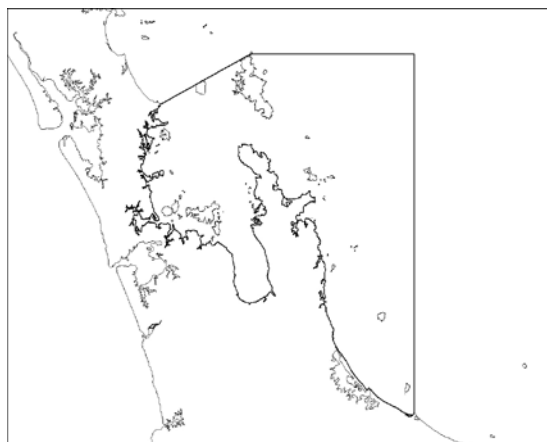


SCALLOPS COROMANDEL (SCA CS)

(*Pecten novaezelandiae*)
Kuakua, Tipa

**1. FISHERY SUMMARY**

Coromandel scallops were introduced into the QMS on 1 April 2002, with a TAC of 48 t, a TACC of 22 t, allowances of 7.5 t for recreational and customary fisheries, and an allowance of 11 t for other sources of mortality (Table 1; values all in meatweight).

Table 1: Total Allowable Commercial Catch (TACC, t) declared for SCA CS since introduction into the QMS.

Year	TAC	Customary	Recreational	Other Mortality	TACC
2002 - present	48	7.5	7.5	11	22

1.1 Commercial fisheries

The Coromandel scallop fishery is a regionally important commercial fishery and runs between Tauranga and Cape Rodney. Fishing is conducted within a number of discrete beds around Little Barrier Island, east of Waiheke Island (though not in recent years), at Colville, north of Whitianga (to the west and south of the Mercury Islands), and in the Bay of Plenty (principally off Waihi, and around Motiti and Slipper Islands). In 2011, fishers discovered that a large area of the Hauraki Gulf contained good densities of large scallops, which supported a large proportion of the fishing during the 2011 and 2012 seasons. That new, deeper (45–50 m water depth) region of the fishery lies mainly within statistical reporting area 2W and a smaller portion in 2S, and was surveyed for the first time in 2012. All commercial fishing is by dredge, with fishers preferring self-tipping “box” dredges to the “ring bag” designs used in the Challenger and Chatham Island fisheries. The fishing year applicable to this fishery is from 1 April to 31 March. The Coromandel commercial scallop fishing season runs from 15 July to 21 December each year.

A wide variety of effort controls and daily catch limits have been imposed in the past, but, since 1992 the fishery has been limited by explicit seasonal catch limits specified in meatweight (adductor muscle with roe attached), together with some additional controls on dredge size, fishing hours and non-fishing days. Catch and catch rates from the Coromandel fishery are variable both within and among years, a characteristic typical of scallop fisheries worldwide. Catch rates typically decline as each season progresses, but such declines are highly variable and depletion analysis cannot be used to assess start-of-season biomass.

Until the 1994 season, the minimum legal size for scallops taken commercially in northern (Coromandel and Northland) scallop fisheries was 100 mm shell length. From 1995 onwards, a

new limit of 90 mm shell length was applied in the Coromandel (but not the Northland) fishery as part of a management plan comprising several new measures. Since 1980 when the fishery was considered to be fully-developed, landings have varied more than 30-fold from less than 50 t to over 1500 t (greenweight). The two lowest recorded landings were in 1999 and 2000.

Northern scallop fisheries are managed under the QMS using individual transferable quotas (ITQ) that are proportions of the Total Allowable Commercial Catch (TACC). Catch limits and landings from the Coromandel fishery are shown in Table 2. Both northern scallop fisheries have been gazetted on the Second Schedule of the Fisheries Act 1996 which specifies that, for certain “highly variable” stocks, the Annual Catch Entitlement (ACE) can be increased within a fishing season. The TACC is not changed by this process and the ACE reverts to the “base” level of the TACC at the end of each season.

Table 2: Catch limits and landings (t meatweight or greenweight) from the Coromandel fishery since 1974. Data before 1986 are from Fisheries Statistics Unit (FSU) forms. Landed catch figures come from Monthly Harvest Return (MHR) forms, Licensed Fish Receiver Return (LFRR) forms, and from the landed section of Catch Effort and Landing Return (CELR) forms, whereas estimated catch figures come from the effort section of CELRs and are pro-rated to sum to the total CELR greenweight. “Hauraki” = 2X and 2W, “Mercury” = 2L and 2K, “Barrier” = 2R, 2S, and 2Q, “Plenty” = 2A–2I. Seasonal catch limits (since 1992) have been specified as ACE or on permits in meatweight (Green¹ assumes the gazetted meatweight recovery conversion factor of 12.5% and probably overestimates the actual greenweight taken in most years). * 1991 landings include about 400 t from Colville; #2011 landings were from a relatively deep (45–50 m) area of 2W fished for the first time in 2011; –, no catch limits set, or no reported catch.

