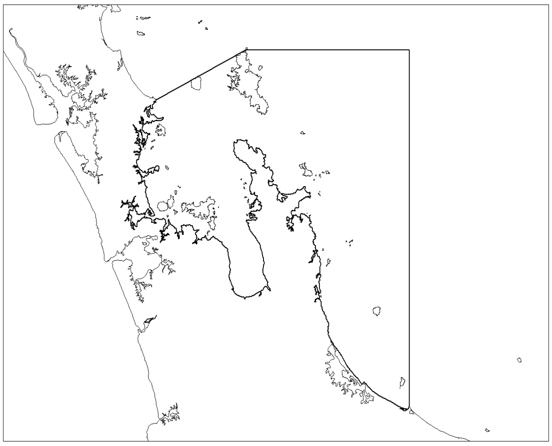
SCALLOPS COROMANDEL (SCA CS)

(*Pecten novaezelandiae*)
Kuakua, Tipa



1. FISHERY SUMMARY

1.1 Commercial fisheries

Scallops support regionally important commercial fisheries between Tauranga and Cape Rodney, the limits of the Coromandel fishery. 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). All commercial fishing is by dredge, with fishers preferring self-tipping “box” dredges to the “ring bag” designs used in 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.

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 fisheries and 7.5 t for customary fisheries, and an allowance of 11 t for other sources of mortality (values all in meatweight). 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 1, while the landings and TACC for this stock are depicted in Figure 1. 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.

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 Current Annual Yield (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. There could be a number of confounding factors that are causing actual catch to be well below the estimated CAY. Currently, MFish project SAP2009-10 (Review of difference between CAY estimates and actual catch for the SCA CS fishery) is determining what factors are most likely to be affecting the difference between estimates of CAY for the commercial Coromandel scallop fishery and the actual commercial catch, and to what degree the different factors may be contributing to the difference.

Table 1: 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 (Green[1] 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; –, no catch limits set, or no reported catch.

			Landings (t)							
	Catch limits (t)		MHR	LFRR	CELR		Scaled estimated catch (t green)			
Season	Meat	Green[1]	Meat	Meat	Meat	Green	Hauraki	Mercury	Barrier	Plenty
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	–	–	–	162	–	1 035	135	576	305	19
1987	–	–	–	384	–	1 431	676	556	136	62
1988	–	–	–	182	–	1 167	19	911	234	3
1989	–	–	–	104	–	360	24	253	95	1
1990	–	–	–	153	–	903	98	691	114	0
1991	–	–	–	203	–	1 392	*472	822	98	0
1992-93	154	1 232	–	147	–	901	67	686	68	76
1993-94	132	1 056	–	62	–	455	11	229	60	149
1994-95	66	528	–	49	–	323	17	139	48	119
1995-96	86	686	–	88	79	574	25	323	176	50
1996-97	88	704	–	81	80	594	25	359	193	18
1997-98	105	840	–	94	89	679	26	473	165	15
1998-99	110	880	–	37	37	204	1	199	2	1
1999-00	31	248	–	6	7	47	0	12	17	18
2000-01	15	123	–	8	10	70	0	24	2	44
2001-02	22	176	–	22	20	161	1	63	85	12
2002-03	35	280	32	32	31	204	0	79	12	112
2003-04	58	464	58	58	56	451	63	153	13	223
2004-05	78	624	78	78	78	624	27	333	27	237
2005-06	118	944	119	119	121	968	21	872	75	0
2006-07	118	944	118	118	117	934	28	846	60	0
2007-08	108	864	59	59	59	471	51	373	45	2
2008-09	95	760	71	71	72	541	12	15	509	5
2009-10	100	800	33	33	33	267	12	184	71	0

