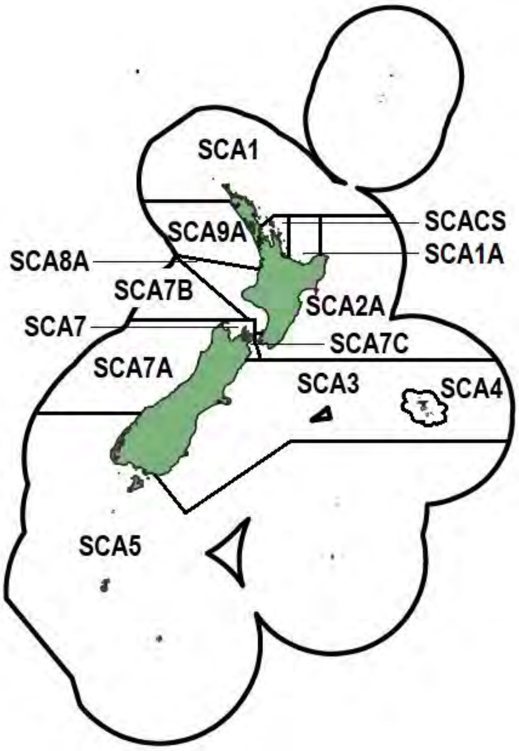
SCALLOPS (SCA)

(*Pecten novaezelandiae*)
Kuakua



1. INTRODUCTION

Scallops are important shellfish both commercially and to non-commercial (customary and recreational) fishers.

For each stock, the Total Allowable Catch (TAC), allowances for customary and recreational fisheries and other sources of mortality, and Total Allowable Commercial Catch (TACC) can be found in Table 1 (all values in meatweight – muscle plus attached roe).

Table 1: TAC, customary allowance, recreational allowance, other sources of mortality allowance and TACC (t) for all scallop stocks.

Fishstock	TAC	Customary allowance	Recreational allowance	Other mortality	TACC
SCA 1 (Northland)	75	7.5	7.5	20	40
SCA 1A (Eastern Bay of Plenty)	8	3	3	1	1
SCA CS (Coromandel)	81	10	10	11	50
SCA 2A (part Central (East))	4	1	1	1	1
SCA 3 (South-East and part Chatham Rise)	4	1	1	1	1
SCA 4 (Chatham Islands)	26	1	1	1	23
SCA 5 (Southland and Sub-Antarctic)	8	3	3	1	1
SCA 7 (Nelson/Marlborough)	520	40	40	40	400
SCA 7A (West Coast)	4	1	1	1	1
SCA 7B (North and West of Farewell Spit)	2	0	0	1	1
SCA 7C (Clarence Pt to West Head, Tory Channel)	4	1	1	1	1
SCA 8A (part Central (Egmont))	4	1	1	1	1
SCA 9A (part Auckland (West))	26	12	12	1	1

Specific Working Group reports are given separately for SCA 1, SCA CS and SCA 7.

1.1 Commercial fisheries

All scallop stocks are managed under the QMS using individual transferable quotas (ITQ). In October 1995, legislation was passed in which annual catch entitlement was determined as a fixed proportion of the Total Allowable Commercial Catch (TACC) rather than being allocated as a fixed tonnage.

The Minister can decide to increase or decrease the Total Allowable Catch (TAC) and/or the TACC that applies each fishing year, after considering certain matters. All scallop stocks, other than SCA 7, are also gazetted on the Second Schedule of the Fisheries Act 1996, which specifies that, for certain 'highly variable' stocks, the TAC and the amount of Annual Catch Entitlement (ACE) can be increased within a fishing season after considering information about abundance during that fishing year. The TACC is not changed by an "in-season increase" and the ACE reverts to the 'base' level of the TACC the following fishing year. There have not been any in-season TAC increases for scallop stocks since 2012.

In 1996, because of the rotational fishing and stock enhancement management strategy being used to manage the stocks in SCA 7, the fishery was placed on the Third Schedule of the Fisheries Act 1996, and was, therefore, able to have an alternative TAC set under s14 of the Act.

Some harbours and enclosed waters are closed to commercial dredging but remain open to recreational fishers. Some other areas are closed to both commercial and recreational fishers. Closures by area have a considerable history of use in New Zealand scallop fisheries, for both allocation issues and more general issues in scallop management.

The fishing year for scallops is from 1 April to 31 March. The commercial fishing seasons and minimum legal sizes can be found in Table 2. The period of fishing within the season may vary from year to year depending on when the industry decides to operate.

Table 2: Commercial fishing seasons and minimum legal sizes (MLS).

Fishstock	Commercial fishing season	MLS (mm)
SCA 1 (Northland)	15 July to 14 February	100
SCA CS (Coromandel)	15 July to 21 December	90
SCA 7 (Nelson/Marlborough) (until closure in 2016–17)	15 July to 14 February	90

Historical landings for the three major commercial fisheries are shown in Figure 1.

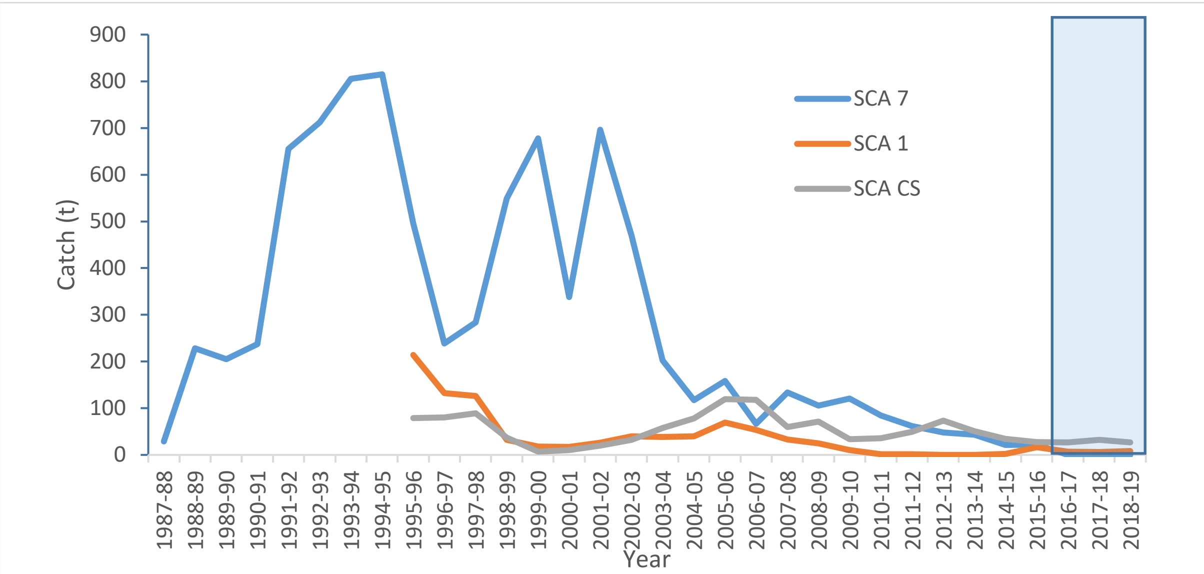


Figure 1: Historical landings for Nelson/Marlborough (SCA 7), Northland (SCA 1) and Coromandel (SCA CS) scallop fisheries. Blue box indicates the closure of the SCA 7 fishery.

All commercial fishing is by dredge. In the Northland and Coromandel fisheries, fishers use a self-tipping 'box' dredge (up to 2.4 m wide, fitted with a rigid tooth bar on the leading bottom edge). Until the fishery closed in 2016–17, vessels in the SCA 7 fishery towed one or two ring-bag dredges up to 2.4 m in width with heavy tickler chains (there are no teeth or tines on the leading bottom edge of the dredges, unlike those of the fixed tooth bars used on dredges in the northern fisheries).

1.2 Recreational fisheries

There is a strong non-commercial interest in scallops in suitable areas throughout the country, mostly in enclosed bays and harbours. Scallops are usually taken by diving using snorkel or scuba, although the use of small dredges is also common practice. In some areas, for example in some 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 beaches in large numbers.

Some harbours and enclosed waters are closed to commercial dredging but remain open to recreational fishers in the Northland and Coromandel scallop fisheries. Some other areas are closed to both commercial and recreational fishers. Closures by area have a considerable history of use in New Zealand scallop fisheries, for both scallop allocation issues and more general issues in scallop management.

The Kaipara harbour was surveyed most recently in 2017 and led to the closure of the harbour to recreational fishers following the severe decline of the stock (Williams et al. 2018). Commercial fishing for scallops in the harbour was already prohibited (Regulation 21(1)(a) Fisheries (Auckland and Kermadec Areas Commercial Fishing) Regulations 1986).

Regulations governing the recreational harvest of scallops include a minimum legal size, a restricted daily harvest (bag limit) and a recreational fishing season (Table 3). 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.

Table 3: Recreational scallop fishing regulations.

Fishstock	Minimum legal size (mm)	Daily bag limit (# of scallops per person)	Recreational fishing season
SCA 1 (Northland)	100	20	1 September to 31 March
SCA CS (Coromandel)	100	20	1 September to 31 March
SCA 5 (Stewart Island: Fiordland Paterson Inlet and Port Pegasus)	100	10	1 October to 15 March
SCA 7 (Nelson/Marlborough) (until closure in 2016–17)	90	50	15 July to 14 February

1.3 Customary fisheries

Scallops were undoubtedly used traditionally as food by Maori. Limited quantitative information on the level of customary take is available from Fisheries New Zealand. Details are provided in the respective Working Group reports.

1.4 Illegal catch

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

1.5 Other sources of fishing mortality

Dredging results in incidental mortality of scallops.

An experimental study conducted on predominantly sandy substrates in the Coromandel fishery found that a box dredge (with teeth or 'tines') caused more breakage and incidental mortality in scallops than a ring-bag dredge, although the ring-bag dredge showed poor efficiency on this substrate type in comparison with the box dredge (Cryer & Morrison 1997). Scallops retained by dredges were more likely to be killed than those that were left on the seabed, and there was increasing mortality with increasing scallop size. Total mortality was 20–30% but potentially as high as 50% for scallops that were returned to the water, i.e., those just under the MLS. 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).

The applicability of these findings to the use of the ring-bag dredge in the sand/silt substrates in the SCA 7 fishery is unknown.

The extent of other sources of fishing mortality is unknown. Dredging results in incidental mortality of scallops.

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 worldwide; most scallop populations undergo large fluctuations. *Pecten novaezelandiae rakiura* is a sub-species found around Stewart Island.

Scallops are found in a variety of coastal habitats, but particularly in semi-enclosed areas where circulating currents are thought to retain larvae.

Scallops are functional hermaphrodites and become sexually mature at a size of about 70 mm shell length (Williams & Babcock 2005). They are extremely fecund and may spawn several times each year. They breed most prolifically in early summer (although partial spawning can occur from at least August to February). Most scallops mature by the end of their first year, but they contribute little to the spawning pool until the end of their second year. Year 1 scallops contain about 500 000 eggs, whereas year 4 and 5 scallops can contain over 40 million. Like other broadcast spawning marine invertebrates, scallops need to be in close proximity during spawning to ensure that sperm concentrations are sufficiently high to fertilise the eggs released; high density beds of scallops are disproportionately more important for fertilisation success during spawning. Scallop veliger larvae spend about three weeks in the plankton. They then attach to algae or some other filamentous material with fine byssus threads. When the spat reach about 5 mm they detach and take up the free-living habit of adults, usually lying in depressions on the seabed and often covered by a layer of silt. Although adult scallops can swim, they appear to move very little (based on underwater observations, the recovery of tagged scallops, and the persistence of morphological differences between adjacent sub-populations). They may, however, be moved considerable distances by currents and storms and are sometimes thrown up in large numbers on beaches.

The very high fecundity of this species, and likely variability in the mortality of larvae and pre-recruits, could lead to high variability in natural 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 and high fishing mortality where the fishery may be supported by only one or two year classes. This variability is characteristic of most scallop populations worldwide, and often occurs independently of fishing pressure.

For more specific information on individual stocks, please refer to the relevant scallop Working Group reports.

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.

Some work has been conducted on the spatial and temporal genetic structure of the New Zealand scallop. Samples were collected from 15 locations to determine the genetic structure across the distribution range of scallops. The low genetic structure detected was expected given the recent evolutionary history, the large reproductive potential and the pelagic larval duration of the species (approximately 3 weeks). A significant isolation by distance signal and a degree of differentiation from north to south was apparent, but this structure conflicted with some evidence of panmixia. A latitudinal genetic diversity gradient was observed that might reflect colonisation and extinction events and insufficient time to reach migration-drift equilibrium during a recent range expansion (Silva 2015, Silva & Gardner 2015).

A seascape genetic approach was used to test for associations between patterns of genetic variation in scallops and environmental variables (three geospatial and six environmental variables). Although the geographic distance between populations was an important variable explaining the genetic variation among populations, it appears that levels of genetic differentiation are not a simple function of distance. Evidence suggests that some environmental factors such as freshwater discharge and suspended particulate matter can be contributing to the patterns of genetic differentiation of scallops (Silva 2015, Silva & Gardner 2016).

For more specific information on individual stocks, please refer to the relevant scallop Working Group reports.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

4.1 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 and salinity), ecological resources (e.g., food, oxygen and habitat), and with intra- and inter-specific interactions (e.g., competition, predation, parasitism and 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. Scallops themselves can also provide structural habitat for other epifauna (e.g., sponges, ascidians and algae).

A two-year project (2017–2019) has been funded to survey the environmental factors correlated with scallop survival and growth in scallop 7.

4.2 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 muricata* and *Luidia maculata*), 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.

4.3 Non-target fish and invertebrate catch

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 and discarding by the fisheries. Non-target fish and invertebrate species catch data are available, however, from various dredge surveys of the scallop stocks, and the non-target catch 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 4. Catch composition varies among the different fishery locations and through time.