Season	Catch limits (t)		Landings (t)			Scaled estimated catch (t green)			
	Meat	Green ¹	MHR	CELR		Hauraki	Mercury	Barrier	Plenty
			Meat	Meat	Green				
1974	–	–	–	–	26	0	26	0	0
1975	–	–	–	–	76	0	76	0	0
1976	–	–	–	–	112	0	98	0	14
1977	–	–	–	–	710	0	574	0	136
1978	–	–	–	–	961	164	729	3	65
1979	–	–	–	–	790	282	362	51	91
1980	–	–	–	–	1 005	249	690	23	77
1981	–	–	–	–	1 170	332	743	41	72
1982	–	–	–	–	1 050	687	385	49	80
1983	–	–	–	–	1 553	687	715	120	31
1984	–	–	–	–	1 123	524	525	62	12
1985	–	–	–	–	877	518	277	82	0
1986	–	–	–	–	1 035	135	576	305	19
1987	–	–	–	–	1 431	676	556	136	62
1988	–	–	–	–	1 167	19	911	234	3
1989	–	–	–	–	360	24	253	95	1
1990	–	–	–	–	903	98	691	114	0
1991	–	–	–	–	1 392	*472	822	98	0
1992-93	154	1 232	–	–	901	67	686	68	76
1993-94	132	1 056	–	–	455	11	229	60	149
1994-95	66	528	–	–	323	17	139	48	119
1995-96	86	686	–	79	574	25	323	176	50
1996-97	88	704	–	80	594	25	359	193	18
1997-98	105	840	–	89	679	26	473	165	15
1998-99	110	880	–	37	204	1	199	2	1
1999-00	31	248	–	7	47	0	12	17	18
2000-01	15	123	–	10	70	0	24	2	44
2001-02	22	176	–	20	161	1	63	85	12
2002-03	35	280	32	31	204	0	79	12	112
2003-04	58	464	58	56	451	63	153	13	223
2004-05	78	624	78	78	624	27	333	27	237
2005-06	118	944	119	121	968	21	872	75	0
2006-07	118	944	118	117	934	28	846	60	0
2007-08	108	864	59	59	471	51	373	45	2
2008-09	95	760	71	72	541	12	509	15	5
2009-10	100	800	33	33	267	12	184	71	0
2010-11	100	800	35	35	281	11	110	160	1
2011-12	50	400	50	50	402	#220	160	20	0

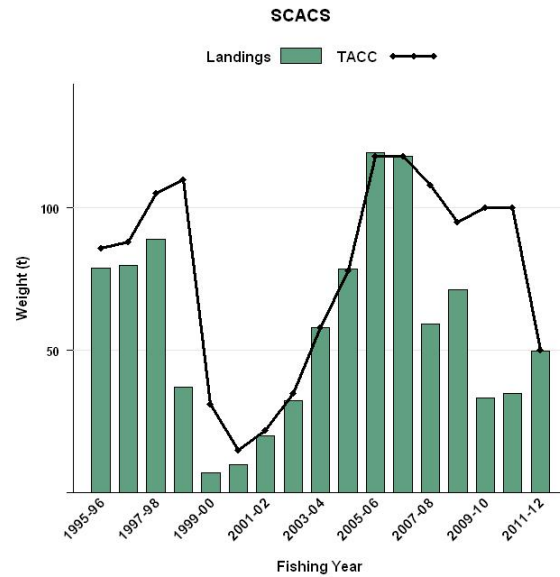


Figure 1: Landings and catch limits for SCACS (Coromandel) from 2002–03 to 2009–10. TACC refers to catch limit, and Weight refers to Meatweight.

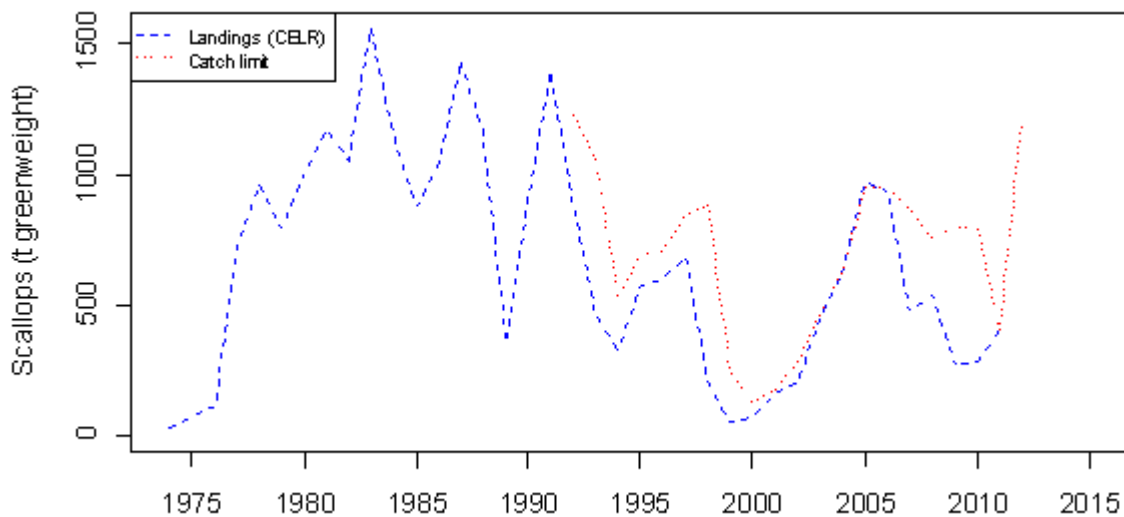


Figure 2: Catch limits and reported landings (from CELRs) in t greenweight for the SCA CS fishery since 1974.

1.2 Recreational fisheries

There is a strong non-commercial (recreational and Maori customary) interest in scallops in suitable areas throughout the Coromandel fishery, mostly in enclosed bays and harbours. Scallops are usually taken by diving using snorkel or scuba, 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. One management tool for northern scallop fisheries is the general spatial separation of commercial and amateur 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 regulated closures. Regulations governing the recreational harvest of scallops from SCA CS include a minimum legal size of 100 mm shell length and a restricted daily harvest (bag limit) of 20 per person. A change to the recreational fishing regulations in 2005 allowed divers operating from a vessel to take scallops for up to two nominated safety people on board the vessel, in addition to the catch limits

for the divers. Until 2006, the recreational scallop season ran from 15 July to 14 February, but in 2007 the season was changed to run from 1 September to 31 March.

A pilot study was conducted in 2007–08 to assess the feasibility of estimating the recreational catch in that part of the Coromandel scallop fishery from Cape Colville to Hot Water Beach (Holdsworth & Walshe 2009). The study was based on an access point (boat ramp) survey using interviewers to collect catch and effort information from returning fishers, and was conducted from 1 December 2007 to 28 February 2008 (90 days) during the peak of the scallop season. The total estimated harvest during the survey period was 205,400 scallops (c.v. = 8.6%), with an estimated 23.9 t greenweight harvested (about 3 t meatweight).

