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in Coromandel recreational fishing areas, 2008

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EXECUTIVE SUMMARY

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Diver surveys of scallops were conducted in June 2008 at two recreational fishing locations within the Coromandel scallop fishery. Survey locations and strata were determined in 2006 after consultation with the Ministry of Fisheries and commercial and recreational fisheries stakeholders. Density and biomass estimates at the time of the survey were made assuming 100% diver efficiency. Variance structure was estimated using a non-parametric bootstrap routine resampling from the survey data. Biomass at 15 July (start-of-season in the commercial fishery) was predicted using a stochastic growth transition matrix, and stochastic scalars for average survival and average recovery of meatweight from greenweight. Variance was again estimated using non-parametric bootstraps. These biomass estimates were treated as estimates of absolute biomass.

The abundance and size structure of scallops varied markedly among the areas surveyed. Absolute start-of-season (15 July) biomass of scallops over 100 mm shell length (the recreational minimum legal size) for the selected Coromandel strata surveyed (with a combined area of 4.6 km²) was predicted to be 78.6 t greenweight with a c.v. of 14%, or 9.9 t meatweight with a c.v. of 21%. Current Annual Yield estimates were also made for the surveyed areas, based on $F_{0.1}$ derived from previous individual-based modelling. Assuming average values for important assumed variables suggested a meatweight yield of 5.7 t for the surveyed areas. It was unclear how current recreational landings relate to the CAY estimates for the areas surveyed, or how a CAY can be incorporated into the current recreational scallop fishery management system.

Scallop densities in areas open and closed to commercial dredging were compared using data from the annual 2006, 2007, and 2008 diver and dredge surveys. Overall, scallop abundance in commercial and some recreational areas seem to have varied in similar ways but it is too early to draw firm conclusions about the nature of this relationship. More data (areas and years) are required for a thorough examination (and further surveys of these same areas are planned for 2009–11).

1. INTRODUCTION

1.1 Overview

This report presents the results of diver surveys of scallops carried out in selected Coromandel recreational fishing areas in June 2008. This work was carried out under the Ministry of Fisheries project SCA2007/03: Abundance of scallops in Northland and Coromandel recreational fishing areas. The overall objective of the project was to establish a relationship between scallop abundance in the main commercial scallop beds estimated each year in pre-season surveys, and scallop abundance in recreational fishing areas in the Northland and Coromandel scallop fisheries. Specific objectives were:

1. to investigate the relationship between scallop abundance in commercial and non-commercial areas in the Northland scallop fishery by undertaking a survey in about May/June 2008 to estimate the absolute abundance and population size frequency of scallops in the recreational scallop beds;
2. to investigate the relationship between scallop abundance in commercial and non-commercial areas in the Coromandel scallop fishery by undertaking a survey in about May/June 2008 to estimate the absolute abundance and population size frequency of scallops in the recreational scallop beds.

Estimates of scallop abundance from diver surveys of recreational fishing areas can be compared to estimates from pre-season dredge surveys of commercial fishing areas. However, unlike in recent years, MFish did not require a pre-season dredge survey of the Northland commercial scallop fishery (SCA 1) in 2008, so it was deemed the diver surveys of scallops in Northland recreational fishing areas (specific objective 1) were not required either.

1.2 Northern scallop fisheries

Scallops (*Pecten novaezelandiae*) support regionally important commercial fisheries and an intense non-commercial interest off the northeast coast of New Zealand's North Island. Both the Coromandel (SCA CS) and Northland (SCA 1) commercial scallop fisheries are managed under the Quota Management System (QMS); the two are divided by a line from Cape Rodney to the northernmost tip of Great Barrier Island (Figure 1). All commercial fishing is by dredge, and is undertaken within discrete beds distributed patchily around the coastline. Catch and catch rates from both fisheries are variable both within and among years (Cryer & Parkinson 2006), a characteristic of scallop fisheries worldwide (Shumway 1991). For the Coromandel fishery in 2007, the Total Allowable Catch (TAC) was 48 t (meatweight) and the Total Allowable Commercial Catch (TACC) was 22 t. For the Northland fishery in 2007, the TAC was 75 t and the TACC was 40 t.

There is an intense non-commercial (recreational and Maori) interest in scallops throughout the Coromandel and Northland fisheries. Scallops are usually taken by scuba diving or snorkelling, although considerable amounts are also taken using small dredges. In some areas, especially in harbours, scallops can be taken by hand from the shallow subtidal and even the low intertidal zones (on spring tides), and, in storm events, scallops can be cast onto lee beaches in large numbers. To some extent, management of northern scallop fisheries has concentrated on spatial separation of commercial and non-commercial fisheries through the closure of harbours and enclosed waters to commercial dredging. There remain, however, areas of contention and conflict, some of which have been addressed using additional voluntary or regulated closures. Regulations restrict the non-commercial daily harvest (bag limit) to 20, and there is a minimum legal size of 100 mm shell length. Until 2006, the recreational scallop season for the Coromandel and Northland fisheries ran from 15 July to 14 February, but in 2007 the season was changed to run from 1 September to 31 March. There is no overall catch limit for the non-commercial sector.

