COCKLES (COC)

(*Austrovenus stutchburyi*)

1. INTRODUCTION

Commercial picking of cockles, *Austrovenus stutchburyi*, is carried out on Snake Bank, Whangarei Harbour (FMA 1), Pakawau Beach, Ferry Point and Tapu Bay in Tasman and Golden Bays (FMA 7), and Papanui and Waitati Inlets, Otago (FMA 3). Cockles were introduced into the QMS on 1 October 2002.

For assessment purposes, individual reports on the major fisheries have been produced separately:

1. Snake Bank, Whangarei Harbour, in COC1A.
2. Papanui Inlet, Waitati Inlet, Purakanui and Otago Harbour, Otago Peninsula in COC 3A.
3. Nelson / Marlborough in COC7A and COC7B.

Information on the general biology of cockles is included below rather than being repeated in the reports for each fishery.

2. BIOLOGY

The cockle, *Austrovenus stutchburyi*, formerly known as *Chione stutchburyi*, is a shallow-burrowing suspension feeder of the family Veneridae. It is found in soft mud to fine sand on protected beaches and enclosed shores around the North and South Islands, Stewart Island and the Chatham Islands (Morton & Miller, 1968). Suspension feeders such as *A. stutchburyi* tend to be more abundant in sediments with a larger grain size. They are also common in eelgrass (e.g., *Zostera* sp.), which often co-occurs with sand flats.

Cockles are found from the lowest high water neap tide mark to the lowest part of the shore; there is some evidence that they may extend to 20 m depth in some areas. Larcombe (1971) suggested that the upper limit is found where submergence is only 3.5 hours per day. *A. stutchburyi* is often a dominant species, and densities as high as 4500/m^2 have been reported in some areas. In Pauatahanui Inlet the biomass has been estimated at 5000 t, 80% of the total intertidal biomass in the Inlet. Cockles may filter 1.6 million cubic metres of water on each tidal cycle at Pauatahanui, with a profound effect on water quality.

Sexes are separate and the sex ratio is usually close to 1:1. Maturity appears to be primarily a function of size rather than age, with sexual maturity occurring at a size of about 18 mm shell length. Spawning extends over spring and summer, and fertilisation is followed by a planktonic larval stage lasting about 3 weeks. Significant depression of larval settlement has been recorded for areas of otherwise suitable substrate from which all live cockles have been removed. This suggests the presence of some conditioning factor.

Quite extensive movements of juveniles and smaller animals have been documented, but individuals >25 mm shell length remain largely sessile, moving only in response to disturbance. Small cockles grow faster than large cockles, but overall, growth is fastest during spring and summer. Growth is slower in the higher tidal ranges and in high density beds. Significant increases in growth rates have been observed for individuals remaining in areas that have been ‘thinned out’ by simulated harvesting.

Given that cockles recruit to the spawning biomass at ~18 mm shell length, but do not recruit to commercial or non-commercial fisheries until closer to 30 mm shell length, there is some protection for the stock against egg overfishing, especially as the Snake Bank and Papanui and Waitati Inlet stocks are probably not isolated as far as recruitment of juveniles is concerned. However, this generality should be treated with some caution, given that some population of adults seems to be required to stimulate settlement of spat.

Natural mortality arises from a number of sources. Birds are a major predator on cockles (up to about 23 mm shell length); however, they appear to have little impact on cockle abundance. Other predators include crabs and whelks. Cockles are also killed after being smothered by sediments shifted during storms or strong tides.

Experimental work on Snake Bank led to estimates of absolute mortality of 17–30% per annum, instantaneous mortality (M) of 0.19–0.35, with a midpoint of M = 0.28. The estimated mortality rates for cockles of >30 mm shell length were slightly greater at 19–37% per annum, (M of 0.21–0.46 with a midpoint of 0.33). This higher estimate was caused by relatively high mortality rates for cockles of >35 mm shell length and, as these are now uncommon in the population, M = 0.30 (range 0.20–0.40) was assumed for yield calculations.

