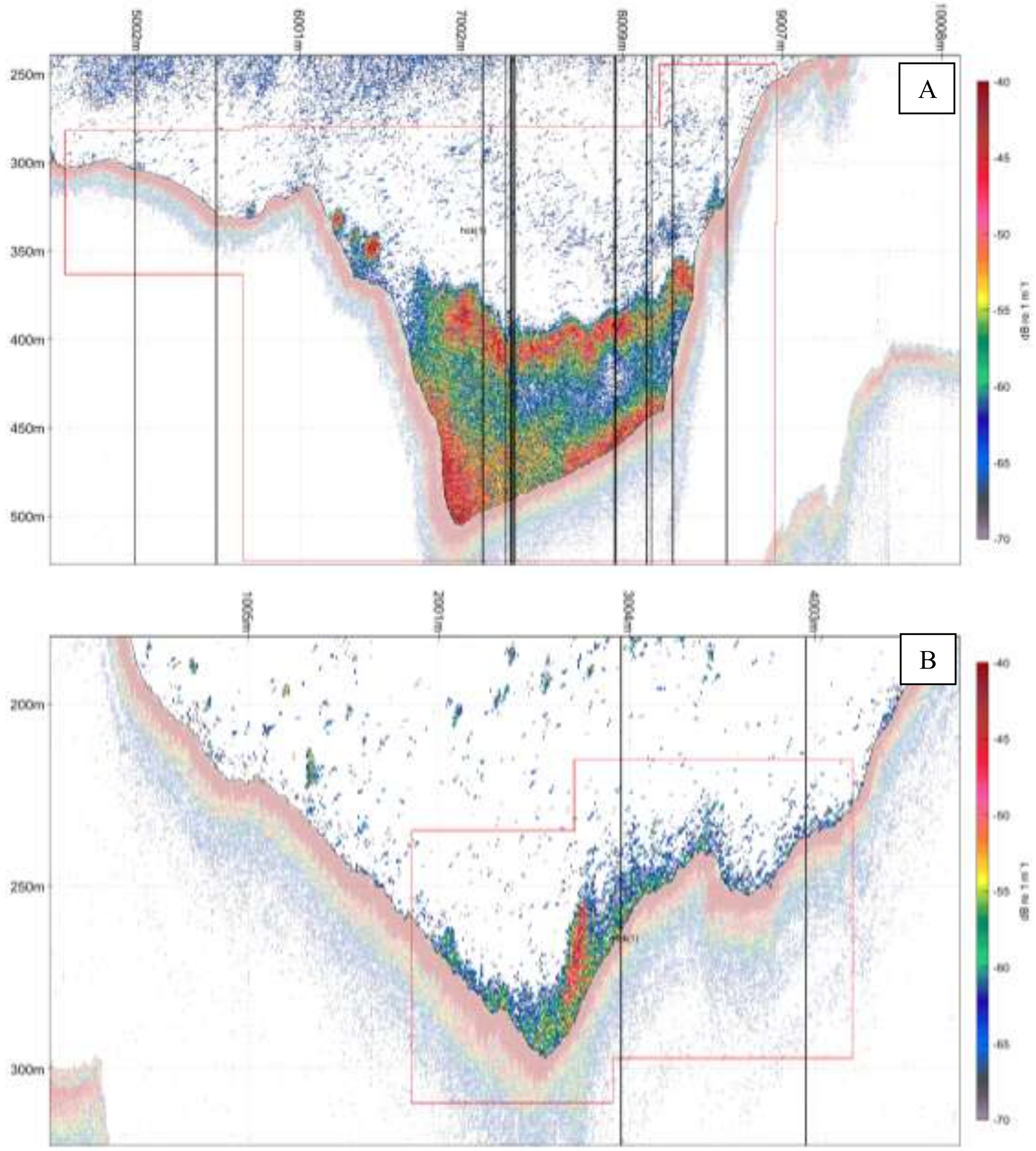


Figure 11: Acoustic echograms showing aggregations of hoki in Cook Strait Canyon (stratum 2) during snapshot 2 (A); Terawhiti Sill (stratum 6) during snapshot 1 (B). Black vertical lines indicate pings that have been excluded from analyses due to noise. Data represent volume backscattering strength (dB re 1 m^{-1}).

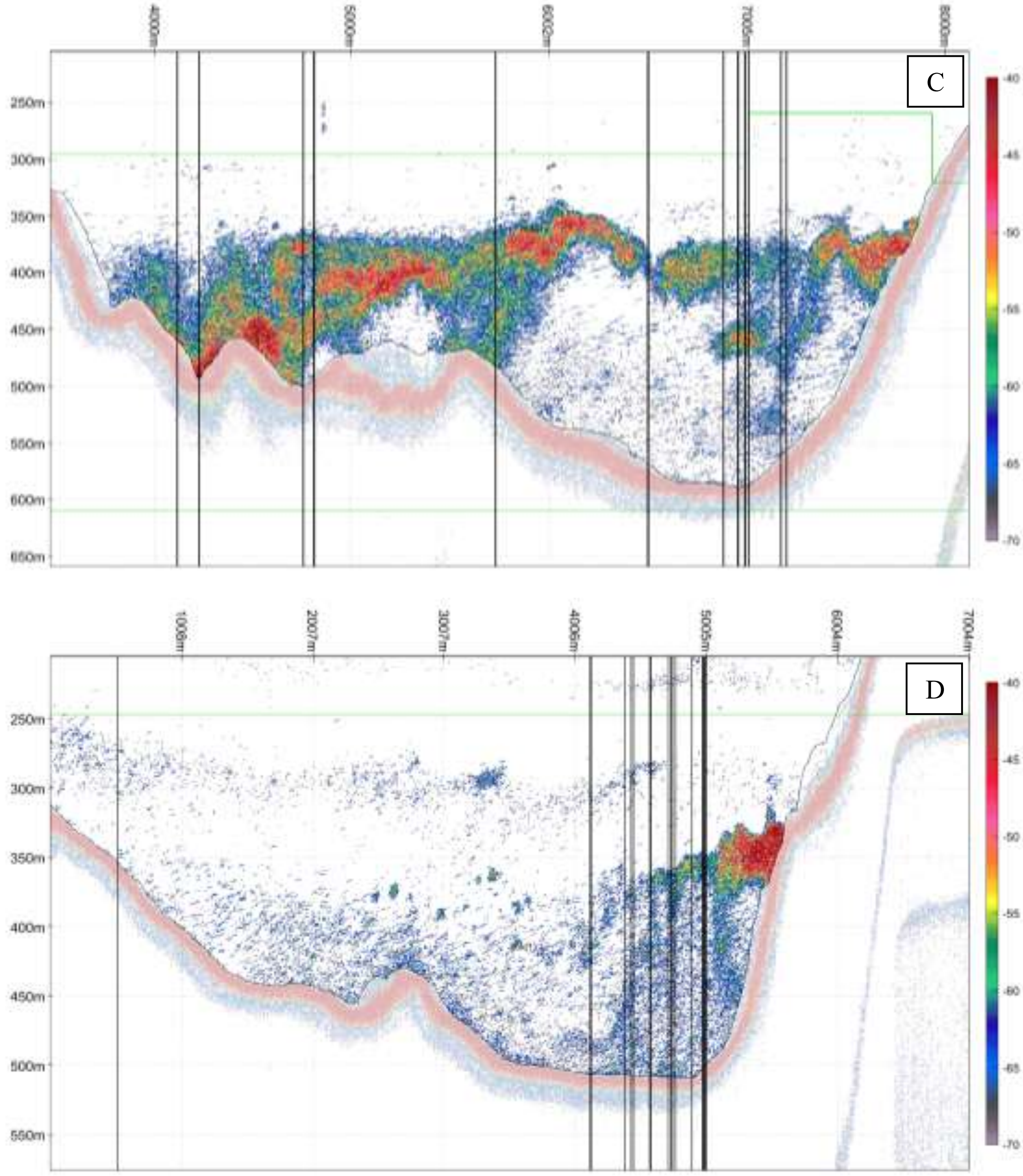


Figure 11: Continued. Acoustic echograms showing aggregations of hoki in Pegasus Canyon south (stratum PCB) during snapshot 4 (C); and Conway Trough (stratum CT) during snapshot 2 (D). Black vertical lines indicate pings that have been excluded from analyses due to noise. Data represent volume backscattering strength (dB re 1 m^{-1}).

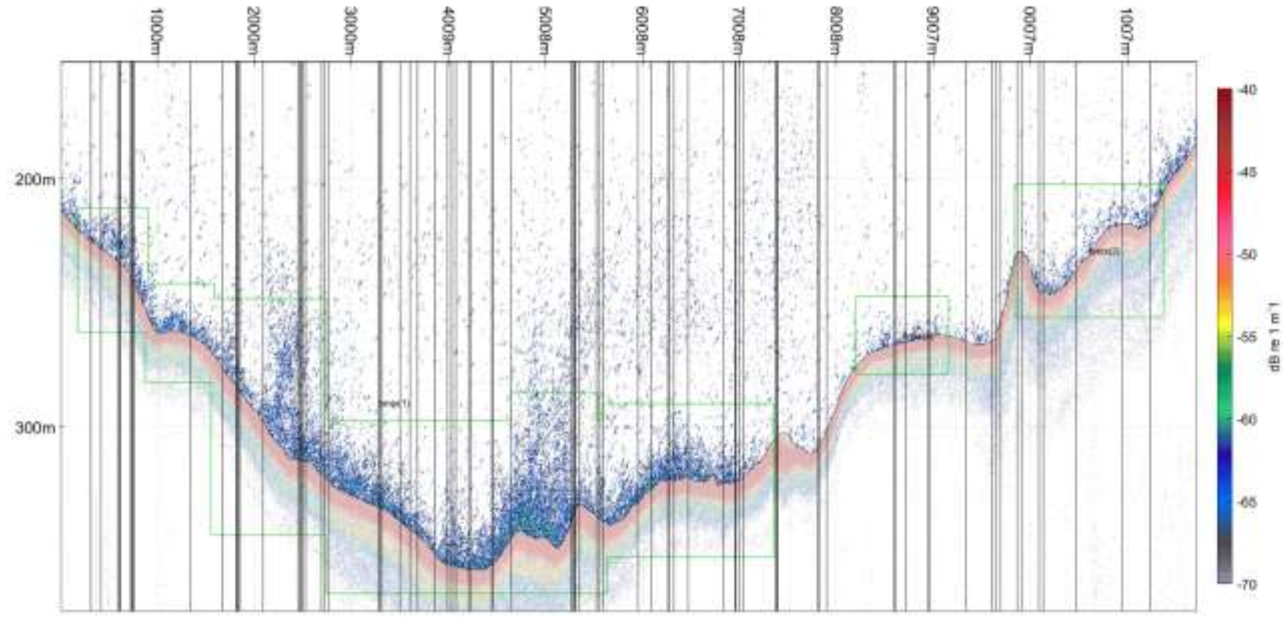


Figure 12: Acoustic echogram from the Narrows Basin (stratum 1) during snapshot 1 showing bottom fuzz (within the green boundary). Black vertical lines indicate pings that have been excluded from analyses due to noise. Data represent volume backscattering strength (dB re 1 m^{-1}).