Currently, there are no reliable fishery-wide estimates of non-commercial harvest of scallops from the Coromandel fishery. Estimates of catch by recreational fishers have been made on four occasions as part of recreational fishing (telephone and diary) surveys (Table 3). A Marine Recreational Fisheries Technical Working Group (FTWG) 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 2000–01 estimates are implausibly high for many important fisheries.”

Given the above concerns about the reliability of fishery-wide non-commercial harvest estimates, it is difficult to make comparisons between the levels of commercial and non-commercial harvest. However, in 1993–94 the recreational harvest estimate was 60–70 t (greenweight) from the area shared with the Coromandel commercial fishery (Bradford 1997). These estimates may include some Maori customary catch. Commercial landings from the Coromandel controlled fishery in the most comparable period (July to December 1994 scallop season) were 323 t, suggesting that, in that year, the recreational catch of scallops was about 16–18% of total removals. It is not known if these estimates are typical of the recreational catch, but the commercial catch was very low and 1993–94 may not have been a typical year.

Table 3: Harvest estimates (numbers, and equivalent greenweight) of scallops taken by recreational fishers in the area shared with the Coromandel scallop fishery from the telephone-diary surveys conducted in 1993–94, 1996, 1999–00, and 2000–01. A Marine Recreational Fisheries Technical Working Group considered that these estimates may be very inaccurate.

Year	Coromandel			Reference
	No. of scallops	CV	Weight (t, green)	
1993–94	626 000	0.14	60.0–70.0	Bradford (1997)
1996	614 000	0.12	62.0	Bradford (1998)
1999–00	257 000	1.01	30.1	Boyd & Reilly (2002)
2000–01	472 000	0.47	55.3	Boyd <i>et al.</i> (2004)

1.3 Customary fisheries

Scallops were undoubtedly used traditionally as food by Maori, and some limited quantitative information on recent levels of customary take is available from MFish (Table 4).

Table 4: MFish records of customary harvest of scallops (reported on customary permits as numbers or greenweight, or units unspecified) taken from the Coromandel scallop fishery, 2003–04 to 2008–09. –, no data.

SCACS Fishing year	Quantity approved, by unit type			Actual quantity harvested, by unit type		
	Weight (kg)	Number	Unspecified	Weight (kg)	Number	Unspecified
2003–04	600	200	–	600	200	–
2004–05	360	50	150	360	–	–
2005–06	3	700	50	0	–	–
2006–07	–	290	–	–	180	–
2007–08	330	630	–	285	280	–
2008–09	–	440	–	–	440	–

1.4 Illegal catch

There is no quantitative information on the level of illegal catch.

1.5 Other sources of mortality

The box dredges in use in the Coromandel commercial fishery have been found to be considerably more efficient, in the generally sandy conditions prevalent in the fishery, than ring-bag or Keta-Ami dredges. However, scallops encountered by box dredges showed modest reductions in growth rate, compared with scallops collected by divers, and quite high mortality (about 20–30% mortality for scallops that are returned to the water. I.e. just under the MLS of 90 mm). Stochastic modelling suggested that, of the three dredge designs tested, box dredges would generate the greatest yield-per-recruit and catch rates. The incidental mortality caused by dredging substantially changed the shape of yield-per-recruit curves for Coromandel scallops, causing generally asymptotic curves to become domed, and decreasing estimates of F_{max} and $F_{0.1}$. More recent field experiments and modelling suggest that dredging reduces habitat heterogeneity, increases juvenile mortality, makes yield-per-recruit curves even more domed, and decreases estimates of F_{max} and $F_{0.1}$ even further.

2. BIOLOGY

Pecten novaezelandiae is one of several species of “fan shell” bivalve molluscs found in New Zealand waters. Others include queen scallops and some smaller species of the genus *Chlamys*. *P. novaezelandiae* is endemic to New Zealand, but is very closely related to the Australian species *P. fumatus* and *P. modestus*. Scallops of various taxonomic groups are found in all oceans and support many fisheries world-wide; most scallop populations undergo large fluctuations.

Scallops are found in a variety of coastal habitats, but particularly in semi-enclosed areas where circulating currents are thought to retain larvae. After the planktonic larval phase and a relatively mobile phase as very small juveniles, scallops are largely sessile and move actively mainly in response to predators. They may, however, be moved considerable distances by currents and storms and are sometimes thrown up in large numbers on beaches.

Scallops are functional hermaphrodites, and become sexually mature at a size of about 70 mm shell length. They are extremely fecund and may spawn several times each year. Fertilisation is external and larval development lasts for about 3 weeks. Initial settlement occurs when the larva attaches via a byssus thread to filamentous material or dead shells on or close to the seabed. The major settlement of spat in northern fisheries usually takes place in early January. After growth to about 5 mm, the byssus is detached and, after a highly mobile phase as a small juvenile, the young scallop takes up the relatively sedentary adult mode of life.

The very high fecundity of this species, and likely variability in the mortality of larvae and pre-recruits, leads to great variability in annual recruitment. This, combined with variable mortality and growth rate of adults, leads to scallop populations being highly variable from one year to the next, especially in areas of rapid growth where the fishery may be supported by only one or two year classes. This variability is characteristic of scallop populations world-wide, and often occurs independently of fishing pressure.

The growth of scallops within the Coromandel fishery is variable among areas, years, seasons and depths, and probably among substrates. In the Hauraki Gulf scallops have been estimated to grow to 100 mm shell length in 18 months or less, whereas this can take three or more years elsewhere (Table 5). In some years, growth is very slow, whereas in others it is very rapid. There is a steep relationship with depth and scallops in shallow water grow much faster than those in deeper water. This is not a simple relationship, however, as scallops in some very deep beds (e.g.,

Rangaunu Bay and Spirits Bay in the far north, both deeper than 40 m) appear to grow at least as fast as those in favourable parts of the Coromandel fishery. Food supply undoubtedly plays a role.

