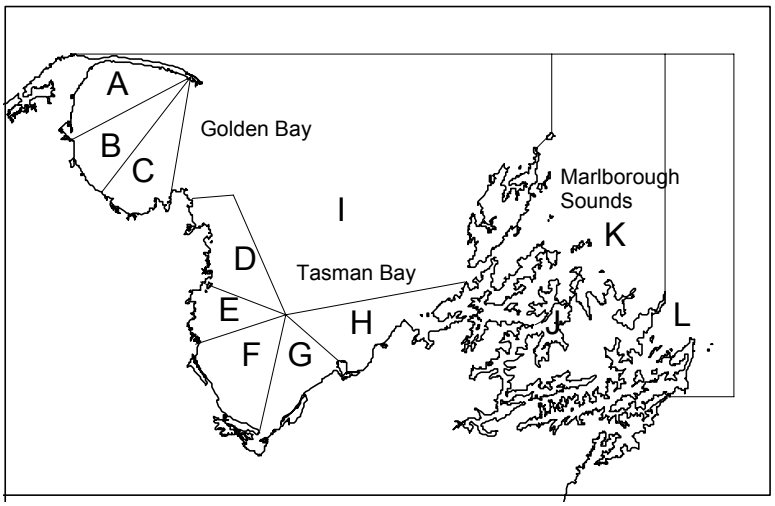
SCALLOPS Nelson/Marlborough (SCA 7)

(*Pecten novaezelandiae*)
Kuakua



1. FISHERY SUMMARY

1.1 Commercial fisheries

The Nelson/Marlborough scallop fishery (SCA 7), often also referred to as the 'Southern' or 'Challenger' fishery, is comprised of 12 sectors (see A–L in the map above) spread across three regions: Golden Bay, Tasman Bay, and the Marlborough Sounds. Up to 1980, the 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 tonnes in 1975, when there were 216 licenced 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). Initially, 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.

The SCA 7 fishery was introduced into a modified form of the Quota Management system (QMS) in 1992. 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 ITQ. 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. The catch limit was set at the level that enabled the fishery to produce the Maximum Economic Yield.

In October 1995, legislation was passed in which annual quotas were fixed proportionally rather than as a fixed tonnage, which 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 also provided for a transition enabling the enhancement programme to be implemented by the Challenger Scallop Enhancement Company (CSEC) under contract to MFish (it had previously been implemented and managed by government).

With the passage of the Fisheries Act 1996, the fishery was able to be managed using an approach that represented an improvement on achieving the Maximum Sustainable Yield, rather than focus on Maximum Economic Yield. In addition, a levy was established which created an ability for the CSEC to collect their own funds from quota owners. This lead to the termination of the contract with MFish, and for CSEC to implement the enhancement programme in accordance with conditions set down by the Minister of Fisheries. In 1998, an amended Enhancement Plan was approved by the Minister of Fisheries to better reflect the new arrangements. Because of the rotationally enhanced nature of the

fishery, the fishery was placed on the Third Schedule to the Fisheries Act 1996, and is, therefore, able to have an alternative TAC set under section 14 of the Fisheries Act 1996.

There has been relatively little change in the process used to manage this fishery in recent years. An annual dredge survey helps define biomass levels and population size structures, by sector 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. The intended strategy has then been to open sectors on a rotational basis, with reseeding at the end of the season. This has not always occurred however, particularly in recent years when reseeding activity has been reduced. In 2000–01 and 2001–02, for example, high levels of natural recruitment in Golden Bay, led to fishing in all three sectors (A, B & C), with the fishery targeting patches of recruited scallops. Further, Sector B has been fished almost every year, with the harvest from this sector accounting for the majority of that taken from Golden Bay. This practise of sub-sector 'rotation' is not consistent with that of three yearly sector rotational fishing regime as recommended by Breen and Kendrick (1997).

Separate catch limits are set each year (by CSEC in consultation with MFish) for the Tasman/Golden Bays and the Marlborough Sounds regions of the fishery. Actual commercial catch is subject to:

- the available sustainable harvest from areas open to fishing in that year,
- 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 in the areas open to fishing being above pre-set levels.

Reported landings (in meatweight i.e., processed weight, being the adductor muscle plus attached roe) from the Challenger scallop fishery are listed in Tables 1 and 2. Figure 1 shows the historical landings and TACC values for the SCA7 stock. The fishing year applicable to this fishery is from 1 April to 31 March. Commercial fishing usually occurs from August to December, although opening and closing dates are defined each year, and may differ between years.

