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SCA 7 in-season survey, October 2015

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An in-fishing season dredge survey of scallops (*Pecten novaezelandiae*) was conducted from 7–9 October 2015 in three key fishery areas in the Marlborough Sounds within the Southern scallop stock, SCA 7. The three areas were Guards Bay, Ship Cove, and Dieffenbach Point. The aims of the survey were to provide estimates of the current status of the scallop beds within the specified areas, and to compare those estimates with relevant data from previous surveys and with recent fine scale catch data. The survey used a stratified random sampling allocation design, with sampling conducted using a chartered commercial fishing vessel and ring-bag scallop dredge.

The highest catches were from tows within key strata which represent banks and bays that support the main scallop beds at Guards, Ship and Dieffenbach. Large proportions of the populations at Guards (46%) and Ship (44%) were of recruited size (90 mm or larger), compared with about one third of the population at Dieffenbach (35%). There were at least two length modes (representing juvenile and adult cohorts) evident in the length frequency distribution in each of the three areas. The presence of clear juvenile modes in all three areas suggests that the settlement and subsequent survival of spat has occurred in the last year.

Absolute biomass of recruited scallops (90 mm or larger) in each area at the time of the in-season survey (7–9 October 2015) were as follows: Guards 22.2 t (95%CI = 15.2–33.2 t; mean = 22.7 t, CV = 0.21); Ship 23.7 t (95%CI = 6.7–60.2 t; mean = 25.8 t, CV = 0.59); Dieffenbach 3.5 t (95%CI = 1.8–6.0 t; mean = 3.6 t, CV = 0.31); the combined total recruited biomass was 49.0 t (95% CI = 28.3–90.2 t, mean = 52.1 t, CV = 0.33). These in-season estimates were compared with estimates made at the time of the May 2015 survey of SCA 7, and with those projected from the May survey to the start of the fishing season (actual start date of 4 October 2015 in the Marlborough Sounds). The results suggested that the estimates produced from the May survey were largely reliable. An analysis of the start of season biomass and the commercial catch already harvested was conducted to assess available catch for the 2015 fishing season. For the three areas of Guards, Ship, and Dieffenbach combined, using exploitation rates of 22% and 35% as reference points, the total available catch for the 2015 fishing season was calculated as 13 t and 20 t, respectively.

1. INTRODUCTION

1.1 Overview

This report summarises the findings of an in-fishing season dredge survey of scallops (*Pecten novaezelandiae*) in specified areas of the Marlborough Sounds within the Southern scallop stock, SCA 7, 7–9 October 2015.

Scallops (*Pecten novaezelandiae*) 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 substocks of Golden Bay, Tasman Bay, and the 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. 2015). 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.

It was proposed that commercial scallop fishing in SCA 7 in the 2015–16 fishing year would occur in Tasman Bay sector H and in the three specified areas in the Marlborough Sounds (Guards Bay, Ship Cove, and Dieffenbach Point) that held the majority of the available recruited scallop biomass. Because of the continued decline in biomass in the commercially fished regions in the Marlborough Sounds, MPI required a mid-fishing season (October 2015) survey of scallops in these specified areas of the Marlborough Sounds in this project (SCA201503). A full survey of the entire SCA 7 stock was also required in November 2015 under a separate project (SCA201504).

1.2 Objectives

This work was carried out under Ministry for Primary Industries project SCA201503: SCA 7 mid-season survey, October 2015. The overall research objective for this project SCA201503 was "to evaluate the status of specified scallop fishing areas in the Marlborough Sounds within the SCA 7 scallop stock". The specific research objectives were to "1) conduct a mid-fishing season biomass survey (most likely in October) in specified areas within the Marlborough Sounds that will provide estimates of the current abundance, length frequency, biomass (in tonnes greenweight and meatweight) and density within the specified areas; and 2) compare the estimates from Objective 1 with relevant data from previous surveys and, if available, all relevant fine scale catch data".

These two specific objectives combine to form a unified project: conducting an in-season survey provided an up-to-date assessment of the scallop population within key areas of the Marlborough Sounds that support fishing, and comparison of estimates from this survey with estimates from the May 2015 survey allowed examination of whether there have been changes in population status associated with recent fishing 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 May 2015 survey of scallops in SCA 7 (Williams et al. 2015), to an in-season survey of Guards Bank conducted in September 2014 (Williams 2014), and to previous annual dredge surveys in the SCA 7 survey series (Williams et al. 2014). It also relates indirectly 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. 2015), 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 was carried out shortly before the associated project SCA201504 (SCA 7 stock survey, November 2015).

1.5 Project approach

In this project, we conducted an in-season survey using a commercial scallop fishing vessel and ring-bag dredge. All methodology proposed was presented to the MPI Shellfish Working Group 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 the specified areas, and compared this with the status in May 2015 to investigate whether changes had occurred in the population. An assessment of possible further available catch was also made for the Marlborough Sounds specified areas.

2. METHODS

2.1 Survey design

An in-season dredge survey was conducted from 7–9 October 2015 using a stratified random sampling allocation design. The sample extent (survey coverage) was restricted to include the following three specified areas in the Marlborough Sounds, and stratification within these areas was based on that used in the May 2015 survey (Figure 1):

- Guards Bay (strata 32, 321, 33, and 34)
- Ship Cove (strata 37 and 38)

- Dieffenbach Point (strata 40 and 41)

Stratum 37 (within Ship Cove) from the May 2015 survey was subdivided into two strata: '371', representing areas that appear to have been fished in the past (from 2012 and 2013 Navman data on vessel positions provided by CSEC); and '37', the remaining area.

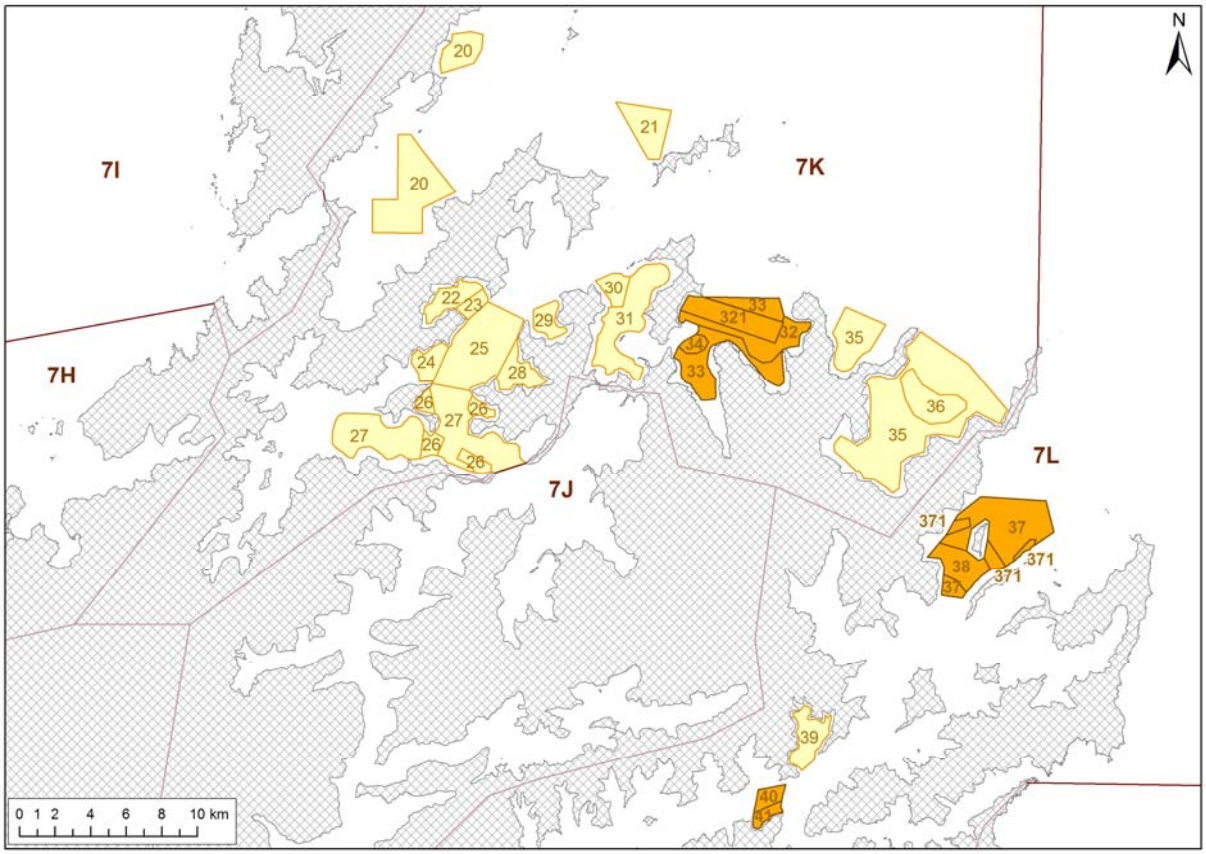

Figure 1: Specified areas (dark orange shading) in the Marlborough Sounds to be surveyed in the SCA 7 in-season survey, October 2015. Number labels (e.g., 321) are stratum codes from the May 2015 SCA 7 survey, number and letter labels (e.g. 7K) are scallop fishery Statistical Reporting Areas.