A variety of studies suggest that average natural mortality in the Coromandel fishery is quite high at $M = 0.50 \text{ y}^{-1}$ (instantaneous rate), and maximum age in unexploited populations is thought to be about 6 or 7 years.

Table 5: Estimates of biological parameters.

Stock	Estimates		Source
1. Natural mortality, M			
Motiti Island	0.4–0.5		Walshe 1984
Coromandel Fishery	Mean 0.5		Cryer 2001a
2. Weight = $a(\text{length})^b$			
	a	b	
Coromandel fishery	0.00042	2.662	Cryer & Parkinson 1999
3. von Bertalanffy parameters			
	L_∞	K	
Motiti Island (1981–82)	140.6	0.378	Walshe 1984
Hauraki Gulf (1982–83)	115.9	1.200	Walshe 1984
Whitianga (1982)	114.7	1.210	Data of L.G. Allen, analysed by Cryer & Parkinson 1999
Whitianga (1983)	108.1	1.197	Data of L.G. Allen, analysed by Cryer & Parkinson 1999
Whitianga (1984)	108.4	0.586	Data of L.G. Allen, analysed by Cryer & Parkinson 1999
Coromandel fishery (1992–97)	108.8	1.366	Cryer & Parkinson 1999
Whitianga mean depth 10.6 m	113.5	1.700	Cryer & Parkinson 1999
Whitianga mean depth 21.1 m	109.0	0.669	Cryer & Parkinson 1999
Whitianga mean depth 29.7 m	110.3	0.588	Cryer & Parkinson 1999

3. STOCKS AND AREAS

Scallops inhabit waters of up to about 60 m deep (apparently up to 85 m at the Chatham Islands), but are more common in depths of 10 to 50 m on substrates of shell gravel, sand or, in some cases, silt. Scallops are typically patchily distributed at a range of spatial scales; some of the beds are persistent and others are ephemeral. The extent to which the various beds or populations are reproductively or functionally separate is not known. It is currently assumed for management that the Northland stock is separate from the adjacent Coromandel stock and from the various west coast harbours, Golden Bay, Tasman Bay, Marlborough Sounds, Stewart Island and Chatham Island areas.

4. STOCK ASSESSMENT

Coromandel scallops are managed using a TACC of 22 t meatweight which can be augmented with additional ACE based on a Current Annual Yield (CAY) calculation using $F_{0.1}$ as a reference point. Surveys of selected scallop beds in the fishery have been conducted on an almost annual basis, as a means of estimating stock size, calculating CAY, and informing potential increases in ACE.

In 2011, however, no survey was conducted; instead, CAY for the 2011 season was calculated using estimates of projected biomass generated by projecting the 2010 survey data forward to the start of the 2011 fishing season. The projection approach used a length-based growth transition matrix (based on tag return data) to grow the scallops from the time of the survey (May 2010) to the start of the fishing season the following year (July 2011), correcting for dredge efficiency, and allowing for natural mortality and fishing mortality (catch and incidental mortality). Uncertainty was incorporated during the projection process by bootstrapping (resampling with replacement) from the various data sources (Tuck 2011).

In 2012, a comprehensive survey was conducted that aimed to provide an index of abundance representative of the status of the overall SCA CS stock. The survey coverage was more extensive than used previously, with the stratification comprising ‘core’ strata (those surveyed and fished consistently in the past), ‘background’ strata (areas of lower densities outside the core strata that formed part of the survey coverage in the past), and ‘new’ strata (those in Hauraki Gulf that had never been surveyed before).

4.1 Estimates of fishery parameters and abundance

Fishing mortality has sometimes been quite high in the Coromandel fishery (Table 6).

CPUE is not presented for this fishery because it is not a reliable index of abundance (Cryer 2001b). However, recent simulation studies have examined the use of CPUE as a basis for some management strategies (Haist & Middleton 2010).

4.2 Biomass estimates

Virgin biomass, B_0 , and the biomass that will support the maximum sustainable yield, B_{MSY} , have not been estimated and are probably not appropriate reference points for a stock with highly variable recruitment and growth such as scallops.

There have been annual surveys and assessments of Coromandel scallops since 1992 (except for 2000 and 2011), in support of a CAY management strategy. Assessments are based on pre-season biomass surveys done by diving and/or dredging (Tables 6–8). Bian *et al.* (2012) modelled the efficiency of box dredges used in northern New Zealand scallop fisheries, and the results suggest the efficiency of these dredges was underestimated previously (2004 to 2010), resulting in overestimation of biomass and yield. The 2012 estimates of abundance and biomass were made using the new parametric model of dredge efficiency (Bian *et al.* 2012) that estimates efficiency with respect to scallop length, water depth, substrate type, and tow termination.

Table 6: Estimated start of season abundance and biomass of scallops of 90 mm or more shell length in the Coromandel fishery since 1998 using historical average dredge efficiency; for each year, the catch (reported on the ‘Landed’ section of CELRs), exploitation rate (catch to biomass ratio), and the estimated fishing mortality (F_{est}) are also given. F_{est} was estimated by iteration using the Baranov catch equation where $t = 5/12$ and $M = 0.50$ spread evenly through the year. Abundance and biomass estimates are mean values up to and including 2003, and median values from 2004, when the analytical methodology for producing the estimates was modified. Note the estimates for 1998–2010 were produced by correcting for dredge efficiency using the method of Cryer & Parkinson (2006), which was replaced by the method of Bian *et al.* (2012) in 2012 (a preliminary version of that method was used in 2011). This, together with changes to survey coverage each year, makes direct comparisons among years difficult. –, no data. There was no survey in 2000 or 2011. The 2011 values are projected estimates generated by projecting forward the 2010 survey data to the start of the 2011 fishing season. Estimates of abundance in numbers (millions) of scallops were not reported in 2011.