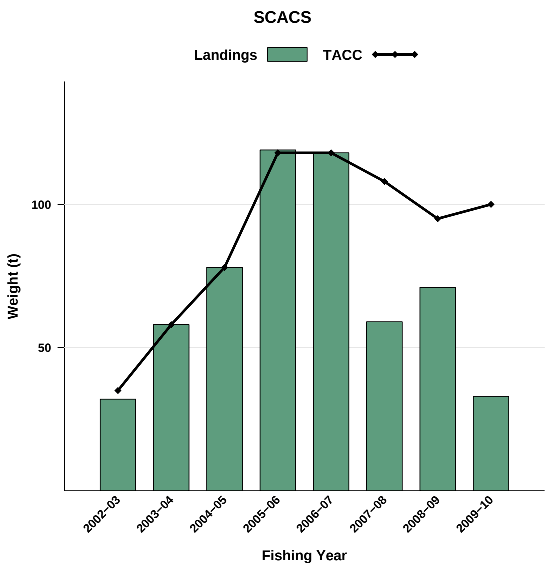


Figure 1: Landings and catch limits (I.e. TACC of 22t plus additional ACE) for SCACS (Coromandel) from 2002–03 to 2009–10. Note that this figure does not show data prior to entry into the QMS. TACC refers to catch limit, and Weight refers to Meatweight.

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, allows 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 2). 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 2: 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.

	Coromandel			
Year	No. of	CV	Weight	Reference
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 and Reilly (2002)
2000–01	472 000	0.47	55.3	Boyd *et al.* (2004)

1.3 Customary non-commercial fisheries

Scallops were undoubtedly used traditionally as food by Maori, and some limited quantitative information on recent levels of customary non-commercial take is available from MFish (Table 3).

Table 3: 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	Quantity approved, by unit type			Actual quantity harvested, by unit type		
Fishing year	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 than ring-bag or Keta-Ami dredges in the generally sandy conditions prevalent in the fishery. However, scallops encountered by box dredges showed modest reductions in growth rate compared with scallops collected by divers, and their mortality was high (up to about 50% for larger size classes). 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 and intertidal 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 4). 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 $M = 0.50\ y^{-1}$ (instantaneous rate), and maximum age in unexploited populations is thought to be about 6 or 7 years.

Table 4: 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 2001
2. Weight = a(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 are distributed throughout the Coromandel fishery area in suitable habitat, although some of the beds are persistent and others are ephemeral. 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 45 m on substrates of shell gravel, sand or, in some cases, silt. The extent to which the various beds or populations are separate reproductively or functionally is not known.

4. ENVIRONMENTAL EFFECTS OF FISHING

This section is new for the May 2010 Plenary and has been considered by the Aquatic Environment Working Group (AEWG). It includes only a summary of the incidental bycatch of marine mammals and seabirds in this fishery and does not consider other potential environmental effects. A more detailed assessment of environmental effects across all fisheries will be available in the Ministry's Aquatic Environment Plenary that is under development.

4.1 Role in the ecosystem

Not discussed by the AEWG.

4.2 Incidental catch (fish and invertebrates)

Not discussed by the AEWG.

4.3 Incidental catch (seabirds and mammals)

Scallops are taken commercially using dredges. Seabirds and mammals are not known to be caught in these fisheries.

4.4 Benthic interactions

Not discussed by the AEWG.

4.5 Other considerations

Not discussed by the AEWG.

5. STOCK ASSESSMENT

Coromandel scallops are managed using a TACC of 22t meatweight which can be augmented with additional ACE based on a Current Annual Yield (CAY) calculation using $F_{0.1}$ as a reference point. Pre-season research (dredge) surveys are used to estimate recruited biomass.

5.1 Estimates of fishery parameters and abundance

Fishing mortality has sometimes been quite high in the Coromandel fishery (Table 5).

CPUE is not presented for this fishery because it is not a reliable index of abundance (Cryer 2001b). However, recent simulation studies have shown that CPUE can be used as a basis for some management strategies (Haist 2010).

5.2 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), in support of a CAY management strategy. Assessments are based on pre-season biomass surveys conducted by diving and/or dredging (Table 5 and Table 6).

Table 5: 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. This, together with changes to survey coverage each year, makes direct comparisons among years difficult. –, no data. There was no survey in 2000.

Year	Abundance		Biomass				Catch	Exploitation rate	F_{est}
	(millions)	c.v.	(t green)	c.v.	(t meat)	c.v.	(t meat)	(catch/biomass)	≥90 mm
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

Estimates of current biomass for the Coromandel fishery are available from the 2009 dredge survey but the only reference biomass that might be calculated is average recruited biomass. Scallop biomass can be expected to vary from one year to the next, so the long-run average is difficult to estimate and not necessarily a good indicator. However, biomass 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 biomass, catch rate, and condition of scallops in 2003 and, especially, 2004, the biomass in 2005 (almost regardless of what was assumed about dredge efficiency) was the highest on record and probably higher than in the mid-1980's when not all of the beds were surveyed. This remarkable resurgence was strongest at the Mercury Islands location, but most beds showed some increase in density. There has been a gradual decline in the overall fishery biomass since about 2005–06, and the biomass in 2009 had dropped below the level of the long term average (1980 to present) for the first time since 2003. As in recent years, most of the fishable biomass was held in the Mercury Islands beds (the mainstay of the fishery), but substantial proportions were held also in beds at Little Barrier and Colville despite their relatively small areas of fishing ground. Biomass in the Bay of Plenty beds was the lowest on record.