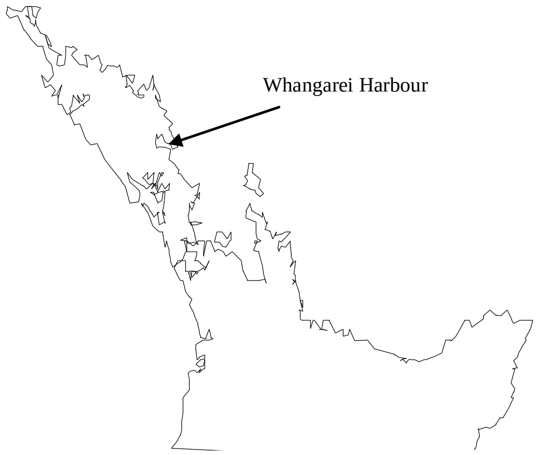
Studies in 1992 and 1993 at Snake Bank to estimate growth rate by sequential length frequency analysis resulted in an estimate of K = 1.10. Such a rate indicates a fairly rapid growth (about 2 years) to the size of interest to both commercial and amateur fisheries (about 30 mm). Further work at Snake Bank in 1996 using length frequency distributions from 1991–96 confirmed the rapid growth rate with an estimate of K = 1.02. This rate is much faster than shown in previous Snake Bank studies (Martin, 1984), where up to 4 or 5 years could be taken for cockles to attain a size of 30 mm. The increased growth rate may be a result of the lower densities of cockles on the bank in recent years.

Growth in Papanui and Waitati Inlets, Purakanui and Otago Harbour (Bed 1) was examined by Breen et al. (1999). They found that notched clams did not exhibit significant growth when recovered after one year, and modes in the length frequency distributions did not shift when measured over four sampling periods within a year. They concluded that it was unlikely that average growth is really as slow as the results indicated, but there may be high interannual variability in growth.

The Snake Bank work also showed moderate differences among years in the level of recruitment of juveniles to the population. The variability of recruitment was estimated as $\sigma_R = 0.41$ using all available data (1983–1996) but as $\sigma_R = 0.31$ using data only from those years since the fishery has been considered to be fully developed (1991–96). Given the variability of most shellfish populations and the shortness of the time series, this is probably an underestimate of the real variability of recruitment in the Snake Bank population.

COCKLES (COC 1A) Snake Bank (Whangarei Harbour)

(*Austrovenus stutchburyi*)



1. FISHERY SUMMARY

(a) Commercial fisheries

Commercial picking in Whangarei Harbour began in the early 1980s and is now undertaken year round, with no particular seasonality. Reported landings of cockles from Snake Bank from 1986/97 are shown in Table1. No reliable catch information is available before 1986, although it is thought that over 150 t of Snake Bank cockles were exported in 1982. There was probably some under reporting of landings prior to 1986, and this may have continued since. Effort and catch information for this fishery has not been adequately reported by all permit holders in the past, and there are problems interpreting the information that is available. Landed weights reported on CELRs only summed to between 52 and 91% of weights reported on LFRRs during the years 1989–90 to 1992–93. No CPUE data are therefore presented for this fishery.

Table 1: Reported commercial landings and catch limits (t greenweight) of cockles from Snake Bank since 1986–87 (from QMR/MHR records). Prior to COC 1A entering the QMS, the fishery was restricted by daily catch limits which summed to 584 t in a 365 day year, but there was no explicit annual restriction. A TACC of 346 t was established in October 2002 when COC 1A entered the QMS. * The figure of 566 t for 1993–94 may be unreliable.

Fishing year	Landings (t)	Limit (t)	Fishing year	Landings (t)	Limit (t)
1986–87	114	584	1996–97	457	584
1987–88	128	584	1997–98	439	584
1988–89	255	584	1998–99	472	584
1989–90	426	584	1999–00	505	584
1990–91	396	584	2000–01	423	584
1991–92	537	584	2001–02	405	584
1992–93	316	584	2002–03	237	346
1993–94	*566	584	2003–04	218	346
1994–95	501	584	2004–05	151	346
1995–96	495	584			