Table 1: Reported landings (t, meatweight) of scallops from Golden Bay, Tasman Bay, the Marlborough Sounds (Marl), and total landings (Total). Landings before 1977 were reported by the Golden Bay and Tasman Bay combined area (Gold/Tas). The fishery was closed for the 1981–82 and 1982–83 scallop fishing years.

Year	Gold/Tas	Golden Bay	Tasman Bay	Marl. Sounds	Total
1959–60	2	–	–	–	2
1960–61	12	–	–	2	14
1961–62	13	–	–	–	13
1962–63	36	–	–	–	36
1963–64	117	–	–	2	119
1964–65	93	–	–	2	95
1965–66	42	–	–	–	42
1966–67	19	–	–	12	31
1967–68	9	–	–	4	13
1968–69	–	–	–	8	8
1969–70	72	–	–	6	78
1970–71	73	–	–	7	80
1971–72	206	–	–	9	215
1972–73	190	–	–	46	236
1973–74	197	–	–	124	321
1974–75	585	–	–	51	636
1975–76	1 174	–	–	72	1 246
1976–77	468	–	–	79	547
1977–78	–	342	168	63	575
1978–79	–	86	4	76	167
1979–80	–	32	30	39	104
1980–81	–	0	14	27	41
1981–82	–	0	0	0	0
1982–83	–	0	0	0	0

Table 2: Reported landings (t, meatweight) of scallops from Golden Bay, Tasman Bay, the Marlborough Sounds (Marl), and total landings (Total). Various landings limits (t, meatweight) are presented: Total Allowable Commercial Catch (TACC); initial industry controlled catch limit (ICCL); Marlborough Sounds catch limit (MSCL, a subset of the AAC/TACC).

Year	Golden Bay	Tasman Bay	Marl. Sounds	Total	TACC	ICCL	MSCL
1983–84	0	164	61	225	–	–	–
1984–85	45	184	138	367	–	–	–
1985–86	43	102	100	245	–	–	–
1986–87	208	30	117	355	–	–	–
1987–88	113	1	105	219	–	–	–
1988–89	127	23	72	222	–	–	–
1989–90	68	42	95	205	–	–	–
1990–91	154	8	80	240	–	–	–
1991–92	629	9	30	672	–	–	–
1992–93	269	247	160	710	–	–	–
1993–94	208	461	135	805	*1 100	–	–
1994–95	415	394	8	850	*850	–	70
1995–96	319	92	76	521	720	–	73
1996–97	123	47	61	231	720	350	61
1997–98	239	2	58	298	720	310	58
1998–99	353	78	117	547	720	450	120
1999–00	514	155	7	676	720	720	50
2000–01	303	19	16	336	720	720	50
2001–02	660	32	25	717	720	720	76
2002–03	370	39	62	471	747	747	(–)
2003–04	28	107	71	206	747	747	(–)
2004–05	20	47	51	118	747	747	(–)
2005–06	35	5	116	157	747	747	(–)
2006–07	26	0	43	68	747	747	(–)
2007–08	128	0	6	134	747	747	(–)
2008–09	76	0	28	104	747	747	(–)

- Annual Allowable Catch (AAC); TACCs came into force 1 October 1995.

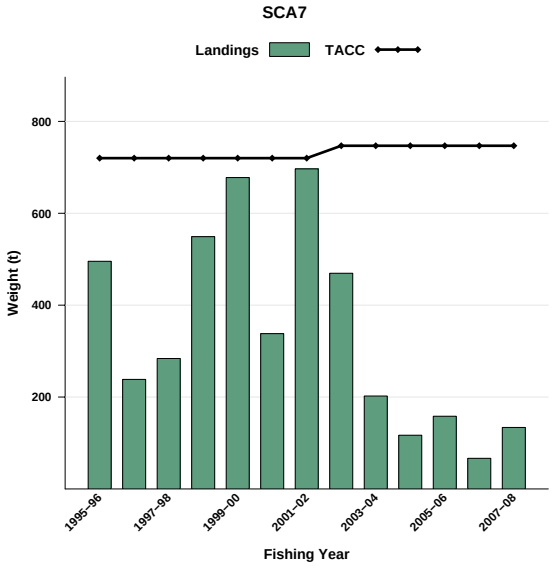


Figure 1: Historical landings and TACC for SCA7 (Nelson Marlborough). Note that this figure does not show data prior to entry into the QMS.