Year	Abundance		Biomass				Catch (t meat)	Exploitation rate (catch/biomass)	F_{est} ≥90 mm
	(millions)	c.v.	(t green)	c.v.	(t meat)	c.v.			
1998	35.4	0.16	2702	0.16	365	0.16	31	0.08	0.237
1999	10.3	0.18	752	0.18	102	0.18	7	0.07	0.189
2000	–	–	–	–	–	–	10	–	–
2001	8.3	0.26	577	0.27	78	0.27	20	0.26	0.796
2002	10.3	0.20	768	0.20	104	0.20	31	0.30	0.954
2003	16.0	0.18	1224	0.18	165	0.18	56	0.34	1.131
2004	111.5	0.22	9024	0.21	1131	0.26	78	0.07	0.191
2005	169.3	0.24	14374	0.23	1795	0.27	121	0.07	0.185
2006	143.1	0.21	12302	0.21	1531	0.25	117	0.08	0.212
2007	101.6	0.20	8428	0.20	1061	0.23	59	0.06	0.152
2008	94.0	0.29	6900	0.28	868	0.31	72	0.08	0.232
2009	64.5	0.23	4676	0.22	595	0.24	33	0.06	0.154
2010	58.8	0.20	4442	0.19	540	0.21	35	0.07	0.180
2011	–	–	5426	0.85	658	0.87	50	0.08	0.211
2012	140.0	0.15	11423	0.15	1380	0.18	–	–	–

The 2012 estimates were produced from a comprehensive survey coverage that included previously unsurveyed areas of the SCA CS stock (e.g., the 40–50 m deep region of Hauraki Gulf, which contained a considerable biomass in 2012).

Discerning trends in the abundance and biomass of recruited scallops is complicated by changes to survey coverage, the establishment of closed areas, and uncertainty about dredge efficiency in any particular year. However, some changes have been so large as to transcend this combined uncertainty. Time series of abundance and biomass estimates of scallops 90 mm or more shell length are shown in Table 7. It is important to note that these time series were produced by correcting for dredge efficiency using the method of Cryer & Parkinson (2006), so the 2012 values were generated using that same method so that all years are comparable. In future, the data should be re-worked using the new method of Bian et al (2012). For 2012, the estimates were generated using data from the ‘core’ strata only (i.e., the ‘background’ strata, and ‘new’ strata in the Hauraki Gulf region, were excluded, the latter because there was no survey from the past; it was surveyed for the first time in 2012).

Estimates around the turn of the century (2000) were consistently at or near the lowest on record and it seems reasonable to conclude that the population was, for unknown reasons, at a very low ebb. In contrast, following reasonable increases in 2003 and, especially, 2004, the abundance and biomass in 2005 were the highest on record and probably higher than in the mid 1980s when not all of the beds were surveyed. This remarkable resurgence was strongest in the Mercury region to the north of Whitianga (the mainstay of the fishery), but most beds showed some increase in density. There has been a gradual decline in the overall recruited population since the peak in 2005, but in 2010 this downward trend appeared to have stalled. For the regions usually fished (i.e. for the core strata only, excluding the ‘new’ area in Hauraki Gulf and the ‘background’ strata) the status of the recruited population in 2012 appears to be fairly similar to that in 2010 (Appendix 8; estimated using Cryer & Parkinson (2006) dredge efficiency method), and again most of the fishable biomass is held in the Mercury beds, but with high densities of recruits in beds at Little Barrier. For the new Hauraki Gulf region of the fishery (2W/2S), it is unknown whether the large biomass of scallops found in 2012 is a consistent part of the population, or a product of successful recruitment in recent years.

Table 7: Estimated abundance and biomass of scallops 90 mm or more shell length at the time of surveys in the five main regions of the Coromandel fishery since 1998. Excludes the “new”, deep fishery region in Hauraki Gulf, which was fished for the first time in 2011, and surveyed for the first time in 2012 (estimated 148.5 million scallops or 13278 t greenweight biomass). Survey data were analysed using a non-parametric re-sampling with replacement approach to estimation (1000 bootstraps). Note these estimates were produced by correcting for dredge efficiency using the method of Cryer & Parkinson (2006), which has now been replaced by the method of Bian et al (2012). Figures are not necessarily directly comparable among years because of changes to survey coverage. –, no survey in a region or year. The 2001 survey totals include scallops surveyed in 7 km² strata at both Kawau (0.5 million, 3 t) and Great Barrier Island (0.8 million, 62 t).

Year	Abundance (millions)						Area surveyed (km ²)
	Barrier	Waiheke	Colville	Mercury	Plenty	Total	
1998	2.0	9.0	0.4	21.3	2.2	36.1	341
1999	0.5	0.5	0.0	7.3	2.7	11.2	341
2000	–	–	–	–	–	–	–
2001	7.4	0.4	–	6.9	2.1	18.1	125
2002	1.8	4.0	–	6.6	2.0	14.7	119
2003	2.5	4.0	4.3	12.3	4.9	28.6	130
2004	4.5	9.8	0.4	58.5	8.2	82.6	149
2005	6.2	3.3	3.0	118.8	12.6	145.3	174
2006	5.6	–	10.3	101.6	6.5	125.3	160
2007	4.2	1.3	4.4	59.9	14.3	84.6	175
2008	2.0	–	1.7	56.3	4.8	65.0	144
2009	10.4	–	3.1	31.8	1.3	46.9	144
2010	9.6	0.8	2.6	28.0	3.9	45.6	149
2011	–	–	–	–	–	–	–
2012	7.7	0.4	2.4	22.8	2.9	36.8	180

Year	Biomass (t green)						Area (km ²)
	Barrier	Waiheke	Colville	Mercury	Plenty	Total	
1998	173	731	30	1 674	205	2 912	341
1999	42	34	1	559	224	873	341
2000	–	–	–	–	–	–	–
2001	554	32	–	525	165	1 362	125
2002	150	289	–	538	163	1 156	119
2003	225	302	387	995	406	2 355	130
2004	348	737	30	4 923	676	6 794	149