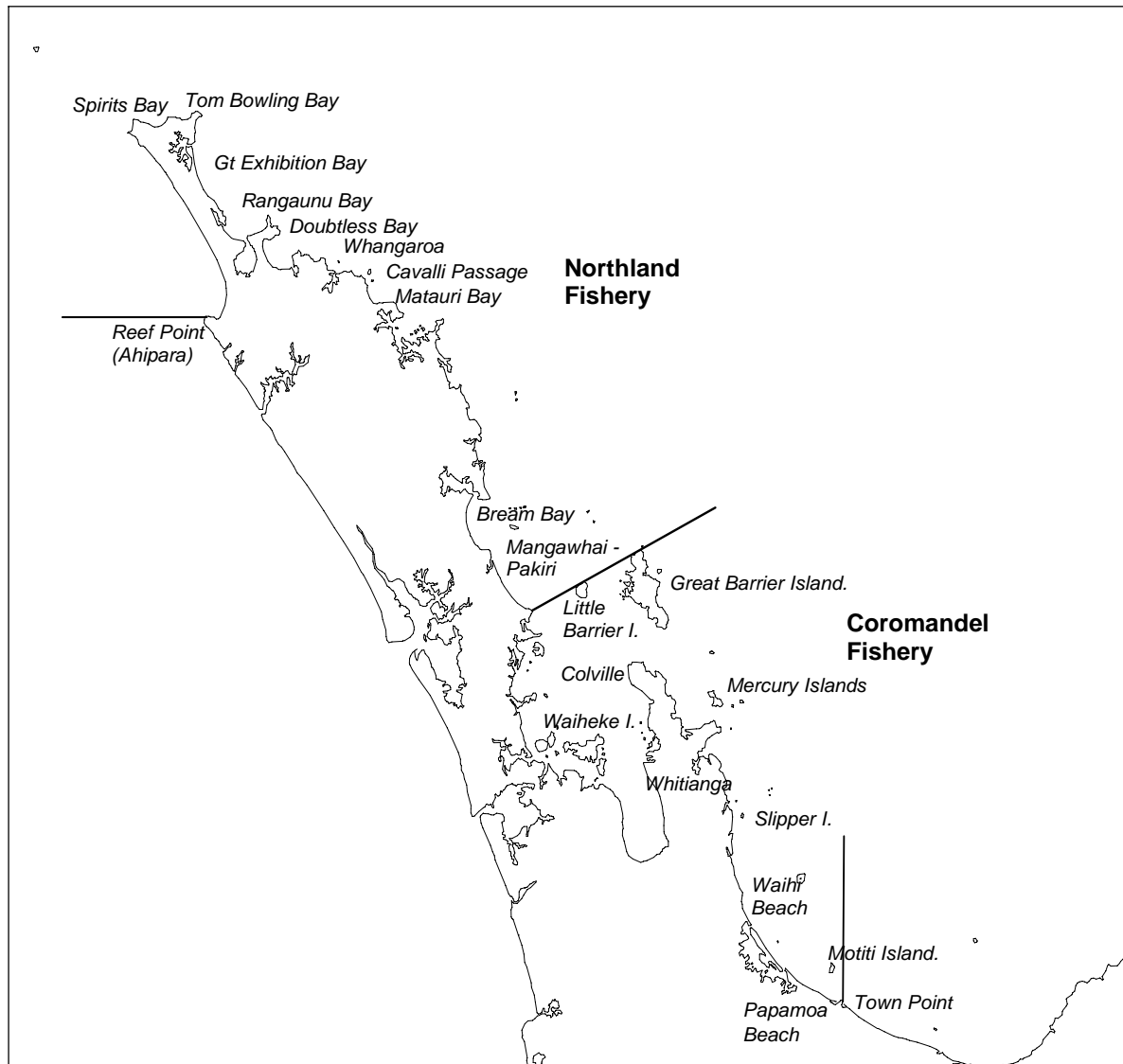


Figure 1: Geographic distribution of the two northern scallop fisheries (after Cryer & Parkinson 2006).

Currently, there are no reliable estimates of non-commercial harvest from the Coromandel or Northland scallop fisheries. Estimates of catch by recreational fishers from both fisheries have been made on four occasions as part of recreational fishing (telephone and diary) surveys (Bradford 1997, 1998, Boyd & Reilly 2002, Boyd et al. 2004). The Marine Recreational Fisheries Technical Working Group reviewed these surveys and recommended “that the telephone-diary estimates be used only with the following qualifications: 1) they may be very inaccurate; 2) the 1996 and earlier surveys contain a methodological error; and 3) the 1999/2000 and 2000/2001 estimates are implausibly high for many important fisheries.”

Annual pre-season surveys have been conducted in the commercial areas of each fishery for many years (Williams 2008c). These surveys provide estimates of pre-season biomass required for stock assessment. Fisheries management now requires some estimates of abundance in the recreational areas to investigate any relationship between scallop abundance in commercial and non-commercial areas. Given the life history of *Pecten novaezelandiae*, in particular the extended larval dispersal phase of 3 to 4 weeks, it is likely that changes in the abundance of scallops in some of the commercial areas might be reflected by similar changes in abundance in the recreational areas. However, the strength of any relationship in abundance between scallops in areas open and closed to commercial fishing will be

influenced by several factors, including population source and sink dynamics, and the degree of geographic separation between areas. The abundance of scallops in some recreational areas may show no relationship with abundance in commercial areas. Presently, little is known about stock structure or population connectivity for scallops, nor the relative influence of environmental conditions and fishing activities on recruitment. This lack of knowledge represents a fundamental obstacle to understanding the population dynamics of scallops.

Under the current research programme, diver surveys of scallop abundance and size structure were conducted in 2006 (Williams et al. 2008) and 2007 (Williams 2008a) at selected scallop beds (strata) in Northland and Coromandel recreational fishing locations. Using the two years of available data, the length frequency distribution and estimated density of scallops from the diver surveys of recreational areas were compared to those from the annual pre-season dredge surveys of the commercial areas. Although there was no clear relationship found between scallop density in the recreational beds and density in the adjacent commercially fished beds, it was acknowledged that several years of survey data are required before this relationship can be examined thoroughly. The present study reports the results of the 2008 diver surveys of scallops in Coromandel recreational fishing areas, marking the third in a series of consecutive surveys of these areas.

2. METHODS

2.1 Survey design

Surveys of scallops in Coromandel recreational fishing areas were conducted from 9 to 20 June 2008 using stratified random sampling by scuba divers. Owing to constraints on vessel time, surveys were of only single phase. Survey locations and strata were determined in 2006 (Williams et al. 2008) after consultation with the Ministry of Fisheries, and commercial and recreational scallop fisheries stakeholders.

Two locations were surveyed in the Coromandel fishery: Kawau Island and the Mercury Islands. These locations were chosen to represent recreational fishing areas spatially separated from (Kawau Island) and adjacent to (Mercury Islands) commercially fished areas, thus allowing us to assess the abundance of scallops in the recreational areas in relation to their proximity to the commercially fished areas.

At each location, two areas (strata) were chosen that represented well known recreational scallop beds that have sustained persistent scallop populations over many years. The four Coromandel strata were: Iris Shoal and Bostaquet Bay (Kawau Island), and Mercury Cove and Opito Bay (Mercury Islands) (Figure 2). Within each stratum, 20 stations were surveyed by divers using circular searches (see below). The allocation of stations was constrained by a minimum of 10 stations per stratum and operational requirements such as steaming time between strata and to conform to the NIWA Code of Scientific Diving Practice. The positions of stations within strata were randomised using computer software, and positions were constrained to keep all stations at least 20 m apart. This software estimates the area of each stratum, and gives the latitude and longitude of each random station.

