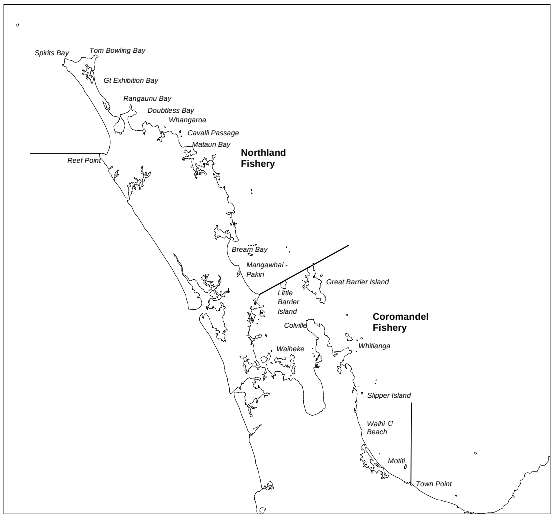
SCALLOPS NORTHLAND (SCA 1)

(*Pecten novaezelandiae*)
Kuakua, Tipa



1. FISHERY SUMMARY

Northland scallops were introduced into the QMS on 1 April 1997. The Northland TAC is 75 t, comprised of a TACC of 40 t, allowances of 7.5 t for recreational and customary fisheries, and an allowance of 20 t for other sources of mortality (Table 1; all values in meatweight).

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

Year	TAC	Customary	Recreational	Other Mortality	TACC
1996 - present	75	7.5	7.5	20	40

1.1 Commercial fisheries

Scallops support regionally important commercial fisheries off the north-east coast of the North Island between Reef Point (Ahipara) and Cape Rodney, the limits of the Northland fishery. Fishing is conducted within discrete beds in Spirits Bay, Tom Bowling Bay, Great Exhibition Bay, Rangaunu Bay, Doubtless Bay, Stevenson’s Island, the Cavalli Passage, Bream Bay, and the coast between Mangawhai and Pakiri Beach. All commercial fishing is by dredge, with fishers preferring self-tipping “box” dredges (up to 2.4 m wide, fitted with a rigid tooth bar on the leading bottom edge) to the “ring bag” designs used in Challenger and Chatham Island fisheries. The fishing year for SCA 1 is from 1 April to 31 March. The Northland commercial scallop season runs from 15 July to 14 February. The minimum legal size (MLS) is 100 mm.

Between 1980–81 and 2009–10, landings varied more than 10-fold from 80 t to over 1600 t (greenweight). There has been a gradual decline in landings since 2005–06, with very low landings of 1 and 2 t in 2010–11 and 2011–12. There was no fishing in 2012–13, as voluntarily agreed by members of the Northland Scallop Enhancement Company (NSEC), representative of the SCA 1 commercial scallop fishing industry.

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 Northland 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 Northland fishery since 1980. Data before 1986 are from Fisheries Statistics Unit (FSU) forms. Landed catch figures come from Quota Management Returns (QMRs), Monthly Harvest Returns (MHRs) forms, and from the landed section of Catch Effort and Landing Returns (CELRs), whereas estimated catch figures come from the effort section of CELRs and are pro-rated to sum to the total CELR landed greenweight. Catch limits for 1996 were specified on permits as meatweights, and, since 1997, were specified as a formal TACC in meatweight (Green1 assumes the gazetted meatweight recovery conversion factor of 12.5% and probably overestimates the actual greenweight taken in most years). In seasons starting in 1999 and 2000, voluntary catch limits were set at 40 and 30 t, respectively. *, split by area not available; –, no catch limits set, or no reported catch (Spirits).