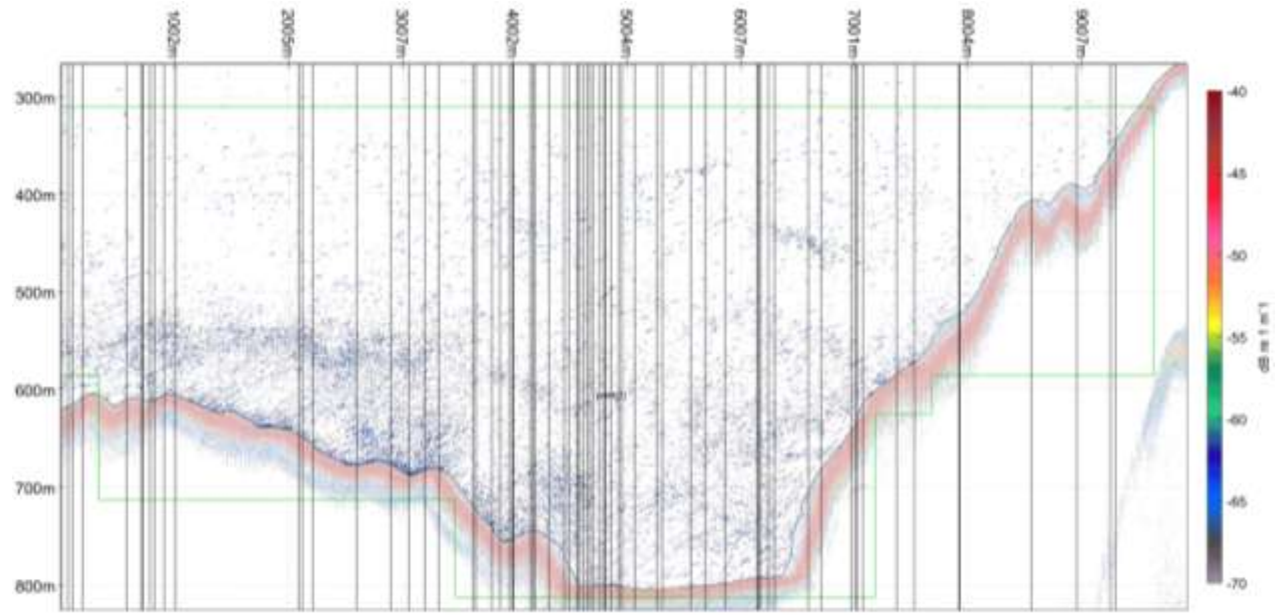


Figure 13: Acoustic echogram from Cook Strait Canyon Extension (stratum 5B) during snapshot 5 showing pelagic fuzz (within the green boundary). Black vertical lines indicate pings that have been excluded from analyses due to noise. Data represent volume backscattering strength (dB re 1 m^{-1}).

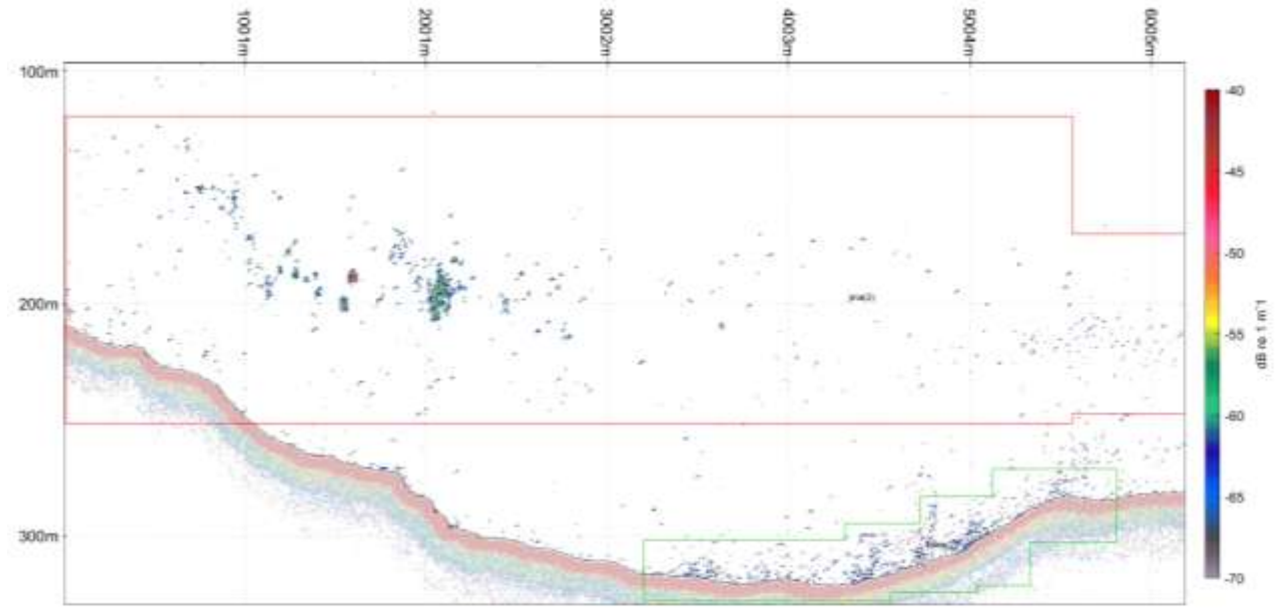


Figure 14: Acoustic echogram from the Narrows Basin (stratum 1) during snapshot 5 showing jack mackerels (within the red boundary) and bottom fuzz (within the green boundary). Black vertical lines indicate pings that have been excluded from analyses due to noise. Data represent volume backscattering strength (dB re 1 m^{-1}).

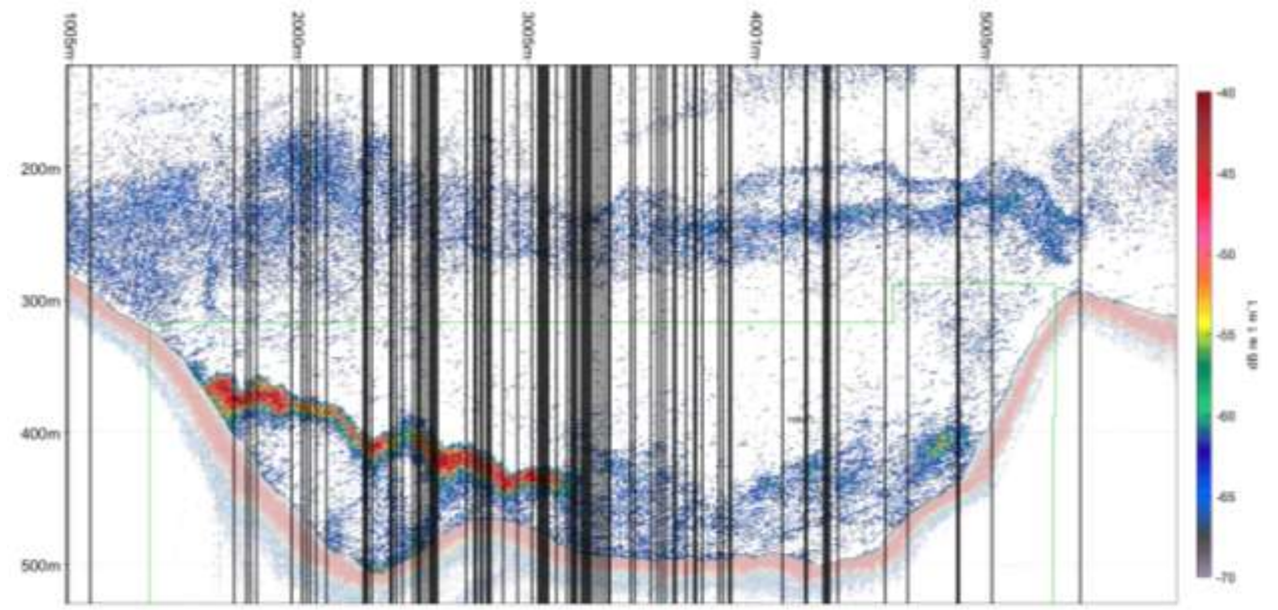


Figure 15: Acoustic echogram showing dense hoki aggregation (within the green boundary) in Cook Strait Canyon (stratum 2) during snapshot 4 on 6 August 2025. Aggregations of mesopelagic fish are also observed between 200 – 300 m. Data represent volume backscattering strength (dB re 1 m^{-1}).

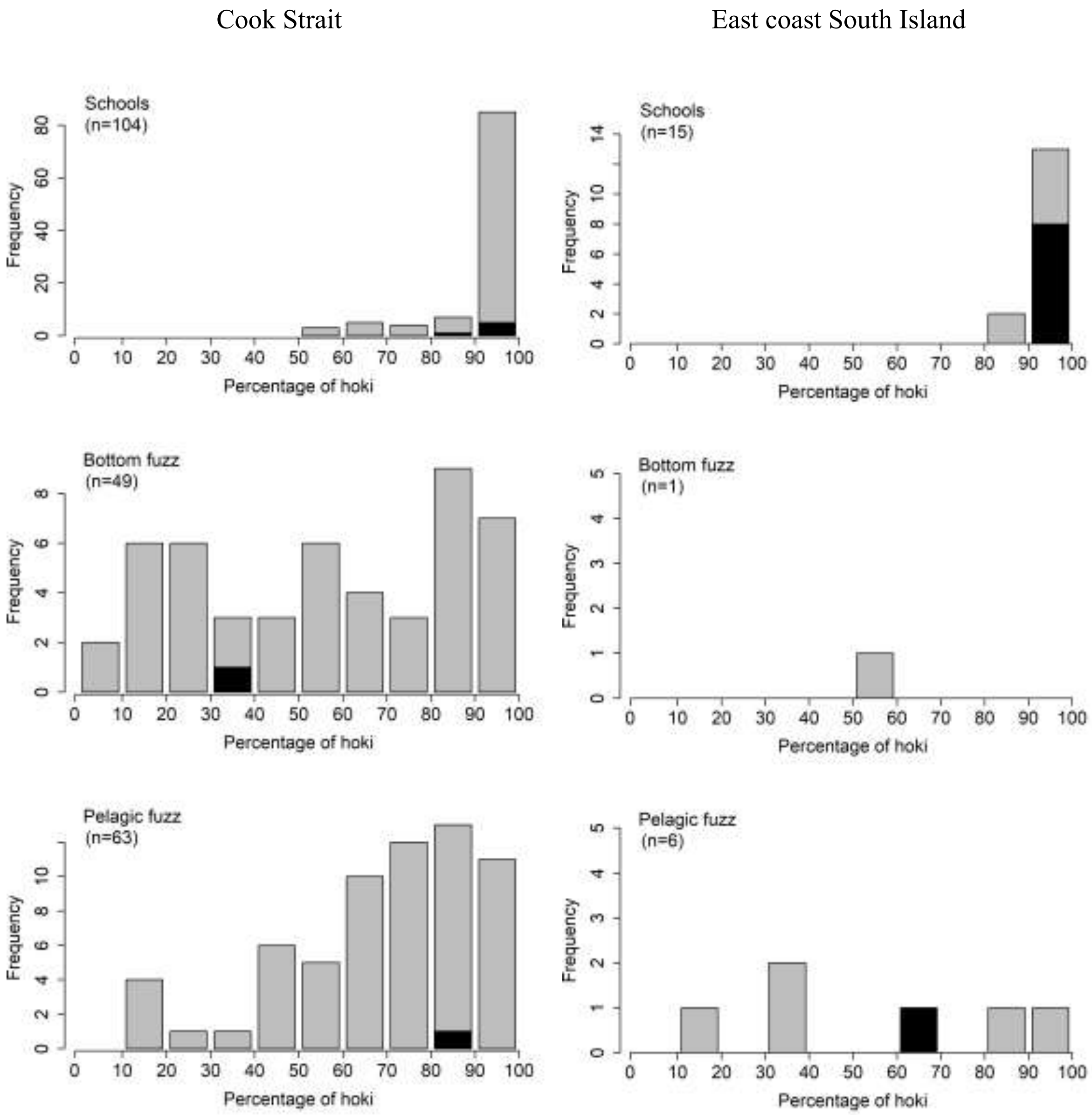
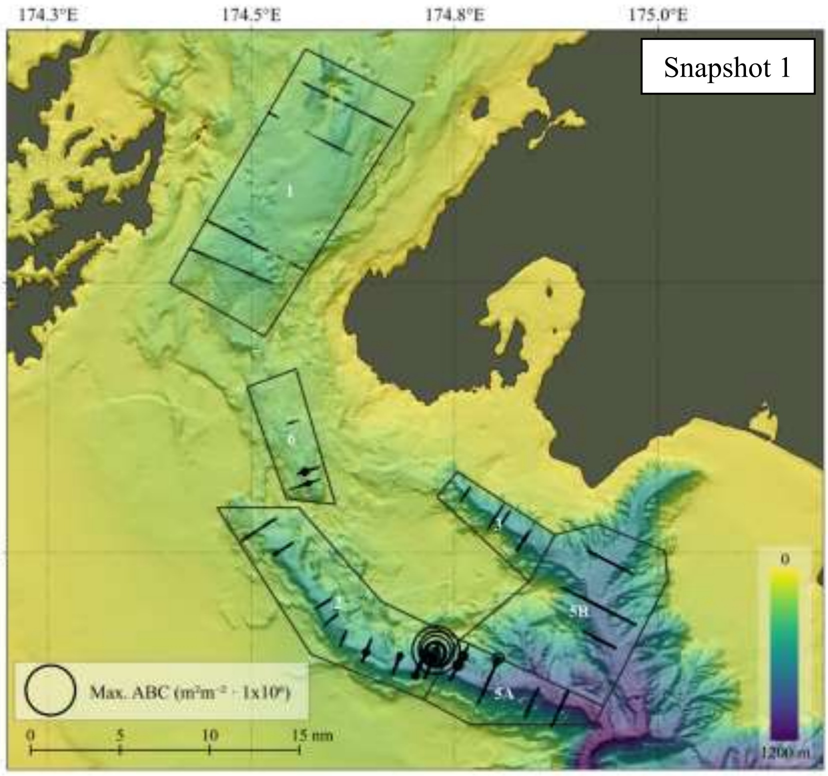


Figure 16: Percentage of hoki by weight in trawls carried out in Cook Strait (left panels) and the east coast South Island (ECSI, right panels) on hoki schools, hoki bottom fuzz, and hoki pelagic fuzz mark types in 2025. Plots show a comparison of the percentage of hoki in each mark type in 2025 (black bars) with the same mark types in previous surveys (grey bars). n values refer to the total number of tows (2001–25 for Cook Strait, and 2019–2025 for the ECSI).