2.2 Station allocation

Station allocation 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. The CV is calculated from historical survey data and the estimated areas of the strata. The strata for the in-season 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. 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. The May 2015 survey sampled a combined total of 35 stations in these areas, and in October we sampled 50 stations in an attempt to achieve precise scallop estimates.

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. Commercial scallop fishing in SCA 7 occurs on 4 days of the week (Sunday to Wednesday), and the other three days (Thursday to Saturday) are designated non-fishing days. The in-season survey work in the specified areas of the Marlborough Sounds was carried out on Wed–Fri 7–9 October. This was immediately after four days of commercial fishing had been carried out in stratum 321 at Guards Bank from Sun–Wed 4–7 October, and before any commercial fishing had been carried out in other areas within Guards Bay or within the Ship Cove or Dieffenbach locations.

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). The actual tow length was calculated with GIS software 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. 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'). 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.

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.

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. 2015).

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 relationship to predict individual scallop weight from length. The length-weight model parameters *a* and *b* are randomly selected from 2000 sets of these parameters, applying them in the length-weight 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 are detailed in Appendix B of the May 2015 survey report (Williams et al. 2015) (from Williams et al. (2013)).

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 2.5 days from 7–9 October 2015. A total of 50 stations (dredge tows) were sampled within the 9 strata. All stations allocated were sampled, and the tow paths were generally in good agreement with the station positions allocated (Appendix 1). Two NIWA technicians (D. Parkinson and L.Olsen) conducted the survey, assisted by the skipper and mate of the chartered vessel.

3.2 Distribution

The catch of scallops per standard tow at each station for the three fishing areas surveyed is shown in Figure 2. The same data are also shown at a larger scale for each individual area in Appendix 2. As expected, the highest catches were from tows within key strata (Guards 321, 32, 34; Ship 371, 38; Dieffenbach 41) which represent the banks and bays that support the main scallop beds. Catches were generally very low in the other strata, except for the large catch on one tow in stratum 37 situated between Ship Cove (stratum 38) and Cannibal Cove (part of stratum 371) (Appendix 2).

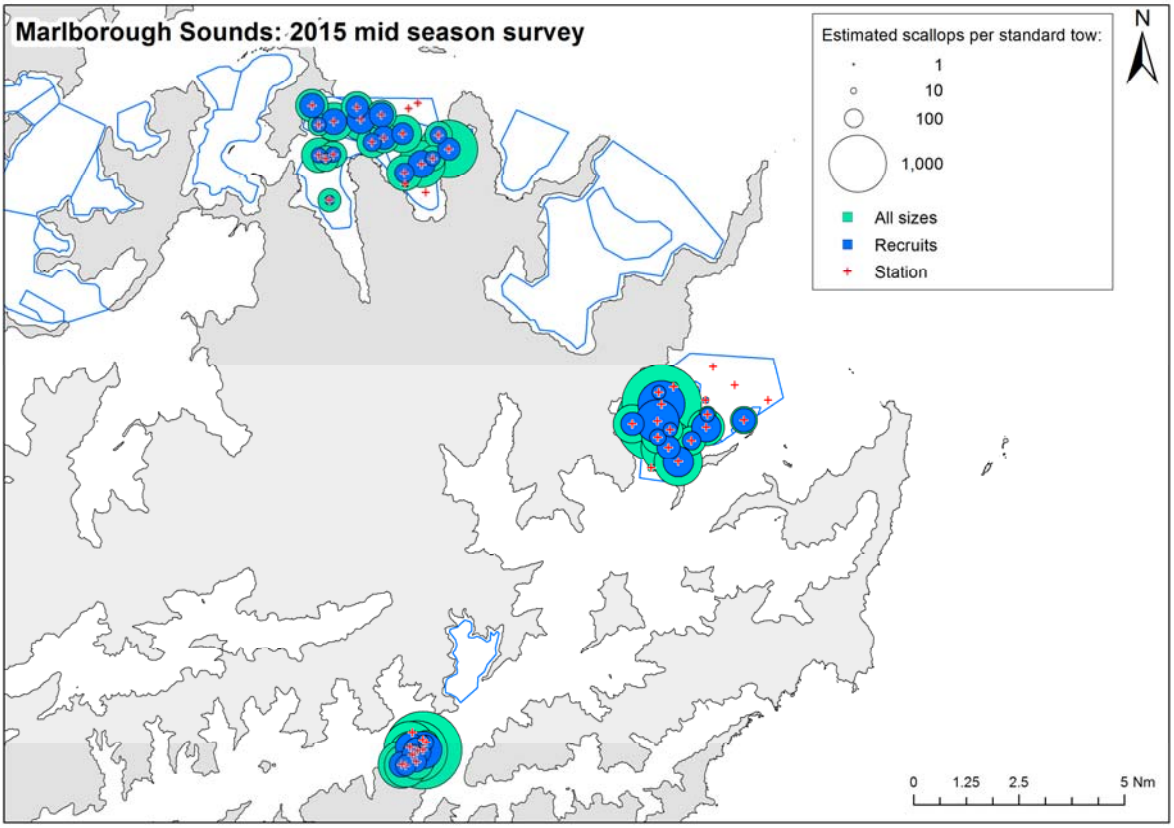

Figure 2: Catch of recruited scallops per standard tow in three fishing areas in the Marlborough Sounds, SCA 7 in-season survey, 7–9 October 2015. Circle area is proportional to the number of recruited scallops (90 mm or larger shell length) caught per standard distance towed (0.4 n.miles). Values are uncorrected for dredge efficiency. Polygons denote survey strata and sector boundaries.

3.3 Length Frequency

Scallop length frequency distributions were plotted for the three fishing areas of Guards, Ship, and Dieffenbach (Figure 3) and also individually for the nine strata within those areas (Figure 4).

Large proportions of the populations at Guards (46%) and Ship (44%) were of recruited size (90 mm or larger), compared with about one third of the population at Dieffenbach (35%) (Figure 3); at the stratum level, the populations were particularly dominated by scallops of recruited size at Guards Bank stratum 321 (60%) and Ship stratum 371 (70%) (Figure 4). The size range of recruited scallops was about 90 to 110 mm at Ship and Dieffenbach, and about 90 to 120 mm at Guards.

There were at least two length modes (representing juvenile and adult cohorts) evident in the length frequency distribution in each of the three areas. Modal lengths were about 55 mm and 90 mm at Guards and Dieffenbach, and about 45 mm and 95 mm at Ship, although it is likely that the larger modes represent multiple cohorts. At Ship, the juvenile (45 mm) mode was particularly strong, and there was also weak evidence of a larger juvenile 60 mm mode. The presence of clear juvenile modes in all three areas suggests that the settlement and subsequent survival of spat has occurred in the last year.