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2005	544	274	316	10 118	1 058	12 404	174
2006	519	–	1 041	8 731	534	10 902	160
2007	376	96	409	5 498	1 110	7 539	175
2008	166	–	150	4 575	367	5 265	144
2009	823	–	257	2 512	102	3 725	144
2010	764	59	219	2 299	291	3 671	149
2011	–	–	–	–	–	–	–
2012	629	32	250	1 855	225	3 027	180

Uncertainty stemming from assumptions about dredge efficiency during the surveys, rates of growth and natural mortality between survey and season, and predicting the average recovery of meatweight from greenweight remain in these biomass estimates. A new model of scallop dredge efficiency (Bian *et al.* 2012) has helped to reduce this uncertainty, as should future research projects aimed at collecting more data on scallop growth and mortality. Managing the fisheries based on the number of recruited scallops at the start of the season as opposed to recruited biomass (the current approach) could remove the uncertainty associated with converting estimated numbers of scallops to estimated meatweight.

Until 1997, assessments for the Coromandel fishery were based on Provisional Yield (PY, estimated as the lower bound of a 95% confidence distribution for the estimated start-of-season biomass of scallops 100 mm or more shell length). Experiments and modelling showed this method to be sub-optimal however. New estimates of the reference fishing mortality rates $F_{0.1}$, $F_{40\%}$ and F_{max} were therefore made, taking into account experimental estimates of incidental fishing mortality. For assessments since 1998, CAY was estimated using these reference fishing mortality rates, and CAY supplanted PY as a yield estimator. Recent experimentation and modelling of juvenile mortality in relation to habitat heterogeneity suggest that even these more conservative reference fishing mortality rates may be too high.

Diver surveys of scallops were conducted annually in June–July from 2006 to 2010 at selected scallop beds in the Coromandel recreational fishing areas (Williams *et al.* 2008, Williams 2009a, b, 2012). For the four small beds (total area of 4.64 km²) surveyed each year, the projected (15 July) biomass of scallops over 100 mm shell length was estimated to be 128 t greenweight (CV of 26%) or 16 t meatweight in 2006, 82 t greenweight (CV of 13%) or 10 t meatweight (CV of 20%) in 2007, and 79 t greenweight (CV of 14%) or 10 t meatweight (CV of 21%) in 2008. Survey stratum boundaries were revised in 2009 to better reflect the extent of the scallop bed at each site, resulting in a slightly reduced total area (3.6 km²) surveyed; the total projected biomass was estimated to be 50 t greenweight or 6 t meatweight (CVs of 13%) in 2009, and 48 t greenweight or 6 t meatweight (CVs of 13 and 16%) in 2010 (Williams 2012).

4.3 Estimation of Maximum Constant Yield (MCY)

MCY has not been estimated for Coromandel scallops and would probably be close to zero.

4.4 Estimation of Current Annual Yield (CAY)

Yield estimates are generally calculated using reference rates of fishing mortality applied to an estimate of current or reference biomass. Cryer & Parkinson (2006) reviewed reference rates of fishing mortality and summarised modelling studies by Cryer & Parkinson (1997) and Cryer *et al.* (2004). $F_{0.1}$ is used as the target reference rate of fishing mortality for scallops.

Management of Coromandel scallops is based on a CAY approach. Since 1998, catch limits have been adjusted in line with estimated start-of-season recruited biomass and an estimate of CAY made using the Baranov catch equation:

$$CAY = \frac{F_{ref}}{F_{ref} + M} (1 - e^{-(F_{ref} + M)t}) B_{beg}$$

where $t = 5/12$ years, F_{ref} is a reference fishing mortality ($F_{0.1}$) and B_{beg} is the estimated start-of-season (15 July) recruited biomass (scallops of 90 mm or more shell length). Natural mortality is

assumed to act in tandem with fishing mortality for the first 5 months of the fishing season, the length of the current Coromandel commercial scallop season. B_{beg} is estimated assuming historical average dredge efficiency at length, average growth (from previous tagging studies), $M = 0.5$ spread evenly through the year, and historical average recovery of meatweight from greenweight. Because of the uncertainty over biomass estimates, growth, and mortality in a given year, and appropriate reference rates of fishing mortality, yield estimates must be treated with caution.

Modelling studies for Coromandel scallops (Cryer & Morrison 1997, Cryer *et al.* 2004) indicate that $F_{0.1}$ is sensitive not only to the direct incidental effects of fishing (reduced growth and increased mortality on essentially adult scallops), but also to indirect incidental effects (such as additional juvenile mortality related to reduced habitat heterogeneity in dredged areas).

Consequently, the most recent CAY estimates were derived in 2012 for two scenarios:

1) CAY including direct effects on adults

By including only the direct incidental effects of fishing on scallops, Cryer *et al.* (2004) derived an estimate of $F_{0.1} = 1.034 \text{ y}^{-1}$ (reported by Cryer *et al.*, 2004, as $5/12 * F_{0.1} = 0.431$). Using this value and the 2012 start of season biomass estimate of 1380 t meatweight (median projected value), the CAY for 2012–13 was estimated to be 439 t meatweight (Williams *et al.* 2012).

2) CAY including direct and indirect effects on adults and juveniles

Cryer *et al.* (2004) modelled the “feedback” effects of habitat modification by the dredge method on juvenile mortality in scallops. They developed estimates of F_{ref} that incorporated such effects, but had to make assumptions about the duration of what they called the “critical phase” of juvenile growth during which scallops were susceptible to increased mortality. To give some guidance on the possible outcome of including “indirect” (as well as direct) effects on yield estimates, Cryer *et al.*s (2004) estimate of $F_{0.1} = 0.658 \text{ y}^{-1}$ (reported as $5/12 * F_{0.1} = 0.274$) was applied here. Using this value and the 2012 start of season biomass estimate of 1380 t (median projected value), the CAY for 2012–13 was estimated to be 300 t meatweight (Williams *et al.* 2012).