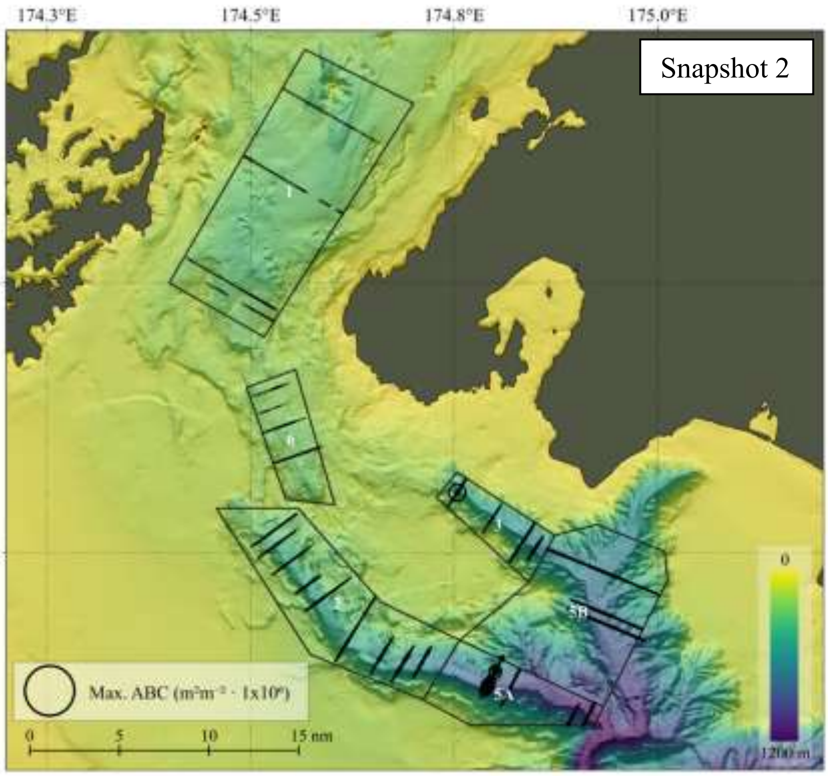
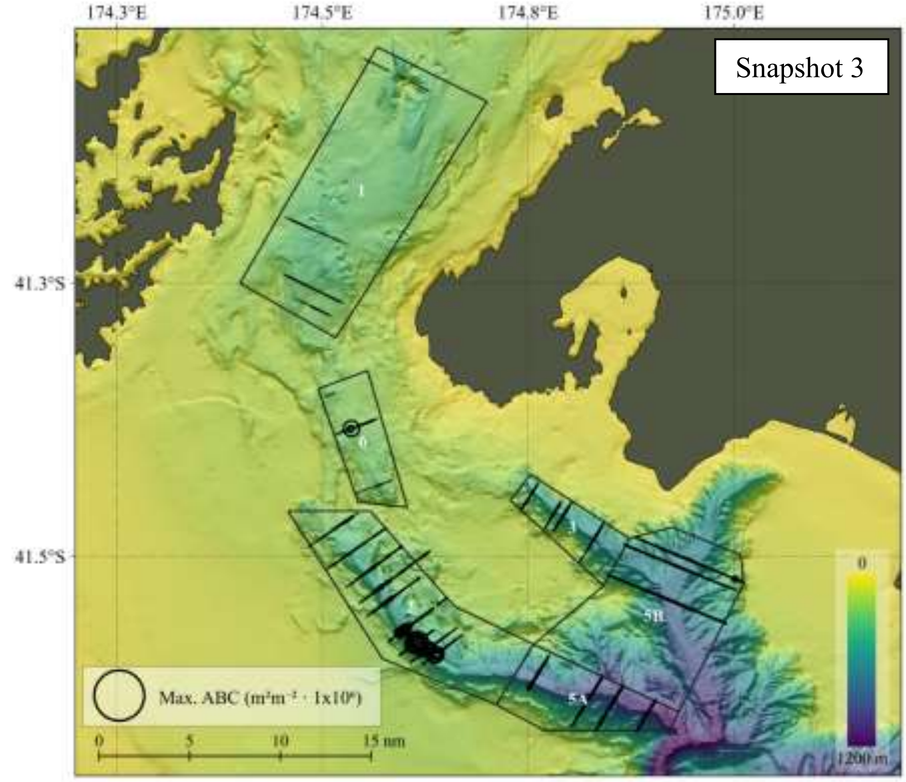


Figure 17: Spatial distribution of hoki acoustic backscatter plotted in 10 pings (~80 m) bins for snapshots in Cook Strait (n = 6) carried out by *Rakaia* in 2025. Symbol size is proportional to the amount of acoustic backscatter coefficient (ABC, maximum 11 037 m^2 m^{-2} 1 × 10^6)



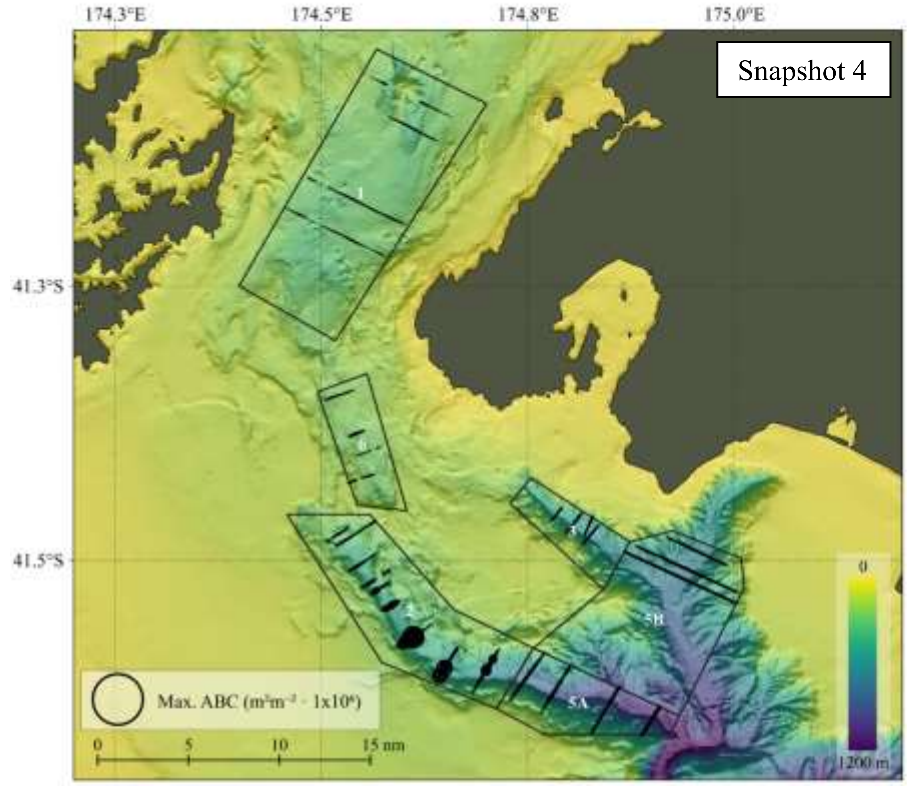
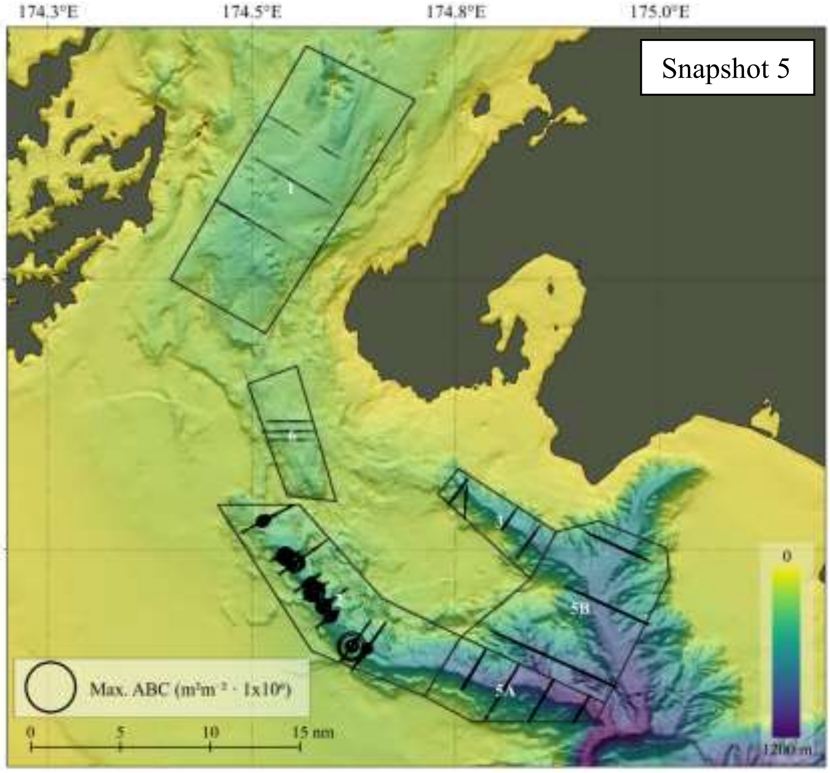


Figure 17: Continued.



