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SCA 7 stock survey, November 2015

New Zealand Fisheries Assessment Report 2015/79

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An extensive dredge survey of scallops (*Pecten novaezelandiae*) was conducted from 30 October to 18 November 2015 within the Southern scallop stock, SCA 7 (Golden Bay, Tasman Bay, and the Marlborough Sounds). The aim was to evaluate the status of the SCA 7 scallop stock, to inform fisheries management decisions for the 1 April 2016 sustainability round. The stock supports highly valued commercial and recreational scallop fisheries, but there is increasing concern about sustainability following substantial declines in biomass that occurred in the 2000s in Golden and Tasman Bays and the continued decreasing biomass observed in the Marlborough Sounds since 2009.

The survey used a stratified random sampling allocation design, with sampling conducted using a chartered commercial fishing vessel and ring-bag scallop dredge. The sample extent (survey coverage) covered all areas between at least 10 and 50 m depth that were appropriate to sample with a commercial dredge, and the survey stratification within these areas was based on multiple information layers. The survey design involved important engagement with fishery stakeholders within a very tight timeframe. A total of 318 valid stations (dredge tows) were sampled within 67 strata, with over 39 000 live scallops caught. As expected, the highest catches of recruited scallops (90 mm or larger) were from tows within key strata, primarily in the Marlborough Sounds, which represent the banks and bays that support the main scallop beds. Catches were generally low in other strata. There were minimal densities of recruited scallops outside of the previously surveyed areas, even though the extent of the November survey was over twice the area of that used in previous annual (May) surveys. There were signs of recent juvenile recruitment, particularly in the Marlborough Sounds, that appeared to be stronger than normally seen in the May surveys, although comparisons are difficult because this could be a result of the different survey timing. Absolute biomass of recruited scallops in the SCA 7 area surveyed in November was 211 t (95% CI = 141–321t, mean = 214 t, CV = 0.21). Recruited biomass was very sensitive to critical density thresholds (the exclusion of areas of low scallop density): excluding areas of very low density (below 0.04 m^{-2}), the SCA 7 biomass was 63 t meatweight, equating to only 30% of the absolute biomass. Only small proportions of the recruited biomass were held in relatively high density scallop beds, which are particularly important for scallop stock productivity (i.e. larval production) as well as for fisheries utilisation. Spawning biomass (70 mm or larger) was substantially higher than recruited biomass (90 mm or more), as can be expected, but almost all of the spawning biomass was held in the Marlborough Sounds. Spawning biomass was less affected by critical density effects than recruited biomass.

Overall the SCA 7 stock continues to decline, and stock status appears to be at the lowest recorded level. Recruited biomass in Golden Bay and Tasman Bay sectors D–G remains at very low levels since the large declines occurred in the 2000s, and although there was some recruited biomass in Tasman Bay sector H it was generally held at low density. Recruited biomass in the Marlborough Sounds is restricted to a small number of areas mainly in the outer Sounds, and overall has continued to follow a declining trend since 2009. Recent commercial fishing (22 t in the 2015 season) has been limited almost exclusively to a few specified areas in the Marlborough Sounds. The level of recreational harvest in 2015 is unknown. The commercial exploitation rate in 2015 in the Marlborough Sounds was 21%, in line with the target exploitation rate of 22% associated with an increasing biomass observed between 1999 and 2008. A minimum reference level has not been established for SCA 7, and, because spatial scale is inherently important in scallop population dynamics and fisheries, a single minimum reference level for the stock would be unsuitable. It is clear, however, that the stocks in Golden and Tasman Bays are below desirable minimum levels, and the stock in the overall Marlborough Sounds is at the lowest recorded level in the survey time series.

1. INTRODUCTION

1.1 Overview

This report summarises the findings of an extensive dredge survey of scallops (*Pecten novaezelandiae*) in the Southern scallop stock, SCA 7, conducted between 30 October and 18 November 2015.

Scallops support important commercial and non-commercial (recreational and customary) fisheries in the Southern, or Challenger, scallop stock 'SCA 7' at the north of New Zealand's South Island. The SCA 7 stock comprises the regions (substocks) of Golden Bay, Tasman Bay, and the Marlborough Sounds, subdivided into constituent Scallop Statistical Reporting Areas (sectors) (Figure 1).

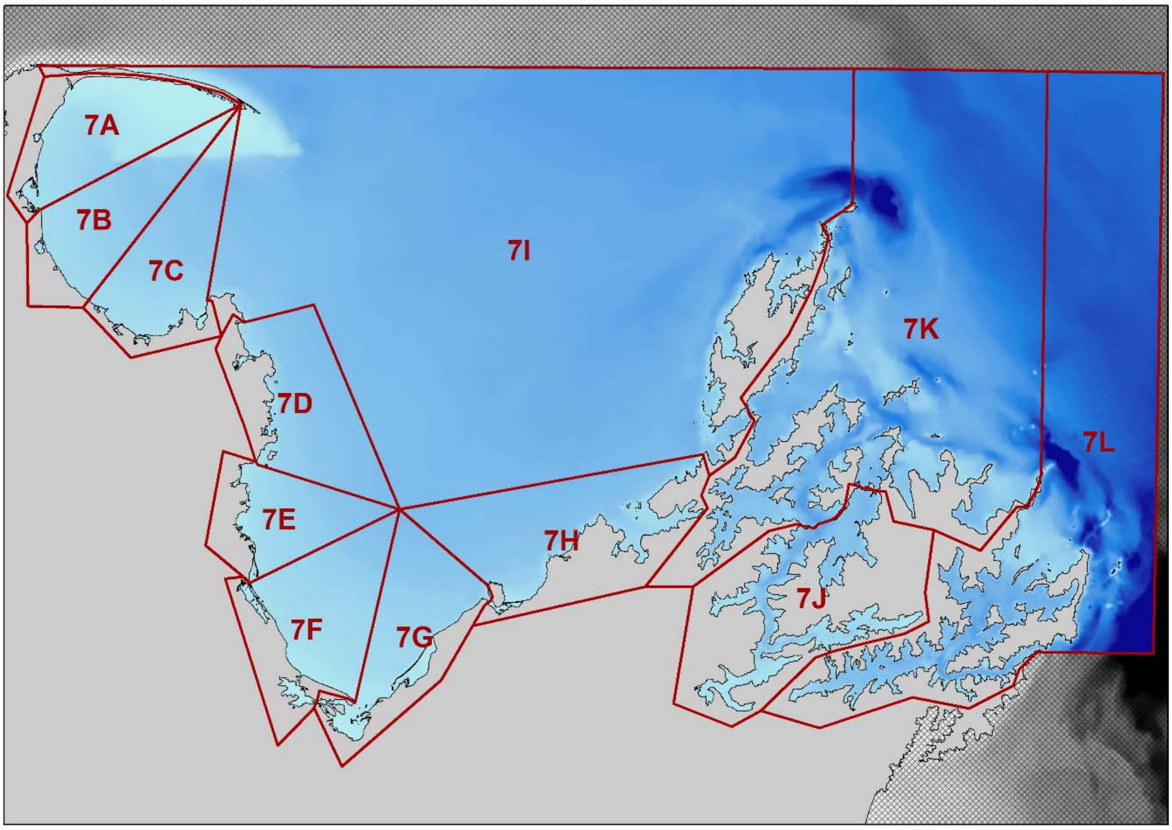


Figure 1: The SCA 7 stock area, subdivided into its constituent Statistical Reporting Areas (sectors) 7A–7C (Golden Bay), 7D–7H (Tasman Bay), 7I (outer Golden/Tasman Bays), and 7J–7L (Marlborough Sounds).

SCA 7 is a Group 2 stock in the draft National Fisheries Plan for Inshore Shellfish (Ministry for Primary Industries 2011), and management objectives for Group 2 stocks in this Plan are 1) "Use Objective – Maximise social, economic and cultural benefits obtained from each stock by enabling annual yield to be maximised"; and 2) "Environment (Stock sustainability) Objective – Maintain stock size at or above an established minimum reference level". Within Group 2, SCA 7 is listed on the Third Schedule of the Act because of a rotational fishing and enhancement approach to management carried out under a Memorandum of Understanding (MoU) agreement between industry (Challenger Scallop Enhancement Company Ltd) and the Ministry for Primary Industries (MPI, formerly Ministry of Fisheries, MFish) (MFish & CSEC 1998).

Annual pre-fishing season dredge surveys have been conducted in May–June in important fishery areas within SCA 7 since 1994 to assess scallop population status and inform management of the fishery before the start of the commercial fishing season (nominally 1 September); the surveys provide data for estimating scallop population distribution, size structure, abundance (numbers and biomass) and yield (Williams et al. 2014). The most recent of these surveys was conducted in May 2015 (Williams et al. 2015a). This survey series has shown that substantial declines in recruited biomass occurred in the 2000s in Golden Bay and Tasman Bay, and scallop populations in these bays have since remained at very low levels. The May 2015 survey confirmed this, but did indicate the presence of some scallop beds in sector H of Tasman Bay. In Marlborough Sounds, recruited biomass generally followed an increasing trend from 1999 to 2009 (with evidence of a peak in 2002), and a decreasing trend from 2009 to 2015.

Because of the continued decline in the previously surveyed areas of SCA 7, and to inform sustainability decisions for the 1st April 2016 sustainability round, MPI required a full November 2015 survey of scallops in the SCA 7 stock in this project (SCA201504). Note that an in-season survey of specified scallop fishing areas in the Marlborough Sounds within the SCA 7 scallop stock was also completed in October 2015 under a separate project, SCA201503 (Williams et al. 2015b).

1.2 Objectives

This work was carried out under Ministry for Primary Industries project SCA201504: SCA 7 stock survey, November 2015. The overall research objective was "to evaluate the status of the SCA 7 scallop stock". The specific research objectives were to "1) conduct a biomass survey that will provide estimates of the current abundance, length frequency, biomass (in tonnes greenweight and meatweight) and density in SCA 7; 2) estimate the biomass of scallops using a range of density thresholds from 0.00 to 0.2 recruited scallops per square metre; and 3) compare the estimates from Objective 1 with relevant data from previous surveys and, if available, all relevant fine scale catch data".

These three specific objectives combined to form a unified project: conducting a full stock survey provided an up-to-date assessment of the scallop populations within the SCA 7 stock area, estimating biomass at a range of density thresholds indicated how much of the absolute biomass was held in the important high density (high productivity) scallop beds, and comparison of estimates from this survey with estimates from previous surveys enabled an assessment of the status of the stock and an examination of whether there have been changes in the recent population status and over the longer term.

1.3 Conceptual framework

The conceptual framework of conducting a dredge survey using stratified random sampling to estimate scallop population abundance is well established. Dredging can provide data for estimating relative abundance because dredges catch only a proportion of scallops within the area of seabed swept by the dredge, but with information on dredge catchability (a combination of the efficiency and size selectivity of the dredge) relative estimates can also be converted to absolute estimates.

1.4 Previous and current research

This project directly relates to the October 2015 in-season survey of scallops in specified areas of the Marlborough Sounds (Williams et al. 2015b), to the May 2015 survey of scallops in SCA 7 (Williams et al. 2015a), to an in-season survey of Guards Bank (Marlborough Sounds) conducted in September 2014 (Williams 2014), and to previous annual dredge surveys in the SCA 7 survey series (Williams et al. 2014). It also indirectly relates to past and present NIWA research on assessing New Zealand scallop resources for MPI, including dredge surveys of commercial scallop beds (e.g. Williams et al. 2007, Williams et al. 2013, Williams et al. 2015a), dive surveys of recreational scallop beds (e.g.Williams 2012), and dredge efficiency modelling (Bian et al. 2012), and is relevant to current NIWA research to improve assessment methods for scallops (MPI project SCA201301). This project (SCA201504) was carried out shortly after completing the associated project SCA201503: SCA 7 in-season survey, October 2015 (Williams et al. 2015b).

1.5 Project approach

In this project, we conducted a post-season survey using a commercial scallop fishing vessel and ring-bag dredge. All methodology proposed was presented to the MPI Shellfish Working Group (SWG) on 30 September 2015 at the initiation of the project, and suggestions or required changes to improve methods were addressed before the survey was conducted. A resampling with replacement (bootstrapping) approach to estimating scallop abundance and biomass was used to analyse the survey data collected. We used the resulting estimates to assess the current status (distribution, size structure, and abundance) of the scallop population in SCA 7, estimated the biomass of scallops using a range of density thresholds from 0.00 to 0.2 recruited scallops per square metre, and compared the current status with the status in previous surveys to investigate whether changes have occurred in the population. The results of the project were presented to the Shellfish Working Group on 26 November 2015.

2. METHODS

2.1 Survey design

The November 2015 dredge survey of scallops in SCA 7 was conducted using a stratified random sampling allocation design. Sampling was single phase only due to logistics. The survey design involved important engagement with fishery stakeholders and authorities (commercial fishers, recreational fishing representatives, MPI, Department of Conservation, Marlborough District Council, environmental consultants) and the use of multiple information layers within a very tight timeframe.

The sample extent (survey coverage) covered all areas that were appropriate to sample with a commercial dredge within the SCA 7 stock. The initial extent (Figure 2, top plot) included all areas bounded by the 10 m and 50 m depth contours plus some additional areas outside of that depth zone where there was quantitative (survey) or anecdotal evidence of scallop beds (e.g. in waters shallower than 10 m in Golden Bay adjacent to Farewell Spit, and in waters deeper than 50 m in Pelorus Sound and Queen Charlotte Sound). The initial extent was subsequently modified by excluding a variety of areas that could not be sampled by dredge (Figure 1, bottom), including rocky reefs, marine reserves, marine farms, ecologically sensitive marine areas informed by Davidson et al. (2011) and Davidson & Richards (2015), the Separation Point fisheries closure area, regulated dredge prohibition areas, the voluntary closure to trawling and dredging in Golden Bay (T. Osborne, pers. comm.), and shallow waters exposed to swell at Outer Farewell Spit.

Within the final extent, the survey area was partitioned into previously surveyed and unsurveyed areas based on the positions of dredge survey tows conducted between 1994 and May 2015 (Figure 3, top) and using local knowledge acquired from engagement with commercial and recreational fishers and from a map showing the historic distribution of scallop beds in Pelorus Sound (Figure 3, bottom) produced by Handley (2015) using information from Bull (unpub.), Stead (1971a), and Stead (1971b).

For the previously surveyed areas, patterns in scallop distribution were explored by producing inverse distance weighted (IDW) interpolations of scallop density (number of recruited scallops per standard tow distance of 0.4 n.miles) (Figure 4). These suggest that in the past the main scallop beds (highest densities of recruited scallops) were generally found between 10 and 20 m depth in Golden Bay, between 15 and 25 m depth in Tasman Bay, and between 10 m and 30 m on banks and in bays in the Marlborough Sounds. The interpolations using the most recent five years of survey data (2011 to 2015) were used to inform the stratification of the surveyed areas, shown overlaid on top of the IDW plots and in relation to the local knowledge of scallop beds map (Figure 5). The previously unsurveyed areas were stratified by depth into 10–30 m and 30–50 m strata, subdivided into separate strata for areas where local knowledge indicated there had been scallop beds in the past.

The final stratification for the SCA 7 stock survey November 2015 is shown in Figure 6, and stratum details are shown in Table 1. There were 67 strata in total (44 in the surveyed areas, 23 in the unsurveyed areas), with a combined total area (survey extent) of 3514 km^2. The strata are shown at a larger scale for the Golden Bay, Tasman Bay, and Marlborough Sounds (north and south) regions in Appendix 1.

2.2 Station allocation

Station allocation for the previously surveyed areas was conducted using the R function *allocate* (Francis 2006), which allocates stations to strata so as to achieve a specified coefficient of variation (CV), or to minimise the CV with a fixed number of stations. For the SCA 7 surveys, station allocation is to minimise the CV with a fixed number of stations. The CV is calculated from historical survey data and the estimated areas of the strata. The strata for the SCA 7 stock survey were intersected with station data from the 2011–2015 SCA 7 surveys (5 years of survey data) to assign catch densities (scallops 90 mm or larger per square metre swept area) to the specified survey strata.

In the unsurveyed areas, stations were allocated to each stratum based on expected relative abundance of scallops: high 10–30 m for areas indicated as past scallop beds; medium 10–30 m, and low 30–50 m.

A total of 320 stations were allocated: 200 in the previously surveyed areas, and 120 in the unsurveyed areas. The specific number of stations allocated to and actually sampled in each stratum is shown in Table 1.

Station positions within strata were randomised using GIS software, constrained to keep stations a minimum distance apart; this software was also used to estimate the area of each stratum.

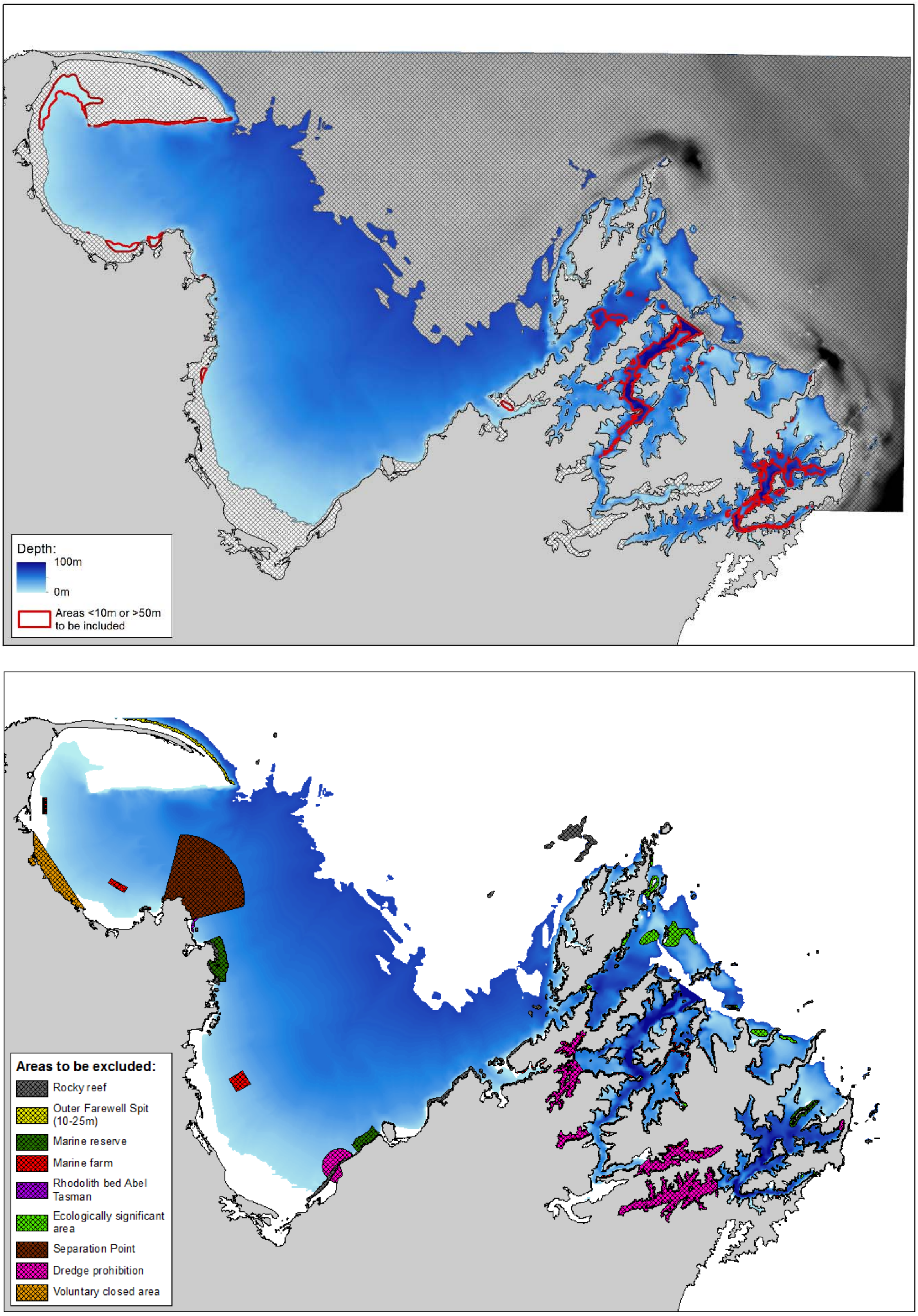


Figure 2: Initial survey extent (top) and exclusion areas (bottom).