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. The findings of current MFish-funded research to model scallop dredge efficiency using existing data should help 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.

Table 6: Estimated biomass (t greenweight, at the time of surveys) of scallops of 95 mm or more shell length in the Coromandel fishery since 1980 using historical average dredge efficiency. Bay of Plenty estimates come from beds at Waihi, Motiti, and Papamoa; 'Other' estimates from other surveyed areas of the fishery (exclusively Colville since at least 2005). Totals include data from all surveyed beds and are not directly comparable among years. –, no survey in a given year; *, not all beds surveyed, estimate of total biomass probably significantly biased low.

	Biomass of scallops 95 mm or larger (t greenweight)					
Year	Little Barrier	Waiheke Island	Mercury Islands	Bay of Plenty	Other	Total
1980	–	–	1 197	–	–	–
1981	–	–	1 092	–	–	–
1982	–	–	725	–	–	–
1983	–	–	998	–	–	–
1984	–	800	1 092	–	–	*1 892
1985	–	2 000	966	–	–	*2 966
1986	–	1 500	1 313	–	–	*2 813
1987	–	–	1 628	–	–	–
1988	–	–	–	–	–	–
1989	–	–	–	–	–	–
1990	–	608	767	–	–	*1 375
1991	–	266	824	–	–	*1 090
1992	–	73	1 272	–	–	*1 345
1993	–	41	748	735	–	*1 524
1994	–	3	481	153	–	*637
1995	258	26	445	509	39	1 277
1996	346	28	619	241	10	1 244
1997	402	508	623	269	37	1 839
1998	99	506	641	132	36	1 414
1999	19	18	176	87	25	325
2000	–	–	–	–	–	–
2001	152	19	142	70	20	403
2002	85	90	255	70	13	513
2003	146	160	428	206	347	1 287
2004	119	471	2 546	340	3	3 479
2005	282	217	5 036	518	259	6 311
2006	321	–	4 397	237	685	5 640
2007	211	51	3 449	365	254	4 329
2008	66	–	1 743	107	88	2 004
2009	270	–	911	27	174	1 382

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 have been conducted annually in June–July since 2006 at selected scallop beds in Coromandel recreational fishing areas (Williams et al. 2008, Williams 2009a, b, 2010). For the four small beds (total area of 4.64 km^2) 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 km^2) surveyed; the total projected biomass was estimated to be 50 t greenweight or 6 t meatweight (CVs of 13%) in 2009 (Williams (2010).

5.3 Estimation of Maximum Constant Yield (MCY)

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

5.4 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). The Ministry of Fisheries Shellfish Working Group recommend $F_{0.1}$ as the most appropriate reference rate (target) 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:

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

where t = 5/12 years, F_{ref} is a reference fishing mortality ($F_{0.1}$) and B_{jul} 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_{jul} 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, CAY is calculated 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 y^{-1} (reported by Cryer et al., 2004, as 5/12 * $F_{0.1}$ = 0.431). Using this value and the 2009 start of season biomass estimates (median projected values), CAY for 2009–10 was estimated to be 1489 t greenweight or 190 t meatweight.

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 y^{-1} (reported as 5/12 * $F_{0.1}$ = 0.274) was applied here. Using this value and the 2009 start of season biomass estimates (median projected values), CAY for 2009–10 was estimated to be 1016 t greenweight or 129 t meatweight.

For both scenarios, the estimates of CAY would have c.v.s at least as large as those of the estimates of start-of-season recruited biomass (21–25%), are sensitive to assumptions about dredge efficiency, growth, and expected recovery of meatweight from greenweight, and relate to the surveyed beds only. The sensitivity of these yield estimates to excluding areas of low density has not been calculated, but excluding stations with scallop density less than 0.04 m^{-2} reduced the fishery-wide time of survey biomass estimate by about 22%, and the start of season biomass estimate by about 24% (depending on which beds were fished). 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). 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.