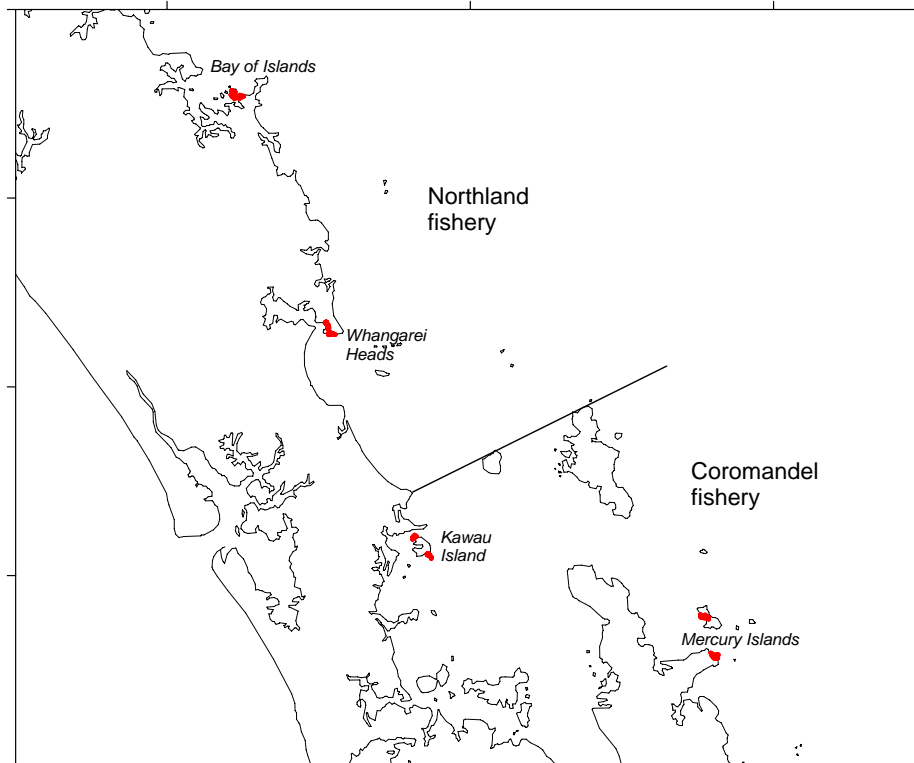


Figure 2: Location of sampling strata for the diver surveys of Northland and Coromandel recreational fishing areas, 2006–08 (see Appendix 1 for stratum details). Northland strata were not surveyed in 2008.

2.2 Diver sampling

Diver surveys were carried out from a purpose-built 15-m research vessel (*Hawere*, operated by the University of Auckland’s Leigh Marine Laboratory). The vessel was navigated to each station in turn by use of a combined Global Positioning System (GPS) and marine plotter. The following sampling methodology was based on that used during the 2006 (Williams et al. 2008) and 2007 (Williams 2008a) surveys of the same strata.

At each station, a buoyed shot line was deployed to mark the centre of the search pattern on the seabed. Two divers descended the shot line to the seabed to begin a circular search sweep for scallops. On reaching the seabed, the lead diver attached to the shot line a sweep rope of 8 m total length marked 3 m from its free end. The search area for each station was defined by the area traversed by the sweep rope, and three alternative search areas were, therefore, available: 1) a circle of radius 8 m (201.05 m²); 2) a circle of radius 5 m (78.54 m²); or 3) a “doughnut” comprising the 8 m circle minus the 5 m circle (122.52 m²).

On approaching the seabed during the descent, the lead diver made a visual assessment of the density of scallops. If the diver considered that a 5 m search was likely to lead to 20 or more near-legal sized scallops, then the smaller search circle was selected. Alternatively, the larger circle was used. The divers progressed to the end of the sweep rope and positioned themselves about 1 m apart. The start position for the search was marked using a small subsurface marker buoy attached to a lead weight. The divers swam a complete circuit of the search pattern while maintaining the sweep rope taut. All scallops passing under the sweep rope were collected by hand and placed in zippered or spring-loaded catch bags. If the larger circle was searched, then only scallops falling outside the 3 m mark were collected on the first circuit. On completion of the first circuit, the divers conferred. If the 5 m circle was being searched or fewer than 20 near legal sized scallops had been collected from the outer ring of the 8 m circle, then the divers each moved about 1 m towards the shot line and continued the search.

The search ended on completion of the chosen circle, or if 20 or more near-legal sized scallops had been collected from the outer ring of the 8 m circle, or if the divers were within 3 minutes of their maximum no-decompression limits.

On completion of the circular search, the divers removed the sweep rope from the shot line and returned to the boat with the bags of scallops. All scallops were measured for shell length (maximum dimension parallel with the shell hinge) to the next whole millimetre down using electronic callipers (mounted on a measuring board) interfaced to a portable, handheld computer (Allegro). These measurements were recorded together with the date, location, stratum, station number, search area, water depth, substratum type, and any other relevant observations. The efficiency of diver searches was assumed to be 100%.

2.3 Density and length frequency estimation

Counts of scallops of any given size at each station were converted to numbers per square metre of seabed according to the area swept by divers. The mean scallop density and its associated variance were calculated for each stratum using standard parametric methods (Snedecor & Cochran 1989). One output statistic from this work, therefore, was the mean density (and variance) of legal (or near-legal) sized scallops per square metre of seabed. This statistic was compared with the mean density of scallops in the Coromandel commercial fishery areas estimated from NIWA's 2008 dredge survey (Williams 2008b). Estimates of commercial scallop densities were not corrected for dredge efficiency.

Station length frequency distributions were estimated by scaling the recorded length frequency distributions to a square metre of seabed. Stratum length frequency distributions were estimated as the average station length frequency distribution for that stratum scaled by the stratum area (m^2). Length frequency distributions for any particular combination of strata were derived by the addition of stratum length frequency distributions.

2.4 Biomass and yield estimation

During the data analysis phase of the 2006 recreational scallop survey project (Williams et al. 2008), and additional to the original objectives of the study, it was requested that estimates of scallop biomass and yield were made for the recreational areas surveyed. To provide estimates of yield, we used a reference rate of fishing mortality (F) from an individual-based model analysis of the Coromandel commercial fishery (Cryer & Morrison 1997). This approach was not strictly correct, because the reference F used was calculated over a shorter period (5 months) than the recreational fishery (7 months); however, this difference is unlikely to be important relative to the other uncertainties in the process of estimating biomass and yield. Yield estimation from recreational fisheries in future studies could be improved by using a revised analysis of the individual-based model (Cryer & Morrison 1997) for a recreational fishery.

The method of estimating biomass was based on that used for commercial scallop surveys (Cryer & Parkinson 2006), and contains the following eight steps.