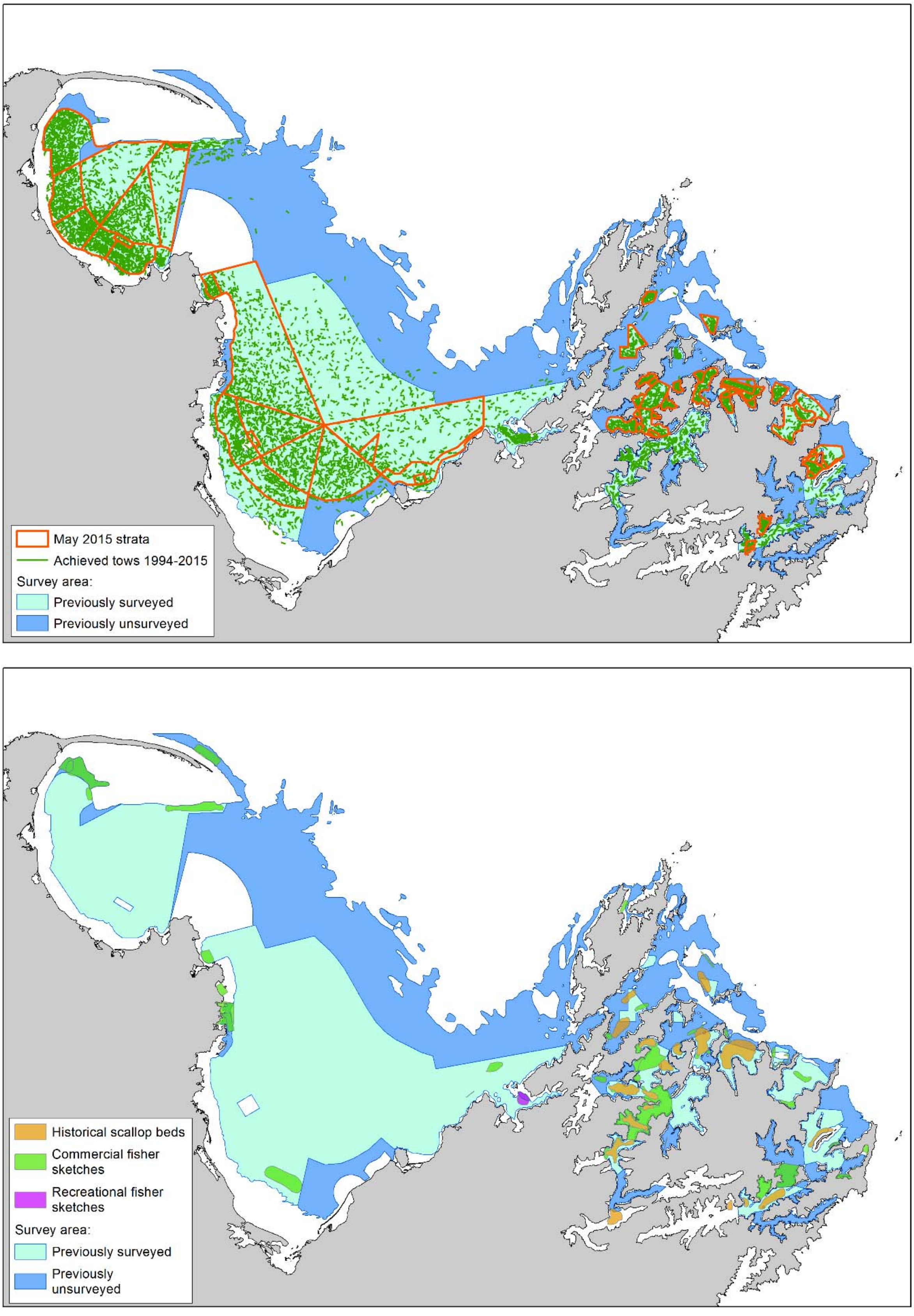


Figure 3: Top: Distribution of survey dredge tows (green line symbols) within SCA 7 between 1994 and May 2015. Shaded areas indicate what was considered to be the extent of the previously surveyed areas (light green shading) and unsurveyed areas (blue shading) within the November 2015 initial survey extent delimited by the 10 m and 50 m depth contours. Orange polygons denote the May 2015 survey stratum boundaries. Bottom: Local (anecdotal) knowledge of historical scallop beds in SCA 7.

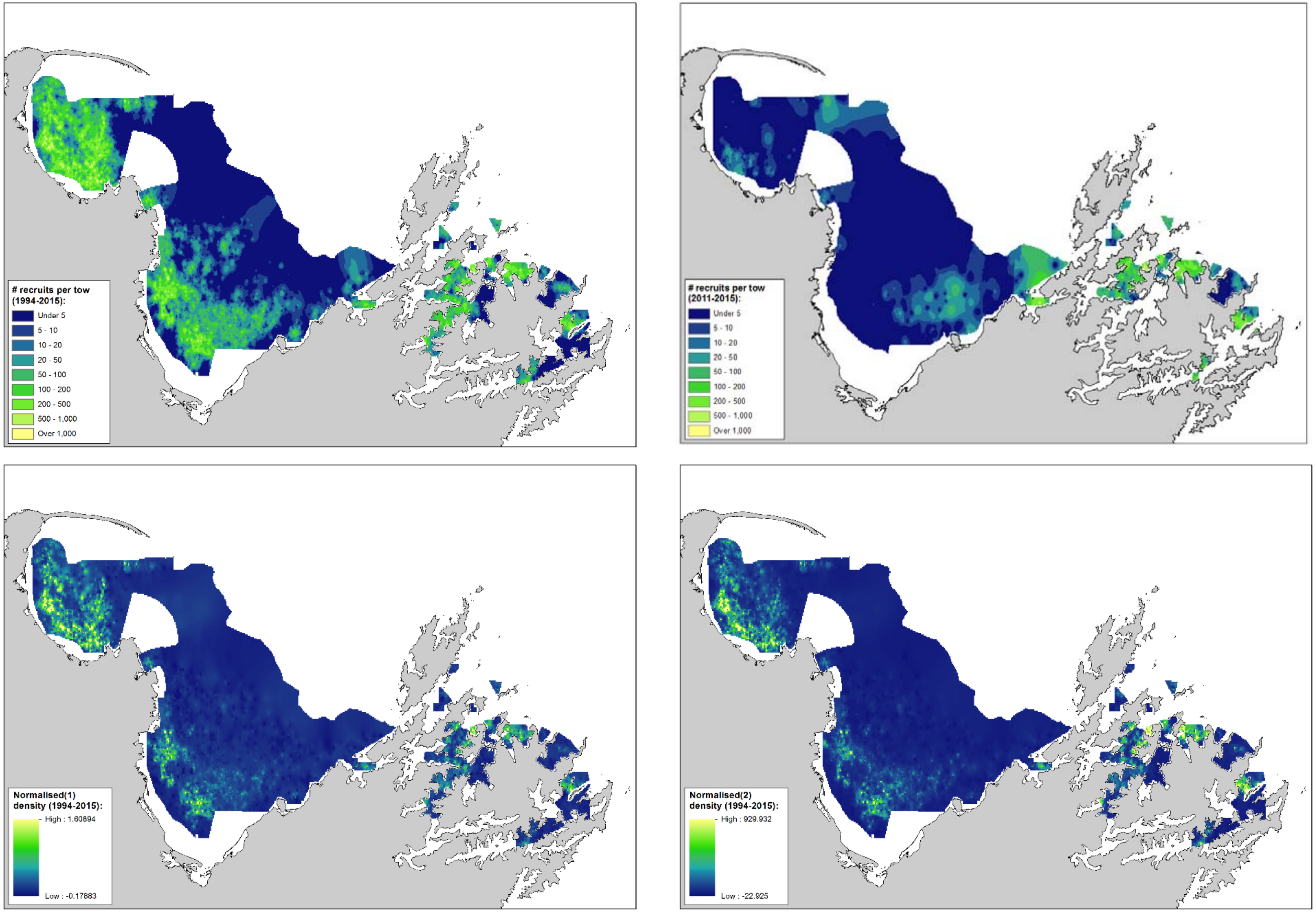


Figure 4: Distribution of recruited size scallops (90 mm or larger) from annual dredge surveys in areas of SCA 7 between 1994 and 2015. Each map is an inverse distance-weighted (IDW) interpolation of scallop density from the survey station data. Top plots show scallop density as the number of recruited scallops per standard tow distance (0.4 n.miles) for the entire survey series (left, 1994–2015) and more recently (right, 2011–2015). Bottom plots were produced by normalising the same data: observed minus the mean (left); and observed minus the mean divided by the standard deviation (right).

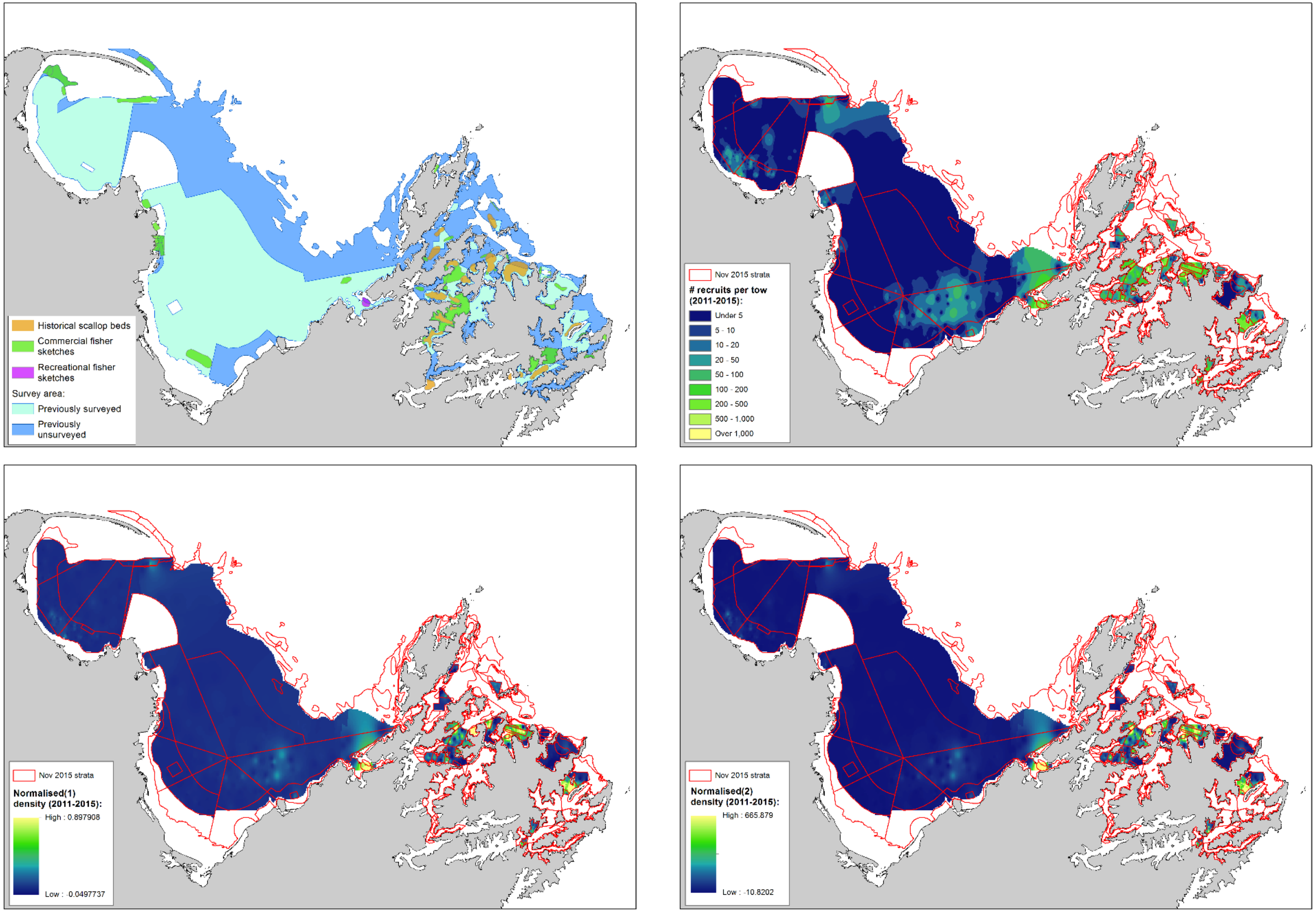


Figure 5: SCA 7 survey strata November 2015 in relation to local anecdotal knowledge of scallop beds (top left) and the distribution of recruited size scallops (90 mm or larger) from annual dredge surveys in areas of SCA 7 between 2011 and 2015. Each of the three distribution maps is an inverse distance-weighted (IDW) interpolation of scallop density from the survey station data. Top right plot shows scallop density as the number of recruited scallops per standard tow distance (0.4 n.miles), and bottom plots were produced by normalising the same data: observed minus the mean (bottom left); and observed minus the mean divided by the standard deviation (bottom right).

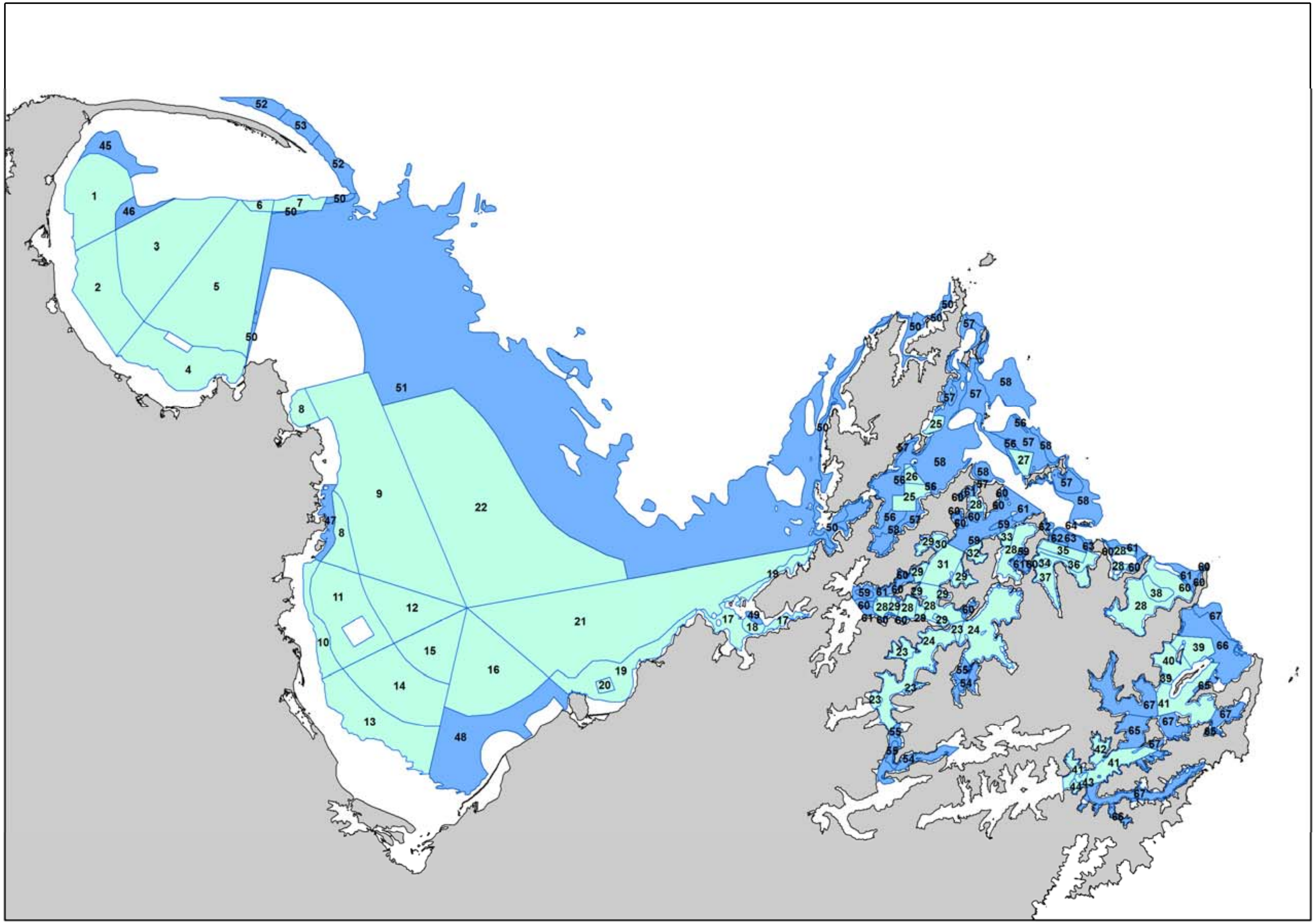


Figure 6: Stratification for SCA 7 stock survey, November 2015. Previously surveyed areas (light green shading) were stratified separately from previously unsurveyed areas (blue shading). Number labels are stratum codes specific to this survey and do not correspond with those used in the May 2015 SCA 7 survey (Williams et al. 2015a).

Table 1: Stratum details for the SCA 7 stock survey, November 2015. Areas were calculated using ArcGIS® software by ESRI; the total survey area (extent) was 3514 km^2. Sector is equivalent to Statistical Reporting Area.

Category	Region	Sector	Stratum	Area (km^2)	Allocated	Sampled
Surveyed	GB	7A	1	62.3	5	5
		7B	2	64.5	9	9
			3	109.0	3	3
		7C	4	61.6	8	8
			5	151.0	6	6
			6	4.1	3	3
	GBTB	7I	7	9.9	6	6
	TB	7D	8	29.4	3	3
			9	227.4	4	4
		7E	10	19.2	3	3
			11	64.4	4	4
			12	46.9	3	3
		7F	13	64.8	3	3
			14	67.9	4	4
			15	39.7	3	3
		7G	16	87.9	3	3
		7H	17	15.7	3	3
			18	3.6	3	3
			19	50.3	3	3
			20	2.9	3	3
			21	243.7	10	10
	GBTB	7I	22	341.6	3	3
	MS	7J	23	10.1	7	7
			24	61.5	4	4
		7K	25	13.0	3	3
			26	3.3	3	3
			27	5.5	3	3
			28	71.2	8	8
			29	17.4	12	10
			30	1.4	3	3
			31	14.1	4	4
			32	3.4	5	5
			33	2.9	4	4
			34	1.2	3	3
			35	6.4	6	6
			36	5.8	4	4
			37	12.1	3	3
			38	6.0	3	3
		7L	39	12.5	6	6
			40	10.0	10	10
			41	42.7	4	4
			42	4.5	3	3
			43	1.4	3	3
			44	1.4	4	4

Table 1 continued

Category	Region	Sector	Stratum	Area (km^2)	Allocated	Sampled
Unsurveyed	GB	7A	45	17.7	4	4
			46	9.4	3	3
	TB	7D	47	10.5	3	3
		7G	48	79.0	3	3
		7H	49	1.6	3	3
	GBTB	7I	50	27.2	6	6
			51	872.4	18	18
			52	19.7	5	5
			53	7.8	5	5
	MS	7J	54	17.2	3	3
			55	6.7	3	3
		7K	56	10.0	6	6
			57	52.9	6	6
			58	123.7	6	6
			59	5.2	6	6
			60	12.2	6	6
			61	48.4	6	6
			62	1.7	4	4
			63	5.6	3	3
			64	2.5	3	3
		7L	65	11.9	6	6
			66	38.7	6	6
			67	57.0	6	6

2.3 Dredging procedures

Dredging was undertaken from the same chartered fishing vessel (FV *Okarito*) using the same survey skipper, mate, and commercial ring-bag dredge gear as used in the May 2015 survey. The SCA 7 stock survey was carried out after the commercial scallop fishing season had ended.

A standard protocol for scallop dredge sampling was followed. The vessel was positioned at each random station position allocated with non-differential GPS. The dredge was deployed and towed for a standard tow length (0.4 n.miles), but the tow length was 0.2 n.miles in some strata (strata 29, 30, 32, 33, 40, and 44) selected *a priori*. The actual tow length can be calculated from the logged GPS positions at the start and end of the tow. Additionally, a potentially more accurate estimate of the tow length was available from the Seaplot doppler log of the vessel path during the tow; this method was used to calculate the tow distance used in the survey analysis. The tow started when the winch brakes were set, and ended when hauling with the winch commenced. The skipper was instructed to fish the gear (tow towards the next station, maintain constant target speed of 2.8 knots, and maintain consistent warp to depth ratio) so as to maximise the total catch at that station while avoiding crossing stratum boundaries, depth contours, foul ground, and obstructions. At the end of the tow, the dredge was retrieved, the percentage fullness of the dredge visually estimated, and the dredge contents emptied onto a sorting tray at the stern of the vessel. Bottom type was categorised (as mud, silt, or sand) after visual inspection of the sediment type present in the dredge contents.

2.4 Catch sampling

A standard dredge catch sampling procedure was followed. All live scallops were sorted from the entire catch and placed into fish cases (‘bins’) (Figure 7). Dead scallops termed ‘cluckers’ (articulated scallop shells, shell hinge still intact) were also sorted from the catch to provide information on levels of recent mortality. All scallops (live scallops and dead ‘cluckers’) were measured for shell length (along the anterior–posterior axis, using digital calipers mounted on a measuring board). The remaining unsorted bycatch was characterised by estimating its volume and the percentage composition in different bycatch categories.

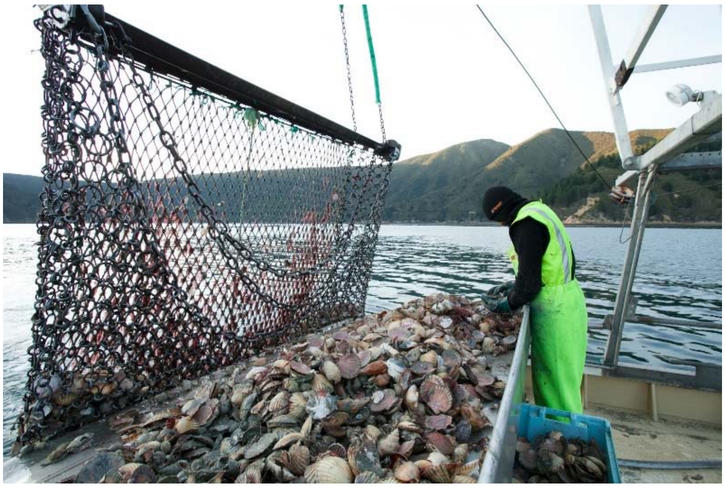


Figure 7: Ring-bag dredge survey catch being sorted at the stern of the vessel.

Additionally, scallops (n = 286) of a broad range in size (38–123 mm) were collected from survey dredge tows in Guards Bay and transferred to the NIWA Nelson laboratory. The scallops were processed using methods described by Williams & Babcock (2005) and Williams & Babcock (2004) to obtain data for investigating relationships between individual scallop size and weight, condition, and reproductive maturity. These data were not examined within the present study, but should be analysed and reported as part of future project work on SCA 7.

2.5 Survey data

The tow data (date, station number, recorder, tow start and finish times and positions, wind force, water depth, dredge fullness, bottom type) and bycatch data (volume and percentage composition) were recorded on pre-printed waterproof forms; the catch data (scallop length data) were captured electronically. The data will be loaded to the MPI '*scallop*' database. Data on Guards Bay scallop size, condition and gonad maturity, and 'GoPro®' video camera footage of dredging operations captured on some of the survey tows, are stored in the NIWA SCA201504 project directory.

2.6 Estimation methods

NIWA use a non-parametric resampling with replacement (bootstrapping) method of estimating the density, abundance, and biomass of scallops from dredge surveys. This method was developed during the 2002 and 2003 Coromandel and Northland scallop survey analyses, which was described by Cryer & Parkinson (2006), and more recently was described in detail by Williams et al. (2013). It has been used to analyse SCA 7 survey data since 2008 (Tuck & Brown 2008), and the same method was used again for the 2015 analysis. The parameters used in this method for the SCA 7 analysis were summarised in the recent review of the SCA 7 fishery by Williams et al. (2014), and were detailed in Section 2.6 of the May 2015 survey report (Williams et al. 2015a).

