FORM 5

Final Research Report

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Author(s):	Richard L. O'Driscoll; Sira L. Ballara, Neil W. Bagley
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EXECUTIVE SUMMARY

This report reviews the trawl and acoustic components of the west coast South Island (WCSI) *Tangaroa* survey to inform future survey design. Specific aspects considered were: a) vessel and gear suitability; b) survey timing for each component; c) spatial and depth coverage of each component; d) vessel days and number of tows in trawl component; e) vessel days and number of snapshots and mark identification tows in acoustic component; f) additional biological sampling; g) quality of the estimates of biomass.

The current acoustic survey area and timing is appropriate for hoki. The time series of acoustic estimates from the WCSI surveys are included in the hoki assessment as relative indices of spawning hoki abundance. In the two model runs in 2014, the fit to the WCSI indices was good, but the WCSI acoustic indices are not particularly influential because of the relatively high estimated CVs which result in low weightings of the indices in assessment. The current stock assessment model does not fit the increase and decline in acoustic observations of hoki abundance on the WCSI in the 1990s. The major source of uncertainty in acoustic estimates of hoki on the WCSI is species decomposition in mixed layers. Consideration should be given to further increasing the level of mark identification trawling in the southern areas to allow for more detailed decomposition by stratum.

The trawl survey component provide fisheries-independent estimates of abundance for hake, ling, and associated middle depth species. Trawl estimates from the northern area do not appear to be providing reliable indices of hoki abundance. Northern trawl indices for hoki were highly variable from 2000–13 and were not consistent with changes in WCSI acoustic indices over the same period, estimated hoki abundance from trawl surveys in the Sub-Antarctic, or western spawning stock biomass estimated from the hoki stock assessment model. Trawl estimates of hake and ling abundance appear to be of high quality, with relatively good precision (coefficients of variation less than 20%), consistent abundance estimates and length and age frequencies between surveys, and appropriate spatial and depth distribution. Trawl abundance estimates from the 2000 and 2012 WCSI surveys were included as inputs into accepted stock assessments for ling and hake in 2013. The WCSI survey also provides potential for monitoring species including lookdown dory, sea perch, javelinfish, dark ghost shark, and ribaldo. For most of these species, the trawl survey provides the only fisheries-independent estimate of abundance on the WCSI, as well as providing biological data (length, sex, reproductive condition, age, etc.). Trawl estimates also provide data that could be used in the future to develop species-based, size-based, and trophodynamic ecosystem indicators.

To allow comparability with results from the 2000–13 surveys, the trawl survey component needs to be carried out from *Tangaroa*. If an alternative vessel and/or gear is used for the trawl component, then this would have a different catchability coefficient and would represent the start of a new time-series, unless inter-calibration experiments are carried out. There is no specific vessel requirement for the acoustic survey component. The survey vessel requires a calibrated 38 kHz echosounder and must be able to carry out directed fishing on marks using both midwater and bottom trawl gear. A towed acoustic system is desirable. It would be possible to carry out the survey components using two or more vessels. For example, the trawling component could be carried out by *Tangaroa*, while the acoustic snapshots could be carried out from another vessel.

The timing of the acoustic survey is determined by the timing of hoki spawning and simulations based on estimated arrival dates and residence times indicate that acoustic surveys of WCSI should have a mid-date of about 5 August. To allow comparability with results from the 2000–13 surveys, the trawl survey component also needs to be carried out in July–August. If an alternate timing is adopted for the trawl component, then this would represent the start of a new time-series. The best available data for the two main target species of the trawl survey (hake and ling) show that the current July–August timing is during the period when commercial catches and catch rates are highest. An earlier (June) timing may also be appropriate for these species, but any later would lead to increased overlap with observed spawning in

September. Carrying out the trawl survey outside the June–September period would be risky, as the distribution and abundance of hake and ling on the WCSI outside the main period of commercial fishing is poorly known. Trawl survey timing was not specifically evaluated in relation to other associated species. With the exception of jack mackerel, most of the catch of other deepwater species on the WCSI is taken in the June to September period of the hoki fishery, with little catch outside this period.

Data from commercial fisheries and the two most recent trawl surveys show that the current trawl survey area appears to have an appropriate spatial and depth distribution in the northern area for hoki, hake, ling, silver warehou, silver dory, alfonsino, smooth skate, sea perch, javelinfish, lookdown dory, and dark ghost shark. Coverage of species with a more inshore distribution (giant stargazer, spiny dogfish, school shark, barracouta, northern spiny dogfish, jack mackerel, frostfish, arrow squid, and tarakihi) was improved by the inclusion of shallower strata (1&2S and 4S) from 200–300 m, but densities of these 9 species are still likely to be considerable inshore of 200 m. The current trawl survey does not extend deep enough for shovelnosed dogfish. Ribaldo also occur deeper and are adequately covered in stratum 4D, but not further north as stratum 1&2 only goes to 650 m. The trawl survey is restricted to the region north of Hokitika Canyon, but commercial and research mark identification catches show that the distribution of many species extends into the Hokitika Canyon and along the shelf to the south. These southern areas are not suitable for a bottom trawl survey.

The minimum requirement for an acoustic survey is two snapshots in the northern area and three acoustic snapshots in the southern area. This requires approximately 23 vessel days (including 4 days for vessel mobilisation and demobilisation, echosounder calibration, and steaming to and from port). The number of trawls required can be estimated based on a statistical analysis of catch rate data from previous surveys. This suggested that about 63 random tows are required, which would take about 15 days on the grounds to complete, as trawling can only be carried out in daylight hours. In a combined survey design, acoustic transects are run in the northern strata during the night. To achieve the minimum combined requirement of two acoustic snapshots and 63 random tows in the northern area and three acoustic snapshots in the southern area requires approximately 29 vessel days (again allowing 4 days for vessel mobilisation and demobilisation, echosounder calibration, and steaming to and from port). This is the same as the time allocated for the 2013 survey,

The current level of biological sampling on the WCSI surveys is among the most comprehensive of any New Zealand survey. All items in the catch are sorted and weighed, and random samples of most fish species are measured and sex determined. We do not recommend additional routine sampling, but note that targeted data collections (e.g., otoliths from additional species, or stomach contents) would be possible if required for specific projects.

1. OBJECTIVES

1.1 Overall Objective

To review the performance west coast South Island (WCSI) trawl/acoustic survey to inform future survey design.

1.2 Specific Objectives

1. Review each component (trawl survey and acoustic survey) of the WCSI surveys for estimation of hoki, hake and ling biomass time series.
2. Review the ability of the WCSI survey to provide information on the wider ecosystem.
3. Identify potential changes that may improve the results of future surveys, both trawl and acoustic components.

2. BACKGROUND

Acoustic surveys of spawning hoki on the west coast South Island (WCSI) were regularly carried out from 1988–2000 (reviewed by O'Driscoll 2002), but were stopped because of uncertainty over the species composition in the acoustic data in the northern area of the survey. In 2012, the survey series was reinstated under the current Deepwater 10-Year Research Programme (10YP) as a combined trawl and acoustic survey, focused on providing an acoustic biomass estimate of spawning hoki and trawl biomass estimates of a number of other species. The overall objective for the WCSI trawl/acoustic survey was to estimate relative abundance indices for hoki, hake and ling. Specific objectives of the survey also included the collection of data to allow for age and size structure information for hoki, hake and ling, estimation of species composition of fish marks measured acoustically during the survey by target trawling, and collection of specimens of unidentified organisms for biodiversity studies.

Two combined trawl and acoustic surveys have now been completed as part of the 10YP (O'Driscoll et al. 2014, 2015). In preparation for the contracting of the next five years of the 10YP, the survey design will be reviewed to ensure that it is fit for purpose.

The biomass indices from the trawl component of the survey are key data inputs to stock assessments for hake and ling and provide additional information for the hoki assessment. The survey is also important to the Marine Stewardship Council (MSC) certifications of hoki, hake and ling, not just for supporting the stock assessments, but also from an ecosystem perspective, where it provides a time series of abundance trends for a wide range of species that are taken as bycatch in these fisheries. This latter component has been repeatedly noted in certification documents.

Because of the very short time-frame allowed for this project (less than two months), we were not able to carry out extensive new analyses. Instead, we compiled, updated, and interpreted existing information (e.g., O'Driscoll et al. 2011a, 2014, 2015). If MPI or the Working Groups request further analyses, then a final reporting date of June 2015 would be more appropriate.

3. METHODS

3.1 Specific Objective 1: Review each component (trawl survey and acoustic survey) of the WCSI surveys for estimation of hoki, hake and ling biomass time series.

The trawl and acoustic components of the survey were reviewed for each of the three main species (hoki, hake and ling) with specific consideration of the following:

a. Vessel and gear suitability
b. Survey timing for each component
c. Spatial and depth coverage of each component
d. Vessel days and number of tows in trawl component
e. Vessel days and number of snapshots (and mark identification tows) in acoustic component
f. Additional biological sampling
g. Quality of the estimates of biomass

A review of the first six items (a–f) was carried out before the first combined survey in 2012 as part of MPI Research Project HOK2010/04A. This review was presented to the Hoki Working Group on 14 December 2011 (O'Driscoll et al. 2011a) and was based on an analysis of commercial fishing catch and effort in FMA7, over the period June–September in all years from 2000 to 2010, and on the previous work on WCSI survey design by Francis & O'Driscoll (2004) and O'Driscoll et al. (2004). Summaries included plots showing timing of commercial catches, depth and spatial distribution of commercial catches, and evidence for timing of spawning based on gonad staging. We updated the analyses of commercial catch data for hoki, hake, and ling carried out by O'Driscoll et al. (2011a) to include the three most recent fishing years (2011–13). We also evaluated results from the 2012 and 2013 surveys (O'Driscoll et al. 2014, 2015).

The two surveys in 2012 and 2013, along with the previous trawl-acoustic survey in 2000 (O'Driscoll et al. 2004) also provide information on the "quality" of abundance estimates for hoki, hake, and ling (item g above). We assessed quality by looking at overall uncertainty of survey estimates (coefficient of variation, CV), consistency of estimates between surveys, spatial distribution, ability to track year-classes, and agreement with other indices of abundance (where available).

3.2 Specific Objective 2: Review the ability of the WCSI survey to provide information on the wider ecosystem.

Trawl estimates from the WCSI surveys also provide abundance indices for a range of other species and the new survey time-series may fulfil an important "ecosystem monitoring" role in the future (e.g., Tuck et al. 2009), as well as providing inputs into single-species stock assessments for bycatch species.

Abundance indices and scaled length frequency distributions from 2012 and 2013 were presented for 20 species by O'Driscoll et al. (2015) (Table 1). Our analyses under Objective 2 will focus on the 17 non-target species (i.e., excluding hoki, hake, and ling) in Table 1. As for hoki, hake, and ling (see Section 3.1), we assessed quality by looking at CVs, survey estimates, consistency of estimates between surveys, spatial distribution, ability to track size classes, and agreement with other indices of abundance (where available).

O'Driscoll et al. (2011a) also summarised the depth, and spatial distribution of commercial catches of barracouta, jack mackerel, silver warehou, frostfish, spiny dogfish, ribaldo, gemfish, stargazer, and lookdown dory over the period June–September in all years from 2000 to 2010. We updated the analyses of commercial catch data for these species to include the three most recent fishing years (2011–13). If MPI or the Working Groups require an updated analysis of commercial catch data to include further species a final reporting date of June 2015 would be more appropriate.

3.3 Specific Objective 3: Identify potential changes that may improve the results of future surveys, both trawl and acoustic components.

The survey design in 2012 and 2013 was based on the same six strata used for previous WCSI acoustic surveys (1988–2000), retaining the sub-stratification for Strata 1&2 and 4 used in the 2000 survey (Cordue 2002). However, there were four main changes to the strata used in 2000 based on the analysis of O'Driscoll et al. (2011a):

- Stratum 1&2 was extended further north from 40.8°S to 40.6°S to better cover the distribution of hoki and ling catches;
- Stratum 4D (650–800 m) was added to fully sample the offshore distribution of hoki, hake, and ribaldo in that area;
- The offshore boundary of the northern part of acoustic stratum 6 (north of 42.85°S) was shifted from 750 m to 850 m to comprehensively sample hake;
- Stratum 1&2S and 4S (200–300 m) were added to improve trawl indices for silver warehou, barracouta, frostfish, and gemfish.

Objectives 1 and 2 re-evaluate the spatial and depth distribution of the trawl component with respect to obtaining informative biomass indices for each of the target species based on results from the 2012 and 2013 surveys (O'Driscoll et al. 2014, 2015). Resulting improvements to survey design (e.g., to increase the range of species covered) are suggested.

As requested by MPI, consideration will also be given to the potential for splitting the survey into two separate surveys, one focussed on obtaining an acoustic biomass estimate for hoki and the other on maximising the trawl-based biomass estimates for other target species, while retaining consistency with the existing time series.

4. RESULTS

4.1 Specific Objective 1: Review each component (trawl survey and acoustic survey) of the WCSI surveys for estimation of hoki, hake and ling biomass time series.

4.1.1 Performance of acoustic survey

Vessel and gear

Hoki on the WCSI were surveyed using acoustics from 1988–2000, and in 2012–13. The research vessel *James Cook* was used for surveys from 1988–90, *Kaharoa* was used in 1991, and surveys since 1992 have been using *Tangaroa* (Table 2).

Survey timing

The timing of previous WCSI acoustic surveys is shown in Table 2 and is based on the timing of hoki spawning. Hoki migrate from the Sub-Antarctic home grounds to the WCSI to spawn between June to September (Figure 1). It is thought that during the spawning season there is a turnover of fish on the grounds. Therefore, there is no time at which all of the spawning fish are available to be surveyed. Francis & O'Driscoll (2004) carried out simulations to investigate the effects of survey timing and number of snapshots on the overall uncertainty of the northern and southern acoustic indices, based on assumptions about arrival dates and residence times (from Harley 2002). Note that the overall uncertainty (expressed as a CV) is not just a measure of the sampling error, but is generated using a simulation procedure that combines uncertainty from each of five main sources: assumptions about timing and duration of spawning and residence time for the plateau model; sampling precision; mark identification; fish weight and target strength; and acoustic calibration (O'Driscoll 2002, 2004). Simulations indicated that acoustic surveys of WCSI should have a mid-date of about 5 August. This timing was adopted in 2012 and 2013, with the 2012 survey from 22 July to 18 August, and the 2013 survey from 29 July to 20 August (Table 2).

Available data indicate that the recent timing of the acoustic survey for hoki is appropriate. Analysis of hoki gonad stages collected by observers shows that spawning hoki are recorded throughout the period from June to September, with the highest proportion of running ripe female hoki recorded from mid-July to the end of August (Figure 2). Highest commercial CPUE for hoki occurs in mid-August (Figure 3).

Spatial and depth coverage

The current acoustic survey area (Figure 4, Table 3) is appropriate for hoki, encompassing almost all of the recent catch from the WCSI (Figure 5). The estimated percentage of biomass of hoki in each strata in 2012 and 2013 is given in Table 4. No hoki marks were detected in the new (trawl) strata 1&2S, 4S, or 4D, or in the offshore extension (750–850 m) in the northern part of acoustic stratum 6. We conclude that the modifications to survey boundaries implemented in 2012 (see Section 3.3) are not required for a hoki acoustic survey.

Quality of abundance indices

The time series of relative acoustic estimates of spawning hoki abundance from the WCSI surveys is given in Table 5. The 'old' methods follow O'Driscoll (2002), and are based on the methods of Cordue (2002) updated using the TS of Macaulay (2001) and using consistent stratum areas. O'Driscoll et al. (2015) also present revised estimates which updated WCSI acoustic abundance indices from 1988–2013 for changes in sound absorption, more accurately estimated stratum areas, and used the latest TS-L relationship of Dunford et al. (2014). At a meeting on 3 March 2014, the Deepwater Fisheries Assessment Working Group (DFAWG) decided to continue to use acoustic estimates calculated using the 'old' method in the 2014 hoki assessment. This decision meant that it would not require re-calculation of the prior for the acoustic catchabilty (q) and also because there was little difference between relative abundance indices calculated using the 'old' and 'revised' method (Table 5). The DFAWG further agreed that 'new' estimates of survey weighting should be used for surveys from 2000 onwards, with 'old' estimates used for previous surveys which had limited mark identification trawling. Revised estimates of survey CVs ranged from 0.28 in 2000 to 0.73 in 1991 (Table 5).

'Old' acoustic estimates estimated that hoki abundance on the WCSI in 2013 was 13% lower than that in 2012 and 10% lower than that in 2000 (Table 5). However the last three acoustic estimates (2000–13) were all within 10% of the average for the 'old' time-series (402 000 t). Recent acoustic abundance indices are consistent with estimates of western hoki spawning stock biomass from the assessment model, which indicate that stock status in 2012–13 is similar to that in 2000 (McKenzie 2015). Acoustic indices contrast with indices based on commercial catch-per-unit-effort (CPUE) on the WCSI which suggest a doubling in CPUE since 2000 (Figure 6). 'Revised' estimates which used the most recent hoki TS-L relationship based on AOS measurements by Dunford et al. (2014), are about 40% lower than 'old' estimates (see Table 5), but relative estimates are similar so choice of TS-L relationship will not have a major impact on hoki assessment.

Species decomposition remains a major source of uncertainty in acoustic estimates of hoki on the WCSI. The standard decomposition method assumes that all species which contribute to the backscatter are caught in the trawl, all species have equal catchability, and that the TS-length relationships for all species are known. None of these assumptions are likely to be fully met (O'Driscoll et al. 2014). Before 2000, there was the further problem that there was little or no research trawl data to carry out species decomposition (Table 6) and commercial data were used to derive estimates of the proportion of hoki (Cordue 2002). This uncertainty is reflected in the revised CVs used for model weighting, which assign lower weights (higher CVs) to surveys before 2000 (see Table 5).

Macaulay & Dunn (2000) investigated the feasibility of using acoustics to estimate hake biomass on the WCSI, and suggested that an acoustic survey for hake could be combined with a hoki acoustic survey. Because hake and hoki are found in similar areas on the WCSI during winter, acoustic data on hoki and hake could potentially be collected concurrently (Macaulay & Dunn 2000). This was the main reason for extending stratum 6 offshore in 2012 and 2013 (see Figure 4). However, no aggregations of hake were encountered along random transects during the acoustic survey in 2012 or 2013.

Use in stock assessment

The time series of acoustic estimates from the WCSI surveys are included in the hoki assessment as relative indices of spawning hoki abundance. In the two model runs in 2014, the fit to the WCSI indices was good (as measured by the standard deviation of the normalised residuals, SDNR). The SDNR of the fit to the WCSI indices for run 1.4 was 0.90 and for run 1.7 was 0.96 (McKenzie 2015). However, the WCSI acoustic indices are not particularly influential because of the relative high estimated CVs (see Table 5) which result in low weightings of the indices in assessment. The current stock assessment model does not fit the increase and decline in acoustic observations of hoki abundance on the WCSI in the 1990s (Figure 7).

An independent panel of experts reviewed the hoki stock assessment in 2014 (Butterworth et al. 2014) and concluded that: "*Surveys play a key role in the assessment and are one of the main contributors to the model result of near-term increases in abundance. The relative importance of the different surveys to the assessment appears to be in rough order:*
1) SA summer bottom trawl
2) Chatham Rise bottom trawl
3) WCSI Acoustic
4) Cook Strait Acoustic
5) SA autumn bottom trawl (only 3 years)
The Chatham Rise bottom trawl surveys appear to be important as an index of incoming year classes and the SA data play an important role as an index for the staging (maturation) of fish heading towards the WCSI spawning grounds."

4.1.2 Performance of trawl survey for hoki, hake, and ling

Vessel and gear

The design of the 2000 survey was modified substantially to investigate species composition in mixed species layers (Cordue 2002). In addition to the acoustic snapshots and conventional mark identification trawls, there was a large, stratified, random trawling component in northern strata. This 2000 survey formed the basis for an ongoing trawl time-series, which was continued in 2012 and 2013. All these surveys used the same vessel (*Tangaroa*) and the same trawl gear (eight-seam hoki bottom trawl with 100 m sweeps, 50 m bridles, 12 m backstrops, 58.8 m groundrope, 45 m headline, and 60 mm codend mesh). This vessel/trawl combination is also used for surveys of hoki and middle depth species on the Chatham Rise (O'Driscoll et al. 2011c) and Sub-Antarctic (Bagley et al. 2013).

Survey timing
O'Driscoll et al. (2011a) explored the timing of the trawl survey component with respect to hoki, hake and ling based on an analysis of commercial fishing catch and effort in FMA7 over the period June–September in all years from 2000 to 2010. They concluded that there are strong reasons why the survey needs to be in July-August for hoki and no clear reasons to indicate more appropriate timing for hake and ling. Our updated analyses support these conclusions. Commercial catches of hake (Figure 8) and ling (Figure 9) are mainly taken from June to September, at the same time as the hoki fishery. There is a small amount of ling longline fishing on the WCSI throughout the year (Figure 9). Most hake target tows are also in June to September (Figure 10). Date does not enter CPUE models for hake as an explanatory variable (Ballara 2013). Trawl CPUE for ling declined from July to August, but was uncertain (Figure 11), while longline CPUE for ling was highest in September (Figure 12). Updated gonad stage data from observed catches from 2000–13 show some evidence of hake (Figure 13) and ling (Figure 14) spawning on the WCSI in late August to September.

In summary, the best available data for the two main target species of the trawl survey (hake and ling) show that the current July–August timing is during the period when commercial catches and catch rates are highest. Estimated CVs for hake and ling from the three trawl surveys in 2000–13 were all less than 20% (see Table 1), which does not suggest that there are particular issues with these species being aggregated at the time of the survey. An earlier (June) timing may also be appropriate for these species, but any later would lead to increased overlap with observed spawning in September. Carrying out the trawl survey outside the June–September period would be risky, as the distribution and abundance of hake and ling on the WCSI outside the main period of commercial fishing is poorly known.

Spatial and depth coverage
The survey area in 2012 and 2013 (see Figure 4, Table 3) was based on the same six strata used in all previous WCSI acoustic surveys, retaining the sub-stratification of Strata 1&2, and 4 used in the 2000 survey (Cordue 2002). There were four changes to the survey area in 2012 to improve coverage of other key species, particularly hake and ling (see Section 3.3). These changes were retained in 2013, so the survey area was the same as that in 2012.

Data from commercial fisheries (Figures 15–16) and the two most recent trawl surveys (Figure 17–18) show that the current trawl survey area appears to have an appropriate spatial and depth distribution in the northern area for hoki, hake, and ling. No hoki, hake or ling were caught in the 200–300 m shallow strata 4S and 1&2S. There is no clear need to extend stratum 1&2 any deeper than the existing 650 m boundary for hake as most of the commercial catch in the northern area is taken within the existing survey area (see Figures 15 and 16).

The trawl survey is restricted to the region north of Hokitika Canyon, but commercial catches (see Figure 15) show that the distribution of hake and ling extends into the Hokitika Canyon and along the shelf to the south. The southern region is characterised by canyons (strata 5A, 5B, and 7) with a steeply sloping shelf in stratum 6 (see Figure 4). The rough bottom topography means that much of the area is unsuitable for bottom trawling and therefore cannot be easily incorporated in a random trawl survey. As a consequence, use of trawl survey estimates from the northern area only as indices for the entire WCSI (or FMA7) relies on the assumption that a constant proportion of the stock resides within the northern trawlable area. This may not be the case for hoki where the proportion of the acoustic estimate in the northern strata has ranged from 10% (in 1991) to 39% (in 2012) (O'Driscoll et al. 2015). Mark identification tows using the bottom trawl in southern strata in 2012 and 2013 had similar or higher catch rates of hake (Figure 19) and ling (Figure 20) as random tows at equivalent depths in the northern trawl survey area.

Biological sampling
An approximately random sample of up to 200 individuals of hoki, hake, and ling was measured and sex determined from each successful trawl. More detailed biological data were also collected on 20 individuals of each species and included fish weight, sex, gonad stage, gonad weight, and occasional observations on stomach fullness, contents, and prey condition. Otoliths were taken from hake, hoki, and ling for age determination. Liver and gutted weights were recorded from up to 20 hoki per tow to determine condition indices.

Using this protocol, length and age frequencies were generated for hoki, hake, and ling. Length frequency distributions were relatively consistent between surveys in 2012 and 2013 (Figure 21), suggesting that the trawl survey was measuring the same population in each survey. Age distributions of hoki in core strata from the 2012 and 2013 WCSI surveys (Figure 22), and hake (Figure 23) and ling (Figure 24) in core strata from the 2000, 2012 and 2013 surveys were compared. Hoki from the 2000 survey were not aged. The 2013 survey showed a mode for hoki at age 2, following on from reasonable numbers of fish observed at age 1 in 2012 (Figure 22). The hoki modal peak at age 3 in the 2012 survey (2009 year-class) did not follow on as a stronger 4 year old age class in 2013. There were few male hoki older than age 6 and few females older than age 8 in 2013 (Figure 22). The age distribution of hake showed a higher proportion of younger fish in 2013 than was observed in 2000, with a mode at age 1 (Figure 23). There were fewer male hake older than age 8 and females older than age 10 in 2013 compared with 2012 and 2000 (Figure 23). Ling had a broad range of ages in all three surveys, with most ling aged from 3–20 years (Figure 24).

Quality of abundance indices

Trawl estimates of hake and ling abundance appear to be of high quality, with relatively good precision (CVs less than 20%), consistency of abundance estimates (see Table 1), length frequencies, (see Figure 21), and age frequencies (see Figures 23–24) between surveys, and appropriate spatial distribution (see Figures 15–18). Trawl abundance estimates from the 2012 WCSI survey were accepted as inputs into stock assessments for accepted ling and hake assessments in 2013 (described below).

Trawl estimates from the northern area do not appear to be providing reliable indices of hoki abundance. Estimates were highly variable between the 2000, 2012, and 2013 trawl surveys (see Table 1). There was a six-fold increase in estimated hoki abundance in core trawl strata between 2000 and 2012, and a halving in 2013. Variability in trawl estimates of hoki was reflected in both the catch rates and the proportion of hoki in the total catch. For example, hoki made up 44–92% of the catch by substrata in the northern area (excluding the new stratum 4D) in 2012, but were only 17–40% of the catch in equivalent strata in 2000, and 36–77% in 2013 (O'Driscoll et al. 2015).

O'Driscoll et al. (2015) explored possible hypotheses to explain the variability in trawl survey abundance of hoki including:

1. Changes in spatial distribution (especially proportion of fish in the northern area);
2. Changes in vertical availability of hoki to the trawl;
3. Differences in survey method.

Although the acoustic survey provided some evidence for an increased proportion of hoki in the northern area in 2012–13 compared to 2000, this was not enough to explain the large changes in trawl abundance. In 2013, about 38% of the hoki acoustic abundance (estimated using the 'old' method) was in the northern strata compared to 39% in 2012 and 25% in 2000.

Similarly, any change in trawl survey catchability between 2000, 2012, and 2013 WCSI surveys was unlikely to be related to changes in gear or gear performance. The trawl has been within consistent specifications in all surveys and the same specifications were used for other middle-depth surveys on the Sub-Antarctic and Chatham Rise. The catch of other species over the same period did not show the same variability as hoki, although core abundance of 12 of the top 20 species decreased from 2012 to 2013 (see Table 1).

O'Driscoll et al. (2015) concluded that the most likely explanation for variability in trawl indices for hoki was that there were changes in vertical availability. Acoustic backscatter observed in the bottom 10 m during bottom tows in 2012 was higher than that observed in 2000 and 2013 for most strata. The vertical distribution of acoustic backscatter recorded in the northern area in 2013 differed from that in 2012, with a higher proportion of backscatter displaced away from the bottom in 2013 (Figure 25). This may help explain the reduced trawl catch rates in 2013.

Regardless of the explanation, the amount of variability in northern trawl estimates on the WCSI is not consistent with changes in WCSI acoustic indices over the same period (see Table 5), estimated hoki abundance from trawl surveys in the Sub-Antarctic (Bagley et al. 2014), or western spawning stock biomass estimated from the hoki stock assessment model (McKenzie 2015). Trawl estimates of hoki on the WCSI were not included in the 2014 hoki assessment.

Annual variability in trawl estimates will also impact acoustic indices because trawl catches were also used to decompose acoustic estimates from hoki fuzz marks. There is a strong positive correlation between hoki catch rates and the proportion of hoki in the catch (number of tows, $n = 62$; Spearman's rank correlation, rho = 0.88; $p < 0.001$ in 2013). However, estimated changes in species composition are much less variable than hoki catch rates, so the effect of any changes in trawl catchability or availability will not be as great on acoustic indices as on trawl estimates. For example, if the catch composition from 2012 was used to decompose acoustic estimates from 2013, then the estimated abundance using the 'old' method would only increase by 3%. This is well within the estimated overall acoustic uncertainty (CV) of 35%.

Use in stock assessment

As noted above, trawl estimates of hoki on the WCSI were not included in the 2014 hoki assessment, as they were highly variable, and were not consistent with changes in WCSI acoustic indices or estimated hoki abundance from trawl surveys in the Sub-Antarctic over the same time period (McKenzie 2015).

Trawl abundance estimates from the 2000 and 2012 WCSI surveys were included as inputs into accepted stock assessments for ling and hake assessments in 2013.

The stock assessment for LIN 7WC (west coast South Island) was updated in 2013 (Dunn et al. 2013). Model input data include catch histories, trawl fishery CPUE, extensive catch-at-age data from the trawl fishery, sparse catch-at-age data from the line fishery, biomass estimates and proportion at age from comparable *Tangaroa* trawl surveys in 2000 and 2012, and estimates of biological parameters. A line fishery CPUE series was available, but was rejected as unlikely to be indexing stock abundance.

Both biomass indices (trawl survey and CPUE) provided information on the minimum biomass of the stock, but little information on the upper limit. The fit of the base run to the biomass indices was not good, with a trend in residuals, and a relatively high standard deviation of normalised residuals (SDNR) (Figure 26). In the base run, the information on the upper limit to estimated stock biomass came as much from priors as from observational data. The prior for the survey q was important in the model and was estimated using the Sub-Antarctic trawl survey priors as a starting point because the survey series in both areas used the same vessel and fishing gear. The WCSI survey area in the 200–650 m depth range comprised 6619 km^2; seabed area in that depth range in the entire LIN 7 WC biological stock area (excluding the Challenger Plateau) is estimated to be about 20 100 km^2. So, because biomass from only 33% of the WCSI ling habitat was included in the indices, the Sub-Antarctic prior on q was modified accordingly (i.e., 0.13 x 0.33 = 0.043), and the bounds were also reduced from [0.02, 0.30] to [0.01, 0.20] (Dunn et al. 2013).

The fits of the base run to the *Tangaroa* survey proportions-at-age observations were reasonable (Figure 27). The relatively poor fit of the base model to the first two recruited ages in the *Tangaroa* proportions-at-age for 2012 could not be resolved. It was suspected that it could even be a model artefact caused by the parameterisation of CASAL, as a base model run with the ageing error reduced to zero produced a better fit (Dunn et al. 2013).

The ling assessment was accepted by the DFAWG, with reservations. Given the issues in the assessment, the DFAWG did not consider that using the models for biomass projection was acceptable. The status of the LIN 7WC stock in 2013 was highly uncertain, although the absolute virgin biomass was highly likely to have been greater than 50 000 t, and the exploitation rate was not high. The data were not very informative about biomass, with the priors contributing as much as the data to the biomass estimates.

A new assessment for HAK 7 was carried out in 2013 using fisheries data up to the end of the 2010–11 fishing year (Horn 2013). The assessment used catch-at-age from the commercial fishery since 1989–90, two comparable *Tangaroa* research surveys (in 2000 and 2012), a CPUE series from 2001 to 2011, and estimates of biological parameters. As for ling (Dunn et al. 2013), the prior for the survey q was informative and was estimated using the Sub-Antarctic hake survey priors as a starting point. The WCSI survey area in the 200–800 m depth range comprised 12 928 km^2; seabed area in that depth range in the entire HAK 7 biological stock area (excluding the Challenger Plateau) is estimated to be about 24 000 km^2. So because biomass from only 54% of the WCSI hake habitat was included in the indices, the Chatham Rise prior on q was modified accordingly (i.e., 0.16 x 0.54 = 0.09), and the bounds were also reduced from [0.01, 0.40] to [0.01, 0.25] (Horn 2013).

Both abundance series (CPUE data since 2001 and biomass data from the two trawl surveys) were well fitted (Figure 28). Likelihood profiling indicated that the fishery catch-at-age data dominated, but the abundance indices were consistent with a B_0 in the relatively narrow range of 80 000–100 000 t (Horn 2013). The model fit to the trawl survey age data was also good (Figure 29).

The HAK 7 assessment in 2013 was accepted by the DFAWG. This was the first accepted assessment for this stock and differed from previous assessments through inclusion of reliable abundance indices: a CPUE series commenced when the deemed value scheme was introduced (2001), and so was believed to be less biased by changes in fishing practice and catch reporting behaviour; and two comparable trawl biomass indices from surveys that had covered a large proportion of the likely hake habitat off WCSI (Horn 2013). The assessment was indicative of a stock that had been steadily fished down throughout the 1990s, but is very likely to be currently above the management target of 40% B_0 set by the Ministry for Primary Industries. Horn (2013) noted that improved confidence in the assessment of this hake stock will probably be achieved if the winter research survey series is continued.

4.2 Specific Objective 2: Review the ability of the WCSI survey to provide information on the wider ecosystem.

4.2.2 Performance of trawl survey for Tier 2 and bycatch species

Survey timing

Trawl survey timing was not specifically evaluated in relation to other associated species. With the exception of jack mackerel, most of the catch of other deepwater species on the WCSI is taken in the June to September period of the hoki fishery, with little catch outside this period (see Appendix 1).

The best available data on the abundance and distribution of species on the WCSI outside June–September is from a series of six research trawl surveys from *W.J. Scott* in 1981–1983 (Hurst & Fenaughty 1985). These surveys covered the region from Cape Farewell to the northern edge of the Hokitika Trench in depths from 20–652 m. Trawls were carried out in a systematic design along transects 5 n. miles wide and 10 n. miles apart (Figure 30). Random tows (each of duration 1 hour) were carried out in nine pre-determined depth ranges, using a trawl with 9 m wingspread, 80 m doorspread, and 100 mm codend. Surveys were carried out in Jun–Aug 1981, Sep 1981 – Feb 1982, Mar–Jul 1982, Jul–Oct, 1982, Oct 1982 – Feb 1983, and Feb–Apr 1983. A number of species (including hoki, hake, common and silver warehou) were most abundant during the winter period, while other species (ling, frostfish, lookdown dory, stargazer, tarakihi, northern spiny dogfish, spiny dogfish) had more consistent abundance estimates between survey periods (Table 7), suggesting that survey timing may be less critical for these species.

Spatial and depth coverage
O'Driscoll et al. (2011a) explored the spatial and depth coverage of the trawl survey component for nine associated species (barracouta, jack mackerel, silver warehou, frostfish, spiny dogfish, ribaldo, gemfish, stargazer, lookdown dory) based on all TCER and TCEPR records of estimated catch in FMA 7, 1 June – 30 September from 2000 to 2010 where bottom depth 100 to 1000 m. Analyses for these species were updated to include commercial data from 2011–13 and to show the 2012–13 survey boundaries. Spatial distribution plots are shown in Figure 31 and depth distribution plots as Figure 32.

Spatial distribution maps based on random trawl catches were also presented for 17 associated species (spiny dogfish, silver warehou, silver dory, giant stargazer, barracouta, school shark, northern spiny dogfish, tarakihi, alfonsino, smooth skate, sea perch, javelinfish, lookdown dory, dark ghost shark, shovelnosed dogfish, ribaldo, and arrow squid) from surveys in 2012 (Figure 33) and 2013 (Figure 34).

Data from commercial fisheries (Figures 31–32) and the two most recent trawl surveys (Figure 33–34) show that the current trawl survey area appears to have an appropriate spatial and depth distribution in the northern area for silver warehou, silver dory, alfonsino, smooth skate, sea perch, javelinfish, lookdown dory, and dark ghost shark.

Coverage of species with a more inshore distribution (giant stargazer, spiny dogfish, barracouta, school shark, northern spiny dogfish, jack mackerel, frostfish, arrow squid, and tarakihi) was improved by the inclusion of shallower strata (1&2S and 4S) from 200–300 m, but densities of these nine species are still likely to be considerable inshore of 200 m.

The survey does not extend deep enough for shovelnosed dogfish. Ribaldo also occur deeper and are adequately covered in stratum 4D, but not further north as stratum 1&2 only goes to 650 m. There would therefore be advantages in adding a deeper stratum 1&2D from 650–800 m for ribaldo.

Biological sampling
In 2012 and 2013, all items in the catch were sorted into species and weighed on Marel motion-compensating electronic scales accurate to about 0.1 kg. Where possible, finfish, squid, and crustaceans were identified to species and other benthic fauna were identified to species, genus, or family. Unidentified organisms were collected and frozen at sea for subsequent identification ashore.

An approximately random sample of up to 200 individuals of each commercial, and some common non-commercial, species from every successful tow was measured and sex determined. More detailed biological data were also collected on a subset of species and included fish weight, sex, gonad stage, gonad weight, and occasional observations on stomach fullness, contents, and prey condition. Otoliths were also taken from silver warehou for future ageing work.

Using this protocol, in 2012, 191 species or species groups was recorded from all trawl tows, 39 842 fish and squid individuals from 100 different species were measured, and 12 001 fish were also individually weighed (Table 8). In 2013, 162 species or species groups were recorded, 38 300 fish and squid individuals from 91 different species were measured, and 12 431 fish were also individually weighed (Table 9).

Scaled length frequency distributions were generated for 16 associated species (sea perch, lookdown dory, tarakihi, giant stargazer, ribaldo, barracouta, dark ghost shark, alfonsino, arrow squid, silver dory, school shark, smooth skate, spiny dogfish, northern spiny dogfish, shovelnosed dogfish, silver warehou) in 2012 and 2013 (Figure 35). Comparison of length frequencies with those from the *Kaharoa* inshore trawl series which covers 20–400 m depth (MacGibbon & Stevenson 2013), showed that the trawl survey component does not catch smaller barracouta, giant stargazer, school shark, spiny dogfish, and tarakihi which were observed by the 2011 and 2013 inshore surveys.

Gonad staging showed that many species were in spawning condition during the survey (O'Driscoll et al. 2015). Most female hoki, hake, and silver warehou were maturing (gonad stage 3). Other species of teleosts with more than 90 females sampled and over 50% of fish in maturing or spawning condition (gonad stages 3–6) included giant stargazer, silver dory, barracouta, Bollon's rattail and Oliver's rattail. Many female lookdown dory and tarakihi were post-spawning (gonad stage 7), while most javelinfish and ribaldo were resting (gonad stage 2). For elasmobranchs, 68% of the spiny dogfish females had pups (stage 5).

Quality of abundance indices
For the 17 non-target species (i.e., excluding hoki, hake, and ling) in Table 1, abundance in core survey strata was relatively precisely estimated (sampling CV less than 25% in 2000–13) for lookdown dory, sea perch, javelinfish, and squid. With inclusion of deeper and shallower strata in 2012–13 relatively precise estimates were also obtained for school shark, giant stargazer, dark ghost shark, tarakihi, and ribaldo (Tables 10–11). The shallow strata between 200–300 m accounted for most of the abundance of giant stargazer, barracouta, northern spiny dogfish and tarakihi, and were also important for school shark and silver dory. The deep stratum 4D (650–800 m) had higher abundance estimates for hake, ribaldo and shovelnosed dogfish (Tables 10–11).

Length frequency distributions for the 16 species plotted were relatively consistent between surveys in 2012 and 2013 (Figure 35), suggesting that the trawl survey was measuring the same population in each survey.