			Landings (t)					
	Catch limits (t)		QMR/ MHR	CELR and FSU		Scaled estimated catch (t green)		
Fishing year	Meat	Green[1]	Meat	Meat	Green	Whangarei	Far North	Spirits
1980–81	–	–	–	–	238	*	*	*
1981–82	–	–	–	–	560	*	*	*
1982–83	–	–	–	–	790	*	*	*
1983–84	–	–	–	–	1 171	78	1 093	–
1984–85	–	–	–	–	541	183	358	–
1985–86	–	–	–	–	343	214	129	–
1986–87	–	–	–	–	675	583	92	–
1987–88	–	–	–	–	1 625	985	640	–
1988–89	–	–	–	–	1 121	1 071	50	–
1989–90	–	–	–	–	781	131	650	–
1990–91	–	–	–	–	519	341	178	–
1991–92	–	–	–	168	854	599	255	–
1992–93	–	–	–	166	741	447	294	–
1993–94	–	–	–	110	862	75	787	1
1994–95	–	–	–	186	1 634	429	1 064	142
1995–96	–	–	–	209	1 469	160	810	499
1996–97	188	1 504	–	152	954	55	387	512
1997–98	188	1 504	–	144	877	22	378	477
1998–99	106	848	28	29	233	0	102	130
1999–00	106	785	22	20	132	0	109	23
2000–01	60	444	15	16	128	0	88	40
2001–02	40	320	38	37	291	14	143	134
2002–03	40	320	40	42	296	42	145	109
2003–04	40	320	38	38	309	11	228	70
2004–05	40	320	40	37	319	206	77	37
2005–06	70	560	69	68	560	559	1	0
2006–07	70	560	53	50	405	404	1	0
2007–08	40	320	33	32	242	9	197	35
2008–09	40	320	25	25	197	0	171	26
2009–10	40	320	10	10	80	0	80	0
2010–11	40	320	1	1	8	0	8	0
2011–12	40	320	2	2	16	0	16	0
2012–13	40	320	0	0	0	0	0	0

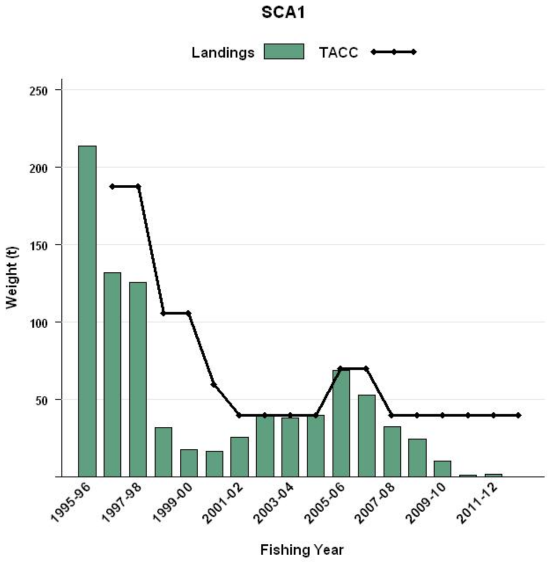


Figure 1: Landings and catch limits for SCA 1 (Northland) from 1997–98 to 2012–13. TACC refers to catch limits and 'Weight' refers to mean weight.

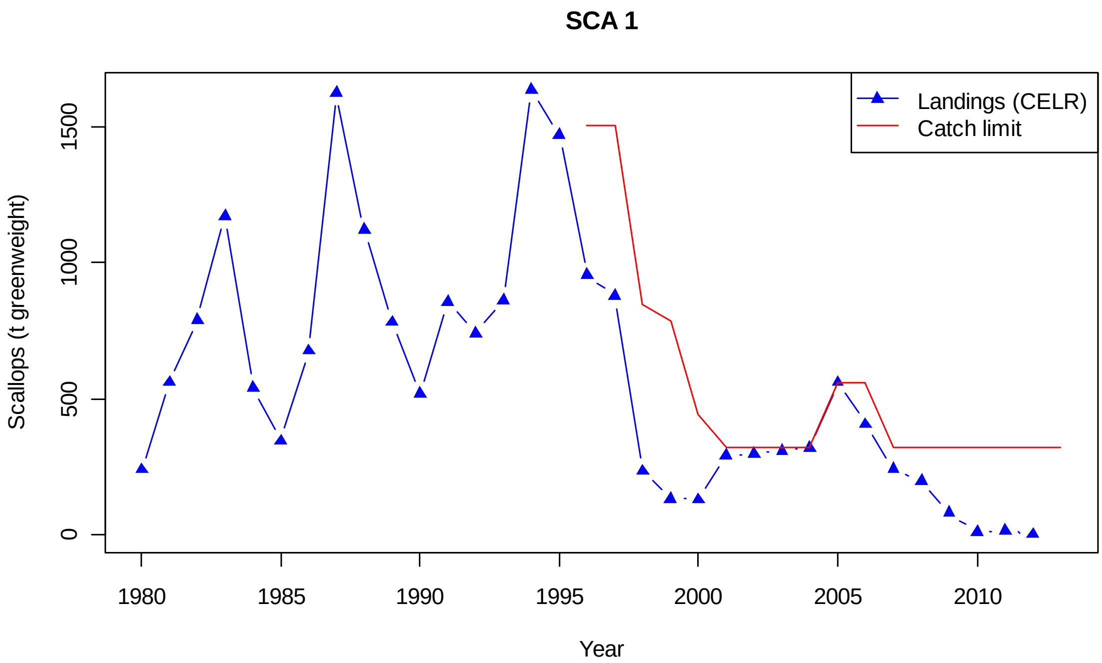


Figure 2: Catch limits and reported landings (from CELRs) in t greenweight for the SCA 1 fishery since 1980.