The estimation method uses bootstrapping (1000 bootstrap iterations) to produce 1000 estimates of the metrics of interest (scallop density, abundance, greenweight biomass, and meatweight biomass). Each of the 1000 bootstrap iterations involves the following five steps:

1. **Sampling fraction.** The "raw" length frequency distribution for each tow is "scaled" by the inverse of the sampling fraction (no. of scallops measured / total no. of scallops counted).
2. **Swept area.** The "scaled" length frequency distribution for each tow is converted to "uncorrected" density at length per unit area of seabed swept by the dredge (assuming the dredge to be 100% efficient for all size classes and assuming that the calculated area swept by the dredge is without error).
3. **Dredge efficiency.** The "uncorrected" density length frequency for each tow is corrected for dredge efficiency to estimated "real" density at length per unit area of seabed. Dredge efficiency is randomly selected from 4000 sets of dredge efficiency at length scalars (the inverse of dredge efficiency) estimated by Tuck & Brown (2008).
4. **Greenweight at length.** The "real" density at length for each tow is converted to a weight at length distribution, using a length-weight (L-W) relationship to predict individual scallop weight from length. The L-W model parameters a and b are randomly selected from 2000 sets of these parameters, applying them in the L-W equation to convert density to weight.
5. **Meatweight at length.** The weight at length for each tow is converted to a meatweight at length, using estimates of the mean recovery of meatweight from greenweight in 13 previous SCA 7 fishing seasons (1996 to 2008). One of the 13 seasonal means is selected and applied to convert greenweight at length to meatweight at length.

Once the 1000 iterations are completed, summary statistics (mean, CV, median and 95% confidence intervals) for the metrics of interest are calculated from the 1000 bootstrapped estimates (produced by the steps followed above) at different levels of grouping (stratum, sector, region, stock). Time of survey estimates of density and abundance, and greenweight and meatweight biomass, are calculated from the results of the steps described above. The calculations (from Williams et al. (2013)) are detailed in Appendix B of the May 2015 survey report (Williams et al. 2015a).

Stratum length frequency distributions are calculated at the time of the survey as the mean tow length frequency distribution for that stratum scaled by the stratum area. Regional length frequency distributions are calculated as the sum of the stratum length frequency distributions for the strata within each region. The stratum areas are considered to be without error.

3. RESULTS

3.1 Sampling conducted

The survey was conducted in 15 days at sea from 30 October to 18 November 2015 (no sampling was conducted on 6–9 and 15 November). A total of 318 valid stations (dredge tows) were sampled within the 67 strata (cf. with 320 stations allocated within the 67 strata) (Figure 8). All stations allocated were sampled except for two stations that could not be sampled satisfactorily which were replaced with alternative stations, and two other stations that could not be sampled satisfactorily and could not be replaced (hence 320 stations sampled, but 318 valid stations for analysis).

The survey was conducted in three legs, with two NIWA technicians per leg. Three NIWA technicians conducted the survey (D. Parkinson, Voyage Leader for legs 1–3; D. MacGibbon, legs 1 and 3; L. Olsen, leg 2), assisted by the skipper and mate of the chartered vessel.

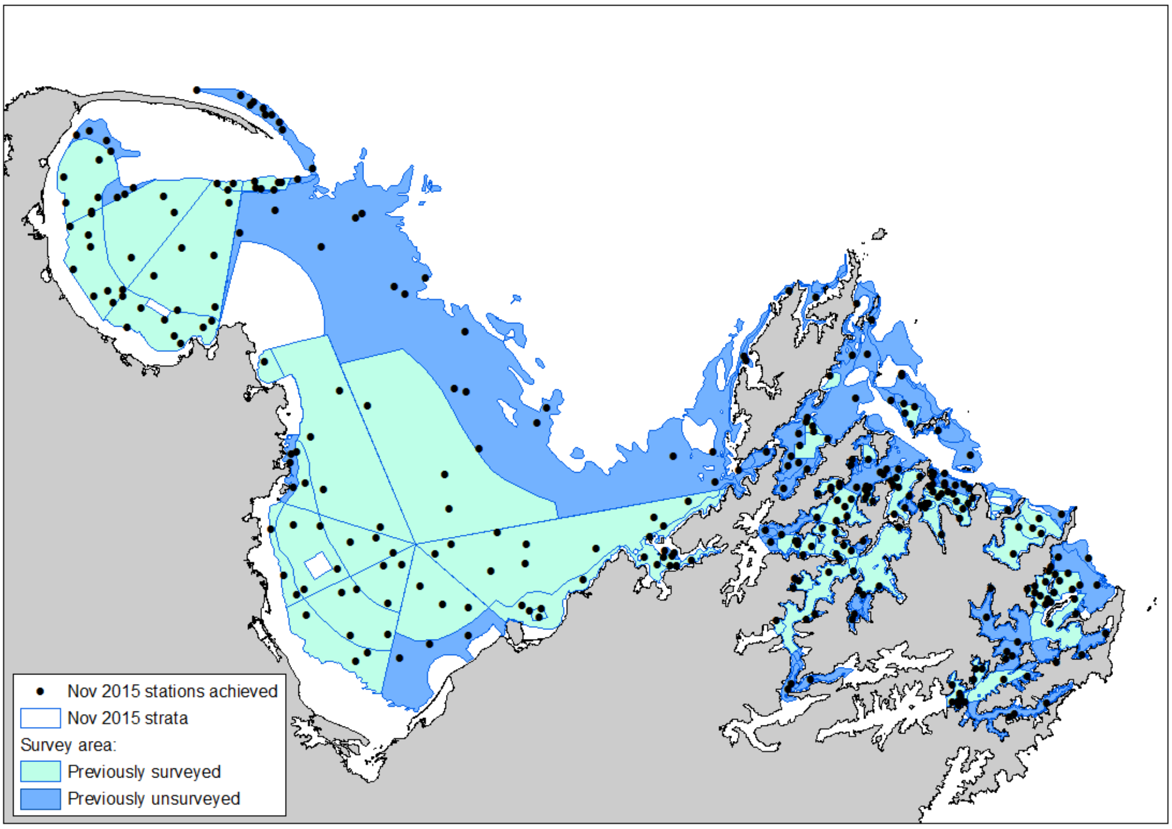


Figure 8: Station positions sampled, SCA 7 stock survey, November 2015.

3.2 Distribution

The catch of scallops per standard tow at each station for the areas surveyed is shown in Figure 9. As expected, the highest catches of recruited scallops (90 mm or larger) were from tows within key strata (primarily in the Marlborough Sounds) which represent the banks and bays that support the main scallop beds. Catches were generally low in other strata.

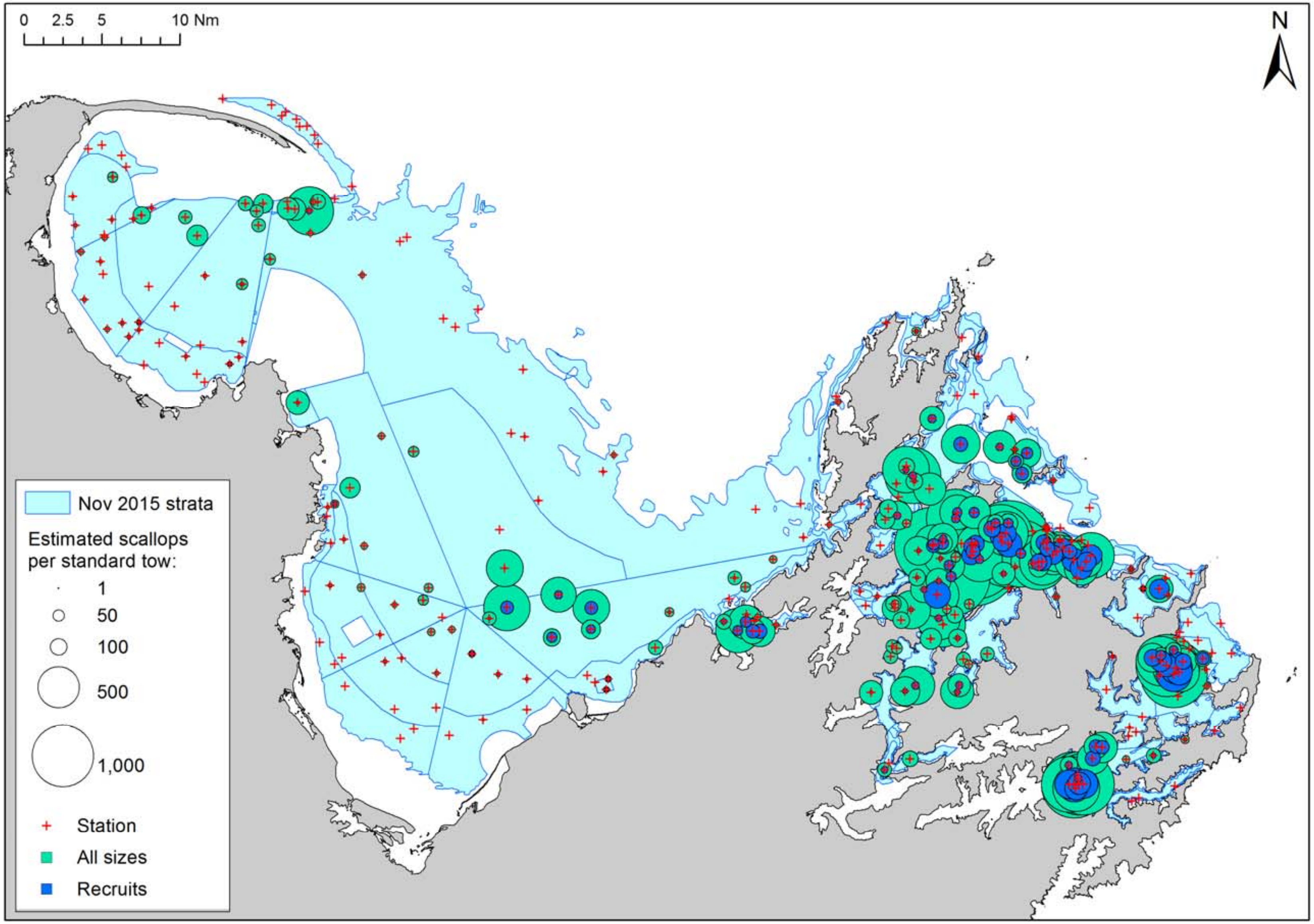


Figure 9: Catch per standard tow, SCA 7 stock survey, November 2015. Circle area is proportional to the number of scallops caught per standard distance towed (0.4 n.miles). Dark blue shaded circles denote scallops of commercial recruited size (90 mm or larger), green shaded circles denote scallops of any size. Values are uncorrected for dredge efficiency. Polygons denote survey strata boundaries.

3.3 Length frequency

Scallop length frequency distributions were plotted for the four regions of Golden Bay, Tasman Bay, Golden/Tasman Bay Outer, and Marlborough Sounds (Figure 10), and also individually for seven selected strata within Golden and Tasman Bays (Figure 11) and for nine selected strata within the Marlborough Sounds (Figure 12). Length frequency distributions at the spatial scales of the overall SCA 7 stock and its constituent sectors (statistical reporting areas) are shown in Appendix 1. Time series of length frequency distributions are shown in Appendix 4.

The regional length frequencies were very different (Figure 10). There were minimal proportions of scallops of recruited size in Golden Bay (8%) and Golden/Tasman Bay Outer (2%), and although the proportions of recruited size scallops were similar in Tasman Bay (16%) and Marlborough Sounds (17%), most of the population in Tasman Bay was held at very low density over the large area of Tasman Bay sector H. It is interesting to note that in the Marlborough Sounds there was a particularly large proportion (39%) of juvenile scallops (nominally less than 70 mm), which is obviously larger than that normally seen in the May surveys (Appendix 4, length frequency time series).

At the stratum level, there were very few strata with high density scallop beds that held large proportions of recruited size scallops, and these were in the Marlborough Sounds (e.g. strata 35 and 36 on Guards Bank and stratum 40 at Ship Cove) (Figure 12).

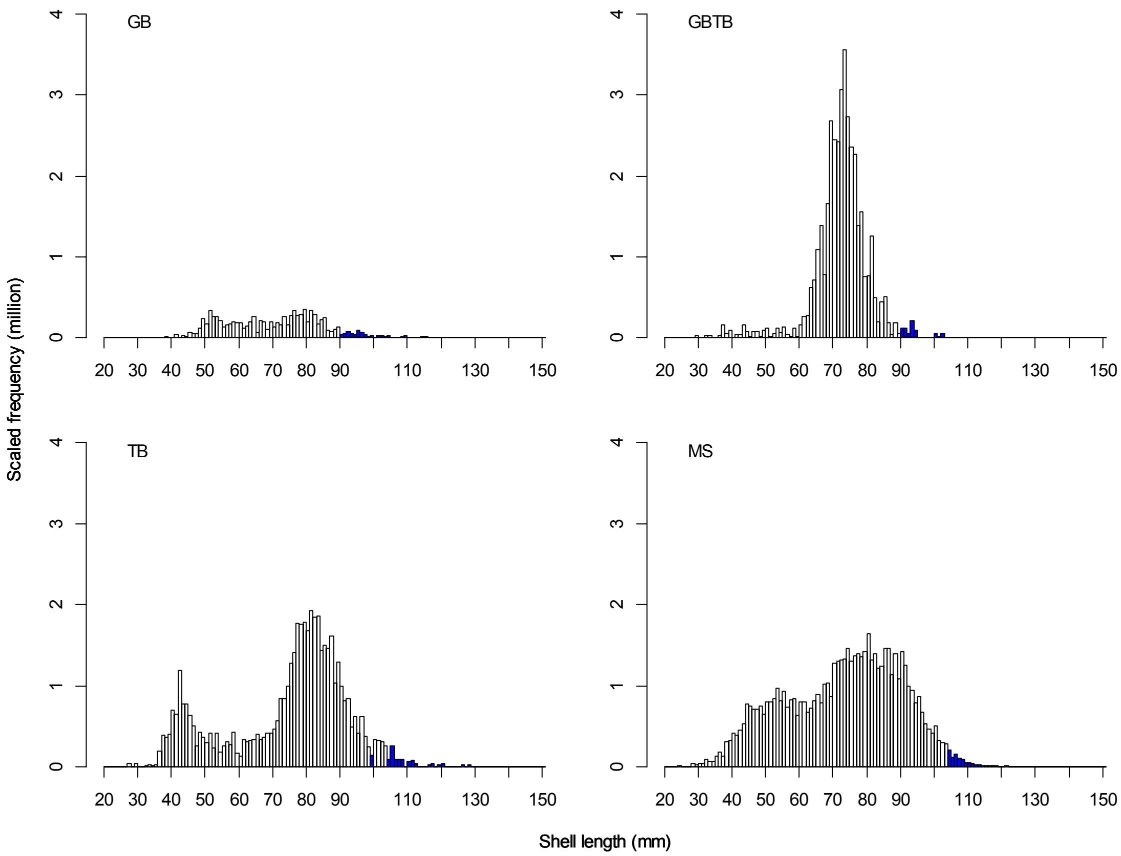


Figure 10: Length frequency distributions for scallops in four regions within SCA 7, November 2015. GB, Golden Bay, TB, Tasman Bay, GBTB, Golden and Tasman Bay Outer (Sector I), MS, Marlborough Sounds. Data corrected for historical average dredge efficiency. Dark shaded bars show recruited scallops (90 mm shell length or larger).

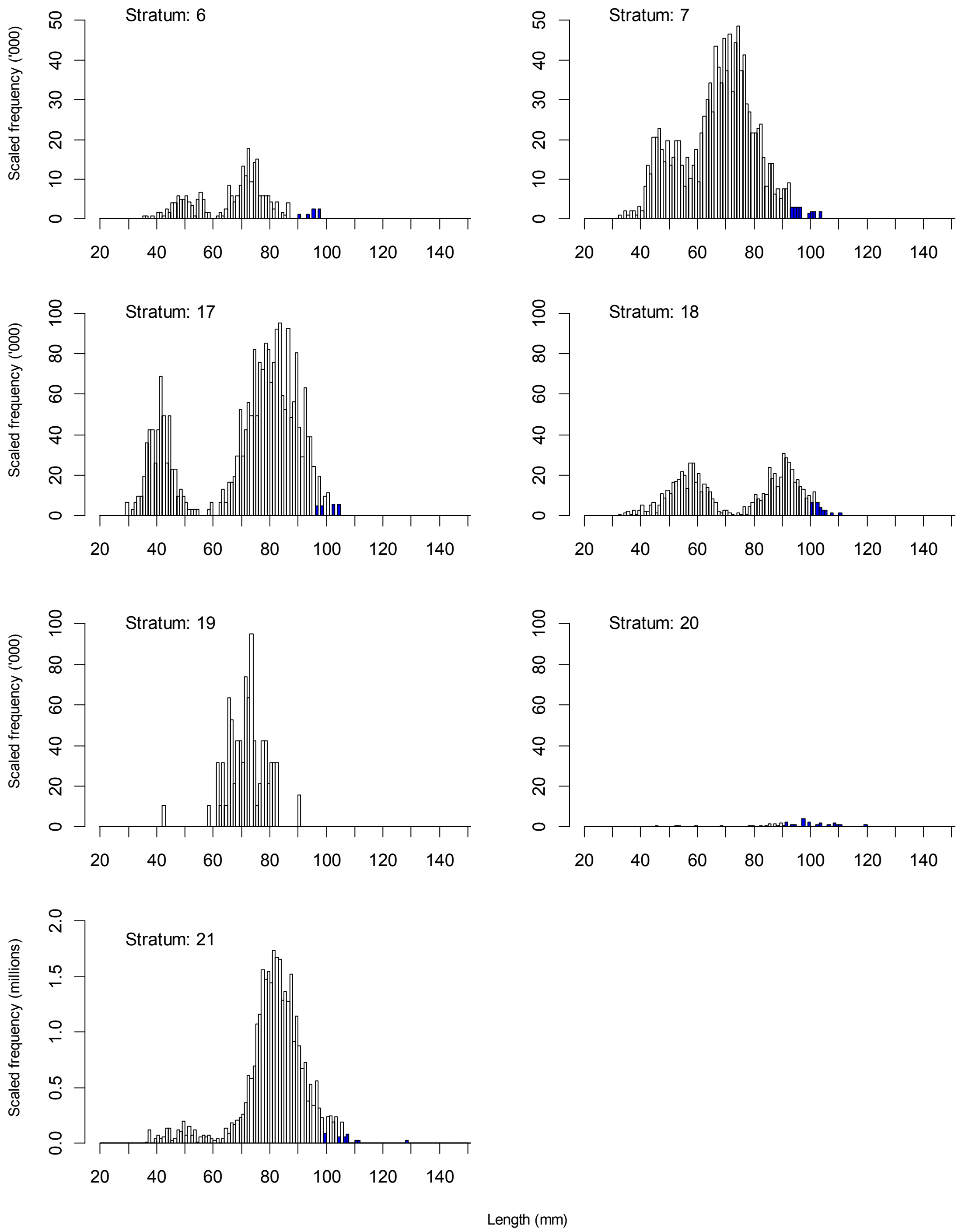


Figure 11: Stratum length frequency distributions for scallops in Golden and Tasman Bays, SCA 7 stock survey, November 2015. Seven strata are shown: 6 and 7, southeast Farewell Spit; 17 and 18, Croisilles Harbour (49, Croisilles Harbour, not shown due to low scallop catch); 19, Delaware Bay; 20; Sector H shallow; 21, Sector H deep. Data corrected for historical average dredge efficiency. Dark shaded bars show recruited scallops (90 mm shell length or larger). Note the y-axis scale varies among the strata plotted.

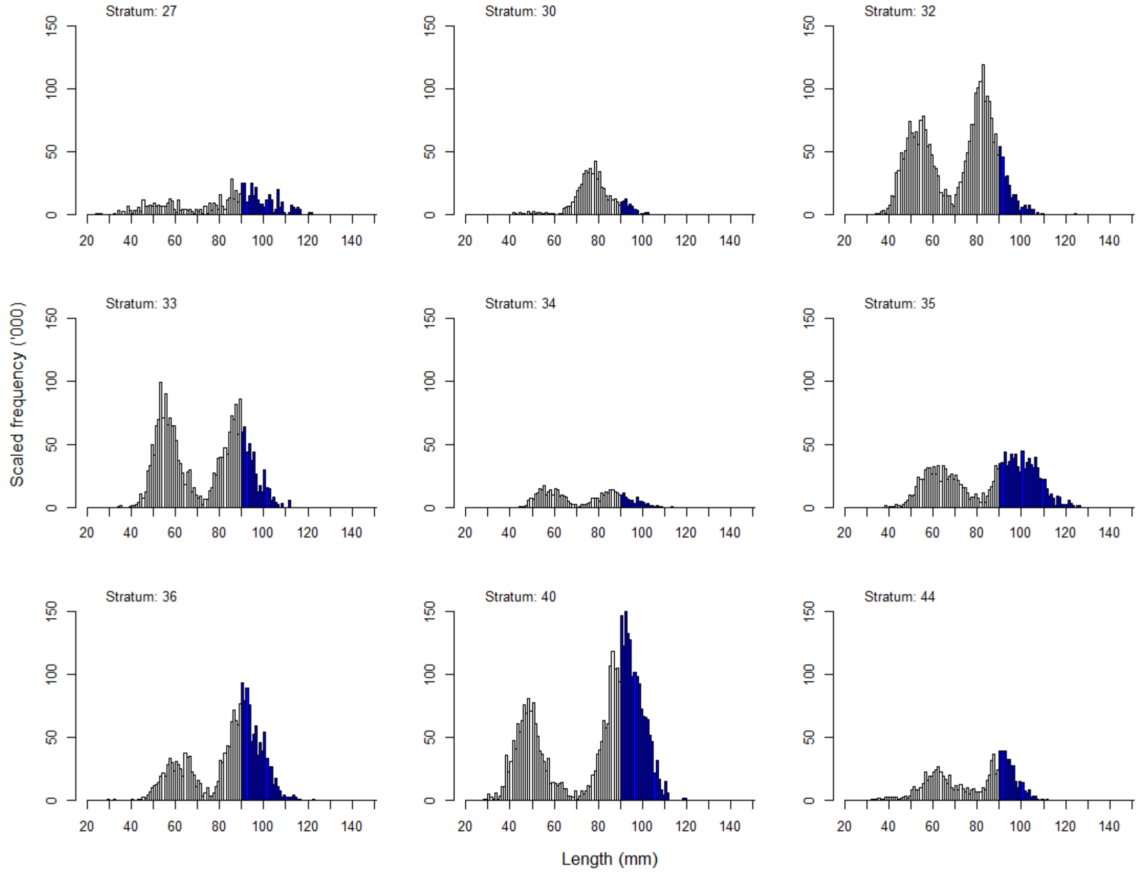


Figure 12: Stratum length frequency distributions for scallops in the Marlborough Sounds, SCA 7 stock survey, November 2015. Nine strata are shown: 27, Chetwodes; 30, Waitata Bank; 32, Ketu Bay; 33, Wynens Bank; 34, Anakoha Bank; 35, Guards Bank Fishing Area; 36, Guards Bank Outer; 40, Ship Cove; 44, Dieffenbach Bank. Data corrected for historical average dredge efficiency. Dark shaded bars show recruited scallops (90 mm shell length or larger).