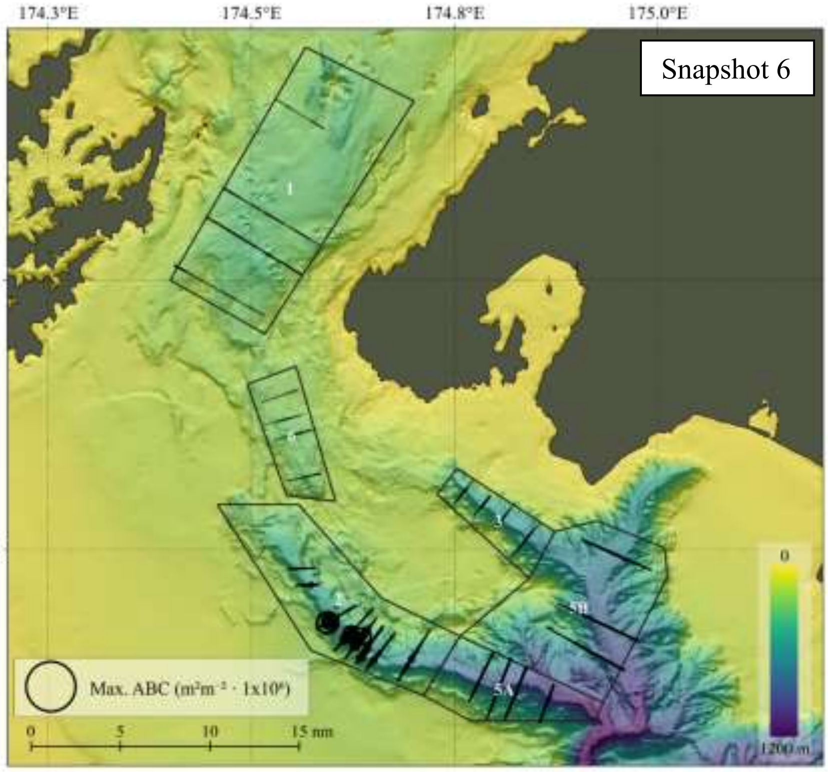
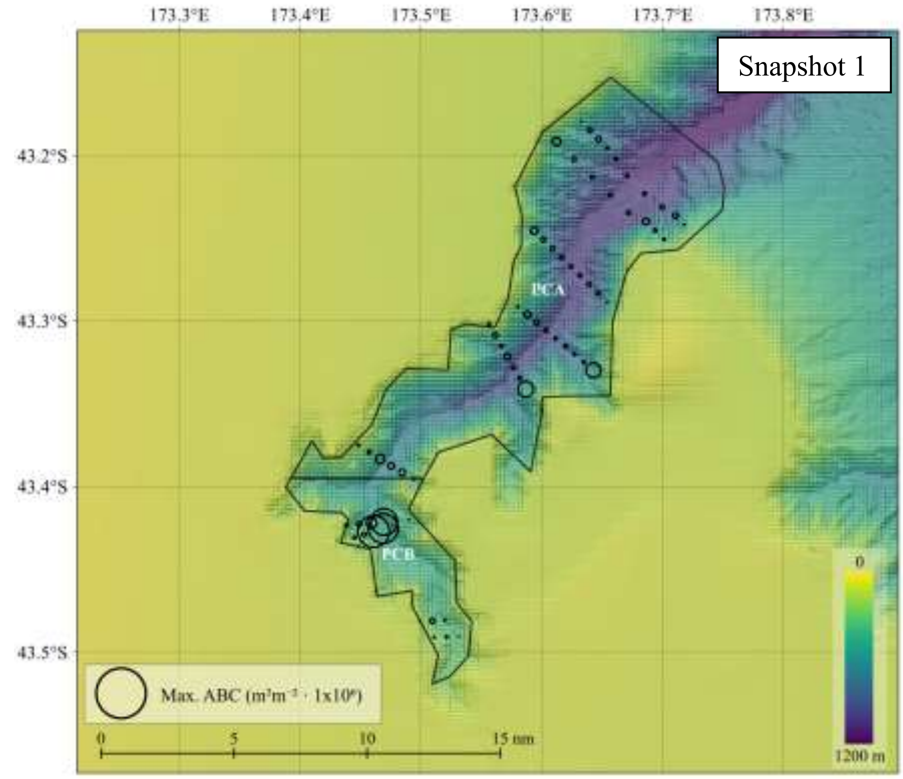


Figure 17: Continued.



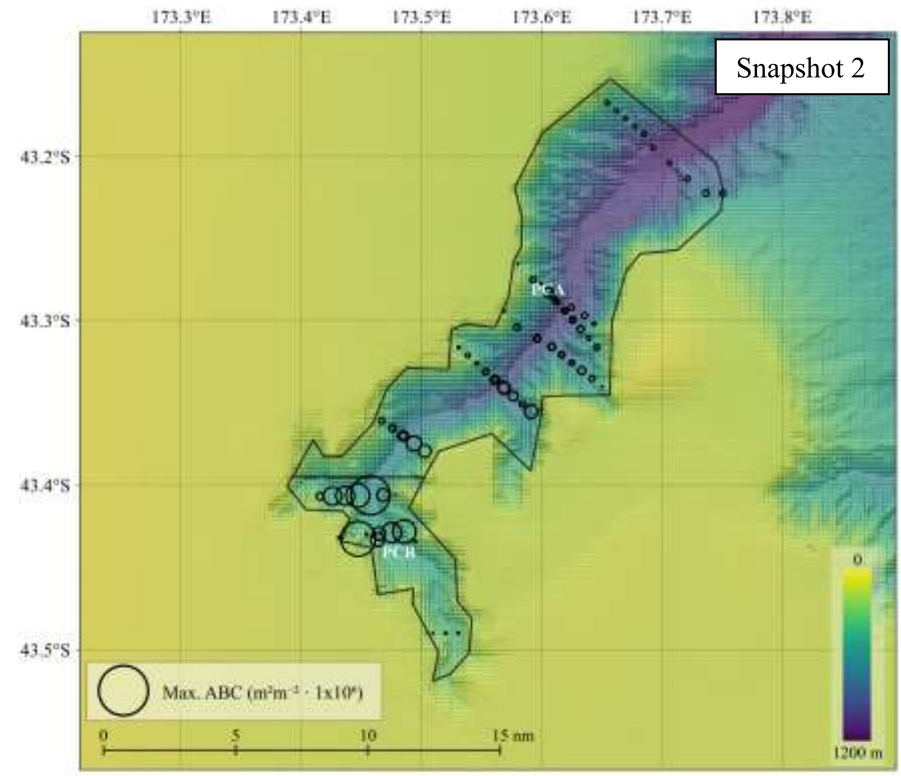
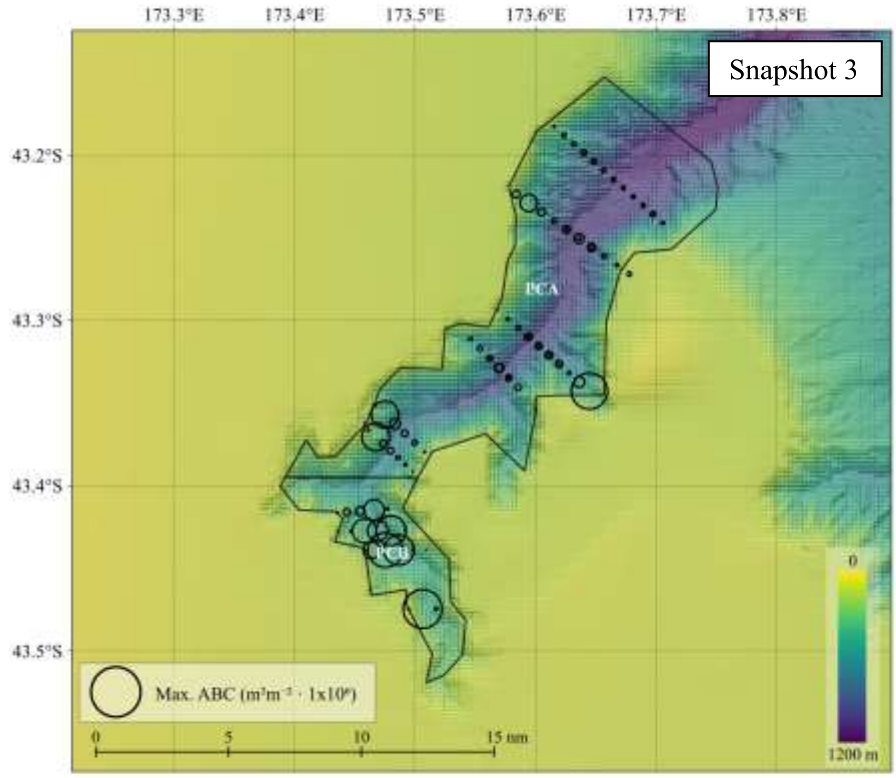


Figure 18: Spatial distribution of hoki acoustic backscatter plotted in 10 ping (~80 m) bins for snapshots in Pegasus Canyon (n = 6) carried out by *Rakaia* in 2025. Symbol size is proportional to the amount of acoustic backscatter coefficient (ABC, maximum 1980 m^2 m^{-2} · 1 × 10^6).



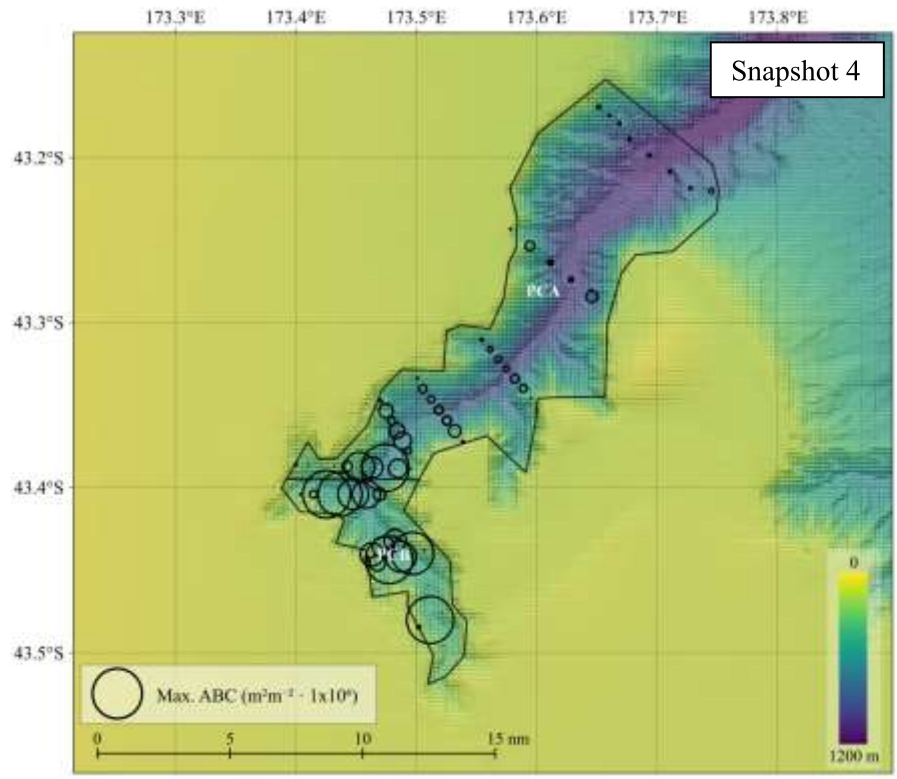
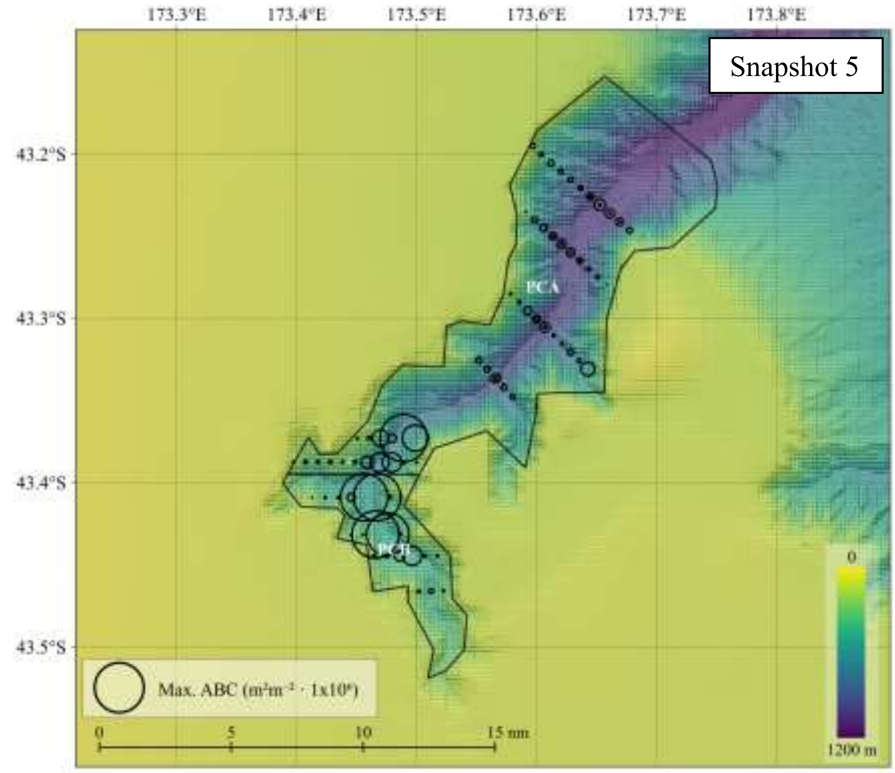


Figure 18: Continued.