For most of the Tier 2 species, the trawl survey provides the only fisheries-independent estimate of abundance on the WCSI, as well as providing biological data (length, sex, reproductive condition, age, etc.). It is difficult to assess the "quality" of trawl estimates for many of these species based on surveys in 2000–13, as there are often no alternative indices of abundance (either from stock assessment or reliable CPUE indices). However, the relatively good precision (CVs) of survey estimates, consistency of abundance estimates and length frequency distributions between surveys, and appropriate spatial and depth distribution, suggest that the WCSI survey provides potential for monitoring species including lookdown dory, sea perch, silver warehou, javelinfish, dark ghost shark, and ribaldo.

McGregor (in press b) developed a CPUE index for silver warehou on the WCSI. The unstandardised arithmetic and geometric CPUE series had a peak in 2000–01, with lower catch rates in 2007–11 (Figure 36). This was broadly consistent with WCSI trawl survey estimates for silver warehou from core strata which declined from 2000 to 2012–13 (see Table 1). However, McGregor (in press b) concludes that CPUE will most likely not provide a reliable relative abundance indicator for silver warehou. Estimates of CPUE for lookdown dory on the WCSI should be relatively free of biases (Ballara 2014). Lookdown dory CPUE indices were also consistent with the trawl survey indices, with neither time-series showing strong trends from 2000–13 (Figure 37). Estimated CPUE from WCSI ribaldo fisheries (MacGibbon in press b) were relatively flat, but ribaldo were not well sampled by the WCSI survey until a deeper (650–800 m) stratum was added in 2012 so there was not a long enough time period to compare CPUE trends with those from the trawl survey (Figure 38). Both Ballara (2014) and MacGibbon (in press b) recommended that continuation of middle depth WCSI trawl surveys would be beneficial for improving monitoring of lookdown dory and ribaldo respectively. Recent fisheries characterizations have also been carried out for sea perch (Bentley et al. 2014b), and dark ghost shark (MacGibbon in press a), but these did not include CPUE series for the WCSI.

Trawl estimates of dark ghost shark, giant stargazer, school shark, spiny dogfish, northern spiny dogfish, sea perch, and tarakihi were compared with those from the *Kaharoa* inshore trawl series which covers 20–400 m depth (MacGibbon & Stevenson 2013). However this comparison was not useful, because all these species have a predominantly inshore distribution and so were poorly sampled by the WCSI trawl and acoustic survey until shallower (200–300 m) strata were added in 2012–13. Estimates from these two years did not span a long enough time period to detect whether estimates for these species showed similar trends to those from the much longer (1992–2013) *Kaharoa* series.

Use in stock assessments
None of the other stocks of species potentially monitored by the WCSI surveys are currently formally assessed (Ministry for Primary Industries 2014).

4.2.3 Ability of survey to provide ecosystem indicators

Understanding change in the marine ecosystem is becoming increasingly important to provide context for fisheries management and decision making about sustainable fishing. Indicators are important for monitoring different types of change, and more than one type of indicator is required, particularly within the context of climate change.

Biological sampling
This level of biological sampling is among the most comprehensive of any New Zealand survey. As noted in Section 4.2.2, all items in the catch are sorted and weighed, and a large numbers of individuals are measured and weighed (see Tables 8–9). In the future this high level of sampling will allow development of ecosystem indicators. Ecosystem indicators derived from trawl survey data have been developed elsewhere, and used successfully to identify the effects of fishing on fish communities (review by Tuck et al. 2009). The most commonly used indicators have been based on measures of diversity or fish size (mean size or size spectra), but indicators incorporating trophic level have also been considered.

Routine data collection of catch weight by species by tow means that most of the species-based indicators could be calculated for the full WCSI trawl data set. Numbers at length allow estimation of size-based indicators for all common species. Additional information on maturity, age, and weight at length are recorded for a subset of species. Life history or functional group and trophic level information is available from the internet, from sites like FishBase, and this would allow application of trophodynamic indicators, even though there are no direct observations on feeding on the WCSI.

Development of ecosystem indicators requires a time-series of surveys with consistent protocols (Tuck et al. 2009). Currently, species-based indicators could be estimated for the core survey area in 2000–13, but size-based indicators could only be calculated for 2012–13, when a much wider range of species was measured.

Acoustic data
As well as along acoustic transects, acoustic data are recorded during all trawls and while steaming between stations during the trawl survey component. On the Chatham Rise and Sub-Antarctic trawl surveys, acoustic data have been analysed to describe mark types (e.g., Bull 2000), to provide estimates of the ratio of acoustic vulnerability to trawl catchability for hoki and other species (O'Driscoll 2003), and to estimate abundance of mesopelagic fish (McClatchie & Dunford 2003, McClatchie et al. 2005, O'Driscoll et al. 2009, 2011b). Acoustic data also provide qualitative information on the amount of backscatter that is not available to the bottom trawl, either through being off the bottom, or over areas of foul ground (see Figure 25).

Mesopelagic fish form a major component of the diet of species such as hoki (Connell et al. 2010) and may also feed on hoki eggs, yet little is understood about how the distribution and abundance of mesopelagic fish influences the spatial distribution, abundance and growth of their predators. The links between mesopelagic biomass and predator-prey consumption estimates are important for input into trophic models, and provide background information with which to make assessments about the status of fishstocks and changes in ecosystem indicators. Acoustic data collected from the water column during the WCSI survey have the potential to determine both the relative abundance of mesopelagic fish from year to year and the distribution throughout the water column and survey areas (e.g., O'Driscoll et al. 2011b). By exploring these data in conjunction with hydrographic data collected during the surveys (see below) and remotely sensed data available from the survey time periods (e.g. SST, chlorophyll a), links to climate and hydrographic conditions may also be discernible.

Oceanography
Measurements of water temperature and salinity were made on all bottom trawls (both random and targeted) in 2012 and 2013 using a calibrated Seabird SM-37 Microcat conductivity-temperature-depth sensor (CTD). Temperature data from earlier WCSI surveys were collected from an uncalibrated net-monitor and were not considered reliable.

These CTD data are potentially useful as a means of ground-truthing remote sensing observations, and as a means of monitoring oceanographic conditions at the time of the survey to help interpret acoustic, trawl, and ecosystem indices. For example, CTD data from the Sub-Antarctic trawl survey were analysed as part of a PhD project (Aitana Forcen-Vazquez, Victoria University of Wellington), and are currently being used to determine whether there are changes in environmental processes which may have driven a change in hoki catchability (Ministry for Primary Industries Research Project DEE2014/01).

4.3 Specific Objective 3: Identify potential changes that may improve the results of future surveys, both trawl and acoustic components.

4.3.1 Potential changes to acoustic survey component

Vessel and gear
There is no specific vessel requirement for the acoustic survey component. The survey vessel requires a calibrated 38 kHz echosounder and must be able to carry out directed fishing on marks using both midwater and bottom trawl gear. A towed acoustic system is desirable as acoustic data quality from hull-mounted transducers deteriorates markedly at wind speeds greater than about 20 knots and swell heights greater than about 2 m. Such conditions occur frequently during the hoki spawning season on the WCSI (e.g., Figure 39). During surveys on research vessels, lost days are minimised by using a towbody which gets the acoustic transducers down about 30 m below the surface, away from surface bubbles, and can be used in up to 40 knots of wind and 4 m swells, greatly increasing the opportunity for acoustic data collection. This option significantly reduces the risks associated with acoustic data collection and also the potential costs by reducing the number of vessel days required. Currently, the NIWA towbody system is not easily deployed from an industry vessel, but other towed systems (e.g., trawl-mounted acoustic optical system, AOS) are available which can be used from industry vessels. A disadvantage of an AOS system for the WCSI acoustic survey is that towing speed is limited to 5–6 knots, compared to the NIWA towed body which is used at 8–10 knots. Each acoustic snapshot of the WCSI typically consists of 1000 n. miles of transects (including joining legs) which takes 4–5 days to complete at 8–10 knots (with no allowance for trawling). The same snapshot would take 8–9 days at 5–6 knots. A multifrequency acoustic system is not required for acoustic surveys of the WCSI as the main species found in association with hoki also have gas-filled swimbladders, so have a similar frequency response.

It would be possible to carry out the survey components using two or more vessels. For example, the trawling component could be carried out by *Tangaroa*, while the acoustic snapshots could be carried out from another vessel(s).

Options for acoustic survey vessels other than *Tangaroa* include *Kaharoa* and also commercial fishing vessels. *Kaharoa* can use NIWA's existing towed acoustic system, but because it is a much smaller than *Tangaroa*, it is unable to work in rough sea conditions and the average time taken to complete a snapshot would be likely to increase. *Kaharoa* is also unable to trawl (for mark identification) deeper than about 400 m. Use of an industry vessel may be more cost effective if the vessel can "pay for itself" by continuing to fish commercially during the survey (e.g., O'Driscoll & Macaulay 2005). However, because of the size of the WCSI survey area, the fishing success of the vessel is likely to be reduced when transects are away from the peak hoki densities, and this will reduce the savings. Snapshots from an industry vessel would also take longer if the vessel is also commercially fishing. As described above, a major limitation for an industry vessel using a hull-mounted acoustic system is the weather.

Criteria for vessel selection for acoustic surveys are described in detail by ICES (2007). Key factors in choosing a vessel are that it has (in order of importance):

- Acoustic and ancillary equipment suitable to support scientific objectives already fitted or able to be installed. A minimum requirement is a stable, digital system, which can be scientifically calibrated, and allows control over the output data (ICES 2007). Systems with split-beam transducers are generally preferred because these systems facilitate calibration and target strength measurements. GPS data are also required and need to be properly interfaced with the acoustic instrument.
- Suitable sea-going, vessel-noise characteristics, and transducer placement so that acoustic data are of scientific quality. Signal quality from hull-mounted transducers typically deteriorates markedly at wind speeds greater than about 20 knots and swell heights greater than about 2 metres. Using towed acoustic systems gets acoustic transducers down below the surface, away from surface bubbles, and can be used in up to 40 knots of wind and 4 m swells, greatly increasing the opportunity for acoustic data collection. However towed systems require specialised winches and equipment for deployment and retrieval which are typically found only on research vessels.
- Demonstrated commitment to scientific research objectives. In particular, the ability to follow protocols related to survey methodology.
- Capability to carry out biological sampling to provide information on the size and species composition of marks observed acoustically. The acoustic survey vessel requires the ability to trawl using both midwater and bottom gear, and must have suitable facilities and space to allow accurate catch estimation and measurement of fish.
- Space for accommodation of a minimum of six scientific personnel for acoustics and biological sampling.
- Competitive pricing.

Survey timing

Available data indicate the recent timing of the acoustic survey for hoki is appropriate. These surveys have centred on 5 August. Simulations by Francis & O'Driscoll (2004) suggested that CVs increased if surveys were either later or earlier. However, the optimal timing of 5 August was strongly determined by the distributions of arrival date and residence time. For example, if the range of mean arrival dates were widened to allow mean arrival to be later in August, then the optimal survey mid-date would also shift later, to 12 August (Francis & O'Driscoll 2004). The analyses of Harley (2002) and Francis & O'Driscoll (2004) could potentially be updated with inclusion of more recent data to better inform timing of the acoustic survey.

Vessel days and sampling effort

As noted above, hoki have a long spawning season on the WCSI and there is a turnover of fish on the grounds. Therefore, there is no time at which all of the spawning fish are available to be surveyed ('transient population'). The acoustic survey design devised to deal with this problem consists of a number of sub-surveys or "snapshots" spread over the spawning season. Each snapshot consists of a series of random transects (following the design of Jolly & Hampton (1990)) across strata covering the known distribution of spawning hoki. Estimates of spawning biomass are calculated for each of the snapshots, and these are then averaged to obtain an estimate of 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.

About 160 hours (6.6 days) is required to complete each acoustic snapshot of the entire WCSI acoustic survey area. This is based on about 1000 n. miles of transects (including joining legs) which take 125 hours (5.2 days) to steam at 8 knots, and allowing 35 hours (1.4 days) for about 10–12 targeted trawls per snapshots (trawls typically take 2–4 hours of survey time depending on depth). This timing does not include allowance made for bad weather, steaming to and from the survey area, vessel mobilisation and demobilisation, or failure of acoustic equipment. Acoustic surveys can be carried out day and night.

Francis & O'Driscoll (2004) carried out simulations to investigate the effects of survey timing and number of snapshots on the overall uncertainty of the northern and southern acoustic indices. Increasing the number of snapshots reduces the expected CV, particularly in the northern area (Table 12). In the south, the gains (in terms of reduction in uncertainty) from increasing the number of snapshots were small relative to those which could be obtained by improving survey timing. We might conclude from Table 12, that two snapshots of the southern area are sufficient to give a low CV (27%)

and there would be little gain from additional snapshots. This is true under the simulation conditions, which assumed that the timing of all simulated surveys, regardless of the number of snapshots, was optimal. If the timing is sub-optimal (or if our assumptions about the distributions of arrival dates and residence time are wrong), then longer surveys with more snapshots are more robust than shorter ones. For example, a survey of the southern area with five snapshots gave an estimated CV less than 30% with survey mid-dates between 28 July and 15 August, while a survey with two snapshots gave a CV less than 30% only if it was centred between 2 and 10 August (Francis & O'Driscoll 2004). This was because a short survey increased the probability of missing the period of peak abundance if there was variation in the timing of the spawning season. In both areas, simulations suggested that there was little advantage in having a survey with more than four snapshots.

Table 12 also shows the estimated time on the grounds required (to the nearest day) for surveys of the northern and southern areas with varying number of acoustic snapshots. The simulated CVs are based on an optimal timing (survey centred on 5 August). The total survey time duration is the sum of the times for the northern and southern components, with approximately 4 days for vessel mobilisation and demobilisation, echosounder calibration, and steaming to and from port. We recommend that the minimum requirement is two acoustic snapshots in the northern area and three acoustic snapshots in the southern area. This would require approximately 6 + 10 + 4 = 20 vessel days. However, the acoustic survey in the northern area relies on extensive trawling to enable species decomposition. In the current combined survey design this is mainly provided by the random trawl survey component. If the acoustic and trawl surveys were decoupled, at least another 3 days (equivalent to 18–24 tows) would need to be allocated to mark identification trawling in the northern area to ensure that there were sufficient trawls for species decomposition. This would bring the minimum number of vessel days required for an acoustic survey to 23.

The acoustic survey in 2012 had three snapshots of both the northern and southern area with a sampling CV of 15% and an overall uncertainty of 34% (39% in the north and 30% in the south) (O'Driscoll et al. 2014). The acoustic survey in 2013 had three snapshots in the southern area and two in the north (i.e., recommended minimum) with a sampling CV of 13% and an overall uncertainty of 35% (50% in the north and 26% in the south) (O'Driscoll et al. 2015).

Quality of abundance indices

The DFAWG recommended that the 'revised' series incorporating the most recent TS-L relationship should be adopted for future hoki assessments, once the priors on acoustic q were formally updated. This would resolve the inconsistency between acoustic estimates from the WCSI and Cook Strait, which are currently calculated using different TS-L relationships and sound absorption.

Although choice of TS-L relationship will not have a major impact on hoki assessment, experimental work should continue to refine estimates of hoki TS. Measurements of TS based on recent AOS data remove uncertainty around target identification (as all are visually verified), but there is potential bias because fish are being herded into a trawl and their orientation may not be representative of free-swimming fish (Dunford et al. 2014). TS measurements from the AOS are also more likely to overestimate TS due to the potential bias in orientation, and therefore underestimate hoki abundance (Dunford et al. 2014).

Species decomposition remains a major source of uncertainty in acoustic estimates of hoki on the WCSI. The 'old' and 'revised' analysis methods assume that hoki contribute 100% of the backscatter from all hoki marks (schools and fuzz) outside the northern area. This is not consistent with catch composition from mark identification trawls on fuzz marks in strata 5B, 6, and 7 in 2012 and 2013. In 2012, 13 tows on fuzz marks south of Hokitika Canyon only caught an average of about 44% hoki by weight (O'Driscoll et al. 2014), and, in 2013, 9 tows caught an (unweighted) average of 57% hoki (O'Driscoll et al. 2015). O'Driscoll et al. (2015) suggested that the assumption of 100% hoki in marks in the southern area does not have a major impact on estimated relative hoki abundance. However, in future WCSI surveys consideration should be given to further increasing the level of mark identification trawling in the southern areas, or even introducing a random trawling component, to allow for more detailed decomposition by stratum.

4.3.2 Potential changes to trawl survey component

Vessel and gear

To allow comparability with results from the 2000–13 surveys, the trawl survey component needs to be carried out from *Tangaroa*. If an alternative vessel and/or gear is used for the trawl component, then this would have a different catchability coefficient and would represent the start of a new time-series, unless inter-calibration experiments are carried out.

Key advantages of using *Tangaroa* for the trawl survey component are:

- *Tangaroa* has been used in all previous surveys in existing time-series in the Chatham Rise, Sub-Antarctic, and the WCSI as described above.
- NIWA will make the *Tangaroa* available for all surveys in the 10YP and probably out to at least 2030 (barring accidents). This will minimise the need to conduct inter-calibration of vessels and gear to potentially once every

40 years. Such inter-calibration, if it follows international best practice, is very expensive and would need to be conducted on a survey specific basis.
- All vessel equipment and gear has been standardised as carefully as possible to ensure consistency between years. Examples include getting trawl mesh custom-built to match existing gear specifications, ensuring consistency when equipment is replaced (e.g., ensuring a new Scantrol winch control system installed in 2008 emulated the original Brattvaag system in use from 1991), and having experienced officers and crew, some of whom have been with the vessel since 1991.
- *Tangaroa* has factory and laboratory facilities custom-designed and built to carry out research surveys, including electronic fish measuring equipment, databases, and IT support. This electronic equipment is essential to allow for the most cost-efficient and effective data capture of the many species processed during trawl survey voyages.
- Accommodation for the large number of science staff (up to 13) required to collect the large amount of data required on multi-species and multi-objective trawl surveys.
- Using the same vessel for all survey series is cost effective in terms of gear preparation and maintenance and may provide relativity between surveys of the Chatham Rise, Sub-Antarctic, and WCSI to allow comparability of catch rates and fish length and age distributions between areas.

If another vessel is considered for the trawl component, then it must have the following key characteristics:
- Suitable sea-going capabilities to withstand weather and sea conditions on the WCSI.
- Demonstrated commitment to scientific research objectives. In particular, the ability to follow protocols related to survey methodology.
- Ability to bottom trawl to depths of 800 m.
- Commitment for the same vessel to be available at the same time of year over the next 10 years (and preferably beyond).
- Guaranteed consistency of trawl equipment including doors, winches, and electronics.
- Accommodation for a minimum of 8 science staff.
- Space for at least two workstations for weighing, measuring, and sampling fish, and for associated IT support.
- Calibrated scientific echosounder.
- Competitive pricing.

Survey timing

The timing of WCSI trawl surveys in 2000 and 2012–13 was driven by the need to obtain a concurrent acoustic index of spawning hoki. To allow comparability with results from the 2000–13 surveys, the trawl survey component needs to be carried out in July–August. If an alternate timing is adopted for the trawl component, then this would represent the start of a new time-series.

Spatial and depth coverage

The current trawl survey area appears to have an appropriate spatial and depth distribution in the northern area for hoki, hake, ling, silver warehou, silver dory, alfonsino, smooth skate, sea perch, javelinfish, lookdown dory, and dark ghost shark.

Coverage of species with a more inshore distribution (giant stargazer, spiny dogfish, barracouta, school shark, northern spiny dogfish, jack mackerel, frostfish, arrow squid, and tarakihi) might be improved by including shallower (100–200 m) strata.

The survey does not extend deep enough for shovelnosed dogfish. Ribaldo also occur deeper and are adequately covered in stratum 4D, but not further north as stratum 1&2 only goes to 650 m. There would therefore be advantages in adding a deeper stratum 1&2D from 650–800 m for ribaldo,

The trawl survey is restricted to the region north of Hokitika Canyon, but commercial catches (see Figures 15 and 31) show that the distribution of many species extends into the Hokitika Canyon and along the shelf to the south. The southern region is unsuitable for bottom trawling. Consideration needs to be given to testing the assumption that a constant proportion of the stock resides within the northern trawlable area.

Vessel days and sampling effort

The trawl estimate is based on a stratified random trawl survey design (after Francis 1984). Trawl procedures, the recording of tow parameters and species caught follow the standardised guidelines recommended by Hurst et al. (1992). All random bottom trawls must be carried out during daylight hours when a greater proportion of fish are near the bottom and catch rates are typically higher (O'Driscoll et al. 2004).

The number of trawls required can be estimated based on a statistical analysis of catch rate data from previous surveys using the allocate programme (Francis 2006). The allocation was re-calculated for this report based on data from the 2012 and 2013 surveys. A minimum of 3 and a maximum of 15 stations per stratum is used, with target sampling CVs of 20% for hoki, hake, and ling, and 25% for silver warehou, giant stargazer, spiny dogfish, sea perch, lookdown dory, and dark ghost shark (Table 13). Additional species can be included in the allocation if required by MPI. This allocation gives a similar number of stations (63) as the survey in 2013 when there were 65 valid tows and in 2012 when there were 63 valid tows. In 2012, CVs of 24% for hoki, 15% for ling, 13% for hake, and 27% for silver warehou were achieved over the entire survey area (O'Driscoll et al. 2014). In 2013, total CVs were 27% for hoki, 18% for ling, 21% for hake, and 22% for silver warehou (O'Driscoll et al. 2015). There is currently no allowance for phase 2 stations.

Based on our experience in 2000–13, an average of 4.2 random bottom tows could be carried out during daylight hours each day. This means that 15 days on the grounds would be required to complete the 63 random trawls required for the trawl estimate of the northern area.

Combined survey

In a combined survey design, acoustic transects are also run in the northern strata during the night, and two acoustic snapshots could also be completed in 15 nights. To achieve the minimum combined requirement of two acoustic snapshots and 63 random tows in the northern area and three acoustic snapshots in the southern area would require approximately 15 + 10 + 4 = 29 vessel days. Again we have allowed approximately 4 days for vessel mobilisation and demobilisation, echosounder calibration, and steaming to and from port. This is the same as the time allocated for the 2013 survey.

Biological sampling

This level of biological sampling is among the most comprehensive of any New Zealand survey. We do not recommend additional routine sampling, but note that targeted data collections (e.g., otoliths from additional species, or stomach contents) would be possible if required for specific projects.

As noted in Section 4.2.3, development of ecosystem indicators requires a time-series of surveys with consistent protocols. Any change to survey protocol (e.g. changes to survey timing, vessel, or gear) would mean future surveys were not comparable and would reduce our ability to provide ecosystem indicators in the next five years.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Utility of acoustic survey

- The WCSI survey provides relative acoustic indices of spawning hoki abundance.
- WCSI acoustic indices are not particularly influential in the current hoki stock assessment because of the relatively high estimated CVs which result in low weightings of the indices, but an independent panel of experts rated this series as the third most important series of surveys for hoki (behind Chatham Rise and Sub-Antarctic trawl surveys).
- The current acoustic survey area and timing is appropriate for hoki.

5.2 Utility of trawl survey

- Trawl surveys provide fisheries-independent estimates of abundance for hake, ling, and associated middle depth species.
- Improved confidence in the (currently uncertain) assessments of HAK 7 and LIN 7WC stocks will probably be achieved if the WCSI research survey series is continued.
- Trawl estimates from the northern area do not appear to be providing reliable indices of hoki abundance.
- The current trawl survey area appears to have an appropriate spatial and depth distribution in the northern area for hoki, hake, ling, silver warehou, silver dory, alfonsino, smooth skate, sea perch, javelinfish, lookdown dory, and dark ghost shark.
- Trawl estimates also provide data that could be used in the future to develop species-based, size-based, and trophodynamic ecosystem indicators.

5.3 Recommendations for future surveys

- To allow comparability with results from the 2000–13 surveys, the trawl survey component needs to be carried out from *Tangaroa*. If an alternative vessel and/or gear is used for the trawl component, then this would have a different catchability coefficient and would represent the start of a new time-series, unless inter-calibration experiments are carried out.

- There is no specific vessel requirement for the acoustic survey component. The survey vessel requires a calibrated 38 kHz echosounder and must be able to carry out directed fishing on marks using both midwater and bottom trawl gear. A towed acoustic system is desirable.

- It would be possible to carry out the trawl and acoustic survey components using two or more vessels. For example, the trawling component could be carried out by *Tangaroa*, while the acoustic snapshots could be carried out from another vessel(s).

- The timing of the acoustic survey is determined by the timing of hoki spawning and simulations based on estimated arrival dates and residence times indicate that acoustic surveys of WCSI should have a mid-date of about 5 August.

- To allow comparability with results from the 2000–13 surveys, the trawl survey component also needs to be carried out in July–August.

- If an alternate timing is adopted for the trawl component, then this would represent the start of a new time-series.

- Carrying out the trawl survey outside the June–September period would be risky, as the distribution and abundance of hake and ling on the WCSI outside the main period of commercial fishing is poorly known.

- The minimum requirement for an acoustic survey is two snapshots in the northern area and three acoustic snapshots in the southern area. This requires approximately 23 vessel days (including 4 days for vessel mobilisation and demobilisation, echosounder calibration, and steaming to and from port).

- The minimum requirement for a trawl survey (to achieve suggested target CVs) requires about 63 random tows. This requires about 15 days on the grounds to complete, as trawling can only be carried out in daylight hours.

- In a combined survey design, acoustic transects are run in the northern strata during the night. To achieve the minimum combined requirement (two acoustic snapshots and 63 random tows in the northern area and three acoustic snapshots in the southern area requires) is approximately 29 vessel days (again allowing 4 days for vessel mobilisation and demobilisation, echosounder calibration, and steaming to and from port).

- The current level of biological sampling on the WCSI surveys is among the most comprehensive of any New Zealand survey. We do not recommend additional routine sampling, but note that targeted data collections (e.g., otoliths from additional species, or stomach contents) would be possible if required for specific projects.

6. PUBLICATIONS

None.

7. DATA STORAGE

No new data were generated for this project. Maps showing distribution of commercial catch of a range of species in FMA7 are included in this report and will be provided electronically.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

Bagley, N.W.; Ballara, S.L.; O'Driscoll, R.L.; Fu, D.; Lyon, W. (2013). A review of hoki and middle depth summer trawl surveys of the Sub-Antarctic, November December 1991–1993 and 2000–2009. *New Zealand Fisheries Assessment Report 2013/41*. 63 p (plus supplements).

Bagley, N.W.; Oeffner, J.; O'Driscoll, R.L. (2014). Trawl survey of hoki and middle-depth species in the Southland and Sub-Antarctic areas, November–December 2012 (TAN1215). *New Zealand Fisheries Assessment Report 2014/12*. 69 p.

Baird, S.J.; Ballara S.L. (in press). Fishery characterisation and standardised CPUE analyses for spiny dogfish, *Squalus acanthias*, 1989–90 to 2010–11. *New Zealand Fisheries Assessment Report*.

Ballara, S.L. (2013). Descriptive analysis of the fishery for hake (*Merluccius australis*) in HAK 1, 4 and 7 from 1989–90 to 2010–11, and a catch-per-unit-effort (CPUE) analysis for Chatham Rise and WCSI hake. *New Zealand Fisheries Assessment Report 2013/45*. 82 p.

Ballara, S.L. (2014). Fishery characterisation and standardised CPUE analyses for lookdown dory, *Cyttus traversi* (Hutton, 1872) (Zeidae), 1989–90 to 2011–12. *New Zealand Fisheries Assessment Report 2014/62*. 263 p.

Ballara S.L.; Baird, S.J. (2012). Fishery characterisation and standardised CPUE analyses for white warehou, *Seriolella caerulea*, 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2012/49*. 265 p.

Ballara, S.L.; O'Driscoll, R.L. (2014a). Hoki data collation: A report to the 2014 Hoki Working Group on the hoki trawl and acoustic surveys, catches, CPUE, size, and age structure of the hoki fishery including the 2012-13 data update. Version 11.1, 1 March 2014.

Ballara, S.L.; O'Driscoll, R.L. (2014b). Catches, size, and age structure of the 2012–13 hoki fishery, and a summary of input data used for the 2014 stock assessment. *New Zealand Fisheries Assessment Report 2014/41*. 123 p.

Bentley, N.; Kendrick, T.H.; MacGibbon, D.J. (2014a). Fishery characterisation and catch-per-unit-effort analyses for frostfish (*Lepidopus caudatus*), 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2014/25.*

Bentley, N.; Kendrick, T.H.; MacGibbon, D.J. (2014b). Fishery characterisation and catch-per-unit-effort analyses for sea perch (*Helicolenus* spp.) in New Zealand, 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2014/27*.

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

Butterworth, D.; Hilary, R.; Ianelli, J. (2014). Report on the review of the New Zealand hoki stock assessment model. Report to the Ministry for Primary Industries, 4 March 2014. 17 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

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

Connell, A.M.; Dunn, M.R.; Forman, J. (2010). Diet and dietary variation of New Zealand hoki *Macruronus novaezelandiae*. *New Zealand Journal of Marine and Freshwater Research 44*: 289–308.

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

Cordue, P.L.; McAllister, M.K.; Pikitch, E.K.; Sullivan, K.J. (1992). Stock assessment of hoki 1991. New Zealand Fisheries Assessment Research Document 92/10. 41 p. (Unpublished report held by NIWA library, Wellington.)

Dunn, M.R.; Edwards, C.T.T.; Ballara, S.L.; Horn, P.L. (2013). Stock assessment of ling (*Genypterus blacodes*) in Cook Strait and off the West Coast South Island (LIN 7), and a descriptive analysis of all ling fisheries, for the 2012–13 fishing year. *New Zealand Fisheries Assessment Report 2013/63*. 102 p.

Dunford, A.J.; O'Driscoll, R.L.; Oeffner, J. (2014). Improvements in estimating an acoustic target strength–length relationship for hoki (*Macruronus novaezeladiae*). *Fisheries Research 162*: 12–19.

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

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

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

Harley, S.J. (2002). Estimation of residence time for hoki on the Cook Strait and west coast South Island spawning grounds. *New Zealand Fisheries Assessment Report 2002/1*. 55 p.

Horn, P.L. (2013). Stock assessment of hake (*Merluccius australis*) on the Chatham Rise (HAK 4) and off the west coast of South Island (HAK 7) for the 2012–13 fishing year. *New Zealand Fisheries Assessment Report 2013/31*. 58 p.

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

Hurst, R.J.; Fenaughty, J.M. (1985). Report on biomass surveys 1980–84: summaries and additional information. Fisheries Research Centre Internal Report No. 21. 53 p. (Unpublished report held in NIWA library, Wellington.)

ICES (2007). Collection of acoustic data from fishing vessels. *ICES Cooperative Research Report No. 287.* 83 p.

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

Macaulay, G. (2001). Estimates of the target strength of hoki. Final Research Report for Ministry of Fisheries Research Project HOK1999/03 Objective 3. 12 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Macaulay, G.J. (2006). Target strength estimates of hoki. Final Research Report for Ministry of Fisheries Project HOK2004/03 Objective 3. 13 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Macaulay, G.J.; Dunn, A. (2000). The feasibility of using acoustic techniques to estimate hake biomass on the west coast, South Island. *New Zealand Fisheries Assessment Report 2000/35*.

MacGibbon, D.J. (in press a). Fishery characterisation and standardised CPUE analyses for dark ghost shark, *Hydrolagus novaezealandiae* (Fowler, 1911) (Chimaeridae), 1989–90 to 2010–11. *New Zealand Fisheries Assessment Report*.

MacGibbon, D.J. (in press b). Fishery characterisation and standardised CPUE analyses for ribaldo, *Mora moro* (Risso, 1810) (Moridae), 1989–90 to 2012–13. *New Zealand Fisheries Assessment Report*.

MacGibbon, D.J.; Stevenson, M.L. (2013). Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2013 (KAH1305). *New Zealand Fisheries Assessment Report 2013/66*. 115 p.

McClatchie, S.; Dunford, A. (2003). Estimated biomass of vertically migrating mesopelagic fish off New Zealand. *Deep-Sea Research Part I 50*: 1263–1281.

McClatchie, S.; Pinkerton, M.; Livingston, M.E. (2005). Relating the distribution of a semi-demersal fish, *Macruronus novaezelandiae*, to their pelagic food supply. *Deep-Sea Research Part I 52*: 1489–1501.

McGregor, V. (in press a). Fishery characterisation and standardised CPUE analyses for barracouta, *Thyrsites atun* (Euphrasen, 1791) (Gempylidae), 1989–90 to 2010–11. *New Zealand Fisheries Assessment Report*.

McGregor, V. (in press b). Fishery characterisation and standardised CPUE analyses for silver warehou (*Seriolella punctata*) in SWA 1, 3 and 4, 1997-98 to 2010–11. *New Zealand Fisheries Assessment Report*.

McKenzie, A. (2015). Assessment of hoki (*Macruronus novaezelandiae*) in 2014. *New Zealand Fisheries Assessment Report* 2015/09.

Ministry for Primary Industries (2014). Report from the Fisheries Assessment Plenary, May 2014: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1381 p.

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

O'Driscoll, R.L. (2003). Determining species composition in mixed species marks: an example from the New Zealand hoki (*Macruronus novaezelandiae*) fishery. *ICES Journal of Marine Science 60*: 609–616.

O'Driscoll, R.L. (2004). Estimating uncertainty associated with acoustic surveys of spawning hoki (*Macruronus novaezelandiae*) in Cook Strait, New Zealand. *ICES Journal of Marine Science 61*: 84–97.

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

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

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

O'Driscoll, R.L.; Gauthier, S.; Devine, J. (2009). Acoustic surveys of mesopelagic fish: as clear as day and night? *ICES Journal of Marine Science 66*: 1310–1317.

O'Driscoll, R.L.; Horn, P.L.; Ballara, S.L.; MacGibbon, D. (2011a). Design & methodology for trawl survey of hoki and middle depth fish abundance on the West Coast South Island. Presentation to the Hoki Fisheries Assessment Working Group, Ministry for Primary Industries, Wellington, 14 December 2011. Project HOK2010/04A.

O'Driscoll, R.L.; Hurst, R.J.; Dunn, M.R.; Gauthier, S.; Ballara, S.L. (2011b). Trends in relative biomass using time series of acoustic backscatter data from trawl surveys. *New Zealand Aquatic Environment and Biodiversity Report No. 76*. 99 p.

O'Driscoll, R.L.; Macaulay, G.J. (2005). Using fish processing time to carry out acoustic surveys from commercial vessels. *ICES Journal of Marine Science 62*: 295–305.

O'Driscoll, R.L.; MacGibbon, D.; Fu, D.; Lyon, W.; Stevens, D.W. (2011c). A review of hoki and middle depth trawl surveys of the Chatham Rise, January 1992–2010. *New Zealand Fisheries Assessment Report 2011/47*. 814 p.

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

Table 1: Trawl abundance estimates, coefficients of variation comparisons for the core strata (300–650 m) from the 2000, 2012, and 2013 WCSI trawl surveys. The 2000 survey abundance estimates were re-calculated using 2012–13 stratum areas. Giant stargazer was coded as STA, and tarakihi was TAR in 2000. From O'Driscoll et al. (2015).

		Core area abundance (t) and CV (%)		
Common name	Code	2000	2012	2013
Hoki	HOK	5 385 (20.6)	32 495 (24.2)	14 184 (26.9)
Ling	LIN	1 861 (17.3)	2 169 (14.8)	2 000 (18.4)
Barracouta	BAR	4 (42.8)	12 (42.8)	5 (52.1)
Silver dory	SDO	113 (62.0)	259 (46.5)	304 (77.9)
Spiny dogfish	SPD	233 (53.6)	1 095 (24.7)	867 (29.0)
Hake	HAK	803 (13.4)	583 (12.8)	331 (17.4)
Silver warehou	SWA	1 507 (24.6)	617 (32.2)	313 (22.7)
Smooth skate	SSK	186 (28.0)	167 (29.5)	228 (19.6)
School shark	SCH	98 (69.8)	186 (24.8)	159 (21.8)
Lookdown dory	LDO	169 (14.4)	155 (11.9)	205 (11.1)
Tarakihi	NMP	22 (32.2)	21 (41.7)	24 (48.5)
Giant stargazer	GIZ	74 (27.3)	97 (22.6)	92 (21.8)
Sea perch	SPE	123 (6.7)	136 (15.9)	126 (9.2)
Javelinfish	JAV	198 (17.4)	166 (11.3)	122 (13.1)
Alfonsino	BYS	14 (41.0)	262 (58.8)	120 (26.2)
Northern spiny dogfish	NSD	96 (23.1)	49 (20.4)	48 (29.5)
Ghost shark (dark)	GSH	77 (32.5)	106 (16.9)	75 (21.4)
Shovelnose spiny dogfish	SND	153 (29.5)	68 (70.6)	49 (24.8)
Arrow squid	SQU	18 (22.6)	95 (18.3)	28 (9.9)
Ribaldo	RIB	104 (26.3)	43 (25.3)	16 (29.9)

Table 2: Vessels, acoustic transducers, and timing of hoki acoustic surveys of the WCSI. From Ballara & O'Driscoll (2014a).

Year	Timing	Vessel	Trip Code	Transducer
1988	29 Jul – 25 Aug	*James Cook*	JCO8808, JCO8809, JCO8810	Simrad 38-26/22-E towed
1989	15 Jul – 15 Aug	*James Cook*	JCO8905, JCO8906, JCO8907	Simrad 38-26/22-E towed
1990	17 Jul – 31 Aug	*James Cook*	JCO9012, JCO9013	Simrad 38-29/25-E hull
1991	14–28 Jul	*Kaharoa*	KAH9108	EDO 6978 38 kHz towed
1992	2–12 Aug	*Tangaroa*	TAN9207	EDO 6978 38 kHz towed
1993	15 Jul – 14 Aug	*Tangaroa*	TAN9307	EDO 6978 38 kHz towed
1997	16 Jul – 9 Aug	*Tangaroa*	TAN9709	Simrad ES38DD_28326 towed Simrad ES38-12 towed
2000	25 Jul – 30 Aug	*Tangaroa*	TAN0007	Simrad ES38DD_28326 towed
2012	22 Jul – 18 Aug	*Tangaroa*	TAN1210	Simrad ES38_23083 hull Simrad ES38DD_28332B towed
2013	29 Jul – 20 Aug	*Tangaroa*	TAN1308	Simrad ES38_23083 hull Simrad ES38DD_28332B towed

Table 3: Stratum depth boundaries and areas for the 2012–13 WCSI surveys. Stratum locations are shown in Figure 4.

Stratum	Depth (m)	Area (km^2)
1&2S	200–300	1 450
1&2A	300–430	1 214
1&2B	430–500	1 028
1&2C	500–650	3 148
4S	200–300	1 600
4A	300–430	786
4B	430–500	592
4C	500–650	1 455
4D	650–800	1 655
5A	300–300	254
5B	position–position	529
6	250–850 (north of 42.85°S) 250–750 (south of 42.85°S)	2 165
7	position–position	565
Total		16 441

Table 4: Percentage of hoki biomass estimates by stratum for WCSI acoustic surveys in 2012 and 2013.

Year	Snapshot	12A	12B	12C	4A	4B	4C	4D	5A	5B	6	7
2012	1	2	3	1	19	8	5	0	25	3	24	10
	2	5	3	5	15	4	2	0	35	5	20	5
	3	22	5	8	3	4	1	0	14	7	32	5
2013	1	6	3	3	9	4	6	0	29	18	18	3
	2	19	10	2	3	1	3	0	13	20	22	6
	3	15	8	3	7	3	5	0	22	8	20	8

Table 5: Acoustic abundance indices for WCSI (from O'Driscoll et al. 2015). Indices using 'old' method updated from O'Driscoll (2002). Indices using 'revised' method based on O'Driscoll et al. (2014) but updated using hoki TS of Dunford et al. (2014) instead of Macaulay (2006). The CV is the estimated model weighting.

Year	'Old' Abundance ('000 t)	'Revised' Abundance ('000 t)	CV
1988	417	237	0.60
1989	249	147	0.38
1990	255	150	0.40
1991	341	203	0.73
1992	345	207	0.49
1993	549	347	0.38
1997	655	415	0.60
2000	397	237	0.28
2012	412	261	0.34
2013	357	210	0.35

Table 6: Number of trawls carried out on WCSI hoki acoustic surveys. From Ballara & O'Driscoll (2014a).

