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Tini a Tangaroa

Review of inshore trawl surveys off the west coast North Island

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E.G. Jones, S. Ballara, R. Bian,
A. Langley, J. McKenzie, R.L. O'Driscoll.

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Fisheries New Zealand
Ministry for Primary Industries
PO Box 2526
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NEW ZEALAND

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EXECUTIVE SUMMARY

Jones, E.J.¹; Ballara, S.¹; Bian, R.¹; Langley, A.²; McKenzie, J.¹; O’Driscoll, R.L.¹ (2023). Review of inshore trawl surveys off the west coast North Island.

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A series of inshore trawl surveys off the west coast North Island (WCNI) using RV *Kaharoa* was resumed in 2018 after a near 20-year gap. The three recent surveys took place between October and November in 2018, 2019, and 2020. By using the same vessel and trawl net, the surveys came as close as possible to replicating the five previous WCNI surveys undertaken between 1989 and 1999. This report reviews the utility of the reinstated survey series for monitoring target species (snapper (*Chrysophrys auratus*), red gurnard (*Chelidonichthys kumu*), tarakihi (*Nemadactylus macropterus*), and John dory (*Zeus faber*)), as well as a range of other commercial and non-commercial inshore species.

A major and unique challenge for this survey series was adapting to the Māui dolphin Threat Management Plan, which resulted in a significant portion of the inshore strata used for the historical surveys being closed to commercial trawling since 2008, and then extended in 2020 and having to be excluded from the recent survey area. Removal of the extended Māui dolphin trawl exclusion zone required further survey-by-survey adjustments to combine strata and achieve minimum sample sizes. For snapper, there were significant differences in size distributions of the survey catch once the original Māui dolphin trawl exclusion zone was removed, particularly for pre-recruit snapper. However, biomass trends were similar for the reduced area to those from the original survey area. For red gurnard, although there were differences in catch rates inside and outside the Māui dolphin trawl exclusion zone, there was little overall difference in abundance trend and length frequencies. For John dory, there was little difference in catch rates, abundance trend, or length frequencies. We concluded that even with the extended trawl exclusion zone, the utility of the survey was not compromised in terms of monitoring the total adult biomass trends for the three inshore target species affected (tarakihi not considered due to mainly deeper occurrence).

The WCNI survey series has good utility for monitoring the target species. A substantial increase in biomass of snapper has occurred since 1999. The size and age range of the population has expanded since the historical surveys, with a considerable component of large, older fish, as well as strong juvenile year 1+ to 4+ year classes. There may be variability in total adult snapper biomass due to survey timing in relation to spawning, and an earlier (mainly October) pre-spawning timing seems preferable. A substantial decline in pre-recruit red gurnard biomass was clear from the northern core time series compared with historical surveys. John dory also declined over the full survey area, but the decline was less apparent in the northern core area. For tarakihi, the survey has never covered the complete range of the commercial fishery in the southern part of the area, but the extended northern area (out to 200 m depth) appears to provide useful indices of abundance.

This survey may have some utility for rig (*Mustelus lenticulatus*) because coefficients of variation (CVs), particularly in the more recent surveys, were below 30%. Based on a qualitative assessment of numbers of individuals caught, depth range coverage, CVs, and consistency of biomass estimates and CVs, the WCNI surveys also likely provide useful information for seven other species: trevally (*Pseudocaranx georgianus*), barracouta, (*Thyrssites atun*), school shark (*Galeorhinus galeus*), spiny dogfish (*Squalus acanthias*), leatherjacket (*Meuschenia scaber*), rough skate (*Zearaja nasuta*) and northern spiny dogfish (*Squalus griffin*). There was no evidence for extreme catchability events for this suite of species in any of the surveys during 1989–2020. A major limitation is the small number of surveys included in the time series. The utility of the survey for some of the other non-target species is likely to be improved with more regular surveys in the future.

¹ National Institute of Water and Atmospheric Research (NIWA), New Zealand.

² Trophica Limited, Kaikōura, New Zealand.

1. INTRODUCTION

1.1 Background

A series of seven trawl surveys were conducted using RV *Kaharoa* off the west coast of the North Island (WCNI) between 1986 and 1999 (Morrison et al. 2001, 2013, Table 1). The aim of this survey series was to estimate the relative year class strength of juvenile snapper (*Chrysophrys auratus*), with estimates of abundance for red gurnard (*Chelidonichthys kumu*), John dory (*Zeus faber*), and tarakihi (*Nemadactylus macropterus*) also being derived. The survey covered a number of key commercial stocks including snapper (SNA 8), tarakihi (TAR 1 & 8), red gurnard (GUR 1 & 8), and John dory (JDO 1 & 2). The perceived value of the survey diminished towards the end of the 1990s, and the series was discontinued (Morrison et al. 2013).

The 2005 SNA 8 assessment (Davies et al. 2006) indicated biomass at the time was 8–12% B_0 and predicted to increase slowly to 20% B_0 after 2018. Based on these results the TACC was reduced by 200 t in October 2005. The 2017 update of commercial catch-per-unit-effort (CPUE) indicated a steep (~4-fold) increase in the index from 2006 (Langley 2017), but ongoing changes in the fishery in relation to target species, timing, and trawl gear configuration necessitated the consideration of a fishery-independent index to validate these increases. The 2005 stock assessment incorporated a tag-recapture estimates of biomass, but this approach was not feasible due to food safety concerns associated with internal tags. The WCNI trawl survey was reinstated in 2018, using the same stratification, timing, vessel, and gear specification to enable comparison with the previous surveys, to validate the SNA 8 CPUE index, along with potentially providing valuable information on other key Quota Management System (QMS) species.

To ensure high comparative power between the historical and renewed survey, three consecutive surveys were completed between 2018 and 2020 (Table 1), as recommended by Francis & Horn (2005). In addition to the core area north of Cape Egmont, the southern strata as far as Mana Island, sampled previously only in 1991, were included in the re-established survey based on anecdotal evidence from the fishers of a change in distributional range, possibly as a response to increasing stock size.

The results of the three recent surveys have been reported (Jones et al. 2022), including time series of relative biomass estimates and scaled length frequencies for four target species and six additional species and one species group, chosen in a previous review of the historical surveys (Morrison et al. 2001).

The starting point for the design for the 2018 survey was the survey boundaries and sub-stratification of the 1999 survey north of Airedale Reef (Morrison & Parkinson 2001) and the original stratum boundaries as defined for the 1991 survey south of Airedale Reef (Drury & Hartill 1993) (see Figure 1 and Appendix 1). This stratification was compared with more recent CPUE data and some additional stratum boundaries added based on this analysis and simulations of historical data to explore coefficient of variation (CV) improvements (Jones et al. 2022).

Table 1: Surveys of the WCNI from RV *Kaharoa*.

Year	Voyage code	Dates	Survey area (km ²)	No. of stations
1986	KAH8612	15–27 Oct	13 473	79
1987	KAH8715	30 Oct–7 Nov	9 493	56
1989	KAK8918	26 Nov–13 Dec	16 532	92
1991	KAH9111	10 Nov–9 Dec	34 636	108
1994	KAH9410	6–22 Oct	15 190	75
1996	KAH9615	15 Oct–3 Nov	21 897	124
1999	KAH9915	12–30 Nov	24 724	100
2018	KAH1806	25 Oct–2 Dec	32 534	111
2019	KAH1906	2 Oct–3 Nov	31 509	102
2020	KAH2005	9 Oct–8 Nov	30 051	109

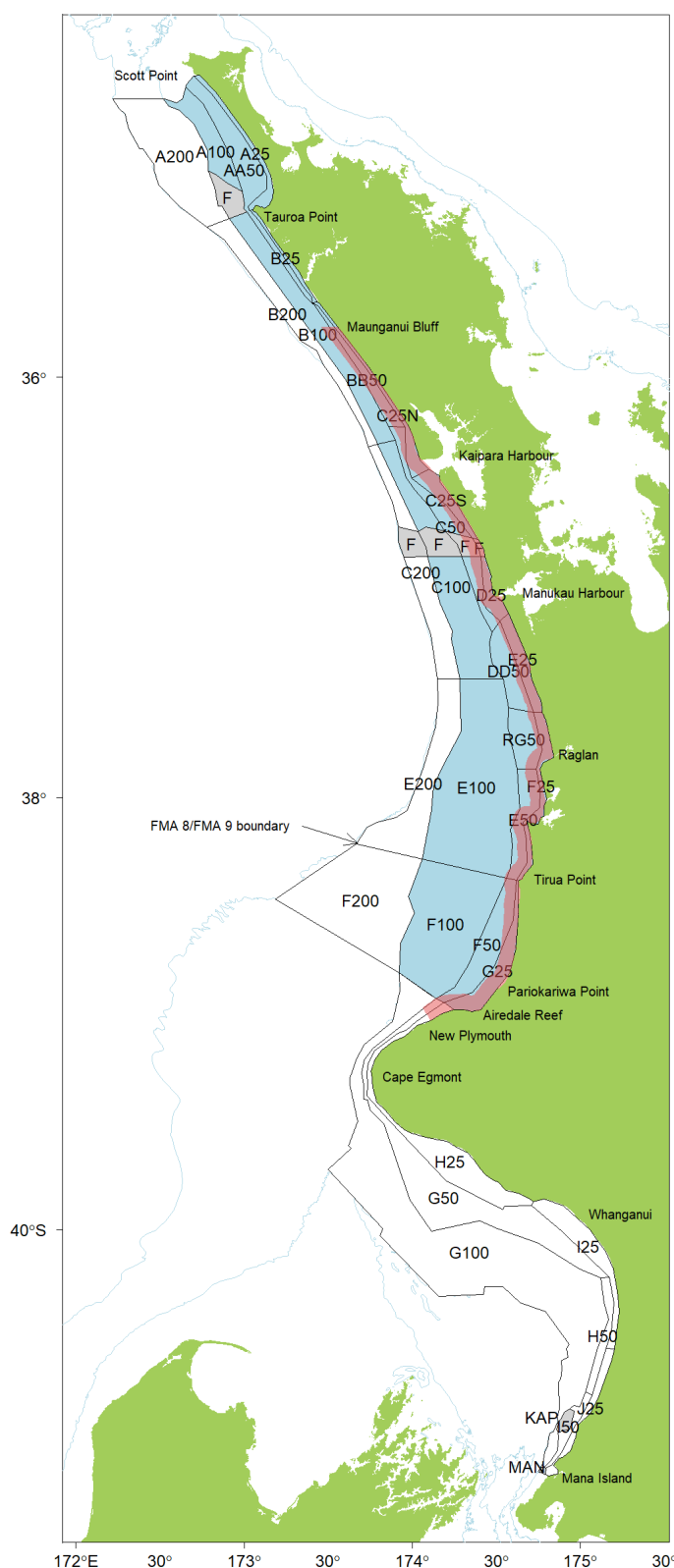


Figure 1: Historical survey boundaries for the WCNI trawl survey from a combination of the 1999 survey north of Airedale Reef and the 1991 survey to the south. The 10–100 m northern strata included in the core area are shaded blue. An extension out to 200 m in the northern area was added in 1991 and retained in subsequent surveys. In 1991, the survey was also extended south as far as Mana Island within the 100 m contour, but these strata were dropped from the later surveys. Areas of foul ground and cable protection areas are shaded grey. The current Māui dolphin trawl exclusion area (shaded pink) is shown for context.

Significant changes to the survey area and stratification were then required to accommodate the decision by Fisheries New Zealand not to permit scientific trawling inside the commercial exclusion zone of the WCNI Marine Mammal Sanctuary, which was established in 2008 to help protect the Māui dolphin. The sanctuary includes the coast and harbours between Maunganui Bluff and Oakura Beach, extending 12 nautical miles (nm) offshore. Within this sanctuary, there is a commercial trawl exclusion zone, which originally extended out to 2 nm between Maunganui Bluff and Pariokariwa Point, and out to 4 nm between the entrance of the Manukau Harbour and Waikato River. This was then extended in 2020 from 2 to 4 nm offshore from Maunganui Bluff, south to the Waiwhakaiho River (New Plymouth) (Figure 1).

The removal of these no-trawl areas required re-definition of affected strata in 2019, and then again ahead of the 2020 survey (Jones et al. 2022, Appendix 1). A re-analysis of historical surveys was also carried out in 2019 following the 2018 survey, and then again in 2020 following the decision to extend the no-trawl zone, with strata consolidated where necessary to make any biomass estimates compatible to maintain the time series. The aim was to establish whether the utility of the survey to monitor the target species, snapper in particular, was compromised by these changes.

Following the 2020 survey and SNA8 stock assessment, a review of the utility of the survey for monitoring the target species and other non-target species was proposed. As part of this review, a further assessment of how the reduced access to inshore areas may have impacted the ability to adequately monitor the significantly increased adult snapper biomass during the pre-spawning / spawning period was also completed. This report describes the re-analysis of historical data and utility review.

1.2 Programme Objectives

This is the final reporting requirement for Fisheries New Zealand research project INT2018-02. The overall objective was to determine the relative abundance and distribution of inshore finfish species off the west coast of the North Island in the 2018–19, 2019–20, and 2020–21 fishing years; focusing on snapper (*Chrysophrys auratus*), tarakihi (*Nemadactylus macropterus*), red gurnard (*Chelidonichthys kumu*), and John dory (*Zeus faber*).

The Specific Research Objectives were:

1. To design an updated WCNI trawl survey focused on estimating the current abundance of snapper, tarakihi, red gurnard, and John dory from Scott Point to Mana Island.
2. To determine the relative abundance and distribution of snapper, tarakihi, red gurnard, and John dory off the west coast of the North Island from the spring (mid-October to mid-November) period of the 2018–19, 2019–20, 2020–21 fishing years, by carrying out trawl surveys over the depth range 10 to 200 m. The target coefficients of variation (CVs) of the biomass estimates for these species are as follows: snapper (20%), tarakihi (20–25%), red gurnard (20%), and John dory (20%).
3. To collect the necessary data and determine the length frequency, length-weight relationship and reproductive condition of snapper, tarakihi, red gurnard, and John dory.
4. To collect otoliths from snapper, tarakihi, red gurnard, and John dory.
5. To age snapper otoliths collected on the surveys.
6. To collect the data to determine the catch weight of all species caught and the length frequencies and spawning condition of all other Quota Management System (QMS) species.
7. To collect data to underpin the development of assessment and monitoring capabilities for biodiversity and ecosystems.
8. To assess the bias created by excluding areas within the Māui dolphin trawl exclusion zone from the inshore WCNI strata.
9. Development of multiple historical time series for the west coast North Island trawl survey.

10. Provision of historical age composition data for the core area of the west coast North Island survey for the 2020 SNA 8 stock assessment.
11. Evaluation of utility of the WCNI inshore trawl survey.

This is the second of two reports. The first (Jones et al. 2022) presented results from the three recent surveys for target species (snapper, tarakihi, red gurnard, and John dory) and eight other species: trevally (*Pseudocaranx georgianus*); two species of jack mackerel (*Trachurus novaezelandiae*, *Trachurus declivis*); kahawai (*Arripis trutta*); barracouta (*Thyrsites atun*); school shark (*Galeorhinus galeus*); rig (*Mustelus lenticulatus*); and spiny dogfish (*Squalus acanthias*), addressing specific objectives 1–7, 9, and 10.

This second report provides an assessment of the bias caused by excluding areas within the Māui dolphin exclusion zone from the inshore WCNI strata (specific objective 8 and work completed under SEA2020–03) and then an evaluation of the utility of this survey for both target and selected other species caught (objective 11).

2. METHODS

2.1 Assessing the bias created by removing areas within the Māui dolphin trawl exclusion zone from the inshore WCNI strata

2.1.1 Comparison of historical catch rates inside and outside the no-trawl zone

The primary value of the re-established WCNI survey is comparability of relative biomass with historical surveys. The decisions made in 2018–20 to exclude inshore portions of the survey area therefore necessitated an assessment of any bias caused by excluding these areas and the stations located within them from the time series.

For this analysis, data on the four target species from all seven historical surveys off the west coast between 1986 and 1999 were extracted from the Fisheries New Zealand's *trawl* database. In a small number of instances data from these surveys contained some errors. Where paper sheets were available, these were checked first, and some input errors resolved. The remaining errors were dealt with as follows:

1. Where length data were recorded but catch weight data were absent, we used a calculated catch weight using appropriate length-weight coefficients for that species (Appendix 2), scaling up to the total weight caught using the percent sampled for that species and station.
2. Where percent sampled was absent, we used appropriate length-weight coefficients for that species (Appendix 2) and the available catch weight data to calculate percent sampled for that species and station.
3. Where the sum of the number of male and female fish measured was higher than from the sum of all fish that was listed for that species, we used the length-weight relationship to check that the number of fish by length seemed correct based on weight recorded in the catch, as well as cross checking with adjacent stations. These checks supported the sum of the number of male and female fish being the correct value.

Of the twelve strata impacted by the first reduction of survey area, seven were either almost entirely outside or entirely inside the trawl exclusion zone and therefore not suitable for this analysis. The remaining strata (BB50, C25N and C25S, E50 and G25) were between 19% and 68% inside the no-trawl zone (Table 2). From these strata, a total of 125 historical stations across 7 historical surveys from 1986 to 1999 were re-allocated to the most recent historical (1999) strata definitions and split into two locations; inside (n = 56) or outside (n = 69) the Māui dolphin trawl exclusion zone. As a first step, to visualise differences inside and outside the no-trawl zone, station-level catch rates, expressed as tonnes per square kilometre, were plotted with the no-trawl zone overlaid and summarised as boxplots by location for each stratum across all survey years, and for each survey year with all strata combined.

Table 2: List of strata impacted by the original and extended Māui dolphin trawl exclusion zone, and proportion of each stratum contained inside the no-trawl zone. Stratum locations are shown in Figure 1.

Stratum	Depth range (m)	Proportion excluded by original no-trawl zone (%)	Proportion excluded by extended no-trawl zone (%)
BB50	25–50	37	83
B100	50–100	0	7
C25N	10–25	68	86
C25S	10–25	66	88
C50	25–50	7	35
D25	10–25	93	95
DD50	25–50	7	18
RG50	25–50	3	25
E25	10–25	88	99
E50	25–50	19	67
F25	10–25	86	96
E100	50–100	0	1
F50	25–50	4	24
G25	10–25	34	92

Historical catch rates were then compared using a Generalised Linear Modelling (GLM) framework to test whether location of stations inside or outside the trawl exclusion zone had a significant effect on the estimated biomass. For this analysis, data were restricted to surveys from 1989 onwards due to sparsity of stations and a lack of catch weight data recorded at some stations in the 1986 and 1987 surveys. Species included in the analysis were snapper, red gurnard, and John dory. Tarakihi was not considered because this key species is mainly found offshore.

Two stepwise GLM analyses were undertaken for each of the three species: a Gaussian model on the magnitude of positive catch data entered as log of the positive catch rate (kg km^{-2}); and a binomial model on the probability of a positive catch. The main fixed predictor term in all model regressions was *Survey year* (levels: 1989, 1991, 1994, 1996, 1999). Two other categorical covariates of interest offered to the positive catch and binomial models were *Stratum* (levels: Bb50, C25N, C25S, E50, and G25), and *Location* (levels: Inside and Outside Māui dolphin trawl exclusion zone). Interaction terms between *Location* and the other categorical covariates were also tested. A forward, stepwise selection process of adding terms based on AIC values was used, with predictor terms retained if they increased the deviance explained (indicated by the R-square value) by at least 1%; however *Survey year* was forced into all stepwise models as the first term. For each species the null hypothesis proposed was that the exclusion of stations in the no-trawl zone would be unlikely to have affected historical survey catch rates. Acceptance of any one of the three *Location* parameter terms in the final model was considered to be grounds to reject the null hypothesis that Māui trawl exclusion zone location was not important.

2.1.2 Comparison of historical population structure inside and outside the no-trawl zone

To examine the effect of removing stations inside the Māui dolphin trawl exclusion zone on the estimated population structure, kernel density estimate (KDE) analysis was carried out as a non-parametric alternative to Kolmogorov-Smirnov (KS) tests for comparing length frequency distributions following the method of Langlois et al. (2012). This approach tests for differences in both relative location (mean length) and shape of the distribution (i.e., skewness). Length data were pooled across stations inside and outside the Māui dolphin zone for each survey, with length-frequency histograms compiled using 1-cm length classes. Separate KDEs were constructed for each with bandwidth (smoothing) selected by the Sheather & Jones (1991) bandwidth selection procedure *dpik* in the R package ‘KernSmooth’ (Wand 2011). The statistical test between pairs of length frequencies was based on a null hypothesis of no difference, using a permutation test. The geometric mean between the bandwidths for the two locations was calculated for each pair, and the mean bandwidth used to construct

KDEs for both locations. If the samples from inside and outside the Māui dolphin trawl exclusion zone represented a similar distribution, the KDEs should only differ in minor ways. The permutation test was implemented using the function *sm.density.compare* from the ‘sm’ R package (Bowman & Azzalini 2010), which compares the area between the pair of KDEs to that resulting from permutations of the data into random pairs. These pooled length frequencies were compared for each target species in each historical survey where data were available.

2.1.3 Comparison of time series trends with and without the no-trawl zone

In addition to comparison of station-level catch rates inside and outside the no-trawl zone in affected strata, the effect of removing this zone from the survey needed to be assessed in the context of whether historical time series trends were changed or not. To construct a time series with which to compare more recent surveys, a review of historical survey stratum definitions and station allocation across each stratum was undertaken to define a useful ‘core’ area. Maps showing historical survey areas are given in Appendix 1. The earliest survey in the series, in 1986, covered between Scott Point to Tirua Point in the 10–100 m depth range; this survey also included stations around North Cape and off the east coast in Great Exhibition Bay. The 1987 survey was even more restricted, sampling from Maunganui Bluff to Tirua Point. In 1989, the survey area was extended north again and further south to Airedale Reef just north of New Plymouth. Original stratification was based on depth (10–25 m, 26–50 m, 51–75 m, and 76–100 m) and latitude. These strata were amalgamated into larger strata for analysis and reporting (Drury & McKenzie 1992). In 1991, the 51–75 m and 76–100 m depth strata were combined into one, and the depth range was extended out to the 200 m depth contour. A large extension south was added to cover the 10–100 m part of the South Taranaki Bight as far as Mana Island. These southern strata were not included in later surveys, with the remaining three surveys (1994, 1996, and 1999) restricted to between Scott Point and Airedale Reef. Some stratification boundary changes were made in 1994 and 1999, based on the distribution of pre-recruit snapper catches from the previous surveys. Extended periods of poor weather in the 1994 survey resulted in seven of the strata being dropped, including those deeper than 100 m and A100 and A25 off Ninety Mile Beach.

For a previous review, Morrison et al. (2001) defined a core area surveyed from 1986 to 1996, that was based on the 1987 survey extent. This excluded strata north of Maunganui Bluff (A strata and the northern portion of the B strata) and ended at the boundary between FMA 8 and FMA 9, excluding strata G25, F50, and F100 (Figure 1). It required prorating down the biomass from the B100 stratum because this extended beyond the upper boundary of the 1987 survey.

For the current time series, the previous historical surveys were re-examined, and a revised core area defined. The existence and validity of stratification definitions was reviewed for each of the historical surveys. Detailed strata definitions were not available for the 1986 and 1987 surveys and their extent was limited, so these surveys were excluded from the series. For the remaining surveys, the stratum files were reviewed, corrected in ArcGIS, and any differences in areas between surveys assessed. Starting the series with the 1989 survey removed the requirement to restrict the area to the 1987 survey extent. The revised core area included all strata in 10–100 m from Scott Point to Airedale Point (shaded blue in Figure 1). These strata were sampled in all surveys from 1989 to 1999, except in 1994, when A100 and A25 were dropped due to extensive bad weather. For the 1994 survey, A100 was merged with B100 and A25 was merged with B25 with data from stations in the B strata scaled to the combined stratum area.

With this core area defined, the portion of each stratum that overlapped with the Māui dolphin trawl exclusion zone for each historical survey was then removed, along with stations located inside the exclusion zone. Where this resulted in the number of stations being reduced below the minimum required ($n = 3$), that stratum was amalgamated with another stratum by selecting the smallest adjacent stratum that was within the same depth zone, where possible. This process was carried out on a survey-by-survey basis. Table 3 summarises the original and adjusted number of strata and stations for each historical survey and lists the strata that were merged, with the original and reduced number of stations, along with the strata they were merged with. There were four strata that could be retained by merging with adjacent strata; B50/BB50 or equivalent, C25, E50/WCSF50, and G25/WCSG25. B strata were

generally merged with adjacent A strata to the north (1989, 1994) since it was usually the northern most part of these strata that remained outside the trawl exclusion zone. When insufficient stations remained in C25, it was merged with B25 (1991, 1994, and 1999), given the smaller stratum to the south (D25) was excluded from the series. In the central part of the core area, D25, E25 and F25 were almost entirely inside the trawl exclusion zone, with either one or no stations outside the no-trawl zone across all three combined strata. At the southern end, G25 had to be merged with the deeper F50 in 1994 and 1999 given there was no adjacent stratum in the same depth range. In 1996, when E50 was required to be merged, it was joined with the smaller RG50 stratum to the north. As a result of these merges, the number of strata in the core area was reduced from 17–21 to between 12 and 16 strata, with 49–73 stations remaining, equating to between 70–78% of the original stations.

Table 3: Summary of strata amalgamations by survey following the removal of areas inside the Māui dolphin trawl exclusion zone ahead of the 2019 survey. For each survey, the original number of strata and stations are listed in the first column underneath the trip code. The affected strata are listed along with the strata with which they were merged. The adjusted number of strata and station numbers are given in the final column.

Survey original no. of strata (original no. of stations)	Original stratum	Original number of stations	No. of remaining stations	Merged with (remaining station count)	New amalgamated stratum station count)	Adjusted core area strata count (adjusted station count)
KAH8918 21 strata (84)	WCSB25	2	2	WCSA25 (6)	WCAB25 (8)	16 strata (66)
	WCSB50	3	1	WCSA50 (4)	WCAB50 (5)	
	WCSD25	4	0	Excluded		
	WCSE25	4	1	Excluded		
	WCSF25	4	0	Excluded		
KAH 9111 17 strata (68)	C25	5	1	B25 (3)	BC25 (4)	12 strata (49)
	D25	3	0	Excluded		
	E25	4	0	Excluded		
	F25	4	0	Excluded		
	G25	4	2	F50 (3)	F50G25 (5)	
KAH 9410 19 strata (73)	A100	0	0	B100 (4)	AB100 (4)	12 strata (51)
	A25	0	0	B25 (3)	ABC25 (3)	
	C25	5	0	B25 (3)		
	D25	4	1	Excluded		
	E25	4	0	Excluded		
	F25	4	0	Excluded		
	G25	4	2	F50 (4)	F50G25 (6)	
KAH 9615 19 strata (95)	D25	4	0	Excluded		15 strata (73)
	E25	4	0	Excluded		
	E50	4	2	RG50 (5)	ERG50 (7)	
	F25	4	1	Excluded		
KAH 9915 20 strata (77)	BB50	3	2	C50 (3)	BC50 (5)	14 strata (55)
	C25N	3	1	C25S (5)	C25 (6)	
	D25	3	0	Excluded		
	E25	3	0	Excluded		
	F25	3	0	Excluded		
	G25	3	1	F50 (3)	F50G25 (4)	
KAH 1806 21 strata (63)	D25	0	0	Excluded		18 strata (63)
	E25	0	0	Excluded		
	F25	0	0	Excluded		

This process had to be repeated in 2020 when the trawl exclusion zone was extended further by Fisheries New Zealand. Table 2 provides the percentage overlap of the extended trawl exclusion zone by stratum, and Table 4 provides a summary of the second strata amalgamation process. The same four strata as previously were affected, but the amalgamation decisions were modified slightly to make the stratification as consistent as possible across surveys. B50 (or equivalent) was always merged with the A strata to the north, as this was the stratum the remaining survey area was directly adjacent to (see survey maps in Appendix 1). For this extension, the same process was also needed for the 2018 and 2019 surveys (see Jones et al. 2022 and Table A1.1 for details).

Table 4: Summary of strata amalgamations by survey following the removal of areas inside the extended Māui dolphin trawl exclusion zone ahead of the 2020 survey. The affected strata are listed along with the strata with which they were merged. In some cases, three strata needed to be merged. The adjusted number of strata and station numbers are given in the final column. D25, E25, and F25 were not listed in this table because they were fully excluded in the previous amalgamation.

Survey	Strata left with < 3 stations (no. of remaining stations)	Merged with	3 rd merge if needed	New amalgamated stratum (Station count)	Core area strata count (station count)
KAH 8918	WCSB25 (2) WCSB50 (1) WCSC25 (1) WCSF50* ¹ (0) WCSG25 (0)	WCSA25 (4) WCSA50 (4) WCSC50 (0) WCSE50* ² (3) Excluded	WCSD50 (3) WCSG50 (2)	WCAB25 (6) WCAB50 (5) C25CD50 (4) EFG50 (5)	11 strata (49)
KAH 9111	C25 (0) E50 (1) G25 (0)	B50* ³ (6) D50 (4) Excluded	F50 (0)	B50C25 (6) DEF50 (5)	10 strata (39)
KAH 9410	BB50 (0) C25 (0) E50 (0) G25 (0)	AA50 (4) C50 (2) RG50 (3) Excluded	DD50 (3)	AB50 (4) C25CD50 (5) ERG50 (3)	9 strata (36)
KAH 9615	B100 (2) B50 (1) C25 (0) E50 (1) G25 (0)	A100 (4) AA50 (4) C50 (5) RG50 (2) Excluded		AB100 (6) AB50 (5) C25C50 (5) ERG50 (3)	11 strata (52)
KAH 9915	BB50 (0) C25N (0) E50 (0) G25 (0)	AA50 (5) C25N (2) RG50 (3) Excluded	C50 (2) F50 (2)	AB50 (5) C25C50 (4) EFRG50 (5)	11 strata (43)
KAH 1806	BB50 (0) C25N (2) E50 (1) G25 (0)	AA50 (3) C25S (1) RG50 (3) Excluded	C50 (5)	AB50 (3) C25C50 (8) RE50 (4)	13 strata (49)
KAH 1906	B50X (0) C25X (1) E50X (2) G25x (0)	AA50 (3) C50 (3) R50X (3) Excluded		AB50 (3) C25C50 (4) ER50 (5)	13 strata (45)

*¹WCSF50 in 1989 equivalent to E50 in later surveys.

*² WCE50 is ~equivalent to DD50/RG50 and WCG50 is equivalent to F50 in future surveys.

*³ B50 in this survey is approximately equivalent to C50 in later surveys.

For the 1991 survey, stratum B50 was effectively an extended version of C50 stratum (see Appendix 1) and did not require merging. In this second re-stratification process, given that the remaining portion of C25 was not physically adjacent to the northerly strata of the same depth band (i.e., B25), it was considered more appropriate to combine this small remaining area, immediately outside the Kaipara Harbour with the adjacent deeper stratum, C50 (or B50 in 1991). This decision was based on the likelihood of catch rates being more similar between these C strata than between C25 and B25. The remains of stratum E50/WCSF50 between Raglan and Tirua Point were left as two separate areas. These were amalgamated with RG50 (formerly WCSE50 in 1989 and D50 in 1991) to the north, but also F50 or the equivalent in some surveys (1989, 1991, and 1999). With this extension, G25 was not a viable stratum in any of the surveys and so was excluded. This re-stratification left 36–52 stations (representing between 49–57% of the original total), spread across 9–13 strata for each historical survey.

Affected stratum areas were re-calculated by extracting the overlapping area from the original area, and *SurvCalc* (Francis & Fu 2012) was used to re-estimate relative biomass and population scaled length frequencies from the remaining valid stations. This provided a “remove initial Māui dolphin trawl exclusion zone” biomass time series for the historical surveys only, and a “remove extended Māui dolphin trawl exclusion zone” series, both of which could be compared with the original biomass series for those historical surveys. Since these series are used in stock assessment models as relative indices, comparison of trends was more important than absolute values. Plots of percentage difference were used to assess differences in trend. Scaled length frequency distributions and cumulative length frequencies were used to compare the original survey and the two reduced area scenarios.

2.2 Evaluation of the wider utility of the west coast North Island inshore survey

The utility of the WCNI trawl survey for both target and non-target species was reviewed, following the methodology of O’Driscoll et al. (2011) and Bagley et al. (2013), with some further analysis for snapper and tarakihi. For each species considered, the following information was summarised:

- 1) The spatial and depth distribution across the survey area;
- 2) Trends in biomass across the survey for three defined time series;
- 3) The size range sampled, mean length, and any trends in size for species that were routinely measured;
- 4) Population scaled length frequency distributions, sex composition, and maturity status where sufficient data were available.

The analysis was based on the eight trawl surveys included in the current series from 1989 to 2020. Data were extracted from the *trawl* database for all stations on these surveys which fulfilled the criteria for ‘biomass’ tows. Abundance indices were calculated for individual species considered to have been accurately identified from all surveys and combinations of species or groups where identification varied over the time series (e.g., jack mackerel species, sea perch, and stargazers). A total of 98 fish and squid species or species groups were collated and are listed in Appendix 2. From this number, 62 species or species groups fulfilled the chosen criteria of having at least 10 kg of catch (combined over all surveys) and occurring in at least 3 of the 8 surveys. These species were selected for data collation and review. From this list, 20 species are fully reviewed in this report, with the remaining 42 listed with brief summary information in Appendix 6. The 20 species included the four target species, six other species, and a species group (JMA) for which the survey has previously been considered of some use, and a further nine other QMS and non-QMS species that were considered of some interest. Benthic invertebrate catch is not considered in this review due to the lack of quantification and/or consistent identification on historical surveys.

2.2.1 Distribution, catch rate plots, and biomass estimation

The spatial distributions of the 62 species or groups that were selected for abundance estimation (Appendix 2) were summarised by depth, latitude, and longitude for all years combined, within the trawl survey boundary, excluding stations that fell inside the extended Māui dolphin no-trawl zone. Catch data were matched to station data using trip codes and station numbers and presence/absence

plots were produced. Depth was divided into 10-m bins. For each species or group, the number of tows for each depth bin in which that species or group was present was summed and divided by the total number of tows in that depth bin to give the proportion of tows for which the species was present. The same process was repeated for latitude using bins of 0.05 degrees, and for longitude using bins of 0.5 degrees.

For each survey, the catch rates (kg km^{-2}) by station and stratum, relative biomass estimates and their associated CVs were calculated by the area swept method (Francis 1981, 1989) using the *SurvCalc* Program (Francis & Fu 2012). The following assumptions were made for calculating biomass estimates with the *SurvCalc* Program.

1. Area swept during each tow equalled the distance between doors multiplied by distance towed.
2. All fish within the swept area were caught and there was no escapement; vulnerability was 1.0.
3. All fish in the water column were below the headline height and available to the net; vertical availability was 1.0.
4. The fishstock being sampled was entirely within the area at the time of the survey; areal availability was 1.0.
5. Within the survey area, fish were evenly distributed over both trawlable and non-trawlable ground.

It is unlikely that all of these assumptions are correct, but they have been adopted for other previous and current trawl surveys of relative biomass (Stevenson & Hanchet 1999) and have been applied consistently to the entire trawl survey time series. It is noted that whilst assumption 5 refers to occasional foul ground encountered within the strata, some areas of foul ground have been excluded from the survey area. This exclusion differs to some other survey time series, where the areas of foul are included in the stratum areas used for scaling up biomass. Given the above conditions, the biomass estimates generated are classed as relative indices of abundance.

Catch rates by station were plotted for each survey year. Total catch for each survey was tabulated, and relative biomass estimates were calculated by stratum, as defined for each survey in the revised time series, and summed together for three key areas:

- The northern core area removing the extended trawl exclusion zone as described above (10–100 m) for all 8 surveys;
- The core + extended deeper northern area (10–200 m depth) for 6 surveys;
- The core + extended northern areas + the southern strata (south of Airedale Reef), i.e., whole survey for 4 surveys.

These relative biomass time series were plotted for all 62 species and also tabulated for the 20 species considered in the main report. Biomass estimates for the southern strata only (south of Airedale Reef) were also tabulated separately for these 20 species.

2.2.2 Estimation of length frequencies

A total of 133 398 individuals from 98 species have been measured on these surveys. Minimum, maximum, and mean sizes for each survey were tabulated for species or species groups where applicable and are given in the species summaries for selected species. Population length frequencies were calculated for those species where there were sufficient length data. This was arbitrarily defined as more than 500 length measurements with consistent sampling across multiple years, although smaller samples sizes were deemed acceptable for some of the elasmobranch species. Length frequencies were scaled by the percentage of the catch sampled, area swept, and stratum area and are presented by sex. The geometric mean functional relationship was used to calculate the length-weight coefficients for species, where sufficient length-weight data were collected (Appendix 3). Data were groomed and outliers where residual values exceeded +0.3 or -0.3 were removed. For species where no or insufficient length-weight data were collected, coefficients were chosen from the *rdh* database or other sources. The reproductive stage data (Appendix 4) are summarised by survey for each of the target species and additional species where enough data were collected.

2.2.3 Species summaries

Species summaries are presented following a standard format adapted from that used by O'Driscoll et al. (2011). Each includes summary information on the number of surveys on which the species was caught, total catch weight and numbers measured, the length range and overall mean size, and number individually weighed. A summary figure of occurrence is provided along with description of how well the survey covers the species occurrence. Area and depth were defined as appropriate if the species or stock distribution was encompassed by the survey area, and usually less than 200 m, and not appropriate if distribution was typically deeper or shallower, known to be pelagic, or extending beyond the boundaries of the survey area. The spatial distributions within the survey are described, based on frequency of occurrence and catch rate plots.

Relative biomass series for the defined areas are presented and assessed as to how precisely estimated they are based on mean CV.

- Very well = mean CV less than 20%
- Well = mean CV 20–30%
- Moderately well = mean CV 30–40%
- Poorly = mean CV more than 40%

Time series trends were assessed if appropriate and, where feasible, compared with fishery-dependent indices. Tables summarising numbers measured, size range, and mean size for each survey are presented and any trends in mean length are highlighted. The use of randomisation tests of ranks of biomass indices and mean lengths, as used by O'Driscoll et al. (2011) and Bagley et al. (2013), were not applied due to the low number of surveys comprising the series.

A summary table was also collated for selected species to provide an overall qualitative judgement of the utility of the WCNI survey for those species. Five assessment criteria were used.

- 1) Are sufficient numbers caught?
- 2) Is the spatial and depth range of the species well sampled?
- 3) How well estimated are the biomass values?
- 4) Are the biomass estimates sensible and consistent over the time series?
- 5) Where scaled length frequency distributions are available, are they consistent over the time series?

For each criteria, one of four qualitative responses were selected: 1) Yes (✓), 2) Probably / adequate / partially (OK), 3) unknown or not confident (?), 4) No / not adequate (✗). The categories were assigned based on the combined opinion of the authors and wider consultation of the expert opinion of the Inshore Working Group. An overall utility score was assigned based on the number of criteria that were assigned a (1) or (2):

Very Good = ✓ ✓ ✓ ✓ ✓

Good = ✓ ✓ ✓ ✓

Reasonable = ✓ ✓ ✓

Limited use = ✓ ✓

Poor = < ✓ ✓

In some assessments, the scores were assigned to a sub-population of the species rather than the whole species; for instance, the survey may provide useful information on juvenile recruitment but is less informative of the adult population.

2.2.4 Further analysis for snapper and tarakihi

Further assessment of the ability of the survey series to monitor adult snapper biomass during the pre-spawning and spawning period was undertaken. For this analysis, the catch rates, reproductive condition, and size and age composition of snapper in the northern core strata were explored in relation to the timing of sampling, the variation in surface water temperatures (SST), sampling depth, and location. Data from

all surveys in the series were extracted from valid biomass stations shallower than 100 m, including stations now inside the Māui dolphin trawl exclusion zone. The following metrics were utilised:

- Catch rate of mature (30+ cm) snapper (numbers per nautical mile);
- Catch rate of juvenile (< 30 cm) snapper (numbers per nautical mile);
- The proportion of ripe mature female snapper per station;
- Average length of mature snapper per station.

Mature snapper were defined as 30+ cm, and ripe female snapper were classed as stages 4–7 (see Appendix 4). These metrics were plotted against the sampling date, depth (maximum depth), and location for each survey. Three regions were defined for examining depth-related trends in biomass of adult snapper over the most recent surveys based on Statistical Areas rather than survey stratum: Ninety Mile Beach and Hokianga Harbour (Statistical Areas 047 and 046); Kaipara and Manukau harbours (Statistical Areas 045 and 042); and the North Taranaki Bight (Statistical Areas 041). Stations were apportioned to these areas based on their start position.

For further comparisons of snapper numbers-at-age from the more recent surveys, the survey age compositions reported by Jones et al. (2022) were partitioned to derive estimated biomass by age class. Ages were incremented to the age assigned at 1 January following the survey, as used in the stock assessment model; e.g., fish aged 1 year were 0+ at the actual time of the survey. These were then overlaid to compare the contributions to overall biomass by different year classes across the successive surveys.

The South Taranaki Bight region (STB) was defined as including the following strata: I25, J25, G50, H50, I50, G100 (1991), or G10N, G10M, and G10S (more recent surveys). A STB relative biomass series including the 1991 and more recent surveys was produced using the standard *SurvCalc* method (see above). To look at the finer scale variation in this region, catch rates, calculated as numbers of fish per square kilometre, for snapper of different size ranges (20–29, 30–39, and 40–50 cm) were plotted by both station depth and station latitude for each of the three most recent surveys. The age composition of snapper sampled in this area in the three most recent surveys was also examined. For the 2018 and 2019 survey, otoliths from the STB strata were selected as part of the whole survey sample of 700 otoliths selected for ageing from the larger sample of otoliths collected. This provided sample sizes of 170 in 2018, but only 117 in 2019. In the 2020 survey, whilst the protocols for collecting otoliths during the survey remained unchanged, the otolith selection for ageing was separated into the northern core ($n = 500$) and the STB region ($n = 200$). The STB ages were used to form an area-specific Age-Length Key (ALK) for each survey using NIWA's catch-at-length and -age analysis software tool CALA (Francis & Bian 2011). For each year, these were then applied to the STB scaled length frequency distributions to provide an estimate of numbers-at-age for male, female, and all snapper from the STB area. These ages were incremented to the age assigned at 1 January following the survey and compared with the northern core age composition as reported by Jones et al. (2022), the 2019 and 2021 west coast South Island trawl surveys including Golden Bay and Tasman Bay strata (MacGibbon 2019, MacGibbon et al. 2022), and catch-at-age data from the SNA 7 commercial bottom trawl fishery in the 2019–20 fishing year (Parsons et al. 2021).

For tarakihi, commercial catch and effort data (Trawl Catch Effort Return and Electronic Reporting System trawl event records) for bottom trawl fisheries between 2007–08 and 2019–20 were provided by Fisheries New Zealand, and total catch (on a natural log scale) and mean catch weight per tow were aggregated by 0.1 degrees of latitude and longitude and plotted (updated from Langley 2017b). To compare trends in the survey catches of tarakihi with the commercial CPUE trends, the CPUE model for the northern west coast single trawl fishery was updated to the 2019–20 fishing year from that published by Langley (2017). This index is based only on catches from the northern part of the west coast, located within Statistical Areas 045–047). Tarakihi catch rates (kilogram per nautical mile) from trawl survey stations conducted in a comparable area (north of 36° S) were used to derive a comparable trawl survey GLM index. The data set was limited to surveys that included the 100–200 m depth range, encompassing the main depth distribution of tarakihi. Individual station catch rates were standardised using a simple GLM including the explanatory variables *latitude*, *depth*, and *survey*. The categorical *survey* variable was

extracted as the abundance index for the survey/year and plotted alongside the CPUE index for comparison.

2.3 Survey representativeness

Representativeness refers to the survey catchability and whether the biomass estimate from a range of species was within an acceptable range (representative) or was extreme (non-representative). This approach was derived from the work by R.I.C.C. Francis et al. (2001) who examined data from 17 trawl survey time series. The method involves ranking each species in order of increasing biomass index and then averaging across species to obtain a mean species rank for each year. The method assumes that species abundances are uncorrelated and that particularly high (or low) estimates across a range of species in a given survey is due to a change to the trawl catchability.

This analysis was carried out for the 8 WCNI surveys during 1989–2020. Species included in the ranking calculations were the 4 target species (snapper, red gurnard, John dory, tarakihi), and 9 other species that are commonly caught on these surveys (rig, trevally, barracouta, school shark, spiny dogfish, leatherjacket, rough skate, northern spiny dogfish). The representativeness analysis was run for 5 species (four target species and rig) and for all 12 species.

2.4 Ancillary data

Brief consideration was also given to utility of other (ancillary) data collected during the survey. This included collection of information on benthic invertebrates and environmental and acoustic data.

3. RESULTS

3.1 Assessing the bias created by removing areas within the Māui dolphin trawl exclusion zone from the inshore WCNI strata

3.1.1 Comparison of historical catch rates inside and outside the no-trawl zone

The distribution of stations inside and outside the Māui dolphin trawl exclusion zone by survey for the five selected strata (BB50, C25N and C25S, E50 and G25) are given in Table 5 for all seven surveys from 1986 to 1999. Not all of the strata were sampled in every survey, and some of the stations from the 1986 and 1987 surveys did not have catch weights recorded in the database and weights estimated from the length frequency distributions were used instead. There was considerable variation in the spread of stations inside and outside the trawl exclusion zone. The proportion of each stratum area that was excluded varied from 19% in E50, resulting in most stations (22 out of a possible 28) occurring outside the no-trawl zone, to 68% in C25N, where only 4 out of a total of 13 stations lay outside the no-trawl zone. This uneven spread of data made survey-by-survey comparisons at the stratum level unviable, and therefore stations were combined across strata for each survey. The combined station level catch rates of two of the key inshore target species (snapper and red gurnard) from seven historical surveys are shown in Figures 2 and 3 with Figure 4 presenting summary box plots by survey. Mean catch rates inside the excluded portion of the five strata were higher on average for snapper and lower for gurnard (Table 6).

Table 5: Summary of station counts inside and outside the original Māui dolphin trawl exclusion zone by survey and stratum. Stratum definitions from the 1999 survey were used for all surveys.

Stratum Survey	BB50		C25N		C25S		E50		G25		Survey Totals	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
KAH8612					2	1	2	4			4	5
KAH8715	2	2	1	1	1	3	1	3			5	9
KAH8918	2	1			2	3		3	3	3	7	10
KAH9111		2	1		3	1		4	2	3	6	10
KAH9410	1	3	1		5		1	3	2	2	10	8
KAH9615	1	4	4	1	3	4	2	2	1	4	11	15
KAH9915	1	2	2	2	8	4		3	2	1	13	12
Totals	7	14	9	4	24	16	6	22	10	13	56	69

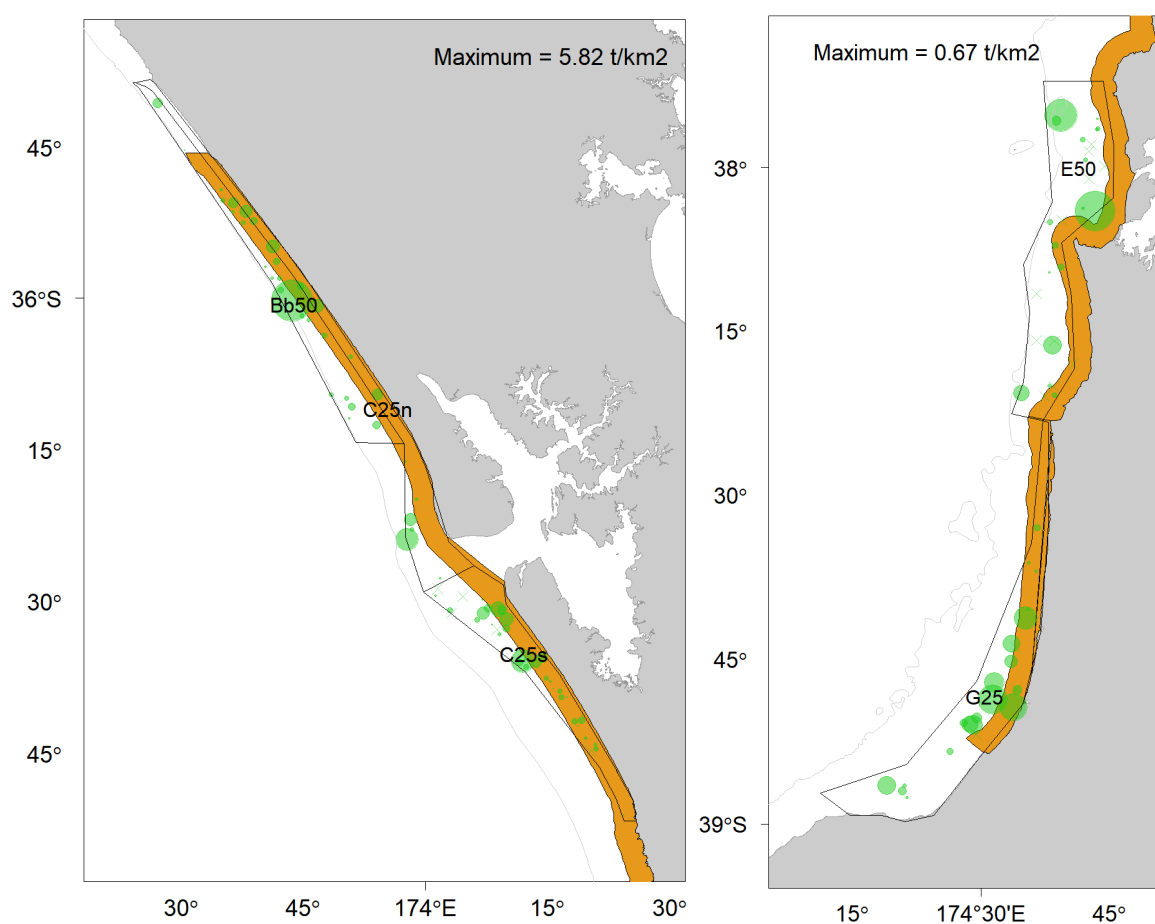


Figure 2: Combined historical catch rates of snapper overlaying the 1999 survey strata and Māui dolphin trawl exclusion zone (in orange). LHS shows strata BB50, C25N, and C25S. RHS shows E50 and G25. Catch rates are scaled to the maximum in each map as shown.

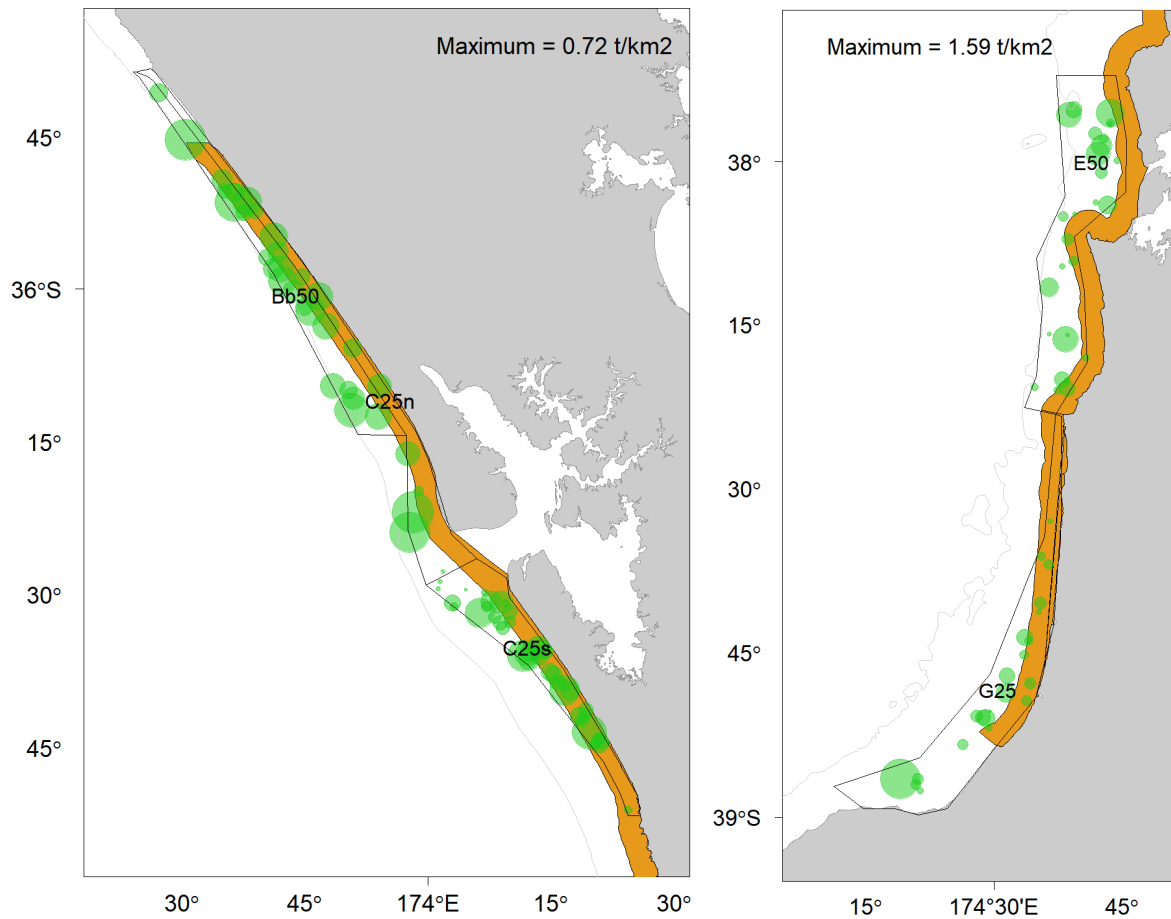


Figure 3: Combined historical catch rates of red gurnard overlaying the 1999 survey strata and Māui dolphin trawl exclusion zone (in orange). LHS shows strata BB50, C25N, and C25S. RHS shows E50 and G25. Catch rates are scaled to the maximum in each map as shown.

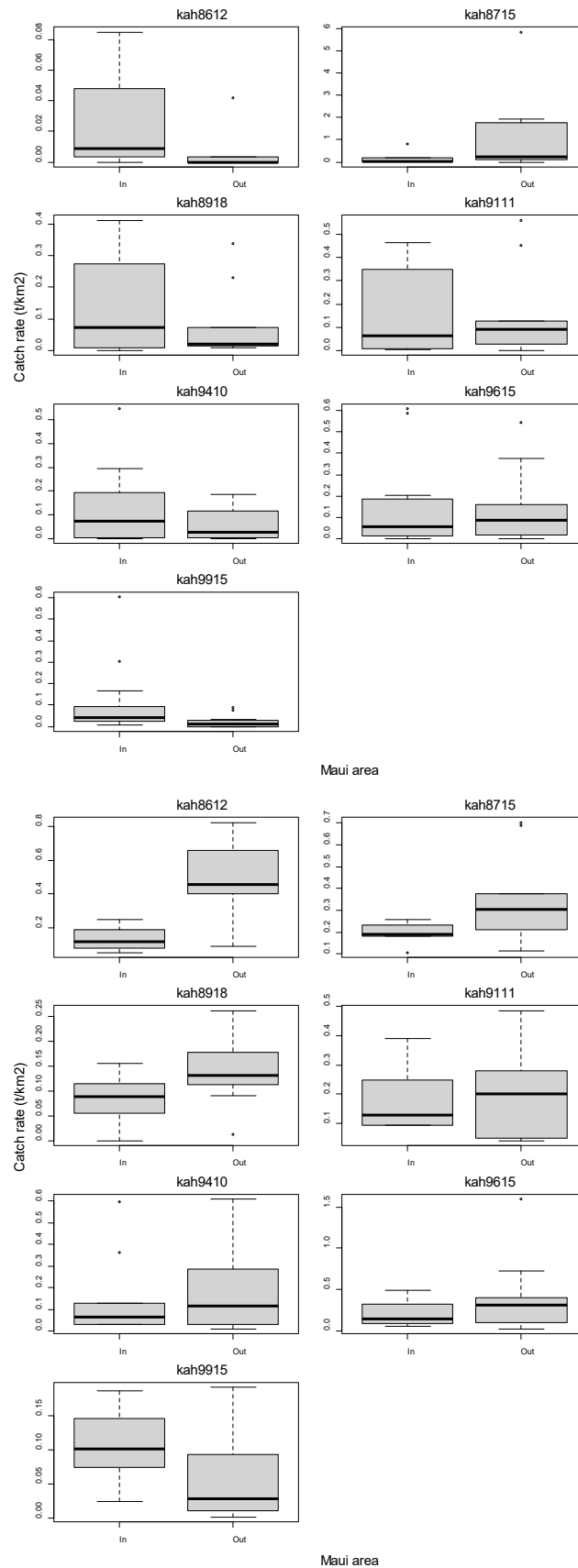


Figure 4: Boxplots of survey level catch rates of snapper (top) and red gurnard (bottom) for five affected inshore strata combined. Each boxplot indicates the median, interquartile range, maximum, minimum, and outlier catch rates for all stations combined falling inside (In) and outside (Out) the Māui dolphin trawl exclusion zone for each survey.

Table 6: Survey level catch rates and standard error (SE) values for snapper and red gurnard for all affected strata combined.

Survey	Catch rates (t km^{-2}) & SE		
	Inside	Outside	All stations
Snapper			
kah8612	0.03 (0.01)	0.01 (0.01)	0.02 (0.01)
kah8715	0.21 (0.09)	1.20 (0.24)	0.85 (0.12)
kah8918	0.15 (0.03)	0.07 (0.01)	0.11 (0.01)
kah9111	0.16 (0.08)	0.15 (0.06)	0.15 (0.05)
kah9410	0.13 (0.06)	0.06 (0.03)	0.10 (0.03)
kah9615	0.16 (0.07)	0.13 (0.04)	0.14 (0.04)
kah9915	0.12 (0.05)	0.02 (0.01)	0.07 (0.03)
Red gurnard			
kah8612	0.13 (0.04)	0.49 (0.12)	0.33 (0.09)
kah8715	0.19 (0.02)	0.35 (0.07)	0.29 (0.05)
kah8918	0.08 (0.02)	0.14 (0.02)	0.11 (0.02)
kah9111	0.18 (0.05)	0.19 (0.05)	0.19 (0.03)
kah9410	0.15 (0.06)	0.19 (0.07)	0.17 (0.04)
kah9615	0.20 (0.04)	0.37 (0.10)	0.30 (0.06)
kah9915	0.11 (0.01)	0.05 (0.02)	0.08 (0.01)

For the GLM analysis, the 1986 and 1987 surveys were excluded due to the aforementioned lack of recorded catch weight data for some stations. When the step-wise GLMs were fitted to the snapper catch data from 1989 to 1999, *Stratum* was retained as an explanatory term in both the Gaussian and binomial models (Appendix 5). *Stratum* was also a significant term in the full Gaussian model anova summary table (Table 7). However, none of the three *Location* terms were retained in the snapper step-wise GLM model selections (Appendix 5), nor were any *Location* terms significant in the full Gaussian model anova summary table (Table 7).

For red gurnard, at least one *Location* term was retained in both the Gaussian and binomial final model selections in addition to *Stratum* (Appendix 5). The *Stratum-Location interaction* term was also significant in the red gurnard full Gaussian model anova summary table in addition to *Survey year* and *Stratum* (Table 7). The John dory GLM analytical results were similar to snapper with none of the offered *Location* parameters being selected (Appendix 5) and none being significant terms in the full model anova table (Table 7).

Table 7: Analysis of variance summary table for the generalised linear model (GLM) with an identity link function fitted to survey catch rates of snapper, red gurnard, and John dory in historical surveys. Explanatory terms were added sequentially (first to last). Significant explanatory model terms are in bold. (Continued on next page)

Snapper		Residual				Pr (F)
		DF	Deviance	DF	Deviance	
Null hypothesis				87	197.68	
Survey year	4		7.962	83	189.72	0.9901
Stratum	4		35.117	79	154.6	0.003284
Location (Inside/Outside)	1		0.160	78	154.44	0.778698
Stratum x Location	4		4.132	74	150.31	0.725804
Survey x Location	4		9.576	70	140.74	0.322537

Table 7: continued. Red gurnard and John dory.

Red gurnard		Residual				
	DF	Deviance	DF	Deviance	F value	Pr (F)
Null hypothesis			100	132.123		
Survey year	4	24.4086	96	107.715	7.0784	0.000059
Stratum	4	13.6115	92	94.103	3.9473	0.005546
Location (Inside/Outside)	1	2.1190	91	91.984	2.4580	0.120731
Stratum x Location	4	13.4520	87	78.532	3.9010	0.005943
Survey x Location	4	6.9798	83	71.552	2.0241	0.098505

John dory		Residual				
	DF	Deviance	DF	Deviance	F value	Pr (F)
Null hypothesis			46	59.394		
Survey year	4	3.2619	42	56.132	0.6615	0.62356
Stratum	4	4.1140	38	52.018	0.8343	0.51413
Location (Inside/Outside)	1	0.0077	37	52.010	0.0062	0.93767
Stratum x Location	3	4.3562	34	47.654	1.1779	0.33462
Survey x Location	4	10.6725	30	36.981	2.1644	0.09721

3.1.2 Comparison of historical population structure inside and outside the no- trawl zone

Figure 5 shows the approximation of the combined length frequency of snapper as estimated by the KDE probability density function from samples inside and outside the no-trawl zone for each survey from 1989 onwards. The grey band represents the null model of no difference between each pair of KDEs. This is centred on the geometric mean KDE between the inside and outside samples and extends one standard error above and below this. Comparing mean length (plots on the left-hand side), the KDE functions for both categories clearly lie outside the standard error band for parts of the length range in all surveys except 1994, indicating significant differences ($p < 0.05$) in mean size (see Figure 5 and Table 8).

The mean size from stations inside the no-trawl zone was smaller in the 1986 (not shown), 1989, 1991, and 1996 surveys with higher numbers at around 20 cm, compared with stations outside the Māui zone where higher numbers of larger fish occurred. In 1999, there were significant differences in mean size, but the pattern was reversed, with a larger average mean size found inside the no-trawl zone. In the 1994 survey, the difference in mean length was not significant for this survey. The shape of the length frequency (location of modal peaks relative to the mean) was significantly different in all surveys except 1986 and 1989 (kah8612 and kah8918).

Table 8 presents the test results for snapper, red gurnard, and John dory. For red gurnard, the differences in mean size were significant in all surveys, with a larger mean size from samples inside the Māui dolphin no-trawl zone in most surveys. Differences in location of modal peak relative to the mean were significantly different in four out of the seven surveys (Table 8, Figure 6). For John dory, the sample sizes were very low in each survey for the limited number of strata utilised and no significant differences in location or shape were able to be detected. KDE plots are not shown for John dory.

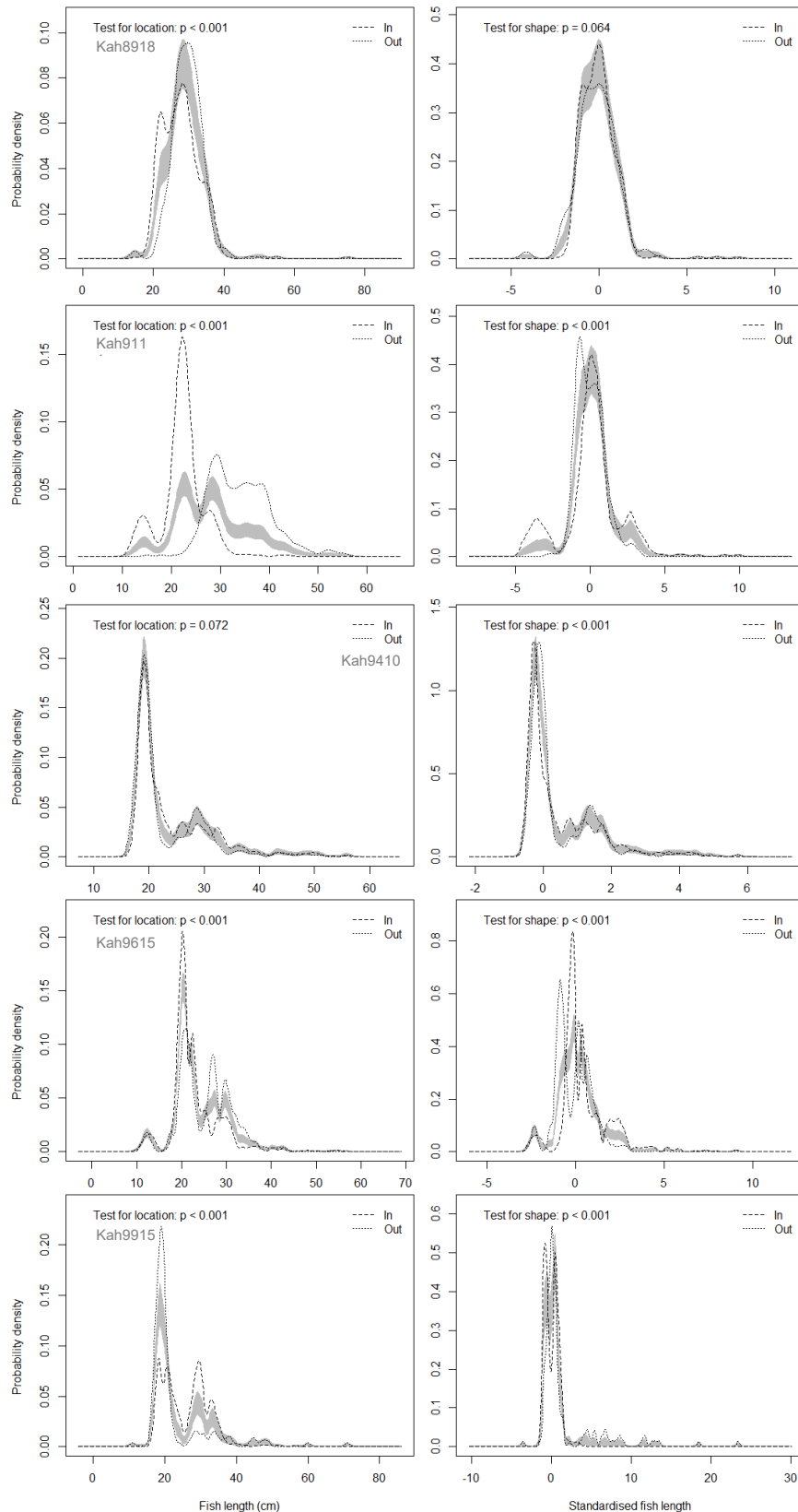


Figure 5: Kernel Density Estimate probability density functions approximating the length frequencies for snapper sampled inside and outside the Māui dolphin trawl exclusion zone in affected strata from historical surveys. Left-hand plots show permutation test results for location (mean length) and right-hand plots show test for shape (location of modal peaks relative to mean). Grey shaded bands represent the null hypothesis of no difference between the pairs centred on the mean KDE and extending 1 SE above and below.

Table 8: Results of the permutation tests comparing the area between the pairs of KDEs for fish length samples from inside and outside the Māui dolphin zones by survey for each of the three target species. The number of fish in each category in each survey is given, along with the p-value of the test result for both location (mean length) and shape (location of modal peaks relative to the mean).

Survey	Sample size		Mean size (cm)		p-value	
	Inside	Outside	Inside	Outside	location	shape
Snapper						
kah8612	17	6	29.4	30.8	0.004	0.426
kah8715	279	273	26.6	23.5	0	0
kah8918	387	271	27.8	29.6	0	0.064
kah9111	388	337	22.2	34.1	0	0
kah9410	521	291	24.1	23.0	0.072	0
kah9615	795	743	22.8	25.2	0	0
kah9915	581	150	26.0	22.6	0	0
All surveys	2 968	2 071			0.008	0
Red gurnard						
kah8612	261	1 280	29.2	25.0	0	0.004
kah8715	384	818	28.1	27.7	0.01	0.044
kah8918	355	711	30.9	30.7	0	0.154
kah9111	366	819	30.3	27.2	0	0.002
kah9410	597	505	28.2	26.8	0	0.004
kah9615	1 058	1 487	26.5	26.8	0	0.066
kah9915	985	660	30.9	26.9	0	0.008
All surveys	4 006	6 280			0	0
John dory						
kah8918	18	28	37.9	38.8	0.992	0.644
kah9410	6	9	28.3	35.1	0.130	0.816
kah9615	8	24	38.5	35.5	0.216	0.766
kah9915	12	10	41.3	34.7	0.300	0.400
All surveys	52	87			0.752	0.478

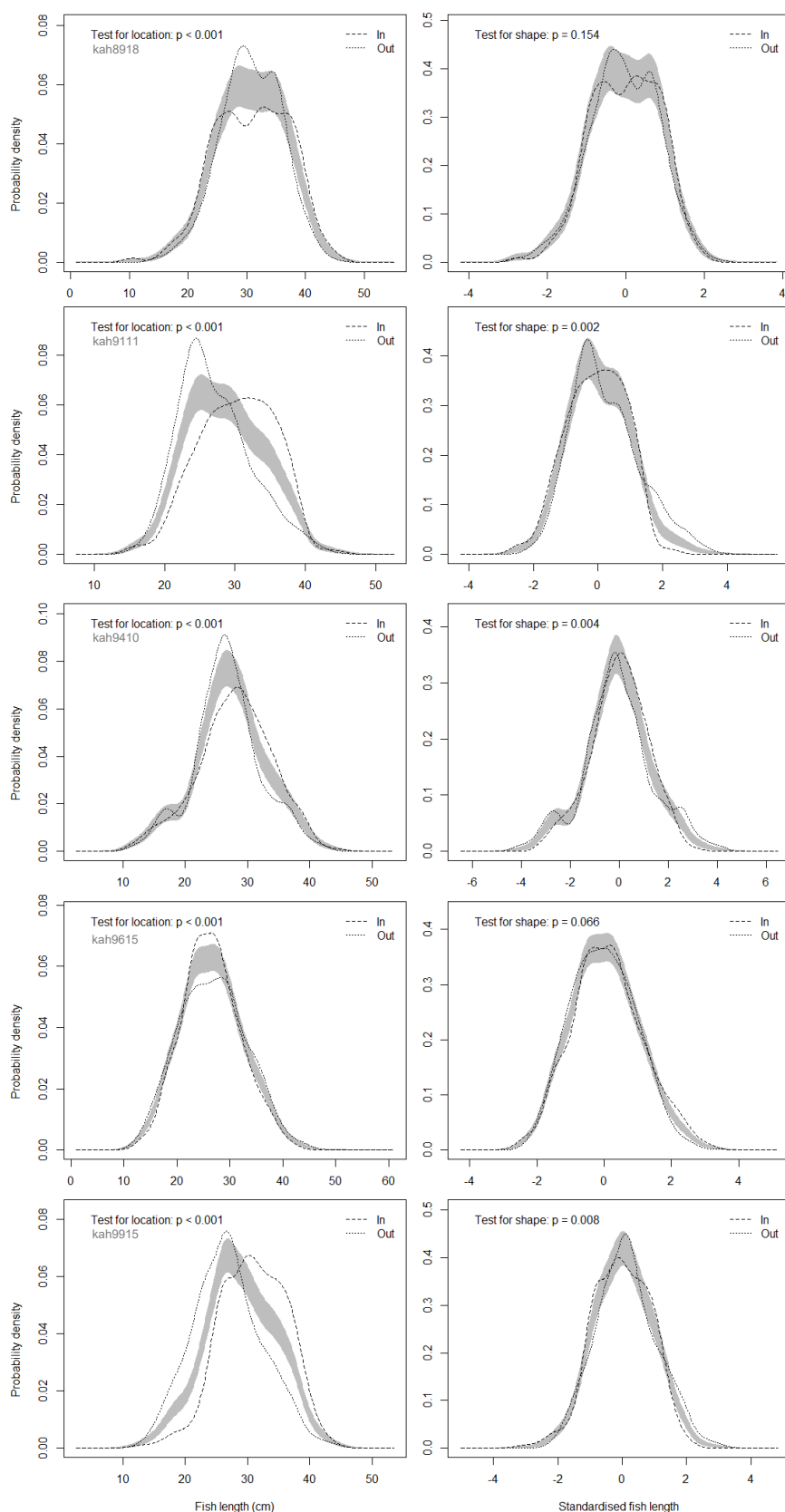


Figure 6: Kernel Density Estimate probability density functions approximating the length frequencies for red gurnard sampled inside and outside the Māui trawl exclusion zone in affected strata from the five historical surveys. Left-hand plots show results for location (mean length) and right-hand plots show shape. The grey shaded band represents the null hypothesis of no difference between the pairs centred on the mean KDE and extending 1 SE above and below.

3.1.3 Comparison of time-series trends with and without the no-trawl zone

Trends in relative biomass estimates for three of the target species (snapper, red gurnard, and John dory) were calculated for the re-defined core area from the original survey data along with trends calculated from the adjusted core with the original Māui dolphin trawl exclusion zone removed and then the extended no-trawl zone (Table 9).

The trends for snapper, along with the percent difference in biomass, are plotted in Figure 7. For the total biomass, with the original trawl exclusion zone removed, the estimates for these historical surveys were reduced by just 2% in 1989, between 12 and 13% in 1991, 1996, and 1999, and by 22.5% in 1994. Despite this variation in proportional drop, the overall biomass trend between surveys was similar, with a decline across the first three surveys, before increasing in 1996 and plateauing in the 1999 survey. Once the no-trawl zone was extended in 2020, there was another 10–25% drop in the biomass; the overall biomass reductions ranged from 11% in 1989 to 42% in 1994 and 20–25% in the other three surveys. Again, the trend across the surveys remained similar. The trends for the recruited biomass were less affected in terms of percentage drop compared with the total biomass. For the pre-recruit sub-population, the biomass drops were larger; there was originally around a 20% drop in 1989, 1996, and 1999, and a greater drop for 1991 (>60%) and 1994 (~40%). The extension increased these differences further. The large difference in the 1991 pre-recruit biomass estimates resulted in a change in trend in this early part of the series, resulting in a decline in biomass between 1989 and 1991, but the subsequent trends in increasing relative biomass were similar for all three definitions albeit with some subtle differences in the gradient between surveys.

Whilst the pattern of trends was similar, the reduction in sample size for the core area was substantial, leaving 36–52 stations in the core area, and CVs were increased at each reduction, ranging from 13.8 to 25.9% after the first reduction in area, but increasing to 14.0–30.4% after the second reduction.

Figure 8 shows the snapper time series extended to include the 2018 and 2019 surveys where the comparison is now just between the biomass trends estimated from the area outside the original no-trawl zone and the extended no-trawl zone introduced ahead of the 2020 survey. The total snapper biomass was reduced by 16% in 2018, and by 12% in 2019 due to reduction in survey area, with the pre-recruited sub-population the most affected at just over 20%. However, as with the historical surveys, the overall biomass trends were similar.

Figure 9 compares the population scaled length frequency distributions for snapper from the original core strata with those constructed from the core area with the original no-trawl zone removed, presented alongside plots of cumulative proportion of length for each of the five historical surveys. The differences in magnitude of pre-recruit snapper (< 25 cm) modes are apparent, particularly in the 1991 and 1994 surveys, with differences in the larger sizes most noticeable in 1994 and 1996. Figure 10 compares the scaled length frequency distribution and cumulative proportion of length class between the populations constructed from the core area outside the original no-trawl zone and that from the core strata adjusted to remove the extended no-trawl zone. This further extension had only slight effects on the length frequency distributions from historical surveys where the major reductions had already occurred. For the more recent surveys, the reduction in the survey area noticeably reduced numbers of fish between 20 and 30 cm.

Table 9: Estimated relative biomass (t) and CVs (%) for snapper in each original historical survey (including all stations), along with recalculated biomass once the original and then extended Māui dolphin trawl exclusion zone was removed from the survey. There are no original estimates for the 2018 and 2019 surveys.

Survey	Original core area biomass (t)	CV (%)	Biomass with original no-trawl zone removed (t)	CV (%)	Biomass with extended no- trawl zone removed (t)	CV (%)	No. stations left
kah8918	1 396.8	24.9	1 370.7	25.7	1 236.3	27.7	49
kah9111	797.4	20.5	704.6	21.4	579.3	30.4	39
kah9410	640.5	16.3	496.4	24.6	372.2	25.0	36
kah9615	1 115.0	23.1	982.1	25.9	846.3	29.9	52
kah9915	1 090.0	12.9	946.6	13.8	859.0	14.0	43
kah1806	—		4 606.0	24.9	3 881.6	22.1	49
kah1906	—		9 122.2	17.6	7 982.1	19.7	45
Red gurnard							
kah8918	2 239.8	12.5	2 139.6	13.1	1 765.2	16.2	49
kah9111	3 790.4	14.0	3 629.6	14.5	3 431.0	15.3	39
kah9410	3 752.6	20.2	3 579.6	27.0	3 336.0	28.8	36
kah9615	3 147.3	9.9	2 851.8	10.4	2 481.9	12.5	52
kah9915	2 047.7	13.6	1 823.7	15.0	1 708.5	16.2	43
kah1806	—		758.6	14.8	647.0	17.1	49
kah1906	—		995.7	12.3	880.9	13.5	45
John dory							
kah8918	284.7	10.6	275.8	11.1	244.4	12.1	49
kah9111	479.1	27.9	476.9	28.0	468.1	28.5	39
kah9410	173.1	30.9	132.0	30.4	128.8	31.1	36
kah9615	347.1	12.1	338.7	12.3	334.8	15.9	52
kah9915	209.0	9.4	198.0	9.8	194.2	9.9	43
kah1806	—		298.1	26.5	287.2	27.4	49
kah1906	—		246.5	18.9	232.0	19.4	45

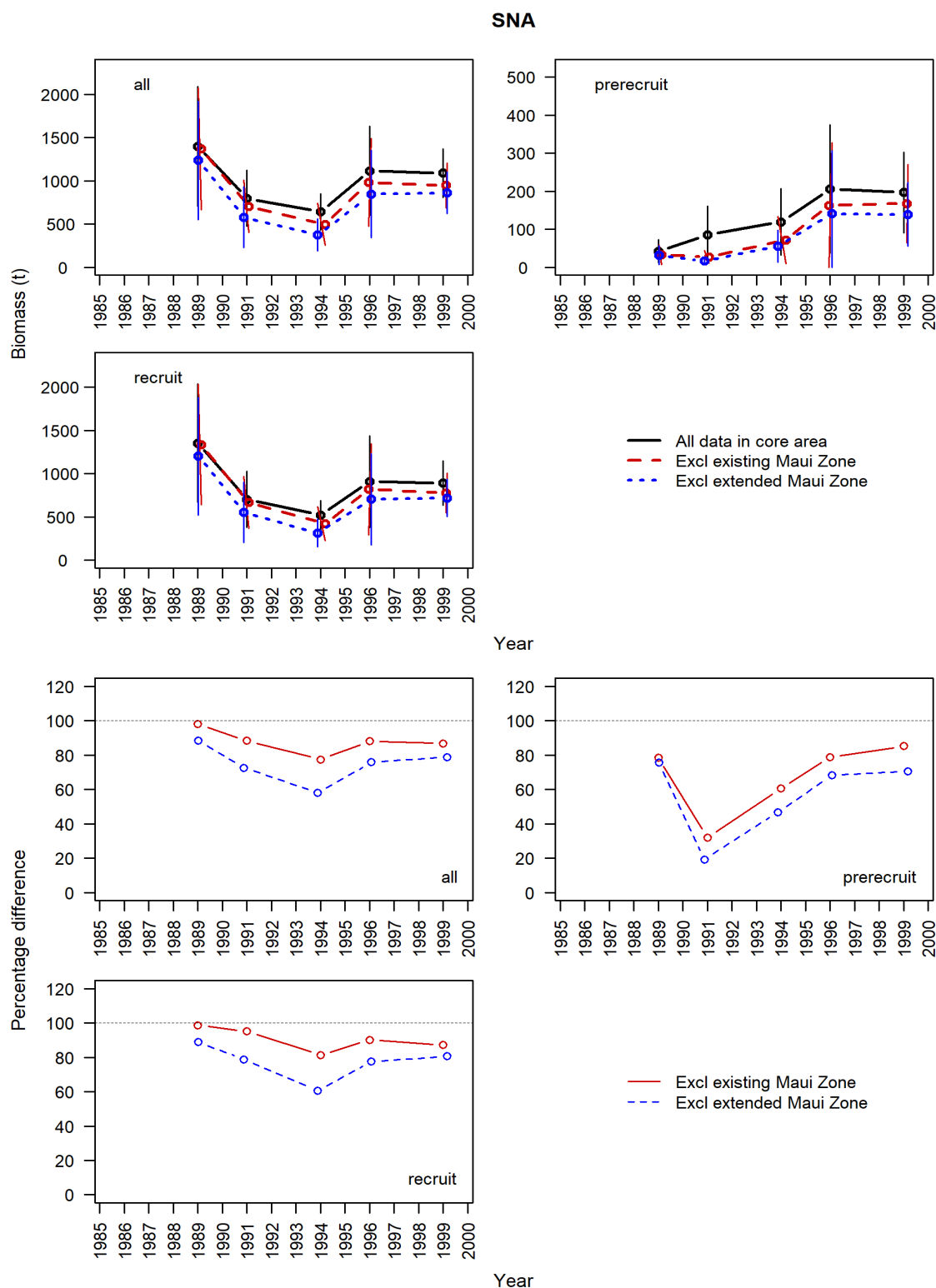


Figure 7: Relative biomass estimates and CVs (top panel) of total, recruited, and pre-recruit snapper from the core area of historical surveys between 1989 and 1999 from all station data (black), excluding the original Māui dolphin no-trawl zone (red) and excluding the extended Māui dolphin no-trawl zone (blue). The bottom panel shows the percentage difference of the two reduced time series trends compared with the original biomass estimate for the total, recruited, and pre-recruit categories.

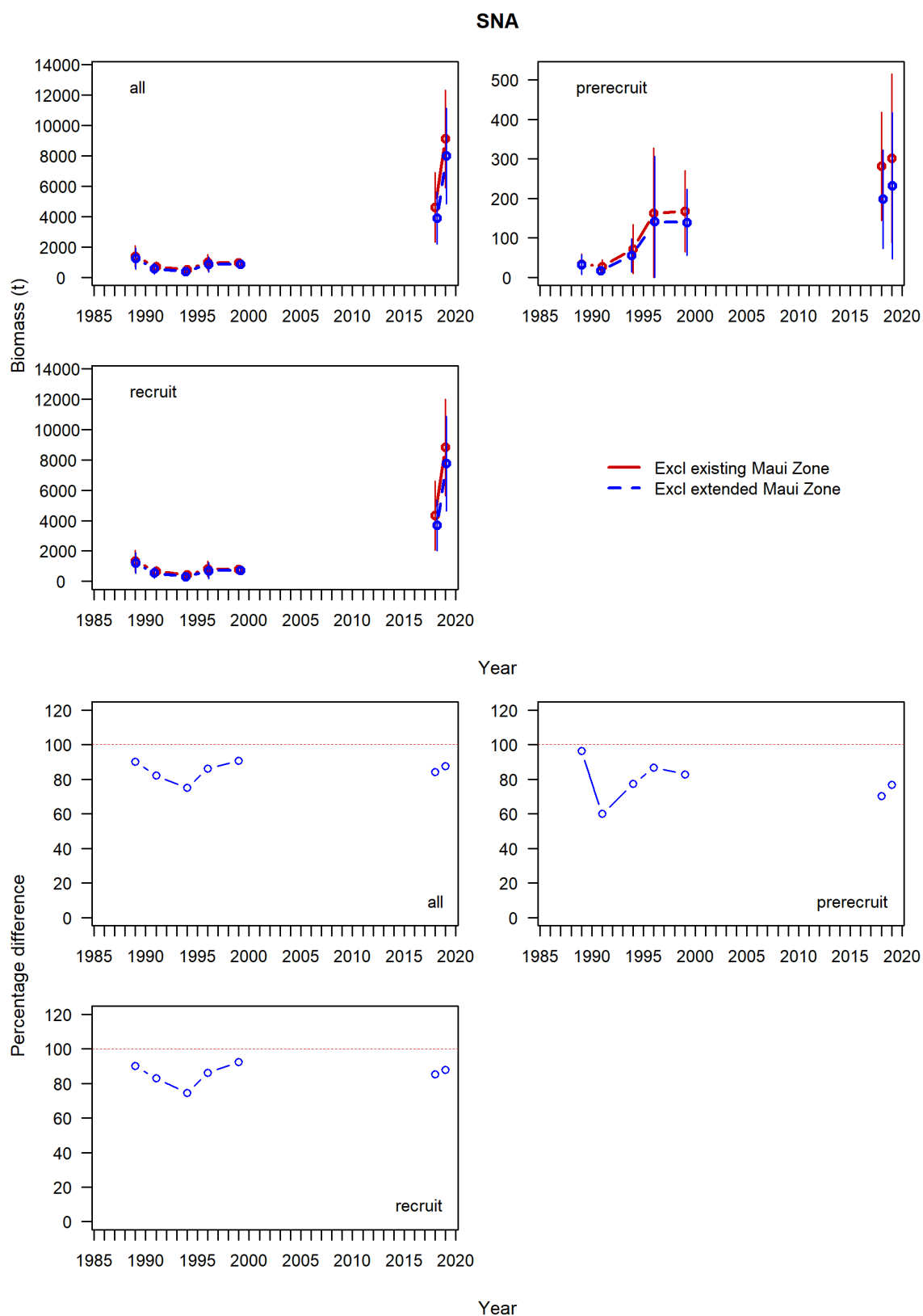


Figure 8: Relative biomass estimates and CVs (top panel) of total, recruited, and pre-recruit snapper from the core area of surveys between 1989 and 2019 estimated from station data excluding the original Māui dolphin no-trawl zone (red) and excluding the extended Māui dolphin no-trawl zone (blue). The bottom panel shows the percentage difference between the extended no-trawl zone series compared with the original no-trawl series for the total, recruited and pre-recruit categories.

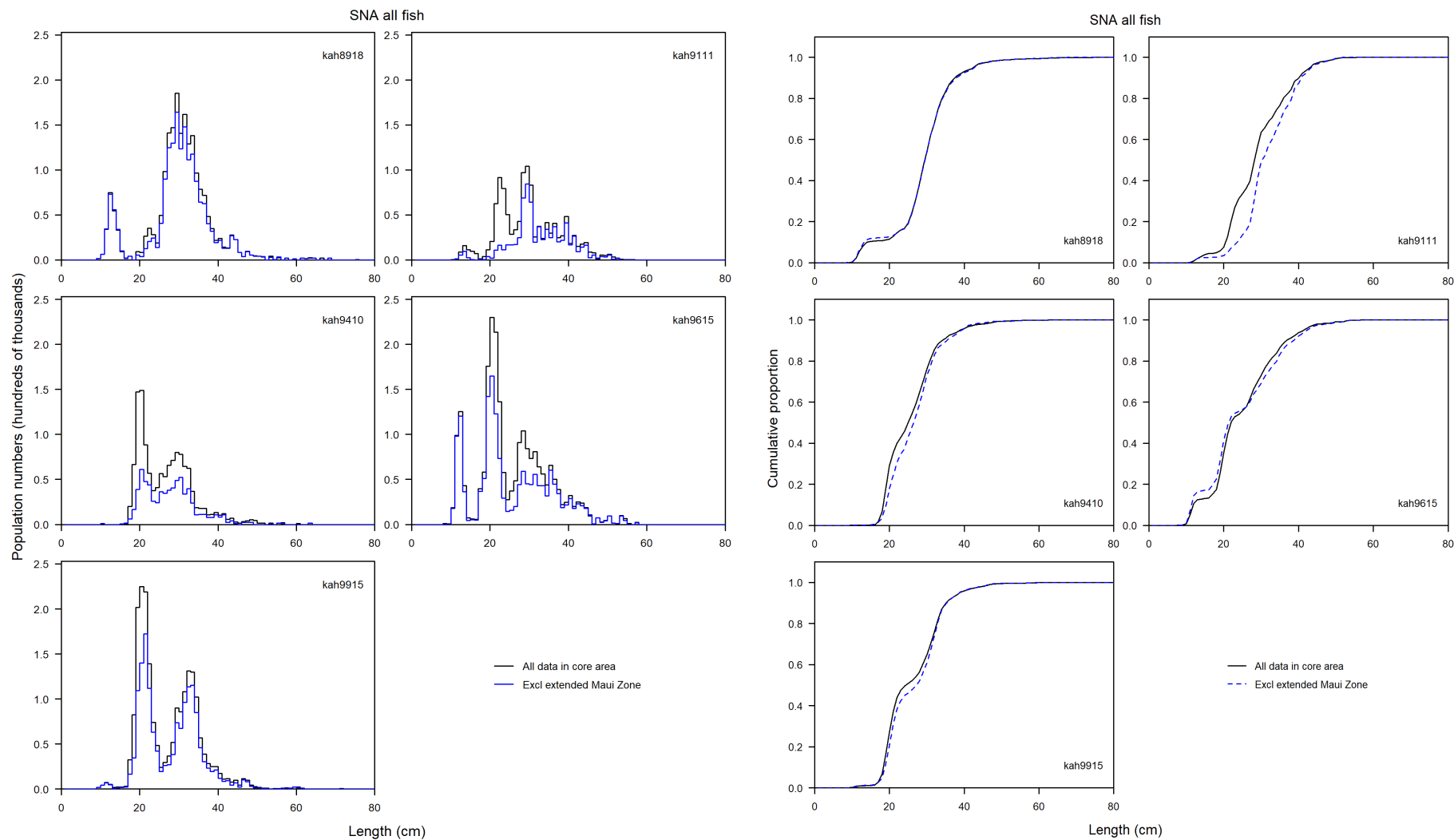


Figure 9: Left; Comparison of population scaled snapper length frequency distributions from the original core survey area (black line) and the core area with extended no-trawl zone removed (blue line) for the five historical surveys from 1989. Right; Cumulative frequency plots for each of the historical surveys.

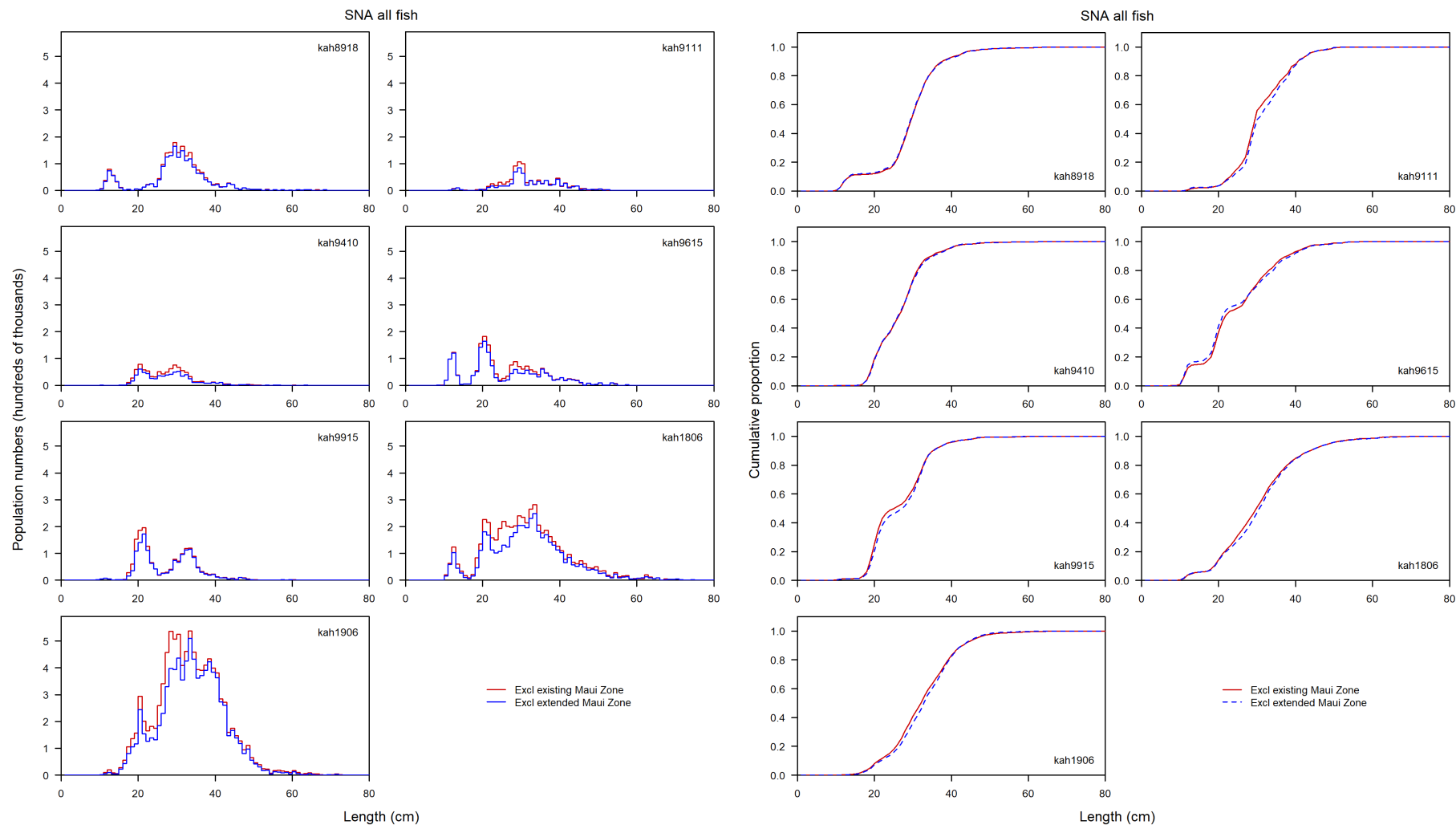


Figure 10: Left; Comparison of population scaled length frequency distributions for snapper from the core survey area with original no-trawl zone removed (red line) and with the extended no-trawl zone removed (blue line) for the five historical surveys from 1989 and two more recent surveys. Right; Cumulative frequency plots for the same surveys.

Figure 11 presents trends in relative biomass estimates for red gurnard calculated for the full core area along with trends calculated from the adjusted core with the original Māui dolphin no-trawl zone removed and then the extended no-trawl zone. The initial removal of the original no-trawl zone reduced total biomass by 4–5% in the first three surveys, and around 10% in the last two surveys. Once the extended no-trawl zone area was removed, a further 5–17% of biomass reduction was observed. However, despite slight changes in gradient between years, the overall biomass trend was not impacted by the extended no-trawl zone. The biomass trends in Figure 12 include the 2018 and 2019 surveys, which are impacted with a 12–15% reduction in biomass with the extended no-trawl zone, but without a major change in overall trend. The CVs for the biomass estimates remained between 13 and 15% after the first reduction for all except the 1994 survey, which increased from 20% up to 27%. After the second reduction in sample size, CVs increased slightly for each survey, ranging between 13 and 27%.

The population scaled length frequency distributions for red gurnard from the complete original core strata are shown in Figure 13, along with those from the adjusted core with extended no-trawl zone removed, and the resulting cumulative length frequency comparisons. There were some small differences, mainly in the 20–30 cm size range. The differences between the extended and initial no-trawl zone are shown in Figure 14, including more recent surveys, and very little change was evident.

Figures 15–18 present the same analysis of biomass trends and size composition for John dory. Removing the original Māui dolphin area resulted in a reduction in the biomass of less than 5% in all surveys except 1994, where a larger difference of 24% in the total biomass & pre-recruit biomass was observed compared with other surveys. With the extended no-trawl zone removed, there were only very slight additional reductions of 1–2%, in biomass estimates for the historical surveys, except for 1989, which incurred a drop of 11%. In the 1996 survey, the pre-recruit biomass estimate for the extended no-trawl zone was higher than estimated previously for the larger core area. This was due to the extended zone slightly overlapping the B100 strata resulting in the loss of one station in 1996, so this large stratum had to be merged with A100 where there were higher catch rates. Aside from the differences in the 1994 estimate, there was little difference in biomass trends or length frequency distributions between the original core area and the reduced core area.

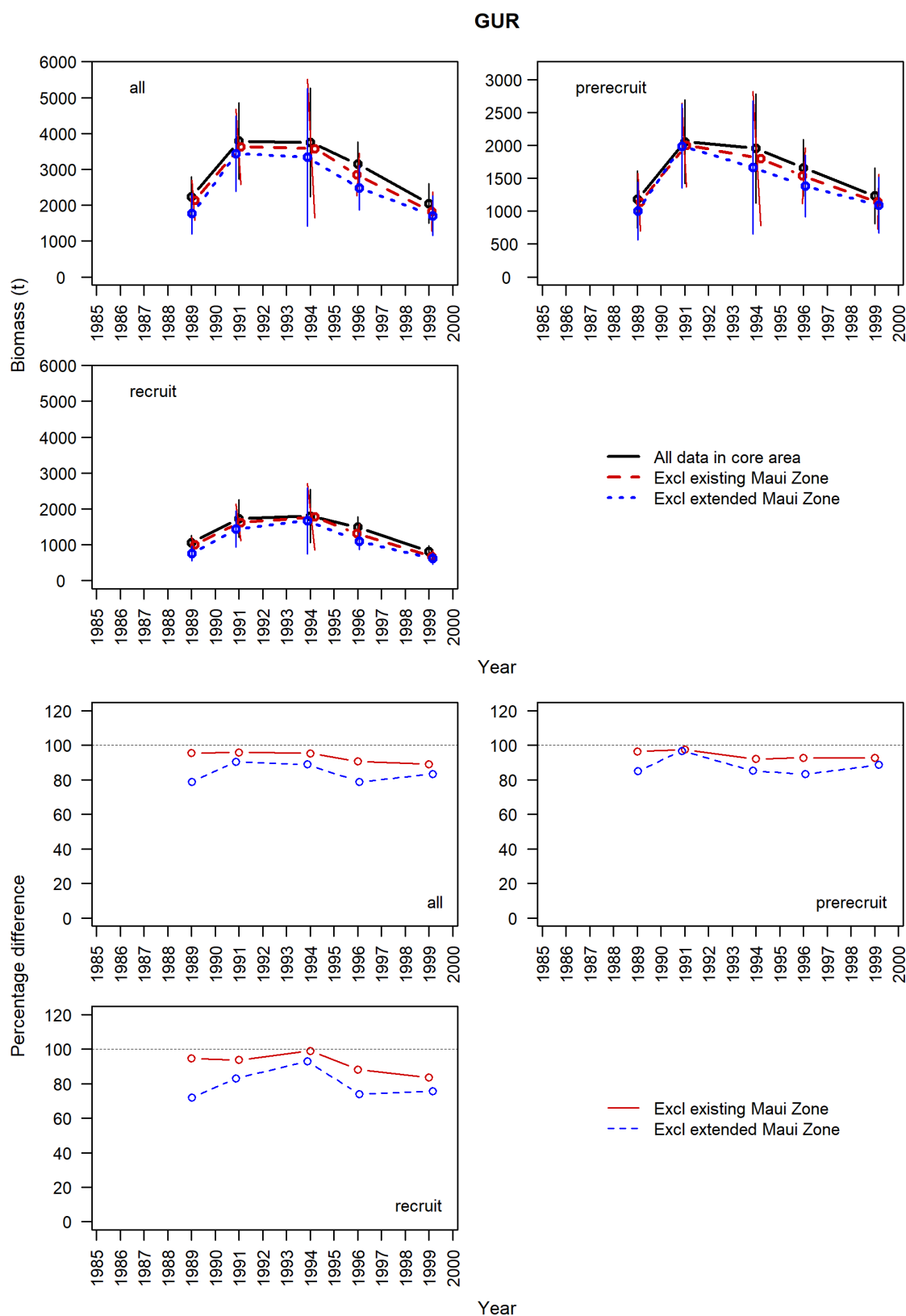


Figure 11: Relative biomass estimates and CVs (top panel) of total, recruited, and pre-recruit red gurnard from the core area of historical surveys between 1989 and 1999 from all station data (black), excluding the original Māui dolphin no-trawl zone (red) and excluding the extended Māui dolphin no-trawl zone (blue). The bottom panel shows the percentage difference of the two reduced time series trends compared with the original biomass estimate for the total, recruited, and pre-recruit categories.

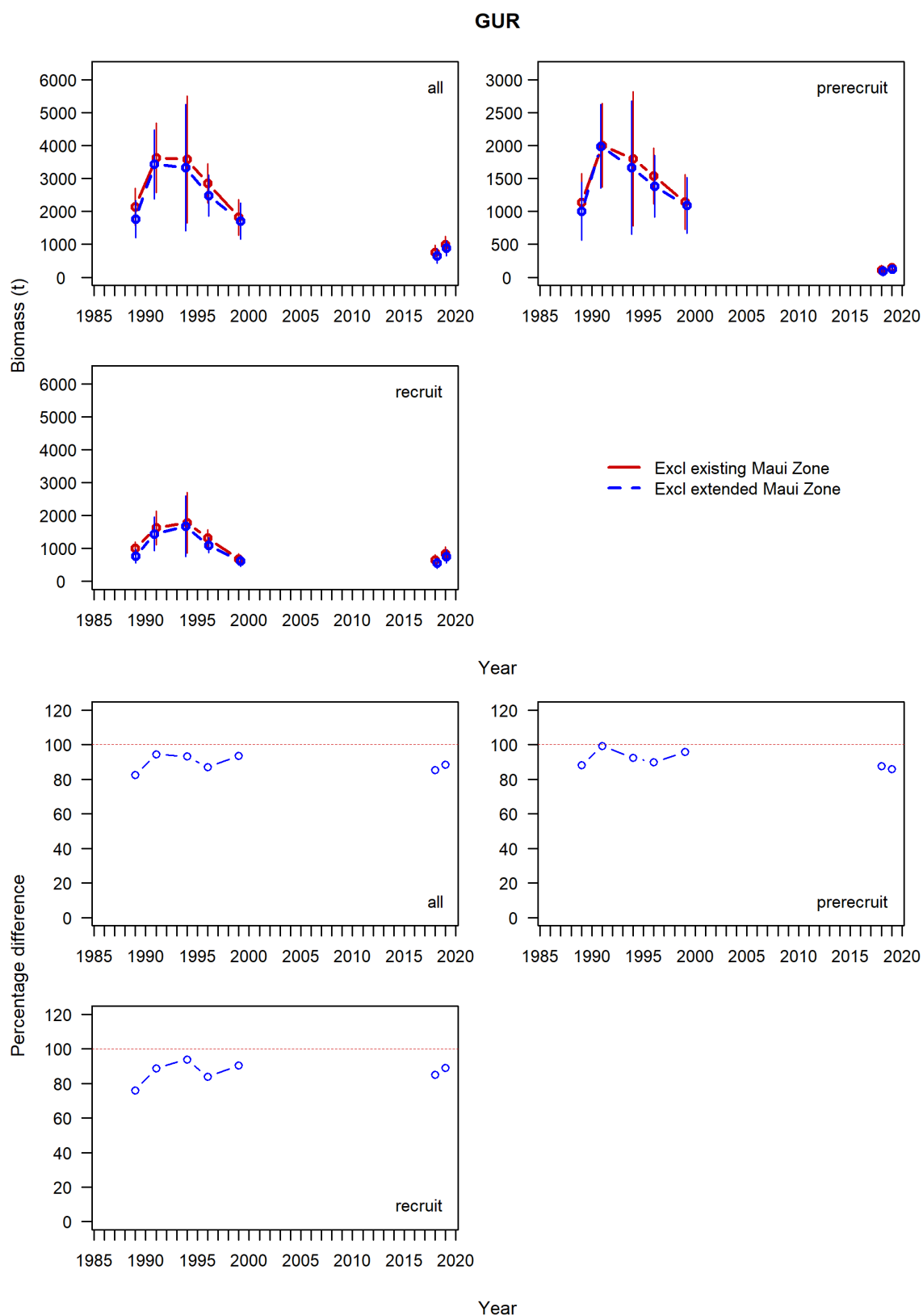


Figure 12: Relative biomass estimates and CVs (top panel) of total, recruited, and pre-recruit red gurnard from the core area of surveys between 1989 and 2019 estimated from station data excluding the original Māui dolphin no-trawl zone (red) and excluding the extended Māui dolphin no-trawl zone (blue). The bottom panel shows the percentage difference between the extended no-trawl zone series compared with the original no-trawl series for the total, recruited, and pre-recruit categories.

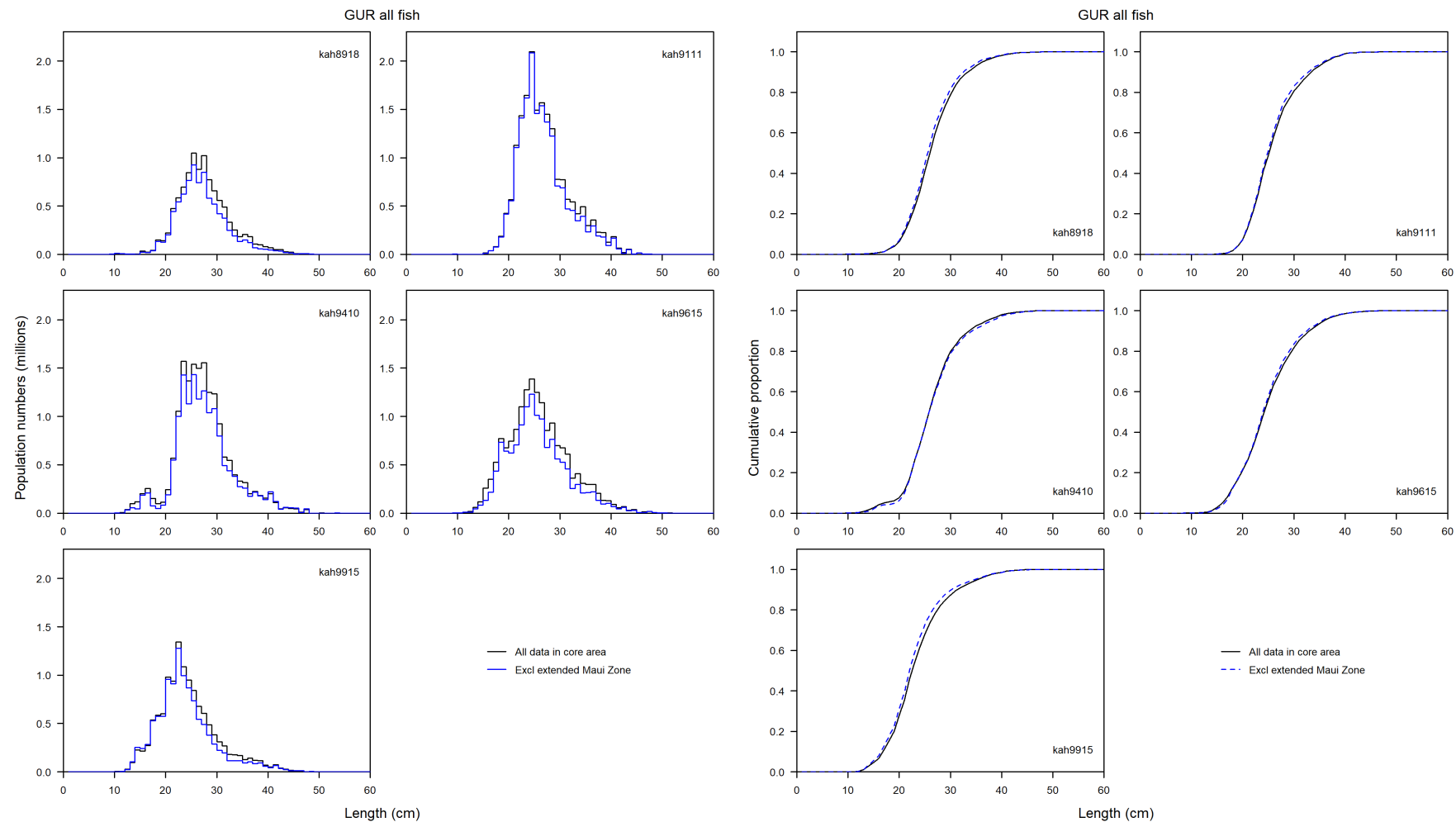


Figure 13: Left; Comparison of population scaled red gurnard length frequency distributions from the original core survey area (black line) and the core area with extended no-trawl zone removed (blue line) for the five historical surveys from 1989. Right; Cumulative frequency plots for each of the historical surveys.

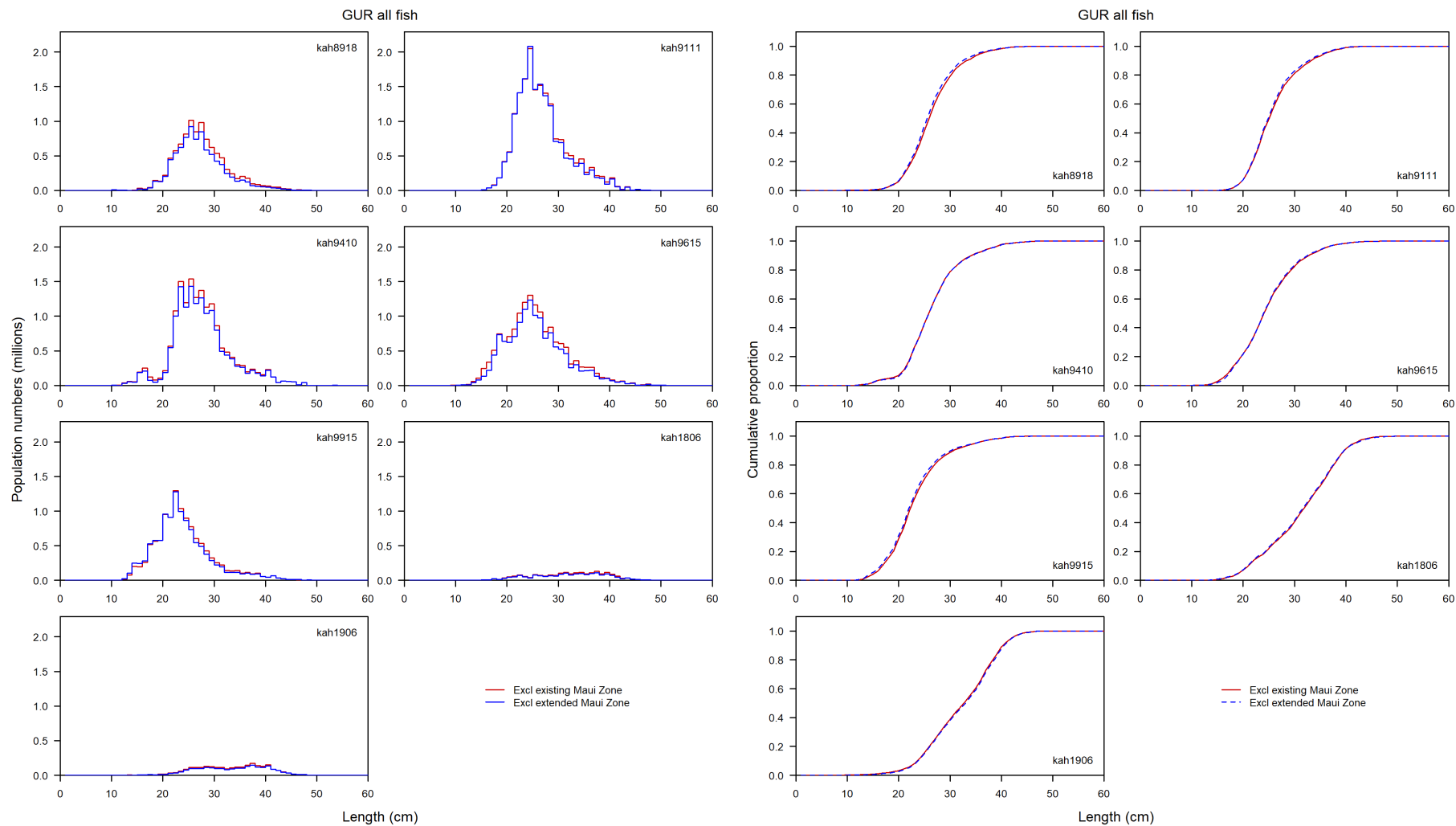


Figure 14: Left; Comparison of population scaled length frequency distributions for red gurnard from the core survey area with original no-trawl zone removed (red line) and with the extended no-trawl zone removed (blue line) for the five historical surveys from 1989 and two more recent surveys. Right; Cumulative frequency plots for the same surveys.