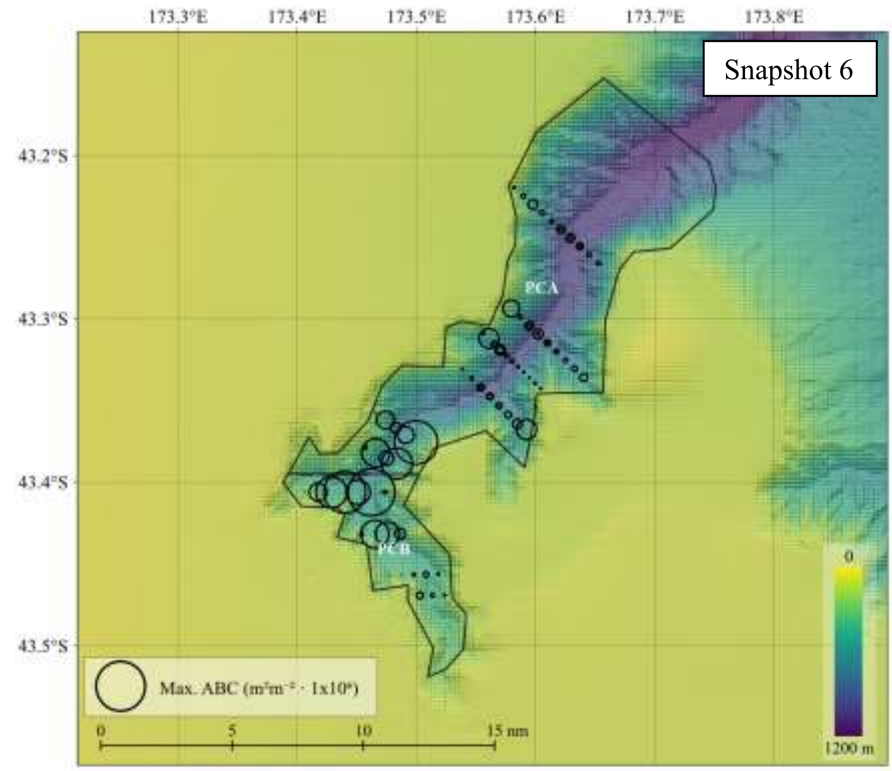
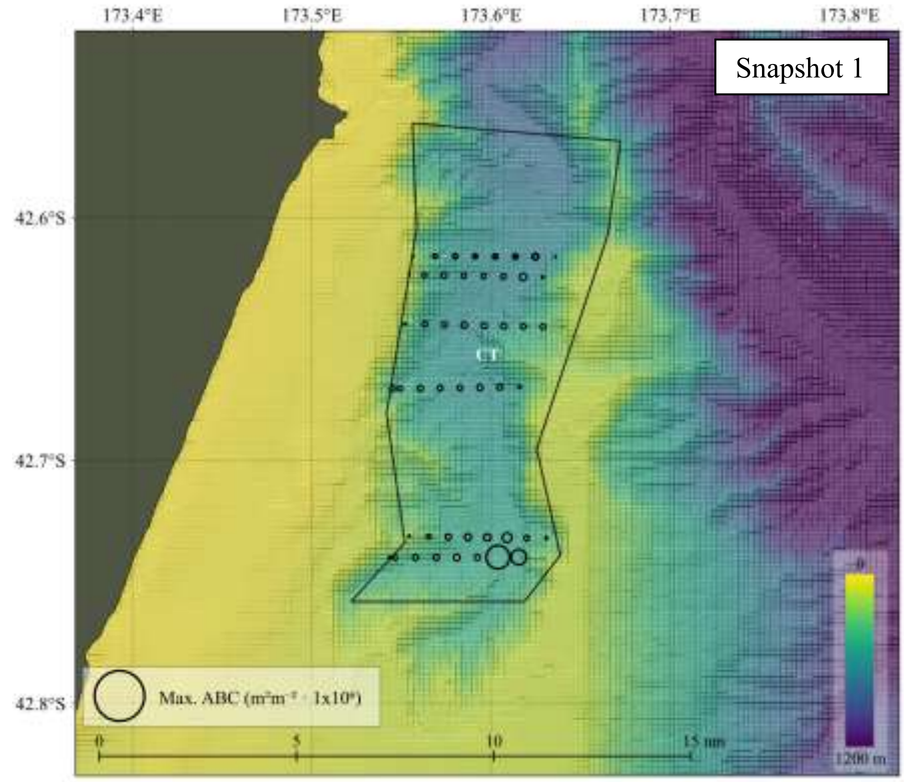


Figure 18: Continued.



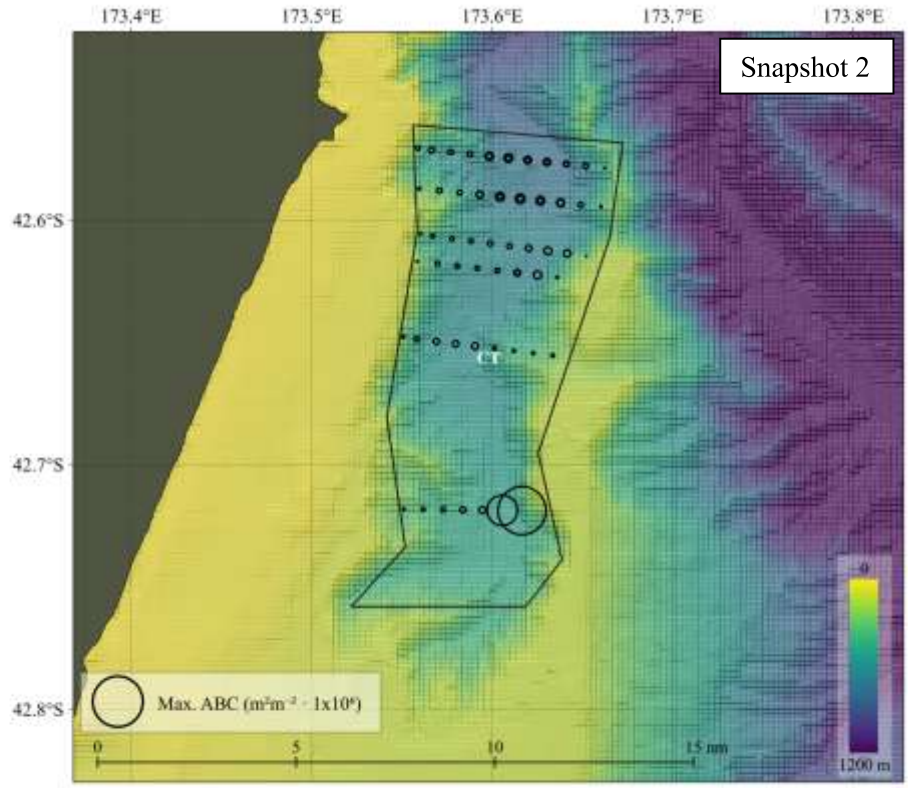


Figure 19: Spatial distribution of hoki acoustic backscatter plotted in 10 ping (~80 m) bins for snapshots in Conway Trough (n = 2) carried out by *Rakaia* in 2025. Symbol size is proportional to the amount of acoustic backscatter coefficient (ABC, maximum 796 m^2 m^{-2} · 1×10^6).

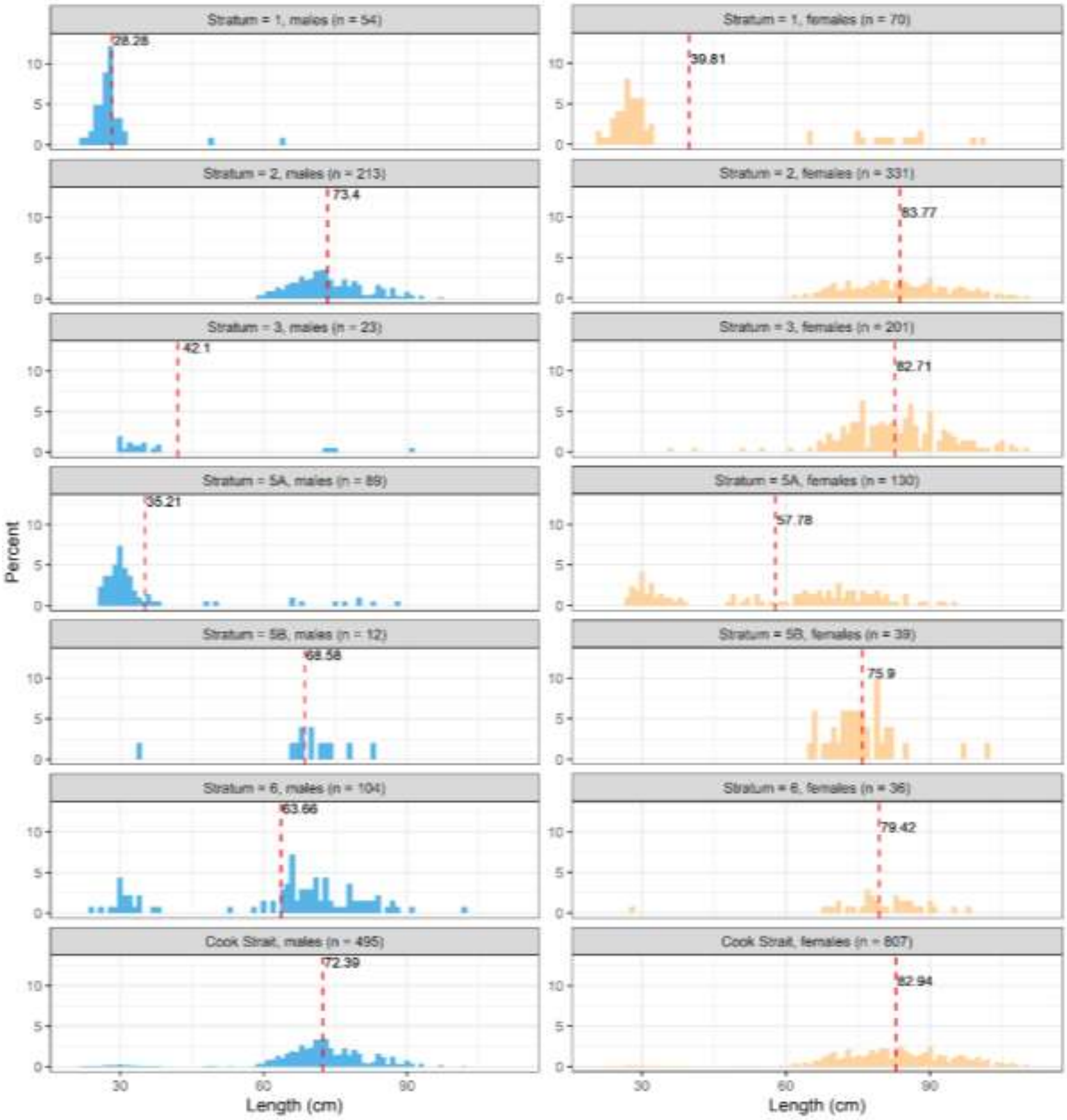


Figure 20: Scaled length frequency distributions of female (left) and male (right) hoki obtained by combining length data from research mark identification tows (n = 6) and commercial tows (n = 3) by stratum in Cook Strait in winter 2025. Length frequencies are expressed as a percentage of the total hoki catch in that stratum. n refers to the number of fish measured. Red-dashed line indicates the mean length.