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 the 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).

In the Northland scallop stock (SCA 1), analysis of historical survey non-target catch 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 non-target catch of the 1994–2013 surveys have been collected but not analysed, except for preliminary estimation of the 1998–2013 non-target catch trajectories (Williams et al. 2014).

Table 4: Species or groups categorised by non-target catch 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*, *Luidia*, *Patiriella*
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

4.4 Incidental catch (seabirds, mammals and protected fish)
There is no known capture of seabirds, mammals or protected fish species from *P. novaezelandiae* scallop fisheries.

4.5 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., 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 Bays region of the southern fishery (SCA 7) (Tuck et al. 2017). The results of these studies are summarised in the Aquatic Environment and Biodiversity Annual Review (Ministry for Primary Industries 2019), 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.

4.6 Other considerations

4.6.1 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 may therefore 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).

4.6.2 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 2019). Certain features of the habitats with which scallops are associated 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 spat bags 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).

5. STOCK ASSESSMENT

The stock assessments of scallop stocks SCA 1, SCA CS and SCA 7 are provided in the relevant Working Group reports.

6. STATUS OF THE STOCKS

The status of scallop stocks SCA 1, SCA CS and SCA 7 are given in the relevant Working Group reports.

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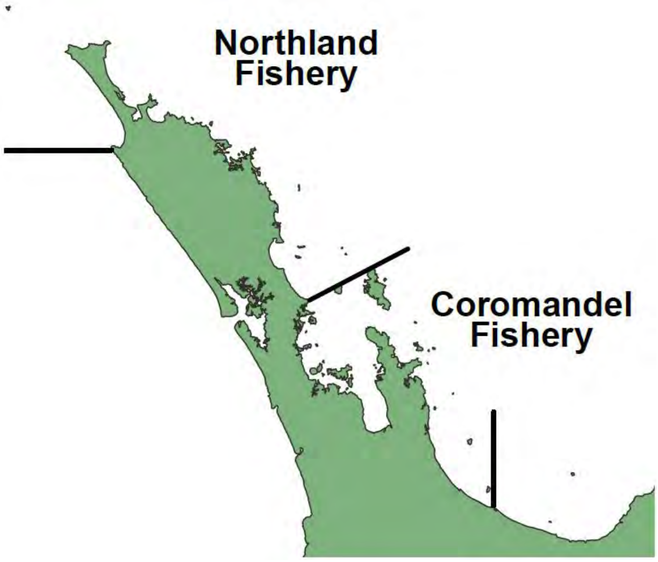
SCALLOPS NORTHLAND (SCA 1)

(*Pecten novaezelandiae*)
Kuakua, Tipa



1. FISHERY SUMMARY

Northland scallops (SCA 1) were introduced into the Quota Management System (QMS) on 1 April 1997. The Northland Total Allowable Catch (TAC) is 75 t, comprising a Total Allowable Commercial Catch (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 – muscle plus attached roe).

Table 1: TAC, customary allowance, recreational allowance, other sources of mortality allowance and TACC (t) for SCA 1.

Year	TAC	Customary	Recreational	Other mortality	TACC
1996–present	75	7.5	7.5	20	40

1.1 Commercial fisheries

SCA 1 has supported a regionally important commercial fishery situated between Reef Point at Ahipara on the west coast and Cape Rodney at Leigh on the east coast. Fishing has been 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 was a gradual decline in landings from 68 t meatweight in 2005–06 to only 1 and 2 t in 2010–11 and 2011–12, respectively. There was no fishing in 2012–13, as voluntarily agreed by members of the Northland Scallop Enhancement Company (NSEC, representing the SCA 1 commercial scallop fishing industry), and only 86 kg and 2 t of meatweight were landed in 2013–14 and 2014–15 respectively. Significant fishing has occurred again in Bream Bay since 2015, with landings of 16 t, 7 t, 6 t and 8 t meatweight over the last 4 fishing years.

SCA 1 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 Northland fishery are shown in Table 2 and Figure 1. SCA 1 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 the following fishing year. Increases occurred in 2005–06 and 2006–07 supported by estimates of biomass derived from annual surveys.

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), 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	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
2013–14	40	320	0.01	0.01	0.086	0.086	0	0
2014–15	40	320	2	2	3	3	0	0
2015–16	40	320	16	16	83	83	0	0
2016–17	40	320	7	7	36	36	0	0
2017–18	40	320	6	6	15	15	0	0
2018–19	40	320	8	8	-	-	-	-

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 100 mm shell width. Estimates of the recreational scallop harvest from SCA 1 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). The annual recreational harvest level is likely to vary substantially through time.

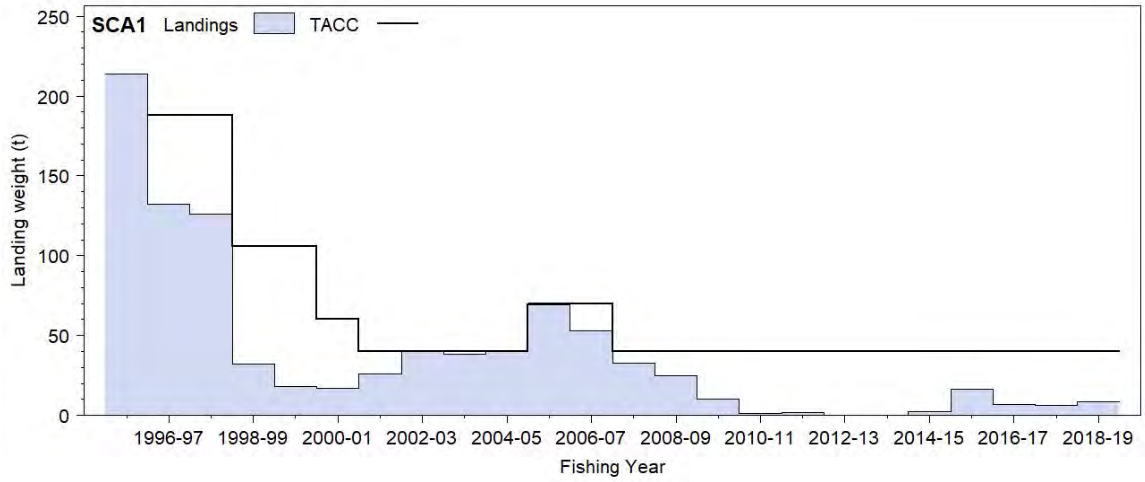


Figure 1: Landings and catch limits for SCA 1 (Northland) since 1995–96. TACC refers to the base TACC and any in-season increase in Annual Catch Entitlement and 'Weight' refers to meatweight.

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 meatweight from green weight).

Year	Area	Survey method	Number	CV	Green (t)	Meat (t)	Reference
1991–93	SCA 1	Phone-diary	391 000	0.17	40–60	5–8	Teirney et al. (1997)
1996	SCA 1	Phone-diary	272 000	0.18	32	4	Bradford (1998)
1999-2000	SCA 1	Phone-diary	322 000	0.32	33	4	Boyd & Reilly (2004)
2000–01	SCA 1	Phone-diary	283 000	0.49	29	4	Boyd et al. (2004)
2011–12	SCA 1	Panel survey	148 905	0.36	16	2	Wynne-Jones et al. (2014)
2017–18	SCA 1	Panel survey	148 905	0.36	16	2	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 the level of customary take is available from Fisheries New Zealand. The kilograms and numbers of scallops harvested under customary permits is given in Table 4, and is likely to be an underestimate of customary harvest.

Table 4: Fisheries New Zealand records of customary harvest of scallops (reported as greenweight and numbers) taken from the Northland scallop fishery, 2006–07 to 2013–14. – no data.

	Weight (kg		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested
2006–07	–	–	1 650	1 650
2007–08	–	–	1 780	1 780
2008–09	–	–	120	120
2009–10	–	–	1 200	1 200
2010–11	–	–	–	–
2011–12	130	130	600	480
2012–13	80	80	2 950	2 640
2013–14	8	8	450	450

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
For information on other sources of mortality refer to the introductory SCA Working Group report.

2. BIOLOGY

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 Working Group report 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 high in the Far North.

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

3. STOCKS AND AREAS

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

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

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

In the Northland scallop stock (SCA 1), analysis of historical survey non-target catch 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. There is no other local information on non-target fish and invertebrate catch for SCA1.

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

5. STOCK ASSESSMENT

Northland scallops are managed using a TACC of 40 t meatweight, which can 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. The last comprehensive biomass survey conducted in SCA 1 was in 2007. However, industry-based surveys of scallops in core commercial fishery areas have been conducted annually between 2012 and 2017 (Williams et al. 2017).

5.1 Estimates of fishery parameters and abundance
Over all of SCA 1, estimated fishing mortality on scallops 100 mm or more 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 scallops because it is not considered to be a reliable index of abundance (Cryer 2001). However, Management Strategy Evaluation (MSE) modelling suggested the potential for CPUE to be used as a basis for some management areas (Haist & Middleton 2010). This may or may not apply to the Northland scallop fishery.
In the absence of survey estimates of abundance from 2007 to 2011, CPUE indices were generated for SCA 1 based on the available data for the period 1991–2011 (Hartill & Williams 2014). 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 1990s, 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.) has worked with NIWA to conduct industry-based stratified random dredge surveys of scallops annually in Bream and Rangaunu Bays, two of the core areas for commercial scallop fishing in SCA 1 (Williams et al. 2017). In 2017, only Bream Bay was surveyed (J. Williams, NIWA, unpublished data). Estimates of scallop population density in the surveyed areas are shown in Figure 2.

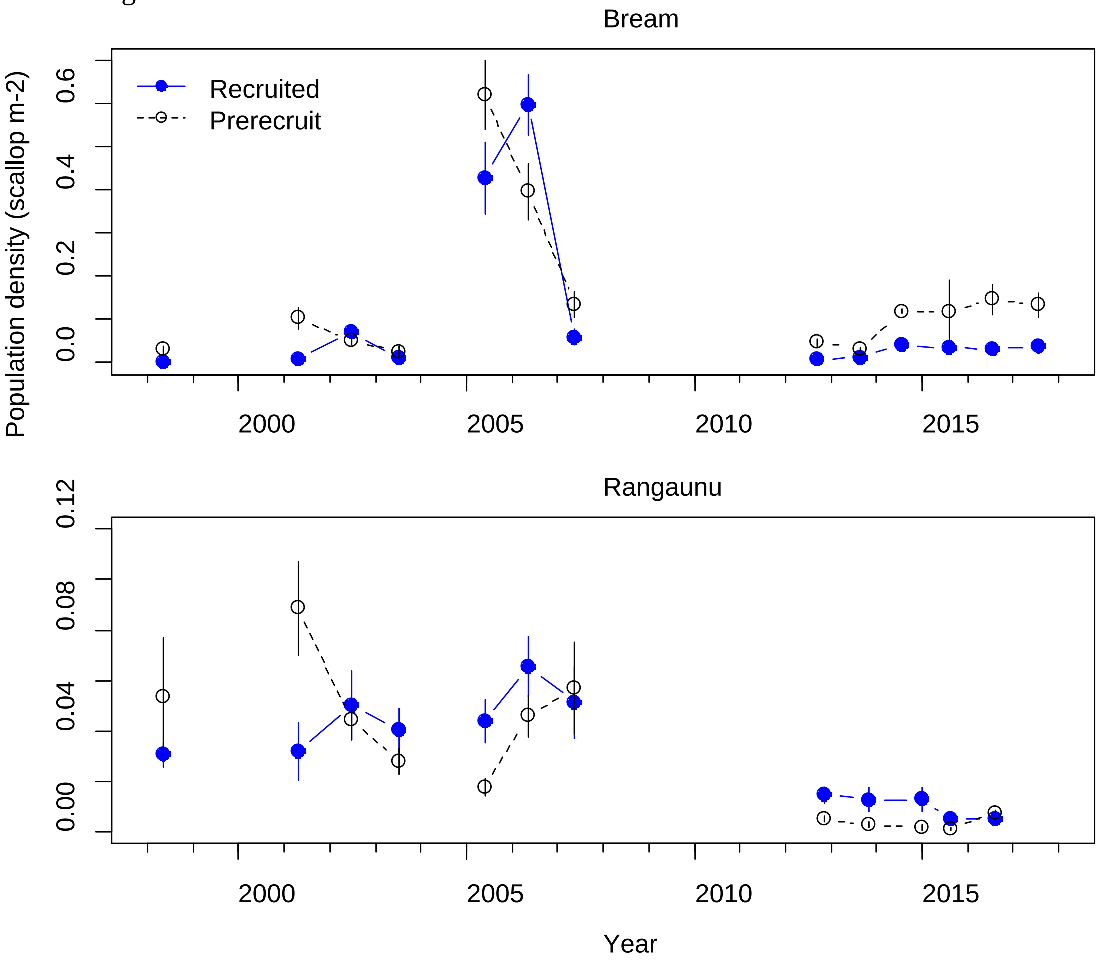


Figure 2: Scallop population density time series, 1998 to 2017. Values plotted are mean density +/- CV. Corrected for historical average dredge efficiency.

The 2012–17 surveys at Bream Bay show there has been an increasing trend in the abundance of pre-recruit sized scallops (< 100 mm) since 2013, but this has not resulted in substantive increases in recruited scallops (100 mm or larger), suggesting relatively slow growth and/or high mortality of these scallops has occurred in recent years. The relatively high commercial landings in 2015 (16 t meatweight, about 36% of the estimated total recruited biomass) in particular may explain why the recruited biomass at the time of the surveys has not increased markedly in response to increasing recruitment. Incidental mortality of undersized scallops caused by dredging may have also contributed. At Rangaunu, there has been no commercial scallop fishing since 2011. The surveys show that recruited abundance at Rangaunu was fairly stable (albeit at a low level) from 2012 to 2015, but had decreased by 2016. This may be expected given the low level of recruitment (large pre-recruits) observed in the 2012 to 2015 surveys. An increase in the abundance of large pre-recruits was evident in 2016. At Bream and especially at Rangaunu, scallop densities in the 2012–17 survey time series were low compared with peak levels previously observed in surveys from 1998 to 2007 (Williams et al. 2017).