Year	Trip Code	Trawls
1988	JCO8808, JCO8809, JCO8810	86+
1989	JCO8905, JCO8906, JCO8907	50+
1990	JCO9012, JCO9013	24
1991	KAH9108	1*
1992	TAN9207	7*
1993	TAN9307	19
1997	TAN9709	30
2000	TAN0007	171
2012	TAN1210	90
2013	TAN1308	83

* Not recorded in trawl database
\+ Some tows outside main acoustic survey area

Table 7: Biomass estimates (B in thousands of tonnes) and percent coefficients of variation (c.v.) from *W.J. Scott* surveys, west coast South Island, 1981–1983. From Hurst & Fenaughty (1985).

	Period											
	1		2		3		4		5		6	
	B	c.v.	B	c.v.	B	c.v.	B	c.v.	B	c.v.	B	c.v.
Arrow Squid	9.7	22	8.8	16	8.1	12	2.9	14	6.3	21	10.8	14
Barracouta	60.3	14	30.4	12	24.7	16	27.0	26	27.8	15	14.1	40
Common warehou	8.8	29	3.1	44	3.3	46	5.9	28	1.1	35	0.5	35
Frostfish	0.6	22	0.3	24	1.1	27	1.1	30	1.5	33	2.6	50
Gemfish	6.1	23	10.0	21	13.3	16	5.7	15	8.6	19	8.6	22
Gurnard	1.8	40	3.5	25	4.3	25	4.6	21	3.7	29	4.2	33
Hake	6.6	30	0.1	33	0.1	51	4.4	35	0.2	34	3.6	51
Hoki	92.4	44	2.2	34	3.1	30	12.6	28	1.7	27	2.4	38
Jack mackerel	4.2	26	1.4	19	1.7	28	2.3	36	1.1	22	1.0	33
Lookdown dory	3.0	21	7.6	20	6.6	17	8.0	16	5.6	22	4.4	29
Ling	4.1	28	3.8	28	3.8	17	9.5	14	2.1	21	2.2	23
Red cod	2.1	52	4.0	39	3.3	24	4.5	34	3.9	23	11.5	33
Rig	1.6	32	4.7	16	3.2	15	3.4	18	3.3	16	2.7	28
School shark	19.9	31	11.3	11	16.1	19	6.4	15	5.7	22	3.2	29
Silver warehou	4.4	37	0.9	60	0.7	19	3.6	33	0.7	74	0.2	31
Nth. spiny dogfish	1.0	27	1.1	30	3.3	16	1.9	19	1.1	22	1.0	18
Sth. spiny dogfish	7.6	29	14.7	15	10.2	12	4.9	15	15.6	22	17.9	24
Stargazer	0.4	22	0.4	20	0.3	22	0.7	21	0.5	15	0.6	17
Tarakihi	11.3	22	9.7	11	9.3	18	9.8	11	8.8	13	5.7	20

* Period 1. 20 Jun.-30 Aug. 1981
2. 2 Sep.-22 Feb. 1982
3. 19 Mar.-2 Jul. 1982
4. 3 Jul.-16 Oct. 1982
5. 22 Oct.-13 Feb. 1983
6. 14 Feb.-21 Apr. 1983

Table 8: Numbers of fish for which length, sex, and biological data were collected on the 2012 WCSI survey.

	Length frequency data				Length-weight data	
	No. of fish measured			No. of	No. of	No. of
Species	Total †	Male	Female	samples	fish	samples
Alfonsino	398	188	108	17	108	14
Arrow squid	1 089	499	529	65	758	52
Austral lanternfish	1	0	0	1	1	1
Banded bellowsfish	4	0	1	2	1	1
Banded rattail	25	12	12	5	23	4
Barracouta	287	143	144	16	237	16
Basketwork eel	3	0	1	1	0	0
Bigeye cardinalfish	58	20	27	7	35	4
Black slickhead	210	122	81	10	29	3
Bluenose	5	2	3	4	5	4
Bogue lanternfish	54	0	0	3	2	1
Bollons rattail	797	471	310	45	476	29
Broadnose sevengill shark	1	1	0	1	1	1
Capro dory	398	1	0	9	1	1
Carpet shark	46	37	9	8	29	5
Common roughy	15	5	9	4	13	2
Common warehou	8	2	6	2	8	2
Cubehead	1	0	0	1	0	0
Cucumber fish	223	85	137	5	18	2
Dana lanternfish	124	0	0	1	50	1
Deepsea cardinalfish	6	2	4	4	6	4
Deepsea flathead	4	0	3	2	3	1
Diaphus spp	22	0	0	2	0	0
Electric ray	1	0	1	1	1	1
Eucla cod	111	2	103	3	0	0
Flaccid lanternfish	1	0	0	1	0	0
Frostfish	166	79	81	22	77	21
Gemfish	24	16	8	10	24	10
Dark ghost shark	741	366	375	35	429	31
Giant stargazer	337	214	123	38	317	37
Greenback jack mackerel	3	1	2	3	3	3
Gurnard	1	0	1	1	1	1
Hairy conger	13	3	5	4	7	2
Hake	899	479	419	55	898	55
Hapuku	30	14	16	14	30	14
Hector's lanternfish	820	0	1	7	0	0
Hoki	12 753	5 630	7 098	83	1 521	75
Hudson's lanternfish	13	0	0	1	0	0
Humpback rattail	1	0	1	1	1	1
Javelin fish	3 400	525	2 069	72	378	24
John dory	22	2	20	4	22	4
Johnson's cod	5	0	3	1	0	0
Leafscale gulper shark	30	13	17	13	30	13
Lighthouse fish	6	0	0	1	6	1
Ling	1 836	1 057	779	72	1 034	72
Longfinned beryx	6	5	1	4	6	4
Longnose velvet dogfish	30	15	15	7	30	7
Long-nosed chimaera	2	2	0	2	2	2
Lookdown dory	744	359	346	61	626	56
Lucifer dogfish	51	17	34	20	50	19
Lucifer lanternfish	5	0	0	1	5	1
Mahia rattail	10	7	3	4	8	2
Nezumia namatahi	1	0	0	1	0	0

Table 8 continued:

	Length frequency data				Length-weight data	
	No. of fish measured			No. of	No. of	No. of
Species	Total †	Male	Female	samples	fish	samples
Norman's lanterrnfish	1	1	0	1	1	1
Northern spiny dogfish	412	221	191	28	268	27
Notable rattail	9	0	1	2	1	1
Oliver's rattail	1 055	277	394	29	69	9
Orange perch	225	119	102	7	107	7
Orange roughy	4	1	3	2	4	2
Ostenfeld's lanternfish	1	0	0	1	0	0
Pale ghost shark	70	35	35	20	70	20
Pearlside	238	0	0	4	0	0
Plunket's shark	13	5	8	9	13	9
Red cod	234	171	55	30	201	27
Redbait	150	66	70	30	149	30
Ribaldo	273	76	197	27	273	27
Rig	2	1	1	2	2	2
Rough skate	17	9	8	12	17	12
Rubyfish	11	3	7	5	11	5
Rudderfish	3	0	3	3	3	3
Scabbardfish	6	2	1	3	6	3
Scampi	53	35	18	16	49	15
School shark	205	104	101	31	203	30
Sea perch	2 732	1 284	1 058	72	521	30
Seal shark	16	6	10	12	16	12
Sharpnose sevengill shark	2	0	2	2	2	2
Shovelnose spiny dogfish	191	97	94	15	160	15
Silver dory	1 141	515	320	13	161	7
Silver roughy	2 171	46	45	37	43	3
Silver warehou	1 551	507	1 044	68	757	68
Silverside	8	0	1	4	1	1
Slender jack mackerel	10	9	1	5	10	5
Slender smooth-hound	91	38	53	13	91	13
Small banded rattail	19	5	12	5	3	2
Smooth skate	75	39	36	31	74	30
Smooth skin dogfish	11	5	6	3	11	3
Softnose longtail skate	2	1	1	2	2	2
Southern rays bream	56	28	26	18	51	16
Spiky oreo	87	59	28	5	28	3
Spineback	2	1	1	2	2	2
Spiny dogfish	1 993	312	1 681	45	697	41
Spotted gurnard	3	2	1	2	3	2
Swollenhead conger	103	72	31	11	45	6
Tarakihi	416	270	146	21	354	21
Two saddle rattail	87	27	60	7	64	4
Viper fish	1	0	0	1	1	1
White rattail	21	10	11	3	18	2
White warehou	45	23	22	14	45	14
Witch	2	0	2	1	2	1
Yellow boarfish	183	44	37	6	84	4
Grand total	39 842	14 922	18 829	91	12 003	90

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

Table 9: Numbers of fish for which length, sex, and biological data were collected on the 2013 WCSI survey.

	Length frequency data				Length-weight data	
	No. of fish measured			No. of	No. of	No. of
Species	Total †	Male	Female	samples	fish	samples
Alfonsino	916	562	354	37	261	21
Arrow squid	483	209	155	47	252	19
Banded rattail	1	0	0	1	1	1
Barracouta	553	274	279	14	256	12
Basketwork eel	12	10	2	1	0	0
Bigeye cardinalfish	170	67	56	12	11	2
Black slickhead	143	66	69	7	91	5
Bluenose	1	1	0	1	1	1
Bollons rattail	1 302	799	489	49	1 133	41
Capro dory	358	0	0	4	0	0
Carpet shark	11	8	3	2	11	2
Common roughy	21	12	9	1	0	0
Cucumber fish	337	12	5	4	108	2
Deepsea cardinalfish	2	2	0	1	2	1
Deepsea flathead	18	3	14	4	18	4
Eucla cod	77	9	68	1	0	0
Frostfish	129	37	46	23	120	19
Gemfish	15	5	10	12	14	11
Ghost shark (dark)	551	319	231	33	335	27
Giant stargazer	328	207	120	37	300	32
Greenback jack mackerel	10	4	6	2	10	2
Gurnard	6	1	5	2	6	2
Hairy conger	5	2	3	2	0	0
Hake	635	259	375	52	633	51
Hapuku	13	4	9	8	13	8
Hector's lanternfish	1	0	0	1	1	1
Hoki	13 662	6 113	7 541	77	1 430	69
Humpback rattail	1	0	1	1	1	1
Javelinfish	3 032	730	1507	61	610	18
John dory	29	4	25	5	29	5
Johnson's cod	21	13	8	2	14	1
Leafscale gulper shark	16	4	12	10	16	10
Lestidiops spp	1	0	0	1	1	1
Lighthouse fish	1	0	0	1	0	0
Ling	1 898	1 083	815	67	824	62
Longfinned beryx	1	1	0	1	1	1
Longnose velvet dogfish	42	19	23	8	39	5
Long-nosed chimaera	1	1	0	1	1	1
Lookdown dory	1 481	660	818	59	1 121	54
Lucifer dogfish	65	26	39	23	42	19
Mahia rattail	21	13	8	5	21	5
Northern spiny dogfish	198	145	53	26	165	23
Notable rattail	2	0	0	1	0	0
Olivers rattail	966	585	261	24	851	22
Orange perch	76	36	40	3	51	2
Orange roughy	72	36	33	3	72	3
Pale ghost shark	52	30	22	21	51	21
Plunket's shark	10	7	3	3	10	3
Prickly deepsea skate	1	1	0	1	1	1
Red cod	405	323	79	31	311	23
Redbait	108	43	65	44	79	30
Ribaldo	129	27	102	31	127	31
Rig	3	2	1	3	3	3

Table 9 continued:

	Length frequency data				Length-weight data	
	No. of fish measured			No. of	No. of	No. of
Species	Total †	Male	Female	samples	fish	samples
Rough skate	13	7	6	8	13	8
Rubyfish	109	50	59	4	41	4
Rudderfish	4	0	4	2	4	2
Scabbard fish	2	1	1	1	2	1
Scaly gurnard	3	1	2	1	3	1
Scampi	69	52	17	25	66	23
School shark	140	75	65	31	110	28
Sea perch	3 167	1 356	951	74	688	29
Seal shark	18	9	9	13	16	11
Serrulate rattail	1	0	1	1	0	0
Sharpnose sevengill shark	8	0	8	5	8	5
Shovelnose spiny dogfish	130	55	75	19	111	17
Silver dory	744	228	286	11	201	2
Silver roughy	2 420	90	137	39	12	1
Silver warehou	587	131	456	57	494	55
Silverside	17	0	0	2	0	0
Slender jack mackerel	1	0	1	1	1	1
Slender smooth-hound	96	46	50	23	86	21
Small-headed cod	2	1	1	1	2	1
Smallscaled slickhead	1	0	1	1	1	1
Smooth deepsea skate	1	1	0	1	1	1
Smooth skate	91	45	46	34	89	32
Smooth skin dogfish	16	7	9	3	16	3
Southern boarfish	1	1	0	1	1	1
Southern rays bream	54	25	29	13	53	12
Spiky oreo	91	43	47	3	91	3
Spineback	1	1	0	1	0	0
Spiny dogfish	1 377	230	1 147	29	349	21
Spotted gurnard	1	1	0	1	1	1
Swollenhead conger	8	2	6	2	2	1
Tarakihi	430	306	124	14	395	13
Two saddle rattail	63	38	25	7	60	6
Viper fish	22	0	1	1	0	0
White rattail	25	8	17	6	17	4
White warehou	19	4	15	12	19	12
Widenosed chimaera	1	0	1	1	1	1
Witch	1	0	1	1	1	1
Yellow boarfish	174	25	27	4	28	1
Total	38 300	15 613	17 389	83	12 431	81

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

Table 10: Estimated trawl biomass (t) and coefficient of variation (% CV) of the top 28 species by stratum in 2012 (from O'Driscoll et al. 2014). – indicates estimated biomass less than 1 t.

	Species code					
Stratum	HOK	LIN	SPD	HAK	SDO	SWA
1&2A	3 071 (23.1)	1 548 (19.8)	1 (100.0)	– (81.2)	1 (37.1)	141 (39.7)
1&2B	3 934 (45.7)	134 (32.7)	51 (74.5)	42 (26.4)	–	22 (50.5)
1&2C	9 042 (68.2)	47 (45.0)	3 (100.0)	171 (33.3)	–	310 (58.2)
4A	5 816 (47.7)	229 (24.3)	833 (30.2)	9 (43.6)	258 (46.7)	96 (58.5)
4B	8 625 (38.3)	158 (40.0)	196 (46.7)	37 (34.6)	1 (63.2)	19 (36.0)
4C	2 007 (59.1)	53 (43.6)	12 (60.4)	323 (13.8)	–	30 (77.4)
Subtotal (core)	32 495 (24.2)	2 169 (14.8)	1 095 (24.7)	583 (12.8)	259 (46.5)	617 (32.2)
1&2S	–	7 (100.0)	1 (100.0)	–	386 (71.0)	238 (50.3)
4S	–	–	356 (52.5)	–	33 (55.1)	12 (49.6)
4D	107 (21.8)	18 (43.8)	–	520 (23.7)	–	10 (41.3)
Total	32 602 (24.1)	2 194 (14.7)	1 453 (22.6)	1 103 (13.0)	677 (44.2)	877 (26.5)

	Species code					
Stratum	SCH	GIZ	SSK	BYS	JAV	SQU
1&2A	86 (34.5)	51 (30.9)	24 (44.0)	258 (59.7)	26 (18.3)	10 (29.1)
1&2B	4 (77.9)	1 (52.4)	40 (59.9)	–	20 (31.6)	3 (31.7)
1&2C	–	–	35 (100.0)	1 (66.2)	65 (21.2)	6 (65.5)
4A	77 (41.0)	39 (38.2)	52 (41.1)	1 (100.0)	26 (29.6)	46 (32.7)
4B	19 (81.4)	7 (54.9)	15 (59.2)	1 (79.7)	13 (36.4)	24 (26.0)
4C	–	–	1 (100.0)	–	15 (23.8)	7 (58.2)
Subtotal (core)	186 (24.8)	97 (22.6)	167 (29.5)	262 (58.8)	166 (11.3)	95 (18.3)
1&2S	87 (15.6)	102 (60.5)	5 (100.0)	–	–	23 (35.1)
4S	50 (34.2)	409 (33.2)	50 (100.0)	–	–	18 (36.3)
4D	–	–	18 (100.0)	–	29 (35.0)	–
Total	323 (15.8)	608 (24.8)	239 (30.4)	262 (58.8)	195 (10.9)	137 (14.9)

	Species code					
Stratum	SPE	GSH	LDO	BAR	NSD	NMP
1&2A	27 (18.8)	67 (21.7)	19 (52.9)	4 (100.0)	34 (26.9)	2 (33.1)
1&2B	15 (13.2)	7 (45.9)	21 (35.7)	–	4 (37.2)	–
1&2C	57 (34.3)	–	70 (11.3)	–	3 (65.9)	–
4A	14 (39.4)	31 (32.0)	9 (40.7)	8 (41.4)	9 (43.4)	19 (46.7)
4B	15 (29.9)	1 (96.5)	9 (26.2)	–	–	–
4C	8 (39.7)	–	27 (37.1)	–	–	–
Subtotal (core)	136 (15.9)	106 (16.9)	155 (11.9)	12 (42.8)	49 (20.4)	21 (41.7)
1&2S	–	14 (50.5)	–	122 (80.5)	93 (34.4)	45 (36.3)
4S	63 (81.1)	26 (40.8)	–	282 (37.7)	126 (54.9)	201 (29.1)
4D	6 (35.4)	–	27 (21.6)	–	–	–
Total	205 (26.9)	146 (15.1)	181 (10.6)	417 (34.8)	269 (28.7)	267 (23.0)

Table 10: continued.

	Species code					
Stratum	SRH	CBO	RIB	SND	HAP	FRO
1&2A	38 (57.3)	2 (65.5)	–	–	12 (64.2)	9 (34.3)
1&2B	6 (32.7)	20 (18.8)	–	–	10 (100.0)	1 (52.1)
1&2C	25 (21.7)	46 (17.3)	28 (35.6)	68 (70.6)	–	1 (100.0)
4A	7 (35.1)	–	–	–	13 (39.5)	19 (80.2)
4B	11 (29.0)	12 (24.3)	–	–	–	–
4C	13 (40.1)	13 (27.1)	15 (30.6)	–	–	–
Subtotal (core)	101 (23.3)	93 (10.8)	43 (25.3)	68 (70.6)	35 (39.3)	30 (51.9)
1&2S	–	–	–	–	59 (41.9)	–
4S	–	–	–	–	5 (100.0)	8 (100.0)
4D	–	13 (48.5)	97 (29.0)	78 (55.9)	–	–
Total	101 (23.3)	105 (11.1)	140 (21.6)	146 (44.4)	99 (29.0)	38 (46.1)

	Species code			
Stratum	WWA	RCO	GSP	RBT
1&2A	–	11 (23.3)	–	1 (51.0)
1&2B	–	2 (76.0)	–	–
1&2C	21 (72.1)	–	30 (30.0)	1 (66.3)
4A	–	7 (35.8)	–	4 (82.5)
4B	–	3 (46.2)	–	6 (46.4)
4C	5 (79.9)	–	2 (69.6)	1 (50.5)
Subtotal (core)	26 (60.4)	22 (17.5)	32 (28.2)	13 (32.2)
1&2S	–	–	–	2 (21.3)
4S	–	–	–	1 (15.8)
4D	39 (40.5)	–	8 (57.9)	–
Total	65 (34.2)	22 (17.5)	40 (25.4)	16 (27.3)

Table 11: Estimated trawl abundance (t) and coefficient of variation (% CV) of the top 20 species by stratum in 2013 (from O'Driscoll et al. 2015). – less than 1 t.

	Species code					
Stratum	HOK	LIN	SPD	HAK	SWA	SDO
1&2A	2 543 (27.4)	1 275 (27.3)	3 (64.6)	4 (65.5)	14 (45.7)	–
1&2B	4 416 (72.5)	73 (15.6)	–	20 (35.1)	36 (35.1)	–
1&2C	664 (13.7)	50 (21.7)	–	73 (27.1)	142 (27.6)	–
4A	4 291 (43.8)	425 (26.3)	683 (34.4)	8 (47.9)	7 (39.8)	304 (77.9)
4B	1 541 (28.4)	135 (25.6)	180 (49.4)	58 (47.3)	6 (41.7)	–
4C	728 (28.8)	42 (35.3)	–	168 (27.1)	108 (53.1)	–
Subtotal (core)	14 184 (26.9)	2 000 (18.4)	867 (29.0)	331 (17.4)	313 (22.7)	304 (77.9)
1&2S	–	–	–	–	1 (100.0)	231 (60.0)
4S	–	–	61 (38.9)	–	2 (100.0)	68 (55.2)
4D	173 (29.9)	8 (49.4)	–	416 (35.6)	1 (100.0)	–
Total	14 356 (26.5)	2 009 (18.3)	928 (27.2)	747 (21.3)	317 (22.4)	602 (45.9)

	Species code					
Stratum	GIZ	BAR	SCH	NSD	NMP	BYS
1&2A	33 (27.3)	2 (100.0)	99 (36.4)	35 (39.1)	1 (100.0)	50 (50.6)
1&2B	2 (66.7)	–	1 (100.0)	7 (41.1)	–	1 (53.1)
1&2C	– (100.0)	–	13 (74.3)	1 (100.0)	–	17 (49.7)
4A	41 (41.8)	3 (50.2)	41 (30.2)	5 (38.0)	23 (50.4)	44 (33.3)
4B	13 (42.1)	–	6 (83.8)	–	–	–
4C	3 (60.0)	–	–	–	–	8 (96.9)
Subtotal (core)	92 (21.8)	5 (52.1)	159 (24.8)	48 (29.5)	24 (48.5)	120 (26.2)
1&2S	49 (52.6)	922 (48.0)	60 (31.5)	47 (34.6)	120 (36.4)	–
4S	448 (27.3)	690 (57.8)	33 (42.7)	36 (57.0)	167 (32.7)	–
4D	2 (100.0)	–	–	–	–	–
Total	592 (21.4)	1 617 (36.8)	252 (18.3)	131 (22.7)	311 (22.8)	120 (26.2)

	Species code					
Stratum	SSK	SPE	JAV	LDO	GSH	SND
1&2A	62 (47.3)	24 (22.3)	26 (40.6)	15 (57.0)	31 (38.2)	–
1&2B	82 (27.7)	19 (16.0)	11 (21.2)	33 (20.2)	6 (48.1)	–
1&2C	33 (60.5)	55 (14.6)	39 (22.1)	124 (15.3)	–	49 (24.8)
4A	40 (35.2)	8 (27.3)	22 (27.9)	1 (78.4)	39 (27.4)	–
4B	11 (42.7)	11 (31.2)	7 (21.7)	5 (28.3)	–	–
4C	–	9 (43.8)	16 (28.1)	29 (23.6)	–	–
Subtotal (core)	228 (19.6)	126 (9.2)	122 (13.1)	205 (11.1)	75 (21.4)	49 (24.8)
1&2S	44 (100.0)	10 (72.6)	–	–	23 (52.0)	–
4S	–	2 (50.0)	–	–	2 (100.0)	–
4D	–	4 (25.3)	19 (14.0)	31 (49.1)	–	46 (51.4)
Total	272 (23.1)	142 (9.8)	1141 (11.5)	226 (11.6)	101 (20.2)	95 (28.0)

Table 11: continued.

	Species code	
Stratum	RIB	SQU
1&2A	–	7 (15.4)
1&2B	–	2 (27.7)
1&2C	12 (35.9)	–
4A	–	13 (14.2)
4B	–	5 (31.4)
4C	3 (59.8)	1 (57.7)
Subtotal (core)	16 (29.9)	28 (9.9)
1&2S	–	13 (38.5)
4S	–	12 (62.3)
4D	41 (33.6)	–
Total	57 (25.7)	52 (17.6)

Table 12: Estimated days on the ground* for surveys of the northern and southern areas of the WCSI with varying numbers of acoustic snapshots. This time budget allows 3–6 targeted trawls during each northern acoustic snapshot and 6 targeted trawls during each southern snapshot. The simulated CVs are estimates of overall uncertainty based on optimal survey timing under the best available assumptions about hoki arrival date and residence time (modified from Francis & O'Driscoll 2004).

	Northern area		Southern area	
Number of snapshots	Survey days	Minimum CV	Survey days	Minimum CV
2	6	0.72	7	0.27
3	10	0.59	10	0.25
4	13	0.51	13	0.24
5	17	0.49	16	0.23
6	20	0.46	20	0.23

* Approximately four additional days are also needed for vessel mobilisation and demobilisation, and steaming to and from Wellington

Table 13: Numbers of stations required to achieve a target CV of 20% for hoki (HOK), ling (LIN), and hake (HAK), and 25% for silver warehou (SWA), giant stargazer (GIZ), spiny dogfish (SPD), sea perch (SPE), lookdown dory (LDO), and dark ghost shark (GSH) are given by species.

	Number of tows									
Stratum	HOK	LIN	HAK	SWA	GIZ	SPD	SPE	LDO	GSH	Total
1&2S	3	3	3	3	3	3	3	3	3	3
1&2A	3	8	3	3	3	3	3	3	4	8
1&2B	10	3	3	3	3	3	3	3	3	10
1&2C	7	3	3	10	3	3	3	3	3	10
4S	3	3	3	3	4	3	3	3	3	4
4A	10	3	3	3	3	11	3	3	4	11
4B	6	3	3	3	3	3	3	3	3	6
4C	3	3	3	4	3	3	3	3	3	4
4D	3	3	7	3	3	3	3	3	3	7
Total	48	32	31	35	28	35	27	27	29	63

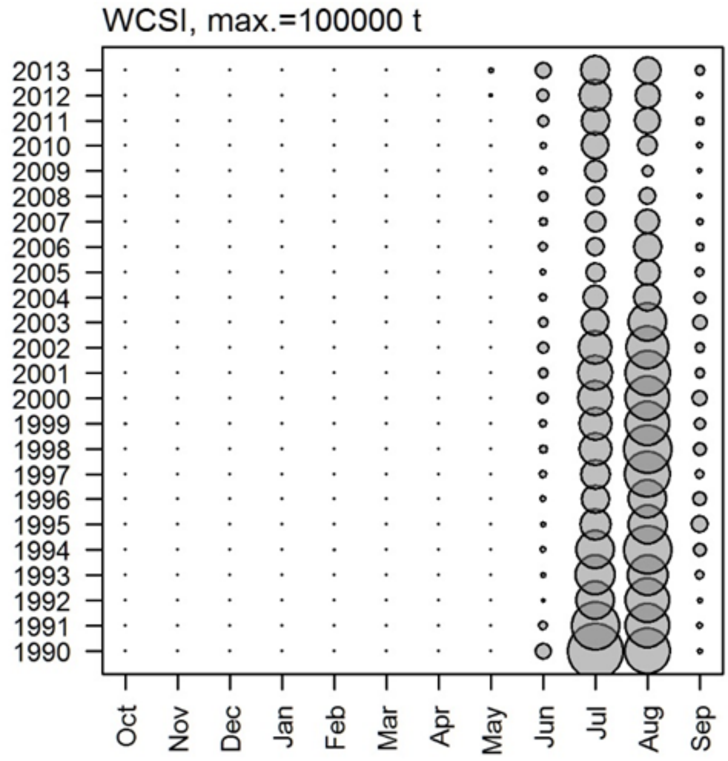


Figure 1: Monthly distribution of commercial catch of hoki on the WCSI for the 1990–2013 fishing years. From Ballara & O'Driscoll (2014b).

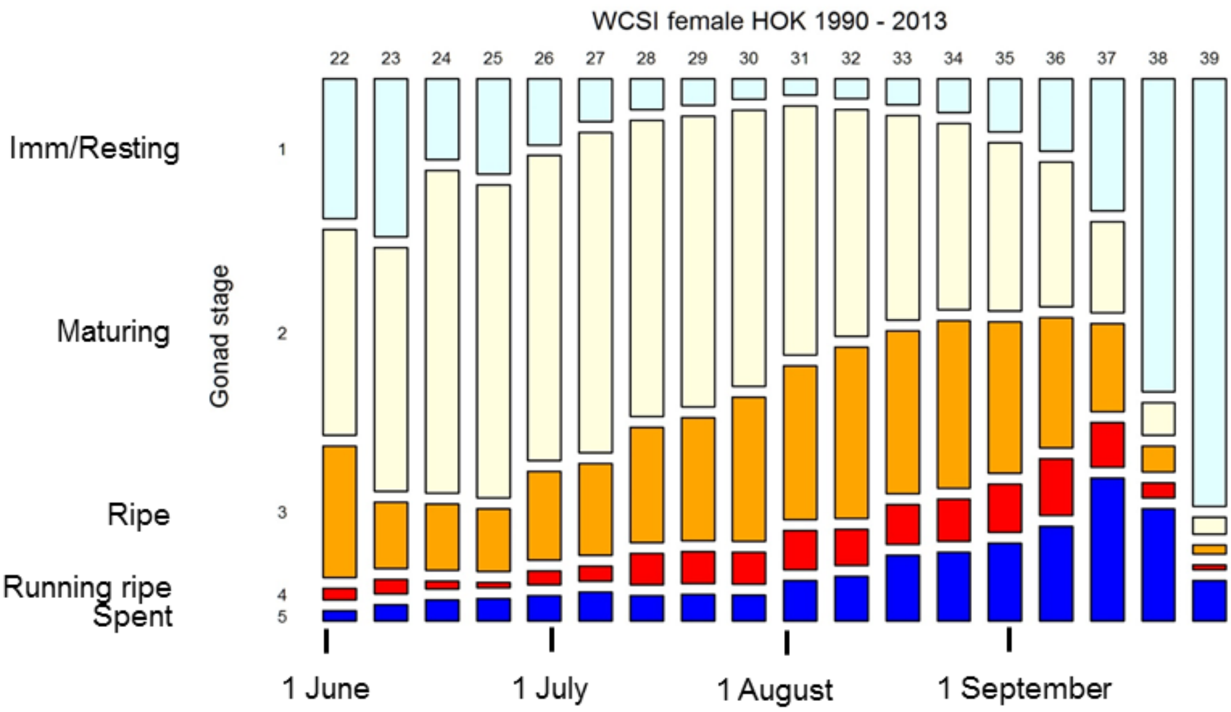


Figure 2: Weekly summary of gonad stages of female hoki from observer data from the WCSI in the 1990–2013 fishing years.

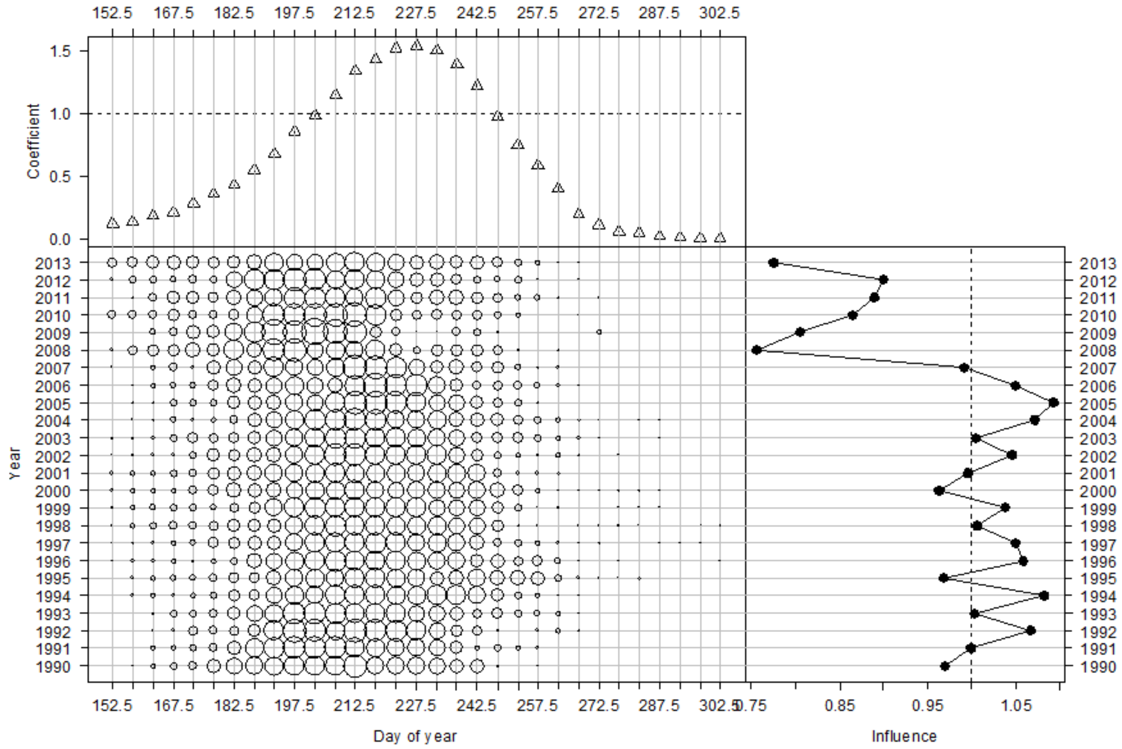


Figure 3: Influence plot showing effect of date on standardised commercial CPUE from hoki target tows on the WCSI for the 1990–2013 fishing years. From Ballara & O'Driscoll (2014b). Peak is at 15 August (Julian day 227).

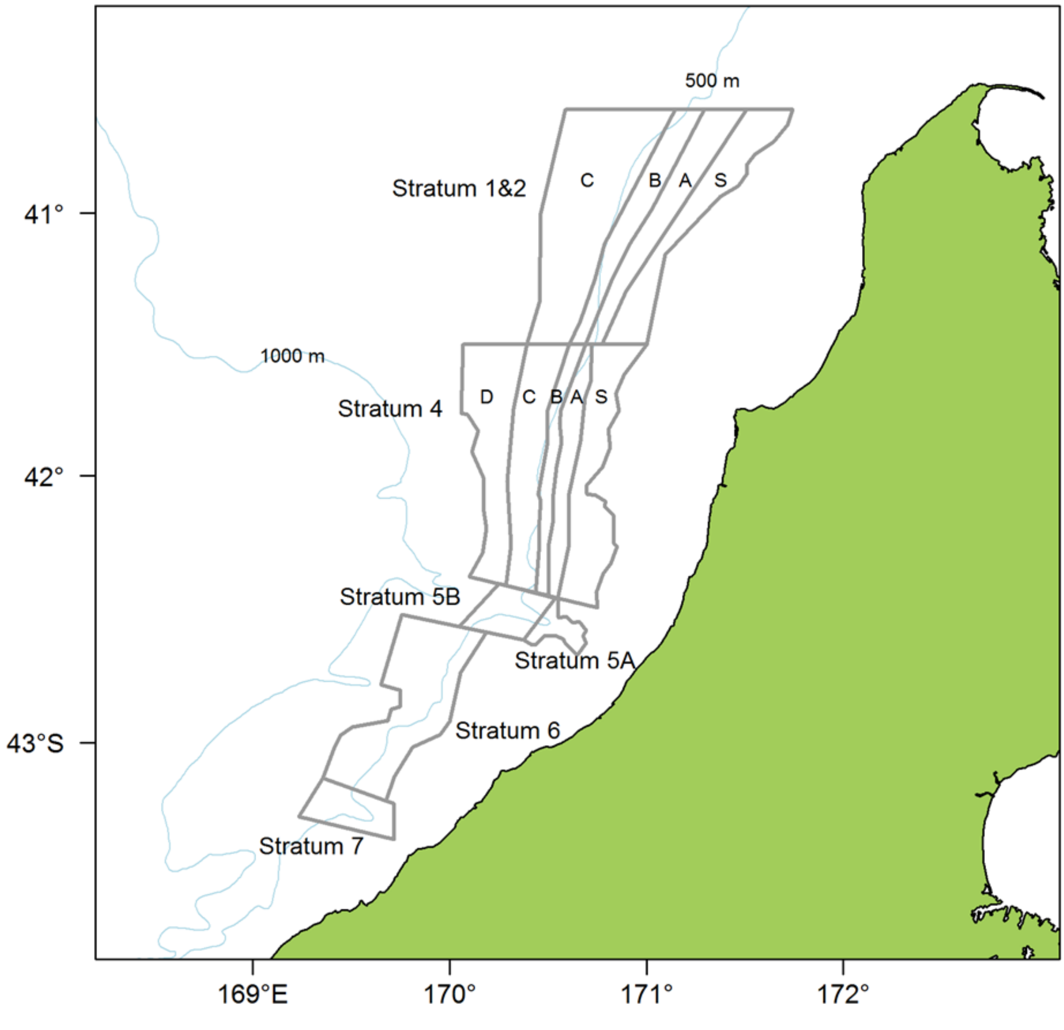


Figure 4: Stratum boundaries for the 2012–13 survey of the WCSI. Stratum areas are given in Table 3.

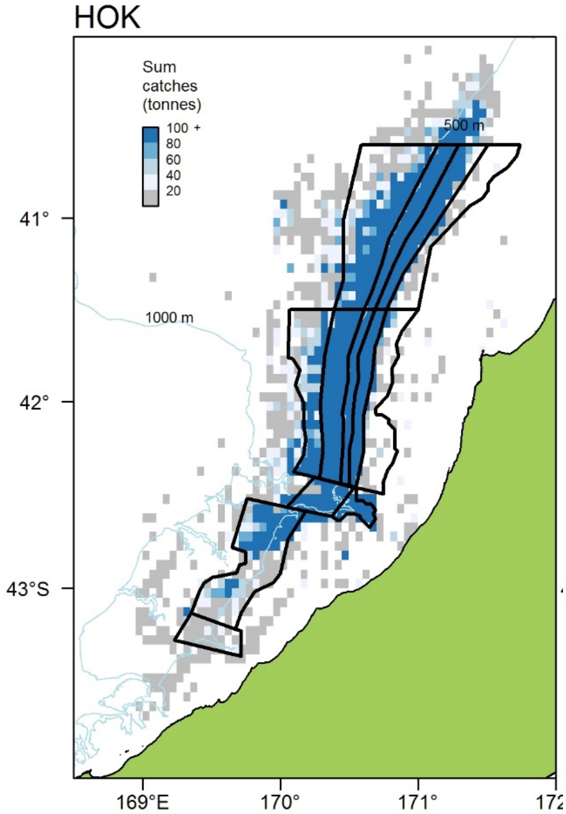


Figure 5: Commercial catch of hoki on the WCSI in June–September from 2000–13 in relation to survey boundaries.

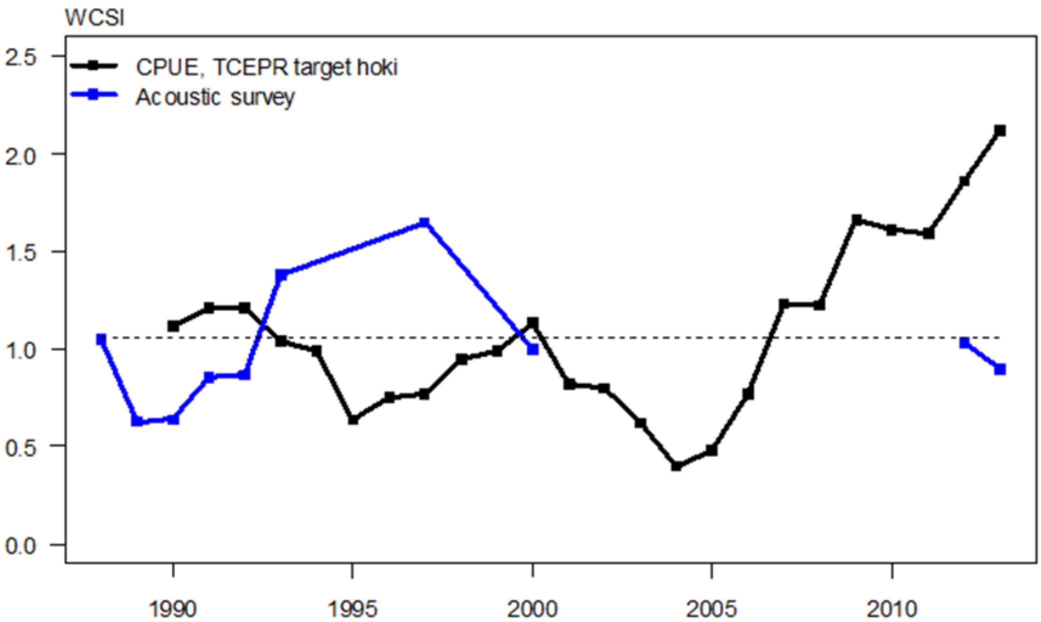


Figure 6: Comparison between the relative acoustic abundance index of spawning hoki on the WCSI and standardised catch-per-unit-effort (CPUE) from commercial tows targeting hoki reported on TCEPR forms from 1990 to 2013 (from O'Driscoll et al. 2015).