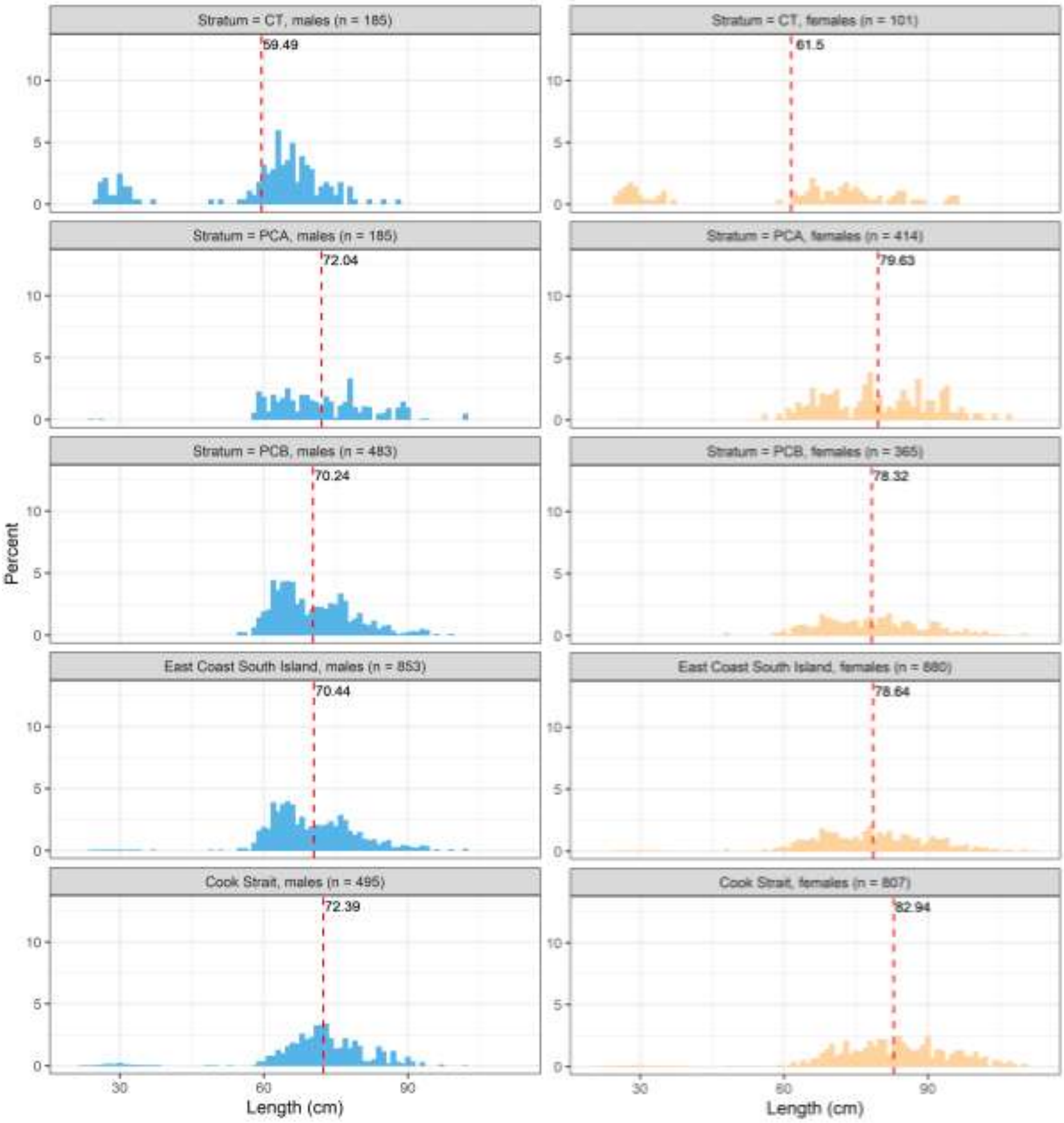
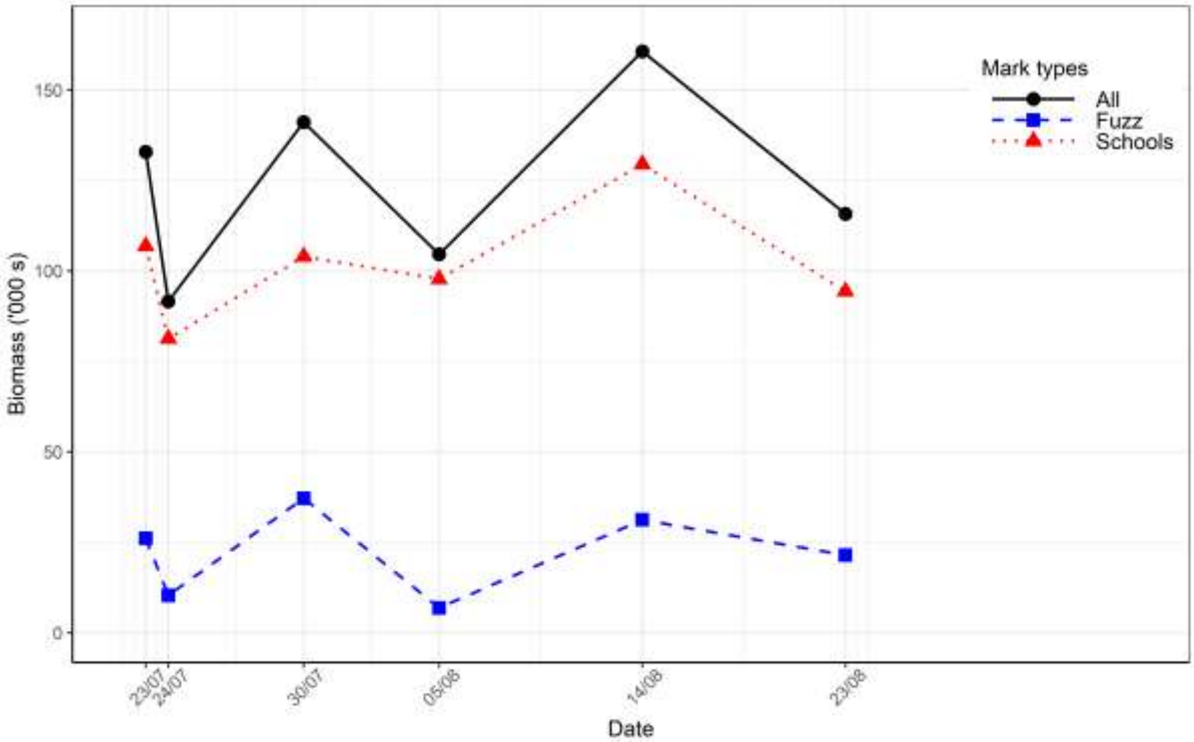


Figure 21: Scaled length frequency distributions of female (left) and male (right) hoki by stratum from research mark identification trawls (n = 7) off the east coast South Island (Pegasus Canyon north (PCA), south (PCB), and Conway Trough (CT)) in winter 2025. Scaled length frequency distribution from Cook Strait is also shown. Length frequencies for each area are expressed as a percentage of the total hoki catch in that area. n refers to the number of fish measured. Red-dashed line indicates the mean length.



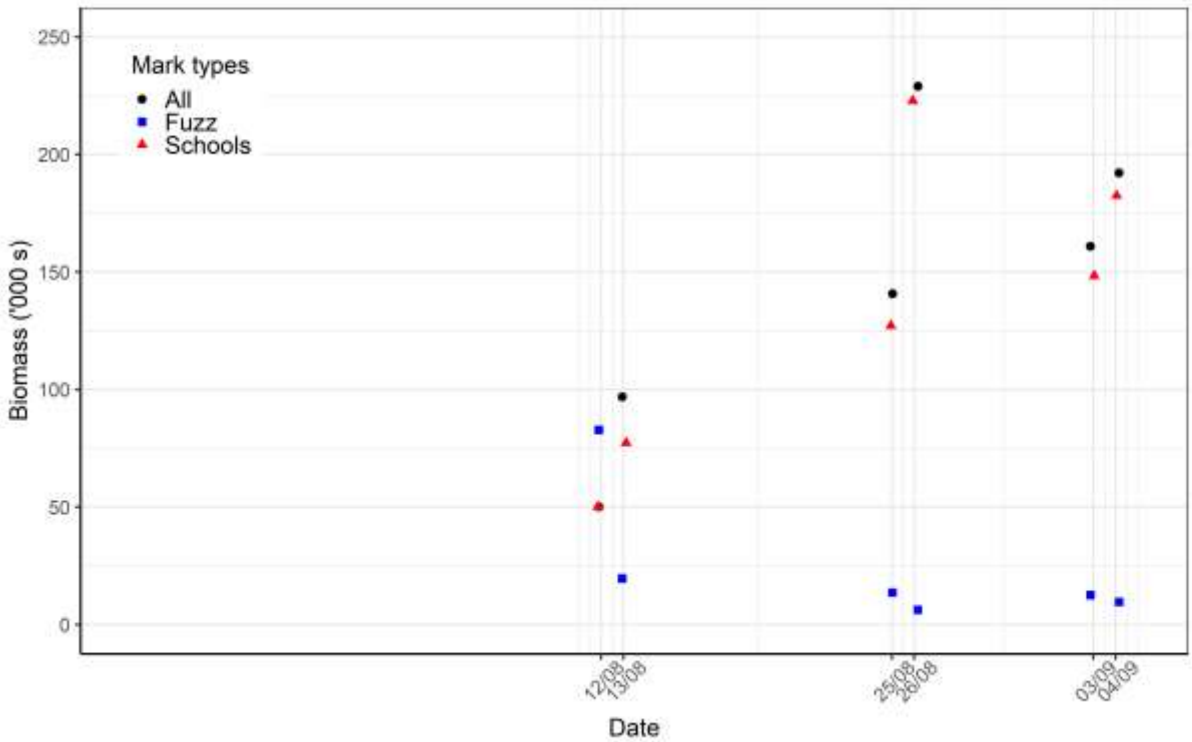


Figure 22: Estimated hoki abundance by snapshot and mark type in Cook Strait (top) and Pegasus Canyon in the 2025 survey period.

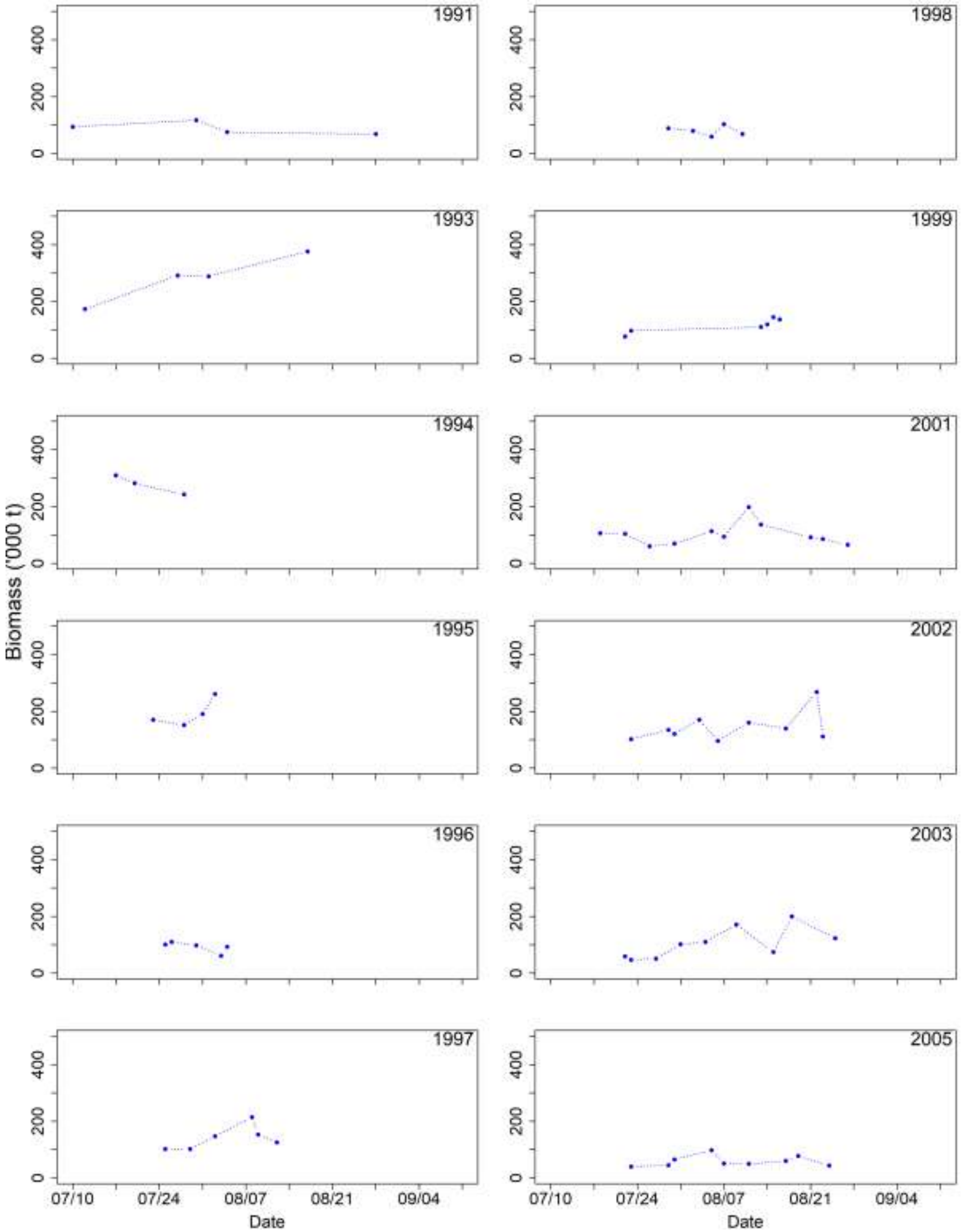


Figure 23: Estimated hoki abundance by snapshot for all acoustic surveys in the Cook Strait time series for 1991– 2025.