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 were reasonably regular assessments of the Northland scallop stock between 1992 and 2007 (Tables 5 and 6), in support of a CAY management strategy. Assessments were 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 stock was not surveyed in 1999, 2000, 2004, or since 2007. 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 (Table 5) 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 model for estimating scallop dredge efficiency in SCA CS was developed by Bian et al. in 2012 but has not yet been used to reanalyse the historical survey time series for SCA 1.

Biomass estimates at the time of the survey for the Northland fishery are shown in Table 6. These estimates were calculated using historical average dredge efficiency for scallops 95 mm or more in shell length. Estimates of current biomass for the Northland stock 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 5: Estimated start of season abundance and biomass of scallops of 100 mm or more shell length in SCA 1 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 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. Estimates from the 2012–17 industry-based surveys of scallops at Bream and Rangaunu Bays are not included here.

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	3 520	0.22	475	0.22	0.27	0.62
1998	13.9	0.13	1 547	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	1 426	0.19	193	0.19	0.21	0.46
2003	9.3	0.19	1 031	0.19	139	0.19	0.28	0.66
2004	–	–	–	–	–	–	–	–
2005	51.3	0.72	5 565	0.70	753	0.71	0.09	0.19
2006	66.6	0.45	7 280	0.43	984	0.44	0.05	0.11
2007	15.1	0.47	1 637	0.45	208	0.46	0.14	0.31

Table 6: Estimated 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 2, wherein 'Far North' landings come from beds described here as 'Whangaroa', 'Doubtless', and 'Rangaunu'. The biomass of scallops 95 mm or larger shell length has not been estimated since 2007.

	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 the dredge efficiency during the surveys, rates of growth and natural mortality between the survey and the start of the fishing 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 any future research 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.

Time series of biomass estimates have also been generated for 1998–2017 from the available data collected during the industry-based surveys in 2012–16 (Williams et al. 2017) and Bream Bay in 2017 (J. Williams, NIWA, unpublished data), and the 1998–2017 surveys (Table 7).

5.3 Estimation of Maximum Constant Yield (MCY)

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

Table 7: Estimated biomass (t greenweight) of recruited scallops 100 mm or more shell length at the time of the surveys at Bream and Rangaunu Bays from 1998 to 2017, assuming historical average dredge efficiency. – indicates no survey in a given year or bay.

Year	Recruited biomass (t green)	
	Bream	Rangaunu
1998	211	475
1999	–	–
2000	–	–
2001	498	1 024
2002	259	564
2003	153	342
2004	–	–
2005	3 326	192
2006	2 514	596
2007	509	652
2008	–	–
2009	–	–
2010	–	–
2011	–	–
2012	317	36
2013	207	21
2014	394	15
2015	600	6
2016	911	61
2017	821	–

5.4 Estimation of Target Harvest (Exploitation) Rate

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

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 & Morrison (1997) and Cryer et al. (2004). The 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:

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

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 seven 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.

5.4.1 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 $F_{0.1} = 0.943\ y^{-1}$ (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).

6. STOCK STATUS

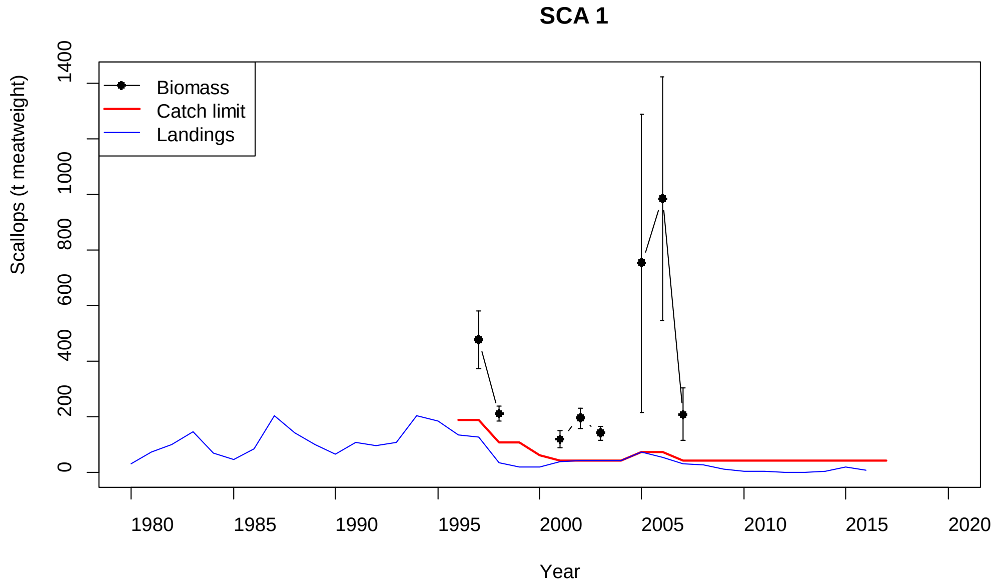
Stock structure assumptions

The stock structure of scallops in New Zealand waters is uncertain. For the purposes of the SCA 1 assessments, 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.

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} as approximated by $F_{0.1}$
Status in relation to Target	Likely (> 60%) to be at or below the target (in 2007–08, F_{est} = 0.31 y^{-1}) in 2007–08; unknown for 2018–19.
Status in relation to Limits	Unknown
Status in relation to Overfishing	Overfishing was Unlikely (< 40%) in 2007–08; unknown in 2018–19.

Historical Stock Status Trajectory and Current Status



Estimated biomass (mean and CV), catch limits, and reported landings of recruited scallops (100 mm or larger shell length) in t meatweight for SCA 1 since 1980. Biomass estimates from the annual 2012–17 industry-based surveys at Bream and Rangaunu Bays are not presented here because the surveys did not cover the full extent of the SCA 1 fishery.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The trend in stock biomass since 2007 is unknown. Industry surveys of core fishery areas, Bream Bay and Rangaunu Bay, in 2012–17 suggest biomass in those areas was low compared with estimates from the 2005–07 surveys, but biomass in Bream Bay followed an increasing trend from 2013 to 2016.
Recent Trend in Fishing Intensity or Proxy	F_{est} cannot be estimated for this fishery for recent years. Landings between 2010–11 and 2014–15 were low (between 0 and 2 t). Fishing intensity has increased in Bream Bay since 2015 (7 to 16 t).
Other Abundance Indices	CPUE is not a reliable index of abundance (Cryer 2001).
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 (> 90%) for the TACC
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Likely (> 90%) for the TACC

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 fishing 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.

Environmental and Ecosystem Considerations	
Observer coverage	No observer coverage
Non-target fish and invertebrate catch	No local information on non-target fish and invertebrate catch. A historical analysis of survey data from a deep area within Spirits Bay highlighted extreme biodiversity, and led to the closure of that area to commercial fishing (including scallop dredging).
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.

7. FOR FURTHER INFORMATION

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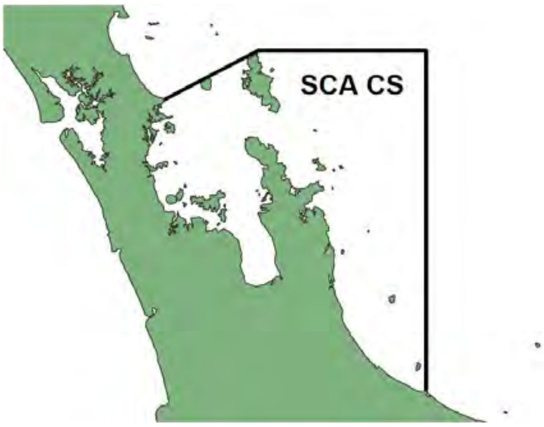
SCALLOPS COROMANDEL (SCA CS)

(*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]

			Landings (t)						
	Catch limits (t)		MHR		CELR	Scaled estimated catch (t green)			
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

	Catch limits (t)		Landings (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	-	-	-	-	-

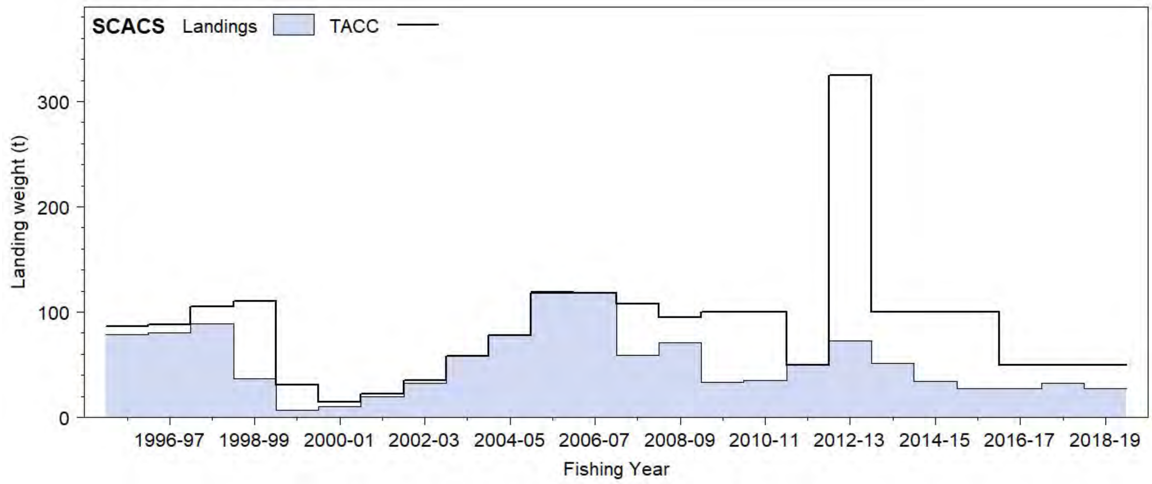


Figure 1: Landings and catch limits for SCA CS (Coromandel) from 1995–98 to 2018–19. TACC refers to catch limit, and Weight refers to meatweight.

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

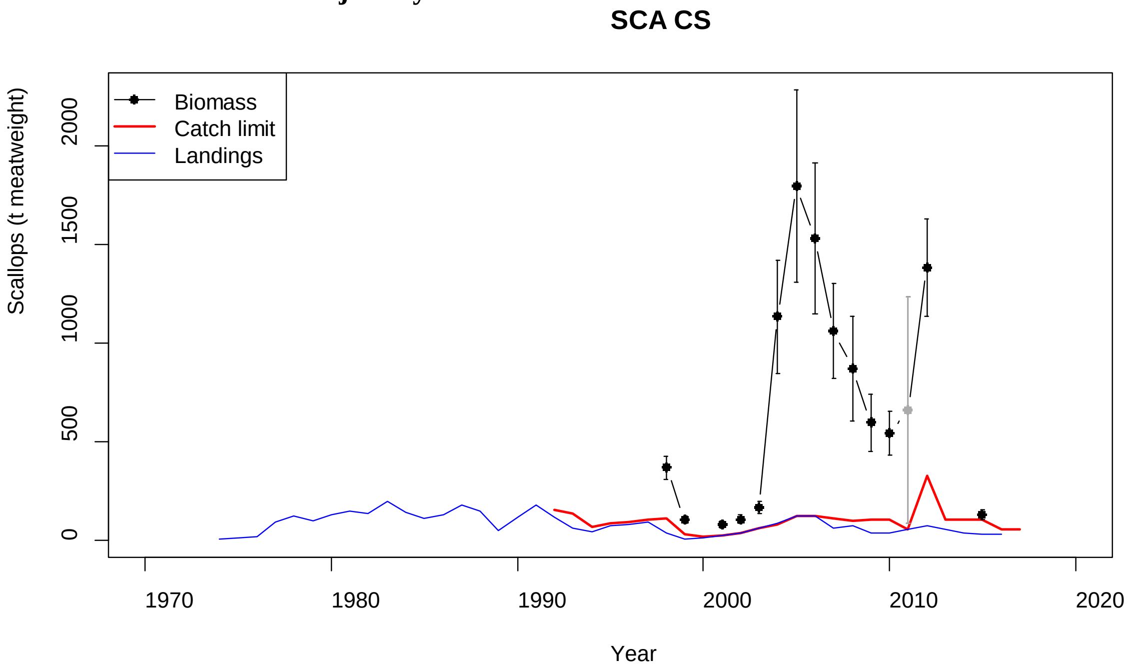
6. STOCK STATUS

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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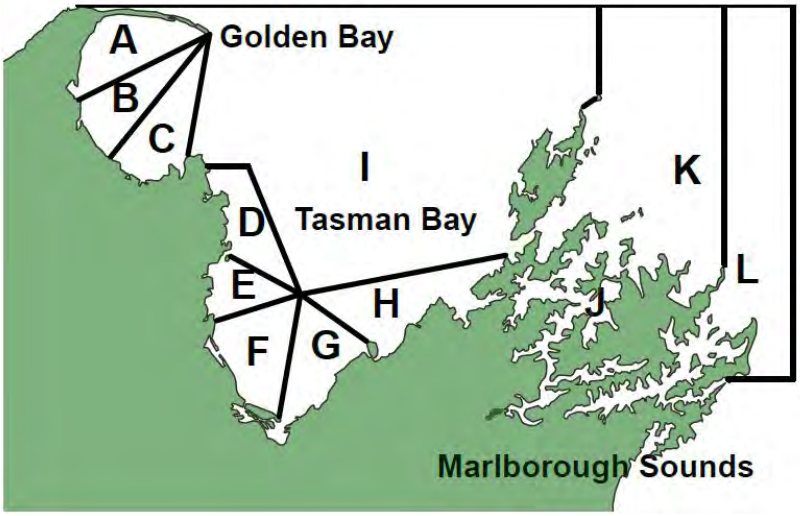
SCALLOPS Nelson/Marlborough (SCA 7)

(*Pecten novaezelandiae*)
Kuakua



1. FISHERY SUMMARY

The Nelson/Marlborough scallop fishery (SCA 7), often referred to as the 'Southern' or 'Challenger' scallop fishery, comprises 12 sectors (see A–L in the map above) spread across three regions: Golden Bay, Tasman Bay and the Marlborough Sounds. SCA 7 was introduced into a modified form of the Quota Management System (QMS) in 1992, and in 1995 an annual TACC was set at 720 t. In 2002 the TACC was increased to 747 t and a TAC set with allowances made for customary and recreational fishing. In 2014 the TACC was decreased to 400 t and an allowance of 40 t for other sources of fishing-related mortality was set within the TAC (Table 1).