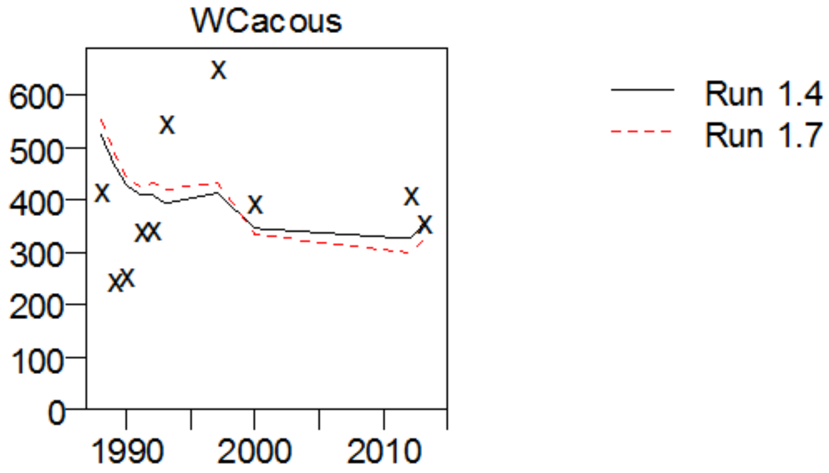


Figure 7: Fit to WCSI biomass indices for 2014 hoki stock assessment runs 1.4 and 1.7 showing observed ('x') and expected values (lines). In model run 1.4 the trawl survey indices are not upweighted, for 1.7 they are. From McKenzie (2015).

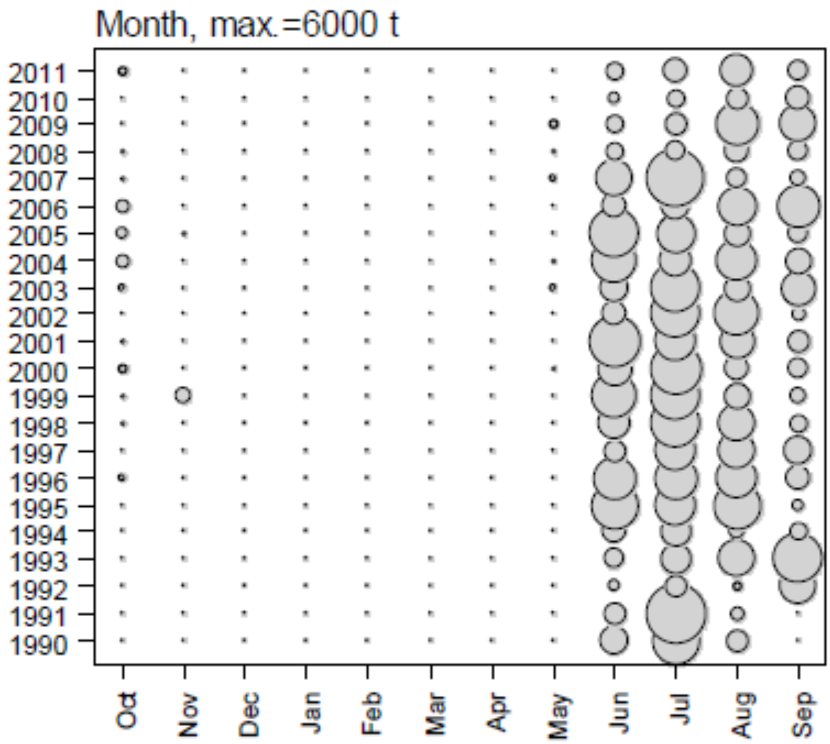


Figure 8: Monthly distribution of commercial catch of hake on the WCSI for the 1990–2011 fishing years. From Ballara (2013).

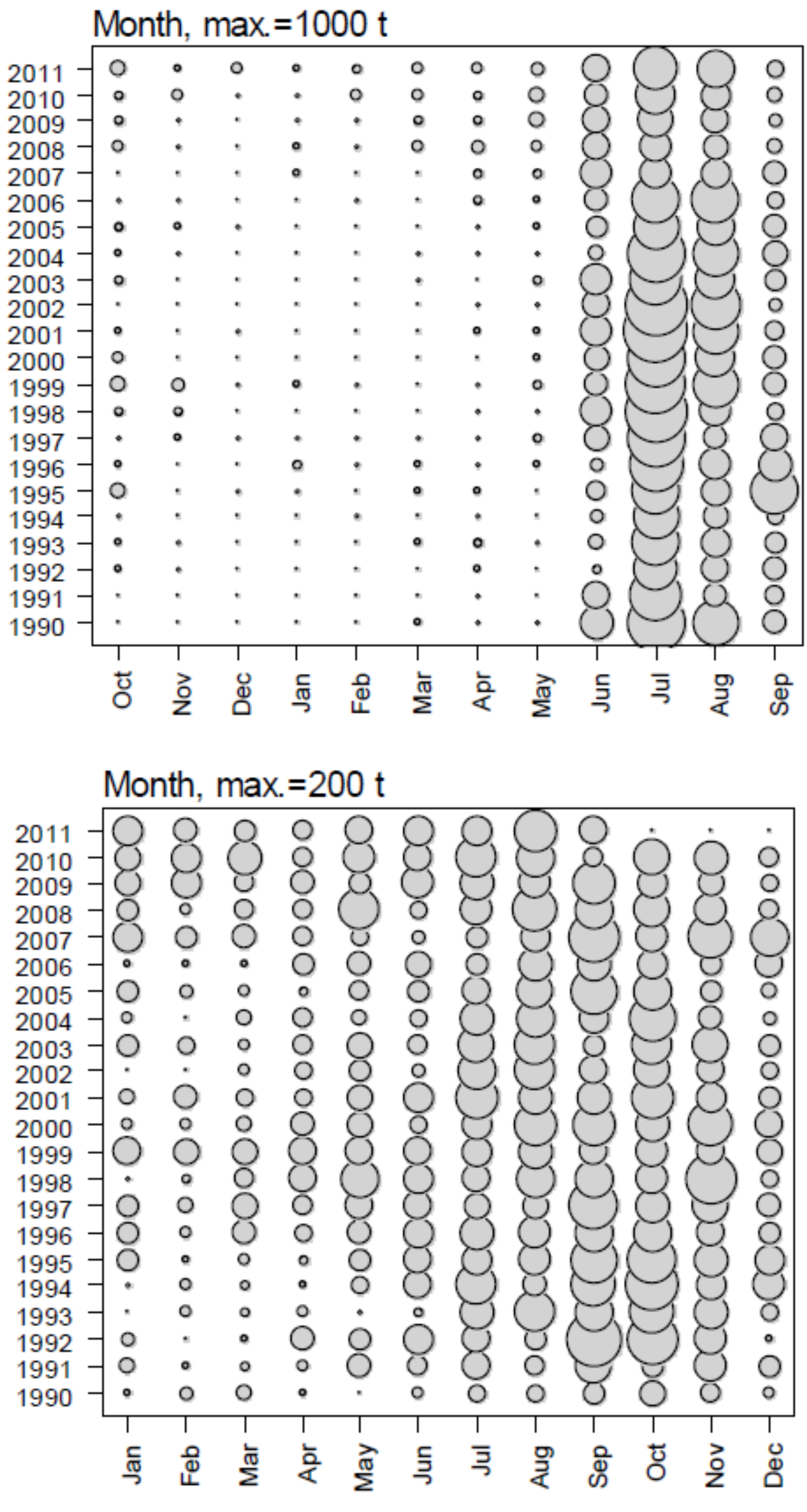


Figure 9: Monthly distribution of commercial catch of ling on the WCSI for the 1990–2011 fishing years by trawl (upper panel) and longline (lower panel). From Dunn et al. (2013).

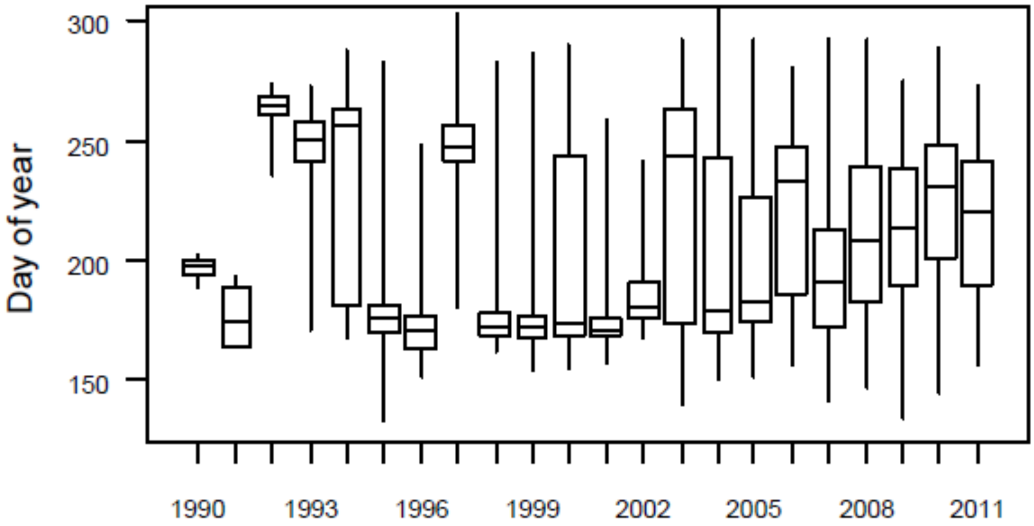


Figure 10: Box and whisker plots of day of year for WCSI vessels targeting hake. The plots show medians and lower and upper quartiles in the box, and whiskers extending up to 1.5 times the interquartile range. Day 150 = 30 May, day 200 = 19 July, day 250 = 7 September, day 300 = 27 October. From Ballara (2013).

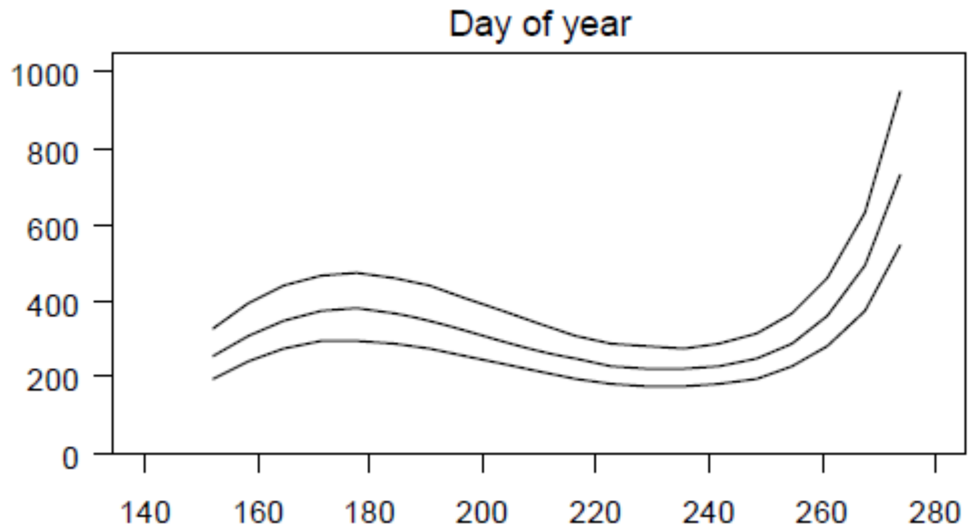


Figure 11: Expected day of year effect from the CPUE lognormal model for the WCSI trawl accurate vessel fishery for ling, 1990–2011. The 95% confidence intervals are shown as bars as upper and lower lines. From Dunn et al. (2013).

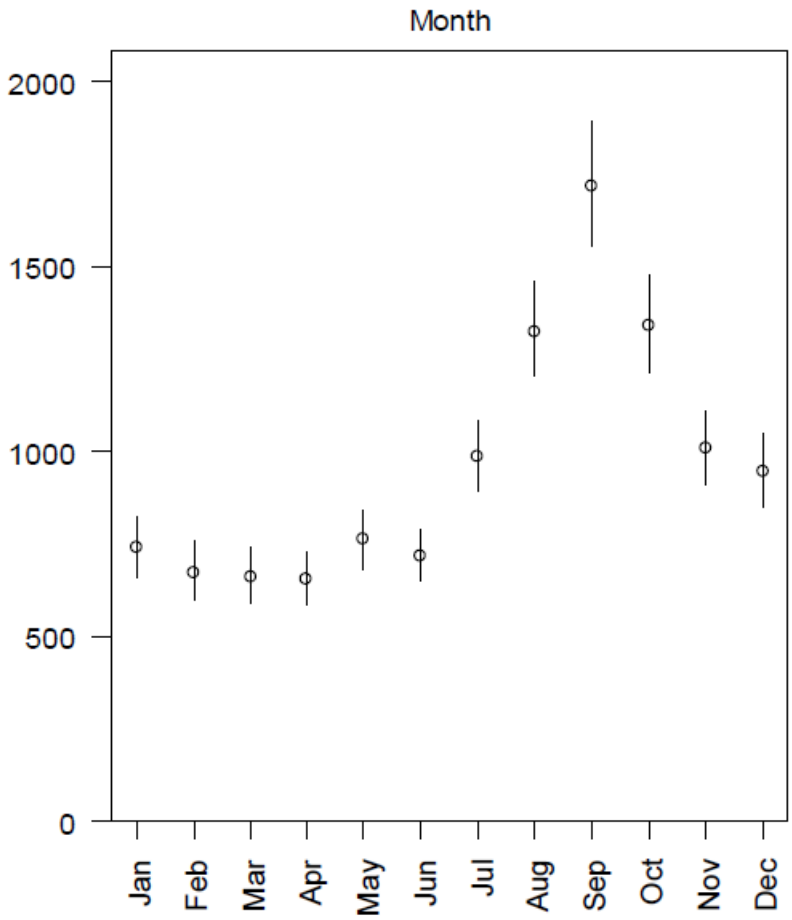


Figure 12: Expected month effect from the CPUE lognormal model for the WCSI ling longline data, 1990–2011. The 95% confidence intervals are shown as bars. From Dunn et al. (2013).

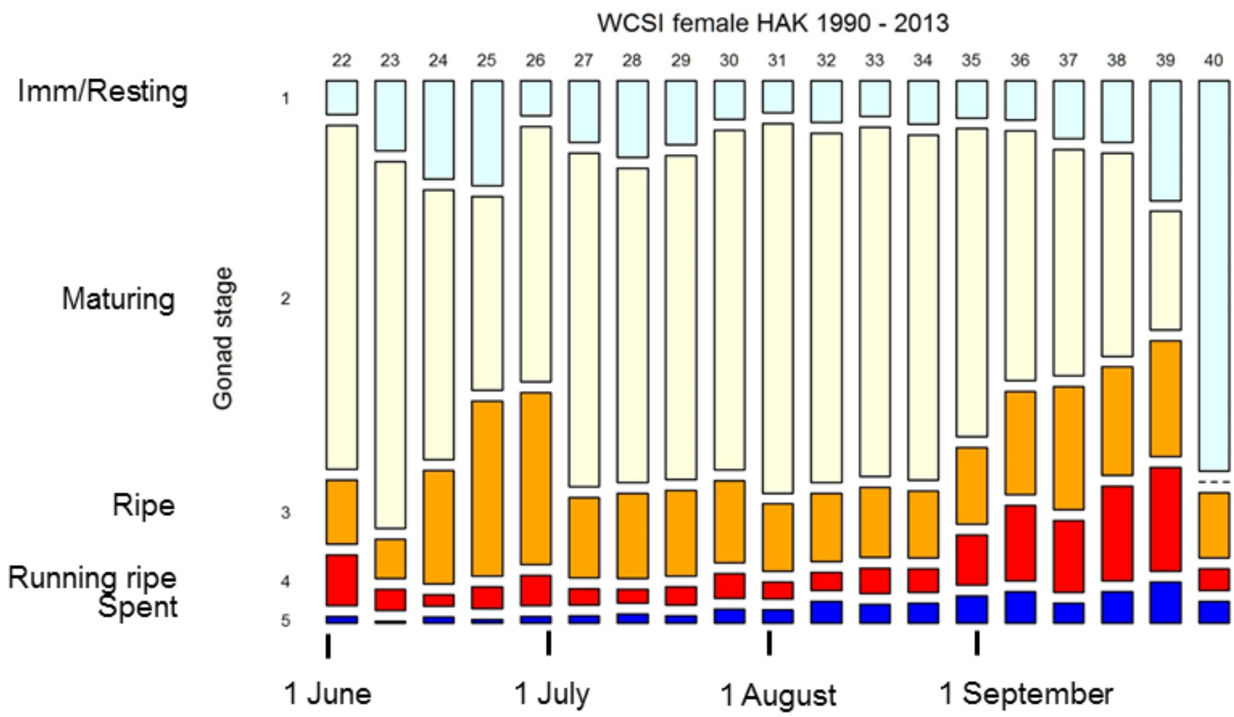


Figure 13: Weekly summary of gonad stages of female hake from observer data from the WCSI in the 1990–2013 fishing years.

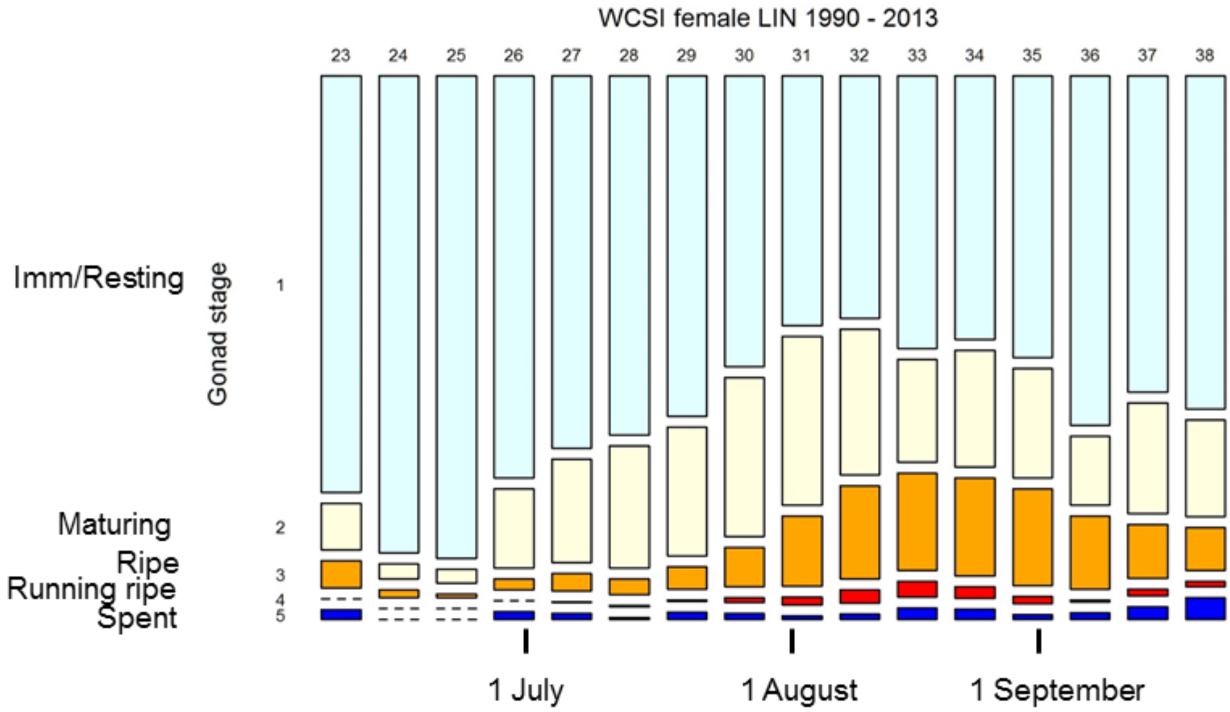


Figure 14: Weekly summary of gonad stages of female ling from observer data from the WCSI in the 1990–2013 fishing years.

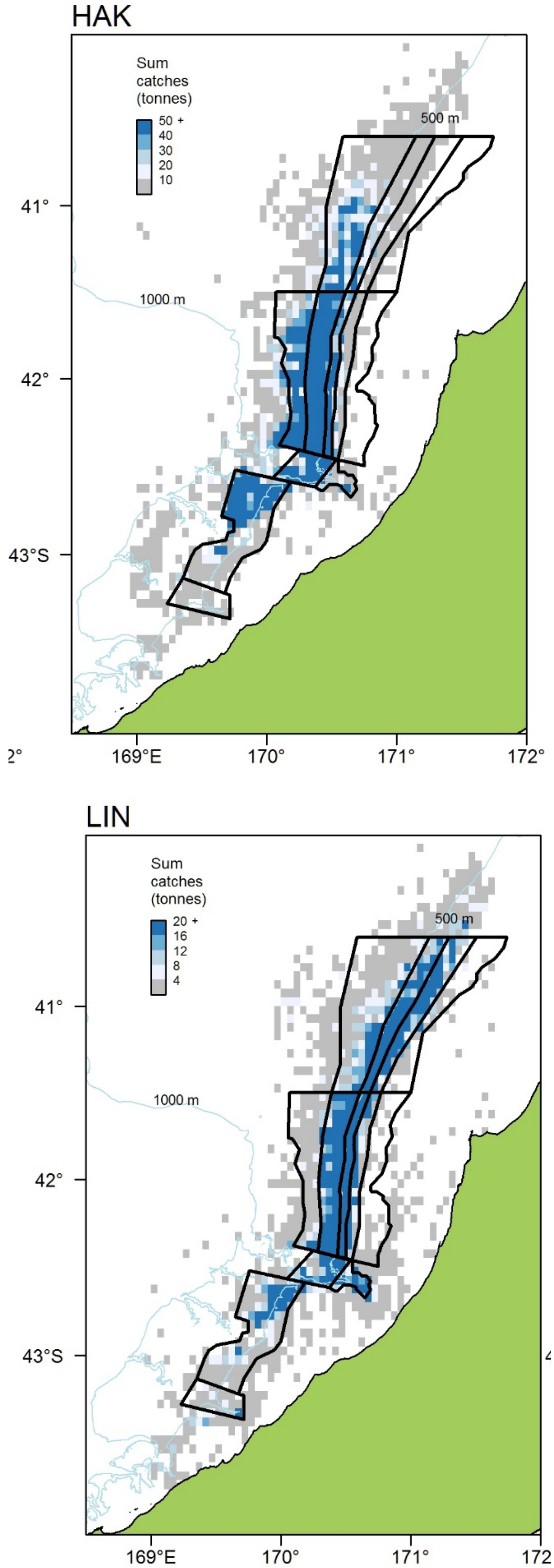


Figure 15: Commercial catch of hake and ling on the WCSI in June–September from 2000–13 in relation to survey boundaries.

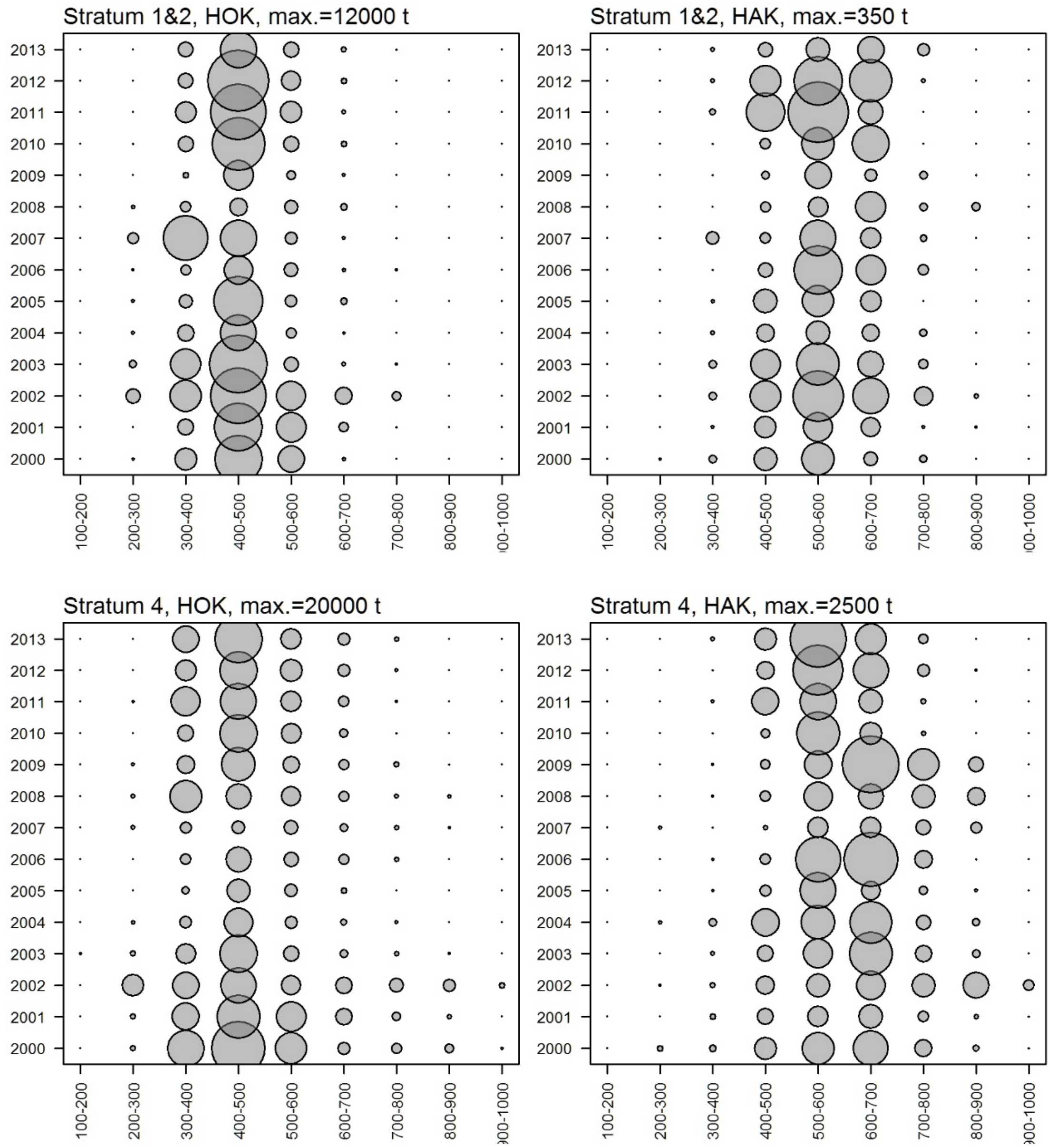
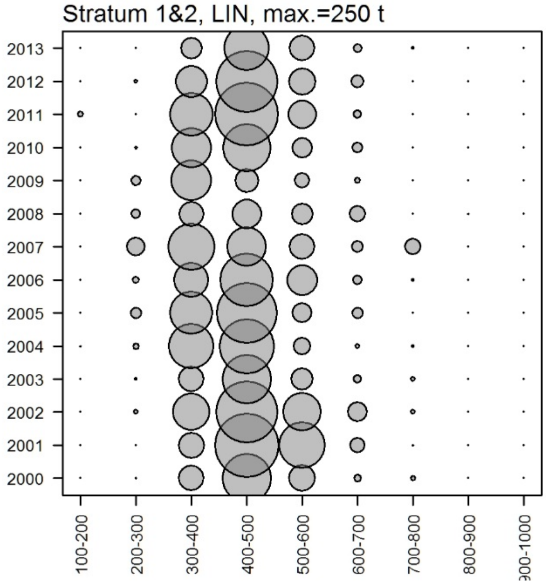


Figure 16: Depth distribution of commercial catch of hoki and hake in strata 1&2 and stratum 4 on the WCSI in June–September from 2000–13.



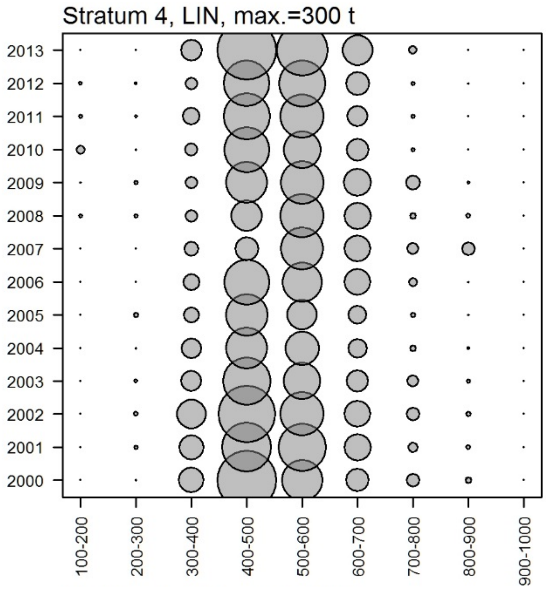


Figure 16 continued: Depth distribution of commercial catch of ling in strata 1&2 and stratum 4 on the WCSI in June–September from 2000–13.

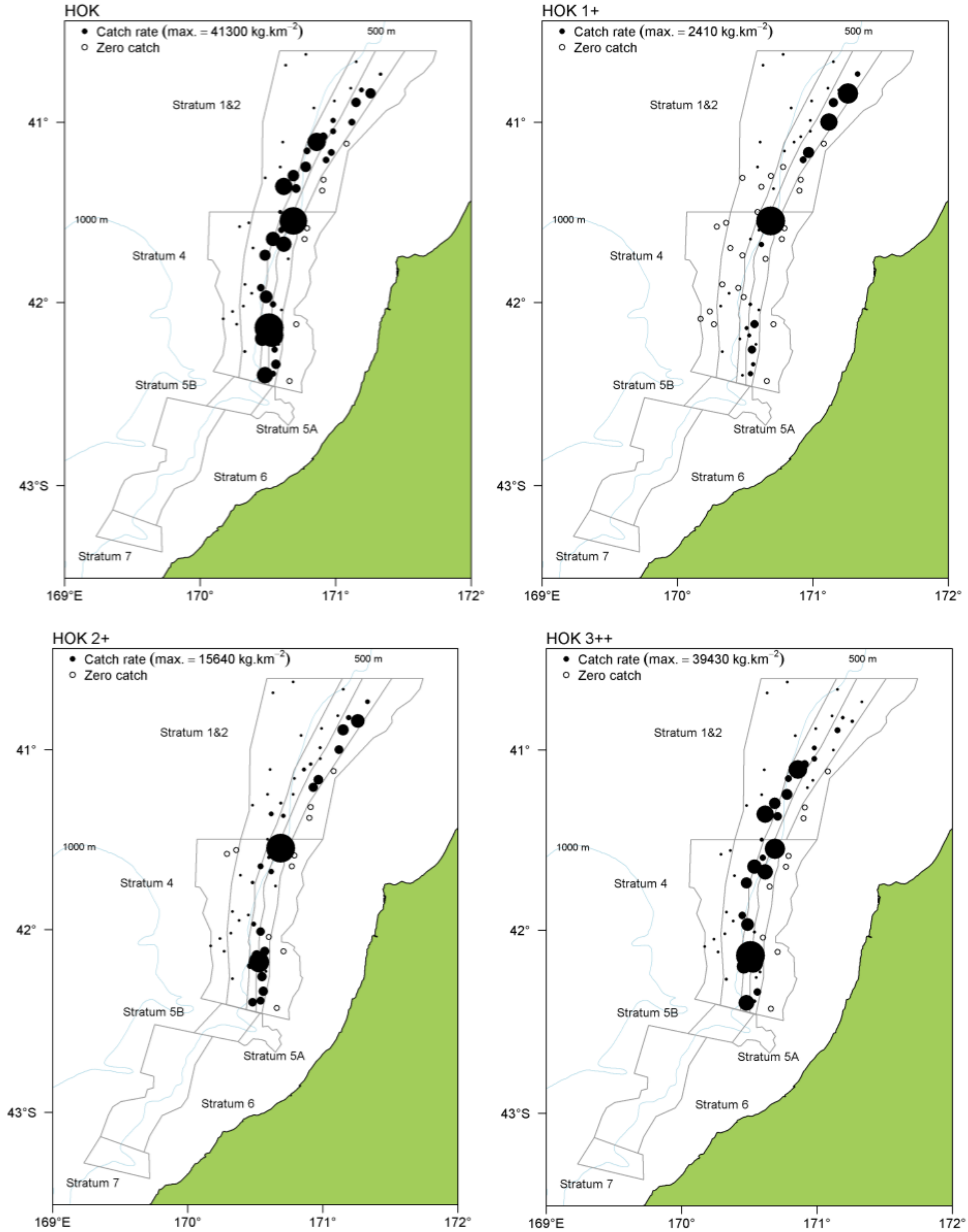
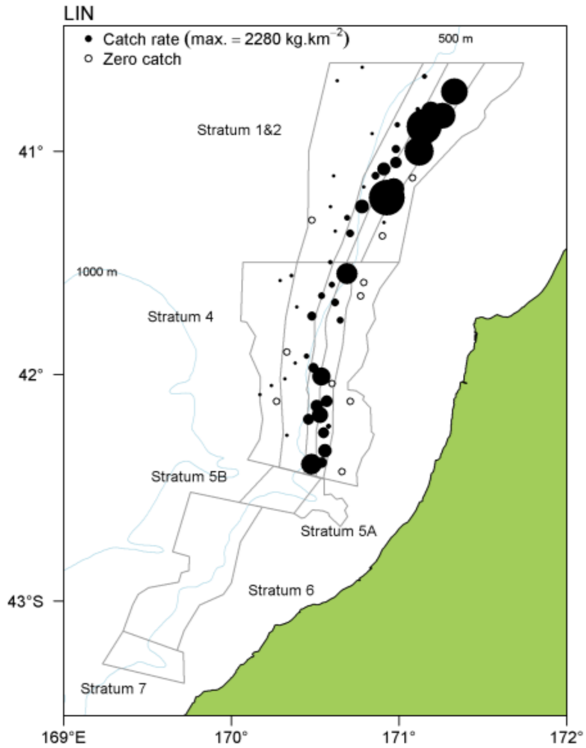


Figure 17: Distribution and catch rates of all, 1+ (less than 48 cm), 2+ (48–62 cm), and 3++ (more than 62 cm) hoki (HOK) on the WCSI 2012 trawl survey. Circle area is proportional to catch rate.



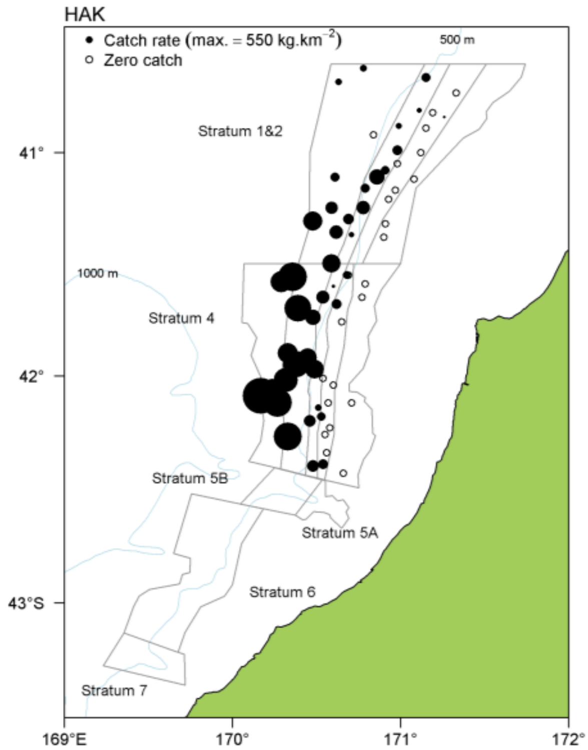


Figure 17 continued: Distribution and catch rates of ling (LIN) and hake (HAK) on the WCSI 2012 trawl survey. Circle area is proportional to catch rate.

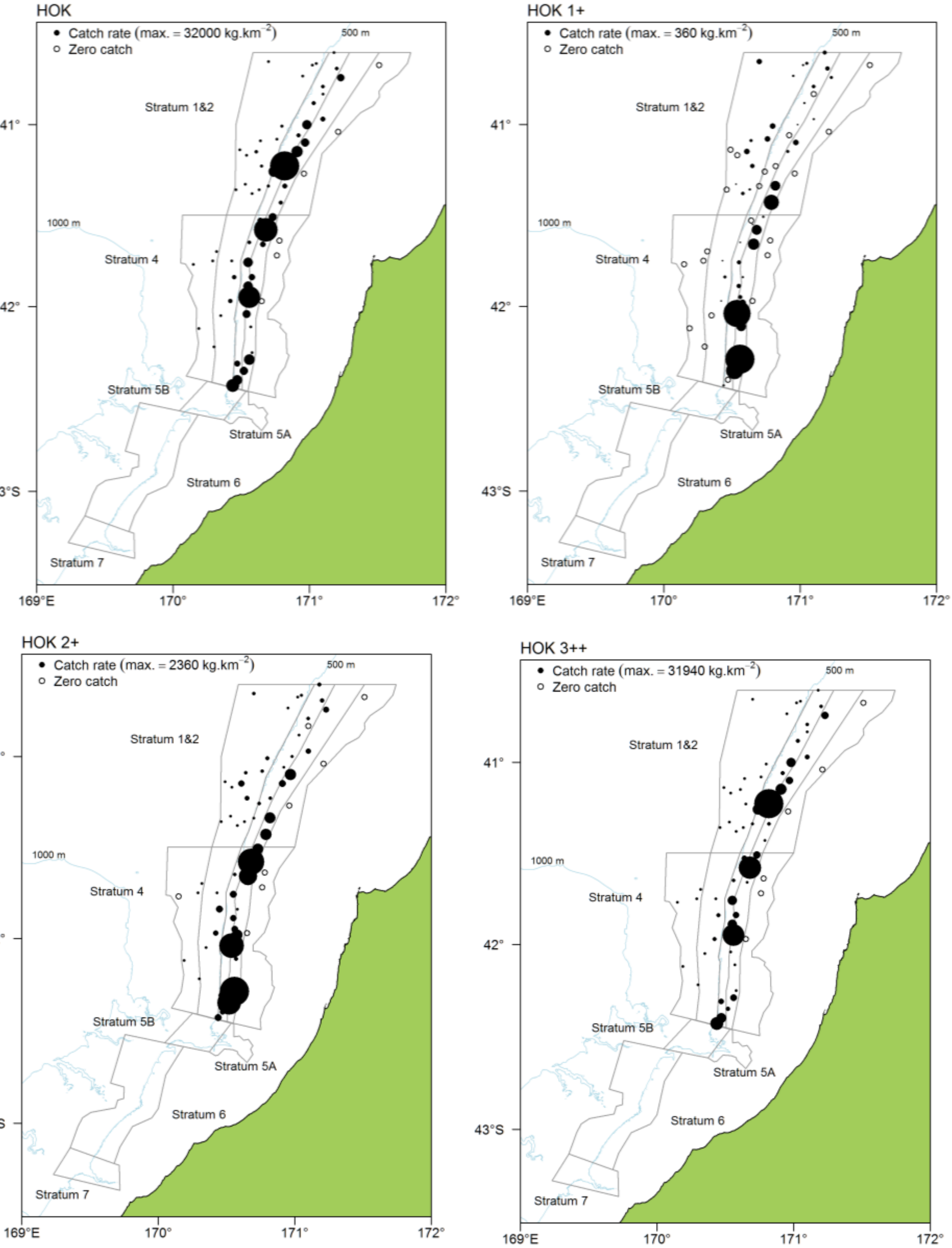
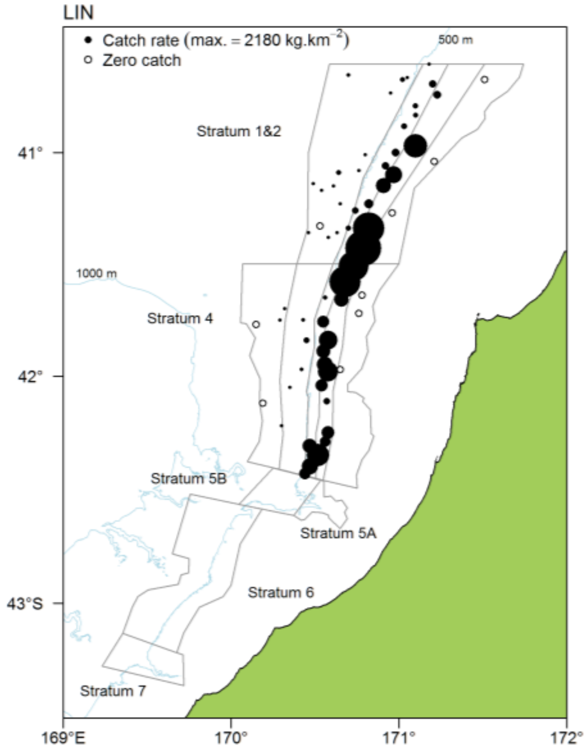


Figure 18: Distribution and catch rates of all, 1+ (less than 39 cm), 2+ (40–54 cm), and 3++ year old (more than 54 cm) hoki (HOK) on the WCSI 2013 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.