1.2 Recreational fisheries

Scallops are taken by recreational fishers, throughout SCA 7, generally by dredge or diving. The recreational fishing season runs from 15 July to 14 February.

Each year the commercial and recreational sectors jointly review the prospects for the recreational fishery based on pre-season abundance and yield surveys. Following those discussions a number of non-commercial areas are routinely established to supplement the various regulatory closures, which apply to the commercial fishery only. Levels of recreational harvest probably vary significantly through time.

The first recreational harvest estimates available were derived from telephone diary programmes in 1992–93 (Tierney et al. 1997), 1996 (Bradford 1998), 1999-00 (Boyd & Reilly 2004), and 2000–01 (Boyd et al. 2004), but these estimates are of dubious reliability (Table 3). In 2004, the Marine Recreational Fisheries Technical Working Group reviewed the harvest estimates of these surveys and concluded that the 1993/94 and 1996 estimates were unreliable due to a methodological error. While the same error did not apply to the 1999/2000 and 2000/01 surveys, it was considered the estimates may still be very inaccurate.

The most recent harvest estimates come from a targeted creel survey of the Golden Bay and Tasman Bay fisheries (Table 3), which was conducted in 2003–04 (Cole et al. 2006). This later estimate may be more accurate, as it is based upon direct, independent, and structured observations of the fishery, but there are no estimates available for the Marlborough Sounds. The scale of these estimates suggests, however, that recreational fishers only account for a small proportion of annual removals.

Table 3: Estimated numbers of scallops harvested by recreational fishers in QMA 7, and a corresponding estimate of meatweight (Mwt, t) based on an assumed mean scallop meat weight of 13 g. The Marine Recreational Fisheries Technical Working Group reviewed the telephone/diary harvest estimates and concluded that the 1993/94 and 1996 estimates were unreliable due to a methodological error, and while the same error did not apply to the 1999/2000 and 2000/01 surveys, it was considered the estimates may still be very inaccurate.

Year	Area	Method	Number	CV	Mwt	% of SCA 7 landings	Source
1992–93	SCA 7	Telephone/diary	1 680 00	15%	21.8	3.0	Tierney et al. (1997)
1996	SCA 7	Telephone/diary	1 456 00	21%	18.9	7.6	Bradford (1998)
1999–00	SCA 7	Telephone/diary	3 391	20%	44.1	6.1	Boyd & Reilly (2004)
2000–01	SCA 7	Telephone/diary	2 867	14%	37.3	10.0	Boyd et al. (2004)
2003–04	Golden & Tasman Bays	Creel survey	860 000	5%	9.4	6.5	Cole et al. (2006)

1.3 Customary non-commercial fisheries

Scallops were undoubtedly used traditionally as food by Maori, although quantitative information on the level of customary non-commercial take is not available.

1.4 Illegal catch

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

1.5 Other sources of fishing mortality

The extent of other sources of fishing mortality is unknown. Incidental mortality of scallops caused by ring-bag dredging is unknown for the Challenger fishery, although studies conducted in the Coromandel fishery showed that mortality was high (up to about 50% for larger size classes) for scallops encountered by box dredges. Stochastic modelling suggested 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 $F_{0.1}$. Other field experiments and modelling suggest that dredging reduces habitat heterogeneity, increases juvenile mortality, makes yield-per-recruit curves even more domed, and decreases estimates of F_{MAX} and $F_{0.1}$ even further.

2. BIOLOGY

Pecten novaezelandiae is a functional hermaphrodite that breeds generally 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. Scallop veliger larvae spend about 3 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).

The relatively high fecundity, and likely variability in the mortality of larvae and pre-recruits, could lead to high variability in natural annual recruitment. This variability is a characteristic of scallop populations worldwide.

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 grew to a shell length of about 60 mm in 1 year, and can reach 100 mm in 2 years. This is typical of the pattern of growth that occurs under the 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 Bay has indicated that scallops generally attain a shell length of 90 mm in just under 2 years, although, in conditions where food is limiting, almost 3 years may be required to reach this size.