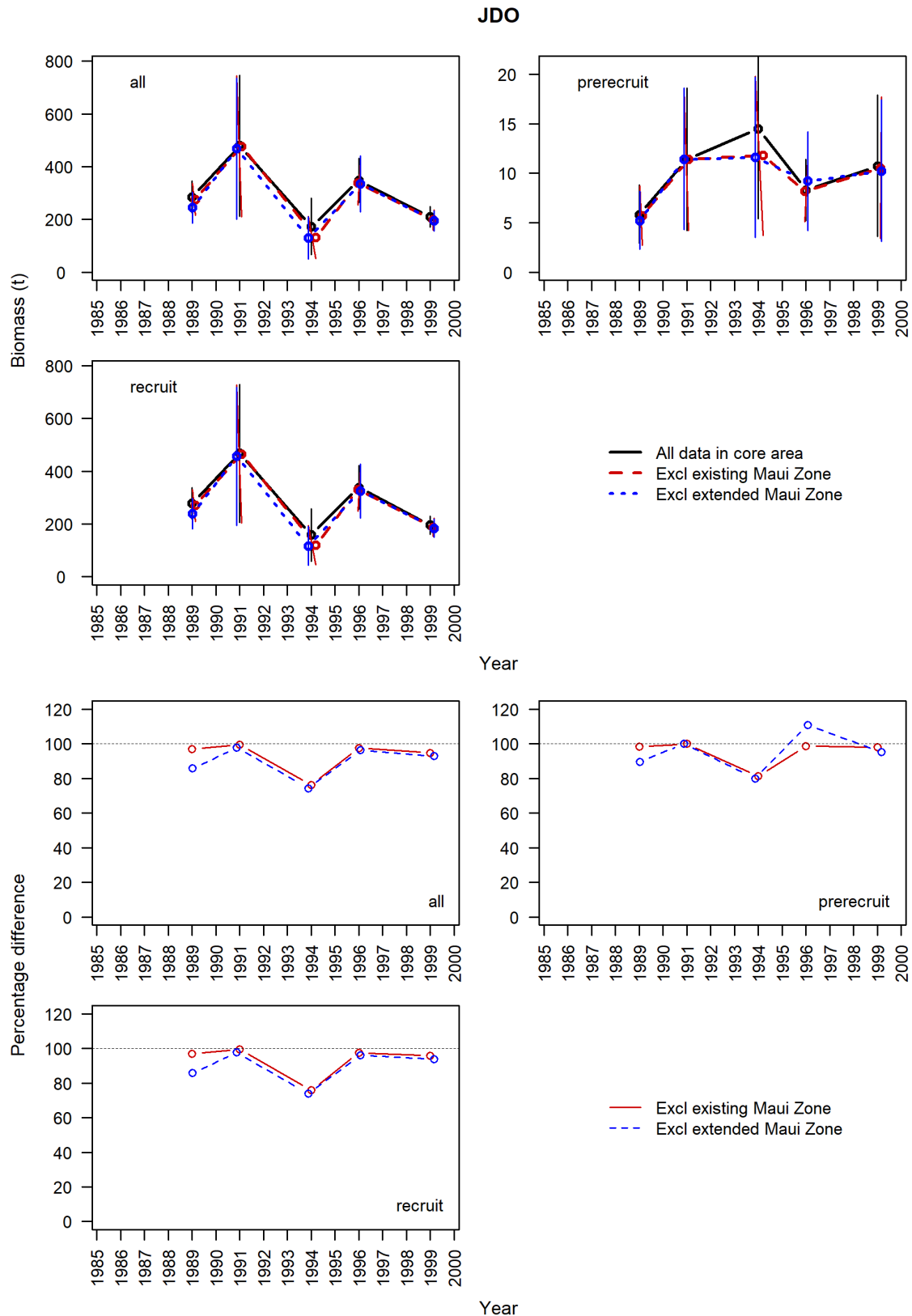


Figure 15: Relative biomass estimates and CVs (top panel) of total, recruited and pre-recruit John dory from the core area of historical surveys between 1989 and 1999 from all stations (black), excluding the original Māui dolphin no-trawl zone (red) and excluding the extended Māui dolphin no-trawl zone (blue). The bottom panel shows the percentage difference of the two reduced time series trends compared with the original biomass estimate for the total, recruited, and pre-recruit categories.

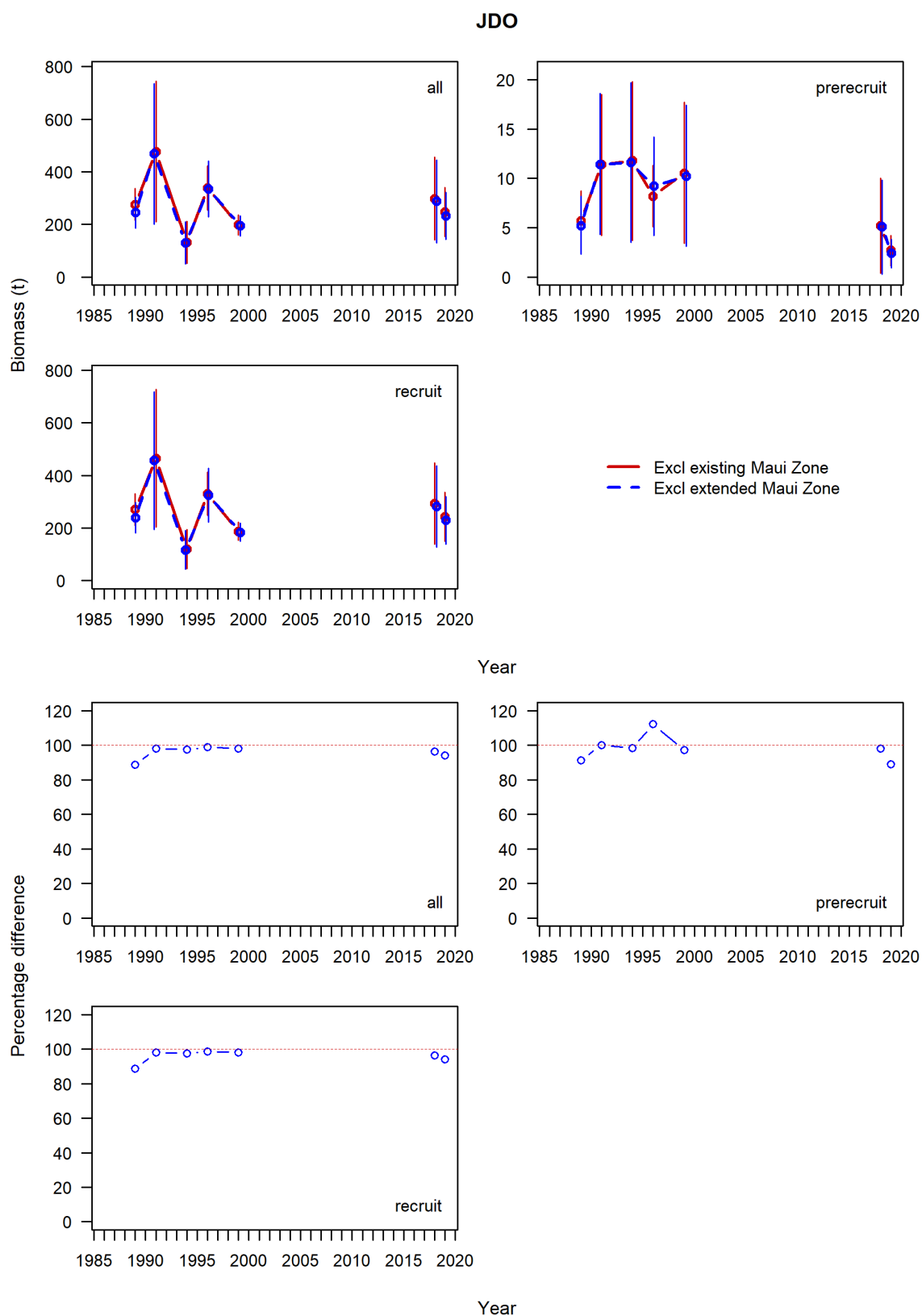


Figure 16: Relative biomass estimates and CVs (top panel) of total, recruited, and pre-recruit John dory from the core area of surveys between 1989 and 2019, estimated from station data excluding the original Māui dolphin no-trawl zone (red) and excluding the extended Māui dolphin no-trawl zone (blue). The bottom panel shows the percentage difference between the extended no-trawl zone series compared with the original no-trawl series for the total, recruited, and pre-recruit categories.

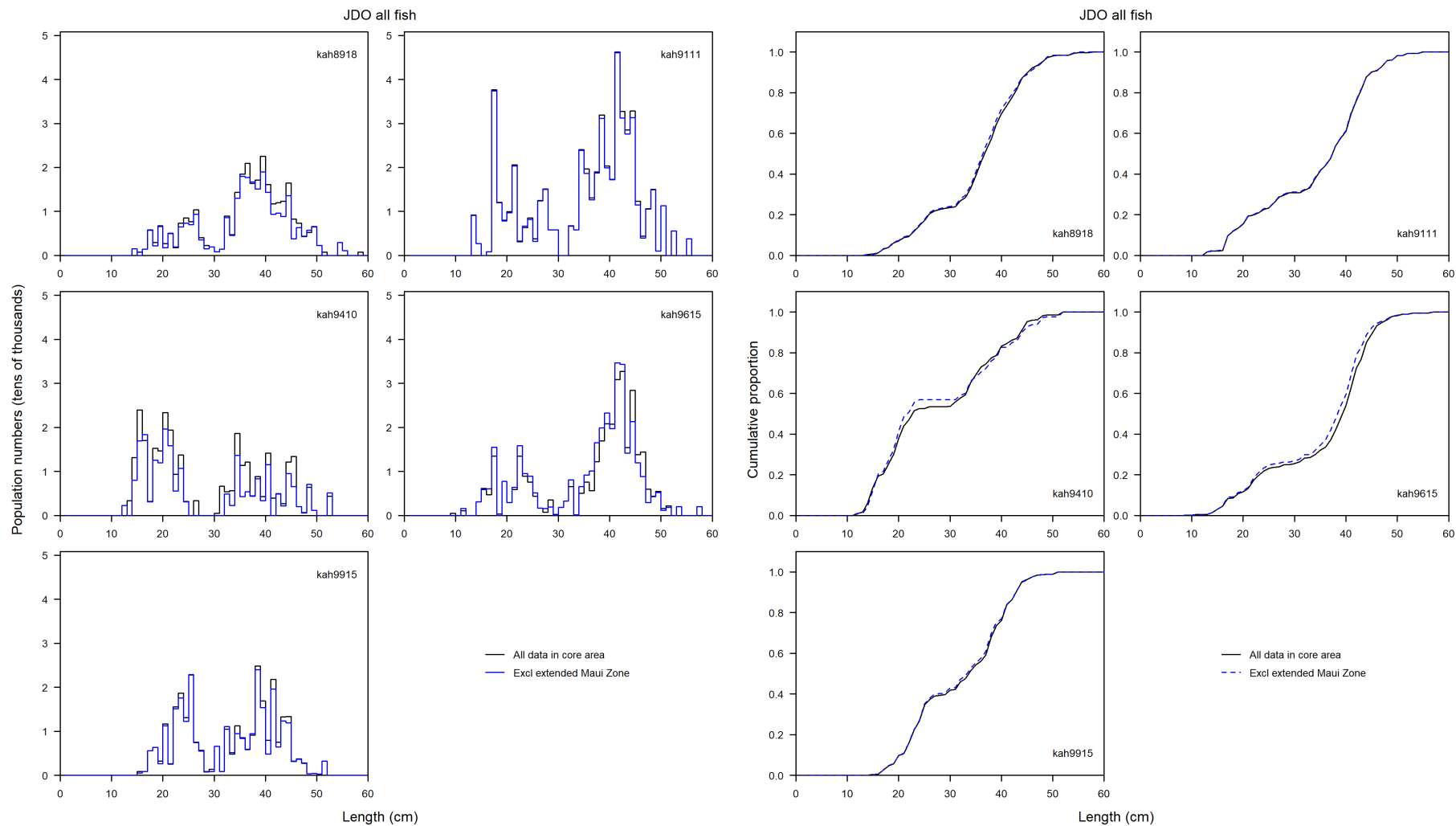


Figure 17: Left; Comparison of population scaled John dory length frequency distributions from the original core survey area (black line) and the core area with extended no-trawl zone removed (blue line) for the five historical surveys from 1989. Right; Cumulative frequency plots for each of the historical surveys.

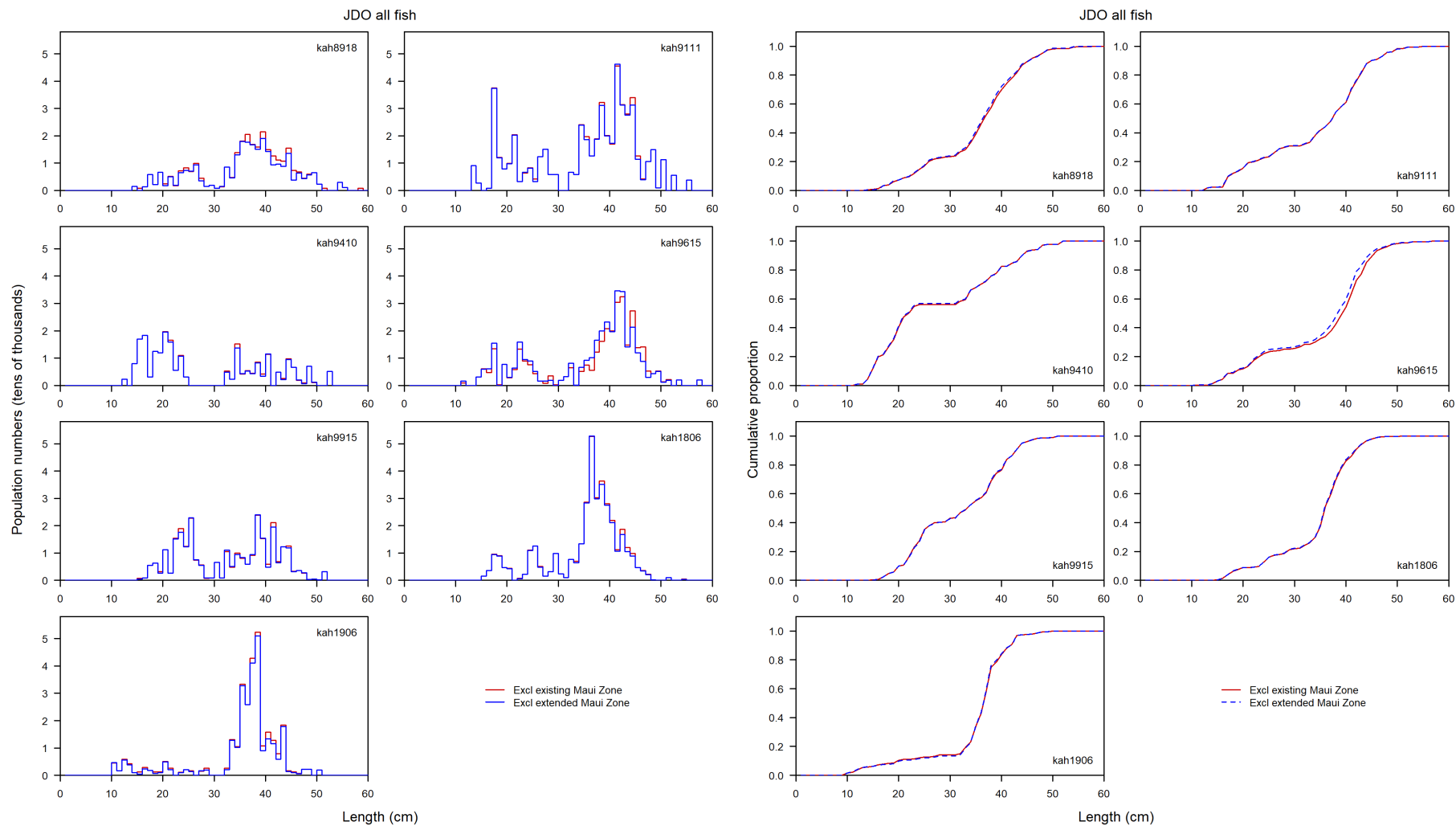


Figure 18: Left; Comparison of population scaled length frequencies for John dory from the core survey area with original no-trawl zone removed (red line) and with the extended no-trawl zone removed (blue line) for the five historical surveys from 1989 and two more recent surveys. Right; Cumulative frequency plots for the same surveys.

3.1.4 Summary of the impact of changes in survey area on key species

In summary, a northern core area was defined for the WCNI trawl survey, and the historical survey series was reconstructed with the Māui dolphin trawl exclusion zone removed from the survey area and strata combined on a survey-by-survey basis to maintain sample sizes across the stratification. The original no-trawl zone excluded 11% of the newly defined core area. The extended zone excluded 22% of the survey area (Table 2).

For snapper, within the affected area, station location inside or outside the no-trawl zone was not a significant explanatory variable in the GLM analysis, but the power of this analysis was low given the small sample size. There were significant differences in population structure once the original Māui dolphin no-trawl zone was excluded, particularly for pre-recruit snapper. Despite slight differences in the gradient of trend line between surveys, no overall difference in the biomass series trends was apparent. Once the extended area was removed, CVs for the historical surveys were higher, but less so with the recent surveys, and the overall biomass trends remained the same. There were reductions in numbers in the 20–30 cm mode.

For red gurnard, the GLM analysis found differences in catch rates inside and outside the no-trawl zone in affected strata. Despite this, the relative biomass time series comparison showed little overall difference in abundance trend and length frequencies, and the extended no-trawl zone had no further tangible impact.

For John dory, the outcome of the GLM analysis was similar to that for snapper in that *location* was not a significant variable, and there were no significant differences in population structure between areas. There was little difference in biomass trend between the full survey series and the series excluding the Māui dolphin no-trawl zone. With the extended exclusion, slight differences in the pre-recruit trend were present, but there was no further significant impact.

Therefore, we conclude that even with the extended trawl exclusion zone removed, the utility of the survey was not compromised in terms of monitoring the total adult biomass trends for the three inshore target species.

3.2 Evaluation of the wider utility of the west coast North Island inshore survey

This report includes detailed analyses for snapper, with less detailed summaries for the other target species (red gurnard, tarakihi, and John dory), the other species included by Jones et al. (2022) (trevally, two species of jack mackerel, kahawai, barracouta, school shark, rig, and spiny dogfish) and nine further species (leatherjacket, rough skate, smooth skate, northern spiny dogfish, anchovy, frofish, kingfish, cucumberfish, and spotted gurnard). Full species names are given in Appendix 2. These species were selected based on being in the top 20 by total biomass and/or of interest for other reasons, such as being an important prey species (e.g., anchovy) or of recent commercial interest (e.g., spotted gurnard). Summary plots for a further 42 species are provided in Appendix 6. We intend to make tables and plots for all species available via an online trawl survey information portal (<https://tsip-uat.niwa.co.nz/home>) in future.

3.2.1 Snapper (SNA)

Number of surveys	8
Total catch weight (kg)	47 961.6
Number measured	37 142
Length range (mean) (cm)	8–81 (34.45)
Number weighed	7638

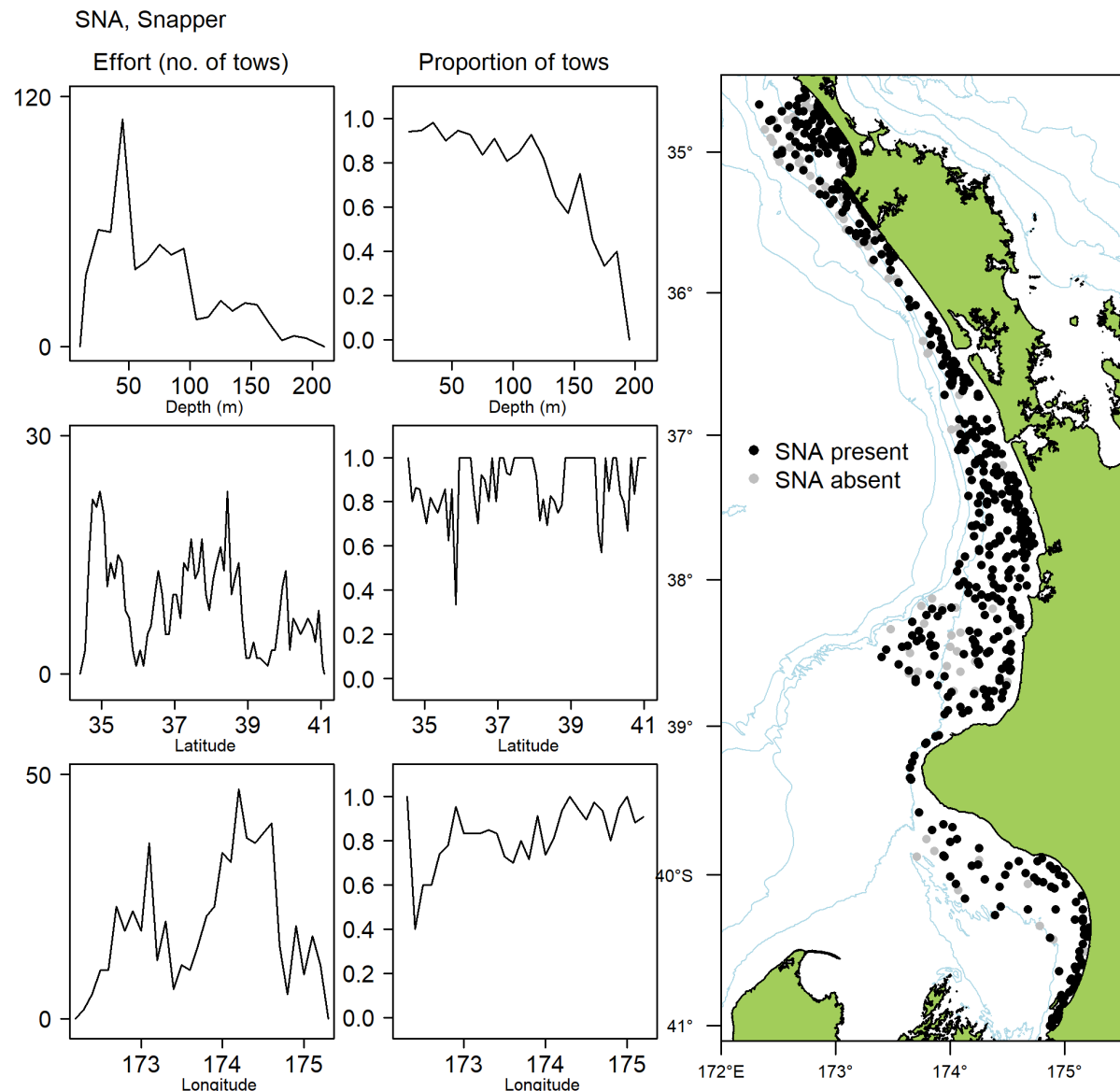


Figure 19: Summary of occurrence of snapper in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which snapper were caught. All valid tows are plotted in the map on the right panel, with black dots showing those where snapper were present.

Snapper is a demersal species found off central and northern New Zealand in depths of a few metres to around 200 m (McMillan et al. 2019). This species was found throughout the survey area, which covers the north-western SNA 8 stock, caught in 12–187 m, in the northern part of the survey that extended beyond 100 m. The decline in proportion of positive catches with depth shown in Figure 19 indicated the depth range was sufficient. However, the prohibition of sampling inside the Māui dolphin trawl exclusion zone truncates the shallow end of its depth range along a large section of the coastline north of Cape

Egmont. The survey also includes Cape Egmont and the South Taranaki Bight, out to a depth of 100 m. This encompasses the southern portion of the SNA 8 stock and a possible mixing zone with SNA 7 stock. A review of commercial fishing effort indicated that very little effort and low catches occurred deeper than 100 m depth (Jones et al. 2022).

The widespread occurrence across the geographic range is apparent in Figure 19, although there is a decline in proportion of tows containing snapper between 35 and 36° S, reflecting the very long narrow shape of the B strata in this part of the survey, which, due to low catch rates rarely attract more than the minimum number of stations. The reduced occurrence in relation to longitude also reflects location of deeper strata where snapper was not always consistently present.

In the three recent surveys, snapper was the most abundant species by catch weight in every survey, found in over 90% of stations, and accounted for between 37.7 and 55.2% of the total catch (Jones et al. 2022). This represents a significant shift from historical surveys, where snapper occurred in 76–88% of stations, but made up a much lower proportion by weight, 9–19%, and was between second and fifth in terms of total catch composition.

Relative biomass for snapper has generally been well estimated in the surveys, with CVs from the northern core strata in the original historical surveys of between 13% and 25%. The re-defining of the survey area has reduced the sampling effort and precision of the re-calculated historical estimates, with some CV values increasing, but recent surveys remain below or close to the target of 20% (Table 10). The time series of the northern core, the extended core out to 200 m, and the whole survey area are given in Figure 20. The survey indicated a four-fold increase in biomass in the core strata between 1999 and 2018.

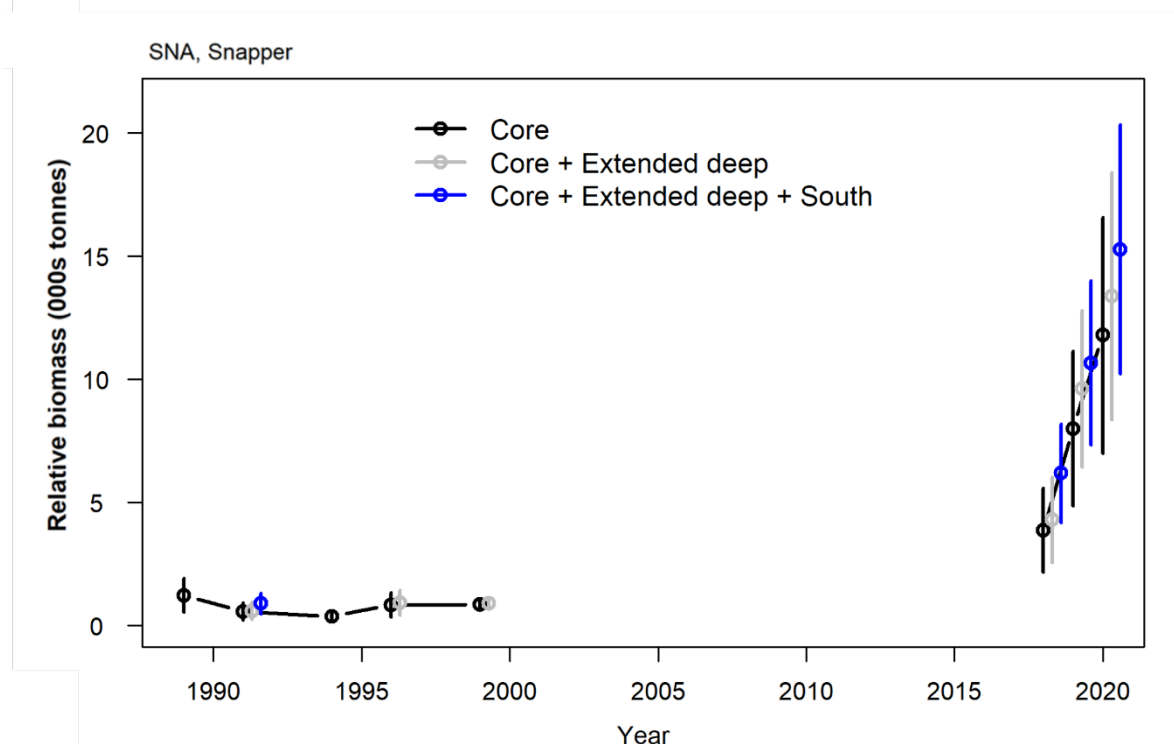


Figure 20: Time series of total relative biomass estimates and 95% confidence intervals for snapper for the northern core area (core), core area with deeper > 100 m strata (core + extended deep), and whole survey (core + extended deep + south). Note that each set of annual points is displaced slightly from each other for clarity.

This increase was consistent with the CPUE series derived from commercial catches from SNA 8, which also indicated an almost four-fold increase, particularly since 2006–07. This CPUE series was derived from catch data from the January–April period, to avoid hyperstability associated with targeting spawning aggregations during October–December and also noting significant changes in fishing gear used and spatial patterns (Langley 2017). However, the year-on-year increases in survey biomass

between 2018 and 2019, and then again in 2020, have been far less plausible, and this has raised concerns about the ability of the survey to monitor the adult spawning stock biomass (Langley 2020, 2021).

Almost 45 000 fish were measured over the 8 surveys, and the size range of snapper caught has been consistent between surveys, ranging from 8–10 cm to 70–80 cm (Table 11). This covers the relevant size range of this species from the settled 0+ year class through recruitment to the commercial fishery at 25 cm. The mean size of snapper measured varied between 28 and 33 cm in the historical surveys and increased to 35–37 cm in recent surveys (Table 11). Patterns in length frequency distributions were consistent between surveys for the northern core area, albeit with a more restricted size range and lower abundance of larger, older fish in historical surveys (Figure 21). The 0+ age group is present in samples in most years to some extent, although was not captured in 1994 once the shallower strata were excluded.

Table 10: Relative biomass estimates (t) and CVs (%) of snapper for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	1 234.01	27.76						
kah9111	576.52	30.45	597.63	29.39	299.72	37.75	897.35	23.28
kah9410	370.96	25.02						
kah9615	844.69	29.94	923.01	27.58				
kah9915	853.75	14.06	907.70	13.36				
kah1806	3 869.36	22.11	4 298.45	20.21	1 886.95	26.07	6 185.39	16.14
kah1906	7 999.04	19.66	9 625.67	16.52	1 046.64	46.99	10 672.32	15.60
kah2005	11 796.72	20.32	13 389.95	18.75	1 918.52	15.56	15 279.68	16.55

Table 11: Summary of catch weight and length measurements of snapper by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	2 393.2	9	75	32.44	3 162
kah9111	1 448.8	10	72	33.08	1 674
kah9410	1 009.0	10	63	30.04	1 830
kah9615	2 443.3	8	57	28.53	3 611
kah9915	2 207.3	9	71	29.90	3 676
kah1806	9 886.9	9	79	35.44	5 627
kah1906	9 314.9	9	81	37.52	7 503
kah2005	19 258.2	8	75	37.38	10 059

The length frequency distributions from data with the addition of the deeper strata covering depths of 100–200 m in some surveys (excluding 1989 and 1994) are shown in Figure 22. Few snapper were caught at these depths historically, but, at the current higher population levels, there are higher numbers of larger fish (> 30 cm) in the more recent surveys, with a bias towards more females.

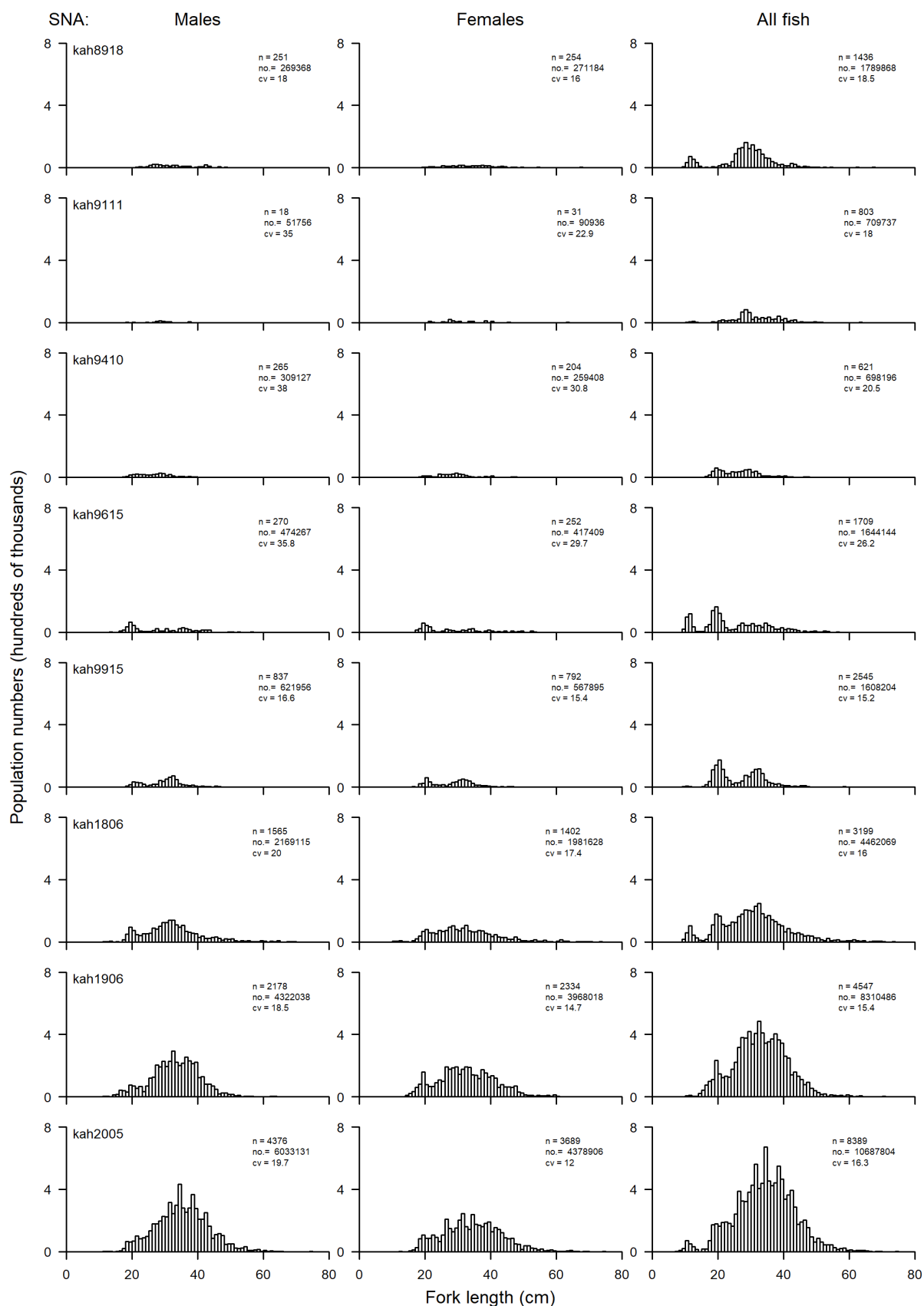
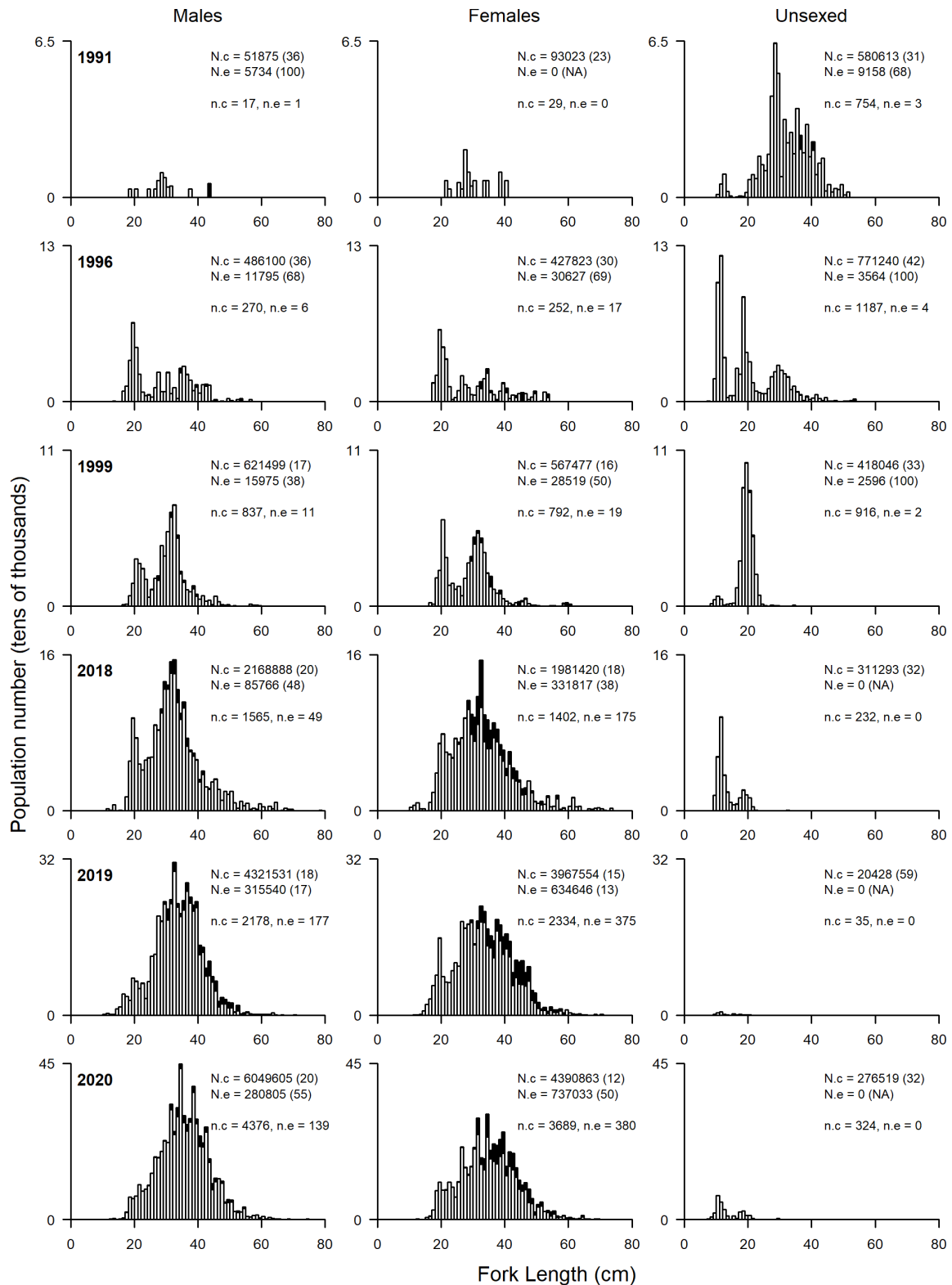


Figure 21: Comparative scaled length frequency distributions for males, females, and all snapper in the northern core strata (<100 m) for the time series of the WCNI surveys. n=number of fish measured, no.= scaled population number, and CV= coefficient of variation. 'All fish' includes unsexed fish.



SNA, Snapper (core.extended: core = white, extended.only=black)

Figure 22: Comparative scaled length frequency distributions for males, females, and unsexed fish from the core (white) and extended deeper strata (black) for the WCNI surveys that included the 100–200 m depth range. N.c.=scaled population number and CV (in brackets) for the core. N.e.=scaled population numbers for the extended strata. n.c=number of fish measured from core. n.e=number of fish measured in the extended strata. Note the different scales for population numbers in different surveys.

Survey timing and sea surface temperatures in relation to snapper spawning

The start date of historical surveys ranged between early October and early November (Table 1), overlapping with the historical period of higher commercial catch rates for red gurnard, John dory, and snapper in spring and early summer (Morrison et al. 2013, Langley 2017). This timing is less optimal for tarakihi, for which peak commercial catches off the west coast were generally between February and May (Morrison et al. 2013, Langley 2017).

Snapper spawning season extends from October to March, peaking in November–December (Crossland 1977), and is dependent on sea surface temperatures (SST) reaching around 15–16 °C (Scott & Pankhurst 1992, Francis 1993). During the spawning season, adult fish are known to make migrations to inshore waters (see review by Parsons et al. 2014), including the coastal waters outside west coast harbours such as the Kaipara and Manukau harbours (Sim-Smith et al. 2011). The timing of the WCNI survey encompasses the start of the spawning season but has varied considerably in the recent and historical surveys, as shown Figure 23. The 1989 survey was the latest in the calendar year, with sampling commencing off Ninety Mile Beach on the 26 November (day 330), working southwards and completing stations in the equivalent of F100 on the 13 December (day 347). Sampling outside the Kaipara Harbour was between 29 November and 3 December. The average surface water temperature measured on the 1989 survey (17.6 °C) was the highest in the series (Figure 24). This is consistent with the estimated sea surface temperature (SST) anomaly values for these months being over 1 °C above average (1985–2012 daily mean) in 1989 (Appendix 7). This survey produced the highest total snapper biomass estimate of the historical surveys, with highest catch rates of adult snapper found in shallow (< 50 m) depths off Ninety Mile Beach and just north of Airedale Reef (WCA25, WCB50, and WCG50, equivalent to F50). A relatively large proportion of 30–40 cm fish were sampled compared with other historical surveys that took place earlier (see Figure 21).

The 1991 survey core area sampling commenced on 20 November (day 324), but most fishing took place after 28 November. Despite similar timing to the 1989 survey, the average SST from the survey was cooler at 16.0 °C (Figure 24), with the SST anomaly values being over 1 °C below baseline values (Appendix 7). The highest catch rates were again concentrated in the shallow strata (< 25 m), but further south around the Kaipara Harbour and south of Tirua Point. The next three surveys were all conducted a month earlier, with sampling generally completed before 1 November (day 305). The 1994 survey was the earliest to start, and the biomass estimate was the lowest in the time series. There were significant periods of rough weather during this survey, which likely contributed to the lowest mean SST of the series (14.3 °C), with SST anomaly values similar or lower to the 1991 values. The highest catch rates were in shallow water (< 50 m) off the Kaipara and Hokianga harbours. There was a lower proportion of fish > 30 cm in this survey compared with the previous two. This was the first year that the reproductive condition was recorded for snapper (Table 12). No ripe or spawning females were reported, with most fish being immature (47%) or resting (46%).

The timing of both the 1996 and 1999 surveys was slightly later, starting in mid-October. SST anomaly values were below baseline in 1996 and above in 1999 (Appendix 7), but temperatures measured during the 1999 survey were more variable. Catch rates were again highest in the shallow (< 50 m) strata, but the size composition was shifted more towards smaller fish and mean size for these surveys was less than 30 cm. No running ripe females were found in any of the surveys, but ripe females were recorded (Table 12). In 1996 only 2% of the sampled females were considered ripe (6 fish from two stations only). In 1999, 17% of female snapper examined were ripe (Table 12), including 11 stations where more than half the sample were recorded as stage 4 (Figure 23). These stations were spread across the core strata, with highest numbers in RG50, DD50, C strata, and E100, from 20 m depth to greater than 80 m.

The first survey in the recent series took place from 25 October to 2 December 2018, with sampling in the northern strata from 3 November following on from gear trials and completing the southern strata. The SST anomaly values for November and December 2018 are similar to those of 1989 and 1999 survey periods, at around 1 °C above baseline. The average SST measured during the survey was 16.9 °C, with a temperature range similar to the 1989 survey. The snapper catch rates in 2018 were highest in shallower water, particularly outside the Kaipara Harbour, in depths less than 50 m, where

temperatures ranged from 16.3 to 17.6 °C. There were some large (> 1 t) catches that were also dominated by larger adult fish. There was a similar overall occurrence of ripe females (18%) in this survey compared with 1999, with 16 stations where more than 50% of the sample were at this stage. These stations were concentrated in the shallow C strata at less than 60 m depth, with lower catch rates in the 50–100 m strata.

It was clear that the later timing in 2018 had coincided with the shift of adult snapper to shallower waters to spawn, with a risk that a proportion had moved into shallow areas no longer sampled by the survey. The timing of the 2019 survey was brought forward to 2 October and 3 November, also accommodating a Hauraki Gulf snapper survey taking place in November. Core area sampling was undertaken from mid-October to match that of the 1999 survey. The mean SST was 15.0 °C, with the SST anomaly values being below baseline (Appendix 7). Like 1994, there were large periods of poor weather, with extreme wind gusts, which likely contributed to the lowered SSTs. Snapper catch rates in the 2019 survey were characterised by an absence of very large (>1 tonne) catches, but high catch rates were more broadly distributed in depths greater than 50 m further offshore. There was a lower proportion of ripe females, 5%, in samples, with only one station where the proportion of ripe fish sampled exceeded 50%. The higher relative biomass estimate in 2019 compared with 2018 was attributed to the higher availability of adult snapper to the survey.

The final survey in the series, in 2020, was timed to match the previous year, but unscheduled vessel maintenance resulted in a delay; the survey was from 9 October to 8 November 2020. Sampling of the northern core strata was still able to commence in mid-October but required southern strata to be sampled afterwards. With more settled weather patterns than 2019, SST anomaly values were higher than 2018 and measured values averaged 16.1 °C (Figure 24). Similar to the 2018 survey, there were some very large and influential catches in inshore strata in 2020, but high catches were also taken in deeper water, including the larger offshore strata such as C100. Overall, there was a slightly lower proportion of females that were ripe (13%) than in 2018, with 15 stations where the proportion was greater than 50%. Unlike both previous surveys, where ripe fish were mainly restricted to water depths < 60 m, in 2020 a higher occurrence of ripe fish was apparent in deeper water, particularly between 50–70 m depth. The 2020 snapper biomass estimate was the highest of the series and was a three-fold increase on the 2018 estimate.

The proportion of females with immature or regressed ovaries was around 6–13% in all surveys except 1994, when almost half of the fish examined were recorded as immature (Table 12). The proportion of resting females ranged from around one third to almost half the sample, with around 30–40% of females classed as developing. As described above, a small but variable proportion of females were recorded as ripe. No running ripe females were found in any of the surveys, even those timed in November–December, but a very small number of spent fish were noted in some years.

Information on male maturity stage was only available from 1999 onwards (Table 12). In 1999, male snapper were mainly stage 3 ‘ripening’. A further 11% of males were ripe, with just 1% running ripe. In the more recent surveys, between 44–50% were classed as ripening with 11–21% of males classed as ripe. In 2018, 14% of males were observed to be running ripe, found in 34 stations across the whole survey area, from the South Taranaki Bight as far as Ninety Mile Beach, mainly in depths less than 60 m. In the earlier-timed 2019 and 2020 surveys, the proportion of running ripe males was zero and 3%, respectively, with most of these fish being observed in five phase 2 trawl samples in the core strata in early November.

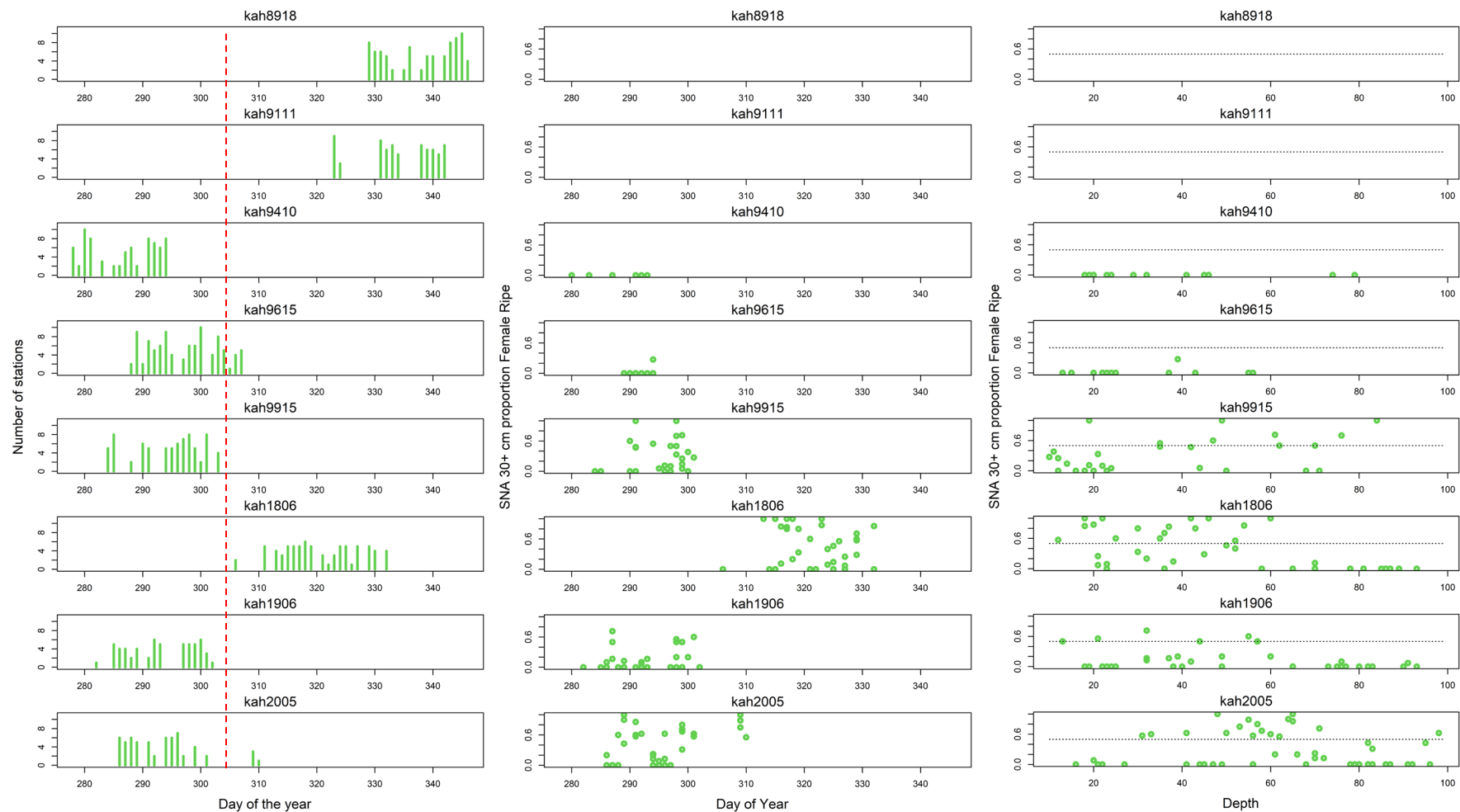


Figure 23: Left hand panel – variation in timing of sampling in the northern core area in historical and recent surveys. Day 305 = 1 November (red dashed line). Middle panel – proportion of ripe female snapper in each sample by day of the year for each survey in the time series. Right hand panel – proportion of ripe female snapper in each sample by station depth (start depth).

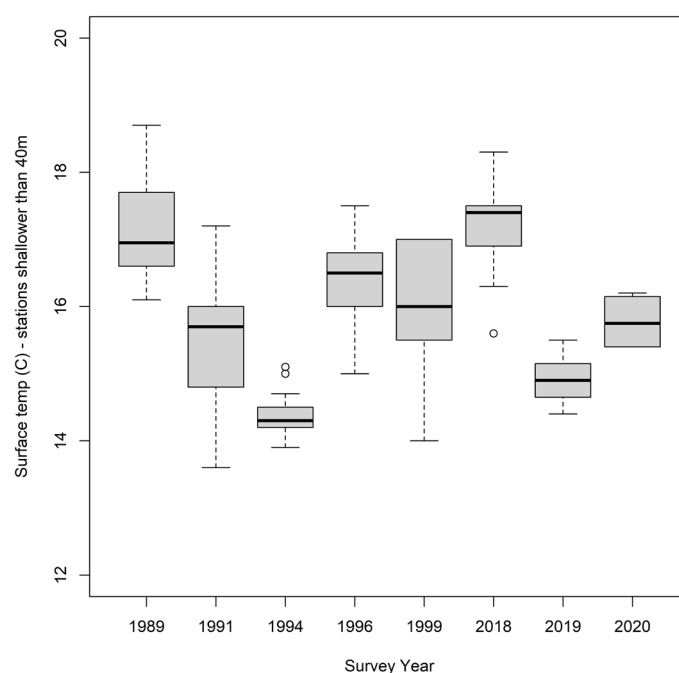


Figure 24: Distribution of sea surface temperature (SST) measured by CTD on stations in the core area (< 40 m) depth during WCNI surveys from 1989 to 2020. Grey boxes indicate the lower and upper quartiles, the black line indicates the median value.

Table 12: Proportion of sampled snapper with gonads at different reproductive stages by survey. Note that for historical surveys up to 1999, a 6-stage only scale was used for females, with stage 6 equating to 'Spent' and no identification of partially spent individuals recognised. For males, no resting stage (stage 2) or partially spent (stage 6) were recognised in the 5-stage scale used (Gonad stages are defined in Appendix 4.).

Year	Maturity Stage							Sample size
	1	2	3	4	5	6	7	
Female								
kah8918								
kah9111								
kah9410	0.47	0.46	0.07	0	0	NA	0	622
kah9615	0.13	0.54	0.31	0.02	0	NA	0	310
kah9915	0.13	0.38	0.32	0.16	0	NA	0.01	670
kah1806	0.10	0.36	0.36	0.17	0	0	0.01	1 000
kah1906	0.09	0.44	0.42	0.04	0	0	0.01	889
kah2005	0.06	0.41	0.4	0.13	0	0	0	1 108
Male								
kah8918								
kah9111								
kah9410								
kah9615								
kah9915	0.17	NA	0.71	0.11	0.01	NA	0	621
kah1806	0.13	0.09	0.44	0.20	0.14			672
kah1906	0.13	0.26	0.49	0.11	0			876
kah2005	0.09	0.17	0.50	0.21	0.03			870

Patterns in snapper catch rate and size across areas and depths

The spatial distribution in catches of snapper in all surveys from 1989 to 2020 are shown in Figure 25. Catch rates were historically much lower, with a small number of larger catches producing stratum level catch rates of $>100 \text{ kg km}^{-2}$, generally in the shallow strata. These have been dwarfed by recent survey catches of up to 3 t. The survey area covers a depth range of 10–200 m, although two of the five historical surveys (1989 and 1994) do not extend beyond 100 m. The overall variation in sampling effort across the survey depth range is given in Figure 26. The greatest effort is concentrated in depths shallower than 50 m; the most frequently sampled depth was 20–25 m, followed by 40–50 m. Most historical survey stations were in 20–50 m depths, with similar median depths between 30–40 m. A trend of increasing sampling depth was apparent in the more recent surveys. This reflects the inshore survey boundary being shifted deeper, necessitated by the Māui dolphin no-trawl zone, as well as the increased sampling effort in deeper strata such as C100 and E100 in 2019 and 2020, necessitated by the higher (and more variable in 2020) catch rates in these strata.

To examine patterns in catch rates of adult snapper specifically, numbers of 30+ cm fish per nautical mile were plotted by maximum station depth for each survey in Figure 27. The higher catch rates in recent surveys are apparent, along with a small number of exceptionally large catches of adult snapper in 2018 and 2020. In 2019, there were higher catches in deeper water compared with 2018, and even more so in 2020, where two exceptionally large catches in C100 are highly influential due to being scaled to such a large stratum area compared with the 2018 catches in the smaller $< 50 \text{ m}$ strata.

SNA, Snapper

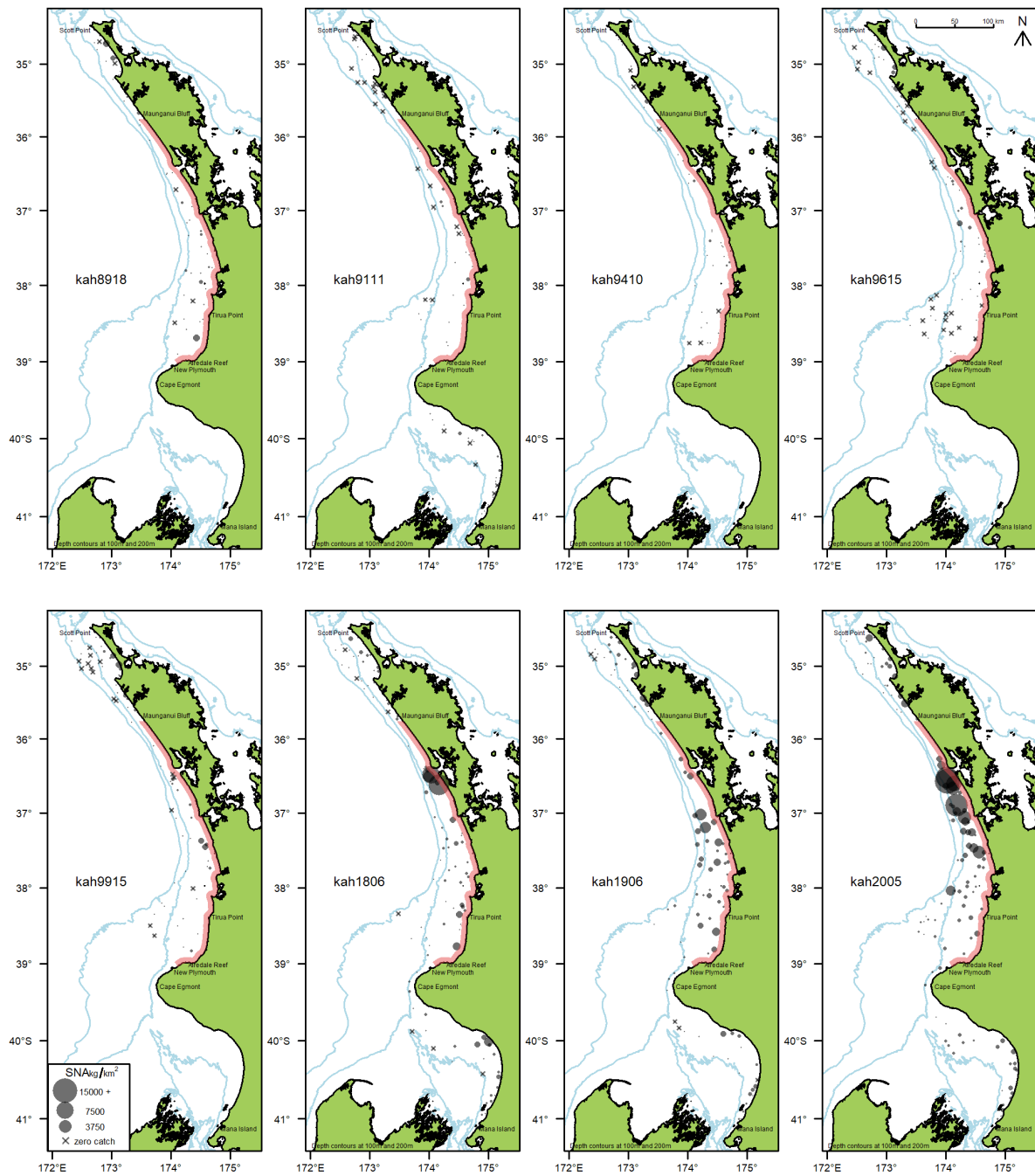


Figure 25: Spatial distribution of catch rates (kg km^{-2}) of snapper in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

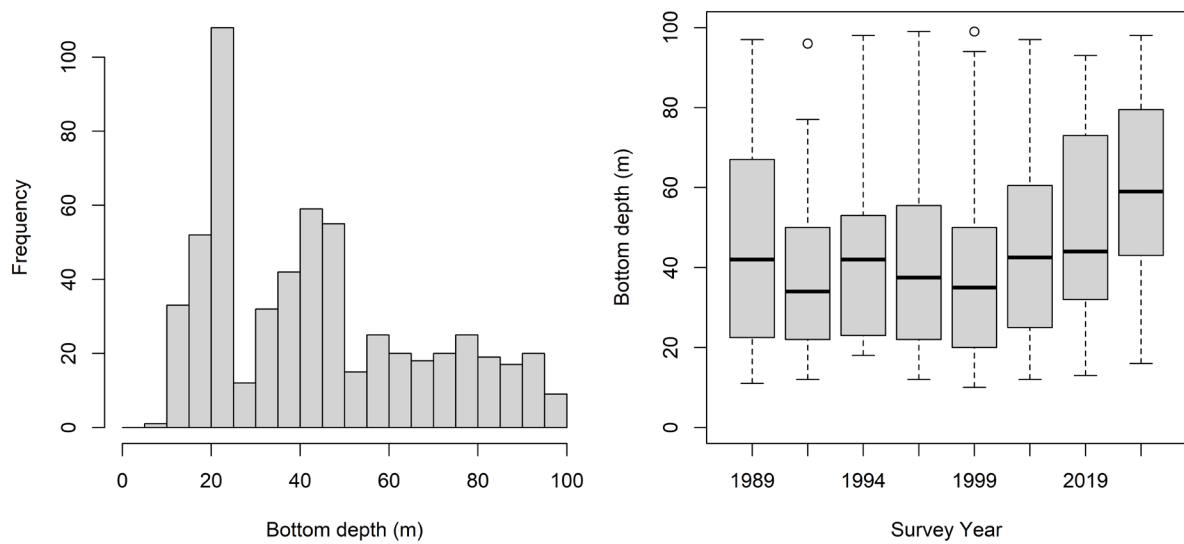


Figure 26: Variation in effort by depth in the core area. Left: frequency of all station depths across the time series, grouped in 5-m depth bins in 10–100 m. Right: Distribution of station depth by survey.

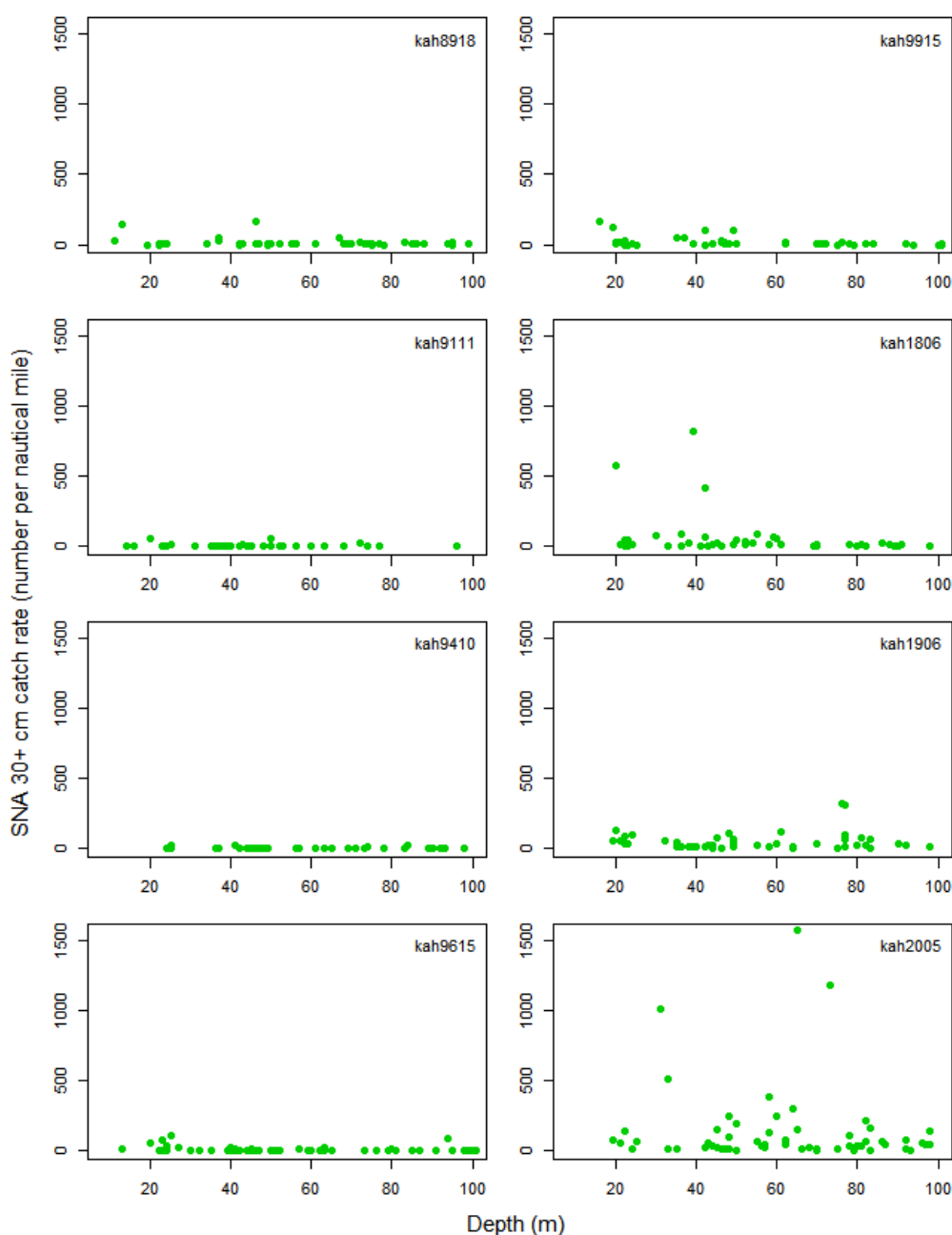


Figure 27: Station catch rates (number per nautical mile) of 30+ cm snapper plotted against depth (maximum) for each survey in the time series.

The average catch rates of small (< 30 cm) and large (30+ cm) snapper by depth band are plotted in Figure 28. The patterns for the smaller fish were reasonably consistent across surveys, with highest catch rates in the 15–19 m and 20–39 m depth ranges and lower rates at greater depths. Catch rates of adult fish were more variable; peaking in shallow depths in some surveys such as 1989, 1999, and the 2018 survey, with lower catch rates at depths over 60 m in all except the two most recent surveys, where peak catch rates were between 60–80 m.

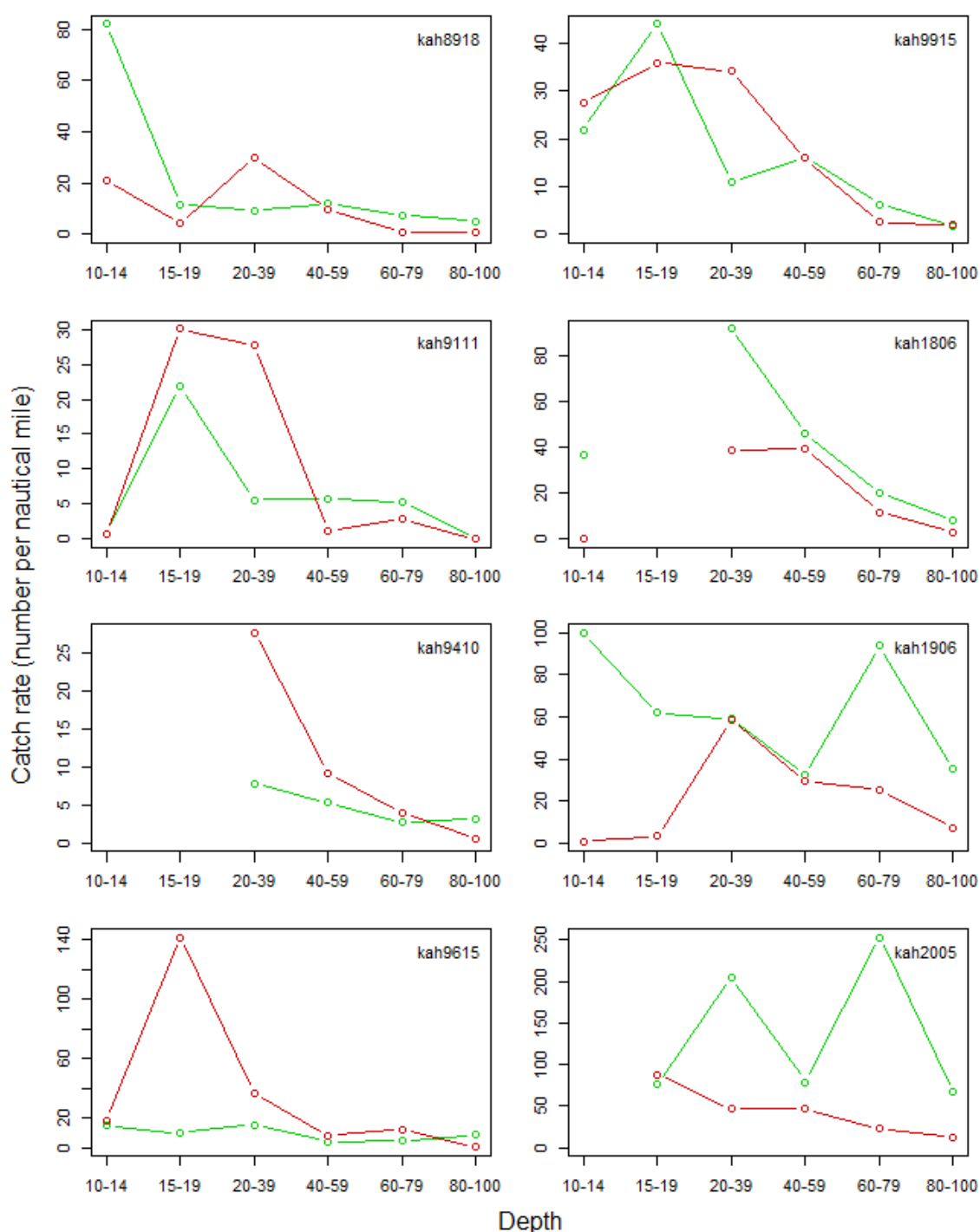


Figure 28: Catch rates (numbers per nautical mile) of two size groups of snapper. Snapper < 30 cm (red) and 30 cm and above (green). Values represent the average rate in each depth bin for each survey.

As shown in Table 11, the higher catch rates of adult snapper in the earliest and more recent surveys were reflected in higher mean length. The variability of mean length of adult snapper by station across sample depths was explored in Figure 29. In the historical surveys, for most stations, the mean length was < 40 cm, with a few stations with higher values, and no clear trend with depth. In more recent surveys, the number of stations where the mean length was > 40 cm increased. In 2018, the stations with larger mean lengths were concentrated at shallower depths < 60 m, but this pattern was not apparent in 2019 or 2020.

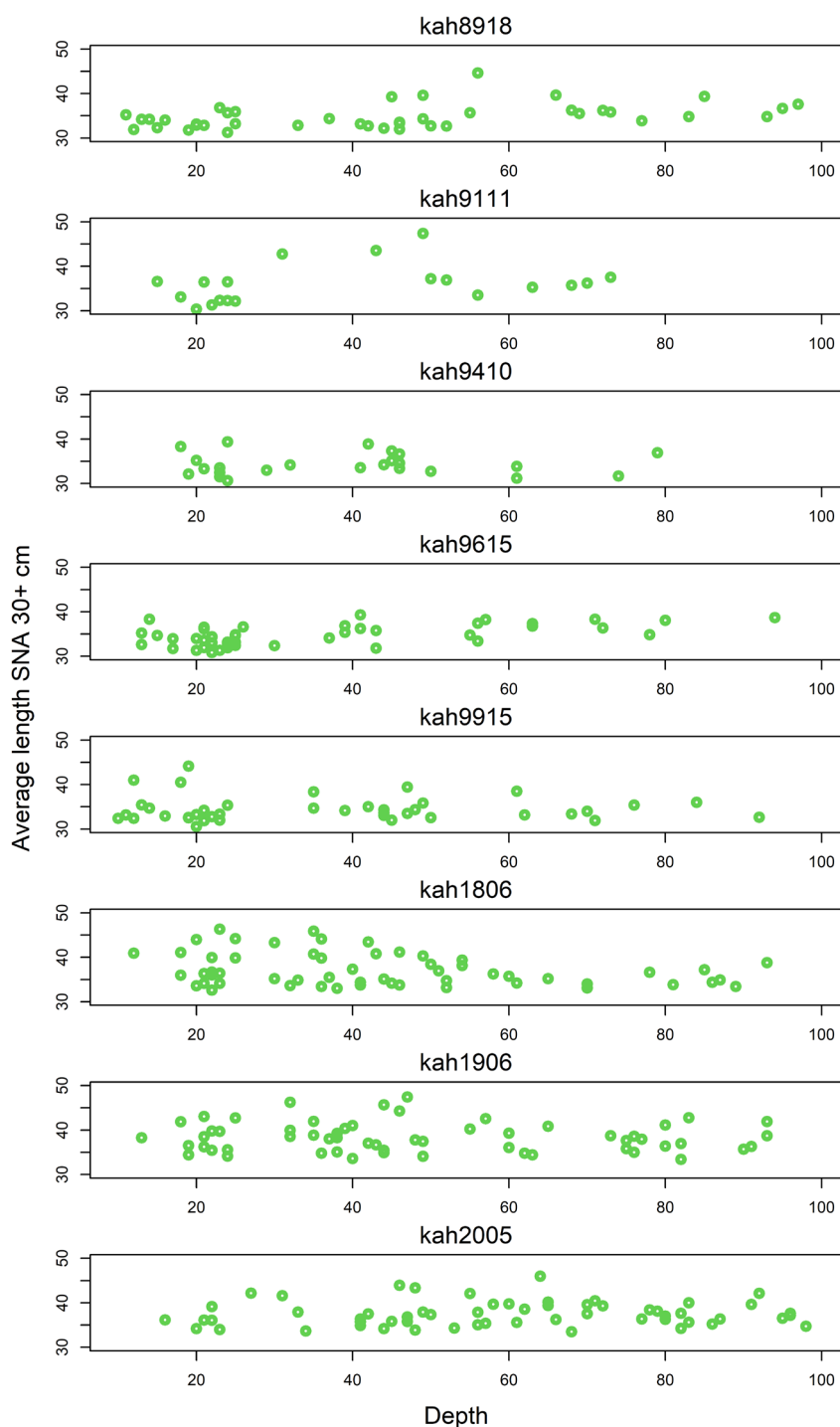


Figure 29: Variation in station mean (average) length of adult (30+ cm) snapper by depth for each survey.

The highest catch rates of snapper were often concentrated in the central part of the core area, particularly outside the Kaipara and Manukau harbours (Figure 25), where adult snapper are known to congregate to spawn (Smith et al. 1978, Paul & Sullivan 1988). Estimated relative biomass for adult snapper for three different regions, (Ninety Mile Beach and Hokianga Harbour, Kaipara and Manukau harbours, and the North Taranaki Bight) are plotted by depth band in Figure 30. The increase in biomass observed in the 2018 survey was, in large part, attributable to catches in the Kaipara-Manukau region in shallow (< 50 m) strata, (i.e., C25, C50) as well as the deeper 50–100 m stratum in the North Taranaki Bight (E100). The biomass increase in the northern part of the survey was more modest. The subsequent increases in 2019 were also mainly from catches in this central region, but this time in the 50–100 m depth band (C100, Figure 31), whilst the biomass in the shallower depth range dropped. There were also increases in the North Taranaki Bight strata, across all depths. The increase in 2020 was once more

largely concentrated in the central harbour region, this time in both the 50–100 m and < 50 m strata, as well as higher biomass in the shallow northern stratum (A50) and the > 50 m strata in the North Taranaki Bight region. The size distribution in key core strata are shown in Figures 31 and 32.

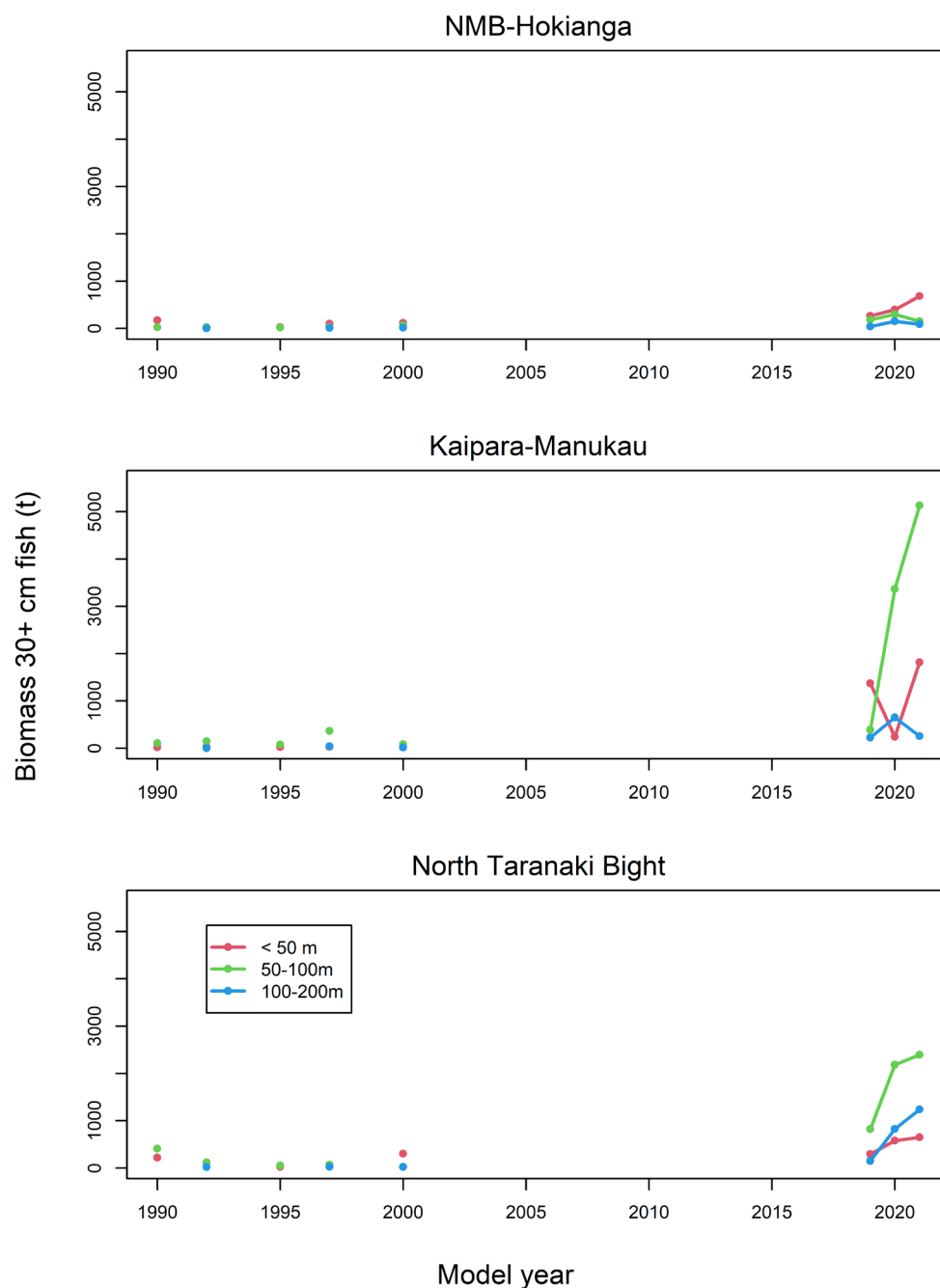


Figure 30: Estimated biomass of 30+ cm snapper in three different depth bands in three regions of the northern core area: Ninety Mile Beach and Hokianga Harbour, Kaipara Harbour and Manukau Harbour, and the North Taranaki Bight region.

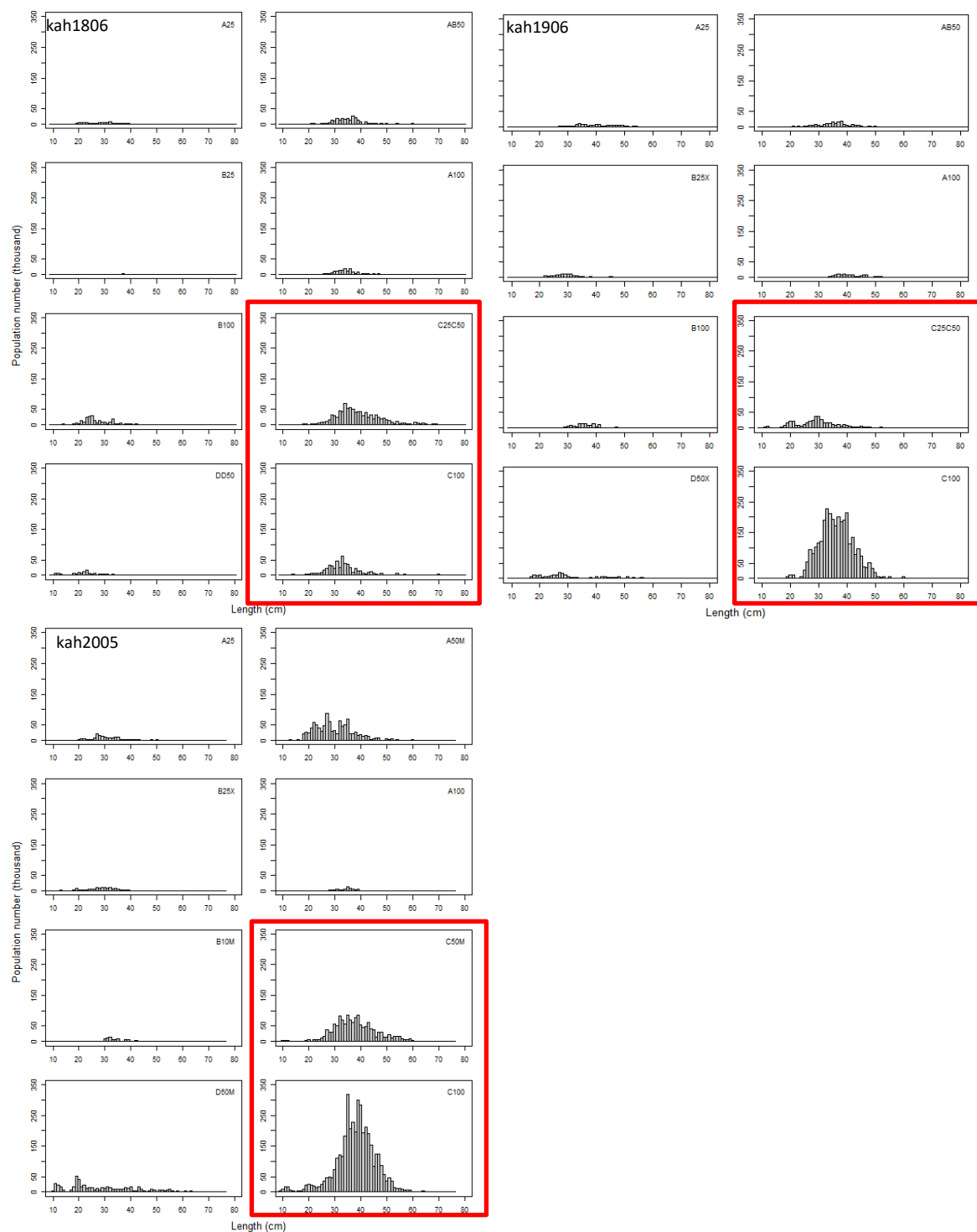


Figure 31: Stratum level scaled length frequency distributions for all snapper in the northern core strata out to 100 m (A, B, C, and D50), for the 2018–2020 WCNI surveys. The red box highlights the strata where the change in biomass was greatest.

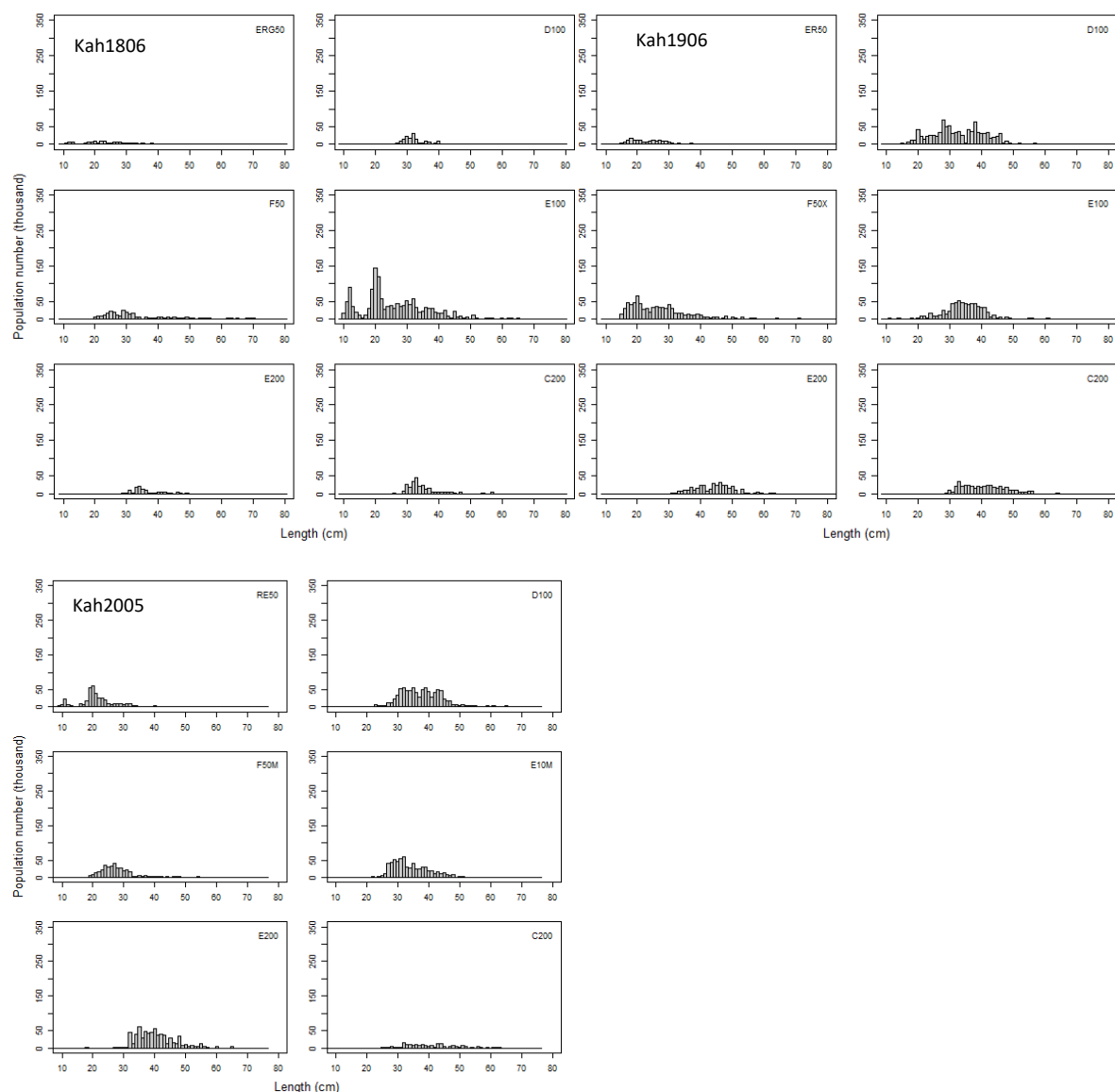


Figure 32: Stratum level scaled length frequency distributions for all snapper in the northern core strata out to 100 m (RG50, E50 or equivalent, F50, D100 and E100), as well as 2 deeper strata (C200 and E200) for the 2018–2020 WCNI survey.

Patterns in snapper age

Snapper otoliths were collected and aged from all surveys in the time series (Figure 33). These were reported by Jones et al. (2022) and were incorporated into the most recent SNA 8 stock assessments (Langley 2020, 2021). Historical surveys showed a population which comprised a narrow age range, with 0+ to 4+ cohorts making up between 72% and 94% of the total by numbers, largely dominated by 1+ to 3+ year classes and few or no fish older than around 6–7 years old.

The 2018 survey catch was still dominated by younger 1+ to 4+ ages, but there was a substantial broadening of the age range with a long right-hand tail of older fish. This pattern is consistent with commercial catches where the 2+, 3+, and 4+ fish (2014–16 year classes) also dominated (Walsh et al. 2019). For the 2019 survey, there were increases in numbers across a wide age range, particularly the 3+ cohort representing the strong 2016 year class, but also noticeably higher numbers of the 5+ to 10+ ages. For the 2020 survey, there were even higher numbers of 5+ to 10+ fish and also of older fish such as the 14+ cohort (2006 year class).

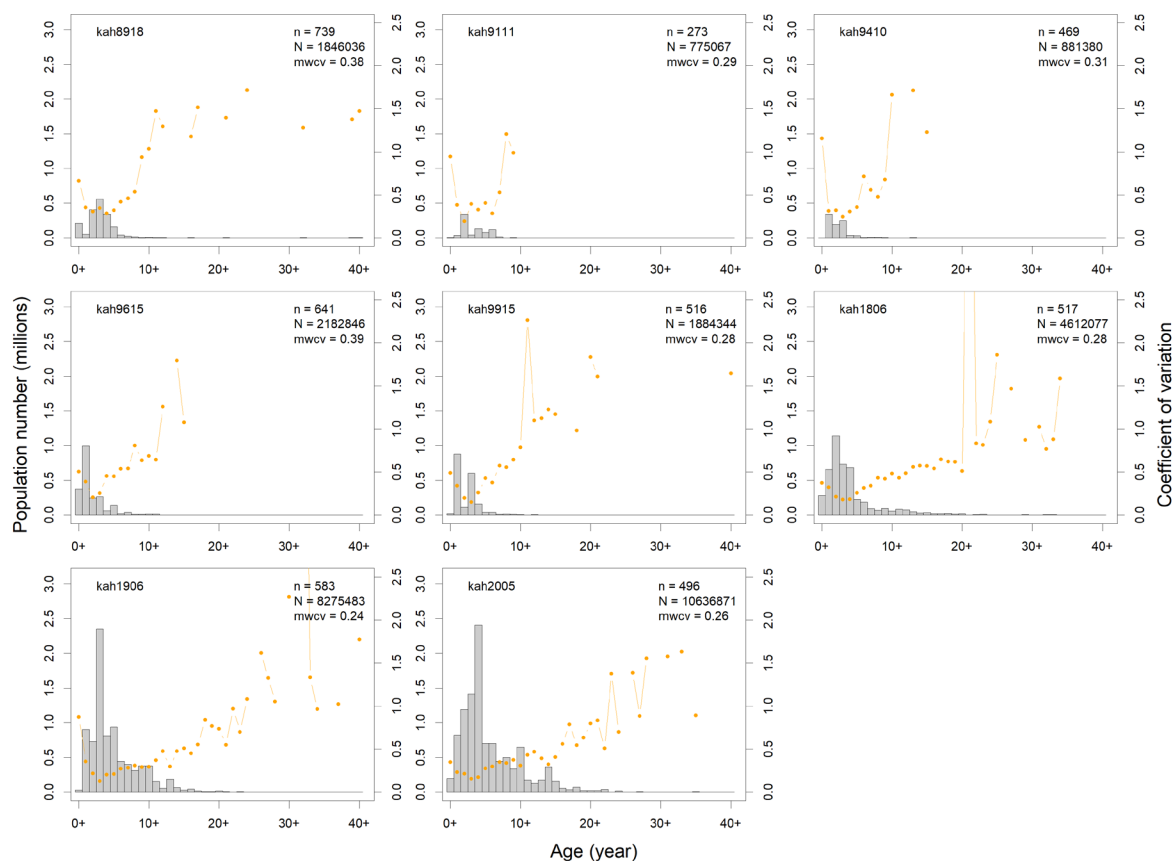


Figure 33: Time series of unsexed proportion-at-age distributions (histogram) and CVs (line) for snapper caught from the northern core area on WCNI surveys from 1989 to 2020 (mwcv=mean weighted coefficient of variation; n=sample size).

The contribution to population biomass by age class is estimated for each survey in Figure 34. There were significant increases in biomass contribution from the 3+ and 4+ year classes between 2018 and the two later surveys, reflecting the progression of the 2016 year class (2+ in 2018). The increase in biomass of the older, larger (30–50 cm) adult fish, caught in greater numbers in the central part of the survey outside the Kaipara and Manukau harbours is also apparent, with the increase in 2020 being strongly influenced by a small number of large catches in C100 stratum which were dominated by this size range.

The later timing of the 2018 survey most likely meant that a substantial portion of the adult snapper biomass was in the shallow areas, where it was no longer accessible to the survey. The earlier timing of the 2019 survey ensured a higher availability of the adult portion of the population to the survey, with larger catches in deeper water compared with the previous year, translating into the large difference in contribution from larger fish, 5 years and older.

The difference between 2019 and 2020 biomass estimates could reflect the impact of year-on-year variability in sea surface temperatures and local weather patterns on spawning snapper movement and behaviour. The larger catches in deeper water could possibly reflect an expansion of the adult snapper distribution into deeper water following recent increases in population biomass. Another possibility is potential influx of older fish from other areas outside the core area, such as the South Taranaki Bight. This would imply a decline of older snapper in the source area, which was not observed (see next section).

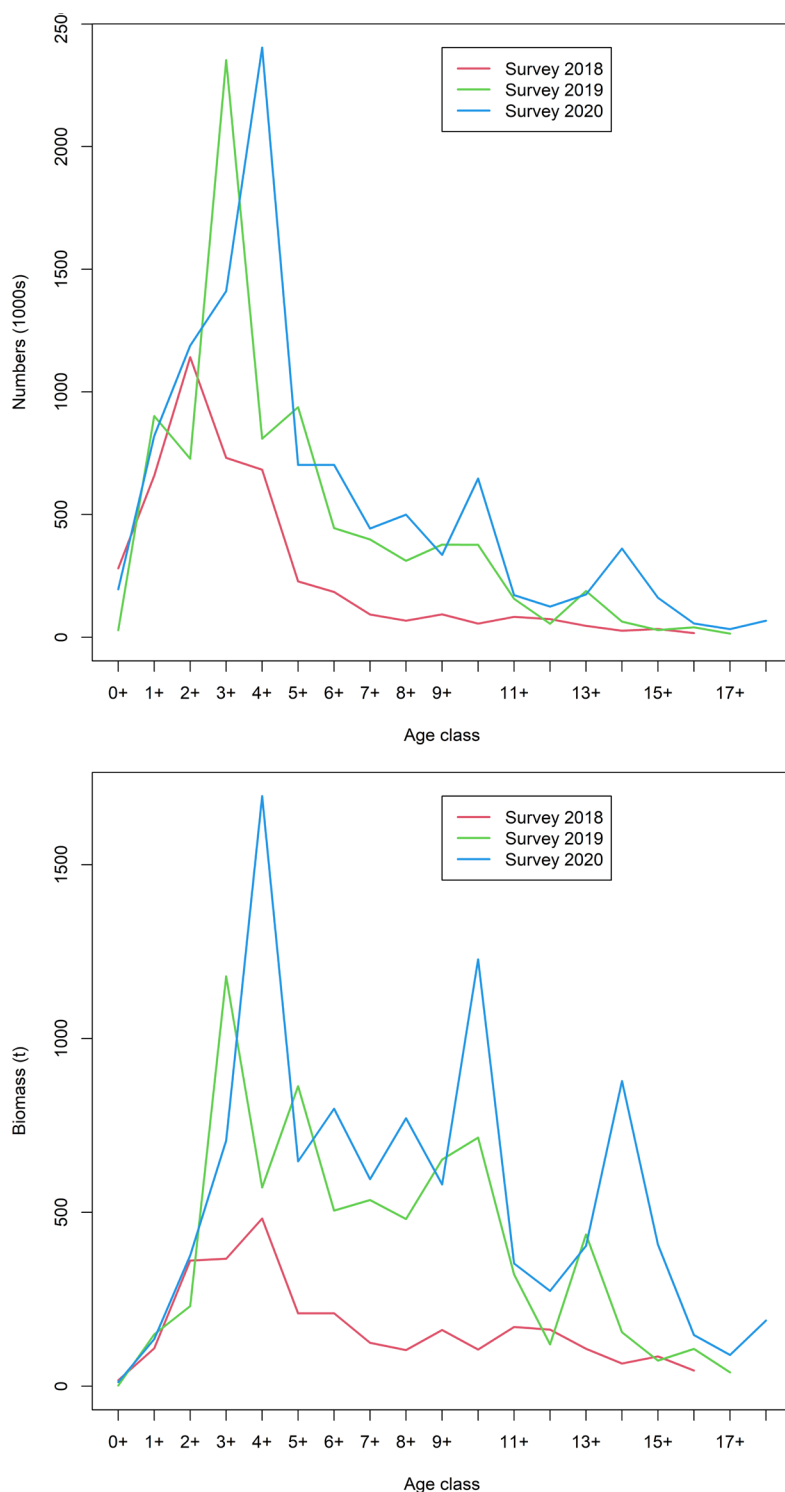


Figure 34: Variation in scaled numbers (top) and estimated biomass (bottom) by age class for the 2018, 2019, and 2020 WCNI trawl surveys.

South Taranaki Bight snapper

The recent surveys have included the southern strata in South Taranaki Bight (STB), sampled only once before in 1991 (Appendix 1). There were originally seven strata covering 10–100 m depths in the 1991 survey. The most northerly 10–25 m stratum (H25) had only one successful station completed, due to the extensive foul ground in this area, so was never included in the biomass estimate (Drury & Hartill 1993). Following poor weather in 2018 and further difficulties identifying fishable station locations,

this stratum was abandoned and designated a foul area. The large single stratum in the 50–100 m range (G100) was subdivided into three sub-strata (Jones et al. 2022).

In all four surveys, catch rates were generally highest around Wanganui in I25, the southern portion of G50, and southwards along the coast towards Otaki (H50 and J25) (Figure 35). These patterns are also shown in Figure 36, which plots the catch rate (numbers per square kilometre) for different size ranges of snapper by depth and latitude. These distribution patterns translated into the highest biomasses being attributable to the G50/G50M stratum in all years, based on its larger area compared with I25, which contributed the second highest biomass in 2018 (Table 13).

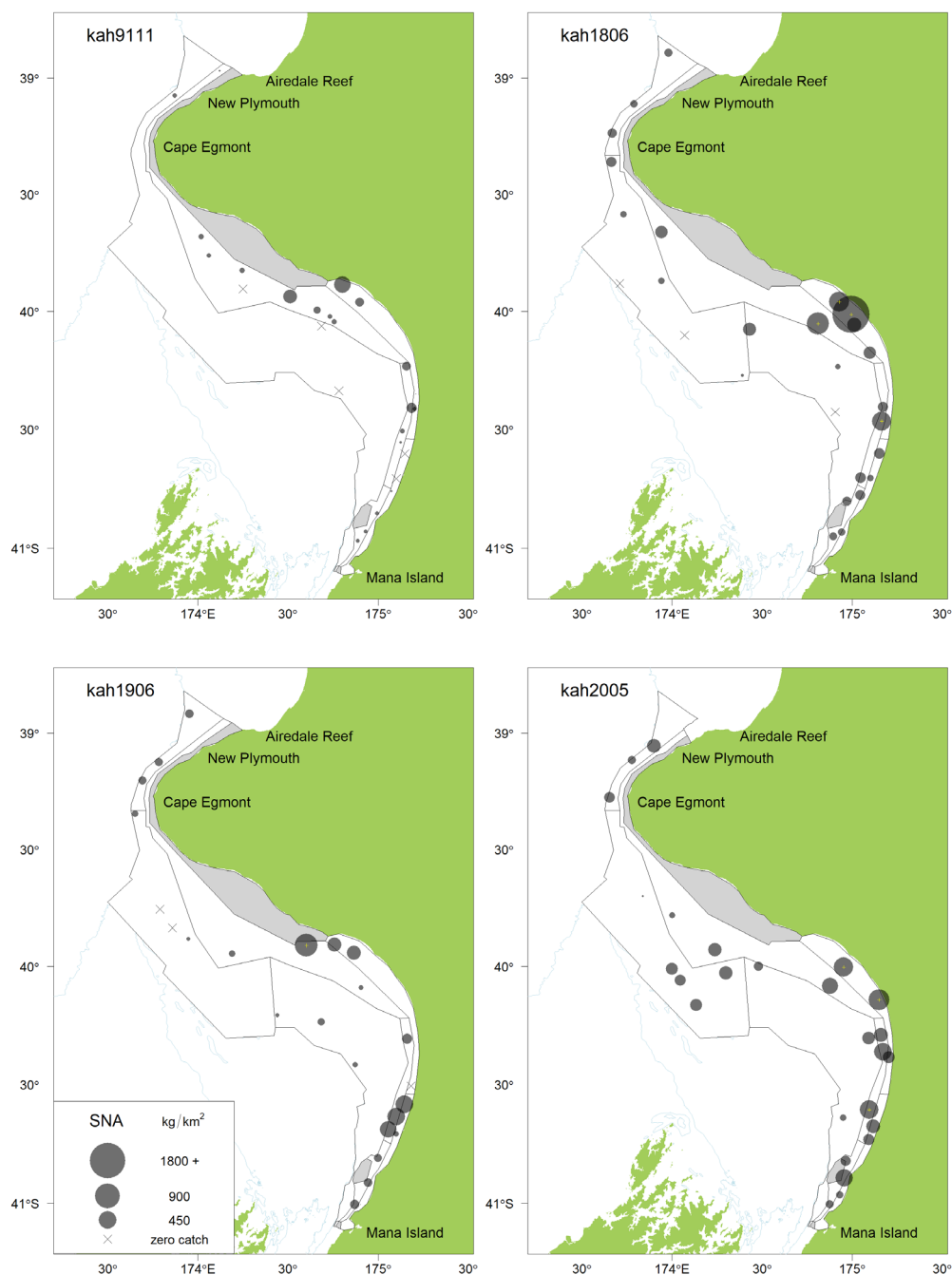


Figure 35: Spatial distribution of catch rates of snapper in the South Taranaki Bight strata for the 1991 and 2018–20 surveys. Catch rates are scaled to the largest catch in this series. Areas that are excluded from the survey are shown in grey, including closed areas around Mana and Kapiti Island and the inshore stratum H25.

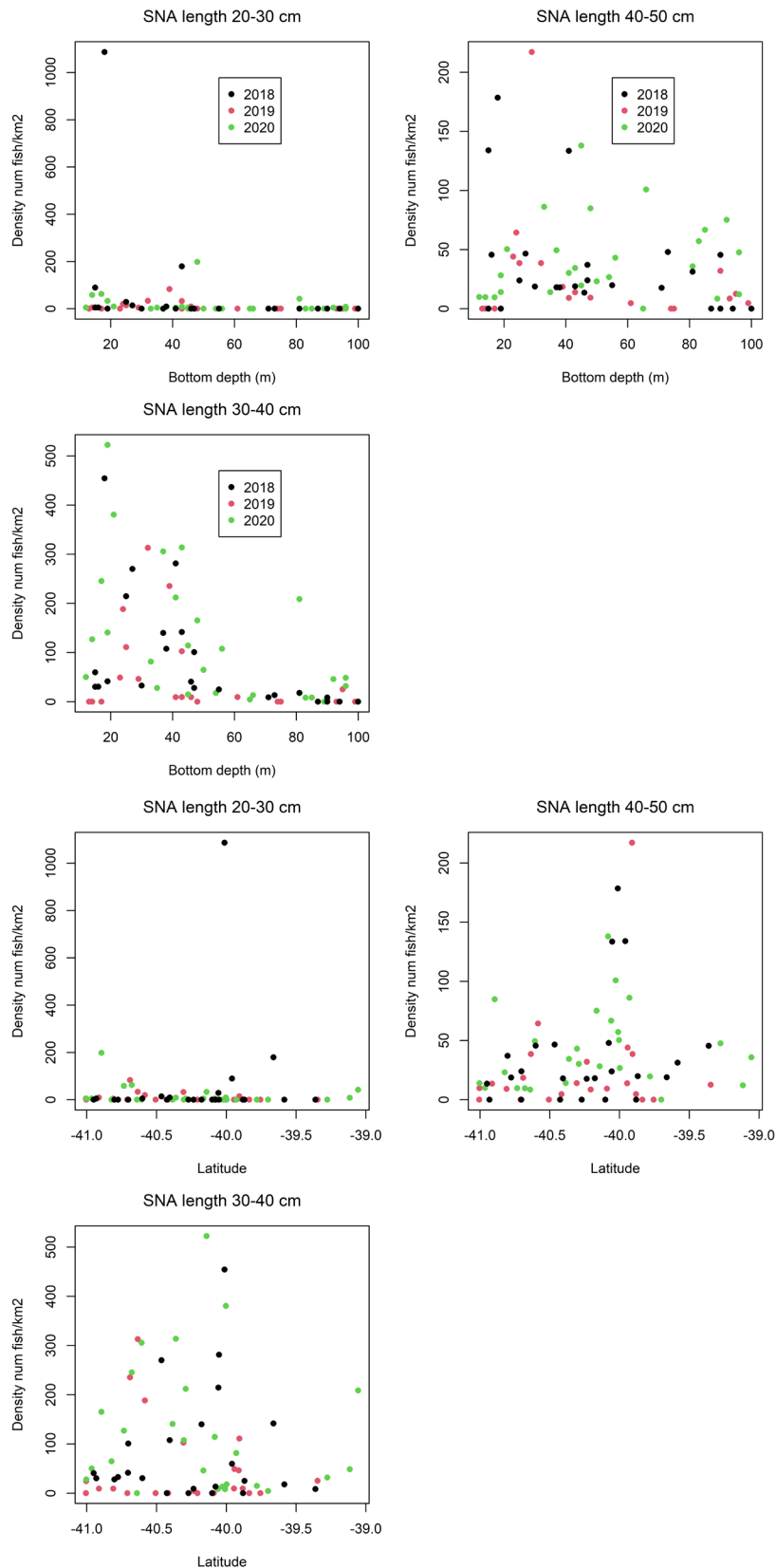


Figure 36: Station catch rates (no. of snapper per square kilometre) for three different size categories by depth (top three panels) and latitude (lower three panels) for the three most recent surveys (black=2018, red =2019, and green=2020).

Table 13: Stratum biomass (t) and CVs (%) for South Taranaki Bight strata in the four surveys that sampled this region. The G100 stratum was split into three strata from 2018 onwards.

Stratum	Kah9111		Kah1806		Kah1906		Kah2005	
	Biomass (t)	CV (%)	Biomass (t)	CV (%)	Biomass (t)	CV (%)	Biomass (t)	CV (%)
I25	83.1	90.7	543.6	54.1	116.1	50.0	270.3	26.8
J25	6.3	94.3	21.7	30.5	36.6	88.4	40.3	34.5
G50/G50M	137.5	47.7	800.9	40.7	577.6	83.7	490.5	41.6
H50	17.2	41.5	64.7	45.4	78.0	28.6	97.7	14.9
I50	3.3	7.0	16.6	14	14.8	8.7	33.7	47.5
G100	52.3	100.0						
G10N/G10X			45.1	11.1	45.4	3.7	84.8	30.2
G10M			131.7	49.6	56.9	72.5	523.6	25.4
G10S			262.7	80.0	121.3	31.1	377.7	40.4

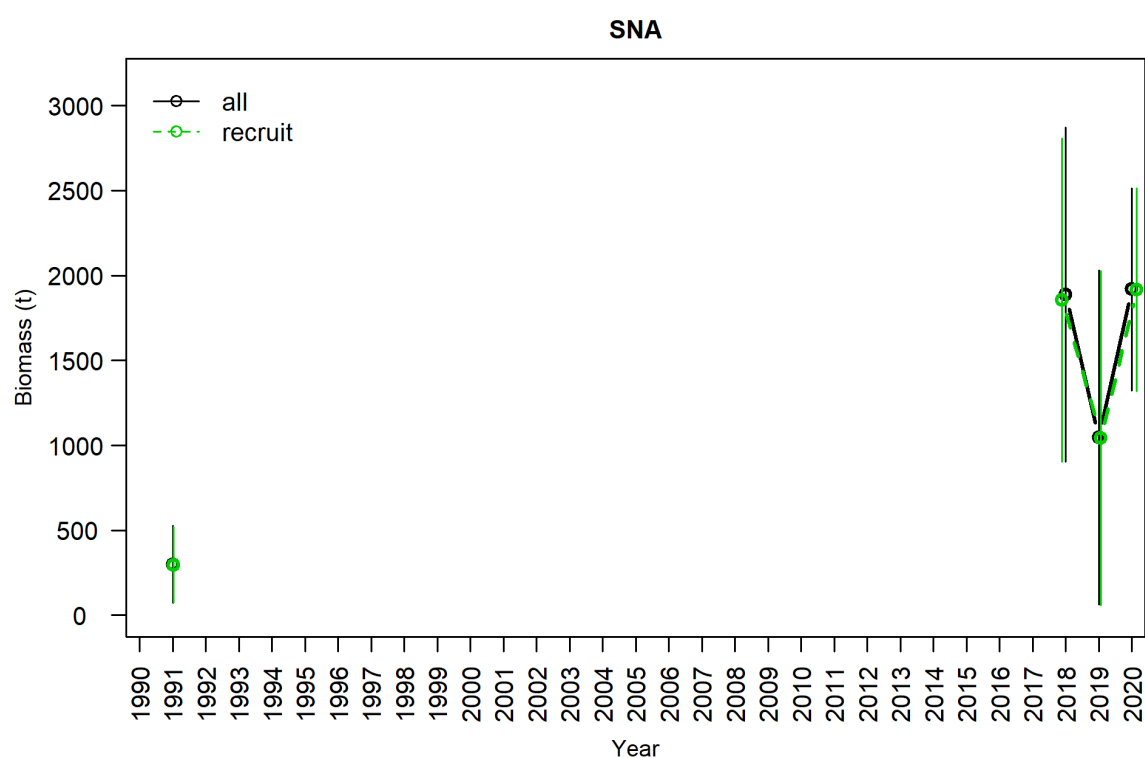


Figure 37: Time series of total (black) and recruited (green) relative biomass estimates and 95% confidence intervals for snapper for the South Taranaki Bight strata only for 1991 and the three recent surveys.

The timing of sampling these strata has varied from early October in 2019, late October/early November in 2018 and 2020 and mid-November in 1991. The relative biomass series for the southern strata only is presented in Figure 37 and shows an increase in biomass from just under 300 t in 1991 to around ~2000 t in the 2018 survey. The estimate was lower in 2019, when fishing took place almost a month earlier than the 2018 survey. The 2020 survey also started earlier in October, but the southern strata were mainly sampled following the completion of the northern strata, so the timing was closer to that in 2018, and the estimated biomass was also similar. The series CVs are high, so the estimates are imprecise, but sampling in this region does provide valuable information on population structure and biology in an area from which snapper are known to move northwards into the northern core region, as well as likely being a mixing zone between SNA 8 and SNA 7 stocks (Walsh et al. 2006).

The population scaled length distributions for all four southern surveys is shown in Figure 38. Snapper from this region had a similar overall size range to those in northern strata, but there were noticeable differences compared with the core area, as well as between years within this area. The main modal

peak in all years was 35–40 cm, with fish over 40 cm making up around 25% of the catch in 1991 and 2018, and 57 and 40% in 2019 and 2020, respectively. Modal peaks at around 25 cm were present in 1991 and in 2018. The latter survey also had a small 0+ mode at around 10–11 cm (mainly from one station between Kapiti and Mana Island). In these two surveys, the pre-recruits made up between 11–14% of the catch. This contrasted with the 2019 and 2020 surveys, where fish in this size range made up 4% and <0.5%, respectively. The low numbers of pre-recruit fish are reflected in the negligible difference between the total and recruited population estimates (Figure 37). Females were more numerous than males in every survey, with the ratio of males to females varying from 1:1.5 up to 1:1.9.

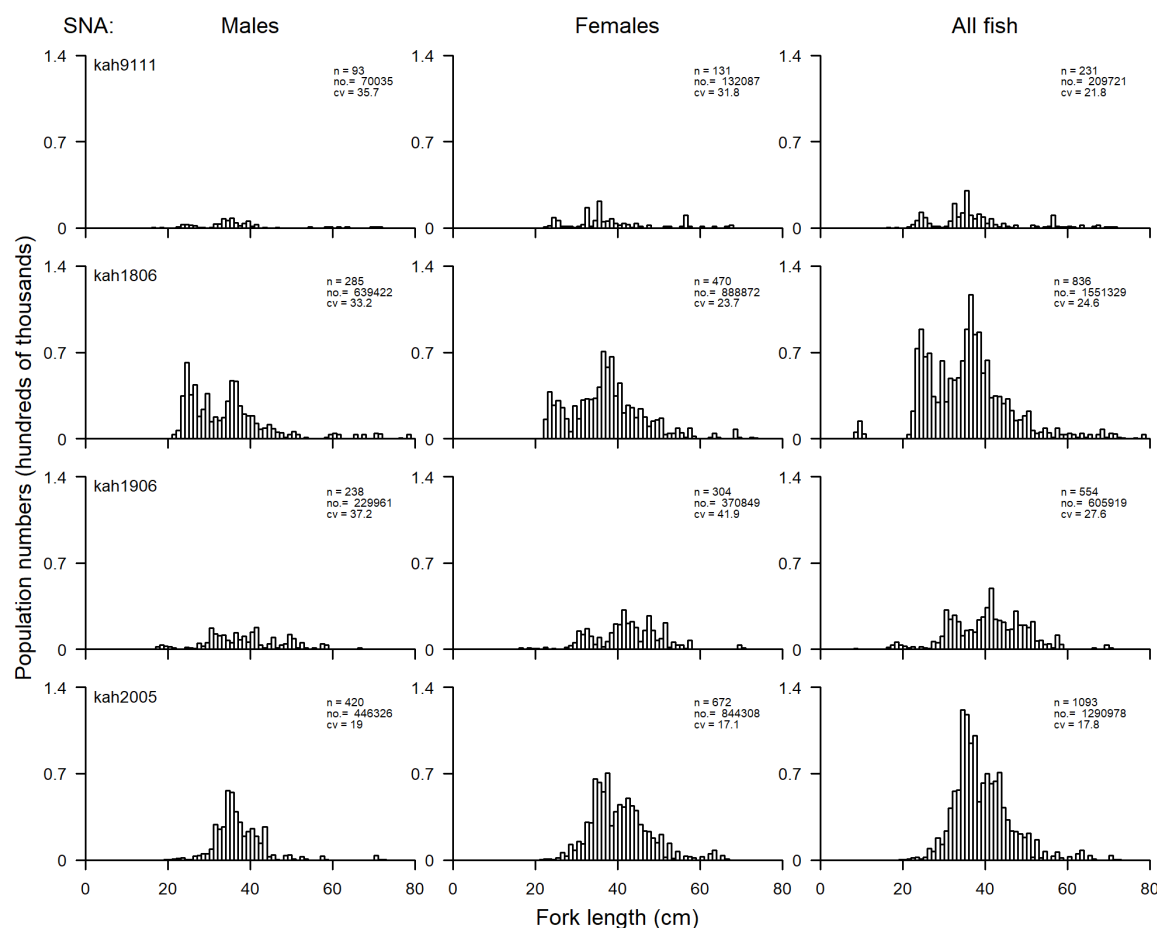


Figure 38: Comparative scaled length frequency distributions for males, females, and all snapper in the southern strata for the four WCNI surveys that included the South Taranaki Bight. n=number of fish measured, no.= scaled population number and CV= coefficient of variation. ‘All fish’ includes unsexed fish.

The age composition for the STB for surveys in 2018–20 is shown in Figure 39. The lower sample sizes from this sub-area of the survey, particularly in 2019, resulted in lower precision; the mean weighted CVs for the 2018 and 2019 survey were 0.47 and 0.59, respectively, improving to 0.32 in the 2020 survey. The 2018 survey was dominated by 2+ to 5+ age classes, including strong 2+ and 4+ classes (2016 and 2014) in particular. There was a small 0+ mode, the only one observed in this area and at the other end of the scale, a prominent 10+ class, which was dominated by female snapper. The age composition of the 2019 survey was flatter, without the same numbers of younger cohorts, but the 0+, 2+, and 4+ cohorts from 2018 were visible as 1+, 3+, and 5+ year classes. A relatively strong 8+ age class was present that was not noticeable in 2018, whilst the previous year’s 10+ cohort was still visible. This year (2019) was the odd survey out in terms of timing, with sampling accomplished in early to mid-October, compared to late October to early November in 2018 and 2020. The 2016 year class was still dominating the STB age composition in the 2020 survey as the 4+ age class, with the now 6+ age class present to a lesser extent. In between these, the 5+ class was also prominent in the 2020 survey,

which was not consistent with previous years in this region. Whilst there were good numbers of 9+ to 12+ classes, the prominence of the 2018 10+ age class was also not apparent in the 2020 survey.