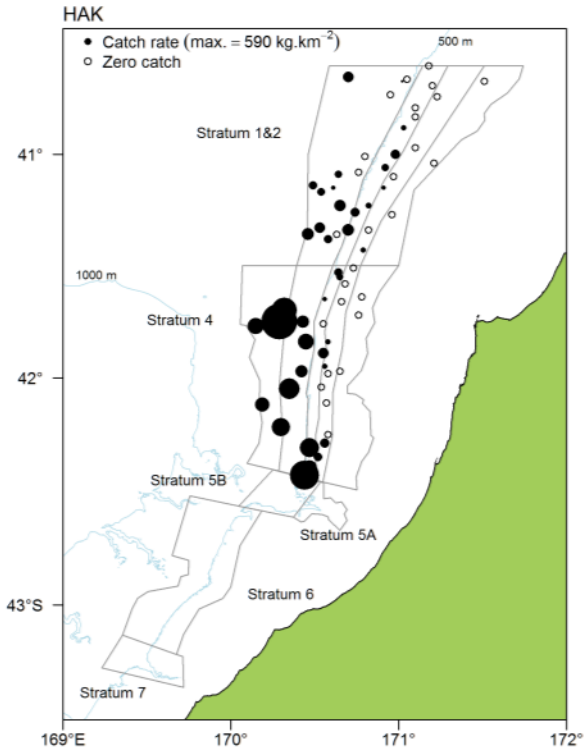
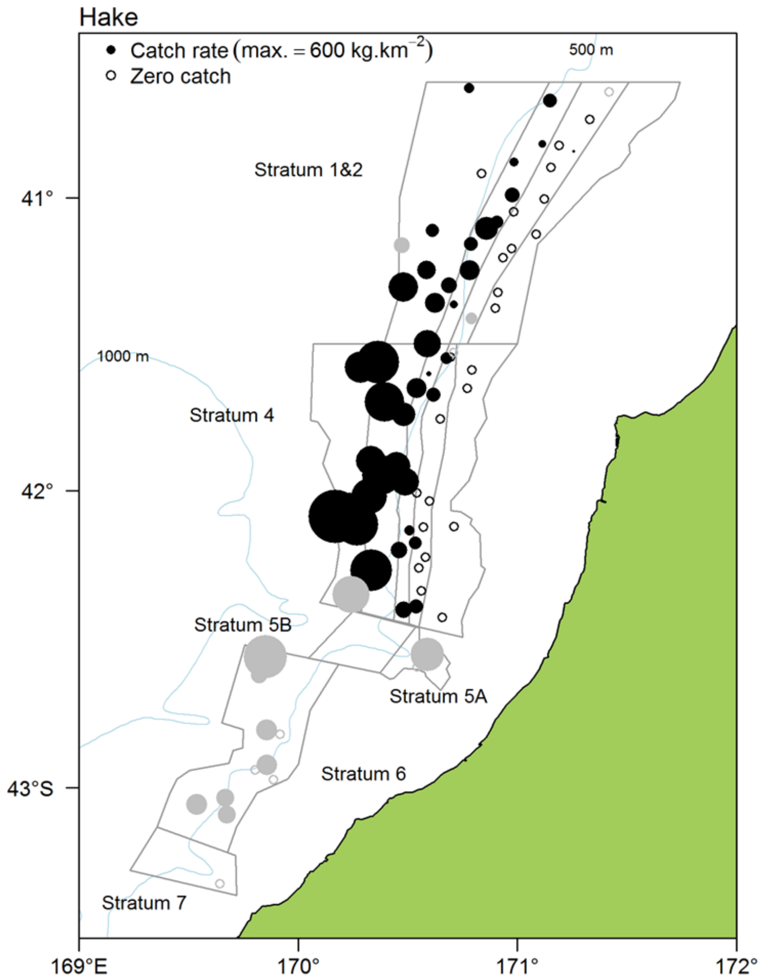


Figure 18 continued: Distribution and catch rates of ling (LIN) and hake (HAK) on the WCSI 2013 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.



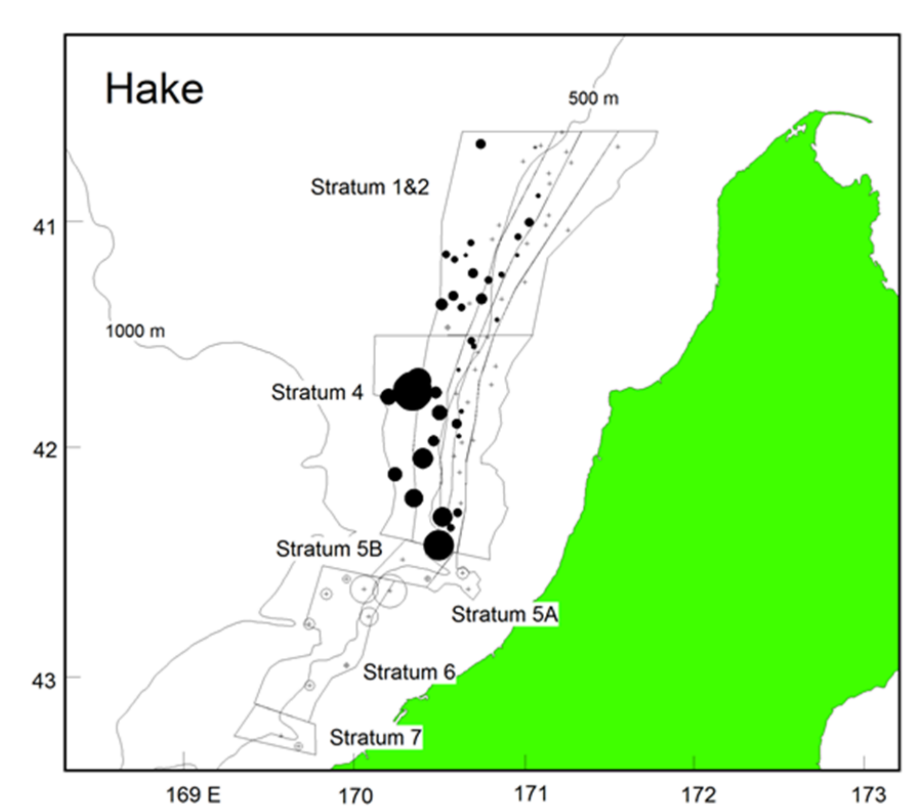
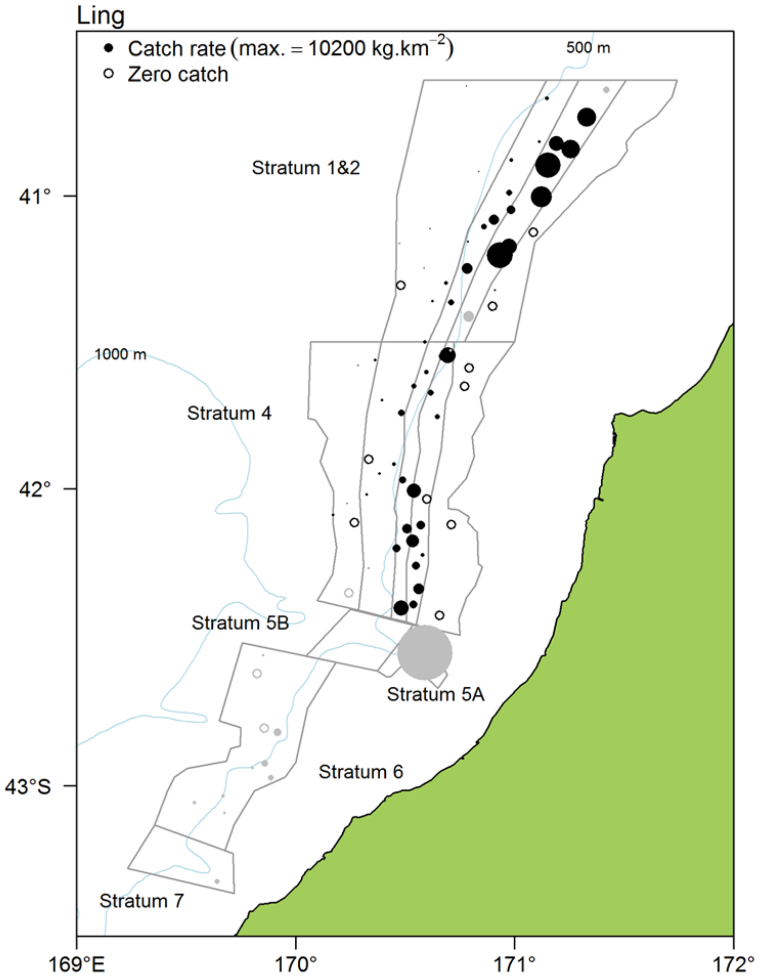


Figure 19: Catch rates (kg km^{-2}) of hake in bottom tows carried out during the random trawl survey (black circles) and tows for mark identification (grey or open circles) during the 2012 (upper plot) and 2013 (lower plot) WCSI survey. Circle area is proportional to catch rate. Maximum symbol size is equivalent to a catch rate of 600 kg km^{-2}. Crosses indicate zero catches.



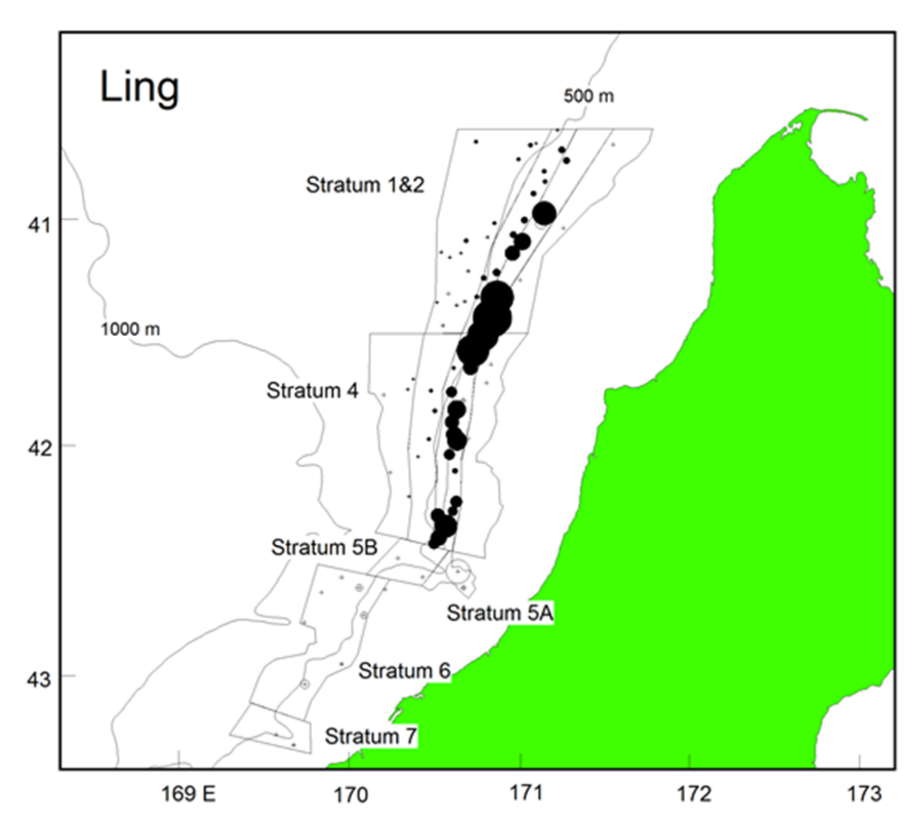


Figure 20: Catch rates (kg km^{-2}) of ling in bottom tows carried out during the random trawl survey (black circles) and tows for mark identification (grey or open circles) during the 2012 (upper plot) and 2013 (lower plot) WCSI survey. Circle area is proportional to catch rate. Maximum symbol size is equivalent to a catch rate of 10200 kg km^{-2} in 2012 and 2200 kg km^{-2} in 2013. Crosses indicate zero catches.

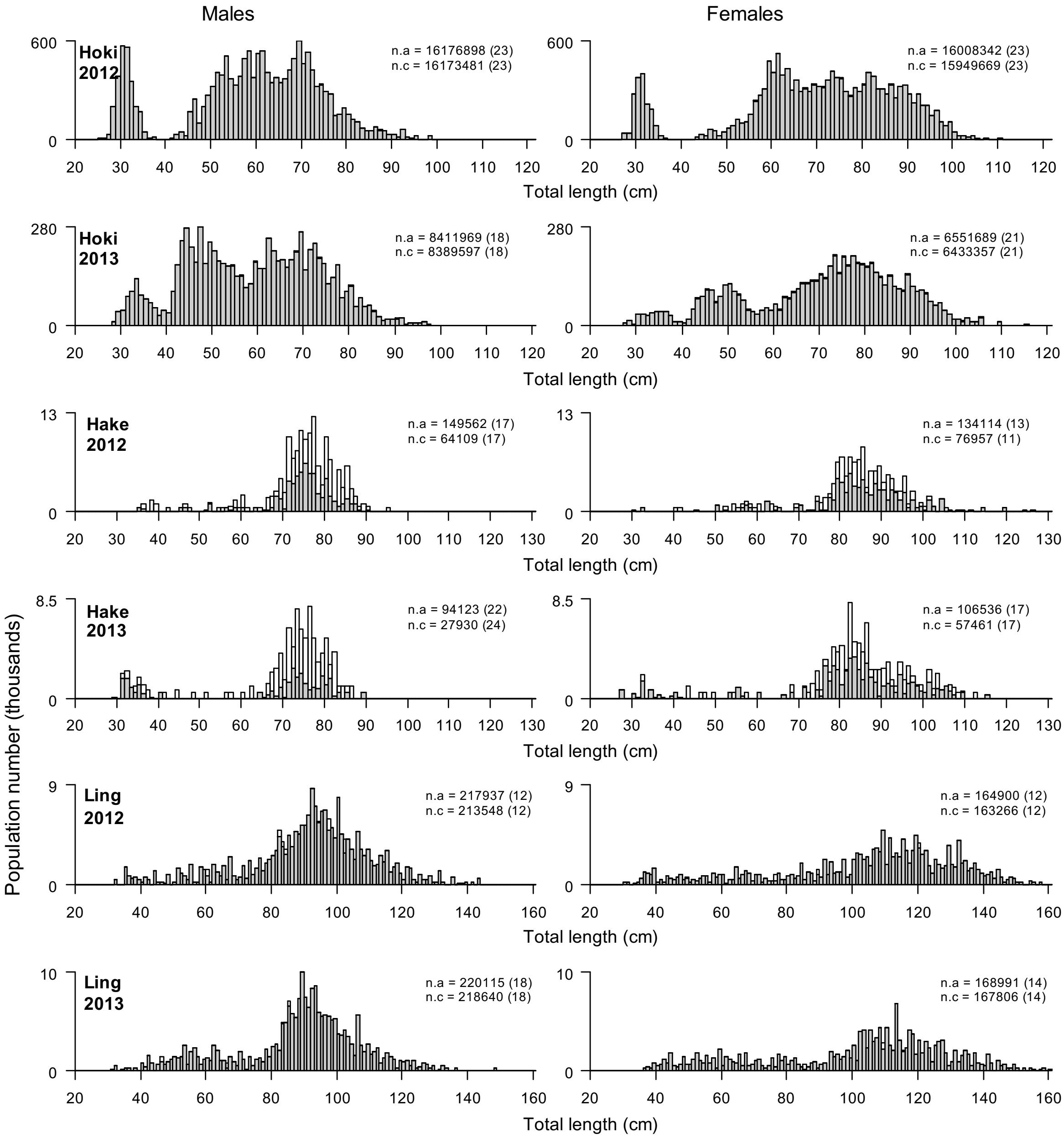


Figure 21: Length frequency distributions by sex of key species for core (grey) and all (white) strata from the 2012 and 2013 WCSI trawl surveys. n.a, estimated scaled total number of fish for all strata; n.c, estimated scaled total number of fish for core strata; and CV, the coefficient of variation (in parentheses). From O'Driscoll et al. (2015).

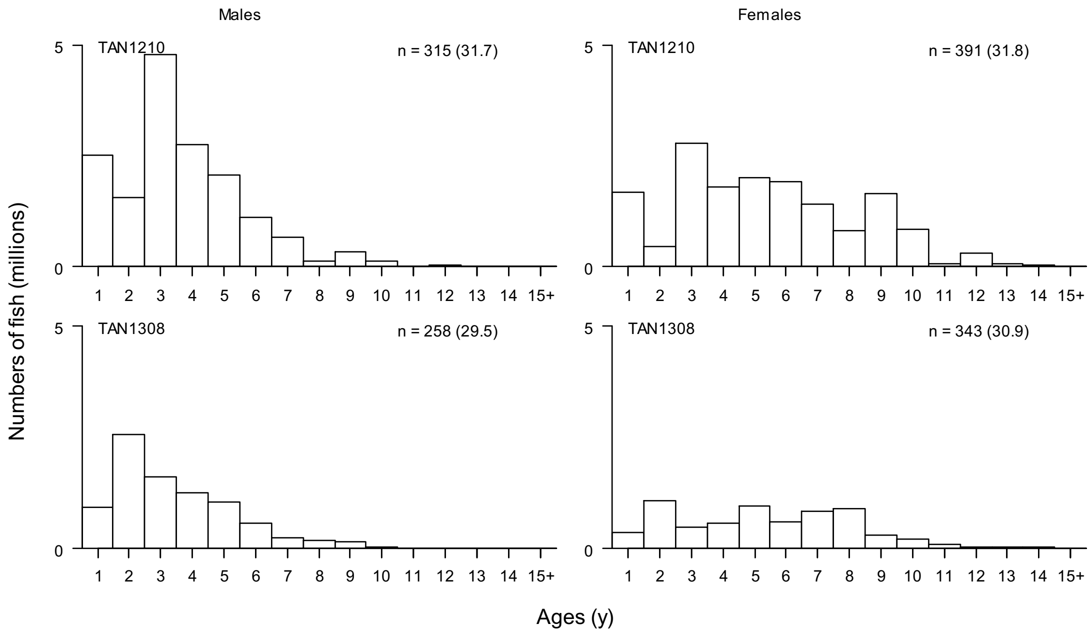


Figure 22: Scaled age frequency for hoki from core strata from the 2012 (TAN1210) and 2013 (TAN1308) WCSI trawl surveys. Number of fish aged (*n* values) are given with CVs in parentheses. Hoki were not aged for the 2000 survey. From O'Driscoll et al. (2015).

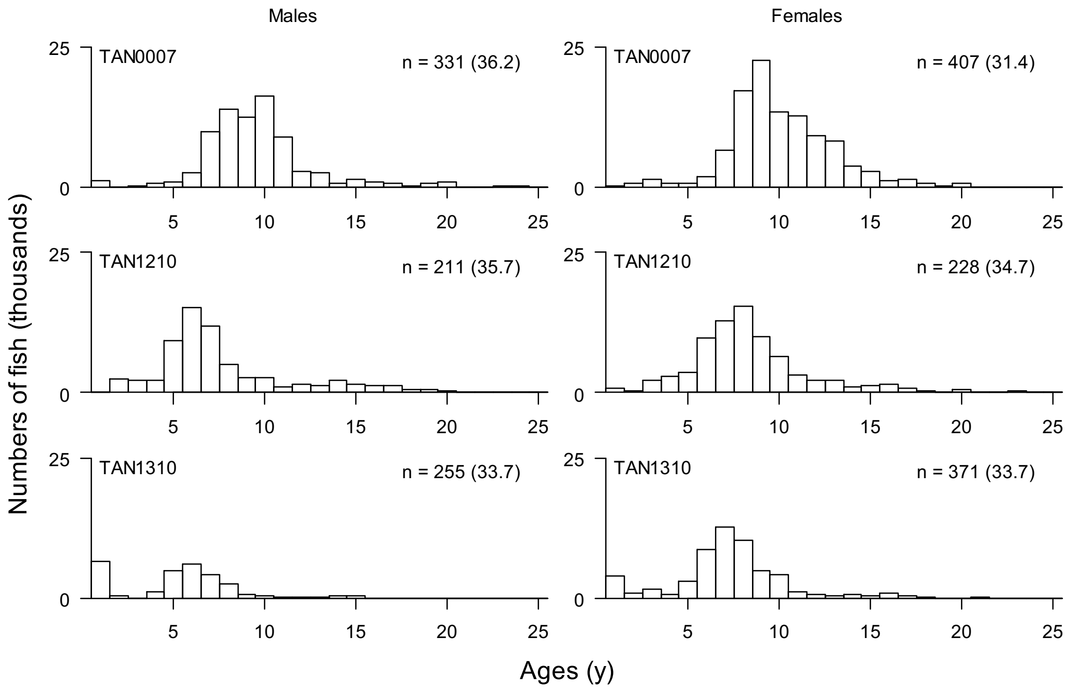


Figure 23: Scaled age frequency for hake in core strata from the WCSI trawl surveys in 2000 (TAN0007), 2012 (TAN1210), and 2013 (TAN1308). Number of fish aged (*n* values) are given with CVs in parentheses. From O'Driscoll et al. (2015).

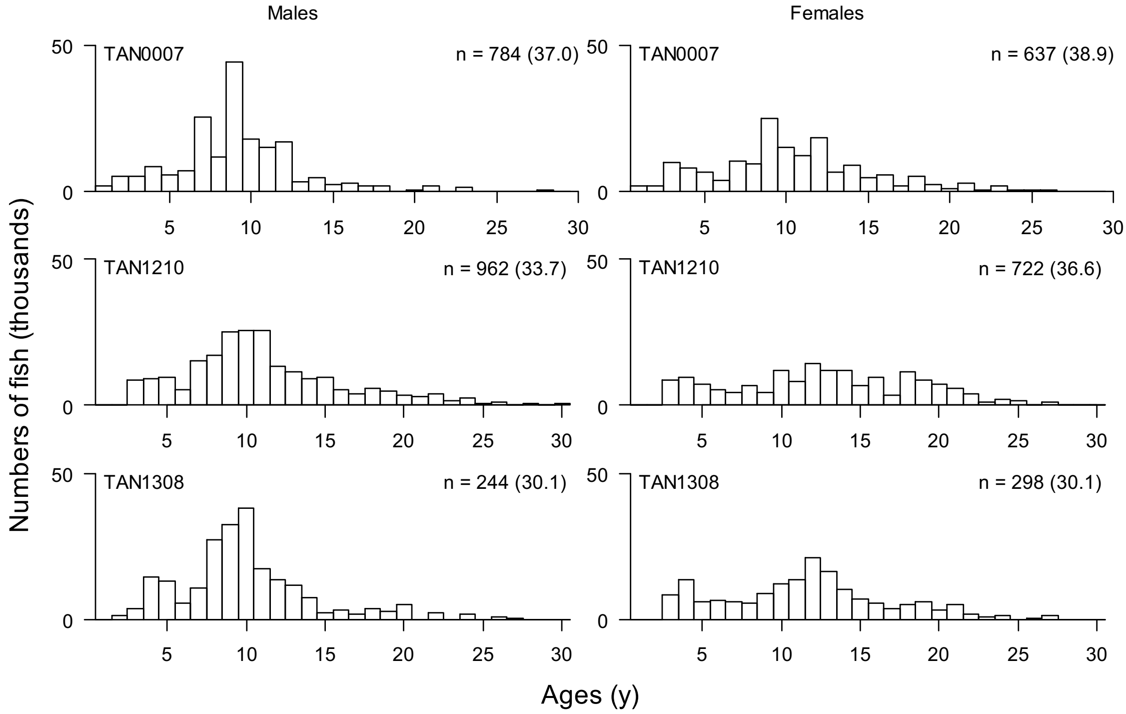


Figure 24: Scaled age frequency for ling in core strata from the WCSI trawl surveys in 2000 (TAN0007), 2012 (TAN1210), and 2013 (TAN1308). Number of fish aged (*n* values) are given with CVs in parentheses. From O'Driscoll et al. (2015).

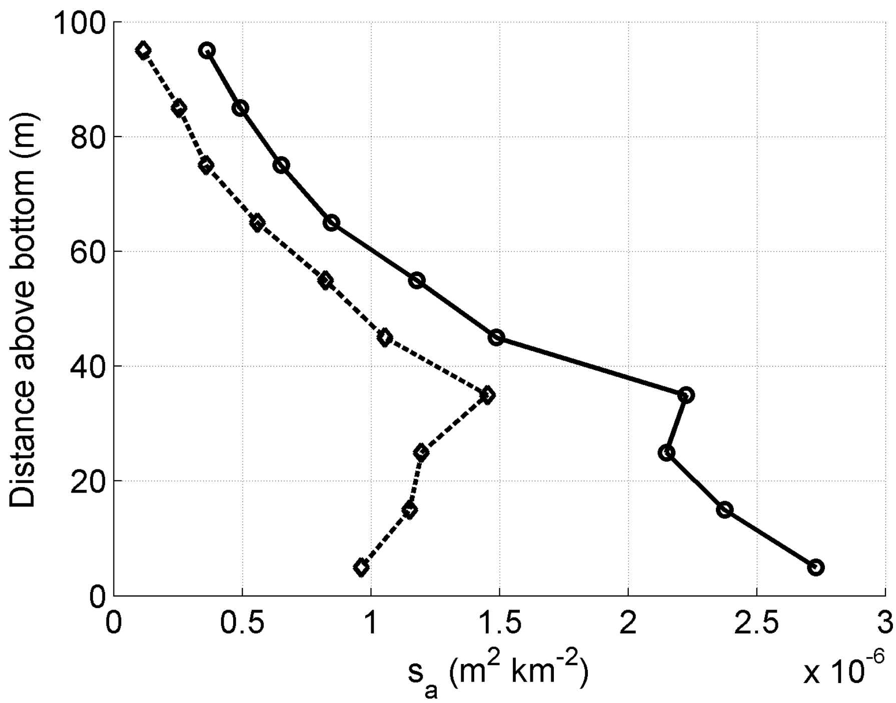


Figure 25: Vertical distribution bottom-referenced acoustic backscatter recorded during random bottom tows during the 2012 (solid line) and 2013 (dotted line) WCSI surveys. From O'Driscoll et al. (2015).

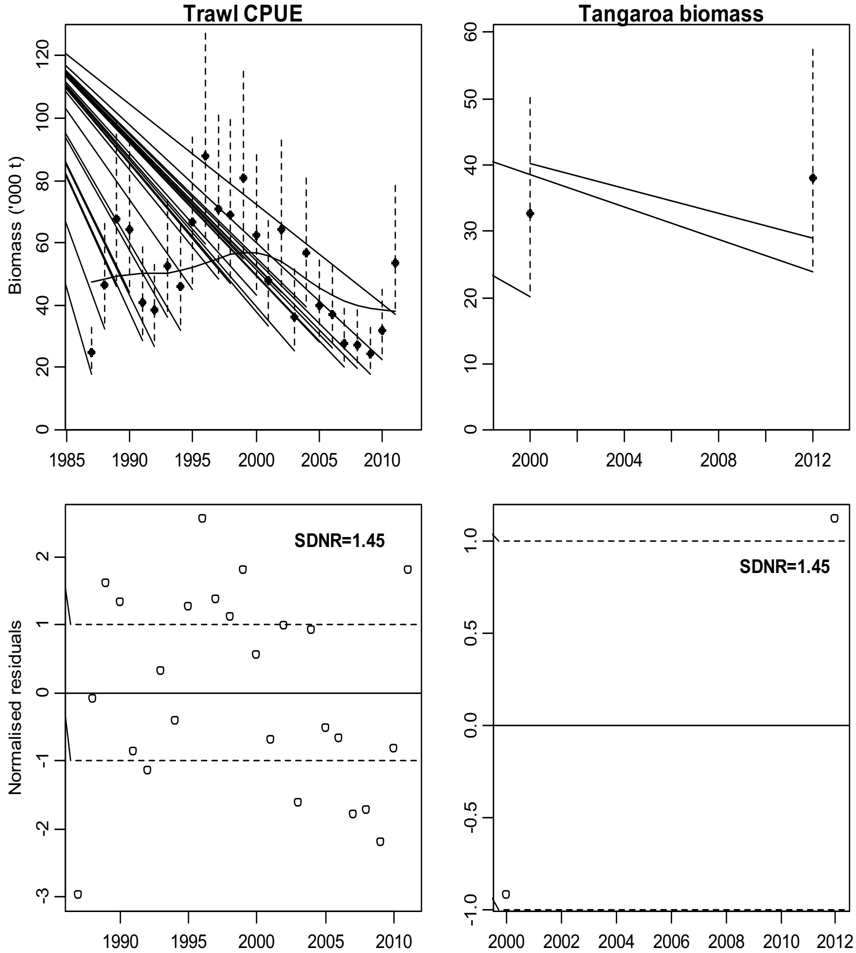


Figure 26: LIN 7WC fits of the MPD model run to the biomass indices in the top panels, and normalised residuals (and standard deviation of normalised residuals). In the top panels, vertical lines indicate the 95% confidence intervals; fits and observations are as estimated biomass; observations are scaled by the estimated catchability. From Dunn et al. (2013).

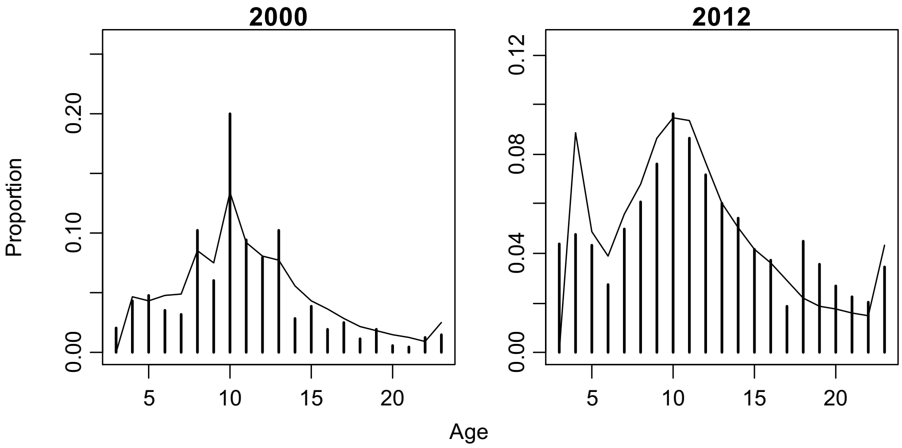


Figure 27: LIN 7WC fits (lines) of the MPD model run to the proportions-at-age in the *Tangaroa* trawl survey series (bars). From Dunn et al. (2013).

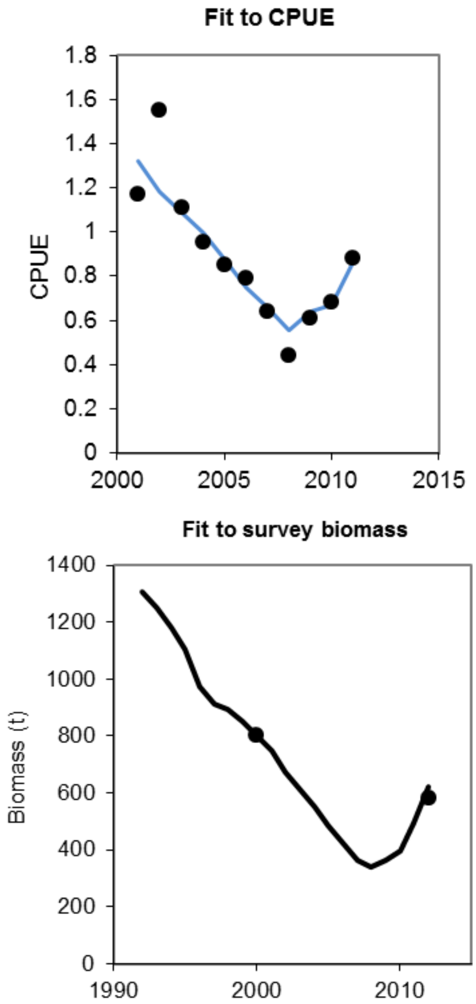


Figure 28: HAK 7 fits of the MPD model run to the biomass indices. Fits and observations are as estimated biomass; observations are scaled by the estimated catchability. From Horn (2013).

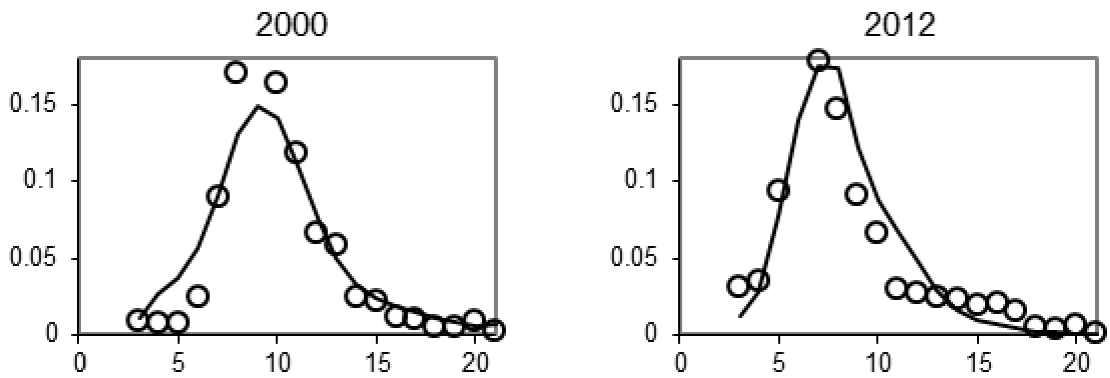


Figure 29: HAK 7 fits (lines) of the MPD model run to the proportions-at-age in the *Tangaroa* trawl survey series (bars). From Horn (2013).

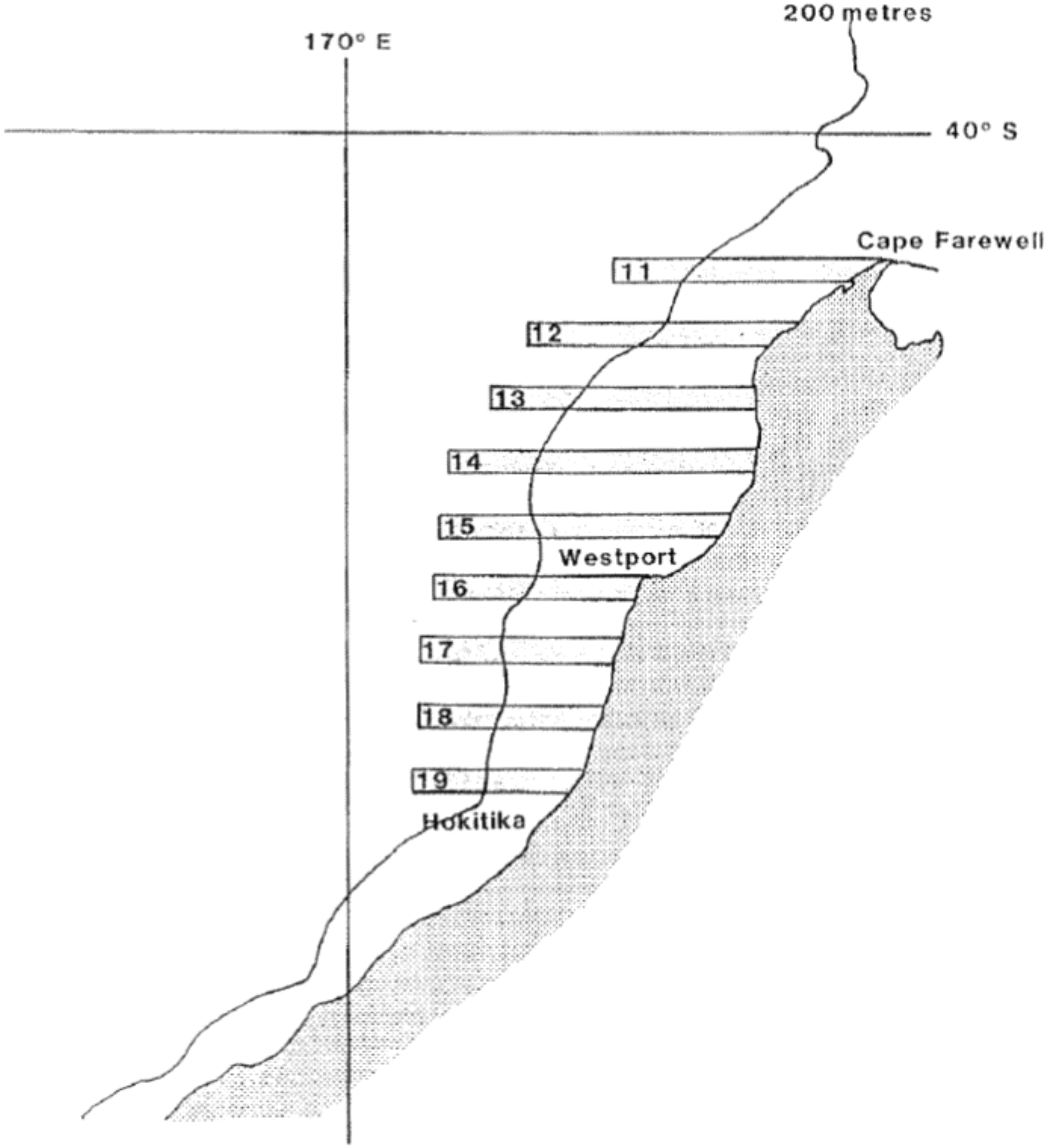


Figure 30: *W.J. Scott* survey transects, 1981–83. From Hurst & Fenaughty (1985).