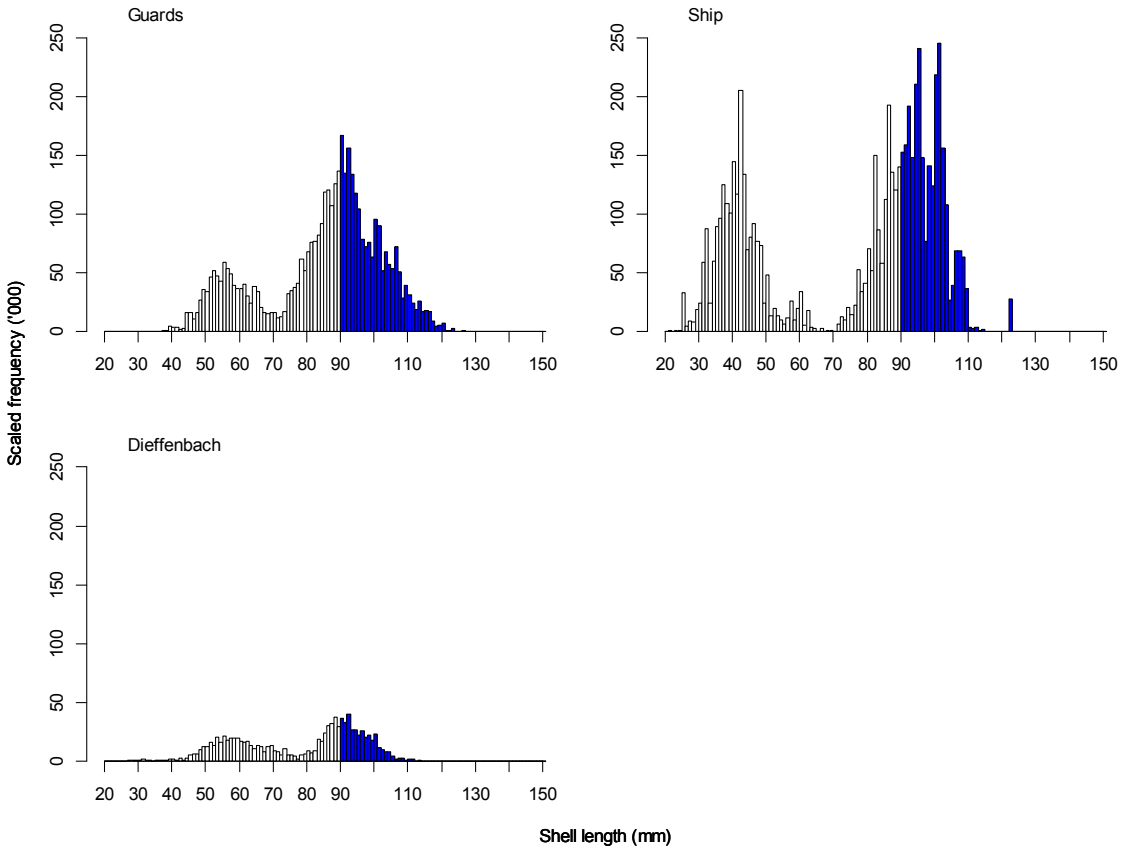

Figure 3: Length frequency distributions for scallops in three fishing areas in the Marlborough Sounds, SCA 7 in-season survey, 7–9 October 2015: Guards, Ship, and Dieffenbach. Data corrected for historical average dredge efficiency. Dark shaded bars show recruited scallops (90 mm shell length or larger).

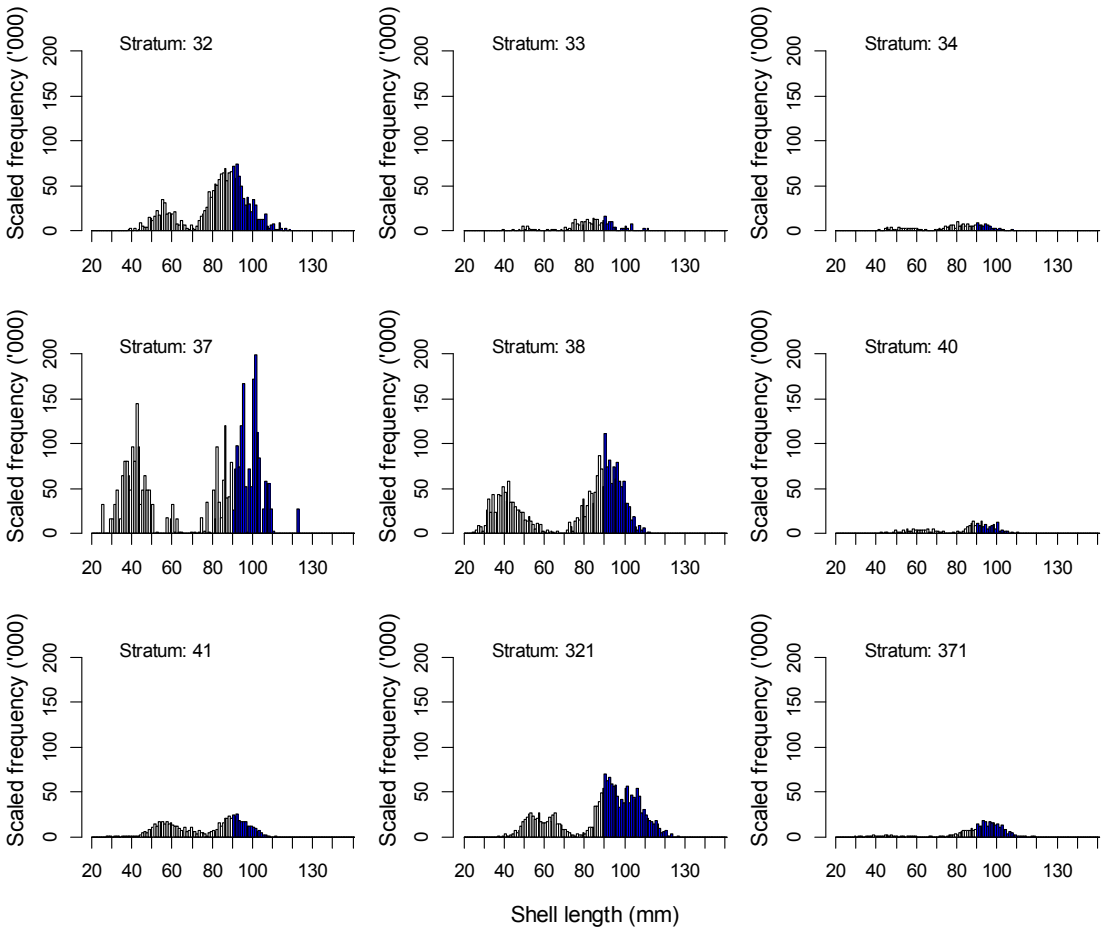

Figure 4: Stratum length frequency distributions for scallops in the Marlborough Sounds, SCA 7 in-season survey, 7–9 October 2015. Nine strata are shown: 321, Guards Bank Fishing Area; 32, Guards Bank Outer; 34, Anakoha Bank; 37, Motu38, Ship Cove; and 41, Dieffenbach High. Data corrected for historical average dredge efficiency. Dark shaded bars show recruited scallops (90 mm shell length or larger).

3.4 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 5) 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 (90mm or larger) at the time of the in-season survey (7–9 October 2015) are presented in Table 1. Recruited biomass in the three specified areas of interest, and for the combined total, were as follows:

- Guards 22.2 t (95%CI = 15.2–33.2 t; mean = 22.7 t, CV = 0.21)
- Ship 23.7 t (95%CI = 6.7–60.2 t; mean = 25.8 t, CV = 0.59)
- Dieffenbach 3.5 t (95%CI = 1.8–6.0 t; mean = 3.6 t, CV = 0.31)

- Combined total 49.0 t (95% CI = 28.3–90.2t, mean = 52.1 t, CV = 0.33).