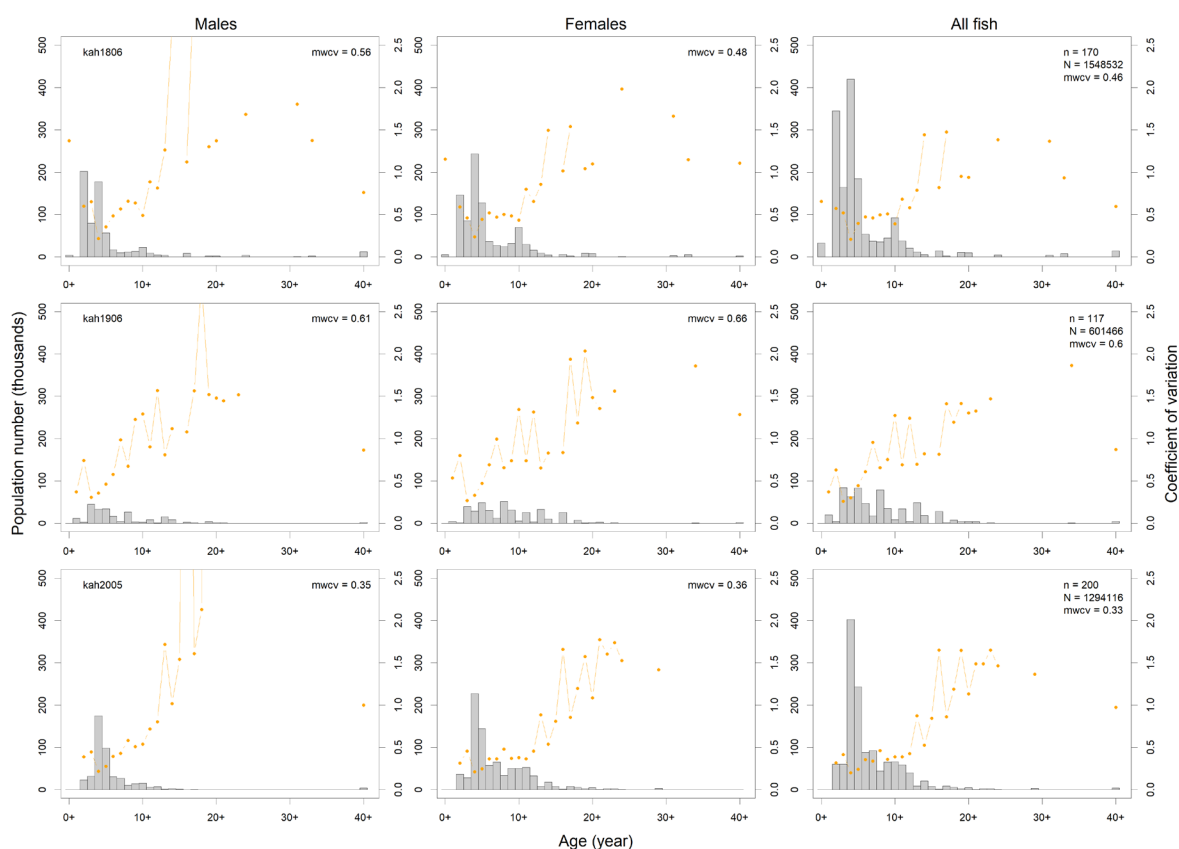


Figure 39: Numbers-at-age distributions (histogram) and CVs (line) for male, female, and all snapper caught from the South Taranaki Bight strata on WCNI surveys in 2018, 2019, and 2020. (N=scaled population number; n=sample size; mwcv=mean weighted coefficient of variation).

The STB snapper age compositions (incremented to the age assigned at 1 January following the survey) are plotted alongside those from the northern core area in Figure 40 for comparison. The 2016 and 2014 age classes were strong in both areas in all years except in 2020, when there was a drop in the proportion of the 2014 class (6+/7 year old). For the cohort in between these two year classes, the 2015 age class (3+/4 year old in 2018 survey) the proportion was not consistent between region, or years, starting off strong in the northern area and declining over time, whilst south of Cape Egmont, the proportion was relatively low in 2018 and 2019, but much higher in the 2020 survey (at 5+/6 year old). A 0+/1 year old cohort is observed in 2018 in both regions and can be tracked through the three surveys in both areas but is stronger in the northern core area. The high numbers of 10+/11 year old fish seen in STB in 2018, and to a lesser extent in the 2019 survey, were also not observed in the northern core age composition. Neither were the small numbers of much older fish (20+ years) that were sampled south of Cape Egmont.

Figure 41 compares the same STB age composition with snapper age data from the west coast South Island (WCSI) trawl surveys, which includes Tasman Bay and Golden Bay (TBGB) (MacGibbon 2019, MacGibbon et al. 2022). The 2018 WCNI ages were compared with the March-April 2019 WCSI survey, and the 2020 WCNI with the March-April 2021 WCSI survey.

Figure 42 provides a comparison with the most recent catch-at-age data from SNA 7 collected in the 2019–20 fishing year (Parsons et al. 2021). The younger, strong year classes present in the STB area in 2018 were not seen in the TBGB trawl survey age composition, but there were similarities in the relative strength of the older year classes. The 10+/11 year old class in 2018 was also prominent in the TBGB

sample in 2019, present as 11+/12 year class in commercial catch sampling in 2019–20, and still present as 12+/13 year olds in the 2020–21 age composition in both areas. This is the 2008 year class, which was one of the strongest cohorts in the TBGB surveys and has dominated the snapper age compositions in subsequent years (MacGibbon 2019). The 7+/8 year class (2011) is also evident in the TBGB age composition and, although not seen in the 2018 STB samples, appears to be present in the 2019 STB survey as 8+/9 year olds, as well as in the commercial catch-at-age data from SNA 7. Similarly, the strong 12+/13 year old class observed in the TBGB trawl survey in 2019, and in the 2019–20 commercial catch-at-age data, is also seen in the 2019 STB survey.

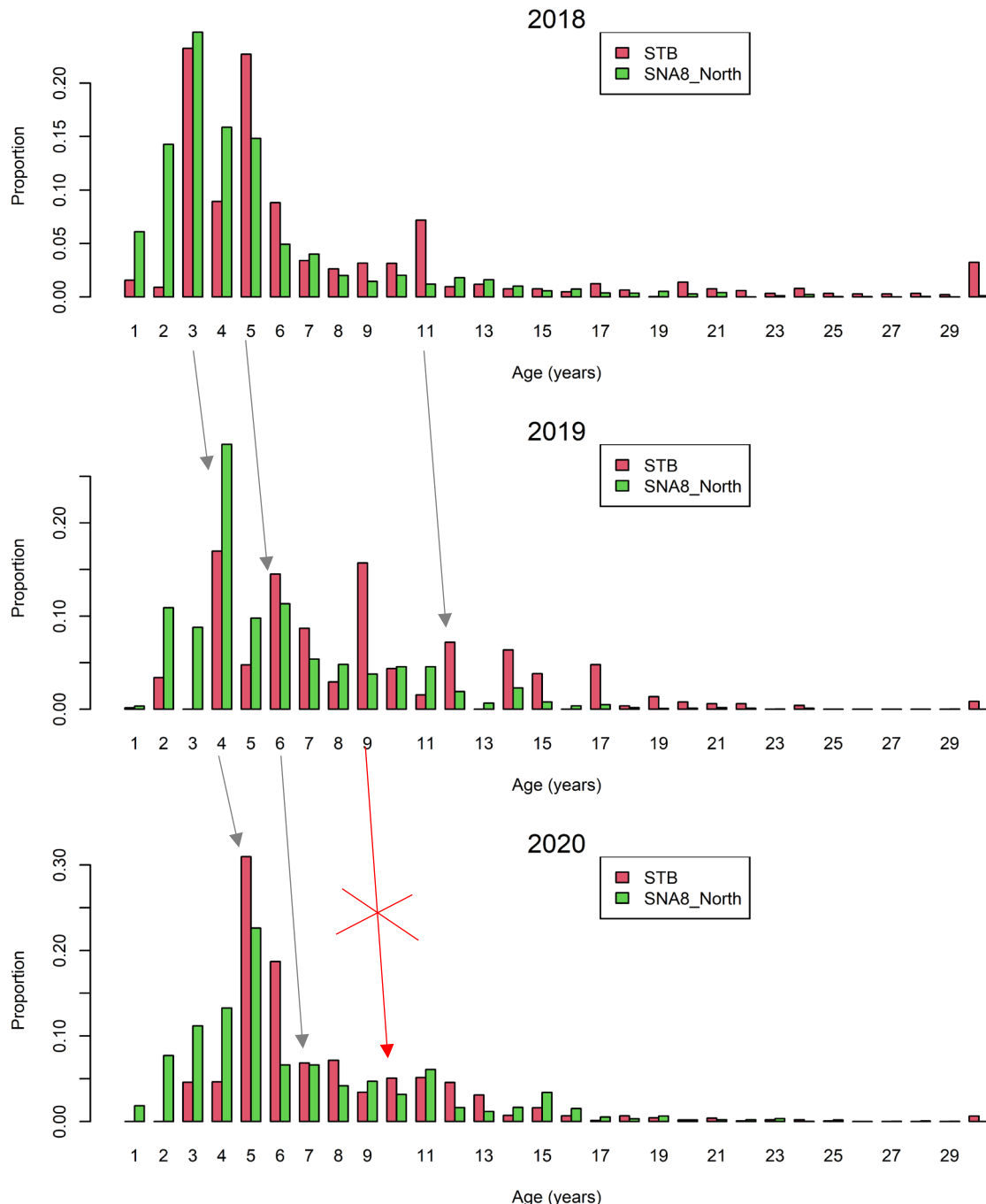


Figure 40: Comparison of proportion-at-age for snapper caught from the South Taranaki Bight strata (STB, pink) and the northern core (SNA8_North, green) on WCNI surveys in 2018, 2019, and 2020. In these plots, fish of age 1 are equivalent to 0+ fish in the numbers-at-age distribution in Figure 39. Grey arrows indicate age classes in successive years. Red arrow show where age classes do not appear to track.

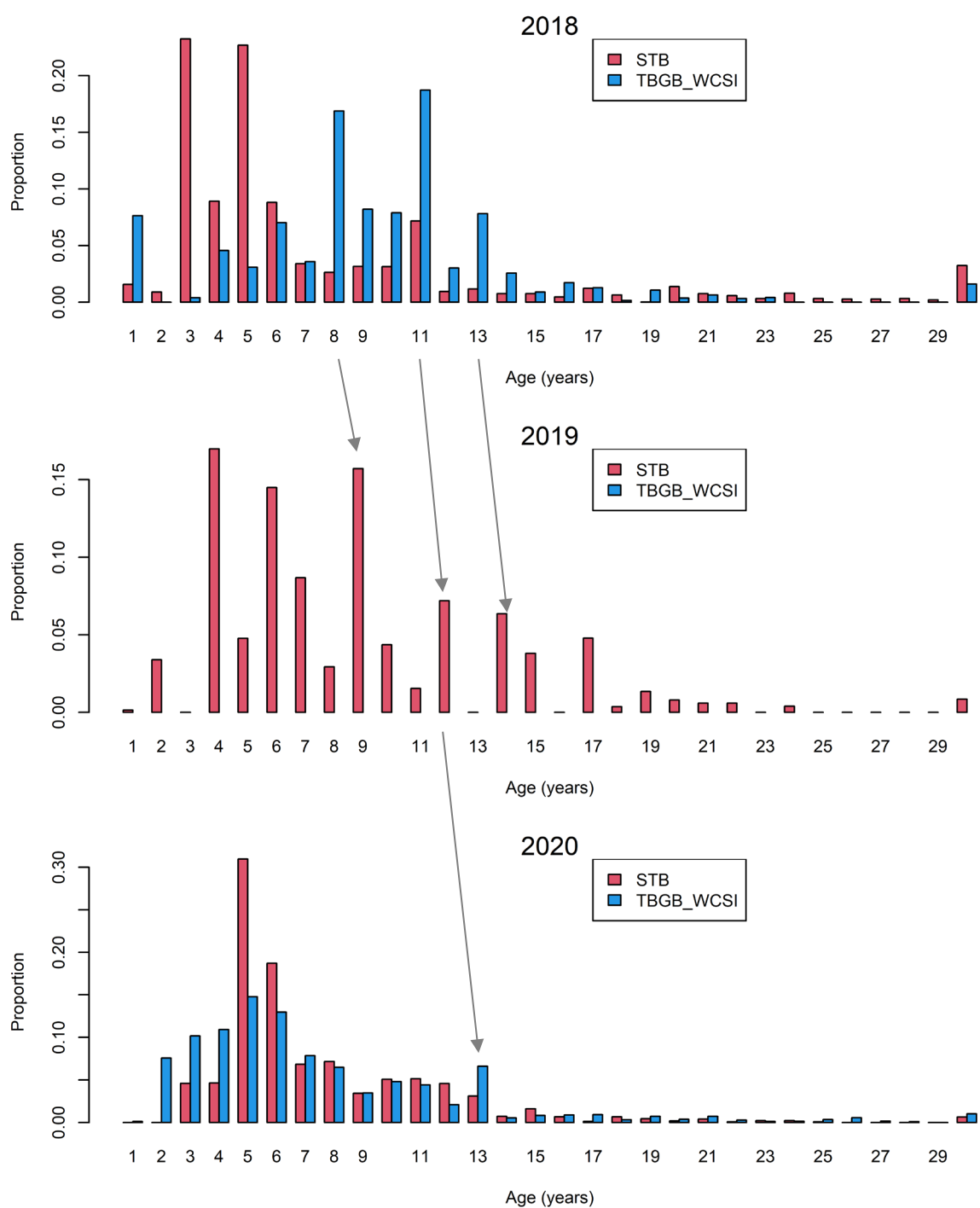


Figure 41: Comparison of proportion-at-age for snapper caught from the South Taranaki Bight strata (STB, pink) in the WCNI surveys and snapper caught in the Tasman Bay and Golden Bay, WCSI trawl survey (TBGB_WCSI, blue) in 2019 (plotted as 2018) and 2021 (plotted in 2020). In these plots, fish of age 1 are equivalent to 0+ fish in the numbers-at-age distribution in Figure 39. Grey arrows indicate age classes in successive years.

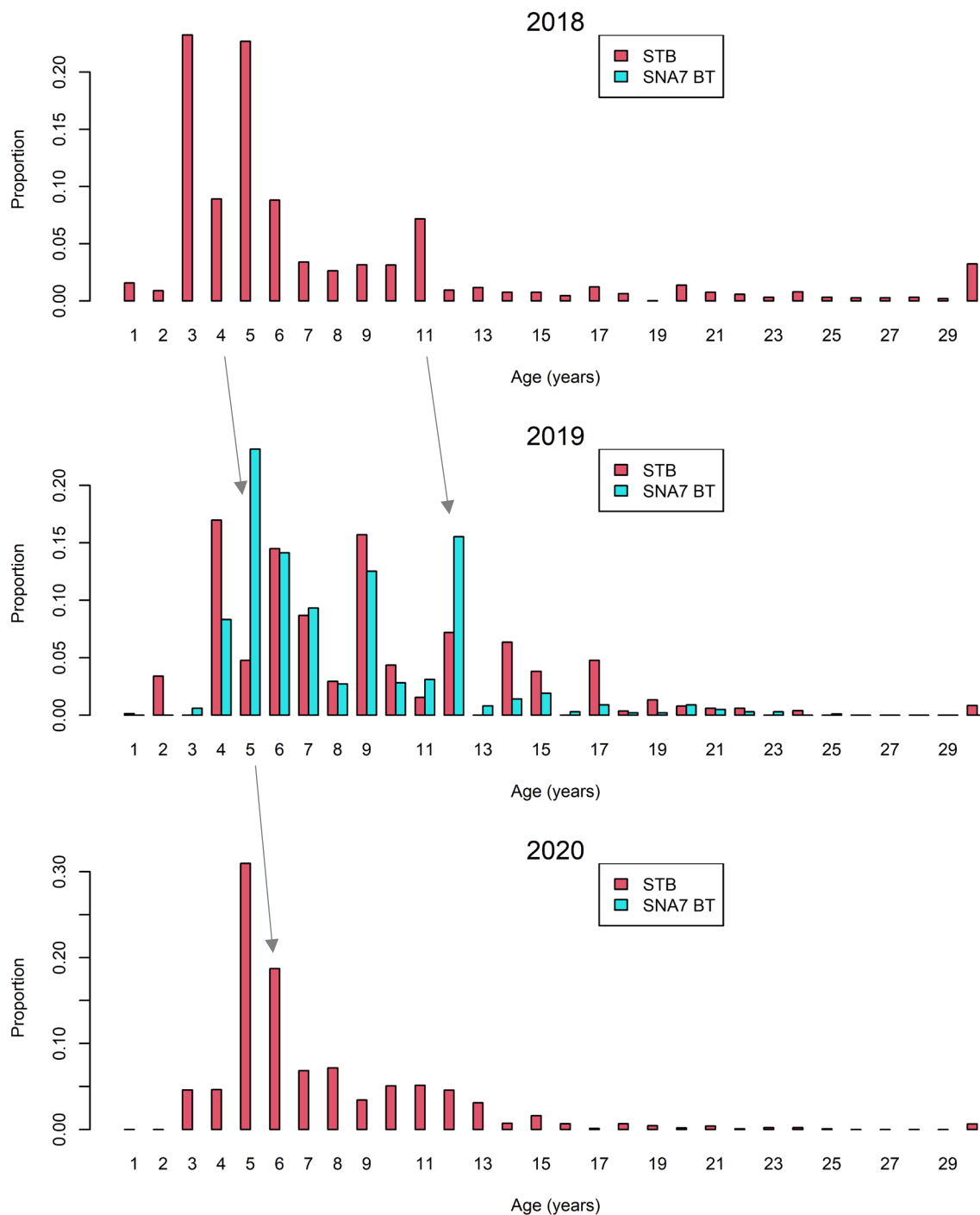


Figure 42: Comparison of proportion-at-age for snapper caught from the South Taranaki Bight strata (STB, pink) in the WCNI surveys and snapper sampled from the SNA 7 commercial bottom trawl fishery (SNA7 BT, blue) in 2019–20 (plotted in 2019). In these plots, fish of age 1 are equivalent to 0+ fish in the numbers-at-age distribution in Figure 39. Grey arrows indicate age classes in successive years.

3.2.2 Red gurnard (GUR)

Number of surveys	8
Total catch weight (kg)	20 861.2
Number measured	44 804
Length range (mean) (cm)	9–53 (30.35)
Number weighed	6641

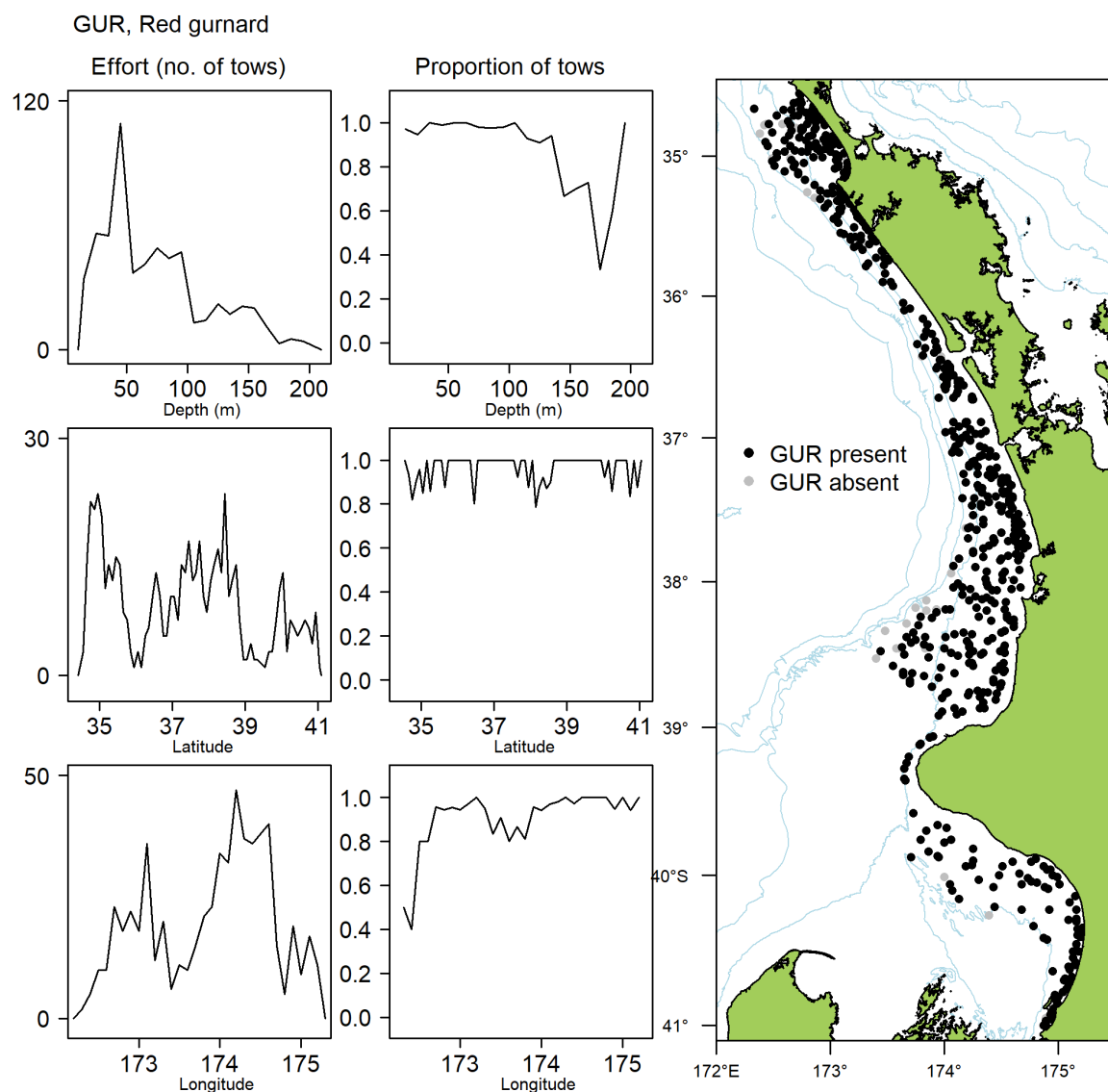


Figure 43: Summary of occurrence of red gurnard in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which red gurnard were caught. All valid tows are plotted in the map on the right with black dots showing those where red gurnard was present.

Red gurnard is a demersal species, widespread around New Zealand in 10–200 m (McMillan et al. 2019). The survey covers the north-western portion of the GUR 1 stock. The geographic and depth range are appropriate for this species (Figure 43), although the exclusion of large areas of the northern core strata shallower than ~30 m truncates the shallow end of the distribution. Red gurnard was historically the most abundant species by weight in every survey, making up a quarter to a third of the catch, and caught in 96–100% of stations. In the more recent surveys, this species was still caught in a high proportion of stations (88, 94, and 96%), but accounted for only 3.5–5.1% of the catch in any one survey, falling to 5th or 6th most abundant species.

Figure 44 shows the variation in catches across the survey area. Catches were concentrated in water depths shallower than 100 m throughout the survey, with the highest rates off Ninety Mile Beach, and between the Kaipara Harbour and Tirua Point. In the southern strata, catch rates were more modest, but consistently higher, in stratum I25 to the south of Wanganui.

Relative biomass was estimated with good precision across the whole survey as well as all sub-areas, with CVs below the target of 20% in all surveys except the 1994 core series (28%) (Table 14). The original estimate for the 1994 survey year was also relatively high (20.2%), with CVs in the original area of all other historical surveys being below 15%.

GUR, Red gurnard

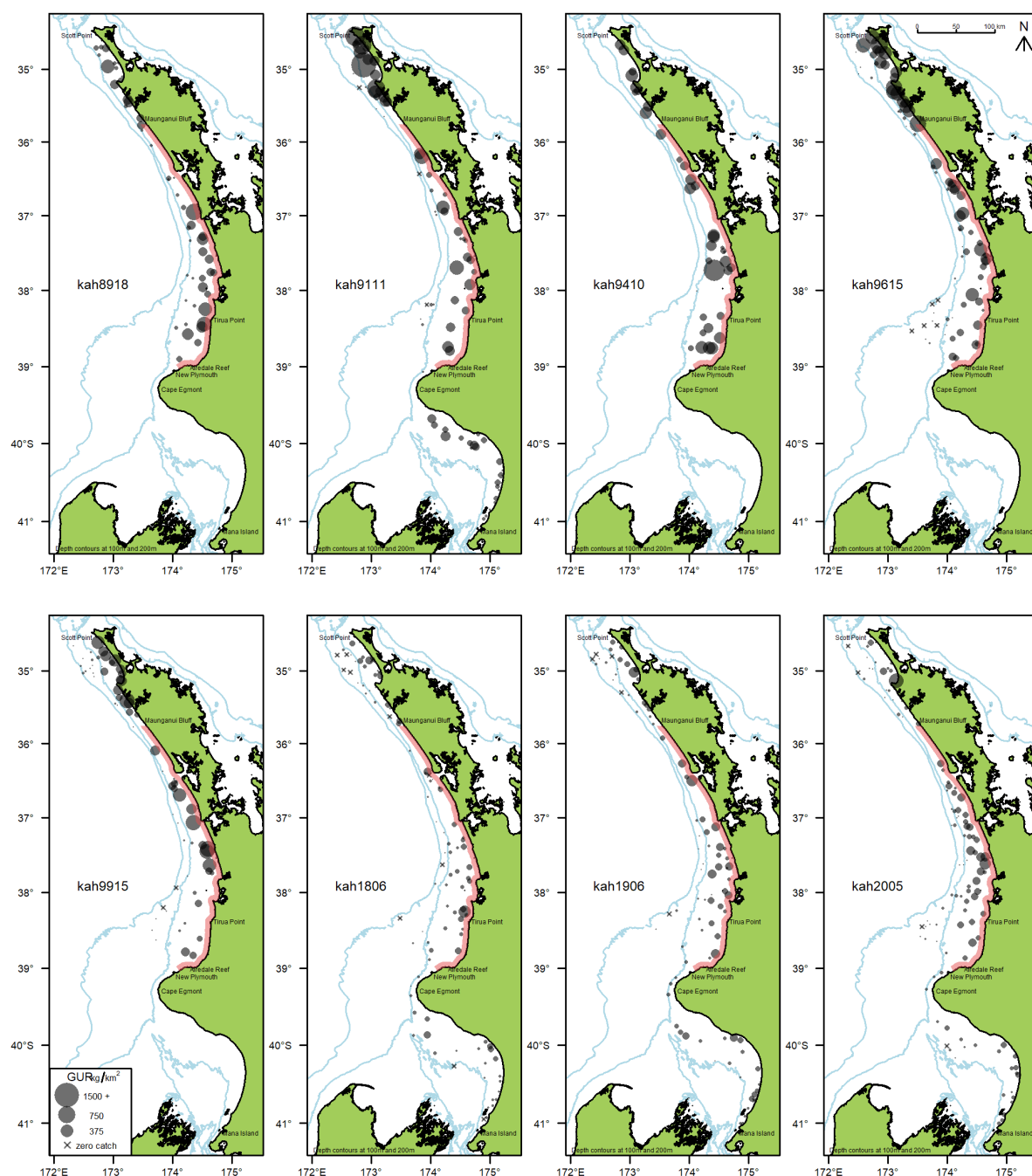


Figure 44: Spatial distribution of catch rates (kg km^{-2}) of red gurnard in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

Table 14: Relative biomass estimates (t) and CVs (%) of red gurnard for the core, extended core, southern strata and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were only sampled previously in 1991.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	1 754.50	16.21						
kah9111	3 404.55	15.39	3 494.35	15.02	400.02	13.98	3 894.36	13.55
kah9410	3 312.89	28.86						
kah9615	2 452.26	12.52	2 540.97	12.11				
kah9915	1 693.36	16.29	1 730.67	15.95				
kah1806	643.71	17.03	686.73	16.04	305.94	18.88	992.66	12.50
kah1906	884.68	13.44	946.72	12.69	409.04	15.92	1 355.77	10.08
kah2005	919.44	12.70	994.99	11.83	291.92	10.47	1 286.52	9.45

The historical survey time series indicated a period of high biomass between 1991 and 1994, followed by a declining trend (Figure 45). The most recent surveys suggest total biomass has declined further, largely driven by a loss of pre-recruits (< 30 cm) from the population sampled in the survey area (Jones et al. 2022). The estimates of recruited biomass (> 30 cm) for the recent surveys were similar to the 1999 estimate (Jones et al. 2022). This absence of smaller fish in recent surveys is also reflected in the increase in mean length from 28–30 cm in the historical surveys to 32.8–33.7cm in the more recent surveys (Table 15).

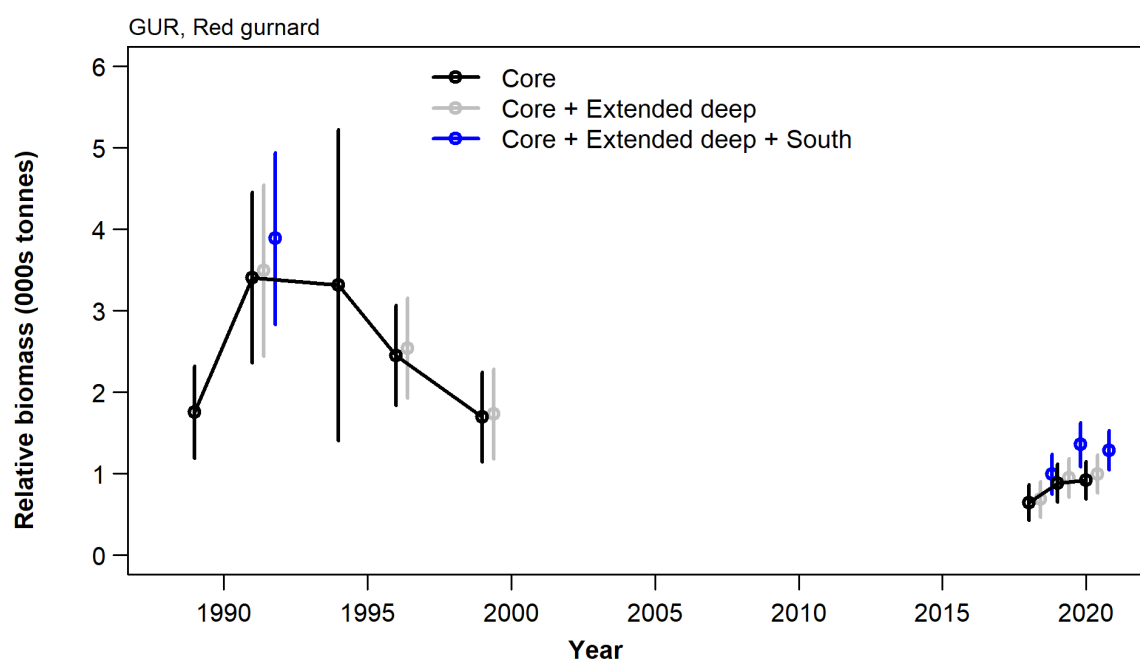


Figure 45: Time series of total relative biomass estimates and 95% confidence intervals for red gurnard for the northern core area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 15: Summary of catch weight and length measurements of red gurnard by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	2 479.9	9	53	29.97	6 431
kah9111	3 795.1	9	52	30.31	5 333
kah9410	3 242.3	10	53	28.88	5 743
kah9615	5 131.7	9	51	28.58	10 274
kah9915	2 728.6	10	48	28.43	9 251
kah1806	1 017.0	14	51	33.69	2 176
kah1906	1 230.8	9	52	32.82	2 848
kah2005	1 235.8	10	51	33.31	2 748

Figure 46 provides the landings and standardised combined model CPUE analyses for GUR 1W, updated in 2022 and including the recruited biomass estimates from the survey for comparison (McKenzie 2022, cited in Fisheries New Zealand 2022). The CPUE index does not extend earlier than 1996, so it is not possible to compare with the historical higher estimates from the earliest surveys, but, since 1996, CPUE has shown cyclical fluctuations, with patterns that broadly match the survey indices for recruited red gurnard overall; a period of decline in the mid to late 1990s, and more recent estimates similar or just above those from the early 2000s, close to the long-term mean.

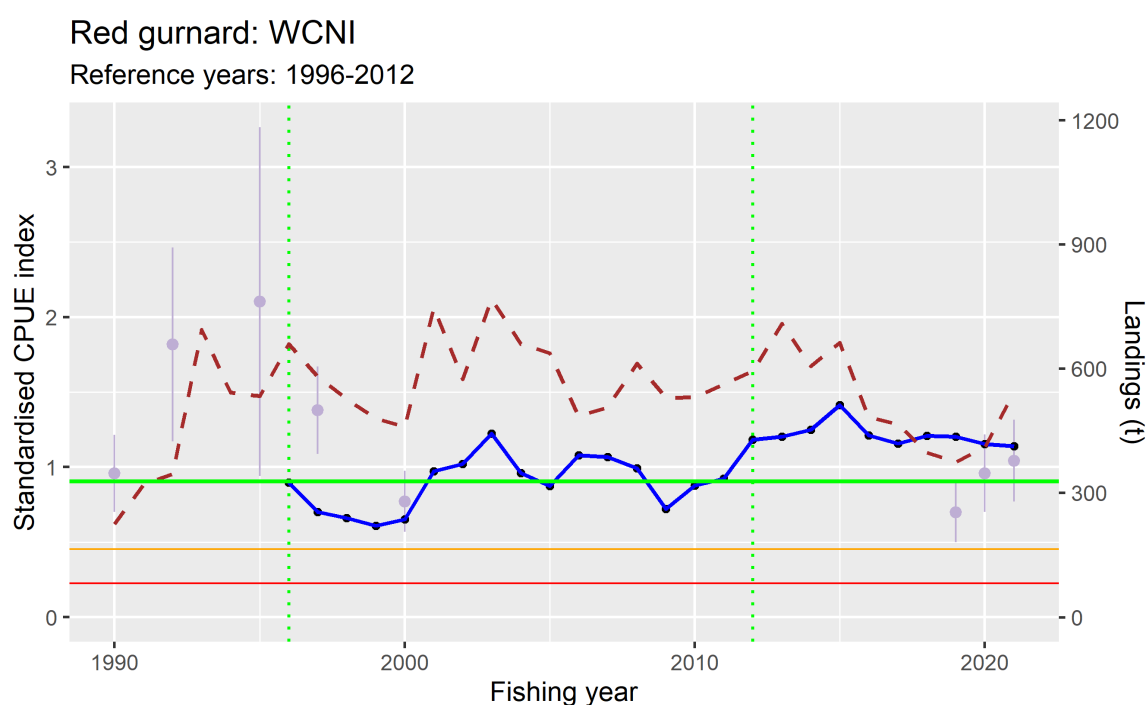


Figure 46: CPUE index for the commercial bottom trawl fishery for red gurnard. Landings (dashed brown line), standardised CPUE combined model using tow by tow data (blue line), and trawl survey recruited biomass indices (purple with error bars $\pm$ two standard deviations). The green, orange, and red horizontal lines represent the target, soft, and hard limits, respectively. Trawl survey recruited biomass indices are scaled to have the same arithmetic mean value as the standardised CPUE indices, over the years they have in common. (Source: Fisheries New Zealand 2022.)

The population scaled length frequency distribution of red gurnard in the northern core time series is shown in Figure 47. The overall size range was consistent from year to year, from around 9–10 cm to 51–53 cm, covering the full size range for this species. However, the population structure has changed markedly in the more recent surveys. The modal peak in the historical surveys was 22–25 cm for males, and around 25–29 cm for females, with over 60% of the population being in the 20–30 cm range. This

contrasts with the more recent series where the 20–30 cm size range accounted for only 30–36% of the population, and male modes were 25–32cm and female modes between 30 and 39 cm. Previous ageing of otoliths from the 1994 and 1996 surveys indicated that fish below 20 cm are predominantly 1 year olds (Hanchet et al. 2000). The authors noted that such 1+ modes were only occasionally present in trawl surveys, notably in 1994 and 1999. A small 1+ mode (16–17 cm) was also present in the 2018 survey, as well as 2–3+ year classes at around 22 cm in all three surveys, indicating that these smaller pre-recruits are captured in the survey. Figure 48 shows the scaled length frequency distributions including the deeper (100–200 m) strata, the ‘extended core’ time series. In most years the numbers caught deeper than 100 m were low.

The sex ratios in the historical surveys were slightly biased towards males (1:0.8–0.9), which were more numerous in the 50–100 m strata. In the more recent surveys, the sex ratios have shifted to favour females (1:1.3–2.6) in both deeper and shallow strata in all areas except off Northland, where males still outnumber females. This change could be due to disproportionate fishing pressure on the smaller, slower-growing males in the 50–100 m depth range.

Table 16 provides information on gonad condition of gurnard sampled from the three recent surveys and the last historical survey. In the 1999 survey, a slightly different maturity scale was used (Clearwater 1992), but most categories were equivalent. Female red gurnard in 1999 were mainly ‘regressed’ (stage 2) or ‘vitellogenic’ (equivalent to stage 3: eggs are visible, but not clear, hydrated), but 17% were hydrated (stage 4, ripe), with a very small number of running ripe fish sampled. Almost 70% of males were classed as ‘Spermatogenic’, (equivalent to middle depth (MD) stage 3 ‘Ripening’) with testes white but without milt present. A further 20% were ‘partially spermiated’ (equivalent to MD stage 4: ripe) along with a small number of running ripe fish. In the more recent surveys, between 40–60% of female red gurnard were classed as ripening, and between 8–11% as ripe, with a very small number of running ripe. A greater proportion of females were classed as partially or fully spent in 2018 and 2019 than in 1999. For males, the majority were classed as resting or ripening, with higher proportions of ripe/running ripe males in 2018 and 2020, than in 2019.

Table 16: Proportion of sampled red gurnard with gonads at different reproductive stages by survey. Note that for historical surveys up to 1999, a 6-stage only scale was used for females, with stage 6 equating to ‘Spent’ and no identification of partially spent individuals recognised. For males, no resting stage (stage 2) or partially spent (stage 6) were recognised in the 5-stage scale used. (Gonad stages are defined in Appendix 4).

	Maturity Stage							
Year	1	2	3	4	5	6	7	Sample
Female								
kah9915	0.06	0.34	0.37	0.17	0.004	NA	0.06*	1 814
kah1806	0.07	0.15	0.40	0.11	0.01	0.03	0.23	926
kah1906	0.09	0.18	0.50	0.08	0.01	0.06	0.07	1 076
kah2005	0.05	0.23	0.58	0.08	0	0.03	0.02	912
Male								
kah9915	0.11	NA	0.67* ²	0.20	0.02	NA	0	838
kah1806	0.10	0.12	0.41	0.15	0.15	0.01	0.04	297
kah1906	0.14	0.40	0.35	0.05	0.03	0.01	0.02	324
kah2005	0.04	0.31	0.45	0.18	0.02	0	0	454

*Clearwater 1992 Stage 6, equivalent MD stage=’7’.

*²Clearwater 1992 Stage 2 ‘Spermatogenic’.

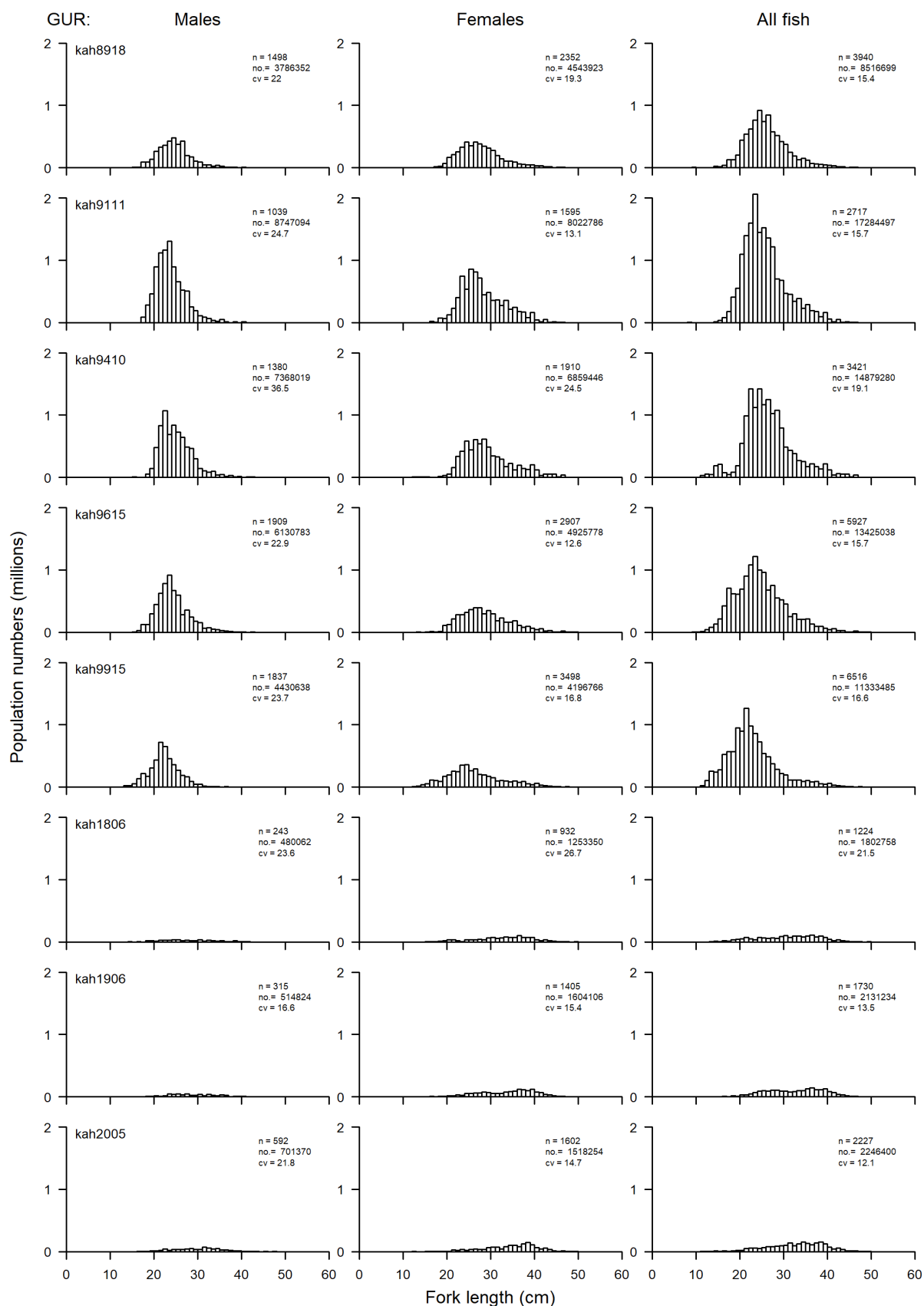
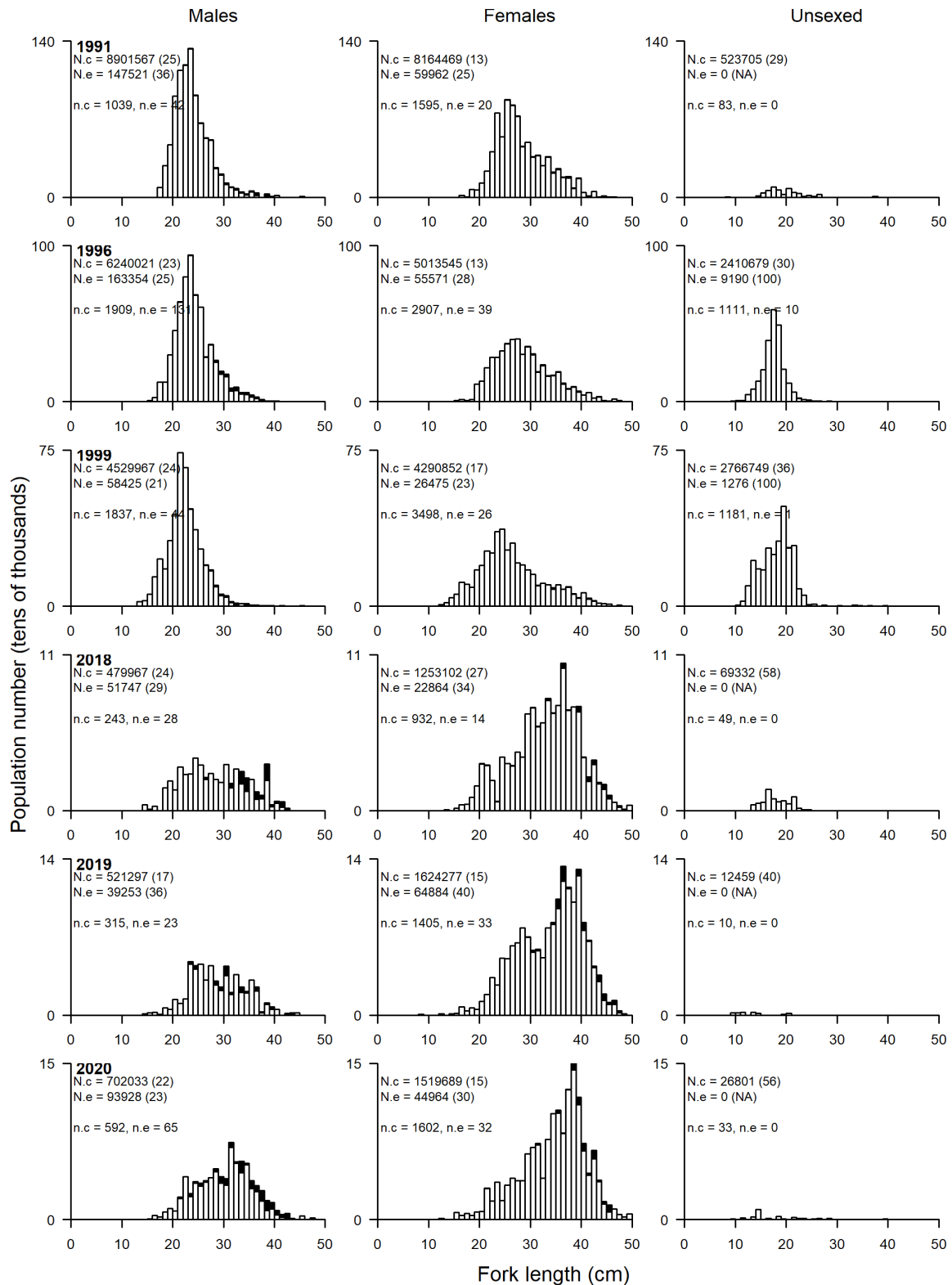


Figure 47: Comparative scaled length frequency distributions for males, females, and all red gurnard in the northern core strata (<100 m) for the time series of the WCNI surveys. n=number of fish measured, no.=scaled population number and CV=coefficient of variation. 'All fish' includes unsexed fish.



GUR, Red gurnard (core.extended: core = white, extended.only=black)

Figure 48: Comparative scaled length frequency distributions for males, females, and unsexed red gurnard from the core (white) and extended deeper strata (black) for the WCNI surveys that included the 100-200 m depth range. N.c.=scaled population number and CV (in brackets) for the core. N.e.=scaled population numbers for the extended strata. n.c.=number of fish measured from core. n.e.=number of fish measured in the extended strata. Note the different scales for population numbers in different surveys.

The strata south of Cape Egmont are included in the whole survey area biomass time series in Figure 45, with a separate ‘South’ time series provided in Figure 49. This part of the survey covers the GUR 8 stock. The relative biomass estimates showed no trend, varying from 290 to 409 t, with CVs of 10.5–18.9%. The overall size range was also similar, with most of the catch between 25 and 45 cm (Figure 50). In 1991 and there was a distinct mode between 19–22 cm, believed to be slow growing 2 year old fish (Hanchet at al. 2000).

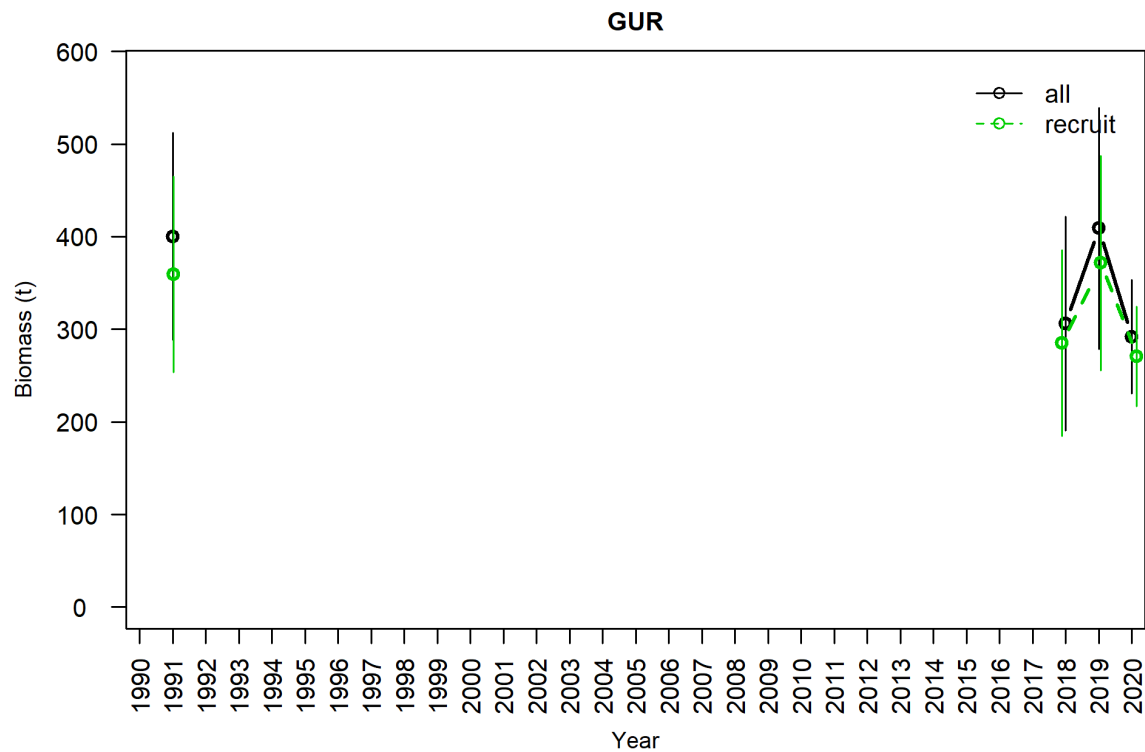


Figure 49: Total (black) and recruited (green) relative biomass estimates and 95% confidence intervals for red gurnard for the South Taranaki Bight (‘South’) time series.

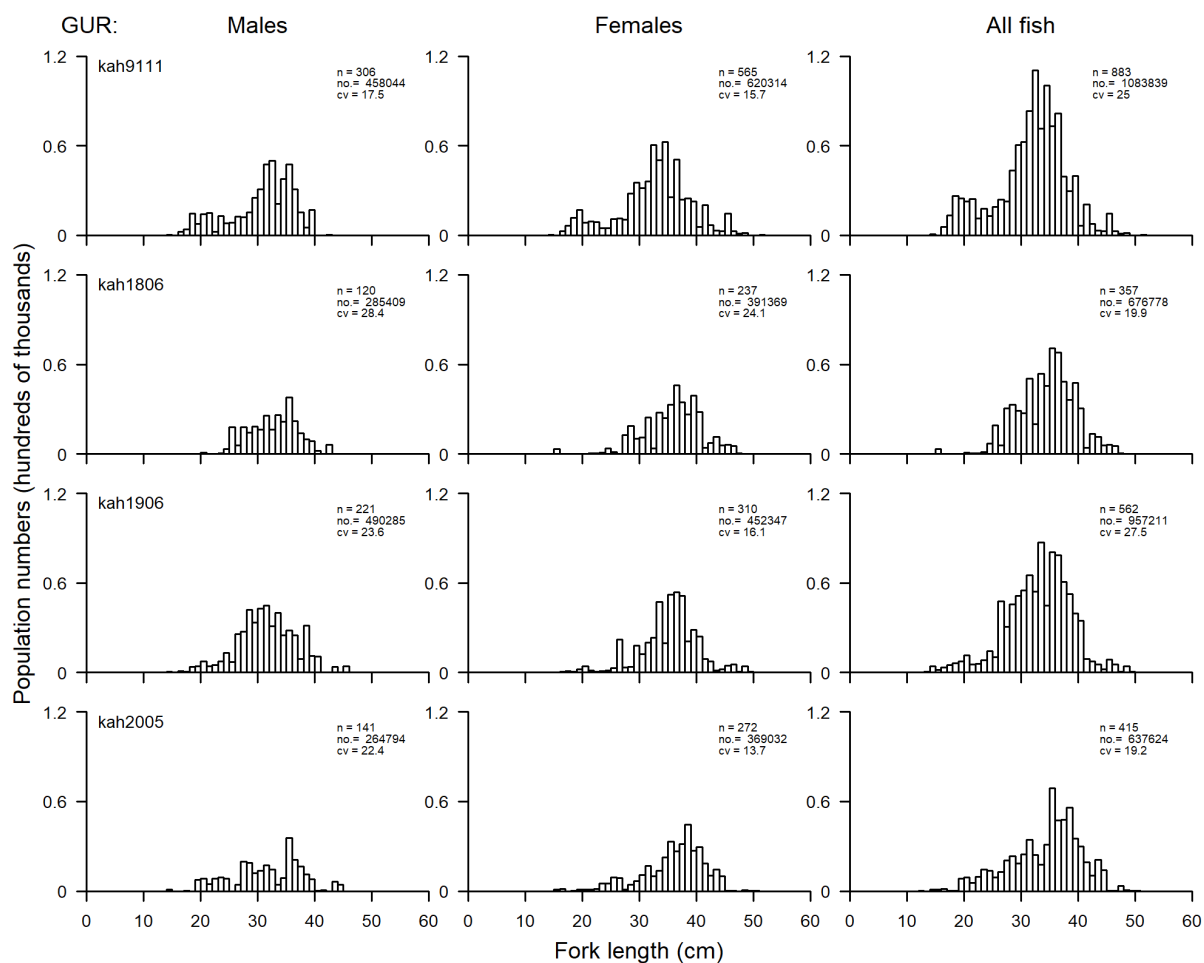


Figure 50: Comparative scaled length frequency distributions for males, females, and all red gurnard in the southern strata for the four WCNI surveys that included the South Taranaki Bight. n=number of fish measured, no.= scaled population number and CV=coefficient of variation. 'All fish' includes unsexed fish.

3.2.3 Tarakihi (NMP)

Number of surveys	8
Total catch weight (kg)	3500.8
Number measured	3678
Length range (mean) (cm)	7–53 (35.9)
Number weighed	1705

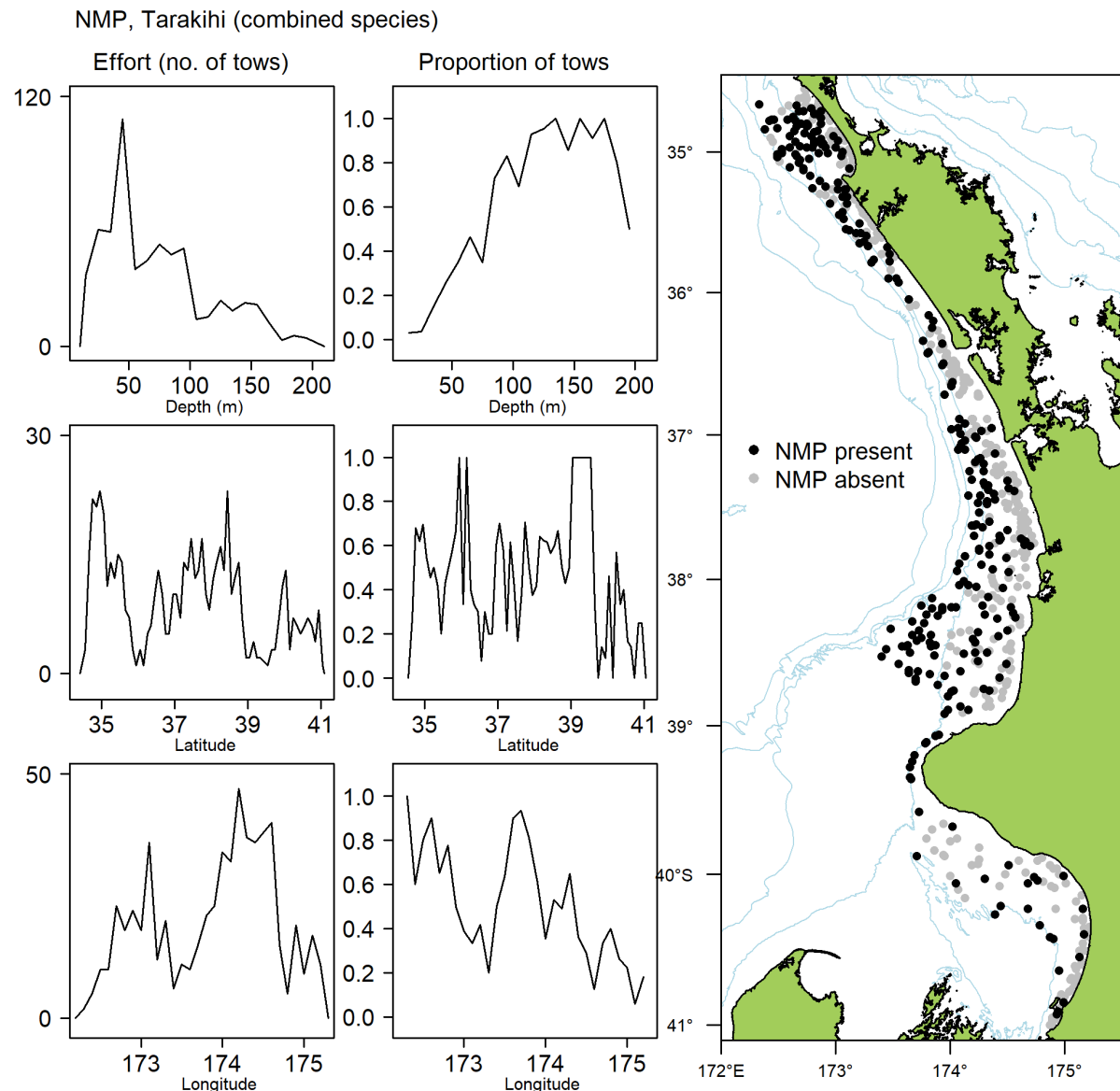


Figure 51: Summary of occurrence of tarakihi in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which tarakihi were caught. All valid tows are plotted in the map on the right with black dots showing those where tarakihi was present.

Tarakihi is a demersal fish found throughout New Zealand from 5–500 m (McMillan et al. 2019). The survey covers the western portion of TAR 1 as far north as Scott Point, and the TAR 8 stock. Occurrence in survey tows increased with increasing depth, being caught as shallow as 18 m, but highest occurrence at depths >100 m (Figure 51). Across the latitudinal range, catches peaked around 35–36° S (Northland and Ninety Mile Beach), and 38–39° S (North Taranaki Bight and Cape Egmont shelf break) and was lower at higher latitudes (South Taranaki Bight).

In reviewing the survey boundaries, Jones et al. (2022) noted that commercial catches of tarakihi extend north of Scott Point and around to the North Cape. This area is known to have rough topography and large areas unsuitable for bottom trawling, which is difficult to incorporate into a random trawl survey (Drury & Hartill 1993). The catches outside the survey boundary are an extension of an area of high catches off Ninety Mile Beach in A200, which is otherwise encompassed largely by the survey. The commercial fishery also extends outside the survey area in a narrow band along the shelf edge off Cape Egmont (close to 200 m depth contour), and out deeper than 100 m in the Cook Strait part of TAR 8. Plots illustrating the spatial distribution of tarakihi commercial catch are not presented here due to the resolution used for analysis being higher than permitted for publication, but similar fine scale plots are given by McKenzie et al. (2021). Although the survey doesn't adequately cover the full depth range of tarakihi, which extends to 500 m (MacMillan et al. 2019), it does cover the main depths of the commercial fishery (50–200 m).

The distribution of survey catch rates across the series is shown in Figure 52. Appropriate coverage of the deeper strata was limited prior to the 1996 survey. Even without full coverage, catch rates off Ninety Mile Beach were generally higher than elsewhere. In 1991, larger catches were also recorded off the Kaipara Harbour, North Taranaki Bight, and Cape Egmont. From 1996 onwards, coverage of the depths greater than 100 m in the northern area was more consistent. Higher catch rates were concentrated in the A and B strata, along with variable catches in the North Taranaki Bight (F200). Catch rates off Cape Egmont and the South Taranaki Bight were also variable.

NMP, Tarakihi (combined species)

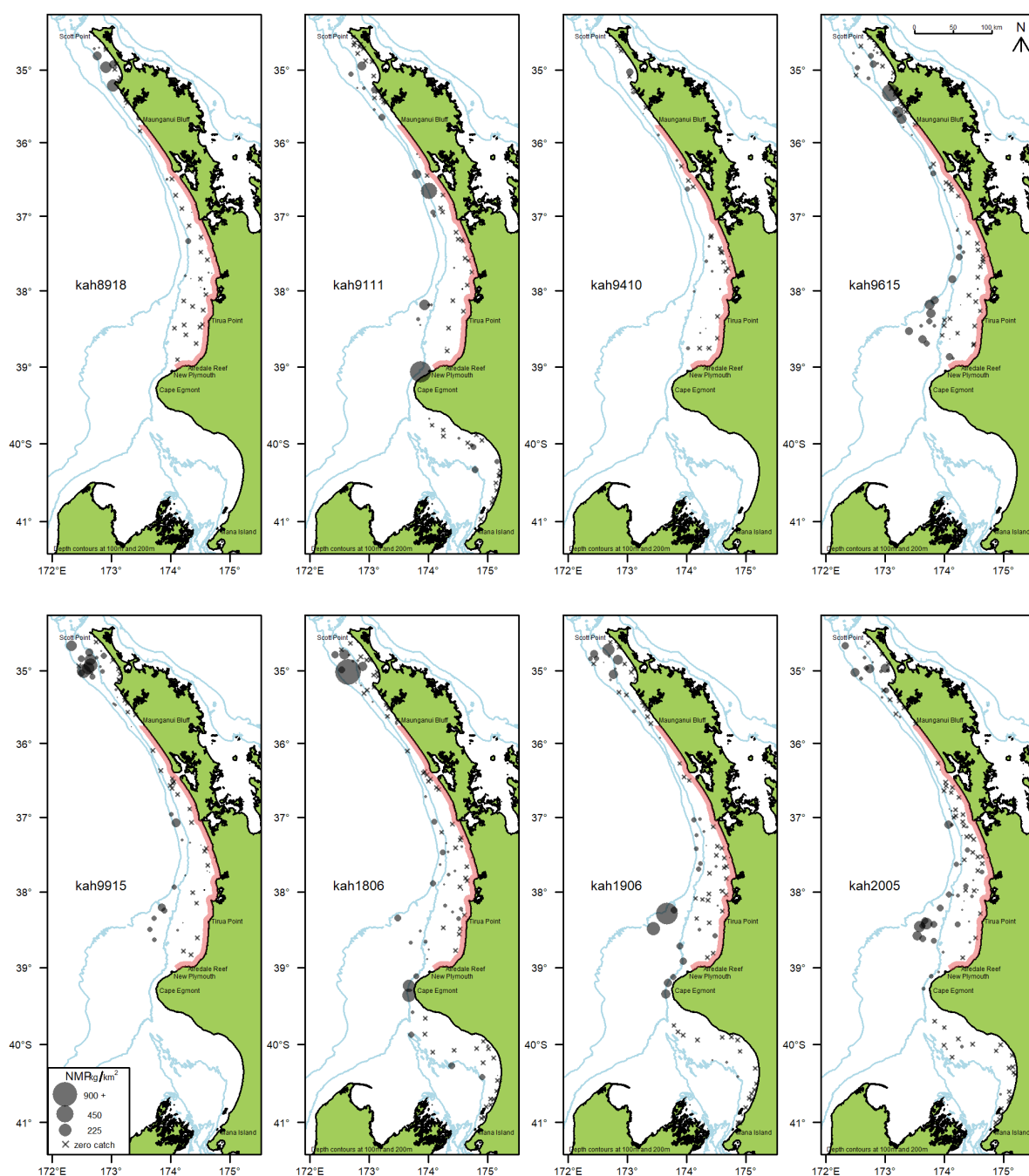


Figure 52: Spatial distribution of catch rates (kg km^{-2}) of tarakihi in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

The relative biomass indices for three series (core, extended core, and whole survey) are shown in Figure 53, with estimates and CVs tabulated in Table 17. In the core area, biomass estimates fluctuated between around 100–270 t, except for a series low in 1999 of 51 t. The CVs in some of the re-estimated historical surveys were well above target (20–25%), improving to 27–32% in the more recent surveys. The extended core series included the deeper strata, elevating biomass estimates to around 500–600 t, but still with relatively large CVs (apart from the 2020 survey) and no clear overall trend. The highest estimate in this series was from the 2019 survey, driven mainly by a several relatively large catches in F200.

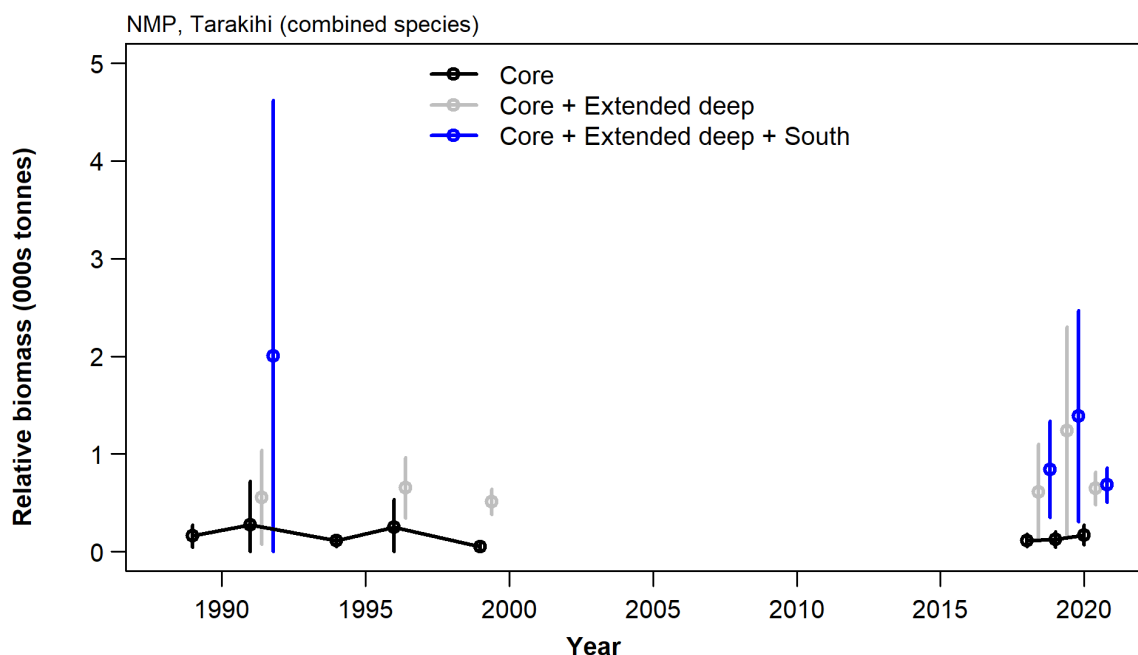


Figure 53: Time series of relative biomass estimates and 95% confidence intervals for tarakihi for the northern core area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 17: Relative biomass estimates (t) and CVs (%) of tarakihi for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass (t)	Core CV	Extended core biomass (t)	Extended ce CV	South biomass (t)	South CV	Whole survey biomass (t)	Whole survey CV
kah8918	160.5	36.36						
kah9111	272.1	83.01	556.3	43.22	1 508.0	85.31	2 064.31	63.4
kah9410	111.4	26.80						
kah9615	248.3	57.88	654.6	23.88				
kah9915	51.1	27.22	511.4	12.64				
kah1806	115.7	28.46	609.7	40.14	277.8	44.65	887.55	30.91
kah1906	125.9	32.20	1 237.1	43.13	151.6	58.31	1 388.6	38.95
kah2005	170.6	30.51	647.9	13.10	32.7	39.83	682.3	13.12

The CPUE index of commercial bottom trawl for TAR 1 West, as described by Langley (2017b), is restricted to the northern Statistical Areas 045–047, which is where most commercial fishing occurs. This index was updated to the 2019–20 fishing year and shows an overall decline over the time period, particularly since 2014–15 (Figure 54). The combined stratum biomass estimates for A, B, and C strata (50–200 m) also show a decline in biomass in the two recent surveys compared with the historical surveys, but the C strata boundaries extend further south than the statistical area boundaries of the commercial index and so are not completely comparable. For a more direct comparison, trawl survey stations falling inside Statistical Areas 045–047 and between 50–200 m were selected and analysed with a similar two-step GLM approach to produce an equivalent trawl survey index, that also showed a decline in biomass in more recent surveys compared with the 1996 and 1999 surveys.

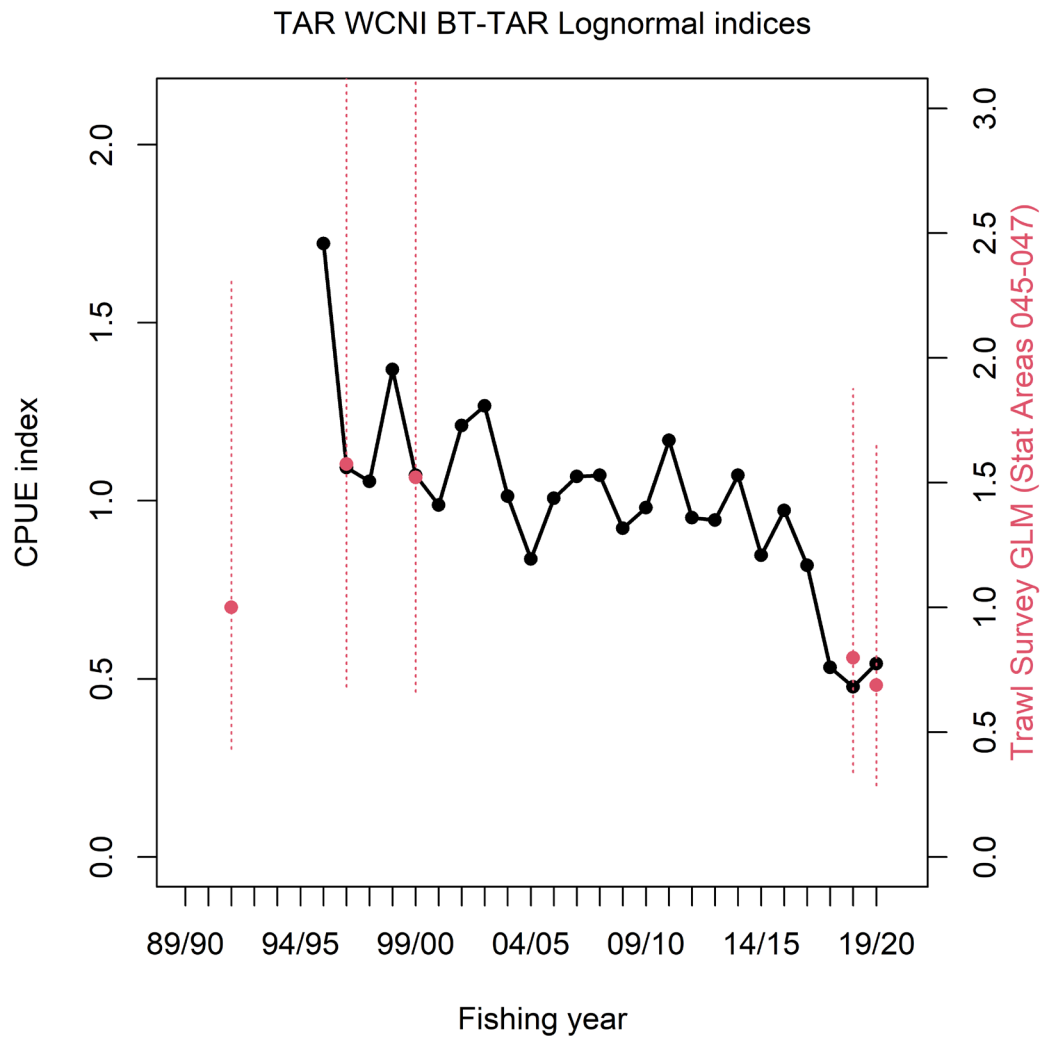


Figure 54: CPUE index of the WCNI commercial bottom trawl fishery (TAR 1W) for Statistical Areas 045-047 (black), overlaid with GLM-derived biomass estimates from trawl survey stations located within the same combined statistical areas (red) with CVs. (Source: Langley 2017b.)

Table 18 provides a summary of catch, length range, and mean length by survey. The size range encompasses recently settled pre-recruits <10 cm in length up to 50+ cm, covering the full range of the species. However, the numbers of fish caught below 30 cm were low, particularly in the recent surveys, with the main modal peaks at 36–40 cm (Figure 55). Smaller modes were present in 1996 at around 22 and 32 cm, in 1999 at around 30 cm, and in 2018 and 2020 at around 32 cm. Overall mean lengths varied between 34 and 35 cm in historical surveys, increasing slightly to 36–38 cm in the more recent surveys. Figure 55 shows that females tended to be larger than males and were more numerous in all surveys.

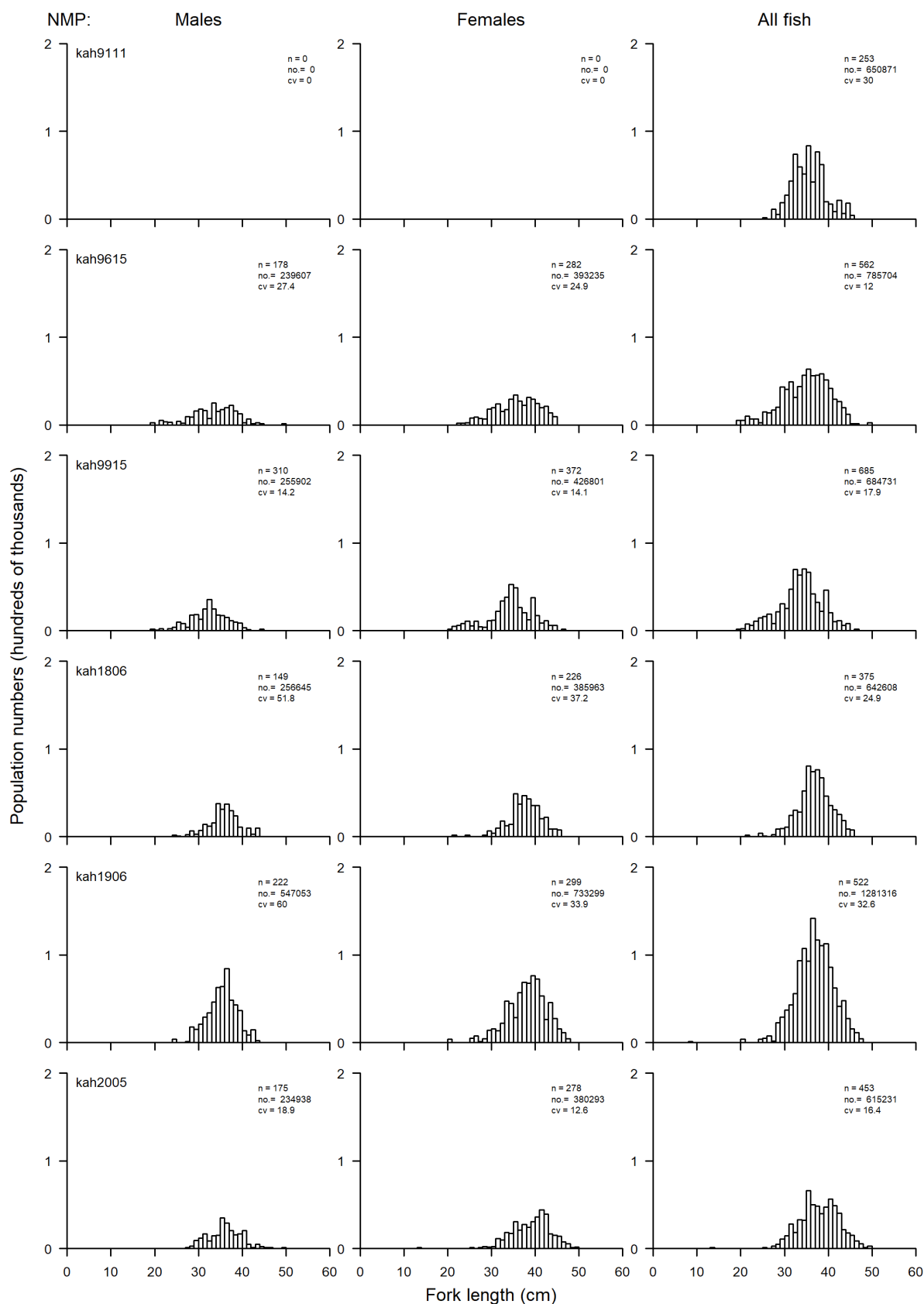


Figure 55: Comparative scaled length frequency distributions for males, females and all tarakihi in the extended northern strata for the WCNI surveys that included the 100–200 m depth range. n=number of fish measured, no.=scaled population numbers. and cv= coefficient of variation. ‘All fish’ includes unsexed fish.

Table 18: Summary of catch weight and length measurements of tarakihi by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	160	15	46	34.92	128
kah9111	485.8	7	48	35.08	469
kah9410	67.3	15	45	35.03	73
kah9615	506.5	20	50	35.03	587
kah9915	503	20	47	33.93	685
kah1806	677.4	16	47	36.15	667
kah1906	586.7	9	53	36.95	599
kah2005	514.1	14	51	38.70	470

Relatively few tarakihi were caught in the southern area, with a declining trend in the recent surveys (Table 17). The higher biomass in the 1991 survey was attributed to a single station just to the north of Cape Egmont, included in the original G100 stratum. The scaled length frequency distributions for this survey had a noticeable proportion of larger fish at 40–50 cm (Figure 56), but, in the more recent surveys, a similar size range was observed to that seen further north.

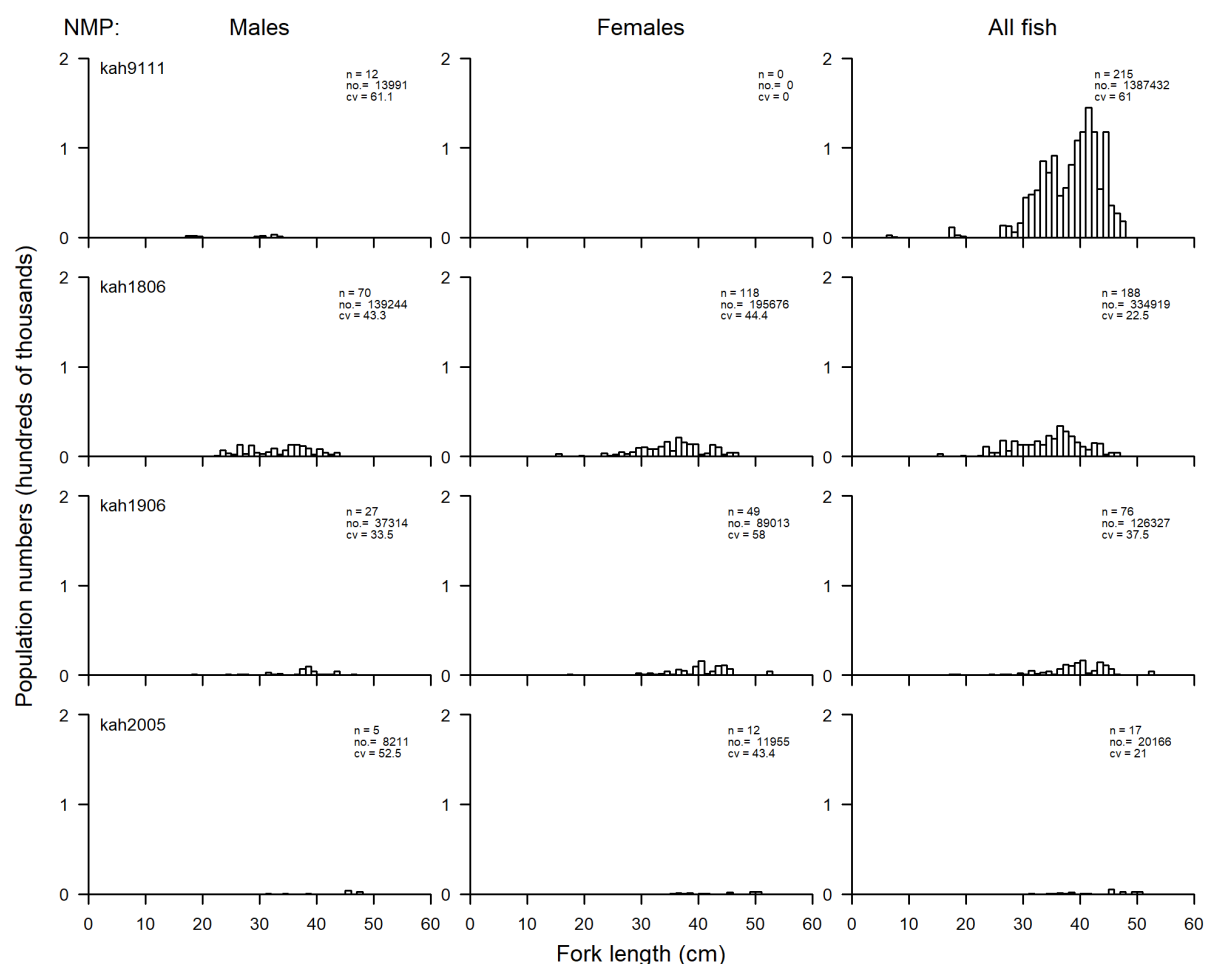


Figure 56: Comparative scaled length frequency distributions for males, females and all tarakihi in the southern strata for the four WCNI surveys that sampled the South Taranaki Bight. n=number of fish measured, no.=scaled population number and cv=coefficient of variation. 'All fish' includes unsexed fish.

Figure 57 provides the scaled length frequency distributions for male, female, and all fish sampled from the commercial catch sampling of the TAR 1 WCNI in the 2018–19 and 2019–20 fishing years (McKenzie et al. 2021). The commercial catch size range was mainly between 25 and 48 cm, with very few fish under 30 cm, and was very similar to the survey catch distribution (Figure 55). The smaller mode at around 32 cm observed in the 2018 trawl survey was also present in the commercial catch data in both years. Figure 58 provides a length frequency distribution for TAR 8 from the New Plymouth region only (sampling in much of the STB region was excluded in this sampling design). The size range was similar to further north, but with larger numbers of smaller tarakihi < 30 cm present in 2018–19 in particular. Overall, the trawl survey length composition is consistent with recent catch sampling from the TAR 8 and TAR 1 WCNI fisheries.

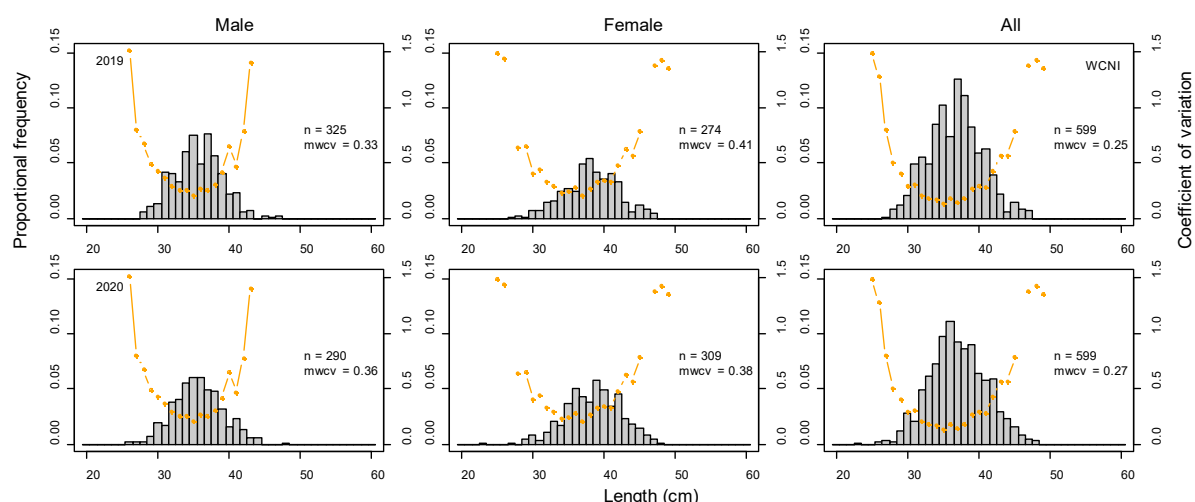


Figure 57: Scaled length frequency distributions and coefficient of variation for each length class for WCNI (TAR 1W) bottom trawl landings by sex and combined sexes in 2018–19 and 2019–20. (Source: McKenzie et al. 2021.)

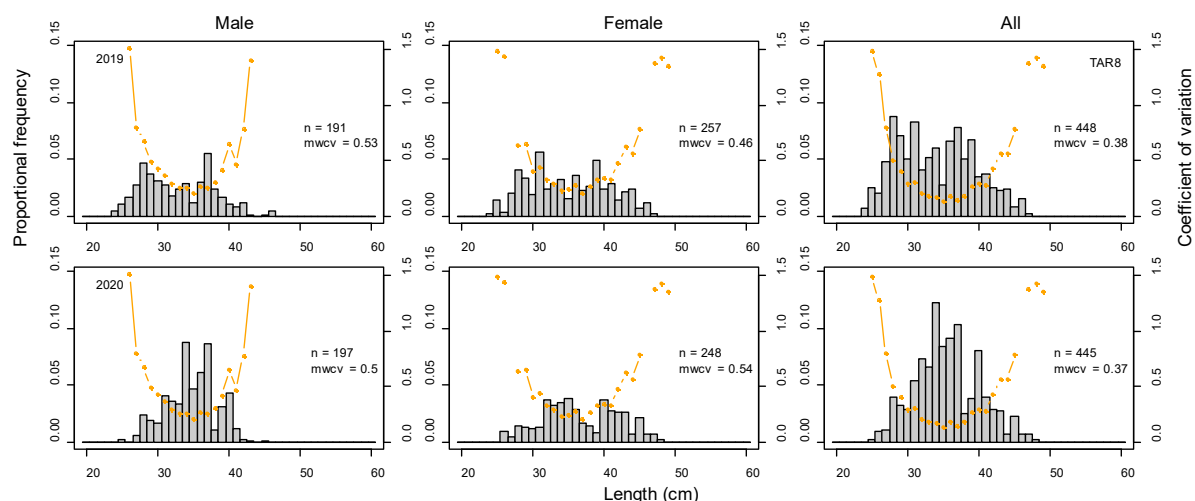


Figure 58: Scaled length frequency distributions and coefficient of variation for each length class for TAR 8 (New Plymouth) bottom trawl landings by sex and combined sexes in 2018–19 and 2019–20. (Source: McKenzie et al. 2021.)

Most tarakihi sampled were immature or resting during the survey period, with no ripe or running ripe fish observed in any survey (Table 19).

Table 19: Proportion of sampled tarakihi with gonads at different reproductive stages by survey. Note that for the 1999, a different maturity scale was used (Tong & Vooren 1972) but stages are equivalent to the currently used middle depth stages (gonad stages are defined in Appendix 4).

Year	Maturity Stage							Sample size
	1	2	3	4	5	6	7	
Female								
kah9915	0.12	0.88	0.00	0	0	0	0.00	250
kah1806	0.10	0.85	0.01	0	0	0	0.04	258
kah1906	0.03	0.97	0.00	0	0	0	0.00	256
kah2005	0	0.98	0.01	0	0	0	0.00	288
Male								
kah9915	0.25	0.72	0.02	0	0	0	0.01	178
kah1806	0.28	0.70	0.01	0	0	0	0.01	141
kah1906	0.08	0.90	0.01	0	0	0	0.00	156
kah2005	0.03	0.96	0.01	0	0	0	0.00	178

3.2.4 John dory (JDO)

Number of surveys	8
Total catch weight (kg)	2792
Number measured	2934
Length range (mean) (cm)	9–58 (34.75)
Number weighed	1503

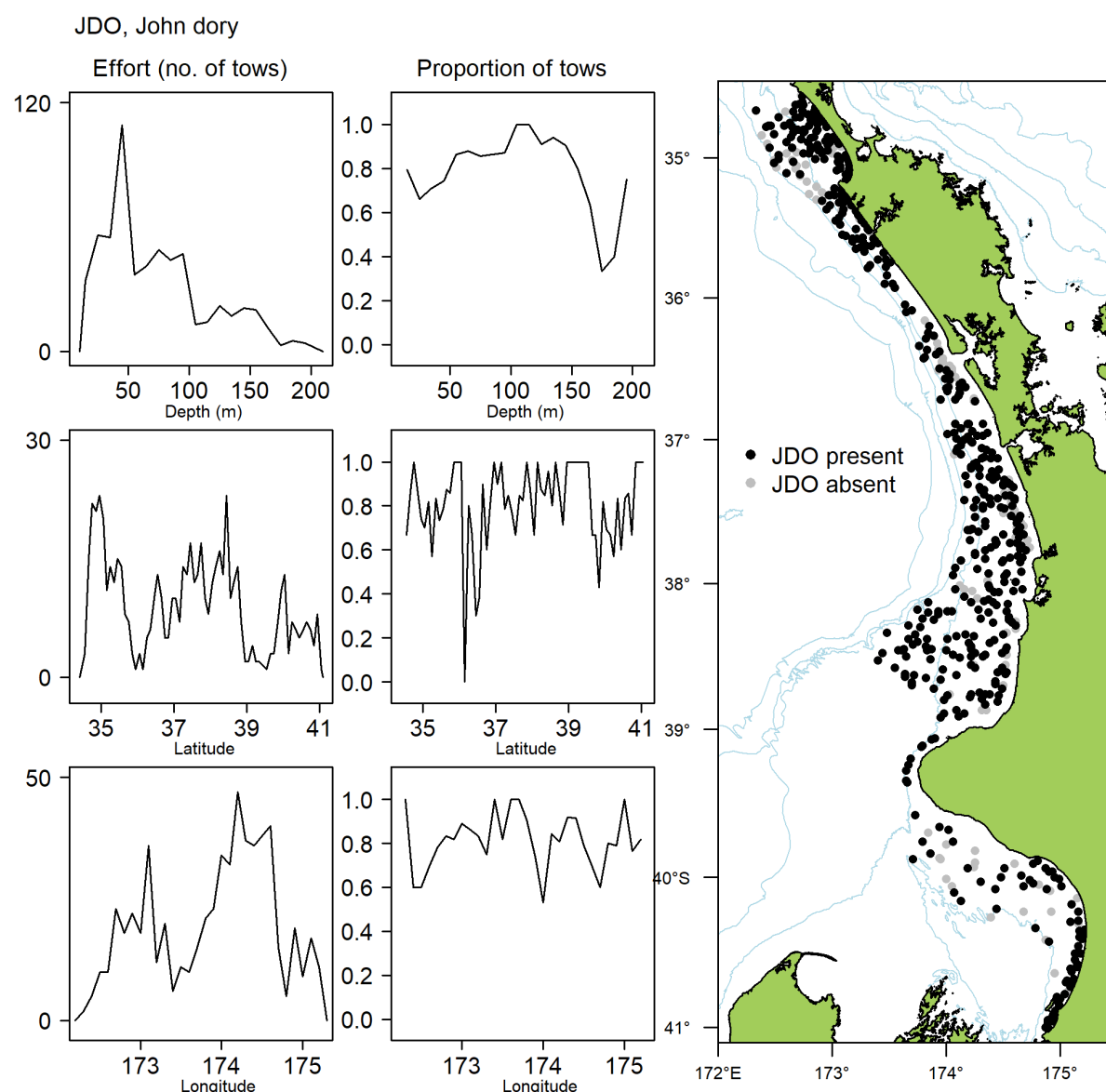


Figure 59: Summary of occurrence of John dory in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which John dory were caught. All valid tows are plotted in the map on the right with black dots showing those where John dory was present.

John dory is widespread around New Zealand, particularly from the Cook Strait northwards, and is found from shallow depths down to 300 m (McMillan et al. 2019). The survey covers the west coast components of JDO 1 and JDO 2, believed likely to be a single west coast stock (Dunn & Jones 2013). It was caught in 50–150 m across the whole survey area (Figure 59). Areas of highest catch rates varied between surveys (Figure 60). Higher catch rates were encountered in A100 in 2018, C100, D100, and E100 in all surveys, and along the Kapiti coast. The large 50–100 m strata made the largest contribution to the total relative biomass estimates, including E100, C100, F100, and G10M.

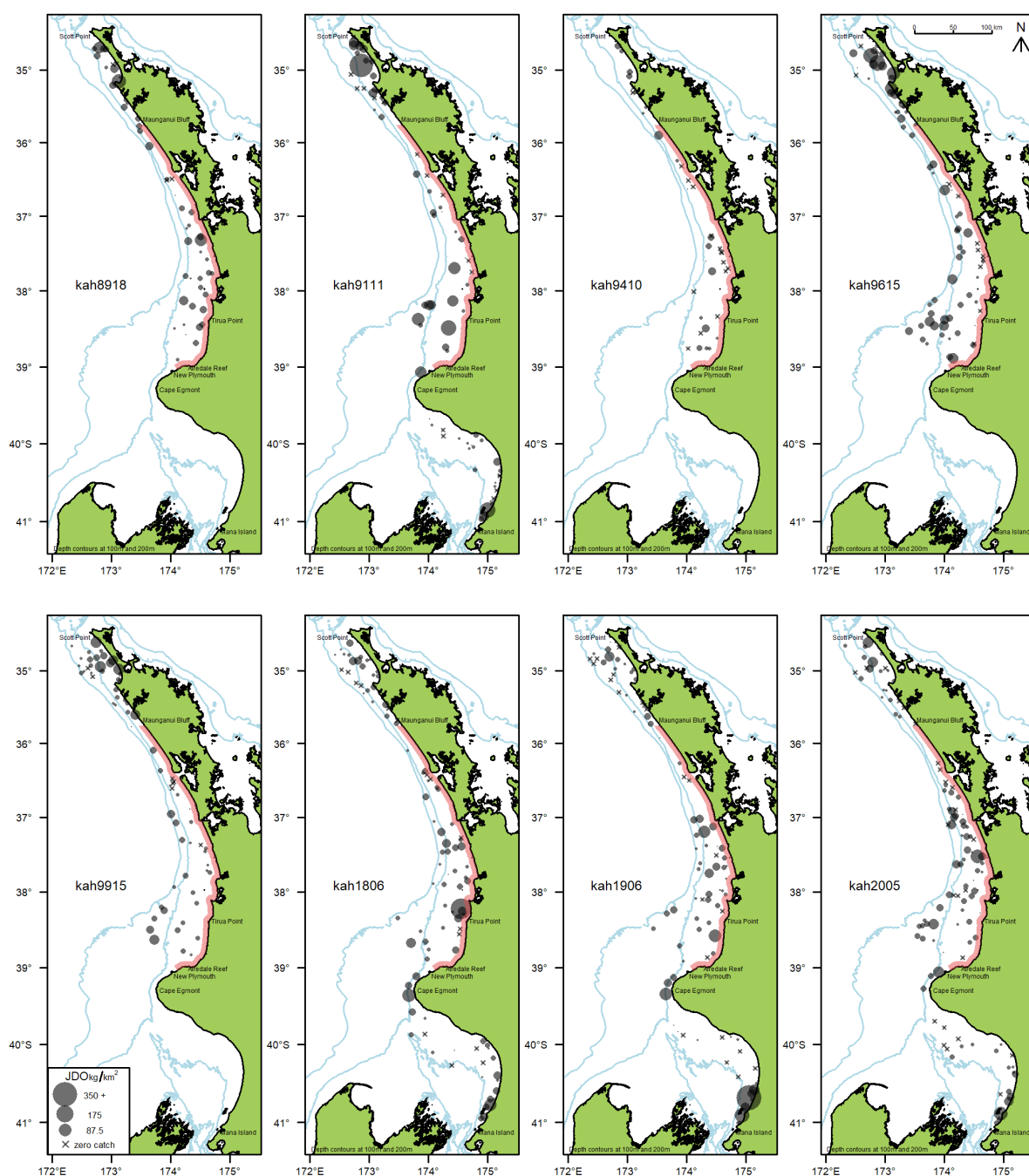


Figure 60: Spatial distribution of catch rates (kg km^{-2}) of John dory in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

Relative biomass estimates for the core, extended core, and whole survey are shown in Figure 61. Biomass within the core area has fluctuated historically, but once the deeper strata were included there was a declining trend. In the whole area (core + extended deep + south) time series, the 1991 John dory relative biomass was approximately double the more recent estimates (Figure 61, Table 20), but with moderately high variance due to some large catches off Ninety Mile Beach and along the Kapiti coast. Whilst the 2018 survey estimates were slightly higher than those of the 1999 survey, there were declines in all series in the three most recent surveys (Figure 61). The CVs indicated that biomass was well estimated, with the revised CVs varying from 10 to 30% in the core area, and $< 25\%$ in the extended core and across the whole survey (Table 20). The South Taranaki Bight strata contributed between 19–26% of the total biomass.

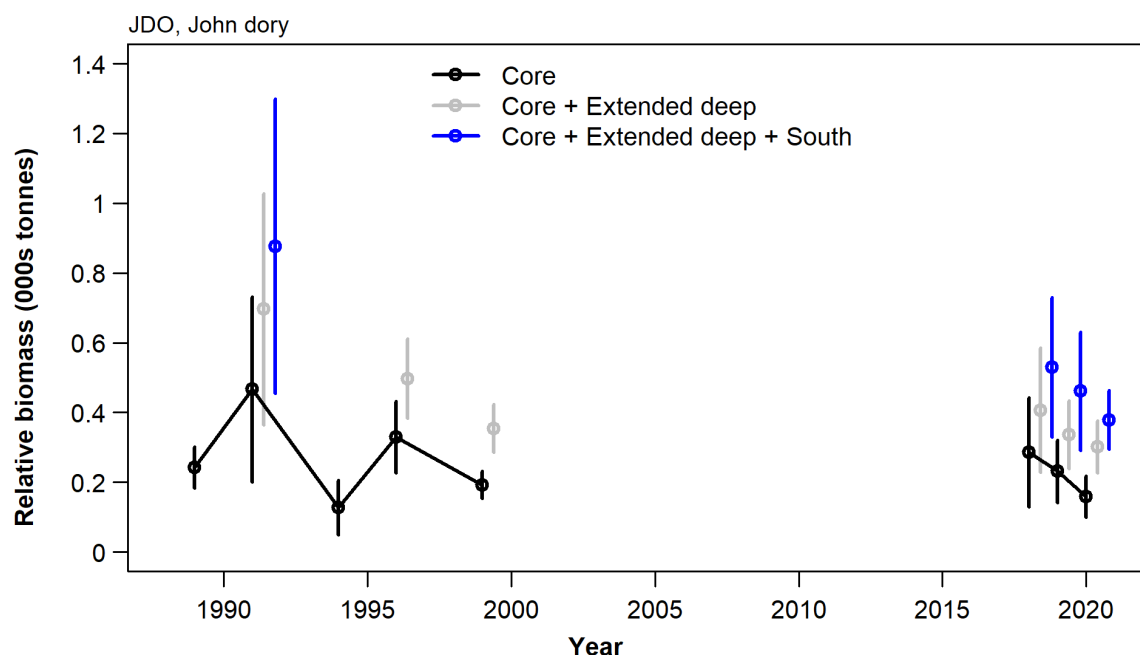


Figure 61: Time series of relative biomass estimates and 95% confidence intervals for John dory for the northern core area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 20: Relative biomass estimates (t) and CVs (%) of John dory for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	242.24	12.20						
kah9111	466.15	28.54	696.18	23.83	207.05	63.08	903.23	23.30
kah9410	127.38	31.02						
kah9615	328.93	15.66	497.15	11.52				
kah9915	192.58	9.96	354.49	9.74				
kah1806	285.19	27.50	406.51	21.98	124.69	36.20	531.20	18.84
kah1906	231.00	19.46	336.96	14.47	124.27	55.93	461.23	18.41
kah2005	158.65	18.43	301.94	12.41	73.26	23.62	378.88	11.04

The commercial fishery off the west coast is reported as occurring largely between 25 and 100 m depths, from Cape Reinga to Cape Egmont, with highest catches reported from the North Taranaki Bight (Statistical Area 041), Ninety Mile Beach (Statistical Area 047) and between the Kaipara and Manukau harbours (Statistical Area 042 and 045) (Langley 2018). This is well covered by the trawl survey. The CPUE index was updated in 2022 using a delta-lognormal model (Fisheries New Zealand 2022). Figure 62 compares the trawl survey core recruited biomass time series to the CPUE trend in JDO 1 over the same periods. There is a similar declining trend in the CPUE in the mid-nineties to 2000. Both the most recent CPUE and trawl survey indices appear to be at a similar level to those in 2000. Whilst the most recent downward trend in trawl survey biomass was not observed in the CPUE, the two series were deemed to have good overall correspondence (Fisheries New Zealand 2022).

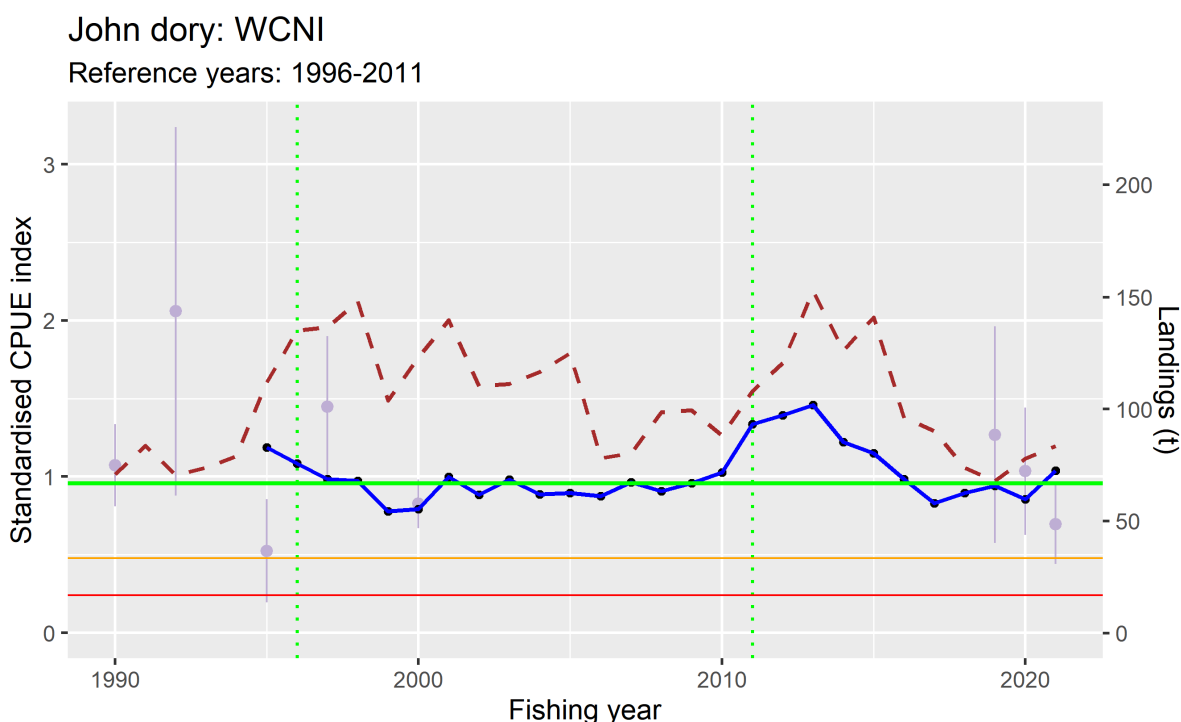


Figure 62: Standardised CPUE indices for John dory in West Coast North Island from combined binomial and lognormal models of catch rate in bottom trawl tows (blue line). Solid horizontal lines indicate the target (green), soft limit (orange), and hard limit (red). The commercial catch from the area (dashed brown line), and trawl survey recruited biomass indices (purple with error bars $\pm$ two standard deviations). (Source: Fisheries New Zealand 2022.)

The size range of John dory caught in the WCNI surveys was 9–58 cm and covers the full size range known from New Zealand. Mean length has been consistently from 34 to 36 cm, except in 1994 when mean length was lower (Table 21). The population scaled length frequency distributions for the northern core area show multiple modes representing both pre-recruit (0+ and 1+) and recruited fish in all surveys, although the individual surveys suggest that pre-recruited fish were more prominent in historical surveys (Figure 63). Females were more numerous in the earlier surveys, with a switch to male dominated populations from 1996 onwards. The scaled length frequency distributions for the extended northern area were very similar to those for the core series (Figure 64).

The catches of John dory around and to the south of Cape Egmont were generally low, but the size range was similar, 11–52 cm, with pre-recruited fish more abundant in the 1991 survey than in the three more recent ones (Figure 65), and greater numbers of larger fish (> 40 cm) than further north.

Table 21: Summary of catch weight and length measurements of John dory by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	301.9	14	58	35.35	303
kah9111	446.1	13	55	34.40	417
kah9410	110.7	12	52	30.40	171
kah9615	490.8	9	58	35.52	479
kah9915	290.0	15	54	34.66	339
kah1806	401.3	14	54	35.73	437
kah1906	386.4	10	54	34.91	363
kah2005	364.8	10	52	34.34	425

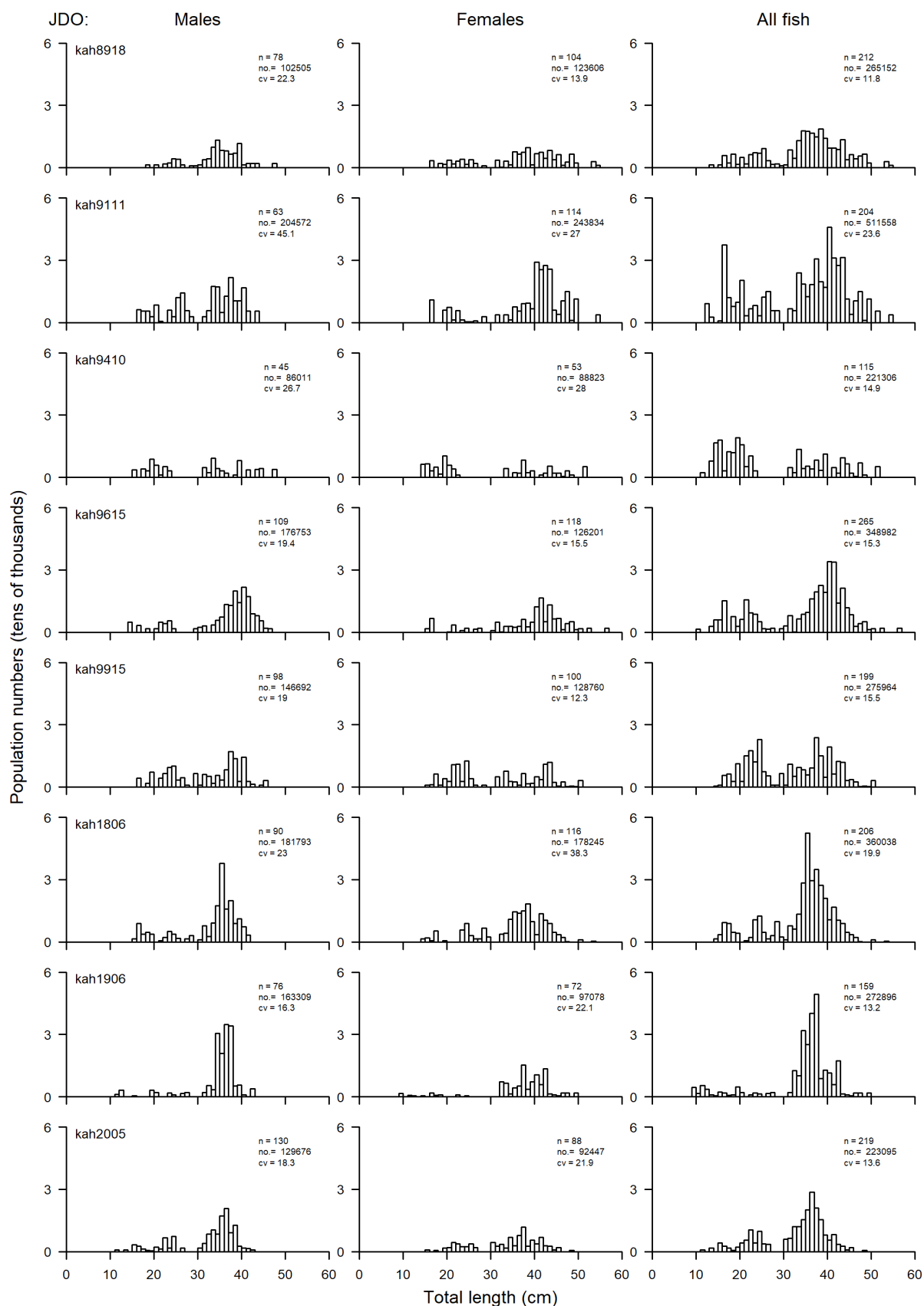


Figure 63: Comparative scaled length frequency distributions for males, females and all John dory in the northern core strata (< 100 m) for the WCNI survey time series. n=number of fish measured, no.=scaled population number and cv=coefficient of variation. 'All fish' includes unsexed fish.

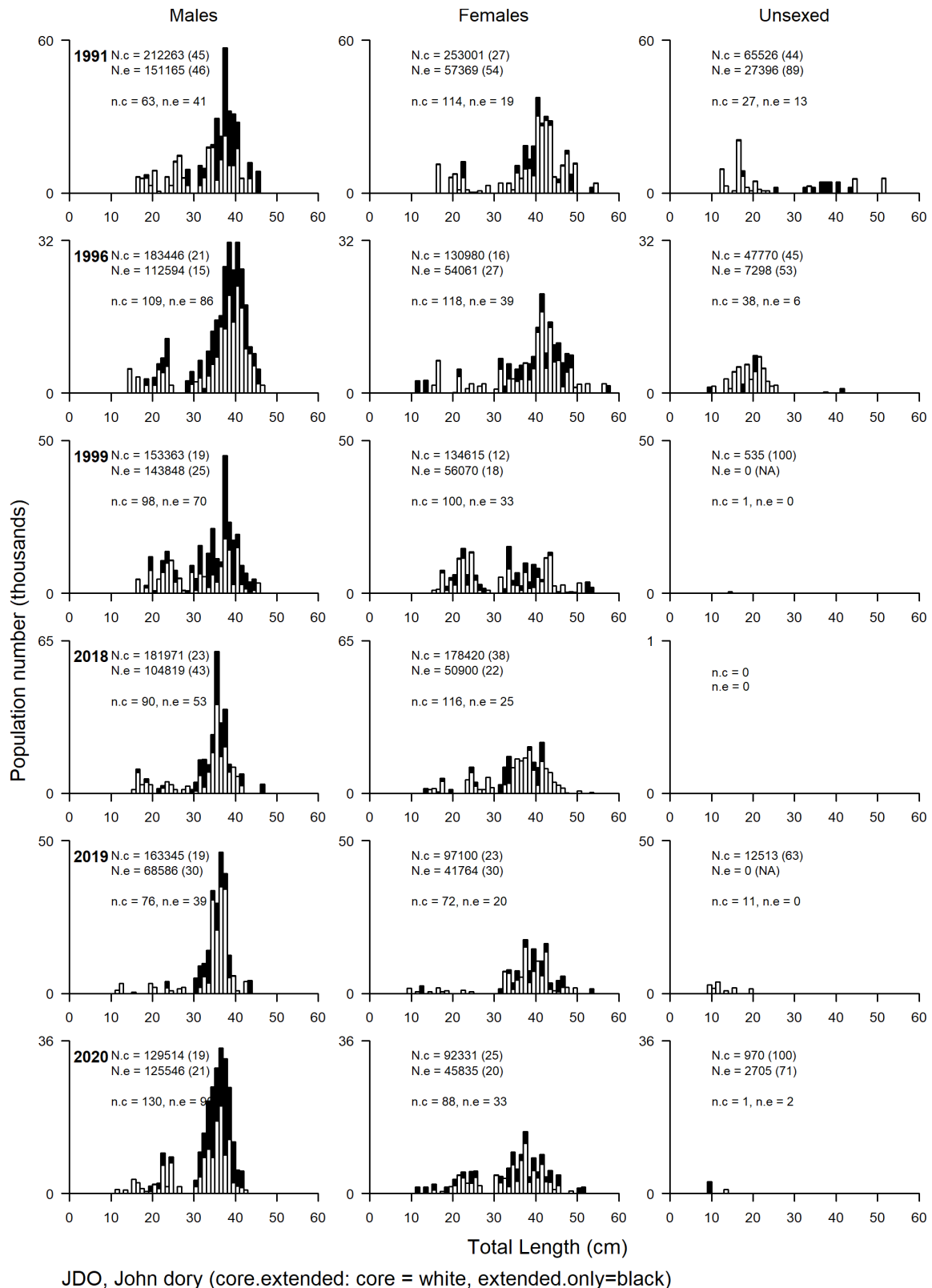


Figure 64: Comparative scaled length frequency distributions for males, females, and unsexed John dory from the core (white) and extended deeper strata (black) for the WCNI surveys that included the 100–200 m depth range. N.c.=scaled population number and CV (in brackets) for the core. N.e.=scaled population numbers for the extended strata. n.c=number of fish measured from core. n.e=number of fish measured in the extended strata. Note the different scales for population numbers in different surveys.