COC 1A was introduced to the QMS in October 2002 with a TAC of 400 t; comprising a customary allowance of 25 t, a recreational allowance of 25 t, an allowance for other fishing related mortality of 4 t, and a TACC of 346 t. Prior to this there were eight permit holders, each allowed a maximum of 200 kg (greenweight) per day by hand-gathering. If all permit holders took their quota every day a maximum of 584 t could be taken in a 365 day year. Landings of less than 200 t prior to 1988–89 rose to 537 t in 1991–92 (about 92% of the theoretical maximum). Landings for the 1992–93 year were much reduced (about 316 t) following an extended closure due to biotoxin contamination, but the fishery subsequently took 400 t to 500 t annually until 2002. Landings have declined markedly since introduction of the fishery into the QMS. Landings in 2004–05 (151 t) were the lowest recorded since 1987–88. There is no minimum legal size for cockles; however, the mean length of the commercial harvest is about 29.5 mm and cockles smaller than 25 mm are less attractive to both commercial and non-commercial fishers.

Snake Bank is not the only cockle bed in Whangarei Harbour, but it is the only bed open for commercial fishing. There are several other cockle beds in the harbour, some on the mainland and some on other sandbanks, notably MacDonald Bank. Fishing on these other beds is exclusively non-commercial.

(b) Recreational fisheries

The recreational fishery is harvested entirely by hand digging, and large cockles (30 mm maximum shell length or greater) are preferred. In 1993–94, amateur harvest in QMA 1 was estimated by telephone and diary surveys to be approximately 2.14 million cockles (Teirney et al., 1997). National recreational diary surveys undertaken in 1996 and 2000 estimated the number of cockles taken in QMA 1 to be 569,000 (Bradford, 1998) and 2,357,000 (Boyd & Reilly 2004). It is not clear to what extent these estimates include customary take. An assumed mean weight of 25 g (for cockles >30 mm recovered from Snake Bank during the 1992 biomass survey) leads to an estimated QMA 1 harvest of 55 t in 1993–94 (about 1 t of which came from Whangarei Harbour), and 14 t QMA 1 recreational cockle harvest in 1996 (Table 2). The Marine Recreational Fisheries Technical Working Group (RTWG) reviewed the harvest estimates the national surveys and concluded that the estimates from 1996 were unreliable due to a methodological error. While the same error did not apply to the subsequent national surveys undertaken in 199/200 and 2000/2001, the estimates for some fishstocks were considered to be unbelievably high. No mean harvest weight for pipi was available. No recreational harvest estimates specific to the Snake Bank fishery are available.

Table 2: Estimated numbers of cockles harvested by recreational fishers in QMA1, and the corresponding harvest tonnage. Figures were extracted from a telephone and diary survey in 1993–94, and the national recreational diary survey in the 1996 and 1999/2000 and 2000/2001.

Year	QMA 1 harvest (millions of cockles)	QMA 1 harvest (t)	*c.v.* (%)	Whangarei harvest (t)
1993–94	2.14	55	18	1
1996	0.57	14	18	-
1999/2000	2.40	59	24	-
2000/2001	2.33	58	27	

(c) Maori customary fisheries

In common with many other intertidal shellfish, cockles are very important to Maori as a traditional food. However, no quantitative information on the level of customary take is available.

(d) Illegal catch

No quantitative information on the level of illegal catch is available.

(e) Other sources of mortality

No quantitative information on the level of other sources of mortality is available. It has been suggested that some methods of harvesting such as brooms, rakes and “hand sorters” cause some mortality, particularly of small cockles, but this proposition has not been tested.

2. STOCKS AND AREAS

Little is known of the stock boundaries of cockles. Given the relatively extended planktonic larval phase, many populations may receive spat fall from other nearby populations and may, in turn, provide spat for these other areas. Where studies have been made, differences in growth and mortality rates have been demonstrated for cockles within and between different beds. These differences may simply reflect environmental differences in temperature and tidal elevation. In the absence of more detailed knowledge, therefore, the commercial fishery area is managed as a discrete population.

3. STOCK ASSESSMENT

Stock assessment for Snake Bank cockles has been conducted annually using absolute biomass surveys, yield per recruit (YPR), and spawning stock biomass per recruit (SSBPR) modelling. A length-based stock assessment model is being developed but the dynamics of the population are proving very difficult to replicate.