Table 1: Total Allowable Commercial Catch (TACC, t) declared for SCA 7 since introduction into the QMS in 1992.

Year	TAC	Customary	Recreational	Other mortality	TACC
1995–2001	–	–	–	–	720
2002–2013	827	40	40	0	747
2014–present	520	40	40	40	400

Due to sustainability concerns, a temporary partial area closure for the taking and possession of scallops by both recreational and commercial fishers in Marlborough Sounds and part of Tasman Bay (sector 7HH) was implemented for the 2016–17 scallop season (15 July 2016 to 14 February 2017) (Ministry for Primary Industries 2016). The closure was extended for the 2017–18 scallop season to cover all areas within SCA 7 and Port Underwood (Ministry for Primary Industries 2017). The closure continued in 2018, and will remain in place until such a date that an opening regime has been developed and implemented. Fisheries New Zealand has established a multisector group (the Southern Scallop Working Group) to work on an agreed view of when the number of scallops has increased sufficiently to allow harvesting, and the rules that will be necessary to ensure that any harvest is sustainable.

1.1 Commercial fisheries

Up to 1980, the commercial fishery was managed with a combination of gear restrictions, closed areas and seasons, and a 100 mm size limit, together with limitations on the number of entrants (from 1977). Landings reached an all-time peak of 1244 t in 1975, when there were 216 licensed vessels involved in the fishery. The fishery then rapidly declined, and in 1981 and 1982 the fishery was closed. Only 48 licences were issued when it re-opened in 1983, with each vessel being allocated a defined, and equal, catch limit on an annual basis. A scallop enhancement programme was initiated in the same year. By 1989 the success of the enhancement programme enabled rotational fishing in Golden and Tasman Bays (Sectors A–I). Under the rotational fishing strategy, several sectors were opened to fishing each year, and were re-seeded following fishing down. Rotational fishing was accompanied by a reduction in the minimum legal size to 90 mm.

In 1992 when SCA 7 was introduced into the QMS an annual harvest limit of 640 t (12 t to each of the 48 licence holders, plus 64 t to Maori) was initially allocated as Individual Transferrable Quota. Provision was also made for any additional quota in excess of the 640 t to be allocated to the Crown for lease, with preference being given to existing quota holders.

Most of the management responsibilities for the fishery were transferred from government to industry in 1994 when the quota owners established the Challenger Scallop Enhancement Company Ltd. (CSEC) as the formal entity to self-govern the fishery subject to conditions agreed with the government. Key documents associated with CSEC self-governance of the fishery include a Memorandum of Understanding agreement (Ministry of Fisheries & CSEC 1998) and fisheries plans (CSEC 1998, 2005).

In October 1995, legislation was passed in which annual quotas were determined as a fixed proportion of the TACC rather than being allocated as a fixed tonnage. This provided for greater flexibility in changing the TACC. A statutory Enhancement Plan was also introduced at this time, to provide for ongoing enhancement of the fishery. The legislation was modified to enable a transition towards the enhancement programme being implemented by the CSEC rather than the Ministry of Fisheries. In 1996, because of the rotational fishing and stock enhancement management strategy being used to manage the stocks in SCA 7, the fishery was placed on the Third Schedule to the Fisheries Act 1996, and was, therefore, able to have an alternative TAC set under s14 of the Act.

A simulation modelling study of the SCA 7 scallop fishery examined the effects of catch limits, exploitation rate limits, rotational fishing and enhancement (Breen & Kendrick 1997). The results suggested that constant catch strategies are risky, but constant exploitation rate strategies are close to optimal if the maximum rate is appropriate. Rotational fishing appeared to be highly stabilising, even without enhancement. Collapses occurred only when short rotation periods were combined with high fishing intensity. Three-year rotation appeared to be safer than two-year rotation. Enhancement appeared to improve safety, catch, and biomass, and slightly reduced the population variability. The conclusions from this study underpinned the agreed rotational and enhancement management framework for the fishery. However, the theory of rotational fishing assumes that scallops, and habitats important for scallops, are distributed approximately evenly among the areas (sectors) to be fished rotationally. This is probably an invalid assumption for the SCA 7 fisheries sectors.

Over time the rotational fishing and stock enhancement management strategy changed considerably. Rotational harvesting was formally implemented in the 1989–90 fishing year. For six years from 1989–90 to 1994–95, rotational fishing was almost entirely carried out at the sector level. In the next three years from 1995–96 to 1997–98 the sector level rotation began to break down (some fishing occurred in areas that would have been closed under sector-level rotation). From 1998–99 onwards, especially in Golden Bay, sector level rotation has not occurred and parts of sectors may be fished wherever scallops are available. In addition, reseeding activity has been significantly reduced. Annual dredge surveys, which estimate biomass levels and population size structure for each sector, are conducted before each season begins. This approach enables the fishery to concentrate in areas where scallops are predominantly above the minimum legal size, and reduces disturbance in areas where most of the population is sub-legal.

CSEC submits, in consultation with MPI, a harvest plan for the Tasman/Golden Bays and the Marlborough Sounds regions of the fishery to the Minister for approval by 15 July each year. The actual commercial catch is set by CSEC within the TACC limits based on knowledge of:

- the biomass in the three regions,
- any adverse effects of fishing on the marine environment being avoided, remedied or mitigated,

- providing for an allowance for non-commercial fishing,
- a biotoxin monitoring programme being maintained, and
- the ratio of legal to non-legal sized fish that are above pre-set levels.

All commercial fishing is by dredge, with fishers using ‘ring bag’ dredges rather than the ‘box’ dredge designs used in the northern (Coromandel and Northland) fisheries. Vessels in the SCA 7 fishery tow one or two ring-bag dredges up to 2.4 m in width with heavy tickler chains (there are no teeth or tines on the leading bottom edge of the dredges in the SCA 7 fishery, unlike those of the fixed tooth bars used on dredges in the northern fisheries).

Reported landings (in meatweight; i.e., processed weight, being the adductor muscle plus attached roe) from the SCA 7 scallop fishery are shown in Figure 1 and listed in Tables 2 and 3. The fishing year applicable to this fishery is from 1 April to 31 March. Commercial fishing in recent years has usually occurred between September and November, although opening and closing dates are defined each year, and may differ between years. Historical landings and TACC changes are shown in Figure 1, Table 2 and 3.

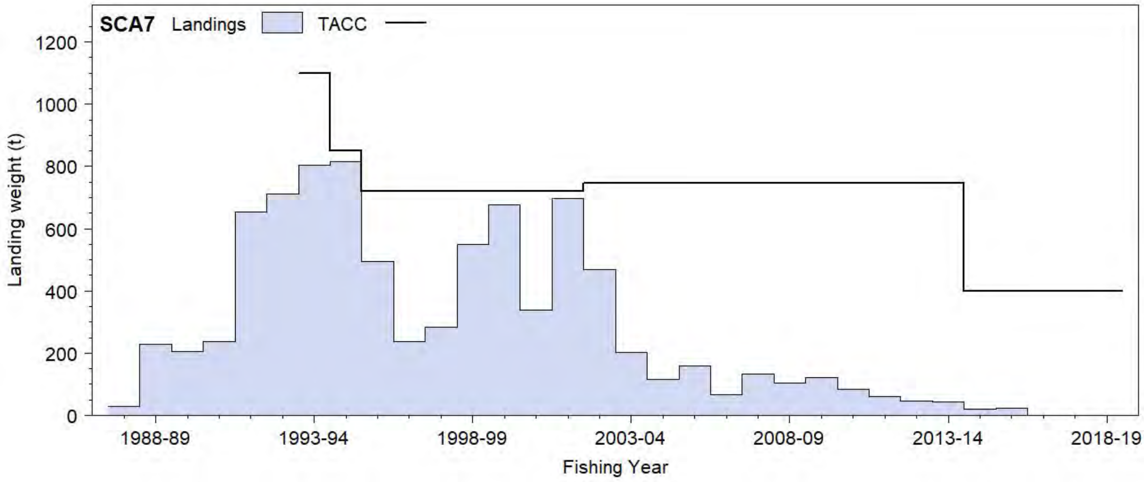


Figure 1: Historical landings and TACC (t, meatweight) for SCA 7 (Nelson/Marlborough). The fishery has been closed since 2016.

Table 2: Reported landings (t, meatweight) of scallops from SCA 7 from 1959–60 to 1982–83. The fishery was closed for the 1981–82 and 1982–83 scallop fishing years. Landings are presented by region (GB, Golden Bay; TB, Tasman Bay; MS, Marlborough Sounds) and total, except before 1977 when landings were reported by the Golden Bay and Tasman Bay combined area (Gold/Tas) (King & McKoy 1984). [Continued on next page]

Year	Gold/Tas	GB	TB	MS	Total
1959–60	1	–	–	0	1
1960–61	4	–	–	2	7
1961–62	19	–	–	0	19
1962–63	24	–	–	< 0.01	24
1963–64	105	–	–	2	107
1964–65	108	–	–	2	110
1965–66	44	–	–	< 0.5	44
1966–67	23	–	–	8	32
1967–68	16	–	–	7	23
1968–69	1	–	–	8	9
1969–70	72	–	–	6	78
1970–71	73	–	–	7	80
1971–72	206	–	–	10	215
1972–73	190	–	–	46	236
1973–74	193	–	–	127	320
1974–75	597	–	–	36	632
1975–76	1 172	–	–	73	1 244

Year	Gold/Tas	GB	TB	MS	Total
1976–77	589	–	–	79	668
1977–78	–	342	168	63	574
1978–79	–	86	4	76	166
1979–80	–	32	30	40	101
1980–81	–	0	14	27	41
1981–82	–	–	–	–	–
1982–83	–	–	–	–	–

Table 3: Catch limits and reported landings (t, meatweight) of scallops from SCA 7 since 1983–84. The fishery was closed for the 1981–82 and 1982–83 scallop fishing years, and was subsequently managed under a rotationally enhanced regime. The fishery was closed in 2016. Two catch limits are presented: TACC, Total Allowable Commercial Catch; MSCL, Marlborough Sounds catch limit (a subset of the TACC, or a subset of the Annual Allowable Catch in 1994–95). Landings data come from the following sources: FSU, Fisheries Statistics Unit; MHR, Monthly Harvest Returns (Quota Harvest Returns before October 2001); CELR, Catch Effort Landing Returns; CSEC, Challenger Scallop Enhancement Company. Landings are also presented by region (GB, Golden Bay; TB, Tasman Bay; MS, Marlborough Sounds) and best total (believed to be the most accurate record) for the SCA 7 Fishstock. – indicates no data.

	Catch limits		Landings				Landings by region and best total				
Year	TACC	MSCL	FSU	MHR	CELR	CSEC	GB	TB	MS	Best total	Source
1983–84	–	–	225	–	–	–	< 0.5	164	61	225	FSU
1984–85	–	–	367	–	–	–	45	184	138	367	FSU
1985–86	–	–	245	–	–	–	43	102	100	245	FSU
1986–87	–	–	355	–	–	–	208	30	117	355	FSU
1987–88	–	–	219	29	–	–	113	1	105	219	FSU
1988–89	–	–	222	228	–	–	127	23	72	222	FSU
1989–90	–	–	–	205	125	–	68	42	95	205	Shumway & Parsons (2004)
1990–91	–	–	–	237	228	–	154	8	66	228	CELR
1991–92	–	–	–	655	659	–	629	9	20	659	CELR
1992–93	–	–	–	712	674	–	269	247	157	674	CELR
1993–94	*1 100	–	–	805	798	–	208	461	129	798	CELR
1994–95	*850	70	–	815	825	–	415	394	16	825	CELR
1995–96	720	73	–	496	479	–	319	92	67	479	CELR
1996–97	#720	61	–	238	224	231	123	47	61	231	CSEC
1997–98	#720	58	–	284	265	299	239	2	58	299	CSEC
1998–99	#720	120	–	549	511	548	353	78	117	548	CSEC
1999–00	720	50	–	678	644	676	514	155	7	676	CSEC
2000–01	720	50	–	338	343	338	303	19	16	338	CSEC
2001–02	720	76	–	697	715	717	660	32	25	717	CSEC
2002–03	747	–	–	469	469	471	370	39	62	471	CSEC
2003–04	747	–	–	202	209	206	28	107	71	206	CSEC
2004–05	747	–	–	117	112	118	20	47	51	118	CSEC
2005–06	747	–	–	158	156	156	35	5	116	157	CSEC
2006–07	747	106	–	67	66	68	26	0	43	68	CSEC
2007–08	747	–	–	134	183	134	128	0	6	134	CSEC
2008–09	747	–	–	103	137	104	76	0	28	104	CSEC
2009–10	747	123	–	120	120	–	19	0	101	120	CELR
2010–11	747	–	–	85	85	–	10	0	74	85	CELR
2011–12	747	–	–	62	61	–	1	0	60	61	CELR
2012–13	747	53	–	48	48	–	0	0	48	48	CELR
2013–14	747	48	–	43	44	43	0.2	0	43	43	CSEC
2014–15	400	30	–	22	22	22	0	0	22	22	CSEC
2015–16	400	23	–	22	22	22	0	0.8	21	22	CSEC
2016–17	400	closure	–	0	0	–	0	0	0	0	CELR
2017–18	400	closure	–	0	0	–	0	0	0	0	CELR
2018–19	400	Closure	-	0	0	-	0	0	0	0	CELR

*Annual Allowable Catch (AAC); TACCs came into force 1 October 1995.
Initial industry controlled catch limit was 350 t in 1996–97, 310 t in 1997–98, and 450 t in 1998–99.