1. The length frequency distribution for each sample is scaled according to the sampling fraction (if any).
2. The length frequency distribution for each sample is converted to density per unit area of seabed, i.e., assuming the divers to be 100% efficient for all size classes. These are combined to estimate the population length frequency distribution.

3. The weight (per unit area) of scallops at or above the minimum legal size (or other length of interest) is estimated using a length-weight regression. Variance associated with the regression is included by bootstrapping from the raw length-weight data.
4. The mean recruited biomass (per unit area) for each stratum and for the whole population (or any subset of strata), together with the sampling variance, are estimated using bootstraps from the sampling data.
5. The absolute recruited biomass at the time of the survey is estimated by scaling the estimate of the mean biomass by the combined area of all pertinent strata. The stratum areas are considered to be without error.
6. The population length frequency distribution (from step 2) is projected to the start of the forthcoming season using a growth transition matrix based on tag return data. Uncertainty about the expected average growth between survey and season is incorporated by bootstrapping, generating a new growth model for each iteration by bootstrapping from the original tag return data.
7. Mortality between survey and season is incorporated by applying an instantaneous rate of $M = 0.5 \text{ y}^{-1}$, bootstrapping (parametrically) from an estimated statistical distribution of M .
8. The absolute recruited biomass at the start of the season is estimated by repeating steps 4–6, again assuming the stratum areas to be without error.

Yield estimates are generally calculated using reference rates of fishing mortality applied in some way to an estimate of current or reference biomass. However, the choice among reference rates is not simple. As with the approach taken with the Coromandel and Northland commercial scallop stock assessments, it is probably useful to use Caddy's (1998) notation of target reference points (TRP) and limit reference points (LRP) where reference points can be measures of fishing mortality (F) or biomass (B).

No reference F values are available for recreational fisheries, but, as a first estimate, values have been taken from commercial fisheries. Cryer & Morrison's (1997) unpublished study of the incidental effects of scallop dredges in the Coromandel fishery allowed the estimation of F_{\max} as an LRP, and $F_{0.1}$ and $F_{40\%}$ as TRPs. Although their study specifically investigated the effects of a dredge fishery, an appropriate scenario for a recreational scallop fishery could be provided by selecting simulations with knife-edge selection at 100 mm, no incidental effects on growth or mortality, and a natural mortality of $M = 0.5$ (although based on a 5 month rather than 7 month fishing season). Making no allowance for incidental effects on mortality and growth also assumes that all catches are taken by divers rather than by recreational dredges, which is likely to have some incidental effects (although this has not been investigated). Under this simulation, $F_{0.1}$ was estimated to be 0.984 for the 5-month commercial fishery. Because of the derivation of this estimate, it should be applied to the modified version of the Baranov equation given by Cryer & Morrison (1997):

$$CAY = \frac{F_{ref}}{F_{ref} + \frac{5M}{12}} * \left[1 - e^{-\left(F_{ref} + \frac{5M}{12}\right)} \right] * B_{beg}$$

where B_{beg} is the estimate of recruited biomass at the start of season. In this formulation of the Baranov equation, natural mortality is assumed to act in tandem with fishing mortality for the first 5 months of the year, the current duration of the Coromandel commercial scallop season (on the basis of which the reference F was calculated). Preliminary investigations suggest the implications of using this commercial fishery value of F are small (M. Cryer, Ministry of Fisheries, Wellington, pers. comm.) but reference F values for recreational fisheries should be investigated.

3. RESULTS

3.1 Scallop population at the time of survey (June 2008)

Stratified random sampling by divers was conducted at 80 valid stations in 2008, sweeping an estimated 11 024 m² of seabed (see Appendix 1); a total of 6457 scallops were collected and measured. Approximate length frequency distributions (scaled to estimated population size) varied considerably among strata (Figure 3), but less so when pooled by their respective locations (Figure 4). Figure 5 shows the size structure of the total population surveyed. Scallops of recreational legal size (100 mm or more shell length) were present in all strata sampled, but were in relatively high abundance only at Iris Shoal and Mercury Cove; all strata were dominated by scallops under legal size. Several cohorts were present at all strata, which could suggest relatively good recruitment to the fishable biomass for the near future. Of particular interest was the relatively high abundance of juvenile scallops 20 to 40 mm at most strata, particularly Bostaquet Bay.

At the level of individual stations (circular searches), the density of scallops of any size ranged from zero to 5.28 m⁻², or zero to 1.07 m⁻² for scallops of 100 mm or more shell length; these high densities were observed at Bostaquet Bay and Iris Shoal, respectively. At the stratum level, the density of scallops of legal size (100 mm or more shell length) was highest at Iris Shoal (0.43 m⁻²), fairly high at Mercury Cove (0.21 m⁻²), intermediate at Bostaquet Bay, and lowest at Opito Bay (0.01 m⁻²) (Table 1). At the location level, the density of legal scallops was highest at Kawau (0.33 m⁻²) and lowest at Mercury (0.11 m⁻²), the latter the result of combining high densities at Mercury Cove with low density at Opito Bay (Table 1).