Bull (1976) estimated the annual natural mortality rate for two populations of adult scallops in Pelorus Sound to be 23% and 39%. Bull & Drummond (1994) estimated the mortality of 0+ and 1+ scallops to be about 38% per year, with mortality of 2+ scallops increasing to 66%. These studies suggest that average natural mortality in the Challenger fishery is quite high (Table 4), and most previous stock assessments have assumed M = 0.46 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 4: Estimates of biological parameters

		Estimates	Source
1. Natural mortality, 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

The stock structure of scallops in New Zealand waters is uncertain. Scallops in Tasman Bay and Golden Bay probably constituted a single genetic stock before enhancement began, owing to the known circulation pattern of water masses in this area and the relatively long duration of the larval planktonic stage. Since enhancement, any genetic differences throughout the Challenger area would almost certainly have been erased. Enhancement in the Marlborough Sounds has been limited, but would have contributed towards homogenising stocks. Water movements eastward through Cook Strait had almost certainly enabled a degree of genetic mixing between Tasman/Golden Bay and Marlborough Sounds stocks before any enhancement began. There is no known stock-recruit relationship for SCA 7 scallops.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

Biomass in the main commercial scallop beds in the Challenger fishery have been estimated annually since 1994 using a two-phase stratified random dredge survey (Tables 5 and 6). Surveys since 1998 are essentially comparable, in that they used the same fishing gear and covered quite similar areas.

Earlier surveys covered smaller areas, although these would generally have included the areas of main 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. The efficiencies of the two dredges at a single site in each of Golden Bay, Tasman Bay, and the Marlborough Sounds were not significantly different. The mean efficiency at these sites (based on a comparison of diver and dredge transects) were 0.58, 0.66, and 0.85, respectively, giving an overall mean efficiency of 0.70. The values in Table 5 are absolute estimates, with different dredge efficiency estimates in different years. A dredge efficiency of 0.4 is assumed for the 1994 survey, based on the mean of 11 efficiency trials using various vessels and the MAF dredge. A dredge efficiency of 0.7 was assumed for all surveys from 1995 to 2003 inclusive (as they used the same vessel and comparable dredges). The difference between the two efficiency estimates (0.4 and 0.7) could be due to a vessel effect. Dredge efficiency in 2004–06 was assumed using the results of Handley et al. (2004); in 2007, average values of 0.7 and Handley et al.'s (2004) results were used; in 2008, dredge efficiency was not assumed, but was estimated using a bootstrapping procedure, resampling with replacement from the available raw data from dredge efficiency experiments (Tuck & Brown 2008).

Up to 1995, a recruit size of ≥ 90 mm (the commercial size limit) was used. A yield per recruit analysis in 1995 indicated that 89 mm was the optimal harvest size, so from 1996 to 2000, recruit estimates were calculated using this value (although harvesters and processors continued to take only scallops ≥ 90 mm, the minimum legal size). In 2001, a recruit size of ≥ 90 mm was again used.

This fishery operates with a feedback loop that checks the reliability of the biomass survey. At the end of each commercial season, landings from each sector fished are compared with the survey biomass estimates for the sector.

Table 5: Historical absolute estimates of pre-recruit numbers (PreN, millions), recruited numbers (RecN, millions), recruited greenweight (RecG, t), and recruited meatweight (MtWt, t) in Golden Bay, Tasman Bay, and the Marlborough Sounds, from dredge surveys in May-June of each year. Dredge efficiency is assumed to be 0.4 in 1994, 0.7 in 1995–2003, 0.34–0.49 in 2004–06, 0.52-0.63 in 2007; dredge efficiency in 2008 was estimated using a bootstrap analysis (Tuck & Brown 2008); *n*, number of dredge samples; Area, area surveyed.