Scallop meatweight recovery (meatweight divided by greenweight) is variable among areas, years, and weeks within the fishing season but in general appears to be highest from scallops in parts of Golden Bay (e.g., sector A) and lowest from those in Tasman Bay (e.g., sector D). Using data on the commercial landings of recruited scallops in the period 1996–2008, the mean annual meatweight recovery was 13.8% for Golden Bay, 11.8% for Tasman Bay, and 13.2% for the Marlborough Sounds. An analysis of meatweight recovery data at the time of the survey and during the fishing season for the years 1996–2007 showed meatweight recovery measured at the time of the survey could not be used to predict meatweight recovery during the fishing season.

1.2 Recreational fisheries

CSEC consults with recreational fishers (and environmental interests) on the results of the annual biomass survey and the CSEC harvest proposals (including commercial closed areas) to seek agreement prior to submitting the Harvest Plan to the Minister. In recent years, before the fishery closure, agreement was not achieved. Estimates of annual recreational scallop harvest from SCA 7 are shown in Table 4. 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) although the fishery in SCA 7 was closed. A creel survey was conducted in 2003–04 (Cole et al. 2006). The annual recreational harvest level is likely to vary substantially through time.

Table 4: Estimates of the annual recreational harvest of scallops from SCA 7. Number, number of scallops; meat, meatweight (assuming 12.5% recovery of meatweight from greenweight). GB/TB, Golden Bay/Tasman Bay. The estimates provided by telephone diary surveys are no longer considered reliable for various reasons. The 2011–12 estimate assumes a 12.5% recovery of meat from greenweight. The fishery was closed in 2017–18.

Year	Area	Survey method	Number	CV	Meat (t)	Reference
1992–93	SCA 7	Telephone diary	1 680 000	0.15	22	Teirney et al. (1997)
1996	SCA 7	Telephone diary	1 456 000	0.21	19	Bradford (1998)
1999–00	SCA 7	Telephone diary	3 391 000	0.20	44	Boyd & Reilly (2002)
2000–01	SCA 7	Telephone diary	2 867 000	0.14	37	Boyd et al. (2004)
2003–04	GB/TB	Creel survey	860 000	0.05	9	Cole et al. (2006)
2011–12	SCA 7	Panel survey	796 164	0.23	11	Wynne-Jones et al. (2014)
2017–18	SCA 7	Panel survey	0	–		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 the level of customary take is available from Fisheries New Zealand. The kilograms and numbers of scallops harvested under customary permits is given in Table 5, and is likely to be an underestimate of customary harvest.

Table 5: Fisheries New Zealand records of customary harvest of scallops (reported as greenweight (kg) or numbers) taken from the Challenger scallop fishery for years for which harvest data is available. – indicates no data.

	Weight (kg)		Numbers	
Fishing year	**Approved**	**Harvested**	**Approved**	**Harvested**
2006–07	–	–	800	800
2007–08	600	600	17 500	15 830
2008–09	–	–	6 300	5 025
2009–10	–	–	31 150	28 560

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 fishing mortality
Dredging has incidental effects on scallops and their habitats, but there has not been any specific research on the level of incidental mortality caused by ring-bag dredging in the SCA 7 fishery.

Incidental mortality of scallops may also result from bottom trawling, although the extent of this is unknown. Observational monitoring of *P. novaezelandiae* spat released in the first three years of enhancement (1984–86) in Golden Bay suggested that spat survival was higher in areas closed to trawling (Bradford-Grieve et al. 1994).

For further information on other sources of mortality refer to the introductory SCA Working Group report.

2. BIOLOGY

All references to 'shell length' in this report refer to the maximum linear dimension of the shell, in an anterior-posterior axis. Scallops in the outer Pelorus Sound grow to a shell length of about 60 mm in one year, and can reach 100 mm in about two to three years (Table 6). This was typical of the pattern of growth that occurred under the initial rotational fishing strategy in Tasman and Golden Bays as well. Growth slows during the winter, and was found to vary between years (it is probably influenced by water temperature, food availability and scallop density). Growth rings form on the shell during winter, but also at other times, precluding the use of ring counts as accurate indicators of age. Experience with enhanced stocks in Tasman and Golden Bays has indicated that scallops generally attain a shell length of 90 mm in just under two years although, in conditions where food is limiting, almost three years may be required to reach this size.

From studies of the ratio of live to dead scallops and the breakdown of the shell hinge in dead scallops, Bull (1976) estimated the annual natural mortality rate for two populations of adult scallops in the Marlborough Sounds (Forsyth Bay and North West Bay in Pelorus Sound) to be 23% (M = 0.26) and 39% (M = 0.49). From a tagging study conducted in Golden and Tasman Bays from 1991 to 1992, Bull & Drummond (1994) estimated the mortality of 0+ and 1+ scallops to be about 38% (M = 0.21) per year, and the mortality of 2+ scallops to be 66% (M = 0.46). These studies suggest that average natural mortality in the SCA 7 fishery is quite high (Table 6), and most previous stock assessments have assumed $M = 0.5\ y^{-1}$ (instantaneous rate). Incidences of large-scale die-off in localised areas have been observed (e.g., mortality associated with storms in 1998).

Table 6: Estimates of biological parameters.

		Estimates	**Source**
1. Natural mortality, M		*M*	
Pelorus Sound		0.26, 0.49	Bull (1976)
Golden & Tasman Bays		0+ & 1+, 0.21	Bull & Drummond (1994)
Golden & Tasman Bays		2+, 0.46	Bull & Drummond (1994)
2. Growth			
Age-length relationship	Age (y)	SL (mm)	
Pelorus Sound	1	60	Bull (1976)
Pelorus Sound	2	97	Bull (1976)
Pelorus Sound	3	105	Bull (1976)
Pelorus Sound	4	111	Bull (1976)
von Bertalanffy parameters	L_∞	K	
	144	0.40	Data of Bull (1976), analysed by Breen (1995)

3. STOCKS AND AREAS

Whether or not scallops in Tasman Bay and Golden Bay constituted a single genetic stock before enhancement began is unknown. Enhancement in the Marlborough Sounds has been limited, but could have contributed towards homogenising stocks. Water movements eastward through Cook Strait could have enabled a degree of genetic mixing between Tasman/Golden Bays and Marlborough Sounds before any enhancement began. It is currently assumed for management that the SCA 7 stock is made up of three individual sub-stocks (Golden Bay, Tasman Bay and Marlborough Sounds) that are separate from the Northland and Coromandel stocks and from the various west coast harbours, Stewart Island and Chatham Island areas.

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

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

In the Southern scallop stock (SCA 7), data on the non-target catch of the 1994–2013 surveys have been collected but not analysed, except for preliminary estimation of the 1998–2013 non-target catch trajectories (Williams et al. 2014).

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

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance

The status of the SCA 7 stock is assessed using data collected from fishery-independent dredge surveys. The survey data are analysed to estimate the spatial distribution, size structure, abundance, and biomass of the population of scallops within the area covered by the survey. Dredges are not 100% efficient at catching all scallops within the area of seabed swept by the dredge, making it necessary to apply dredge efficiency corrections to the raw survey data to obtain estimates of absolute abundance and biomass. Information on dredge efficiency, the proportion of the scallops in the path of the gear that are caught, has been generated from a dedicated study using paired sampling by divers and dredges (Tuck et al. 2018). Efficiency-corrected dredge survey estimates form the basis of SCA 7 science advice to fisheries management.

Surveys of scallops in the main commercial scallop beds in SCA7 have been conducted almost annually since 1994, using stratified random sampling by dredging. The surveys are usually conducted in May but the surveys in 2017 and 2018 were conducted in January in time to inform fisheries management decisions required for the 1 April sustainability round. Two-phase sampling was used in surveys until 2008, and single-phase sampling was used in the 2009–19 surveys. In 2013, 2018 and 2019, only the Marlborough Sounds sub-stock was surveyed; Golden Bay and Tasman Bay were not surveyed because of the expected low abundance of scallops in those bays. In 2015 three surveys were conducted: a pre-fishing season survey in May (Williams et al. 2015a), an in-fishing season survey of key scallop beds in October (Williams et al. 2015b) and a post-fishing season survey in November (Williams et al. 2015c). The purpose of the November 2015 survey was to survey the accessible areas of the entire SCA 7 stock and not just survey those areas utilised by the commercial fishery, as is usually the case with the pre-fishing season surveys. There was no survey in 2016.

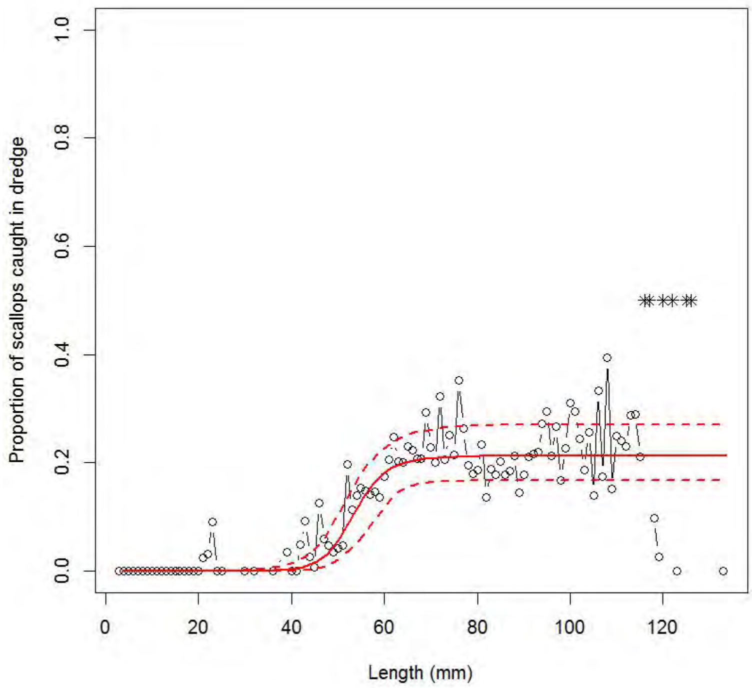


Figure 2: **SCA 7 ring-bag dredge efficiency (from Tuck et al. 2018). The plotted curve is a logistic capped selectivity ogive (L50 = 53.3mm, a95=7.3mm, amax=0.21) fitted to the proportion of scallops retained in the dredge. Solid line represents the fit to all data in the 2018 study, dashed lines represent 95% CI of selectivity at each length.**

Surveys were conducted in January in 2017 (Williams et al. 2017) and 2018 (Williams et al. 2018), to evaluate the status of the SCA 7 scallop stock (Marlborough Sounds sub-stock only in 2018) in time to inform fisheries management decisions for the 1 April sustainability round. In the January 2017 survey (Williams et al. 2017; the most recent survey to employ 'full' coverage of Golden Bay, Tasman Bay, and Marlborough Sounds), the highest catches of recruited scallops (90 mm or larger) were from tows within key strata (primarily in Marlborough Sounds, but also in Croisilles Harbour in Tasman Bay), which represent the banks and bays that support the main scallop beds; catches were very low in other strata (Figure 3). The January 2018 (Williams et al. 2018) and May 2019 (Williams et al. 2019) surveys of scallop in Marlborough Sounds found a similar pattern: most of the recruited scallop population was held in a limited number of scallop beds, mostly in the outer Sounds.

With the exception of the in-season and post-season surveys in 2015, surveys since 1998 are broadly comparable, in that they used the same fishing gear and covered similar areas. Earlier surveys covered smaller areas, although these may have included the main areas of recruited scallop densities.

Surveys up to 1995 used the 'MAF' dredge, while from 1997 the 'CSEC' dredge was used. In 1996, both dredges were used, with data from the CSEC dredge being used for the biomass analysis. Analysis of the survey data involves applying estimates of dredge efficiency to produce absolute population estimates at the time of the surveys (May–June) and at the nominal start of the fishing season (September). The analysis uses a resampling with replacement analytical procedure to better account for uncertainty in the estimates (Williams et al. 2019). The time series of scallop population estimates published in earlier versions of the Plenary report were produced by applying historical estimates of dredge efficiency derived from previous studies of dredge efficiency by Cranfield et al. (1996) and Handley et al. (2004). New research on dredge efficiency conducted in 2018 in Marlborough Sounds estimated that the average efficiency of the survey dredge was 0.21 (95% CI from 0.17 to 0.27) (Tuck et al. 2018), which is substantially lower than estimated previously (mean historical efficiency of 0.56). Williams et al. (2019) re-analysed the 1997–2019 time series of surveys by applying the new dredge efficiency parameters derived by Tuck et al. (2018) and conducting growth projections using an inverse logistic model (Tuck & Williams 2012).

From the revised SCA 7 survey series analysis conducted by Williams et al. (2019), abundance indices were generated for pre-recruits (undersize scallops 53–89 mm in length) and recruited scallops (90 mm or larger) (Figure 4). Strong patterns of recruitment are evident, illustrated by peaks in recruited numbers lagging one year after peaks in undersize scallop numbers. At the overall sub-stock scale (Golden Bay, Tasman Bay, Marlborough Sounds), recruitment (as measured by the abundance of pre-recruits) has been low (or following a declining trend in some areas) since at least 2010.