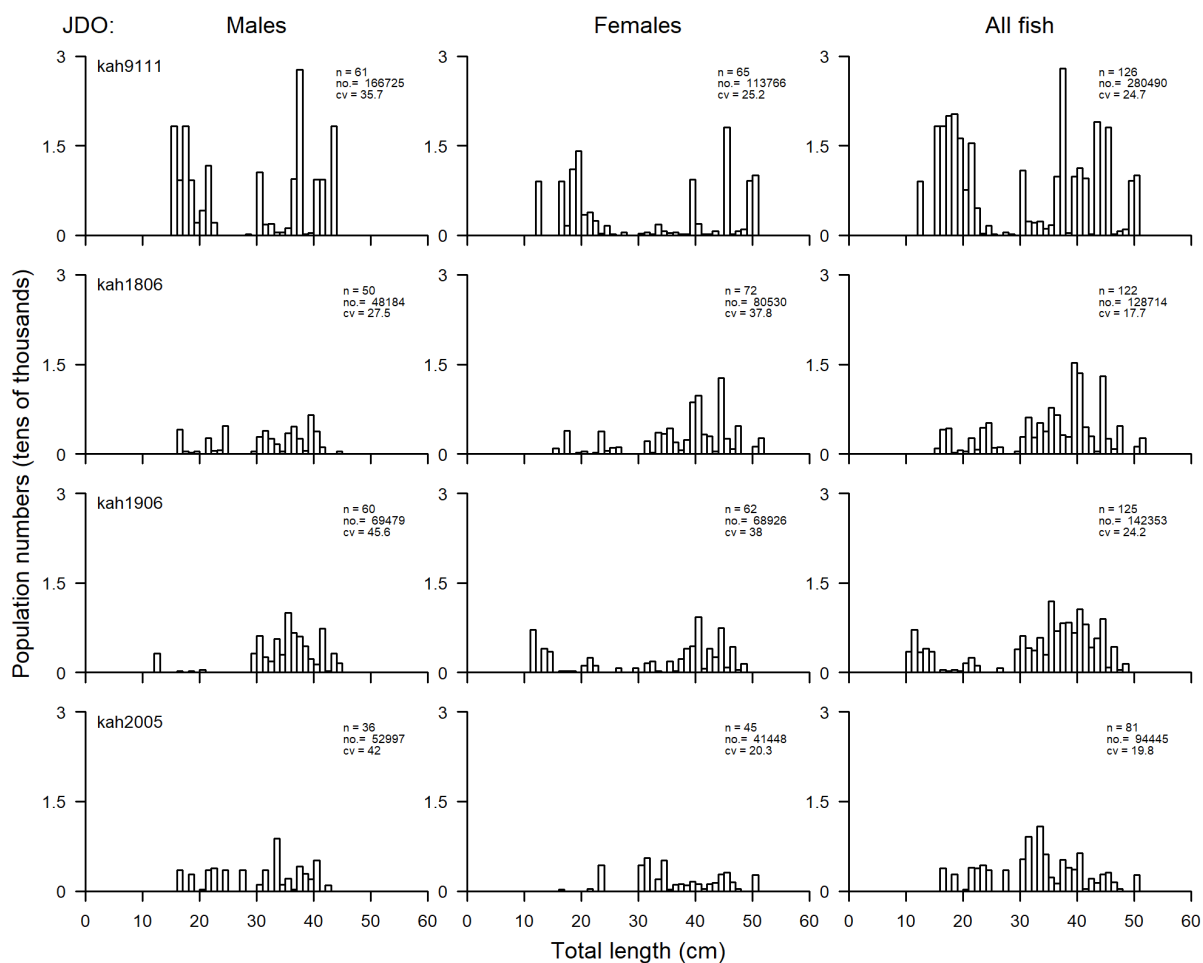


Figure 65: Comparative scaled length frequency distributions for males, females and all John dory in the southern strata for the four WCNI surveys that included the South Taranaki Bight. N=number of fish measured, no.=scaled population number and cv=coefficient of variation. 'All fish' includes unsexed fish.

In the years when maturity stage was assessed, between 51 and 66% of the females sampled were ripening or ripe (stages 3 or 4), suggesting that fish were pre-spawning at the time of the survey (Table 22).

Table 22: Proportion of sampled John dory with gonads at different reproductive stages by survey. Note that for 1999, a different maturity scale was used (Hore 1982) and stages were converted to equivalent middle depths stages (Gonad stages are defined in Appendix 4).

Year	Maturity Stage							Sample size
	1	2	3	4	5	6	7	
Female								
kah9915	0.02	0.41	0.23	0.28	0.05	0.01	0.01	150
kah1806	0.10	0.13	0.63	0.03	0.00	0.00	0.10	230
kah1906	0.12	0.15	0.64	0.01	0.00	0.00	0.08	163
kah2005	0.06	0.27	0.54	0.02	0.01	0.07	0.02	165
Male								
kah9915	0.10	0.56	0.31	0.02	0.01			162
kah1806	0.14	0.21	0.48	0.17	0.01	0.00	0.00	199
kah1906	0.10	0.41	0.29	0.17	0.03	0.00	0.00	182
kah2005	0.04	0.13	0.32	0.50	0.00	0.00	0.00	252

3.2.5 Trevally (TRE)

Number of surveys	8
Total catch weight (kg)	12 412.1
Number measured	13 903
Length range (mean) (cm)	3–66 (32)
Number weighed	1170

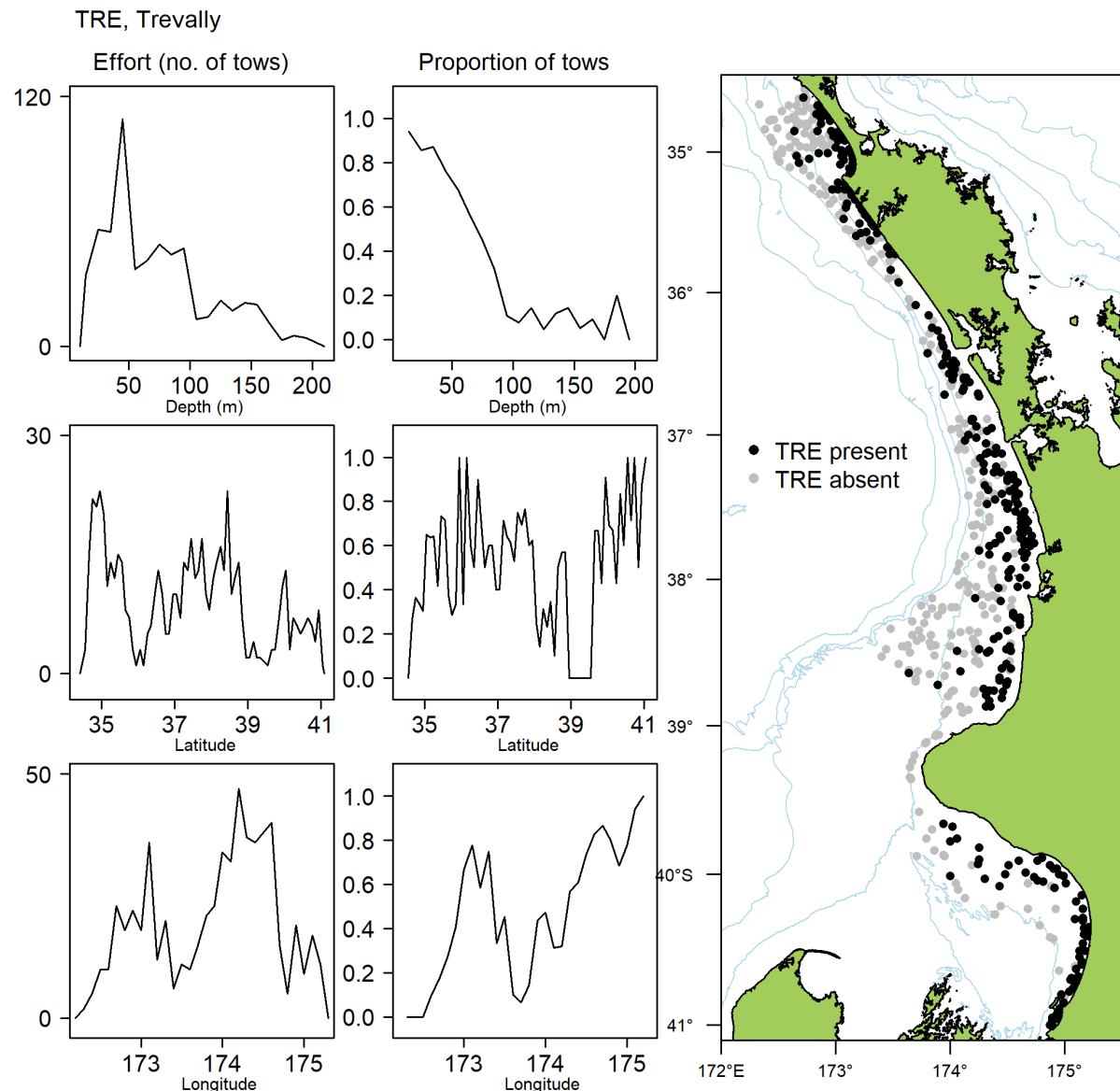


Figure 66: Summary of occurrence of trevally in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which trevally were caught. All valid tows are plotted in the map on the right with black dots showing those where trevally were present.

Trevally is widespread in central and northern New Zealand with a depth range from very shallow down to 240 m and can be both pelagic and demersal (MacMillan et al. 2019). This species was caught throughout the latitudinal range of the survey, usually in tows shallower than 100 m and most common in depths < 50 m (Figure 66). North of Hokianga Harbour and at the southern end of the South Taranaki Bight, their occurrence was tightly restricted to shallow depths, but the Māui dolphin trawl exclusion zone truncates coverage in the central part of the survey. There was also a gap in occurrence around

Cape Egmont, where there were limited shallow stations due to the extremely steep and narrow topography in this part of the survey. Overall, the survey provides good geographic coverage of the species in this northern part of the TRE 7 stock, including the three known fishing areas: Ninety Mile Beach (NMB), South Taranaki Bight (STB), and the core area of the fishery between North Taranaki Bight and Tauroa Point (KMNTB) (Fisheries New Zealand 2021).

Catch rates were patchy, likely due to variable catchability based on environmental conditions. The highest rates generally occurred off Ninety Mile Beach, around the Kaipara Harbour and South Taranaki Bight, with lower catches in the central part of the survey. These areas reflect the commercial fishing areas (Figure 67). The survey tow speed is not optimal for this species, and net avoidance is likely.

TRE, Trevally

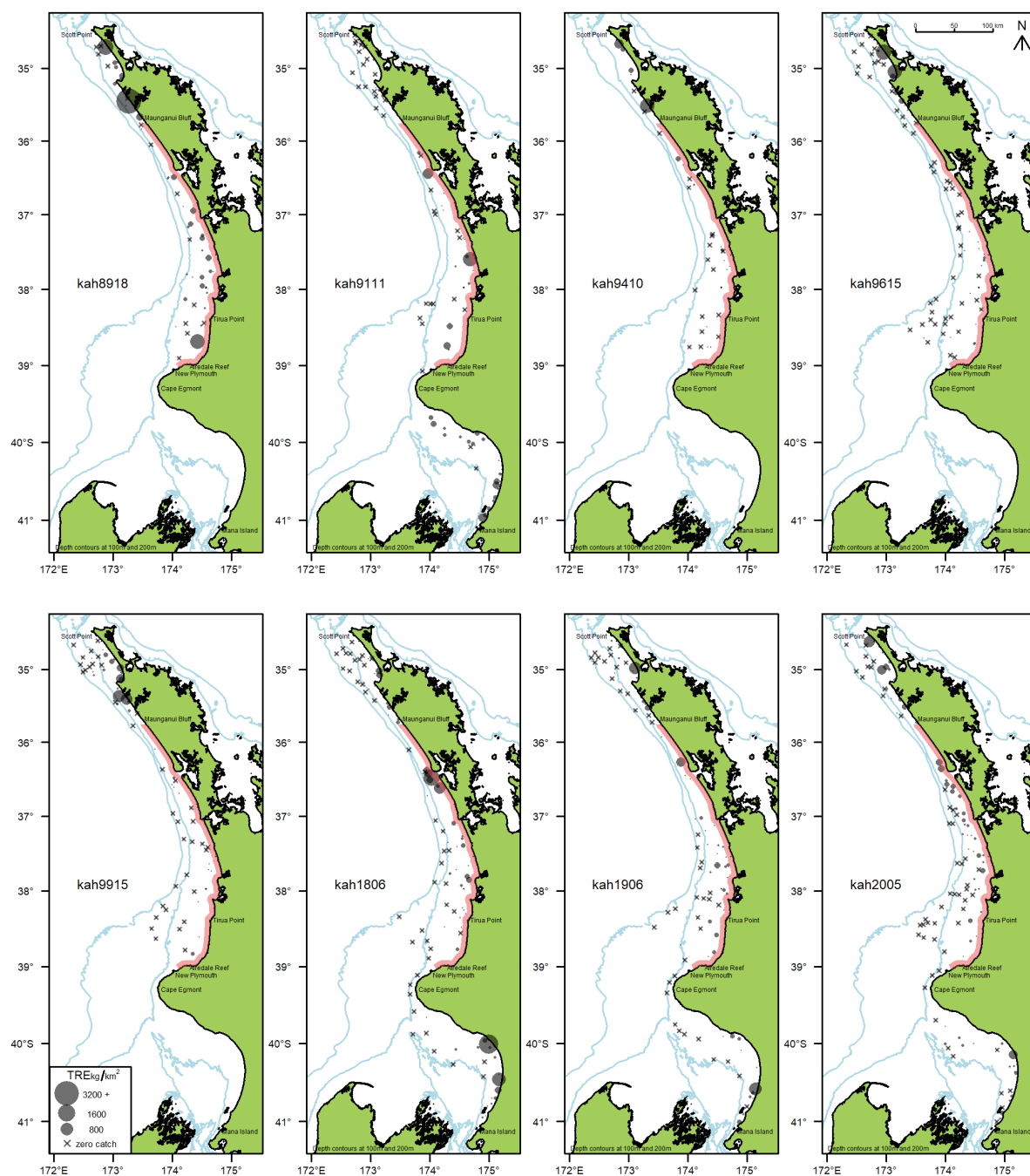


Figure 67: Spatial distribution of catch rates (kg km^{-2}) of trevally in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

Adjusted relative biomass estimates for the survey time series are plotted in Figure 68 and values and CVs are provided in Table 23. The whole survey series indicated very similar estimates for both the 1991 and recent surveys. In the northern core area, a series minimum was recorded in 1996, but recalculated historical estimates had moderate to high CVs (31–57%). In the more recent years, CVs were between 22.6% and 31.5%, suggesting that future surveys could estimate biomass moderately well. The extended core series added little due to the shallow occurrence of this species.

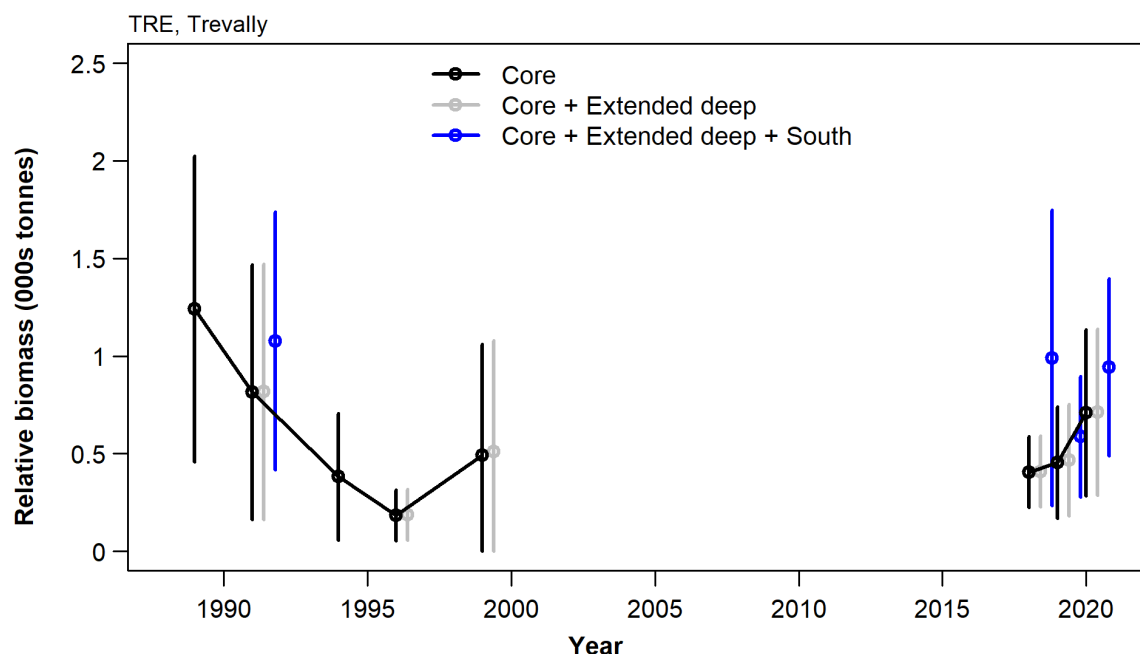


Figure 68: Time series of relative biomass estimates and 95% confidence intervals for trevally for the northern core area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 23: Relative biomass estimates (t) and CVs (%) of trevally for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	1 241.53	31.55						
kah9111	815.44	40.10	817.22	40.01	261.32	17.26	1 078.54	30.61
kah9410	382.50	42.49						
kah9615	182.87	35.84	186.88	35.13				
kah9915	492.66	57.51	511.60	55.44				
kah1806	405.88	22.56	409.12	22.40	580.29	63.28	989.41	38.25
kah1906	454.10	31.48	466.27	30.71	120.67	48.41	586.94	26.35
kah2005	709.13	30.05	711.91	29.94	229.48	34.11	941.39	24.12

The current TRE 7 stock assessment model is limited to the KMNTB sub-area, which accounts for a large proportion of the catch. The assessment model shows a declining and stabilising trend in the 1990s which continued into the 2000s, with an increase after 2010 (Langley et al. 2015). The historical survey series is broadly consistent with this pattern and, whilst the recent estimates are not significantly higher, there is an increasing trend.

The size range of trevally caught in the WCNI survey series was 5–66 cm (Table 24). The mean size varied from 35 cm in 1989 to 28–29 cm in 1996 and 1999. The population scaled length frequency distributions for the northern core time series are shown in Figure 69. There were multiple modes in most years, starting with 0+ modes at 10–15 cm, followed by a mode around 22–25 cm (1+), and a third merged mode around 30–35 cm representing 2+ and 3+ fish. Most fish were between 20–40 cm, with very few larger fish; the proportion of fish over 40 cm was generally 5% or less except in 1989 and 1994 when this size range made up 8.5% and 15.5%, respectively. Trevally were not regularly sexed in historical surveys, except for 1994, but catches in this and recent surveys were male dominated. The male and female length frequency distributions were generally similar. The size range sampled in the survey overlaps with the smaller component of the commercial catches, which include a significant proportion of fish at 40–50 cm, with a mean length of 40.8 cm (Walsh et al. 2014) (Figure 70).

The scaled length frequency distributions for the southern strata only are shown in Figure 71. The large catches in I50 in the 2018 survey were evident in the high numbers of fish measured in this year compared with others, with the size range at these stations dominated by fish at 20–30 cm. The sex ratios were also more variable in this region.

Table 24: Summary of catch weight and length measurements of trevally by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	3 432.4	5	66	35.12	3 100
kah9111	1 399.5	3	59	33.11	1 542
kah9410	936.2	8	55	33.38	736
kah9615	1 231.2	8	57	28.62	1 418
kah9915	1 338.4	8	56	28.82	2 432
kah1806	2 162.6	8	58	33.26	1 936
kah1906	979.9	6	54	30.29	1 404
kah2005	931.9	6	55	31.93	1 335

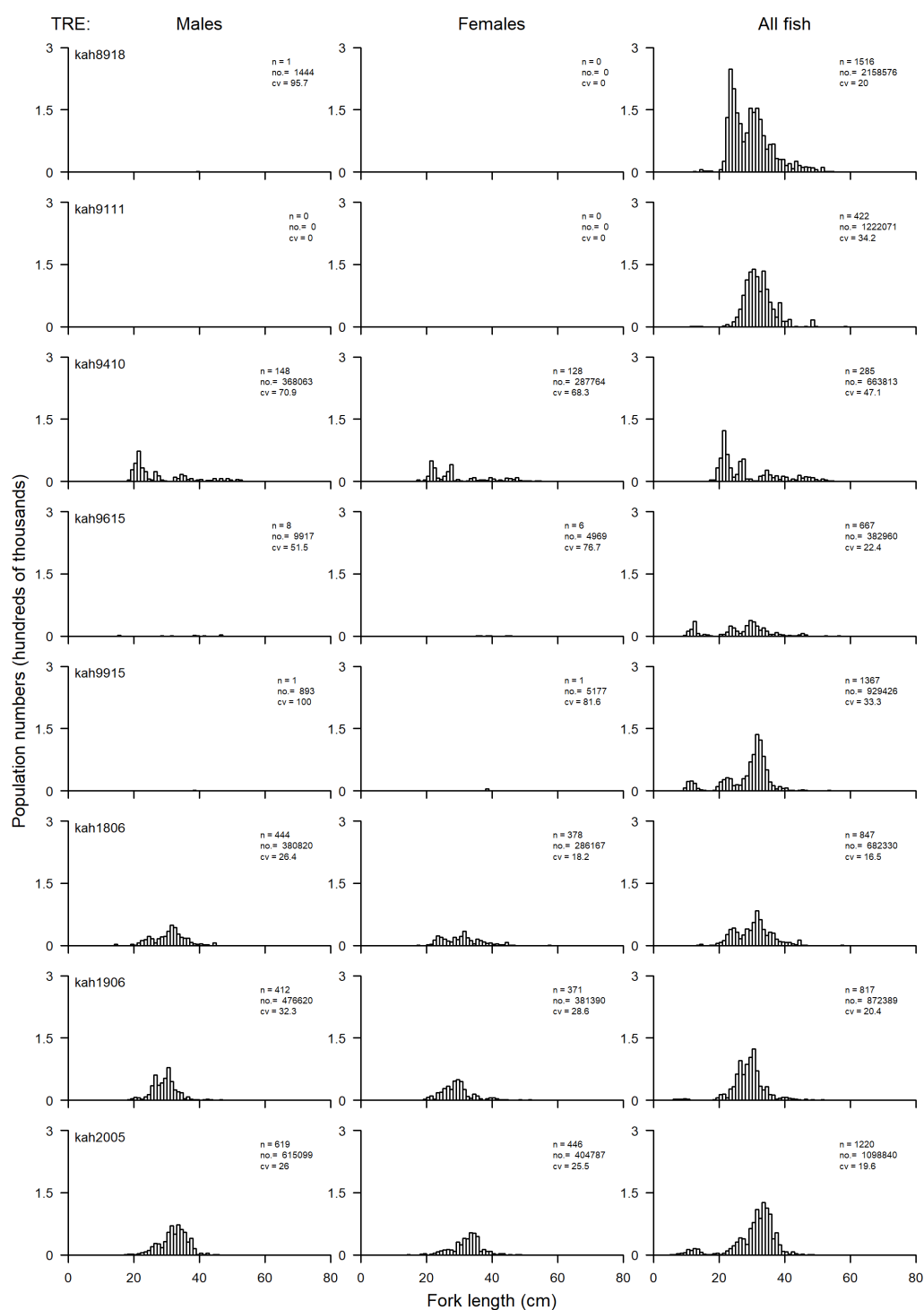


Figure 69: Comparative scaled length frequency distributions for males, females, and all trevally in the northern core strata (< 100 m) for the WCNI survey time series. n=number of fish measured, no.=scaled population number, and cv=coefficient of variation. ‘All fish’ includes unsexed fish.

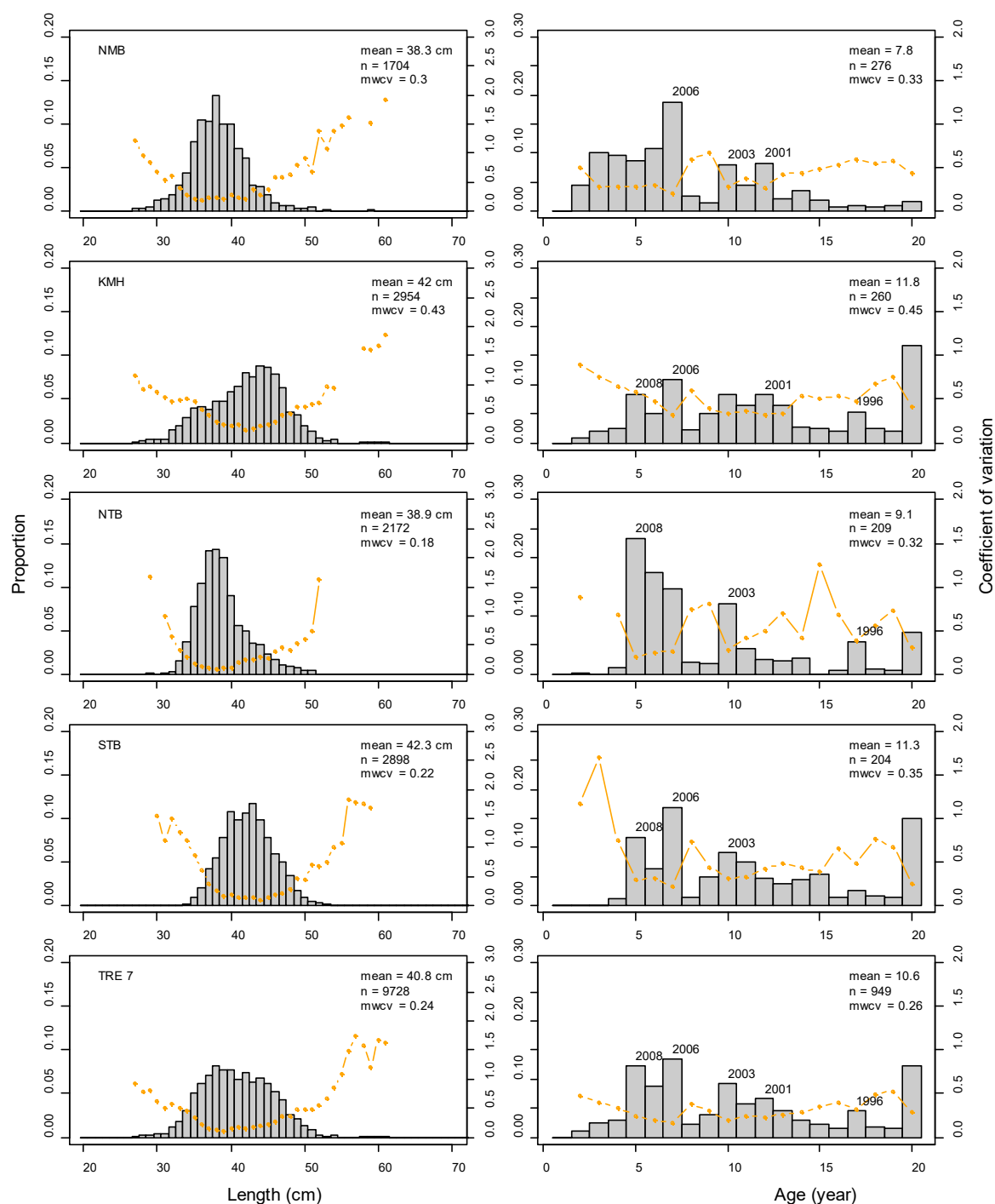


Figure 70: Proportion-at-length and -age distributions (bars) and bootstrap CVs (orange lines) from trevally landings sampled in TRE 7 in 2012–13. (Source: Walsh et al. 2014.)

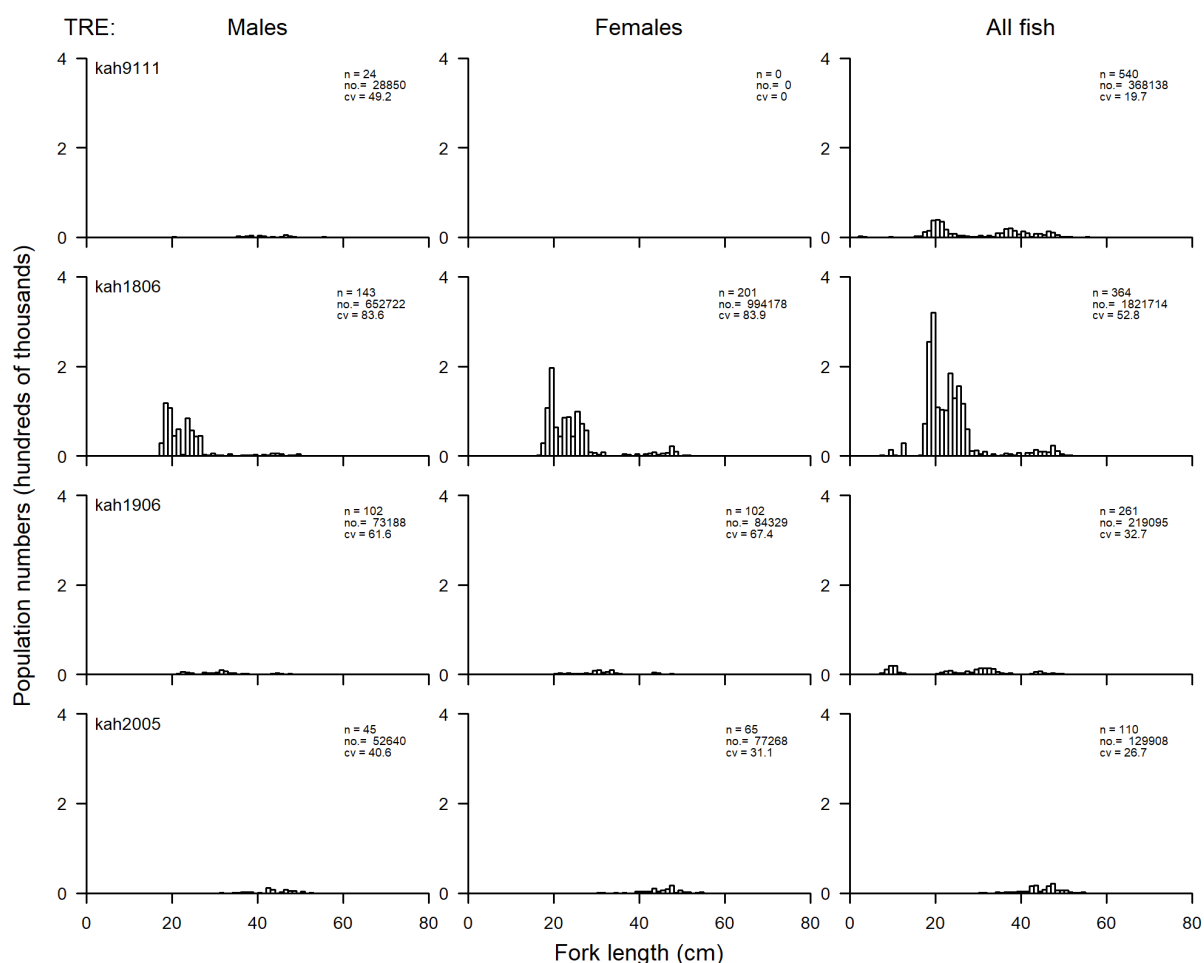


Figure 71: Comparative scaled length frequency distributions for males, females, and all trevally in the southern strata for the four WCNI surveys that included the South Taranaki Bight. n=number of fish measured, no.=scaled population number, and cv=coefficient of variation. 'All fish' includes unsexed fish.

The reproductive condition of trevally was only assessed in the most recent three surveys (Table 25). In 2018, females were mostly developing (stage 3), with 9% ripe and 1% running ripe. In males, 40% were ripe and 22% running ripe. In the earlier-timed 2019 survey, the majority of both sexes were resting or developing. In 2020, resting or developing were again the most commonly observed stages, although a greater proportion of fish had started to develop compared with in 2019.

Table 25: Proportion of sampled trevally with gonads at different reproductive stages by survey. (Gonad stages are defined in Appendix 4.)

Year	Maturity Stage							Sample size
	1	2	3	4	5	6	7	
Female								
kah1806	0.08	0.16	0.64	0.09	0.01	0.00	0.01	85
kah1906	0.10	0.62	0.24	0.02	0.00	0.00	0.01	246
kah2005	0.03	0.51	0.46	0.01	0.00	0.00	0.00	231
Male								
kah1806	0.05	0.06	0.27	0.40	0.22	0.00	0.00	108
kah1906	0.17	0.41	0.40	0.02	0.00	0.00	0.00	250
kah2005	0.07	0.24	0.55	0.09	0.04	0.00	0.00	250

3.2.6 Yellowtail jack mackerel (JMN) and greenback jack mackerel (JMD)

Number of surveys	8
Total catch weight (kg)	23 312.8
Number measured	39 990
Length range (mean) (cm)	2–58 (20.75)
Number weighed	716

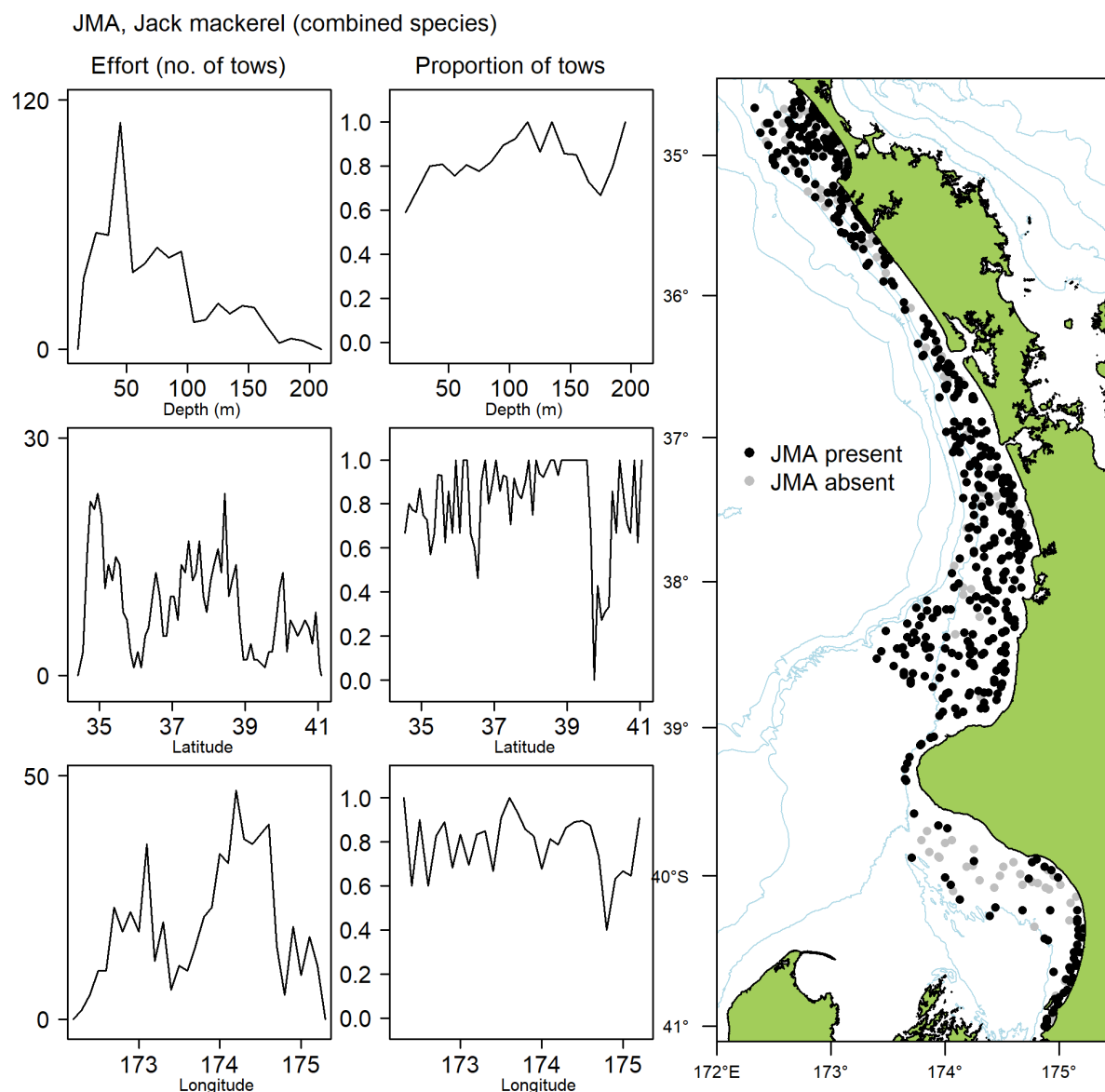


Figure 72: Summary of occurrence of combined jack mackerel species (JMN and JMD) in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which jack mackerel were caught. All valid tows are plotted in the map on the right with black dots showing those where jack mackerel were present.

Yellowtail jack mackerel (*Trachurus novaezelandiae*) was the second or third most abundant species in the catch of the recent surveys (Jones et al. 2022). Greenback jack mackerel (*T. declivis*) often occurred at the same stations but were less common. Because jack mackerel were not identified to species level during historical surveys, the two species are combined, and population scaled length frequency distribution plots are not presented. The combined species occurred widely, in all depths, but were less common in the 50–100 m depths of South Taranaki Bight (Figures 72 and 73).

The two pelagic species have similar but overlapping depth ranges; yellowtail are more common in water depths less than 150 m, whilst greenback jack mackerel tend to occur deeper, generally in less than 300 m (McMillan et al. 2019). A third species, *T. murphyi* (JMM), was also encountered on the survey, but at much lower abundance and a generally larger size range (24–58 cm). This species is described separately in Appendix 6.

JMA, Jack mackerel (combined species)

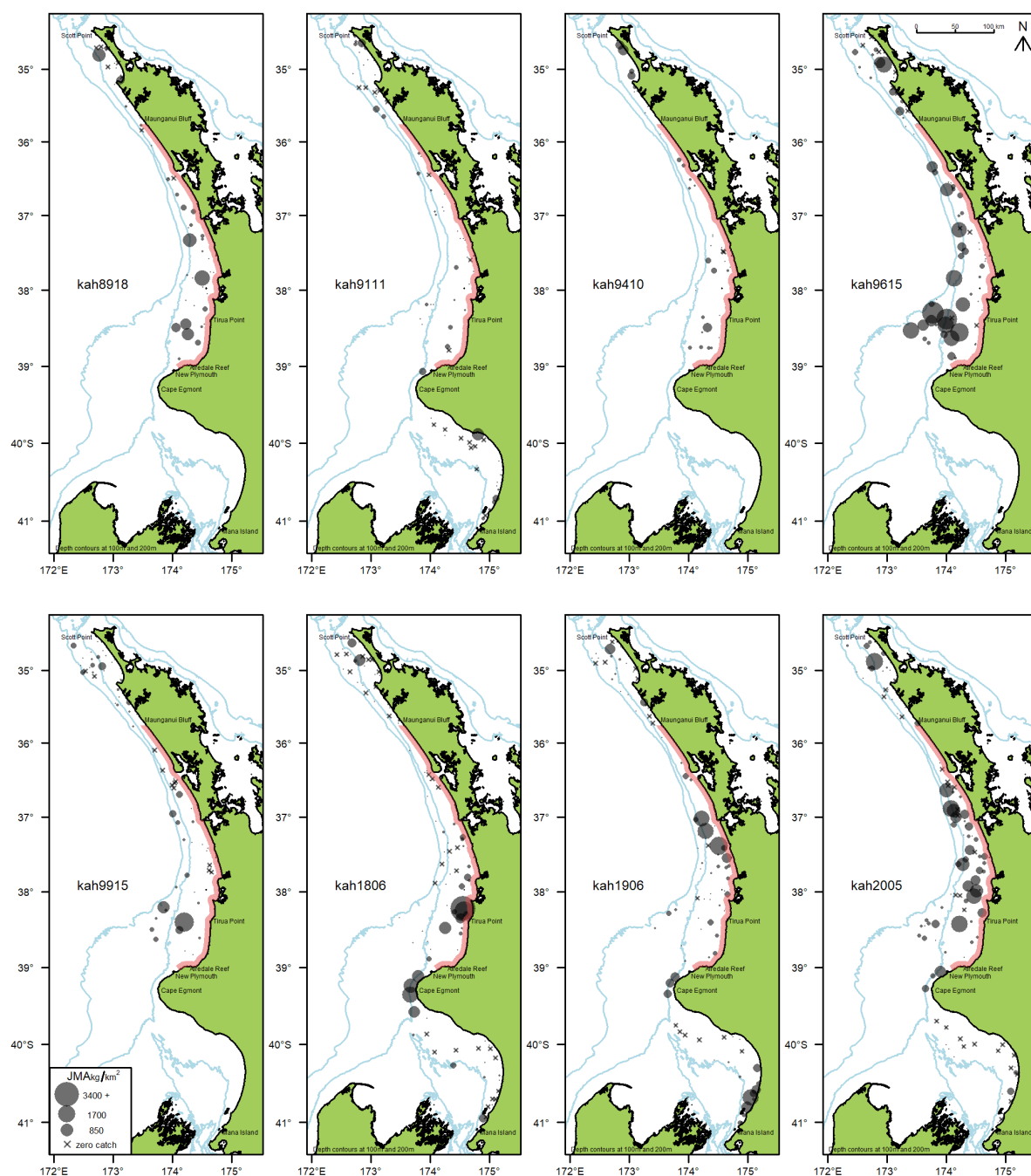


Figure 73: Spatial distribution of catch rates (kg km^{-2}) of jack mackerel (JMN and JMD) in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

Biomass of combined jack mackerel was relatively low during the early to mid-1990s for all three area combinations (Figure 74, Table 26). There was no clear trend in abundance and biomass was not well estimated (core area CVs > 35%).

Most yellowtail and greenback jack mackerel caught in the recent WCNI surveys were juvenile pre-recruits less than 25 cm, with a few larger greenback jack mackerel up to 50 cm in length caught in 2018 (Jones et al. 2022). For all three of the recent surveys and for both jack mackerel species combined, there was only one main size mode present, generally at 10–15 or 10–20 cm. Few jack mackerel of either species were sexed relative to the overall number measured, so inferences about sex ratio or relative length frequencies by sex were not possible.

Whilst the historical time series has limited utility, and the availability of these pelagic species is variable, the data collected in the more recent surveys provide information on juvenile species composition and abundance in JMA 7 (Jones et al. 2022).

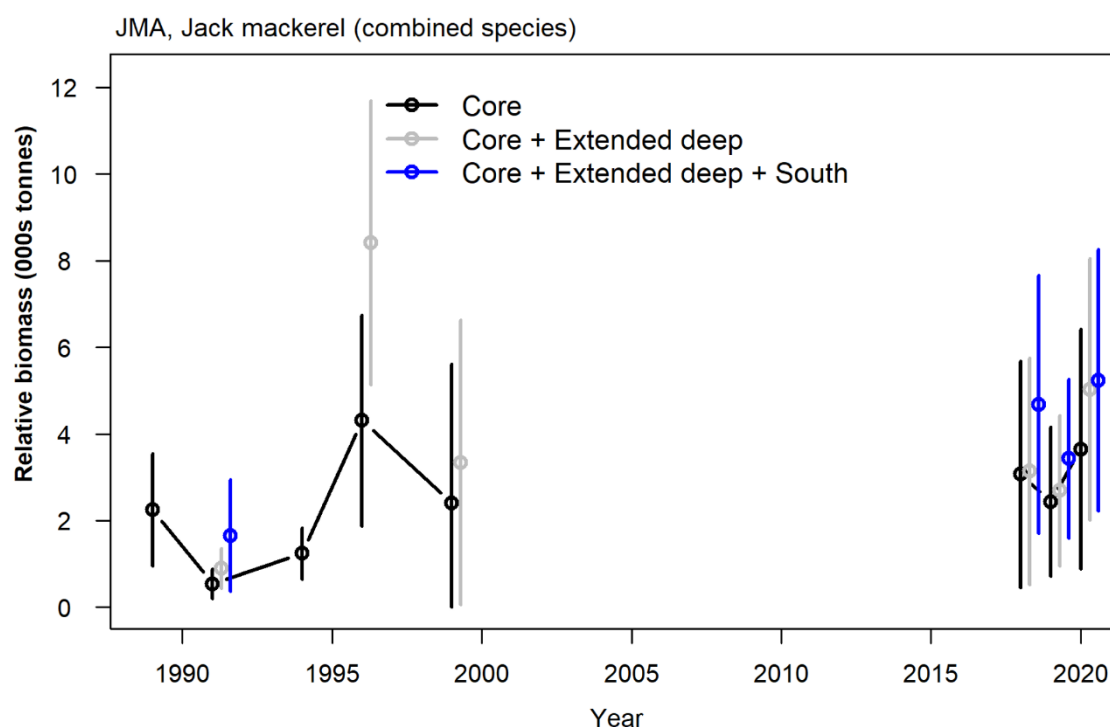


Figure 74: Time series of total relative biomass estimates and 95% confidence intervals for jack mackerel (JMN and JMD combined) for the northern core area (core in black), core area with deeper >100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 26: Relative biomass estimates (t) and CVs (%) of jack mackerel (JMN and JMD combined) for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	2 246.20	28.81						
kah9111	541.23	31.16	892.64	25.83	764.93	78.30	1 657.57	38.84
kah9410	1 243.56	23.75						
kah9615	4 310.03	28.27	8 414.16	19.43				
kah9915	2 406.46	66.61	3 341.12	49.18				
kah1806	3 071.04	42.56	3 139.47	41.63	1.00	46.40	4 677.85	31.84
kah1906	2 437.66	35.29	2 692.40	32.28	737.74	39.32	3 430.14	26.71
kah2005	3 647.97	37.98	5 030.63	29.98	217.34	35.03	5 239.19	28.84

3.2.7 Kahawai (ATT)

Number of surveys	8
Total catch weight (kg)	1372.2
Number measured	3323
Length range (mean) (cm)	7–55 (29.67)
Number weighed	156

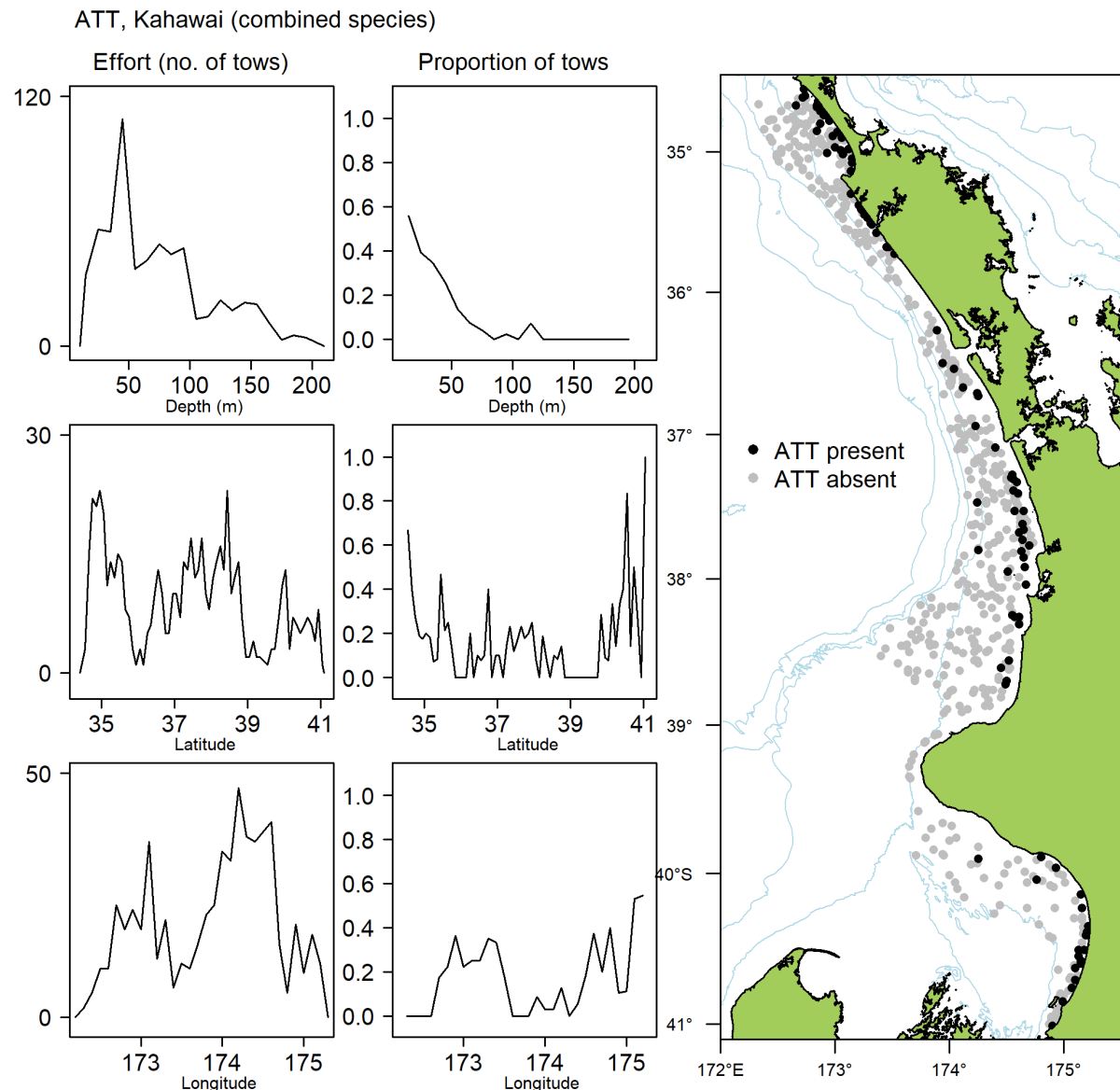


Figure 75: Summary of occurrence of kahawai in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which kahawai were caught. All valid tows are plotted in the map on the right with black dots showing those where kahawai were present.

This pelagic species extends throughout New Zealand but is more abundant north of the Cook Strait, including the west coast, and known to occur to depths of around 150 m (McMillan et al. 2019). The survey covers the north-western portion of this species' distribution. Most catches were in depths less than 50 m (Figure 75).

Total kahawai catches were modest, ranging from 30 to 300 kg in each survey, and accounting for 1% or less of the total catch and caught in 15–20% of stations. Spatial patterns in catch rates were patchy, and variable and between surveys, but higher catch rates were observed off Ninety Mile Beach, south of Manukau Harbour, and in the South Taranaki Bight (J25 and I25) (Figure 76).

ATT, Kahawai (combined species)

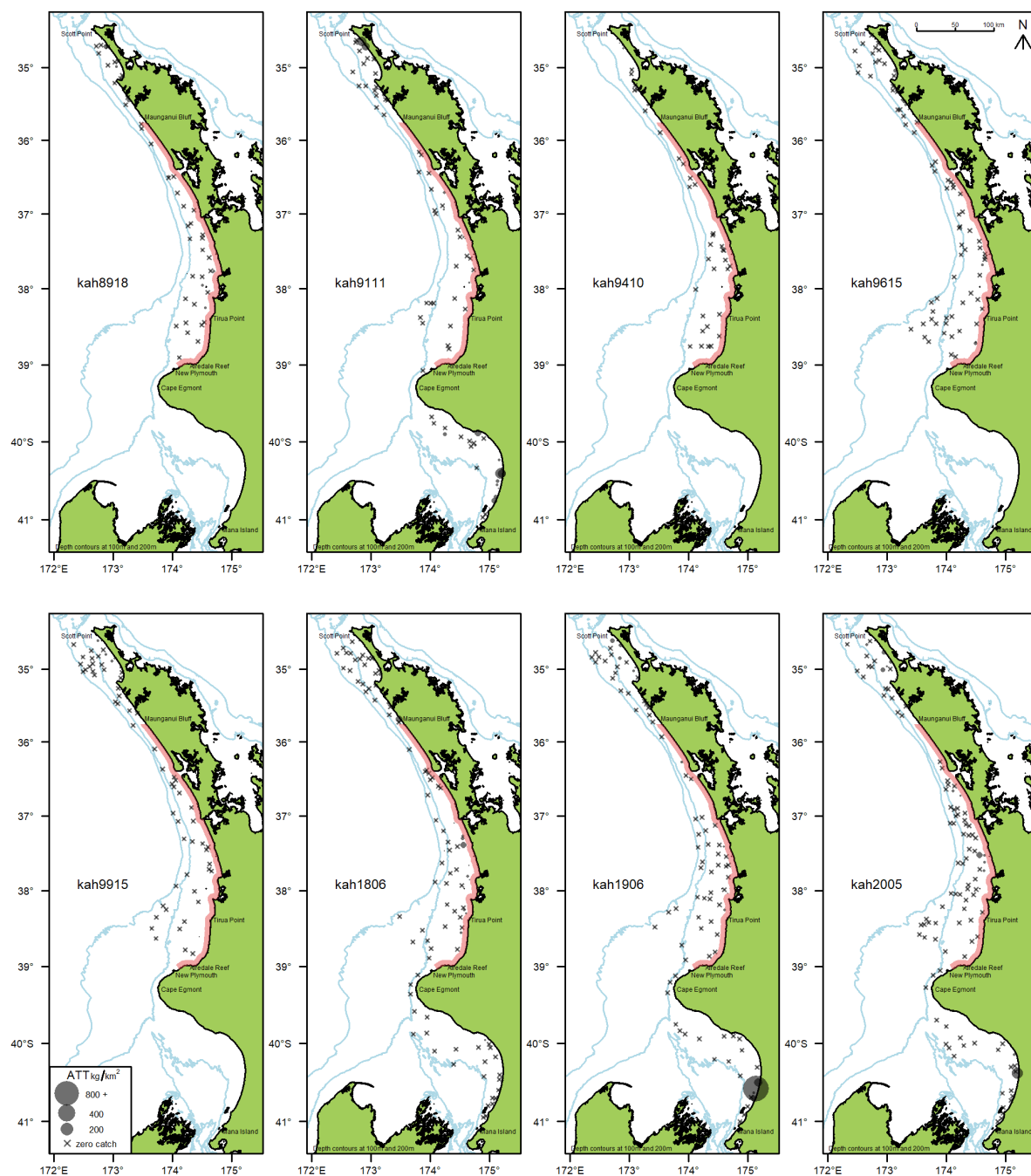


Figure 76: Spatial distribution of catch rates (kg km^{-2}) of kahawai in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

Biomass of this species is moderately estimated in the core and extended core area, with CVs for the core survey area between 30 and 40% for six of eight surveys (Figure 77, Table 27). Biomass estimates were lower between 1994–99, compared with the two early surveys (1989 and 1991) and the three more recent ones. There was no discernible change between the three recent surveys in 2018–20 (Figure 77). The

shallow distribution of this species limited the value of the extended core time series. The estimates for the whole survey showed variable contributions from the South Taranaki Bight strata (see Table 27).

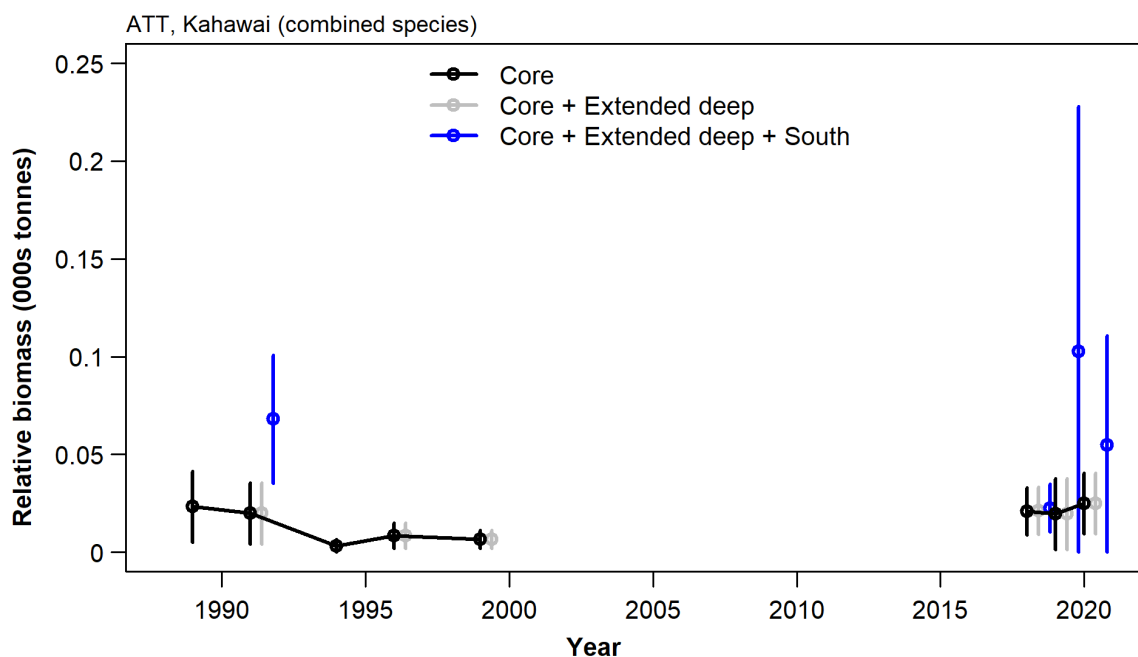


Figure 77: Time series of total relative biomass estimates and 95% confidence intervals for kahawai for the northern core area (core in black), core area with deeper strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 27: Relative biomass estimates (t) and CVs (%) of kahawai for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass (t)	Core CV (%)	Extended core biomass (t)	Extended core CV (%)	South biomass (t)	South CV (%)	Whole survey biomass (t)	Whole survey CV (%)
kah8918	23.21	39.31						
kah9111	19.79	39.93	19.79	39.93	48.22	29.91	68.01	24.18
kah9410	3.08	58.88						
kah9615	8.34	39.16	8.34	39.16				
kah9915	6.70	34.65	6.70	34.65				
kah1806	20.94	28.88	21.32	28.42	1.24	100.00	22.56	27.42
kah1906	19.53	46.60	19.53	46.60	82.97	74.72	102.50	61.13
kah2005	24.92	31.05	24.92	31.05	29.70	90.59	54.62	51.26

The surveys sampled a wide size range for kahawai, from 7 to 55 cm, covering both juvenile and mature adults (Table 28). Numbers were sparse, but multiple size modes were discernible at around 20 and 30 cm and > 40 cm (Figure 78). There was no trend in mean length since the start of the series, although a greater number of > 40 cm fish were caught in the more recent surveys, particularly in 2020. Two clear modes were apparent in kahawai length frequency distributions from southern strata in 1991 and 2019 (Figure 79). Kahawai were not sexed in earlier surveys but had even sex ratios in the more recent ones. The male and female length frequency distributions were generally similar.

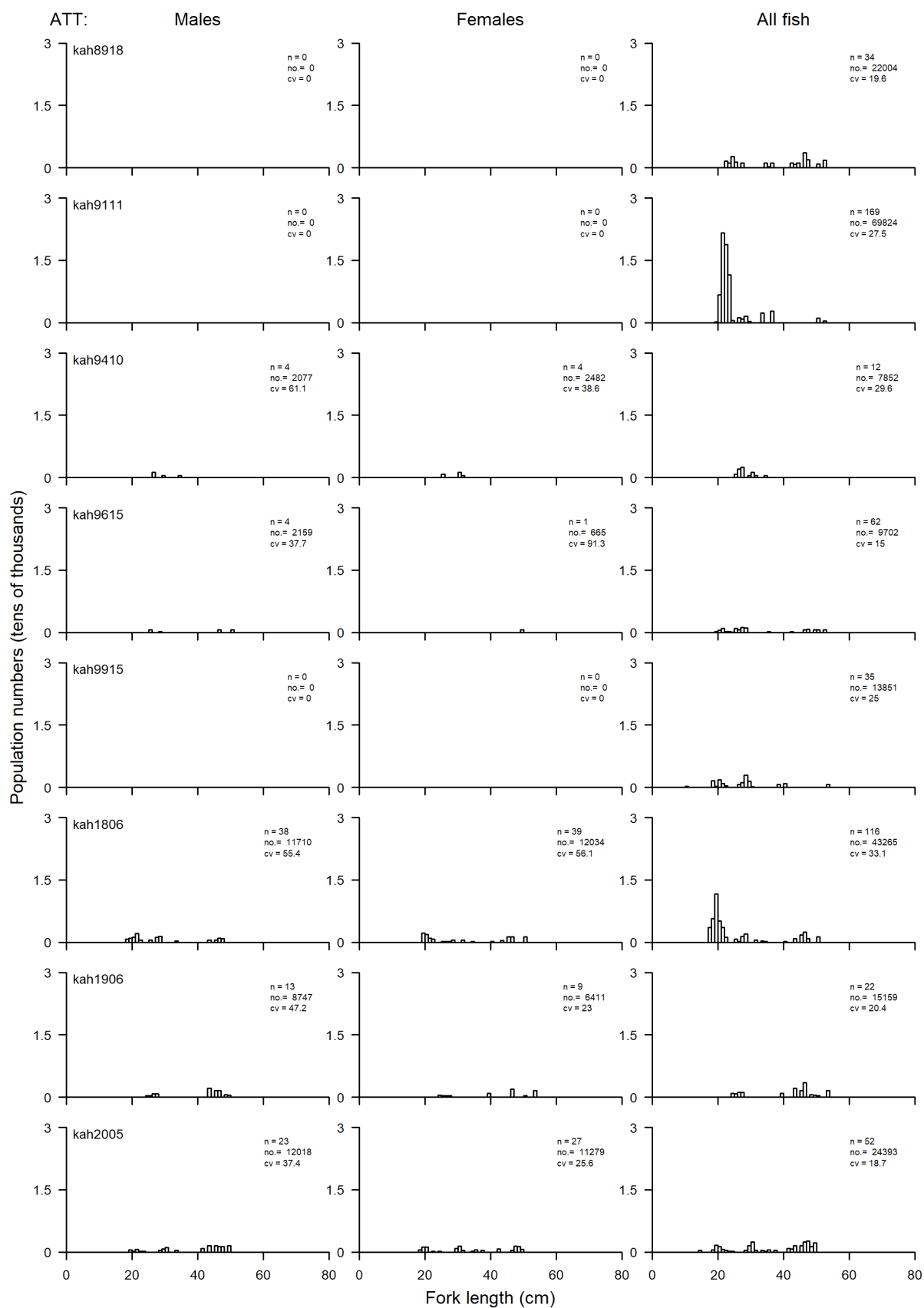


Figure 78: Comparative scaled length frequency distributions for males, females, and all kahawai in the northern core strata (<100 m) for the time series of the WCNI survey. n=number of fish measured, no.=scaled population number, and cv=coefficient of variation. ‘All fish’ includes unsexed fish.

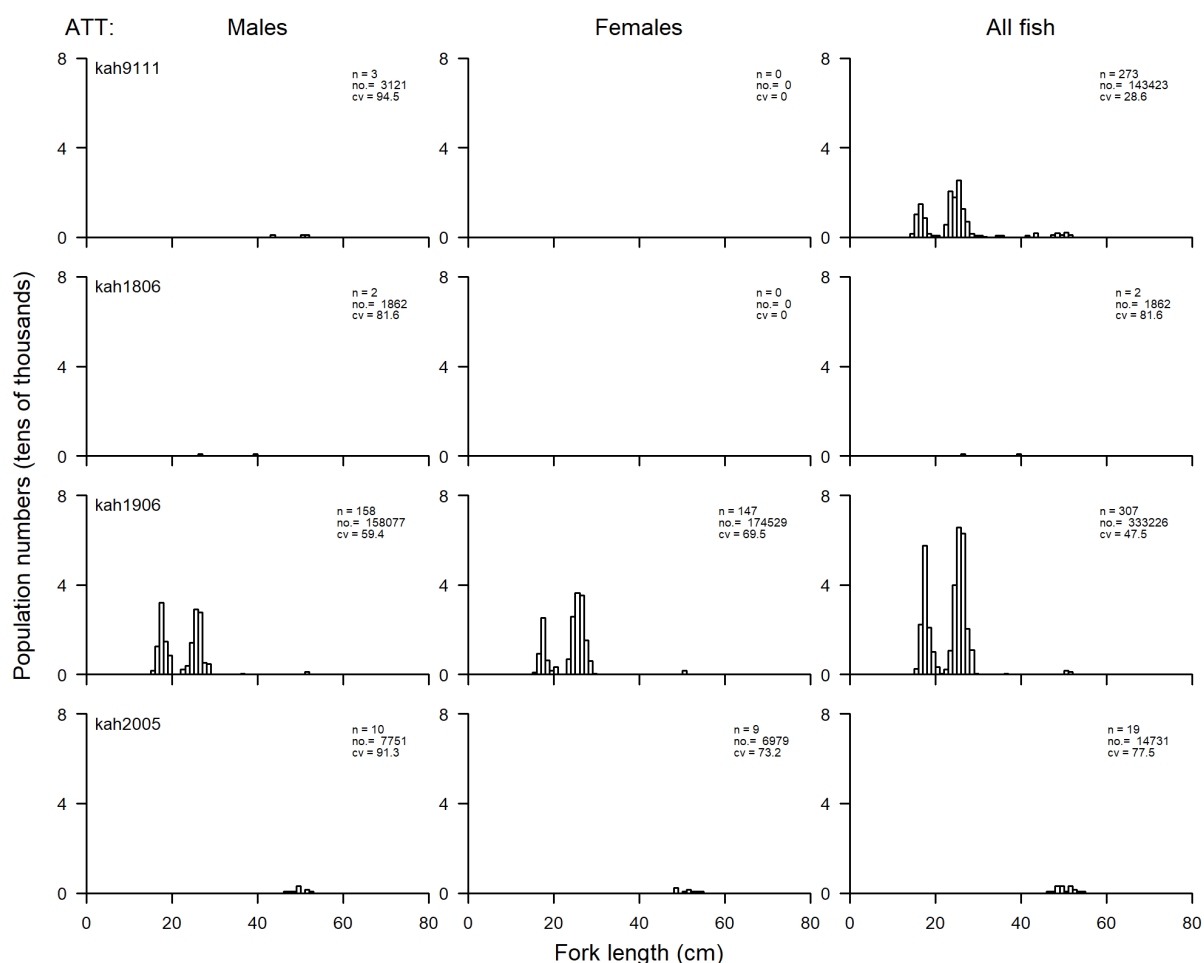


Figure 79: Comparative scaled length frequency distributions for males, females, and all kahawai in the southern strata for the four WCNI surveys that included the South Taranaki Bight. n=number of fish measured, no.=scaled population number, and cv=coefficient of variation. 'All fish' includes unsexed fish.

Table 28: Summary of catch weight and length measurements of kahawai by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	330.2	12	55	29.79	816
kah9111	272.9	7	53	27.16	765
kah9410	32.9	18	52	34.05	48
kah9615	98.6	17	53	27.52	372
kah9915	237.1	11	54	28.57	631
kah1806	82.7	14	51	29.04	260
kah1906	234.4	16	54	31.97	342
kah2005	83.4	15	55	38.75	89

Biological sampling of kahawai for reproductive stage was carried out on recent surveys and was limited (Table 29). The 2018 maturity data were derived from a single station off Maunganui Bluff where the size range of fish was 19–48 cm. The 2019 sample was taken from 6 stations with a size range from 35–51 cm and, in 2020, 9 stations were sampled, covering a size range of 19–55 cm. In all three surveys the females examined were largely resting or immature, with no developing or ripe fish observed. Males were also mostly immature or resting, although a small proportion of fish were ripening and ripe in the 2020 survey.

Table 29: Proportion of sampled kahawai with gonads at different reproductive stages by survey. (Gonad stages are defined in Appendix 4.)

Year	Maturity Stage							Sample size
	1	2	3	4	5	6	7	
Female								
kah1806	0.12	0.85	0.00	0.00	0.00	0.00	0.03	34
kah1906	0.00	1.00	0.00	0.00	0.00	0.00	0.00	11
kah2005	0.24	0.76	0.00	0.00	0.00	0.00	0.00	42
Male								
kah1806	0.73	0.27	0.00	0.00	0.00	0.00	0.00	30
kah1906	0.00	1.00	0.00	0.00	0.00	0.00	0.00	9
kah2005	0.57	0.33	0.07	0.03	0.00	0.00	0.00	30

3.2.8 Barracouta (BAR)

Number of surveys	8
Total catch weight (kg)	6889
Number measured	4078
Length range (mean) (cm)	10–106 (65.02)
Number weighed	794

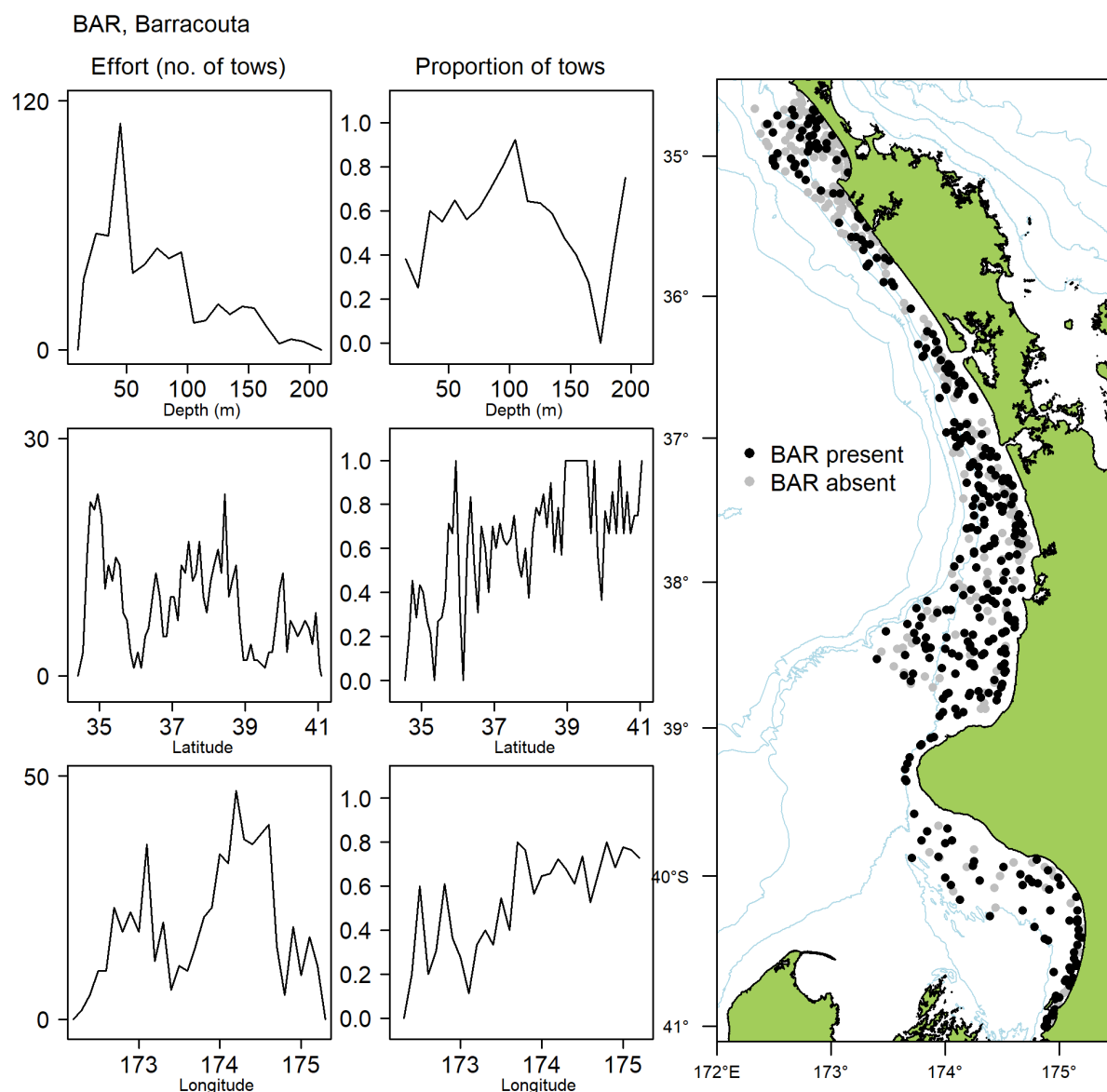


Figure 80: Summary of occurrence of barracouta in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which barracouta were caught. All valid tows are plotted in the map on the right with black dots showing those where barracouta were present.

Barracouta is a semi-demersal species extending throughout New Zealand waters, including off the west coast, and known to occur to a depth of around 400 m. The survey covers the north-western portion of this species' distribution but does not encompass the full depth range. Within the survey area, most catches were between 50–100 m, with a declining occurrence towards the northern end of the survey (Figures 80 and 81).

BAR, Barracouta

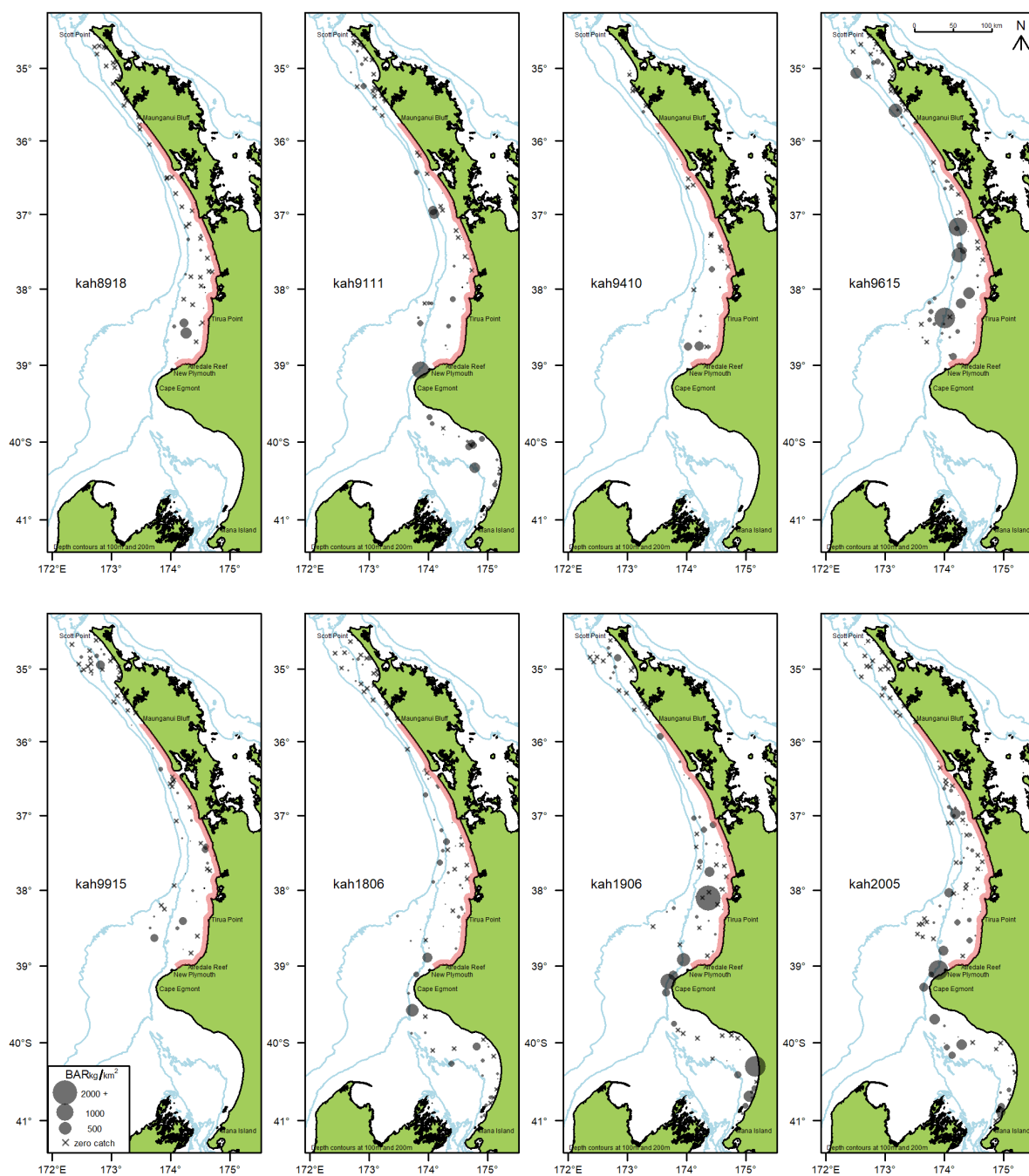


Figure 81: Spatial distribution of catch rates (kg km^{-2}) of barracouta in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

The relative biomass estimates for the whole survey time series are given in Figure 82 and Table 30. The highest estimate was from the 1991 survey but with large CV of almost 40%. In the extended core series, CVs were below 30% for four out of six surveys, with peak biomass in 1996 and 2019. There was no discernible trend in the survey time series.

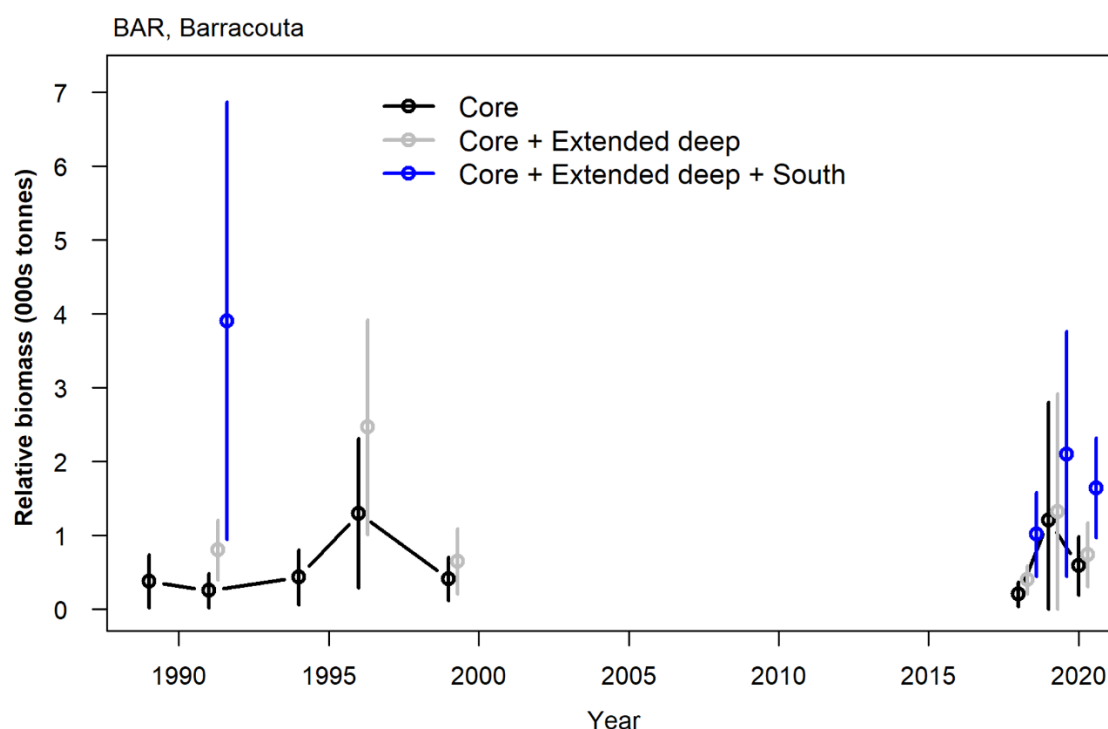


Figure 82: Time series of total relative biomass estimates and 95% confidence intervals for barracouta for the northern core area (core in black), core area with deeper strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 30: Relative biomass estimates (t) and CVs (%) of barracouta for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	380.45	47.72						
kah9111	254.29	45.75	803.41	25.29	3102.01	47.28	3 905.42	37.90
kah9410	435.78	42.63						
kah9615	1 298.73	38.99	2 465.91	29.45				
kah9915	412.32	35.66	647.60	34.12				
kah1806	204.99	41.62	403.99	23.89	611.84	44.02	1 015.83	28.16
kah1906	1 209.98	65.90	1 324.35	60.30	779.04	28.98	2 103.39	39.46
kah2005	591.40	33.68	740.77	29.37	906.26	28.75	1 645.86	20.63

The size range of barracouta caught was 10–106 cm (Table 31) and comprised up to three pre-recruit length modes (10–18 cm, 18–25 cm, 30–50 cm) and a strong recruited length mode at 60–80 cm (Figure 83). These pre-recruit size classes were particularly apparent in 2018, sampled in a number of stations from Cape Egmont and northwards. Catches from the southern area also showed clear pre-recruit and recruit length modes (Figure 84). Fish were not always sexed on historical surveys. An even ratio was observed in the 1996 survey in the northern strata, but females tended to be more numerous than males in more recent surveys, whilst the opposite was observed in the southern strata.

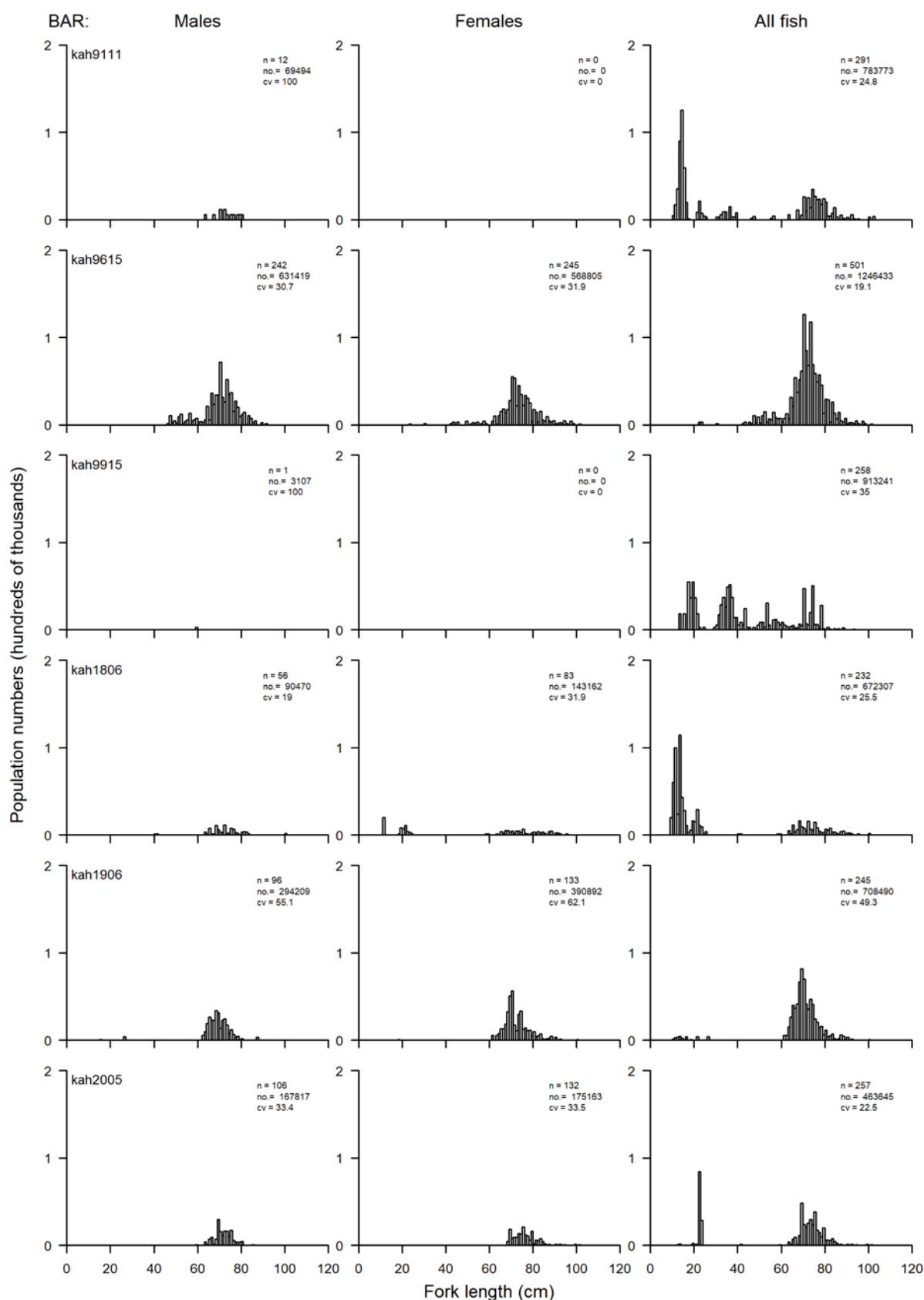


Figure 83: Comparative scaled length frequency distributions for males, females, and all barracouta in the extended northern core for WCNI surveys that included the 100–200 m depth range. n=number of fish measured, no.=scaled population number and cv = coefficient of variation. ‘All fish’ includes unsexed fish.

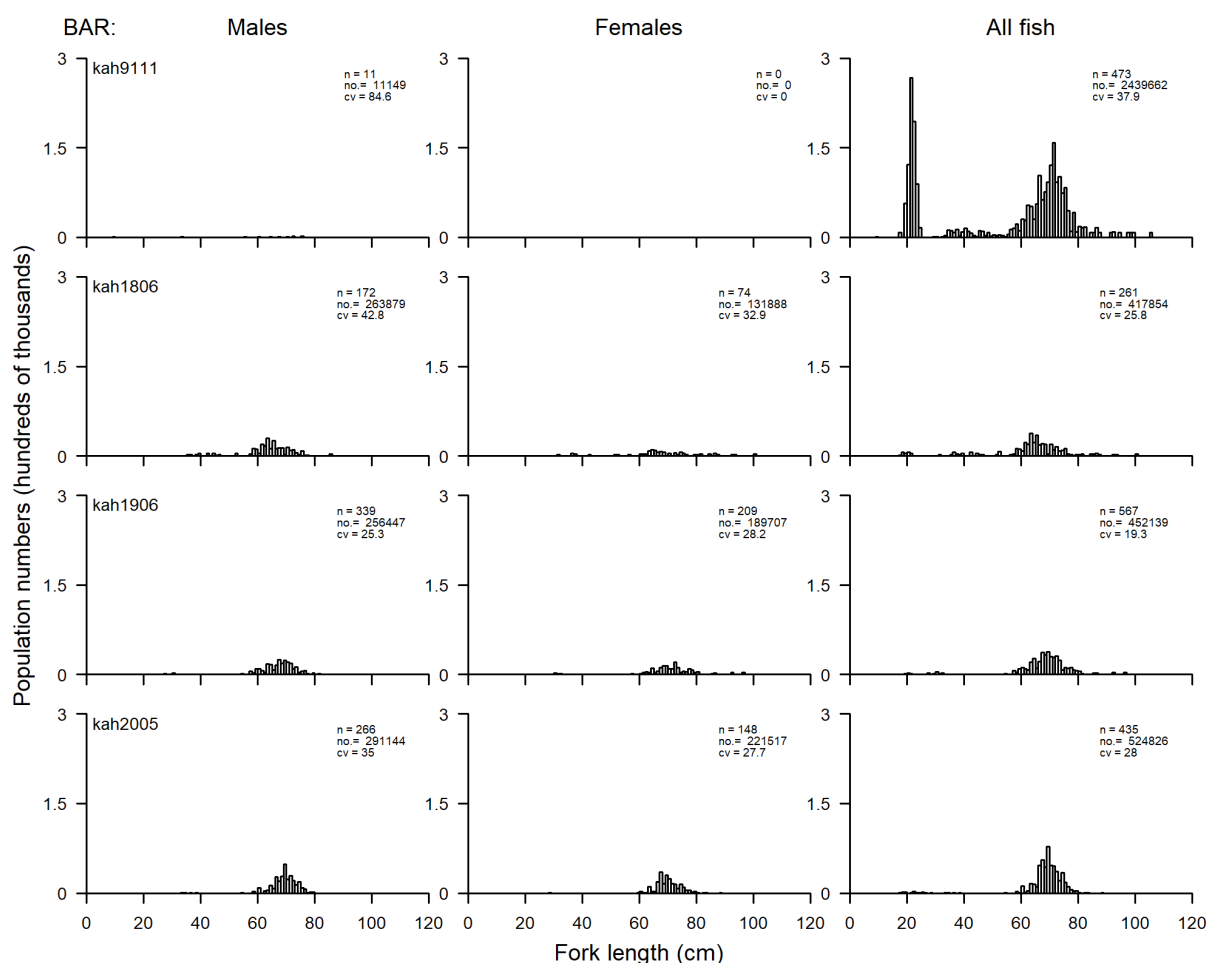


Figure 84: Comparative scaled length frequency distributions for males, females, and all barracouta in the southern strata for the four WCNI surveys that included the South Taranaki Bight. n=number of fish measured, no.=scaled population number, and cv=coefficient of variation. 'All fish' includes unsexed fish.

Table 31: Summary of catch weight and length measurements of barracouta by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	215.6	12	87	64.80	134
kah9111	910.9	10	106	59.80	793
kah9410	262.0	10	98	59.16	233
kah9615	1 646.6	23	102	72.24	567
kah9915	378.9	11	94	57.68	317
kah1806	622.6	10	101	63.46	505
kah1906	1 706.2	11	101	66.64	836
kah2005	1 146.2	13	102	68.58	693

Biological sampling of barracouta was only carried out on the more recent surveys (Table 32). In the 2018 survey, almost 50% of male gonads were ripe, but none were running ripe, with almost 20% spent and another 20% resting. Most female barracouta were resting or developing. In the earlier-timed 2019 and 2020 surveys, most males were running ripe, while most females were developing, with a small proportion of ripe, running ripe, and spent individuals also observed. Barracouta are reported to spawn in August-September in this region, with males developing ahead of the females prior to the spawning season (Fisheries New Zealand 2022).

Table 32: Proportion of sampled barracouta with gonads at different reproductive stages by survey. (Gonad stages are defined in Appendix 4.)

Year	Maturity Stage							Sample size
	1	2	3	4	5	6	7	
Female								
kah1806	0.04	0.46	0.32	0	0	0.04	0.14	28
kah1906	0.02	0.19	0.53	0.04	0.04	0.11	0.05	166
kah2005	0.01	0.19	0.67	0.01	0.02	0	0.1	121
Male								
kah1806	0.07	0.20	0.05	0.48	0	0.03	0.17	40
kah1906	0.01	0	0.03	0.1	0.85	0	0	268
kah2005	0.02	0.02	0.08	0.2	0.68	0	0.01	171

3.2.9 School shark (SCH)

Number of surveys	8
Total catch weight (kg)	3876.9
Number measured	835
Length range (mean) (cm)	27–200 (83.5)
Number weighed	61

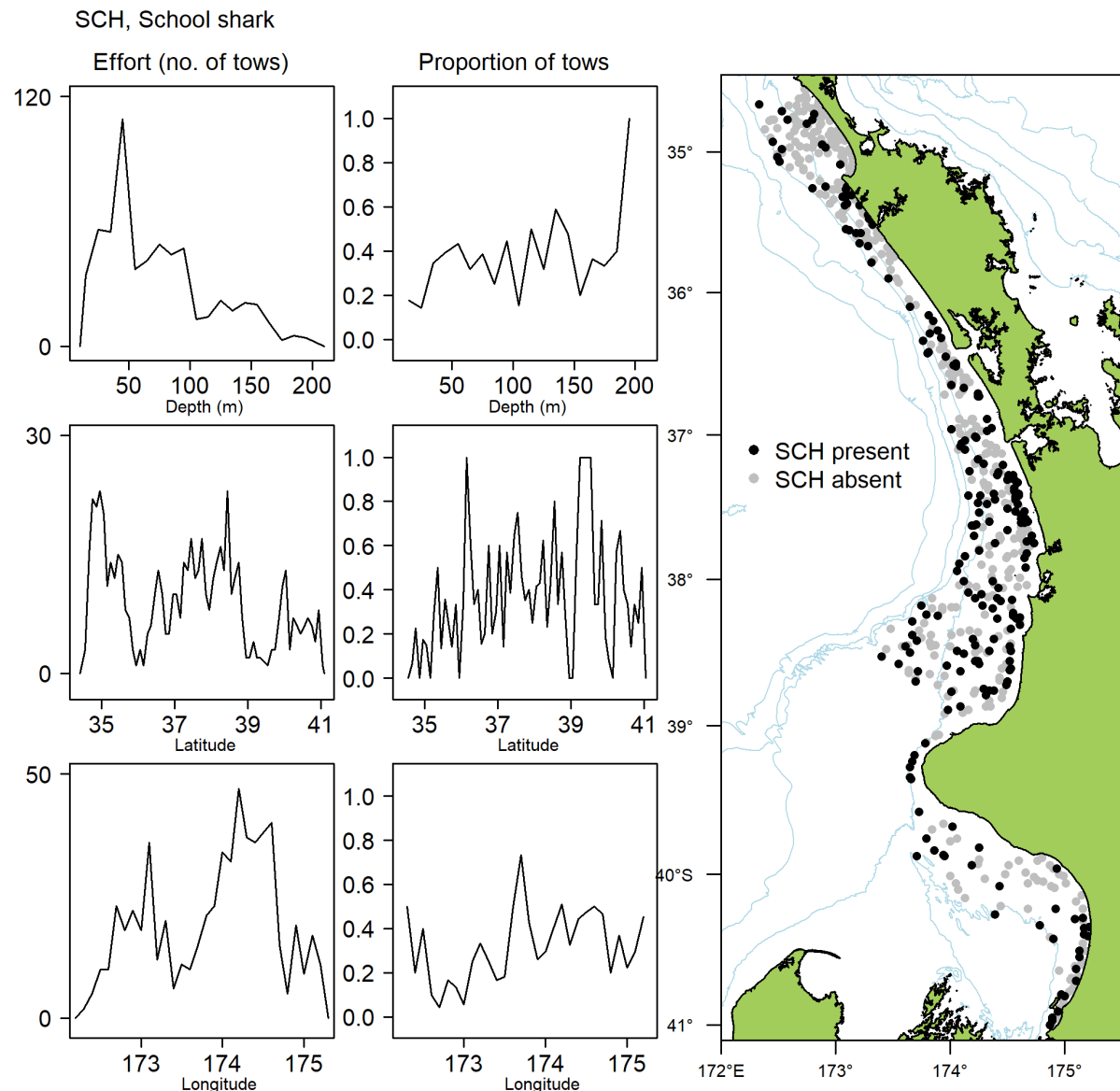


Figure 85: Summary of occurrence of school shark in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which school shark were caught. All valid tows are plotted in the map on the right with black dots showing those where school shark were present.

School shark are widespread around New Zealand, in both demersal and pelagic waters, from shallow to as deep as 1100 m (McMillan et al. 2019). The survey covers the north-western portion of the distribution, but not the full depth range, as shown by the pattern of increasing occurrence with depth (Figure 85). Higher catch rates were observed in different areas in different years but include Ninety Mile Beach, and between Manukau and Raglan Harbours (Figure 86).

SCH, School shark

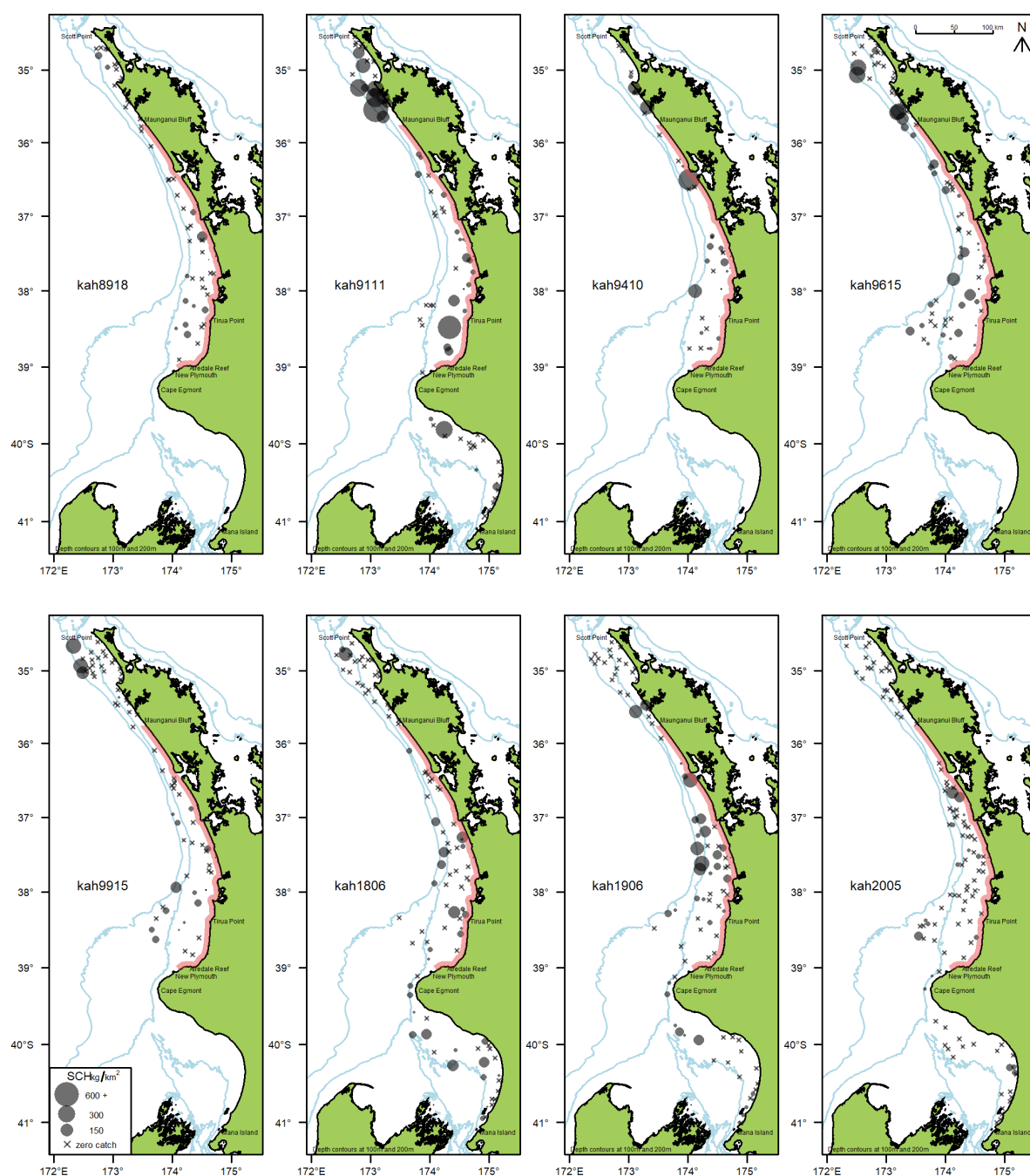


Figure 86: Spatial distribution of catch rates (kg km^{-2}) of school shark in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

The biomass estimate in 1991 for the whole survey was much higher than any of the recent surveys, but also had the highest CV of the series (Figure 87, Table 33). In contrast, the 2020 estimate was the lowest in the series. The 1991 survey also recorded the highest biomass in the northern core time series, declining over the next three surveys to 107.7 t, which was almost identical to the 2018 estimate (108.6 t), 19 years later. The 2020 biomass estimate was also the lowest in the core series. The CVs for school shark have been variable but were between 20 and 40% for the extended and whole areas and could therefore be considered moderately well estimated (Table 33).

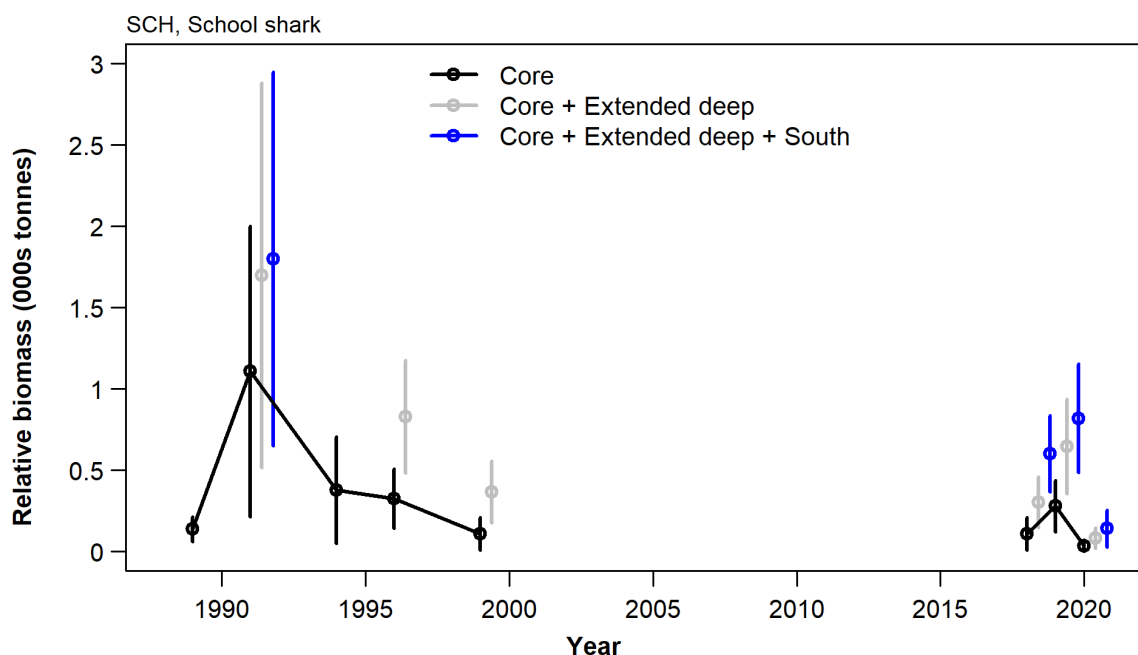


Figure 87: Time series of total relative biomass estimates and 95% confidence intervals for school shark for the northern core area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 33: Relative biomass estimates (t) and CVs (%) of school shark for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	137.63	27.96						
kah9111	1 107.41	40.32	1 698.51	34.81	109.24	71.01	1 807.75	32.99
kah9410	376.97	43.63						
kah9615	325.90	28.20	828.23	21.01				
kah9915	107.66	46.47	366.09	25.88				
kah1806	108.61	46.97	302.37	26.15	308.25	29.28	610.61	19.65
kah1906	278.85	28.20	647.48	22.45	171.93	48.58	819.40	20.46
kah2005	33.63	55.13	82.13	38.01	54.56	85.71	140.93	40.69

Length data for school shark are very sparse, with fewer than 100 fish measured in most years (Table 34). The population scaled length frequency distributions for each survey in the extended northern core area time series (i.e. including 100–200 m depth strata) are shown in Figure 88. The size range of school shark caught in each survey was similar, ranging from 27 cm up to 200 cm, which includes immature and mature fish of both sexes, but there were very few mature specimens (> 130 cm) or individuals smaller than 50 cm. This contrasts with the west coast South Island trawl surveys, where the length frequencies often include two juvenile modes under 50 cm (e.g., MacGibbon 2019). However, these smaller sizes are known to occur inside the Kaipara Harbour, which is a likely nursery ground from where they migrate out into coastal waters (Francis et al. 2012). The length data for the southern strata were too sparse to be presented but were similar to the distributions for the northern area. This survey samples mainly the sub-adult portion of the population.

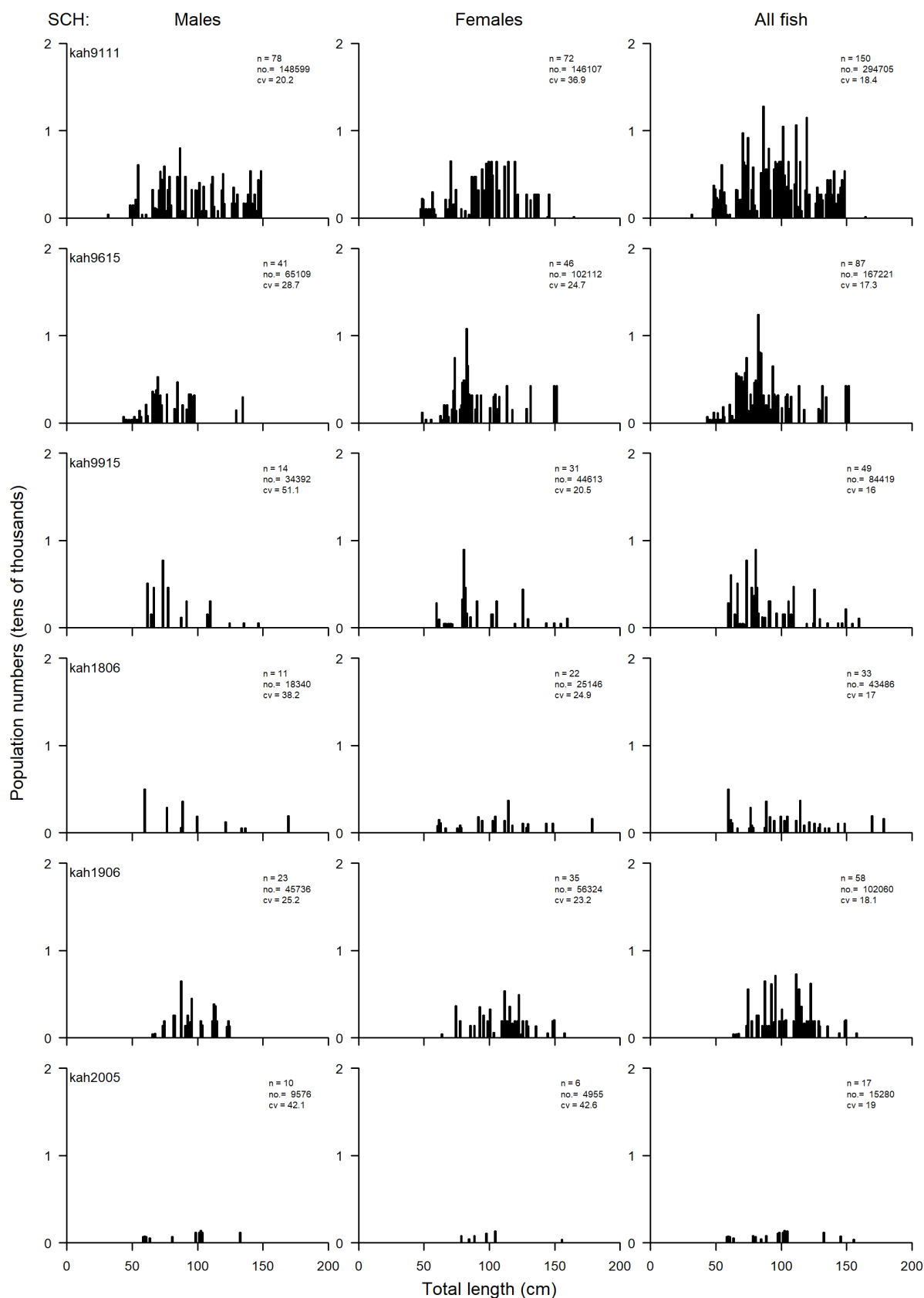


Figure 88: Comparative scaled length frequency distributions for males, females, and all school shark in the extended northern core strata for the WCNI surveys that included the 100–200 m depth range. n=number of fish measured, no.=scaled population number and cv=coefficient of variation. ‘All fish’ includes unsexed fish.

Table 34: Summary of catch weight and length measurements of school shark by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	117.0	32	119	62.35	58
kah9111	1 128.7	27	165	83.86	259
kah9410	353.3	38	168	77.66	97
kah9615	769.7	28	200	73.58	148
kah9915	318.6	43	160	82.67	85
kah1806	523.9	58	179	99.41	77
kah1906	542.3	64	158	101.1	86
kah2005	123.4	59	156	94.16	25

In 2018 and 2019, school shark were released alive when likely to survive, thus most females were not assessed for maturity stage. Of those that were, all females and most males were immature, with a small number of males classed as maturing and mature (Jones et al. 2022). In the 2020 survey, school shark less than 1 m long were retained for detailed examination and both males and females were subsequently confirmed as immature. Larger individuals were tagged and released; females were not staged, and males were maturing with one mature male captured (133 cm).

3.2.10 Rig (SPO)

Number of surveys	8
Total catch weight (kg)	3103.8
Number measured	1820
Length range (mean) (cm)	13–138 (70.41)
Number weighed	132

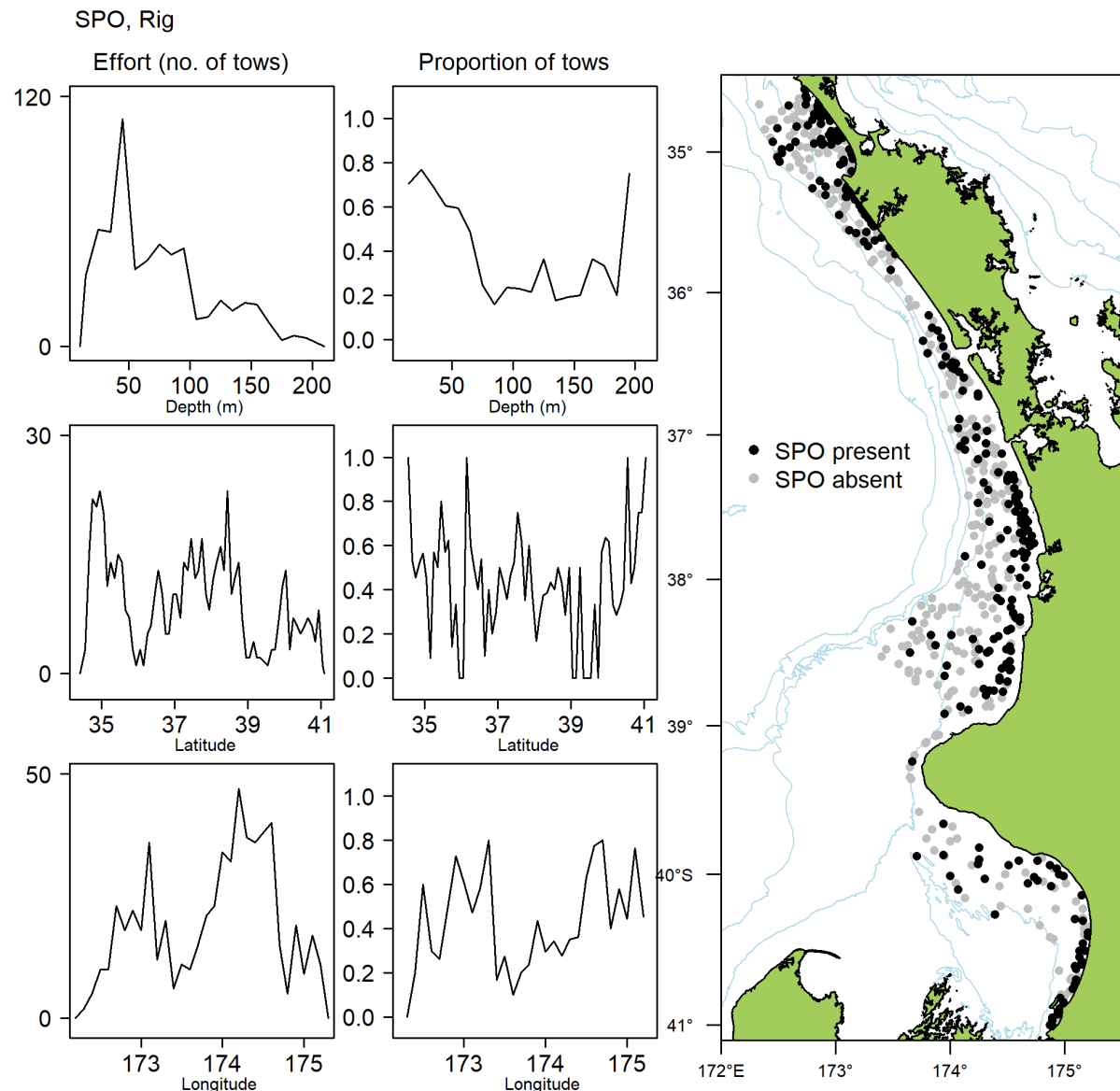


Figure 89: Summary of occurrence of rig in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which rig were caught. All valid tows are plotted in the map on the right with black dots showing those where rig were present.

Rig are demersal, found from shallow water to 400 m depth. This species was the second or third most important elasmobranch in the catch by weight in the three most recent surveys. Almost all catches were at depths below 100 m (Figure 89), with the highest catch rates generally from inshore shallow waters outside harbours (Figure 90), where female rig migrate into to pup (Francis et al. 2012). The exclusion of sampling within the Māui dolphin trawl exclusion areas undoubtedly impacts the effectiveness of this survey for sampling the adult female population.

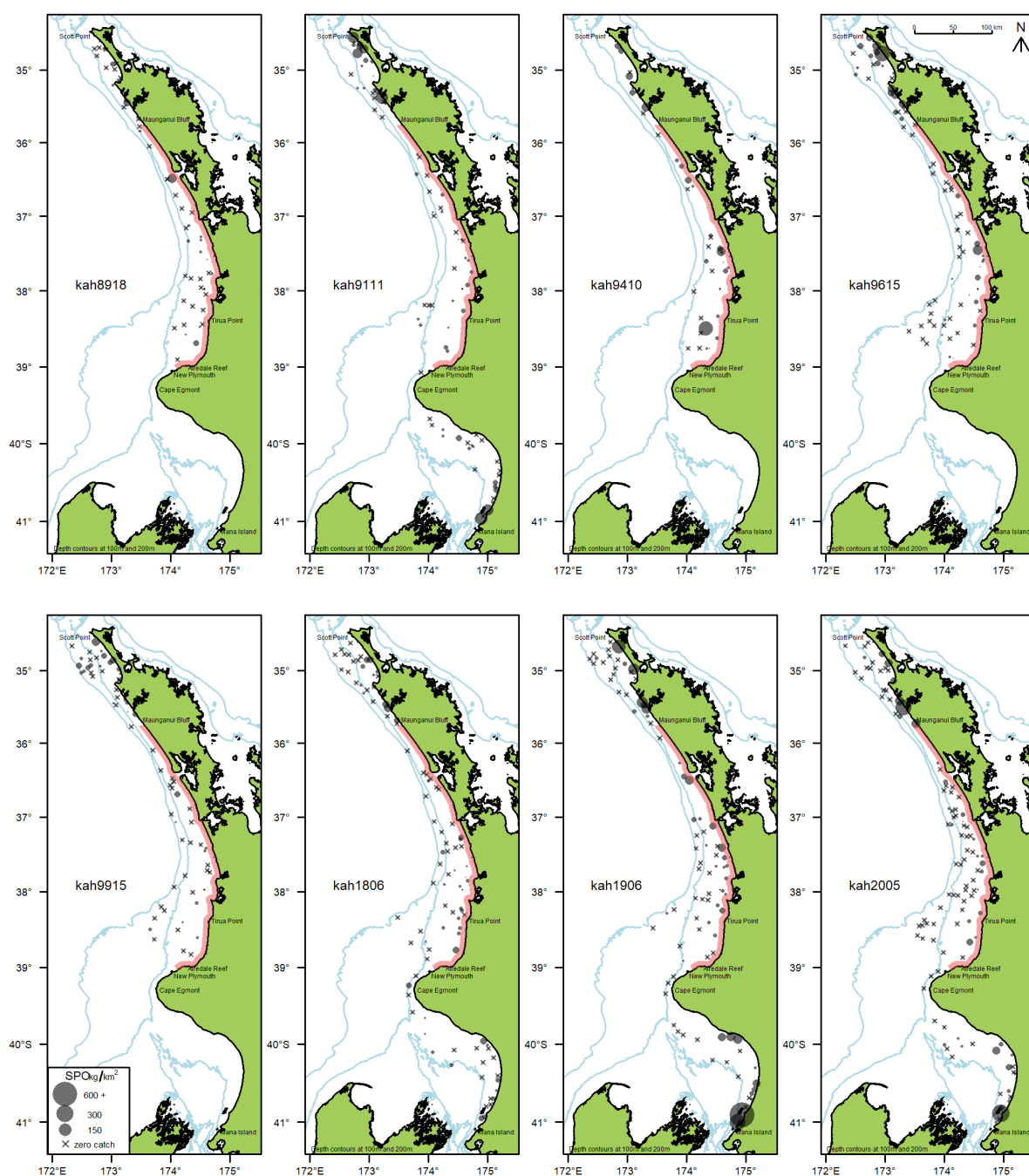


Figure 90: Spatial distribution of catch rates (kg km^{-2}) of rig in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

Most of the rig biomass was classed as pre-recruit (under 90 cm in total length), with recruited biomass around 20% of the total in 2018 and 2019 and just 13% in 2020 (Jones et al. 2022). The northern core series peaked in 1994, but the large CV over 40% in that year indicated it was not a precise estimate (Figure 91, Table 35). The CVs for the other years in the series ranged from 20 to 33%. The biomass estimates for the extended core and whole survey series were more reliably estimated, with CVs < 30%, however no clear trend was apparent. In the whole survey time series, the 1991 survey biomass was similar to the more recent surveys in 2019 and 2020, which reflected higher catch rates in the southern inshore strata (Figure 90). The commercial CPUE series for this stock (SPO 1W) includes both coastal bottom trawl (BT) and set net indices. Like the survey, the commercial BT index, which is not considered representative of mature females, started at a high level in the early 1990s, then fluctuated,

but was relatively flat during the 1990s and 2000s, before an increase around 2008 and fluctuating around a higher level since then (Fisheries New Zealand 2022).

