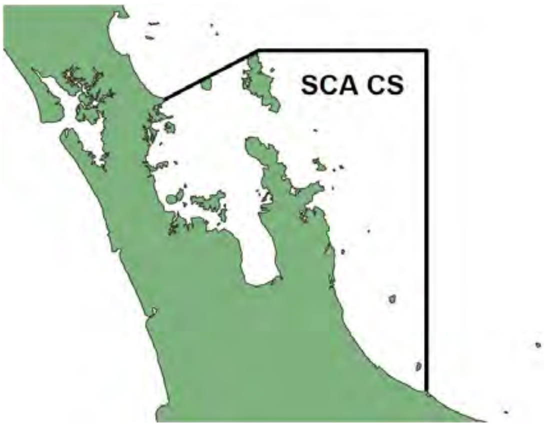
SCALLOPS COROMANDEL (SCA CS)

(*Pecten novaezelandiae*)
Kuakua, Tipa



1. FISHERY SUMMARY

Coromandel scallops (SCA CS) were introduced into the QMS on 1 April 2002 with a TAC of 48 t, comprising 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. Following a review of the TAC in 2012–13 (Ministry for Primary Industries 2013), on 1 April 2013 the TAC was changed to 131 t, comprising a TACC of 100 t, allowances of 10 t for recreational and customary fisheries, and 11 t for other sources of mortality. Following a further review (Ministry for Primary Industries 2016), on 1 April 2016 the TAC was reduced to 81 t, and the TACC was reduced to 50 t (allowances for recreational, customary and other mortality were not changed) (Table 1; values all in meatweight: adductor muscle plus attached roe).

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

Year	TAC	Customary	Recreational	Other mortality	TACC
2002–12	48	7.5	7.5	11	22
2013–15	131	10	10	11	100
2016–present	81	10	10	11	50

1.1 Commercial fisheries

SCA CS supports a regionally important commercial fishery situated between Cape Rodney at Leigh in the north and Town Point near Tauranga in the south. Fishing has been conducted within 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 from 2011 to 2013. This new, deeper (45–50 m water depth) bed was found mainly within statistical reporting area 2W and a smaller portion in 2S, and was surveyed for the first time in 2012. However, fishing of this area ceased soon after, despite catches below the catch limits informed by the survey. Results of an industry-based survey suggested biomass in the surveyed part of that area was very low in 2015.

All commercial fishing is by dredge, with fishers preferring self-tipping ‘box’ dredges (1.5–2.4 m wide, fitted with a rigid tooth bar on the leading bottom edge) 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. Until the 1994 season, the minimum legal size was 100 mm shell length. From 1995 onwards, a new minimum legal size of 90 mm shell length was applied in the commercial fishery (but not the recreational or customary fisheries) as part of a management plan comprising several new measures.

A wide variety of effort controls (e.g., dredge size, fishing hours or non-fishing days) and daily/explicit seasonal catch limits specified in meatweight (adductor muscle with roe attached) have been imposed over the years. In 2017, six vessels were operating in the commercial fishery.

The SCA CS commercial fishing industry is represented by the Coromandel Scallop Fishermen's Association (CSFA). Since 2010, in addition to CELR reporting, CSFA has implemented a voluntary management strategy, the 'CPUE limit rule' that aims to ensure that scallop beds will not be fished below a specified level of CPUE. Once a specified lower CPUE limit has been reached, fishing within that area of the fishery ceases for the remainder of the season. To inform this approach, CSFA have carried out a logbook programme that involves recording fishery data (catch and effort) at a fine spatial scale within the broader CELR statistical reporting areas. Meatweight recovery, and the proportion of legal size scallops in the catch, are also monitored and used to determine fishing patterns. In addition, the fishery is open for five days per week and daily catch limits apply, by agreement of the quota holders.

Catch and catch rates from the Coromandel fishery are variable both within and among years, a characteristic typical of most scallop fisheries worldwide. Catch rates typically decline as each season progresses, but such declines are highly variable and depletion analysis has not been successfully used to assess start-of-season biomass. Since 1980 when the fishery was considered to be fully developed, landings have varied more than 30-fold from less than 6 t to over 188 t (meatweight). The two lowest recorded landings were in 1999 and 2000.