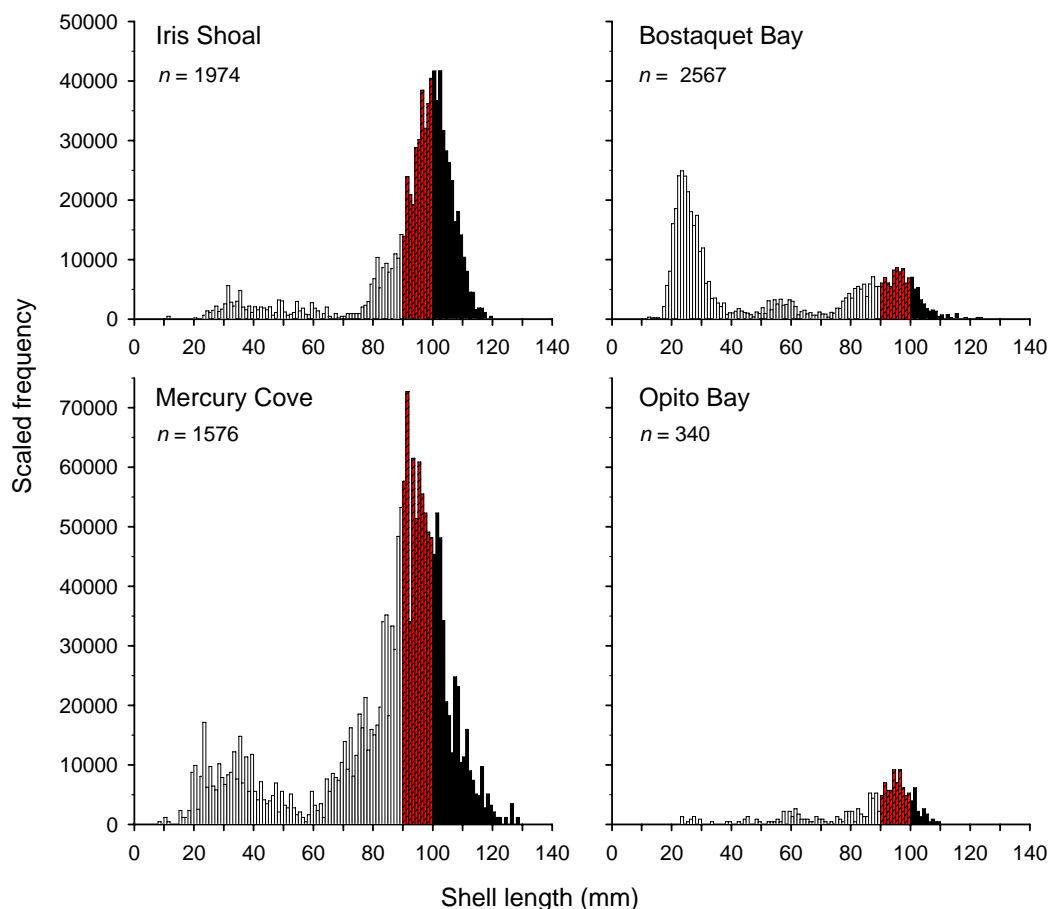


Figure 3: Length frequency distributions for the four strata surveyed during the 2008 surveys of scallops in Coromandel recreational fishing areas. Shaded bars show scallops 90 mm or more shell length and black bars show scallops 100 mm or more. *n*, number of scallops collected.

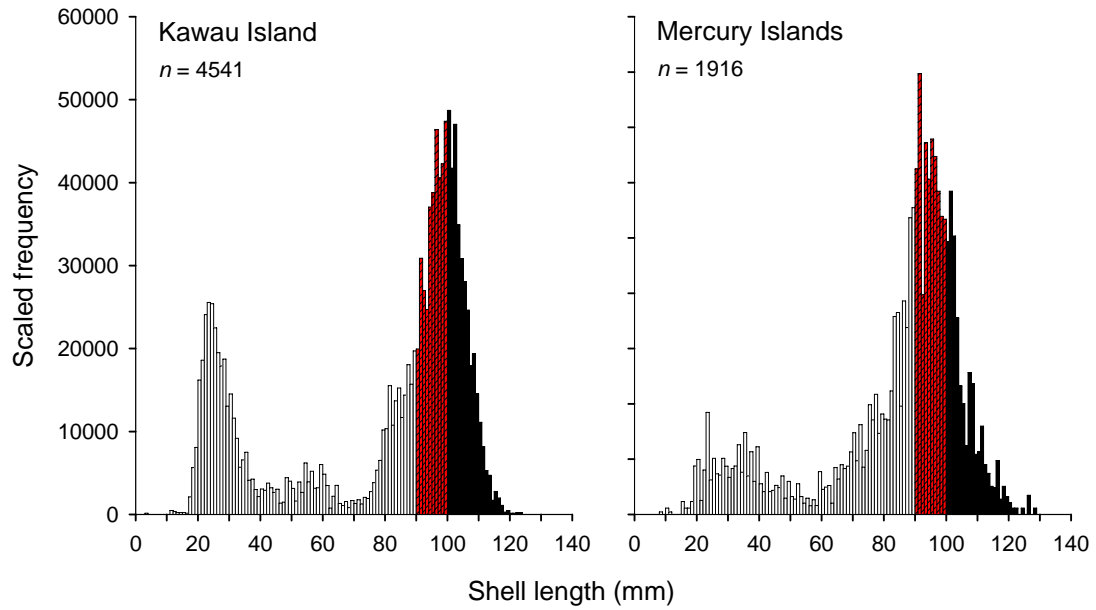


Figure 4: Length frequency distributions for the two locations surveyed during the 2008 surveys of scallops in Coromandel recreational fishing areas. Shaded bars show scallops 90 mm or more shell length and black bars show scallops 100 mm or more. n , number of scallops collected.

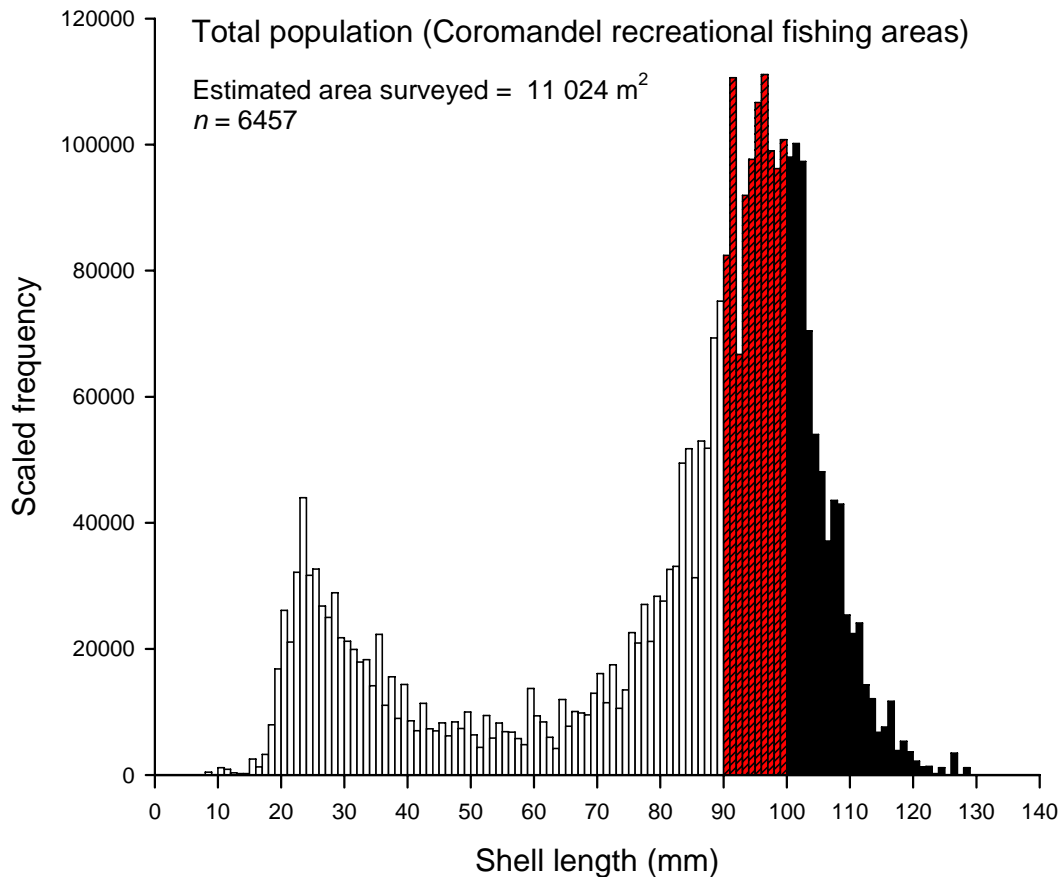


Figure 5: Length frequency distribution for the total area surveyed during the 2008 surveys of scallops in Coromandel recreational fishing areas. Shaded bars show scallops 90 mm or more shell length and black bars show scallops 100 mm or more. n , number of scallops collected.