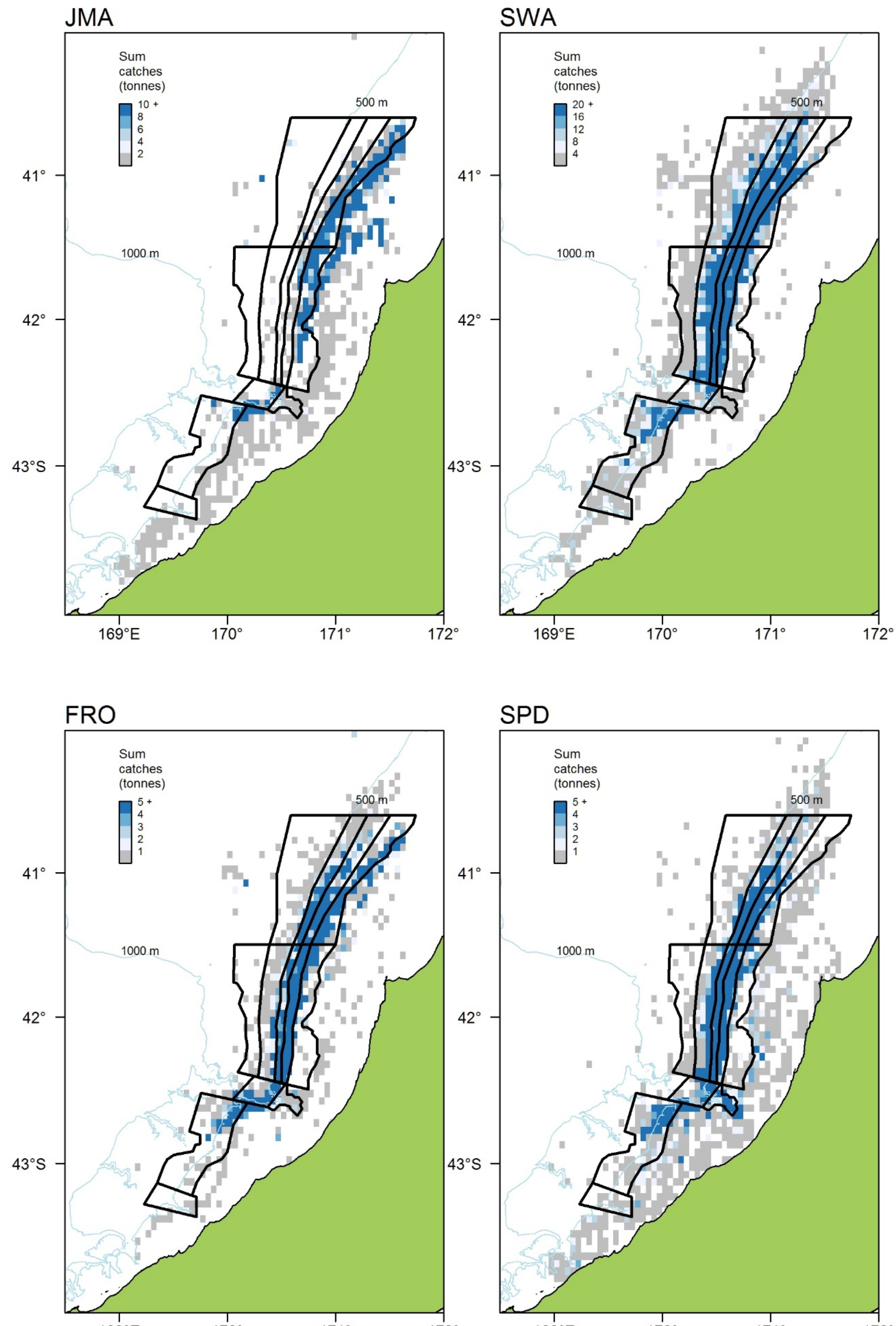


Figure 31: Commercial catch of jack mackerel, silver warehou, frostfish, and spiny dogfish on the WCSI in June–September from 2000–13 in relation to survey boundaries.

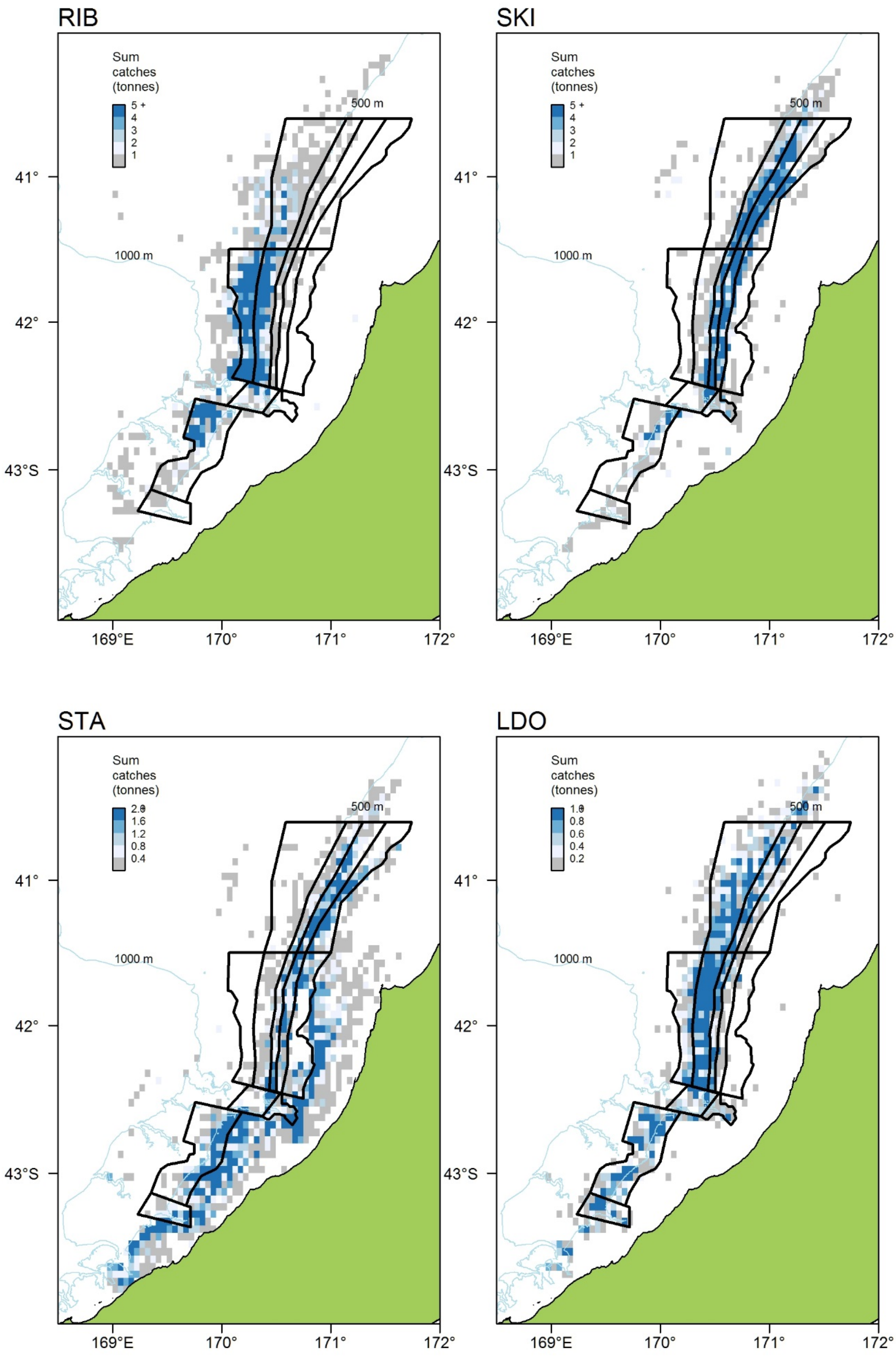


Figure 31 continued: Commercial catch of ribaldo, gemfish, giant stargazer, and lookdown dory on the WCSI in June–September from 2000–13 in relation to survey boundaries.

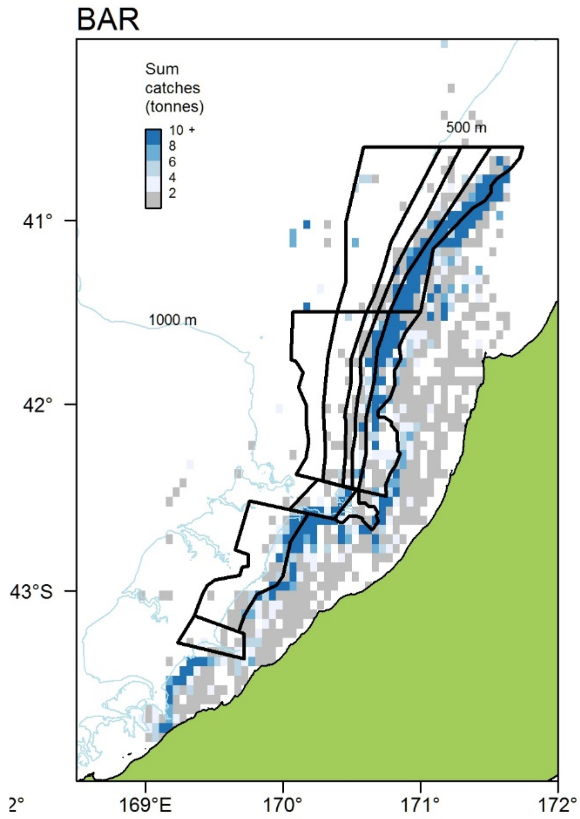


Figure 31 continued: Commercial catch of barracouta on the WCSI in June–September from 2000–13 in relation to survey boundaries.

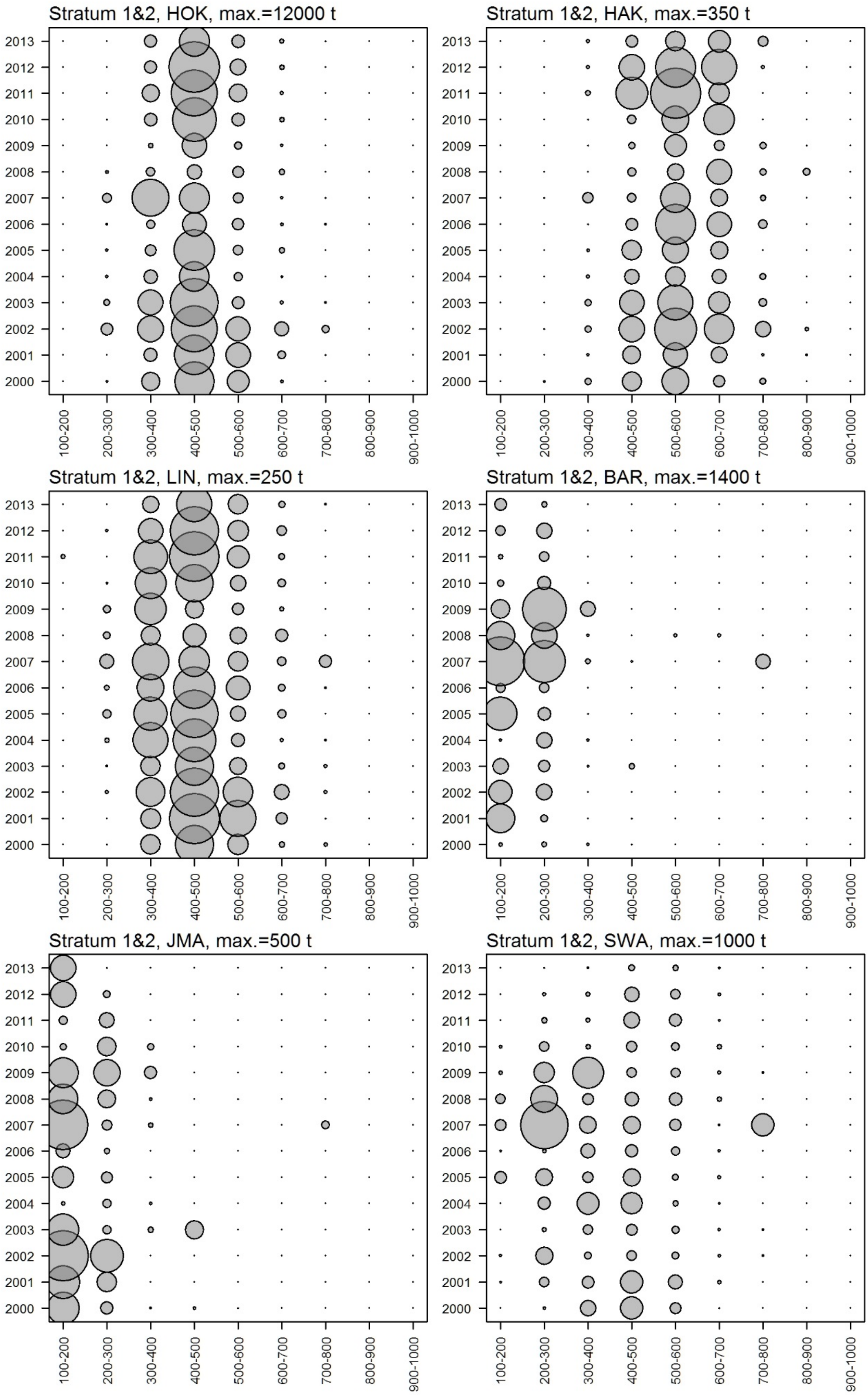


Figure 32: Depth distribution of commercial catch of hoki, hake, ling, barracouta, jack mackerel, and silver warehou in stratum 1&2 on the WCSI in June–September from 2000–13.

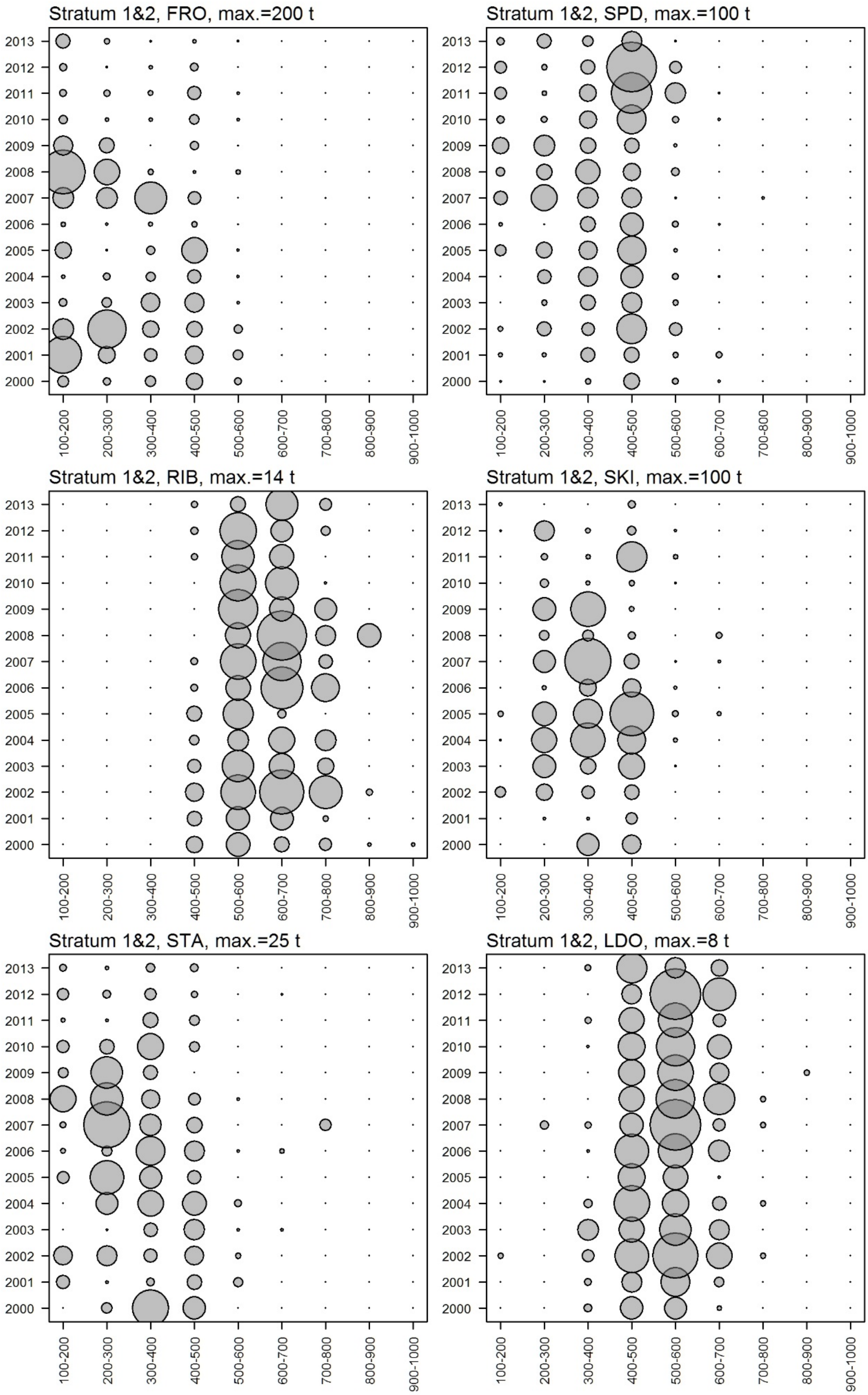


Figure 32 continued: Depth distribution of commercial catch of frostfish, spiny dogfish, ribaldo, gemfish, giant stargazer, and lookdown dory in stratum 1&2 on the WCSI in June–September from 2000–13.

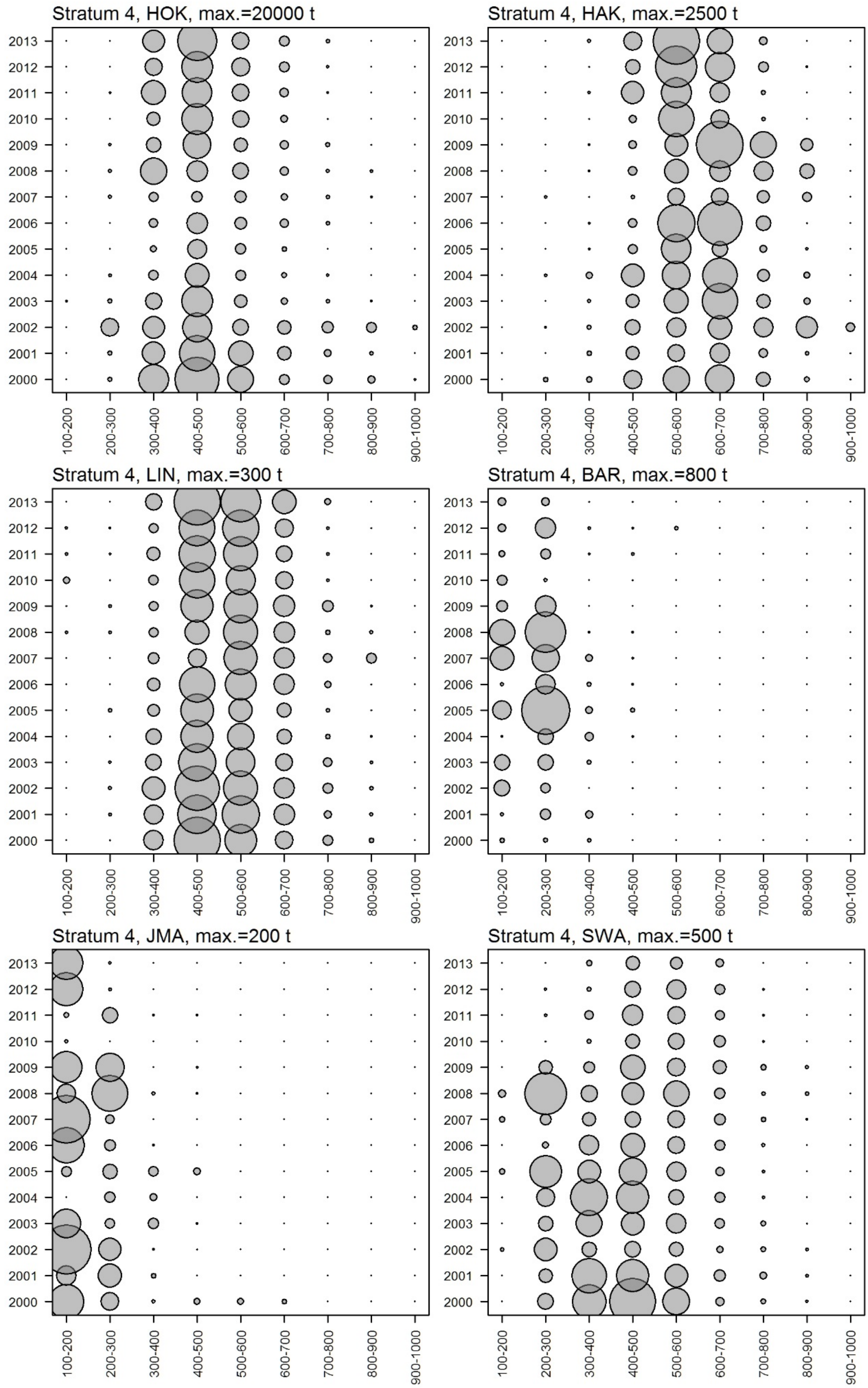


Figure 32 continued: Depth distribution of commercial catch of hoki, hake, ling, barracouta, jack mackerel, and silver warehou in stratum 4 on the WCSI in June–September from 2000–13.

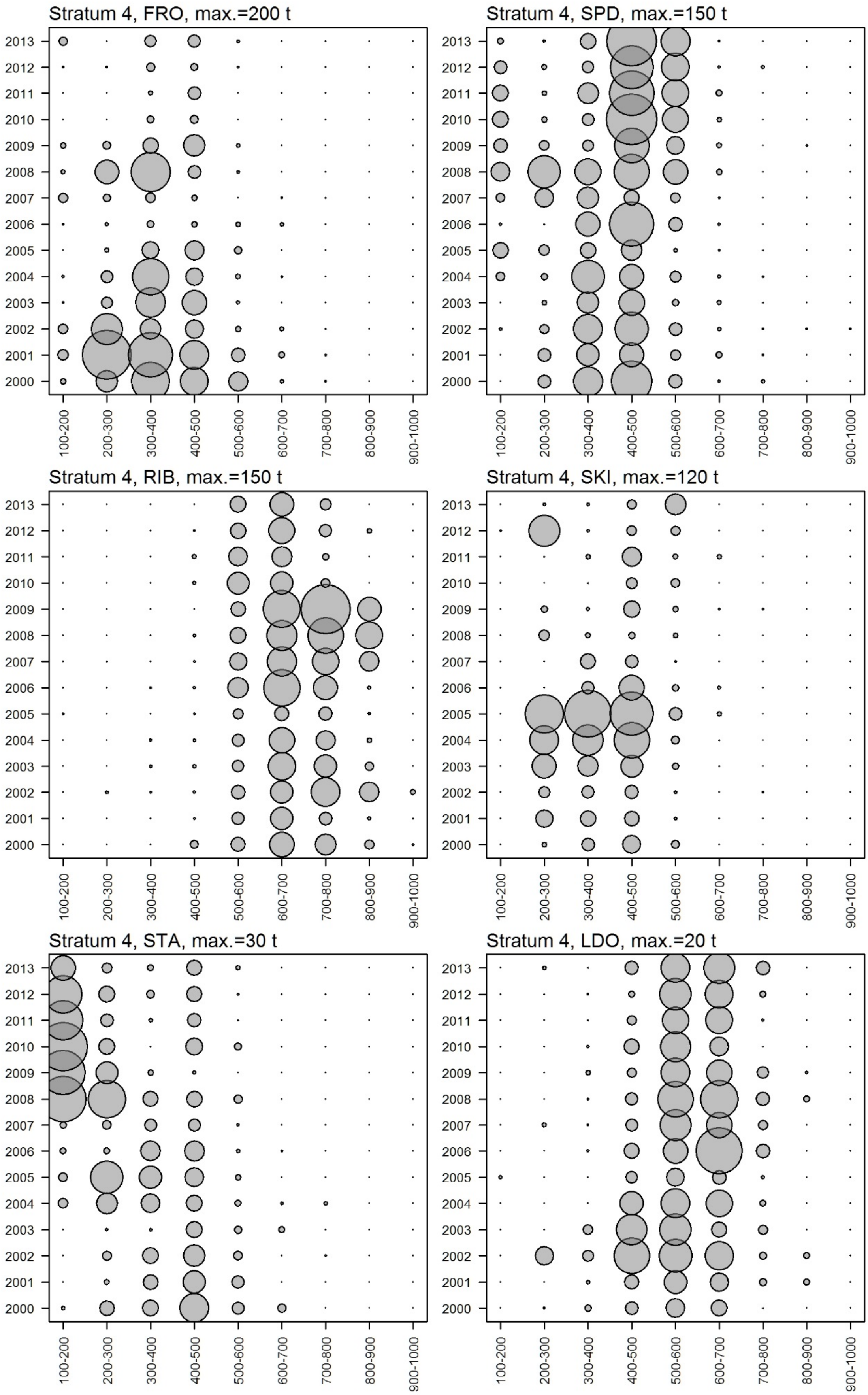
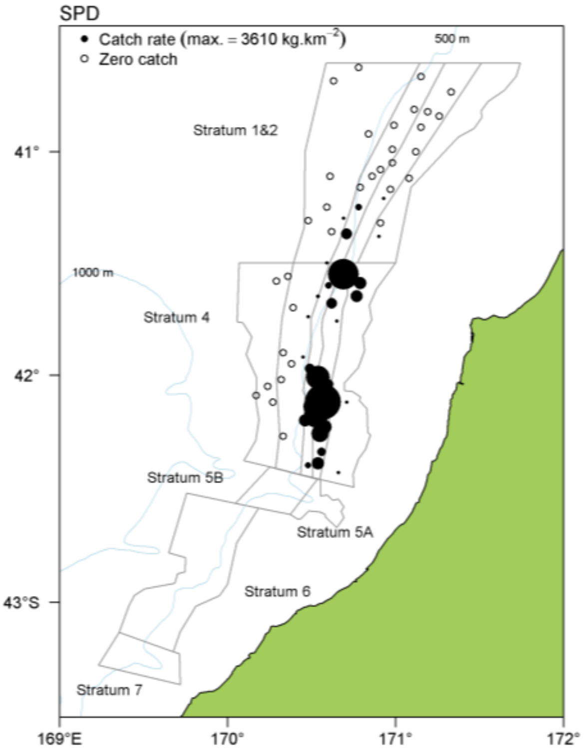


Figure 32 continued: Depth distribution of commercial catch of frostfish, spiny dogfish, ribaldo, gemfish, giant stargazer, and lookdown dory in stratum 4 on the WCSI in June–September from 2000–13.



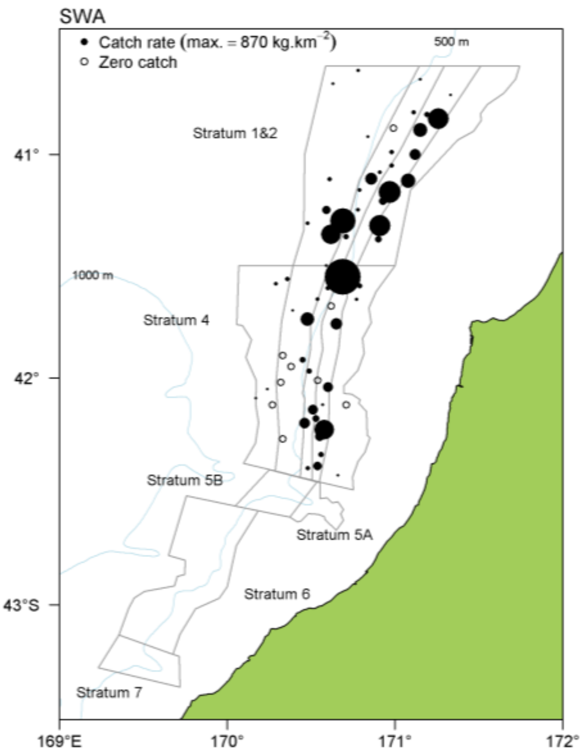


Figure 33: Distribution and catch rates of spiny dogfish (SPD) and silver warehou (SWA) on the WCSI 2012 trawl survey. Circle area is proportional to catch rate.

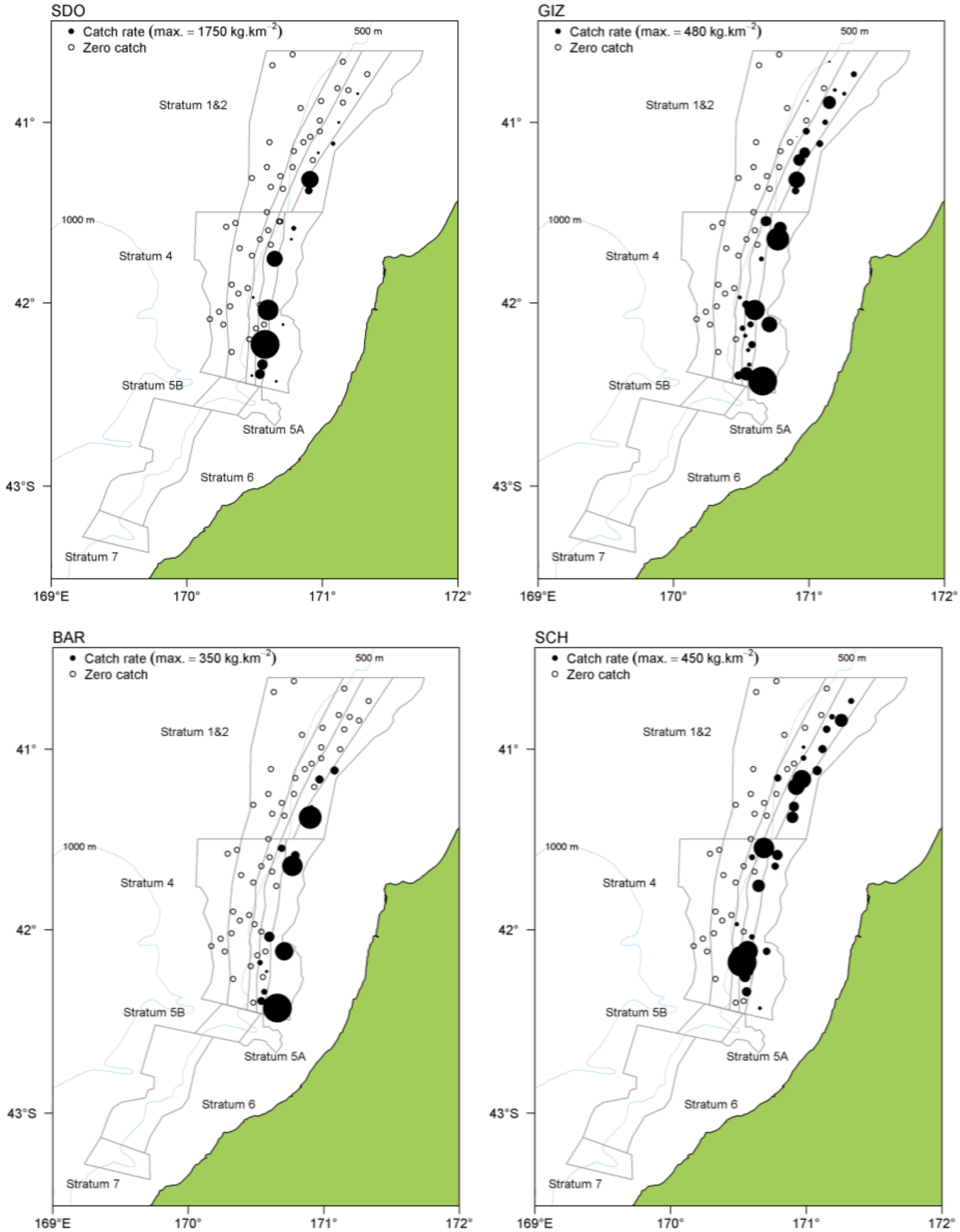


Figure 33 continued: Distribution and catch rates of silver dory (SDO), giant stargazer (GIZ), barracouta (BAR), and school shark (SCH) on the WCSI 2012 trawl survey. Circle area is proportional to catch rate.

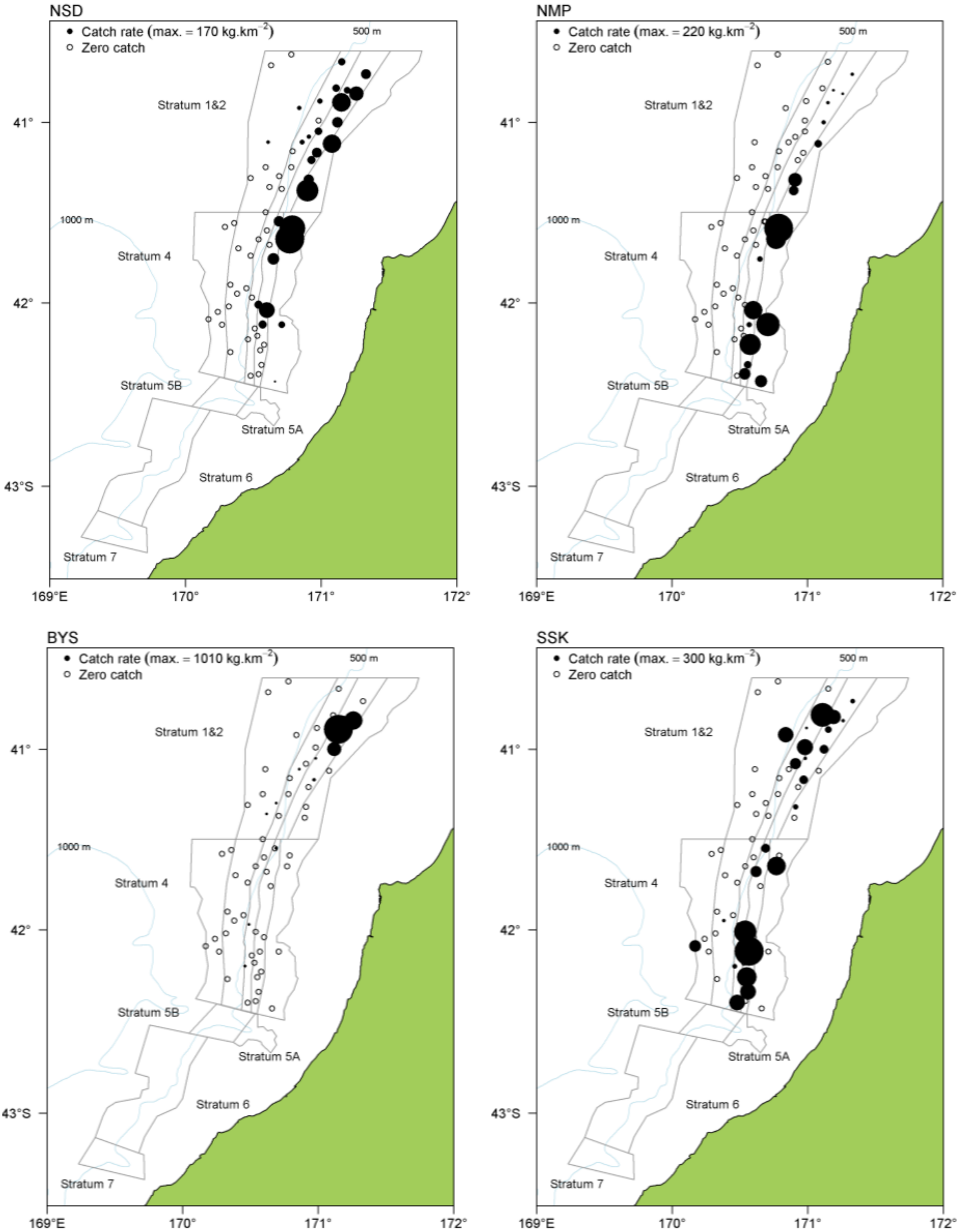


Figure 33 continued: Distribution and catch rates of northern spiny dogfish (NSD), tarakihi (NMP), alfonsino (BYS), and smooth skate (SSK) on the WCSI 2012 trawl survey. Circle area is proportional to catch rate.

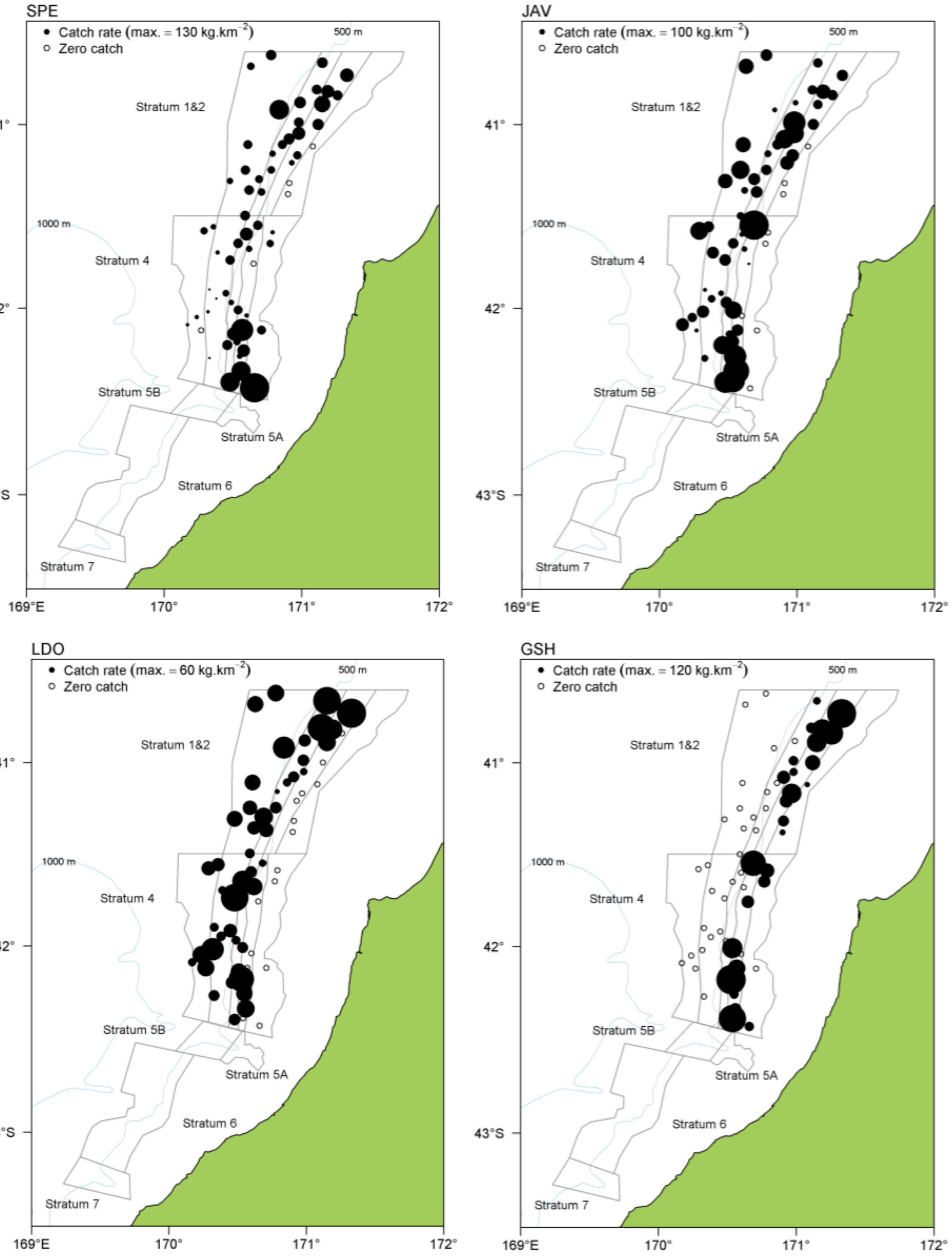


Figure 33 continued: Distribution and catch rates of sea perch (SPE), javelinfish (JAV), look down dory (LDO), and dark ghost shark (GSH) on the WCSI 2012 trawl survey. Circle area is proportional to catch rate.