SCA CS is 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 and Figure 1. SCA CS is 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. From 1992 up to and including the 2012 fishing year, the base TACC for SCA CS was 22 t; requests from the commercial fishers for an increase in ACE were usually supported by estimates of biomass derived from (mostly) annual surveys, and also required a consultation process with all relevant stakeholders, prior to being implemented. In 2013, the base TACC was raised from 22 t to 100 t. The purpose of the increase was to reduce management and research costs by reducing the need for the annual survey and consultation processes that were required to support requests for increases in TACC. In 2016 the TACC was reduced to 50 t.

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 (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; # a large proportion of the 2011, 2012 and 2013 landings were from a relatively deep (45–50 m) area of 2W fished for the first time in 2011; – indicates no catch limits set, or no reported catch. [Continued on next page]

	Catch limits (t)		Landings (t)			Scaled estimated catch (t green)			
			MHR	CELR					
Season	Meat	Green[1]	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

			Landings (t)						
	Catch limits (t)		MHR	CELR		Scaled estimated catch (t green)			
Season	**Meat**	**Green[1]**	**Meat**	**Meat**	**Green**	**Hauraki**	**Mercury**	**Barrier**	**Plenty**
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
2012–13	325	2600	73	73	584	#572	1	11	0
2013–14	100	800	51	68	545	#344	133	68	0
2014–15	100	800	34	35	280	27	186	64	4
2015–16	100	800	27	33	264	11	153	32	0
2016–17	50	400	27	27	216	0	94	152	0
2017–18	50	400	32	32	307	22	204	81	
2018–19	50	400	27	27	-	-	-	-	-

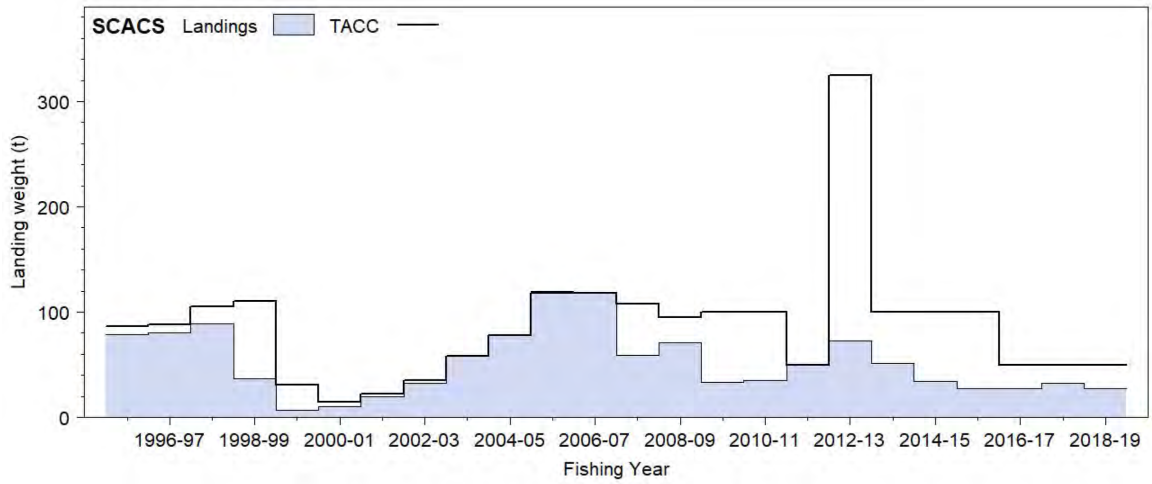


Figure 1: Landings and catch limits for SCA CS (Coromandel) from 1995–98 to 2018–19. TACC refers to catch limit, and Weight refers to meatweight.

1.2 Recreational fisheries

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. Fishers may take up to 20 scallops per day with a minimum legal size of 90 mm shell width. Estimates of the recreational scallop harvest from SCA CS are shown in Table 3. The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The panel survey was repeated in 2017–18 using directly comparable methods (Wynne-Jones et al. 2019). A creel survey 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 2014). 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 annual recreational harvest level is likely to vary substantially through time.

Table 3: Estimates of the recreational harvest of scallops from SCA CS. Number, number of scallops; green, greenweight; meat, meatweight (assuming 12.5% recovery of meatweight from greenweight). The 2007–08 estimates are for a 90-day period of the summer in a defined area (Coromandel peninsula) within SCA CS only.