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 (e.g., using a confidence interval). One way to do this is to decide how confident one wishes to be that a particular CAY will not cause fishing mortality to exceed $F_{0.1}$. For example, a range of one-sided confidence intervals can be formed for CAY at different levels of confidence; the lower limit of each interval is the TACC which gives the specified level of confidence that $F_{0.1}$ will not be exceeded (Table 7).

Table 7: Decision table to evaluate the confidence of not exceeding $F_{0.1}$ given a variety of alternative catch limits (TACCs). $F_{0.1}$ was estimated using two approaches: excluding and including putative habitat effects.

Potential TACC for 2009–10	Confidence that fishing mortality is less than $F_{0.1}$	
(t meatweight)	Excl. habitat effects (%)	Incl. habitat effects (%)
60	100.0	99.9
70	100.0	99.6
80	100.0	97.8
90	99.9	92.8
100	99.6	85.5
110	98.8	75.6
120	97.1	62.4
130	93.6	49.2
140	89.3	36.5
150	83.1	27.2
160	76.0	18.8
170	67.9	12.5
180	58.9	8.1
190	49.6	4.9

5.5 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.

6. STOCK STATUS

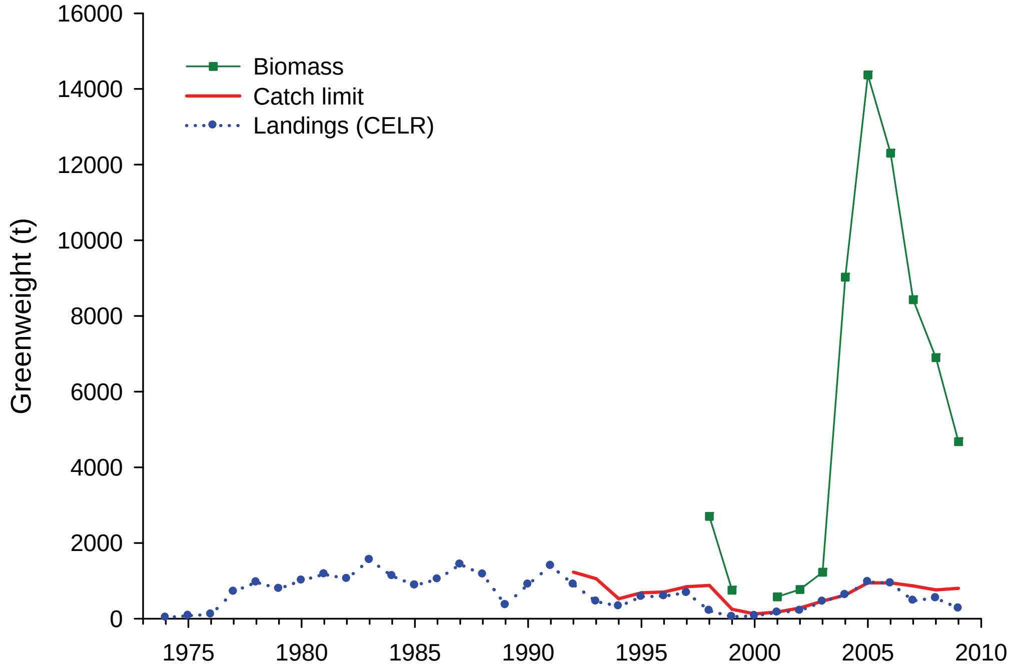
Stock Structure Assumptions

Current management assumes the Coromandel fishery is separate from the other New Zealand scallop fisheries (i.e., Northland, the various west coast harbours, Golden Bay, Tasman Bay, Marlborough Sounds, Stewart Island, and Chatham Islands). The stock structure of this fishery is assumed to be a single biological stock, although the extent to which the various beds or populations are separate reproductively or functionally is not known.