Year	*n*	Area	Golden Bay				Tasman Bay				Marlborough Sounds			
		(ha)	PreN	RecN	RecG	MtWt	PreN	RecN	RecG	MtWt	PreN	RecN	RecG	MtWt
1994	166	35 330	–	84.5	–	1 101	–	67.6	–	981	–	13.2	–	192
1995	149	78 890	–	–	–	253	–	–	–	104	–	–	–	63
1996	299	54 770	–	–	–	108	–	–	–	126	–	–	–	90
1997	292	119 620	–	–	–	358	–	–	–	37	–	–	–	83
1998	509	196 852	54.4	44.5	4 114	506	77.1	51.5	4 419	553	23.7	16.4	1 438	168
1999	482	213 414	29.1	56.0	5 842	637	110.8	42.4	4 396	536	19.1	10.1	991	106
2000	382	209 438	285.5	71.5	6 144	658	611.3	30.0	2 977	302	44.6	9.0	854	75
2001	337	206 780	194.1	114.7	10	1 297	662.5	32.1	3 036	317	58.5	11.7	1 100	113
2002	368	208 188	83.7	62.4	5 755	872	674.7	33.7	3 015	416	85.8	13.2	1 192	179
2003	376	209 571	44.0	16.7	1 527	160	308.9	39.8	3 502	392	76.7	9.6	850	101
2004	447	210 325	34.4	6.4	554	69	210.3	37.9	3 339	395	180.0	17.6	1 510	151
2005	432	213 015	28.6	12.1	1 052	126	49.8	16.0	1 437	162	201.2	25.5	2 191	226
2006	461	213 296	155.4	10.2	941	110	54.3	2.8	251	25	189.3	15.2	1 344	136
2007	340	213 169	60.8	53.2	4 809	529	15.2	1.6	154	16	80.2	16.3	1 492	153
2008	285	212 362	43.3	26.2	2 119	278	6.0	0.7	55	7	47.8	19.3	1 563	190

Historical survey data were reanalysed in 2009 using a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the time of survey biomass estimates (Table 6).

Table 6: Revised absolute estimates and CVs of recruited numbers of scallops 90 mm or more shell length (RecN, millions), recruited greenweight (RecG, t), and recruited meatweight (MtWt, t) in Golden Bay, Tasman Bay, the Marlborough Sounds, and for the SCA 7 fishery total, from dredge surveys in May-June of each year. Values in this table were derived by reanalysing the historical survey data using a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the time of survey biomass estimates.

Year	Golden Bay						Tasman Bay					
	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV
1997	40.1	0.24	3 471	0.25	437	0.29	3.1	0.25	245	0.25	31	0.29
1998	55.7	0.18	4 605	0.19	584	0.24	66.2	0.19	5 108	0.18	645	0.23
1999	60.4	0.20	5 323	0.20	673	0.25	55.3	0.21	4 724	0.21	602	0.27
2000	87.8	0.18	6 896	0.18	872	0.24	36.3	0.18	3 027	0.18	386	0.23
2001	151.5	0.22	11 510	0.21	1 456	0.26	37.8	0.18	2 977	0.18	378	0.23
2002	106.6	0.18	8 326	0.18	1 053	0.24	55.3	0.18	4 272	0.18	544	0.23
2003	28.9	0.18	2 269	0.17	287	0.23	67.9	0.18	5 192	0.18	661	0.23
2004	5.6	0.20	432	0.20	55	0.25	31.8	0.18	2 386	0.18	304	0.24
2005	10.9	0.20	871	0.20	110	0.25	13.1	0.19	1 012	0.19	129	0.23
2006	10.3	0.20	858	0.20	109	0.25	2.4	0.19	186	0.19	24	0.23
2007	55.6	0.20	4 411	0.20	557	0.24	1.6	0.22	131	0.22	17	0.27
2008	27.0	0.20	2 198	0.20	278	0.25	0.8	0.32	58	0.32	7	0.35

Year	Marlborough Sounds						SCA 7 fishery total					
	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV
1997	9.0	0.23	781	0.24	99	0.29	52.1	0.22	4 497	0.23	568	0.26
1998	20.8	0.25	1 731	0.25	220	0.29	142.7	0.17	11 444	0.18	1 450	0.20
1999	11.6	0.18	969	0.19	123	0.23	127.2	0.18	11 016	0.19	1 399	0.21
2000	11.4	0.19	962	0.19	122	0.24	135.5	0.17	10 885	0.17	1 380	0.20
2001	14.0	0.20	1 124	0.20	143	0.24	203.3	0.20	15 611	0.19	1 977	0.22
2002	24.8	0.21	2 048	0.22	260	0.26	186.7	0.17	14 646	0.18	1 857	0.20
2003	16.6	0.21	1 325	0.21	168	0.26	113.3	0.17	8 786	0.17	1 116	0.19
2004	14.5	0.19	1 120	0.19	142	0.24	51.9	0.17	3 937	0.17	501	0.20
2005	21.6	0.20	1 690	0.20	214	0.25	45.7	0.18	3 574	0.18	453	0.20
2006	13.6	0.22	1 041	0.22	132	0.27	26.3	0.19	2 085	0.19	264	0.22
2007	16.7	0.23	1 326	0.23	169	0.28	74.0	0.19	5 868	0.19	742	0.22
2008	19.8	0.21	1 611	0.21	205	0.26	47.6	0.19	3 867	0.19	490	0.22