Year	Area	Survey method	Number	CV	Green (t)	Meat (t)	Reference
1991–93	SCA CS	Phone-diary	654 000	0.14	60–70	8–9	Teirney et al. (1997)
1996	SCA CS	Phone-diary	614 000	0.12	62	8	Bradford (1998)
99–2000	SCA CS	Phone-diary	257 000	1.01	30	4	Boyd & Reilly (2004)
2000–01	SCA CS	Phone-diary	472 000	0.47	55	7	Boyd et al. (2004)
2007–08	Coro. peninsula	Creel survey	205 400	0.09	24	3	Holdsworth & Walshe (2014)
2011–12	SCA CS	Panel survey	605 466	0.27	67	8	Wynne-Jones et al. (2014)
2017–18	SCA CS	Panel survey	335 864	0.18	37	5	Wynne-Jones et al. (2019)

For further information on recreational fisheries refer to the introductory SCA Working Group report.

1.3 Customary fisheries

Limited quantitative information on recent levels of customary take is available from Fisheries New Zealand (Table 4).

Table 4: Fisheries New Zealand 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 2017–18. – indicates no data.

SCA CS	Quantity approved, by unit type				Actual quantity harvested, by unit type			
Fishing year	Weight (kg)	Number	Bin/Bucket/ Bag/Sack	Unspecified	Weight (kg)	Number	Bin/Bucket/ Bag/Sack	Unspecified
2005–06		600				500		
2006–07	60	290	19	6 340	0	180	2	1 579
2007–08	370	3 190	950	13 825	310	1 340	500	4 410
2008–09	370	2 390	11	13 550	82	2 090	4	4 476
2009–10	150	1 260	1	15 510	65	1 000	202	4 500
2010–11	555	2 300		18 800	190	1 400		6 485
2011–12	125	640		22 080	125	0		10 270
2012–13	125	80	3	30 200	75	80	200	11 440
2013–14				23 080				7 315
2014–15	80			12 850	35			6 948
2015–16				21 750				12 234
2016–17				19 977				11 767
2017–18	–			24 110				11 226

For further information on customary fisheries refer to the introductory SCA Working Group report.

1.4 Illegal catch

For information on illegal catch refer to the introductory SCA Working Group report.

1.5 Other sources of mortality

Research on the incidental effects of commercial scallop dredges in the Coromandel scallop fishery showed that scallops encountered by box dredges compared with scallops collected by divers had quite high mortality (about 20–30% mortality but potentially as high as 50% for scallops that are returned to the water; i.e., those just under the MLS) (Cryer & Morrison 1997). 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 (Talman et al. 2004) and modelling (Cryer et al. 2004) 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 (Cryer & Parkinson 2006).

2. BIOLOGY

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). 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 5: Estimates of biological parameters.

Stock	Estimates		Source
1. Natural mortality, *M*			
Motiti Island	0.4–0.5		Walshe 1984
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

For further information on biology refer to the introductory SCA Working Group report.

3. STOCKS AND AREAS

It is currently assumed for management that the Coromandel stock is separate from the adjacent Northland stock and from the various west coast harbours, Golden Bay, Tasman Bay, Marlborough Sounds, Stewart Island and Chatham Island areas.

Dispersal of scallops was investigated at a small spatial and temporal scale in the Coromandel fishery using genetic markers integrated with hydrodynamic modelling. Results showed small but significant spatial and temporal genetic differentiation, suggesting that the Coromandel fishery does not form a single panmictic unit with free gene flow and supporting a model of source-sink population dynamics (Silva 2015).

For further information on stocks and areas refer to the introductory SCA Working Group report.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

In the Coromandel scallop stock (SCA CS), a photographic approach was used in the 2006 dredge survey to provisionally examine non-target catch groups (Tuck et al. 2006), but a more quantitative and comprehensive study was conducted using non-target catch data collected in the 2009 dredge survey (Williams et al. 2010) with survey catches quantified by volume of different component categories. Over the whole 2009 survey, scallops formed the largest live component of the total catch volume (26%), followed by assorted seaweed (11%), starfish (4%), other live bivalves (4%), coralline turfing algae (1%) and other live components not exceeding 0.5%. Dead shell (identifiable and hash) formed the largest overall component (45%), and rock, sand and gravel formed 8%. Categories considered to be sensitive to dredging were caught relatively rarely. Data on non-target catch of the 2010 and 2012 surveys of SCA CS were also collected but not analysed; those data have been loaded to the Fisheries New Zealand database ‘scallop’ for potential future analysis (Williams & Parkinson 2010, Williams et al. 2013).

Refer to the introductory SCA Working Group report for general information on environmental and ecosystem considerations.