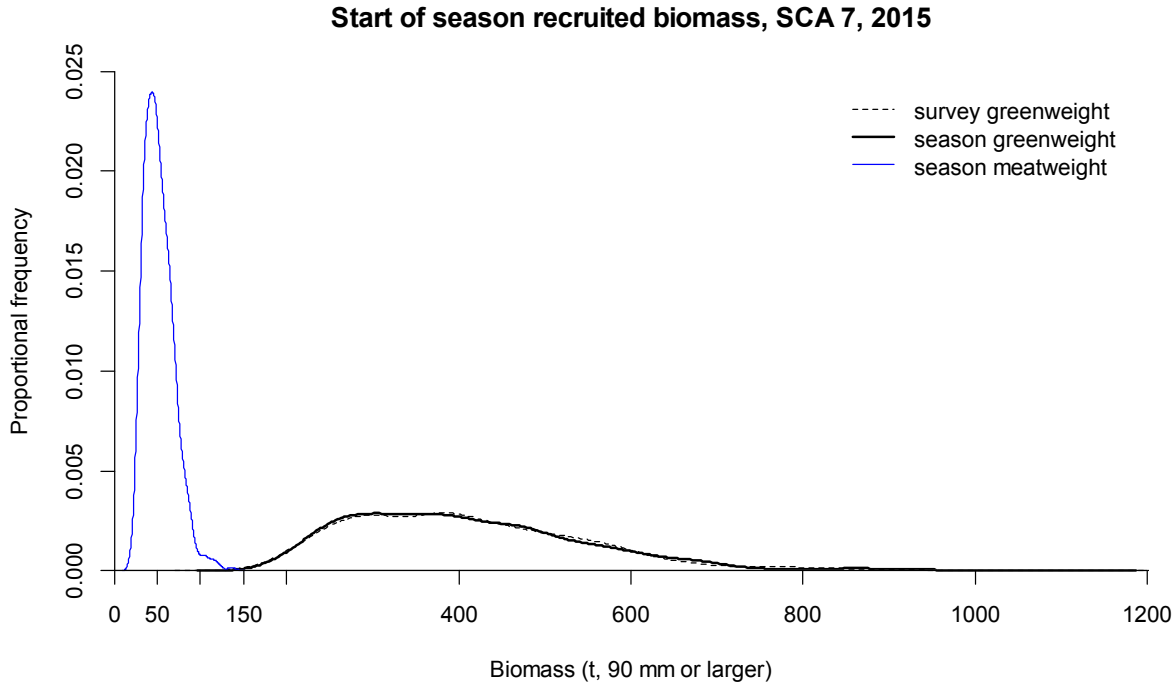

Figure 5: Proportional frequency distribution of the biomass of recruited scallops in specified areas in SCA 7 at the time of the in-season survey, 7–9 October 2015. Recruited scallops are those measuring 90 mm or larger. The results of a non-parametric resampling with replacement approach to estimating 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).

Comparison

The scallop population estimates from the 7–9 October 2015 in-season survey (Table 1) can be compared with estimates for the same areas surveyed in May 2015 (Table 2) to assess whether changes have occurred in the scallop beds within the specified areas. The May 2015 survey data (Williams et al. 2015) were also reanalysed to provide estimates of meatweight by the same groupings (Guards, Ship, Dieffenbach) in May 2015 (Table 3), and on 4 October (Table 4; May-projected estimates) which was the actual start of the fishing season in Marlborough Sounds in 2015. Figure 6 shows the May and May-projected (to 4 October) estimates in relation to the in-season survey estimates (7–9 October).

At Guards, the estimated biomass at the time of the May pre-season survey (32 t) was similar to that predicted for the start of the season on 4 October (33 t, May-projected estimate), but was lower at the time of the in-season survey 7–9 October (22 t).

At Ship, the May and May-projected estimates were similar (both 19 t), and, although the in-season estimate was higher (24 t), the uncertainty associated with the in-season estimate was large. This uncertainty was associated with the strong influence of one station with a large catch in stratum 37 (otherwise considered a stratum of low scallop density).

At Dieffenbach, the biomass was 5 t in May, was predicted to have increased to 6 t by the start of the season, but was an estimated 3.5 t at the time of the in-season survey.

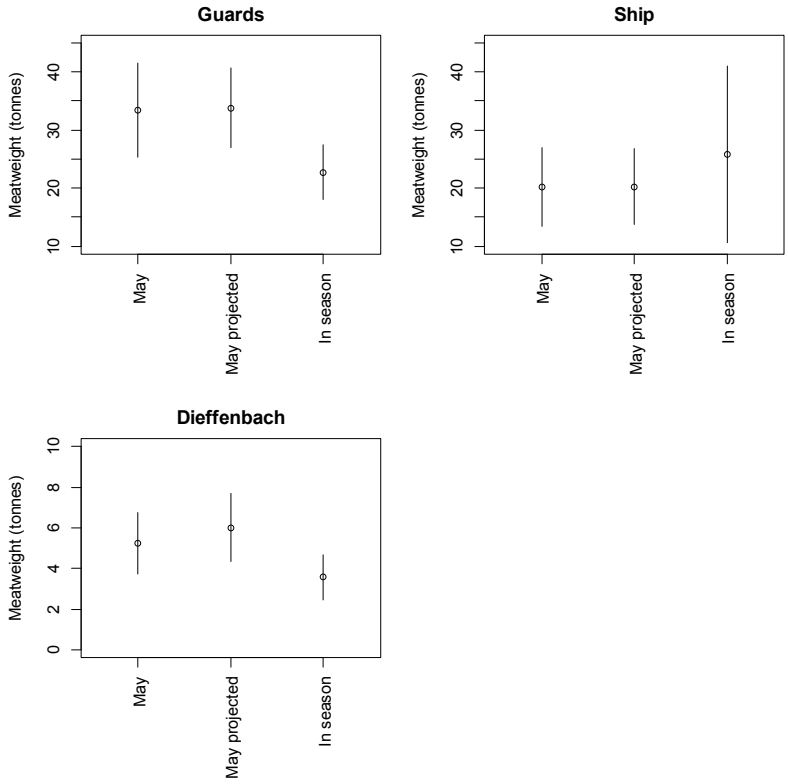

Figure 6: Estimates of recruited biomass (mean and CV) in specified fishing areas of the Marlborough Sounds, SCA 7 in-season survey, October 2015. Three estimates are presented for each of the three fishing areas (Guards, Ship, Dieffenbach): 1) 'May', at the time of the May survey (21–22 May); 2) 'May projected', at the start of the fishing season (4 Oct), projected from the May survey; and 3) 'In-season', at the time of the in-season survey (7–9 October).

Table 1: In-season estimates of scallops in specified areas of SCA 7, surveyed 7–9 October 2015. Estimates were produced for 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																					
	321	6.419	7	0.174	0.19	0.169	0.123–0.25	1.115	0.19	1.087	0.788–1.604	91.9	92.0	102	0.20	100	73–149	14.1	0.21	13.7	9.7–20
Stratum	32	5.902	7	0.107	0.22	0.105	0.069–0.162	0.634	0.22	0.617	0.405–0.955	81.1	80.8	51	0.23	50	33–79	7.1	0.24	6.9	4.4–10.8
	33	10.774	5	0.007	0.55	0.006	0.001–0.015	0.072	0.55	0.066	0.012–0.165	78.8	79.4	6	0.51	5	1–13	0.8	0.52	0.7	0.2–1.7
	34	1.199	3	0.052	0.23	0.051	0.03–0.077	0.063	0.23	0.062	0.037–0.092	78.5	78.6	5	0.24	5	3–7	0.7	0.25	0.7	0.4–1.1
	371	2.092	5	0.107	0.40	0.103	0.035–0.2	0.223	0.40	0.215	0.073–0.418	84.1	84.2	19	0.40	18	6–35	2.2	0.41	2.1	0.7–4
	37	13.887	6	0.110	0.93	0.104	0–0.339	1.521	0.93	1.448	0–4.704	87.7	87.8	133	0.93	127	0–413	15.7	0.94	14.6	0–48.6
	38	4.647	7	0.183	0.35	0.176	0.086–0.323	0.849	0.35	0.819	0.4–1.503	79.5	79.3	68	0.34	65	32–119	8.0	0.35	7.6	3.7–14.1
	40	1.597	4	0.078	0.57	0.073	0.01–0.171	0.124	0.57	0.117	0.016–0.274	81.0	81.1	10	0.57	9	1–22	1.3	0.57	1.2	0.2–2.9
	41	1.144	6	0.189	0.28	0.182	0.11–0.317	0.217	0.28	0.208	0.126–0.363	79.0	78.6	17	0.29	16	10–29	2.3	0.30	2.2	1.3–4
Region	Guards	24.295	22	0.078	0.19	0.076	0.055–0.11	1.884	0.19	1.840	1.345–2.679	87.3	87.2	164	0.19	160	117–237	22.7	0.21	22.2	15.2–33.2
	Ship	20.626	18	0.126	0.56	0.117	0.034–0.285	2.594	0.56	2.410	0.708–5.882	84.7	84.3	220	0.58	203	58–507	25.8	0.59	23.7	6.7–60.2
	Dieffenbach	2.742	10	0.124	0.30	0.121	0.063–0.202	0.341	0.30	0.331	0.172–0.552	79.8	79.7	27	0.30	26	14–45	3.6	0.31	3.5	1.8–6
Total	All combined	47.663	50	0.101	0.33	0.096	0.053–0.175	4.818	0.33	4.571	2.542–8.32	85.4	85.2	411	0.35	389	215–729	52.1	0.33	49.0	28.3–90.2

Table 2: Projected estimates of recruited scallops by stratum at the nominal start of the season, 1 September 2015 (from Williams et al. (2015).