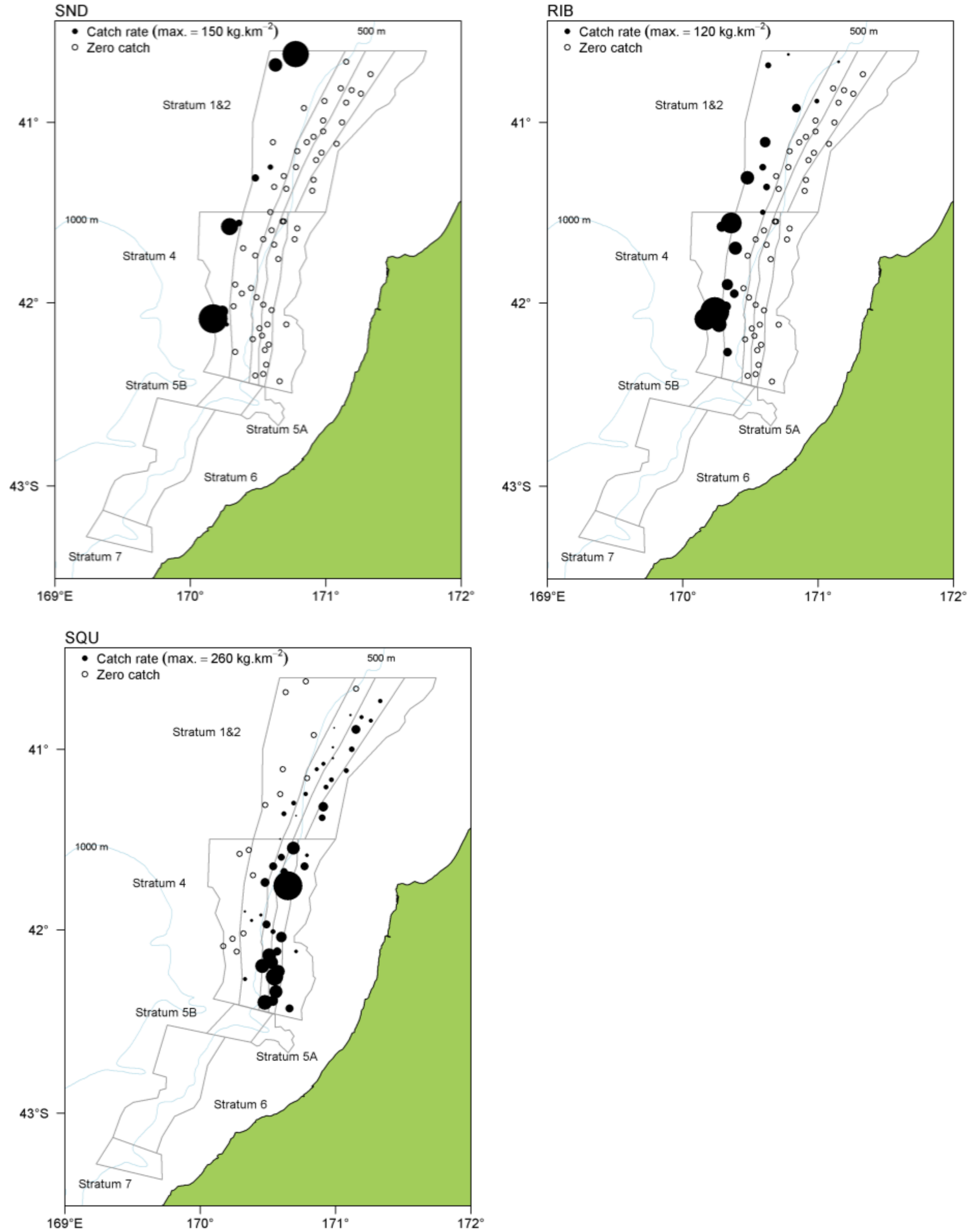


Figure 33 continued: Distribution and catch rates of shovelnosed dogfish (SND), ribaldo (RIB), and arrow squid (SQU) on the WCSI 2012 trawl survey. Circle area is proportional to catch rate.

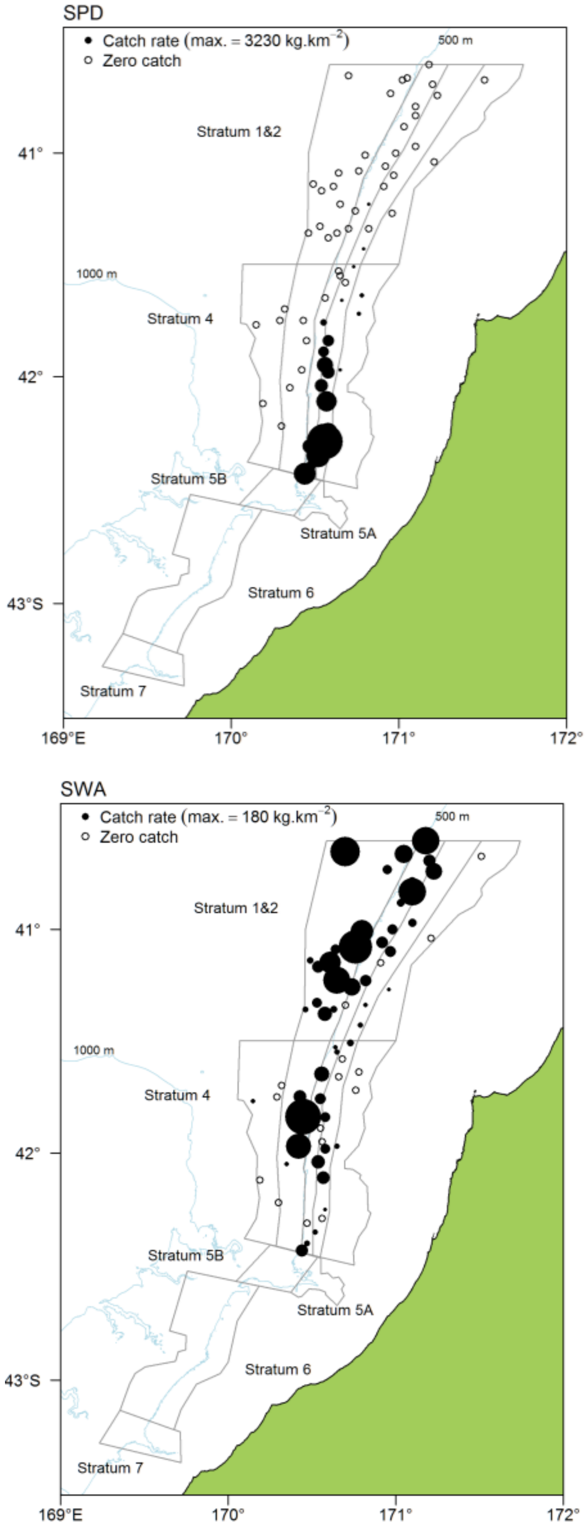


Figure 34: Distribution and catch rates of spiny dogfish (SPD) and silver warehou (SWA) on the WCSI 2013 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.

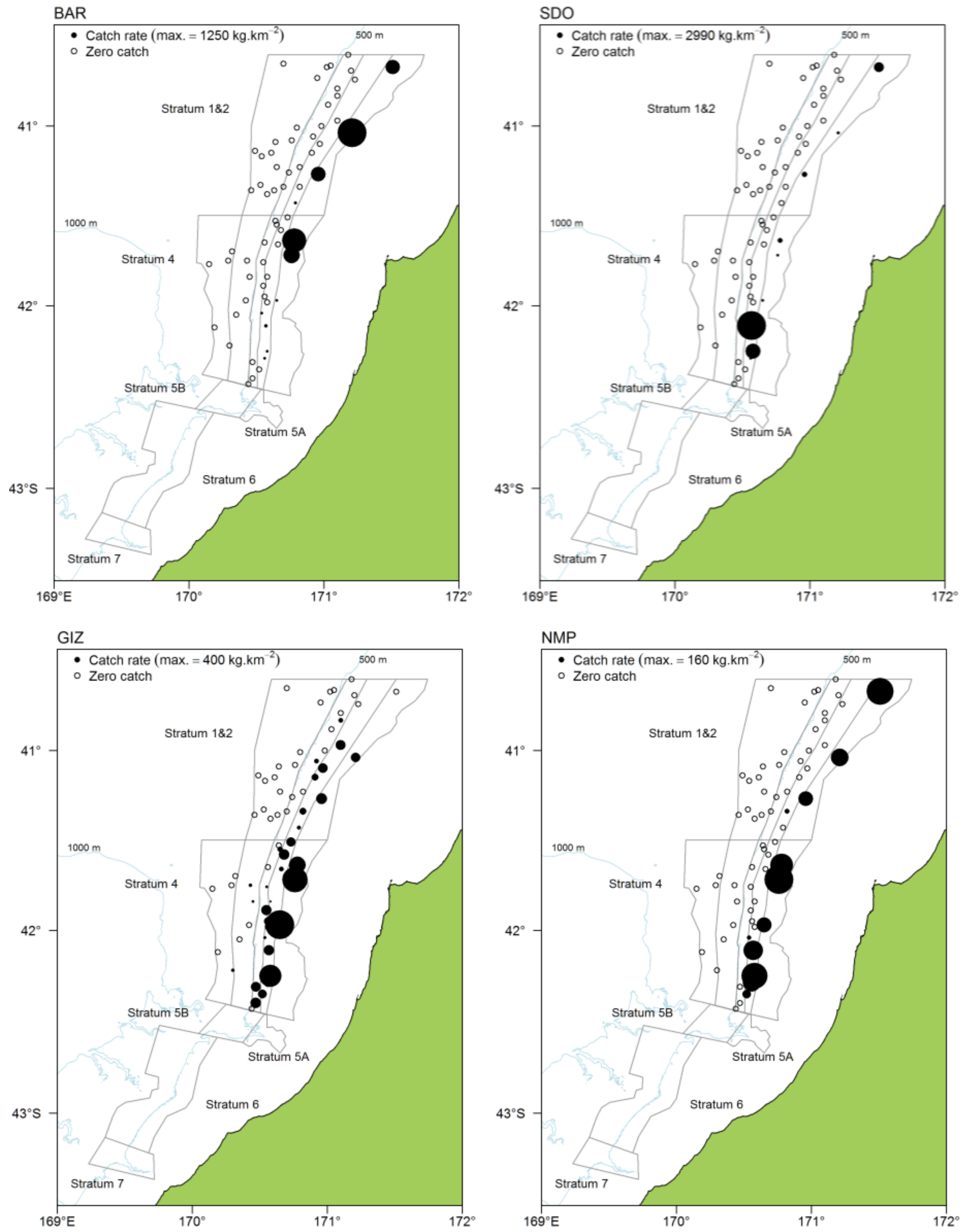


Figure 34 continued: Distribution and catch rates of barracouta (BAR), silver dory (SDO), giant stargazer (GIZ), and tarakihi (NMP) on the WCSI 2013 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.

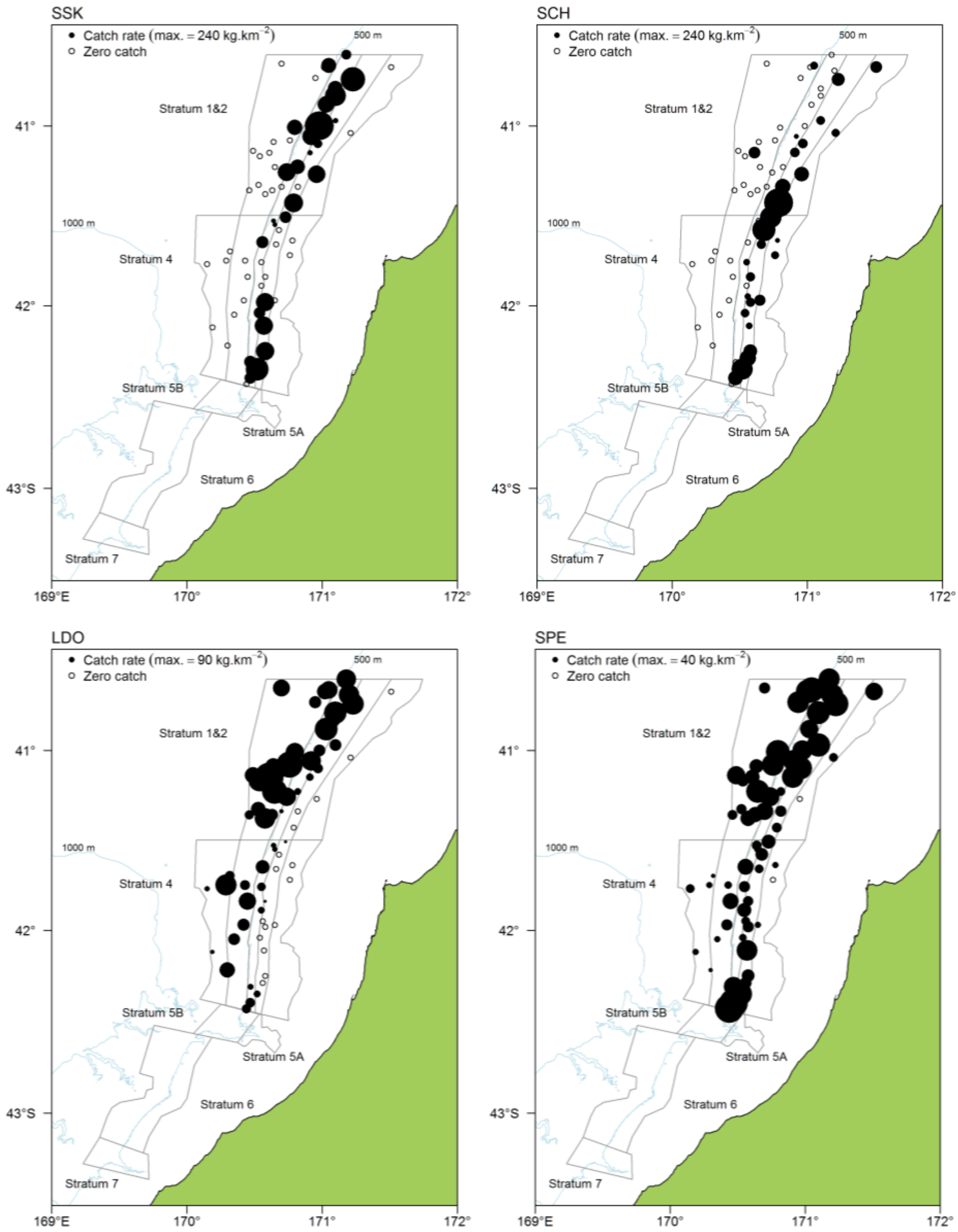


Figure 34 continued: Distribution and catch rates of smooth skate (SSK), school shark (SCH), look down dory (LDO) and sea perch (SPE) on the WCSI 2013 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.

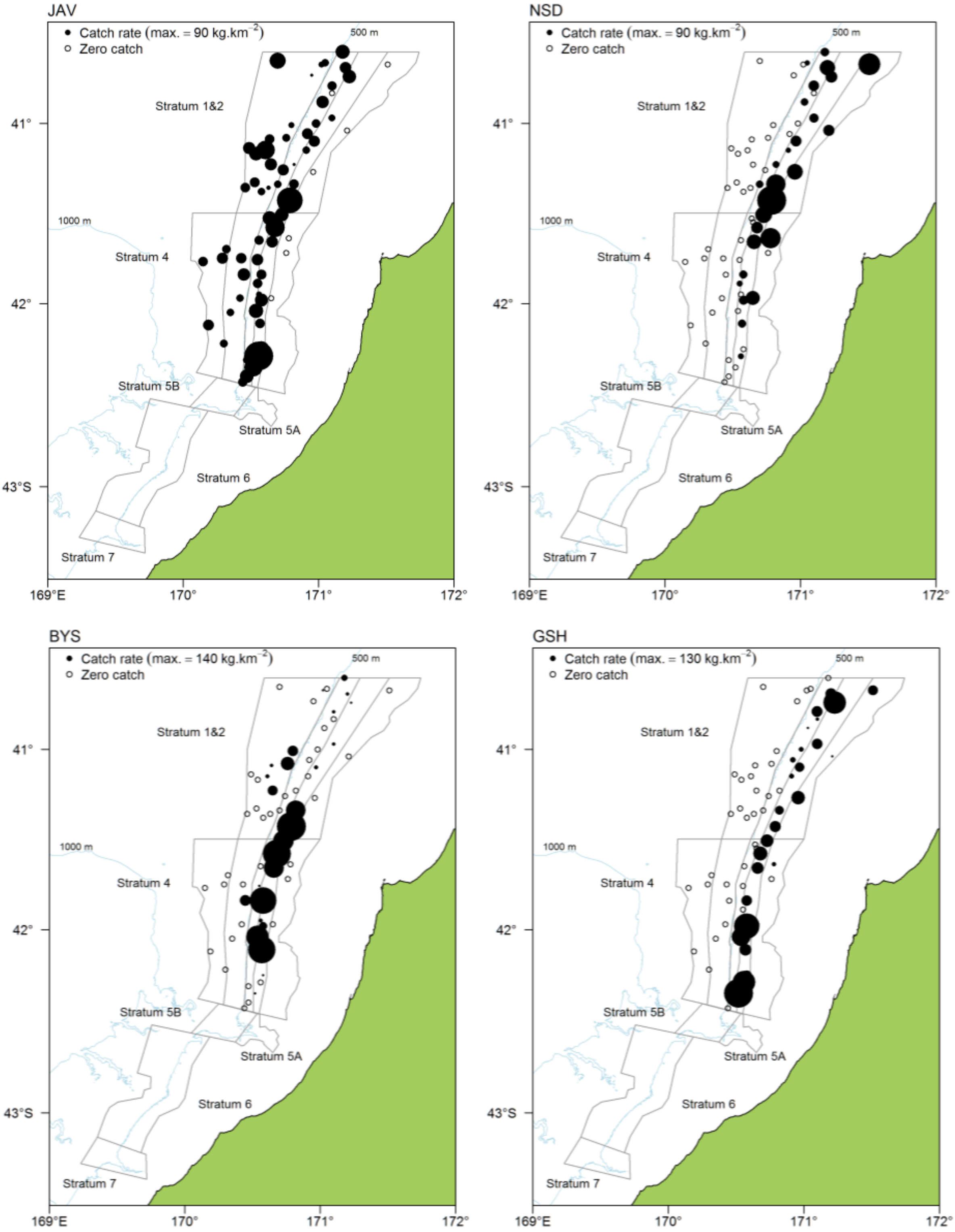


Figure 34 continued: Distribution and catch rates of javelinfish (JAV), northern spiny dogfish (NSD), alfonsino (BYS), and dark ghost shark (GSH) on the WCSI 2013 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.

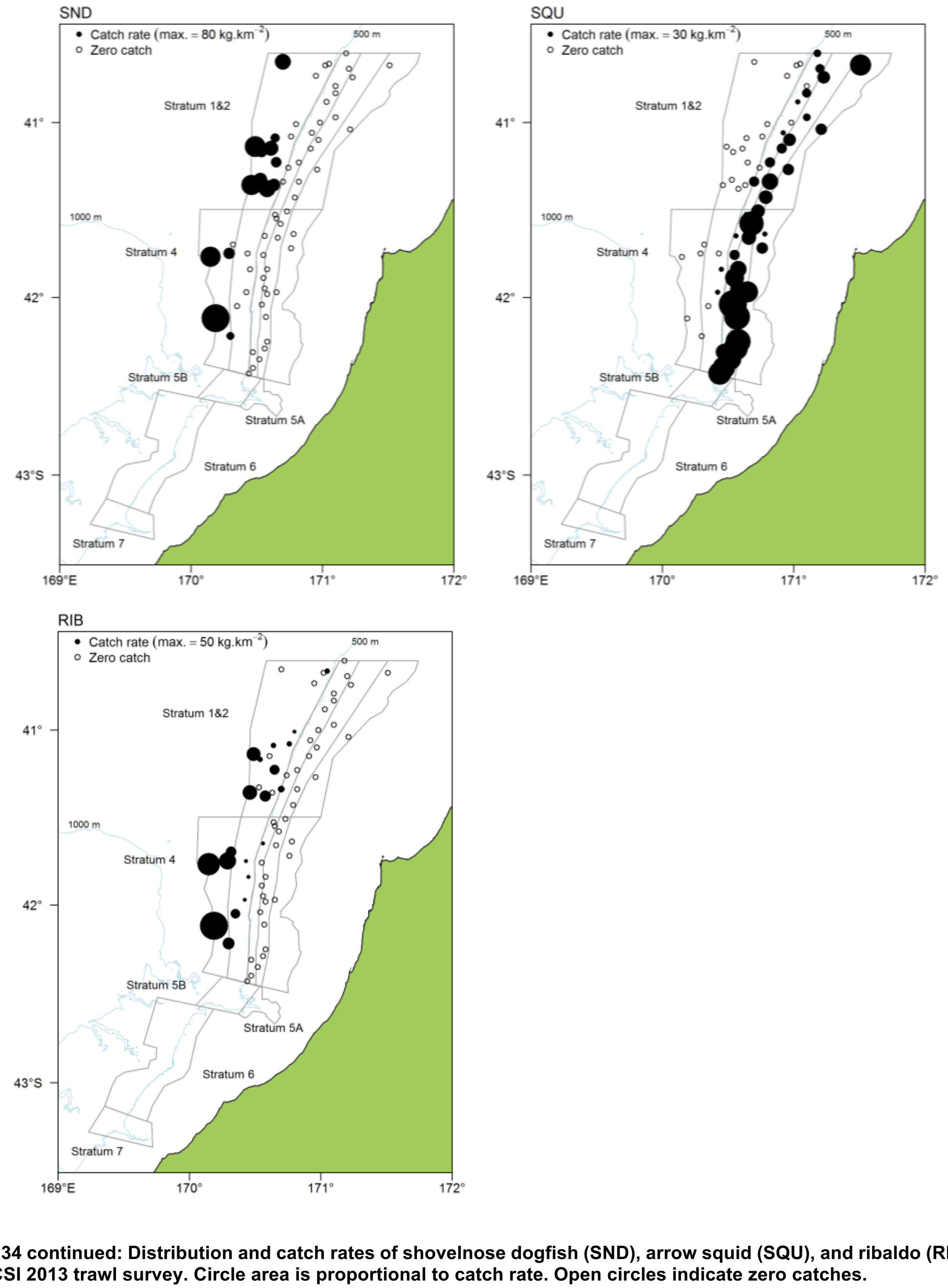


Figure 34 continued: Distribution and catch rates of shovelnose dogfish (SND), arrow squid (SQU), and ribaldo (RIB), on the WCSI 2013 trawl survey. Circle area is proportional to catch rate. Open circles indicate zero catches.

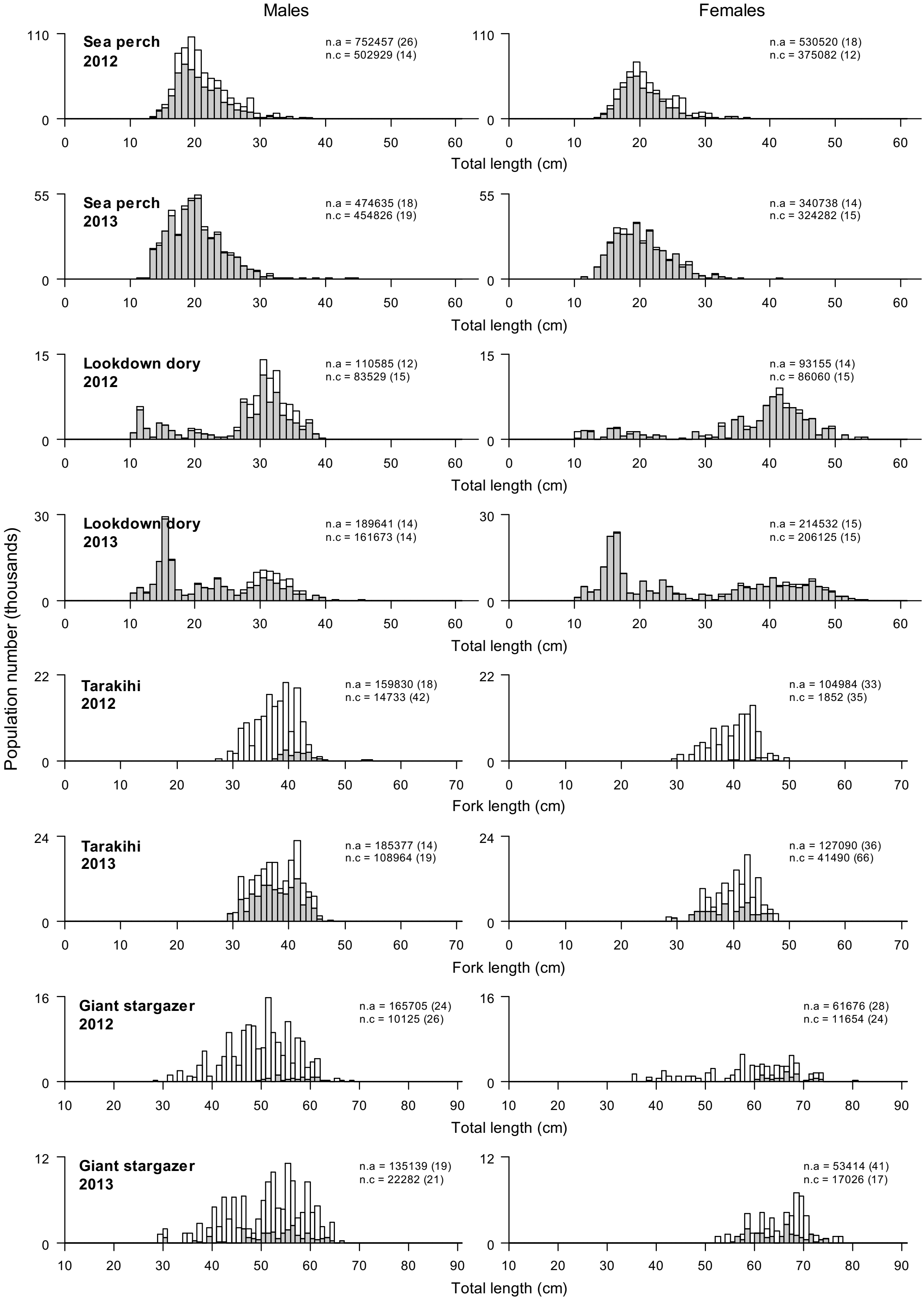


Figure 35: Length frequency distributions by sex of key species for core (grey) and all (white) strata from the WCSI 2012 and 2013 trawl surveys. n.a, estimated scaled total number of fish for all strata; n.c, estimated scaled total number of fish for core strata; and CV, the coefficient of variation (in parentheses). From O'Driscoll et al. (2015).

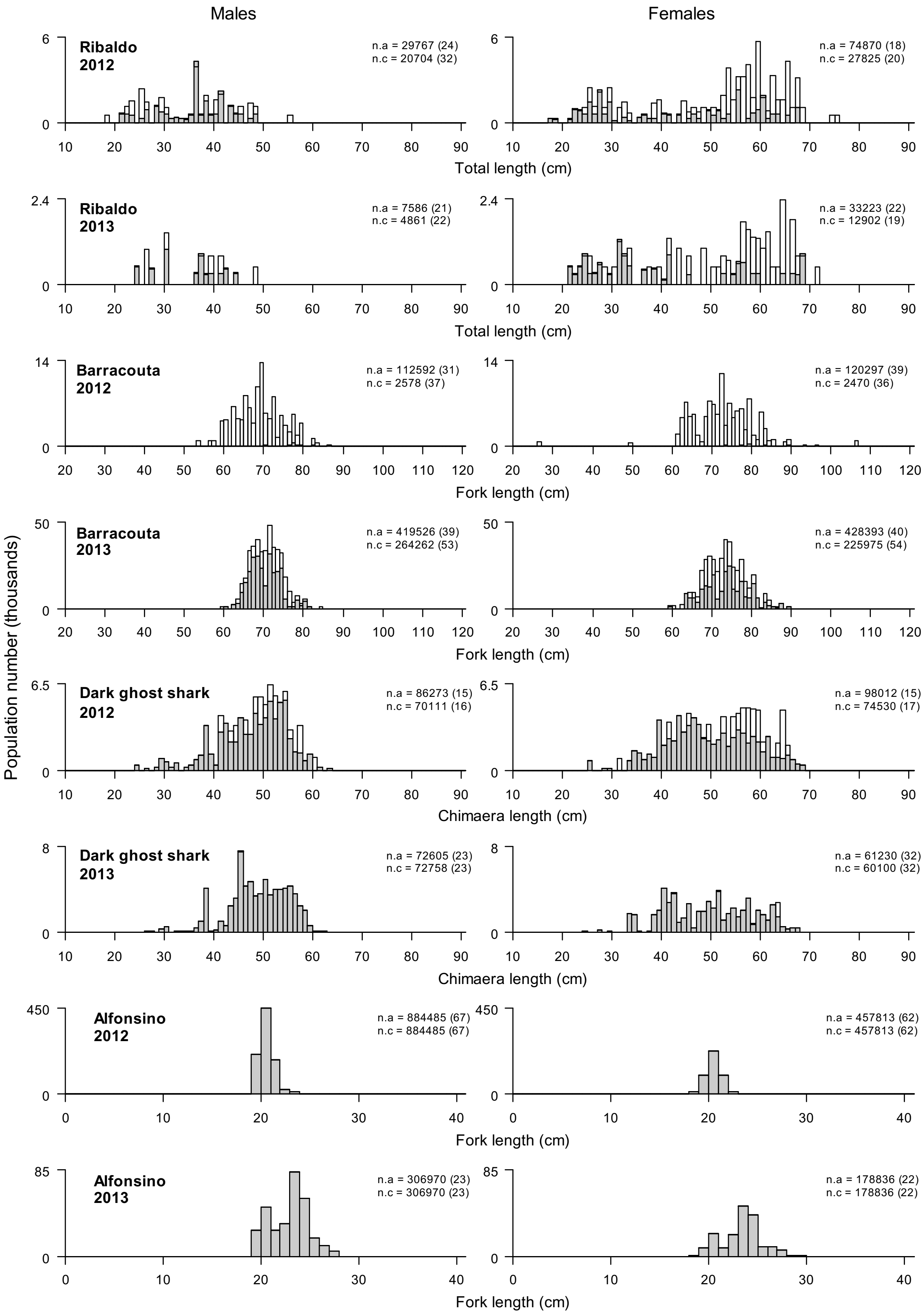


Figure 35 continued: Length frequency distributions by sex of key species for core (grey) and all (white) strata from the 2012 and 2013 WCSI trawl surveys. n.a, estimated scaled total number of fish for all strata; n.c, estimated scaled total number of fish for core strata; and CV, the coefficient of variation (in parentheses). From O'Driscoll et al. (2015).

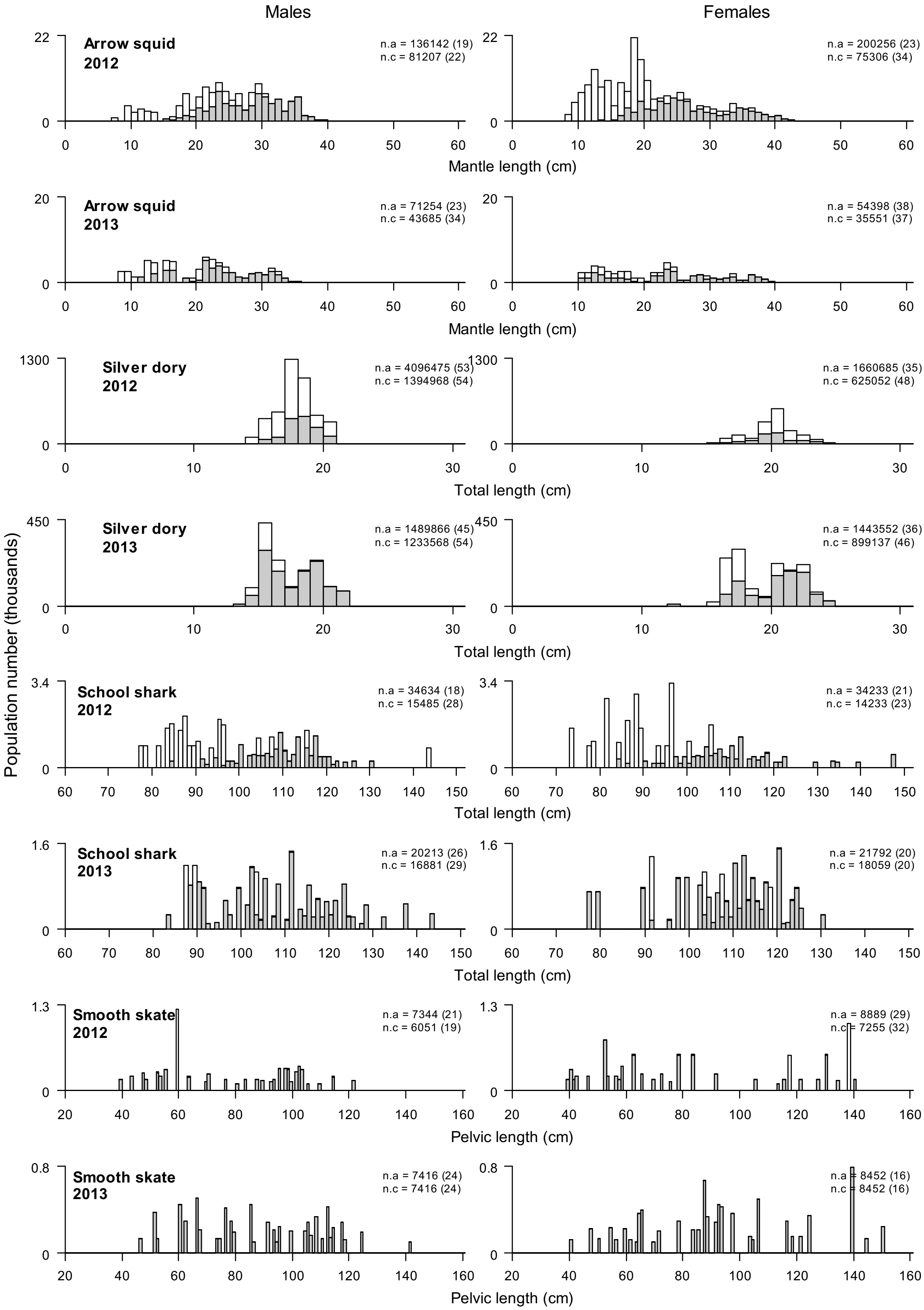


Figure 35 continued: Length frequency distributions by sex of key species for core (grey) and all (white) strata from the 2012 and 2013 WCSI trawl surveys. n.a, estimated scaled total number of fish for all strata; n.c, estimated scaled total number of fish for core strata; and CV, the coefficient of variation (in parentheses). From O'Driscoll et al. (2015).

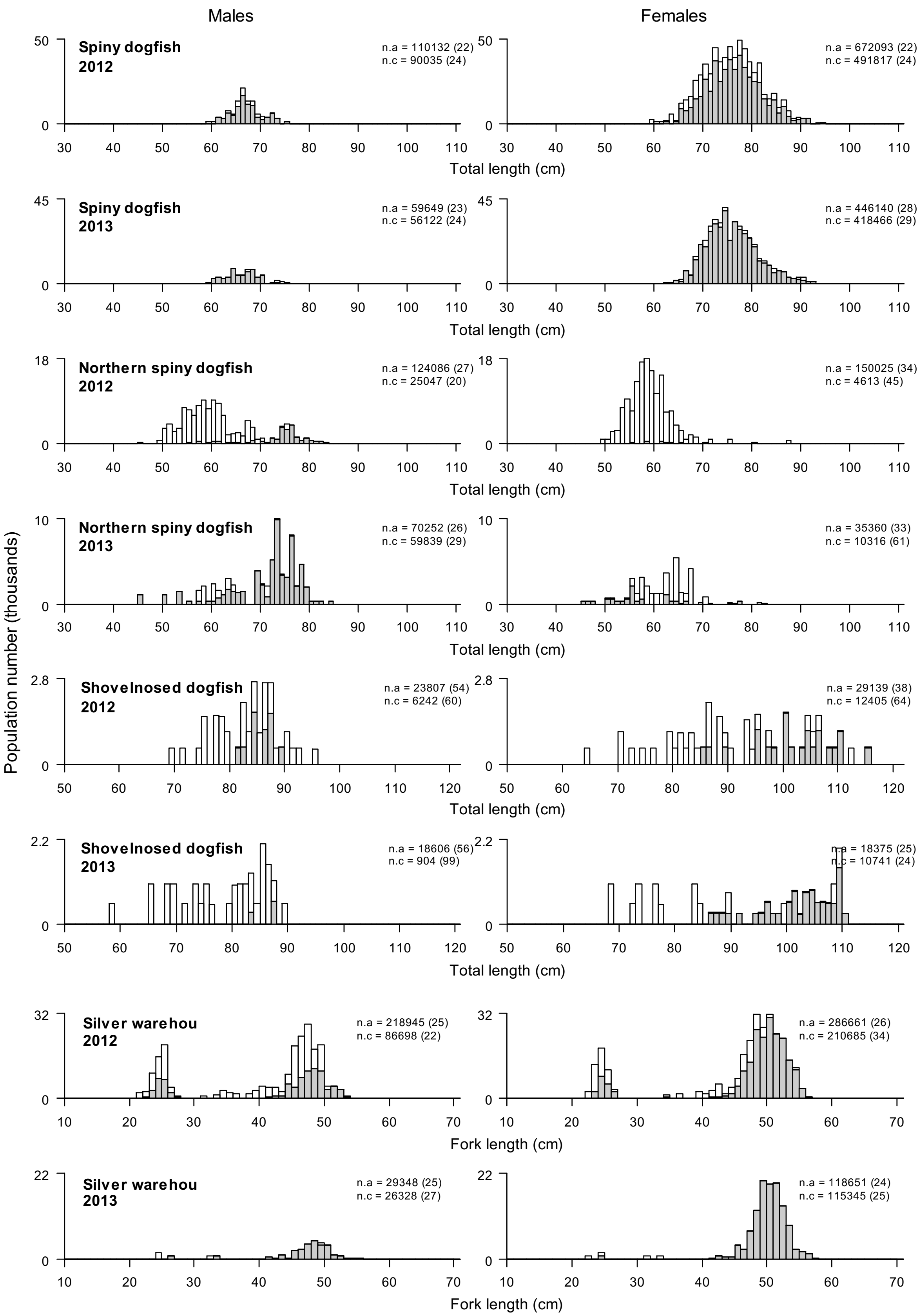


Figure 35 continued: Length frequency distributions by sex of key species for core (grey) and all (white) strata from the 2012 and 2013 WCSI trawl surveys. n.a, estimated scaled total number of fish for all strata; n.c, estimated scaled total number of fish for core strata; and CV, the coefficient of variation (in parentheses). From O'Driscoll et al. (2015).

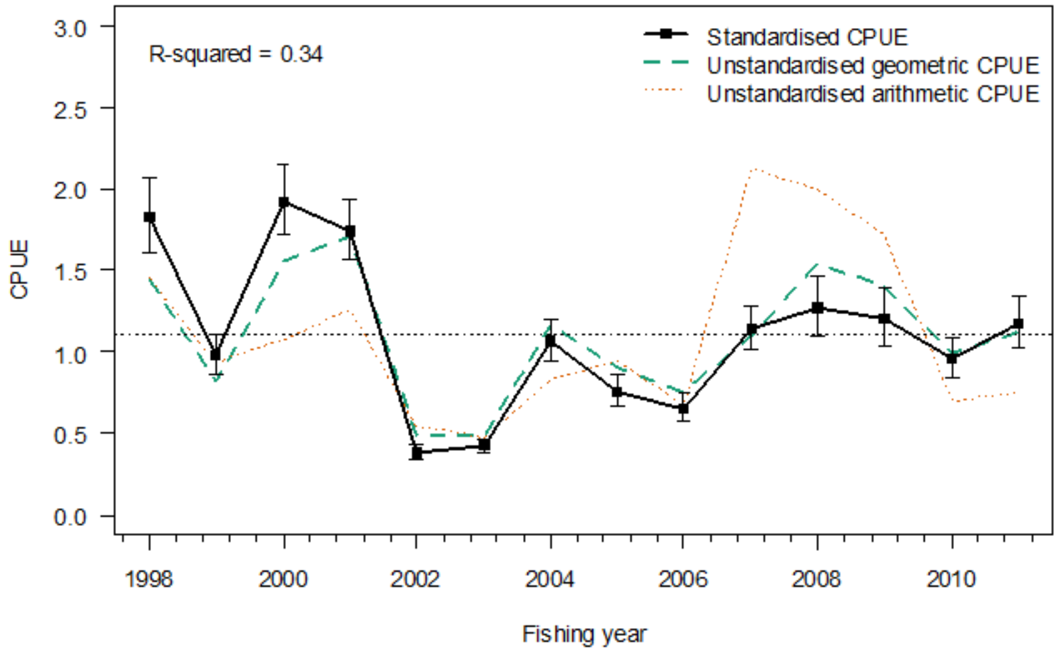


Figure 36: Arithmetic, geometric, and standardised CPUE indices for silver warehou on the WCSI from 1998–2011. From McGregor (in press b).