1.2 Recreational fisheries

There is a strong non-commercial (recreational and Maori customary) interest in scallops in suitable areas throughout the Northland 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 voluntary or regulated closures. Regulations governing the recreational harvest of scallops from SCA 1 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.

Estimates of the recreational scallop harvest from SCA CS are shown in Table 3; note the estimates provided by telephone diary surveys are no longer considered reliable for various reasons (for more information, see Ministry for Primary Industries 2013: pp 1101–1105 of the snapper section of the Fisheries Assessment Plenary 2013). Note the 2011–12 panel survey (Wynne-Jones et al in review) was still under review at the time that this report was written, but appears to provide plausible results. The annual recreational harvest level is likely to vary substantially through time.

Table 3: Estimates of the recreational harvest of scallops from SCA 1. Number, number of scallops; green, greenweight; meat, meatweight (assuming 12.5% recovery of meat weight from green weight). The estimates provided by telephone diary surveys are no longer considered reliable for various reasons. Note the 2011–12 panel survey was still under review at the time that this report was written, but appears to provide plausible results.

Year	Area	Survey method	Number	CV	Green (t)	Meat (t)	Reference
1993–94	SCA 1	Telephone diary	374 000	0.17	40–60	5–8	Bradford (1997)
1996	SCA 1	Telephone diary	272 000	0.18	32	4	Bradford (1998)
1999–00	SCA 1	Telephone diary	634 000	0.34	70	9	Boyd and Reilly (2002)
2000–01	SCA 1	Telephone diary	820 000	0.31	90	11	Boyd et al (2004)
2011–12	SCA 1	Panel survey	148 905	0.36	16	2	Wynne-Jones et al (in review)

1.3 Customary fisheries

Limited quantitative information on the level of customary take is available from the Ministry for Primary Industries (MPI) (Table 4).

Table 4: Ministry for Primary Industries records of customary harvest of scallops (reported as numbers or greenweight, or units unspecified) taken from the Northland scallop fishery, 2003–04 to 2008–09. –, no data.

SCA1	Quantity approved, by unit type			Actual quantity harvested, by unit type		
Fishing year	Weight (kg)	Number	Unspecified	Weight (kg)	Number	Unspecified
2006–07	–	1650	–	–	1650	–
2007–08	–	1780	–	–	1780	–
2008–09	120	–	300	120	–	300

1.4 Illegal catch

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

1.5 Other sources of mortality

There is no quantitative information on other sources of mortality for Northland scallops. The box dredges in use in the Northland commercial fishery have been found to be considerably more efficient than ring-bag or Keta-Ami dredges. However, scallops encountered by box dredges in the Coromandel scallop fishery showed modest reductions in growth rate, compared with scallops collected by divers, and 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 of 100 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 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.

Little detailed information is available on the growth and natural mortality of Northland scallops, although the few tag returns from Northland indicate that growth rates in Bream Bay are similar to those in the nearby Coromandel fishery (see the chapter for SCA CS). The large average size of scallops in the northern parts of the Northland fishery and the consistent lack of small animals there suggests that growth rates may be very fast in the far north.

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 purposes 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

Northland scallops are managed using a TACC of 40 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. Pre-season research (dredge) surveys are used to estimate recruited biomass. The last biomass survey conducted in SCA 1 was in 2007.

4.1 Estimates of fishery parameters and abundance

At the fishery-wide level, estimated fishing mortality on scallops 100 mm or more in the Northland fishery was in the range F_{est} = 0.33–0.78 y^{-1} (mean F_{est} = 0.572 y^{-1}) between 1997–98 and 2003–04, but was lower in the period 2005–07 (mean F_{est} = 0.203 y^{-1}) (Table 5). The level of fishing mortality in more recent years is unknown because of the lack of surveys to estimate biomass. There is no known stock-recruit relationship for Northland scallops.