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																					
Guards	321	6.419	8	0.269	0.21	0.264	0.174-0.405	1.728	0.21	1.691	1.119–2.597	90.88	89.87	157	0.24	152	98–245	20.8	0.24	20.2	12.7–33.3
	32	5.902	7	0.165	0.19	0.164	0.11-0.231	0.977	0.19	0.967	0.65–1.363	75.24	74.66	73	0.19	72	50–103	9.7	0.20	9.6	6.4–13.8
	33	10.774	2	0.004	0.57	0.004	0.001-0.008	0.039	0.57	0.039	0.007–0.082	63.57	63.96	2	0.58	2	0–5	0.3	0.58	0.3	0.1–0.7
	34	1.199	3	0.159	0.38	0.154	0.052-0.292	0.190	0.38	0.185	0.063–0.351	74.00	75.09	14	0.36	14	5–25	1.9	0.37	1.8	0.6–3.4
Ship	371	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	37	15.979	3	0.043	0.74	0.042	0-0.111	0.692	0.74	0.671	0–1.78	81.27	81.11	56	0.76	54	0–147	7.4	0.77	7.2	0–20.3
	38	4.647	6	0.340	0.24	0.336	0.202-0.513	1.582	0.24	1.562	0.938–2.386	75.46	75.22	119	0.24	118	72–181	15.8	0.25	15.7	9.3–24.2
Dieffenbach	40	1.597	3	0.144	0.37	0.143	0.032-0.249	0.230	0.37	0.228	0.05–0.397	74.95	74.82	17	0.37	17	4–30	2.3	0.37	2.3	0.5–4
	41	1.144	3	0.352	0.34	0.346	0.129-0.590	0.403	0.34	0.396	0.148–0.675	70.66	70.94	29	0.34	28	10–48	3.8	0.35	3.7	1.4–6.6

Table 3: May 2015 estimates (May 2015 survey reanalysed to produce estimates by fishing area, and in meatweight).

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																					
Stratum	321	6.419	8	0.262	0.25	0.252	0.165–0.427	1.684	0.25	1.619	1.057–2.738	96.6	96.5	163	0.27	156	100–270	22.5	0.28	21.4	13.8–37.6
	32	5.902	7	0.135	0.21	0.131	0.092–0.2	0.798	0.21	0.773	0.544–1.178	82.5	82.4	66	0.21	64	45–99	9.0	0.22	8.7	6.1–14.1
	33	10.774	2	0.002	0.70	0.002	0–0.005	0.023	0.70	0.022	0–0.052	74.2	74.4	2	0.70	2	0–4	0.2	0.71	0.2	0–0.5
	34	1.199	3	0.128	0.35	0.124	0.045–0.218	0.153	0.35	0.149	0.053–0.262	82.1	82.6	13	0.34	12	4–21	1.7	0.35	1.7	0.6–3
	371	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	37	15.979	3	0.043	0.73	0.041	0–0.114	0.682	0.73	0.649	0–1.826	85.5	85.5	58	0.75	56	0–160	6.8	0.76	6.5	0–19.1
	38	4.647	6	0.305	0.25	0.295	0.175–0.484	1.417	0.25	1.372	0.814–2.251	80.2	80.1	114	0.25	110	65–180	13.4	0.27	12.8	7.6–21.8
	40	1.597	3	0.125	0.37	0.123	0.033–0.219	0.199	0.37	0.197	0.053–0.349	79.6	80.0	16	0.37	16	5–28	2.1	0.37	2.1	0.6–3.7
	41	1.144	3	0.270	0.34	0.266	0.092–0.464	0.309	0.34	0.304	0.105–0.531	76.8	77.0	24	0.34	23	8–41	3.1	0.35	3.1	1–5.4
Region	Guards	24.295	20	0.109	0.22	0.106	0.075–0.169	2.657	0.22	2.568	1.827–4.118	91.4	90.9	243	0.23	234	162–386	33.4	0.24	32.0	21.8–54.4
	Ship	20.626	9	0.102	0.32	0.099	0.051–0.175	2.098	0.32	2.033	1.058–3.609	81.9	81.8	172	0.33	166	84–298	20.2	0.34	19.4	10.2–35.9
	Dieffenbach	2.742	6	0.185	0.28	0.182	0.096–0.302	0.507	0.28	0.498	0.263–0.827	77.9	78.0	40	0.28	39	20–64	5.2	0.29	5.1	2.7–8.5
Total	All combined	47.663	35	0.110	0.22	0.106	0.074–0.169	5.263	0.22	5.075	3.531–8.031	86.3	86.4	454	0.22	438	304–710	58.9	0.22	56.7	38.6–93.3

Table 4: Start of season 4 October estimates (May 2015 survey projected to 4 October)

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																					
Stratum	321	6.419	8	0.266	0.21	0.259	0.18–0.395	1.708	0.21	1.659	1.156–2.533	89.6	89.3	153	0.23	148	101–239	21.2	0.24	20.6	13.2–33.5
	32	5.902	7	0.174	0.20	0.170	0.117–0.247	1.025	0.20	1.001	0.69–1.455	72.9	73.0	75	0.19	73	52–105	10.3	0.19	10.1	7–14.6
	33	10.774	2	0.005	0.56	0.004	0.001–0.01	0.050	0.56	0.048	0.01–0.105	59.3	59.7	3	0.57	3	1–6	0.4	0.57	0.4	0.1–0.9
	34	1.199	3	0.174	0.40	0.166	0.053–0.318	0.209	0.40	0.199	0.064–0.381	70.9	71.2	15	0.38	14	5–26	2.0	0.39	1.9	0.7–3.7
	371	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	37	15.979	3	0.042	0.75	0.041	0–0.111	0.676	0.75	0.662	0–1.77	79.9	79.6	54	0.78	53	0–142	6.3	0.79	6.1	0–16.8
	38	4.647	6	0.342	0.23	0.336	0.207–0.512	1.588	0.23	1.563	0.961–2.381	73.9	74.2	117	0.23	116	72–175	13.8	0.24	13.6	8.2–21.1
	40	1.597	3	0.142	0.37	0.143	0.029–0.245	0.227	0.37	0.228	0.047–0.391	73.8	73.5	17	0.36	17	4–28	2.2	0.36	2.2	0.5–3.8
	41	1.144	3	0.367	0.33	0.358	0.152–0.624	0.421	0.33	0.409	0.174–0.714	68.6	68.9	29	0.33	28	12–49	3.8	0.34	3.7	1.5–6.6
Region	Guards	24.295	20	0.123	0.18	0.120	0.088–0.169	2.991	0.18	2.912	2.141–4.098	82.1	81.9	246	0.19	238	174–355	33.8	0.20	33.0	23.1–49
	Ship	20.626	9	0.110	0.30	0.106	0.056–0.182	2.264	0.30	2.177	1.159–3.746	75.7	75.4	171	0.31	164	86–291	20.2	0.32	19.3	10.1–35.1
	Dieffenbach	2.742	6	0.236	0.27	0.233	0.125–0.375	0.647	0.27	0.638	0.342–1.029	70.4	70.2	46	0.27	45	24–72	6.0	0.28	5.9	3.2–9.7
Total	All combined	47.663	35	0.124	0.19	0.121	0.085–0.172	5.902	0.19	5.774	4.058–8.222	78.4	77.7	462	0.19	449	318–669	60.0	0.19	58.5	41.3–86.8

3.5 Analysis

Table 5 provides a summary of the estimates referred to in the following description of the analysis.