Using a simple parametric approach to estimation (and assuming 100% diver efficiency), the recruited biomass of scallops (100 mm or more shell length) at the time of the survey ranged from 2 to 39 t greenweight for the individual strata surveyed, with c.v.s ranging from 16 to 40% (Table 1). It should be noted that the strata were of quite different sizes (range 0.33–1.82 km², see Appendix 1) and, to a certain extent, biomass estimates were related to stratum area. Pooling the strata into their locations, biomass estimates were 35 and 41 t for Kawau and the Mercury Islands, respectively. The biomass estimate for the total area surveyed was 75 t greenweight. A more sophisticated bootstrapping approach to variance estimation (re-sampling stations within strata and length-weight regressions) made very little difference to the estimates, or their uncertainty (Table 2).

Table 1: Estimated density and biomass of scallops 100 mm or more shell length at the time of the 2008 surveys (using a simple parametric approach to estimation).

Stratum/ Location/ Fishery	Area (km ²)	Stations	Mean density (m ⁻²)	SEM	c.v.	Millions	Mean weight (g)	Mean biomass (g m ⁻²)	SEM	c.v.	Biomass (t green)
Iris Shoal	0.72	20	0.4325	0.0660	0.15	0.312	99.78	43.15	6.71	0.16	31.17
Bostaquet	0.33	20	0.1004	0.0260	0.26	0.033	98.86	9.92	2.51	0.25	3.31
Mercury Cove	1.82	20	0.2055	0.0525	0.26	0.374	103.72	21.32	5.61	0.26	38.78
Opito Bay	1.76	20	0.0114	0.00	0.40	0.020	94.57	1.08	0.43	0.40	1.90
Kawau	1.06	40	0.3275	0.0459	0.14	0.346	99.69	32.65	4.66	0.14	34.48
Mercury	3.58	40	0.1101	0.0268	0.24	0.394	103.25	11.37	2.86	0.25	40.69
Coromandel	4.64	80	0.1596	0.0232	0.15	0.740	101.59	16.22	2.45	0.15	75.17

Table 2: Estimated density and biomass of scallops 100 mm or more shell length at the time of the 2008 surveys (using a resampling with replacement approach to estimation).

Stratum/ Location/ Fishery	Area (km ²)	Stations	Mean density (m ⁻²)	SEM	c.v.	Millions	Mean weight (g)	Mean biomass (g m ⁻²)	SEM	c.v.	Biomass (t green)
Iris Shoal	0.72	20	0.4365	0.0148	0.15	0.315	100.39	43.82	1.52	0.16	31.66
Bostaquet	0.33	20	0.1002	0.0056	0.25	0.033	99.62	9.99	0.55	0.25	3.33
Mercury Cove	1.82	20	0.2021	0.0114	0.25	0.368	104.45	21.11	1.24	0.26	38.41
Opito Bay	1.76	20	0.0114	0.0010	0.38	0.020	95.23	1.08	0.09	0.38	1.91
Kawau	1.06	40	0.3302	0.0073	0.14	0.349	100.32	33.13	0.75	0.14	34.99
Mercury	3.58	40	0.1083	0.0041	0.24	0.388	103.97	11.26	0.45	0.25	40.32
Coromandel	4.64	80	0.1589	0.0025	0.14	0.737	102.24	16.25	0.27	0.15	75.31

3.2 Projected scallop population at the start of the commercial season (July 2008)

Biomass at 15 July (the start of the commercial fishing season) can be estimated from the time of survey biomass (Table 2) by allowing for growth and assumed natural mortality ($M = 0.5$, spread evenly through the year) using a “resampling” approach to variance estimation (resampling stations within strata, length-weight regressions, and growth). The total biomass projected from the time of the survey to the start of the season was estimated to be 78.6 t greenweight for the surveyed areas. Projected biomass was, therefore, very similar to the time of survey biomass. Projecting meatweight biomass at the start of season is complicated by the unpredictability of the average meatweight recovery fraction (which depends on fisher behaviour as well as scallop biology). Using historical annual average meatweight recovery data and a resampling with replacement approach to estimation resulted in an overall estimate of 9.9 t meatweight (Table 3).

Table 3: Mean projected biomass of scallops 100 mm shell length or more at 15 July 2008 (using a resampling with replacement approach to estimation, $M = 0.5$ spread evenly through the year, and average recovery of meatweight from greenweight).

Stratum/ Location/ Fishery	Area (km ²)	Stations	Mean density (m ⁻²)	SEM	c.v.	Millions	Mean weight (g)	Mean biomass (g m ⁻²)	SEM	c.v.	Biomass (t green)	Biomass (t meat)
Iris Shoal	0.72	20	0.4541	0.0151	0.15	0.328	99.20	45.05	1.52	0.15	32.54	4.1
Bostaquet Bay	0.33	20	0.1125	0.0060	0.24	0.038	97.67	10.98	0.57	0.23	3.67	0.5
Mercury Cove	1.82	20	0.2156	0.0113	0.23	0.392	102.63	22.13	1.19	0.24	40.26	5.1
Opito Bay	1.76	20	0.0130	0.0011	0.38	0.023	93.71	1.22	0.11	0.39	2.14	0.3
Kawau	1.06	40	0.3462	0.0074	0.14	0.366	99.05	34.29	0.75	0.14	36.21	4.5
Mercury	3.58	40	0.1160	0.0041	0.22	0.415	102.14	11.84	0.43	0.23	42.39	5.3
Coromandel	4.64	80	0.1684	0.0025	0.13	0.781	100.69	16.96	0.27	0.14	78.60	9.9

3.3 Yield estimates

Current Annual Yield (CAY) estimates were provided for each of the surveyed areas on the basis of average start-of-season stock biomass projections. This ‘average’ outlook approach (assuming average growth, natural mortality of $M = 0.5$ spread evenly through the year, and historical average meatweight recovery) led to a start of season total recruited (100 mm in shell length or greater) biomass estimate of 78.6 t greenweight, or 9.9 t meatweight, for the recreational strata surveyed. The projected ‘average’ estimates of start of season biomass (Table 3) and the reference fishing mortality rate $F_{0.1}$ (0.984) were used to calculate CAY for the areas surveyed (Table 4). These estimates of CAY would have a c.v. at least as large as that of the estimates of start of season biomass, are sensitive to assumptions about recovery of meatweight from greenweight, and relate to the surveyed beds only.