3.4 Recruited biomass

Our estimation approach used non-parametric re-sampling with replacement (1000 bootstraps) to produce a sample of 1000 estimates of scallop biomass (or other metric of interest). A frequency distribution plot of those estimates (Figure 13) provides the most complete description of the nature of the variation in our sample and can be viewed as an approximation of the uncertainty in our knowledge of the biomass. The CV (standard deviation divided by the mean) is a good measure of the dispersion of that sample. The median (as opposed to the mean) is the best measure of central tendency for our sample, and the 95% confidence interval (CI) is used to express the uncertainty in our estimate.

The estimates of recruited scallops (90 mm or larger) at the time of the SCA 7 stock survey (30 October to 18 November 2015) at the stock, region, and sector levels are presented in Table 2, and at the stratum level in Appendix 3 (Table 5: Golden and Tasman Bays previously surveyed areas; Table 6: Marlborough Sounds previously surveyed areas; Table 7: previously unsurveyed areas).

Recruited biomass (t meatweight) in each region (substock) of SCA 7, and for the combined total, were as follows:

- Golden Bay 9 t (95%CI = 5–16 t; mean = 9 t, CV = 0.31)
- GBTB Outer 7 t (95%CI = 2–15 t; mean = 7 t, CV = 0.49)
- Tasman Bay 81 t (95%CI = 43–141 t; mean = 84 t, CV = 0.29)
- M. Sounds 111 t (95% CI = 74–173 t; mean = 114 t, CV = 0.23)

- SCA 7 211 t (95% CI = 141–321t, mean = 214 t, CV = 0.21).

Based on mean estimates of recruited biomass (see values presented in Appendix 3), about 40 t (19%) of the total SCA 7 biomass was held in the previously unsurveyed areas, and the majority of that biomass (about 36 t, or 17% of the total) was held in the Marlborough Sounds.

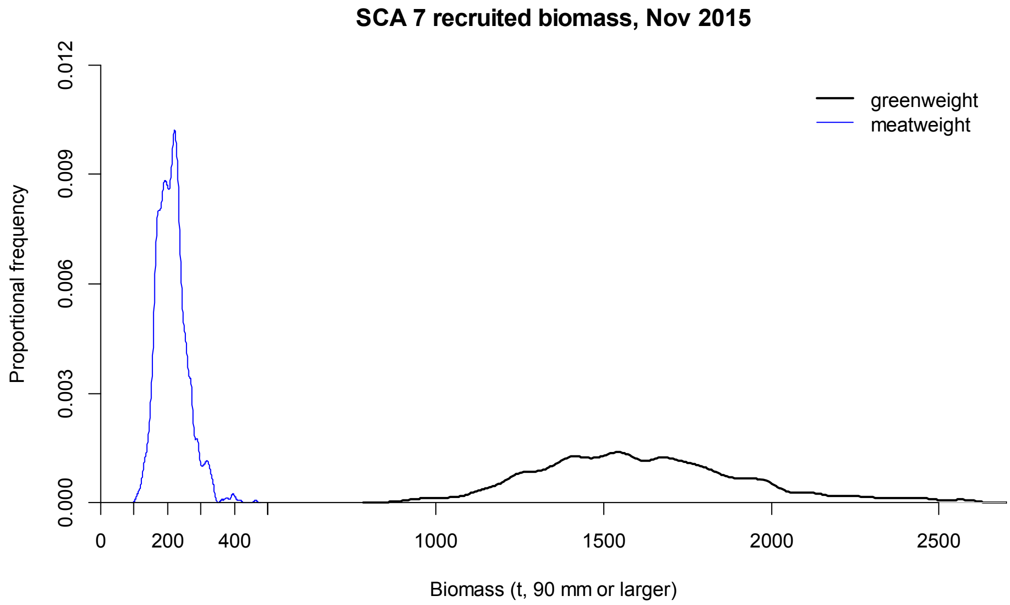


Figure 13: Proportional frequency distribution of the biomass of recruited scallops in SCA 7 at the time of the stock survey, 30 October to 18 November 2015. Recruited scallops are those measuring 90 mm or larger. The results of a non-parametric resampling with replacement approach to estimating biomass (1000 bootstraps) are shown in tonnes greenweight (solid black line, on the right hand side of the plot) and meatweight (blue line, on the left hand side of the plot).

Table 2: Population estimates of scallops in SCA 7, November 2015. Estimates were produced for commercial size recruited scallops (90 mm or larger), assuming historical average dredge efficiency and predicting weight from length. The analysis used a non-parametric resampling with replacement approach to estimation (1000 bootstraps).

Grouping	Location	Area	Tows	Density (scallops.m^{-2})				Abundance (millions)				Scallop weight (g)		Biomass (t green)				Biomass (t meat)			
		(km^2)	*n*	Mean	CV	Median	95%CI	Mean	CV	Median	95%CI	Mean	Median	Mean	CV	Median	95%CI	Mean	CV	Median	95%CI
RECRUITED																					
Statistical area	7A	89	12	0.001	0.76	0.001	0–0.002	0.077	0.76	0.071	0.003–0.211	83.4	83.2	6.4	0.79	5.9	0.2–18	0.9	0.79	0.8	0–2.5
	7B	174	12	0.001	0.30	0.001	0.001–0.002	0.191	0.30	0.181	0.11–0.342	94.2	93.6	18.0	0.37	16.9	8.8–35.3	2.5	0.38	2.3	1.1–4.9
	7C	217	17	0.002	0.36	0.002	0.001–0.004	0.504	0.36	0.483	0.212–0.915	83.7	84.3	42.2	0.37	40.7	17.9–76.6	5.8	0.36	5.6	2.4–10.5
	7I	1279	43	0.001	0.48	0.001	0–0.001	0.771	0.48	0.733	0.18–1.637	76.3	76.0	58.8	0.48	55.7	13.9–126.7	6.9	0.48	6.5	1.7–14.6
	7D	267	10	0.001	0.46	0.001	0–0.001	0.196	0.46	0.194	0–0.386	73.2	73.2	14.4	0.46	14.2	0–28	1.9	0.47	1.8	0–3.8
	7E	131	10	0.002	0.39	0.002	0.001–0.003	0.217	0.39	0.211	0.069–0.41	92.0	91.3	20.0	0.40	19.3	6.2–37.5	2.6	0.40	2.5	0.8–5
	7F	172	10	0.000	0.47	0.000	0–0	0.040	0.47	0.038	0.01–0.083	77.4	77.1	3.1	0.47	3.0	0.8–6.5	0.4	0.48	0.4	0.1–0.8
	7G	167	6	0.004	0.53	0.003	0.001–0.008	0.606	0.53	0.554	0.2–1.357	111.1	111.1	67.3	0.49	61.6	25–143.1	8.9	0.50	8.0	3.3–19.6
	7H	318	25	0.021	0.32	0.021	0.01–0.036	6.722	0.32	6.535	3.113–11.473	79.1	79.0	531.8	0.32	516.0	245.1–903	70.6	0.33	68.6	31.9–124.1
	7J	95	17	0.005	0.31	0.005	0.002–0.008	0.452	0.31	0.440	0.215–0.767	74.9	75.0	33.8	0.31	33.0	16.5–56.8	4.4	0.32	4.3	2.1–7.6
	7K	426	108	0.018	0.27	0.017	0.01–0.029	7.576	0.27	7.336	4.407–12.421	80.1	80.2	607.0	0.27	588.3	355.3–989.2	79.6	0.27	76.7	46.5–132.6
	7L	180	48	0.016	0.23	0.016	0.01–0.024	2.882	0.23	2.824	1.848–4.257	79.5	79.2	229.1	0.23	223.8	147.8–339.9	30.0	0.23	29.3	18.8–46
Region	GB	480	41	0.002	0.29	0.002	0.001–0.003	0.772	0.29	0.751	0.411–1.275	86.3	85.4	66.6	0.29	64.2	34.9–112.5	9.2	0.31	8.8	4.6–15.6
	GBTB	1279	43	0.001	0.48	0.001	0–0.001	0.771	0.48	0.733	0.18–1.637	76.3	76.0	58.8	0.48	55.7	13.9–126.7	6.9	0.49	6.5	1.6–14.9
	TB	1055	61	0.007	0.29	0.007	0.004–0.012	7.781	0.29	7.521	4.036–12.968	81.8	81.6	636.5	0.29	613.6	332.5–1062	83.8	0.29	80.7	43.3–140.5
	MS	702	173	0.016	0.23	0.015	0.01–0.024	10.909	0.23	10.656	6.964–16.526	79.7	79.9	869.9	0.22	851.4	560.1–1331.5	114.3	0.23	111.3	73.6–173.3
Stock	SCA 7	3514	318	0.006	0.21	0.006	0.004–0.009	20.233	0.21	19.783	13.308–30.218	80.7	80.3	1631.9	0.21	1588.6	1087.6–2440.6	214.2	0.21	210.7	141–320.7

3.5 Sensitivity of recruited biomass to ‘critical density’

Estimates of biomass are sensitive to the exclusion of areas of low scallop density, and in the past it has generally been assumed that 0.04 m^{-2} (one recruited scallop for each 25 m^{-2} of seabed) is a reasonable working definition for the lowest limit of economic fishing, although this will vary with market price and costs. Working at a station level, the survey data were reanalysed assuming that all stations where scallops were scarcer than 0.04 m^{-2} had zero density, and stations where scallops were denser than 0.04 m^{-2} had a density of the actual density minus 0.04 m^{-2}.

In SCA 7 survey analyses before 2012, these ‘critical density’ corrections were applied before scaling for dredge efficiency, so the estimates were very conservative. In the present study, the critical density corrections were applied after first correcting for efficiency, as we consider this to be more appropriate, representing actual scallop density on the seabed, but this means that the relative effect of applying critical densities is now different from surveys before 2012.

Adjusting for critical density, the time of survey population was estimated using the same bootstrapping methodology as used previously. This approach was repeated to produce biomass estimates for assumed critical densities in the range 0.00 to 0.20 scallops m^{-2}.

The estimated recruited biomass in SCA 7 in November 2015 was sensitive to the exclusion of areas of low scallop density (Figure 14 and Table 3): excluding areas of very low density (below 0.04 m^{-2}), the SCA 7 biomass was 63 t meatweight, equating to only 30% of the absolute biomass (i.e. 211 t biomass, with no critical density threshold).

At the regional level, the Marlborough Sounds recruited biomass estimates gradually decreased as the critical threshold density was increased. Excluding areas where the density was less than 0.04 m^{-2} reduced the Marlborough Sounds biomass to 50 t (45% of absolute biomass); using a critical density of 0.08 m^{-2} reduced the biomass to 26 t (24% of the absolute biomass) and using a high critical density of 0.2 m^{-2} reduced the biomass to 5 t (4% of absolute biomass).

The Tasman Bay recruited biomass estimates were more sensitive to the exclusion of areas of low scallop density, with only 12 t (15% of absolute biomass) remaining at a critical density of 0.04 m^{-2}, and zero recruited biomass remaining at a critical density of 0.08 m^{-2}.

The Golden Bay and ‘GBTB Outer’ estimates were the most sensitive to the exclusion of areas of low scallop density, with zero recruited biomass remaining at a critical density of 0.04 m^{-2}.

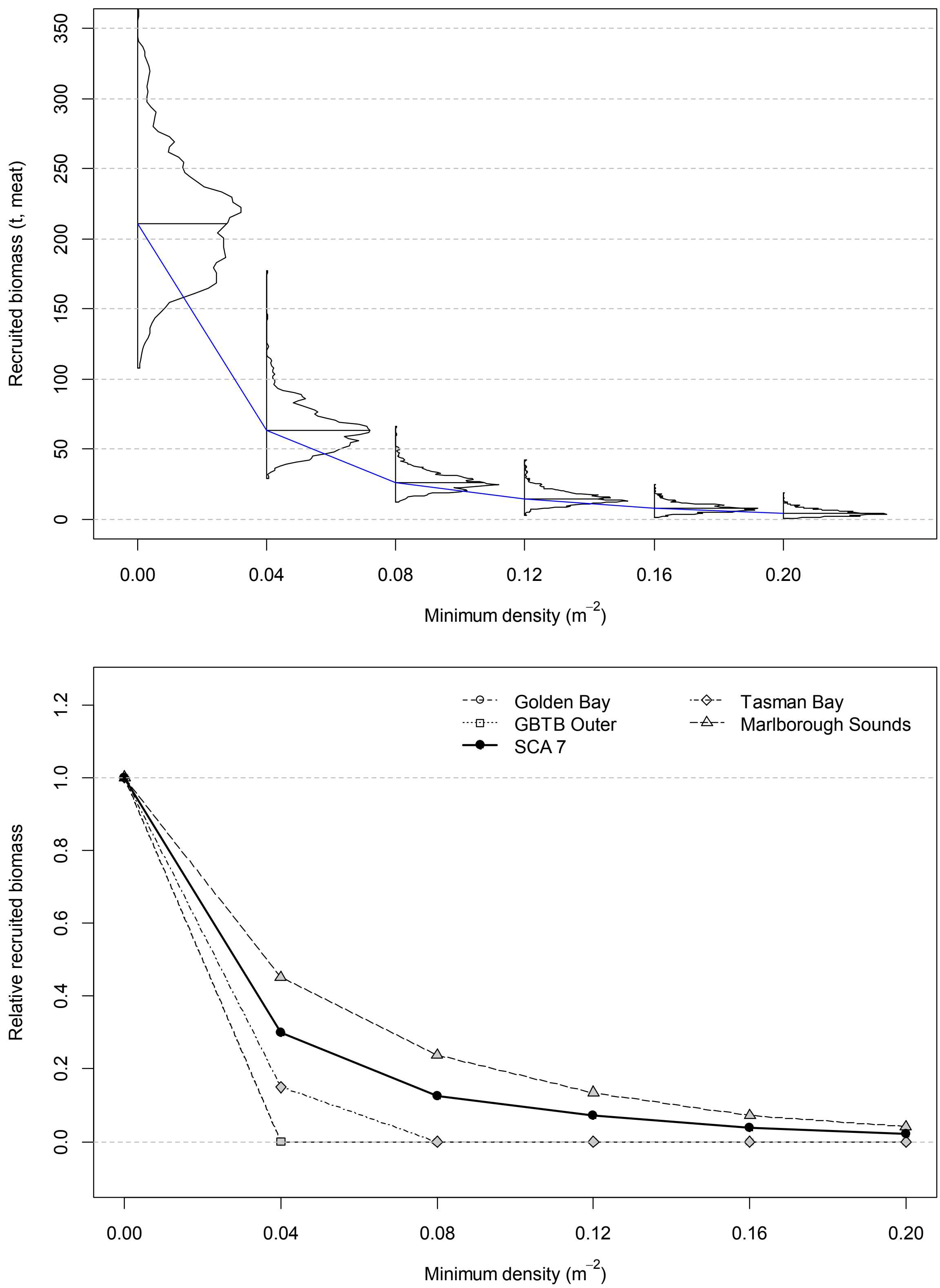


Figure 14: Effect of excluding areas of low scallop density on recruited biomass, SCA 7, November 2015. Critical density corrections were applied after correcting for dredge efficiency. Top plot: for each minimum ('critical') density, the distribution and median (horizontal line) of the recruited biomass in SCA 7 are shown. Bottom plot: Trend in the proportion of the total recruited biomass with increasing critical density.

Table 3: Sensitivity of the SCA 7 November estimates of recruited scallop biomass (t meatweight) to the exclusion of areas of low scallop density. Critical density thresholds in the range 0.04–0.20 scallops m^{-2} were assumed, below which fishing becomes uneconomic. The estimates were produced using a non-parametric resampling with replacement approach (1000 bootstraps) to estimation. Critical density corrections were applied after correcting for dredge efficiency.

Grouping	Location	Critical density (scallops.m^{-2})																	
		0			0.04			0.08			0.12			0.16			0.20		
		mean	CV	median	mean	CV	median	mean	CV	median	mean	CV	median	mean	CV	median	mean	CV	median
RECRUITED																			
Statistical area	7A	0.88	0.79	0.82	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	7B	2.48	0.38	2.30	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	7C	5.80	0.36	5.58	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	7I	6.92	0.48	6.54	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	7D	1.90	0.47	1.85	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	7E	2.63	0.40	2.50	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	7F	0.41	0.48	0.39	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	7G	8.87	0.50	8.03	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	7H	70.59	0.33	68.62	12.74	0.54	12.02	0	–	0	0	–	0	0	–	0	0	–	0
	7J	4.45	0.32	4.31	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	7K	79.61	0.27	76.73	34.47	0.31	32.96	14.93	0.28	14.38	6.65	0.41	6.21	2.32	0.63	2.12	0.76	0.84	0.68937
	7L	30.05	0.23	29.27	17.82	0.27	17.31	12.24	0.33	11.74	8.97	0.37	8.51	6.02	0.45	5.71	4.16	0.53	3.84227
Region	GB	9.17	0.31	8.80	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	GBTB	6.90	0.49	6.50	0	–	0	0	–	0	0	–	0	0	–	0	0	–	0
	TB	83.85	0.29	80.70	12.70	0.54	12.06	0	–	0	0	–	0	0	–	0	0	–	0
	MS	114.28	0.23	111.27	52.26	0.26	50.19	27.21	0.25	26.37	15.58	0.31	15.01	8.35	0.38	7.90	4.93	0.48	4.51259
Stock	SCA 7	214.20	0.21	210.72	64.96	0.25	63.31	27.21	0.25	26.37	15.58	0.31	15.01	8.35	0.38	7.90	4.93	0.48	4.51259

Summary by region and stock. Prop, proportion of absolute biomass.

Median	0	0.04	0.08	0.12	0.16	0.2	Prop	0	0.04	0.08	0.12	0.16	0.2
GB	9	0	0	0	0	0	GB	1	0	0	0	0	0
GBTB	7	0	0	0	0	0	GBTB	1	0	0	0	0	0
TB	81	12	0	0	0	0	TB	1	0.15	0	0	0	0
MS	111	50	26	15	8	5	MS	1	0.45	0.24	0.13	0.07	0.04
SCA 7	211	63	26	15	8	5	SCA 7	1	0.30	0.13	0.07	0.04	0.02

3.6 Spawning biomass

Scallops become sexually mature at a shell length of about 70 mm (Williams & Babcock 2005). Assuming all scallops 70 mm or larger are sexually mature, the spawning biomass (t meatweight, scallops 70 mm or larger) in each region (substock) of SCA 7, and for the combined total, were as follows:

- Golden Bay 36 t (95%CI = 16–68 t; mean = 38 t, CV = 0.36)
- GBTB Outer 125 t (95%CI = 16–357 t; mean = 135 t, CV = 0.70)
- Tasman Bay 251 t (95%CI = 113–475 t; mean = 261 t, CV = 0.36)
- M. Sounds 275 t (95% CI = 170–449 t; mean = 283 t, CV = 0.24)

- SCA 7 697 t (95% CI = 423–1162 t, mean = 717 t, CV = 0.27) (Figure 15).

Spawning biomass was less sensitive to critical density thresholds than recruited biomass (Figure 16).