Proposed commercial catch

Before the 2015 fishing season, CSEC proposed the following commercial catch limits (in t meatweight) for each of the three fishing areas:

- Guards 13 t
- Ship 7.5 t
- Dieffenbach 2.5 t

Actual commercial catch

CSEC provided the following information on the SCA 7 commercial fishery at the start of the 2015 fishing season (J. Reid, pers. comm.). Before the in-season survey commenced, commercial scallop fishing in SCA 7 was conducted in Tasman Bay sector H from 29–30 September and in Marlborough Sounds stratum 321 on Guards Bank from 4–7 October; no fishing had been carried out in other areas before the in-season survey. A total commercial catch of 8131.15 kg meatweight was landed from within stratum 321 during the 4–7 October period, and this area was closed to any further commercial fishing on Sunday 11 Oct. Fishers suggested that only about half of the area within 321 had been fished, and that they were still catching good scallops at a rate of 430–444 kg greenweight per hour of fishing. Some of the scallops had red algae attached to their shells, perhaps indicating that they came from the northern boundary of stratum 321. After the closure of 321 on 11 Oct, CSEC allowed fishing outside of stratum 321 in Guards Bay, and also in the Reach and both sides of Maude Island within Pelorus Sound.

Start of season biomass

The actual start date of the commercial fishing season in Marlborough Sounds was 4 October 2015. Start of season biomass was calculated as the current biomass (estimated from the in-season survey) plus the catch already harvested since commercial fishing commenced in the Marlborough Sounds on 4 October. Incidental mortality associated with that catch was ignored, as was any catch from other sources (e.g. recreational fishing). Ideally, the start-of-season biomass would be estimated as the current (in-season) biomass, plus the catch already harvested, plus or minus any biomass change that had occurred due to scallop growth (biomass increase) and mortality (biomass decrease) since the start of the season. However, given the very short period (3.5 days) between the start of fishing at Guards and the in-season survey, we expect any biomass change due to growth and mortality during this period would be negligible. For example, for the CSEC regulated area on Guards Bank (stratum 321), the current biomass of 13.7 t (median value) plus the 8.1 t of catch already harvested results in an estimated start of season biomass of 21.8 t. This is slightly higher than the median estimate from the May survey projected to 1 September (20.2 t), but is within the range of uncertainty for that estimate (95% CI = 12.7–33.3 t).

Available catch for 2015

The above information on start of season biomass and the catch already harvested was used to assess whether any further commercial catch would be available for the remainder of the 2015 fishing season. To do this, we followed the same approach as that used in the in-season assessment of Guards Bank in September 2014 (Williams 2014). Available catch in each specified area was calculated by applying a specified exploitation rate to the start of season biomass. Exploitation rates of 22 and 35% were used. Additionally, for scenarios in which the catch limits proposed by CSEC were actually fished, the corresponding exploitation rates were calculated for each area (i.e. proposed catch divided by start of season biomass). For example, applying an exploitation rate of 35% to the Guards area start of season biomass produced an available catch for the season of 10.6 t. If the proposed 13.5 t commercial catch limit for Guards was actually caught, this would equate to fishing at an exploitation rate of 43%.

Table 5: Biomass, proposed catch, actual catch to date, available catch, and exploitation rates (U) for 2015 in specified Marlborough Sounds fishing areas: Guards, Ship, Dieffenbach.

				Catch		Catch	Bcurr		Bbeg	Available		
Grouping	Location	B_1Sep	CV	proposed	Uequiv	4–7Oct	B_7–9Oct	CV	Best_4Oct	U22	U35	Uproposed
Stratum	321	20.2	0.24	–	–	8.1	13.7	0.21	21.8	4.8	7.6	–
	32	9.6	0.20	–	–	0.0	6.9	0.24	6.9	1.5	2.4	–
	33	0.3	0.58	–	–	0.0	0.7	0.52	0.7	0.2	0.3	–
	34	1.8	0.37	–	–	0.0	0.7	0.25	0.7	0.1	0.2	–
	371	–	–	–	–	0.0	2.1	0.41	2.1	0.5	0.7	–
	37	7.2	0.77	–	–	0.0	14.6	0.94	14.6	3.2	5.1	–
	38	15.7	0.25	–	–	0.0	7.6	0.35	7.6	1.7	2.7	–
	40	2.3	0.37	–	–	0.0	1.2	0.57	1.2	0.3	0.4	–
	41	3.7	0.35	–	–	0.0	2.2	0.30	2.2	0.5	0.8	–
Region	Guards	31.9	–	13.0	0.41	8.1	22.2	0.21	30.4	6.7	10.6	0.43
	Ship	22.9	–	7.5	0.33	0.0	23.7	0.59	23.7	5.2	8.3	0.32
	Dieffenbach	6.0	–	2.5	0.42	0.0	3.5	0.31	3.5	0.8	1.2	0.72
Total	All combined	60.8	–	23	0.38	8.1	49.0	0.33	57.2	12.6	20.0	0.40

The results of the in-season survey suggested that the estimates of start of season biomass projected from the pre-season (May) survey were largely reliable. The magnitude of the reduction in biomass at Guards between the start of the season and the in-season survey corresponded well with the level of commercial catch harvested. While there had been no commercial harvesting at Ship or Dieffenbach before the in-season survey, the biomass reduction observed at Dieffenbach could be associated with a high level of recreational scallop harvest from that area, which was reported anecdotally by several fishers. At Ship, the large uncertainty associated with the in-season estimate made comparisons with the May and May-projected estimates difficult. Greater precision could be achieved in future surveys by reviewing the stratification at Ship.

For the three areas of Guards, Ship, and Dieffenbach combined, using exploitation rates of 22% and 35% as reference points, the total available catch for the 2015 fishing season was 13 t and 20 t, respectively.