For both scenarios, the estimates of CAY would have C.V.s at least as large as those of the estimate of start-of-season recruited biomass (18%), are sensitive to assumptions about dredge efficiency, growth, and expected recovery of meatweight from greenweight, and relate to the surveyed beds only. Further, the second approach which includes indirect incidental effects (putative “habitat effects”) is sensitive to the duration of any habitat-mediated increase in juvenile mortality. There is also additional uncertainty associated with using a point estimate of $F_{0.1}$ (i.e., variance associated with the point estimate of $F_{0.1}$ was not incorporated in the analysis), and the fact that the estimates of $F_{0.1}$ were generated using estimates of dredge efficiency that are different to those used to estimate current biomass; the latter may have resulted in underestimates of yield.

Regardless of the approach used to estimate CAY, the production of a single ‘best estimate’ of CAY should be treated with caution; it is better to work with a range of estimates. For the projections to the 2012 start of season, the 1000 combined greenweight estimates were converted to meatweight (resampling from the meatweight greenweight conversion ratio data).. The median of this meatweight distribution was 1380 tonnes. Using the existing target reference $F_{0.1}$ values for Coromandel scallops, this meatweight distribution was converted into a distribution of CAY estimates and a range of catch limit options were compared with this distribution to provide a decision table (Table 9).

Table 9: Decision table showing probability that a particular catch limit (t meatweight) would exceed reference fishing mortality values, for the Coromandel scallop (SCA CS) 2012–13 fishing year. $F_{0.1}$ (direct effects) represents the probability that the estimate of $F_{0.1} = 1.034$ incorporating direct incidental mortality effects is exceeded. $F_{0.1}$ (direct & indirect effects) represents the probability that the estimate of $F_{0.1} = 0.658$ incorporating direct and indirect incidental mortality effects is exceeded. These probabilities were generated from an analysis using estimates of absolute biomass within the surveyed area (i.e., a critical density of 0.00 scallops m^{-2}).

Catch limit (t)	F0.1 (direct effects)	F0.1 (direct & indirect effects)
150	0.000	0.000
160	0.000	0.000
170	0.000	0.001
180	0.000	0.002
190	0.000	0.005
200	0.000	0.011
210	0.000	0.018
220	0.000	0.036
230	0.000	0.063
240	0.001	0.109
250	0.001	0.162
260	0.002	0.217
270	0.002	0.285
280	0.007	0.351
290	0.010	0.429
300	0.016	0.510
310	0.020	0.577
320	0.033	0.645
330	0.050	0.706
340	0.070	0.772
350	0.104	0.817
360	0.138	0.850
370	0.179	0.886
380	0.213	0.914
390	0.259	0.933
400	0.306	0.950
410	0.353	0.960
420	0.402	0.974
430	0.460	0.985
440	0.513	0.988

4.5 Other yield estimates and stock assessment results

The estimation of Provisional Yield (PY) is no longer accepted as appropriate, and assessments since 1998 have used a CAY approach.

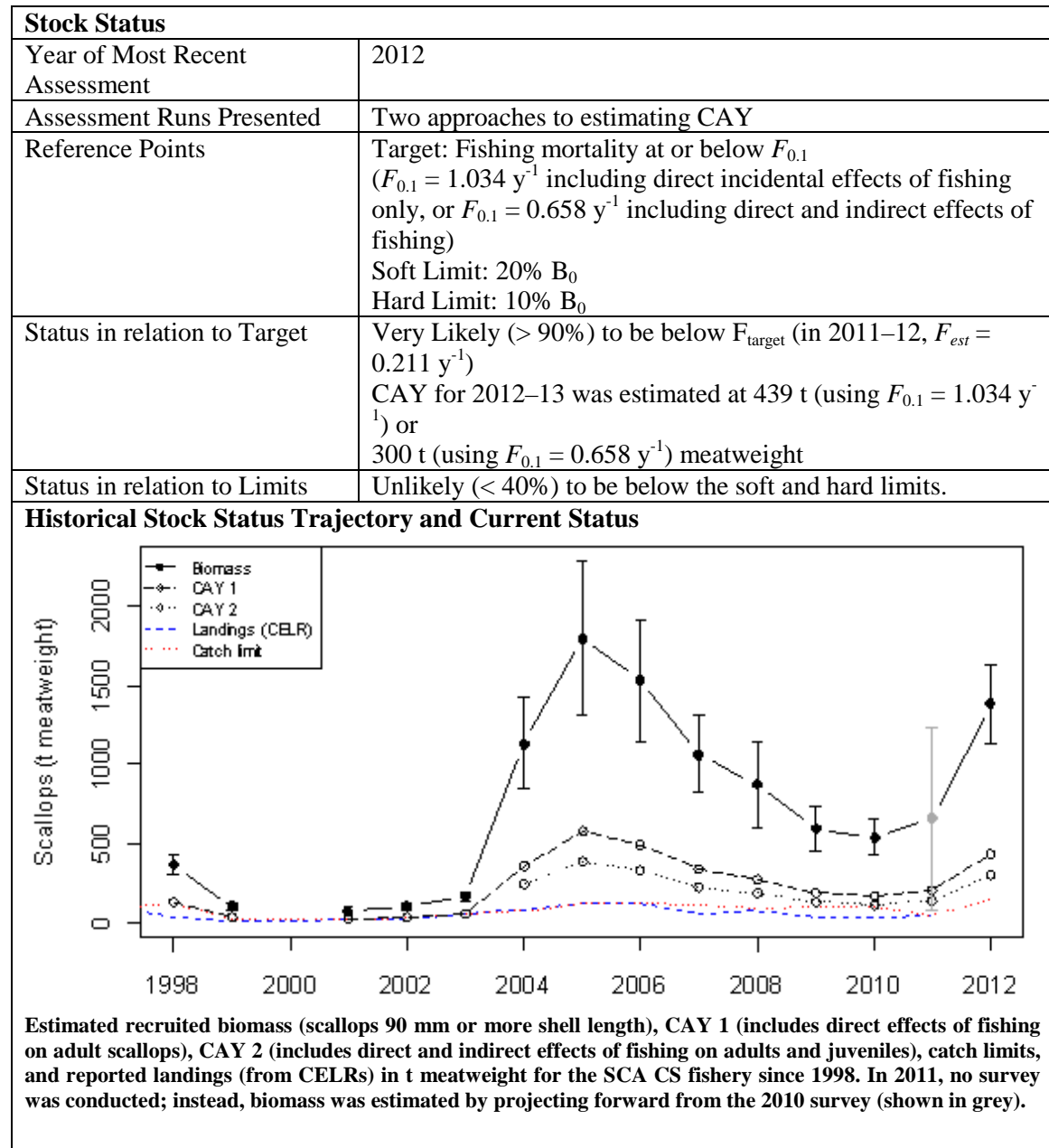
Stochastic yield-per-recruit (YPR) and spawning-stock-biomass-per-recruit (SSBPR) modelling has been conducted for the Coromandel scallop fishery, including the incidental effects on growth and mortality of the dredge method in use throughout the fishery. Estimates of reference rates of fishing mortality from this study have been used to estimate CAY since 1998. More recent experimental and modelling studies indicate that even these reference rates of fishing mortality may be too high if habitat effects and juvenile scallop mortality are taken into account, causing a positive bias in CAY. CAY may also be over-estimated when either the efficiency of the dredge used during the survey is greater than that assumed in calculations (i.e., the multiplier used to account for dredge efficiency is optimistic), or the density of scallops is low and part of the biomass occurs at a density not viable for commercial fishing.