5. STOCK ASSESSMENT

Coromandel scallops are managed using a TACC of 50 t meatweight, which could be augmented with additional ACE after considering information about the abundance during the current fishing year. Previous in-season increases were based on the results from a pre-season biomass survey and the subsequent Current Annual Yield (CAY) estimates, using $F_{0.1}$ as a reference point.

From 1992 to 2010, biomass surveys of selected scallop beds in the fishery were conducted annually (excluding 2000 when no survey was conducted), as a means of estimating stock size and informing management decisions on potential increases in the annual TACC.

A survey was not conducted in 2011; instead, biomass estimates were 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 (Williams et al. 2013) that aimed to provide an estimate 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).

There was no survey conducted in 2013. Industry-based surveys were conducted in 2014 (D. Middleton, unpublished data) and 2015 (Williams 2015), with design and analytical assistance provided by research providers. Surveys have not been conducted since 2016.

5.1 Estimates of fishery parameters and abundance

Fishing mortality has been variable over time in the Coromandel fishery (Table 6).

Standardised CPUE from the statutory catch and effort returns is not considered a reliable index of abundance at the stock level (Cryer 2001). Simulation studies have, however, examined the use of local area CPUE as a basis for some management strategies (Haist & Middleton 2014) and this approach has subsequently informed a voluntary management approach in the commercial fishery.

5.2 Biomass estimates

From 1992 to 2012, biomass surveys were conducted almost annually (Tables 6 and 7). Average biomass in the absence of fishing, 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.

Assessments of current yields were based on pre-season biomass surveys done by diving and/or dredging (Tables 6 and 7). 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 estimates of abundance and biomass for 2012 (Williams et al. 2013) and 2015 (Williams 2015) 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.

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. 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); the 2012 values were generated using that same method so that all years are comparable. 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).

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. There was no survey in 2000, 2011, 2013, 2016, 2017 or 2018. 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. Industry-based surveys were conducted in 2014 and 2015, although estimates from the 2014 survey were unavailable for inclusion in this table. – indicates no data. [Continued on next page]

Year	Abundance		Biomass				Catch	Exploitation rate	F_{est}
	(millions)	CV	(t green)	CV	(t meat)	CV	(t meat)	(catch/biomass)	≥90 mm
1998	35.4	0.16	2 702	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	1 224	0.18	165	0.18	56	0.34	1.131

Year	Abundance		Biomass				Catch	Exploitation rate	F_{est}
	(millions)	CV	(t green)	CV	(t meat)	CV	(t meat)	(catch/biomass)	≥90 mm
2005	169.3	0.24	14 374	0.23	1 795	0.27	121	0.07	0.185
2006	143.1	0.21	12 302	0.21	1 531	0.25	117	0.08	0.212
2007	101.6	0.20	8 428	0.20	1 061	0.23	59	0.06	0.152
2008	94.0	0.29	6 900	0.28	868	0.31	72	0.08	0.232
2009	64.5	0.23	4 676	0.22	595	0.24	33	0.06	0.154
2010	58.8	0.20	4 442	0.19	540	0.21	35	0.07	0.180
2011	–	–	5 426	0.85	658	0.87	50	0.08	0.211
2012	140.0	0.15	11 423	0.15	1 380	0.18	73	0.05	0.145
2013	–	–	–	–	–	–	–	–	–
2014	–	–	–	–	–	–	–	–	–
2015	14.5	0.17	1 065	0.18	128	0.20			
2016	–	–	–	–	–	–	–	–	–
2017	–	–	–	–	–	–	–	–	–
2018	–	–	–	–	–	–	–	–	–

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).

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. It 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 13 278 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. – indicates no survey in a region or year. The 2001 survey totals include scallops surveyed in 7 km^2 strata at both Kawau (0.5 million, 3 t) and Great Barrier Island (0.8 million, 62 t).

Year	Abundance (millions)						Area surveyed
	Barrier	Waiheke	Colville	Mercury	Plenty	Total fishery	(km^2)
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
2013	–	–	–	–	–	–	–
2014	–	–	–	–	–	–	–
2015	1.9	–	0.4	9.6	–	11.8	60
2016	–	–	–	–	–	–	–
2017	–	–	–	–	–	–	–
2018	–	–	–	–	–	–	–
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
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
2013	–	–	–	–	–	–	–
2014	–	–	–	–	–	–	–
2015	136	–	27	698	–	861	60
2016	–	–	–	–	–	–	–
2017	–	–	–	–	–	–	–
2018	–	–	–	–	–	–	–

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. 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.