Table 4: Estimates of Current Annual Yield (scallop 100 mm shell length or more) at 15 July 2008 at the Coromandel recreational fishing areas surveyed. CAY values were calculated using the modified version of the Baranov equation given by Cryer & Morrison (1997) and the reference fishing mortality rate $F_{0.1}$ (0.984).

Stratum/Location/Fishery	Area (km ²)	Biomass (t green)	Biomass (t meat)	CAY (t green)	CAY (t meat)
Iris Shoal	0.72	32.5	4.1	18.7	2.3
Bostaquet Bay	0.33	3.7	0.5	2.1	0.3
Mercury Cove	1.82	40.3	5.1	23.1	2.9
Opito Bay	1.76	2.1	0.3	1.2	0.2
Kawau	1.06	36.2	4.5	20.8	2.6
Mercury	3.58	42.4	5.3	24.4	3.1
Coromandel	4.64	78.6	9.9	45.2	5.7

4. DISCUSSION

4.1 Comparison of scallop densities in commercial and non-commercial areas

The overall objective of this research programme is to investigate the relationship in scallop abundance between the main commercial and recreational scallop beds. The diver surveys of scallops in recreational fishing areas conducted in 2006 (Williams et al. 2008), 2007 (Williams 2008a), and 2008 (present study) were the first three surveys of these non-commercial scallop beds for a number of years, and data collected over a series of years will be required before this relationship can be fully examined. For the current preliminary analysis, however, these diver survey data can be used in conjunction with data from the 2006–08 pre-season dredge surveys of scallops in the commercial fishing areas (Williams et al. 2007, Williams 2008b, 2008c) to compare scallop densities in areas open and closed to commercial dredging. Overall, the density (m^{-2}) of scallops 100 mm or more shell length was highest in 2006 and has since declined (Figure 6). This decrease from 2006 to 2008 was consistent across almost all strata, regardless of their status as either commercial or recreational fishing areas, except for the Iris Shoal and Opito Bay recreational strata, which showed an increase in density between 2007 and 2008 (Figure 7). However, we must be cautious with interpreting this putative link in abundance between the commercial and recreational scallop beds because three years of survey data (N.B. only two years for the Northland fishery) are insufficient to conclude a trend. Further surveys of these same areas are planned for 2008–11, and this relationship should be re-examined as more data are collected.

There are several factors to take into account when making comparisons between the commercial and recreational areas surveyed. First, different survey methods were used in the commercial (dredge) and recreational (diver) areas. Dredge tows sample a much larger area of seabed than circular searches by divers, and, because of the patchiness inherent in the spatial distribution of scallops, this probably reduces the observed variability in scallop density among stations. Ideally, the same survey methodology should be applied to both commercial and non-commercial areas to allow fair comparisons between the two. Although sampling recreational fishing areas with a commercial dredge may be inappropriate, diver surveys of the commercial areas of interest could be worthwhile in future studies. Other factors to be considered are that the adjacent commercial strata were much larger (2.7–62.9 km^2) and deeper (mean depth 22 m) than the recreational strata surveyed (0.3–2.1 km^2 , mean depth 11 m). However, despite these factors, data on the relative density of scallops among different areas will be sufficient to detect any strong links in scallop abundance among areas.

Historical data from previous (1990s) scallop surveys in the Northland and Coromandel fisheries were used by Williams (2008a) to conduct a retrospective analysis of the relationship in scallop abundance between areas open and closed to commercial fishing. Before about 1997, some of the shallower, inshore scallop beds formed part of the commercial scallop fishery areas, and, therefore, were surveyed as part of earlier commercial scallop biomass surveys. During the mid to late 1990s, commercial fishers voluntarily agreed not to fish in some of these areas, which were of high interest to recreational fishers (Cryer & Parkinson 1999). Subsequently, certain voluntary closed areas (VCAs) became legally closed to commercial scallop fishing in an attempt to separate, as far as possible, the commercial and non-commercial fisheries. Discerning trends in the historical abundance of scallops in these areas was difficult because of the limited data available, but, for the Mercury Islands region of the Coromandel fishery, scallop density appeared to be reasonably well linked between the areas formerly open and now closed to commercial dredging (Williams 2008a). The existence of such a link may not be surprising because the open and closed areas form part of the same embayment at each site, so each area could be expected to receive a similar supply of scallop larvae and have similar physical and environmental conditions which affect scallop growth and mortality. Future studies could investigate whether a close link in abundance is apparent between distant (spatially separated) strata which are open and closed to commercial dredging. Any recruitment and/or environmental drivers affecting scallops may be less consistent between distant or geographically isolated populations.

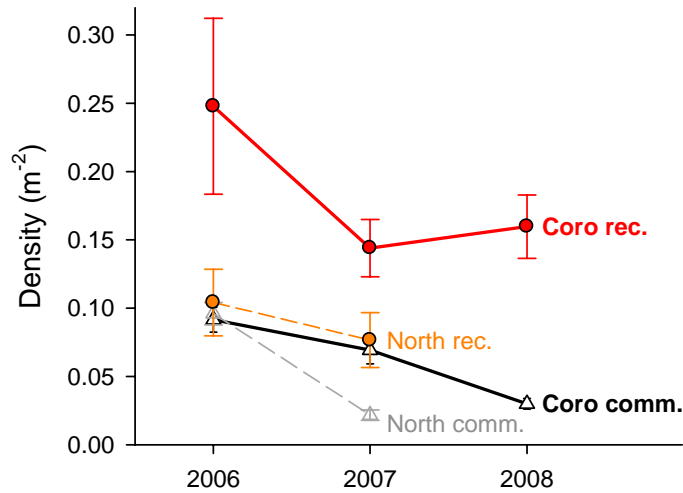


Figure 6: Mean density (m^{-2} , \pm s.e.) of scallops 100 mm or more shell length at recreational (closed circles) and commercial (open triangles) strata surveyed in the Coromandel (solid lines) and Northland (dashed lines) scallop fisheries, 2006–08. Commercial strata were surveyed by dredge (values presented here have not been corrected for dredge efficiency) in May of each year. Recreational strata were surveyed by divers in June of each year.