4. ACKNOWLEDGMENTS

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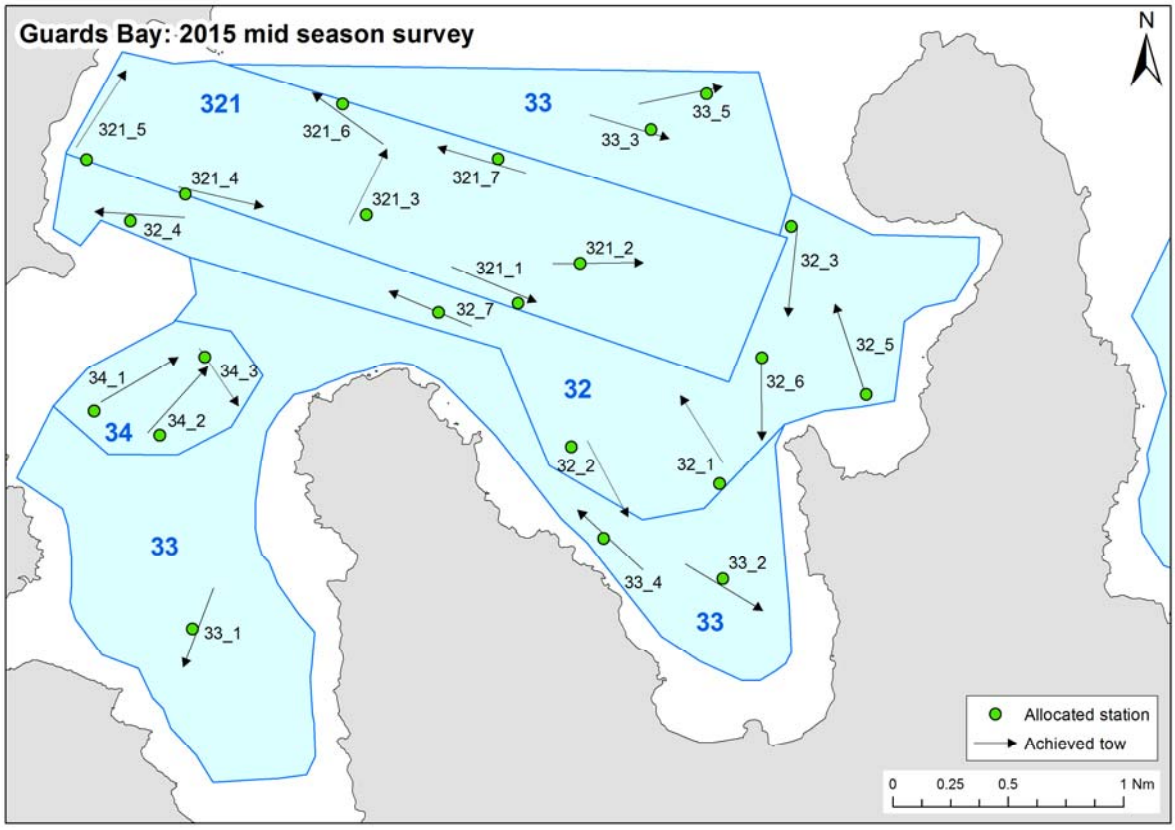
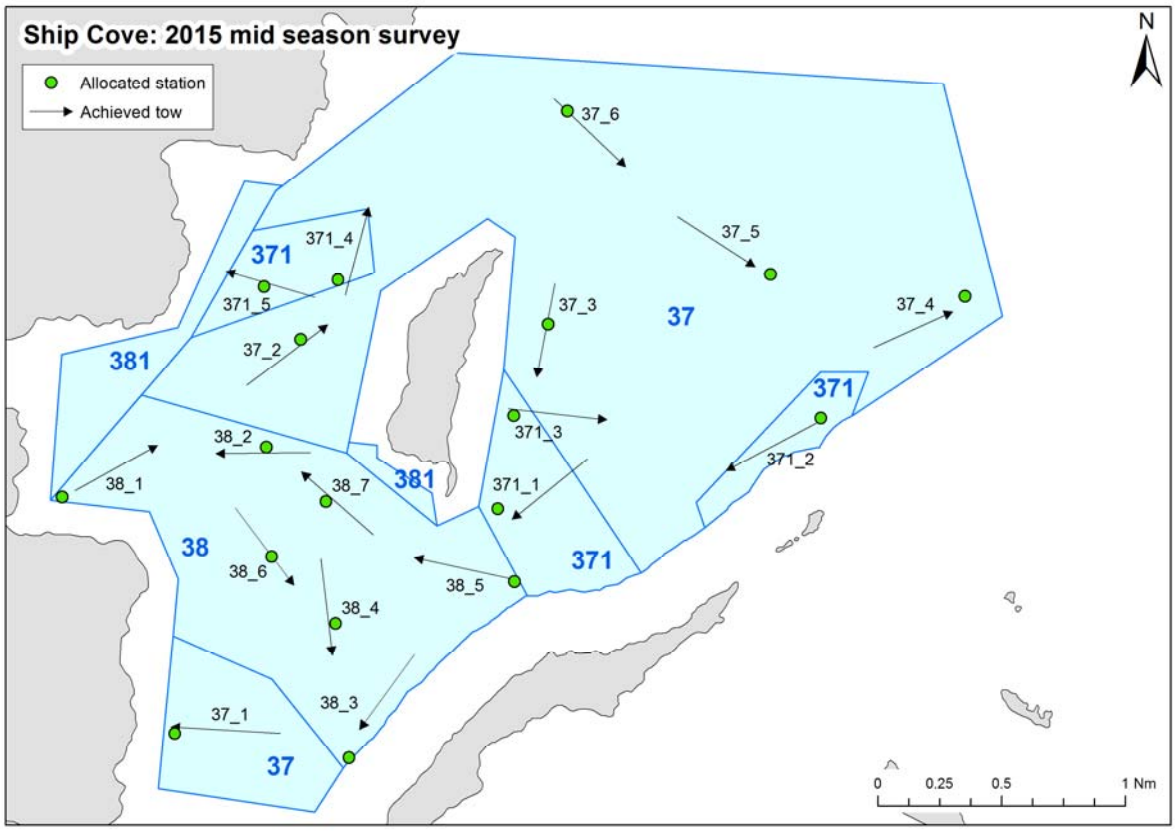
APPENDIX 1

Positions sampled compared to positions allocated, by fishing area





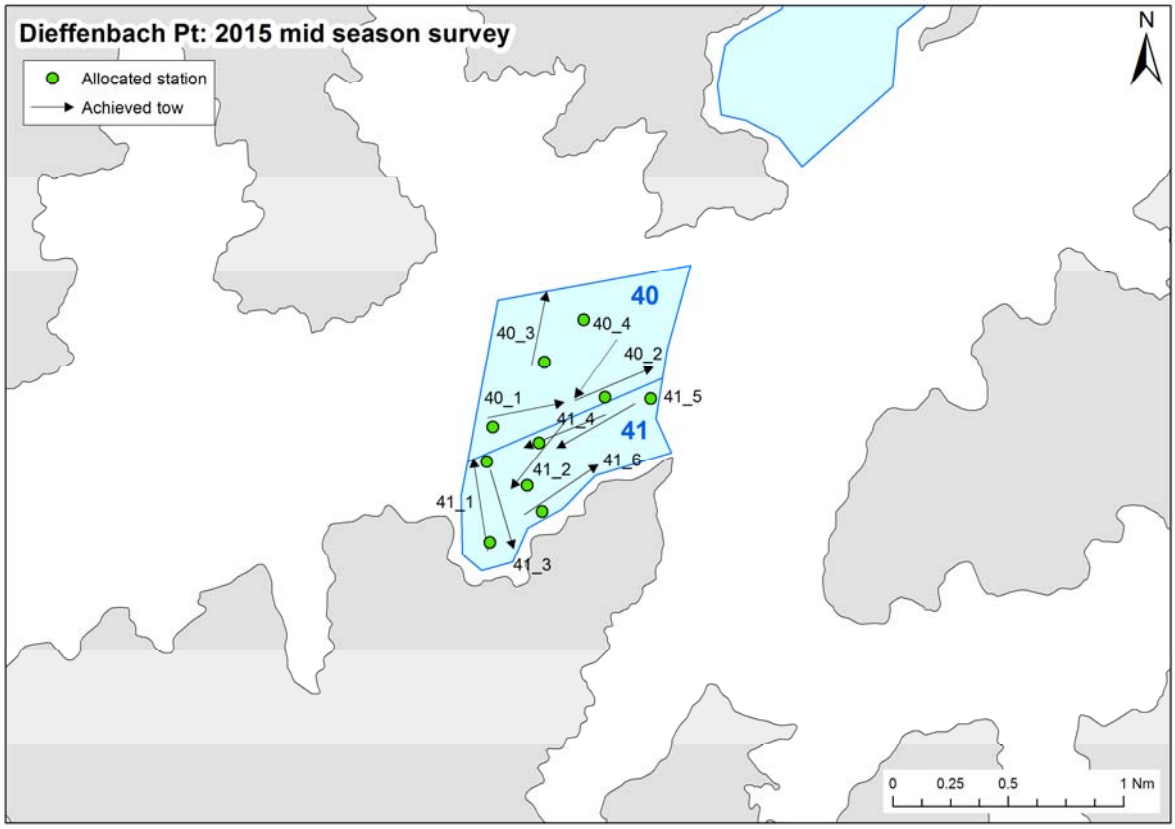
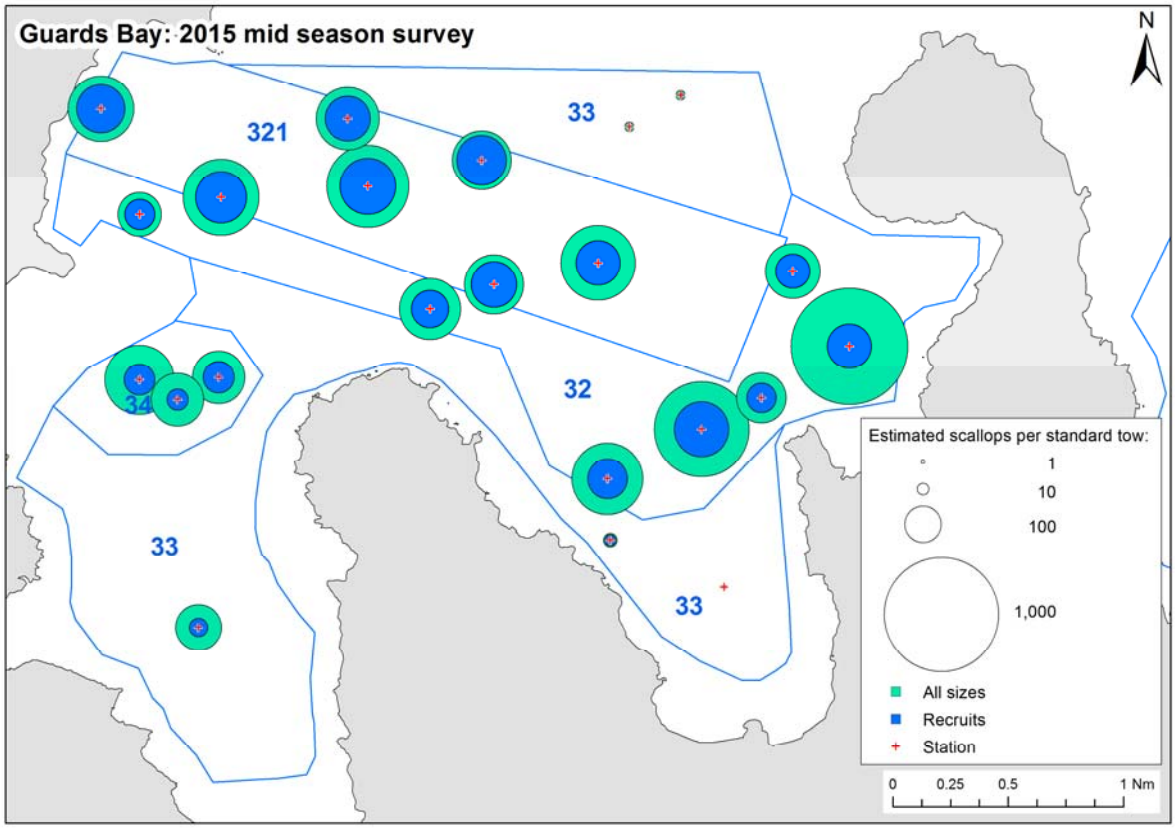
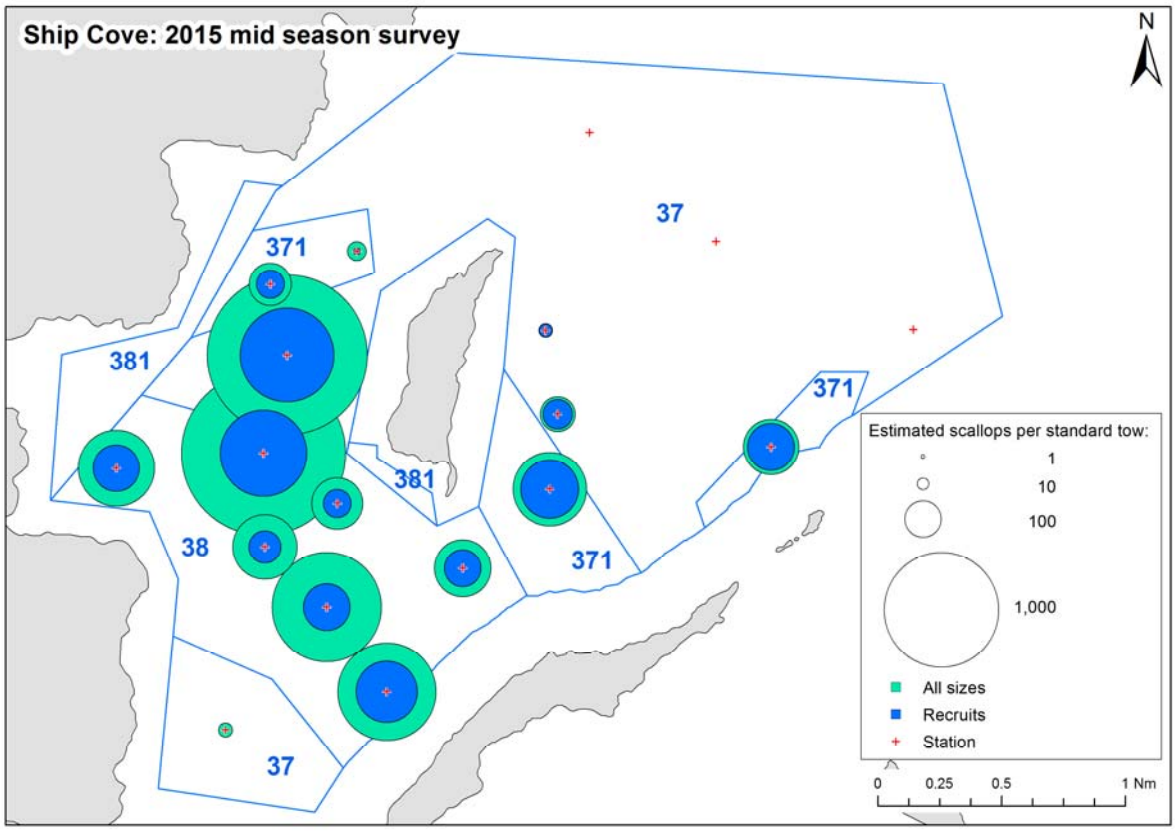