CPUE is not usually presented for this fishery because it is not a reliable index of abundance (Cryer 2001b). However, recent simulation studies in the Coromandel scallop fishery have shown that CPUE could be used as a basis for some management strategies (Haist & Middleton 2010). This may or may not apply to the Northland scallop fishery.

In the absence of survey estimates of abundance in recent years, CPUE indices in 2011 were generated for SCA 1 based on the available data for the period 1991–2011 (Hartill & Williams 2012). Almost all commercial fishing during this period has taken place in three statistical reporting areas, but none of these areas has been fished continuously; in any given year, fishers tend to select the most productive area(s). A stock-wide CPUE index, produced by combining data from the different areas, suggests that the abundance of scallops throughout SCA 1 declined in the late 1990's, and then steadily increased substantially until 2005–06, after which there has been a steady decline; such an index, however, must be regarded with caution. The limitations of CPUE as an index of abundance are well understood, but are particularly severe for sedentary species like scallops. The nature of the relationship between CPUE and abundance is unclear, but is likely to be hyperstable.

Since 2012, the SCA 1 commercial scallop fishing industry (represented by NSEC, the Northland Scallop Enhancement Company Ltd.) have worked with NIWA to conduct industry surveys using standardised dredge tows in core areas of SCA 1. Preliminary analysis by NIWA suggests scallop abundance in the areas surveyed (Bream Bay and Rangaunu Bay) in 2012 and 2013 was low compared with most of the 2005–07 survey estimates.

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.

Table 5: Estimated start of season abundance and biomass of scallops of 100 mm or more shell length in the Northland fishery from 1997 to 2007 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 = 7/12 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 2005, when the analytical methodology for producing the estimates was modified. This, together with changes to survey coverage each year, make direct comparisons among years difficult. –, no data. There were no surveys in 1999, 2000, 2004, or 2008–11.

Year	Abundance		Biomass				Exploitation rate	F_{est}
	(millions)	C.V.	(t green)	C.V.	(t meat)	C.V.	(catch/biomass)	≥100 mm
1997	34.9	0.22	3520	0.22	475	0.22	0.27	0.62
1998	13.9	0.13	1547	0.13	209	0.13	0.15	0.33
1999	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–
2001	8.9	0.27	871	0.27	118	0.27	0.32	0.78
2002	13.2	0.19	1426	0.19	193	0.19	0.21	0.46
2003	9.3	0.19	1031	0.19	139	0.19	0.28	0.66
2004	–	–	–	–	–	–	–	–
2005	51.3	0.72	5565	0.70	753	0.71	0.09	0.19
2006	66.6	0.45	7280	0.43	984	0.44	0.05	0.11
2007	15.1	0.47	1637	0.45	208	0.46	0.14	0.31

There were reasonably regular assessments of Northland scallops between 1992 and 2007 (Table 5 and Table 6), in support of a CAY management strategy. Assessments are based on pre-season biomass surveys conducted by diving and/or dredging. Composite dive-dredge surveys were conducted annually from 1992 to 1997, except in 1993 when only divers were used. From 1998, surveys were conducted using dredges only. The Northland fishery was not surveyed in 1999, 2000, 2004, or 2008–12. Where dredges have been used, absolute biomass must be estimated by correcting for the efficiency of the particular dredges used. Previously, estimates were corrected for dredge efficiency using scalars (multipliers) which were estimated by directly comparing dredge counts with diver counts in experimental areas (e.g., Cryer & Parkinson 1999). However, different vessels were used in the most recent surveys and no trials were conducted on the efficiency of the particular dredges used. Estimating start-of-season biomass and yield is, therefore, difficult and contains unmeasurable as well as measurable uncertainty. For some years, the highest recorded estimate of dredge efficiency has been used, but more recent surveys have had a range of corrections applied from no correction (the most conservative) to the historical average across all studies (the least conservative). A new model of scallop dredge efficiency (Bian et al 2012) is now available, but has not yet been used to re-analyse the historical survey time series for SCA 1 (or SCA CS).