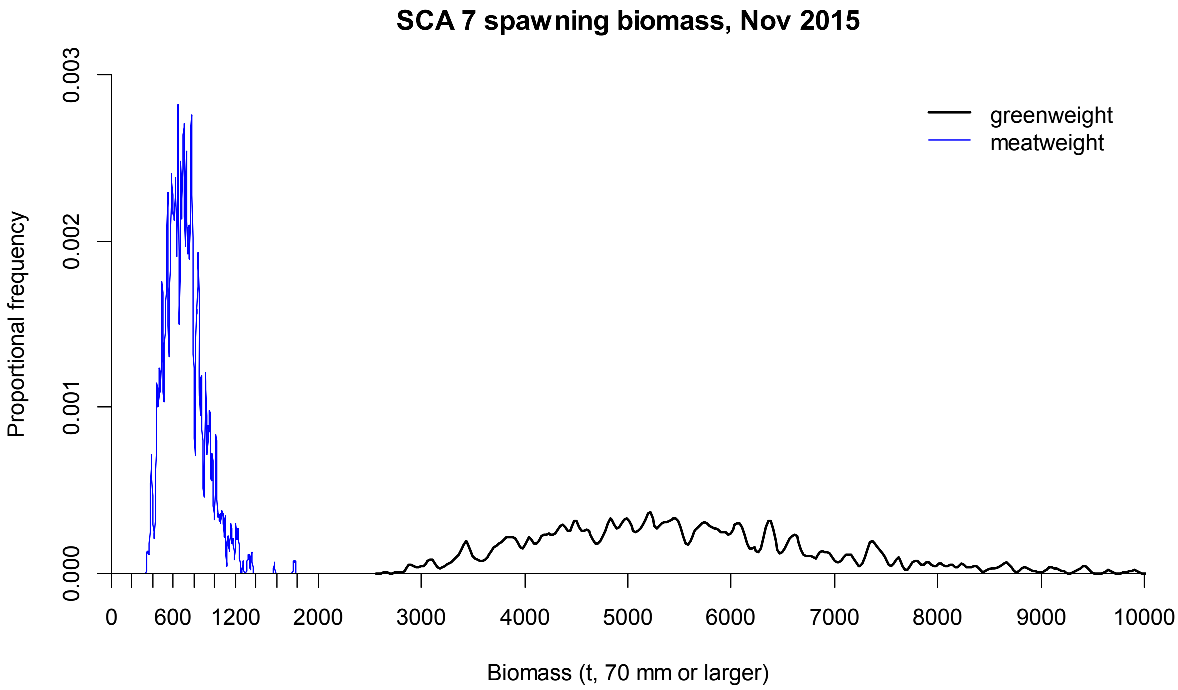
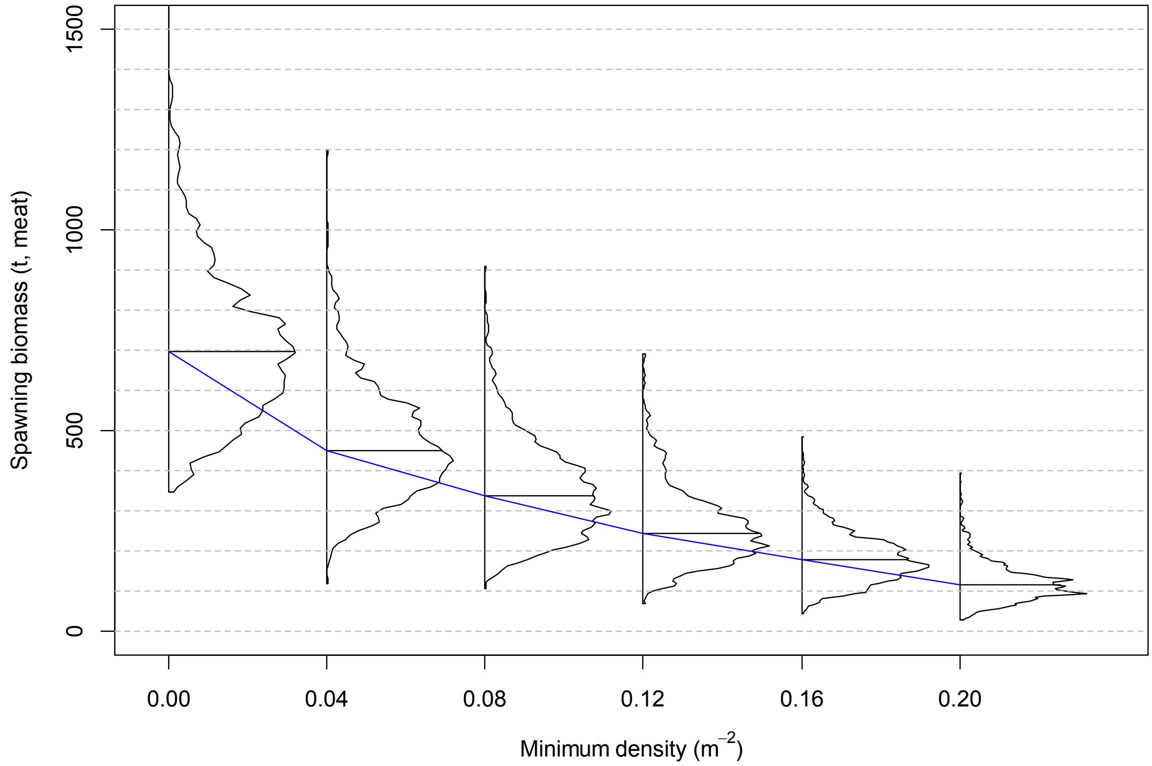


Figure 15: Proportional frequency distribution of the spawning biomass (of scallops 70 mm or larger) in SCA 7 at the time of the stock survey, 30 October to 18 November 2015. The results of a non-parametric resampling with replacement approach to estimating biomass (1000 bootstraps) are shown in tonnes greenweight (solid black line, on the right hand side of the plot) and meatweight (blue line, on the left hand side of the plot).



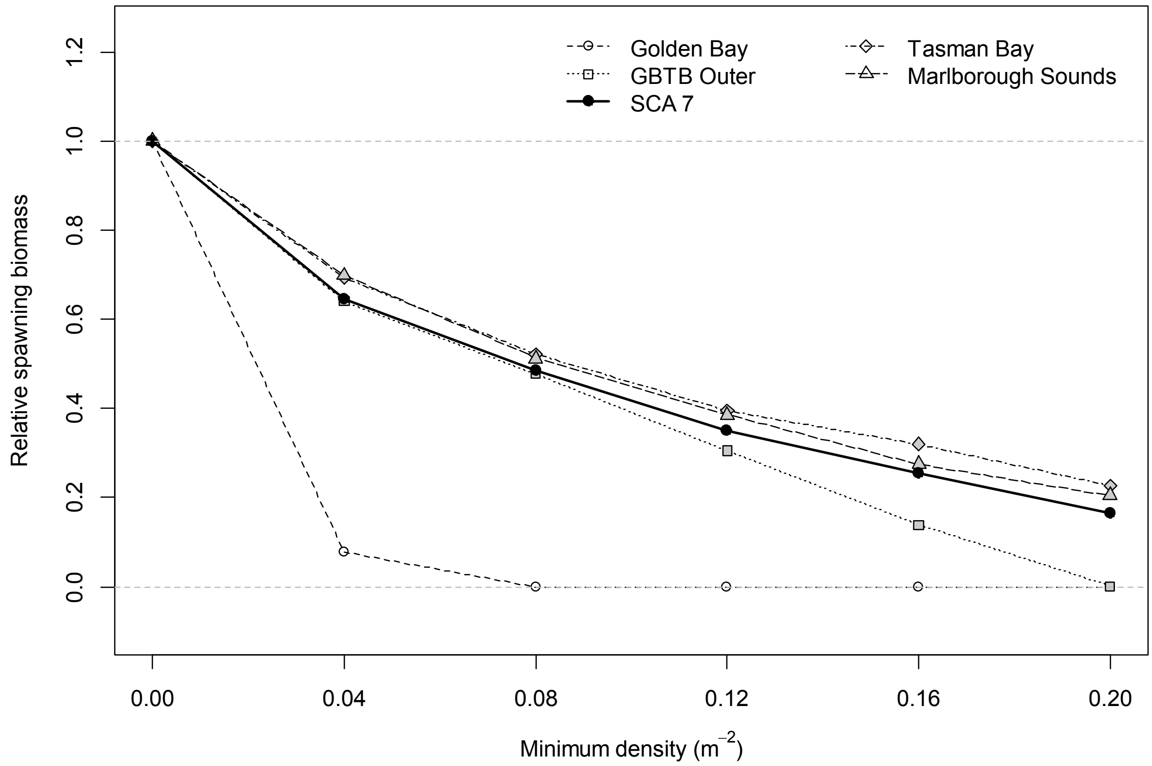


Figure 16: Effect of excluding areas of low scallop density on spawning biomass, SCA 7, November 2015. Critical density corrections were applied after correcting for dredge efficiency. Top plot: for each minimum ('critical') density, the distribution and median (horizontal line) of the recruited biomass in SCA 7 are shown. Bottom plot: Trend in the proportion of the total spawning biomass with increasing critical density.

3.7 Comparison with May 2015 survey estimates

The extent of the November 2015 survey (3514 km^2) was considerably larger than in previous surveys (e.g. 1442 km^2 in May 2015), so, to enable direct comparison of the November estimates with those from the May 2015 survey, and with other previous surveys, a subset of the November survey data were selected and reanalysed. The November 2015 survey stations were plotted in relation to the May 2015 survey strata (Figure 17), and data from those stations that intersected with the May strata were selected and used to re-estimate recruited biomass. Within the same area of the SCA 7 stock as that surveyed in May 2015 (i.e. using the November stations that intersected with the May strata), recruited biomass (t meatweight) was 153 t in November 2015, compared with 203 t predicted for the start of the fishing season (1 September 2015, projected from the May 2015 survey) (Table 4). Frequency distributions of the recruited biomass are shown in Figure 18.

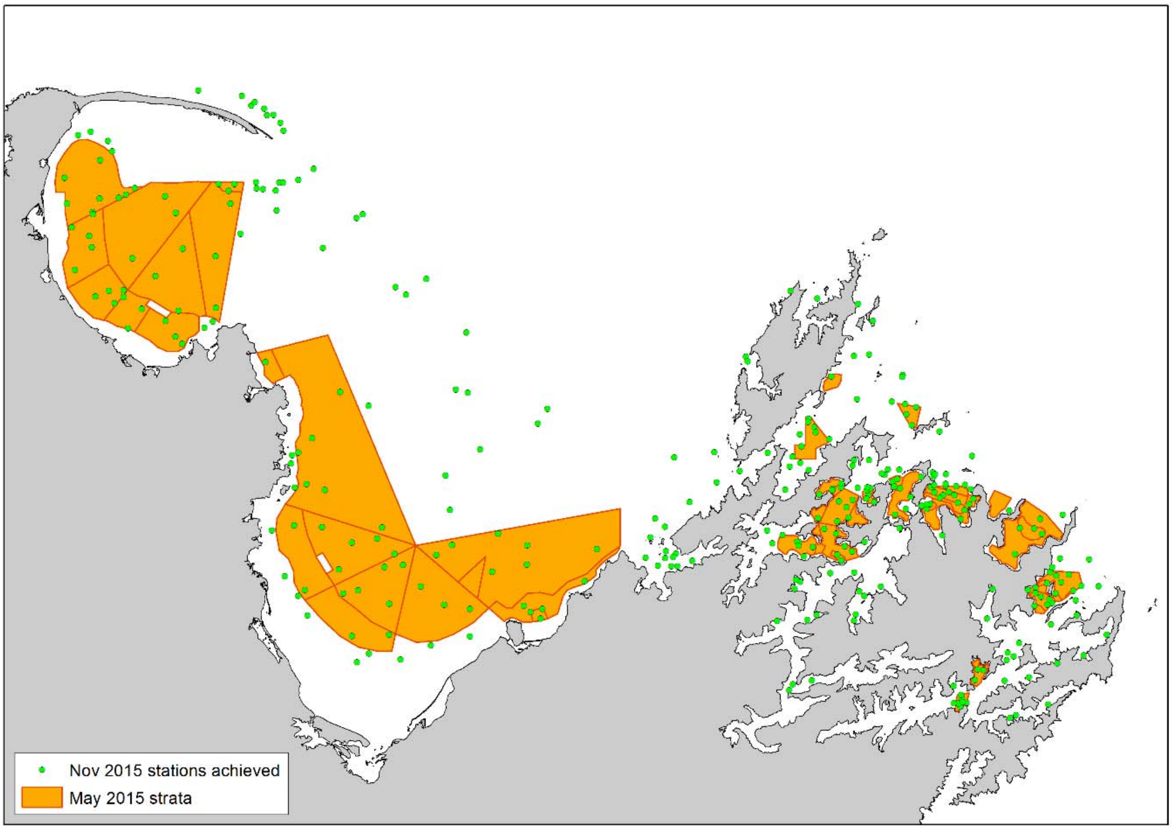


Figure 17: Station positions sampled in November 2015 (green circles) compared with the strata surveyed in May 2015 (orange polygons). November stations that intersected with the May strata were used to re-estimate recruited biomass and spawning biomass, enabling direct comparisons between the November 2015 and the May 2015 survey estimates.

Table 4: Population estimates of scallops in SCA 7 in September (May survey-projected values) and November 2015. Estimates were produced for commercial size recruited scallops (90 mm or larger), assuming historical average dredge efficiency and predicting weight from length. The analysis used a non-parametric resampling with replacement approach to estimation (1000 bootstraps).

Grouping	Location	Area	September (May survey projected) biomass (t meat)					November biomass (t meat)				
		(km^2)	*n* tows	Mean	CV	Median	95%CI	*n* tows	Mean	CV	Median	95%CI
RECRUITED												
Region	GB	459	39	15.2	0.30	14.8	7.2–25.4	35	8.5	0.30	8.2	4.5–14.0
	TB	789	52	87.7	0.27	84.5	49–141.7	36	77.7	0.29	75.0	42.4–126.0
	MS	186	89	104.4	0.19	102.3	72.7–147.7	81	70.7	0.20	68.6	48.6–106.2
Stock	SCA 7	1434	180	207.3	0.19	202.6	140.9–304.2	152	156.9	0.22	153.0	105.8–235.8

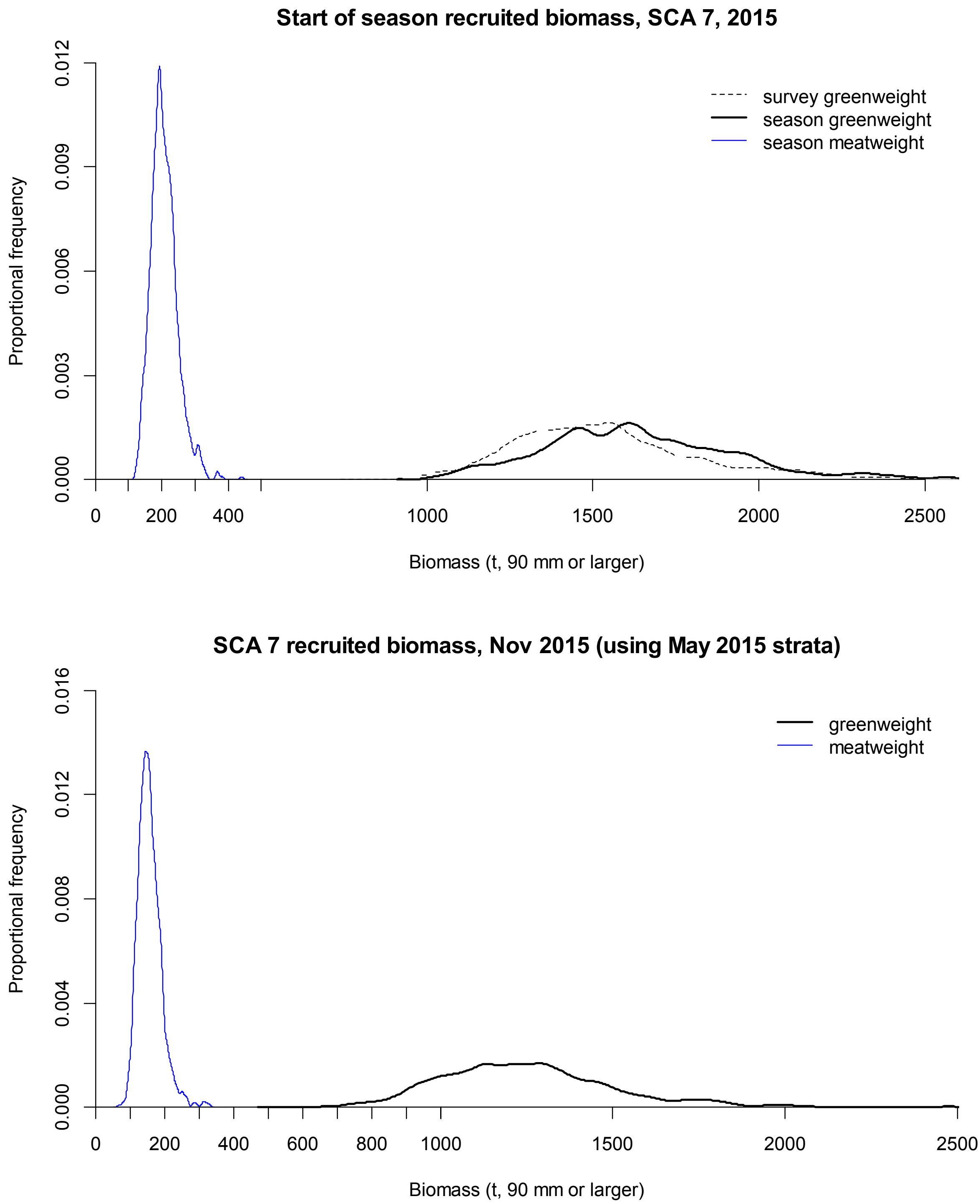


Figure 18: Proportional frequency distributions of the SCA 7 recruited biomass at the nominal start of the fishing season on 1 September (top plot, May-projected values) and in November 2015 (bottom plot) within the same area of the SCA 7 stock as that surveyed in May 2015 (i.e. November stations intersected with May strata). In each plot, the results of a non-parametric resampling with replacement approach to estimating biomass (1000 bootstraps) are shown in tonnes greenweight (solid black line, on the right hand side of the plot) and meatweight (blue line, on the left hand side of the plot).

3.8 Trends in biomass and exploitation rate

Williams et al. (2015a) plotted recruited biomass by region and for the overall SCA 7 stock to assess trends since the 1998 survey, the first with extensive coverage of the SCA 7 stock area (Figure 19, reproduced from Williams et al. (2015a) with the November 2015 estimates included). In Golden Bay, biomass increased from 1999 to reach a major peak in 2001, but rapidly decreased to 2004; biomass increased again to reach a second, smaller peak in 2007, but subsequently decreased and remained at very low levels from 2011 to 2015. In Tasman Bay there was a similar large increase and decrease in biomass that occurred with slightly later timing: biomass increased in Tasman Bay from 2000 to reach a peak in 2002–03, but subsequently decreased and remained at very low levels from 2006 to 2015. The exception to this is sector H in Tasman Bay which has seen an abundance of scallops (at generally low density) in 2015 that has not been seen since surveys in the early 2000s. In Marlborough Sounds, biomass generally followed an increasing trend from 1999 to 2009 (with evidence of a peak in 2002), and a decreasing trend from 2009 to 2015.

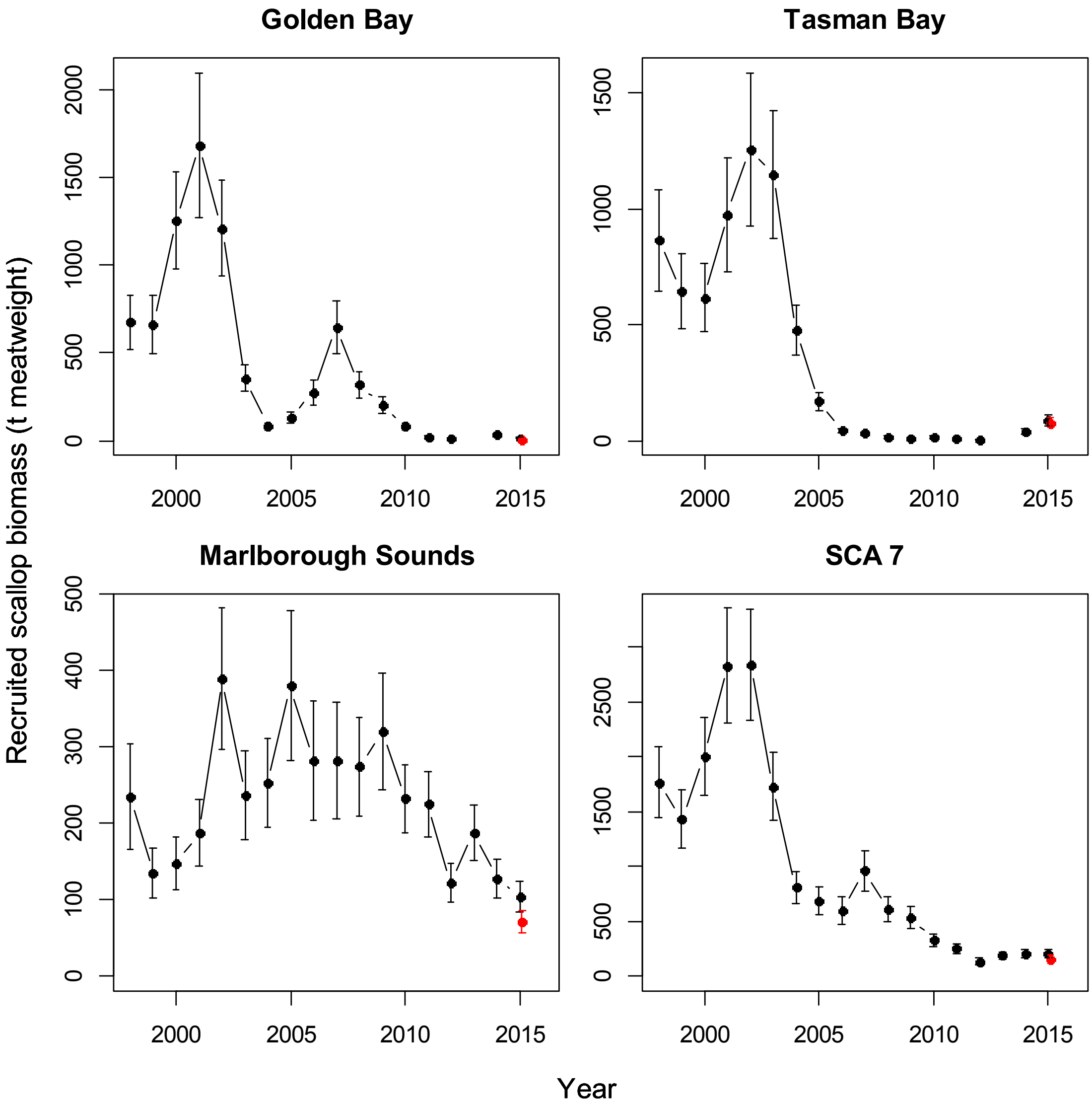


Figure 19: Trends in projected start of season recruited scallop biomass (t meatweight) by region and for the total SCA 7 stock, 1998–2015. Estimates from the November 2015 survey (for the same strata as those surveyed in May 2015) are also shown as red symbols slightly offset from the May 2015 points. Values are the estimated mean and CV of the recruited biomass. Note: Golden and Tasman Bays were not surveyed in 2013.