4.2 Biomass estimates

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

Start of season (nominally 1 September) recruited biomass is estimated each year (Table 7) from a pre-season dredge survey, which is usually conducted in May. Estimates were derived using the 'old' analytical procedure which assumed that near legal scallops grow 3 mm between the time of survey and the start of season, and the mean meatweight of scallops is 13 g. Coefficients of variation (CVs) were not calculated, but would be at least as large as those on the estimates of time of survey biomass (Table 5).

Historical survey data were reanalysed in 2009 using a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the start of season biomass estimates (Table 8).

Table 7: Historical estimates of mean projected meatweight biomass (t) of recruited scallops (90 mm or longer shell length) at 1 September in the survey year. Estimates were derived using the 'old' analytical procedure which assumed that near legal scallops grow 3 mm between the time of survey and the start of season (1st September), and the mean meatweight of scallops is 13 g. CVs were not calculated, but would be at least as large as those on the estimates of time of survey biomass (Table 5).

Year	Golden Bay	Tasman Bay	Marl. Sounds	Total SCA 7
1997	510	31	79	620
1998	575	482	191	1 247
1999	859	572	127	1 557
2000	1 343	611	142	2 096
2001	1 782	643	181	2 606
2002	1 350	1 024	327	2 702
2003	372	1 157	230	1 758
2004	108	694	376	1 178
2005	187	261	513	961
2006	232	50	336	618
2007	886	19	264	1 168
2008	449	8	333	789

Table 8: Revised estimates of median projected meatweight biomass (t) of recruited scallops (90 mm or longer shell length) at 1 September in the survey year. Estimates were derived using the revised analytical procedure described by Tuck & Brown (2008).

Year	Golden Bay	CV	Tasman Bay	CV	Marl. Sounds	CV	Total SCA 7	CV
1997	432	0.26	38	0.27	98	0.26	572	0.20
1998	659	0.22	847	0.25	228	0.29	1 737	0.17
1999	642	0.24	626	0.25	132	0.24	1 404	0.19
2000	1 236	0.21	606	0.23	143	0.22	1 969	0.17
2001	1 640	0.24	945	0.25	185	0.23	2 798	0.18
2002	1 186	0.22	1 225	0.25	378	0.24	2 787	0.18
2003	354	0.22	1 110	0.24	232	0.24	1 692	0.18
2004	79	0.23	468	0.22	246	0.24	797	0.17
2005	132	0.21	169	0.21	370	0.25	675	0.18
2006	265	0.25	43	0.24	272	0.26	580	0.21
2007	636	0.23	32	0.28	273	0.27	940	0.19
2008	313	0.22	15	0.31	270	0.23	597	0.18

4.3 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.

4.4 Estimation of Current Annual Yield (CAY)

Historically, CAY has not been estimated for Golden and Tasman Bays because those areas operate under a fishing plan that involves enhancement and rotational fishing. Under legislation (section 14 of the Fisheries Act 1996), the catch limit for those parts of the fishery can be set at a level other than at the Maximum Sustainable Yield. Recently, however, Williams et al. (2009) estimated CAY retrospectively for Golden Bay, Tasman Bay, and the Marlborough Sounds from 1997 to 2008 as part of a project to review the Southern scallop fishery.

There is no enhancement or rotational fishing plan for the Marlborough Sounds, so sustainable harvests need to be set there each year. For the Marlborough Sounds, CAY was calculated using CAY = B_{beg} (1 – exp(–F_{ref})) (Method 1,MFish 2008), where B_{beg} is the projected (i.e., 1 September) recruited meatweight biomass estimate and F_{ref} is $F_{0.1}$. This equation is appropriate where fishing occurs over a short period of the year.