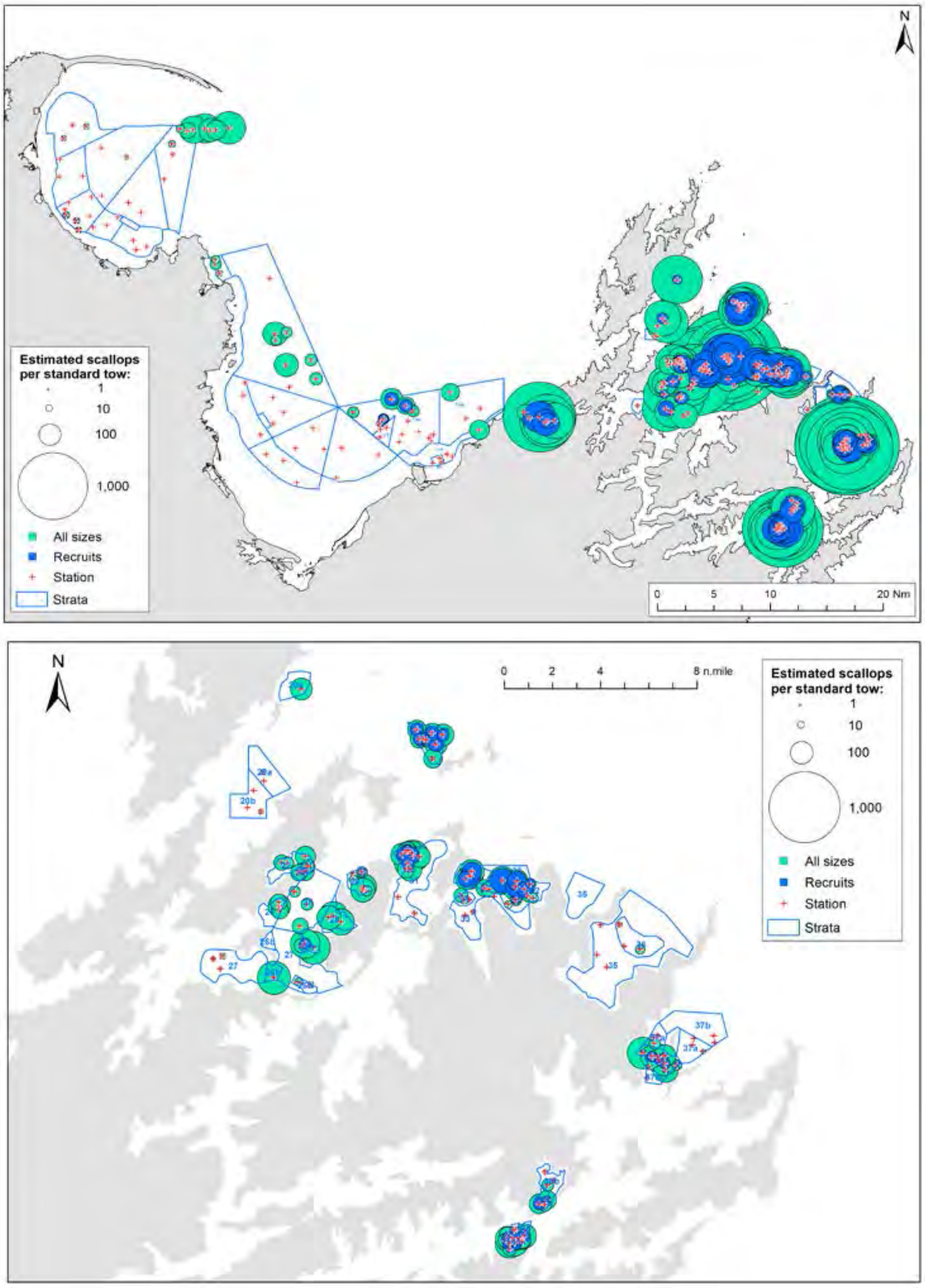


Figure 3: Time of survey catch per standard tow. Top: SCA 7 stock survey, January 2017. Bottom: Marlborough Sounds sub-stock survey, May 2019. Circle area is proportional to the number of scallops caught per standard distance towed (0.4 nautical miles). Dark blue shaded circles denote scallops of commercial recruited size (90 mm or larger), green shaded circles denote scallops of any size. Values are uncorrected for dredge efficiency. Polygons denote survey strata boundaries.

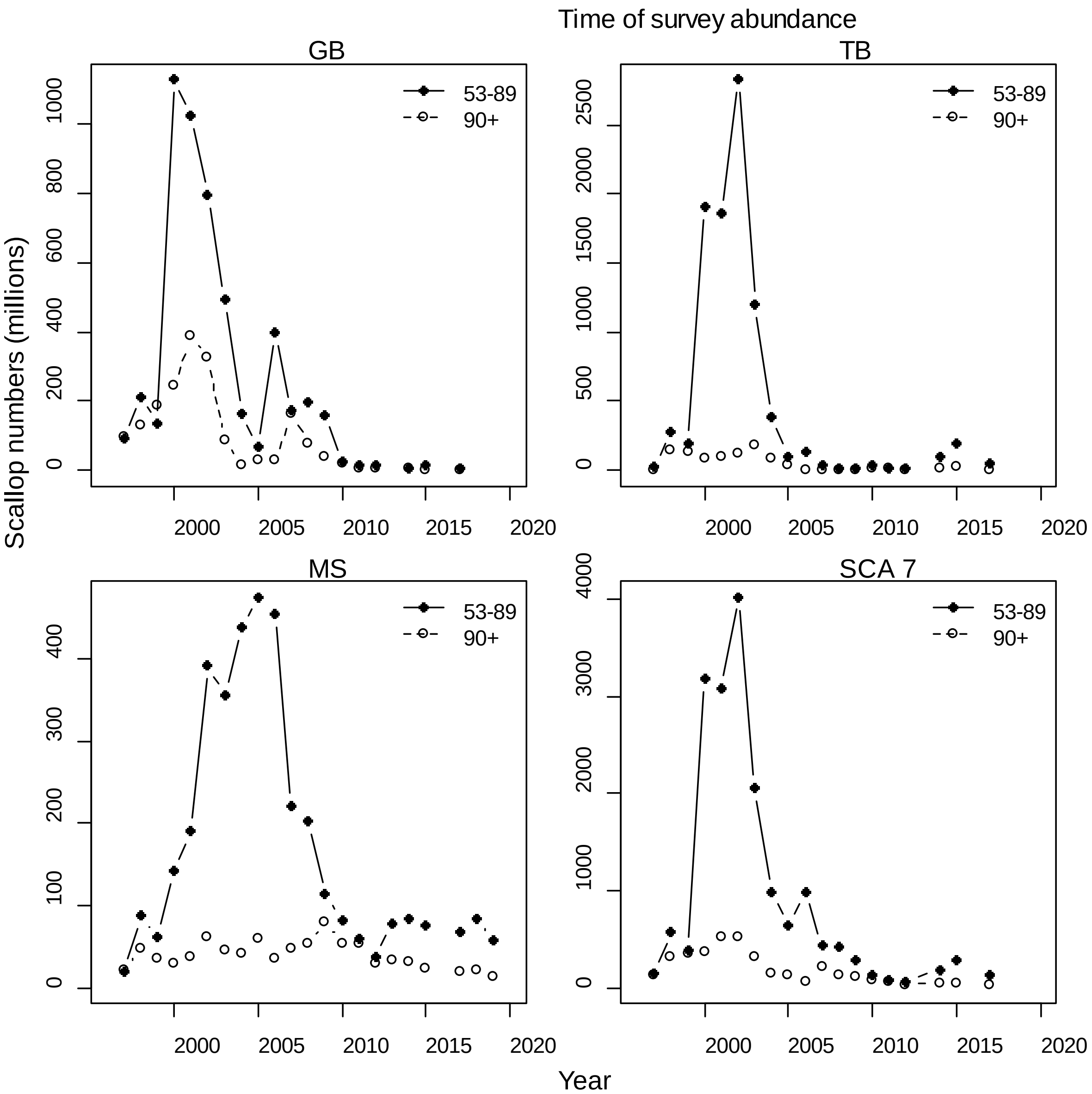


Figure 3: Time of survey abundance indices 1997 to 2019 for undersize (53– 89 mm) and recruited scallops (90 mm or larger) in Golden Bay (top left), Tasman Bay (top right), Marlborough Sounds (bottom left), and SCA 7 (all areas combined; bottom right). Golden Bay and Tasman Bay were not surveyed in 2013, 2016, 2018 or 2019. Marlborough Sounds was not surveyed in 2016. Values are median estimates of abundance (scallop numbers), corrected for dredge efficiency (Tuck et al. 2018).

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.

Start of season (nominally 1 September) absolute recruited biomass is estimated each year from a pre-season dredge survey, which is usually conducted in May (N.B. January in 2017 and 2018). Estimates were derived by Williams et al. (2019) by re-analysing the 1997–2019 survey data, applying new dredge efficiency parameters (Tuck et al. 2018) and conducting growth projections with an inverse logistic model (Tuck & Williams 2012), using a resampling with replacement analytical procedure described to account for uncertainty in the start-of-season biomass estimates (Table 7).

Table 7: Projected median biomass (and CV) of recruited scallops (90 mm or longer shell length) at the nominal start of season (1 September) in the survey years, 1997 to present. Golden Bay and Tasman Bay were not surveyed in 2013, 2016, 2018 or 2019. No survey was conducted in 2016. Estimates were derived by Williams et al. (2019) by re-analysing the 1997–2019 survey data using a resampling with replacement analytical procedure, applying new dredge efficiency parameters (Tuck et al. 2018) and conducting growth projections with an inverse logistic model (Tuck & Williams 2012). For each year, the catch (reported on the 'Landed' section of CELRs) and exploitation rate (catch to recruited biomass ratio) are also given. Biomass and catch are in t meatweight.

				Golden Bay					Tasman Bay
Year	Biomass	CV	Catch	Catch/Biomass	Year	Biomass	CV	Catch	Catch/Biomass
1997	1253	0.17	239	0.19	1997	110	0.19	2	0.02
1998	1857	0.17	353	0.19	1998	1617	0.17	78	0.05
1999	2202	0.18	514	0.23	1999	1425	0.18	155	0.11
2000	4155	0.17	303	0.07	2000	1570	0.21	19	0.01
2001	5271	0.17	660	0.13	2001	2460	0.26	32	0.01
2002	4537	0.16	370	0.08	2002	3267	0.27	39	0.01
2003	1419	0.17	28	0.02	2003	2997	0.18	107	0.04
2004	337	0.23	20	0.06	2004	1269	0.18	47	0.04
2005	410	0.18	35	0.09	2005	477	0.17	5	0.01
2006	965	0.27	26	0.03	2006	106	0.21	0	–
2007	2214	0.18	128	0.06	2007	86	0.30	0	–
2008	1071	0.19	76	0.07	2008	29	0.38	0	–
2009	608	0.21	19	0.03	2009	39	0.32	0	–
2010	240	0.22	10	0.04	2010	128	0.65	0	–
2011	62	0.29	1	0.02	2011	121	0.65	0	–
2012	50	0.32	0.2	0.00	2012	47	0.41	0	–
2013	–	–	0	–	2013	–	–	0	–
2014	92	0.21	0	–	2014	190	0.30	0	–
2015	43	0.33	0	–	2015	498	0.34	0.8	0.00
2016	–	–	0	–	2016	–	–	0	–
2017	25	0.33	0	–	2017	178	0.35	0	–
2018	–	–	0	–	2018	–	–	0	–
2019	–	–	0	–	2019	–	–	0	–

				Marl. Sounds					SCA 7 Total
Year	Biomass	CV	Catch	Catch/Biomass	Year	Biomass	CV	Catch	Catch/Biomass
1997	252	0.16	58	0.23	1997	1620	0.15	299	0.18
1998	520	0.18	117	0.22	1998	3990	0.16	548	0.14
1999	378	0.16	7	0.02	1999	4024	0.16	676	0.17
2000	373	0.17	16	0.04	2000	6084	0.17	338	0.06
2001	449	0.17	25	0.06	2001	8219	0.18	717	0.09
2002	862	0.19	62	0.07	2002	8705	0.19	471	0.05
2003	542	0.17	71	0.13	2003	4992	0.16	206	0.04
2004	543	0.18	51	0.09	2004	2154	0.17	118	0.05
2005	712	0.18	116	0.16	2005	1606	0.16	157	0.10
2006	541	0.21	43	0.08	2006	1613	0.23	68	0.04
2007	662	0.22	6	0.01	2007	2986	0.17	134	0.04
2008	695	0.17	28	0.04	2008	1803	0.17	104	0.06
2009	920	0.20	101	0.11	2009	1571	0.17	120	0.08
2010	641	0.15	74	0.12	2010	1020	0.17	85	0.08
2011	669	0.16	60	0.09	2011	846	0.18	61	0.07
2012	361	0.17	48	0.13	2012	458	0.17	48	0.10
2013	416	0.17	43	0.10	2013	–	–	43	–
2014	376	0.17	22	0.06	2014	658	0.17	22	0.03
2015	305	0.17	21	0.07	2015	853	0.24	22	0.03
2016	–	–	0	–	2016	–	–	0	–
2017	345	0.19	0	–	2017	554	0.23	0	0.00
2018	335	0.17	0	–	2018	–	–	0	–
2019	203	0.20	0	–	2019	–	–	0	–

Biomass is held at various spatial densities (scallops per unit area), typically with smaller areas of high density aggregations commonly known as 'beds' distributed among larger areas of low densities or no scallops. High-density scallop beds are important both for sustainability (i.e., larval production) and for fisheries utilisation (i.e., high catch rates). It is possibly more useful for management purposes to focus on biomass trends in the higher density areas. In addition to estimates of absolute biomass, the biomass at different commercial threshold ('critical') densities (in the range 0–0.2 scallops m^{-2}) is also estimated each year.