Estimates for the Northland fishery calculated using historical average dredge efficiency are shown for scallops 95 mm or more in Table 6. Estimates of current biomass for the Northland fishery are not available (the last biomass survey of the Northland fishery was in 2007), and there are no estimates of reference biomass with which to compare historical estimates of biomass. A substantial increase in biomass was observed between 2003 and 2006, which resulted in the 2006 biomass estimate being the highest recorded for Northland. In 2005 and 2006, estimates of biomass were considerably higher than those in 2003 for some beds (notably Bream Bay), but similar or lower in others. There appeared to have been a "shift" in biomass away from the Far North and towards Bream Bay and Mangawhai/Pakiri Beach. This was the "reverse" of the shift towards the Far North that occurred in the early 1990s. However, the 2007 survey results suggested that the biomass in Bream Bay and Mangawhai/Pakiri had declined markedly since 2006, and, consequently, the overall fishery biomass was far lower in 2007 than in previous years. The beds in Rangaunu Bay seem more consistent between years, although the 2007 biomass estimate was the highest on record. The biomass in Spirits/Tom Bowling Bays was higher in 2007 than 2006 but was low compared with historical levels.

Table 6: Estimated recruited biomass (t greenweight) of scallops of 95 mm or more shell length at the time of the surveys in various component beds of the Northland scallop fishery from 1992 to 2007, assuming historical average dredge efficiency. – indicates no survey in a given year; there have been no surveys of SCA 1 since 2007. Estimates of biomass given for 1993 are probably negatively biased, especially for Rangaunu Bay (*), by the restriction of diving to depths under 30 m, and all estimates before 1996 are negatively biased by the lack of surveys in Spirits Bay (†). Totals also include biomass from less important beds at Mangawhai, Pakiri, around the Cavalli Passage, in Great Exhibition Bay, and Tom Bowling Bay when these were surveyed. Commercial landings in each year for comparison can be seen in Table 1, wherein "Far North" landings come from beds described here as "Whangaroa", "Doubtless", and "Rangaunu".

						Biomass (t)
	Bream Bay	Whangaroa	Doubtless	Rangaunu	Spirits Bay	Total
1992	1 733	–	78	766	–	3 092 †
1993	569	172	77	170 *	–	1 094 *
1994	428	66	133	871	–	1 611 †
1995	363	239	103	941	–	1 984 †
1996	239	128	32	870	3 361	5 098
1997	580	117	50	1 038	1 513	3 974
1998	18	45	37	852	608	1 654
1999	–	–	–	–	–	–
2000	–	–	–	–	–	–
2001	110	8	0	721	604	1 451
2002	553	10	–	1 027	1 094	2 900
2003	86	33	3	667	836	1 554
2004	–	–	–	–	–	–
2005	2 945	–	–	719	861	4 676
2006	5 315	–	–	1 275	261	7 539
2007	795	–	–	1 391	432	2 694

Substantial 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 stock assessments. 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.

Diver surveys of scallops were conducted in June 2006 and June–July 2007 at selected scallop beds in Northland recreational fishing areas (Williams et al 2008, Williams 2009). For the four small beds (total area of 4.35 km^2) surveyed, start-of-season biomass of scallops over 100 mm shell length was estimated to be 49.7 t greenweight (CV of 23%) or 6.2 t meatweight in 2006, and 42 t greenweight (CV of 25%) or 5 t meatweight (CV of 29%) in 2007.

4.3 Yield estimates and projections

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

Yield estimates are generally calculated using reference rates of fishing mortality applied in some way 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 for Primary Industries' Shellfish Working Group recommend $F_{0.1}$ as the most appropriate reference rate (target) of fishing mortality for scallops.

Management of Northland scallops is based on a CAY approach. Since 1998, in years when biomass surveys have been conducted, 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 = 7/12 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 7 months of the fishing season, the length of the current Northland 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). Cryer & Morrison's (1997) yield-per-recruit model for the Coromandel fishery was modified to incorporate growth parameters more suited to the Northland fishery and estimate reference fishing mortality rates. Including direct incidental effects of fishing only, and for an assumed rate of natural mortality of M = 0.50, $F_{0.1}$ was estimated as $F_{0.1}$ = 0.943 y^{-1} (reported by Cryer et al 2004, as 7/12 * $F_{0.1}$ = 0.550) for SCA 1, but estimates of $F_{0.1}$ including direct and indirect incidental effects of fishing were not estimated.

Consequently, the most recent CAY estimates were derived in 2007 (the year of the last biomass survey) for one scenario only:

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 $F_{0.1}$ = 0.943 y^{-1} (reported by Cryer et al, 2004, as 7/12 * $F_{0.1}$ = 0.550). Using this value and the 2007 start of season biomass estimates (median projected values), CAY for 2007–08 was estimated to be 609 t greenweight or 77 t meatweight.