To better enable comparison of the results of the 2012 and 2015 surveys, data from the 2012 survey were reanalysed using the 2015 survey extent (comprising the core strata fished in SCA CS). Abundance and biomass estimates from this reanalysis are shown in Table 8. The recruited scallop population in the surveyed area of Hauraki Gulf experienced a major population decrease from 77 million in 2012 to 3 million in 2015; in the other areas surveyed in both years, recruited abundance in 2015 (12 million) was about half the size of that in 2012 (23 million).

Table 8: Estimated start-of-season abundance and biomass of scallops of 90 mm or more shell length in core areas of the Coromandel fishery in 2012 and 2015, using historical average dredge efficiency.

Year	**Location**	**Area**		**Abundance**				**Biomass**
	(grouping)	**(km^2)**	**(millions)**	**CV**	**(t green)**	**CV**	**(t meat)**	**CV**
2012	Barrier	4	6.4	0.23	466	0.20	57	0.24
	H. Gulf	205	77.1	0.23	6 505	0.23	794	0.26
	Colville	10	1.8	0.28	156	0.31	19	0.34
	Mercury	46	15.4	0.16	1 147	0.15	137	0.20
	Total	**265**	**100.4**	**0.18**	**8255**	**0.19**	**1 014**	**0.21**
2015	Barrier	4	1.9	0.36	136	0.37	16	0.39
	H. Gulf	205	2.6	0.29	191	0.29	23	0.32
	Colville	10	0.4	0.45	27	0.45	3	0.47
	Mercury	46	9.6	0.25	698	0.25	83	0.29
	Total	**265**	**14.5**	**0.17**	**1 065**	**0.18**	**128**	**0.20**

In the recreational SCA CS fishing areas, diver surveys of scallops were conducted annually in June–July from 2006 to 2010 (Williams et al. 2008, Williams 2009a, b, 2012). 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, and 48 t greenweight or 6 t meatweight (CVs of 13% and 16%) in 2010 (Williams 2012).

5.3 Estimation of Maximum Constant Yield (MCY)

MCY has not been estimated for Coromandel scallops because it is not thought to be a reasonable management approach for highly fluctuating stocks such as scallops.

5.4 Estimation of Target Harvest (Exploitation) Rate

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). However, experiments and modelling showed this method to be sub-optimal. New estimates of the reference fishing mortality rates $F_{0.1}$, $F_{40\%}$ and F_{max} were 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. This may have resulted in overestimation of potential yield, particularly when fishing tends to focus on small proportions of the biomass.

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 & Morrison (1997) and Cryer et al. (2004). $F_{0.1}$ is used as the target reference rate of fishing mortality for scallops. From 1998 to 2012, 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:

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

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 five 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 adult scallops), but also to indirect incidental effects (such as additional juvenile mortality related to reduced habitat heterogeneity in dredged areas). 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). Cryer et al. (2004) also 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, the Cryer et al. (2004) estimate of $F_{0.1}$ = 0.658 y^{-1} (reported as 5/12 * $F_{0.1}$ = 0.274) was also applied in calculations of CAY.

For both scenarios, the estimates of CAY would have CVs at least as large as those of the estimate of start-of-season recruited biomass, 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.

The last biomass survey was undertaken in 2012 and the CAY estimates calculated (t meatweight):