Commercial scallop fishing in SCA 7 in the 2015–16 fishing year occurred over a limited period (about 3 weeks in October) in a limited number of areas in the Marlborough Sounds (Guards Bay, Ship Cove, and Dieffenbach Point) which held the majority of the available recruited scallop biomass, and in sector H in Tasman Bay. The total commercial catch landed was 22.040 t meatweight, comprising landings of 9.858 t from Guards Bay / Titirangi (biotoxin area G46), 7.769 t from Ship Cove/ Long Island (G29), 0.900 t from Dieffenbach Point (G29), 2.738 t from the Chetwode Islands (G100), and 0.775 t from Tasman Bay sector 7H (landings data provided by J. Reid, CSEC).

Exploitation rate in the Marlborough Sounds was 21% in the 2015–16 fishing year (2015 'season', which actually took place during October 2015), calculated as the 2015 season commercial catch (21.3 t; J. Reid, CSEC, pers. comm.) divided by the start of season recruited biomass of 102.3 t (Williams et al. 2015a). This calculated exploitation rate was used to update a plot of trends in biomass and exploitation rate for the combined sectors 7K–7L (Figure 20, updated from that plotted by Williams et al. (2015a)). The 7KK-7LL series shows an increasing biomass trend from 1999 to 2009, and a decreasing biomass trend from 2009 to 2015. Exploitation rate was lower (mean E = 0.22 for 1999 to 2008) during the period of increasing biomass from 1999 to 2009, and was higher (mean E = 0.28 for 2009 to 2015) during the biomass decline observed from 2009 to 2015.

This suggested that, at the broad spatial scale of the 7KK-7LL sectors combined, fishing at an exploitation rate of 0.22 tends to result in increasing biomass (avoids biomass declines), and this was chosen as an appropriate target reference point for calculating yield in 2014 and 2015. This approach of determining an appropriate target reference point for the fishery as the exploitation rate that avoids biomass declines is used in scallop fisheries in Atlantic Canada (Smith & Hubley 2012).

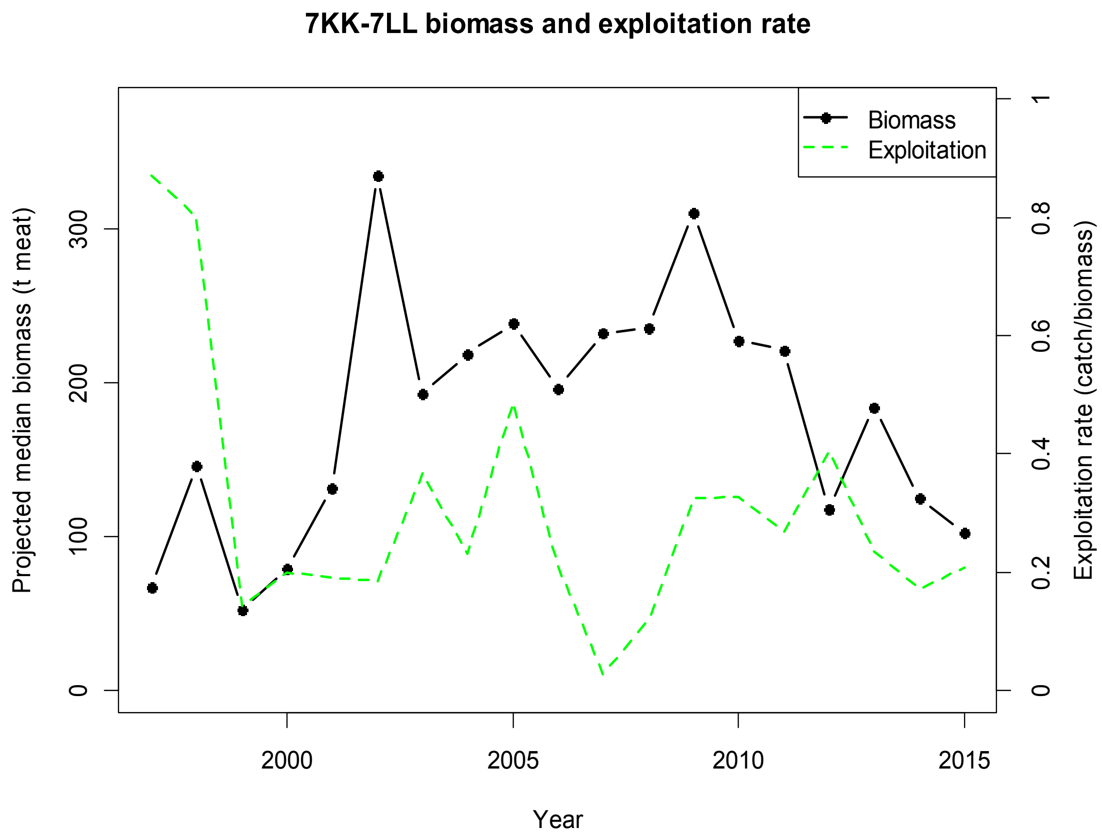


Figure 20: Trends in biomass and exploitation rate for the combined areas surveyed in sectors 7KK and 7LL in the Marlborough Sounds, 1997–2015. Mean exploitation rate was 0.22 from 1999 to 2008 (associated with increasing biomass trend 1999 to 2009), and was 0.28 from 2009 to 2015 (associated with decreasing biomass trend 2009 to 2015).

4. DISCUSSION

The results of the November 2015 survey show that there was minimal recruited biomass held in high density scallop beds outside of the previously surveyed areas, even though the extent of the November survey was over twice the area of that used in previous May surveys. This suggests that the May surveys are sampling the main scallop beds. Before future surveys are carried out, we recommend that the extent and stratification of the SCA 7 survey are reviewed and standardised.

Overall the SCA 7 stock continues to decline, and stock status appears to be at the lowest recorded level. Recruited biomass in Golden Bay and Tasman Bay sectors D–G remains at very low levels since the large declines occurred in the 2000s, and although there was some recruited biomass in Tasman Bay sector H it was held at low density. Recruited biomass in the Marlborough Sounds is restricted to a small number of areas mainly in the outer Sounds, and overall has continued to follow a declining trend since 2009.

Only small proportions of the recruited biomass were held in relatively high density scallop beds, which are particularly important for scallop stock productivity (in terms of successful spawning and fertilisation of eggs i.e. larval production) as well as for fisheries utilisation.

Spawning biomass was substantially higher than recruited biomass, as can be expected, but almost all of the spawning biomass was held in the Marlborough Sounds. Spawning biomass was less affected by critical density effects than recruited biomass.

There were signs of recent juvenile recruitment, particularly in the Marlborough Sounds. There were larger proportions of small scallops in the November survey than normally seen in the May surveys (Appendix 4), although comparisons are difficult because this difference could be a result of the different survey timing. Anecdotally, commercial fishers suggest that the recruitment of undersize scallops in the main scallop beds fished in Marlborough Sounds (particularly at Ship Cove) is much stronger than normally seen.

Recent commercial fishing has been limited to only a few specified areas, with 22 t of commercial catch landed, most from the Marlborough Sounds. The level of recreational harvest in 2015 is unknown. The commercial exploitation rate in 2015 at the level of the Marlborough Sounds sectors 7K and 7L combined was 21%. This is in line with the current target exploitation rate of 22%, which is associated with the biomass increase observed in the Marlborough Sounds between 1999 and 2008. The Environment (Stock sustainability) Objective for Group 2 stocks in the draft National Fisheries Plan for Inshore Shellfish (Ministry for Primary Industries 2011) is to “maintain stock size at or above an established minimum reference level”. A minimum reference level has not been established for SCA 7, and, because spatial scale is so inherently important in scallop population dynamics and fisheries, a single minimum reference level for the entire stock would probably be unsuitable. One approach to a minimum reference level could be the minimum biomass from which the stock has recovered in the past. While examination of appropriate minimum reference levels was beyond the scope of this project, it is clear that the stocks in Golden and Tasman Bays are below desirable minimum levels, and the stock in the overall Marlborough Sounds region is at the lowest recorded level in the survey time series. Commercial fishers suggest that scallop populations in the key fished areas (Guards Bay, Ship Cove) do not show the same declining trend as that observed at the broad spatial scale of the overall Marlborough Sounds area, but it was not possible to examine this within this project.

There were a number of data sets collected on the survey (clucker length frequency; scallop length-weight, condition, and maturity; bycatch) that were beyond the objectives of the present study, and other analyses that that were identified as being useful to do but were not possible within the timeframe that this report was required by managers. These were discussed and noted by the Shellfish Working Group and should be explored in future work on SCA 7.

5. ACKNOWLEDGEMENTS

This work was funded by the Ministry for Primary Industries (MPI) through project SCA201504. Thanks to MPI science and managers for helpful input, particularly Julie Hills, Martin Cryer, Allen Fraser, Erin Breen, Tony Brett and Tracey Osborne. Special thanks to the survey skipper Cris West and mate Raymond Green for their help in conducting the dredge survey aboard the chartered commercial fishing vessel FV *Okarito*, and to Grant Roberts (Rongo Marie Ltd) for coordinating the charter arrangements. Thanks to Challenger Scallop Enhancement Company staff John Reid (Executive Officer) and Doug Loder (Chairman) for their helpful input. We really appreciate valuable input from SCA 7 commercial fishers on the locations of past and present scallop beds, and engagement with other interested parties who provided information which helped with our design of the survey, including representatives of recreational fishers (Des Boyce, Michael Connelly, Andrew Caddie, and Geoff Rowling), Department of Conservation (Andrew Baxter, Greg Napp, Roy Grose), Marlborough District Council (Steve Urlich), and Davidson Environmental (Rob Davidson). Thanks also to Richard Bian for assistance with coding, and to the team at NIWA Nelson (Ashleigh Watts, Megan Carter, Colin Sutton, Anna Bradley and Niki Davey) for processing scallops in the laboratory. We are grateful to members of the Shellfish Fisheries Working Group for their appraisal of the survey methodology and review of the results. This report was reviewed at NIWA by Ian Tuck.

6. REFERENCES

Bian, R.; Williams, J.R.; Smith, M.; Tuck, I.D. (2012). Modelling scallop dredge efficiency for the Coromandel and Northland scallop fisheries. Final Research Report for Ministry for Primary Industries project SAP200913. 46 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bull, M. (unpub.). Distribution of commercial scallop grounds, with a note on the occurence of *Amphioxus* (the lancet) in Croisilles Harbour. Ministry of Fisheries map. 1 p. (Unpublished map held by NIWA, Nelson).

Cryer, M.; Parkinson, D.M. (2006). Biomass surveys and stock assessments for the Coromandel and Northland scallop fisheries, 2005. *New Zealand Fisheries Assessment Report 2006/34*. 53 p.

Davidson, R.J.; Duffy, C.A.J.; Gaze, P.; Baxter, A.; DuFresne, S.; Courtney, S.; Hamill, P. (2011). Ecologically significant marine sites in Marlborough, New Zealand. Co-ordinated by Davidson Environmental Limited for Marlborough District Council and Department of Conservation. 172 p.

Davidson, R.J.; Richards, L.A. (2015). Significant marine site survey and monitoring programme: Summary 2014-2015. Prepared by Davidson Environmental Limited for Marlborough District Council. Survey and monitoring report number 819. 52 p.

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

Handley, S. (2015). The history of benthic change in Pelorus Sound (Te Hoiere), Marlborough. NIWA Client Report NEL2015-001 prepared for Marlborough District Council. 47 p.

MFish; CSEC (1998). Memorandum of understanding between the Ministry of Fisheries and Challenger Scallop Enhancement Company Limited. Agreement between the Chief Executive of the Ministry of Fisheries and CSEC Ltd regarding the provision of information necessary to manage the SCA 7 fishery. 16 p. (Unpublished agreement held by Ministry for Primary Industries, Wellington, and CSEC, Nelson.)

Ministry for Primary Industries (2011). Draft National Fisheries Plan for Inshore Shellfish. http://www.fish.govt.nz/en-nz/Fisheries+Planning/default.htm 54 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Smith, S.J.; Hubley, P.B. (2012). Reference points for scallop fisheries in the Maritimes Region. *Department of Fisheries and Oceans Canadian Science Advisory Secretariat Research Document 2012/018*: ii + 16 p. (Erratum: August 2012).

Stead, D.H. (1971a). A preliminary survey of mussel stocks in Pelorus Sound December 1968 - January 1969. Report by the Marine Department, Wellington. (Unpublished report held by NIWA, Nelson.)

Stead, D.H. (1971b). Pelorus Sound : mussel survey December 1969. Report by the Marine Department, Wellington. (Unpublished report held by NIWA, Nelson.)

Tuck, I.D.; Brown, S. (2008). Survey of scallops and oysters in Golden Bay, Tasman Bay, and the Marlborough Sounds, 2008. NIWA Client Report: NEL2008-022 prepared for Challenger Scallop Enhancement Company. NIWA Project: CSE08403. (Unpublished report held by NIWA Auckland.) 37 p.

Williams, J.R. (2012). Abundance of scallops (*Pecten novaezelandiae*) in Coromandel recreational fishing areas, 2009 and 2010. *New Zealand Fisheries Assessment Report 2012/24*. 32 p.

Williams, J.R. (2014). Survey of scallops on Guards Bank, 24/09/2014. Report to MPI under project SEA2014/01 6 p. (Unpublished report held by NIWA, Auckland.)

Williams, J.R.; Babcock, R.C. (2004). Patterns of reproduction and spawning behaviour for scallops *Pecten novaezelandiae* in northeastern New Zealand [abstract of paper presented at the International Triennial Meeting of the World Aquaculture Society, the National Shellfisheries Association, and the American Fisheries Society Fish Culture Section, Honolulu, Hawaii, 1–5 March 2004]. *Journal of Shellfish Research 23*: 318–318.

Williams, J.R.; Babcock, R.C. (2005). Assessment of size at maturity and gonad index methods for the scallop *Pecten novaezelandiae*. *New Zealand Journal of Marine and Freshwater Research 39*: 851–864.

Williams, J.R.; Bian, R.; Parkinson, D.; Roberts, C.L. (2015a). Survey of scallops in Golden Bay, Tasman Bay, and Marlborough Sounds, 2015. NIWA Client Report AKL2015-019 prepared for Challenger Scallop Enhancement Company Ltd. NIWA Project CSE15301. 71 p. (Unpublished report held by NIWA, Auckland.)

Williams, J.R.; Hartill, B.; Bian, R.; Williams, C.L. (2014). Review of the Southern scallop fishery (SCA 7). *New Zealand Fisheries Assessment Report 2014/07*. 71 p.

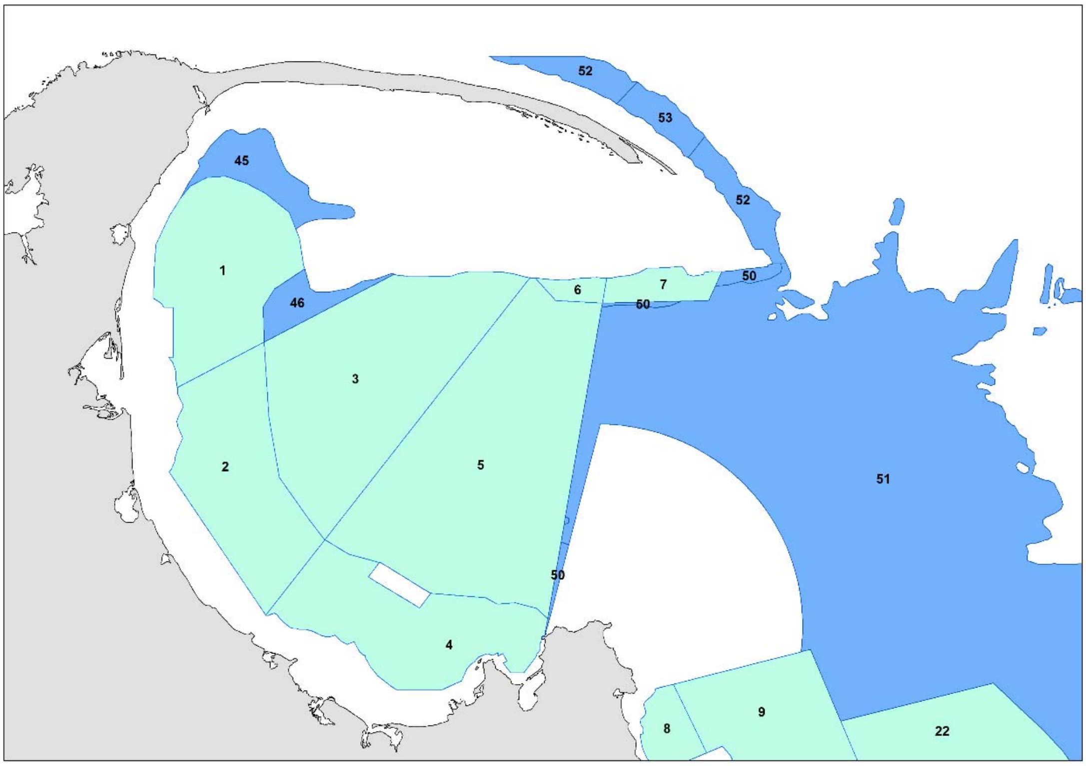
Williams, J.R.; Parkinson, D.M.; Bian, R. (2013). Biomass survey and yield calculation for the Coromandel scallop fishery, 2012. *New Zealand Fisheries Assessment Report 2013/18*. 57 p.

Williams, J.R.; Parkinson, D.M.; Olsen, L.; Roberts, C.L. (2015b). SCA 7 in-season survey, October 2015. *New Zealand Fisheries Assessment Report 2015/72*. 20 p.

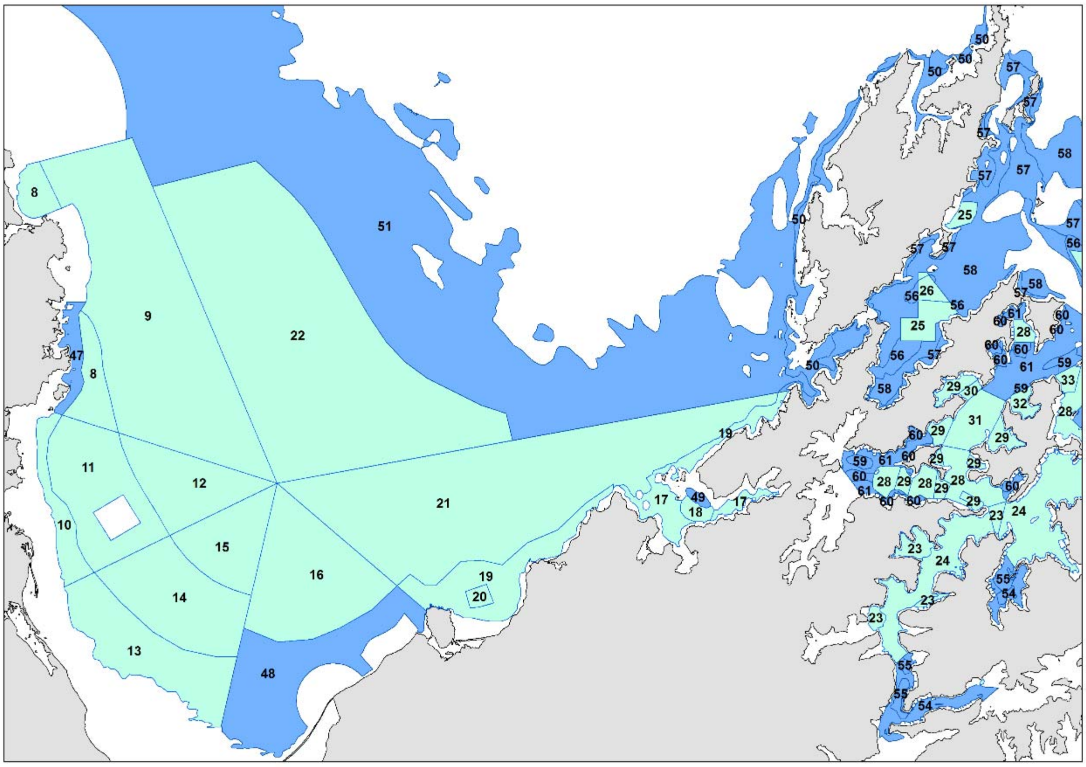
Williams, J.R.; Tuck, I.D.; Parkinson, D.M. (2007). Biomass surveys and stock assessments for the Coromandel and Northland scallop fisheries, 2006. *New Zealand Fisheries Assessment Report 2007/24*. 41 p.

APPENDIX 1

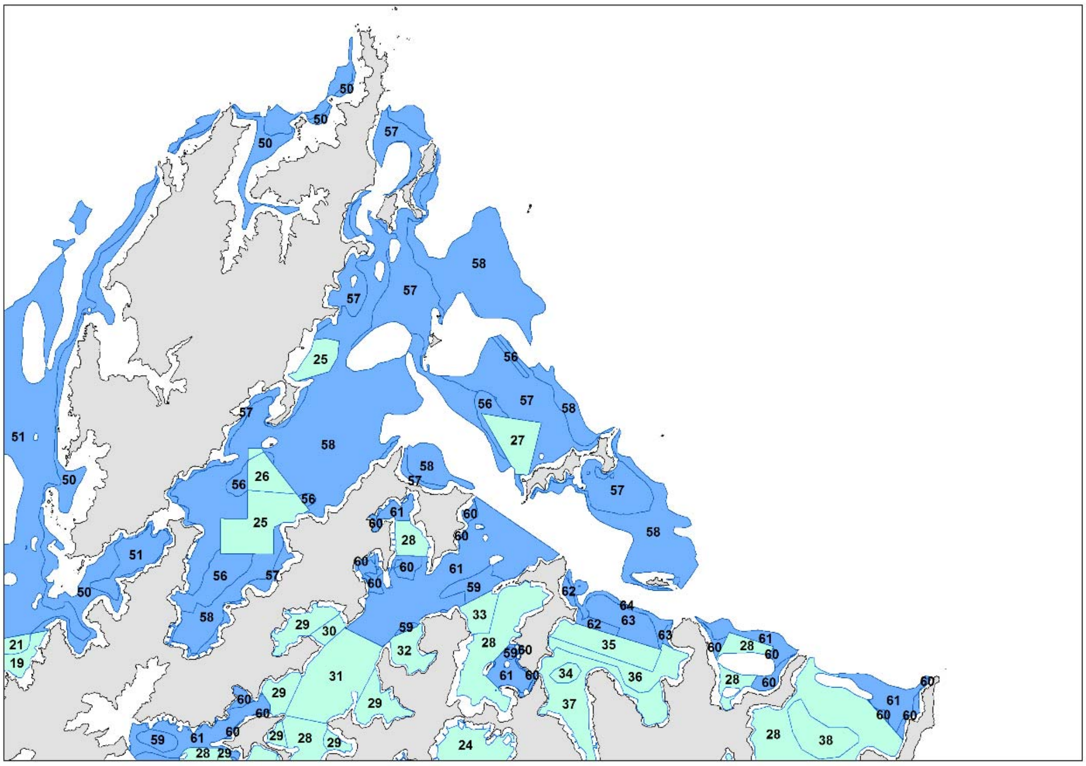
Survey stratification by region, SCA 7 stock survey November 2015.