These estimates of CAY would have a CV at least as large as that of the estimate of start-of-season recruited biomass (50–51%), 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 0.02 m^{-2} and 0.04 m^{-2} reduced the fishery-wide time of survey biomass estimate by 95 and 100%, respectively. It should be noted that these low-density exclusions were calculated before correcting for average historical dredge efficiency, so these estimates are conservative. However, even if corrections for dredge efficiency were applied and no exclusions were made, the density of scallops 100 mm or more was low in all areas of the fishery surveyed in 2007. 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).

4.4 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.

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This is a new section that was reviewed by the Aquatic Environment Working Group for the November 2013 Fisheries Assessment Plenary. A broader summary of information on a range of issues related to the environmental effects of fishing and aspects of the marine environment and biodiversity of relevance to fish and fisheries is available in the Aquatic Environment & Biodiversity Annual Review (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644) (Ministry for Primary Industries 2012).

5.1 Role in the ecosystem

Scallops (*Pecten novaezelandiae*) are subtidal, benthic, epifaunal, sedentary, bivalve molluscs, which have a pelagic larval dispersal phase. They are found patchily distributed at a range of scales in particular soft sediment habitats in inshore waters of depths generally to 50 m and exceptionally up to 85 m. They exhibit relatively fast growth, high mortality, and variable recruitment. The rates of these processes probably vary in relation to environmental conditions (e.g., temperature, water flow, turbidity, salinity), ecological resources (e.g., food, oxygen, habitat), and with intra- and inter-specific interactions (e.g., competition, predation, parasitism, mutualism), and the combination of these factors determines the species distribution and abundance (Begon et al 1990). Scallops are considered to be a key component of the inshore coastal ecosystem, acting both as consumers of primary producers and as prey for many predators; the scallops themselves can also provide structural habitat for other epifauna (e.g., sponges, ascidians, algae).

5.1.1 Trophic interactions

Scallops are active suspension feeders, consuming phytoplankton and other suspended material (benthic microalgae and detritus) as their food source (Macdonald et al 2006). Their diet is the same as, or similar to, that of many other suspension-feeding taxa, including other bivalves such as oysters, clams, and mussels.

Scallops are prey to a range of invertebrate and fish predators, whose dominance varies spatially. Across all areas, reported invertebrate predators of scallops include starfish (*Astropecten polyacanthus*, *Coscinasterias calamaria*, *Luidia varia*), octopus (*Pinnoctopus cordiformis*), and hermit crabs (*Pagurus novaezelandiae*), and suspected invertebrate predators include various carnivorous gastropods (e.g., *Cominella adspersa* and *Alcithoe arabica*); reported fish predators of scallops include snapper (*Pagrus auratus*), tarakihi (*Nemadactylus macropterus*), and blue cod (*Parapercis colias*), and suspected fish predators include eagle rays (*Myliobatis tenuicaudatus*) and stingrays (*Dasyatis* sp.) (Morton & Miller 1968, Bull 1976, Morrison 1998, Nesbit 1999). Predation varies with scallop size, with small scallops being generally more susceptible to a larger range of predators.

5.2 Incidental catch (fish and invertebrates)

A range of non-target fish and invertebrate species are caught and discarded by dredge fisheries for *P. novaezelandiae* scallops. No data are available on the level or effect of this incidental catch (bycatch) and discarding by the fisheries. Bycatch data are available, however, from various dredge surveys of the scallop stocks, and the bycatch of the fisheries is likely to be similar to that of the survey tows conducted in areas that support commercial fishing.

Species or groups that have been caught as incidental catch in the box dredges and ring-bag dredges used in surveys of commercial scallop (*P. novaezelandiae*) fishery areas in New Zealand are shown in Table 7. Catch composition varies among the different fishery locations and through time.

In the Coromandel scallop stock (SCACS), a photographic approach was used in the 2006 dredge survey to provisionally examine bycatch groups (Tuck et al 2006), but a more quantitative and comprehensive study was conducted using bycatch 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%) plus 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 the bycatch of the 2010 and 2012 surveys of SCA CS were also collected but not analysed; those data have been loaded to the MPI database 'scallop' for potential future analysis (Williams & Parkinson 2010, Williams et al 2013b).

In the Northland scallop stock (SCA 1), analysis of historical survey bycatch from a localised deep area within Spirits Bay showed an unusually high abundance and species richness of sponges (Cryer et al 2000), and led to the voluntary and subsequent regulated closure of that area to commercial fishing.