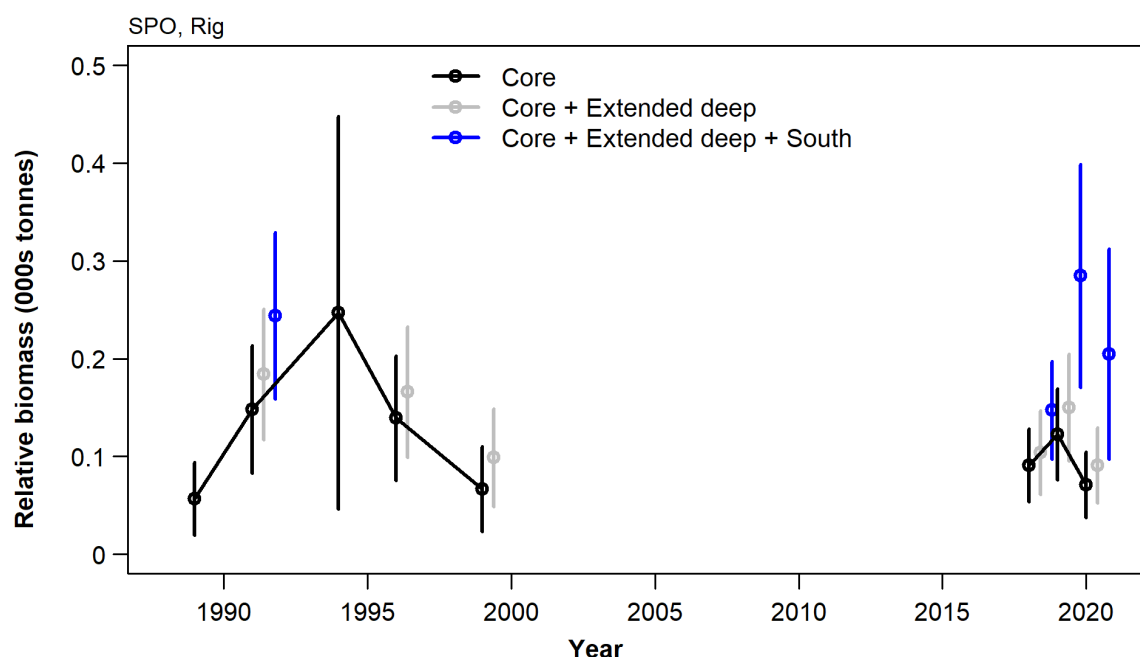


Figure 91: Time series of total relative biomass estimates and 95% confidence intervals for rig for the core northern area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 35: Relative biomass estimates (t) and CVs (%) of rig for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	56.68	32.66						
kah9111	147.93	22.05	183.90	18.18	59.45	43.57	243.36	17.38
kah9410	246.94	40.65						
kah9615	139.09	22.92	165.85	20.09				
kah9915	66.61	32.81	98.69	25.34				
kah1806	91.06	20.45	104.04	20.57	40.84	31.66	144.87	17.05
kah1906	122.59	19.02	149.93	18.24	134.67	37.11	284.60	20.02
kah2005	70.94	23.65	90.92	21.23	113.87	44.12	204.79	26.28

The size range of rig caught in the trawl was from 21 cm up to > 130 cm, with a mean length of 65–78 cm in each survey (Table 36). In the northern core area, the length distribution was mainly between 50 cm, and 95 cm for males and 100 cm for females, with low numbers above 90 cm (Figure 92). Only five females larger than 100 cm were caught in the three recent surveys; four at 103–138 cm were retained in 2019. In 2019, a small number of 29–31 cm individuals were also measured. Given that size at birth is reported as 25–30 cm, and females are known to enter harbours to pup, these could have been aborted pups from females that were not retained in the trawl. The larger sample size in the 2019 survey also included juvenile and sub-adult modes around 51–56 cm and 65–67 cm, a peak at around 77 cm of mainly males, and a female mode at around 84 cm. Length frequencies from the core area in earlier surveys showed a similar overall size range of 40–100 cm, with relatively few rig over 90 cm (Figure 92). Population scaled length frequency distributions for the southern strata are sparse for most years except 2019 and are shown in Figure 93. Similar to school shark, 0+ rig < 46 cm are found in

west coast harbours such as the Kaipara and Raglan (Francis et al. 2012), and likely move out onto the coast as they grow, where they become available to the survey. It is possible that, like the east coast South Island survey, this survey could provide an index of pre-recruits. The sex ratio for this species was approximately even in most surveys or biased towards females in some years.

Table 36: Summary of catch weight and length measurements of rig by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	189.5	43	100	68.17	129
kah9111	528.5	28	133	71.76	300
kah9410	390.3	21	97	69.31	228
kah9615	675.6	13*	131	65.28	514
kah9915	208.9	43	109	65.78	154
kah1806	239.7	50	98	75.19	114
kah1906	577.9	29	138	77.89	251
kah2005	293.4	40	102	76.76	130

*Likely to be an error as size at birth is reported to be 25–30 cm.

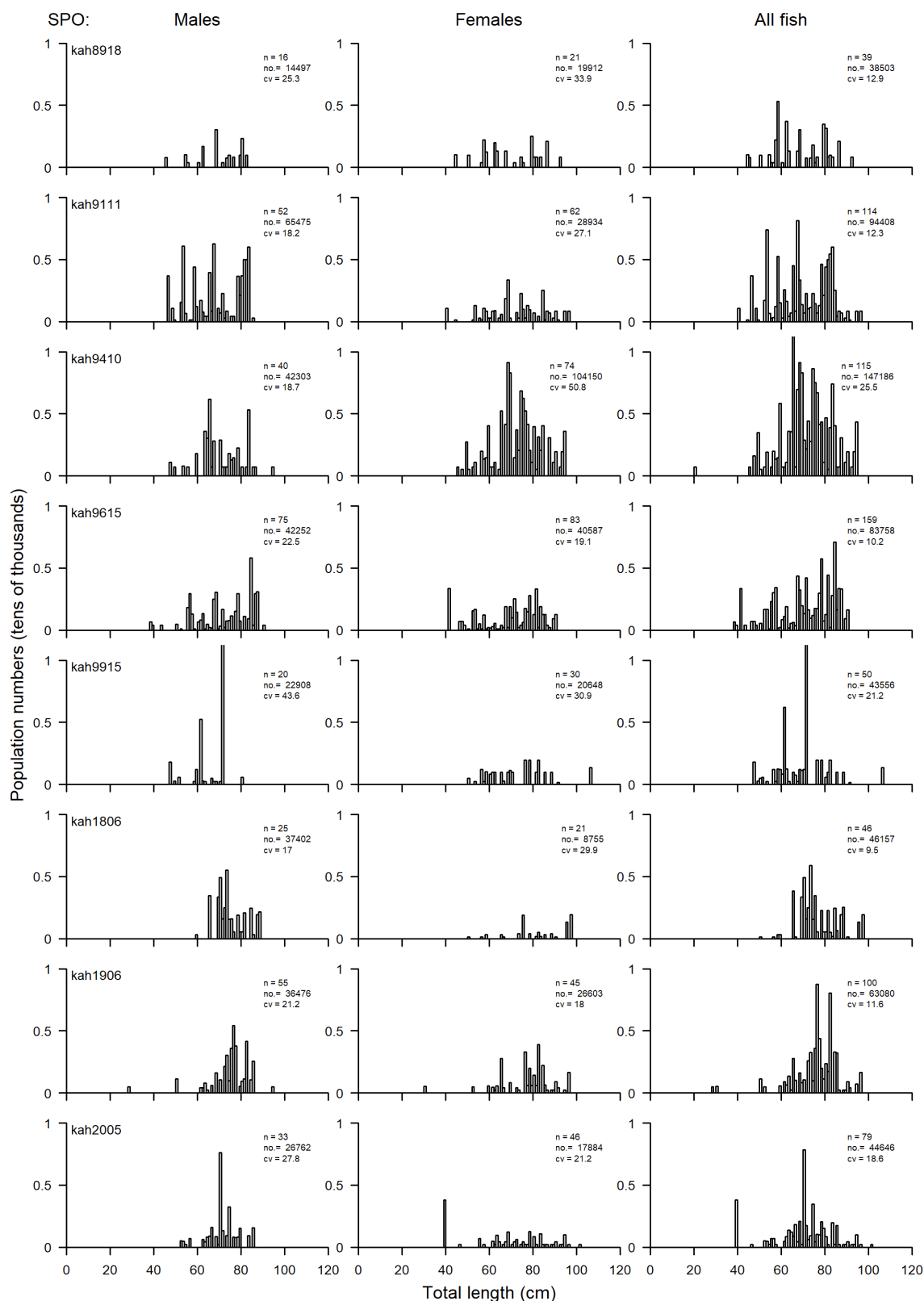


Figure 92: Comparative scaled length frequency distributions for males, females, and all rig in the northern core strata (<100 m) for the WCNI survey time series. n=number of fish measured, no.=scaled population number, and cv=coefficient of variation. 'All fish' includes unsexed fish.

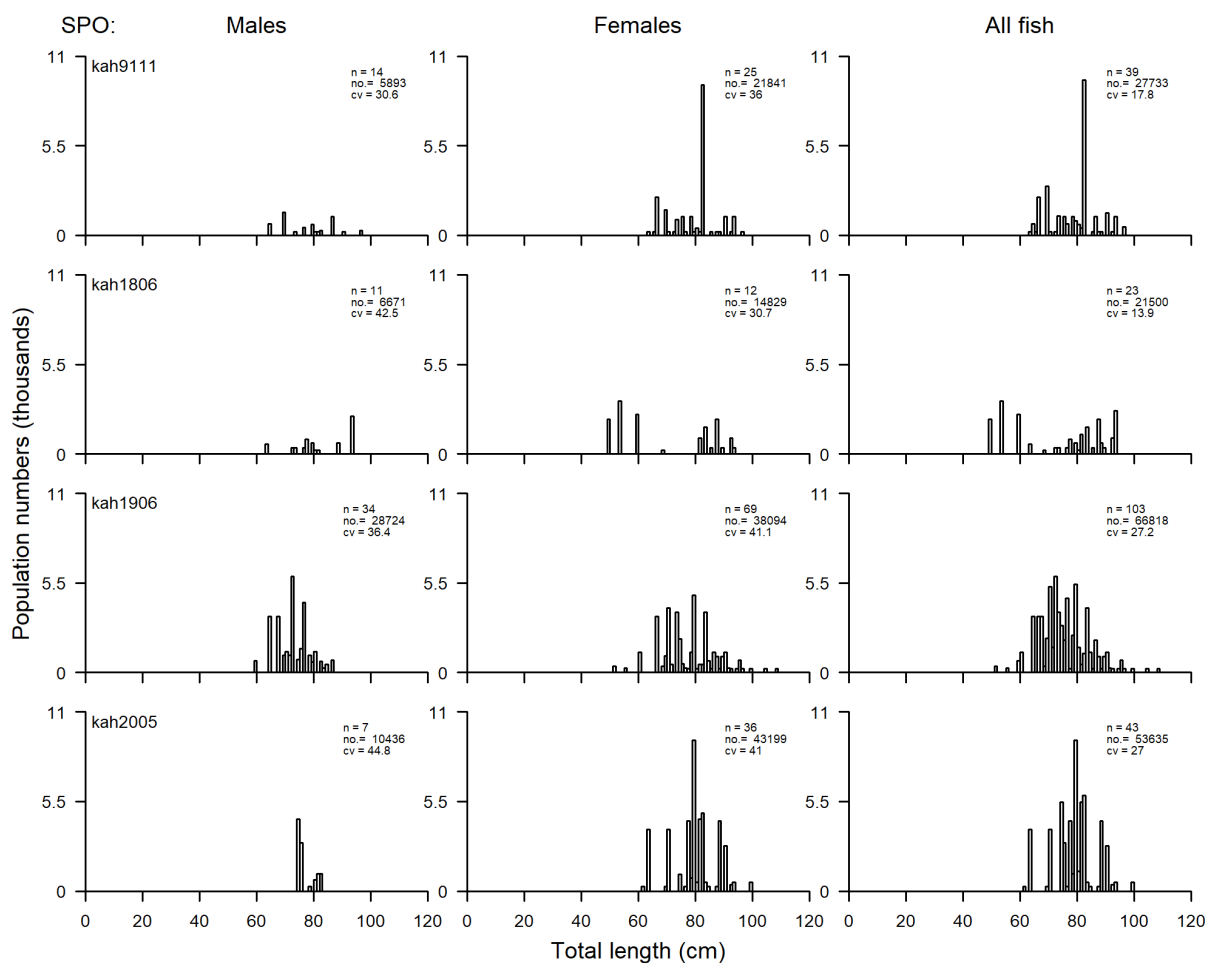


Figure 93: Comparative scaled length frequency distributions for males, females, and all fish in the southern strata for the four WCNI surveys that included the South Taranaki Bight. n=number of fish measured, no.=scaled population number, and cv=coefficient of variation. 'All fish' includes unsexed fish.

Few fish were staged, except in 2019. Most staged males larger than 70 cm were mature (Jones et al. 2022). A small number of females were retained for biological sampling, with those > 80 cm assessed as mature and/or gravid (Jones et al. 2022).

3.2.11 Spiny dogfish (SPD)

Number of surveys	8
Total catch weight (kg)	9203.8
Number measured	3121
Length range (mean) (cm)	15–93 (68.11)
Number weighed	478

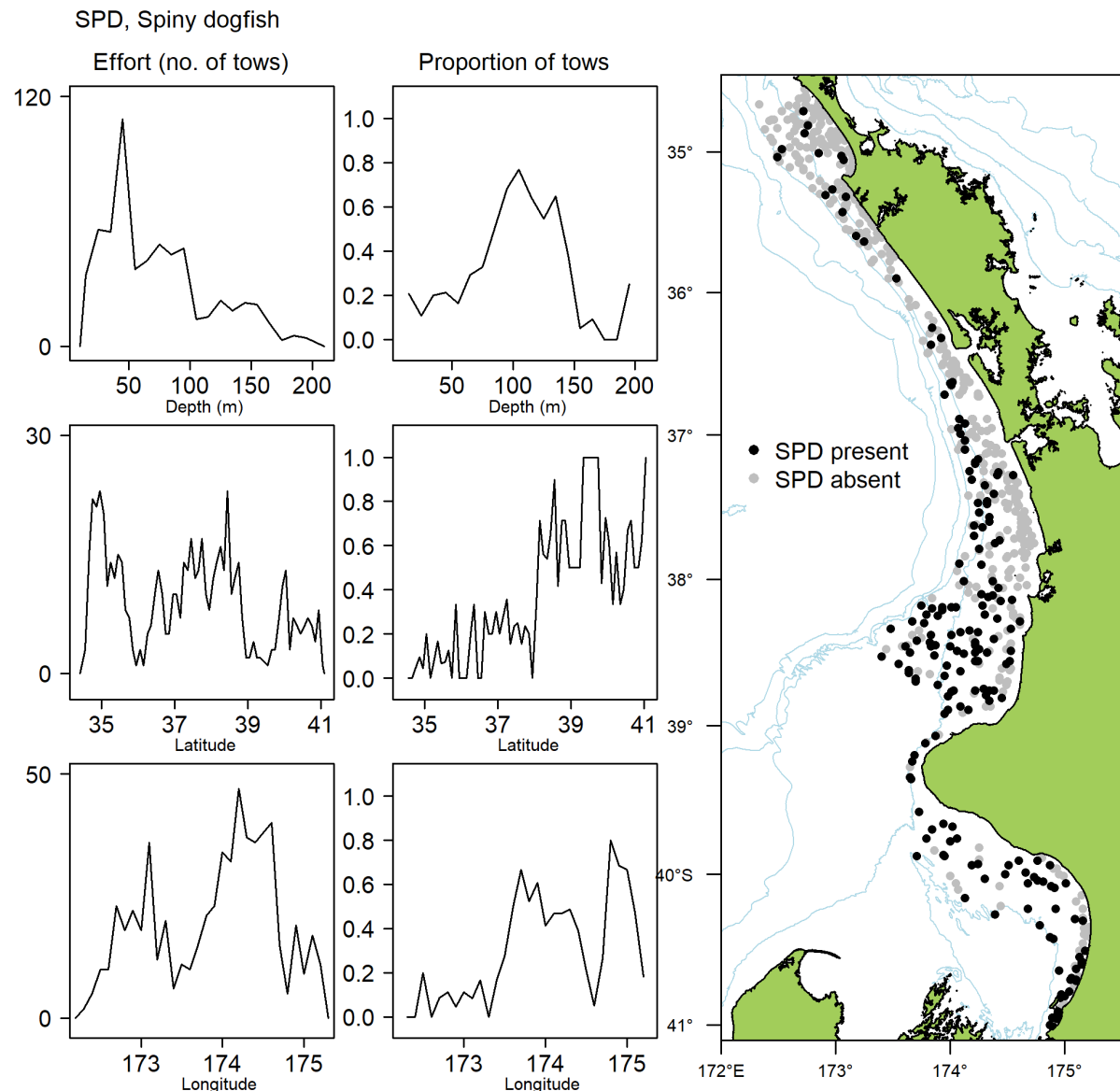


Figure 94: Summary of occurrence of spiny dogfish in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which spiny dogfish were caught. All valid tows are plotted in the map on the right with black dots showing those where spiny dogfish were present.

Spiny dogfish are widespread around New Zealand, but most common around the South Island, particularly along the east coast. This pattern is reflected in Figure 94, with the increasing trend in occurrence at higher latitude and longitude and patchier catches north of the Manukau Harbour. The depth range of occurrence in the survey was from 10 m to 150 m, although this species is found as deep as 700 m (McMillan et al. 2019). Spiny dogfish are a schooling species, and catch rates were highly

variable, but this species was more numerous in the South Taranaki Bight (Figures 94 and 95). In the 2018 survey, a very large catch (2.6 t) was taken in around 40 m water depth in G50, which accounted for 90% of the biomass in that survey (Figure 95). This species was the most abundant elasmobranch caught in the more recent surveys, compared with historical surveys where school shark was often the most abundant by catch weight.

SPD, Spiny dogfish

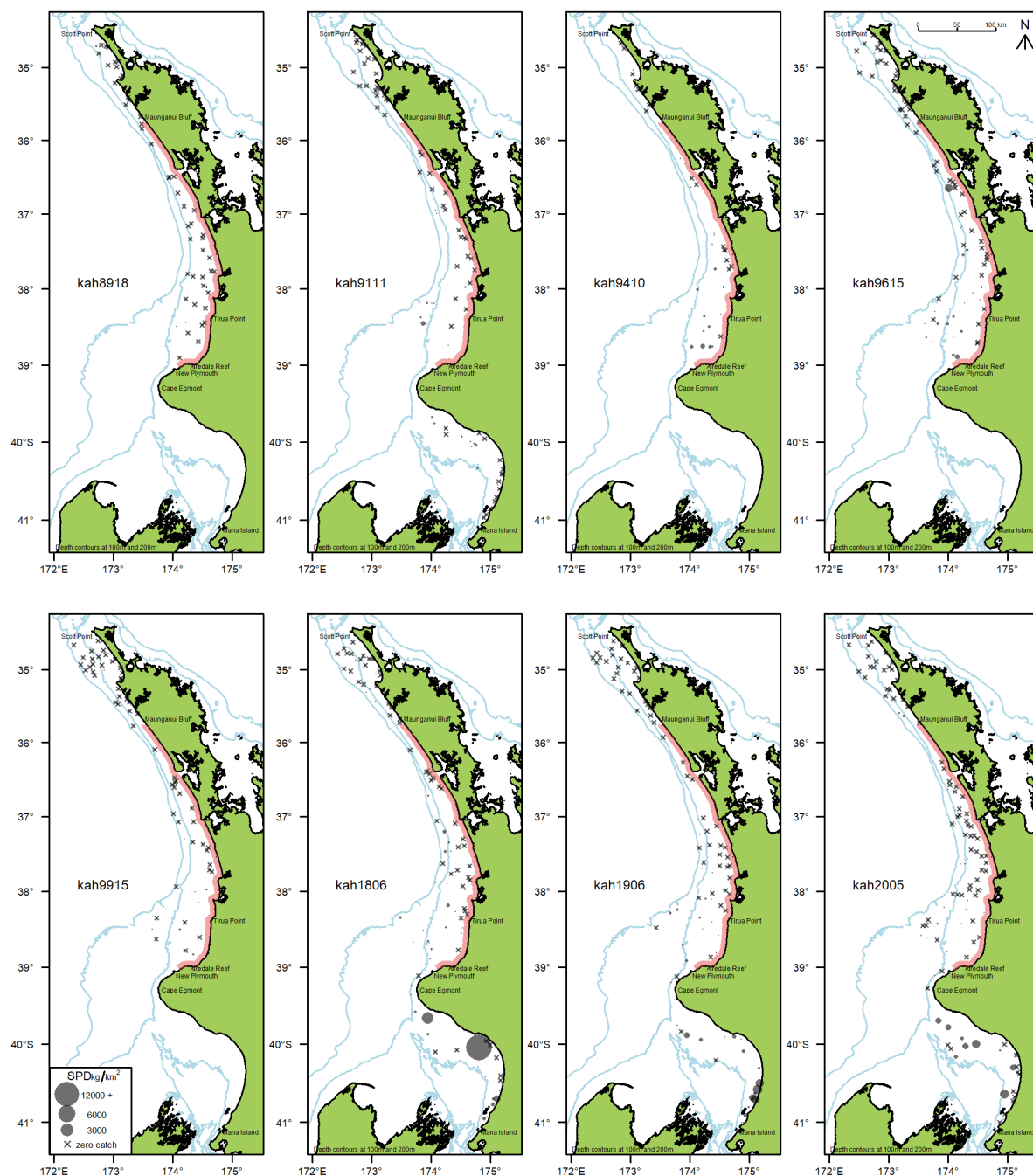


Figure 95: Spatial distribution of catch rates (kg km^{-2}) of spiny dogfish in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

The time series of relative biomass estimates are given in Figure 96 and Table 37. Biomass estimates were highly variable, with low precision, but the northern core and extended core biomass estimates, north of Cape Egmont, were much lower than for the southern strata in surveys where those were

sampled. The high CVs make any trends difficult to discern, but there is a decline in the three recent surveys north of Cape Egmont.

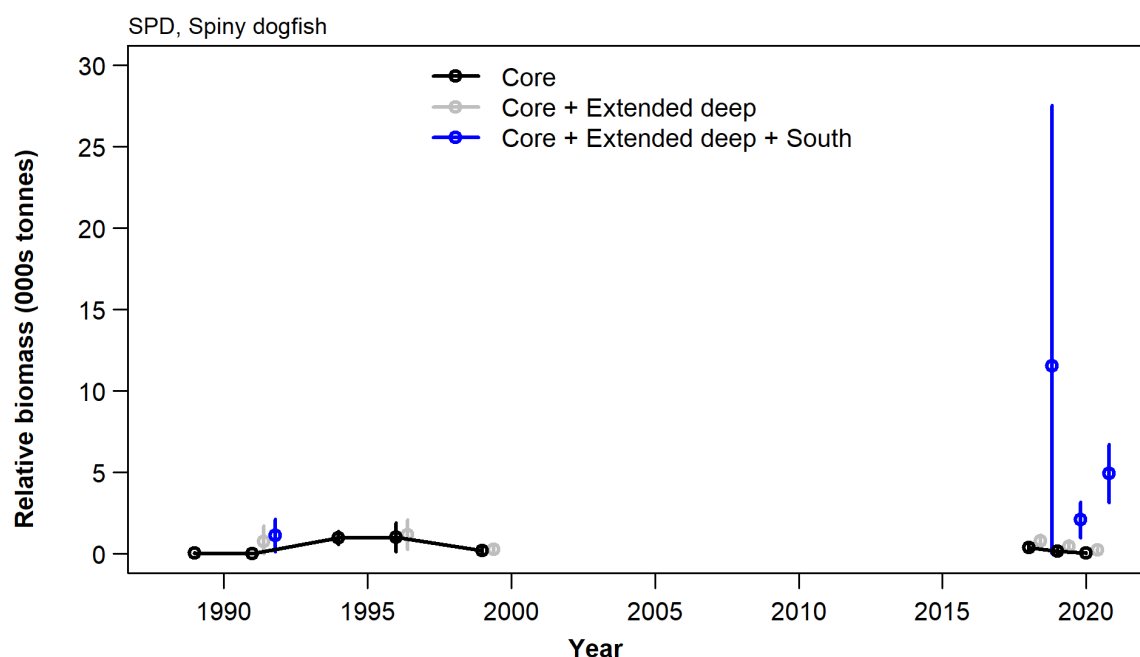


Figure 96: Time series of total relative biomass estimates and 95% confidence intervals for spiny dogfish for the northern core area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 37: Relative biomass estimates (t) and CVs (%) of spiny dogfish for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	35.39	56.51						
kah9111	4.76	79.76	768.18	62.62	373.35	39.60	1 141.53	44.08
kah9410	983.82	20.41						
kah9615	1 009.62	44.54	1 177.91	38.53				
kah9915	202.67	55.63	261.67	45.06				
kah1806	392.24	28.16	805.23	22.12	10 732.54	74.56	11 537.77	69.37
kah1906	151.73	52.09	462.29	38.40	1 614.51	32.02	2 076.81	26.32
kah2005	50.98	41.17	219.55	23.46	4 706.04	19.03	4 931.55	18.19

The population scaled length frequency distributions of spiny dogfish caught in the whole survey series are shown in Figure 97. The size ranged from 48 cm to 92 cm. Numbers of juveniles (< 50 cm) were low or absent, contrasting with the west coast South Island survey, where these smaller fish were present, forming a separate mode in some years (MacGibbon et al. 2022). A mature male mode around 60 cm was present in all years. An adult female mode, between 60–80 cm was observed, but very few fish over 80 cm were caught, despite females being known to reach 110 cm in length (Hanchet 1986, 1988). Across the whole survey, females were more abundant than males. The core area time series of spiny dogfish length frequency distributions are presented in Figure 98. Length data were sparse or absent from three of the five historical surveys (Table 38). Females were largely absent from the northern core area in the recent surveys, in contrast to the historical 1994 and 1996 surveys, where mature females were present in greater numbers than the males in the northern core region. This may however reflect the tendency of this species to segregate by size and sex.

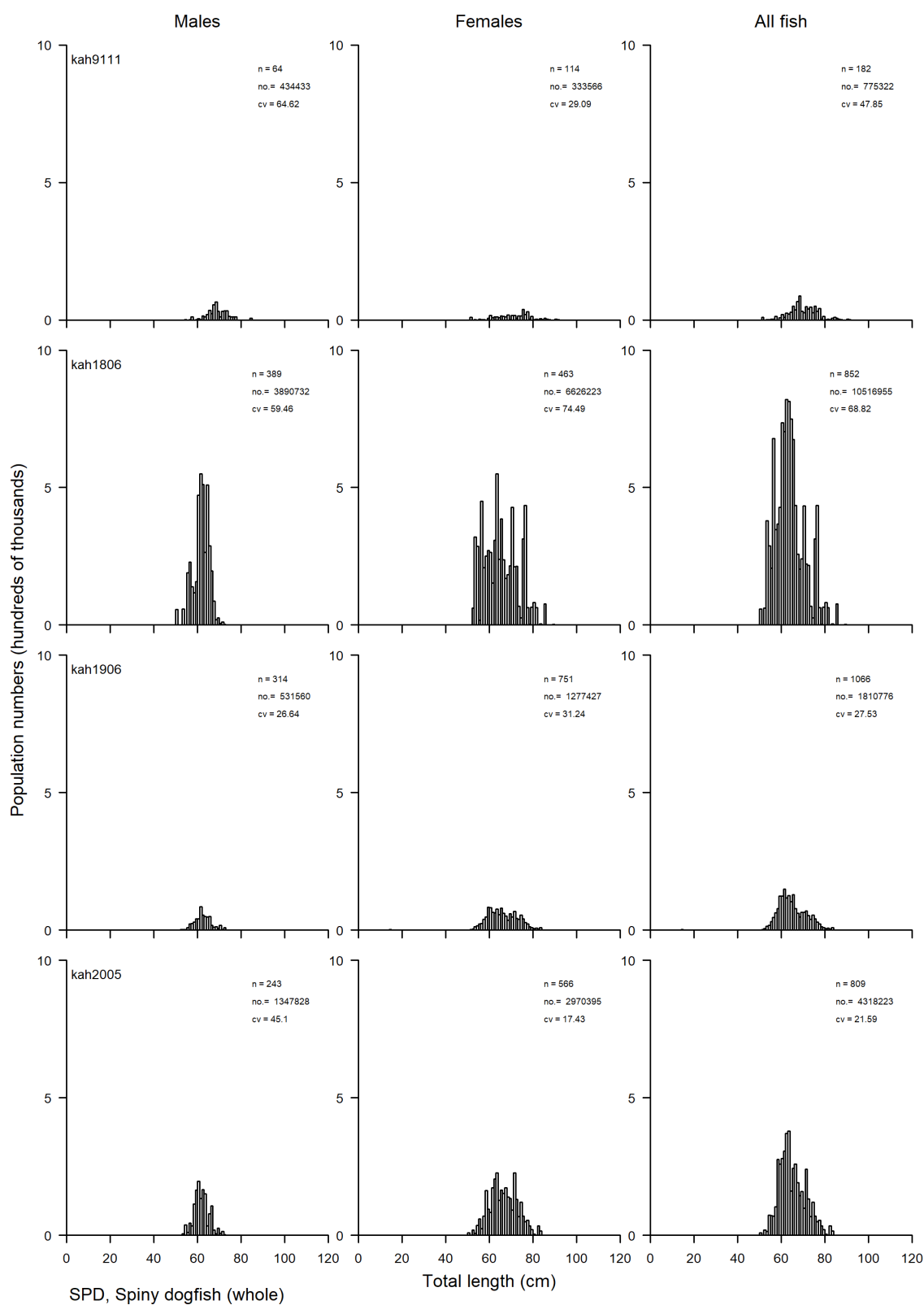


Figure 97: Comparative scaled length frequency distributions for males, females, and all spiny dogfish for the whole survey (core + extended deep + south). n=number of fish measured, no.=scaled population number, and cv= coefficient of variation. 'All fish' includes unsexed fish.

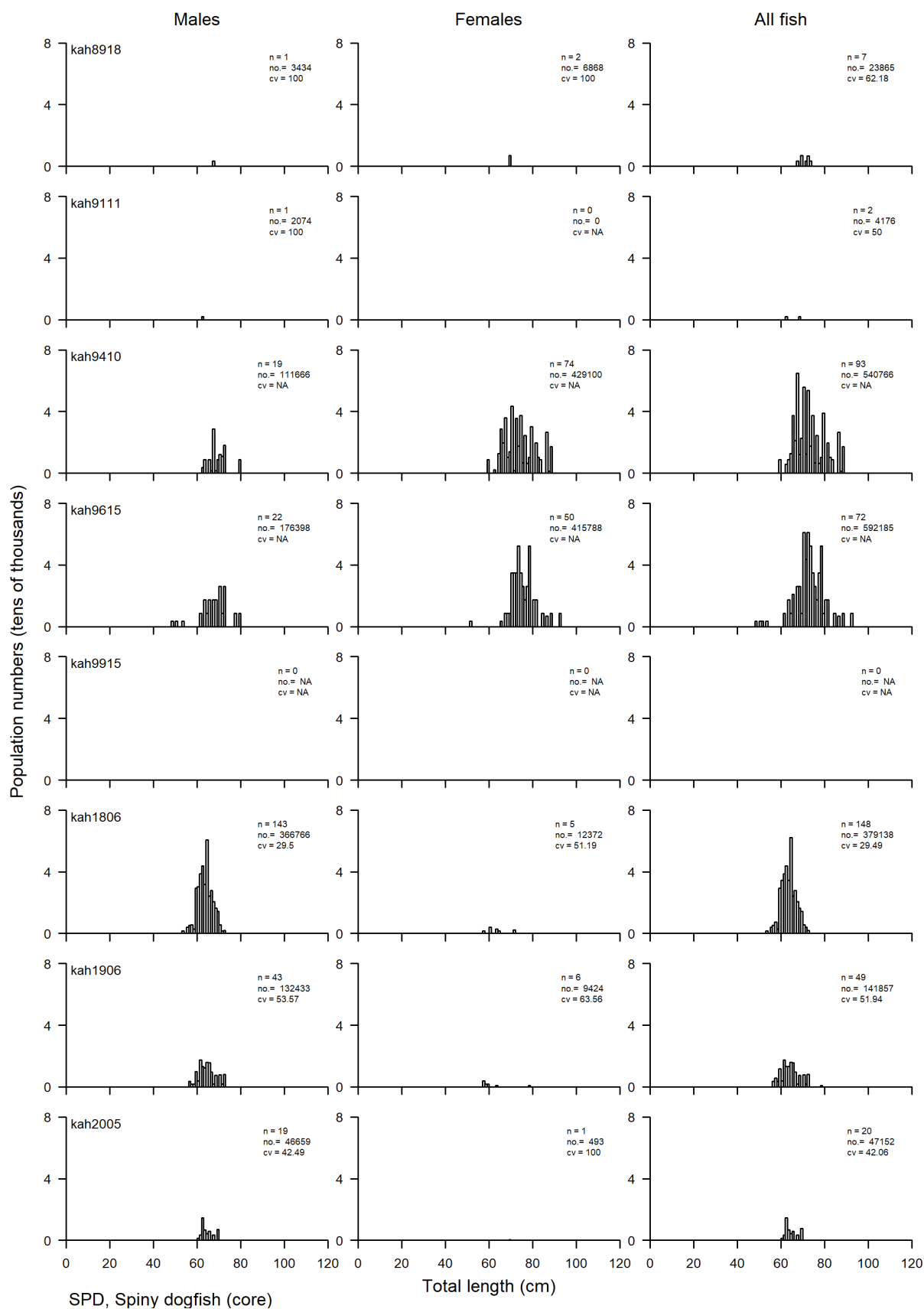


Figure 98: Comparative scaled length frequency distributions for males, females and all spiny dogfish in the northern core strata (<100 m) for the WCNI survey time series. n=number of fish measured, no.=scaled population number and cv=coefficient of variation. 'All fish' includes unsexed fish.

Table 38: Summary of catch weight and length measurements of spiny dogfish by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	21.5	68	74	71.40	7
kah9111	344.2	52	92	71.51	182
kah9410	513.7	60	89	73.21	100
kah9615	725.7	49	93	72.80	98
kah9915	104.4				
kah1806	4 100.6	51	91	66.79	859
kah1906	1 834.9	15	88	66.28	1 066
kah2005	1 558.8	51	84	68.23	809

The lack of immature specimens was evident in the biological sampling; of the 478 fish that were staged across the three surveys, most males were classed as stage 3 mature, and 50–60% of females in the 2019 and 2020 survey were ripe or pregnant (Table 39).

Table 39: Proportion of sampled spiny dogfish with gonads at different reproductive stages by survey. No females were examined in 2018. Note, a 6-stage scale is used for female sharks and 3-stage scale for males. (Gonad stages are defined in Appendix 4.)

Year	Maturity stage							Sample size
	1	2	3	4	5	6	7	
Female								
kah1806								0
kah1906	0.04	0.36	0.24	0.19	0.16	0.01	NA	165
kah2005	0	0.5	0.12	0.12	0.25	0	NA	8
Male								
kah1806	0.04	0.04	0.93	NA	NA	NA	NA	54
kah1906	0.01	0.08	0.91	NA	NA	NA	NA	228
kah2005	0	0	1	NA	NA	NA	NA	23

3.2.12 Leatherjacket (LEA)

Number of surveys	8
Total catch weight (kg)	3460.3
Number measured	4645
Length range (mean) (cm)	8–34 (23.73)
Number weighed	25

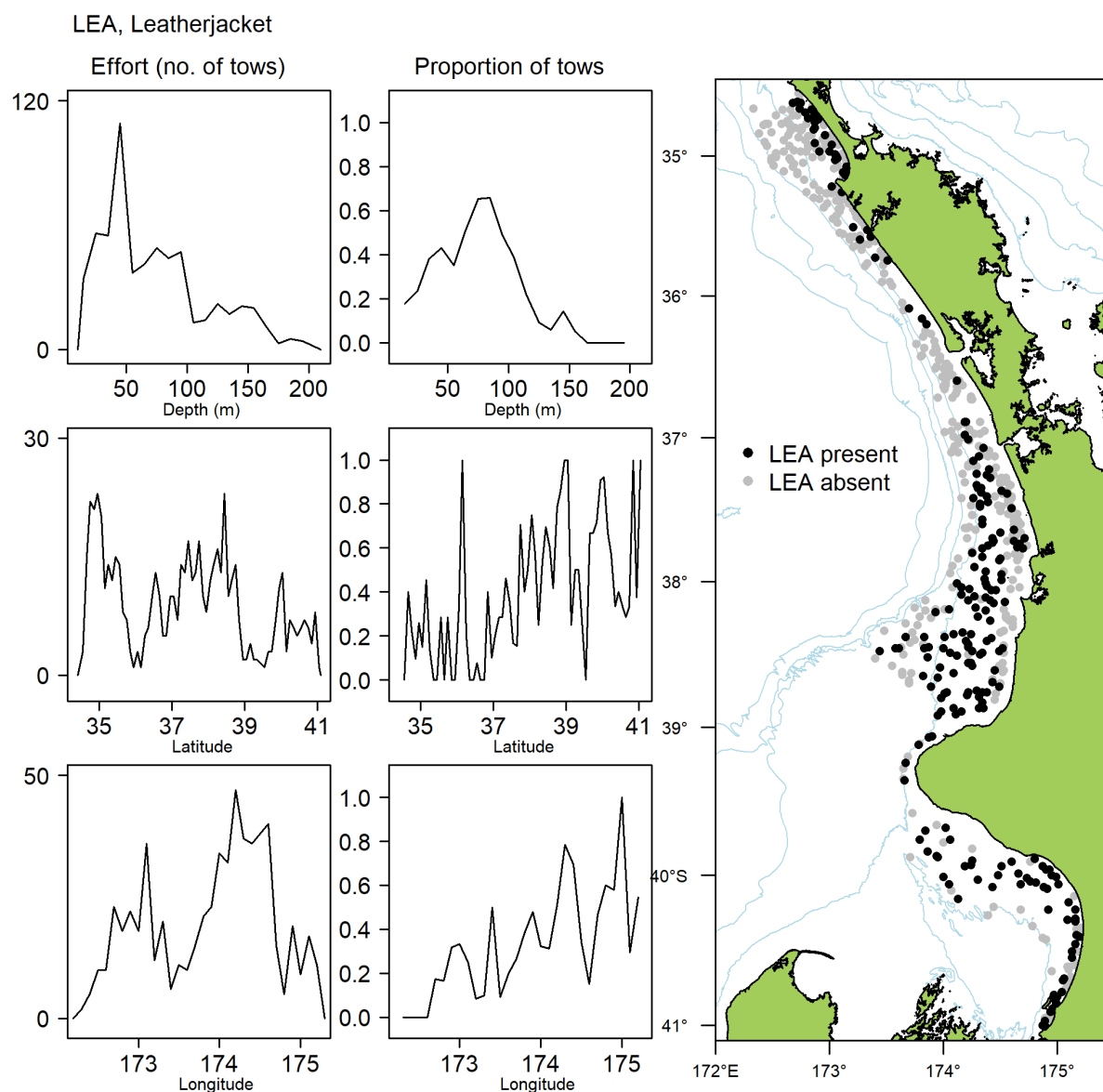


Figure 99: Summary of occurrence of leatherjacket in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, and by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which leatherjacket were caught. All valid tows are plotted in the map on the right with black dots showing those where leatherjacket were present.

Leatherjacket are demersal and found throughout coastal New Zealand to around 300 m, although more abundant in central and northern areas (McMillan et al. 2019). In the trawl survey, this species was mainly caught in 50–100 m and was most common in the central part of the survey between Airedale Reef and the Manukau Harbour (Figure 99). Some large catches ranging from 100 to 500+ kg were taken in the South Taranaki Bight during the 1991 survey when this species was the second most abundant by weight after red gurnard, but this catch rate has not been seen in the more recent surveys (Figure 100).

LEA, Leatherjacket

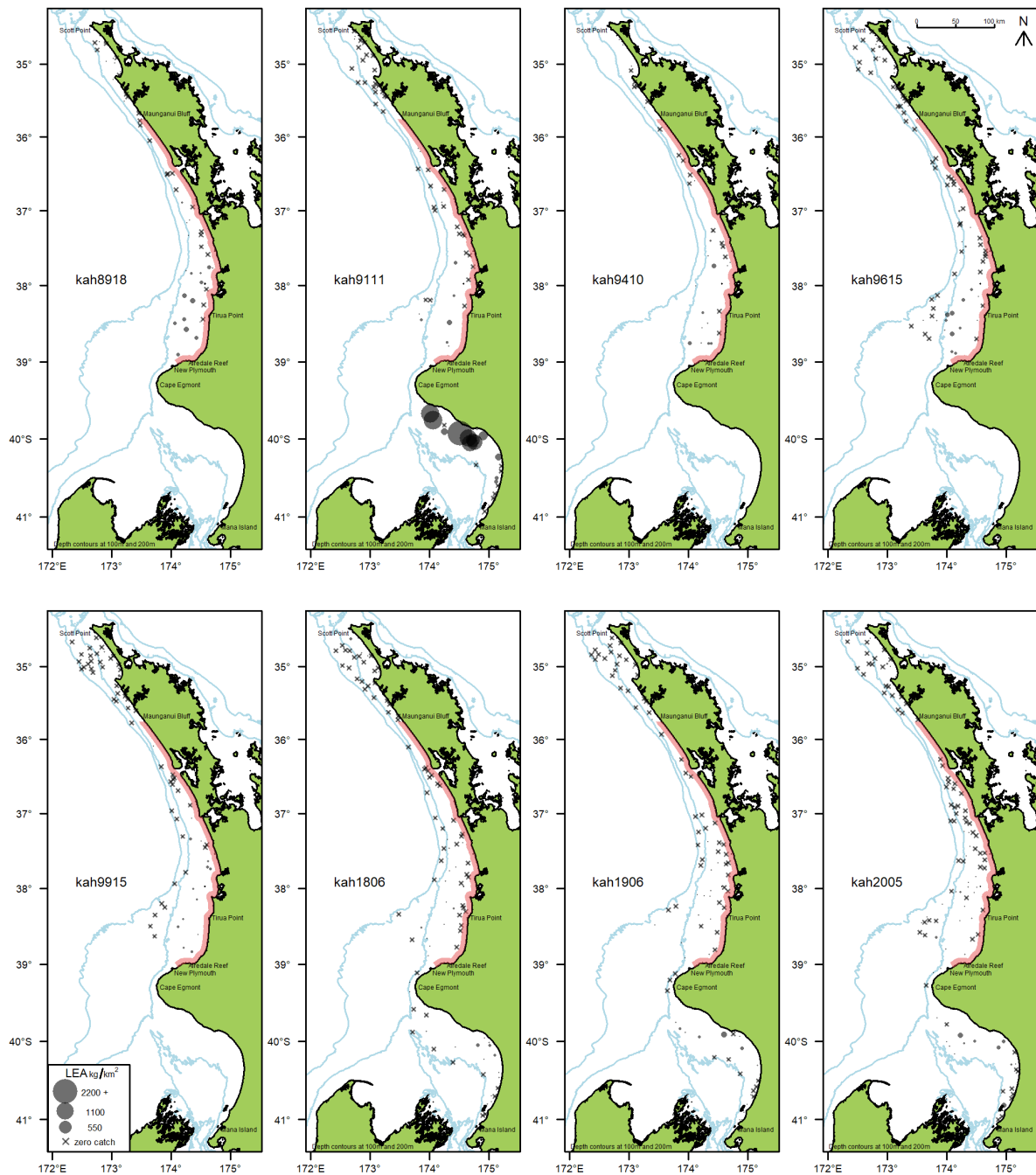


Figure 100: Spatial distribution of catch rates (kg km^{-2}) of leatherjacket in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

The estimated relative total biomass was low in all surveys except 1991, with variable precision, with lowest catch rates in the core area in the recent surveys compared with historical surveys (Figure 101, Table 40). There is no characterisation or stock assessment for LEA 1, but landings have halved since 2012–13 (Fisheries New Zealand 2022).

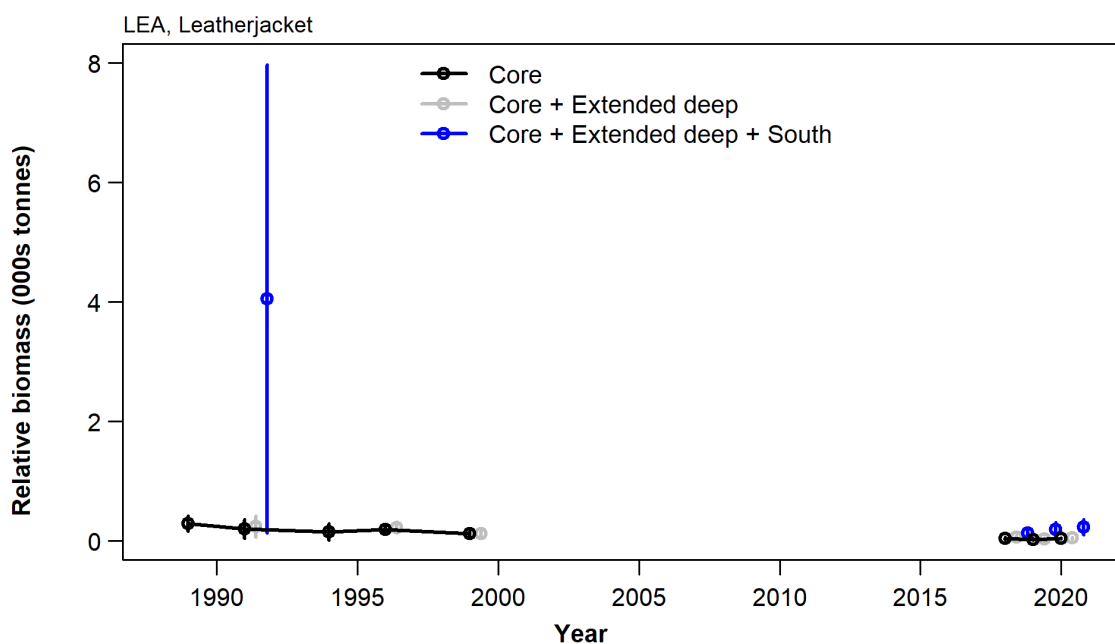


Figure 101: Time series of relative biomass estimates and 95% confidence intervals for leatherjacket for the core northern area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 40: Relative biomass estimates (t) and CVs (%) of leatherjacket for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	286.98	22.21						
kah9111	195.89	40.70	239.11	37.10	3 809.05	51.42	4 048.16	48.43
kah9410	149.49	45.66						
kah9615	194.29	21.66	222.32	21.40				
kah9915	122.22	19.66	122.22	19.66				
kah1806	39.94	24.54	56.66	34.21	72.66	43.37	129.32	28.61
kah1906	25.13	35.14	32.23	31.01	162.61	34.42	194.84	29.18
kah2005	39.54	15.19	46.21	18.01	184.43	34.57	231.43	27.81

The size range sampled in the northern core strata ranged from 8 to 34 cm, covering juvenile and adult sizes, but most fish were between 20 and 30cm, with modal peaks at 23–25 cm in each year, and no change in mean size over the time series (Table 41 and Figure 102). Numbers of fish under 20 cm were very low. The population scaled length frequency distributions for the southern strata are shown in Figure 103, with much higher numbers of fish in the earlier survey.

Table 41: Summary of catch weight and length measurements of leatherjacket by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	770.7	14	34	23.67	1 627
kah9111	2 186.5	12	30	23.43	1 377
kah9410	70.4	13	28	23	194
kah9615	125.3	12	28	22.49	306
kah9915	61.7	16	30	23.98	272
kah1806	65.1	20	31	24.69	225
kah1906	68.7	14	30	23.51	243
kah2005	111.9	8	33	24.6	401

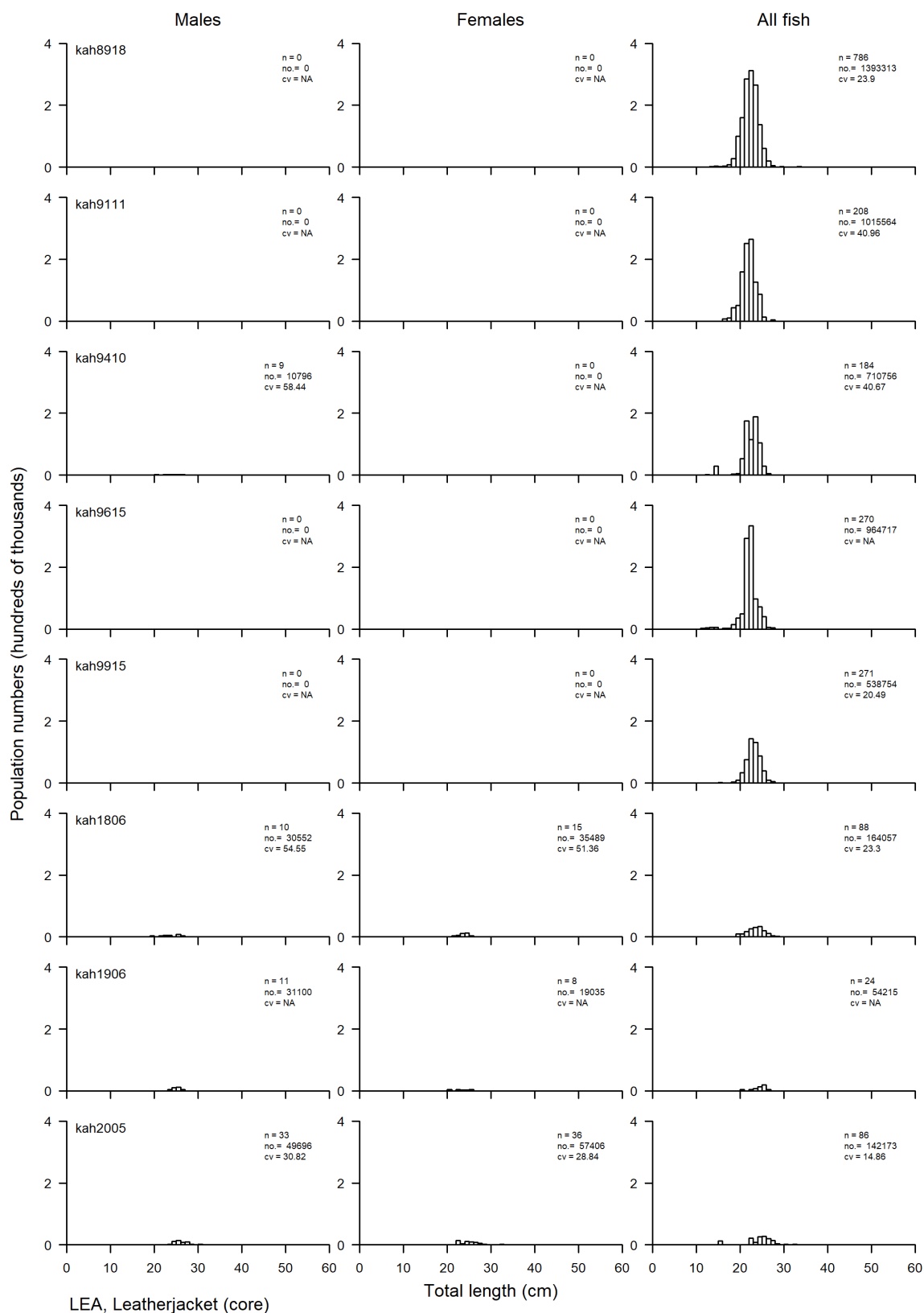


Figure 102: Comparative scaled length frequency distributions for males, females and all leatherjacket in the northern core strata (<100 m) for the time series of the WCNI surveys. n=number of fish measured, no.=scaled population number, and cv=coefficient of variation. 'All fish' includes unsexed fish.

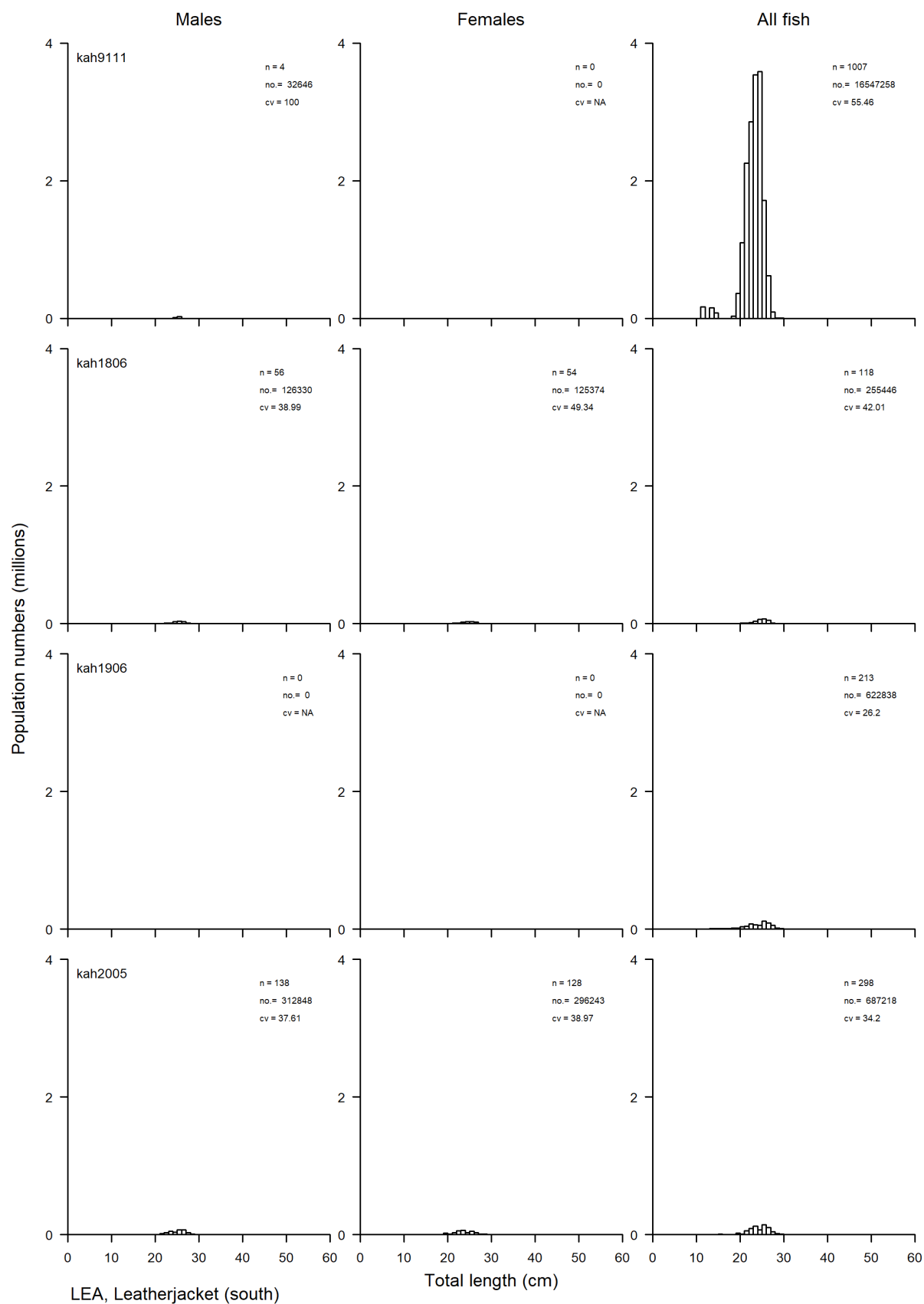


Figure 103: Comparative scaled length frequency distributions for males, females, and all leatherjacket in the southern strata for the four WCNI surveys that included the South Taranaki Bight. n=number of fish measured, no.= scaled population number and CV=coefficient of variation. 'All fish' includes unsexed fish.

3.2.13 Rough Skate (RSK)

Number of surveys	7
Total catch weight (kg)	750.5
Number measured	222
Length range (mean) (cm)	23–62 (46.3)
Number weighed	34

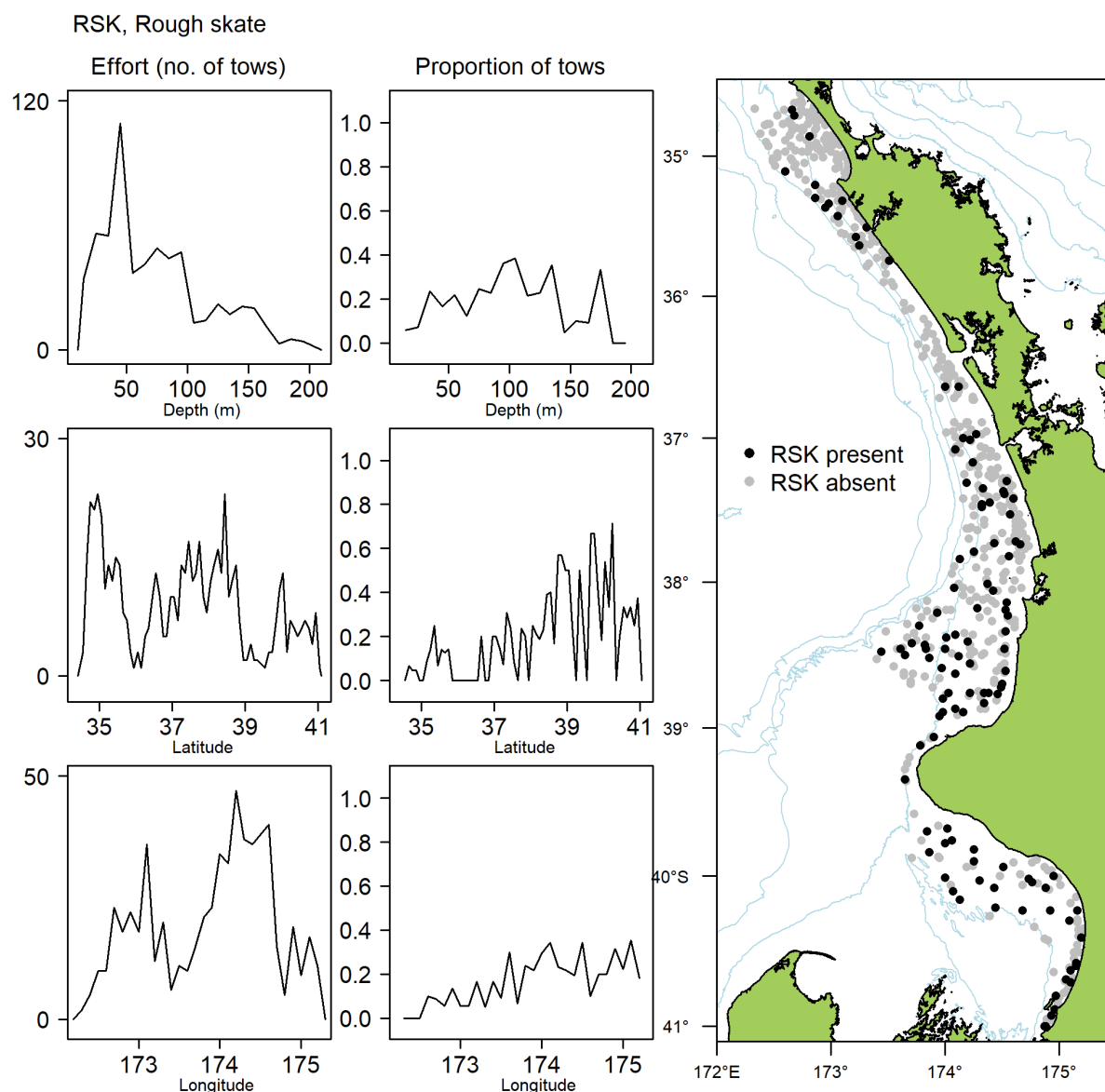


Figure 104: Summary of occurrence of rough skate in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, and by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which rough skate were caught. All valid tows are plotted in the map on the right with black dots showing those where rough skate were present.

Rough skate occur all around New Zealand from shallow depths to 600 m depth (McMillan et al. 2019). This species was found throughout the survey area, but occurrence was patchy north of the Manukau Harbour, and more commonly caught at higher latitudes (Figure 104). Skate caught in 1989 were not identified to species and were recorded as SKA. In 1991, skate caught south of Cape Egmont were identified as rough or smooth skate, whilst those caught to the north were recorded as SKA and likely

to be a mixture of both rough and smooth skate. Therefore zero biomass estimates for RSK for the two earliest surveys for strata north of Cape Egmont should be ignored. The species are considered to be reasonably well identified from 1994 onwards.

Most rough skates were caught shallower than 150 m. Catch rates are highly variable; there were high catches north of Cape Egmont in 1996 (Figure 105). The catches from 1999 and more recent surveys were more modest, concentrated off Ninety Mile Beach, the North Taranaki Bight, and in the southern strata (Figure 105).

RSK, Rough skate

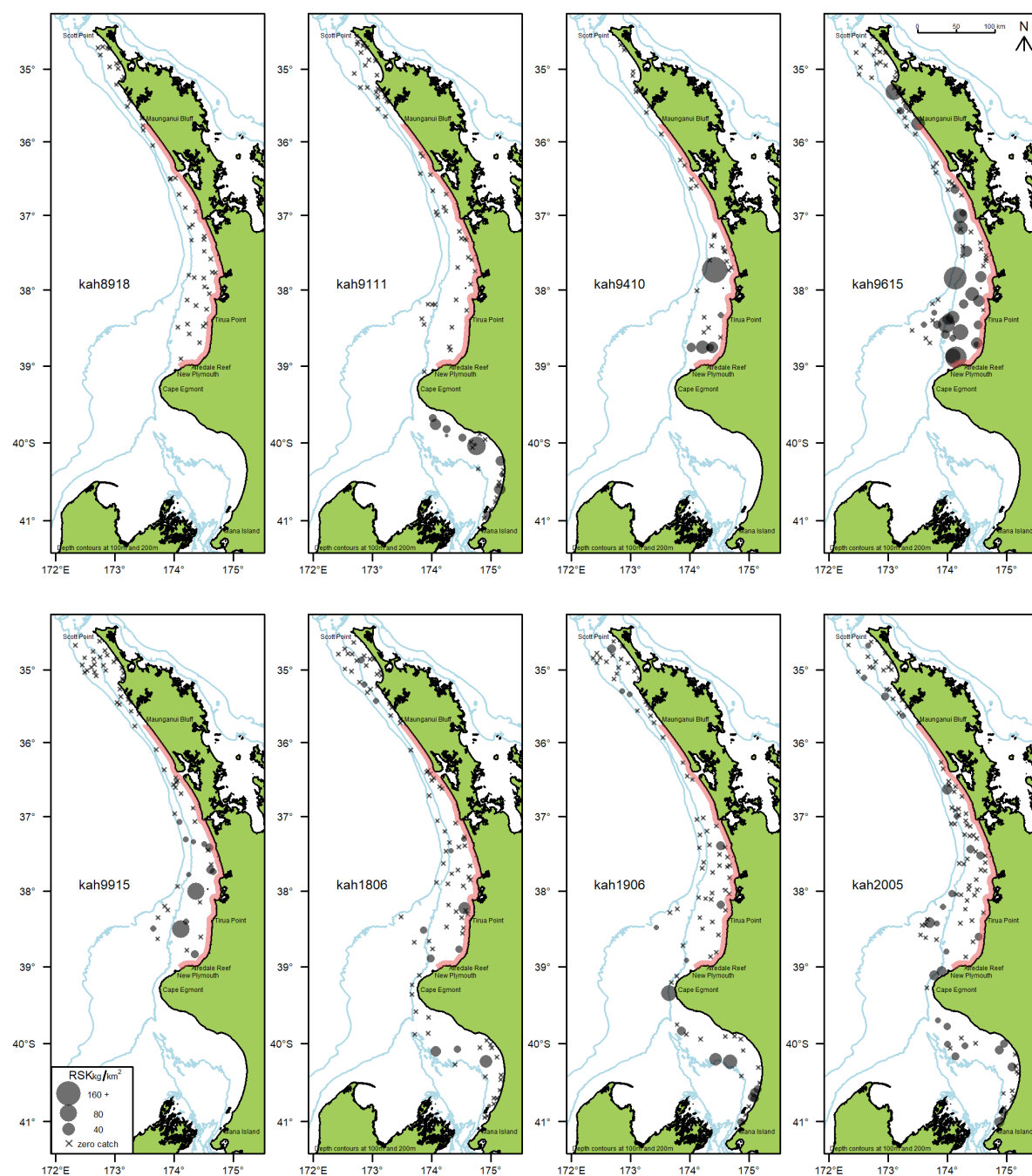


Figure 105: Spatial distribution of catch rates (kg km^{-2}) of rough skate in the WCNI surveys. Catch rates are scaled to the largest catch in the series. Zero catches in 1989 and in the northern strata in 1991 are due to lack of identification to species in these surveys.

Relative biomass estimates were unreliable prior to 1994, and had low precision in later historical surveys. More recent biomass estimates in the northern strata are lower, and relatively stable (Figure 106, Table 42), but with CVs ranging from 28 to 50%, indicating the precision of the biomass estimates was often still poor. Recent surveys of the whole survey area had lower CVs between 21–37% (Table 42).

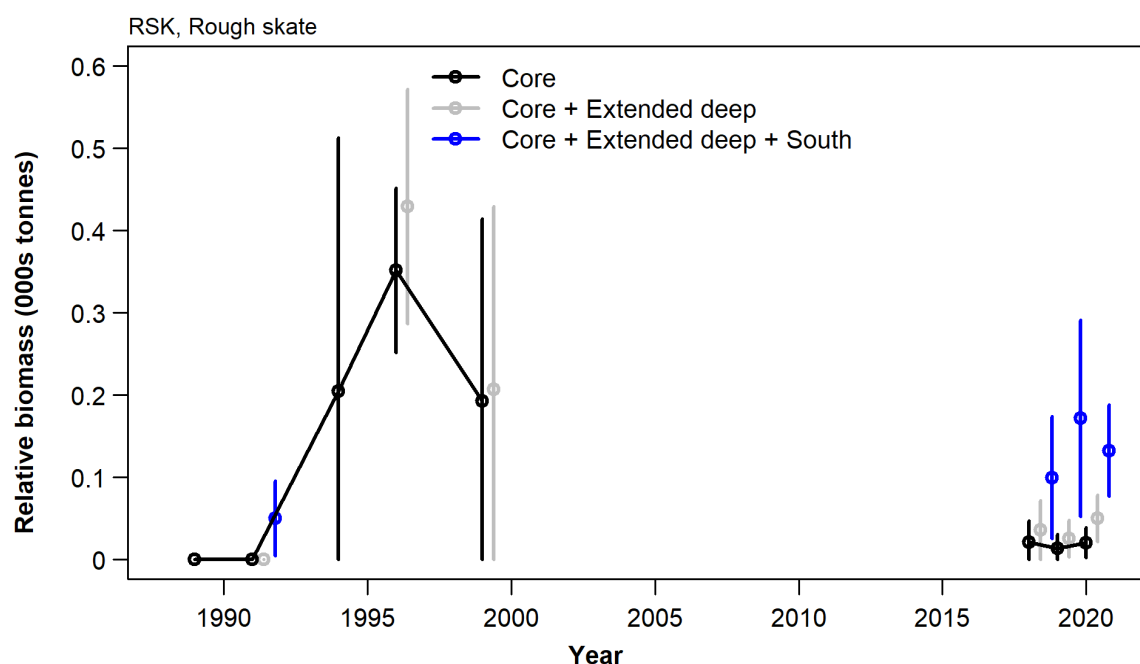


Figure 106: Time series of total relative biomass estimates and 95% confidence intervals for rough skate for the northern core area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 42: Relative biomass estimates (t) and CVs (%) of rough skate for the core, extended core, southern strata, and whole survey areas. Skate were not identified to species in 1989 and were only identified to species in the southern strata in 1991. Deeper strata of the extended core were not sampled in the 1994 survey. South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918								
kah9111					50.11	45.51	50.11	45.51
kah9410	204.78	75.14						
kah9615	351.27	14.24	429.35	16.59				
kah9915	192.69	57.40	207.03	53.60				
kah1806	21.13	61.74	35.99	49.58	61.29	53.15	97.28	38.18
kah1906	13.63	61.69	25.68	43.32	145.84	40.18	171.51	34.77
kah2005	20.52	45.00	50.25	28.22	80.79	29.08	132.36	20.96

The size range of measured rough skate was 23–62 cm (pelvic fin length) (Table 43), which encompasses juveniles as well as mature male specimens (L_{50} for males is 52 cm, M.P. Francis et al. 2001). Most of the male skate that were assessed in recent surveys ($n=29$), were classed as either maturing or mature. Few mature females were encountered (L_{50} females is 59 cm, M.P. Francis et al. 2001). The mean length was stable across the surveys at around 48 cm, except in 1996, when mean length was 43.6 cm. This survey recorded the highest number of rough skate, including higher numbers of juveniles < 40 cm. In other surveys, most rough skate were between 40 and 60 cm pelvic fin length (Figure 107).

Table 43: Summary of catch weight and length measurements of rough skate by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918					
kah9111	63.3	32	56	48	23
kah9410	89.6				
kah9615	312.9	23	57	43.60	117
kah9915	73.1				
kah1806	43	35	55	48.33	15
kah1906	77.5	31	62	48.43	31
kah2005	91.1	36	57	49.64	36

Holmes et al. (2022) reviewed the utility of all available trawl time series for use in a partial quantitative assessment of skates and concluded that the WCNI survey series was potentially useful for monitoring rough skate in RSK 8 once a longer time series of estimates were available for the wider area. They concluded that the coverage of the depth range by the wider survey was “very good”, the number of fish measured and consistency of length frequencies were “reasonable”, and the precision and consistency of the biomass estimates were “good”.

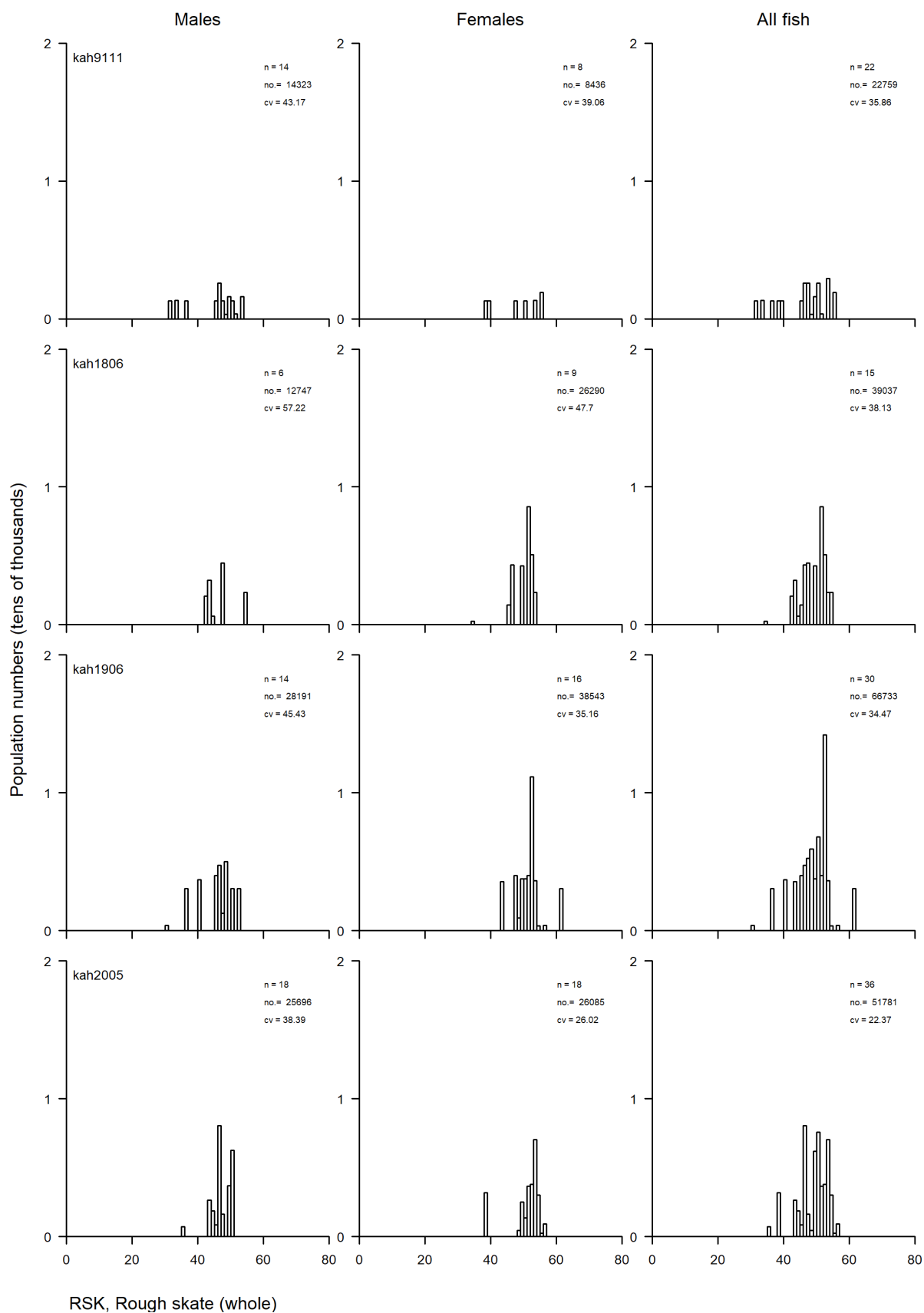


Figure 107: Comparative scaled length frequencies for males, females and all rough skate in the whole area (including extended deep northern and southern strata). n=number of fish measured, no.=scaled population number and cv=coefficient of variation. 'All fish' includes unsexed fish.

3.2.14 Smooth skate (SSK)

Number of surveys	7
Total catch weight (kg)	698.8
Number measured	141
Length range (mean) (cm)	13–110 (54.9)
Number weighed	12

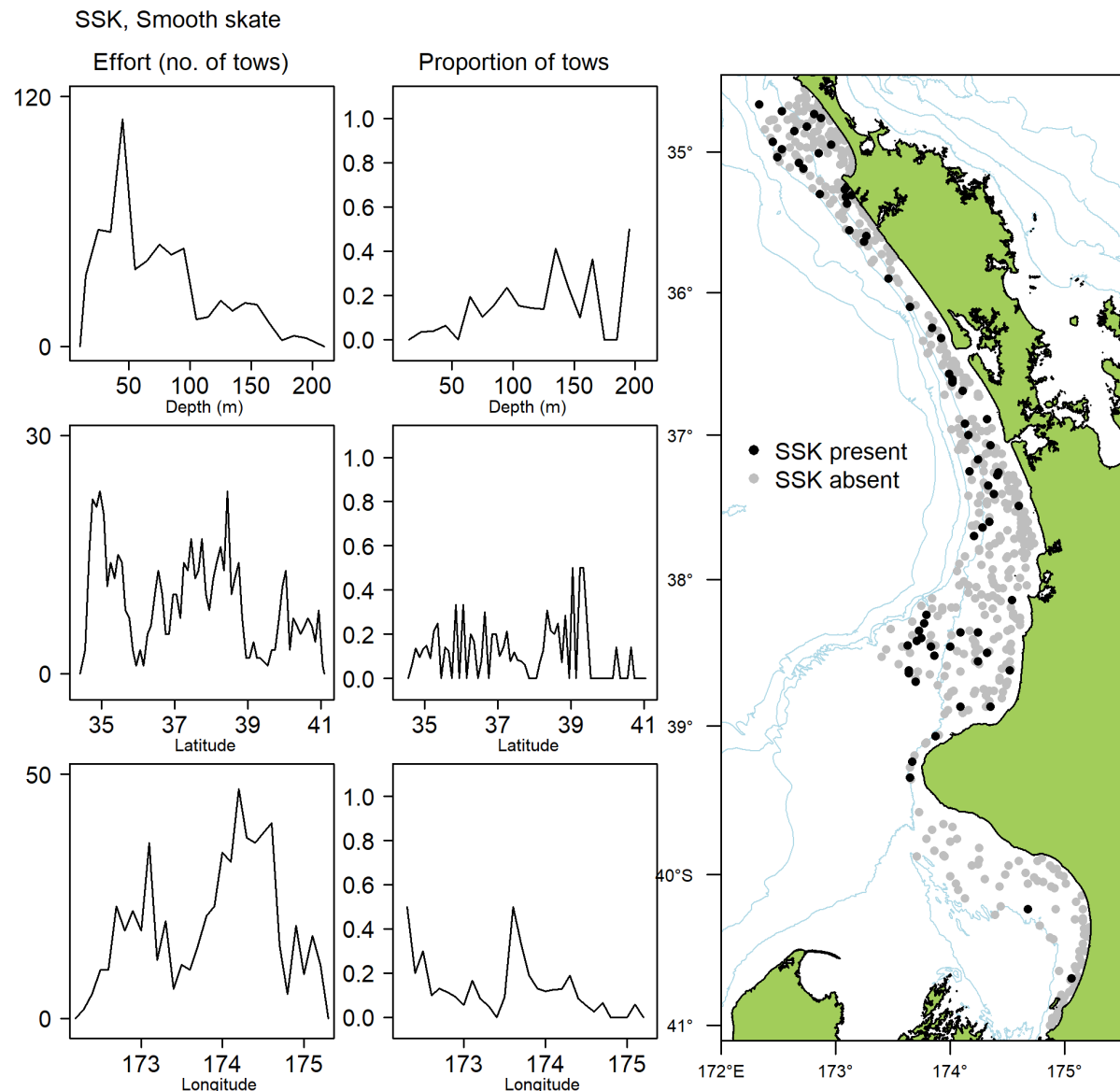


Figure 108: Summary of occurrence of smooth skate in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, and by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which smooth skate were caught. All valid tows are plotted in the map on the right with black dots showing those where smooth skate were present.

Smooth skate is widespread around New Zealand and found to depths of 800 m (McMillan et al. 2019). As noted in the previous section, skate caught in 1989 were not identified to species and were recorded as SKA. In 1991, skate caught south of Cape Egmont were identified to species, whilst skate caught to the north were recorded as SKA. Therefore zero biomass estimates for SSK for the two earliest surveys for strata north of Cape Egmont should be ignored. The species are likely to be reasonably well identified from 1994 onwards. The occurrence of smooth skate in the survey is shown in Figure 108.

Most smooth skates were caught deeper than 100 m, from Ninety Mile Beach to the Kapiti coast (Figures 108 and 109). Catch rates were variable with no clear spatial patterns (Figure 109).

SSK, Smooth skate

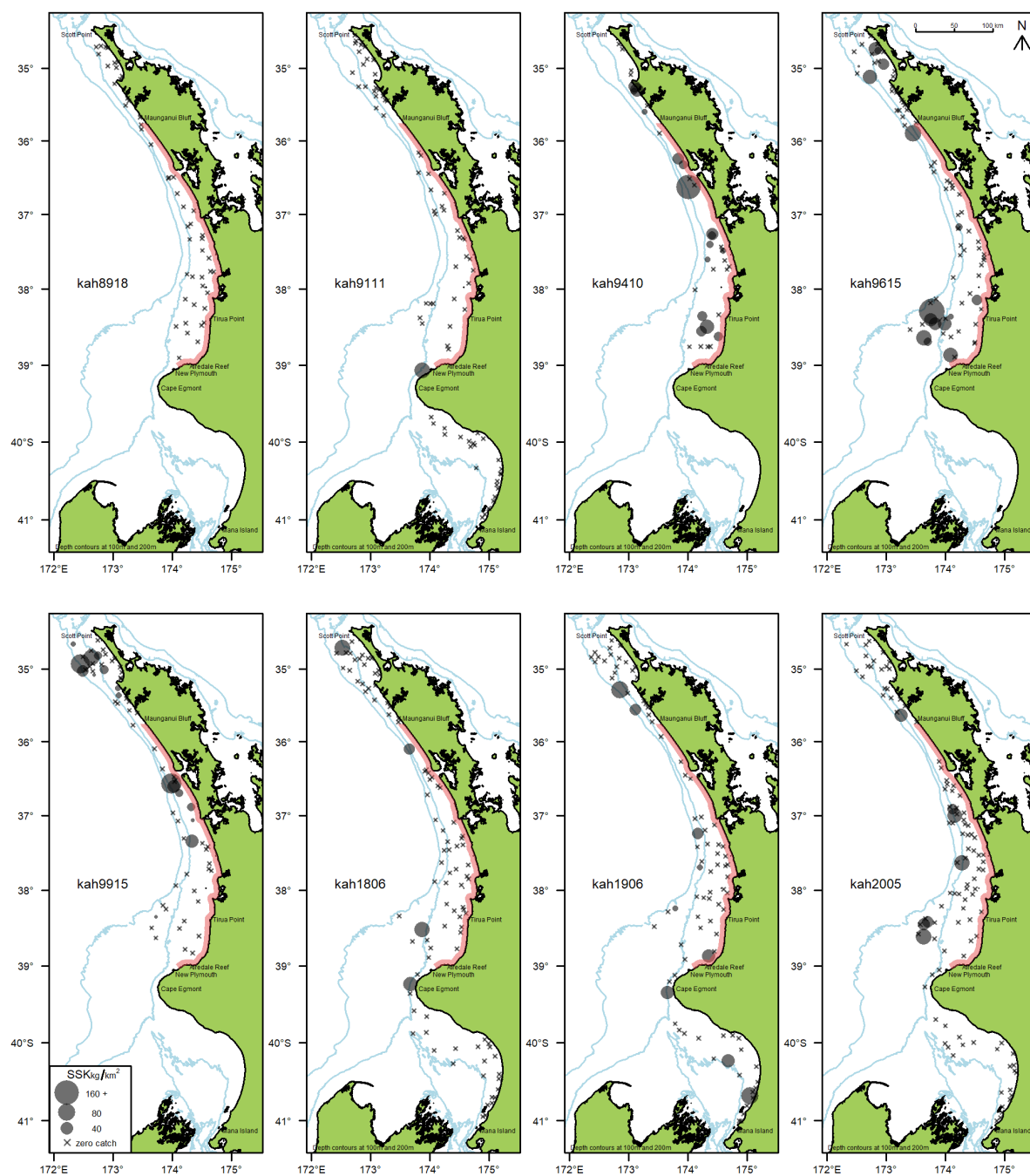


Figure 109: Spatial distribution of catch rates (kg km^{-2}) of smooth skate in the WCNI surveys. Catch rates are scaled to the largest catch in the series. Zero catches in 1989 and in the northern strata in 1991 are due to lack of identification to species in these surveys.

Biomass estimates for northern strata prior to 1994 are zero due to lack of species identification. Subsequent estimates are poorly estimated with no clear trend (Figure 110, Table 44).

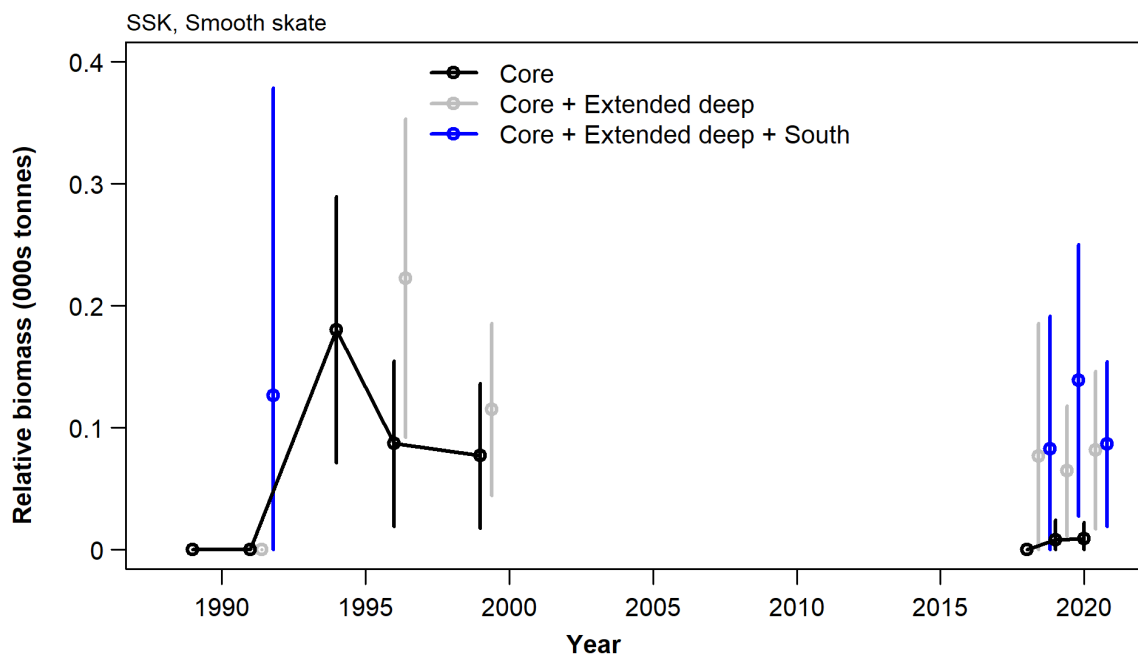


Figure 110: Time series of relative biomass estimates and 95% confidence intervals for smooth skate for the core northern area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 44: Relative biomass estimates (t) and CVs (%) of smooth skate for the core, extended core, southern strata, and whole survey areas. Skate were not identified to species in 1989 and were only identified to species in the southern strata in 1991. Deeper strata of the extended core were not sampled in 1994 surveys. South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918								
kah9111					126.23	100.00	126.23	100.00
kah9410	180.39	30.31						
kah9615	86.97	38.99	222.59	29.33				
kah9915	77.09	38.51	114.90	30.67				
kah1806	0		76.78	71.00	7.99	100.00	84.76	64.99
kah1906	8.11	100.00	64.60	41.44	74.28	65.89	138.88	40.17
kah2005	9.22	72.81	81.66	39.73	0		86.52	39.07

The size range of smooth skate measured was 13–110 cm (pelvic fin length) (Table 45), and included juveniles and mature male specimens (L50% for males is 93 cm, M.P. Francis et al. 2001). The maximum size observed in each survey was usually 100 cm or less, which does not adequately include mature females (L50% females is 112 cm, M.P. Francis et al. 2001). No female SSK were staged in these surveys, instead being released back overboard alive. The mean length was variable between surveys with small sample sizes (Table 45).

Holmes et al. (2022) reviewed the utility of all available trawl time series for use in partial quantitative assessment of skates and concluded that abundance estimates for smooth skate from the WCNI surveys were unlikely to be useful for monitoring abundance in SSK 8. The coverage of the depth range, number of fish measured, and precision of the abundance estimates were all “poor”.

Table 45: Summary of catch weight and length measurements of smooth skate by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918					
kah9111	15.2				
kah9410	161.1	13	97	45.80	61
kah9615	170.4	20	91	60.09	22
kah9915	141.7	34	102	50.97	35
kah1806	49.0	77	93	85.50	4
kah1906	86.4	44	110	70.83	12
kah2005	75.0	63	97	82.71	7

3.2.15 Northern spiny dogfish (NSD)

Number of surveys	7
Total catch weight (kg)	768.8
Number measured	336
Length range (mean) (cm)	36–115 (68.3)
Number weighed	139

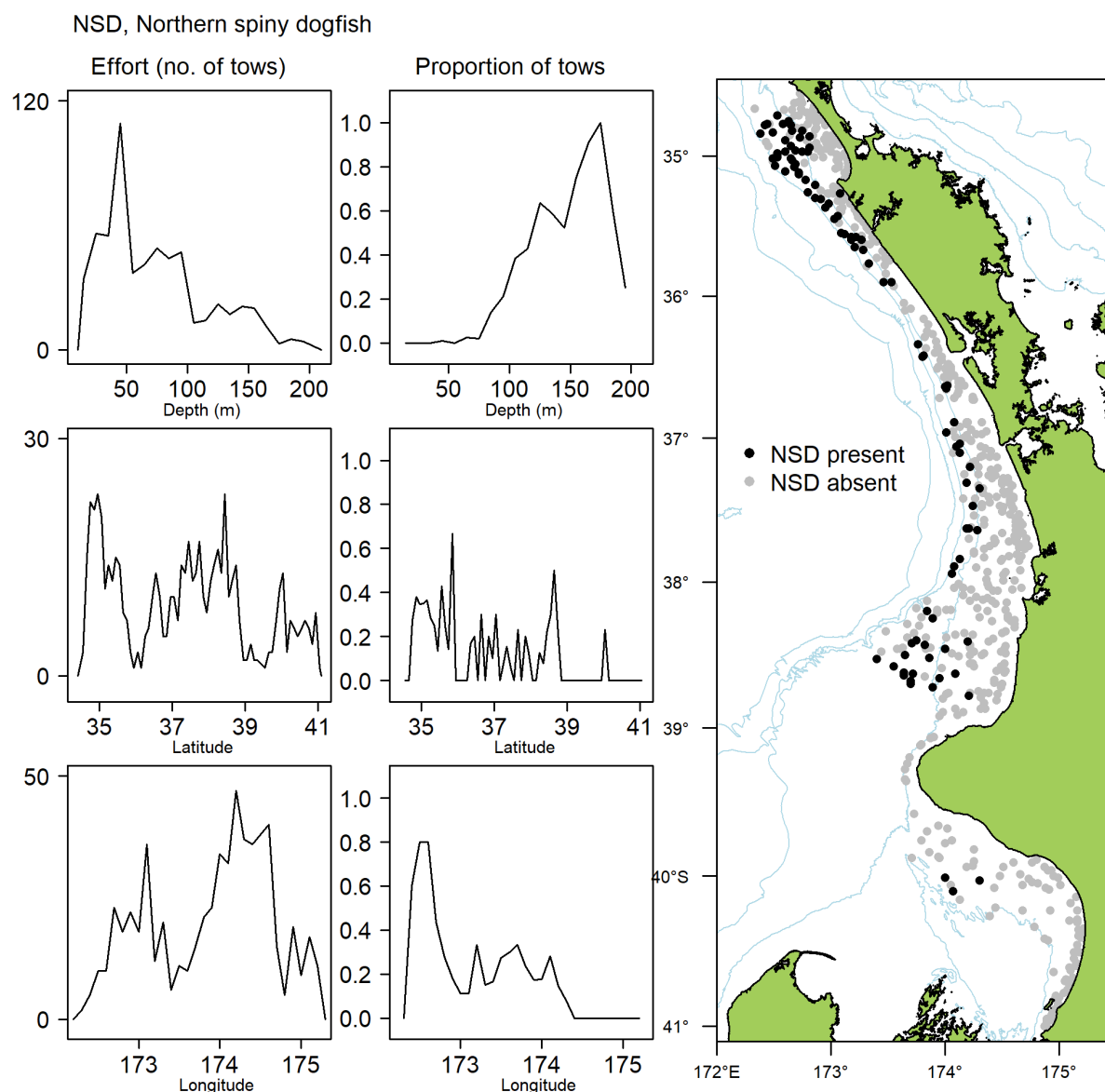


Figure 111: Summary of occurrence of northern spiny dogfish in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, and by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which northern spiny dogfish were caught. All valid tows are plotted in the map on the right with black dots showing those where northern spiny dogfish were present.

This demersal species is widespread around the North Island and most common off the west coasts of both the North Island and South Island, found in 15–660 m depth (McMillan et al. 2019). The survey covers the north-western portion of this species' distribution but does not fully cover its depth range. Although it is noted to be found as shallow as 15 m; in this survey northern spiny dogfish was most commonly found in the 100–200 m strata (Figure 111). Highest catches were in the northern part of the

survey area, along the outer shelf of the North Taranaki Bight, and in a small area of the outer South Taranaki Bight (Figure 112).

NSD, Northern spiny dogfish

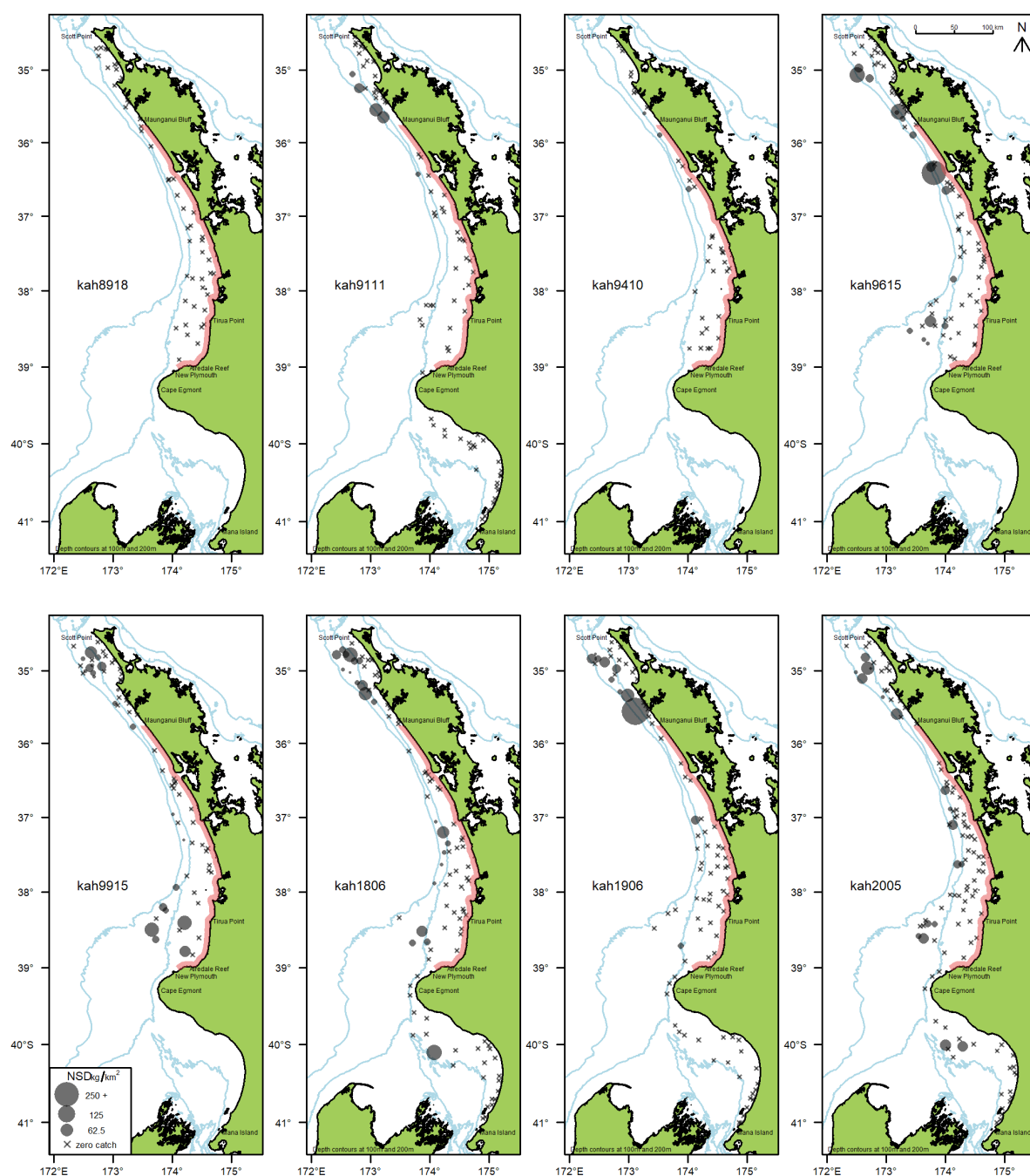


Figure 112: Spatial distribution of catch rates (kg km^{-2}) of northern spiny dogfish in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

Biomass of this species is not likely to be well estimated given the poor spatial coverage, with moderate to high CVs between 24–49% for the extended core area north of Cape Egmont (Figure 113, Table 46). There is no clear trend since the start of the survey series.

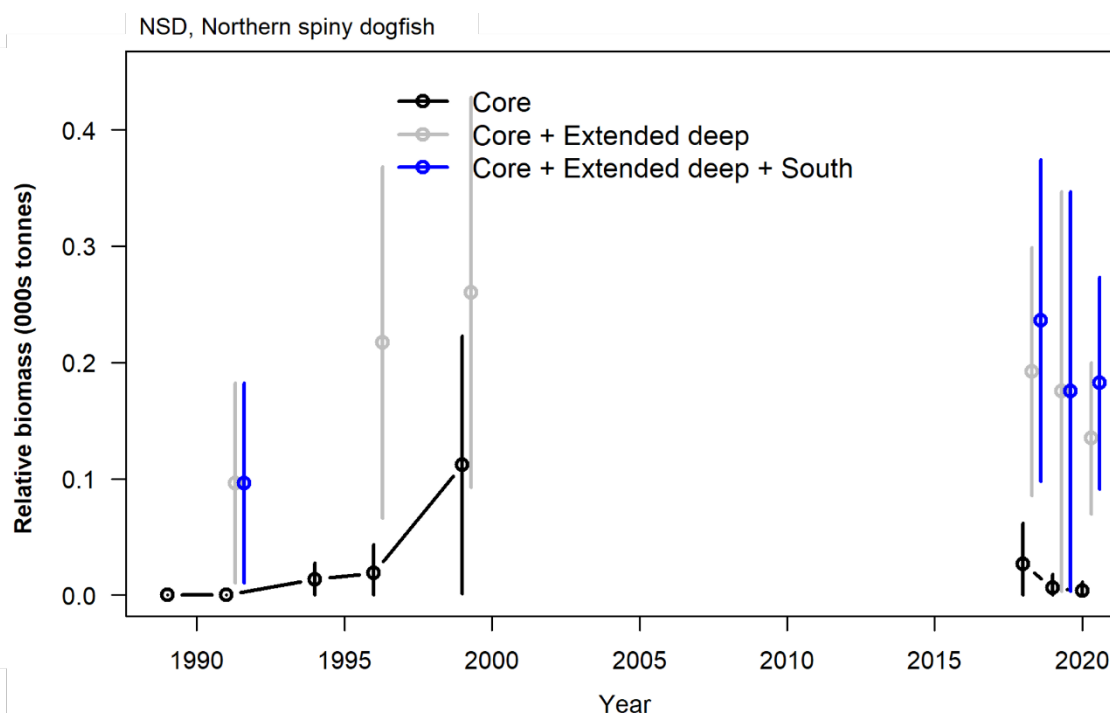


Figure 113: Time series of total relative biomass estimates and 95% confidence intervals for northern spiny dogfish for the northern core area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 46: Relative biomass estimates (t) and CVs (%) of northern spiny dogfish for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	0							
kah9111	0		96.44	44.60	0.00		96.43	44.60
kah9410	13.43	53.09						
kah9615	18.93	64.52	217.35	34.75				
kah9915	111.87	49.50	260.32	32.20				
kah1806	26.82	65.45	182.08	29.29	44.11	100.00	236.14	29.31
kah1906	6.08	100.00	175.13	49.02	0.00		175.13	49.02
kah2005	3.84	100.00	134.92	24.12	51.11	61.32	182.34	24.99

The size range sampled in the survey ranged from 36 to 115 cm (this maximum size is larger than the maximum size previously recorded for this species and may be a misidentification) (Table 47), covering both juvenile and mature adults. No trend in mean length has been detected since the start of the survey series. Length frequency distributions have multiple modes (Figure 114).

Gonad stage data have only been collected since 2018 but indicated that the majority of males were immature or maturing, whilst the majority of females were mature.

Table 47: Summary of catch weight and length measurements of northern spiny dogfish by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918					
kah9111	44.8	42	115	67.68	23
kah9410	7.8	36	56	49.33	7
kah9615	163.7	45	96	67.28	72
kah9915	131.2				0
kah1806	158.1	48	97	70.41	80
kah1906	135.0	39	92	63.93	96
kah2005	128.0	49	92	74.00	58

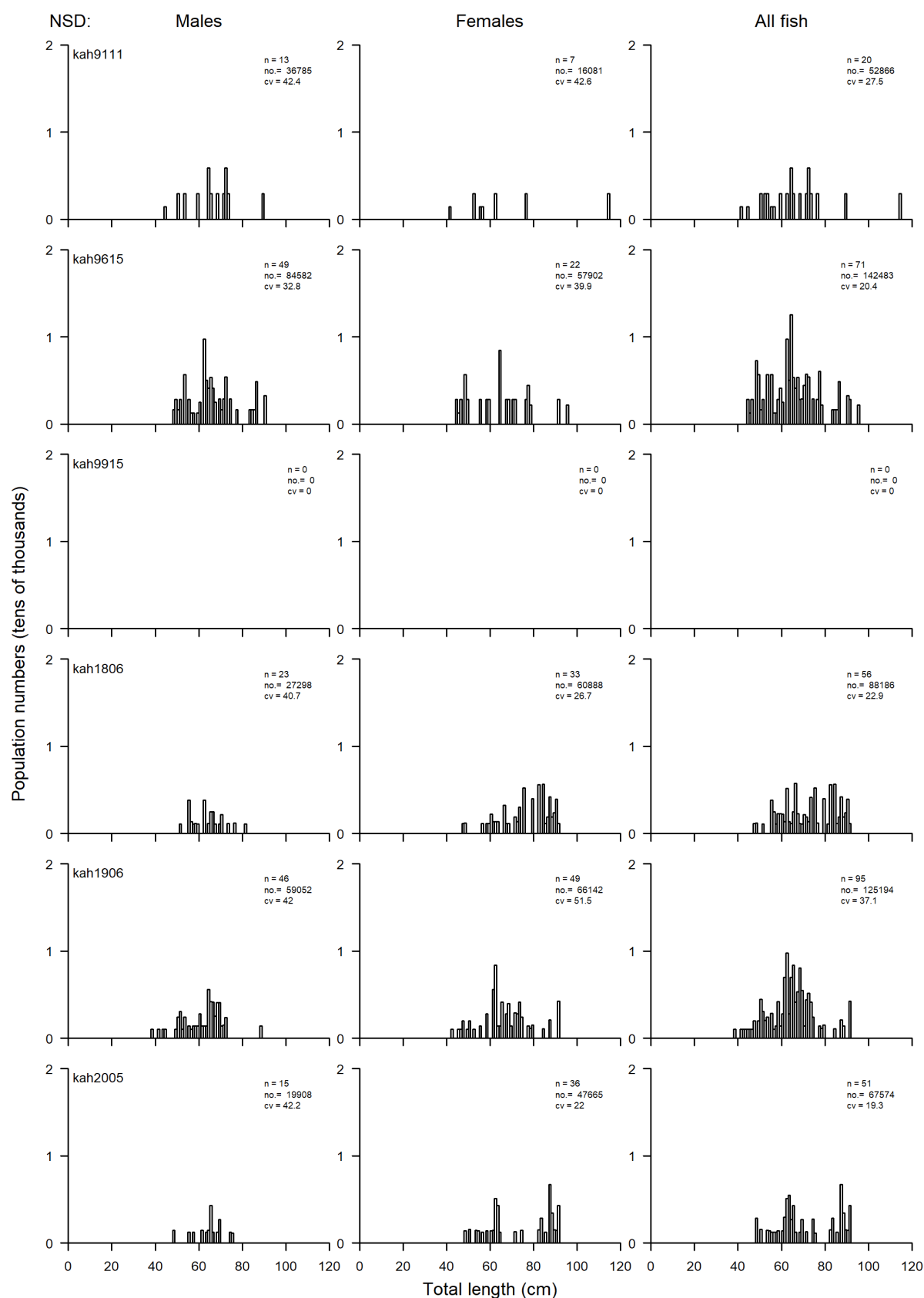


Figure 114: Comparative scaled length frequency distributions for males, females, and all northern spiny dogfish in the extended core strata for the WCNI surveys that included the 100–200 m depth range. n=number of fish measured, no.=scaled population number and cv=coefficient of variation. ‘All fish’ includes unsexed fish. Note: no fish measured in kah9915.

3.2.16 Anchovy (ANC)

Number of surveys	8
Total catch weight (kg)	199.3
Number measured	1 323
Length range (mean) (cm)	4–14 (9.85)
Number weighed	0

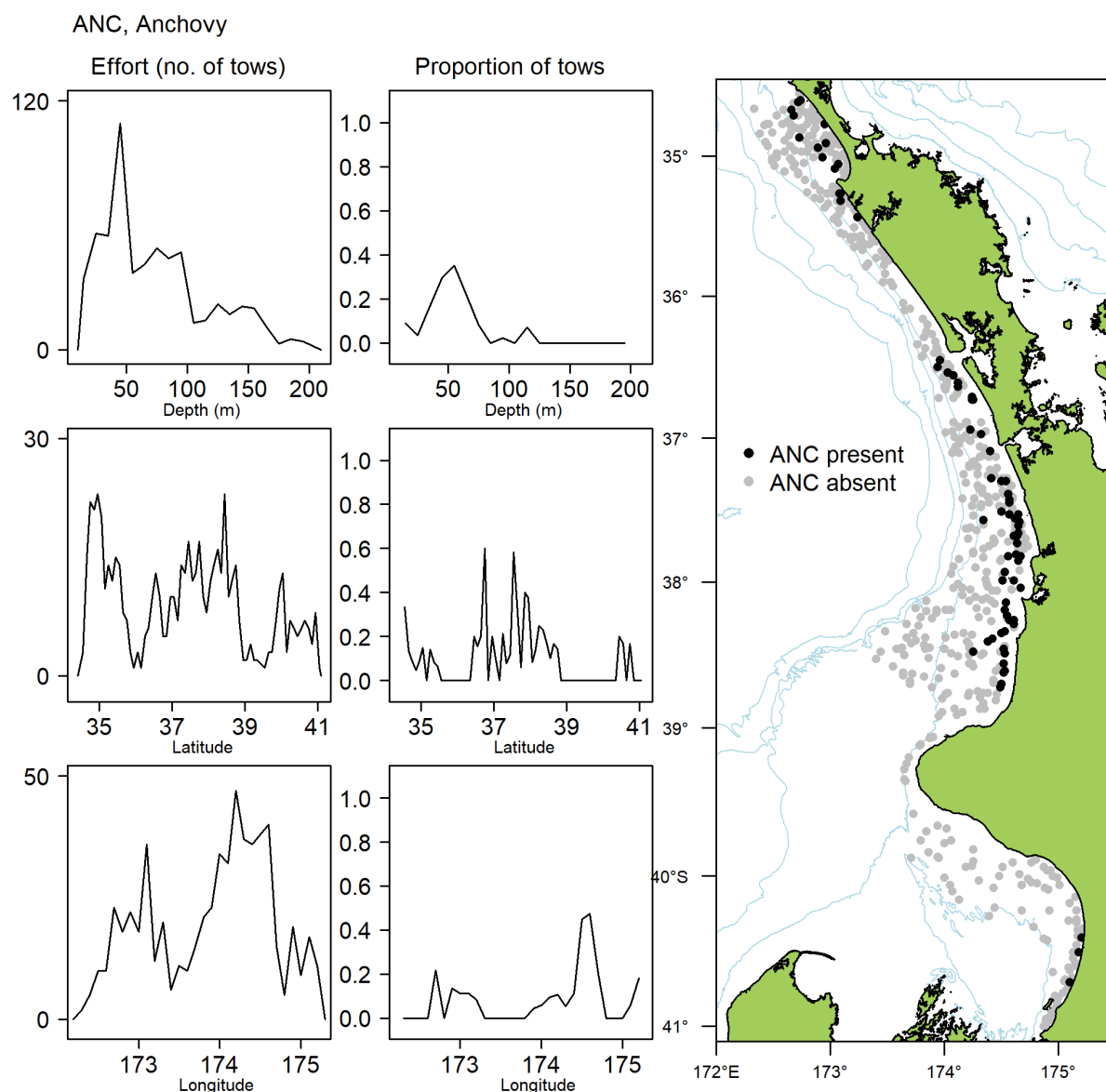


Figure 115: Summary of occurrence of anchovy in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, and by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which anchovy were caught. All valid tows are plotted in the map on the right with black dots showing those where anchovy were present.

This is a pelagic species, mainly occurring in shallow water, which is unlikely to be well sampled by the survey trawl. In this survey series anchovy were seldom caught in bottom depths greater than 75 m (Figure 115). Catches were very patchy, but with most in the northern and central survey area, north of 39° S, with occasional catches inshore of Kapiti Island (Figure 116).

ANC, Anchovy

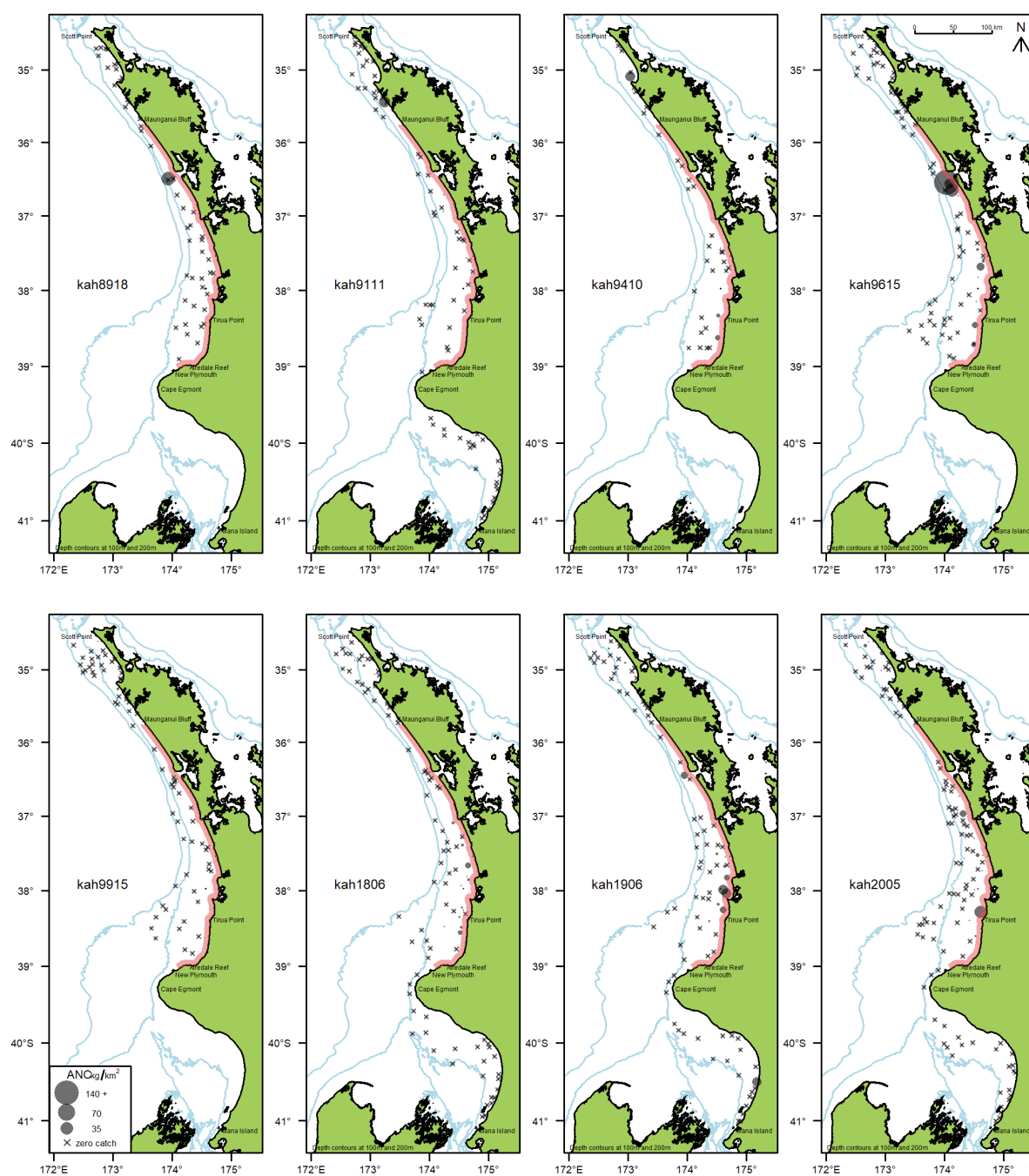


Figure 116: Spatial distribution of catch rates (kg km^{-2}) of anchovy in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

The biomass of the species is poorly estimated by the survey, with no clear trend (Figure 117 and Table 48).

Length ranged from 4 to 14 cm and was unimodal, with an average size of 9 to 10 cm in all years (Table 49).