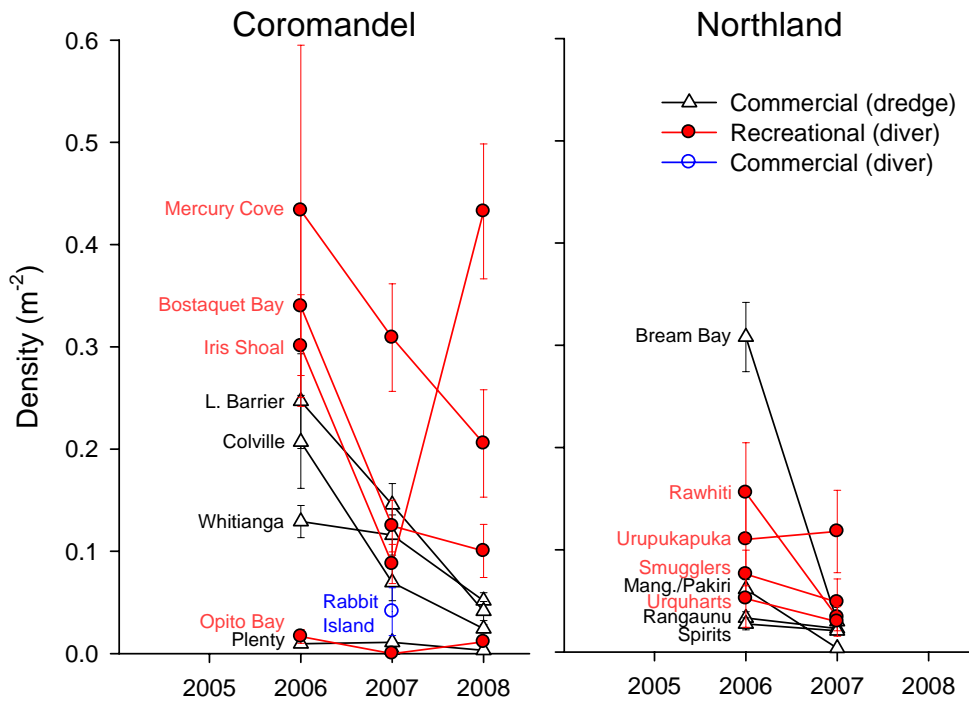


Figure 7: Mean density (m^{-2} , \pm s.e.) of scallops 100 mm or more shell length at recreational (closed circles) and commercial (open triangles) strata surveyed in the Coromandel (left) and Northland (right) scallop fisheries, 2006–08. Commercial strata were surveyed by dredge (values presented here have not been corrected for dredge efficiency) in May of each year. Recreational strata were surveyed by divers in June of each year.

4.2 CAY estimates

Estimates of CAY were based on biomass estimates from the survey and a reference F calculated on the basis of the commercial fishery. Although the latter is not ideal, the potential error introduced is considered to be small (M. Cryer, Ministry of Fisheries, Wellington, pers comm.). Future studies could investigate specific reference fishing mortality rates for recreational fisheries.

The recreational fishery is currently managed on the basis of a daily bag limit (20 scallops per person), a minimum legal size (100 mm), and a restricted fishing season (1 September to 31 March as of 2007, previously 15 July to 14 February). However, the distribution and overall level of landings (current and historic) from the recreational scallop fishery are uncertain, and there is no limit on the overall level of fishing effort or catch.

The CAY estimates presented here are specific to the four recreational strata surveyed, which, in total, represent a small (4.6 km²) but unknown proportion of the Coromandel recreational scallop fishing area. There is no information on how current non-commercial scallop landings from these specific areas relate to these yield estimates, and, therefore, to what extent the scallop populations in these areas are being exploited. Within the existing management system, management of the non-commercial scallop fishery to a CAY (or other landings limit) would require a good understanding of the relationship between effort, the bag limit, and total landings, which is currently not available.

5. CONCLUSIONS

1. Diver surveys of two Coromandel recreational scallop fishing locations (four recreational strata) were conducted in June 2008, which involved sampling at 80 stations. This was the third time these Coromandel recreational scallop beds had been surveyed (the first and second were in 2006 and 2007, respectively).
2. Absolute start-of-season (15 July) biomass over 100 mm (the recreational minimum legal size) for the areas surveyed was predicted to be about 78.6 t greenweight or 9.9 t meatweight with c.v.s of about 14% and 21%, respectively.
3. Yield estimates (CAY based on $F_{0.1}$) varied depending on assumptions about growth between the survey and the season, and the meatweight recovery fraction. Assuming average values for important assumed variables suggested a meatweight yield of 5.7 t for the surveyed areas.
4. It was unclear how current recreational landings relate to the CAY estimates for the areas surveyed, or how a CAY can be incorporated into the current recreational scallop fishery management system.
5. Scallop densities in areas open and closed to commercial dredging were compared using data from the 2006, 2007, and 2008 diver and dredge surveys.
6. Scallop abundance in commercial and some recreational areas seem to have varied in similar ways but it is too early to draw firm conclusions about the nature of this relationship. More data (areas and years) are required for a thorough examination (and further surveys of these same areas are planned for 2009–11).

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Appendix 1: Stratum definitions and station allocations for the diver surveys of recreational scallop areas in the Coromandel fishery, June 2008. Locations and strata were developed in 2006 (Williams et al. 2008) after consultation with the Ministry of Fisheries, and commercial and recreational scallop fishers. The locations and strata surveyed in 2008 were the same as those surveyed in 2006 (Williams et al. 2008) and 2007 (Williams 2008a), except Northland areas were not surveyed in 2008.

Location	Stratum	Area (km ²)	Stations	Stations km ⁻²	Area swept (m ²)	Depth (m)			Scallops
						mean	min	max	
Kawau	Iris Shoal	0.72	20	27.78	2227	10.2	8.0	12.3	1974
	Bostaquet Bay	0.33	20	60.61	2469	13.5	6.6	18.8	2567
Mercury	Mercury Cove	1.82	20	10.99	2306	13.2	6.9	22.4	1576
	Opito Bay	1.76	20	11.36	4021	10.8	3.7	16.3	340
Total	4	4.63	80	17.28	11024	11.9	3.7	22.4	9118