In the Southern scallop stock (SCA 7), data on the bycatch of the 1994–2013 surveys have been collected but not analysed, except for preliminary estimation of the 1998–2013 bycatch trajectories (Williams et al 2013a).

Table 7: Species or groups categorised by bycatch type caught as incidental catch in dredge surveys of commercial scallop (*P. novaezelandiae*) fishery areas in New Zealand.

Type	Species or groups
habitat formers	sponges, tubeworms, coralline algae (turf, maerl), bryozoa
starfish	*Astropecten*, *Coscinasterias*, cushion stars, carpet stars
bivalves	dog cockles, horse mussels, oysters, green-lipped mussels, *Tawera*
other invertebrates	anemones, crabs, gastropods, polychaetes, octopus, rock lobster
Fish	gobie, gurnard, John dory, lemon sole, pufferfish, red cod, sand eel, snake eel, stargazer, yellowbelly flounder
seaweed	*Ecklonia,* other brown algae, green algae, red algae
Shell	whole shells, shell hash
substrate	mud, sand, gravel, rock
Other	rubbish

5.3 Incidental catch (seabirds, mammals, and protected fish)

There is no known bycatch of seabirds, mammals or protected fish species from *P. novaezelandiae* scallop fisheries.

5.4 Benthic interactions

It is well known that fishing with mobile bottom contact gears such as dredges has impacts on benthic populations, communities, and their habitats (e.g., see Kaiser et al 2006, Rice 2006). The effects are not uniform, but depend on at least: "the specific features of the seafloor habitats, including the natural disturbance regime; the species present; the type of gear used, the methods and timing of deployment of the gear, and the frequency with which a site is impacted by specific gears; and the history of human activities, especially past fishing, in the area of concern" (Department of Fisheries and Oceans 2006). The effects of scallop dredging on the benthos are relatively well-studied, and include several New Zealand studies carried out in areas of the northern fisheries (SCA 1 and SCA CS) (Thrush et al 1995, Thrush et al 1998, Cryer et al 2000, Tuck et al 2009, Tuck & Hewitt 2012) and the Golden/Tasman Bay region of the southern (SCA 7) fishery (Tuck et al 2011). The results of these studies are summarised in the Aquatic Environment & Biodiversity Annual Review (Ministry for Primary Industries 2012), and are consistent with the global literature: 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.

5.5 Other considerations

5.5.1 Spawning disruption

Scallop spawning occurs mainly during spring and summer (Bull 1976, Williams & Babcock 2004). Scallop fishing also occurs during these seasons, and is particularly targeted in areas with scallops in good condition (reproductively mature adults ready to spawn). Fishing also concentrates on high density beds of scallops, which are disproportionately more important for fertilisation success during spawning (Williams 2005). Fishing, therefore, may disrupt spawning by physically disturbing scallops that are either caught and retained (removal), caught and released, not caught but directly contacted by the dredge, or not caught but indirectly affected by the effects of dredging (e.g., suspended sediments).

5.5.2 Habitat of particular significance to fisheries management

Habitat of particular significance for fisheries management (HPSFM) does not have a policy definition (Ministry for Primary Industries 2012) although work is currently underway to define one. Certain features of the habitats which scallops are associated with are known to influence scallop productivity by affecting the recruitment, growth and mortality of scallops, and therefore may in the future be useful in terms of identifying HPSFM. Scallop larval settlement requires the presence of fine filamentous emergent epifauna on the seabed, such as tubeworms, hydroids, and filamentous algae, hence the successful use of synthetic mesh spatbags held in the water column as a method for collecting scallop spat. Survival of juveniles has been shown to vary with habitat complexity, being greater in more complex habitats (with more emergent epifauna) than in more homogeneous areas (Talman et al 2004). The availability of suspended microalgae and detritus affects growth and condition (Macdonald et al 2006). Suspended sediments can reduce rates of respiration and growth, the latter by 'diluting' the food available; scallops regulate ingestion by reducing clearance rates rather than increasing pseudofaeces production. Laboratory studies have demonstrated that suspended sediments disrupt feeding, decrease growth and increase mortality in scallops (Stevens 1987, Cranford & Gordon 1992, Nicholls et al 2003).