Projected recruited biomass in SCA 7 in September 2017 was very sensitive to the critical density levels examined (Figure 5). In Golden Bay (excluding stratum 9b) and Tasman Bay (excluding Croisilles Harbour strata 17 and 18), there was zero recruited biomass held at potentially fishable densities (higher than 0.04 m^{-2}, or 1 scallop per 25 m^2). Of the Marlborough Sounds absolute biomass (115 t), 64% (74 t) was held in areas with a critical density of 0.04 m^{-2} or higher, and this reduced to 46% (53 t) at 0.08 m^{-2}, and 32% (37 t) at 0.12 m^{-2}. These are median point estimates, which have increasingly large uncertainty as the critical density threshold increases.

Estimates of projected recruited biomass in Marlborough Sounds are available from analysis of the January 2018 (Williams et al. 2018) and May 2019 (Williams et al. 2019) surveys, with estimated biomass gradually decreasing with increasing critical threshold density. Of the Marlborough Sounds absolute projected biomass (203 t), 84% (171 t) was held in areas with a critical density of 0.04 m^{-2} or higher; with increasing critical density, the available biomass reduced: 115 t (57%) was held in areas with a critical density of 0.2 m^{-2} or higher.

Overall, from the most recent stock survey of all three regions (Golden and Tasman Bays, and Marlborough Sounds) in 2017, the SCA 7 stock appeared to be similar to the lowest recorded level (Figure 6). The key findings in 2017 were that recruited biomasses in Golden and Tasman Bays (excluding Croisilles Harbour) were at negligible levels, similar to those observed since the large declines in the 2000s, and the declining trend in recruited biomass observed in Marlborough Sounds since 2009 appeared to have discontinued. The size structure of the January 2017 population in Marlborough Sounds provided evidence of successful spat settlement and survival in 2016.

The May 2019 survey analysis (Williams et al. 2019) provides the most recent information to assess the status of the Marlborough Sounds scallop population. The key finding is that the Marlborough Sounds recruited biomass estimate for 2019 in the overall area surveyed is the lowest on record. Virtually all the recruited biomass at potentially fishable densities is held in five scallop beds, at Guards Bay, Ship Cove, the Chetwodes, Wynens Bank, and Dieffenbach Point. Population projections predicted the Marlborough Sounds recruited biomass in September 2019 to be 203 t meat weight. The estimated abundance of small scallops (53–89 mm) in 2019 is low compared with historical estimates, especially from the early 2000s, suggesting that recruitment in the short term is likely to be relatively poor.

Before the 2016–present fishery closures, recent commercial fishing (e.g. 22 t in the 2015 season) was limited almost exclusively to a few specified areas in the Marlborough Sounds. The level of recreational harvest in most years is unknown. The commercial exploitation rate in 2015 in the Marlborough Sounds was in line with the target exploitation rate associated with an increasing biomass observed between 1999 and 2008 (see Section 5.4). A minimum reference level has not yet been established for SCA 7, and, because spatial scale is inherently important in scallop population dynamics and fisheries, a single minimum reference level for the stock would be unsuitable. It is clear, however, that the stocks in Golden and Tasman Bays are well below desirable minimum levels, and the stock in the overall Marlborough Sounds is recovering from one of the lowest recorded levels in the survey time series.

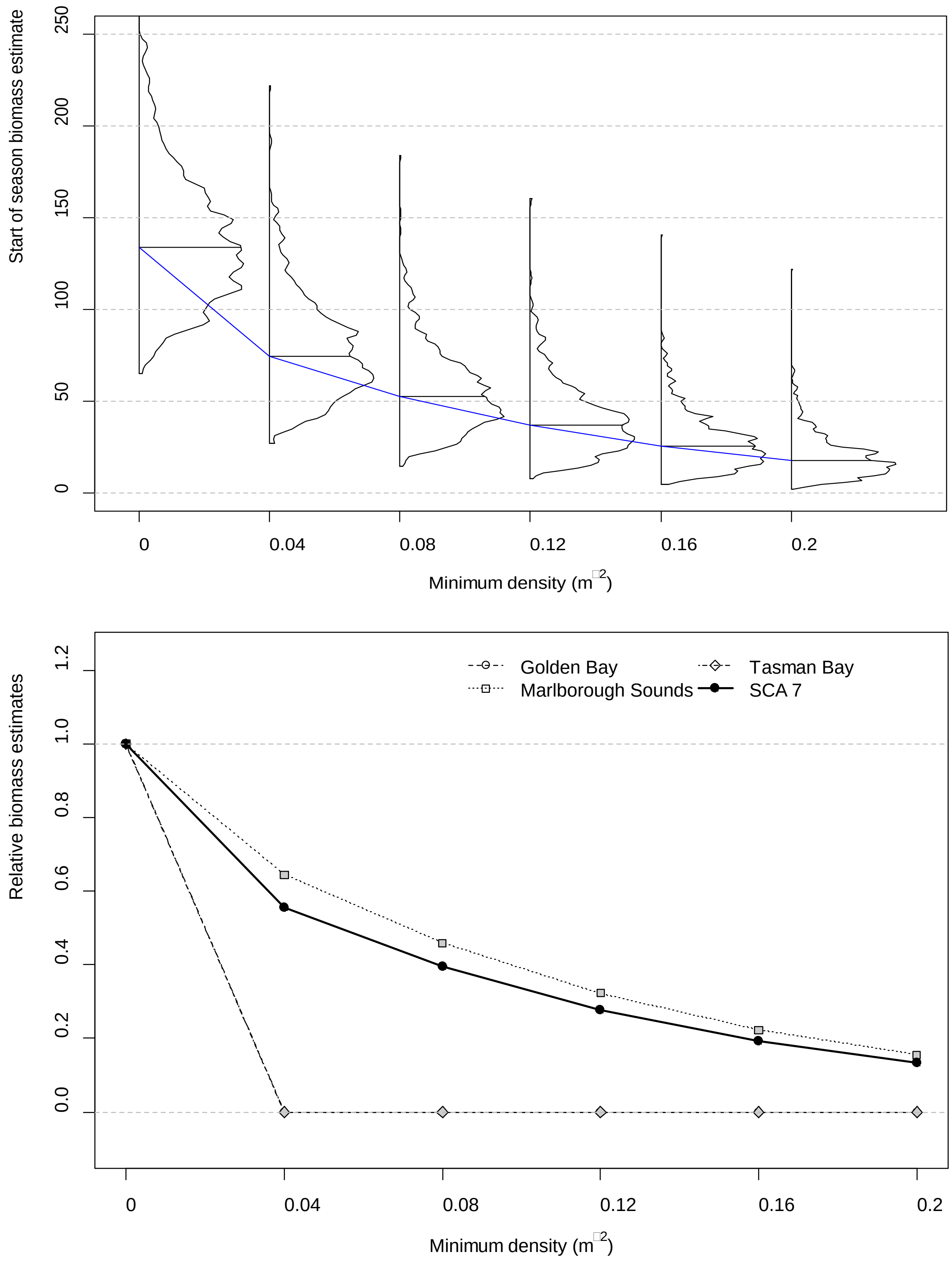


Figure 5: Effect of excluding areas of low scallop density on projected estimates of recruited biomass, SCA 7, September 2017. Estimates were produced using a Multifan projection approach. Critical density corrections were applied after correcting for historical dredge efficiency. [Top]: for each minimum ('critical') density, the distribution and median (horizontal line) of the recruited biomass in SCA 7 are shown. [Bottom]: Trend in the proportion of the total recruited biomass with increasing critical density, by sub-stock: Golden Bay (circles) symbols are obscured by Tasman Bay (diamonds) symbols; Marlborough Sounds (squares); SCA 7 (black circles joined by solid black line).

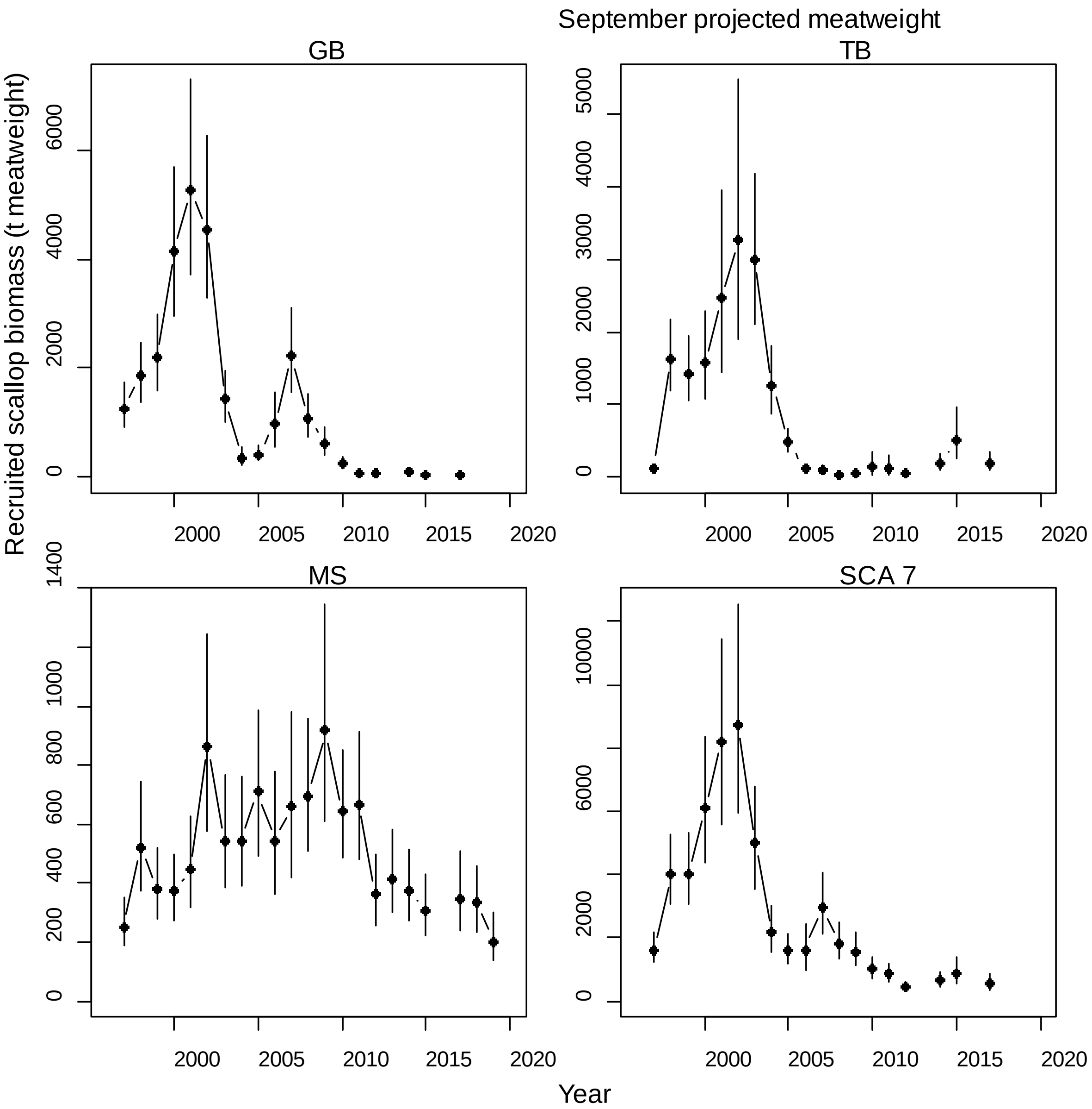


Figure 6: Trends in projected start of season (1 September, black symbols) biomass (t, meatweight) of recruited scallops (90 mm or larger) by sub-stock and for the total SCA 7 stock, 1997–2019. Values are the estimated median and 95% confidence intervals of the recruited biomass, derived using dredge efficiency estimated by Tuck et al. (2018). Golden and Tasman Bays were not surveyed in 2013, 2016, 2018 or 2019. Marlborough Sounds was not surveyed in 2016.

5.3 Estimation of Maximum Constant Yield (MCY)

MCY has not been estimated for SCA 7 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

Historically, Current Annual Yield (CAY) has not been estimated for Golden and Tasman Bays because those areas are managed under s14 of the Fisheries Act 1996.

For the Marlborough Sounds, CAY has historically been estimated using $F_{0.1}$ as the reference fishing mortality. Estimates of $F_{0.1}$ have been high and the Plenary agreed that this has resulted in overestimation of potential yield, particularly when fishing tends to focus on a small proportion of the biomass. The agreed new approach is to calculate an empirical target harvest (exploitation) rate based on a period when the Marlborough Sounds biomass was stable or increasing (i.e., the aim is to avoid harvest rates that tend to lead to biomass decline). The previous estimate of this target was a harvest rate (catch to biomass ratio) of 0.22, which was the mean harvest rate in the period 1999–2008 calculated using biomass estimates derived by applying historical dredge efficiency parameters. However, using the revised estimates of 1999–2008 biomass (Williams et al. 2019) generated by applying the new dredge efficiency parameters (Tuck et al. 2018) suggests a target harvest rate of 7% of the absolute recruited biomass. Further research is required to inform the setting of appropriate target and biomass limit reference points.