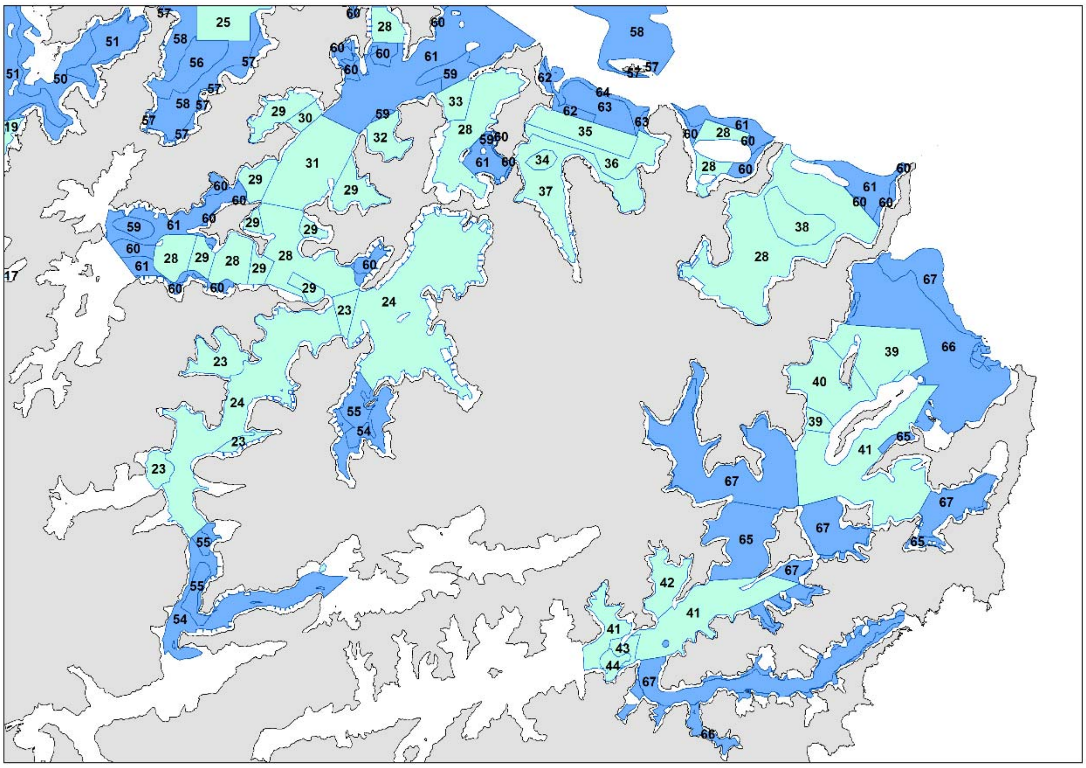
Golden Bay



Tasman Bay



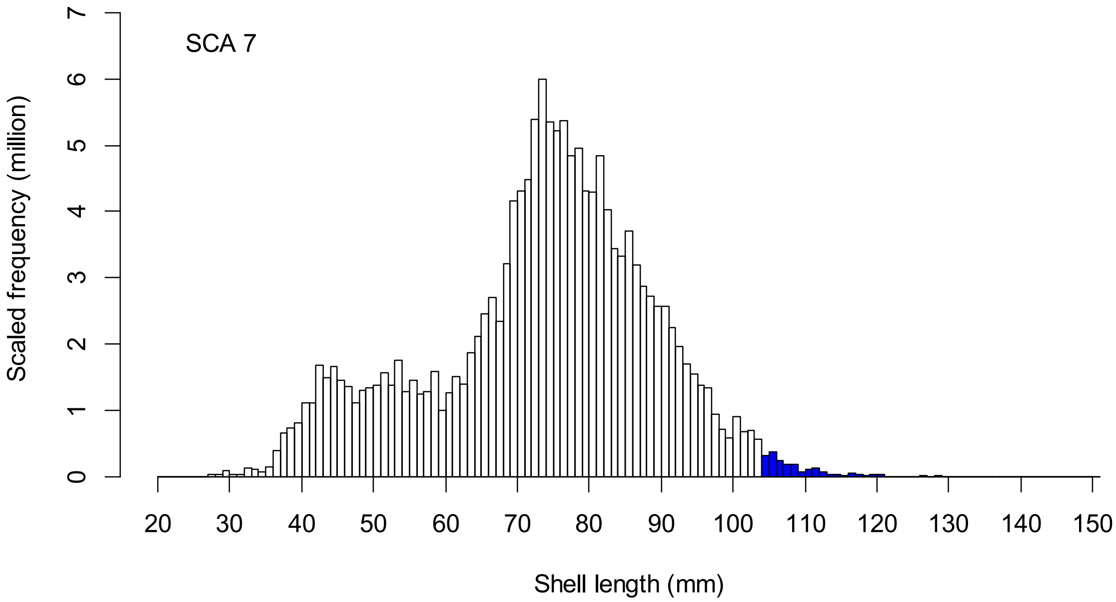
Marlborough Sounds (north)

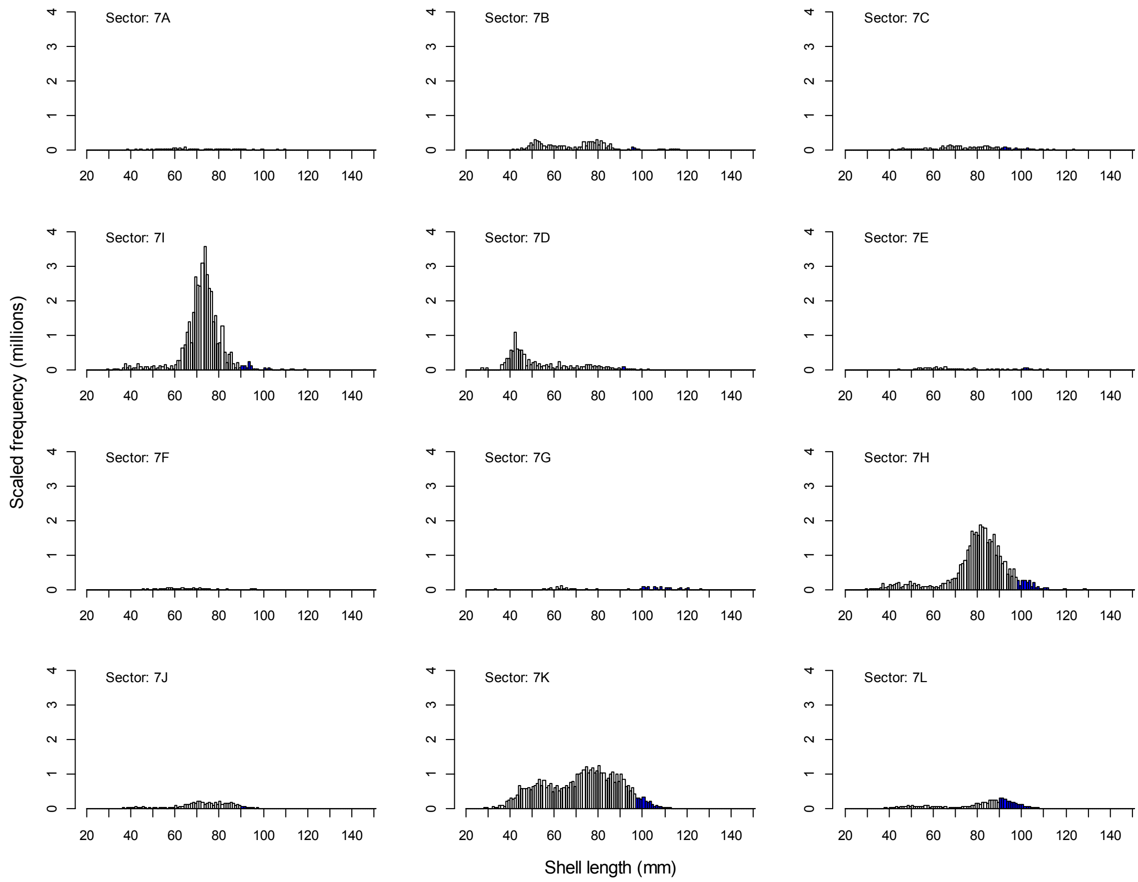


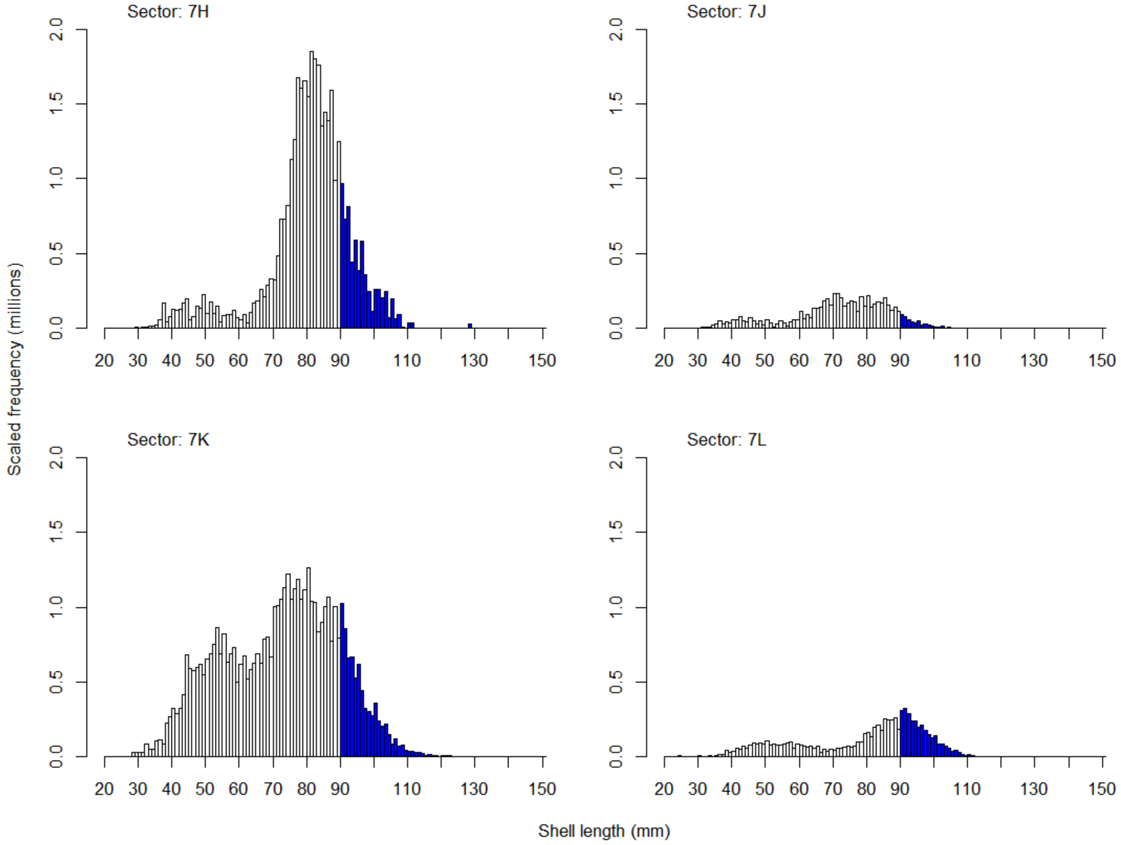
Marlborough Sounds (south)

APPENDIX 2

Stock and sector length frequency distributions, November 2015.






Sector: 7H
Sector: 7J
Sector: 7K
Sector: 7L
Scaled frequency (millions)
0.0
0.5
1.0
1.5
2.0
20 30 40 50 60 70 80 90 110 130 150
Shell length (mm)

APPENDIX 3

Stratum estimates of recruited biomass, November 2015.

Table 5: Stratum estimates of scallops in previously surveyed areas of Golden and Tasman Bays within SCA 7, November 2015. Estimates were produced for commercial size recruited scallops (90 mm or larger), assuming historical average dredge efficiency and predicting weight from length. The analysis used a non-parametric resampling with replacement approach to estimation (1000 bootstraps).

Grouping	Location	Area	Tows	Density (scallops.m^{-2})				Abundance (millions)				Scallop weight (g)		Biomass (t green)				Biomass (t meat)			
	Stratum	(km^2)	*n*	Mean	CV	Median	95%CI	Mean	CV	Median	95%CI	Mean	Median	Mean	CV	Median	95%CI	Mean	CV	Median	95%CI
RECRUITED																					
GB	1	62	5	0.001	0.96	0.001	0–0.003	0.059	0.96	0.057	0–0.187	85.6	84.4	5.0	0.96	4.8	0–16.4	0.7	0.97	0.7	0–2.3
	2	64	9	0.001	0.58	0.001	0–0.003	0.089	0.58	0.081	0.02–0.222	112.6	112.1	10.0	0.63	9.0	2–25.9	1.4	0.63	1.2	0.3–3.6
	3	109	3	0.001	0.17	0.001	0.001–0.001	0.102	0.17	0.100	0.074–0.145	78.3	77.8	8.0	0.19	7.8	5.5–11.5	1.1	0.20	1.1	0.7–1.6
	4	62	8	0.003	0.53	0.002	0–0.006	0.163	0.53	0.153	0.027–0.353	95.2	94.8	15.5	0.53	14.5	2.3–34	2.1	0.54	2.0	0.3–4.9
	5	151	6	0.002	0.46	0.002	0.001–0.004	0.334	0.46	0.319	0.083–0.679	78.2	78.2	26.1	0.47	25.0	6.2–52.3	3.6	0.48	3.4	0.8–7.5
	6	4	3	0.002	0.17	0.002	0.001–0.003	0.008	0.17	0.007	0.005–0.011	76.6	77.3	0.6	0.18	0.6	0.4–0.8	0.1	0.20	0.1	0.1–0.1
GBTB	7	10	6	0.005	0.60	0.004	0.001–0.011	0.045	0.60	0.042	0.007–0.107	74.8	74.9	3.4	0.62	3.1	0.5–8.3	0.4	0.63	0.4	0.1–1
TB	8	29	3	0.007	0.46	0.007	0–0.013	0.196	0.46	0.194	0–0.386	73.2	73.2	14.4	0.46	14.2	0–28	1.9	0.47	1.9	0–3.6
	9	227	4	0.000	–	0.000	0–0	0.000	–	0.000	0–0	–	–	0.0	–	0.0	0–0	0.0	–	0.0	0–0
	10	19	3	0.000	–	0.000	0–0	0.000	–	0.000	0–0	–	–	0.0	–	0.0	0–0	0.0	–	0.0	0–0
	11	64	4	0.002	0.48	0.002	0–0.005	0.153	0.48	0.149	0.029–0.315	94.7	94.0	14.4	0.48	14.0	2.6–29.9	1.9	0.49	1.9	0.3–4
	12	47	3	0.001	0.55	0.001	0–0.003	0.064	0.55	0.062	0–0.139	85.7	86.2	5.5	0.53	5.4	0–11.7	0.7	0.54	0.7	0–1.6
	13	65	3	0.000	–	0.000	0–0	0.000	–	0.000	0–0	–	–	0.0	–	0.0	0–0	0.0	–	0.0	0–0
	14	68	4	0.000	0.89	0.000	0–0.001	0.016	0.89	0.015	0–0.048	75.6	75.4	1.2	0.89	1.1	0–3.6	0.2	0.90	0.1	0–0.5
	15	40	3	0.001	0.46	0.001	0–0.001	0.024	0.46	0.024	0–0.046	78.5	78.3	1.9	0.47	1.9	0–3.7	0.3	0.48	0.2	0–0.5
	16	88	3	0.006	0.59	0.006	0.002–0.014	0.529	0.59	0.485	0.144–1.254	112.7	111.7	59.6	0.54	54.2	19.9–135.4	7.9	0.54	7.1	2.7–17.9
	17	16	3	0.019	0.47	0.018	0.003–0.038	0.297	0.47	0.289	0.044–0.595	74.9	74.8	22.3	0.47	21.6	3.3–44.3	2.9	0.47	2.8	0.4–5.9
	18	4	3	0.064	0.19	0.063	0.044–0.093	0.229	0.19	0.226	0.155–0.331	77.5	77.6	17.8	0.20	17.5	11.8–25.9	2.3	0.20	2.3	1.5–3.4
	19	50	3	0.000	0.87	0.000	0–0.001	0.015	0.87	0.015	0–0.044	67.0	67.1	1.0	0.88	1.0	0–2.9	0.1	0.88	0.1	0–0.4
	20	3	3	0.007	0.38	0.007	0.001–0.013	0.021	0.38	0.021	0.004–0.037	91.4	90.9	1.9	0.38	1.9	0.4–3.4	0.3	0.39	0.2	0.1–0.5
	21	244	10	0.025	0.34	0.025	0.011–0.044	6.157	0.34	5.990	2.584–10.769	79.4	79.1	488.7	0.34	473.9	200.7–851.6	64.7	0.34	63.1	27.1–114.8
GBTB	22	342	3	0.001	0.57	0.001	0–0.003	0.433	0.57	0.415	0–0.987	70.8	70.9	30.7	0.57	29.4	0–69.3	3.6	0.57	3.5	0–8.2

Table 6: Stratum estimates of scallops in previously surveyed areas of Marlborough Sounds within SCA 7, November 2015. Estimates were produced for commercial size recruited scallops (90 mm or larger), assuming historical average dredge efficiency and predicting weight from length. The analysis used a non-parametric resampling with replacement approach to estimation (1000 bootstraps).