6. STOCK STATUS

Stock Structure Assumptions

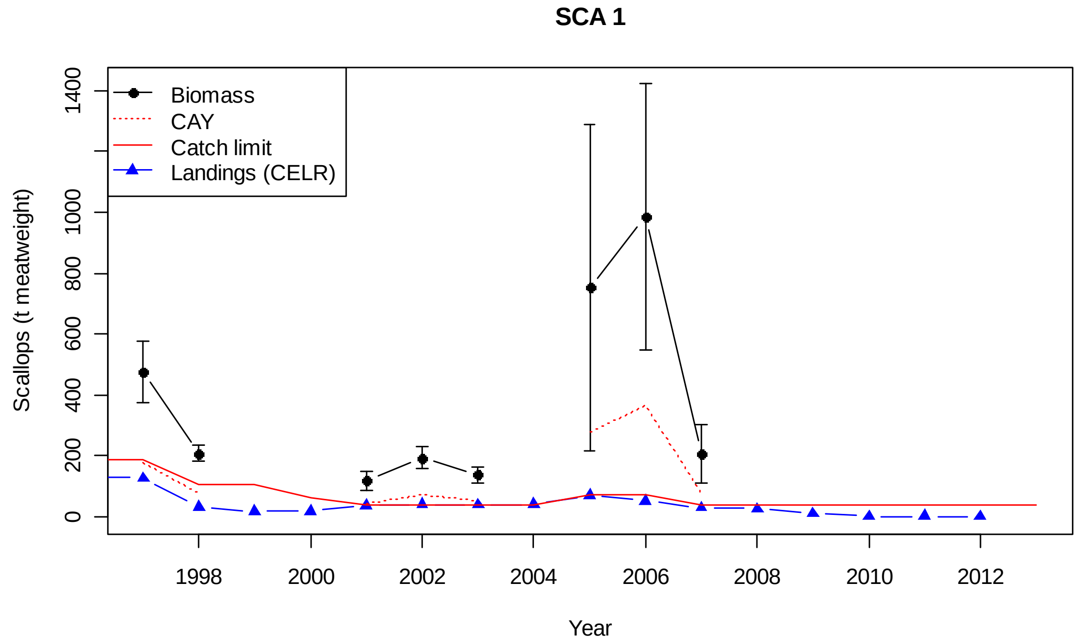
The stock structure of scallops in New Zealand waters is uncertain. For the purposes of this assessment, SCA 1 is assumed to be a single biological stock, although the extent to which the various beds or populations are separate reproductively or functionally is not known.

- **Northland scallops, SCA 1**

Stock Status	
Year of Most Recent Assessment	2007
Assessment Runs Presented	Estimate of CAY for 2007
Reference Points	Target: Fishing mortality at or below $F_{0.1}$ ($F_{0.1}$ = 0.943 y^{-1} including direct incidental effects of fishing only) Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Unlikely (< 40%) to be at or below the target (in 2007–13, F_{est} = 0.145 y^{-1}). There was very limited fishing in 2010–11 and 2011–12, and no fishing in 2012–13.

Status in relation to Limits	Unknown
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Recruited biomass (scallops 100 mm or more shell length), CAY (includes direct effects of fishing on adult scallops), catch limits, and reported landings (from CELRs) in t meatweight for the SCA 1 fishery since 1997.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The recent (2008 to 2012) trend in biomass is unknown. Industry surveys of core fisheries areas in 2012 and 2013 suggest scallop abundance in those areas was low compared with estimates from the 2005–07 surveys.
Recent Trend in Fishing Intensity or Proxy	F_{est} cannot be estimated for this fishery for recent years. Catches in 2010–11 and 2011–12 were the lowest on record. There was no fishing in 2012–13.
Other Abundance Indices	CPUE is not a reliable index of abundance (Cryer 2001b).
Trends in Other Relevant Indicator or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections are not available.
Probability of Current Catch causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current TACC causing Biomass to remain below or to decline below Limits	Very Likely (> 60%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Biomass surveys and CAY management strategy	
Assessment Dates	Latest assessment: 2007	Next assessment: Unknown
Overall Assessment Quality Rank	1 – High Quality	
Main data inputs (rank)	Biomass survey: 2007	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	Current model has been in use since 2005	
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 Northland 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. This fishery is managed with a CAY management strategy with a base TACC. However, the management strategy currently resembles a constant catch strategy because there have been no surveys since 2007.

Fishery Interactions
A bycatch survey was conducted in the Coromandel fishery in 2009 under project SCA2007-01B. The results are summarised below and may or may not be relevant to the Northland scallop fishery. 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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