Figure 7: Dredge tow positions conducted compared with station positions allocated, SCA 7 in-season survey, October 2015. Circles denote station positions initially allocated that were subsequently sampled. Arrows denote the estimated position and direction of the dredge tows sampled. Polygons denote survey strata boundaries.

APPENDIX 2

Distribution plots by fishing area





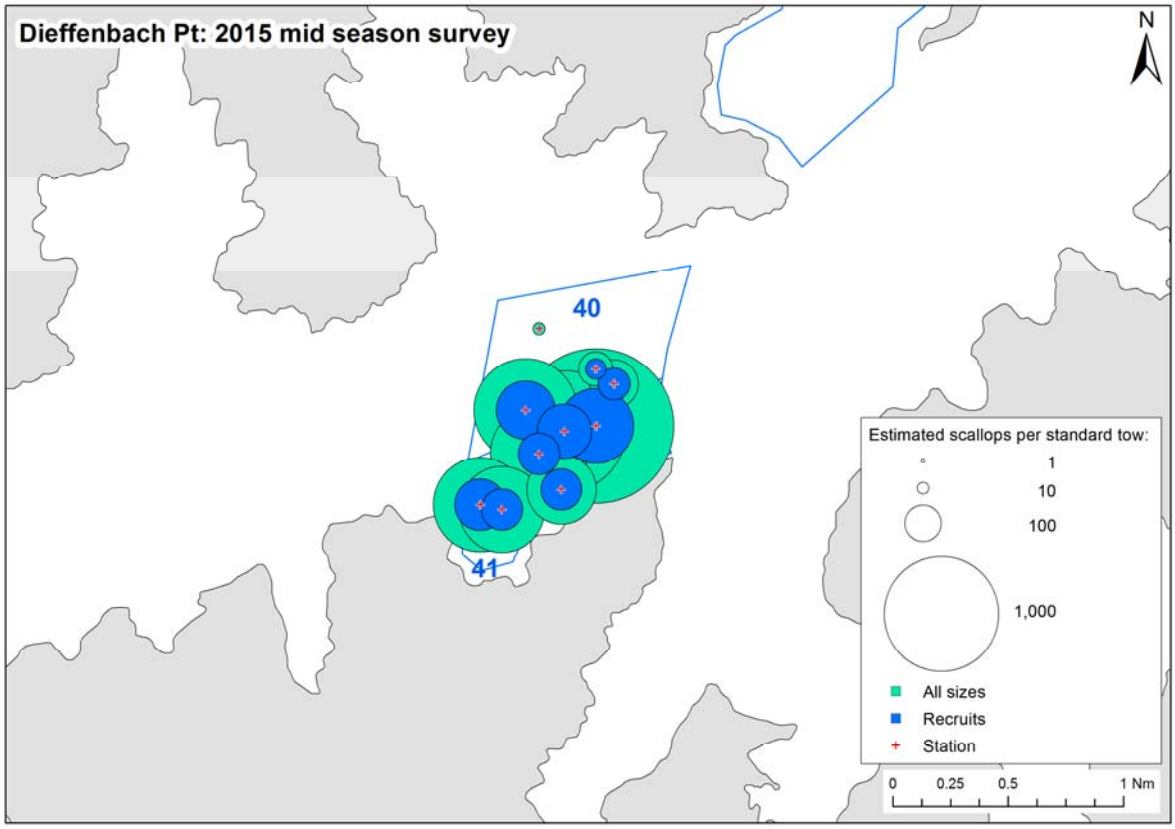


Figure 8: Catch of recruited scallops per standard tow in three fishing areas in the Marlborough Sounds, SCA 7 in-season survey, October 2015. Circle area is proportional to the number of recruited scallops (90 mm or larger shell length) caught per standard distance towed (0.4 n.miles). Values are uncorrected for dredge efficiency. Polygons denote survey strata boundaries.