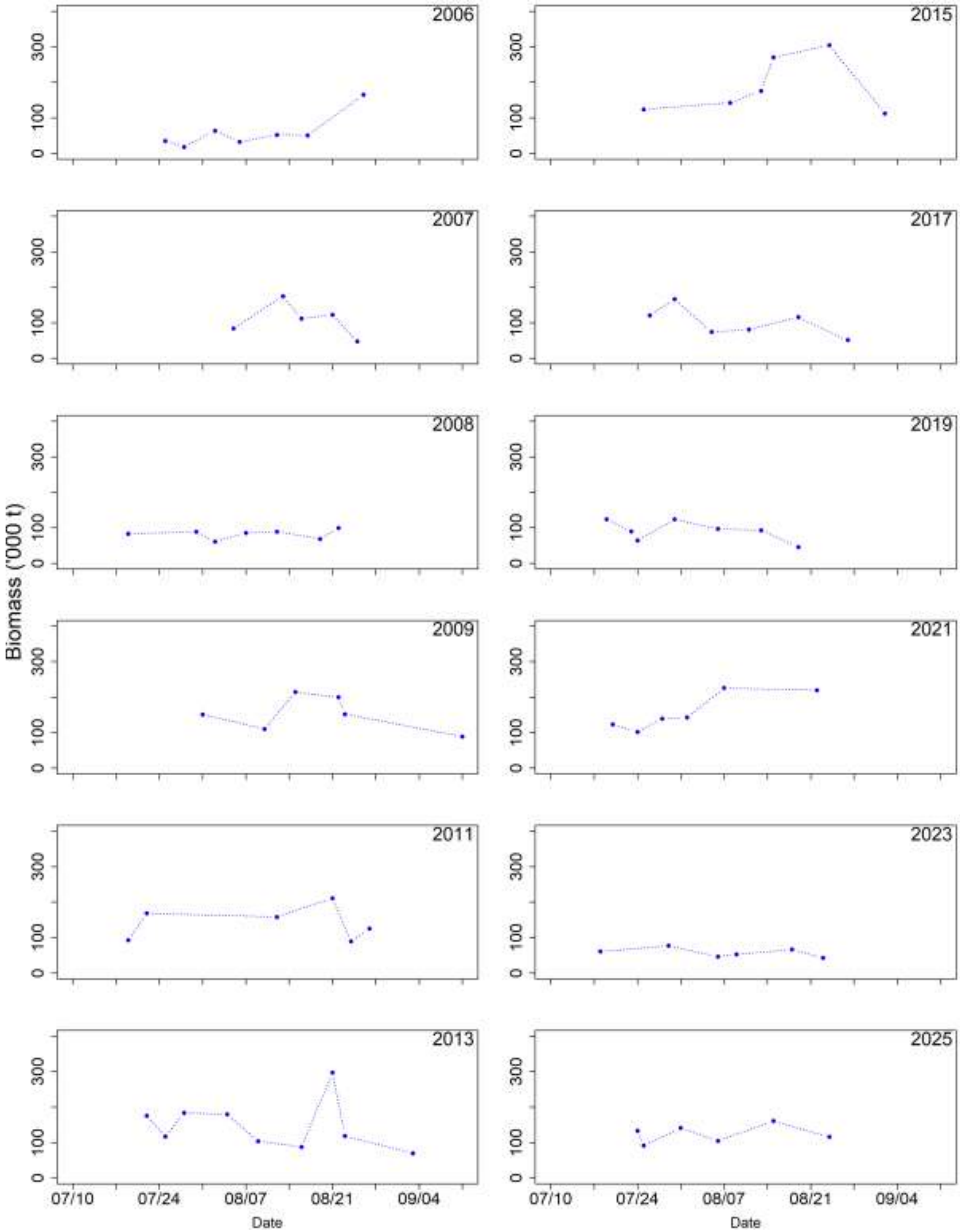


Figure 23: Continued.

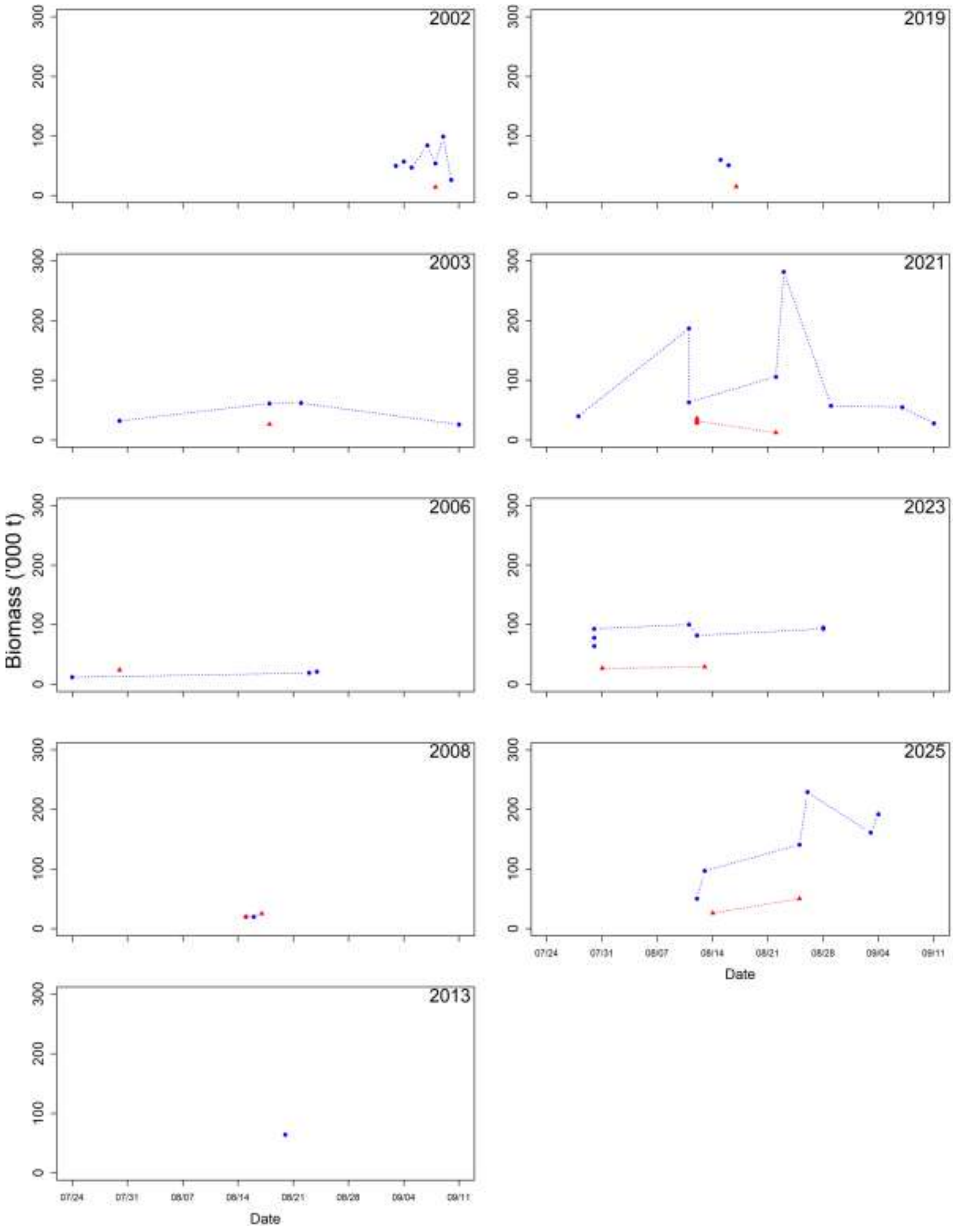


Figure 24: Estimated hoki abundance by snapshot for all acoustic surveys in the east coast of South Island from 2002–25 for Pegasus Canyon (blue dots) and Conway Trough (red dots). Surveys in 2002, 2003, 2013, and 2025 were carried out by fishing vessels. Surveys in 2006, 2008, 2019, and 2023 were carried out from research vessels. The 2021 survey used both research and industry vessels.

Appendix 1: Calibration

The echosounder system on FV *Rakaia* consists of a general purpose transceiver (GPT), connected to a 38 kHz hull-mounted transducer. The acquisition software was the ES80 version 24.1.0. The echosounder onboard *Rakaia* was calibrated in Tasman Bay (41°03.16’ S 173°25.52’ E) on 22 July 2025. The calibration was conducted following the standard protocols described in Demer et al. (2015). Range below the transducer to the seafloor was about 35 m. This was the first calibration of the ES80 echosounder system onboard *Rakaia* carried out by Earth Sciences NZ staff.

A weighted line was passed under the keel before the vessel was anchored, to facilitate setting up the three calibration braided lines and calibration sphere. The calibration sphere was suspended below the transducer using a nylon monofilament line to minimise the risk of causing variation on the measured target strength due to microbubbles trapped in braided lines. A lead weight was deployed about 4 m below the sphere to steady the lines.

The weather conditions were good, with light northerly winds (<5 knots) and no swell.

The calibration started at 15:30 NZST. The calibration was carried using 1.024 ms pulse length and 2000 W power. The sphere was centred in the beam to obtain data for the on-axis calibration and then moved around the beam to obtain data for the beam shape calibration. Calibration was completed at 16:44 NZST.

The calibration data were recorded in two Simrad ES80 raw format files: srk2501-D20250722-T033735.raw and srk2501-D20250722-T035016.raw. The files were stored in the *acoustics* database. The transceiver settings in effect during the calibration are given in Table A1.1.

Water temperature and salinity measurements were taken using a RBR *Concerto* datalogger (serial no. 60418). An estimate of acoustic absorption was calculated using the formulae in Francois & Garrison (1982) and an estimate of sound speed was calculated using the formulae of Fofonoff & Millard (1983).

Analysis

The data in the ES80 files were extracted using the software ESP3 (version 1.80.0) (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 is 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:

$$S_{a,corr} = 5\,log_{10}\left(\frac{\sum P_i}{4P_{max}}\right),$$

where Pi is the sphere echo power measurement and $Pmax$ the maximum sphere echo power measurement. A value for $Sa,corr$ is calculated for all valid sphere echoes and the mean over all sphere echoes is used to determine the final $Sa,corr$.

Results and Discussion

The results from the RBR *Concerto* cast are given in Table A1.2, along with estimates of the sphere target strength, sound speed, and acoustic absorption.

The estimated beam pattern and coverage for the calibration are given in Figure A1.1. The symmetrical nature of the pattern and the centring on zero indicates that the transducer and ES80 transceiver was operating correctly. The fit between the theoretical beam pattern and the sphere echoes from the calibration are shown in Figure A1.2 and indicate that the transducer beam pattern was shaped correctly at both calibration settings. The RMS of the difference between the Simrad beam model and the sphere echoes out to 3.6º was 0.16 dB, indicating a calibration of excellent quality (<0.4 dB is acceptable, 0.2–0.3 dB good, and <0.2 dB excellent). The transducer peak gain (G_0) and s_a correction values from the calibration are presented in Table A1.3.

References

Demer, D.A.; Berger, L.; Bernasconi, M.; Bethke, E.; Boswell, K.; Chu, D.; Domokos, R.; Dunford, A.; Fässler, S.; Gauthier, S.; Hufnagle, L.T.; Jech, J.M.; Bouffant, N.; Lebourges-Dhaussy, A.; Lurton, X.; Macaulay, G.J.; Perrot, Y.; Ryan, T.; Parker-Stetter, S.; Stienessen, S.; Weber, T.; Williamson, N. (2015). Calibration of acoustic instruments. *ICES Cooperative Research Report Nº 326*. 133 p.