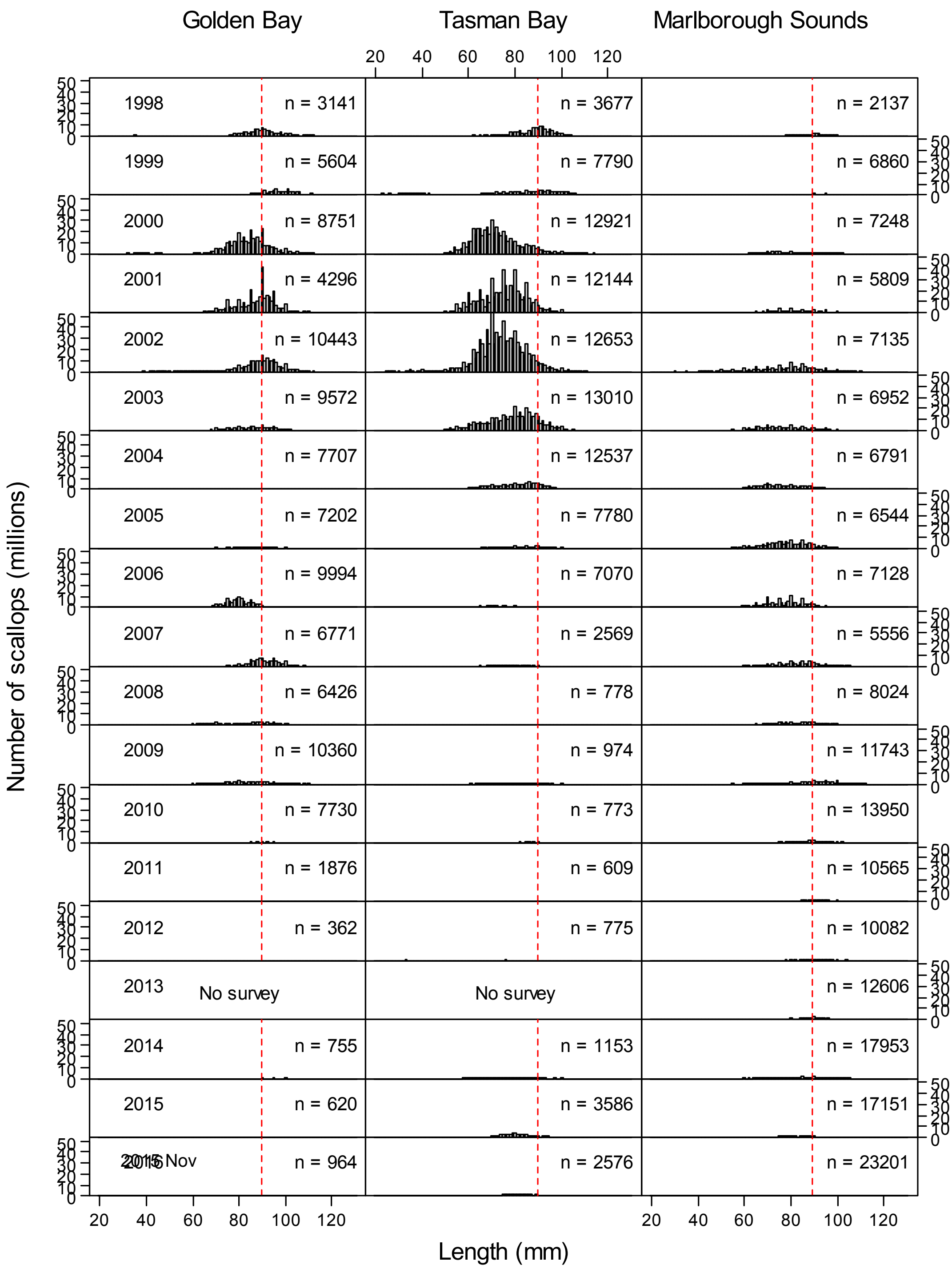
Grouping	Location	Area	Tows	Density (scallops.m^{-2})				Abundance (millions)				Scallop weight (g)		Biomass (t green)				Biomass (t meat)			
	Stratum	(km^2)	*n*	Mean	CV	Median	95%CI	Mean	CV	Median	95%CI	Mean	Median	Mean	CV	Median	95%CI	Mean	CV	Median	95%CI
RECRUITED																					
MS	23	10	7	0.009	0.40	0.009	0.004–0.018	0.094	0.40	0.089	0.036–0.182	74.4	74.6	7.0	0.39	6.6	2.8–13.5	0.9	0.39	0.9	0.4–1.8
	24	62	4	0.001	0.90	0.001	0–0.004	0.072	0.90	0.068	0–0.222	72.5	72.6	5.2	0.90	4.9	0–16.3	0.7	0.91	0.6	0–2.2
	25	13	3	0.009	0.90	0.009	0–0.027	0.113	0.90	0.111	0–0.347	78.9	78.7	8.9	0.90	8.7	0–27.1	1.2	0.90	1.1	0–3.6
	26	3	3	0.017	0.28	0.017	0.009–0.028	0.057	0.28	0.055	0.029–0.092	73.7	73.8	4.2	0.27	4.0	2.2–6.7	0.5	0.28	0.5	0.3–0.9
	27	5	3	0.053	0.19	0.052	0.038–0.076	0.293	0.19	0.285	0.208–0.42	88.4	87.7	25.9	0.20	25.0	18.3–37.8	3.4	0.21	3.3	2.4–5
	28	71	8	0.005	0.48	0.004	0–0.009	0.333	0.48	0.315	0.032–0.673	73.7	73.7	24.5	0.49	23.2	2.1–49.3	3.2	0.49	3.0	0.3–6.6
	29	17	10	0.036	0.63	0.033	0.006–0.089	0.630	0.63	0.576	0.109–1.558	77.6	77.6	48.9	0.65	44.7	7.8–122.7	6.4	0.66	5.9	1–16.4
	30	1	3	0.048	0.28	0.047	0.025–0.077	0.069	0.28	0.067	0.036–0.11	74.6	75.0	5.2	0.28	5.0	2.7–8.2	0.7	0.28	0.7	0.4–1.1
	31	14	4	0.015	0.49	0.014	0.003–0.03	0.208	0.49	0.198	0.04–0.419	76.0	76.3	15.8	0.49	15.1	3.1–32.8	2.1	0.50	2.0	0.4–4.4
	32	3	5	0.084	0.24	0.083	0.05–0.126	0.286	0.24	0.282	0.169–0.427	76.3	76.5	21.8	0.24	21.5	12.8–32.9	2.9	0.24	2.8	1.7–4.4
	33	3	4	0.161	0.19	0.158	0.111–0.231	0.460	0.19	0.452	0.317–0.659	78.0	77.9	35.9	0.19	35.2	25.2–51.4	4.7	0.20	4.6	3.2–6.9
	34	1	3	0.073	0.43	0.073	0.003–0.135	0.088	0.43	0.088	0.003–0.162	79.0	79.0	6.9	0.43	6.9	0.2–12.9	0.9	0.43	0.9	0–1.7
	35	6	6	0.125	0.23	0.121	0.081–0.19	0.802	0.23	0.777	0.521–1.225	92.5	92.0	74.2	0.24	71.5	47.8–115.1	9.8	0.25	9.3	6.3–15.2
	36	6	4	0.145	0.18	0.141	0.104–0.208	0.844	0.18	0.825	0.604–1.21	80.9	80.8	68.3	0.18	66.7	48.9–97.4	9.0	0.20	8.7	6.3–13.3
	37	12	3	0.003	0.84	0.002	0–0.007	0.031	0.84	0.030	0–0.089	70.6	70.7	2.2	0.85	2.1	0–6.2	0.3	0.85	0.3	0–0.8
	38	6	3	0.053	0.73	0.050	0.002–0.138	0.317	0.73	0.299	0.013–0.824	84.4	84.0	26.8	0.72	25.1	1.2–68.3	3.5	0.73	3.3	0.2–9.2
	39	12	6	0.001	0.78	0.001	0–0.003	0.012	0.78	0.011	0–0.034	80.2	81.4	0.9	0.77	0.9	0–2.7	0.1	0.78	0.1	0–0.3
	40	10	10	0.157	0.28	0.153	0.09–0.255	1.570	0.28	1.530	0.898–2.547	81.2	81.2	127.5	0.28	124.2	72.4–205.6	16.8	0.28	16.2	9.4–27.2
	41	43	4	0.007	0.72	0.007	0–0.02	0.298	0.72	0.282	0.015–0.842	75.6	74.7	22.5	0.71	21.1	1.6–61.8	3.0	0.71	2.8	0.2–7.9
	42	5	3	0.075	0.17	0.074	0.053–0.106	0.339	0.17	0.332	0.24–0.477	77.7	77.5	26.3	0.18	25.7	18.8–37.2	3.5	0.19	3.4	2.4–4.9
	43	1	3	0.098	0.74	0.094	0.003–0.26	0.136	0.74	0.131	0.004–0.359	80.1	79.8	10.9	0.73	10.4	0.3–28.4	1.4	0.74	1.4	0–3.8
	44	1	4	0.234	0.22	0.228	0.15–0.347	0.339	0.22	0.330	0.217–0.502	78.0	77.8	26.4	0.22	25.7	16.9–39.5	3.5	0.23	3.4	2.2–5.3

Table 7: Stratum estimates of scallops in previously unsurveyed areas within SCA 7, November 2015. Estimates were produced for commercial size recruited scallops (90 mm or larger), assuming historical average dredge efficiency and predicting weight from length. The analysis used a non-parametric resampling with replacement approach to estimation (1000 bootstraps).

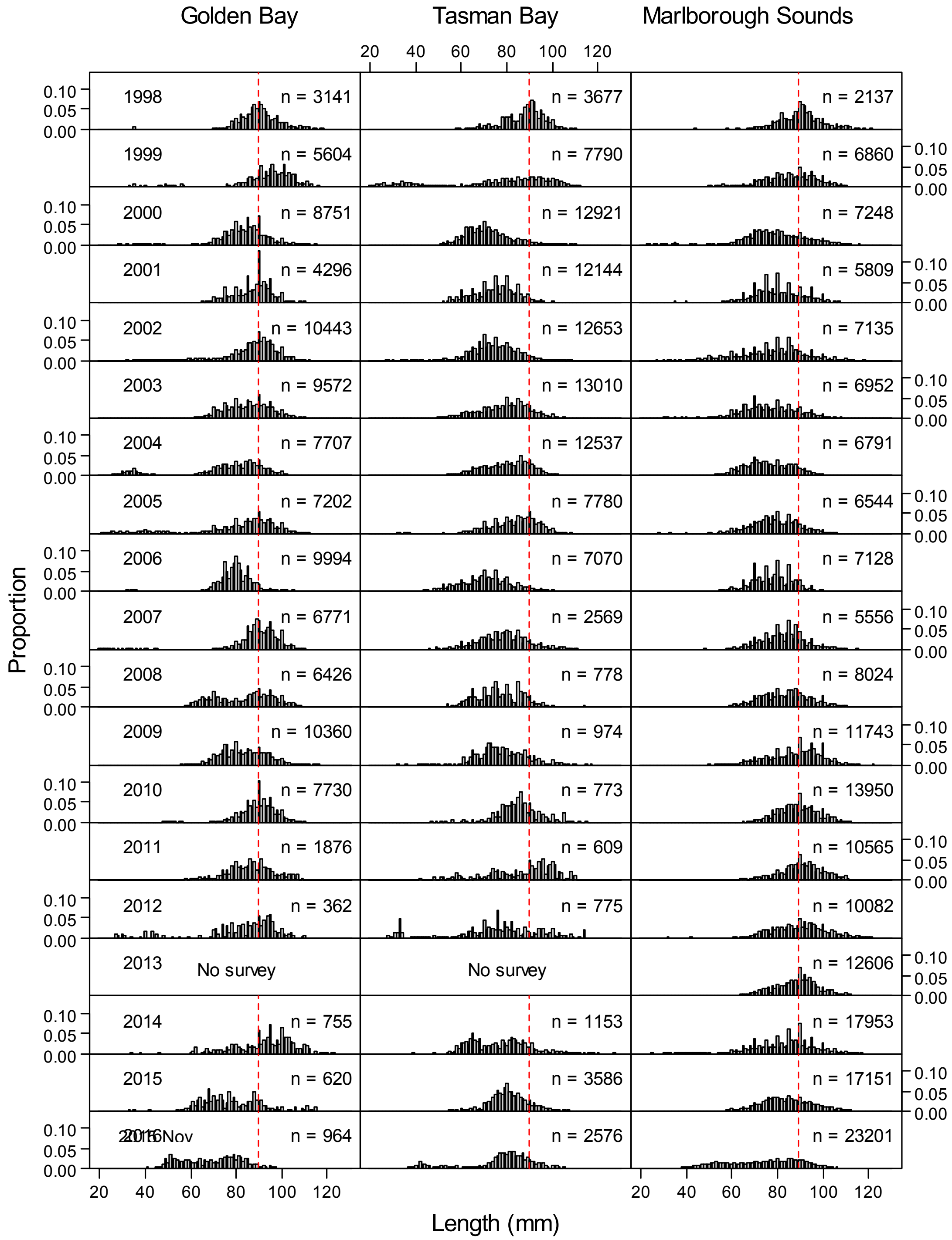
Grouping	Location	Area	Tows	Density (scallops.m^{-2})				Abundance (millions)				Scallop weight (g)		Biomass (t green)				Biomass (t meat)			
	Stratum	(km^2)	*n*	Mean	CV	Median	95%CI	Mean	CV	Median	95%CI	Mean	Median	Mean	CV	Median	95%CI	Mean	CV	Median	95%CI
RECRUITED																					
GB	45	18	4	0.000	–	0.000	0–0	0.000	–	0.000	0–0	–	–	0.0	–	0.0	0–0	0.0	–	0.0	0–0
	46	9	3	0.002	0.67	0.002	0–0.005	0.018	0.67	0.017	0–0.045	76.2	76.3	1.4	0.69	1.3	0–3.5	0.2	0.69	0.2	0–0.5
TB	47	10	3	0.000	–	0.000	0–0	0.000	–	0.000	0–0	–	–	0.0	–	0.0	0–0	0.0	–	0.0	0–0
	48	79	3	0.001	0.49	0.001	0–0.002	0.077	0.49	0.074	0–0.158	100.0	100.7	7.7	0.48	7.5	0–15.3	1.0	0.47	1.0	0–2
	49	2	3	0.002	0.47	0.002	0–0.003	0.003	0.47	0.003	0–0.005	89.1	89.4	0.2	0.48	0.2	0–0.5	0.0	0.48	0.0	0–0.1
GBTB	50	27	6	0.002	0.78	0.002	0–0.005	0.052	0.78	0.048	0.003–0.139	98.5	98.7	5.1	0.82	4.8	0.2–14	0.6	0.83	0.6	0–1.7
	51	872	18	0.000	1.03	0.000	0–0.001	0.236	1.03	0.222	0–0.837	81.6	81.7	19.3	1.03	18.1	0–68.3	2.3	1.04	2.1	0–8.1
	52	20	5	0.000	0.94	0.000	0–0.001	0.004	0.94	0.004	0–0.014	91.7	90.8	0.4	0.95	0.4	0–1.3	0.0	0.96	0.0	0–0.1
	53	8	5	0.000	–	0.000	0–0	0.000	–	0.000	0–0	–	–	0.0	–	0.0	0–0	0.0	–	0.0	0–0
MS	54	17	3	0.014	0.38	0.014	0.003–0.025	0.234	0.38	0.234	0.049–0.423	76.4	76.2	17.9	0.38	17.8	3.8–31.7	2.3	0.38	2.3	0.5–4.2
	55	7	3	0.008	0.81	0.007	0–0.021	0.052	0.81	0.049	0–0.142	72.6	72.4	3.8	0.81	3.5	0–10.4	0.5	0.81	0.5	0–1.4
	56	10	6	0.005	0.77	0.004	0–0.013	0.047	0.77	0.043	0–0.134	77.7	76.4	3.6	0.74	3.2	0–10.2	0.5	0.75	0.4	0–1.3
	57	53	6	0.001	0.66	0.001	0–0.003	0.073	0.66	0.069	0–0.181	91.7	90.8	6.7	0.67	6.2	0–16.7	0.9	0.68	0.8	0–2.3
	58	124	6	0.018	0.70	0.016	0–0.048	2.227	0.70	2.016	0–5.945	78.1	78.3	173.9	0.70	157.8	0–457.8	22.9	0.70	20.6	0–60.1
	59	5	6	0.035	0.43	0.033	0.011–0.068	0.180	0.43	0.171	0.059–0.351	81.1	80.4	14.6	0.44	13.7	4.6–29	1.9	0.45	1.8	0.6–3.8
	60	12	6	0.016	0.52	0.015	0.002–0.033	0.192	0.52	0.187	0.025–0.406	78.3	78.3	15.0	0.50	14.7	2.3–30.8	2.0	0.50	1.9	0.3–4.1
	61	48	6	0.006	0.89	0.006	0–0.019	0.311	0.89	0.291	0–0.943	71.8	71.8	22.3	0.88	20.9	0–67	2.9	0.89	2.7	0–8.9
	62	2	4	0.008	0.51	0.008	0.001–0.017	0.014	0.51	0.013	0.002–0.029	96.2	96.2	1.3	0.50	1.3	0.2–2.7	0.2	0.50	0.2	0–0.4
	63	6	3	0.000	–	0.000	0–0	0.000	–	0.000	0–0	–	–	0.0	–	0.0	0–0	0.0	–	0.0	0–0
	64	3	3	0.001	0.51	0.001	0–0.002	0.002	0.51	0.002	0–0.005	72.9	73.2	0.2	0.50	0.2	0–0.4	0.0	0.51	0.0	0–0
	65	12	6	0.001	0.78	0.001	0–0.003	0.012	0.78	0.011	0–0.031	71.9	72.2	0.8	0.80	0.8	0–2.3	0.1	0.80	0.1	0–0.3
	66	39	6	0.002	0.56	0.001	0–0.003	0.060	0.56	0.057	0.009–0.132	76.9	77.9	4.6	0.53	4.5	0.8–10	0.6	0.54	0.6	0.1–1.3
	67	57	6	0.002	0.87	0.002	0–0.006	0.117	0.87	0.110	0–0.352	76.5	75.8	8.9	0.86	8.3	0–26.6	1.2	0.86	1.1	0–3.5

APPENDIX 4

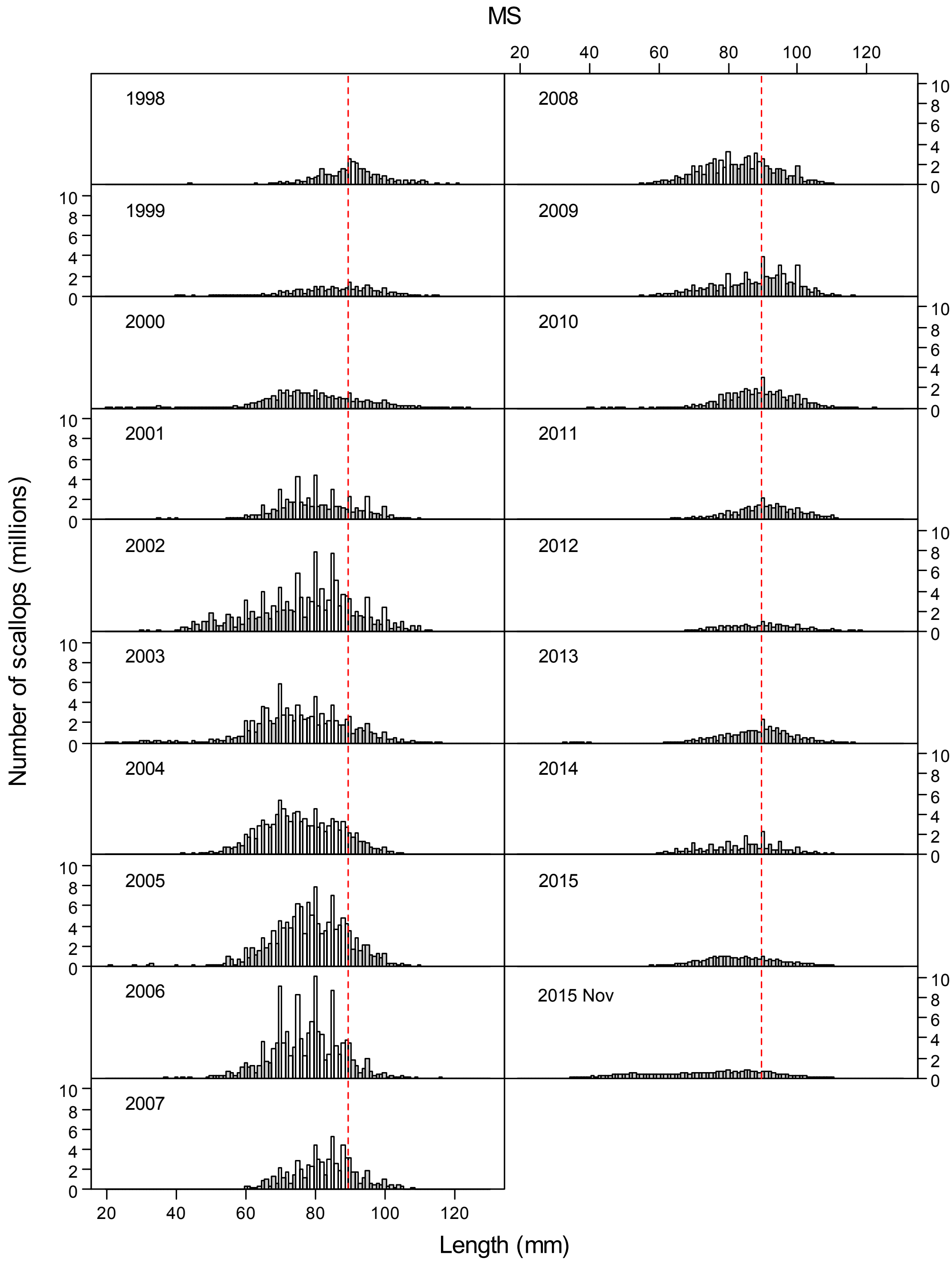
Time series of SCA 7 scallop length frequency distributions, 1998 to 2015.



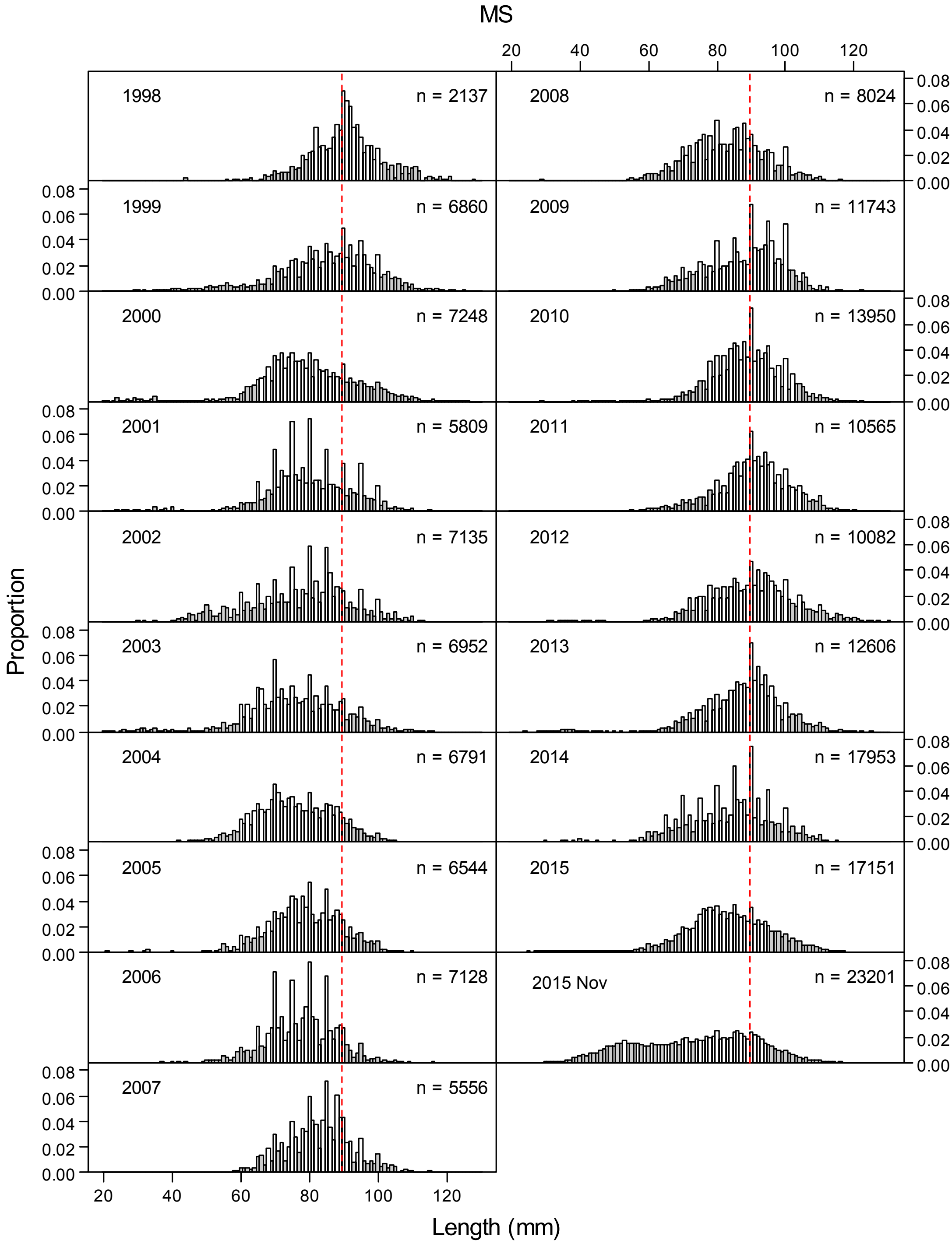
Scaled length frequency distributions by region



Proportional length frequency distributions by region



Scaled length frequency distributions, Marlborough Sounds



Proportional length frequency distributions, Marlborough Sounds