5. STOCK STATUS

Stock Structure Assumptions

The stock structure of scallops in New Zealand waters is uncertain. For the purposes of this assessment, SCA CS is assumed to be a single biological stock, although the extent to which the various beds or populations are reproductively or functionally separate is not known.

- **Coromandel scallops, SCA CS**



SCALLOPS (SCA CS)

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated recruited biomass (t meatweight of scallops ≥ 90 mm shell length) in the core areas of the fishery between 1999–2003 was consistently at or near the lowest on record (78 t meatweight in 2001), but increased dramatically to record high levels in 2005 (1795 t) and 2006 (1531 t). There has been a recent trend of decreasing biomass from the peak in 2005 to the 2009 estimate of 595 t, but this downward trend appears to have abated in 2010 (540 t). In addition to the core areas, the comprehensive 2012 survey coverage included a large new area of the fishery in Hauraki Gulf, and showed that it held a considerable biomass. It is unknown whether the large biomass of scallops found in 2012 is a consistent part of the population, or a product of successful recruitment in recent years. Including that ‘new’ area, projected biomass in 2012 was an estimated 1380 t.
Recent Trend in Fishing Mortality or Proxy	At the fishery-wide level, estimated fishing mortality on scallops 90 mm or more was relatively low in the periods 1998–99 and 2004–11 (mean $F_{est} = 0.19 \text{ y}^{-1}$), but much higher between 2001 and 2003 (mean $F_{est} = 0.96 \text{ y}^{-1}$).
Other Abundance Indices	None.
Trends in Other Relevant Indicator or Variables	None

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections beyond the start of the 2012 season are not available. Catch, catch rates and growth are highly variable both within and among years. Recruitment is also highly variable between years.
Probability of Current Catch / TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology	
Assessment Type	Level 2 - Partial quantitative stock assessment
Assessment Method	Biomass surveys and CAY management strategy
Assessment Dates	Latest assessment: 2012 Next assessment: 2013
Overall Assessment Quality Rank	1 – High Quality
Main data inputs (rank)	Biomass survey: 2012 1 – High Quality
Data not used (rank)	Not applicable
Changes to Model Structure and Assumptions	None since the 2009 assessment. Current model has been in use since 1998. In 2011, however, no survey was conducted; instead, CAY was calculated using estimates of projected biomass generated by projecting forward the 2010 survey data to the 2011 season.
Major Sources of Uncertainty	These include assumptions about: dredge efficiency during the survey, growth rates and natural mortality between the survey and the start of the season, predicting the average recovery of meatweight from greenweight and the extent to which dredging causes incidental mortality and affects recruitment.

Qualifying Comments
In the Coromandel fishery some scallop beds are persistent and others are ephemeral. The

extent to which the various beds or populations are reproductively or functionally separate is not known.

At the Shellfish Fishery Assessment Working Group held on 21–22 January 2010, concerns were raised about the large discrepancy that has been observed over recent years between the CAY estimates for the commercial Coromandel scallop fishery and the actual catch taken by the fishers. Fishers that attended the SFWG meeting believe that it is not possible to catch the CAY. MFish project SAP2009-10 (Williams *et al.* 2011) investigated a number of factors which could affect the difference between CAY and the actual commercial catch, and found that the calculated dredge efficiency was the major factor contributing to the difference. Project SAP200913 (Bian *et al.* 2012) modelled the efficiency of box dredges used in northern New Zealand scallop fisheries; results suggest the efficiency of these dredges was underestimated previously (2004 to 2010), resulting in overestimation of biomass and yield. The new model of dredge efficiency (Bian *et al.* 2012) was used in the 2012 assessment.

Fishery Interactions

A bycatch survey was conducted in the Coromandel fishery in 2009 under project SCA2007-01B. The results are summarised below. The bycatch of the fishery is likely to be similar to that of the survey.

Bycatch composition

Live components

- Scallops 26%
- Seaweed 11%
- Starfish 4%
- Other bivalves 4%
- Coralline turf 1%

Dead components

- Dead shell 45%
- Rock and gravel 8%

Bycatch data were also collected during the 2010 and 2012 surveys of SCA CS; the data were loaded to the MPI database “*scallop*” for use in future work.

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