The projected meatweight biomass estimate for the Marlborough Sounds from the 2008 survey, assuming a commercial density threshold of 0.00 or 0.01 scallops per m^2 and a mean meatweight of 13 g, or the resampled meatweight conversion factor (Tuck & Brown 2008), ranged from 263 to 333 t. Using the range of $F_{0.1}$ of 0.55 to 0.63 gives CAY estimates (in tonnes meatweight) as follows:

	$F_{0.1}$ = 0.55	$F_{0.1}$ = 0.63
B_{beg} = 263 t	111 t	123 t
B_{beg} = 333 t	141 t	156 t

This gives a CAY range of 111 to 156 tonnes meatweight at 1 September 2001. These estimates of CAY would have a CV at least as large as that of the estimate of start-of-season recruited biomass, are sensitive to assumptions about dredge efficiency, growth, expected recovery of meatweight from greenweight, commercial threshold densities (i.e., densities of recruited scallops below which it is uneconomic to fish), and relate to the surveyed beds only. The level of risk to the putative Marlborough Sounds scallop substock of fishing at the estimated CAY level cannot be determined.

The actual catch limit (MSCL in Table 2) is usually set at, or close to, the level of recruited relative meatweight biomass as determined in the pre-season abundance survey. This approach usually produces a value in the middle of the CAY range.

4.5 Other yield estimates and stock assessment results

A simulation modelling study of the Challenger 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 not safe, but constant exploitation rate strategies are safe, if the maximum rate is appropriate. Rotational fishing appears to be highly stabilising, even without enhancement; collapses occurred only when the short rotational periods are combined with high intensity. Three-year rotation appears to be safer than two-year rotation. Enhancement appears to improve safety, catch, and biomass, and slightly reduces 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 fishery sectors.

$F_{0.1}$ was estimated for the Challenger fishery from a yield per recruit analysis using a size at recruitment of 90 mm and values of M of 0.40 and 0.50 (Breen & Kendrick 1999). $F_{0.1}$ was 0.553 and 0.631, respectively. For similar values of minimum size and natural mortality, Cryer (1999) estimated $F_{0.1}$ to be 0.469 and 0.508 in the northern scallop fishery. Consequently, $F_{0.1}$ for the Challenger fishery is assumed to be in the range 0.47 to 0.63.

Scallop meatweight recovery (meatweight divided by greenweight) is variable among years and areas, but in general appears to highest in scallops from Golden Bay and lowest from those in Tasman Bay. 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.

5. STATUS OF THE STOCKS

An estimate of current biomass is available for the SCA 7 fishery. Estimates of B_0 and B_{MSY} are not available, and are probably not appropriate reference points for a stock with highly variable recruitment and growth such as scallops.

There has been a substantial decline in the biomass of scallops in both Golden Bay and Tasman Bay since about 2002; current biomass is extremely low in Tasman Bay. In contrast, biomass in the Marlborough Sounds has remained relatively stable over the same period. The cause of the biomass decline in Golden Bay and Tasman Bay is unknown, but it is thought to be associated with factors other than simply the direct removals of scallops by fishing. Indirect effects of fishing and/or environmental factors could have influenced scallop abundance.

Recent SCA 7 landings have been low, and Tasman Bay has been completely closed to commercial harvesting since 2006. Catch has been consistently below the TACC, which is set at a relatively high level under section 14 of the Fisheries Act 1996 because of the rotationally enhanced management strategy. The intended strategy was to open sectors on a three yearly rotational basis, with reseeding at the end of the season. This has not always occurred however, particularly in recent years. It is thought

now that the current practise of 'rotational' fishing on its own is probably not a sufficient strategy for the sustainable management of this fishery.

We do not understand the processes that result in large fluctuations in scallop abundance. To get sustainable yield from such a variable stock it is necessary to alter the catch every year. Management of the Marlborough Sounds region of the SCA 7 fishery and other New Zealand scallop fisheries (SCA1 and SCA CS) has been based on a Current Annual Yield (CAY) approach using $F_{0.1}$ as an appropriate reference point, which is considered both appropriate and conservative.

Table 9: Yield estimates, TACC, and reported landings of scallops in SCA 7 for the most recent fishing season.

					2008–09
Fishstock	Area	MCY	CAY	TACC	Landings
SCA 7	All three areas	–	–	747	104
	Golden Bay	–	133–146	–	76
	Tasman Bay	–	6–7	–	0
	Marlborough Sounds	–	111–156	–	28

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