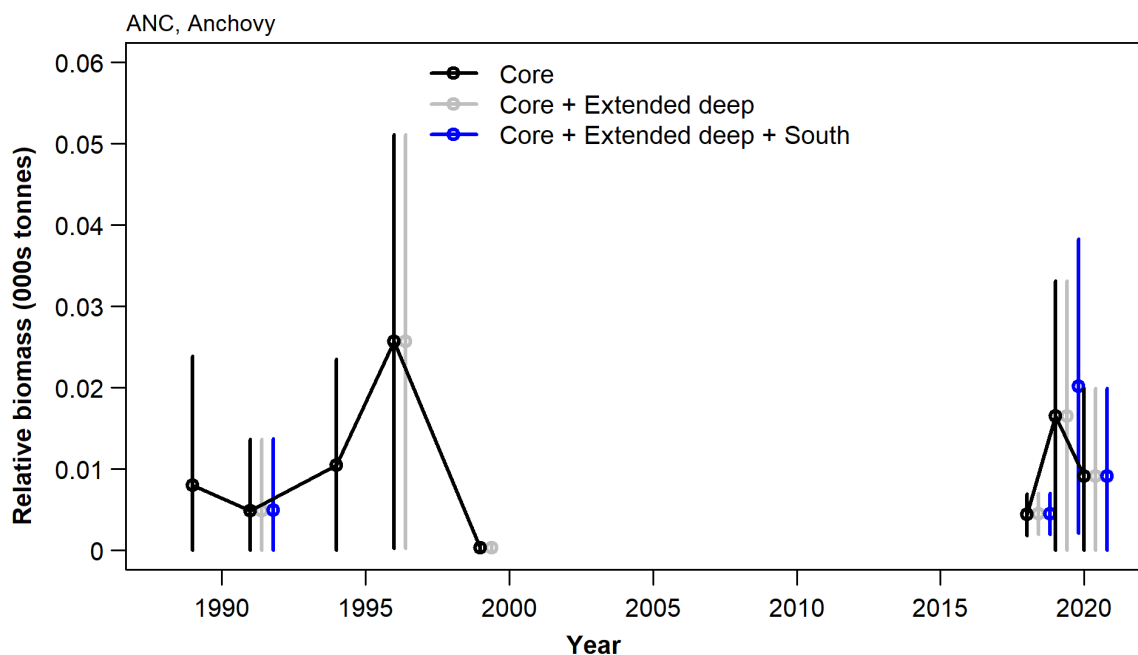


Figure 117: Time series of relative biomass estimates and 95% confidence intervals for anchovy for the core northern area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 48: Relative biomass estimates (t) and CVs (%) of anchovy for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	7.96	100.00						
kah9111	4.87	90.31	4.87	90.31	0.09	100.00	4.96	88.70
kah9410	10.47	62.20						
kah9615	25.66	49.56	25.66	49.56				
kah9915	0.34	73.07	0.34	73.07				
kah1806	4.38	29.10	4.49	28.52	0.00		4.48	28.59
kah1906	16.52	50.32	16.52	50.32	3.66	97.15	20.18	44.80
kah2005	9.11	59.40	9.11	59.40	0.00		9.11	59.40

Table 49: Summary of catch weight and length measurements of anchovy by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	35.0				0
kah9111	7.9	7	14	10.36	104
kah9410	26.9				0
kah9615	71.7	7	13	10.68	274
kah9915	8.3				0
kah1806	11.8	5	13	9.52	154
kah1906	23.8	4	14	9.47	667
kah2005	13.9	5	14	9.40	124

3.2.17 Frostfish (FRO)

Number of surveys	8
Total catch weight (kg)	646.4
Number measured	586
Length range (mean) (cm)	14–156 (87.01)
Number weighed	20

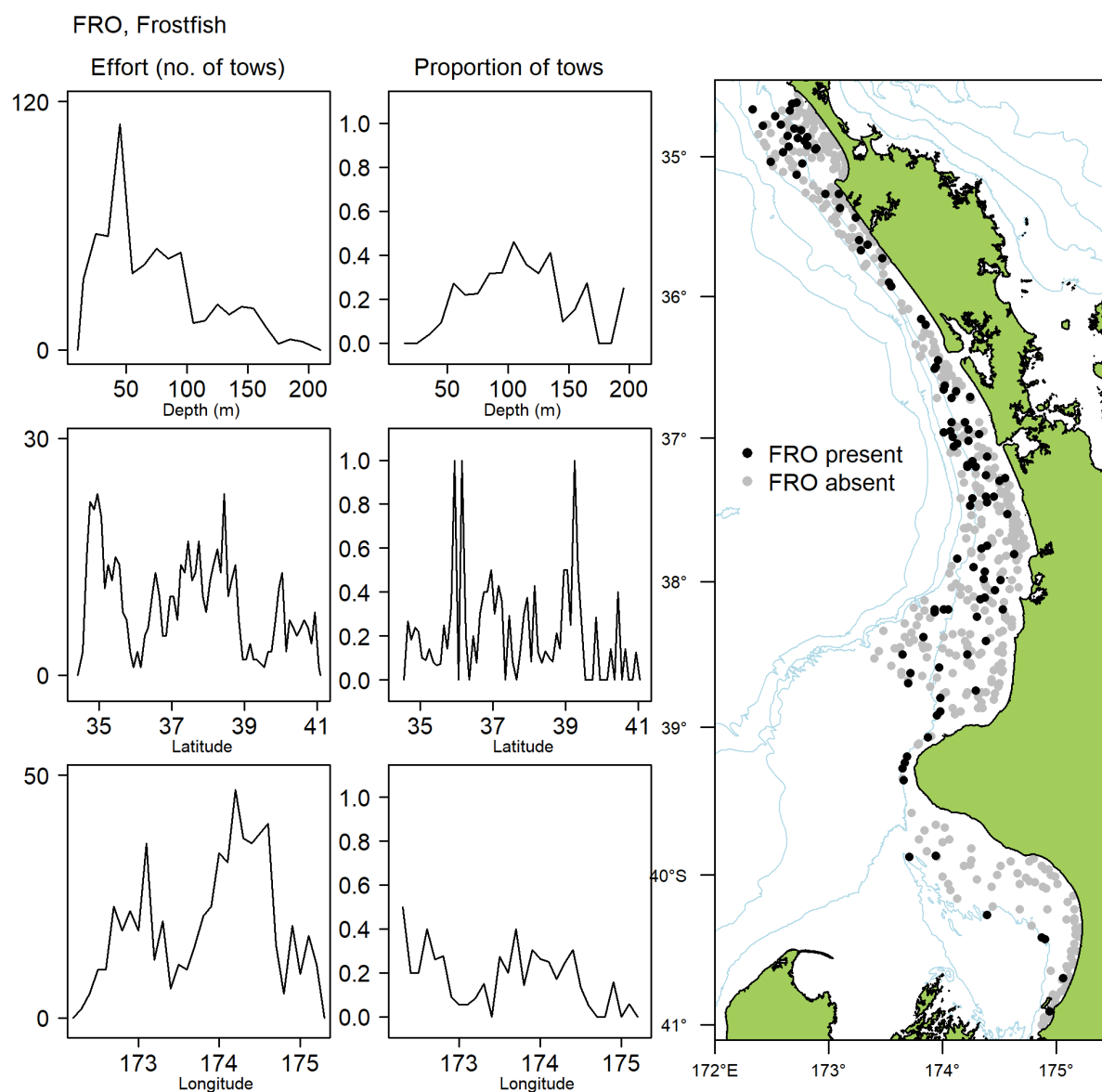


Figure 118: Summary of occurrence of frostfish in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, and by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which frostfish were caught. All valid tows are plotted in the map on the right with black dots showing those where frostfish were present.

Frostfish are demersal, but are also found in midwater, and are widespread around central and northern New Zealand in 50–600 m depth (McMillan et al. 2019). This species was caught throughout the survey area in low numbers, mainly in 50–150 m (Figures 118 and 119). The survey represents the north-western portion of this species' distribution around New Zealand.

FRO, Frostfish

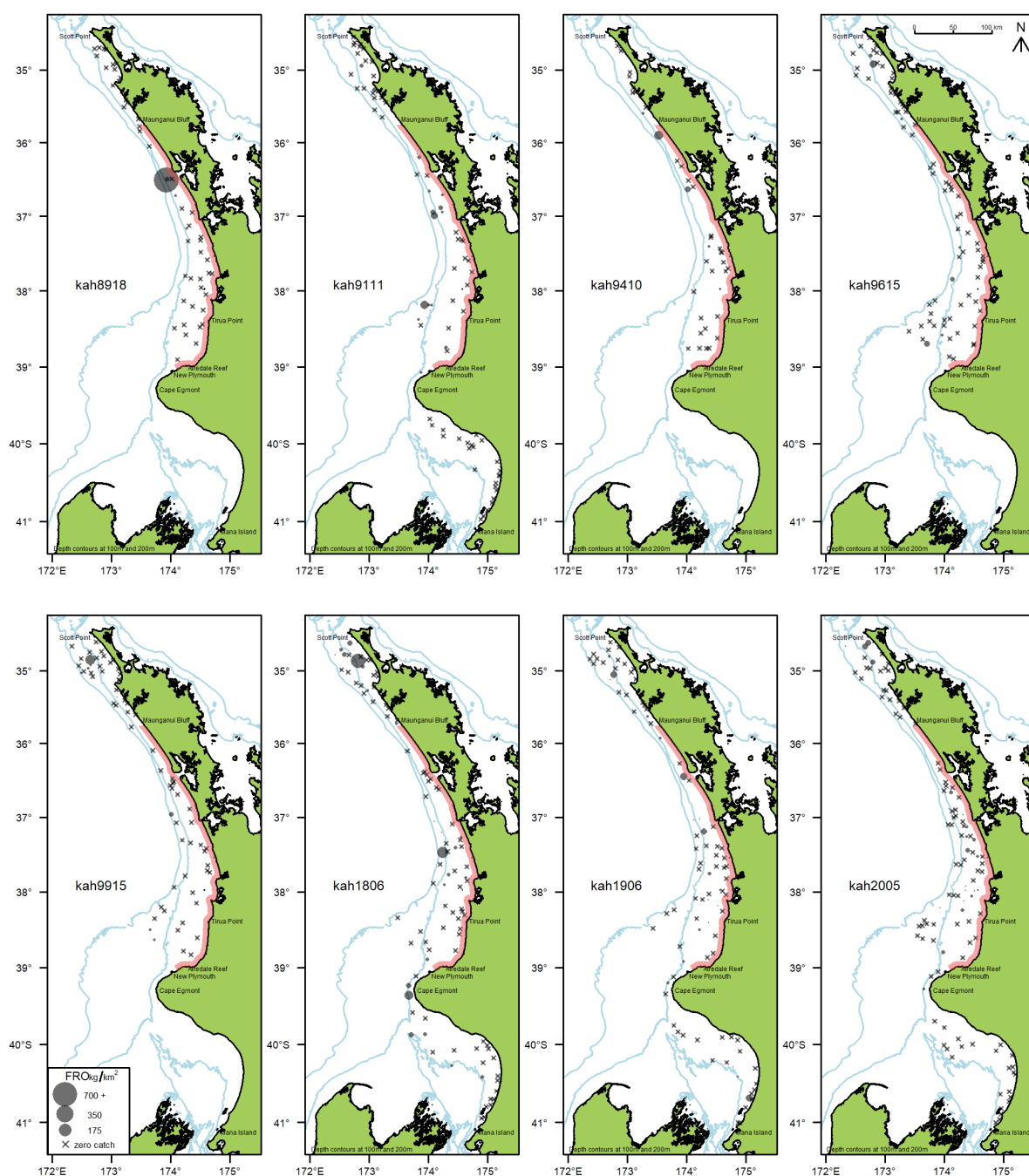


Figure 119: Spatial distribution of catch rates (kg km^{-2}) of frostfish in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

The biomass of the species is likely not well estimated by the survey, with moderate to poor precision and no clear trend (Figure 120, Table 50).

Size ranged from 14 to 56 cm, including a juvenile mode < 50 cm in most years, and a mature mode > 100 cm (Table 51 and Figure 121). Between 21 and 116 fish were measured per survey, with mean length highly variable from 66 to 125 cm, depending on the proportions of the two size modes in each survey (Table 51).

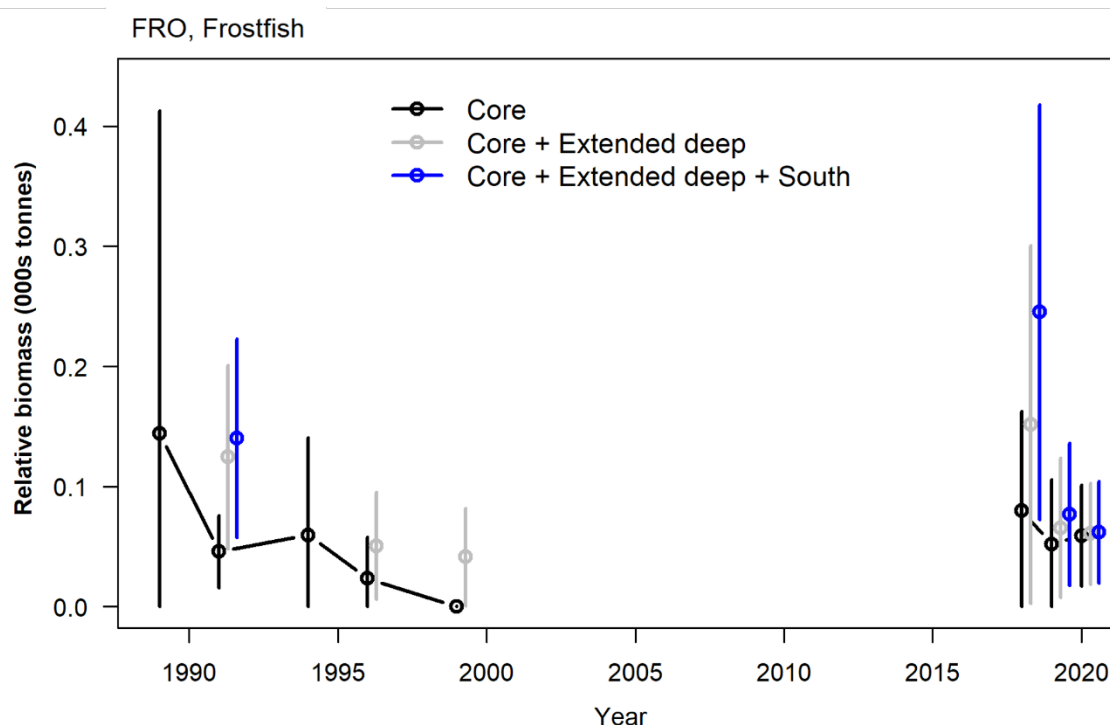


Figure 120: Time series of relative biomass estimates and 95% confidence intervals for frostfish for the core northern area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 50: Relative biomass estimates (t) and CVs (%) of frostfish for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in only 1991.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	144.33	93.06						
kah9111	45.90	32.81	124.54	30.67	15.78	100.00	120.61	32.23
kah9410	59.56	68.23						
kah9615	23.36	74.16	50.76	43.70				
kah9915	0.18	100.00	41.31	49.00				
kah1806	79.74	51.88	151.67	49.15	93.44	46.44	243.64	35.38
kah1906	52.00	51.78	65.71	44.18	11.02	54.47	76.73	38.63
kah2005	59.17	35.65	60.74	34.77	1.19	100.00	61.93	34.15

Table 51: Summary of catch weight and length measurements of frostfish by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean Length (cm)	No. fish measured
kah8918	174.6	109	145	125.39	72
kah9111	76.5	15	156	85.28	73
kah9410	33.0	20	142	74.97	61
kah9615	45.2	44	148	123.15	21
kah9915	42.4	25	132	77.41	69
kah1806	158.7	21	140	103.93	116
kah1906	60.9	23	141	77.09	73
kah2005	55.1	14	139	66.24	101

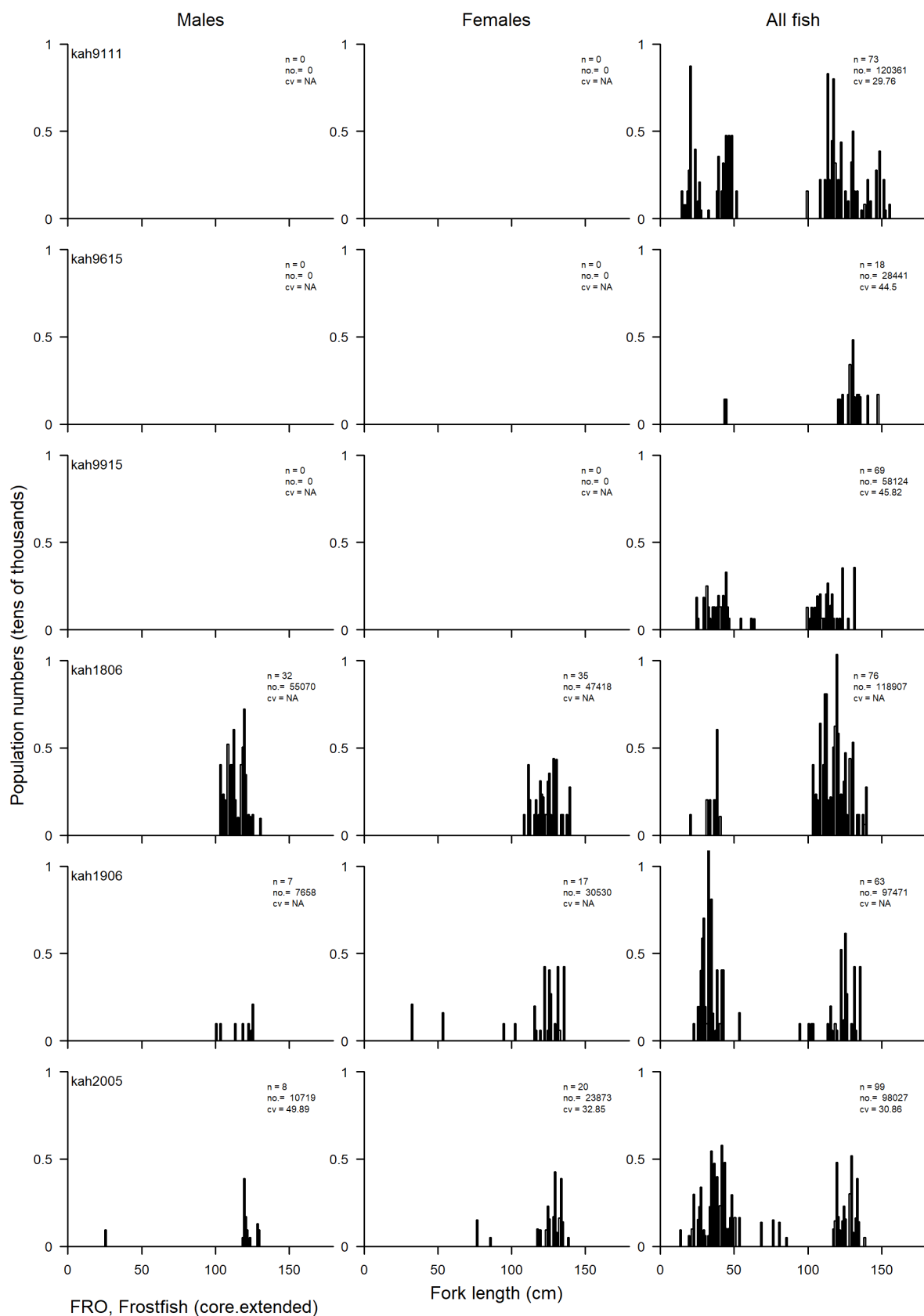


Figure 121: Comparative scaled length frequency distributions for males, females, and all frostfish in the extended northern core strata for the WCNI surveys that included the 100–200 m depth range. n=number of fish measured, no.=scaled population numbers. and cv= coefficient of variation. ‘All fish’ includes unsexed fish

3.2.18 Kingfish (KIN)

Number of surveys	7
Total catch weight (kg)	1 065.1
Number measured	165
Length range (mean) (cm)	38–124 (73.98)
Number weighed	5

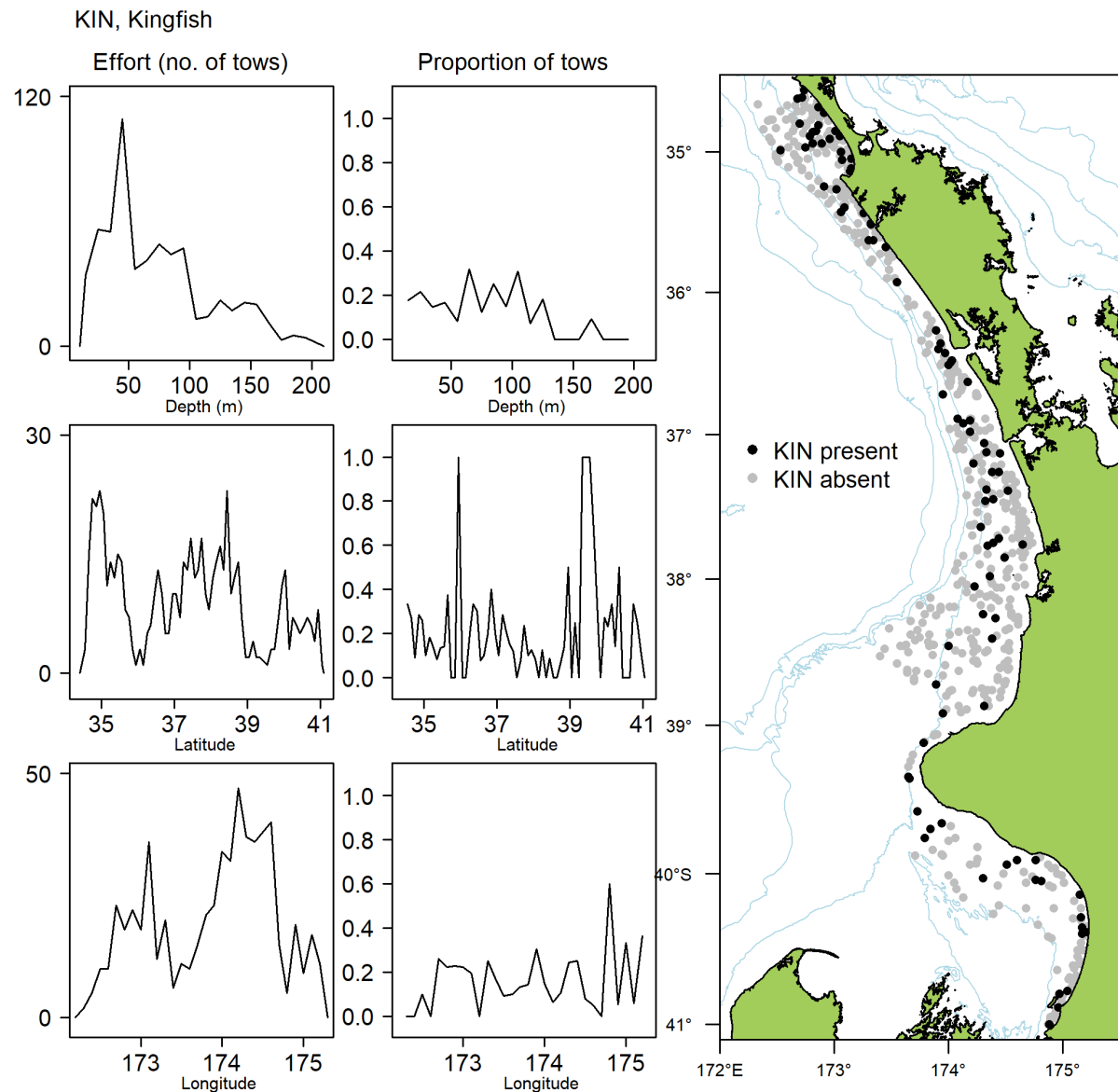


Figure 122: Summary of occurrence of kingfish in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, and by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which kingfish were caught. All valid tows are plotted in the map on the right with black dots showing those where kingfish were present.

Kingfish is a large pelagic species which is unlikely to be well sampled by the survey trawl. It is found throughout the North Island waters from shallow to 200 m (McMillan et al. 2019). This species was caught in a low proportion of tows throughout the survey area with no particular spatial pattern (Figures 122 and 123).

KIN, Kingfish

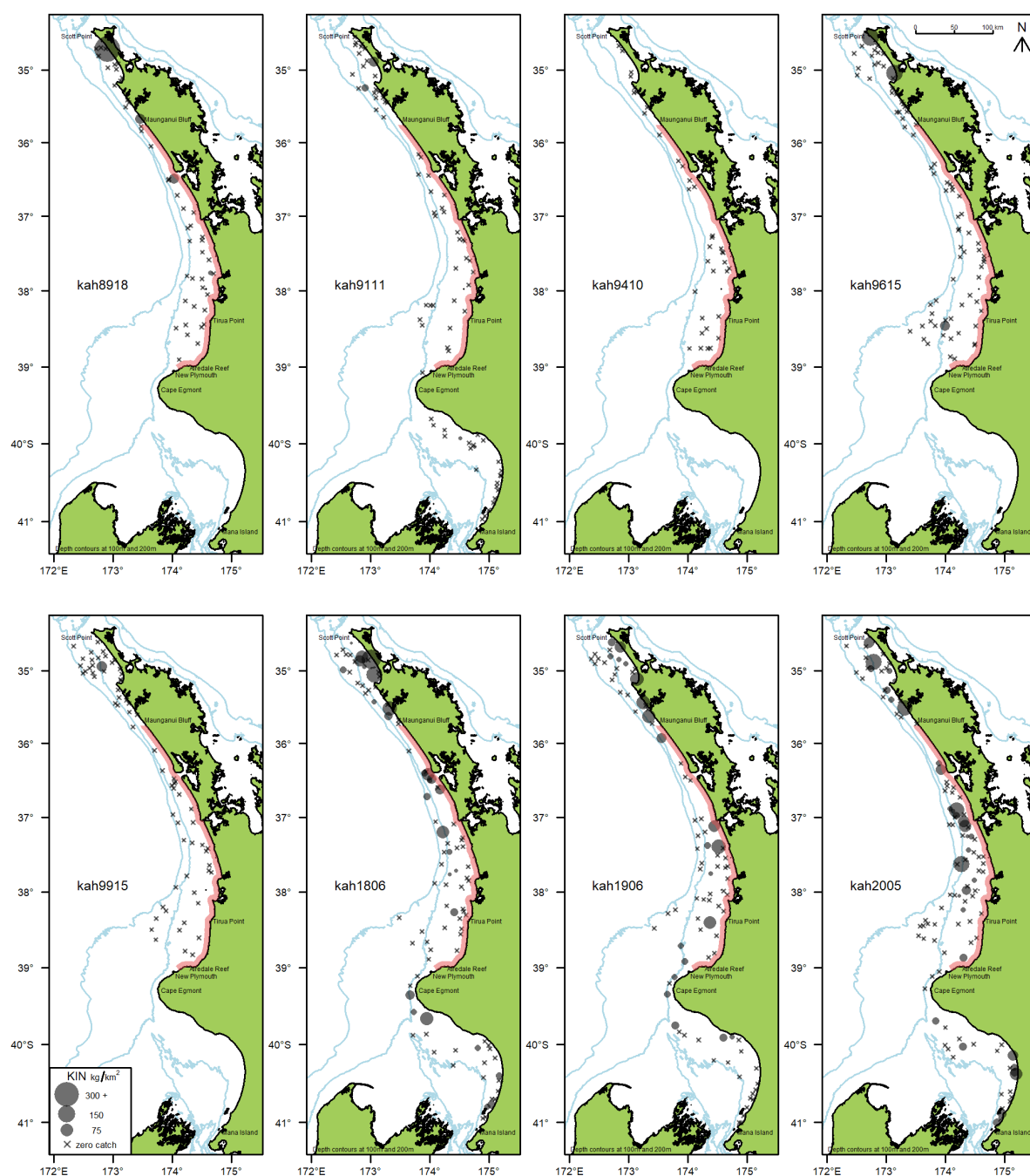


Figure 123: Spatial distribution of catch rates (kg km^{-2}) of kingfish in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

Biomass is unlikely to be well estimated, with poor precision in historical surveys. Relative biomass estimates were higher in all areas in more recent surveys, with lower CVs between 25–40% (Figure 124 and Table 52). Kingfish were released overboard alive and no information was collected on reproductive status.

The numbers of fish measured were low, with sizes ranging from 38 to 124 cm and no trend in mean length (Table 53).

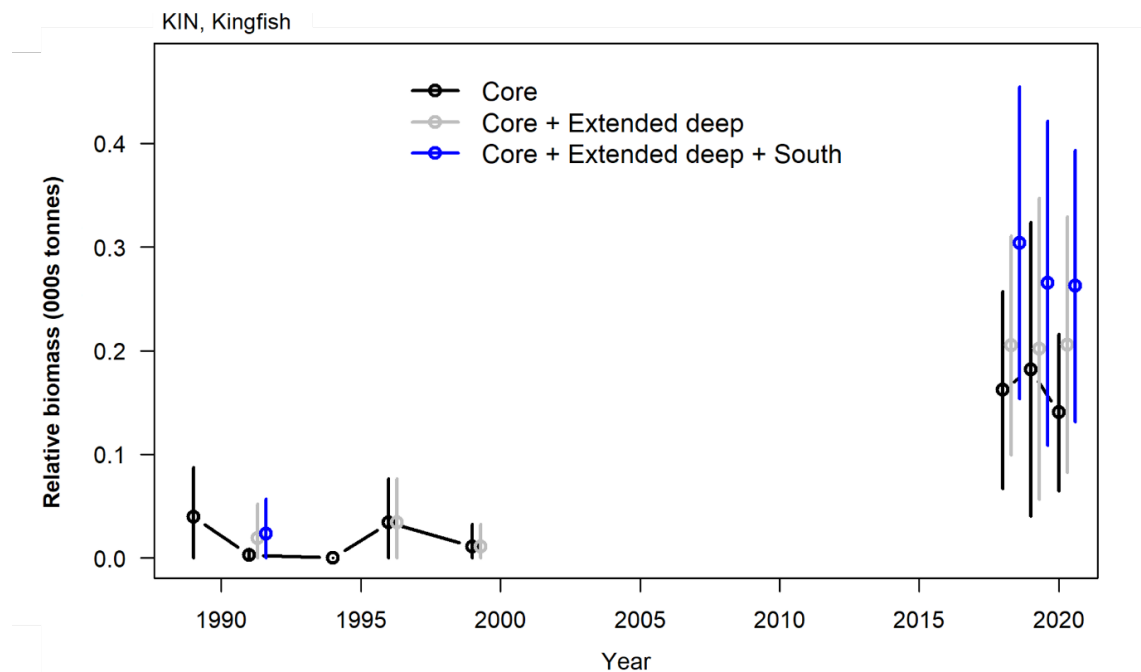


Figure 124: Time series of relative biomass estimates and 95% confidence intervals for kingfish for the core northern area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 52: Relative biomass estimates (t) and CVs (%) of kingfish for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. The South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	39.56	60.49						
kah9111	2.90	100.00	19.18	86.21	4.28	65.57	23.46	71.49
kah9410	0.00							
kah9615	34.10	62.57	34.10	62.57				
kah9915	10.93	100.00	10.93	100.00				
kah1806	162.20	29.31	205.02	25.78	99.04	54.03	304.06	24.73
kah1906	181.95	38.98	201.96	36.02	63.36	45.28	265.33	29.47
kah2005	140.44	26.91	206.01	29.92	63.09	36.93	262.50	24.98

Table 53: Summary of catch weight and length measurements of kingfish by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	86.3	56	113	93.14	7
kah9111	65.6	45	89	67.57	7
kah9410	75.2	92	112	103.8	5
kah9615	27.1	56	111	66.83	7
kah9915	333.6	39	124	72.98	54
kah1806	178.4	38	120	72.19	31
kah1906	298.9	43	106	72.36	54
kah2005	86.3	56	113	93.14	7

3.2.19 Cucumberfish (CUC)

Number of surveys	8
Total catch weight (kg)	679.3
Number measured	1 507
Length range (mean) (cm)	7–21 (13.8)
Number weighed	none

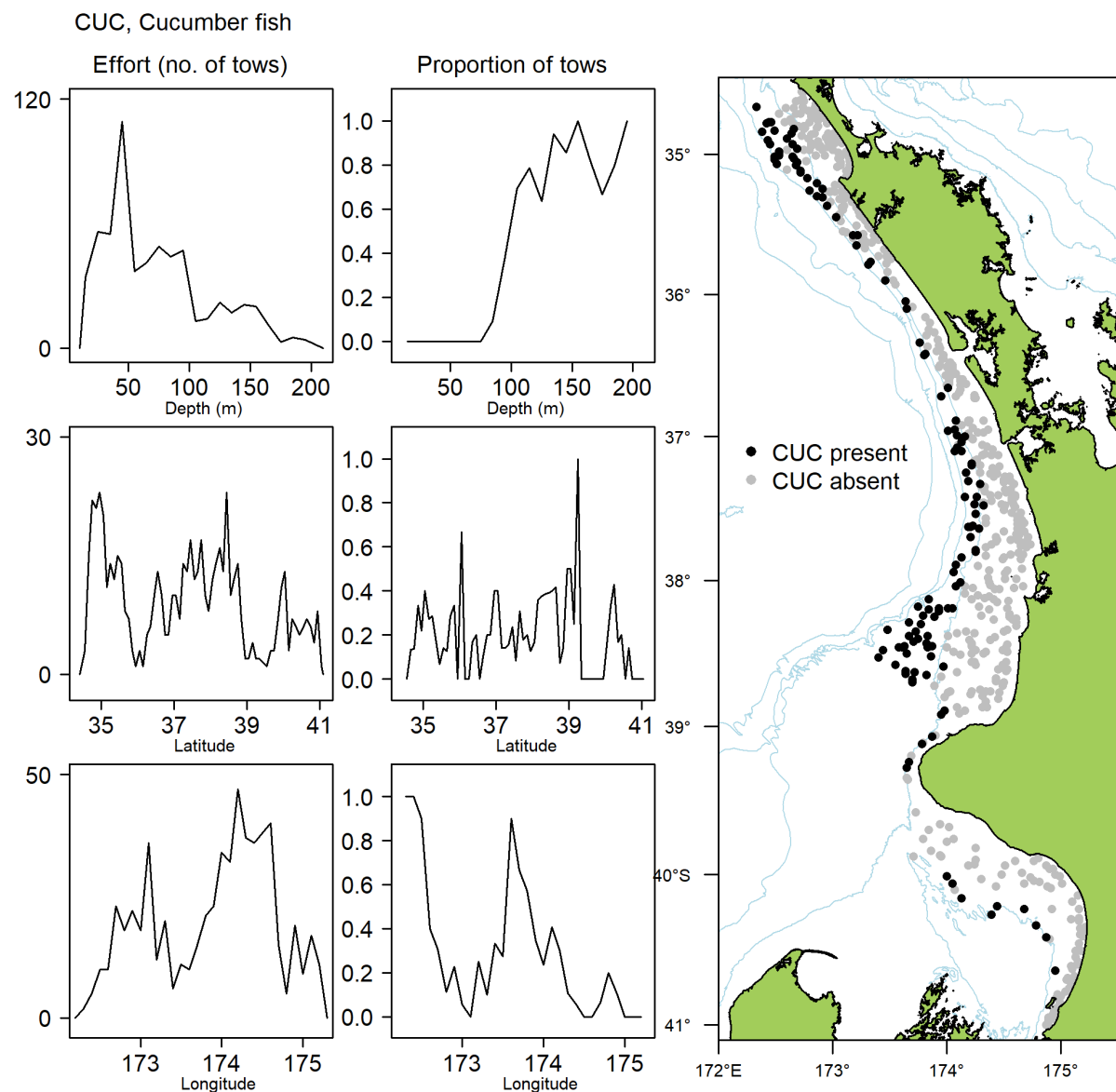


Figure 125: Summary of occurrence of cucumberfish in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, and by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which cucumberfish were caught. All valid tows are plotted in the map on the right with black dots showing those where cucumberfish were present.

Cucumberfish (*Paraulopus nigripinnis*) occur demersally around North Island and upper South Island, to depths of 600 m (McMillan et al. 2019). The survey does not occur deep enough to cover the full range of this species, with highest catch rates in the deep strata between 100–200 m, particularly in A200 off Ninety Mile Beach and F200 in the North Taranaki Bight (Figure 125 and Figure 126).

CUC, Cucumber fish

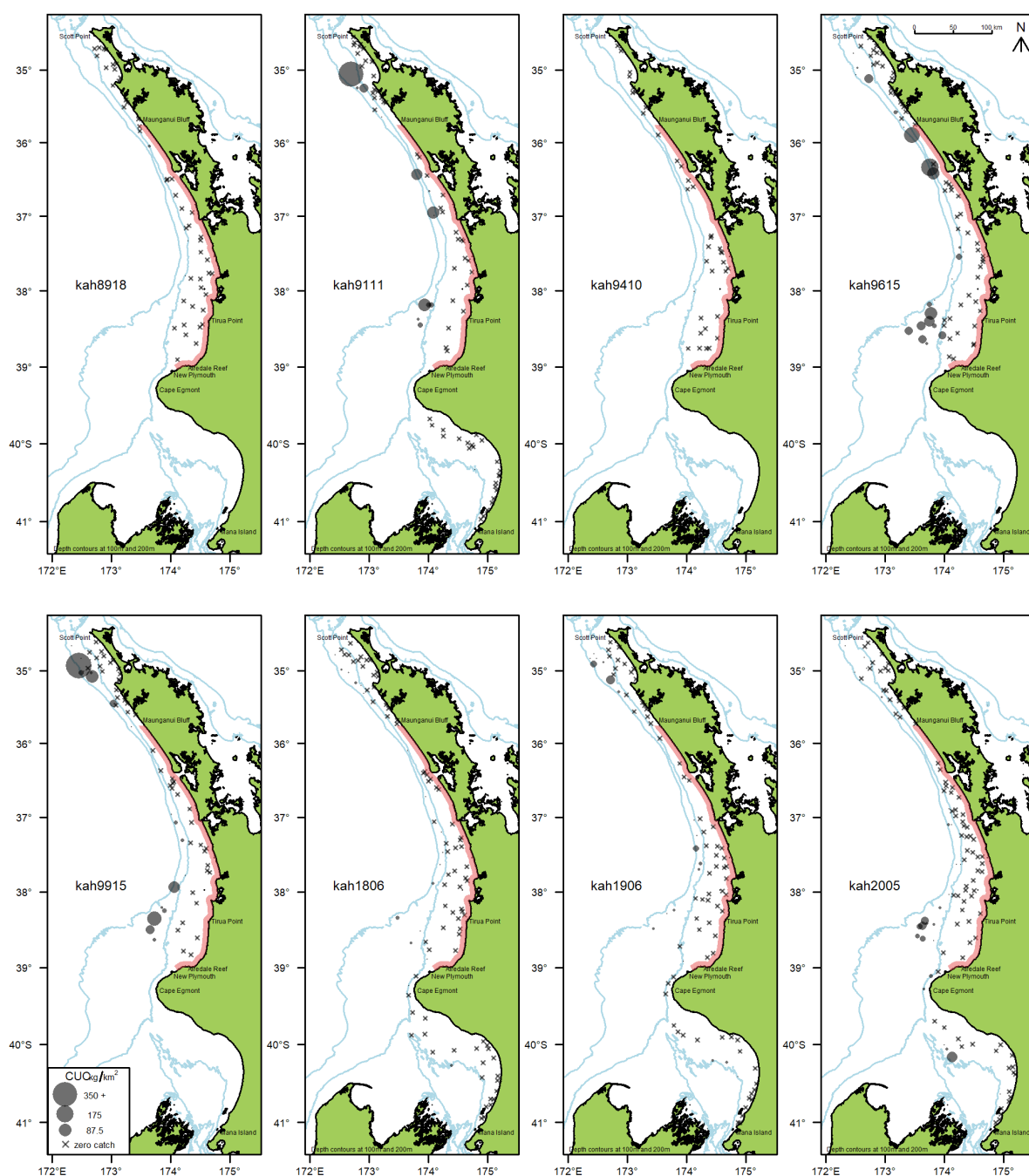


Figure 126: Spatial distribution of catch rates (kg km^{-2}) of cucumberfish in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

Relative biomass estimates in historical surveys that included extended deepwater strata were higher than in the more recent surveys, with moderate precision in 1996 and 1999, but likely to be poorly estimated (Figure 127, Table 54). With such large inter-survey variation, this may be a sampling artefact.

Length distributions were unimodal with a size range of 8–21cm and mean lengths of 13–15 cm (Table 55). This does not cover the full size range of this species which is known to reach 30 cm (McMillan et al. 2019).

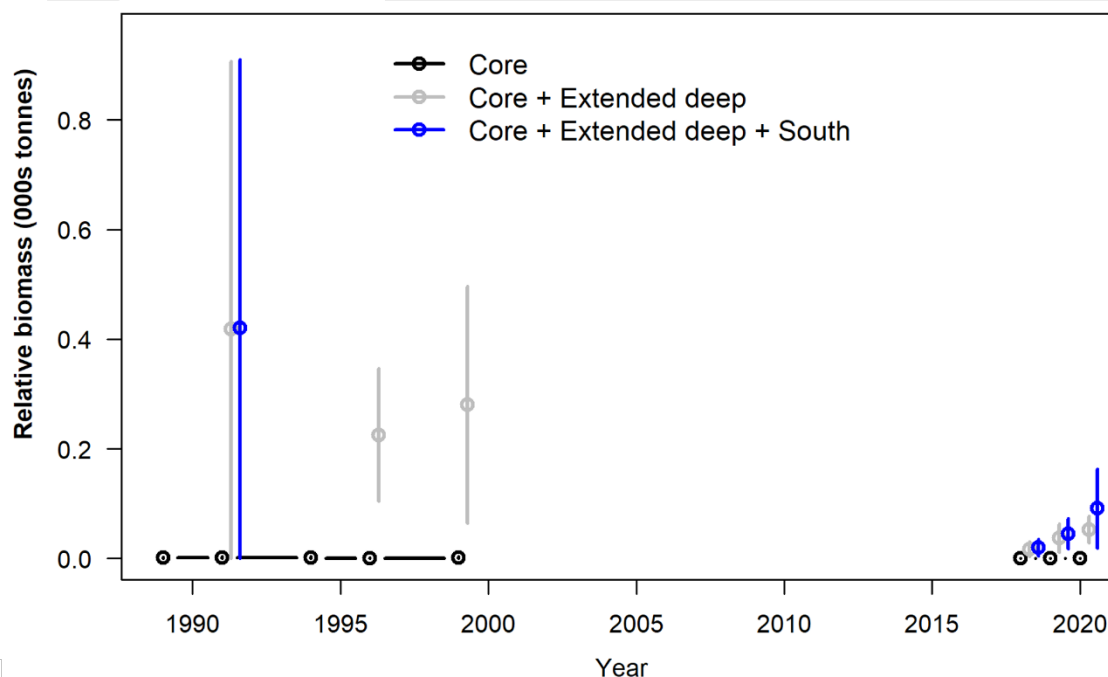


Figure 127: Time series of relative biomass estimates and 95% confidence intervals for cucumberfish for the core northern area (core in black), core area with deeper >100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 54: Relative biomass estimates (t) and CVs (%) of cucumberfish for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. South Taranaki Bight strata were only sampled previously in 1991.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	1.15	78.44						
kah9111	1.19	100.00	417.95	58.54	2.49	57.74	420.44	58.20
kah9410	1.12	100.00						
kah9615	0.32	100.00	225.68	26.92				
kah9915	1.07	100.00	280.63	38.45				
kah1806	0.00		17.24	40.81	3.11	95.64	20.34	37.53
kah1906	0.00		37.38	35.33	7.94	44.53	45.32	30.17
kah2005	0.05	100.00	52.83	23.01	39.61	84.42	91.46	39.50

Table 55: Summary of catch weight and length measurements of cucumberfish by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	1.3	14	17	15.50	2
kah9111	171.9	8	19	14.03	623
kah9410	0.3				
kah9615	185.0	8	21	14.55	362
kah9915	214.5				
kah1806	10.9	9	16	12.86	53
kah1906	31.9	7	19	13.02	347
kah2005	63.5	9	18	13.38	120

3.2.20 Spotted gurnard (JGU)

Number of surveys	8
Total catch weight (kg)	366.8
Number measured	494
Length range (mean) (cm)	10–46 (28.24)
Number weighed	23

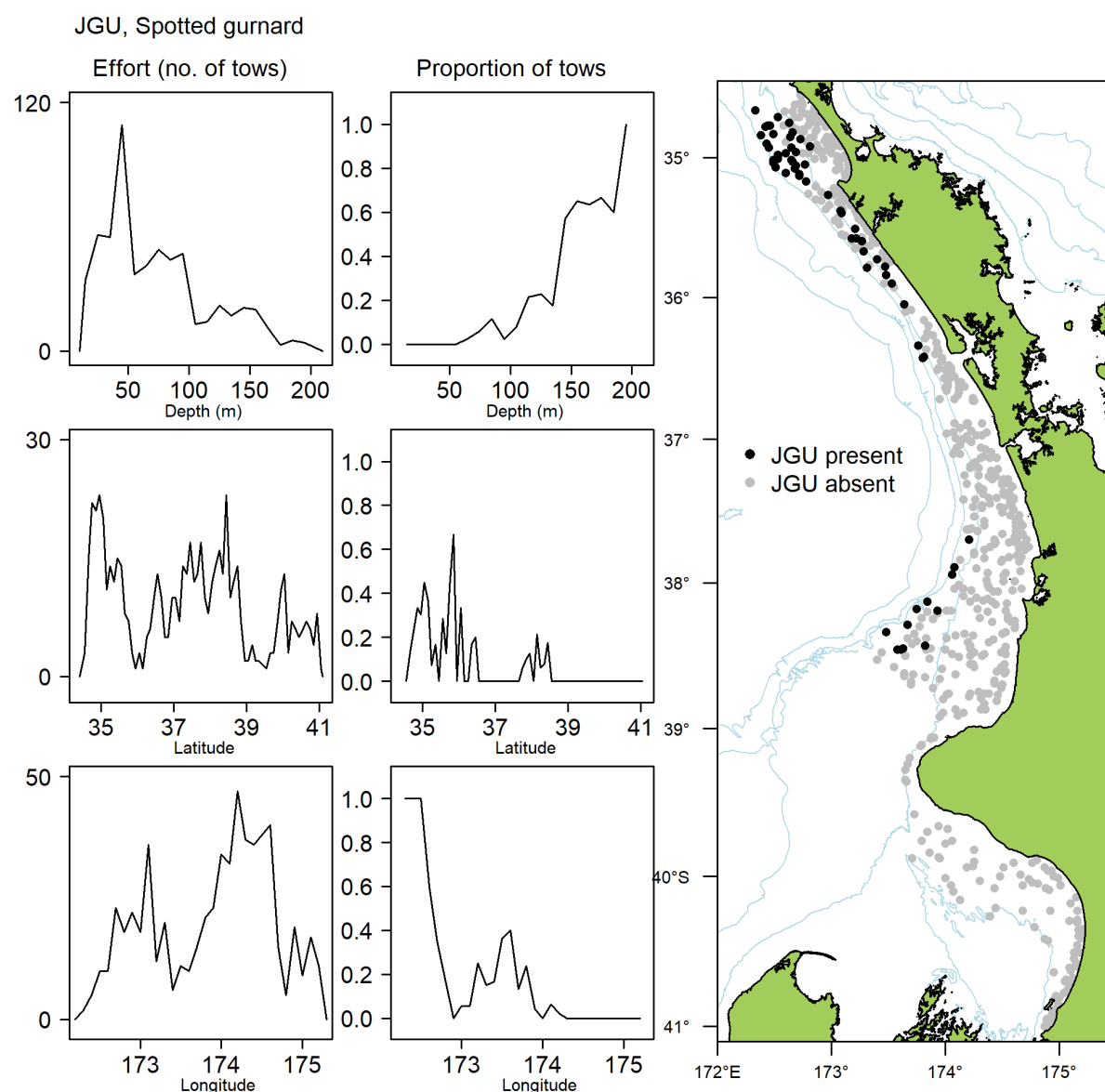


Figure 128: Summary of occurrence of spotted gurnard in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, and by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which spotted gurnard were caught. All valid tows are plotted in the map on the right with black dots showing those where spotted gurnard were present.

Spotted gurnard is a demersal species found in central and northern New Zealand in 100–500 m (McMillan et al. 2019). In the survey, spotted gurnard were caught in the deeper strata in 100–200 m, mainly off Northland and the outer shelf of the North Taranaki Bight. The increasing occurrence with increasing depth confirms the survey does not cover the complete range for this species (Figures 128 and 129). No spotted gurnard were caught in the southern strata, which did not extend beyond 100 m.

JGU, Spotted gurnard

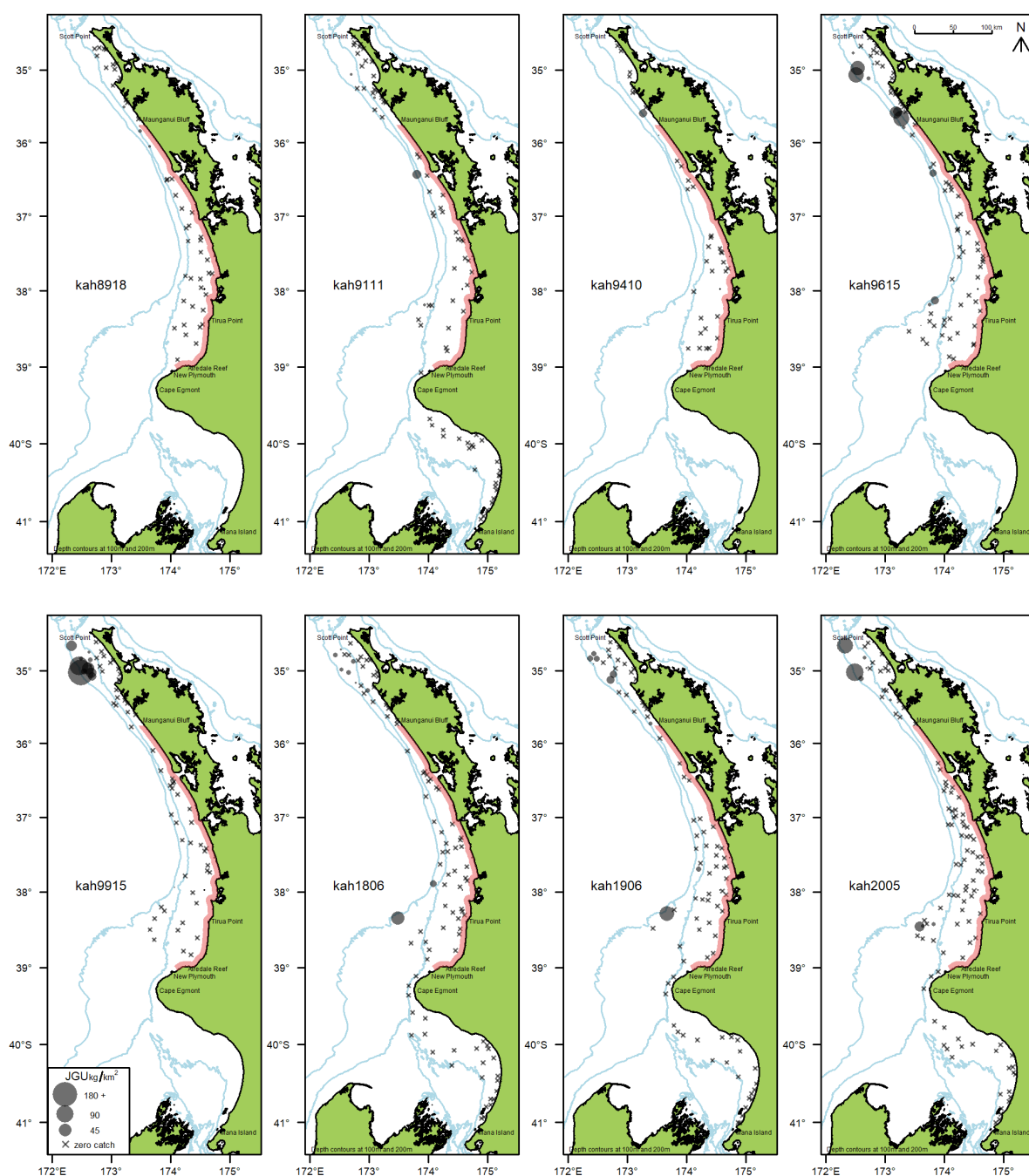


Figure 129: Spatial distribution of catch rates (kg km^{-2}) of spotted gurnard in the WCNI surveys. Catch rates are scaled to the largest catch in the series.

Relative biomass estimates in the extended core series were consistent between 1996 and 1999 and the most recent surveys, showing no clear trend, but were poorly estimated with low precision (Figure 130, Table 56).

Sizes ranged from 10 to 46 cm, covering the full size range of this species (maximum size was reported as 40 cm by McMillan et al. 2019), with mean lengths of 25–30 cm (Table 57) and multiple modes apparent in the population scaled length distributions (Figure 131).

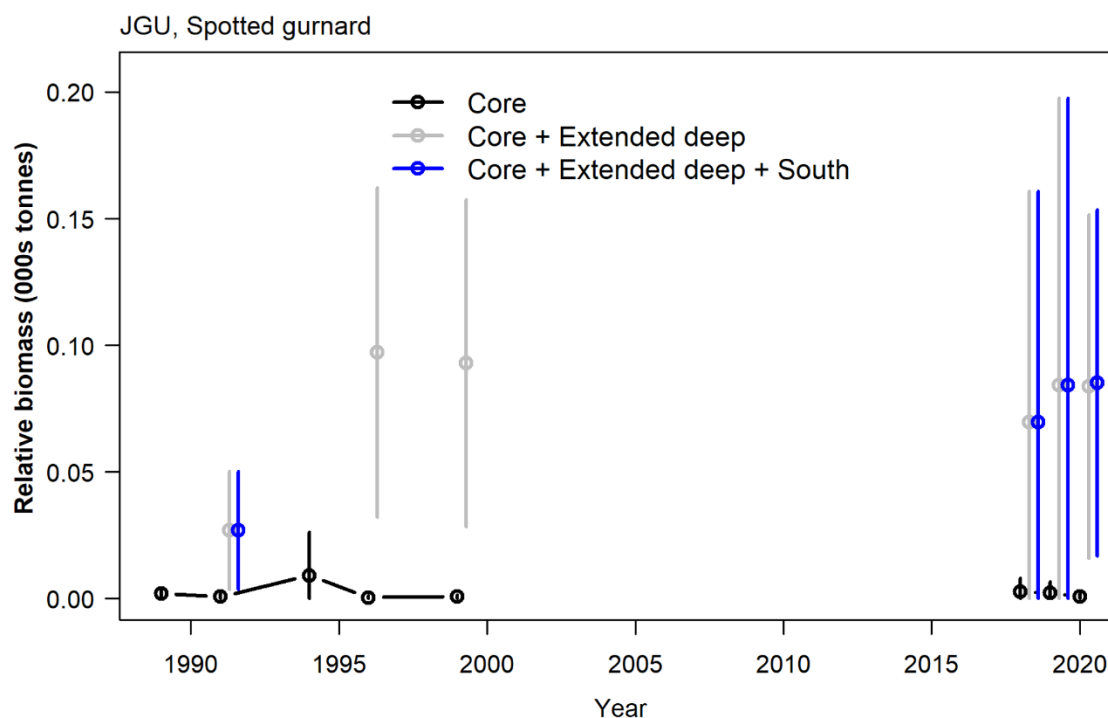


Figure 130: Time series of relative biomass estimates and 95% confidence intervals for spotted gurnard for the core northern area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Table 56: Relative biomass estimates (t) and CVs (%) of spotted gurnard for the core, extended core, southern strata, and whole survey areas. Deeper strata of the extended core were not sampled in 1989 and 1994 surveys. South Taranaki Bight strata were sampled previously in 1991 only.

Survey	Core biomass	Core CV	Extended core biomass	Extended core CV	South biomass	South CV	Whole survey biomass	Whole survey CV
kah8918	1.96	41.54						
kah9111	0.70	100.00	26.92	43.43	0.00		26.92	43.42
kah9410	9.11	94.29						
kah9615	0.42	100.00	97.19	33.52				
kah9915	0.00		92.98	34.69				
kah1806	2.73	100.00	69.53	65.58	0.00		69.53	65.58
kah1906	2.24	100.00	84.29	67.17	0.00		84.29	67.17
kah2005	0.70	100.00	83.80	40.46	0.00		85.22	40.09

Table 57: Summary of catch weight and length measurements of spotted gurnard by survey.

Survey	Weight (kg)	Min length (cm)	Max length (cm)	Mean length (cm)	No. fish measured
kah8918	3.3	19	39	26.00	11
kah9111	12.8	13	40	25.79	41
kah9410	4.6	19	34	25.42	18
kah9615	68.7	12	46	29.44	160
kah9915	136.9				
kah1806	32.8	10	42	27.21	20
kah1906	39.2	19	41	29.50	54
kah2005	68.5	11	44	28.52	190

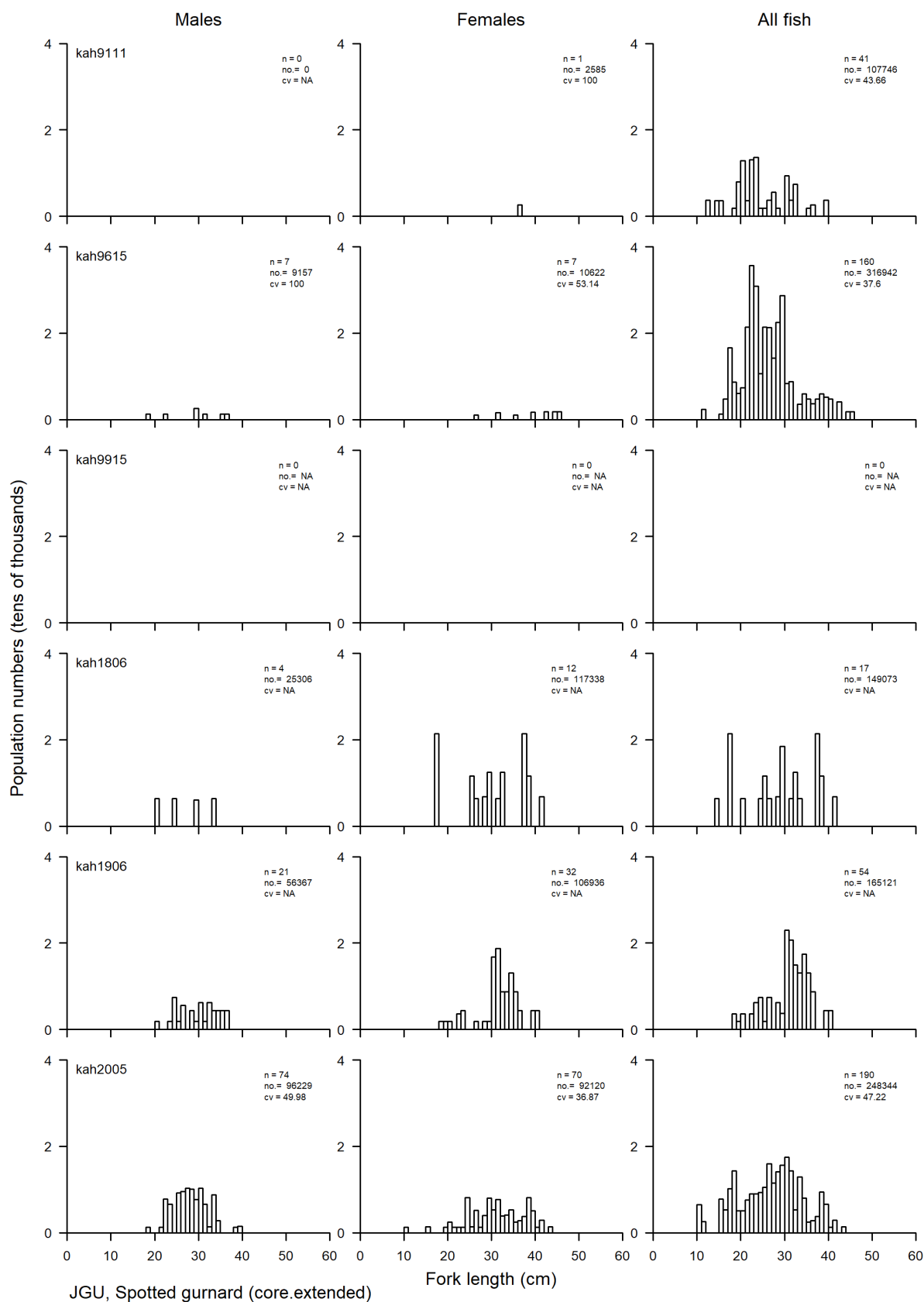


Figure 131: Comparative scaled length frequency distributions for males, females, and all spotted gurnard in the extended northern core strata for the WCNI surveys that included the 100–200 m depth range. n=number of fish measured, no.=scaled population numbers, and cv= coefficient of variation. ‘All fish’ includes unsexed fish

3.3 Overall assessment of survey utility

Table 58 summarises qualitative assessment of the survey utility for the 20 species or groups considered in Section 3.2. Another 42 species were reviewed (see Appendices 2 & 6); all were ranked with an overall utility score of low.

The WCNI survey series has good utility for monitoring the target species (snapper, red gurnard, tarakihi, and John dory), with the caveats described in Section 3.2 and summarised in Section 4.

This survey series may have some utility for pre-recruit rig as coefficients of variation (CVs), particularly in the more recent surveys, were below 30%. The lack of access to the areas inside the Māui dolphin trawl exclusion zone may impact sampling of some of the larger female rig if these are moving closer to shore to pup within harbours during the survey period.

Based on a qualitative assessment of numbers of individuals caught, depth range coverage, CVs, and consistency of biomass estimates and CVs, the WCNI surveys also likely provide useful, but limited information for seven other species: pre-recruit trevally, barracouta, school shark, spiny dogfish, leatherjacket, rough skate, and northern spiny dogfish.

Jack mackerel were not considered because the species (JMN and JMD) were not separated in the earlier surveys. However, data collected in the more recent surveys may provide information on juvenile species composition and abundance.

Table 58: Summary table of 20 species caught in the WCNI trawl survey series with scores for overall survey utility. Species in bold are those for which the utility of the survey was considered to be good or of some use. Another 42 species were reviewed (see Appendices 2 & 6); all were ranked with an overall utility score of low.

Species	Catch weight (kg)	No. surveys	No. meas.	Min Len (cm)	Max Len (cm)	Mean Len (cm)	No. weigh.	Mean CV (range)	Optimal survey area	No. caught sufficient?	Spatial and depth range covered?	Biomass estimate CV's reasonable?	Consistency of biomass estimates?	LF consistent?	Overall Suggested Utility score
SNA	47 961.6	8	37 142	8	81	34.45	7 638	21.0 (14–30)		✓	✓	✓	✓	✓	V. Good for younger year classes (2–4 years). Currently less utility for adult biomass due to variable catchability
									Core / Ext.						
GUR	20 861.2	8	44 804	9	53	30.35	6 641	16.6 (13–29)	Core / Ext.	✓	✓	✓	✓	✓	V. Good
JDO	2 792.0	8	2 934	9	58	34.75	1 503	15.7 (12–16)	Extended	✓	✓	✓	✓	✓	V. Good
NMP	3 500.8	8	3 678	7	53	35.93	1 705	29.4 (13–43)		✓	OK	OK	✓	✓	Reasonable for northern area only, especially in combination with other trawl surveys
									Extended						Reasonable. May provide useful juvenile recruitment index, but limited use for adults.
SPO	3 103.8	8	1 820	13	138	70.41	132	20.6 (19–33)		✓	OK	✓	✓	?	Limited use for adult biomass but may provide useful juvenile recruitment indices
									Ext. / Whole						
TRE	12 412.1	8	13 903	3	66	32.03	1 170	35.6 (22–55)		✓	OK	?	?	✓	Limited use
									Extended						
BAR	6 889.0	8	4 078	10	106	65.12	794	33.7 (24–60)	Ext. / Whole	✓	OK	?	?	?	Limited use

Species	Catch weight (kg)	No. surveys	No. meas.	Min Len (cm)	Max Len (cm)	Mean Len (cm)	No. weigh.	Mean CV (range)	Optimal survey area	No. caught sufficient?	Spatial and depth range covered?	Biomass estimate CV's reasonable?	Consistency of biomass estimates?	LF consistent?	Overall Suggested Utility score
SCH	3 876.9	8	835	27	200	83.54	61	28.1 (21–38)	Ext. / Whole	Low	✓	✓	?	?	Limited use
SPD	9 203.8	8	3 121	15	93	68.11	478	39.6 (18–69)	Whole	OK	✓	✗	?✗	?	Limited use Limited use. Current numbers caught much lower than historical surveys
LEA	3 460.3	8	4 645	8	34	23.73	25	34.7 (26–52)	Whole	Low	✓	✓	?	?	Limited use
NSD	768.6	7	336	36	115	68.29	139	37.5 (24–49)	Ext. / Whole	Low	✗	✓	?	?	Limited use Limited use currently, but continuation of whole survey series may improve the value
RSK ^{*1}	750.5	7	222	23	62	46.34	34	37.0 (16–49)	Ext. / Whole	Low	OK	?✗	?✗	?	
JMA ^{*2}	23 312.8	8	39 990	2	58	20.75	716	36.9 (24–67)	Extended / Core	OK	✗	✗	✗	✗	Poor
ATT	1 372.2	8	3 323	7	55	29.67	156	36.6 (28–46)							
ANC	199.3	8	1 323	4	14	9.85	NA	60.1 (32–90)	Ext. / Core	✗	✗	✗	✗	?	Poor
FRO	646.4	8	586	14	156	87.01	20	44.5 (43–46)	Ext. / Whole	✗	✗	✗	✗	?	Poor
CUC	679.3	8	1 507	7	21	13.79	NA	55.0 (23–85)	Ext. / Whole	✗	✗	✗	✗	?	Poor
JGU	366.8	8	494	10	46	28.24	23	53.3 (33–75)	Ext. / Whole	✗	✗	✗	✗	?	Poor
KIN	1 065.1	7	165	38	124	73.98	5	62.5 (35–100)	Ext. / Whole	✗	✓	✗	✗	?	Poor
SSK ^{*1}	698.8	7	141	13	110	54.90	12	61.3 (39–100)	Ext. / Whole	✗	✗	✗	✓	?	Poor

^{*1}RSK and SSK likely not well identified in earliest surveys, considered from 1994 onwards only.

^{*2} Combined jack mackerel species as not always separated in earlier surveys. Not considered at this stage.

3.4 Survey representativeness

The representativeness analyses, showing the mean species ranking for the WCNI trawl surveys are shown in Figure 132. Regardless of whether 5 species or 12 species were included, none of the 8 surveys during 1989–2020 were outside the 95% confidence intervals; so none were considered to have had extreme catchability by the definition of R.I.C.C. Francis et al. (2001).

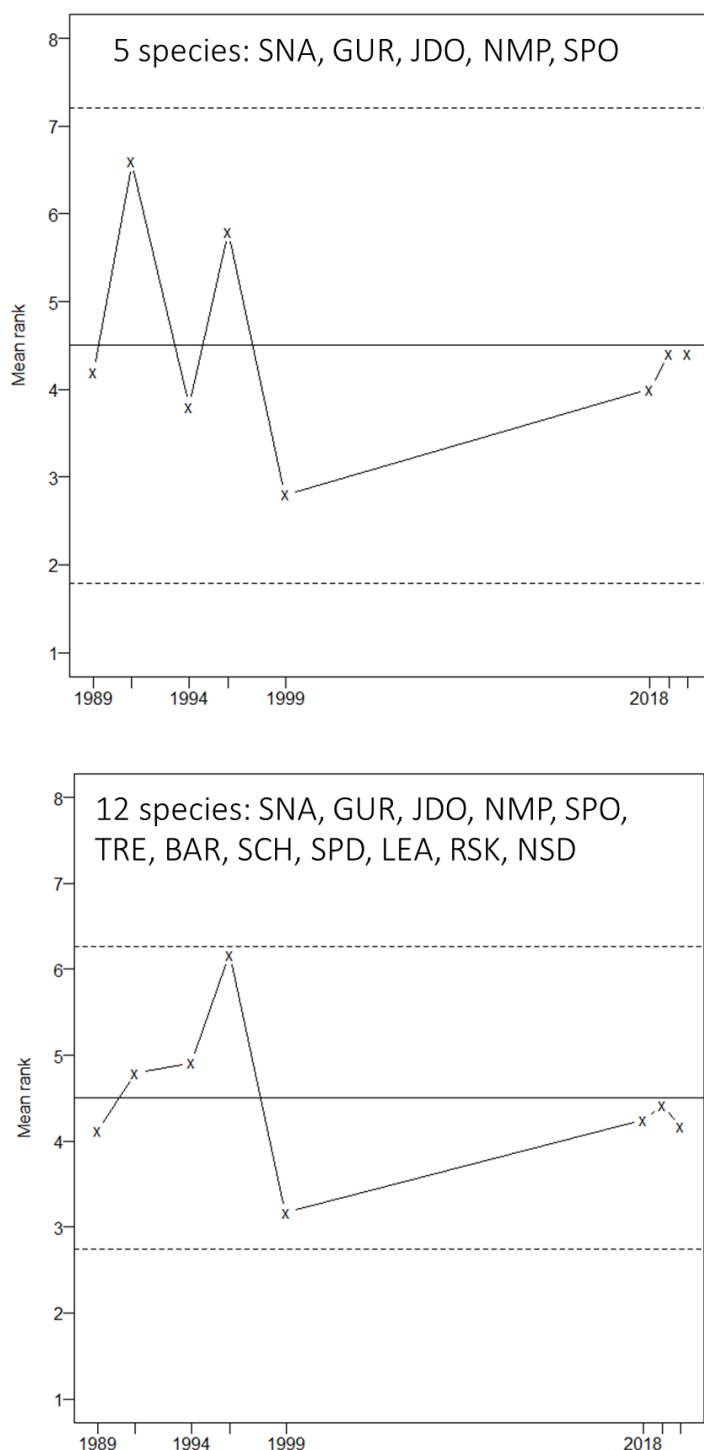


Figure 132: Mean ranks for the WCNI trawl surveys during 1989–2020 for 5 species (the target species and rig) and 12 species. The solid line indicates the overall mean rank. Mean ranks outside the broken lines (95% confidence intervals) have extreme catchability.

3.5 Ancillary data

Although not considered in detail here, additional data were collected in 2018–20 to underpin the development of assessment and monitoring capabilities for biodiversity and ecosystems. In addition to abundance trends and biological data collected on non-target species, this included collection and enumeration of benthic invertebrates, data on water properties from trawl-mounted CTDs, acoustic data from the *Kaharoa* hull-mounted 38-kHz echosounder, and collection of generic and other biological specimens for New Zealand and overseas researchers (Jones et al. 2022). We anticipate that any future surveys would continue to collect similar data for improved ecosystem monitoring, achieving broader outcomes, and public good benefits.

4. CONCLUSIONS

The WCNI survey series has good utility for monitoring year-to-year changes for snapper, red gurnard, John dory, and tarakihi in some parts of its distribution.

For snapper, the survey series is affected by variability in total adult biomass due to survey timing, the presence of inshore spawning aggregations, and restricted access to the inshore trawl exclusion zone. The observed variability in adult snapper biomass has limited the utility of the survey in the current stock assessment model, which has instead used abundance of individual year classes for ages 2–5 (Langley 2020, 2021). To maintain these recruitment indices, the survey needs to be conducted triennially or biennially to have overlap of one to two year classes.

It is clear that the timing of the survey, even if maintained in October is likely to be impacted by variability in adult snapper movements and distribution. As such, adult biomass estimates are likely to continue to be variable from year to year, but still provide longer indicative term trends over a 5–6-year period. A longer time series may enable a re-evaluation of the dynamics of adult snapper, how they may be changing with increasing stock size and in relation to environmental factors. This may also provide sufficient observations to reliably estimate the right-hand limb of the selectivity function in the assessment model. Other considerations include the use of alternative, non-extractive sampling methods that could be used in the inshore areas currently closed to trawling, or starting a new time series at a different time of year where snapper distribution patterns are more stable, such as winter. However, changing the timing of the survey could have an impact on other target species, and this would need to be carefully considered.

The South Taranaki Bight (STB) survey strata provide good coverage of the spatial distribution of commercial fishing effort for snapper in this region, which sits largely inside the 100 m contour, and outside the H25 stratum or ‘Rolling grounds’ region designated as foul in this survey (Walsh et al. 2019). Excluding this H25 stratum does, however, limit the sampling coverage in shallow coastal depths, and distribution of snapper in this area is therefore unknown. The current low numbers of otoliths selected for ageing do not provide good precision but could be increased. The age composition in this STB area appears to reflect a mixing zone between the SNA 8 and SNA 7 stocks, with contributions from the two stocks potentially varying between years. The younger age classes, better represented in the 2018 and 2020 surveys, were most consistent with the northern SNA 8 age compositions in the same year, with strong 2014 and 2016 classes. The older year classes appeared more consistent with strong year classes from the SNA 7 stock, such as the 10+/11 year old class observed in 2018, and the 8+/9 year old class seen in 2019. It is unknown how much the differences in survey timing could impact availability in relation to movement of fish north or south. These data are potentially of relevance to stock assessments in both SNA 7 and SNA 8, although a more complex spatial assessment model would be required to fully utilise this information.

For red gurnard, although there were differences in catch rates inside and outside the Māui dolphin no-trawl zone, there was little overall difference in abundance trend and length frequencies. The WCNI survey series is therefore likely to monitor abundance of red gurnard. A recent decline in red gurnard

pre-recruit biomass abundance was apparent in the time series based on the northern strata (Jones et al. 2022).

Although the survey doesn't adequately cover the full depth range of tarakihi, especially in the south, it does cover the main depths of the commercial fishery (50–200 m) in the northern area. We concluded the survey is likely to be adequate to monitor tarakihi in the northern part of the survey area, i.e., off Ninety Mile Beach and Northland, and could potentially provide region-specific relative biomass estimates.

The WCNI survey has good utility for John dory, providing a fishery-independent source of data to compare with the CPUE time series which has had some concerns around reporting of small catches and changes of gear and target species to avoid snapper (Langley et al. 2018). The survey also provides some information on pre-recruit John dory less than 29 cm.

The survey also appears to provide reasonable information on pre-recruit rig biomass and size distributions, despite the relatively low numbers caught. Restricted access to the inshore areas may mean larger pupping females are not available to the survey, although bottom trawl is not an optimum method for these larger individuals.

The survey probably provides useful information for seven other species: trevally, barracouta, school shark, spiny dogfish, leatherjacket, rough skate, and northern spiny dogfish. This information includes indications of gross trends in biomass, spatial distribution, and size structure.

For trevally, the survey misses the very shallow areas where juveniles congregate. Avoidance of the net is also likely because the tow speed is not optimal (too slow) for adult trevally. The mix of demersal and pelagic habitat, including surface schooling behaviour, means there are probably issues with vertical availability. Catchability may vary year to year based on environmental conditions, including water temperature and clarity. However, the survey may be useful as a recruitment index of 2–3 year olds.

Whilst the historical time series has limited utility for jack mackerel because the two common species were not separated, and the availability of these pelagic species is probably variable, the data collected in the more recent surveys provide information on juvenile species composition and abundance in JMA 7.

Holmes et al. (2022) reviewed the utility of all available trawl time series for use in partial quantitative assessment of rough and smooth skates and concluded that the WCNI survey series was potentially useful for monitoring rough skate in RSK 8 once a longer time series of estimates were available for the wider area. The same study concluded that abundance estimates for smooth skate from the WCNI surveys were unlikely to be useful for monitoring abundance in SSK 8.

A major current limitation is the small number of surveys included in the time series. The utility of data for some of the other non-target species is likely to be improved with more regular surveys in the future.

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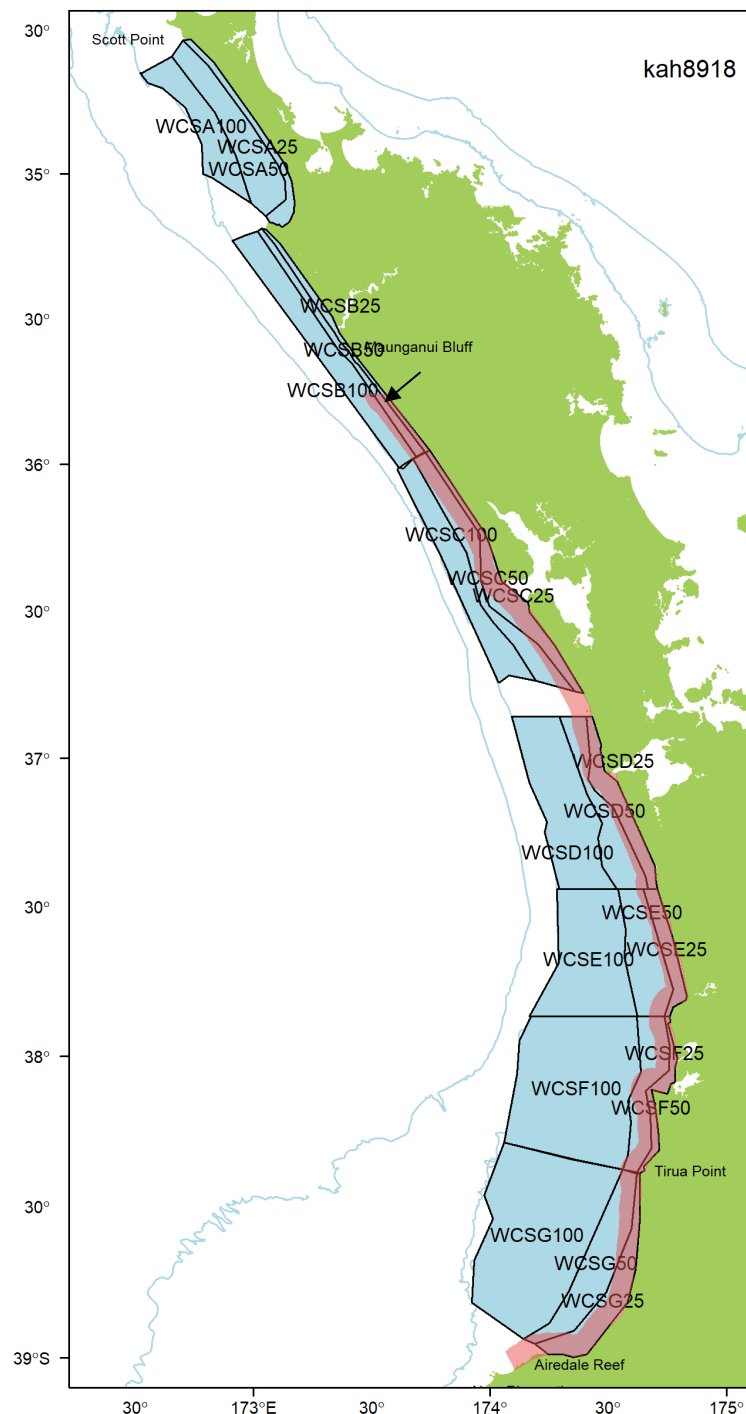
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APPENDIX 1: Survey Areas

Survey boundaries for the WCNI trawl survey from 1989 to 2020. In each survey, the original stratification notation is shown. An extension out to 200 m in the northern area was added in 1991 and retained in subsequent surveys. In 1991 the survey was also extended south as far as Mana Island within the 100 m contour, but these strata were dropped from the later surveys. Areas of foul ground are shaded grey. The current Māui dolphin no-trawl area (shaded pink) is shown for context. Strata within the current northern core boundary are shaded blue.



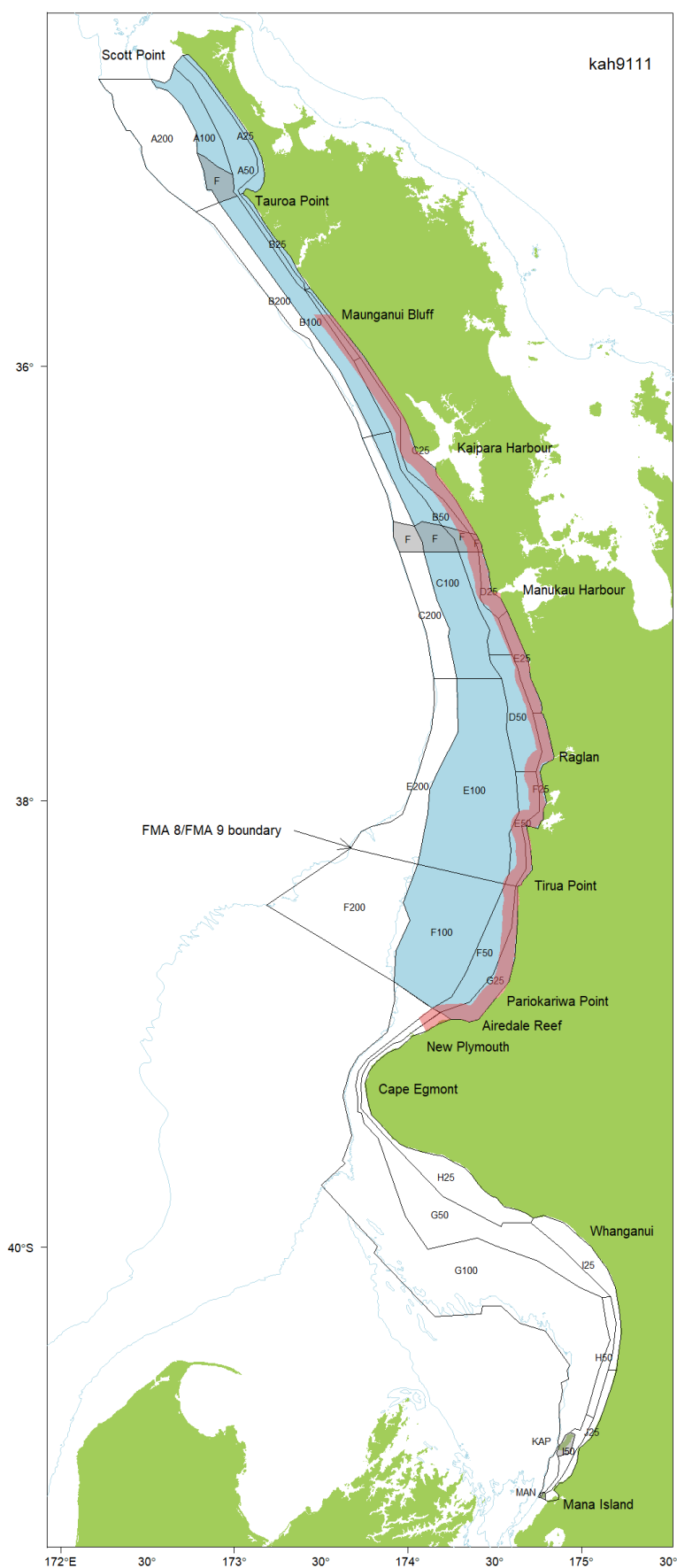


Figure A1.2: 1991. Deeper strata (100–200 m) added, as well as additional strata in the South Taranaki Bight. Revised stratification and labels used.

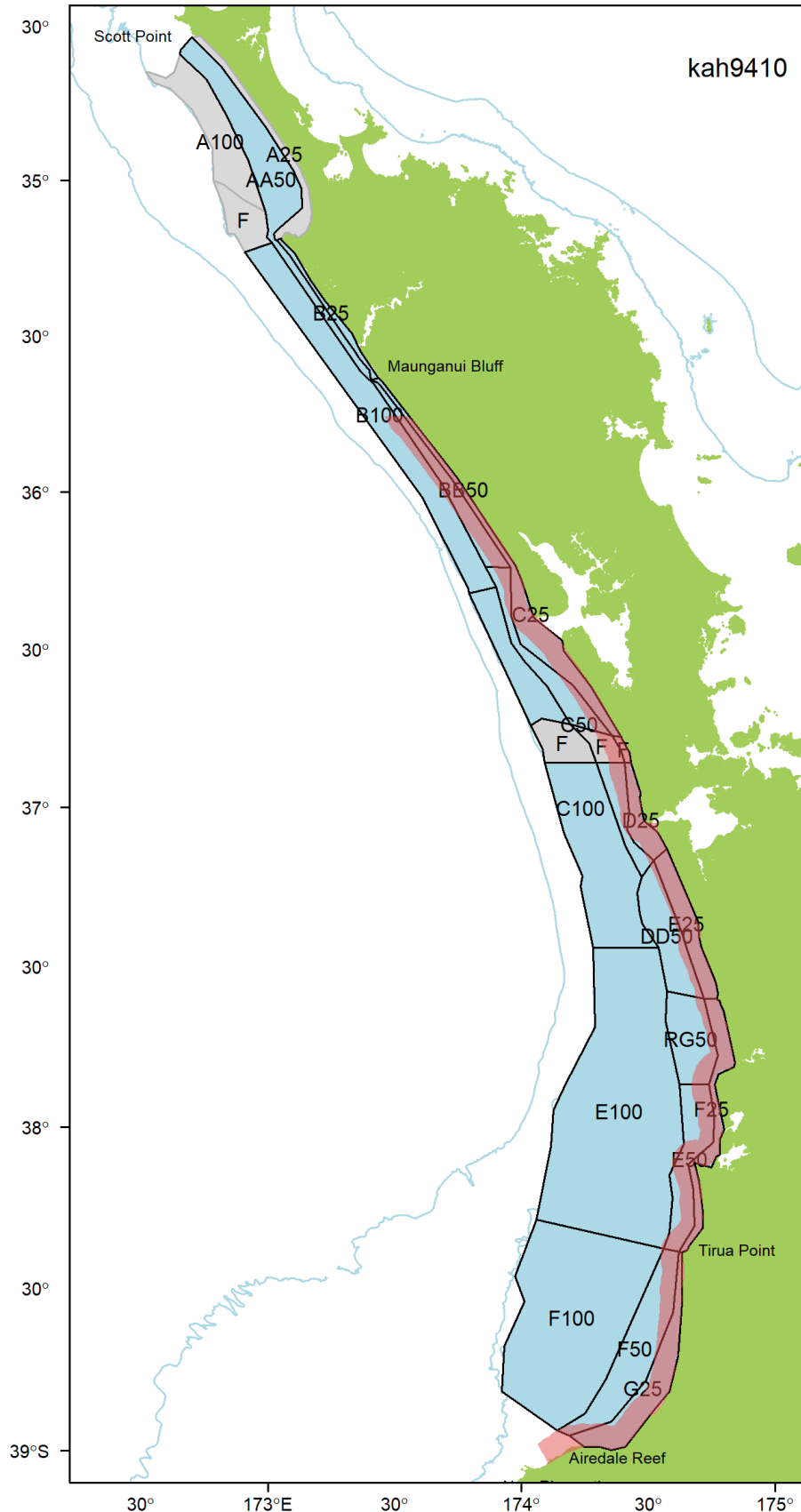


Figure A1.3: 1994. Stratification changes: A50 and B50 reduced in size (renamed AA50 and BB50), C50 created; D50 reduced (DD50) and RG50 created; A25 and A100 not sampled due to extended bad weather. The deep strata between 100–200 m were also not sampled for the same reason.

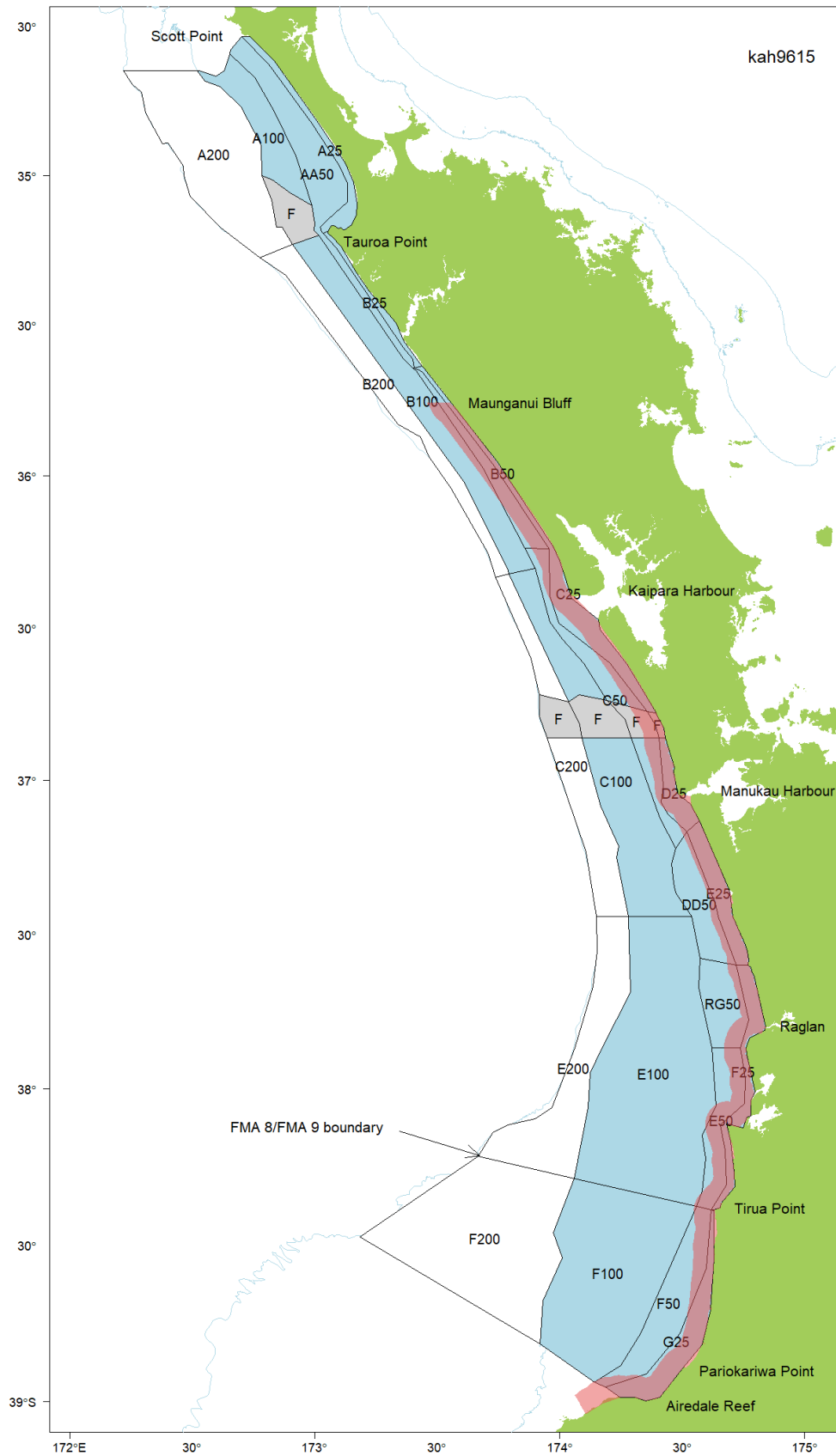


Figure A1.4: 1996: Stratification the same as for the 1994 survey.

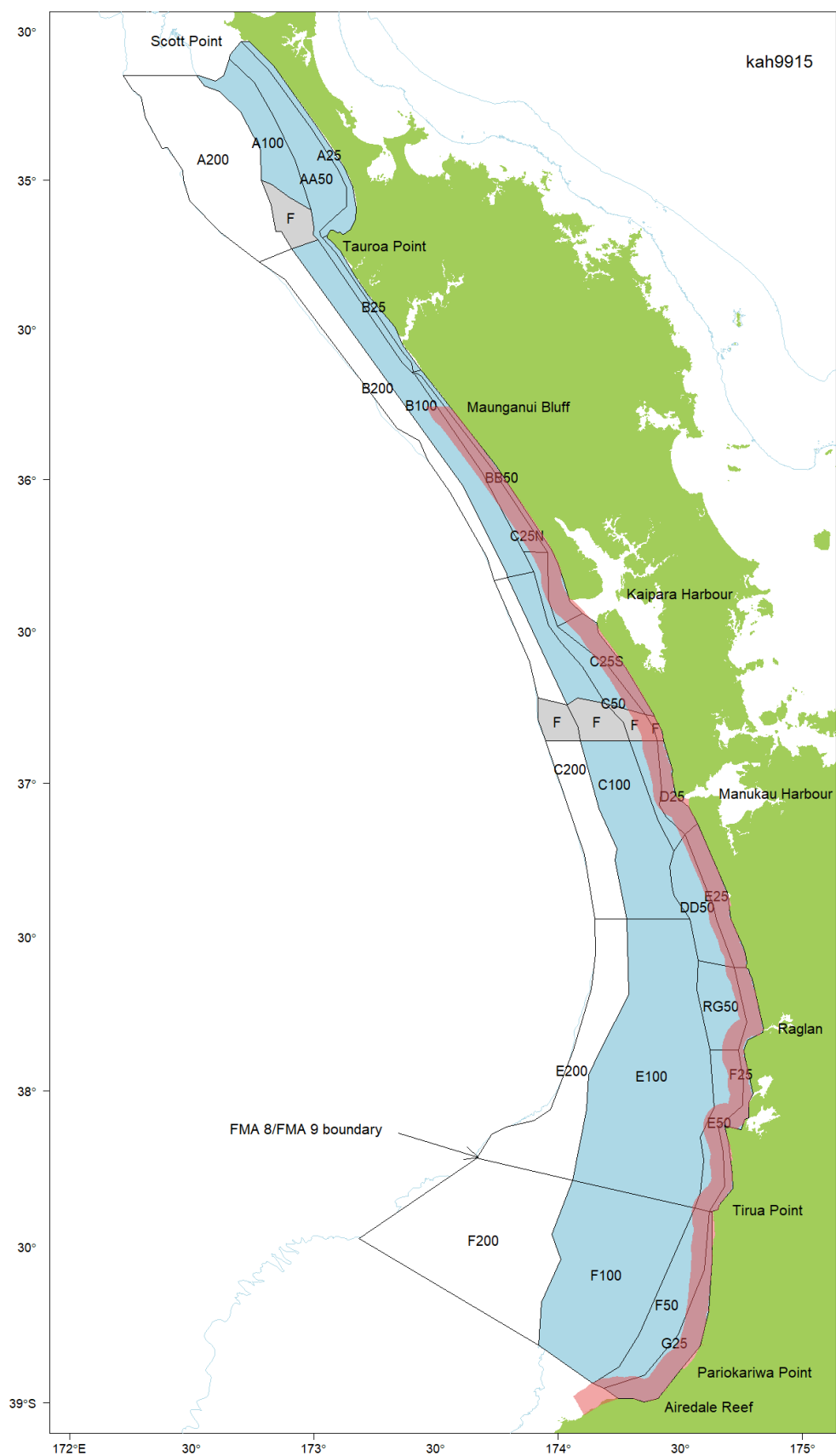


Figure A1.5: 1999. Stratification changes: C25 divided into C25N and C25S.

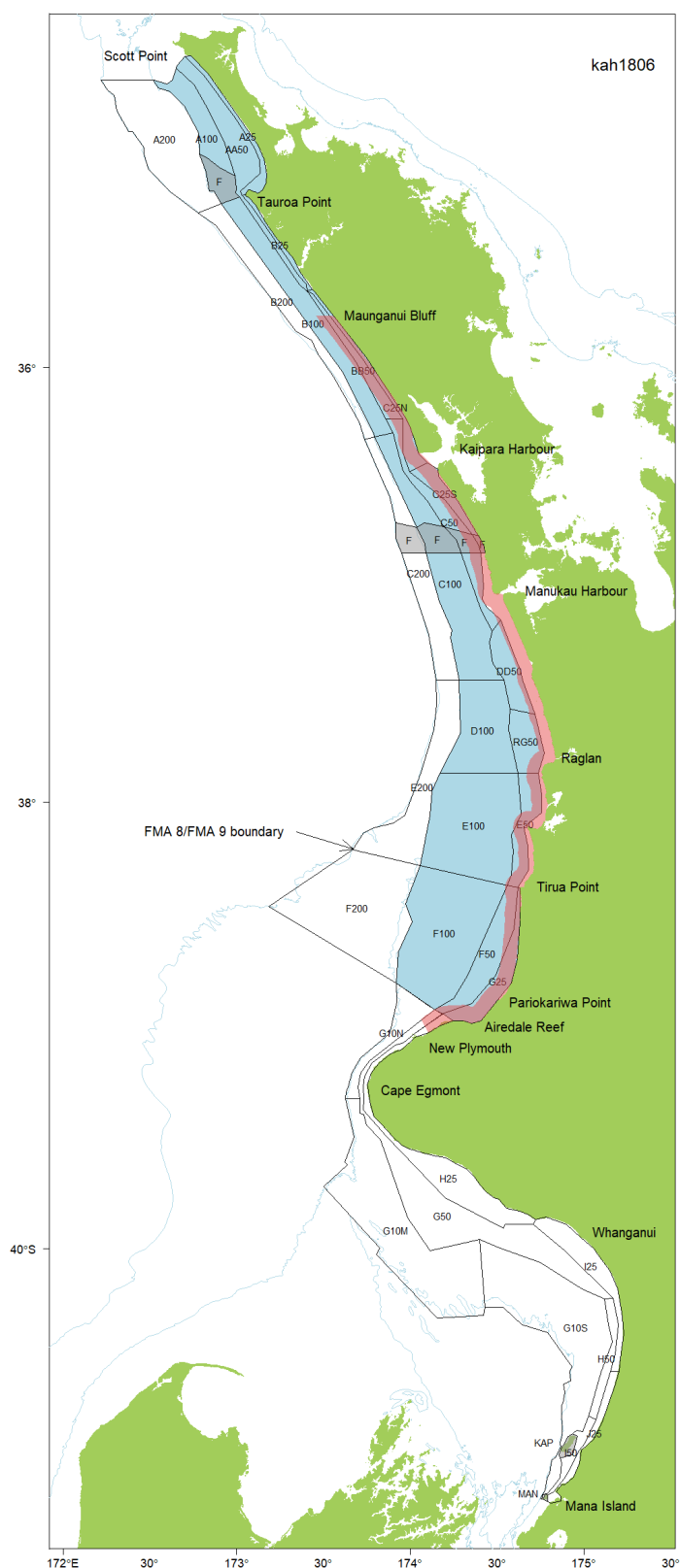


Figure A1.6: 2018. Stratification changes: E100 divided into D100 and E100; G100 divided into G10N, G10M, G10S. H25 included here but dropped from the survey due to poor weather curtailing the ability to find suitable tows. D25, E25, and F25 excluded being fully inside the Māui dolphin no-trawl. C25N, C25S, and G25 included and partially sampled.

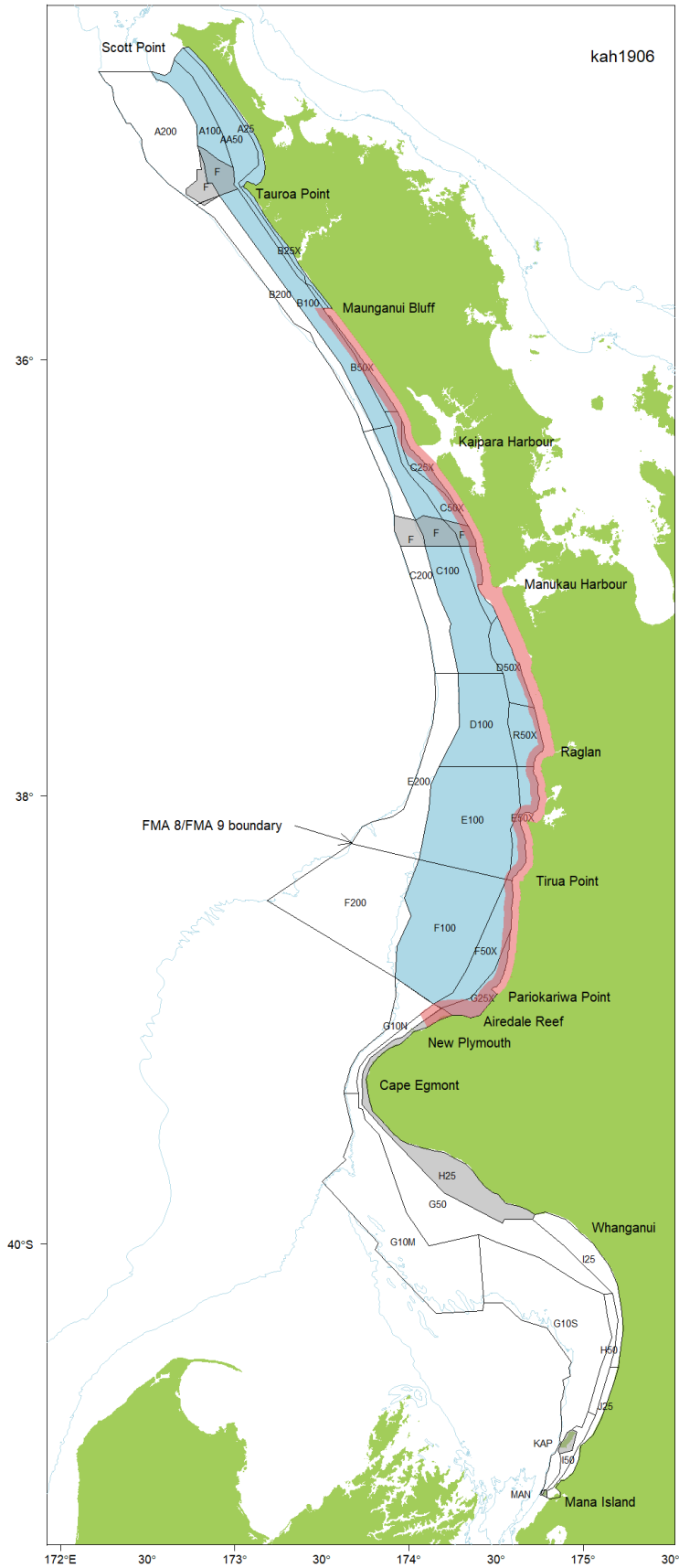


Figure A1.7: 2019. Stratification changes: northern inshore strata re-defined to exclude Māui dolphin no-trawl zone and additional foul area created in A200. H25 excluded from the survey due to extensive foul and lack of previous sampling.

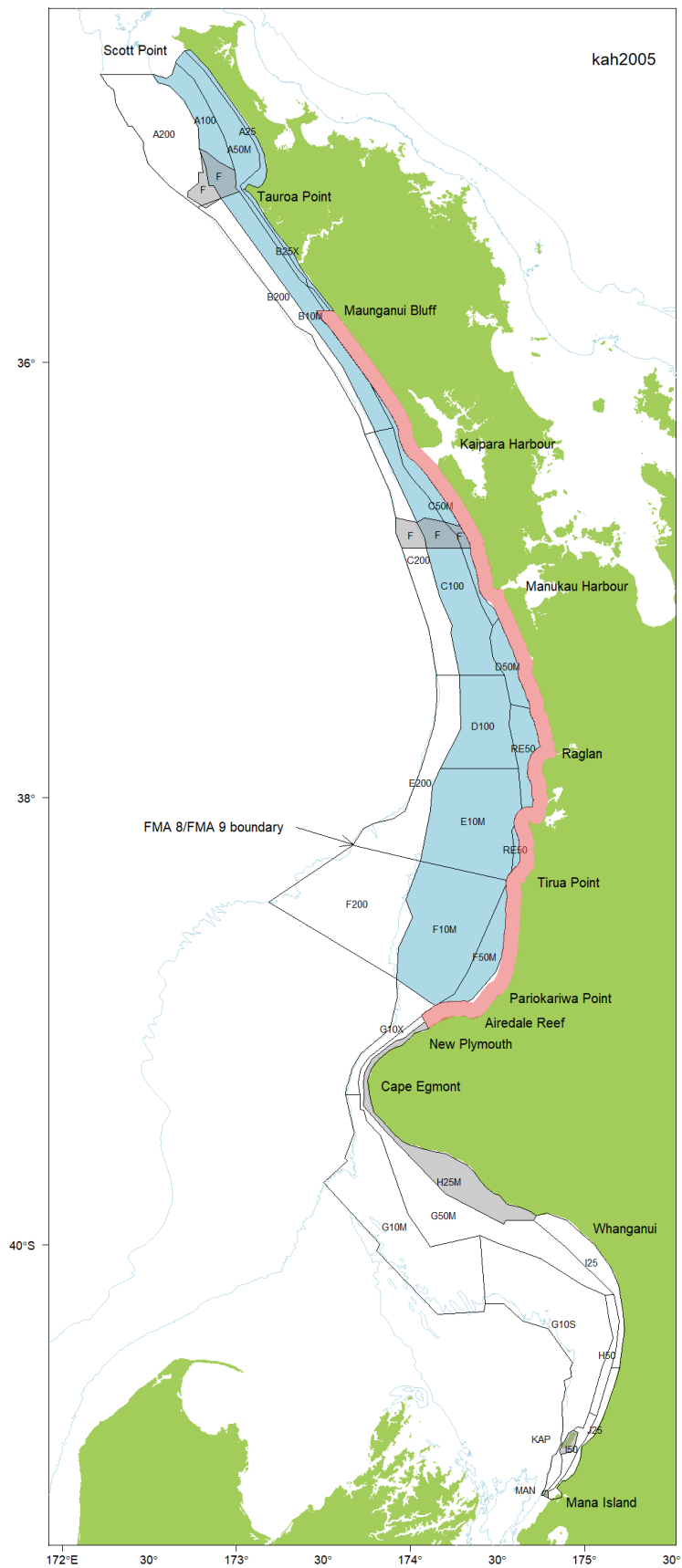


Figure A1.8: 2020. Stratification changes: inshore strata re-defined to exclude the extended Māui dolphin no-trawl zone.

Table A1.1: Summary of WCNI trawl survey strata changes across the three recent surveys, including revised areas, name changes, and type of change provided by survey (E = stratum expanded, R = stratum area reduced, Ex = stratum entirely excluded). The areas for D25, E25, F25, and H25 are provided in round brackets; these historical strata were not sampled in any of the recent surveys and were not included in the total survey area. Core strata are in bold. Stratum locations are shown in Figures A1.6–A1.8.

2018 survey			2019 survey			2020 survey	
Stratum	Depth (m)	Area (km ²)	Stratum	Area (km ²)		Stratum	Area (km ²)
A25	10–25	253	A25	253		A25	253
AA50	25–50	937	AA50	937		A50M	968 E
A100	50–100	621	A100	621		A100	621
A200	100–200	1 987	A200* ¹	1 812	R	A200	1 812
B25	10–25	103	B25X	127	E	B25X	127
BB50	25–50	321	B50X	202	R		Ex
B100	50–100	1 326	B100	1 326		B10M	1 234 R
B200	100–200	963	B200	952	R	B200	952
C25N	10–25	295	C25X	180	R		Ex
C25S	10 – 25	259					
C50	25 – 50	608	C50X	577	R	C50M * ²	462 R
C100	50 – 100	1 725	C100	1 725		C100	1 725
C200	100 – 200	1 039	C200	1 039		C200	1 039
D25	10 – 25	(190)	Ex		Ex		Ex
DD50	25 – 50	459	D50X	426	R	D50M	372 R
D100	50 – 100	1 308	D100	1 308		D100	1 308
E25	10 – 25	(310)	Ex		Ex		Ex
RG50	25 – 50	438	R50X	423	R	RE50	489
E50	50 – 100	484	E50X	395	R		
E100	50 – 100	2 304	E100	2 304		E10M	2 292 R
E200	100 – 200	1 415	E200	1 415		E200	1 415
F25	10 – 25	(327)	Ex		Ex		Ex
G25	10 – 25	489	G25X	320	R		Ex
F50	25 – 50	736	F50X	703	R	F50M	556 R
F100	50 – 100	2 473	F100	2 473		F100	2 473
F200	100 – 200	2 706	F200	2 706		F200	2 706
H25	10 – 25	(1 061)	Ex		Ex	H25M	Ex
G50	25 – 50	2 080	G50	2 080		G50M	2 044 R
G100N	50 – 100	477	G10N	477		G10X	475 R
G100M	50 – 100	2 911	G10M	2 911		G10M	2 911
I25	10 – 25	576	I25	576		I25	576
J25	10 – 25	218	J25	218		J25	218
H50	25 – 50	234	H50	234		H50	234
I50	25 – 50	147	I50	147		I50	147
G100S	50 – 100	2 642	G10S	2 642		G10S	2 642
Total		32 534		31 509			30 051

*¹ An extension of foul ground into A200 reduced the area of this stratum. *² The remainder of C25X was incorporated into C50M. and part of B50X, but overall area was still reduced.

APPENDIX 2: Species considered in review

Species in **bold** are reported in detail in the main report. Summaries for the other species are in Appendix 6.

Species code	Common name	Scientific name	Total weight (kg)	No. of trips	No. of fish measured	Length min. (cm)	Length max (cm)	Mean length (cm)	Number weighed
SNA	Snapper	<i>Chrysophrys auratus</i>	47 961.6	8	37 142	8	81	34.45	7 638
JMA	Yellowtail and greenback jack mackerel	<i>Trachurus novaezelandiae & Trachurus declivis</i>	23 312.8	8	39 990	2	58	20.75	716
GUR	Red gurnard	<i>Chelidonichthys kumu</i>	20 861.2	8	44 804	9	53	30.35	6 641
TRE	Trevally	<i>Pseudocaranx georgianus</i>	12 412.1	8	13 903	3	66	32.03	1 170
SPD	Spiny dogfish	<i>Squalus acanthias</i>	9 203.8	8	3 121	15	93	68.11	478
BAR	Barracouta	<i>Thyrsites atun</i>	6 889.0	8	4 078	10	106	65.12	794
POP* ¹	Porcupine fish	<i>Allomycterus pilatus</i>	5 620.7	5	NA	NA	NA	NA	NA
SCH	School shark	<i>Galeorhinus galeus</i>	3 876.9	8	835	27	200	83.54	61
NMP	Tarakihi	<i>Nemadactylus macropterus</i>	3 500.8	8	3 678	7	53	35.93	1 705
LEA	Leatherjacket	<i>Meuschenia scaber</i>	3 460.3	8	4 645	8	34	23.73	25
SPO	Rig	<i>Mustelus lenticulatus</i>	3 103.8	8	1 820	13	138	70.41	132
JDO	John dory	<i>Zeus faber</i>	2 792.0	8	2 934	9	58	34.75	1 503
EGR	Eagle ray	<i>Myliobatis tenuicaudatus</i>	1 782.4	8	224	17	71	30.41	8
STR	Stingray combined sp.	<i>Bathytoshia brevicaudata and Bathytoshia lata</i>	1 375.4	8	43	24	85	49.7	7
ATT	Kahawai	<i>Arripis trutta</i>	1 372.2	8	3 323	7	55	29.67	156
KIN	Kingfish	<i>Seriola lalandi</i>	1 065.1	7	165	38	124	73.98	5
NSD	Northern spiny dogfish	<i>Squalus griffini</i>	768.6	7	336	36	115	68.29	139
RSK*²	Rough skate	<i>Zearaja nasuta</i>	750.5	7	222	23	62	46.34	34
SSK*²	Smooth skate	<i>Dipturus innominatus</i>	698.8	7	141	13	110	54.90	12
CUC	Cucumberfish	<i>Paraulopus nigripinnis</i>	679.3	8	1 507	7	21	13.79	NA
FRO	Frostfish	<i>Lepidopus caudatus</i>	646.4	8	586	14	156	87.01	20
SQU	Arrow squid combined sp.	<i>Nototodarus sloanii & N. gouldi</i>	542.9	8	2329	3	35	14.52	NA
RCO	Red cod	<i>Pseudophycis bachus</i>	445.5	8	959	10	64	32.79	59
CAR	Carpet shark	<i>Cephaloscyllium isabellum</i>	444.0	8	71	39	90	63.22	4

Species code	Common name	Scientific name	Total weight (kg)	No. of trips	No. of fish measured	Length min. (cm)	Length max (cm)	Mean length (cm)	Number weighed
JGU	Spotted gurnard	<i>Pterygotrigla picta</i>	366.8	8	494	10	46	28.24	23
SNI	Snipefish	<i>Macroramphosus scolopax</i>	321.6	7	235	5	15	10.33	NA
WAR	Common warehou	<i>Seriolella brama</i>	305.0	8	448	3	63	23.23	15
JMM	Slender jack mackerel	<i>Trachurus murphyi</i>	252.7	5	167	24	58	49.17	21
HHS	Hammerhead shark	<i>Sphyrna zygaena</i>	213.4	8	42	59	155	94.33	6
ANC	Anchovy	<i>Engraulis australis</i>	199.3	8	1 323	4	14	9.85	NA
SPE* ³	Seaperch	<i>Helicolenus</i> spp.	164.1	8	912	6	37	17.21	24
PAR	Parore	<i>Girella tricuspidata</i>	143.8	3	54	33	45	38.93	
MOK	Moki	<i>Latridopsis ciliaris</i>	135.1	3	39	46	73	59.30	32
GSH	Dark ghost shark	<i>Hydrolagus novaezealandiae</i>	131.8	6	83	43	71	59.10	4
THR	Thresher shark	<i>Alopias vulpinus</i>	127.6	7	5	82	225	158.00	1
SDO	Silver dory	<i>Cyttus novaezealandiae</i>	126.8	5	141	9	44	15.14	NA
TUR* ⁴	Turbot	<i>Colistium nudipinnis</i>	120.6	8	156	14	54	36.80	8
GIZ* ⁵	Giant stargazer	<i>Kathetostoma giganteum</i>	115.6	5	101	13	63	35.82	NA
SCG	Scaly gurnard	<i>Lepidotrigla brachyoptera</i>	104.3	8	525	6	17	11.64	NA
LFB	Longfin boarfish	<i>Zanclistius elevatus</i>	97.9	5	134	13	32	25.54	12
ESO	NZ sole	<i>Peltorhamphus novaezeelandiae</i>	96.3	8	496	12	41	25.59	NA
SEV	Sevengill shark	<i>Notorynchus cepedianus</i>	93.9	4	5	115	163	148.80	3
RSO	Gemfish	<i>Rexea solandri</i>	82.5	6	40	32	94	63.32	11
YEM	Yellow eyed mullet	<i>Aldrichetta forsteri</i>	80.9	8	555	13	29	20.64	NA
ERA	Electric ray	<i>Torpedo fairchildi</i>	74.4	5	14	21	41	29.15	NA
EMA	Blue mackerel	<i>Scomber australasicus</i>	65.3	8	489	11	52	20.30	NA
SPZ	Spotted stargazer	<i>Genyagnus monopterygius</i>	60.3	8	108	13	45	29.73	1
LSO	Lemon sole	<i>Pelotretis flavilatus</i>	55.3	8	208	9	39	27.10	NA
CON	Conger eel	<i>Conger</i> spp.	53.3	5	5	86	150	110.80	NA
BOA	Giant boarfish	<i>Paristiopterus labiosus</i>	53.2	6	36	18	76	32.14	1
PIL	Pilchard	<i>Sardinops sagax</i>	46.8	8	279	6	23	12.54	NA

Species code	Common name	Scientific name	Total weight (kg)	No. of trips	No. of fish measured	Length min. (cm)	Length max (cm)	Mean length (cm)	Number weighed
HAP	Hāpuku	<i>Polyprion oxygeneios</i>	44.4	6	12	53	78	65.50	3
BRZ	Brown stargazer	<i>Xenoccephalus armatus</i>	42.7	5	25	37	60	44.78	8
POR	Porae	<i>Nemadactylus douglasii</i>	35.2	3	20	26	61	43.00	NA
SFL	Sand flounder	<i>Rhombosolea plebeia</i>	32.4	8	135	14	39	24.70	NA
BCO	Blue cod	<i>Parapercis colias</i>	23.8	5	35	19	48	34.00	NA
PCO	Āhuru	<i>Auchenoceros punctatus</i>	21.3	7	788	5	16	11.58	NA
BSQ	Broad squid	<i>Sepioteuthis australis</i>	18.4	7	38	8	27	16.62	NA
BPE	Butterfly perch	<i>Caesioperca lepidoptera</i>	17.9	6	50	11	28	21.60	NA
WIT	Witch	<i>Arnoglossus scapha</i>	17.3	8	90	10	31	24.49	NA
RBT	Redbait	<i>Emmelichthys nitidus</i>	13.7	6	31	6	19	11.65	NA
SWA	Silver warehou	<i>Seriola punctata</i>	11.5	5	100	8	26	13.93	NA

*1 Porcupinefish are not listed as caught in historical surveys prior to 1996 and were not weighed on the 1996 and 1999 surveys due to water inflation, so were mentioned as a footnote only. Weights presented here are of fish in various states of water inflation and therefore should be interpreted with caution.