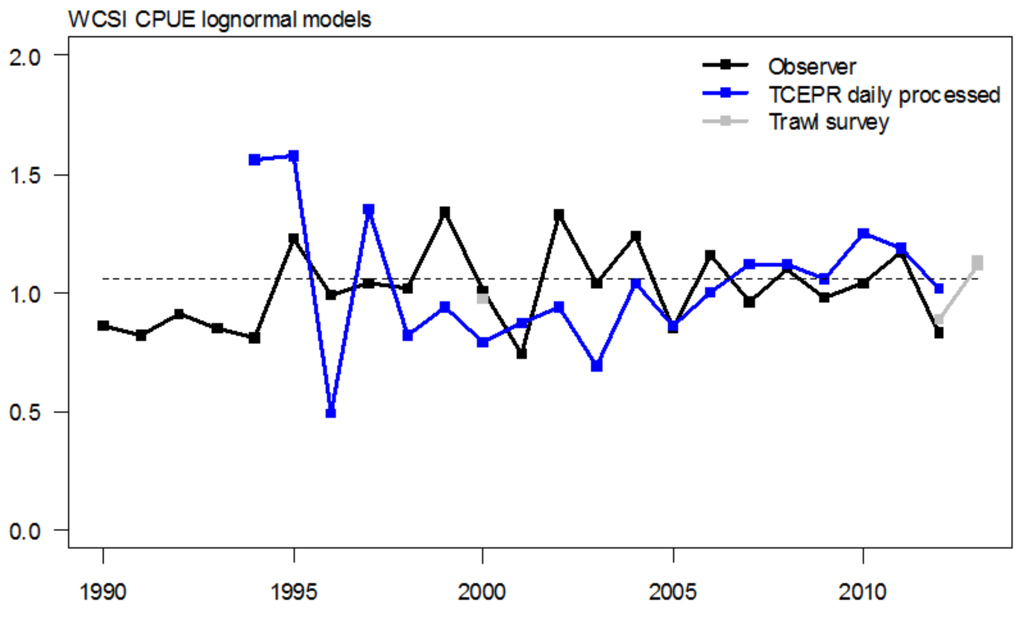


Figure 37: Comparison of lognormal standardised CPUE indices for lookdown dory on the WCSI from 1990–2012 with indices from research trawl surveys. Fishing year defined as June–September. From Ballara (2014).

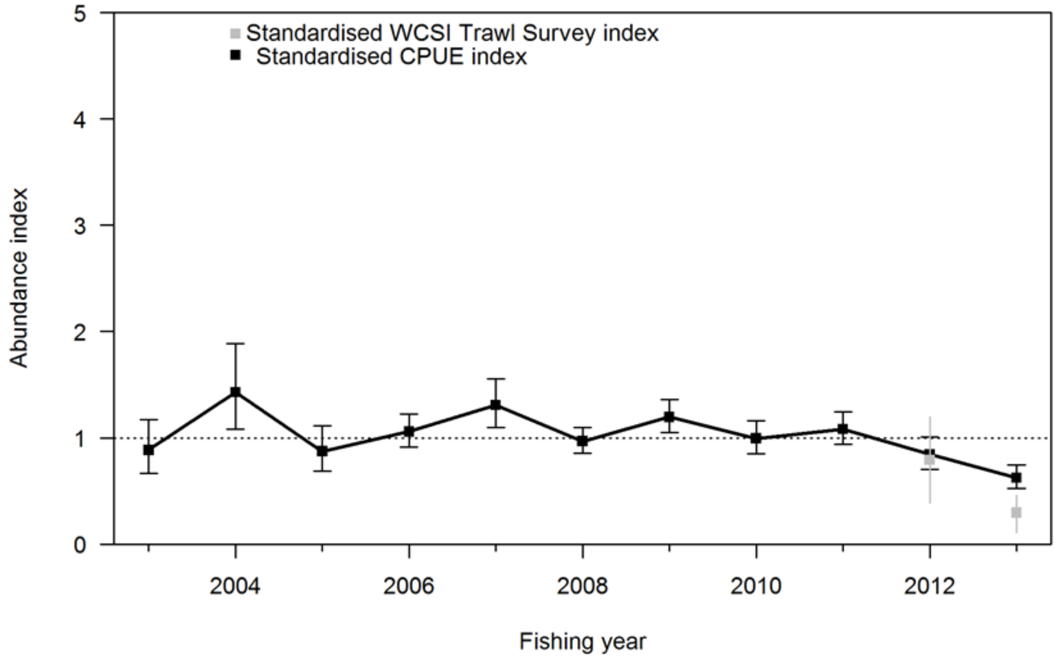


Figure 38: Comparison of the WCSI standardised CPUE and standardised trawl survey abundance indices for ribaldo in fishing years 2003–2013. From MacGibbon (in press b).

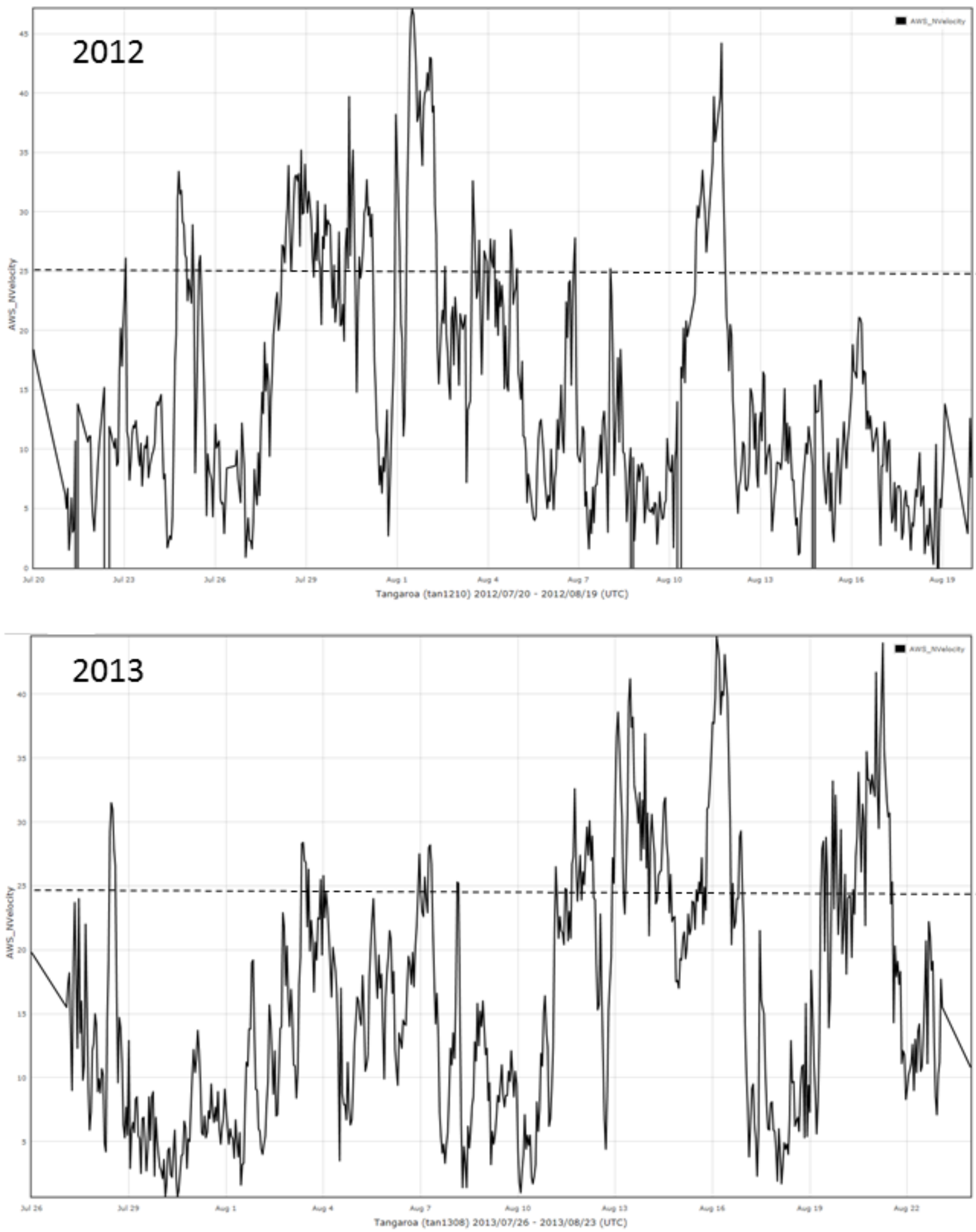
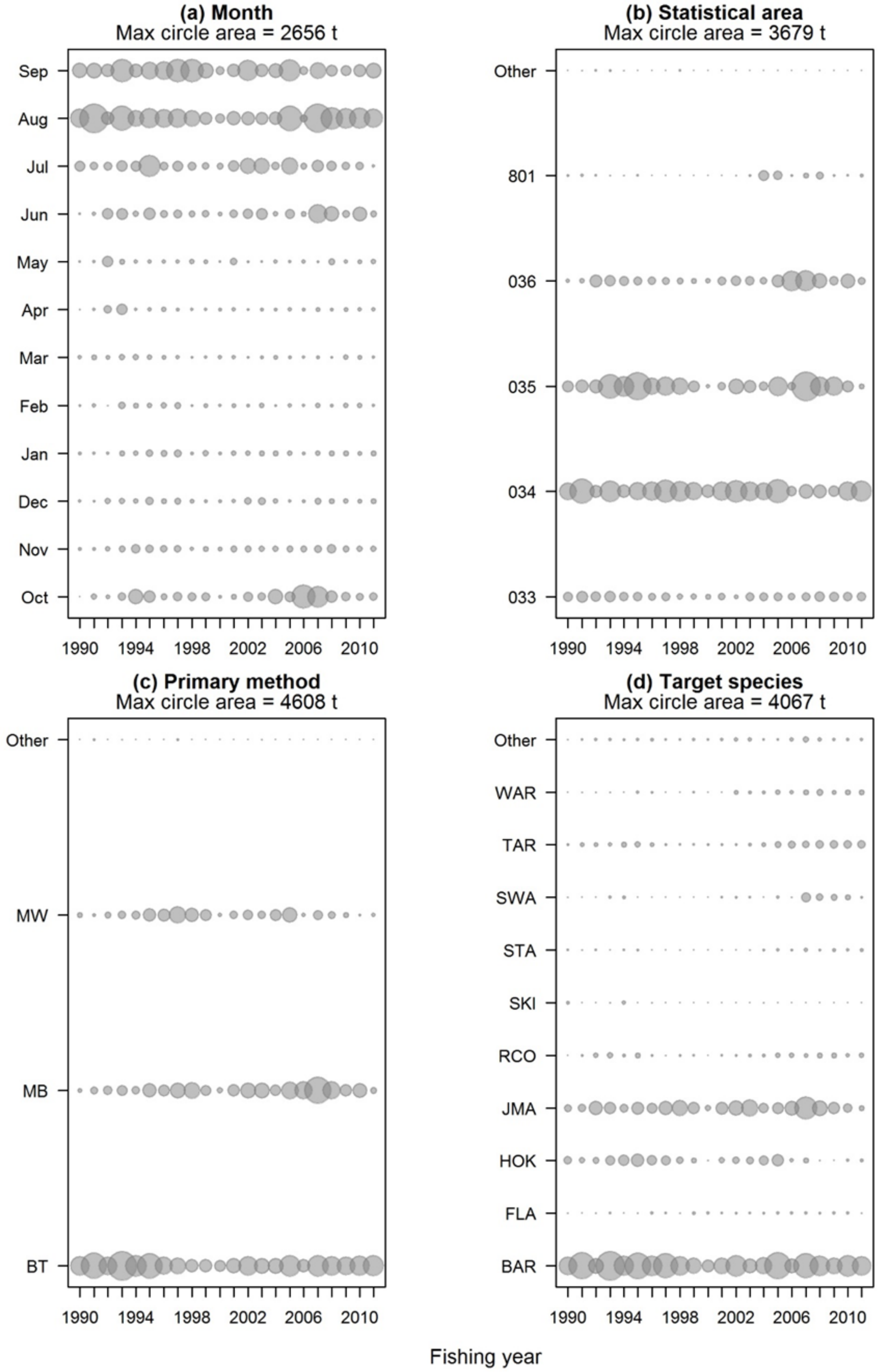


Figure 39: Mean hourly wind speed (knots) recorded on *Tangaroa* during WCSI surveys in 2012 and 2013. Dotted line shows (indicative) 20 knot threshold for acoustic data collection with hull-mounted transducer.

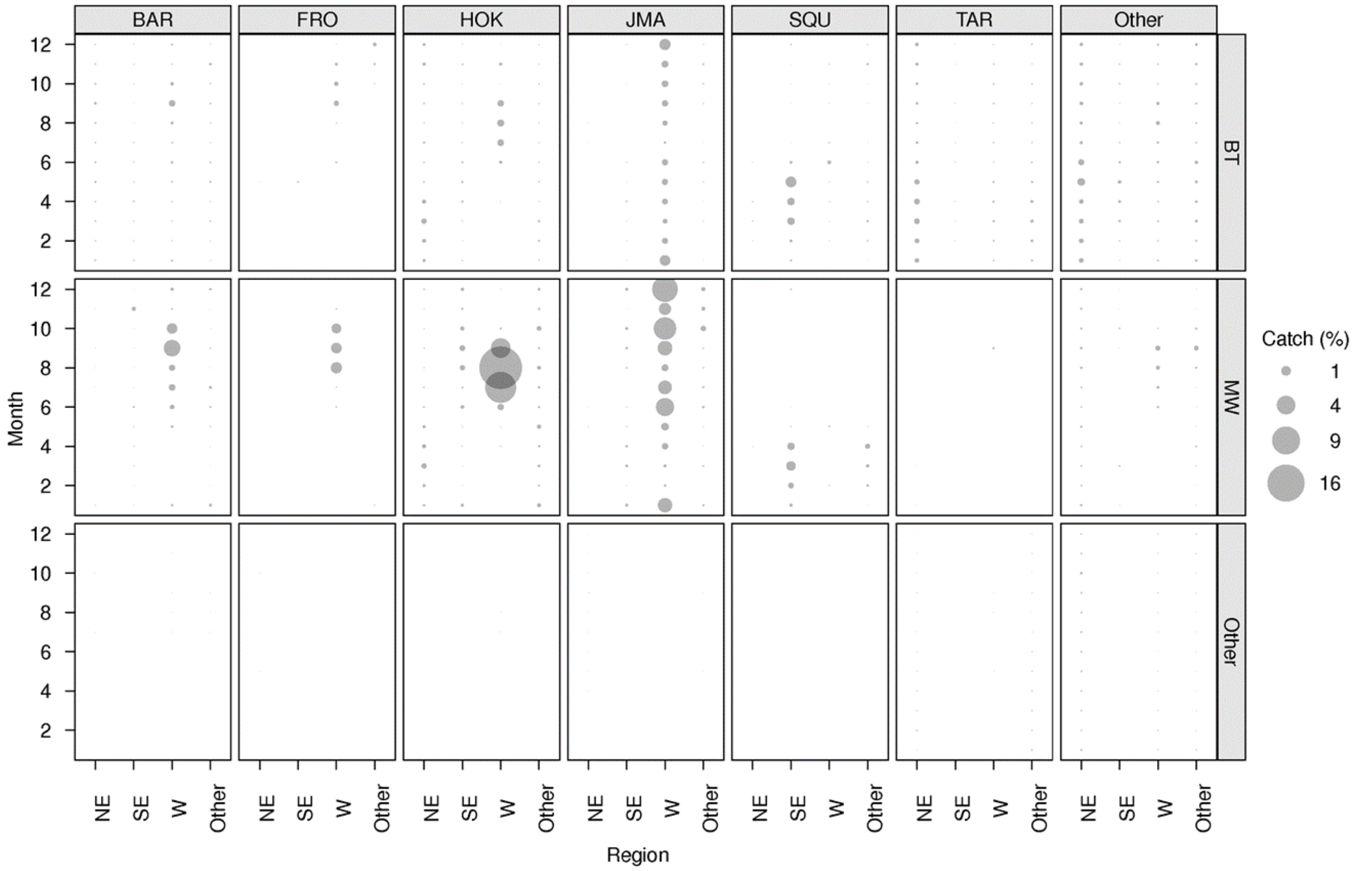
APPENDIX 1: Timing of commercial catch of other species on the WCSI

Barracouta



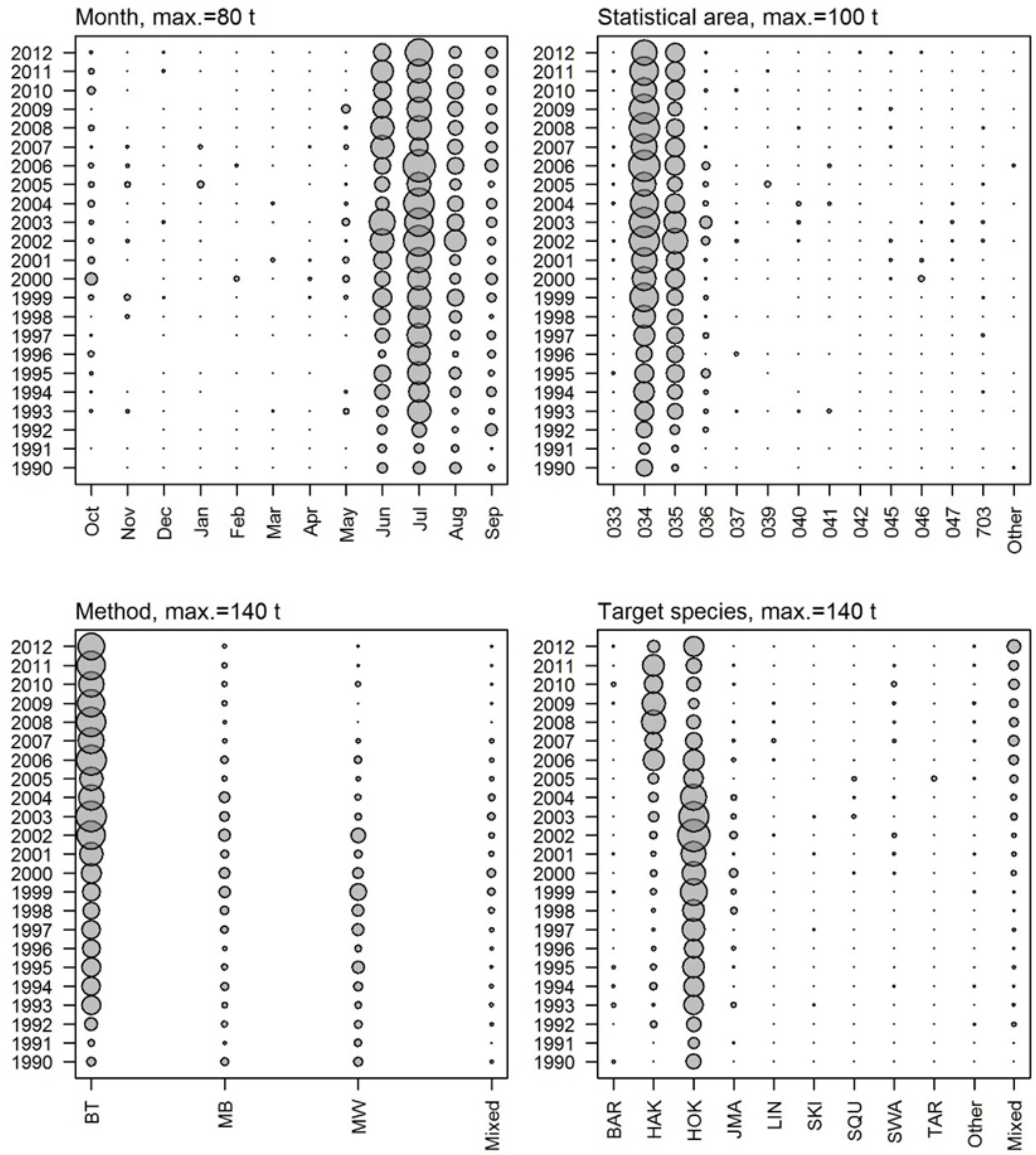
Distribution of barracouta commercial catch in the WCSI area for fishing years 1990–2011 in relation to a) month, b) statistical area, c) fishing method, and d) target species. From McGregor (in press a).

Frostfish



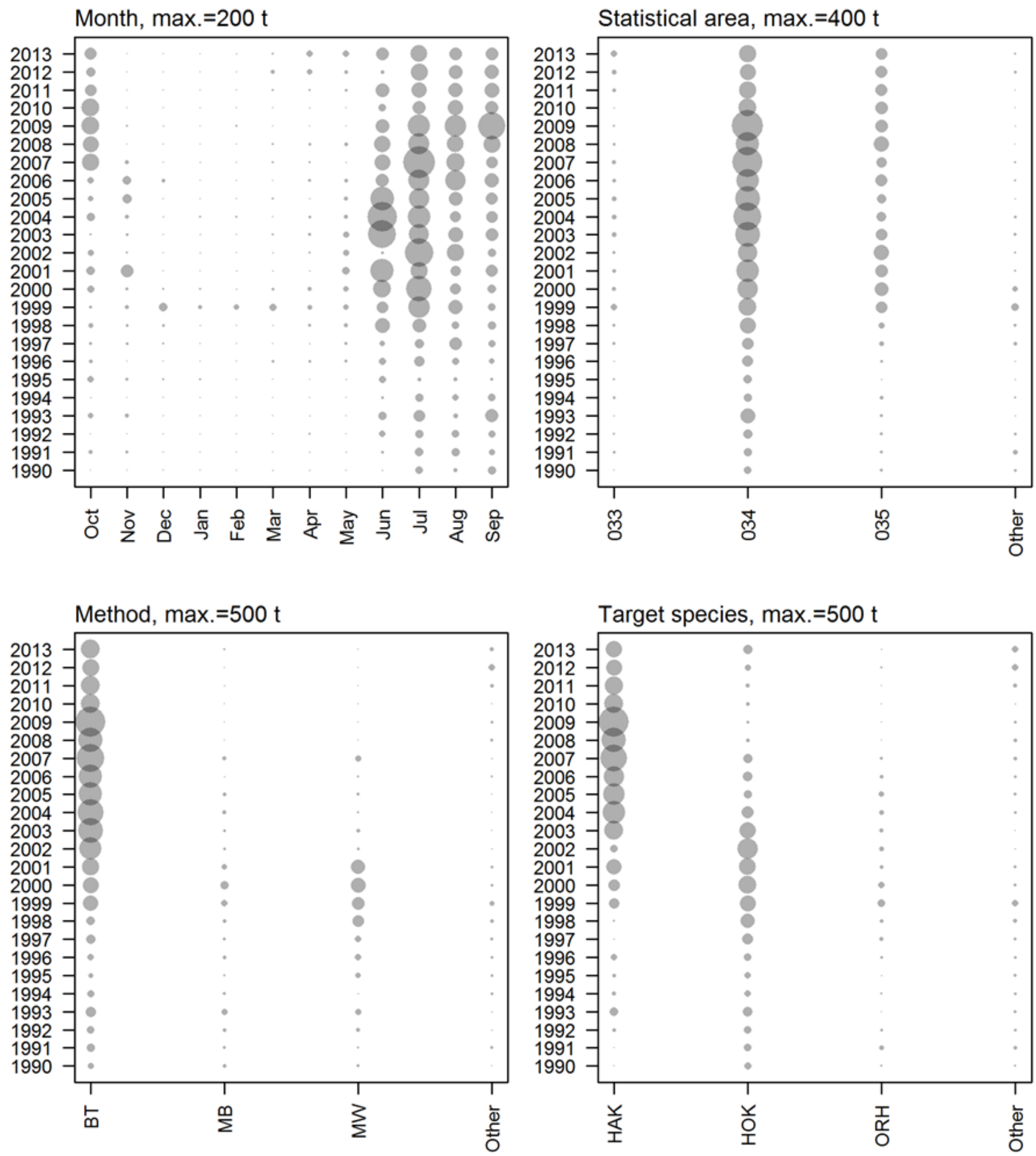
Proportion of frostfish catches by method, target species, month and region over all fishing years, 1989–90 to 2009–10. Regions are defined on the basis of statistical areas, West (W): 034-042 includes WCSI. From Bentley et al. (2014a).

Lookdown dory



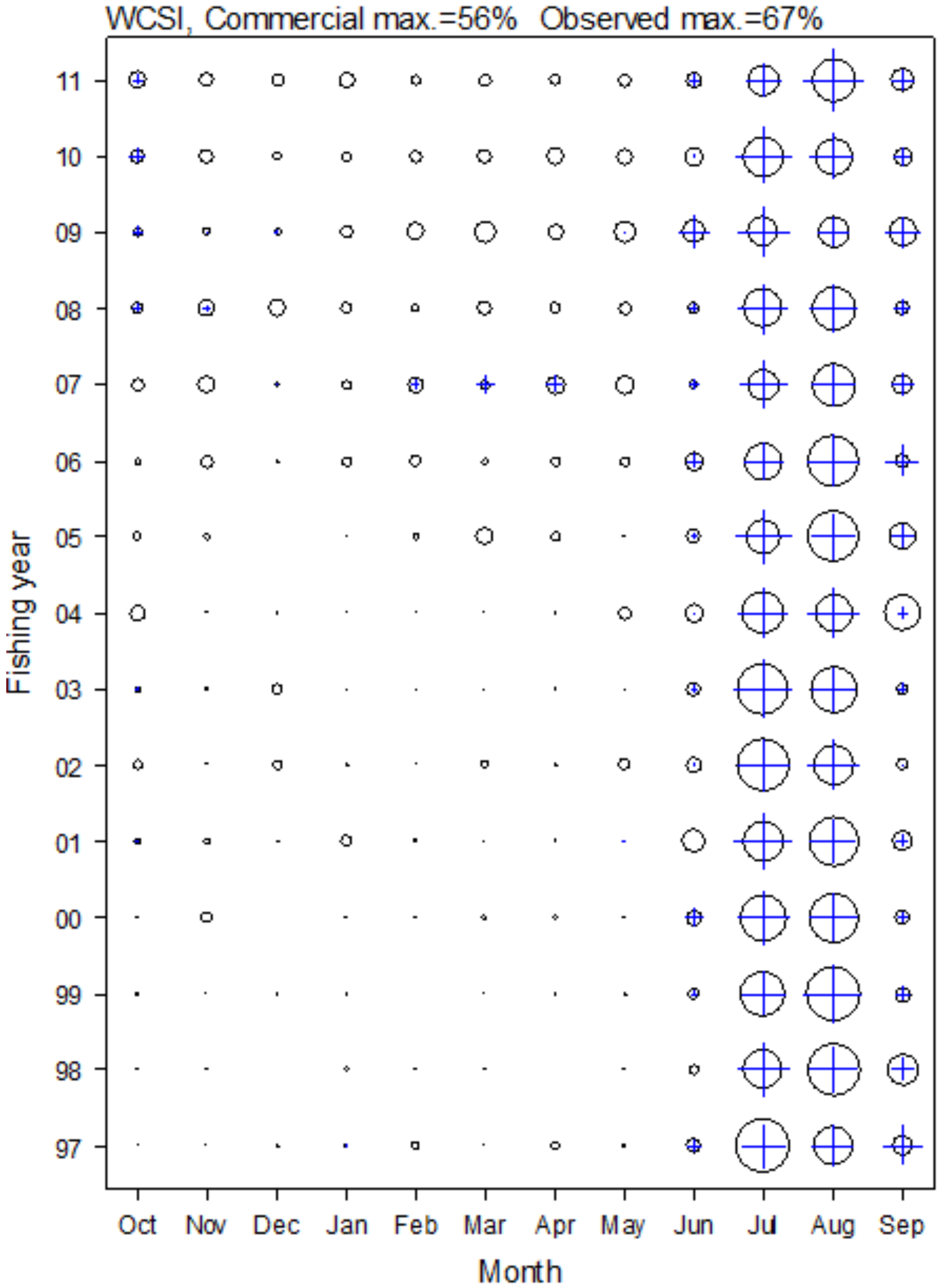
Distribution of annual lookdown dory catch by month, statistical area, method, and target species for West Coast merged daily processed data. From Ballara (2014).

Ribaldo



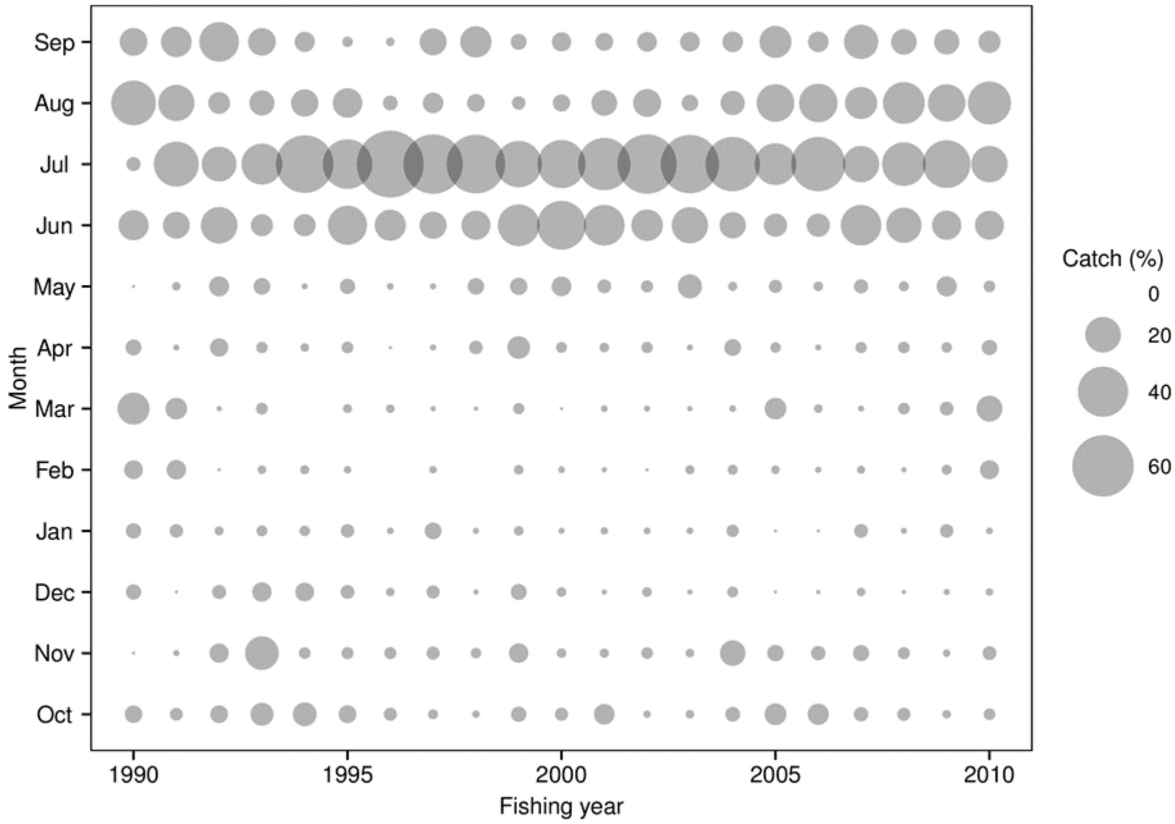
Distribution of annual ribaldo catch by month, statistical area, method, and target species for the west coast South Island for all merged data. Circle size is proportional to catch; maximum circle size is indicated on each plot.. From MacGibbon (in press b).

Spiny dogfish



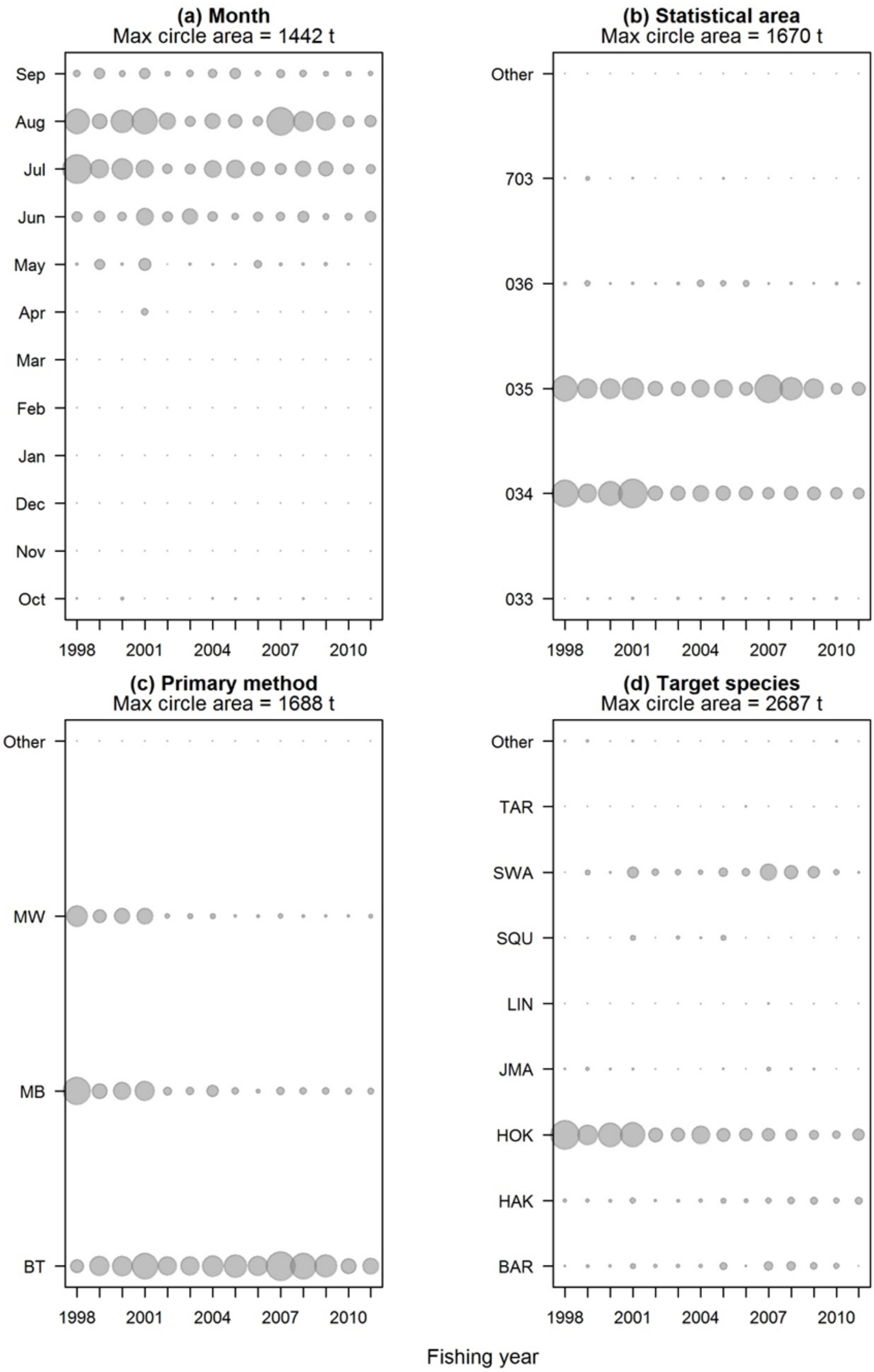
Proportion of spiny dogfish commercial trawl catch (circle) and observer catch (+) for WCSI, by fishing year, where 97 represents fishing year 1996–97, and by month. From Baird & Ballara (in press).

Sea perch



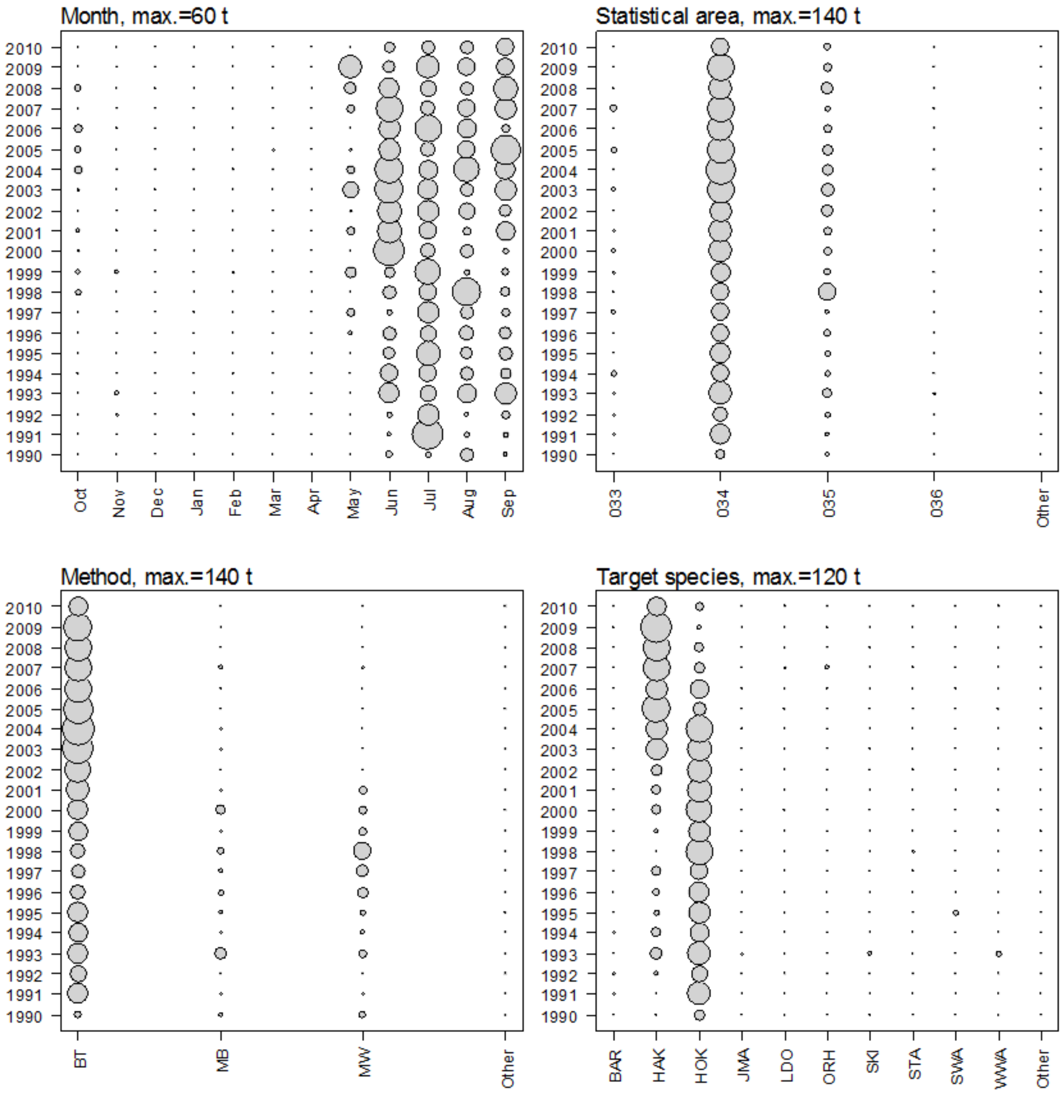
Percentage of sea perch catch by month for each fishing year for the West Coast South Island region. The most recent year is given for each fishing year; i.e. ‘1990’ = 1989–90 fishing year. From Bentley et al. (2014b).

Silver warehou



Distribution of silver warehou catch in the West Coast South Island region for 1991–2011 fishing years in relation to a) month, b) statistical area, c) fishing method, and d) target species. From McGregor (in press b).

White warehou



Distribution of annual catch of white warehou by month, statistical area, method, and target species for WCSI merged data, by fishing year 1989–90 (1990) to 2009–10 (2010). From Ballara & Baird (2012).