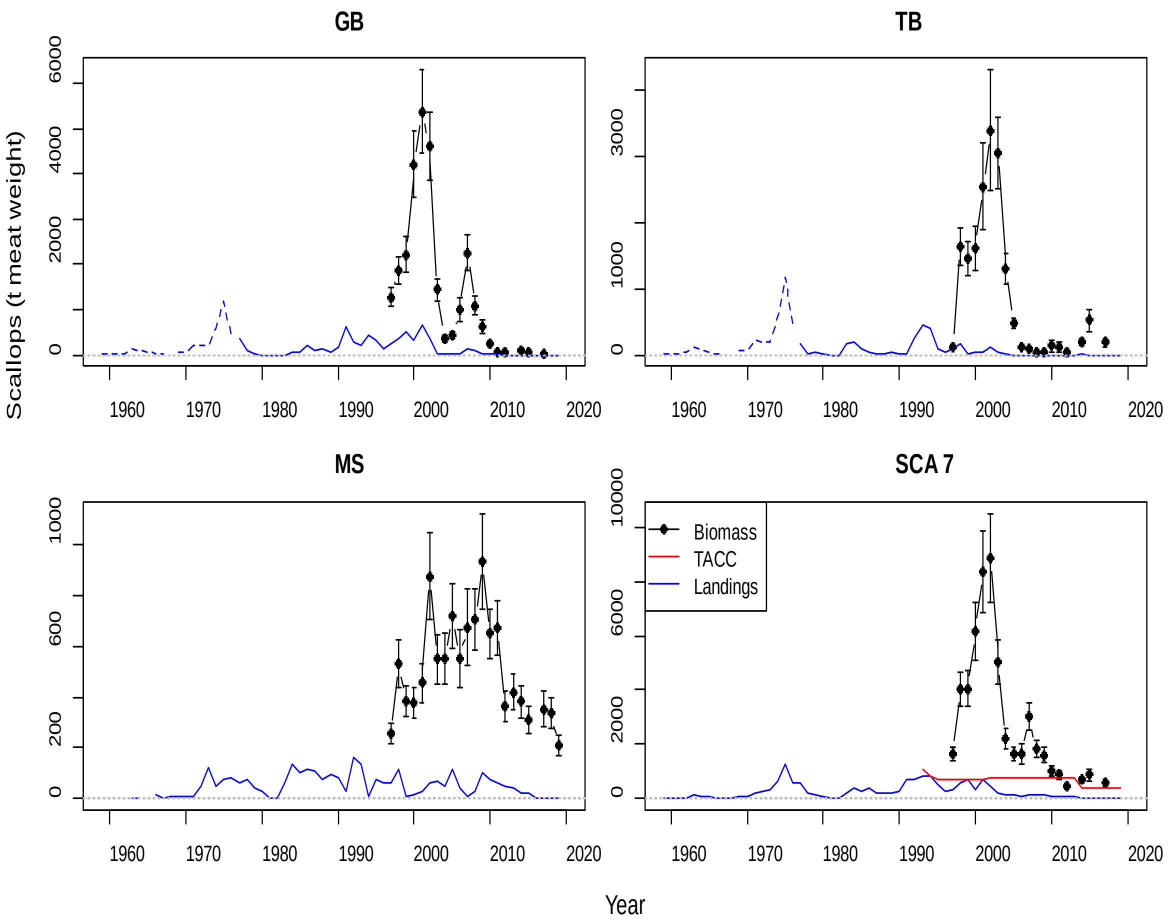
6. STATUS OF THE STOCKS

Stock structure assumptions

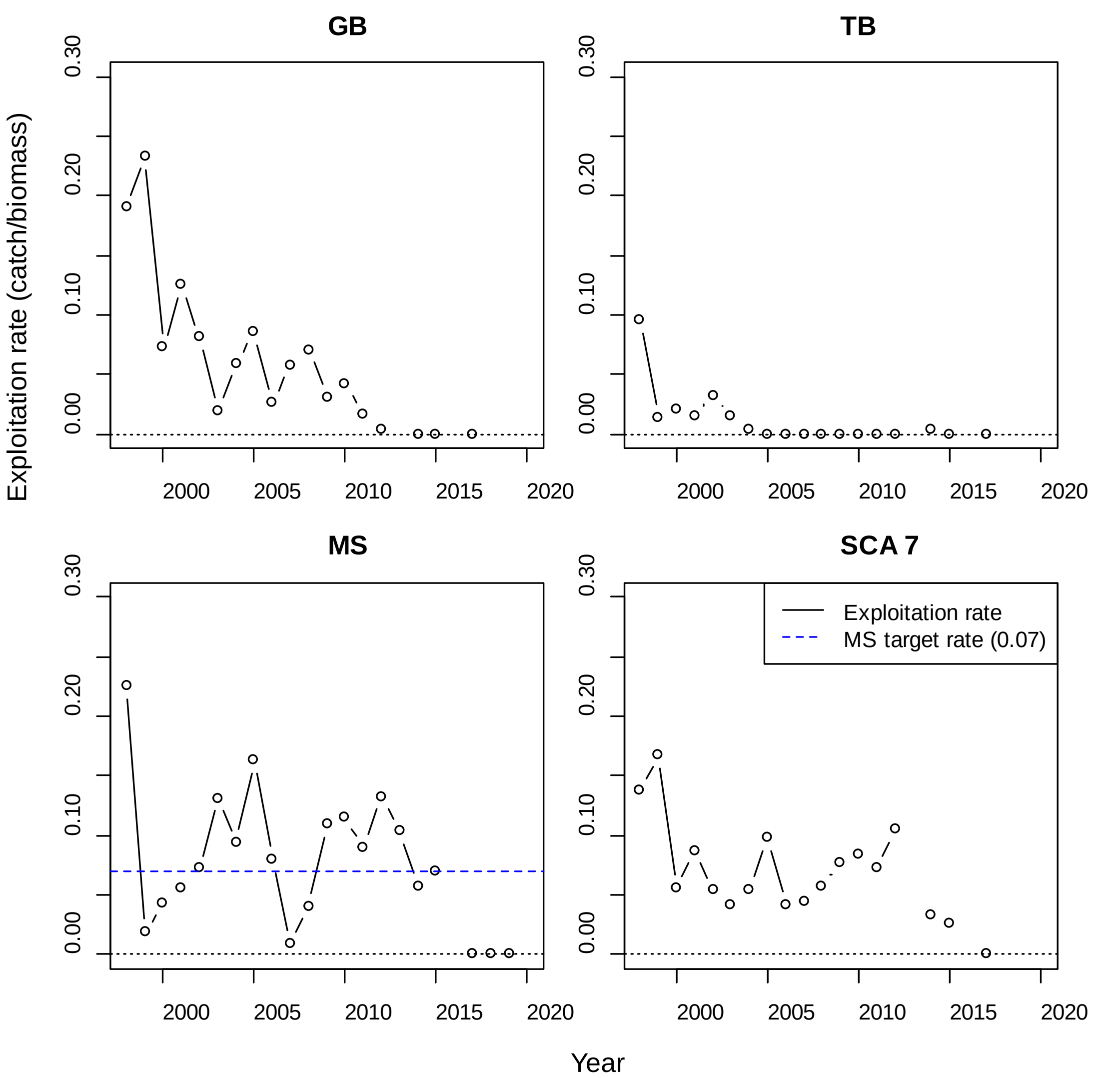
The stock structure of scallops in New Zealand waters is uncertain. For the purposes of this assessment and due to the different management regimes, Golden Bay, Tasman Bay and Marlborough Sounds are assumed to be individual and separate sub-stocks of SCA 7.

Stock Status	
Year of Most Recent Assessment	2017 (Golden and Tasman Bays) and 2019 (Marlborough Sounds
Assessment Runs Presented	Biomass estimates for Golden and Tasman Bays up to 2017; biomass estimates for Marlborough Sounds up to 2019.
Reference Points	Target: Empirical target harvest (exploitation) rate: U_{MSY} = U_{target} = 0.07 for Marlborough Sounds. No targets have been set for Golden Bay or Tasman Bay; B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Very Likely (> 90%) to be at or below U_{target} for Marlborough Sounds. Very Unlikely (< 10%) to be at or above the biomass target for Golden Bay or Tasman Bay
Status in relation to Limits	Unknown for the soft and hard limits for Marlborough Sounds Very Likely (> 90%) to be below the soft limit for Golden Bay and Tasman Bay Likely (> 60%) to be below the hard limit for Golden Bay and Tasman Bay
Status in relation to Overfishing	For sustainability reasons, the SCA 7 fishery was partially closed during the 2016–17 fishing year and the closure was extended to the entire SCA 7 QMA plus Port Underwood from the 2017–18 fishing year. The closure will remain in place until such a time as the scallop population has recovered. Therefore, overfishing is Very Unlikely (< 10%) to have occurred in 2018–19.

Historical Stock Status Trajectory and Current Status



Estimated biomass (mean and CV), TACC, and reported landings of recruited scallops (90 mm or larger shell length) in t meatweight by sub-stock (GB, Golden Bay; TB, Tasman Bay; MS, Marlborough Sounds) and overall SCA 7 stock since 1959. Biomass estimated using historical dredge efficiency parameters. Landings before 1977 from Golden and Tasman Bays were reported as combined values from the two bays (shown as a dotted blue line). Biomass estimates from surveys before 1997 are not presented because the surveys did not cover the full extent of the SCA 7 fishery. Scale differs between plots. Note that the fishery was closed for the 1981–82 and 1982–83 scallop fishing years, and was subsequently managed under a rotationally enhanced regime. The fishery in the Marlborough Sounds and Tasman Bay sector H areas were closed for the 2016–17 scallop fishing year, and the fishery closure was extended in 2017–18 to cover the entire SCA 7 stock and adjacent Port Underwood area. The closure continues and will remain in place until such a time as the scallop population has recovered.



Harvest or exploitation rate (catch divided by biomass) trends for recruited scallops by region and for the overall SCA 7 stock (solid black lines). For the Marlborough Sounds, the target harvest rate value of 0.07 is shown as a horizontal dashed line, calculated using revised estimates of biomass derived by Williams et al. (2019); this is an empirical target based on the mean harvest rate (catch to biomass ratio) in the period 1999–2008 when the Marlborough Sounds biomass was stable or increasing (i.e., the aim is to avoid harvest rates that tend to lead to biomass decline). This target has been in place since 2014. N.B. the previous estimate of this target was a harvest rate of 0.22, calculated using biomass derived by applying historical dredge efficiency, which has since been superceded by the new dredge efficiency parameters derived by Tuck et al. (2018).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Recruited biomass in Marlborough Sounds generally declined from 2009 to 2015, showed little change to 2018, and declined further to reach the lowest recorded level in 2019. Golden Bay and Tasman Bay were last surveyed in 2017 when biomasses remained extremely low with no indication of rebuilding.
Recent Trend in Fishing Intensity or Proxy	Marlborough Sounds harvest rate (catch to recruited biomass ratio) was high at 23% and 22% in 1997 and 1998 but dropped to 2% in 1999, followed by a general increase to reach 16% in 2005. The harvest rate subsequently decreased to 1% in 2007, followed by an increasing trend to reach 13% in 2012. In the years 2013 to 2015

	the harvest rate was in the range 6–10%. The fishery was closed in 2016. In Golden Bay, the harvest rate was high in the period 1997–99 (19–23%), followed by a decreasing trend with fluctuation from 2000, and was very low (<1%) in 2012. No fishing has occurred in Golden Bay since the 2012 fishing season. The fishery was closed in the 2017–18 fishing year. In Tasman Bay, the peak harvest rate in the time series was 11% in 1999, but otherwise has been low. No fishing occurred in Tasman Bay between 2006 and 2014, and there was minimal (exploratory) fishing in Tasman Bay in 2015 (harvest rate of <1%). Sector 7HH in Tasman Bay was closed in the 2016–17 fishing year and the entire Tasman Bay area was closed in the 2017–18 fishing year.
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections are not available. The success of natural settlement, survivorship on the seabed and the magnitude of incidental mortality are unknown.
Probability of Current Catch or TAC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TAC causing Overfishing to continue or commence	For sustainability reasons, the SCA 7 fishery was partially closed during the 2016–17 fishing year and the closure was extended in 2017–18 to cover the entire SCA 7 QMA plus Port Underwood. The closure continues and will remain in place until such a time as the scallop population has recovered.

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Biomass surveys	
Assessment Dates	Latest assessment: 2019 (Marlborough Sounds) 2017 (Golden Bay, Tasman Bay and Marlborough Sounds)	Next assessment: 2020
Overall Assessment Quality Rank	1 – High Quality	
Main data inputs (rank)	Biomass survey: 2019 (Marlborough Sounds) 2017 (Golden Bay, Tasman Bay and Marlborough Sounds)	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Use of an empirical harvest rate (U_{target}) in preference to $F_{0.1}$	
Major Sources of Uncertainty	- dredge efficiency (efficiency and selectivity) 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 for the time of the fishing season	

	- the spatial scale at which the assessment is conducted (currently, the target harvest rate is calculated at a broad scale using estimates of absolute biomass, but fishing occurs only in a few high-density scallop beds that support productive fishing, and are also likely to be the most important spawning beds) - the extent to which dredging causes incidental mortality and affects recruitment - appropriate limit reference points for scallops- appropriate limit reference points for scallops

Qualifying Comments
The extent to which the various beds or populations are reproductively or functionally separate is not known. In addition to direct fishing mortality, a combination of other anthropogenic (e.g., land-based influences, indirect effects of fishing) and natural (e.g., oceanographic) drivers may have affected the productivity of the SCA 7 fishery. Declines in stocks of other shellfish (oysters and mussels) have also been observed in Golden Bay and Tasman Bay.

Environmental and Ecosystem Considerations	
Observer coverage	No observer coverage
Non-target fish and invertebrate catch	Non-target catch data were routinely collected during the 1994–2013 annual surveys but not analysed, except for preliminary estimation of the 1998–2013 non-target catch trajectories. Non-target catch can include dredge oysters, green-lipped mussels, and a range of other benthic invertebrates.
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 the 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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