		$F_{0.1}$=0.431	$F_{0.1}$=0.274
B_{beg}	1 380 t	439 t	300 t

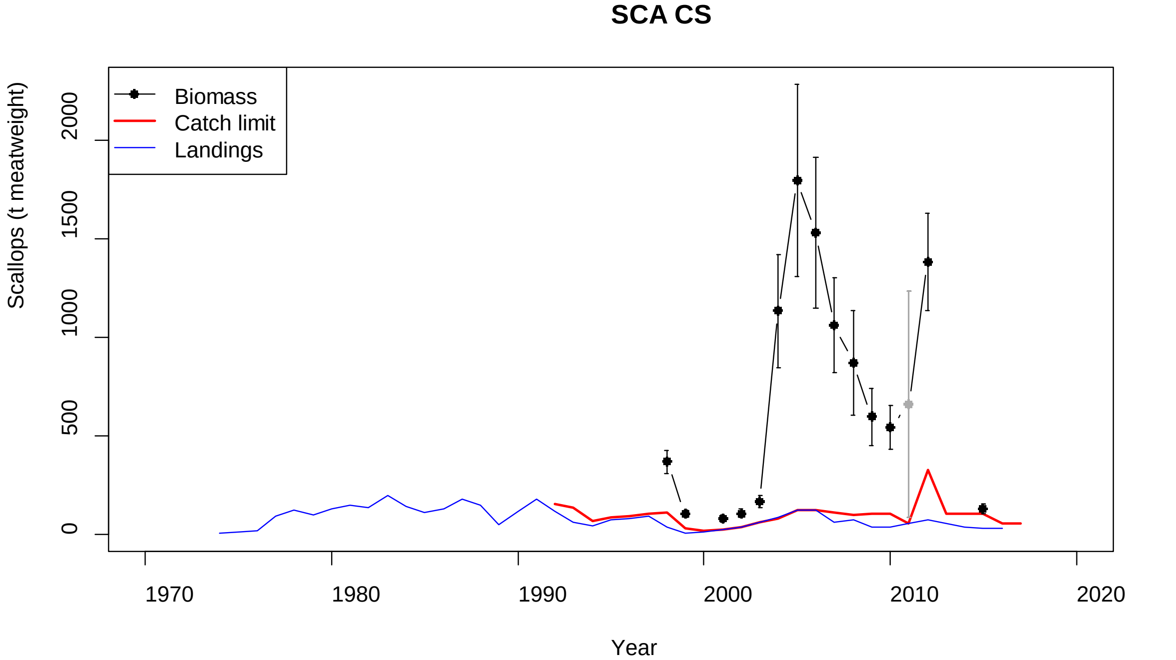
6. STOCK STATUS

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.

Stock Status	
Year of Most Recent Assessment	2012–13 fishing year
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 Overfishing threshold: F_{MSY} as approximated by $F_{0.1}$
Status in relation to Target	Likely (> 60%) to be at or below F_{target} (in 2012–13, F_{est} = 0.145 y^{-1}) in 2012–13 Unknown for 2018–19
Status in relation to Limits	Unknown
Status in relation to Overfishing	Overfishing was Unlikely (< 40%) to be occurring in 2012–13 Unknown for 2018–19

Historical Stock Status Trajectory and Current Status



Estimated biomass (mean and CV), catch limits, and landings of recruited scallops (90 mm or larger shell length) in t meatweight for SCA CS since 1974. Research surveys were not conducted in 2000, 2011 or 2013–18. In 2011, biomass was estimated by projecting forward from the 2010 survey. Industry-based surveys were conducted in 2014 and 2015, although information from the 2014 survey was not available to be included here; biomass in the core fishery areas surveyed in 2015 was an estimated 128 t.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The comprehensive 2012 survey coverage included a large new area of the fishery in Hauraki Gulf, and showed that it held a considerable biomass (794 t). It is unknown whether the large biomass of scallops found in 2012 was a consistent part of the population, or a product of successful recruitment in the years leading up to that survey. Including that ‘new’ area, estimated biomass in 2012 was an estimated 1014 t. The recruited scallop population in the surveyed area of Hauraki Gulf experienced a major population decrease from 794 t in 2012 to 23 t in 2015; in the other areas surveyed in both years, recruited biomass in 2015 (102 t) was about half the size of that in 2012 (213 t).

Recent Trend in Fishing Intensity 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 2004–12 (mean F_{est} = 0.19 y^{-1}).
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	-

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 or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Biomass surveys and CAY estimate	
Assessment Dates	Latest assessment: 2012	Next assessment: Unknown
Overall Assessment Quality Rank	1 – High Quality	
Main data inputs (rank)	Biomass survey: 2012	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	None since the 2009 assessment	
Major Sources of Uncertainty	- 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 - 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.

Environmental and Ecosystem Considerations	
Observer coverage	No observer coverage
Non-target fish and invertebrate catch	The catch composition of the scallop fishery was expected to be similar to that of the non-target catch survey conducted in the Coromandel fishery in 2009. Scallops made up 26% of the catch volume. Other taxa caught were seaweeds (11%), starfish (4%), other bivalves (4%) and coralline turf (1%).
Incidental catch of seabirds	There is no known incidental catch of seabirds from *P. novaezelandiae* scallop fisheries.
Incidental catch of mammals	There is no known incidental catch of mammals from *P. novaezelandiae* scallop fisheries.

Incidental catch of other protected species	There is no known incidental catch of protected species from *P. novaezelandiae* scallop fisheries.
Benthic interactions	There have been several studies in New Zealand to assess effects of scallop dredging on benthic habitats. Generally with increasing fishing intensity there are decreases in the density and diversity of benthic communities and, especially, the density of emergent epifauna that provide structured habitat for other fauna.

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