*2 As noted in the individual sections, the SKA code was used in the 1989 survey, and on some occasions on the 1991 (n = 18), 1994 (n = 2), and 1999 (n = 1), totalling 123 kg, not included here.

*3 SPE is a combined species code for *Helicolenus percoides* and *H. barathri*. The SPE species code has been used historically, whilst in more recent surveys, with updated taxonomic information available, sea perch have generally been confirmed to be the shallower dwelling *H. percoides* (HPC).

*4 TUR code in this list combines both turbot and brill due to some uncertainty about previous identification. Only turbot has been identified from recent surveys, but some historical identifications of brill may have been erroneous as this species is only known from central and southern New Zealand.

*5 Current GIZ code is combined with the STA code previously used for this species on four historical surveys.

Species not considered in review

Species that did not meet criteria of total catch weight > 10 kg and occurring in 3 or more surveys that were not considered in this review.

Species code	Common name	Scientific name	Total weight (kg)	No. of trips	No. of fish measured	Length min. (cm)	Length max (cm)	Mean length (cm)	Number weighed
SWE	Sweep	<i>Scorpius lineolatus</i>	204.9	2	95	13	32	23.06	NA
RBV	Rubyfish	<i>Plagiogeneion rubiginosum</i>	21.7	1	47	13	44	27.38	NA
OPE	Orange perch	<i>Lepidoperca aurantia</i>	17.0	2	44	14	28	22.42	NA
STG* ⁶	Stargazer unidentified		9.5	2	12	20	63	31.58	NA
LIN	Ling	<i>Genypterus blacodes</i>	9.3	5	8	40	91	58.62	NA
RHY	Common roughy	<i>Paratrachichthys trailli</i>	9.2	2	49	15	22	18.50	NA
SPR	Sprat	<i>Sprattus antipodum</i> , <i>S. muelleri</i>	8.8	3	NA	NA	NA	NA	NA
HOK	Hoki	<i>Macruronus novaezelandiae</i>	5.9	5	38	7	82	19.19	NA
MDO	Mirror dory	<i>Zenopsis nebulosa</i>	5.0	4	2	25	43	34.00	NA
CBI	Two saddle rattail	<i>Coelorinchus biclinozonalis</i>	4.8	2	NA	NA	NA	NA	NA
RMU	Goatfish	<i>Upeneichthys porosus</i>	4.4	4	4	24	32	29.25	NA
ELE	Elephantfish	<i>Callorhynchus milii</i>	3.4	1	1	90	90	90.00	NA
STY	Spotty	<i>Notolabrus celidotus</i>	3.1	5	9	17	30	22.78	NA
BRC	Northern bastard cod	<i>Pseudophycis breviuscula</i>	3.0	5	5	18	40	30.40	NA
CDO	Capro dory	<i>Capromimus abbreviatus</i>	2.6	1	NA	NA	NA	NA	NA
RSN	Red snapper	<i>Centroberyx affinis</i>	1.8	1	1	43	43	43.00	NA
LDO	Lookdown dory	<i>Cyttus traversi</i>	1.7	1	NA	NA	NA	NA	NA
YBF	Yellowbelly flounder	<i>Rhombosolea leporina</i>	1.7	4	6	26	41	30.83	NA
RAT	Rattail unidentified	Macrouridae	1.6	1	8	23	42	35.33	NA
SRH	Silver roughy	<i>Hoplostethus mediterraneus</i>	1.5	1	NA	NA	NA	NA	NA
SSI	Silverside	<i>Argentina elongata</i>	1.4	4	1	12	12	12.00	NA
FOX	Foxfish	<i>Bodianus flavipinnis</i>	1.3	2	1	37	37	37.00	NA
GLB* ⁷	Globe fish	<i>Contusus richiei</i>	1.9	4	54	5	14	9.47	NA
WHI	Whitebait	Galaxiidae (juvenile)	1.0	2	NA	NA	NA	NA	NA
OSE	Snake eel	<i>Ophisurus serpens</i>	0.8	1	NA	NA	NA	NA	NA

Species code	Common name	Scientific name	Total weight (kg)	No. of trips	No. of fish measured	Length min. (cm)	Length max (cm)	Mean length (cm)	Number weighed
BGZ	Banded stargazer	<i>Kathetostoma binigrasella</i>	0.7	1	1	29	29	29.00	NA
BYX	Longfinned beryx	<i>Beryx decadactylus</i>	0.7	1	1	38	38	38.00	NA
PIG	Pigfish	<i>Congiopodus leucopaecilus</i>	0.7	1	NA	NA	NA	NA	NA
WSE	Wrasses	Labridae	0.6	1	NA	NA	NA	NA	NA
YCO	Yellow cod	<i>Parapercis gilliesi</i>	0.6	2	1	23	23	23.00	NA
CEP	Red band fish	<i>Cepola haastii</i>	0.3	2	2	32	39	35.50	NA
HAK	Hake	<i>Merluccius australis</i>	0.2	1	1	22	22	22.00	NA
SBR	Southern bastard cod	<i>Pseudophycis barbata</i>	0.2	1	NA	NA	NA	NA	NA
CFL	Crested flounder	<i>Lophonectes gallus</i>	0.1	1	NA	NA	NA	NA	NA
GAR	Garfish	<i>Hyporhamphus ihi</i>	0.1	1	1	23	23	23.00	NA
OPA	Opalfish	<i>Hemerocoetes</i> spp.	0.1	1	NA	NA	NA	NA	NA
SHO	Seahorse	<i>Hippocampus abdominalis</i>	0.1	1	NA	NA	NA	NA	NA

*6 STG, unidentified stargazer was used on two surveys (1991 and 1996).

*7 GLB was combined with PUF which was the code used for *C. richiei* in 1994 and 1991.

APPENDIX 3: Length-weight relationship parameters

Used to scale length frequencies and calculate length class biomass estimates for each individual survey. *rdh*, Fisheries New Zealand research database; *n* = sample size. Species codes are given in Appendix 2. Source of data: “WCNI” refers to all *Kaharoa* WCNI surveys combined; “WCNI & WCSI” refers to all WCNI and west coast South Island *Kaharoa* surveys combined; FAR 2018-18 refers to a length-weight relationship cited by Stevenson & MacGibbon (2018).

Species codes	Trip	<i>a</i>	<i>b</i>	<i>r</i> ²	<i>n</i>	Length range (cm)	Source
SNA	kah8918	0.025389	2.946318	99.32	1 479	10.5-71.0	kah9915
SNA	kah9111	0.025389	2.946318	99.32	1 479	10.5-71.0	kah9915
SNA	kah9410	0.025389	2.946318	99.32	1 479	10.5-71.0	kah9915
SNA	kah9615	0.025389	2.946318	99.32	1 479	10.5-71.0	kah9915
SNA	kah9915	0.025389	2.946318	99.32	1 479	10.5-71.0	kah9915
SNA	kah1806	0.034414	2.863557	99.29	1 667	9.3-79.2	kah1806
SNA	kah1906	0.039180	2.841420	99.41	1 662	9.7-81.1	kah1906
SNA	kah2005	0.040510	2.832167	99.20	1 939	9.5-75.9	kah2005
GUR	kah8918	0.006435	3.120780	98.58	2 574	12.3-48.2	kah9915
GUR	kah9111	0.006435	3.120780	98.58	2 574	12.3-48.2	kah9915
GUR	kah9410	0.006435	3.120780	98.58	2 574	12.3-48.2	kah9915
GUR	kah9615	0.006435	3.120780	98.58	2 574	12.3-48.2	kah9915
GUR	kah9915	0.006435	3.120780	98.58	2 574	12.3-48.2	kah9915
GUR	kah1806	0.009436	3.013198	98.00	1 218	14.0-51.7	kah1806
GUR	kah1906	0.008164	3.065401	98.44	1 318	13.6-52.1	kah1906
GUR	kah2005	0.006505	3.117976	98.29	1 305	13.3-51.2	kah2005
NMP	kah8918	0.021759	2.930881	95.81	460	20.6-47.1	kah9915
NMP	kah9111	0.021759	2.930881	95.81	460	20.6-47.1	kah9915
NMP	kah9410	0.021759	2.930881	95.81	460	20.6-47.1	kah9915
NMP	kah9615	0.021759	2.930881	95.81	460	20.6-47.1	kah9915
NMP	kah9915	0.021759	2.930881	95.81	460	20.6-47.1	kah9915
NMP	kah1806	0.018773	2.983526	97.63	372	16.4-47.9	kah1806
NMP	kah1906	0.019733	2.970662	97.21	413	9.3-53.0	kah1906
NMP	kah2005	0.023438	2.925320	95.39	457	26.5-51.0	kah2005
JDO	kah8918	0.002811	3.481470	98.26	310	16.7-54.2	kah9915
JDO	kah9111	0.002811	3.481470	98.26	310	16.7-54.2	kah9915
JDO	kah9410	0.002811	3.481470	98.26	310	16.7-54.2	kah9915
JDO	kah9615	0.002811	3.481470	98.26	310	16.7-54.2	kah9915
JDO	kah9915	0.002811	3.481470	98.26	310	16.7-54.2	kah9915
JDO	kah1806	0.003952	3.399980	98.18	403	14.2-54.6	kah1806
JDO	kah1906	0.005108	3.336181	98.74	355	10.6-54.1	kah1906
JDO	kah2005	0.004639	3.359420	98.51	415	10.0-52.1	kah2005
TRE	kah8918	0.023450	2.933688	99.18	1 112	7.8-54.6	WCNI
TRE	kah9111	0.023450	2.933688	99.18	1 112	7.8-54.6	WCNI
TRE	kah9410	0.023450	2.933688	99.18	1 112	7.8-54.6	WCNI
TRE	kah9615	0.023450	2.933688	99.18	1 112	7.8-54.6	WCNI
TRE	kah9915	0.023450	2.933688	99.18	1 112	7.8-54.6	WCNI
TRE	kah1806	0.020109	2.973114	97.86	190	20.7-53.7	kah1806

Species codes	Trip	<i>a</i>	<i>b</i>	<i>r</i> ²	<i>n</i>	Length range (cm)	Source
TRE	kah1906	0.030289	2.859809	99.21	486	8.7-54.6	kah1906
TRE	kah2005	0.022807	2.944384	99.28	447	6.3-55.5	kah2005
JMA	kah8918	0.011488	3.004831	98.42	2 579	7.7-52.4	WCNI
JMA	kah9111	0.011488	3.004831	98.42	2 579	7.7-52.4	WCNI
JMA	kah9410	0.011488	3.004831	98.42	2 579	7.7-52.4	WCNI
JMA	kah9615	0.011488	3.004831	98.42	2 579	7.7-52.4	WCNI
JMA	kah9915	0.011488	3.004831	98.42	2 579	7.7-52.4	WCNI
JMA	kah1806	0.009637	3.064377	97.95	346	6.7-46.7	kah1806
JMA	kah1906	0.011721	2.999552	98.52	1 213	7.0-50.5	kah1906
JMA	kah2005	0.010920	3.014902	98.19	1 005	8.1-52.4	kah2005
ATT	kah8918	0.023600	2.890000	NA	170	5.0-60.0	FAR 2018-18
ATT	kah9111	0.023600	2.890000	NA	170	5.0-60.0	FAR 2018-18
ATT	kah9410	0.023600	2.890000	NA	170	5.0-60.0	FAR 2018-18
ATT	kah9615	0.023600	2.890000	NA	170	5.0-60.0	FAR 2018-18
ATT	kah9915	0.023600	2.890000	NA	170	5.0-60.0	FAR 2018-18
ATT	kah1806	0.023600	2.890000	NA	170	5.0-60.0	FAR 2018-18
ATT	kah1906	0.023600	2.890000	NA	170	5.0-60.0	FAR 2018-18
ATT	kah2005	0.023600	2.890000	NA	170	5.0-60.0	FAR 2018-18
BAR	kah8918	0.005460	2.951402	98.75	102	16.7-97.5	WCNI
BAR	kah9111	0.005460	2.951402	98.75	102	16.7-97.5	WCNI
BAR	kah9410	0.005460	2.951402	98.75	102	16.7-97.5	WCNI
BAR	kah9615	0.005460	2.951402	98.75	102	16.7-97.5	WCNI
BAR	kah9915	0.005460	2.951402	98.75	102	16.7-97.5	WCNI
BAR	kah1806	0.005460	2.951402	98.75	102	16.7-97.5	WCNI
BAR	kah1906	0.005460	2.951402	98.75	102	16.7-97.5	WCNI
BAR	kah2005	0.005460	2.951402	98.75	102	16.7-97.5	WCNI
SCH	kah8918	0.001944	3.196263	99.28	2 261	31.9-179.0	WCNI & WCSI
SCH	kah9111	0.001944	3.196263	99.28	2 261	31.9-179.0	WCNI & WCSI
SCH	kah9410	0.001944	3.196263	99.28	2 261	31.9-179.0	WCNI & WCSI
SCH	kah9615	0.001944	3.196263	99.28	2 261	31.9-179.0	WCNI & WCSI
SCH	kah9915	0.001944	3.196263	99.28	2 261	31.9-179.0	WCNI & WCSI
SCH	kah1806	0.001944	3.196263	99.28	2 261	31.9-179.0	WCNI & WCSI
SCH	kah1906	0.001944	3.196263	99.28	2 261	31.9-179.0	WCNI & WCSI
SCH	kah2005	0.001944	3.196263	99.28	2 261	31.9-179.0	WCNI & WCSI
SPO	kah8918	0.002363	3.128354	99.29	1 461	29.0-147.0	WCNI & WCSI
SPO	kah9111	0.002363	3.128354	99.29	1 461	29.0-147.0	WCNI & WCSI
SPO	kah9410	0.002363	3.128354	99.29	1 461	29.0-147.0	WCNI & WCSI
SPO	kah9615	0.002363	3.128354	99.29	1 461	29.0-147.0	WCNI & WCSI
SPO	kah9915	0.002363	3.128354	99.29	1 461	29.0-147.0	WCNI & WCSI
SPO	kah1806	0.002363	3.128354	99.29	1 461	29.0-147.0	WCNI & WCSI
SPO	kah1906	0.002363	3.128354	99.29	1 461	29.0-147.0	WCNI & WCSI
SPO	kah2005	0.002363	3.128354	99.29	1 461	29.0-147.0	WCNI & WCSI
SPD	kah8918	0.000673	3.421011	97.14	4 888	27.0-96.9	WCNI & WCSI
SPD	kah9111	0.000673	3.421011	97.14	4 888	27.0-96.9	WCNI & WCSI
SPD	kah9410	0.000673	3.421011	97.14	4 888	27.0-96.9	WCNI & WCSI

Species codes	Trip	<i>a</i>	<i>b</i>	<i>r</i> ²	<i>n</i>	Length range (cm)	Source
SPD	kah9615	0.000673	3.421011	97.14	4 888	27.0-96.9	WCNI & WCSI
SPD	kah9915	0.000673	3.421011	97.14	4 888	27.0-96.9	WCNI & WCSI
SPD	kah1806	0.000673	3.421011	97.14	4 888	27.0-96.9	WCNI & WCSI
SPD	kah1906	0.000673	3.421011	97.14	4 888	27.0-96.9	WCNI & WCSI
SPD	kah2005	0.000673	3.421011	97.14	4 888	27.0-96.9	WCNI & WCSI
RSK	kah8918	0.026241	2.937528	98.77	691	14.7-62.0	WCNI & WCSI
RSK	kah9111	0.026241	2.937528	98.77	691	14.7-62.0	WCNI & WCSI
RSK	kah9410	0.026241	2.937528	98.77	691	14.7-62.0	WCNI & WCSI
RSK	kah9615	0.026241	2.937528	98.77	691	14.7-62.0	WCNI & WCSI
RSK	kah9915	0.026241	2.937528	98.77	691	14.7-62.0	WCNI & WCSI
RSK	kah1806	0.026241	2.937528	98.77	691	14.7-62.0	WCNI & WCSI
RSK	kah1906	0.026241	2.937528	98.77	691	14.7-62.0	WCNI & WCSI
RSK	kah2005	0.026241	2.937528	98.77	691	14.7-62.0	WCNI & WCSI
SSK	kah8918	0.022891	2.950348	99.54	205	16.9-139.0	WCNI & WCSI
SSK	kah9111	0.022891	2.950348	99.54	205	16.9-139.0	WCNI & WCSI
SSK	kah9410	0.022891	2.950348	99.54	205	16.9-139.0	WCNI & WCSI
SSK	kah9615	0.022891	2.950348	99.54	205	16.9-139.0	WCNI & WCSI
SSK	kah9915	0.022891	2.950348	99.54	205	16.9-139.0	WCNI & WCSI
SSK	kah1806	0.022891	2.950348	99.54	205	16.9-139.0	WCNI & WCSI
SSK	kah1906	0.022891	2.950348	99.54	205	16.9-139.0	WCNI & WCSI
SSK	kah2005	0.022891	2.950348	99.54	205	16.9-139.0	WCNI & WCSI
LEA	kah8918	0.120639	2.360456	83.29	482	16.0-31.2	WCNI
LEA	kah9111	0.120639	2.360456	83.29	482	16.0-31.2	WCNI
LEA	kah9410	0.120639	2.360456	83.29	482	16.0-31.2	WCNI
LEA	kah9615	0.120639	2.360456	83.29	482	16.0-31.2	WCNI
LEA	kah9915	0.120639	2.360456	83.29	482	16.0-31.2	WCNI
LEA	kah1806	0.120639	2.360456	83.29	482	16.0-31.2	WCNI
LEA	kah1906	0.120639	2.360456	83.29	482	16.0-31.2	WCNI
LEA	kah2005	0.120639	2.360456	83.29	482	16.0-31.2	WCNI
NSD	kah8918	0.000519	3.515997	98.17	164	39.0-92.8	WCNI
NSD	kah9111	0.000519	3.515997	98.17	164	39.0-92.8	WCNI
NSD	kah9410	0.000519	3.515997	98.17	164	39.0-92.8	WCNI
NSD	kah9615	0.000519	3.515997	98.17	164	39.0-92.8	WCNI
NSD	kah9915	0.000519	3.515997	98.17	164	39.0-92.8	WCNI
NSD	kah1806	0.000519	3.515997	98.17	164	39.0-92.8	WCNI
NSD	kah1906	0.000519	3.515997	98.17	164	39.0-92.8	WCNI
NSD	kah2005	0.000519	3.515997	98.17	164	39.0-92.8	WCNI
FRO	kah8918	0.000622	3.075627	99.63	1605	11.0-177.3	WCNI
FRO	kah9111	0.000622	3.075627	99.63	1605	11.0-177.3	WCNI
FRO	kah9410	0.000622	3.075627	99.63	1605	11.0-177.3	WCNI
FRO	kah9615	0.000622	3.075627	99.63	1605	11.0-177.3	WCNI
FRO	kah9915	0.000622	3.075627	99.63	1605	11.0-177.3	WCNI
FRO	kah1806	0.000622	3.075627	99.63	1605	11.0-177.3	WCNI
FRO	kah1906	0.000622	3.075627	99.63	1605	11.0-177.3	WCNI
FRO	kah2005	0.000622	3.075627	99.63	1605	11.0-177.3	WCNI

Species codes	Trip	<i>a</i>	<i>b</i>	<i>r</i> ²	<i>n</i>	Length range (cm)	Source
JGU	kah8918	0.004553	3.314346	98.33	148	11.5-53.1	WCNI
JGU	kah9111	0.004553	3.314346	98.33	148	11.5-53.1	WCNI
JGU	kah9410	0.004553	3.314346	98.33	148	11.5-53.1	WCNI
JGU	kah9615	0.004553	3.314346	98.33	148	11.5-53.1	WCNI
JGU	kah9915	0.004553	3.314346	98.33	148	11.5-53.1	WCNI
JGU	kah1806	0.004553	3.314346	98.33	148	11.5-53.1	WCNI
JGU	kah1906	0.004553	3.314346	98.33	148	11.5-53.1	WCNI
JGU	kah2005	0.004553	3.314346	98.33	148	11.5-53.1	WCNI

APPENDIX 4: Gonad stage descriptions

Finfish (middle depths gonad staging)

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

Surveys from 1994–99 used Pankhurst et al. (1987) for snapper, which were defined as follows (with equivalent middle depth (MD) stages):

Females

- 1 = Immature or regressed; ovary clear, no oocytes visible = MD1
- 2 = Resting; ovary pink or clear, small clear oocytes visible against the light = MD2
- 3 = Developing; opaque orange ovary, oocytes present = MD3
- 4 = Ripe; hyaline oocytes present = MD4
- 5 = Ovulated; free flowing eggs when light pressure applied to abdomen = MD5
- 6 = Spent; ovary flaccid and “bloody”, residual eggs sometimes present in oviduct = MD 6 + 7

Males

- 1 = Immature; testis white threads = MD1+2
- 2 = Spermatogenic; testis firm and ivory white = MD3
- 3 = Partially spermiated; testis firm, ivory white in colour with viscous milt in spermaduct = MD4
- 4 = Fully spermiated; testis firm, ivory white in colour with free flowing milt in spermaduct = MD5
- 5 = Spent; testis spent and bloody in colour and flaccid = MD6+7

Sharks and skates

Males

1. Immature – claspers shorter than pelvic fins, soft and uncalcified, unable or difficult to splay open.
2. Maturing – claspers longer than pelvic fins, soft and uncalcified, unable or difficult to splay open or rotate forwards.
3. Mature - claspers longer than pelvic fins, hard and calcified, able to splay open and rotate forwards to expose clasper spine.

Females

1. Immature – no visible eggs in the ovary.
2. Maturing– visible eggs in ovary, some enlarged, white or cream coloured
3. Mature - large yolked eggs in the ovary
4. Gravid - yolked eggs or egg cases in the uterus but no embryos visible
5. Pregnant - embryos visible in the uterus (not applicable to egg-laying sharks or skates)
6. Spent - uterus flabby and bloodshot, yolked eggs may be in the ovary.

APPENDIX 5: Stepwise GLM analysis results

Snapper:

Final Gaussian model

$\log(\text{kg_km2}) \sim \text{survey_year} + \text{stratum}$

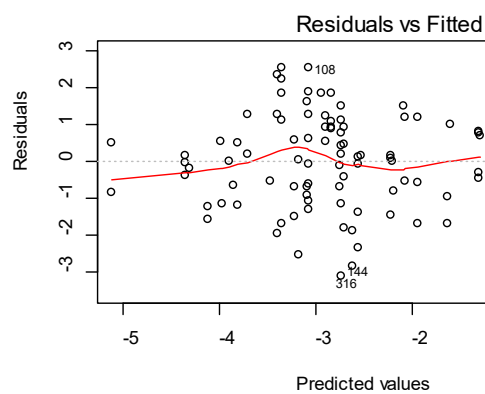
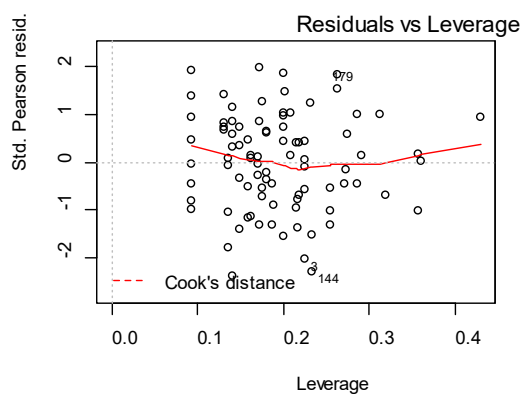
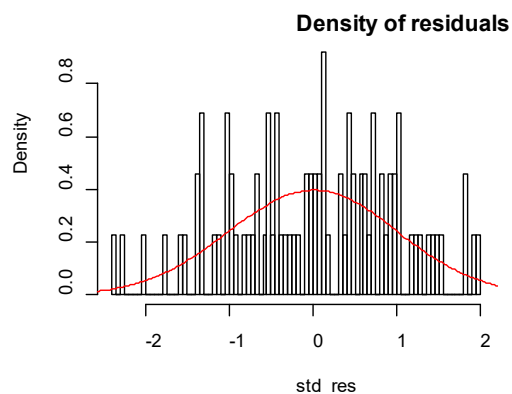
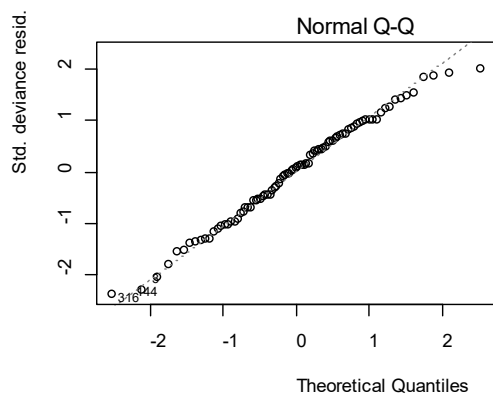
Predictors		Df	R.squared	AIC
survey_year		4	0.04	329
stratum	4	0.22	319	

Final Binomial model

$P[\text{catch}] \sim \text{survey_year} + \text{stratum}$

Predictors		Df	R.squared	AIC
survey_year		4	0.04	88
stratum	4	0.25	79	

Gaussian model fitting diagnostics



Appendix 5 continued

Red gurnard:

Final Gaussian model

$\log(\text{kg_km}^2) \sim \text{survey_year} + \text{stratum} + \text{Maui} + \text{stratum:Maui} + \text{survey_year:Maui}$

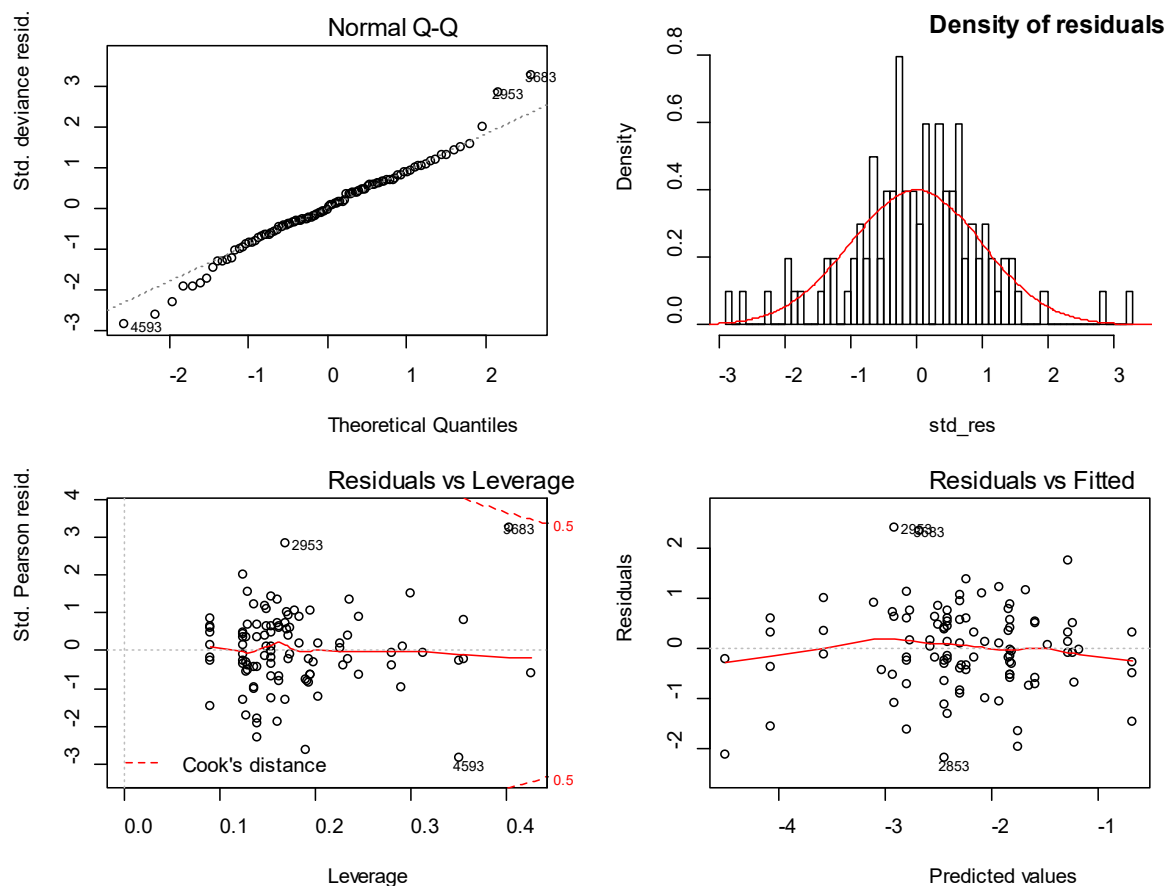
Predictors		Df	R.squared	AIC
survey_year		4	0.18	305
stratum	4	0.29	299	
Maui		1	0.3	299
stratum:Maui		4	0.41	291
survey_year:Maui		4	0.46	290

Final Binomial model

$P[\text{catch}] \sim \text{survey_year} + \text{stratum} + \text{Maui}$

Predictors		Df	R.squared	AIC
survey_year		4	0.32	18
stratum	4	0.52	23	
Maui		1	0.66	24

Gaussian model fitting diagnostics



Appendix 5 continued

John dory:

Final Gaussian model

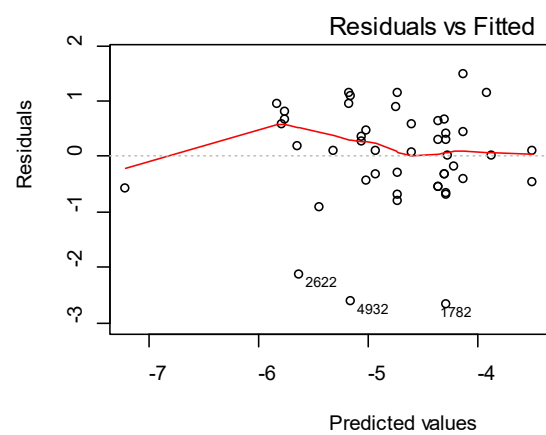
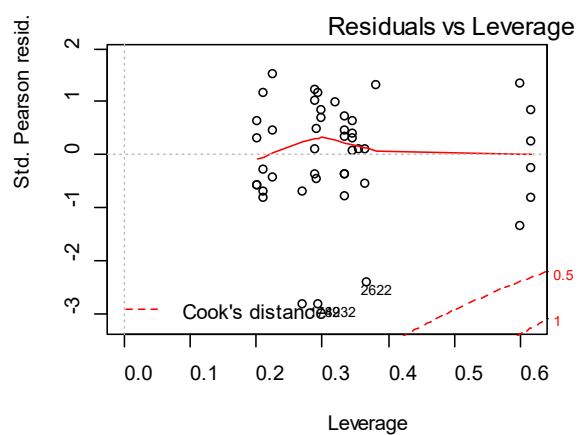
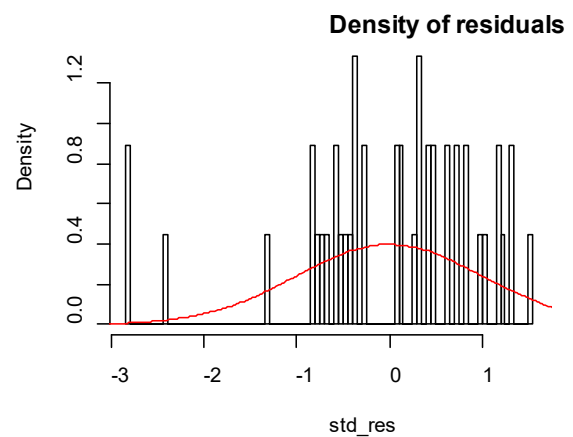
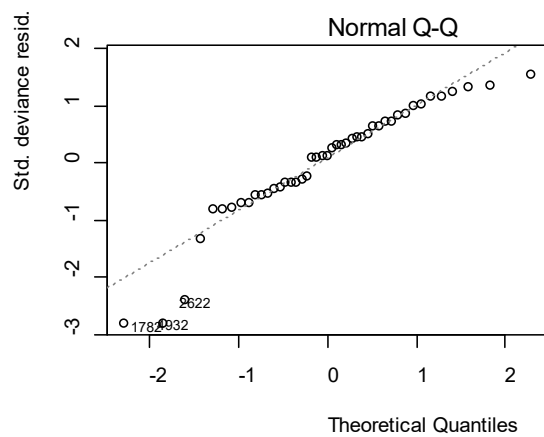
$\log(\text{kg_km2}) \sim \text{survey_year} + \text{stratum}$

Predictors		Df	R.squared	AIC
survey_year		4	0.05	154
stratum	4	0.12	158	

Final Binomial model

$P[\text{catch}] \sim \text{survey_year} + \text{stratum}$

Predictors		Df	R.squared	AIC
survey_year		4	0.07	141
stratum	4	0.24	125	



APPENDIX 6: Plots and information for other species

For each species, there is a text summary of available information followed by two figures.

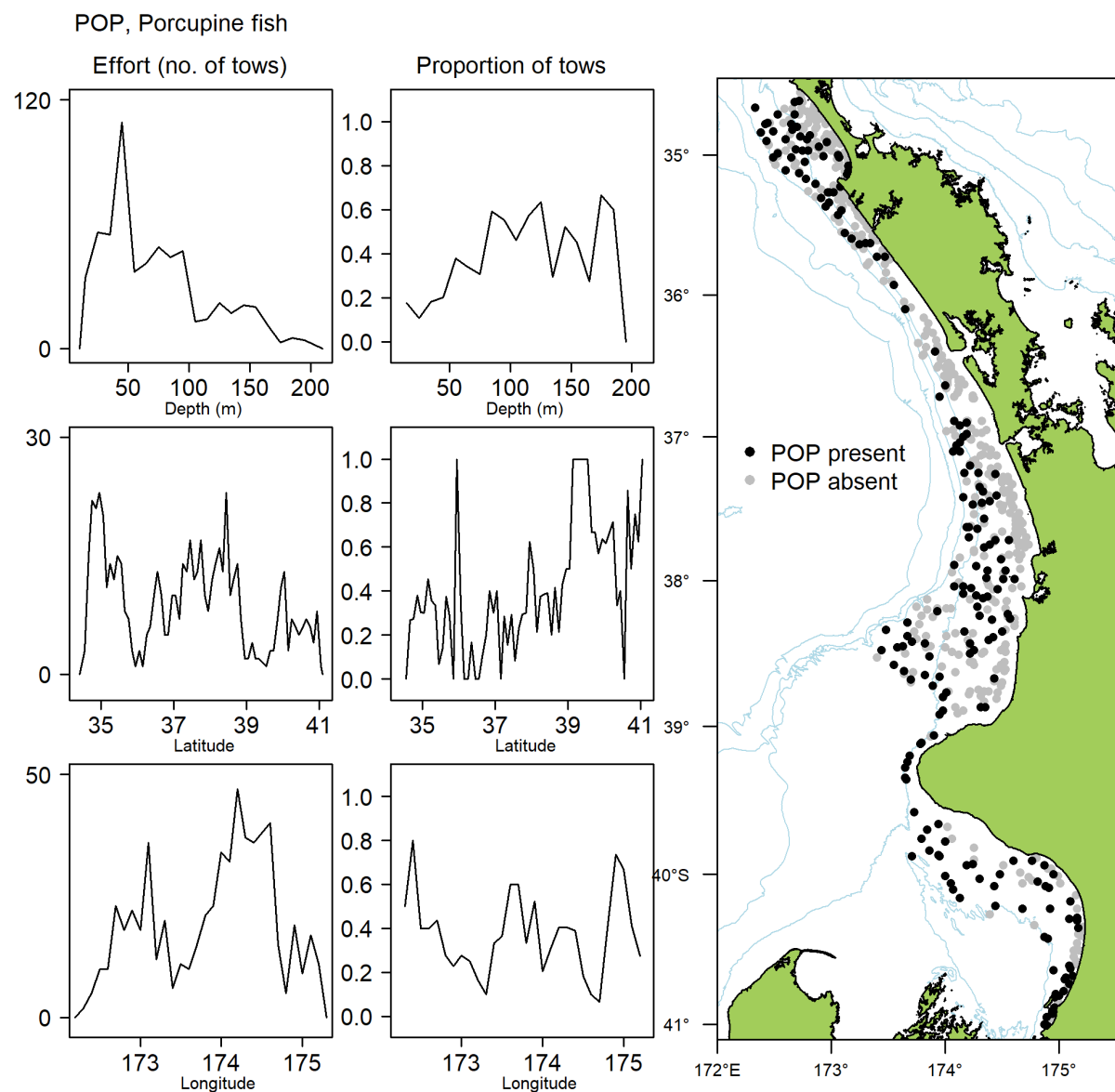
The first figure shows summary of occurrence in the WCNI inshore surveys. Left panel provides an overview of the sampling effort across the depth range, and by latitude and longitude. The centre panel plots the proportion of tows at each depth and location in which the species was caught. All valid tows are plotted in the map on the right with black dots showing those where the species was present.

Second figure shows time series of relative biomass estimates and 95% confidence intervals for the species for the core northern area (core in black), core area with deeper > 100 m strata (core + extended deep in grey), and whole survey (core + extended deep + south in blue). Note that each set of annual points is displaced slightly from each other for clarity.

Porcupine fish (POP)

Number of surveys	5
Total catch weight (kg)	5620.7
Number measured	NA
Length range	NA
Number weighed	NA

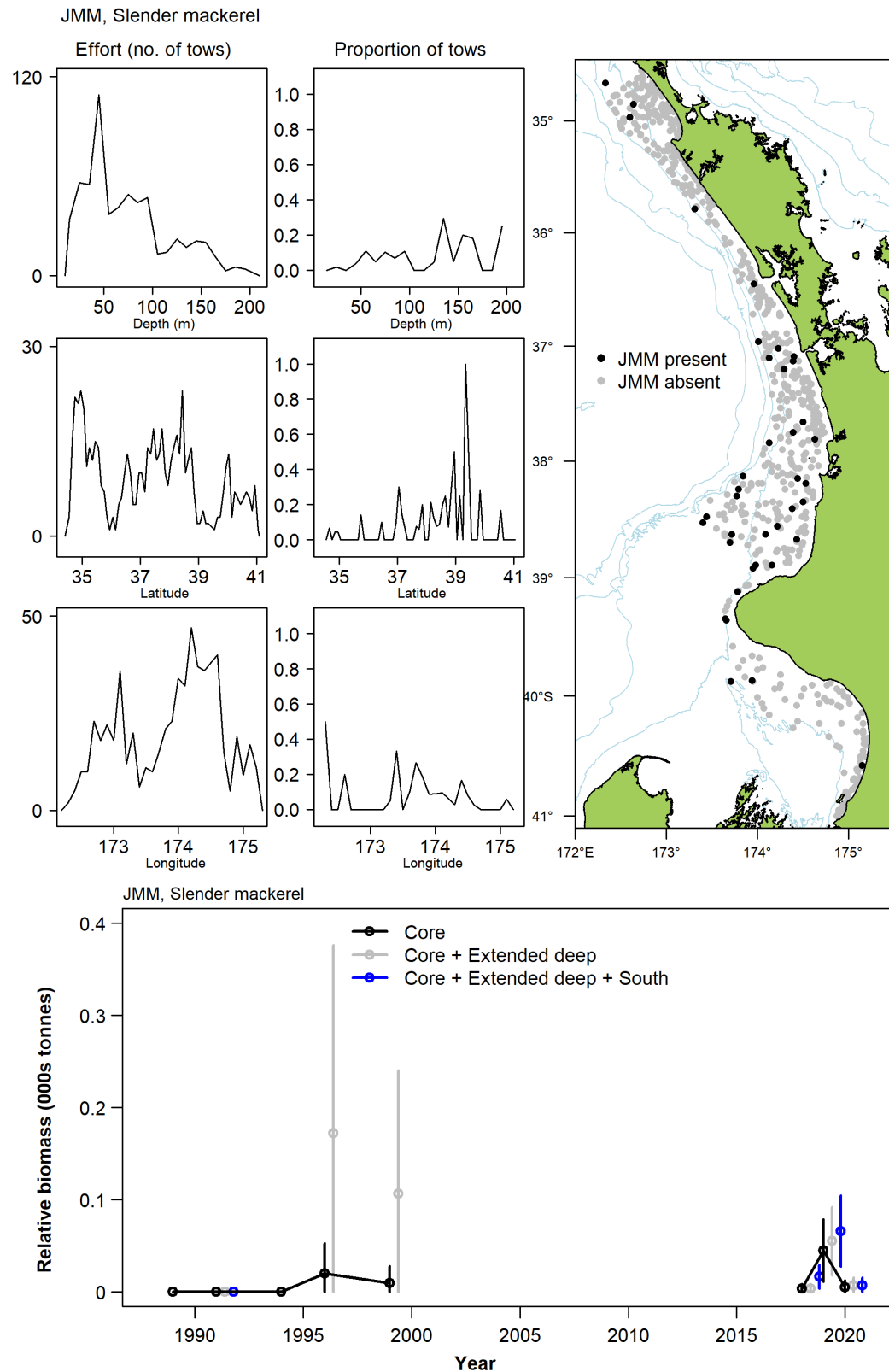
Porcupine fish are not referred to in survey reports before 1996. In the 1996 and 1999 surveys they are listed as caught but not weighed due to water inflation. The weights for the more recent surveys are not accurate due to this water inflation.



No biomass trend plotted because of issues with water inflation confounding catch weight recording.

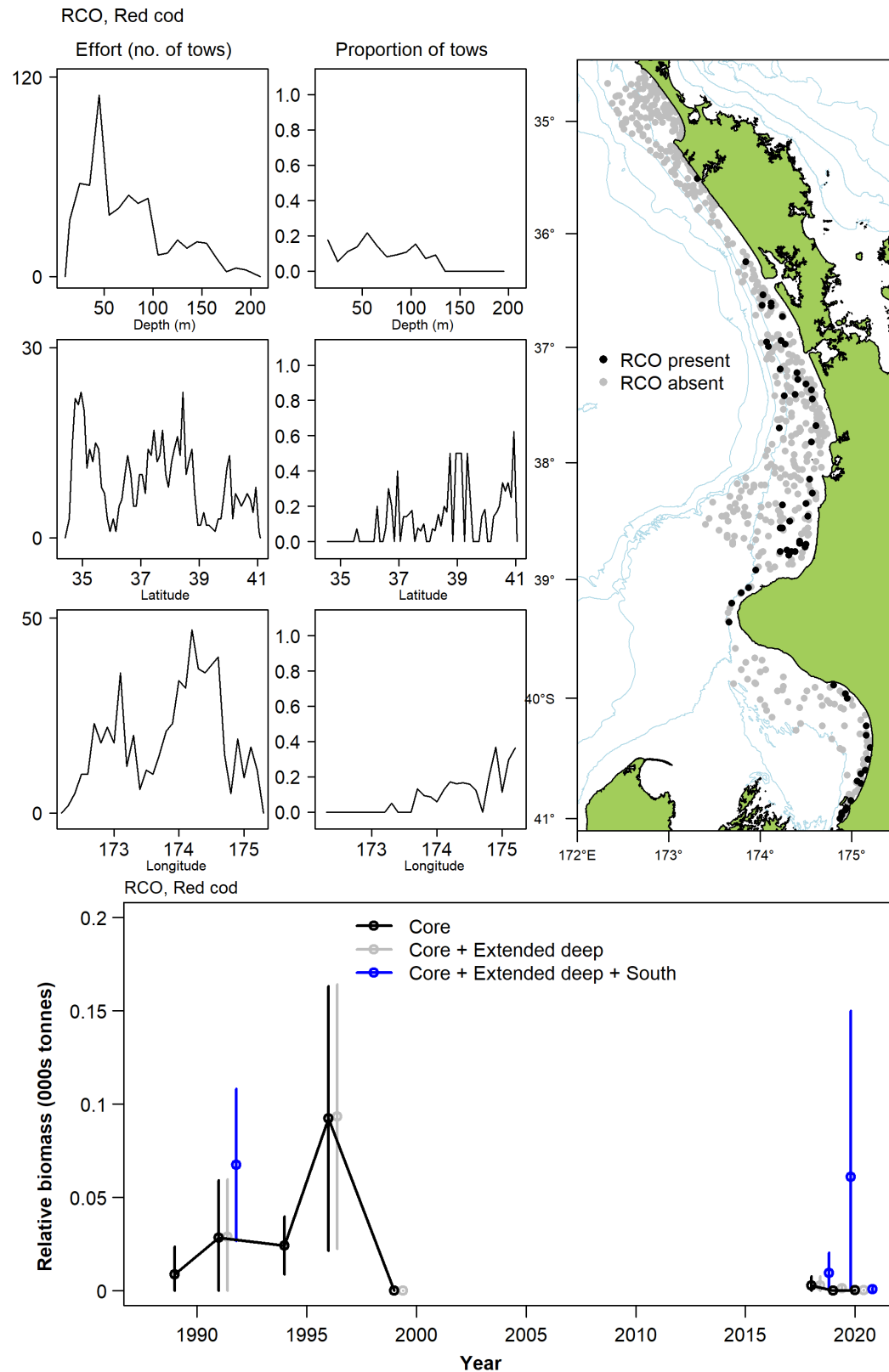
Slender jack mackerel (JMM)

Number of surveys	5
Total catch weight (kg)	252.7
Number measured	167
Length range (mean) (cm)	24–58 (49.17)
Number weighed	21



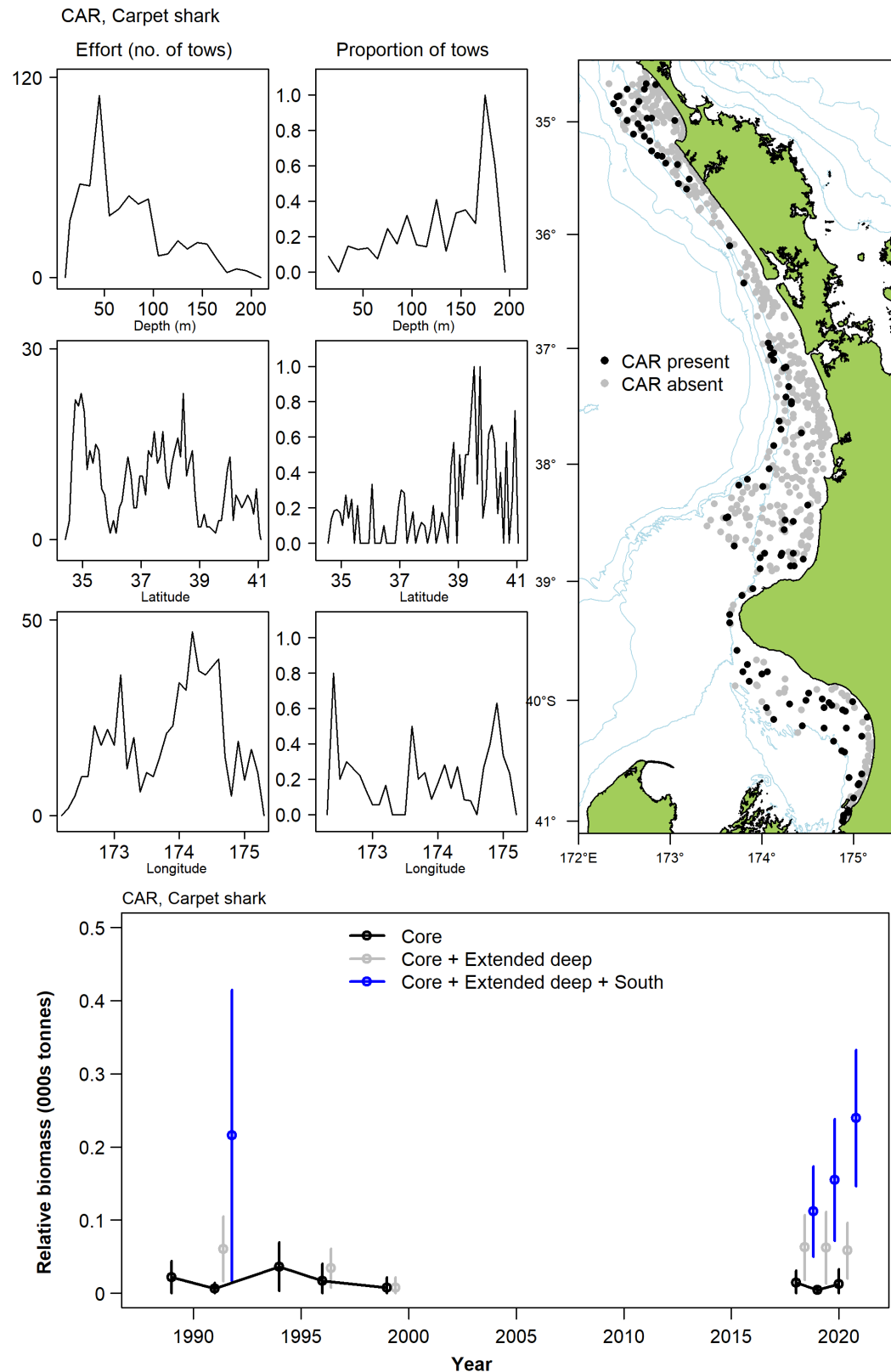
Red cod (RCO)

Number of surveys	8
Total catch weight (kg)	445.5
Number measured	959
Length range (mean) (cm)	10–64 (32.79)
Number weighed	59



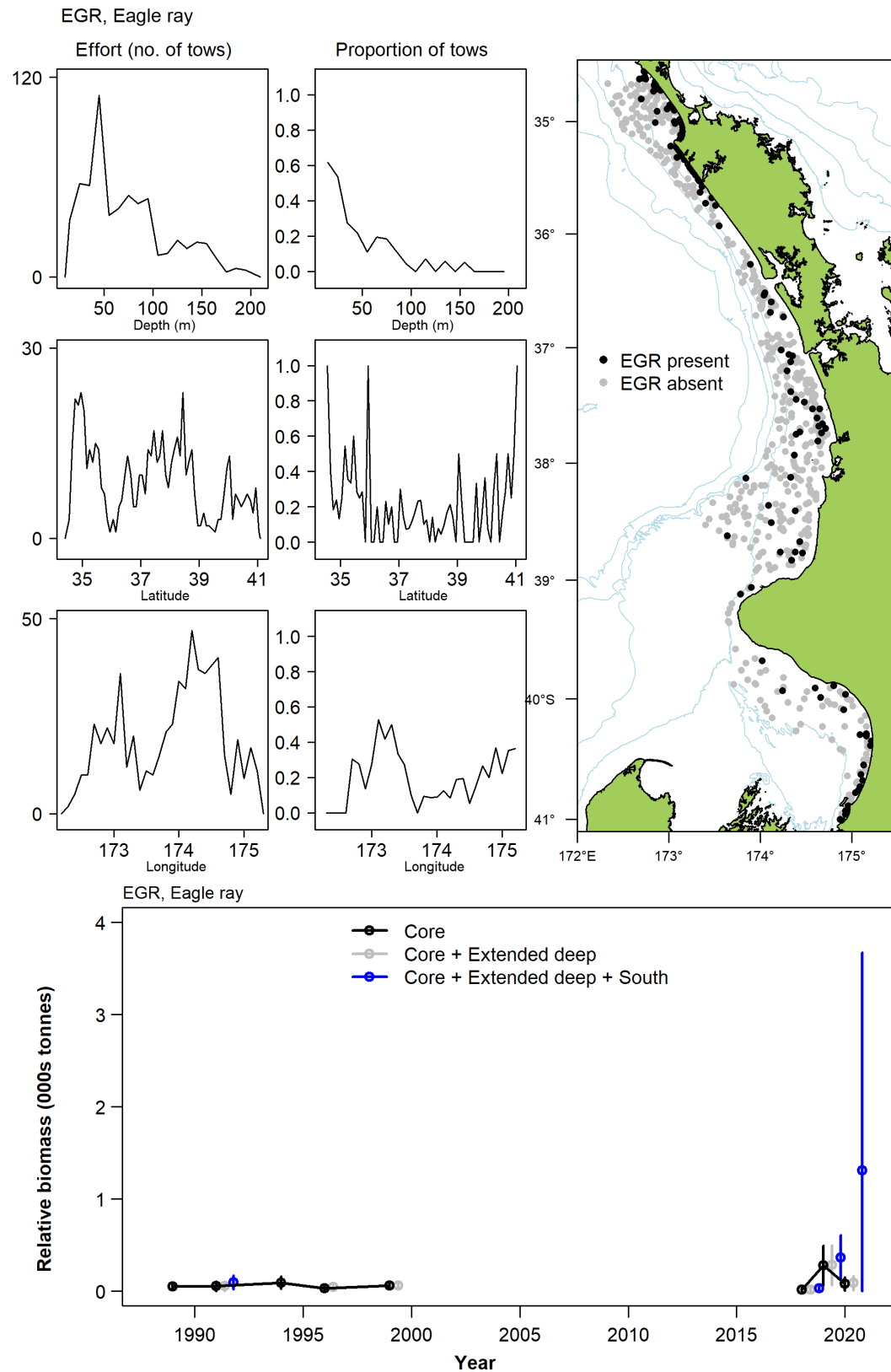
Carpet shark (CAR)

Number of surveys	8
Total catch weight (kg)	444.0
Number measured	71
Length range (mean) (cm)	39–90 (63.22)
Number weighed	4



Eagle ray (EGR)

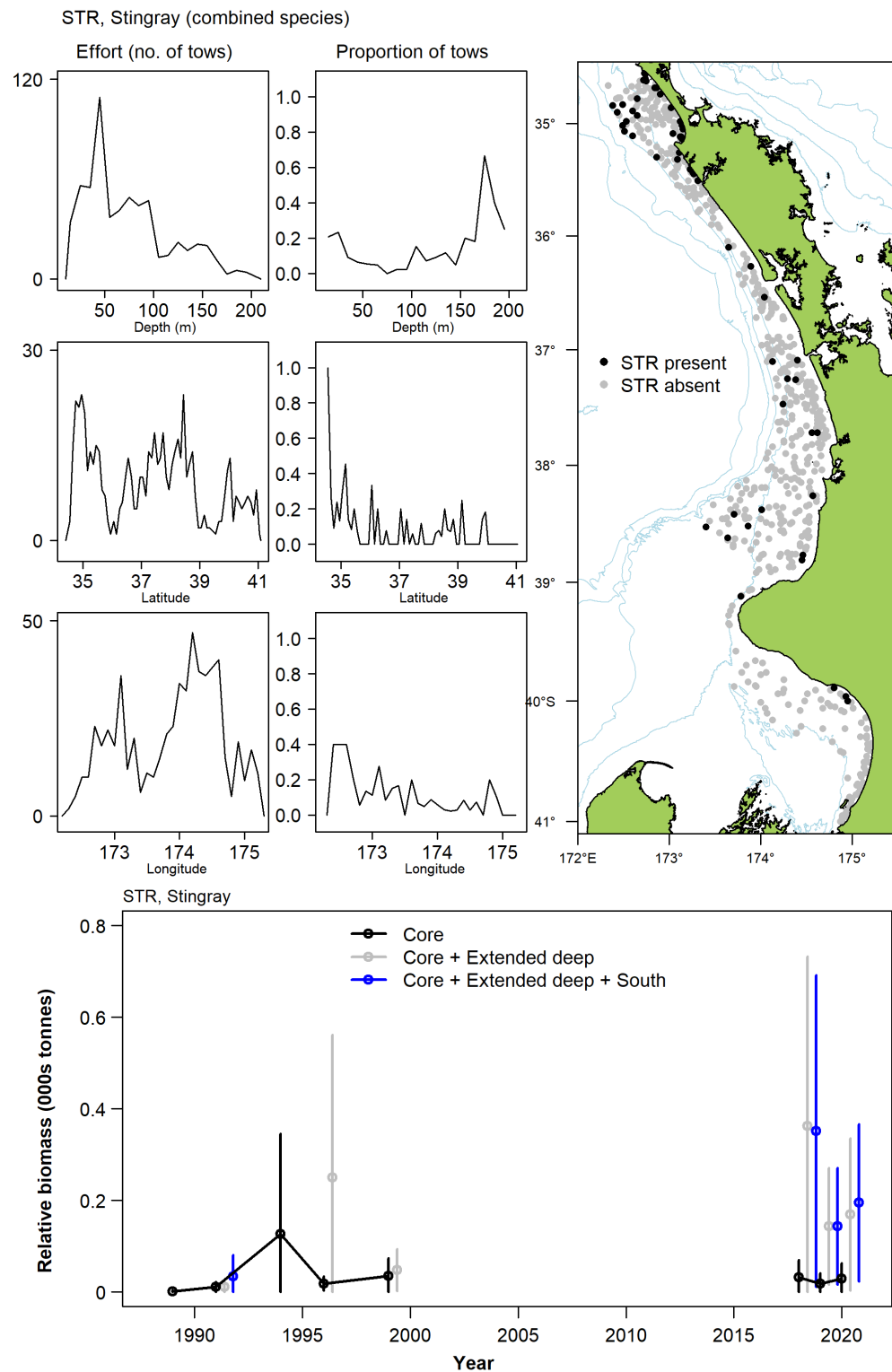
Number of surveys	8
Total catch weight (kg)	1782.4
Number measured	224
Length range (mean) (cm)	17–71 (30.41)
Number weighed	8



Stingrays (combined species) (STR)

Number of surveys	8
Total catch weight (kg)	1375.4
Number measured	43
Length range (cm)	24–85 (49.7)
Number weighed	7

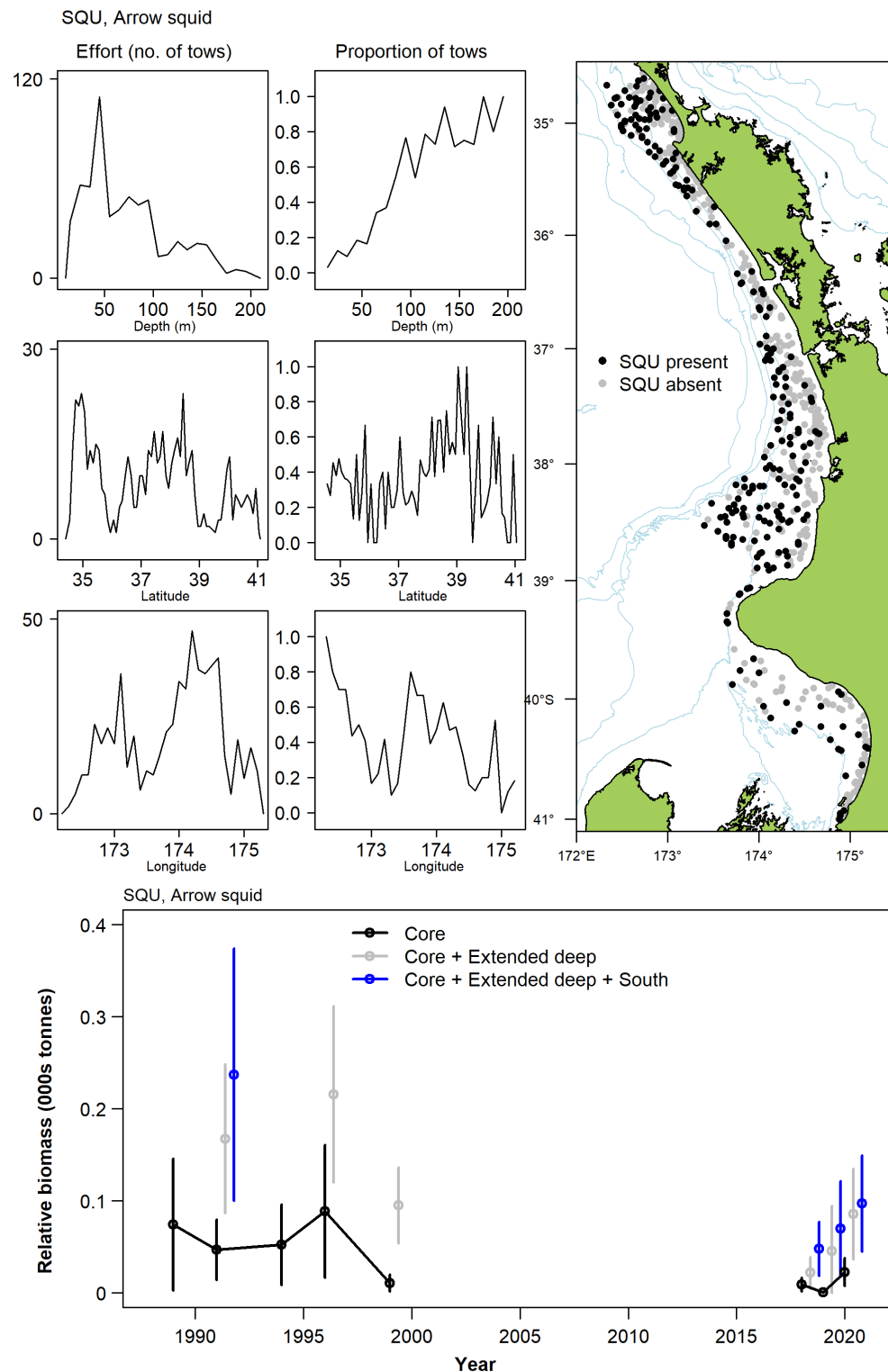
The codes for long-tail sting ray (*Bathytoshia lata*) (used in 7 trips, 650.5 kg) and short-tail stingray (*Bathytoshia brevicaudata*) (7 trips, 663.6 kg) were combined with STR (4 trips, 61.3 kg).



Arrow squid (combined species) (SQU)

Number of surveys	8
Total catch weight (kg)	542.9
Number measured	2329
Length range (mean) (cm)	3–35 (14.52)
Number weighed	none

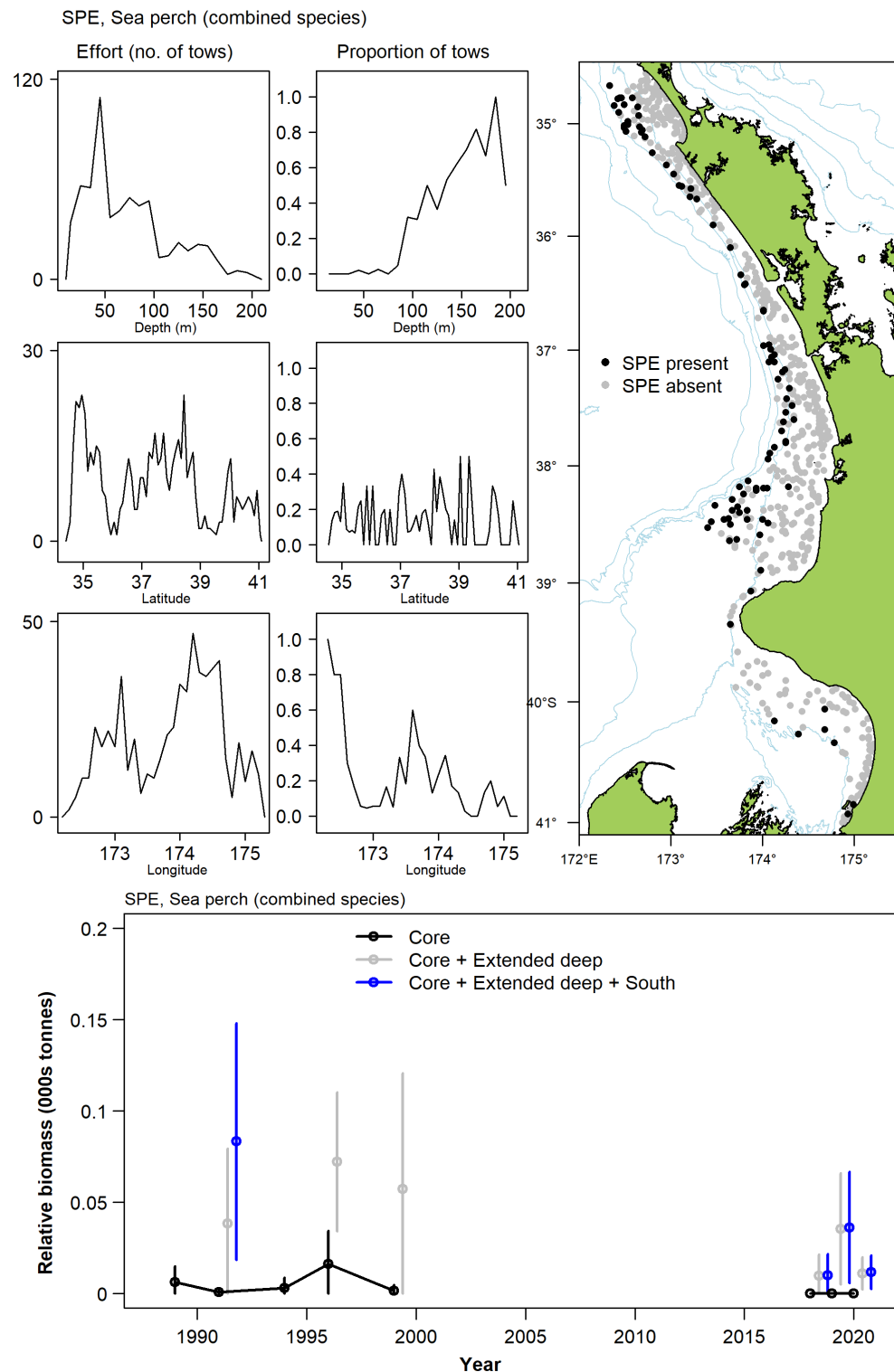
This code includes both northern and southern arrow squid *Nototodarus sloanii* & *N. gouldi*, as it is not easy to distinguish the two species.



Sea perch (combined species) (SPE)

Number of surveys	8
Total catch weight (kg)	164.1
Number measured	912
Length range (mean) (cm)	6–37 (17.21)
Number weighed	24

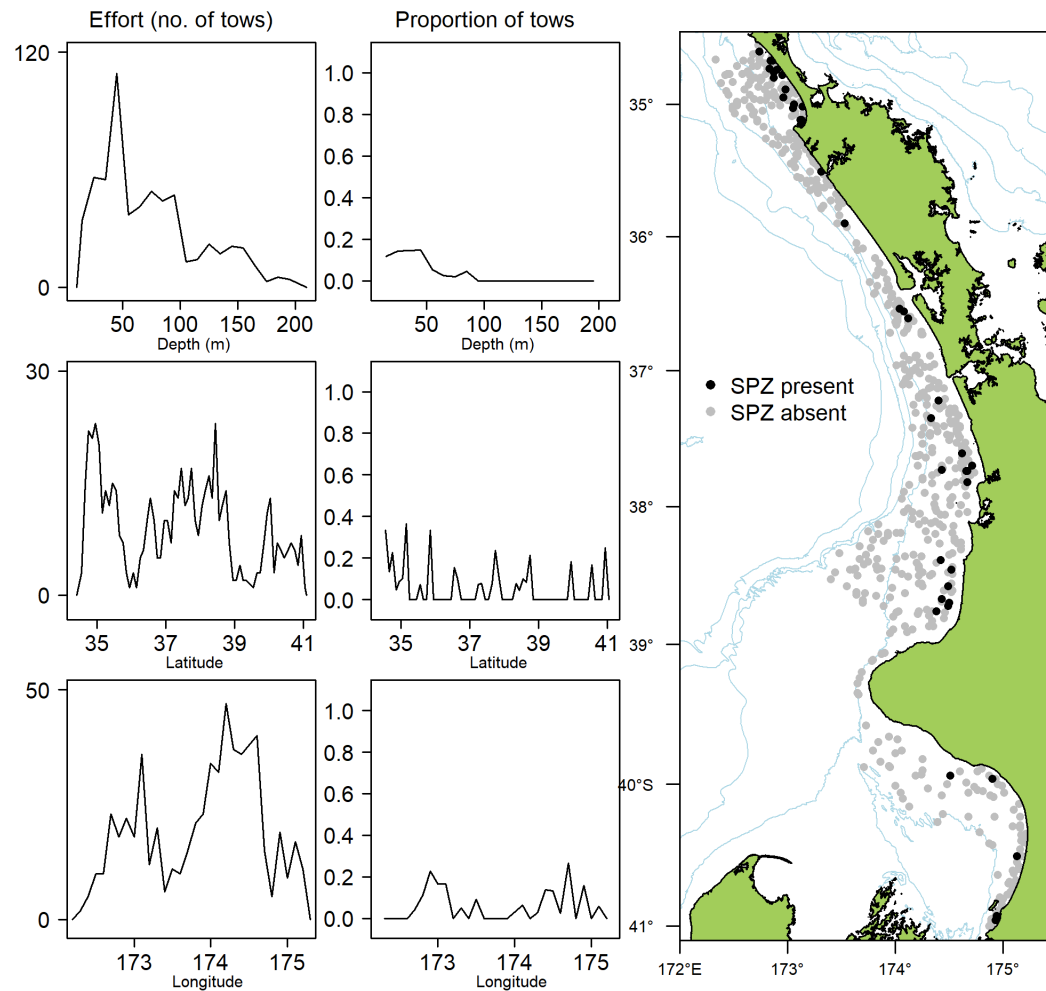
SPE (combined code for *Helicolenus percoides* and *H. barathri*) was used historically. With updated taxonomic information, recent surveys have confirmed sea perch largely as the shallower *H. percoides*.



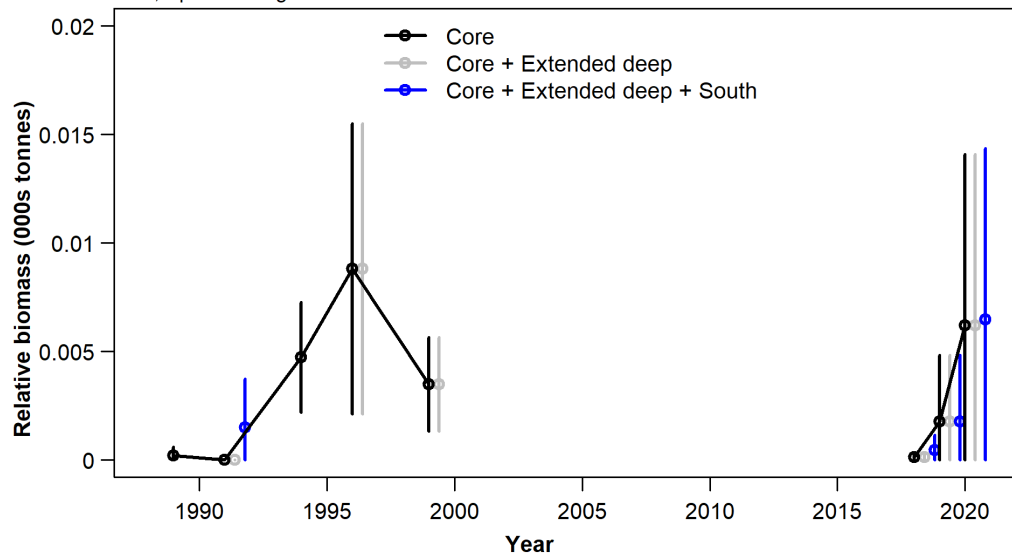
Spotted stargazer (SPZ)

Number of surveys	8
Total catch weight (kg)	60.3
Number measured	108
Length range (mean) (cm)	13–45 (29.73)
Number weighed	1

SPZ, Spotted stargazer

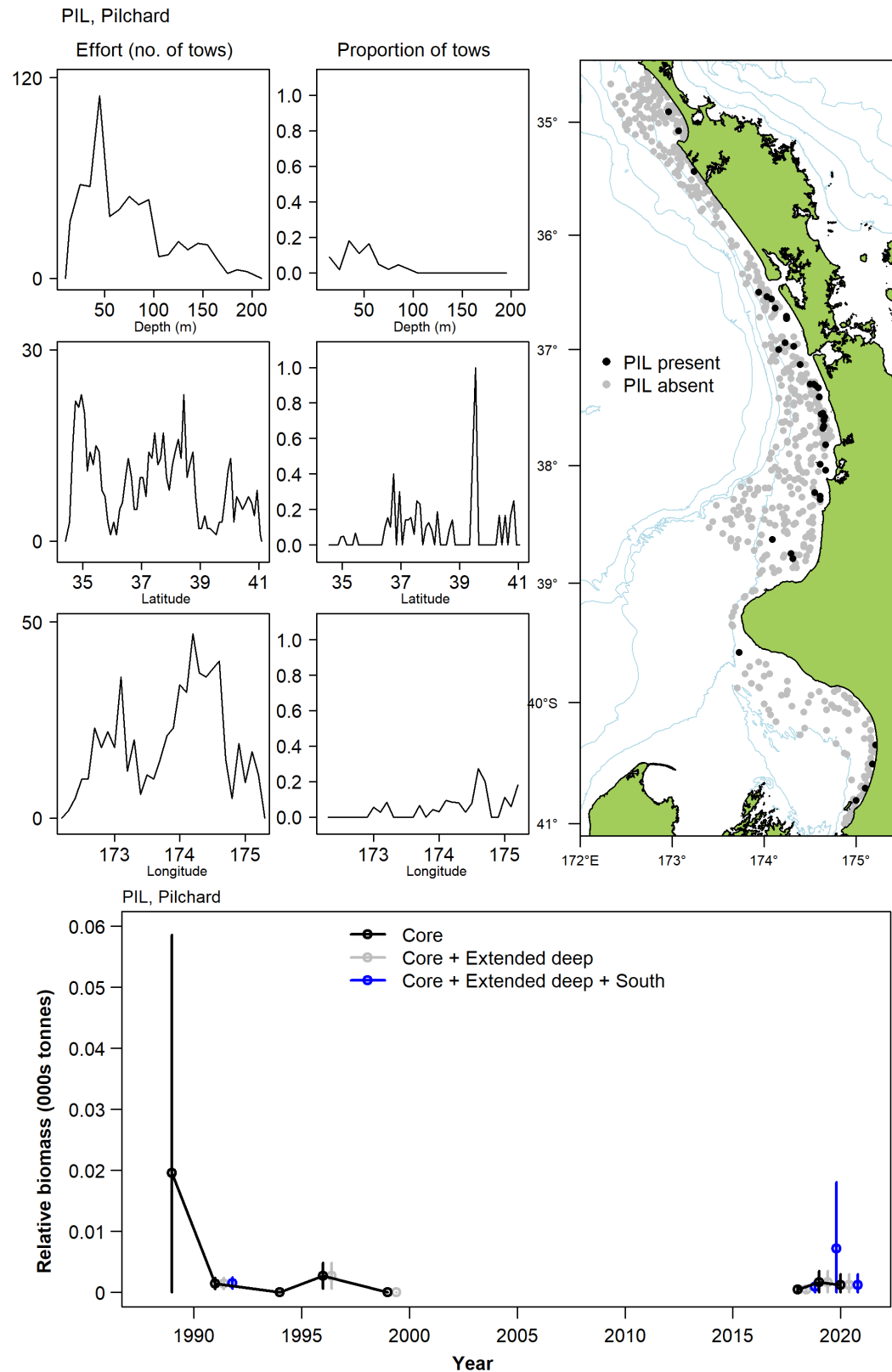


SPZ, Spotted stargazer

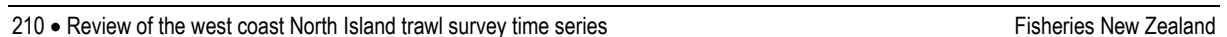


Pilchard (PIL)

Number of surveys	8
Total catch weight (kg)	46.8
Number measured	279
Length range (mean) (cm)	6–23 (12.54)
Number weighed	NA

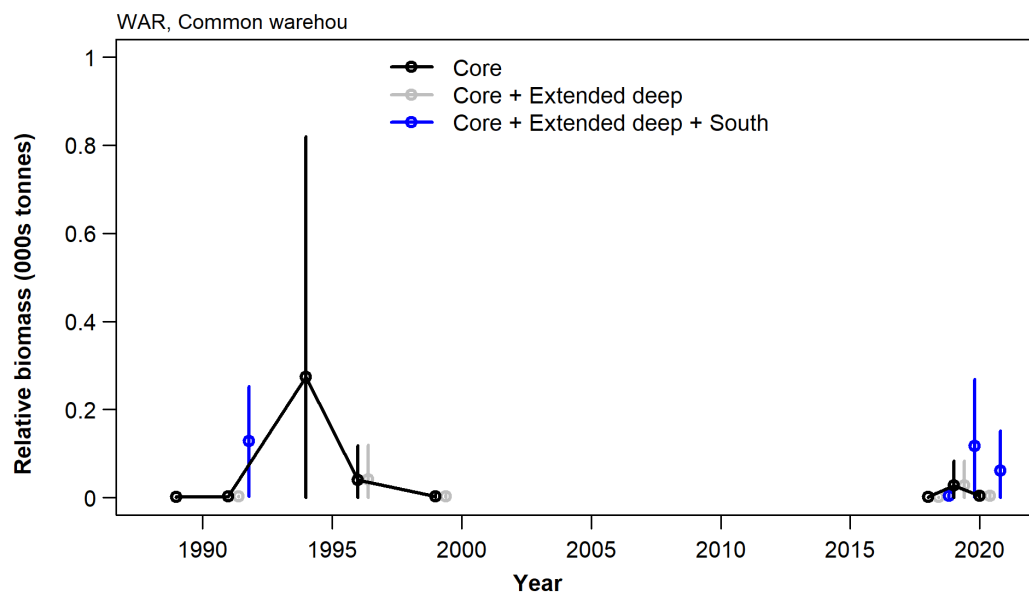
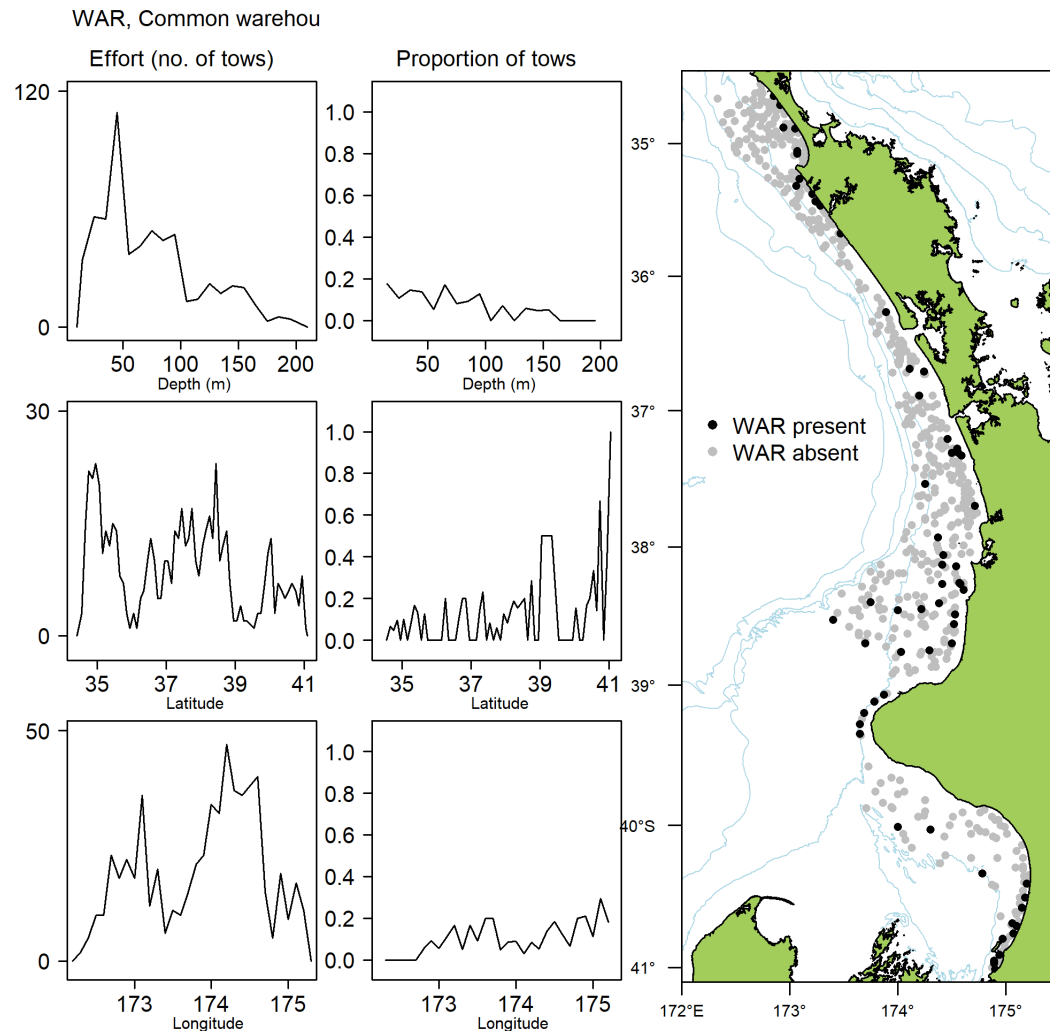


Number of surveys	7
Total catch weight (kg)	321.6
Number measured	235
Length range (mean) (cm)	5–15 (10.33)
Number weighed	NA



Common warehou (WAR)

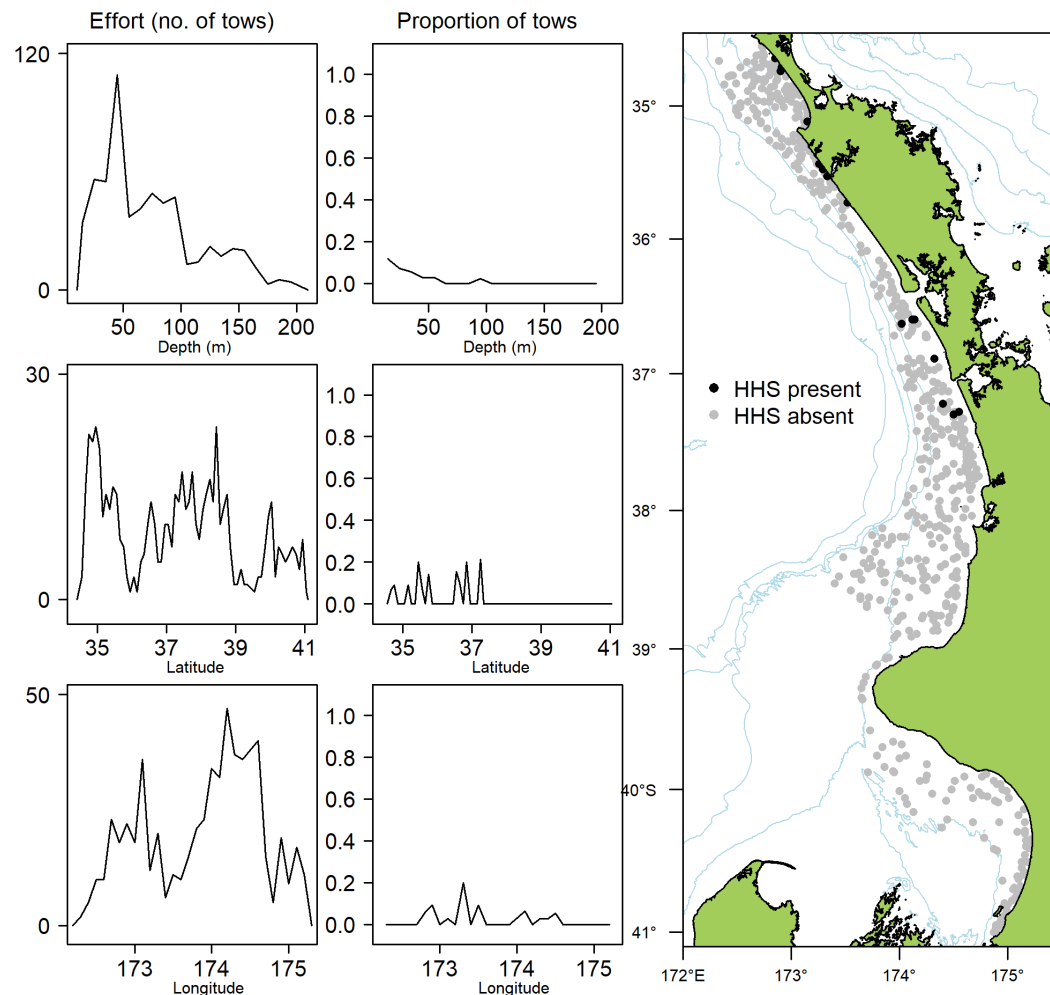
Number of surveys	8
Total catch weight (kg)	305.0
Number measured	448
Length range (mean) (cm)	3–63 (23.23)
Number weighed	15



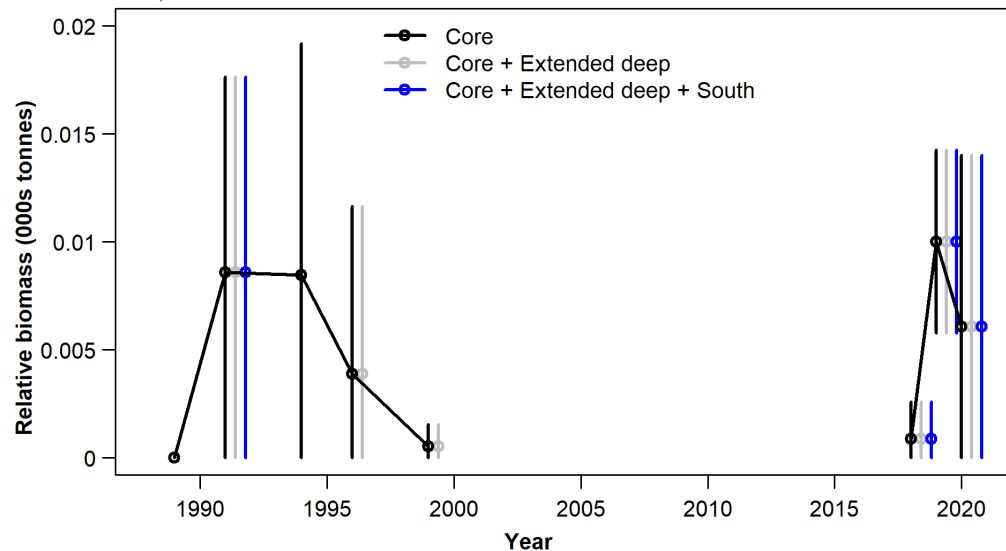
Hammerhead shark (HHS)

Number of surveys	8
Total catch weight (kg)	213.4
Number measured	42
Length range (cm)	59–155 (94.33)
Number weighed	6

HHS, Hammerhead shark

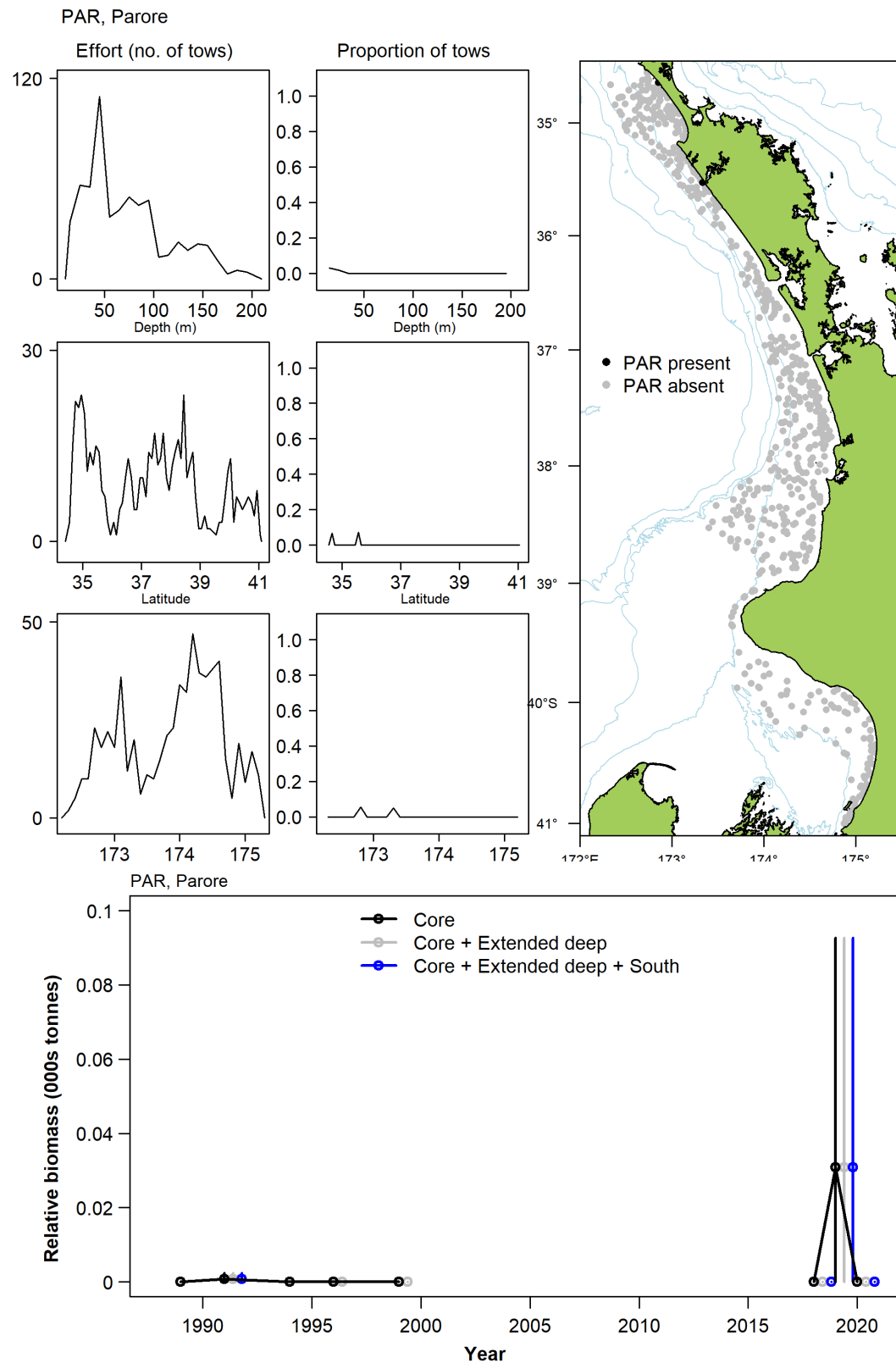


HHS, Hammerhead shark



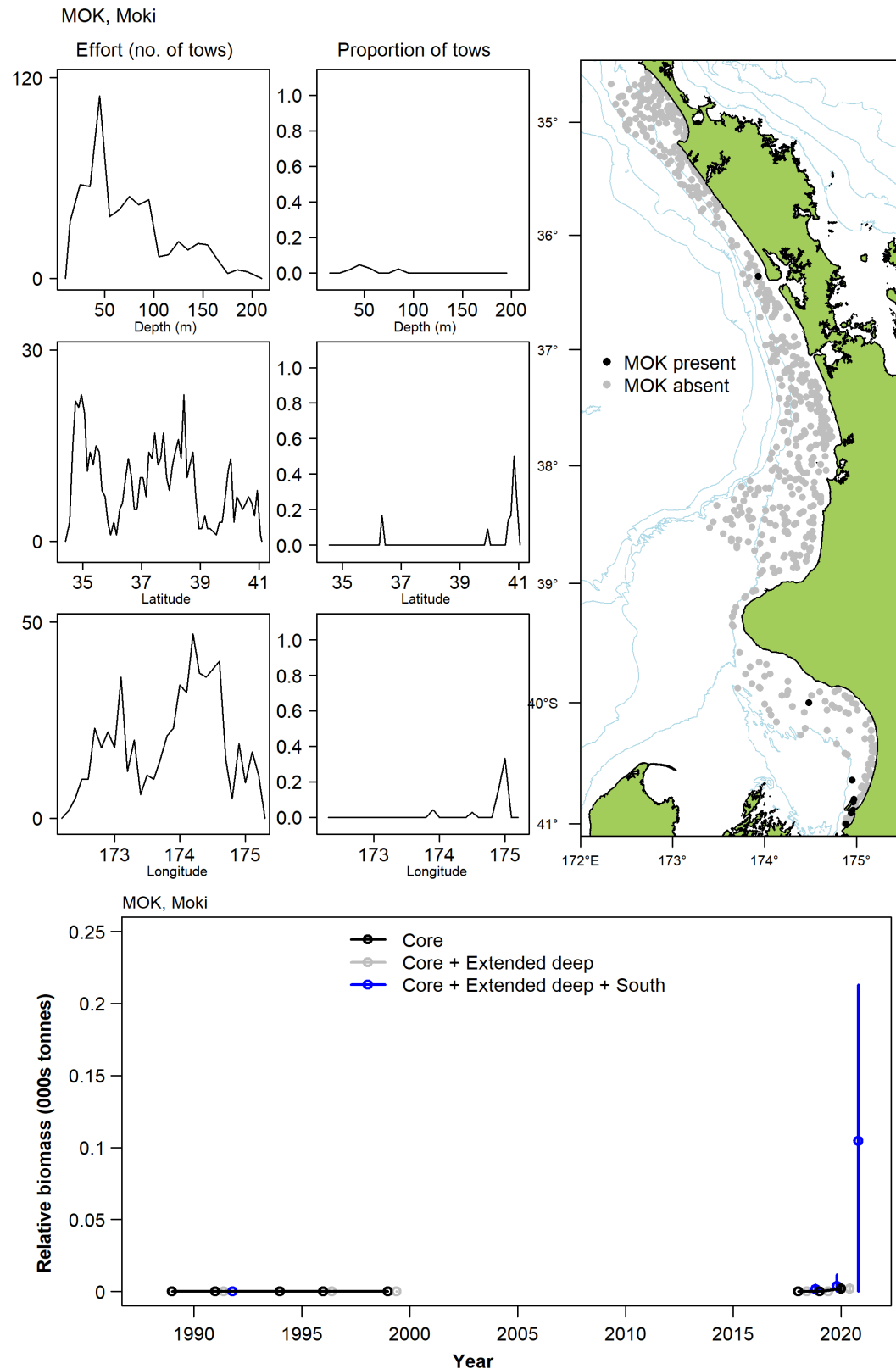
Parore (PAR)

Number of surveys	3
Total catch weight (kg)	143.8
Number measured	54
Length range (mean) (cm)	33–45 (38.93)
Number weighed	NA



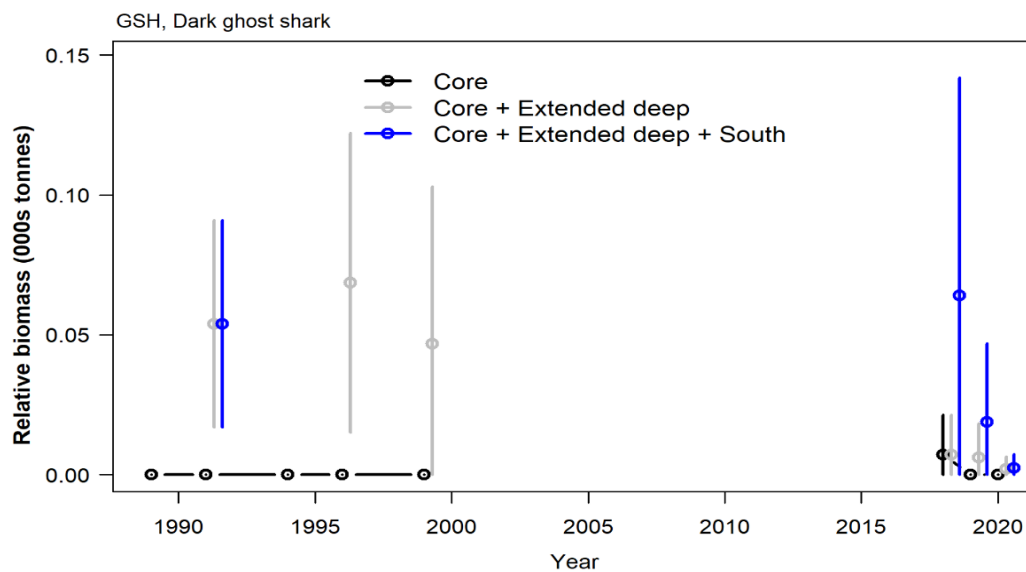
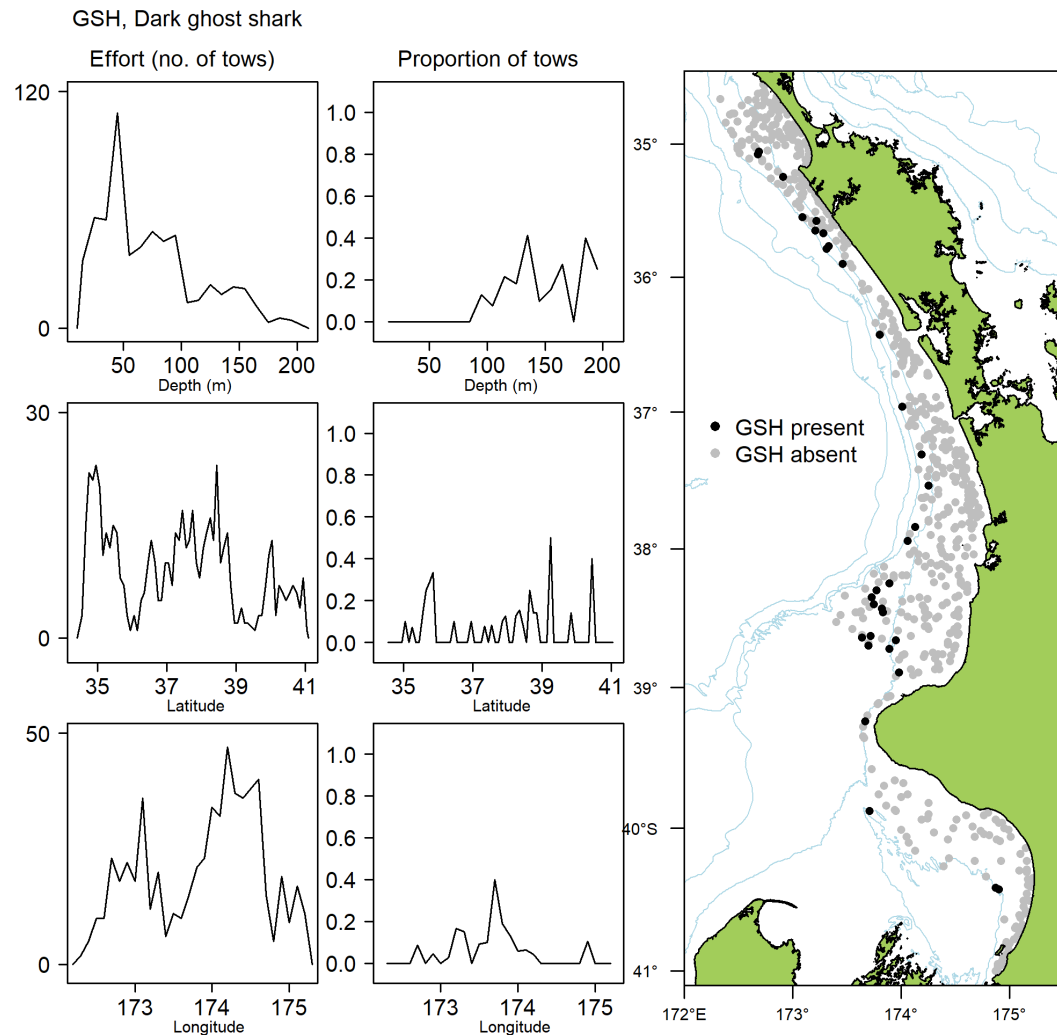
Moki (MOK)

Number of surveys	3
Total catch weight (kg)	135.1
Number measured	39
Length range (mean) (cm)	46–73 (32)
Number weighed	32



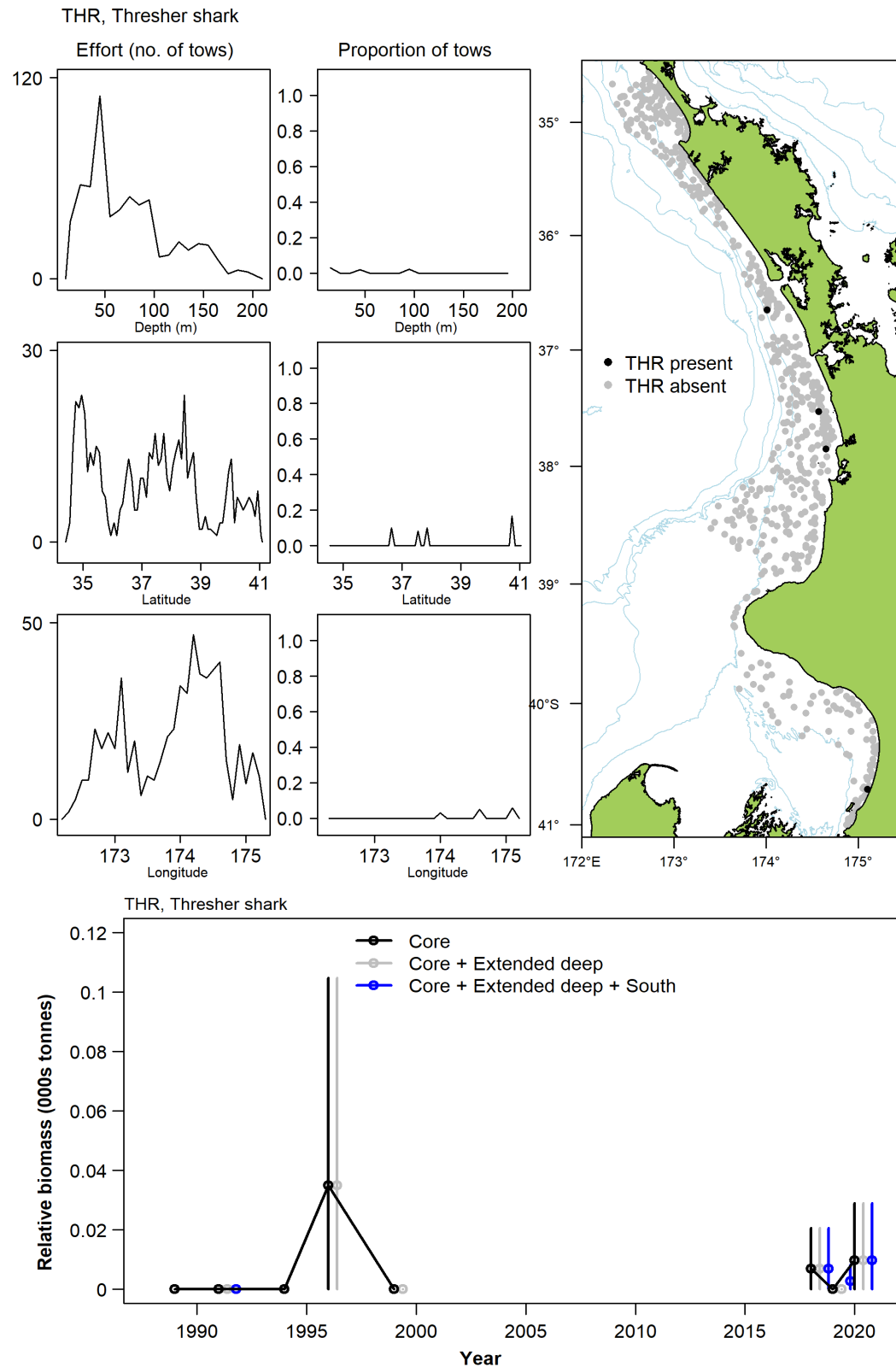
Dark ghost shark (GSH)

Number of surveys	6
Total catch weight (kg)	131.8
Number measured	83
Length range (mean) (cm)	43–71 (59.1)
Number weighed	4



Thresher shark (THR)

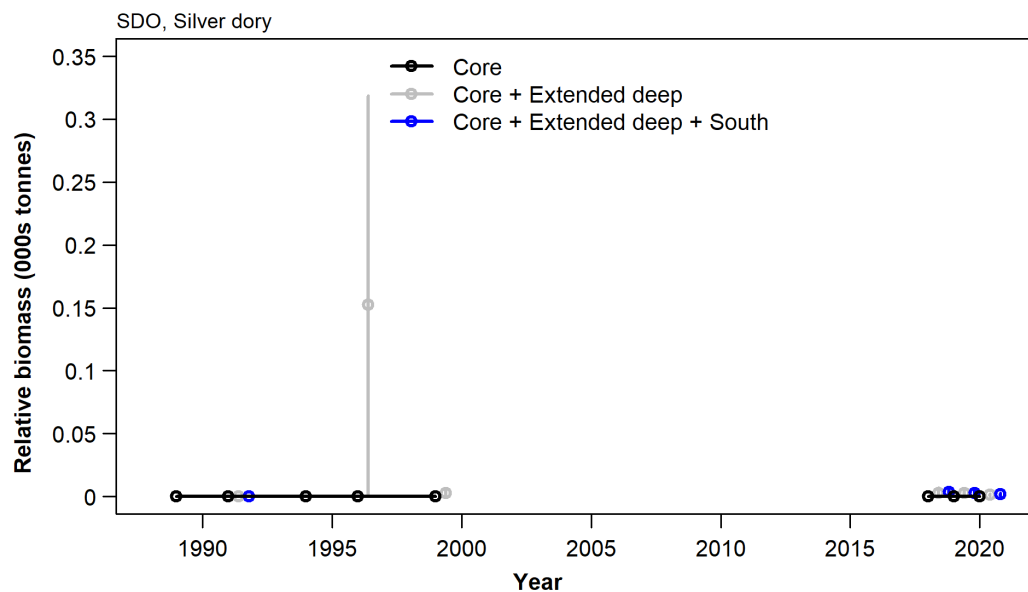
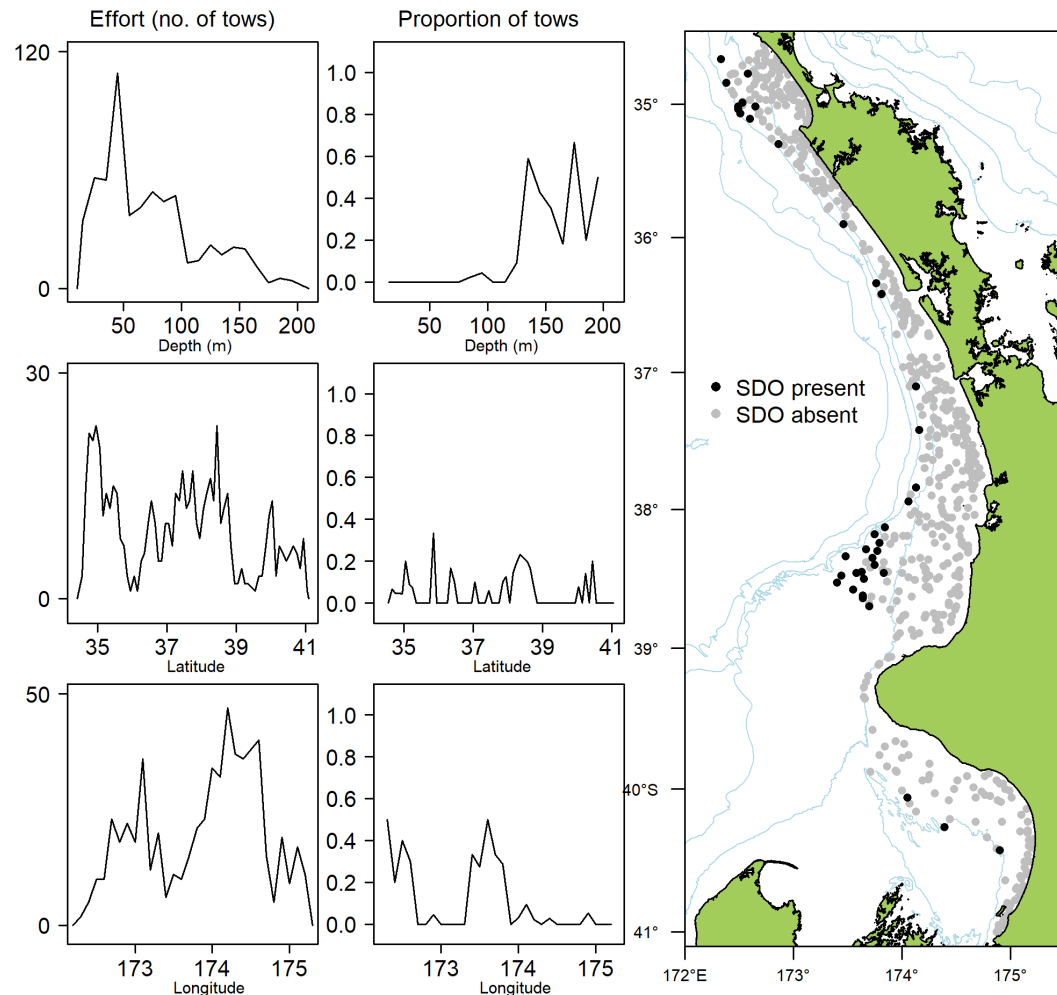
Number of surveys	7
Total catch weight (kg)	127.6
Number measured	5
Length range (mean) (cm)	82–225 (158)
Number weighed	1



Silver dory (SDO)

Number of surveys	5
Total catch weight (kg)	126.8
Number measured	141
Length range (mean) (cm)	9–44 (15.14)
Number weighed	NA

SDO, Silver dory

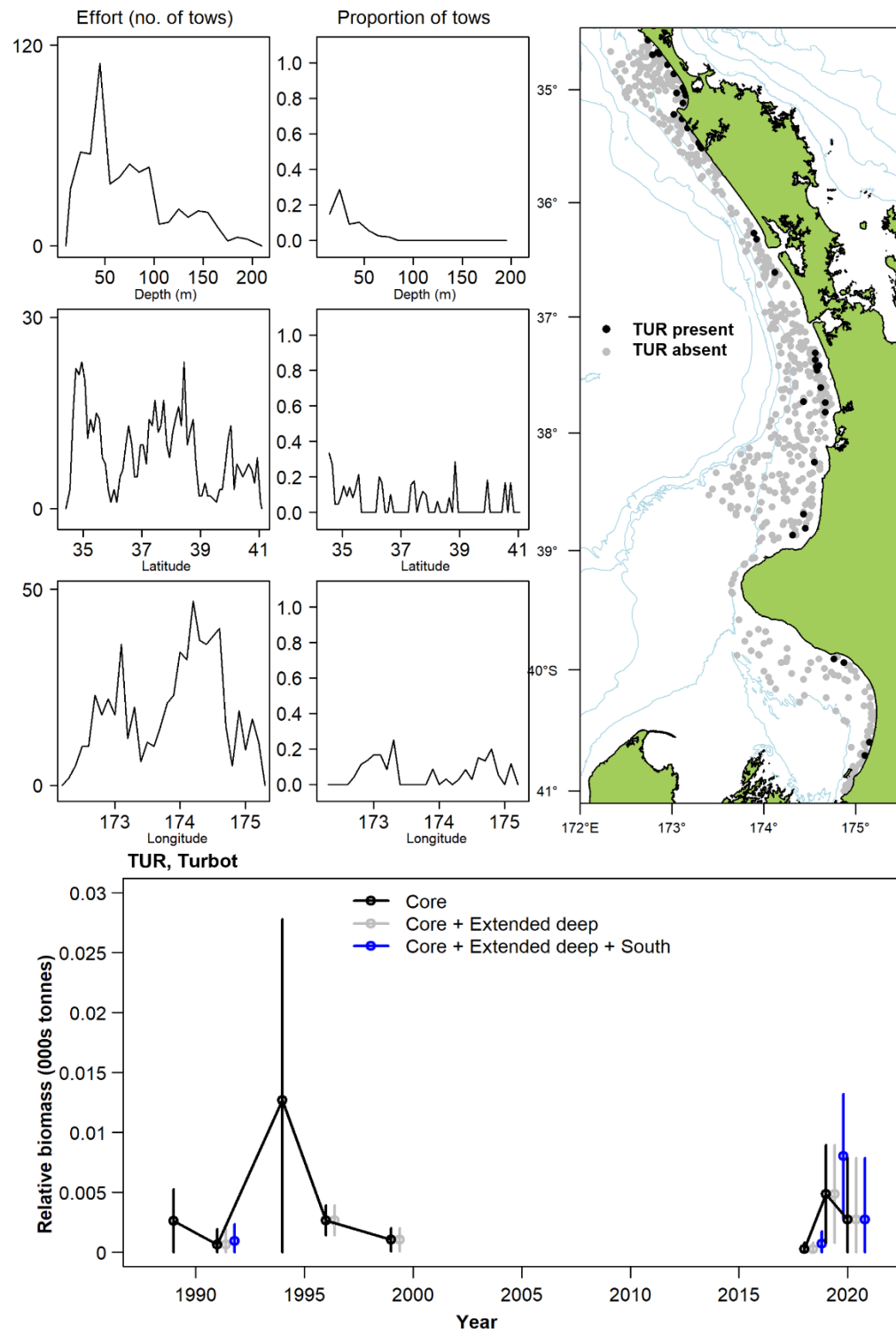


Turbot (combined species) (TUR)

Number of surveys	8
Total catch weight (kg)	120.6
Number measured	156
Length range (mean) (cm)	14–54 (36.8)
Number weighed	8

The TUR code used here combines both turbot and brill due to uncertainty about records of brill in historical surveys that may be erroneous. Brill is only known from central and southern New Zealand.