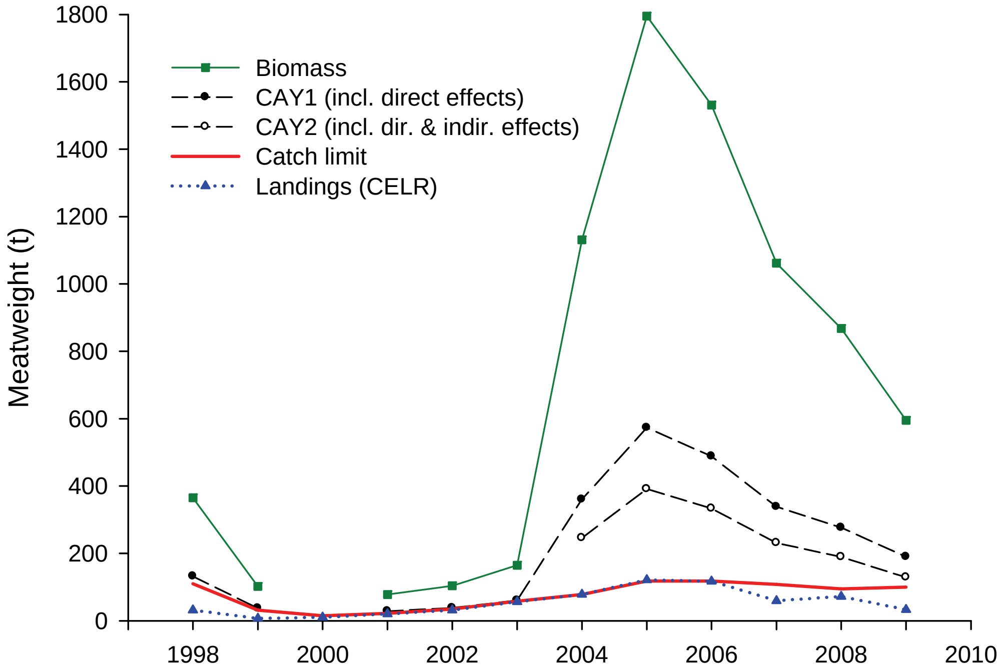
- **Coromandel scallops, SCA CS**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	Two approaches to estimating CAY
Reference Points	Target: Fishing mortality at or below $F_{0.1}$ ($F_{0.1}$ = 1.034 y^{-1} including direct incidental effects of fishing only, or $F_{0.1}$ = 0.658 y^{-1} including direct and indirect effects of fishing) Soft Limit: 20% B_0 Hard Limit: 10% B_0

Status in relation to Target	Very Likely (> 90%) below F_{target} (in 2009–10, $F_{est} = 0.154$ y^{-1}) CAY for 2009–10 was estimated at 190 t (using $F_{0.1} = 1.034$ y^{-1}) or 129 t (using $F_{0.1} = 0.658$ y^{-1}) meatweight
Status in relation to Limits	Unknown
Historical Stock Status, Trajectory and Current Status	



Recruited biomass estimates (scallops 90 mm or more shell length), catch limits, and reported landings (CELR) in t green weight for the SCA CS fishery since 1974.



Recruited biomass estimates (scallops 90 mm or more shell length), CAY estimates, catch limits, and reported landings (CELR) in t meatweight for the SCA CS fishery since 1998.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated recruited biomass (t meatweight of scallops ≥ 90 mm shell length) 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.
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 2004–09 (mean $F_{est} = 0.19$ y^{-1}), but much higher between 2001 and 2003 (mean $F_{est} = 0.96$ y^{-1}).
Other Abundance Indices	None. CPUE is not a reliable index of abundance (Cryer 2001b). However, recent simulation studies have shown that CPUE can be used as a basis for some management strategies (Haist 2010).
Trends in Other Relevant Indicator or Variables	None

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections 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	
Main data inputs	Abundance and length-frequency data from annual dredge surveys	
Period of Assessment	Latest assessment: 2009	Next assessment: 2010
Changes to Model Structure and Assumptions	None since the 2009 assessment. Current model has been in use since 1998	
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 Current Annual Yield (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. There could be a number of confounding factors that are causing actual catch to be well below the estimated CAY. Currently, MFish project SAP2009-10 (Review of difference between CAY estimates and actual catch for the SCA CS fishery) is determining what factors are most likely to be affecting the difference between estimates of CAY for the commercial Coromandel scallop fishery and the actual commercial catch, and to what degree the different factors may be contributing to the difference.

Fishery Interactions

A bycatch survey was conducted in the Coromandel fishery in 2009 under project SCA2007-01B. The results are summarised below.

Bycatch composition Live components • Scallops 26% • Seaweed 11% • Starfish 4% • Other bivalves 4% • Corraline turf 1% Dead components • Dead shell 45% Rock and gravel 8%

7. FOR FURTHER INFORMATION

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