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

Francois, R.E.; Garrison, G.R. (1982). Sound absorption based on ocean measurements. Part II: Boric acid contribution and equation for total absorption. *The 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 open-source software for the quantitative processing of hydro-acoustic data. *SoftwareX 12*:100581

Table A1.1. ES80 transceiver settings and other relevant parameters during the calibrations.

Parameter	Value
Echosounder	ES80
GPT model/serial	GPT 0090720649f8-1
GPT software version	70413
ES80 software version	24.1.0
Transducer model	ES38B
Transducer serial number	N/A
Sphere type/size	tungsten carbide/38.1 mm diameter
Operating frequency (kHz)	38
Transducer draft setting (m)	0
Transmit power (W)	2000
Pulse length (ms)	1.024
Transducer peak gain (dB)	25.5
Sa correction (dB)	0.0
Sample interval (m)	0.256
Two-way beam angle (dB)	–20.70
Absorption coefficient (dB/km)	10.13
Speed of sound (m/s)	1490
Angle sensitivity (dB) alongship/athwartship	23.0/23.0
3 dB beamwidth (º) alongship/athwartship	7. 0/7. 0
Angle offset (º) alongship/athwartship	0.0/0.0

Table A1.2. Auxiliary calibration parameters derived from depth and temperature measurements.

Parameter	Value
	1.024 ms
Mean sphere range (m)	29.62
S.D. of sphere range (m)	0.56
Mean sound speed (m/s)	1500.7
Mean salinity (PSU)	34.35
Mean temperature (deg C)	13.21
Mean absorption (dB/km)	9.32
Sphere TS (dB re 1m^2)	-42.42

Table A1.3. Calculated calibration parameters at 1.024 ms using ESP3 from the calibration of the ES80 echosounder onboard FV *Rakaia* in 2025. Transducer peak gain was estimated from mean sphere TS.

Parameter	2025
Pulse length (ms)	1.024
Mean TS within 0.11° of centre	-43.58
Std dev of TS within 0.11° of centre	0.32
Max TS within 0.11° of centre	-42.91
No. of echoes within 0.11° of centre	435
On axis TS from beam-fitting	-43.57
Transducer peak gain (dB) mean TS	25.26
Sa correction (dB)	-0.68
Beamwidth (º) along/athwartship	6.83/6.86
Beam offset (º) along/athwartship	0.05/-0.03
RMS deviation	0.16
Number of echoes	34 419

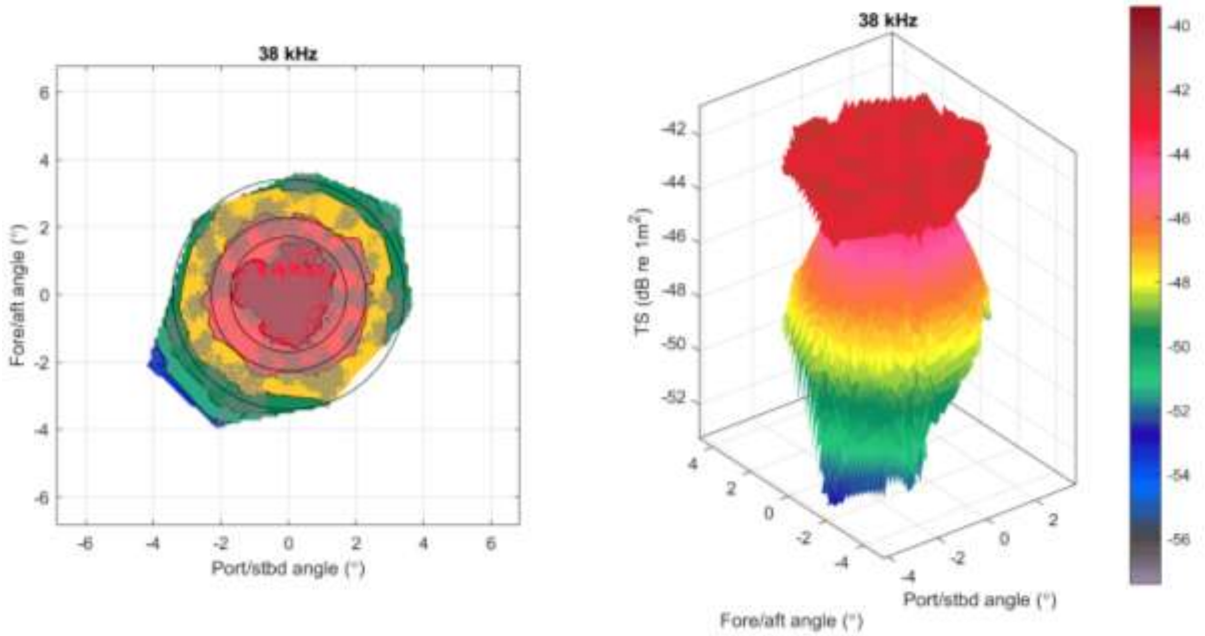


Figure A1.1. The estimated beam pattern from the sphere echo strength and position for the calibration. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength (dB re 1 m^2).

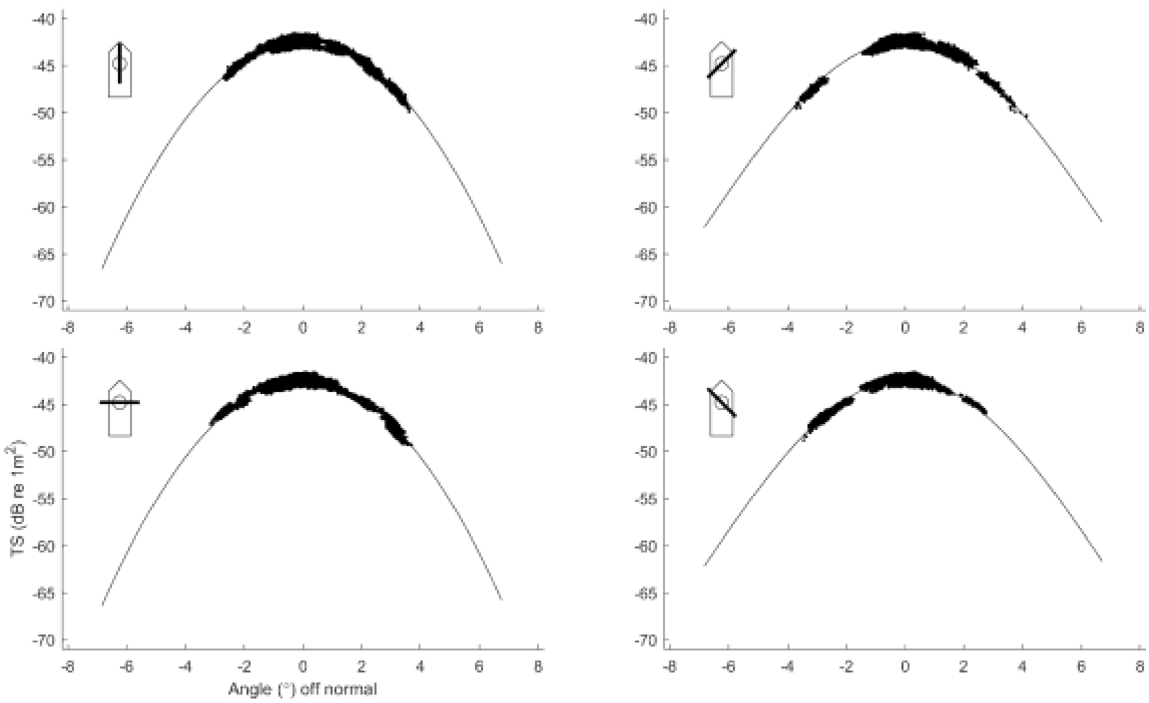


Figure A1.2. Beam pattern results from the calibration. The solid line is the theoretical beam pattern fit to the sphere echoes (points) for four slices through the beam.

Appendix 2: Description of gonad stages of hoki

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 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.

Appendix 3: Catch composition from the survey mark identification and commercial trawling

Code	Scientific Name	Common Name	Catch Weight (Kg)
AGR	*Agrostichthys parkeri*	Ribbonfish	0.7
BEN	*Benthodesmus* spp.	Scabbardfish	0.1
CBO	*Coelorinchus bollonsi*	*Bollon's rattail*	34.4
CDO	*Capromimus abbreviatus*	Capro dory	0.1
CFA	*Coelorinchus fasciatus*	Banded rattail	0.3
CHA	*Chauliodus sloani*	Viper fish	0.5
CHQ	Cranchiidae	Cranchiid squid	0.1
COL	*Coelorinchus oliverianus*	Oliver's rattail	7.7
CSQ	*Centrophorus squamosus*	Leafscale gulper shark	16.8
CYP	*Centroscymnus crepidater*	Longnose velvet dogfish	1.0
DCS	*Bythaelurus dawsoni*	Dawson's catshark	0.2
DDA	*Diaphus danae*	Dana lanternfish	0.3
DHU	*Diaphus hudsoni*	Hudson's lanternfish	0.1
EMA	*Scomber australasicus*	Blue mackerel	1.2
EPO	*Melanostigma gelatinosum*	Limp eel pout	6.2
ETL	*Etmopterus lucifer*	Lucifer dogfish	23.7
FIS		Unidentified fish	0.2
FRO	*Lepidopus caudatus*	Frostfish	13.7
HAK	*Merluccius australis*	Hake	17.5
HAS	*Halargyreus* sp.	Australasian slender cod	0.1
HOK	*Macruronus novaezelandiae*	Hoki	94 629.8
IAT	*Idiacanthus atlanticus*	Common black dragonfish	1.4
IRM	*Stoloteuthis maoria*	Bobtail squid	0.1
JAV	*Lepidorhynchus denticulatus*	Javelin fish	4.3
JFI		Jellyfish	0.5
JMD	*Trachurus declivis*	Greenback jack mackerel	25.0
LAU	*Lampanyctus australis*	Austral lanternfish	1.7
LHE	*Lampanyctodes hectoris*	Hector's lanternfish	2.4
LIN	*Genypterus blacodes*	Ling	234.7
LIT	*Lampanyctus intricarius*	Intricate lanternfish	0.3
LNT	*Lampadena notialis*	Notal lanternfish	0.1
MIQ	*Moroteuthopsis ingens*	Rough-skinned clubhook squid	0.2
MMU	*Maurolicus australis*	Pearlside	15.4
MSQ	*Mastigoteuthis* sp.	*Mastigoteuthis* sp.	0.2
OPP	*Oplophorus* spp.	*Oplophorus* spp.	0.6
PAS	*Pasiphaea* spp.	*Pasiphaea* spp.	1.2
PED	*Aristaeopsis edwardsiana*	Scarlet prawn	0.1
PER	*Persparsia kopua*	Common tubeshoulder	0.1
PHO	*Phosichthys argenteus*	Lighthouse fish	0.5
PRO	*Protomyctophum* spp.	*Protomyctophum* spp.	0.2
RCO	*Pseudophycis bachus*	Red cod	8.1
RHY	*Paratrachichthys trailli*	Common roughy	0.3
RSO	*Rexea solandri*	Gemfish	22.7

Code	Scientific Name	Common Name	Catch Weight (Kg)
SBP	*Symbolophorus boops*	Bogue lanternfish	0.8
SCH	*Galeorhinus galeus*	School shark	41.7
SEP	*Sergia potens*	*Sergia potens*	0.1
SER	*Sergestes spp.*	Sergestid prawn	1.0
SPD	*Squalus acanthias*	Spiny dogfish	1 097.6
SPU	*Sternoptyx pseudodiaphana*	False oblique hatchetfish	0.1
SQU	*Nototodarus sloanii & N. gouldi*	Arrow squid	3.7
SQX		Squid	0.1
SWA	*Seriolella punctata*	Silver warehou	90.2
TPE	*Teuthowenia pellucida*	*Teuthowenia pellucida*	0.2
VSQ	*Histioteuthis spp.*	Violet squid	1.0
		Total weight	96 311.3