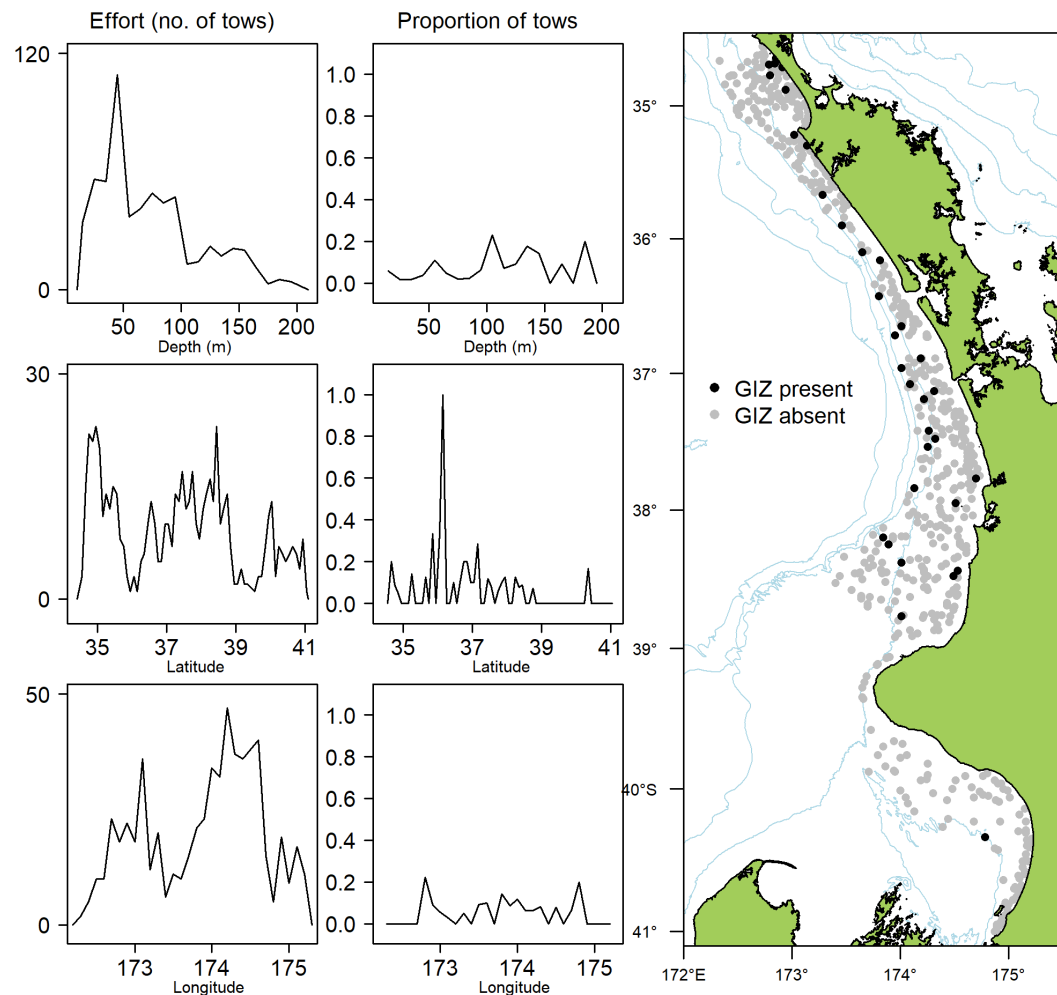
TUR, Turbot



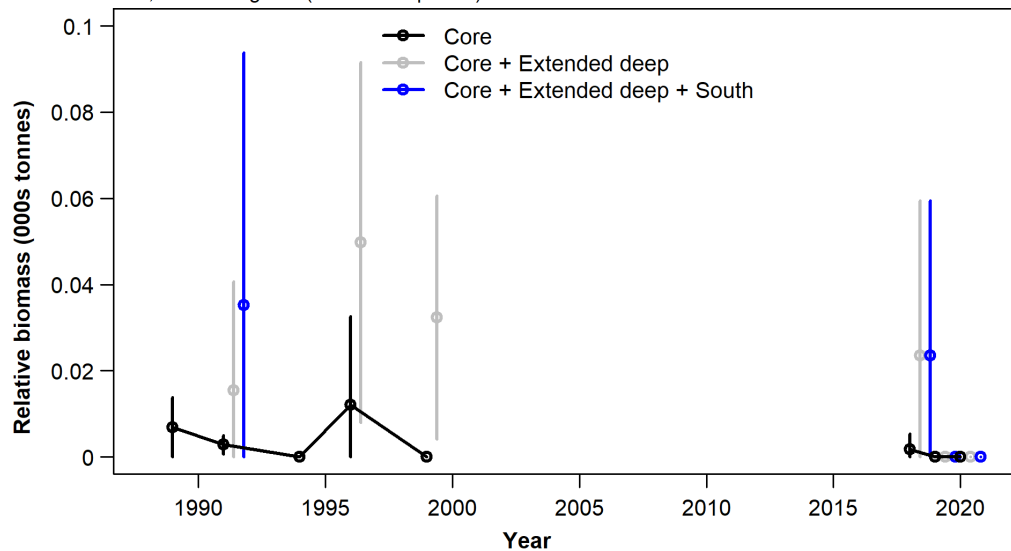
Giant stargazer (GIZ)

Number of surveys	5
Total catch weight (kg)	115.6
Number measured	101
Length range (mean) (cm)	13–63 (35.82)
Number weighed	NA

GIZ, Giant stargazer (combined species)

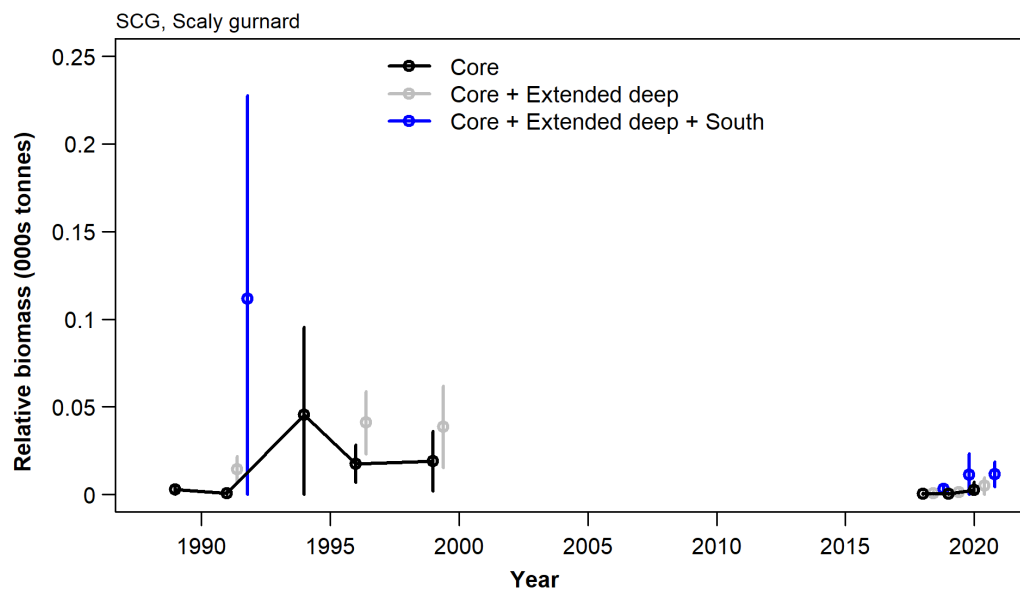
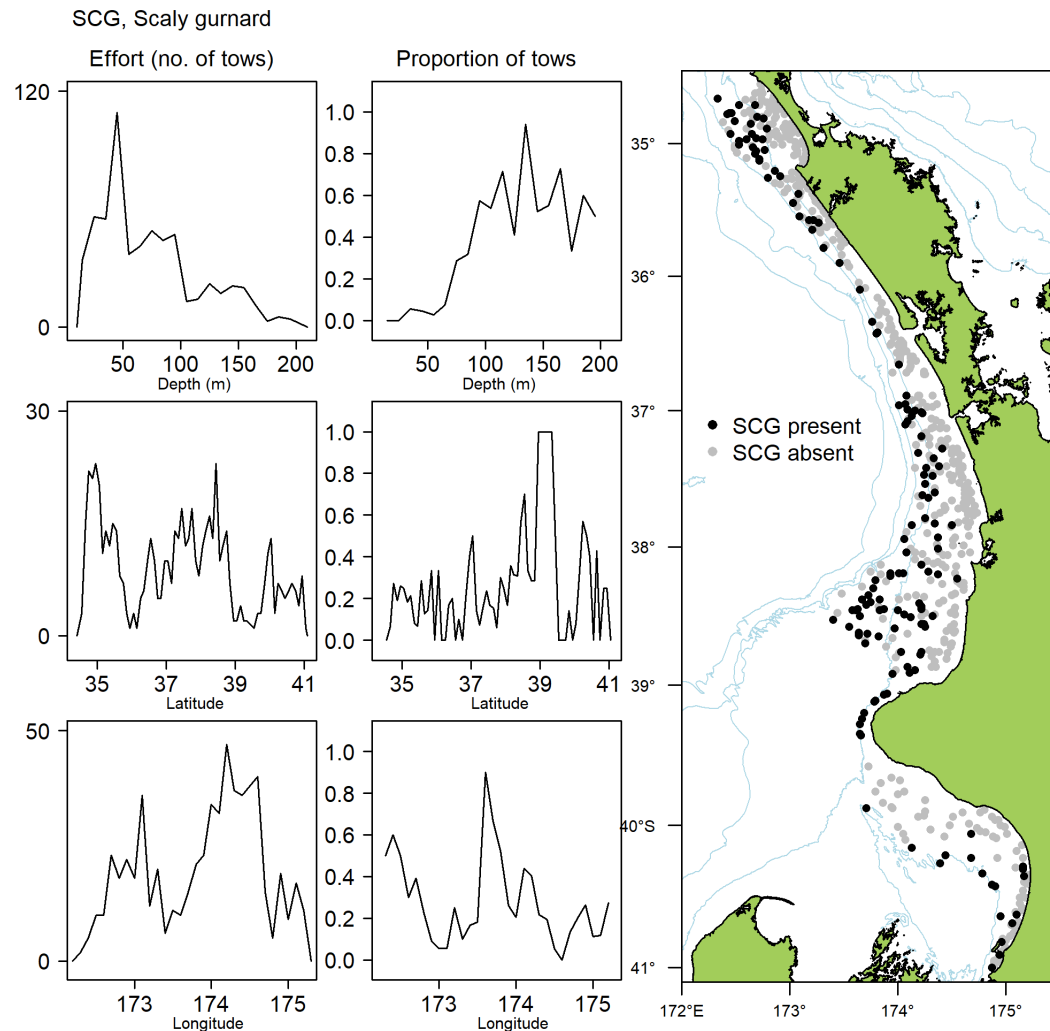


GIZ, Giant stargazer (combined species)



Scaly gurnard (SCG)

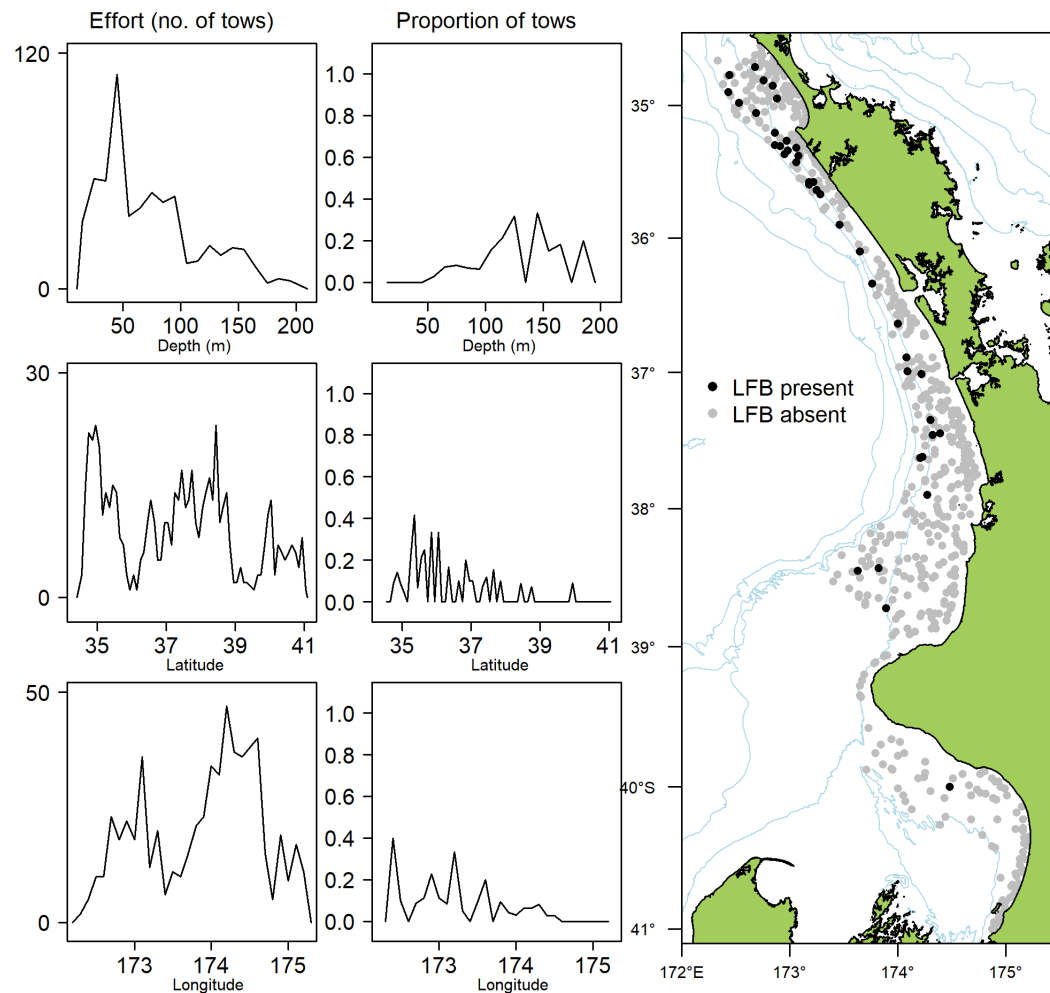
Number of surveys	8
Total catch weight (kg)	104.3
Number measured	525
Length range (mean) (cm)	6–17 (11.64)
Number weighed	NA



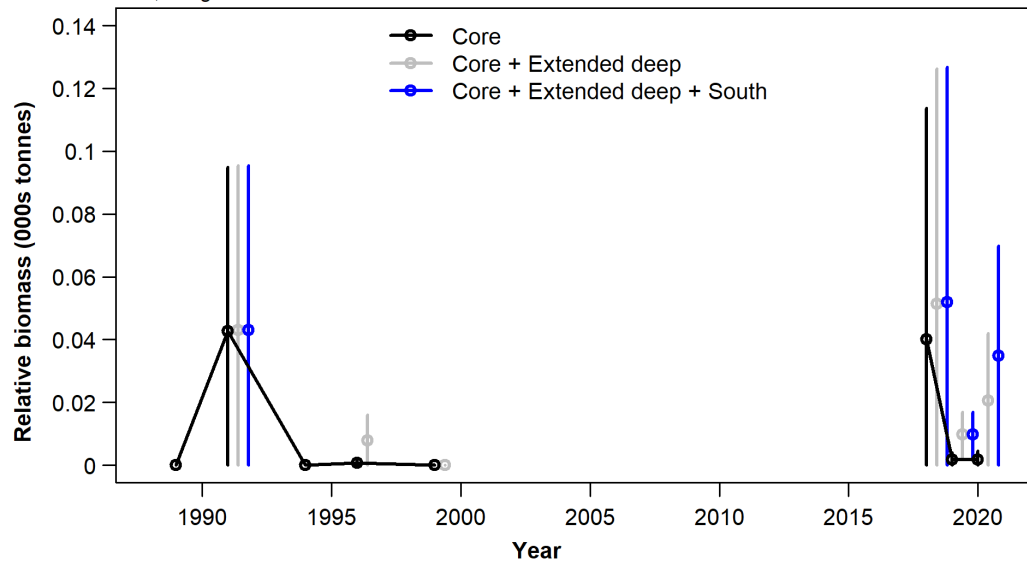
Longfin boarfish (LFB)

Number of surveys	5
Total catch weight (kg)	97.9
Number measured	134
Length range (mean) (cm)	13–32 (25.54)
Number weighed	12

LFB, Longfinned boarfish



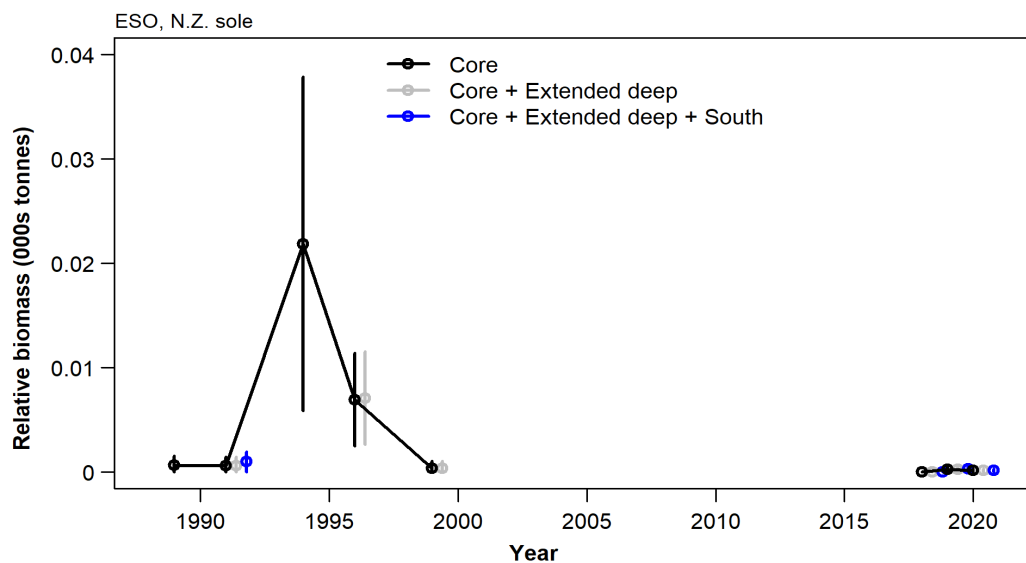
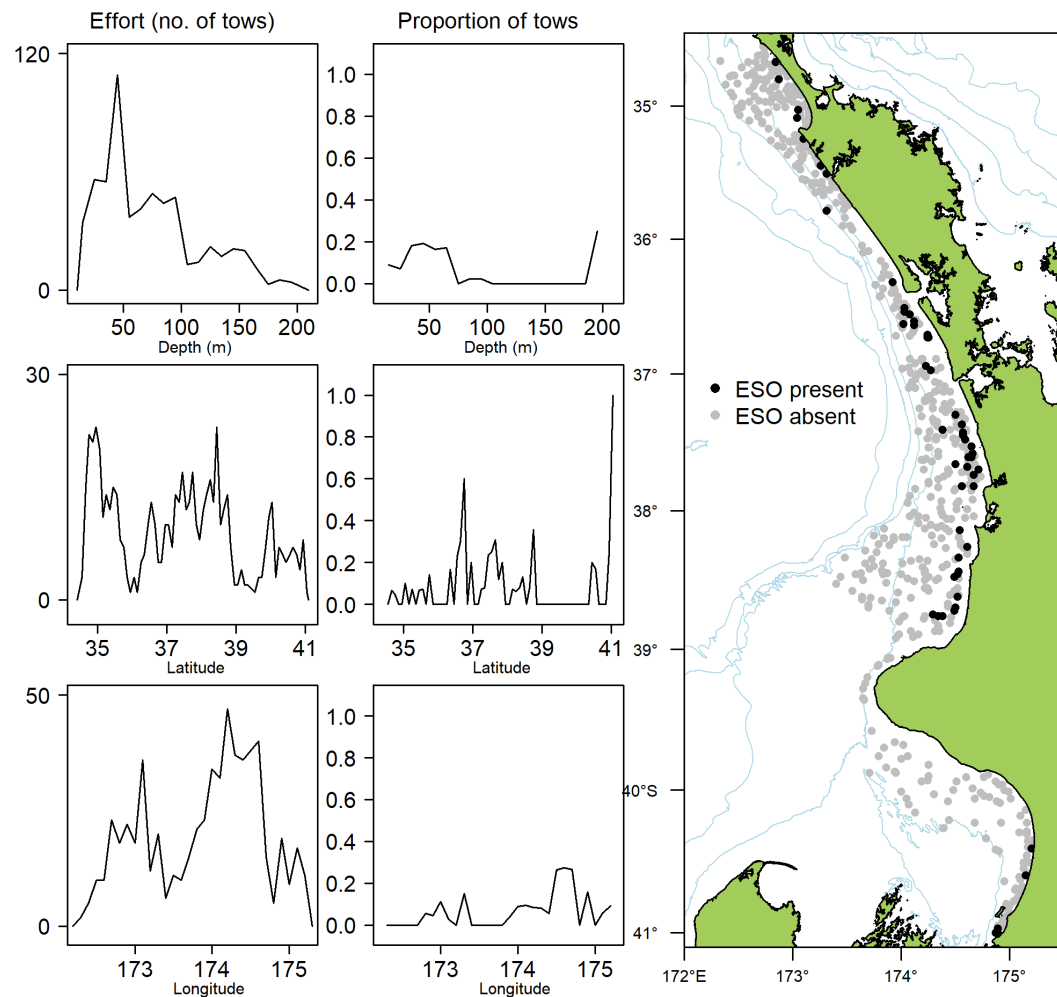
LFB, Longfinned boarfish



New Zealand sole (ESO)

Number of surveys	8
Total catch weight (kg)	96.3
Number measured	496
Length range (mean) (cm)	12–41 (25.59)
Number weighed	NA

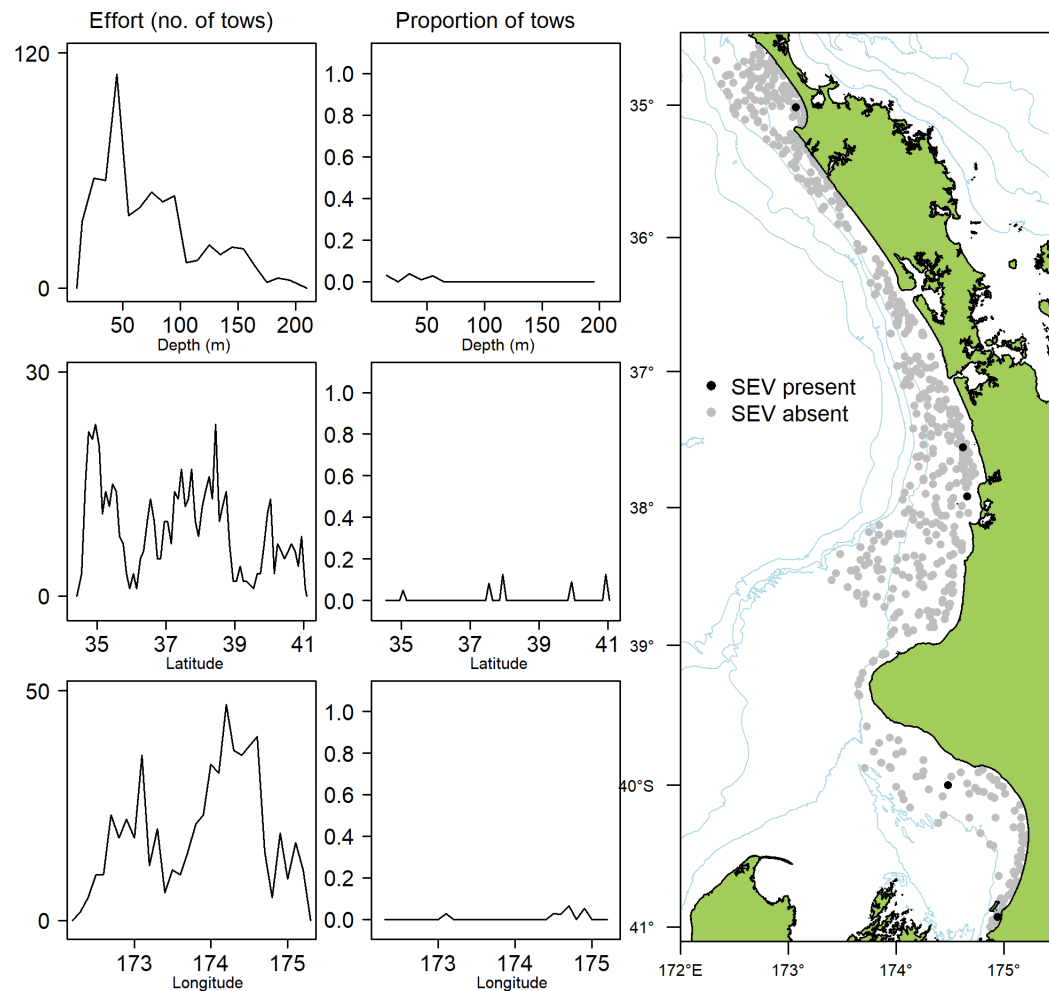
ESO, N.Z. sole



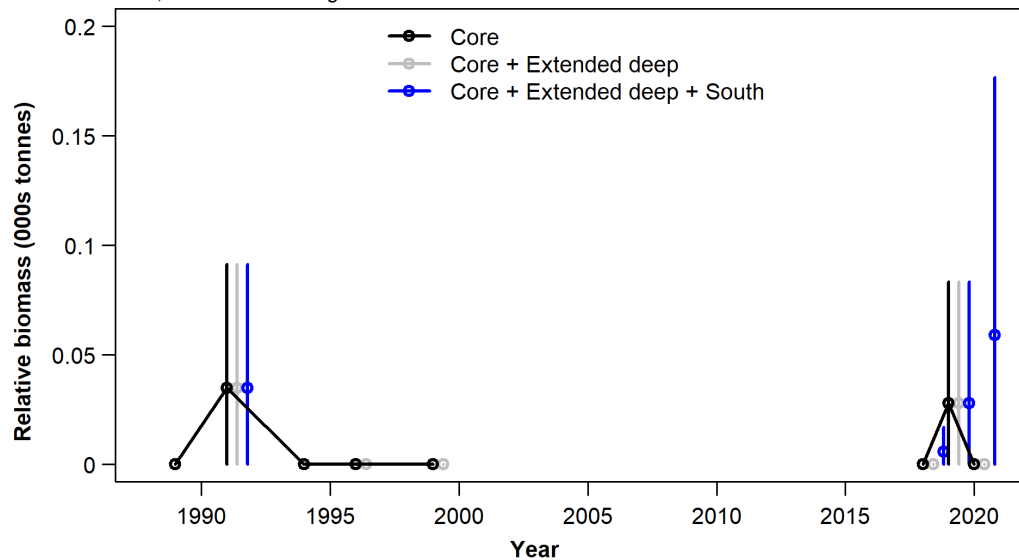
Sevengill shark (SEV)

Number of surveys	4
Total catch weight (kg)	93.9
Number measured	5
Length range (mean) (cm)	115–163 (148.8)
Number weighed	3

SEV, Broadnose sevengill shark



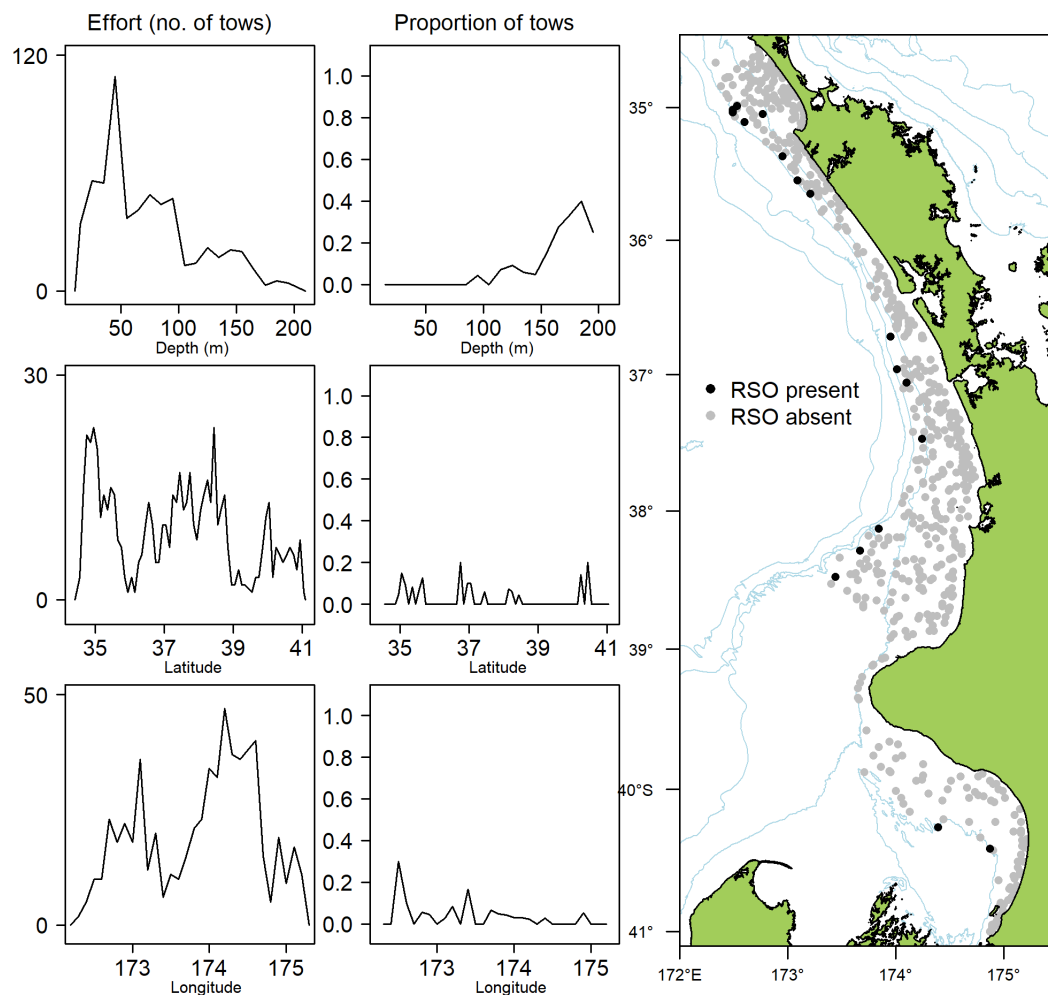
SEV, Broadnose sevengill shark



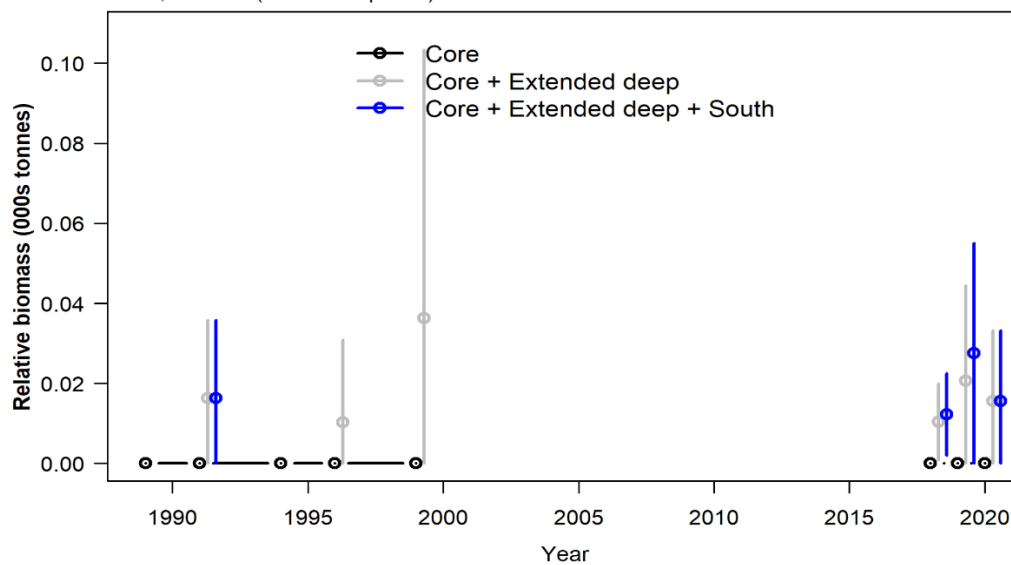
Gemfish (RSO)

Number of surveys	6
Total catch weight (kg)	82.5
Number measured	40
Length range (mean) (cm)	32–94 (63.32)
Number weighed	11

RSO, Gemfish (combined species)



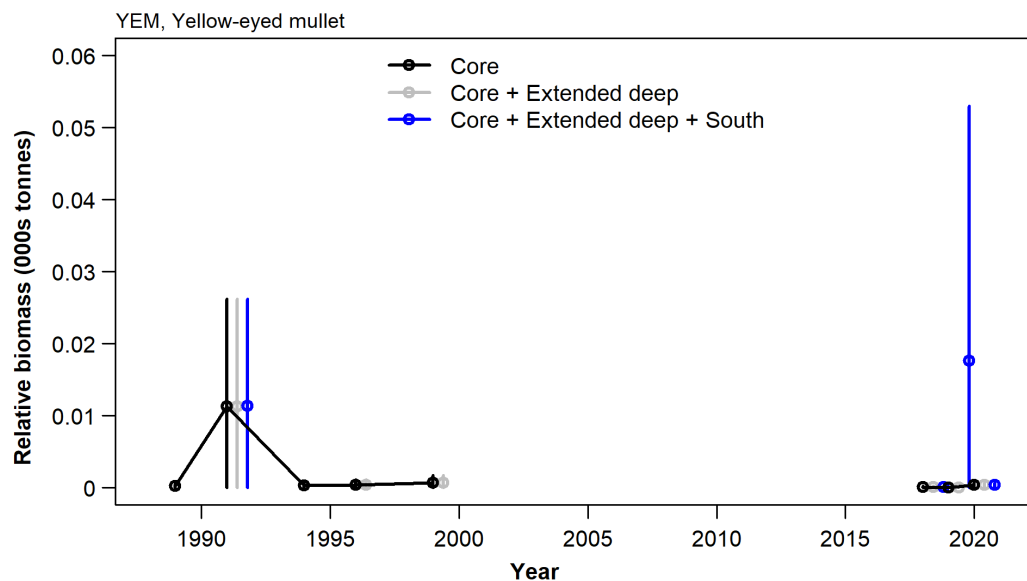
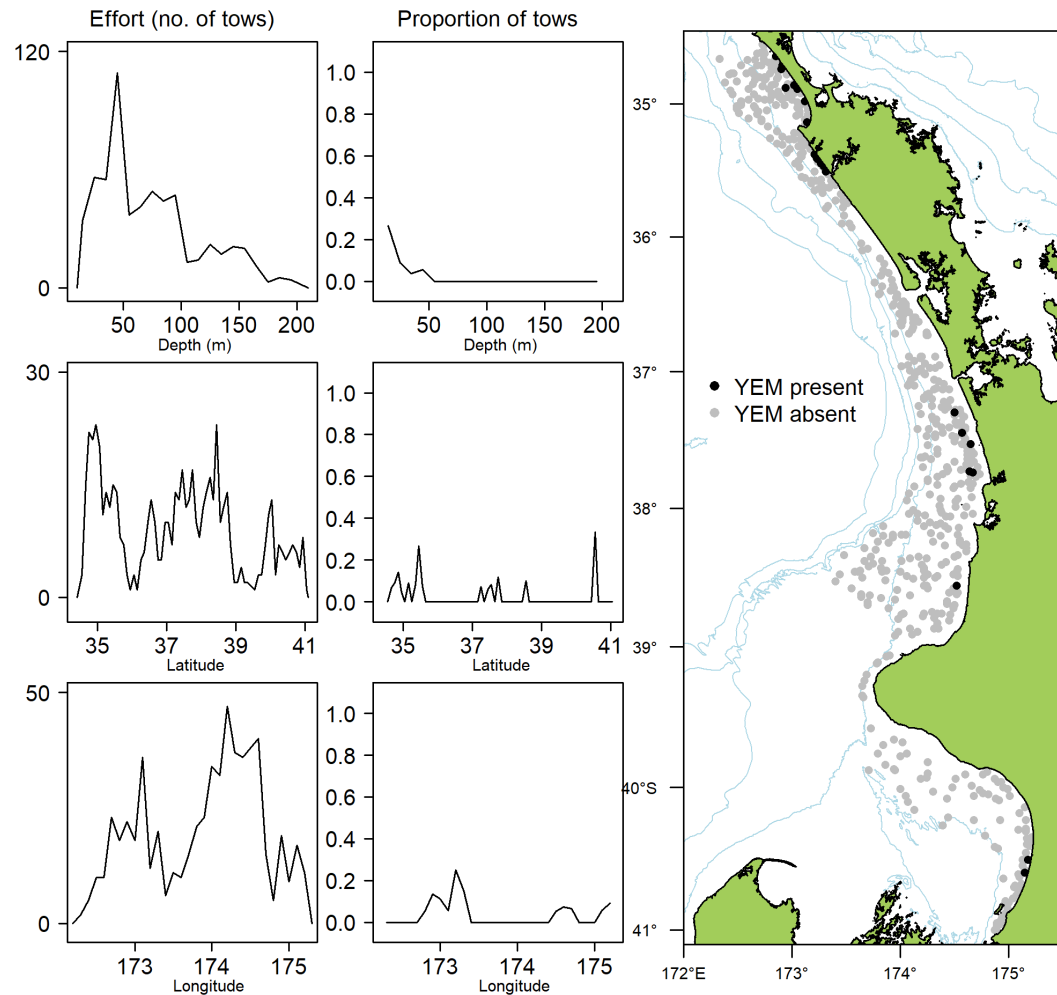
RSO, Gemfish (combined species)



Yelloweye mullet (YEM)

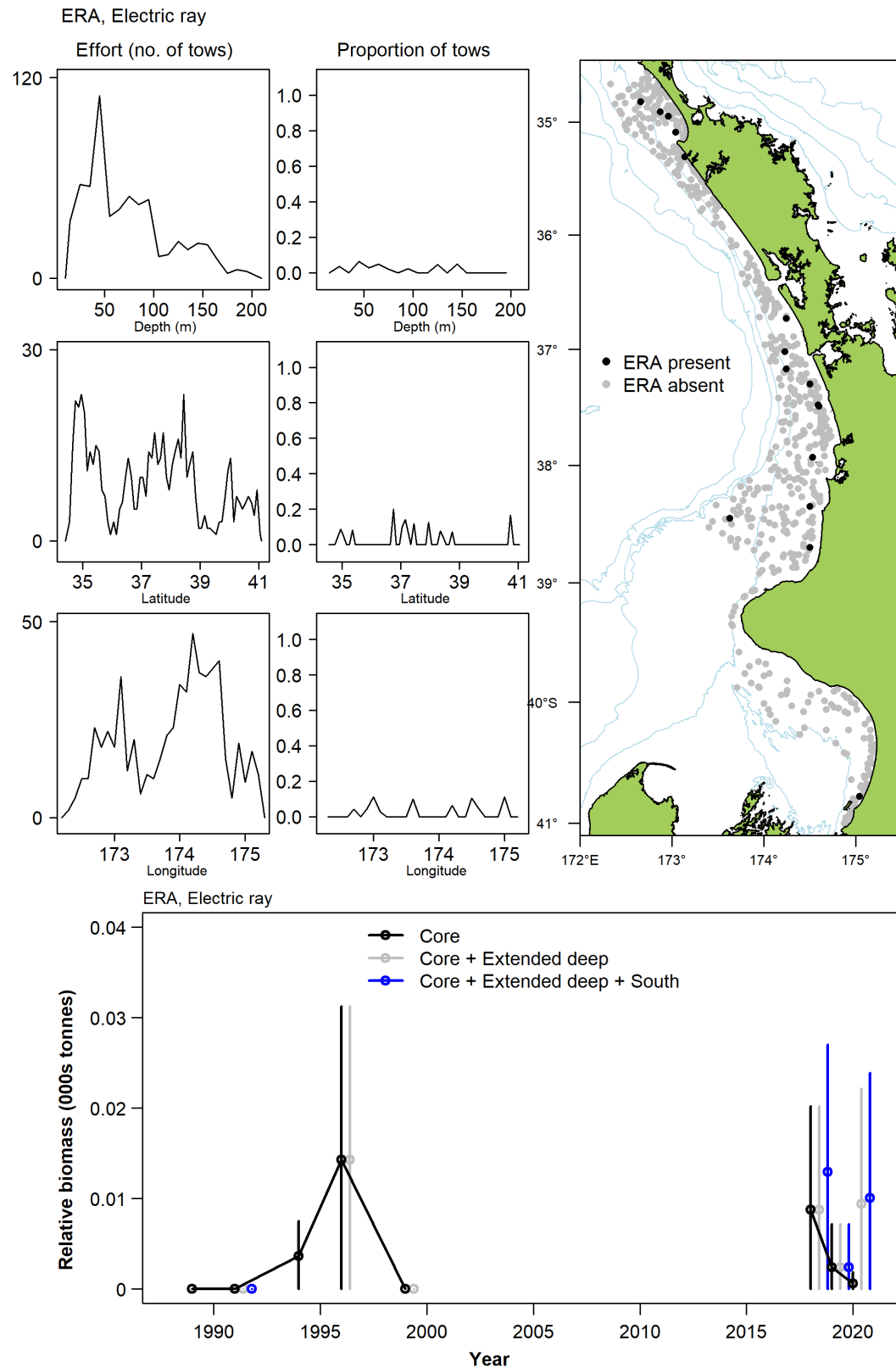
Number of surveys	8
Total catch weight (kg)	80.9
Number measured	555
Length range (mean) (cm)	13–29 (20.64)
Number weighed	NA

YEM, Yellow-eyed mullet



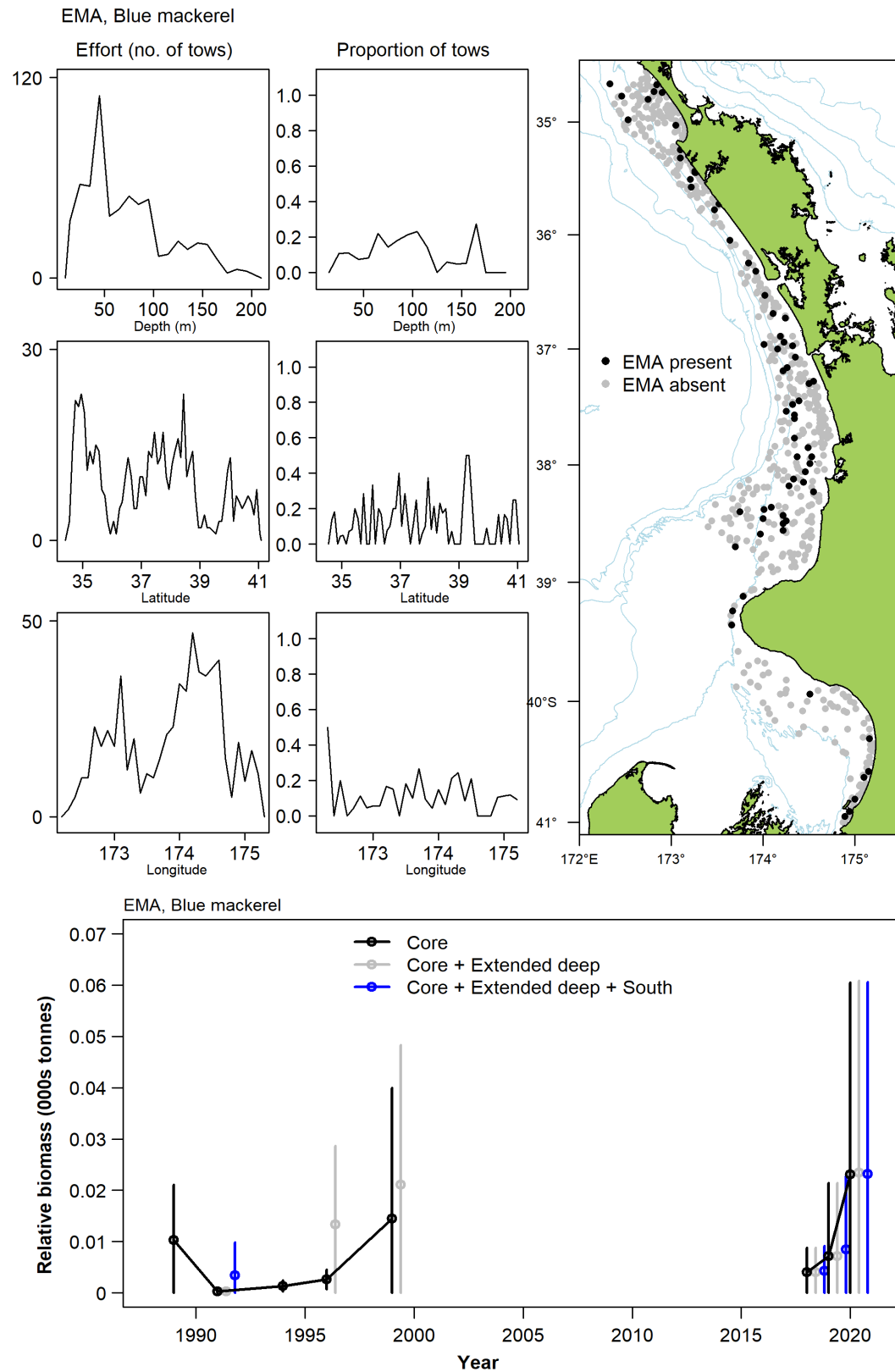
Electric ray (ERA)

Number of surveys	5
Total catch weight (kg)	74.4
Number measured	14
Length range (mean) (cm)	21–41 (29.15)
Number weighed	NA



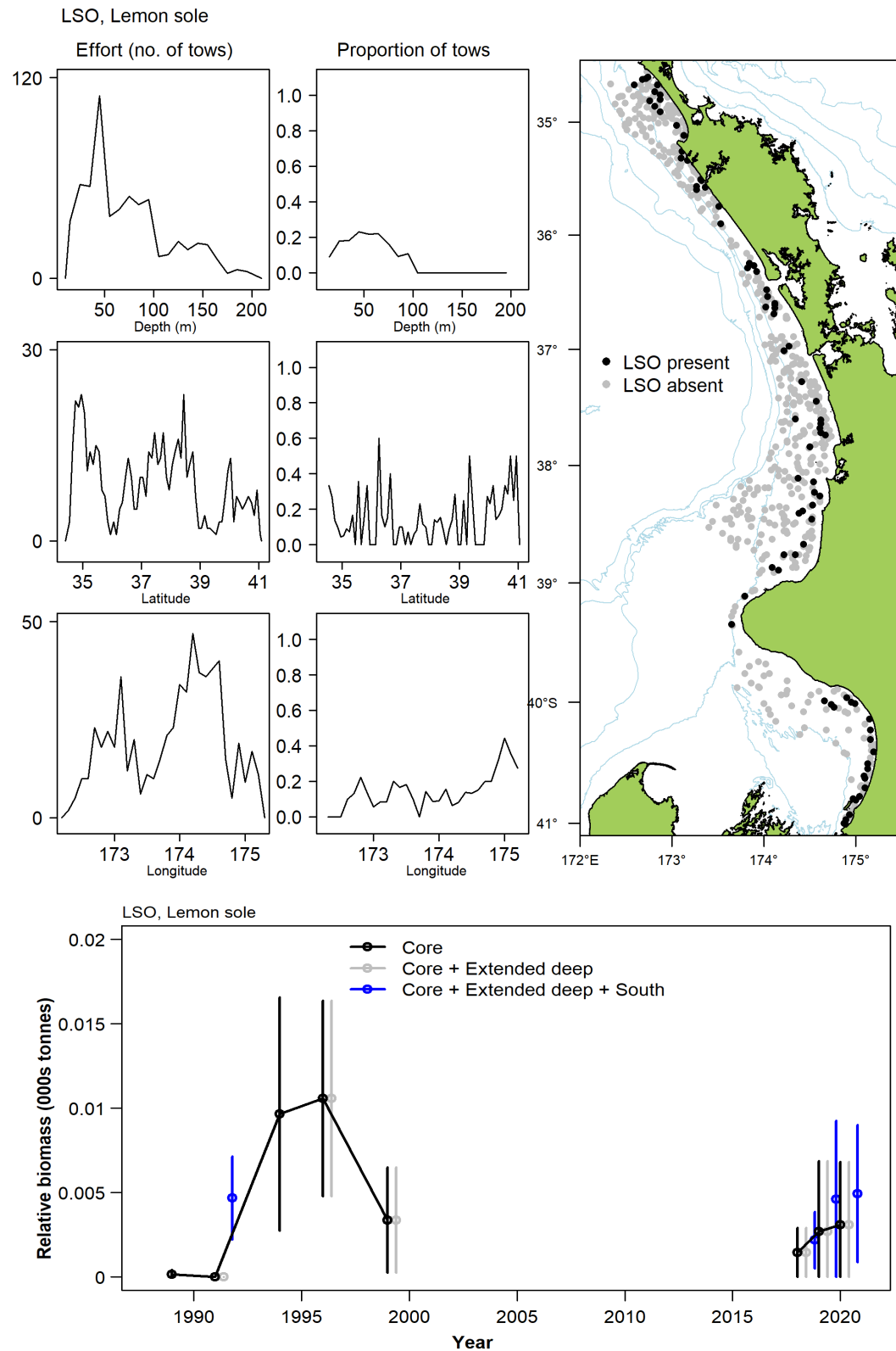
Blue mackerel (EMA)

Number of surveys	8
Total catch weight (kg)	65.3
Number measured	489
Length range (mean) (cm)	11–52 (20.3)
Number weighed	NA



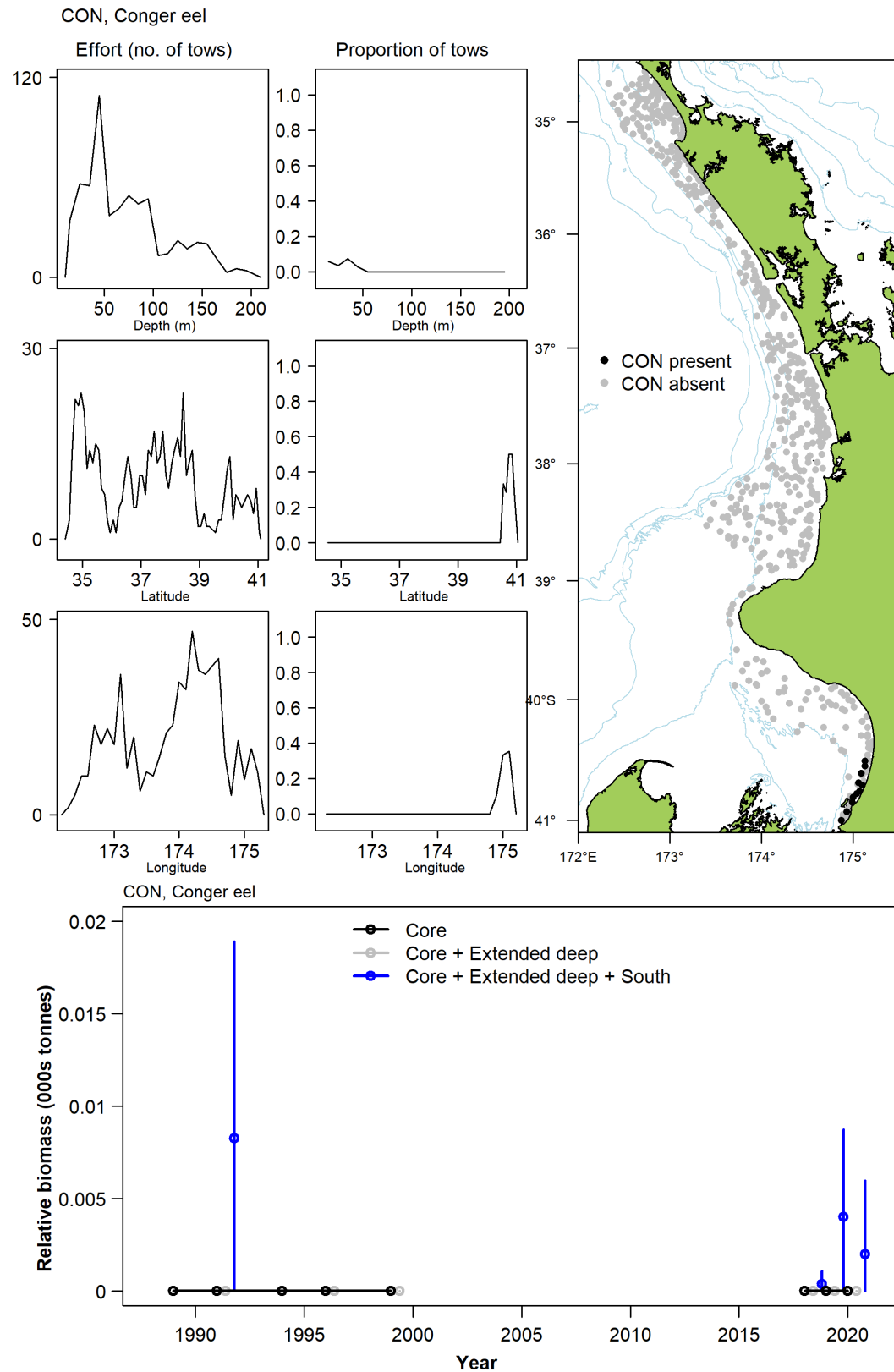
Lemon sole (LSO)

Number of surveys	8
Total catch weight (kg)	55.3
Number measured	208
Length range (mean) (cm)	9–39 (27.1)
Number weighed	NA



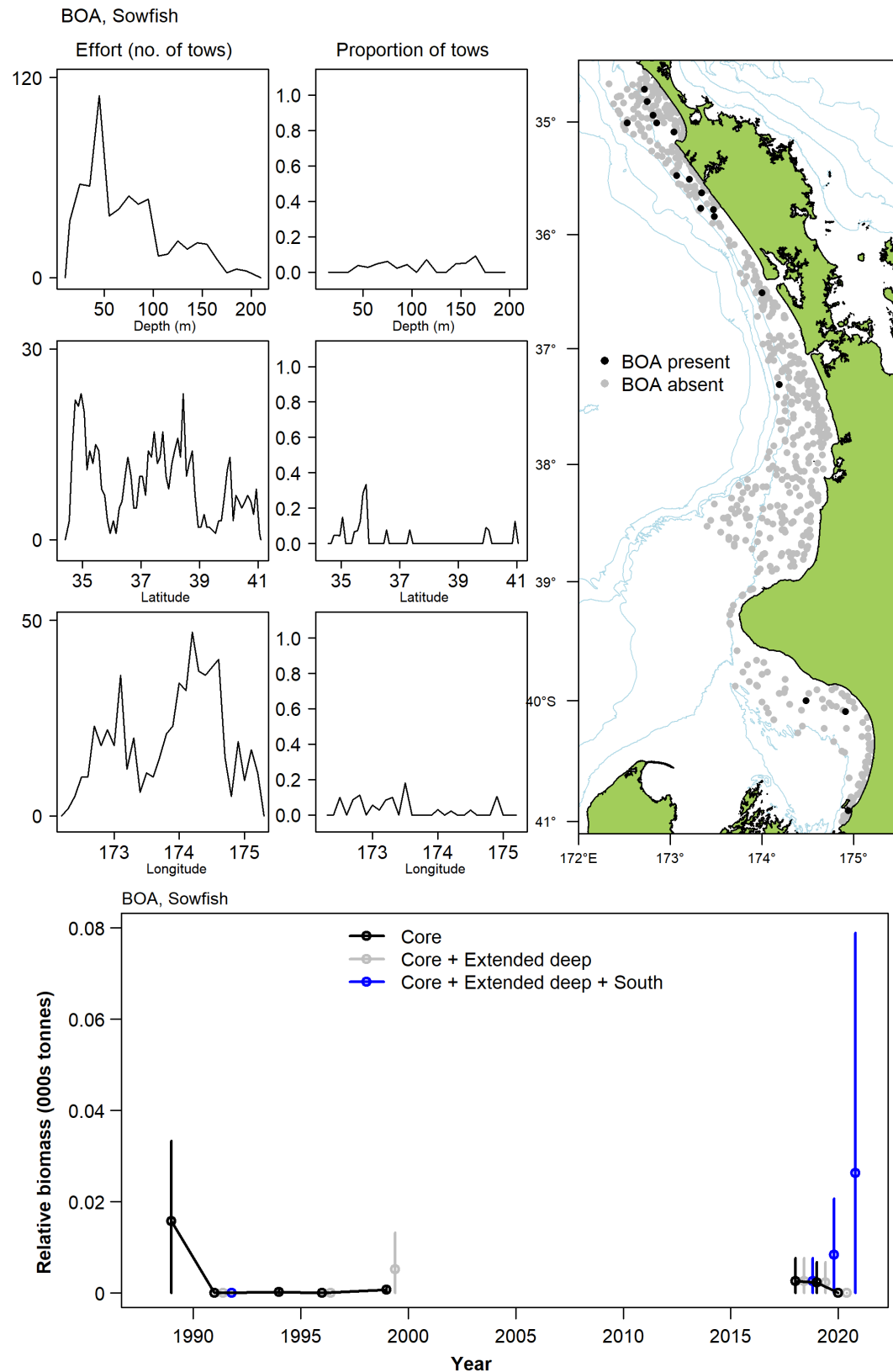
Conger eel (CON)

Number of surveys	5
Total catch weight (kg)	53.3
Number measured	5
Length range (mean) (cm)	86–150 (110.8)
Number weighed	NA



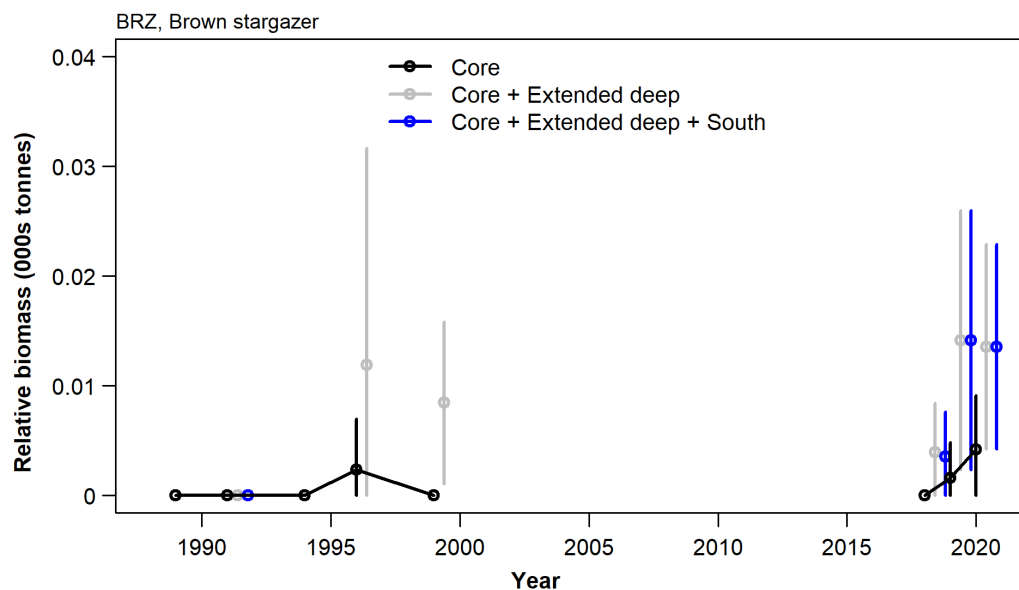
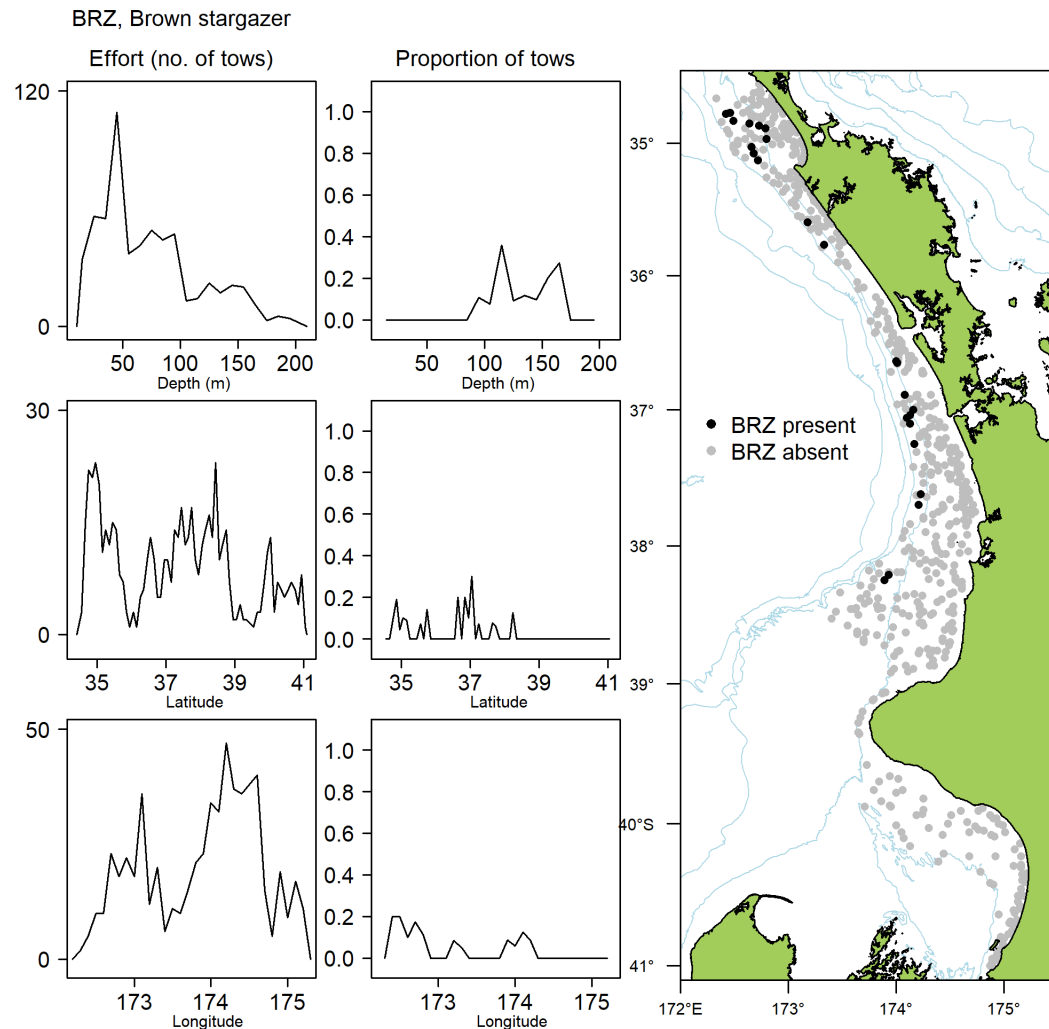
Giant boarfish (BOA)

Number of surveys	6
Total catch weight (kg)	53.2
Number measured	36
Length range (mean) (cm)	18–76 (32.14)
Number weighed	1



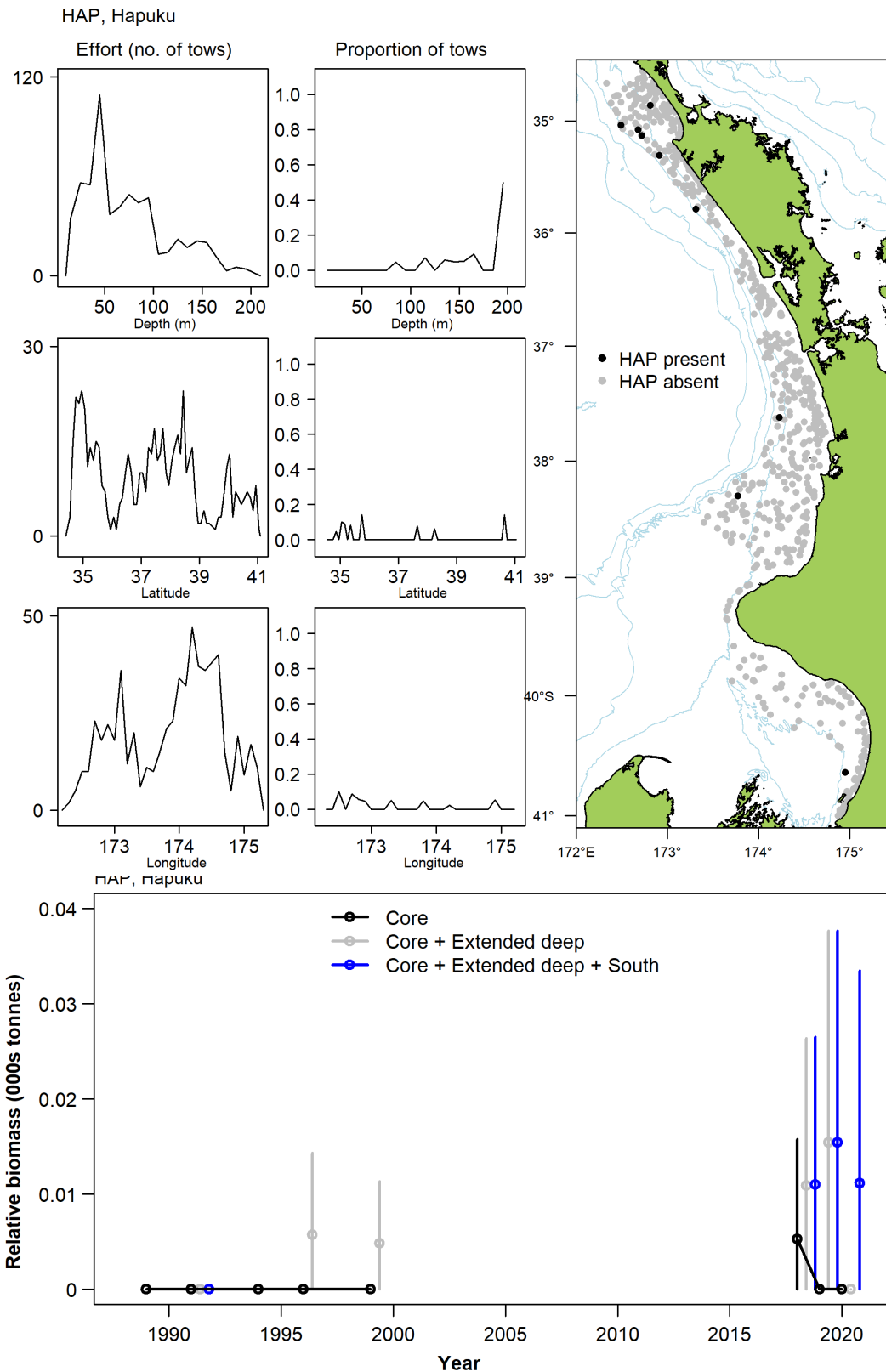
Brown stargazer (BRZ)

Number of surveys	5
Total catch weight (kg)	42.7
Number measured	25
Length range (mean) (cm)	37–60 (44.78)
Number weighed	8



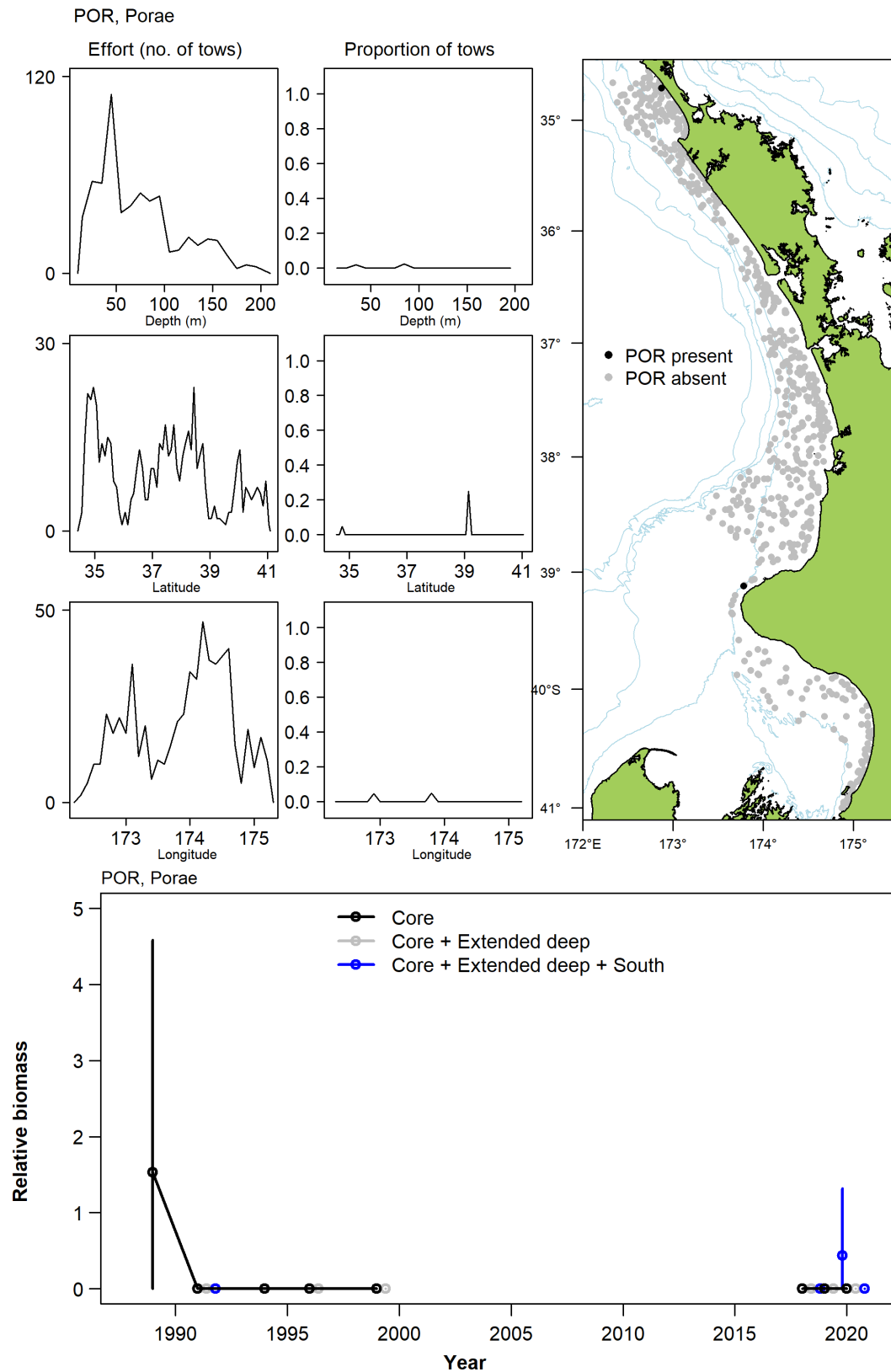
Hāpuku (HAP)

Number of surveys	6
Total catch weight (kg)	44.4
Number measured	12
Length range (mean) (cm)	53–78 (65.5)
Number weighed	3



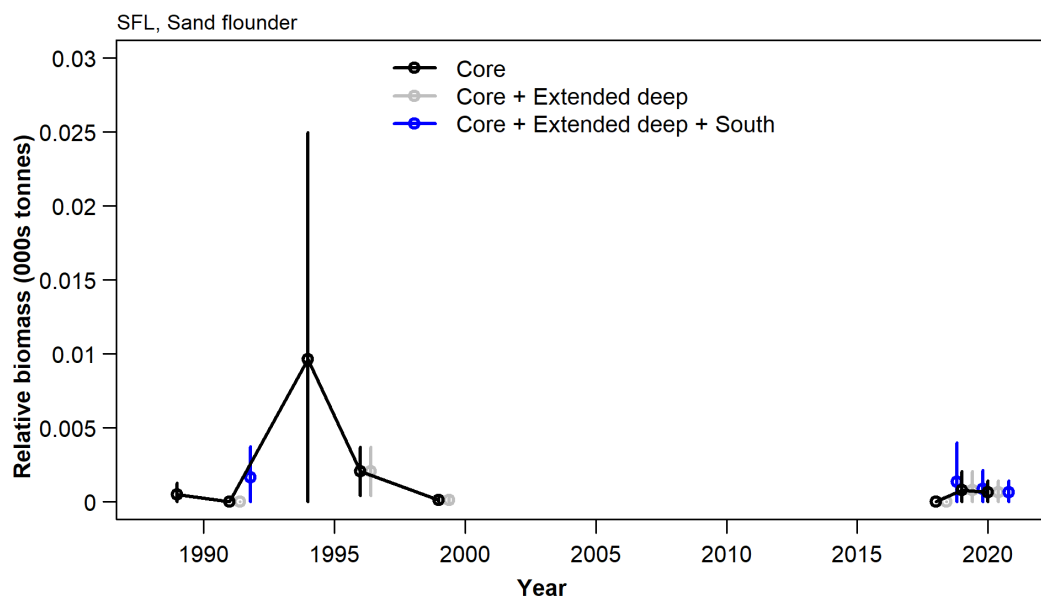
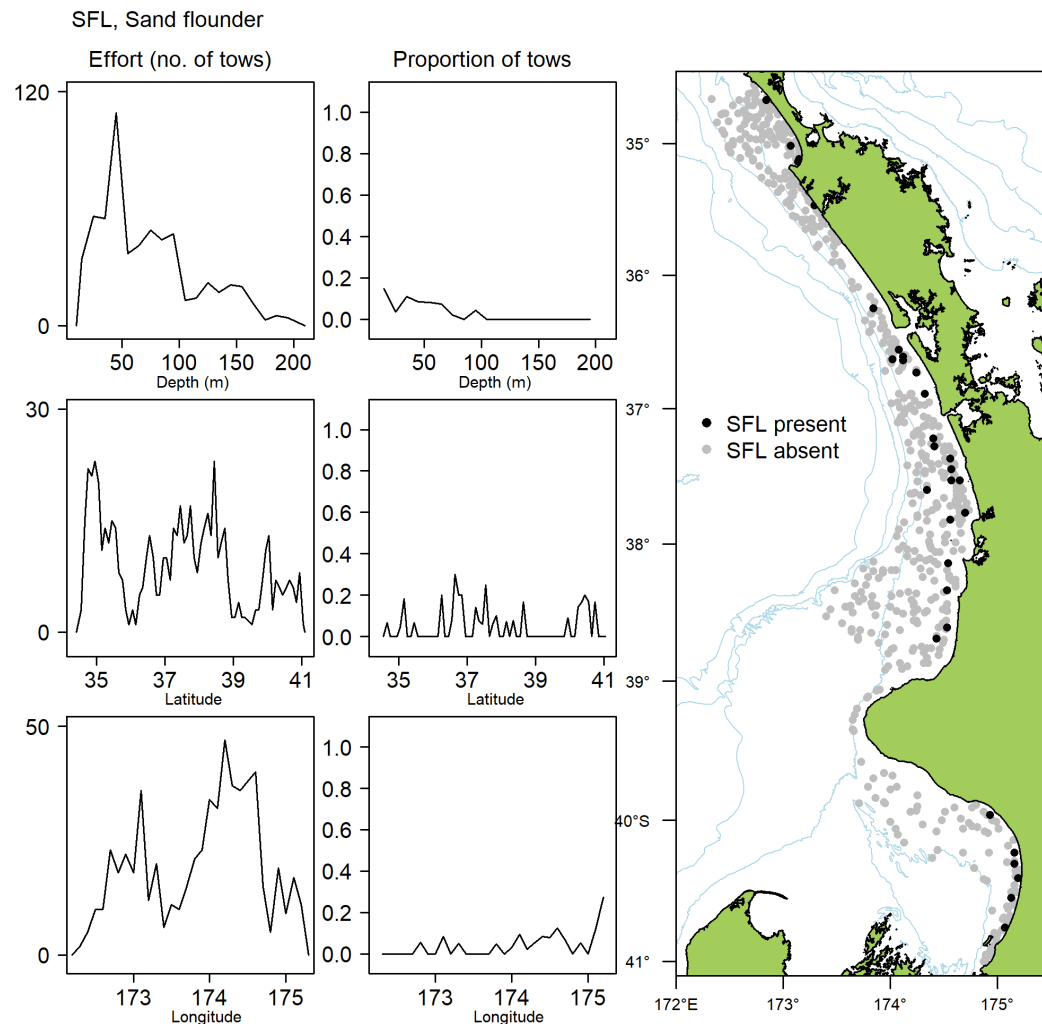
Porae (POR)

Number of surveys	3
Total catch weight (kg)	35.2
Number measured	20
Length range (mean) (cm)	26–61 (43)
Number weighed	NA



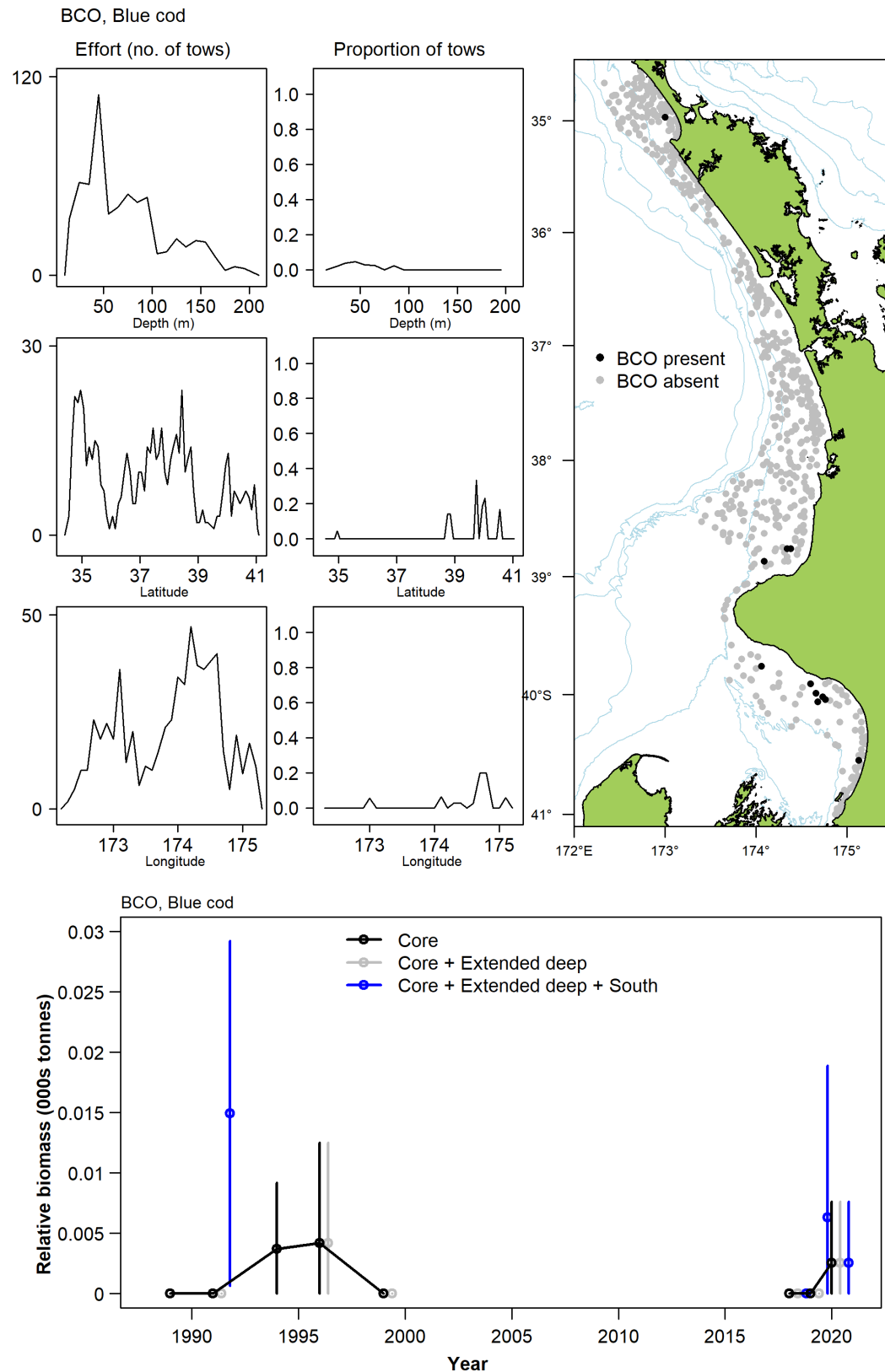
Sand flounder (SFL)

Number of surveys	8
Total catch weight (kg)	32.4
Number measured	135
Length range (mean) (cm)	14–39 (24.7)
Number weighed	NA



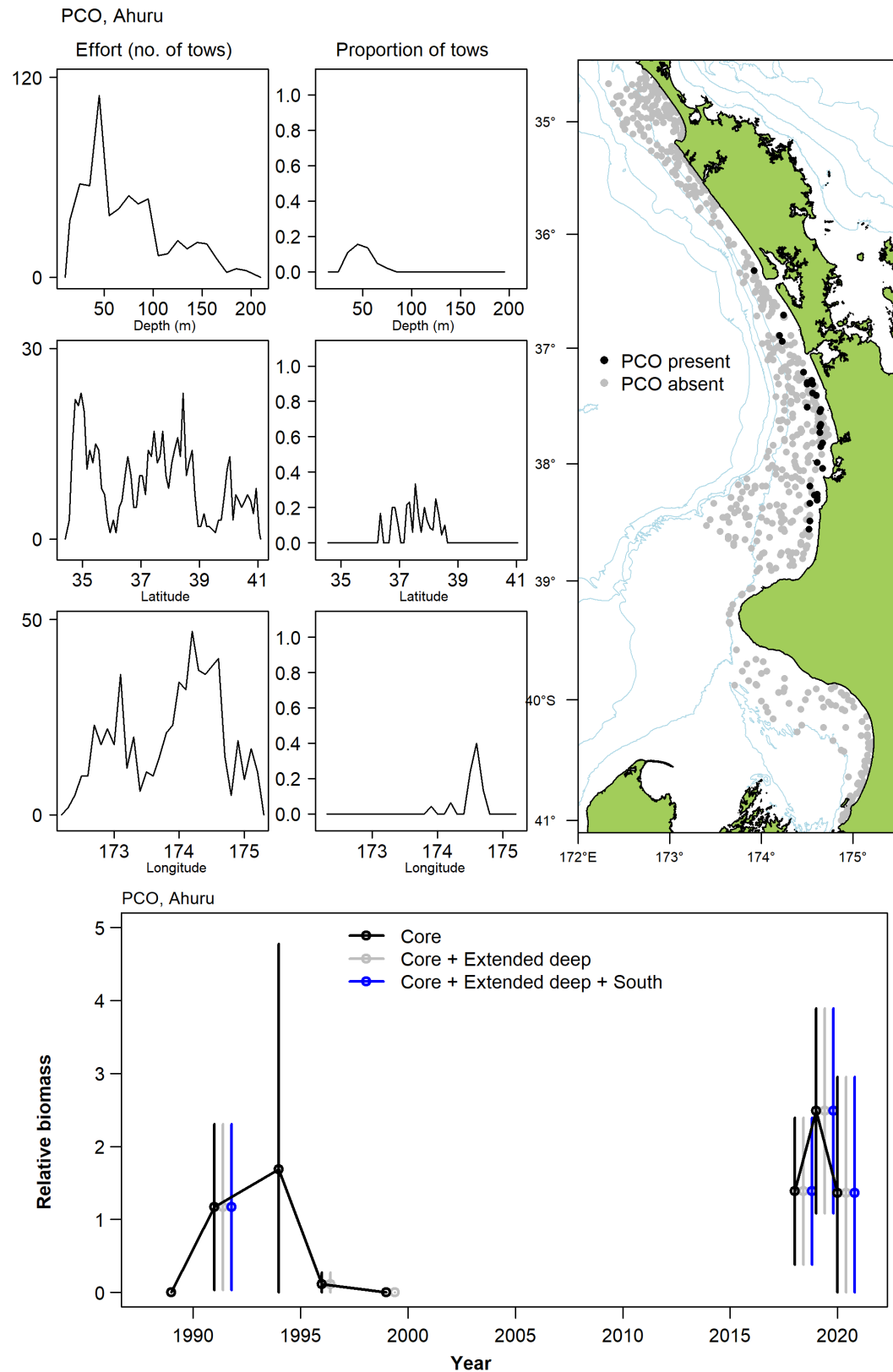
Blue cod (BCO)

Number of surveys	5
Total catch weight (kg)	23.8
Number measured	35
Length range (mean) (cm)	19–48 (34)
Number weighed	NA



Āhuru (PCO)

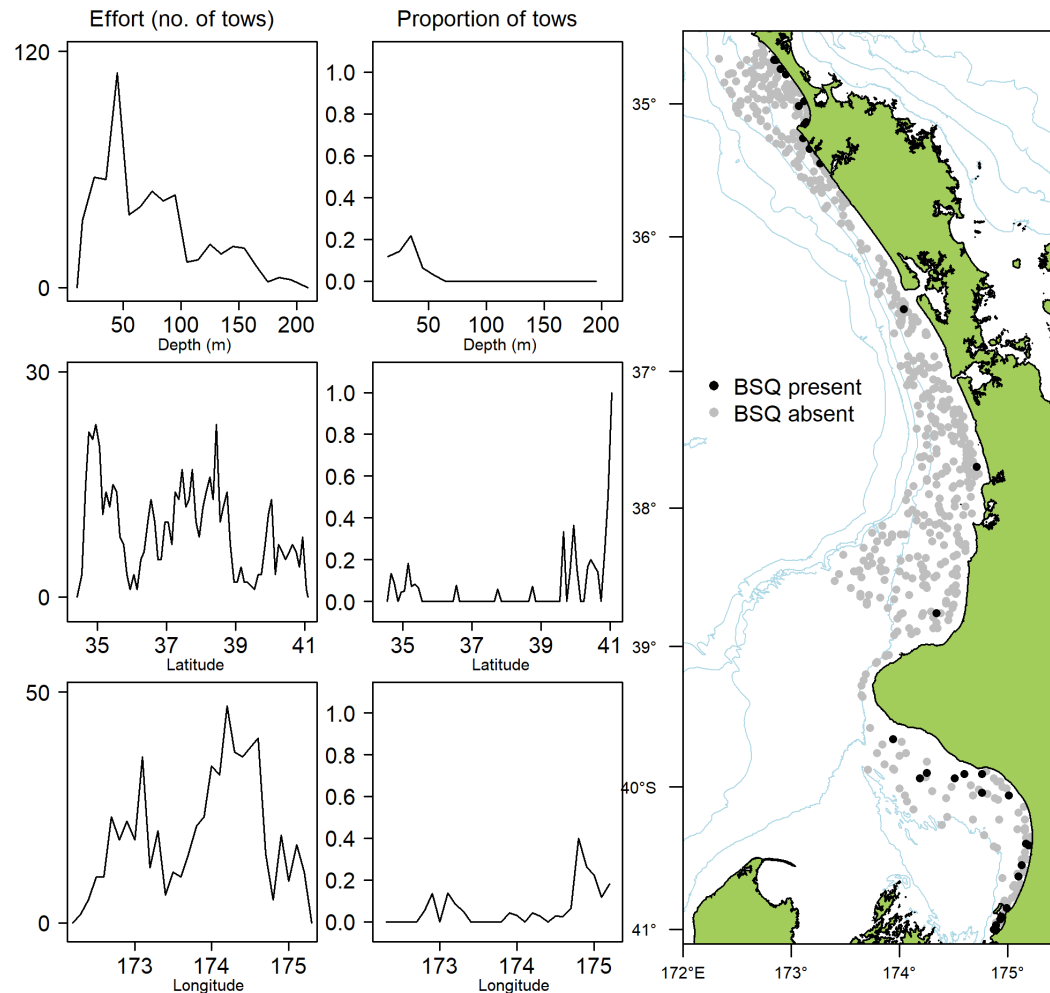
Number of surveys	7
Total catch weight (kg)	21.3
Number measured	788
Length range (mean) (cm)	5–16 (11.58)
Number weighed	none



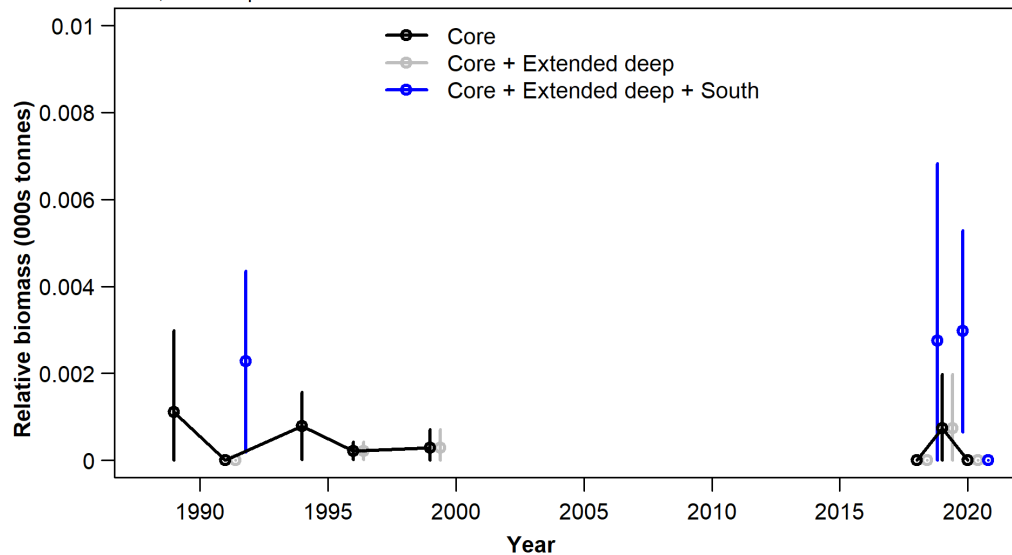
Broad squid (BSQ)

Number of surveys	7
Total catch weight (kg)	18.4
Number measured	38
Length range (mean) (cm)	8–27 (16.62)
Number weighed	none

BSQ, Broad squid

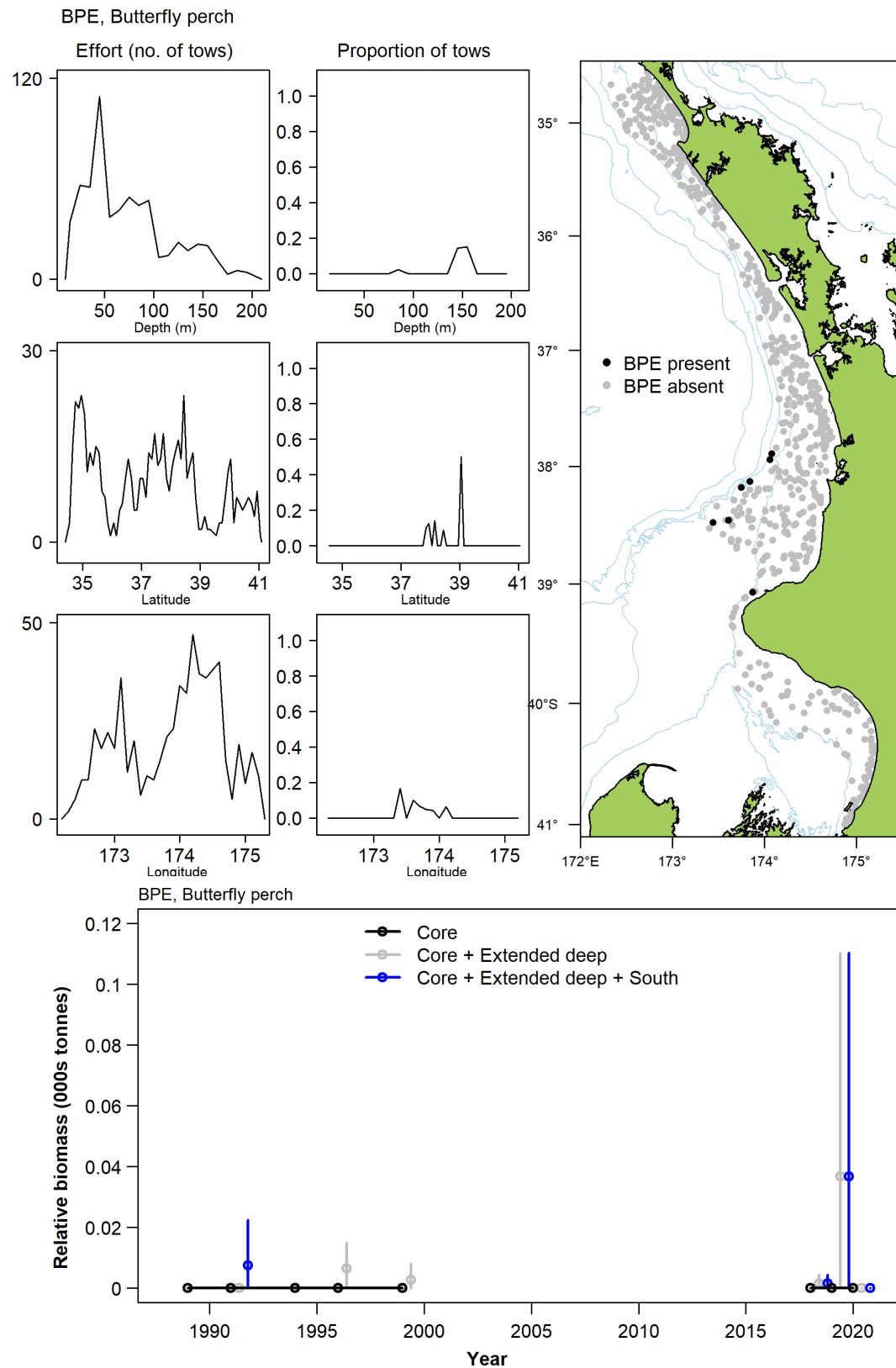


BSQ, Broad squid



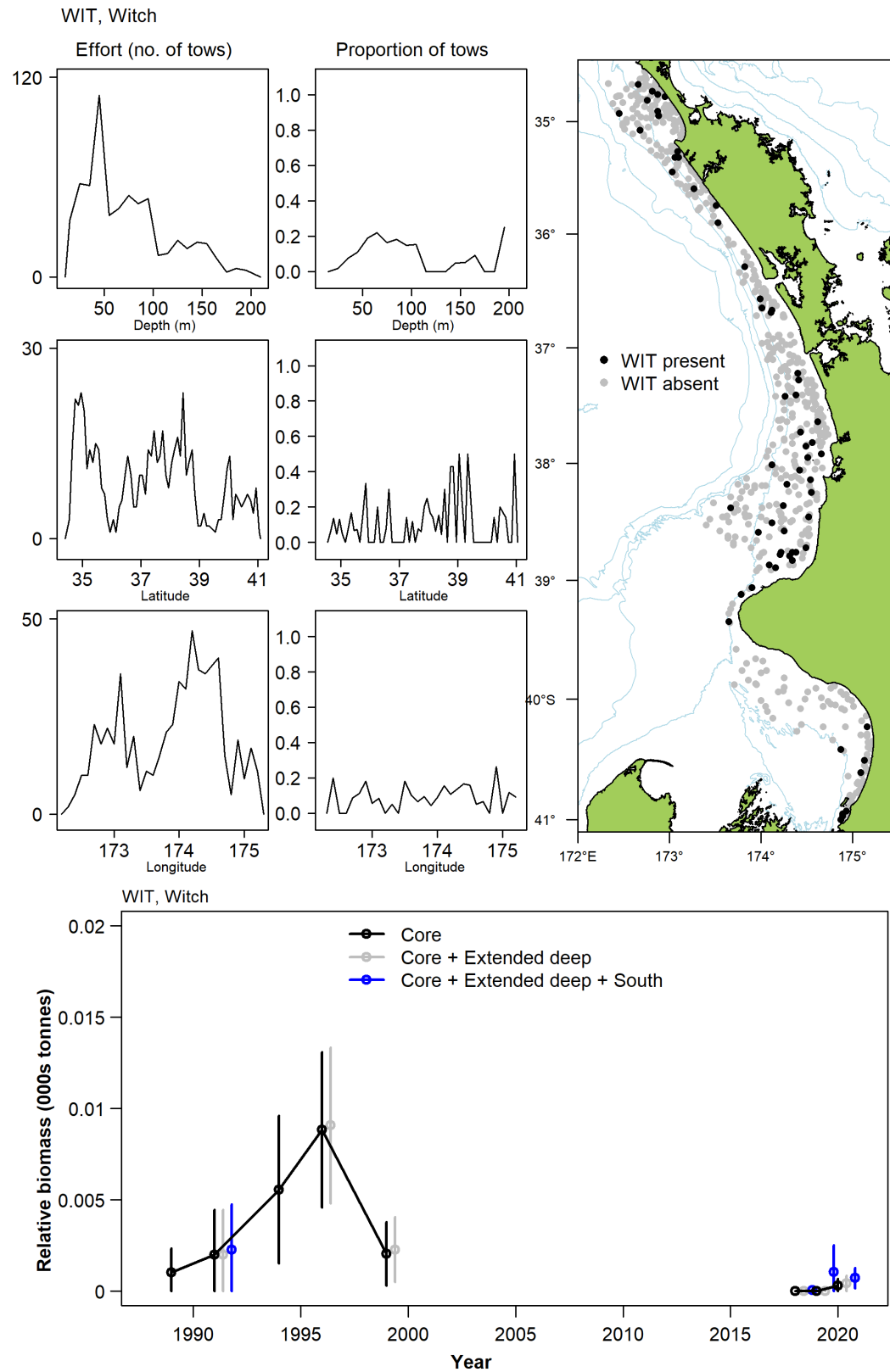
Butterfly perch (BPE)

Number of surveys	6
Total catch weight (kg)	17.9
Number measured	50
Length range (mean) (cm)	11–28 (21.6)
Number weighed	NA



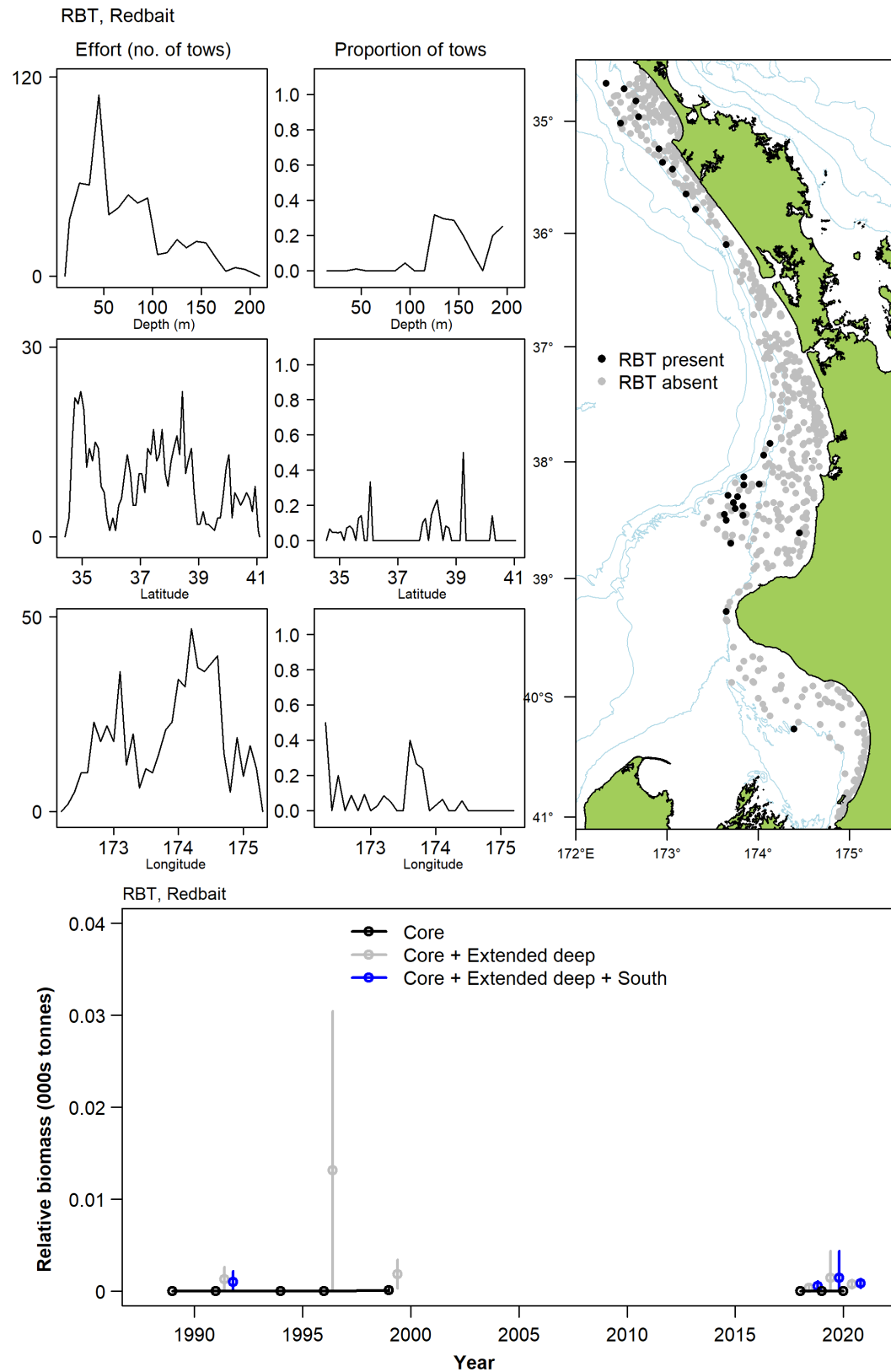
Witch (WIT)

Number of surveys	8
Total catch weight (kg)	17.3
Number measured	90
Length range (mean) (cm)	10–31 (24.49)
Number weighed	NA



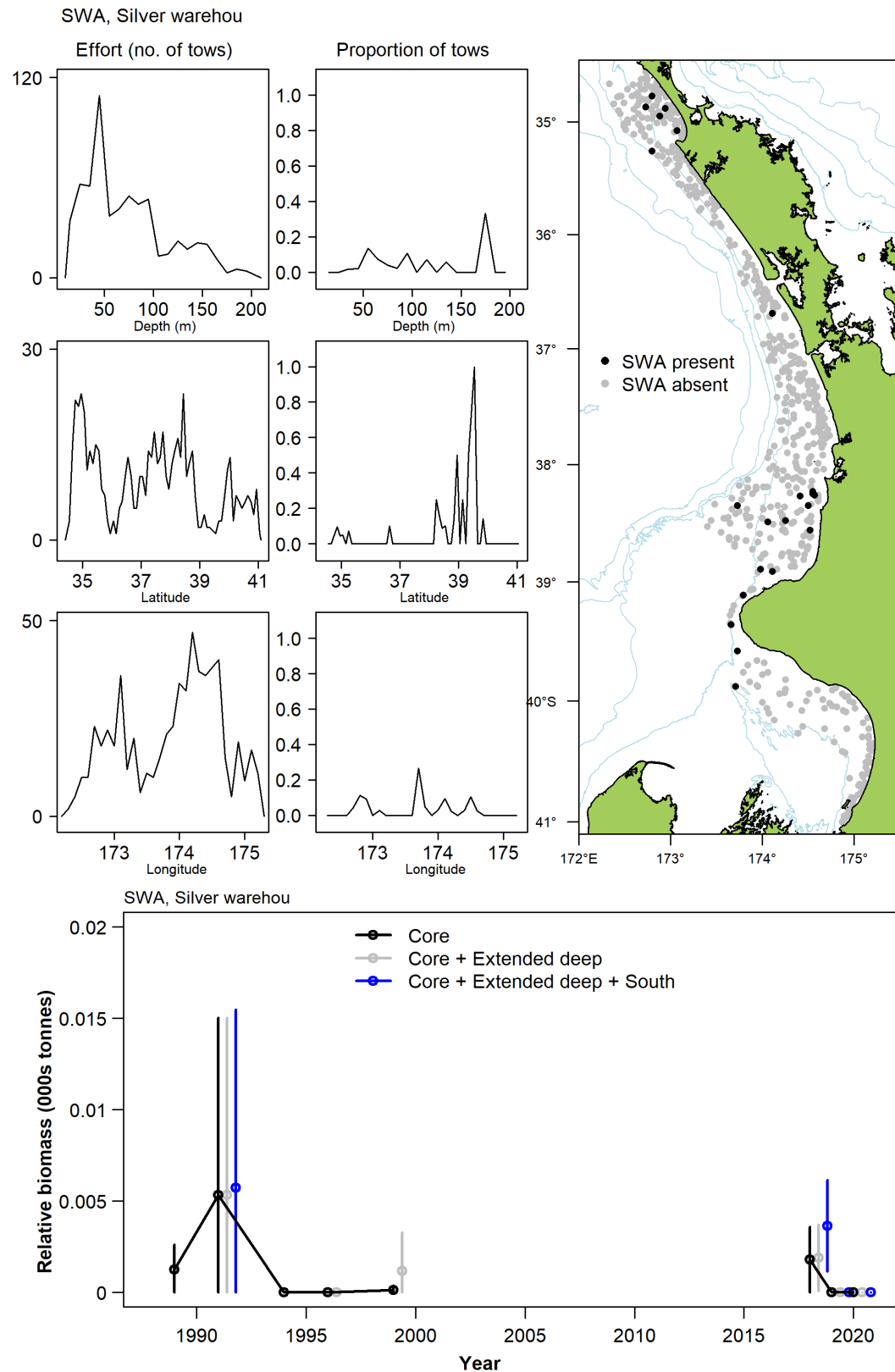
Redbait (RBT)

Number of surveys	6
Total catch weight (kg)	13.7
Number measured	31
Length range (mean) (cm)	6–19 (11.65)
Number weighed	NA

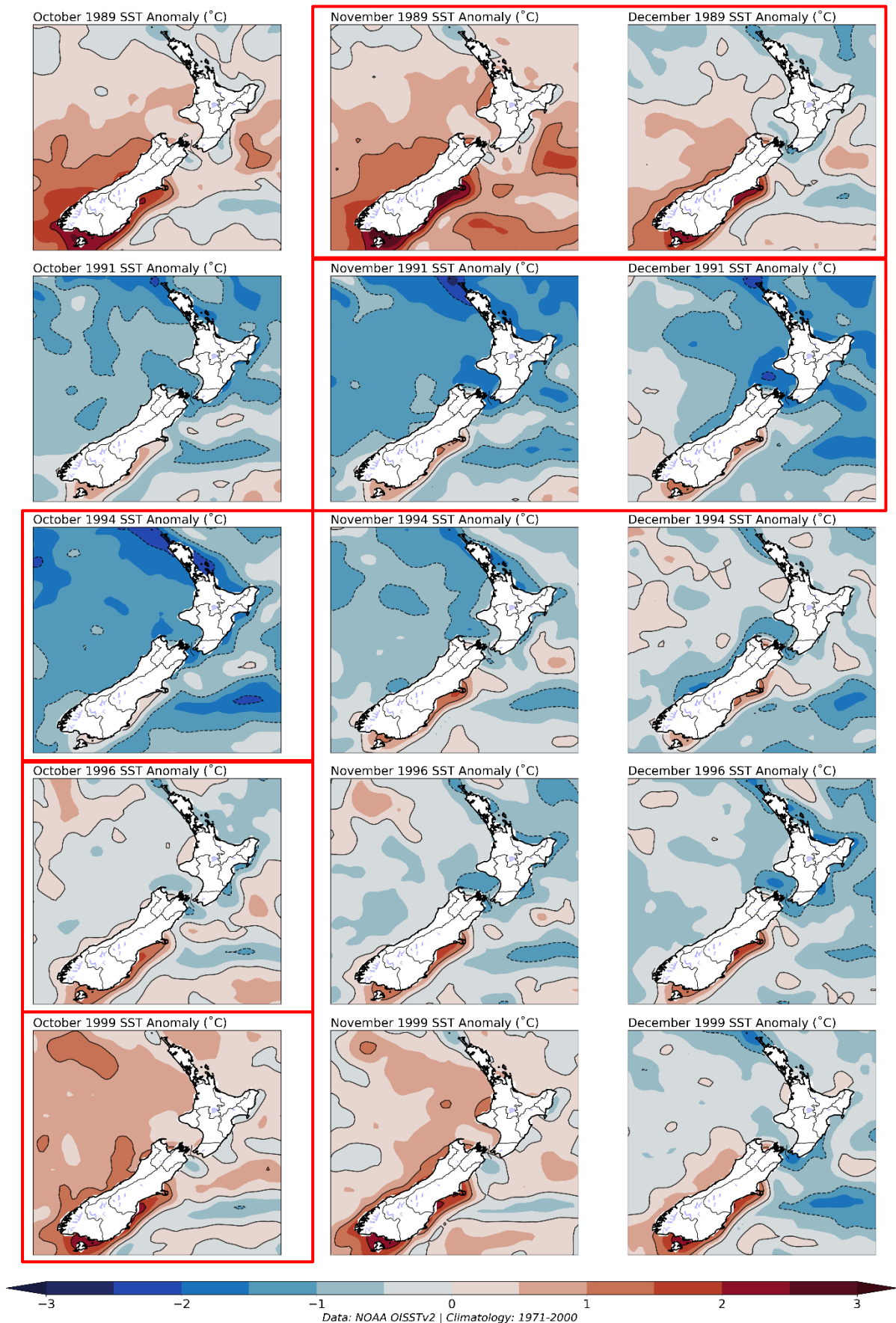


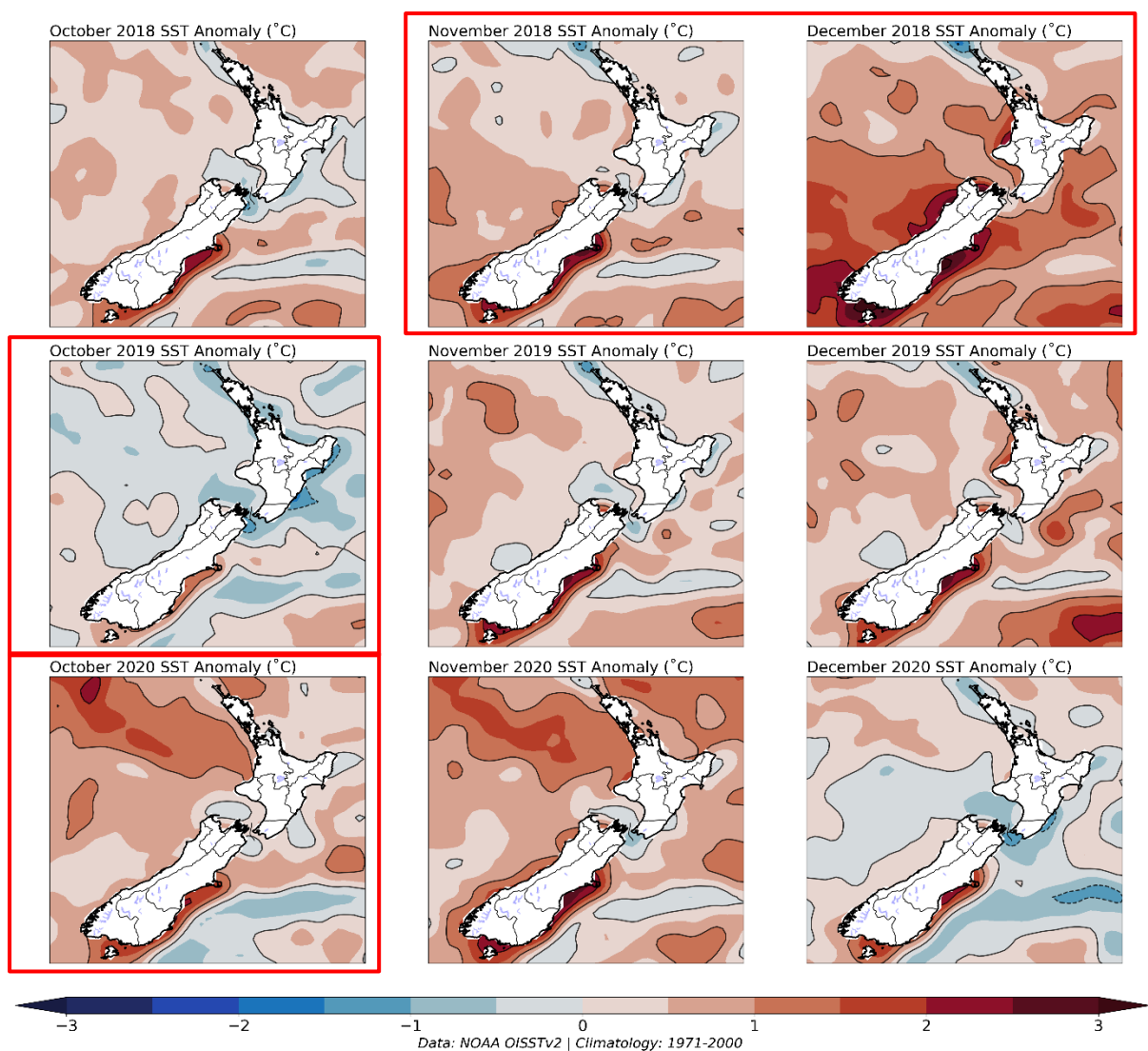
Silver warehou (SWA)

Number of surveys	5
Total catch weight (kg)	11.5
Number measured	100
Length range (mean) (cm)	8–26 (13.93)
Number weighed	NA



APPENDIX 7: Sea surface temperature anomaly patterns for survey years





High Resolution Sea Surface Temperature (SST) anomaly data for October, November, and December in each of the survey years from 1989–2020. Red boxes bound the months of the survey in each year. The anomaly values are relative to a baseline reference period of 1982–2010 (NOAA 2022).