(a) Estimates of fishery parameters and abundance

Estimated and reference fishing mortality rates, and estimates of total mortality are given for Snake Bank in Table 3. $F_{0.1}$ and F_{max} were estimated using a yield per recruit (YPR) model using quarterly (rather than the more usual annual) increments and critical sizes (rather than ages) for recruitment to the spawning stock and to the fishery. The following input information was used: growth rate parameters from a MULTIFAN analysis of 1991–96 length frequencies; an estimate of M = 0.30 (range 0.20–0.40) from a tagging study in 1984; length weight data from 1992, 1995 and 1996 combined; size at maturity of 18 mm; and size at recruitment of 30 mm from an analysis of fisher selectivity. For the base case analysis, $F_{0.1}$ = 0.41 and F_{max} = 0.62. These estimates were neither sensitive to the length weight regression used, nor to the value of M chosen ($F_{0.1}$ = 0.38–0.45, and F_{max} = 0.56–0.69, for M = 0.20–0.40), but were more sensitive to the assumed length at recruitment ($F_{0.1}$ = 0.34 and F_{max} = 0.52 for L_{recr} = 25 mm).

Table 3: Estimates of fishery parameters.

Population and years	**Estimate**	**Source**
1. Estimated Fishing Mortality (F_{est}, recruited size classes only)		
Snake Bank, 1991–92	1.55	Cryer (1997)
Snake Bank, 1992–93	0.62	Cryer (1997)
Snake Bank, 1995–96	0.50	Cryer (1997)
Snake Bank, 1991–96	0.89	Cryer (1997)
2. Reference Fishing Mortality (F_{ref}, recruited size classes only)		
Snake Bank, $F_{0.1}$	0.41	Cryer (1997)
Snake Bank, F_{max}	0.62	Cryer (1997)
Snake Bank, $F_{50\%}$	4.52	Cryer (1997)
3. Total Instantaneous Mortality (Z, all size classes)		
Snake Bank, 1992–93	0.46	Cryer & Holdsworth (1993)

(b) Biomass estimates

Biomass estimates for the Snake Bank cockle population from 1982–1996 were made using grid surveys, and surveys from 1998 have used a stratified random approach (Table 4). The data given here differ from those in reports prior to 1997 because the assumptions made when estimating biomass have changed. The surveys conducted in 1985 and 1991 did not cover the whole area of the bank, and results from these surveys have been corrected in the table by assuming that the cockle population occupied the same area of the bank in these years as it did in 1982 (the first and largest survey). For the estimation of variance for the grid based surveys it was assumed that samples were taken at random from the bank, although variance estimators not requiring this assumption gave very similar results in 1995 and 1996. The post 1997 surveys also incorporated a large area of low density cockles not included in previous surveys, although this adds only a small tonnage of biomass to the total figure. In 1998 and 2000, biomass surveys were undertaken at MacDonald Bank using a stratified random approach (Table 5). Cryer et al. (2003) reported biomass estimates for several locations in Whangarei Harbour in 2002, including a new MacDonald Bank stratum (Table 5).

Between the start of the commercial fishery in 1982 and the survey in 1992, there was a consistent decline in the biomass of large cockles (>35 mm shell length) on Snake Bank. The biomass of these large individuals averaged 10.5% of its virgin level between 1991 and 1999 (range 9–17%). A decrease in the proportion and biomass of large, old individuals can be expected with the development of a commercial fishery, and the biomass of “acceptable” or “recruited” cockles (>30 mm shell length) had averaged about 43% (range 33–63%) of its 1982 level over this same period. Instances of highly prolific year-classes led to peaks in recruited biomass in 1995, 1999, 2003 and 2005. However, it is noted that each of these peaks is lower than the previous peak.

Virgin biomass, B_0, is assumed for the purpose of this assessment to be equal to the estimated biomass of cockles >30 mm shell length in 1982 (2340 t). This biomass was estimated using length frequency distributions, a length weight regression, and a direct estimate of the biomass of cockles >35 mm shell length in 1982 (1825 t).

The biomass that will support the maximum sustainable yield, B_{msy}, is not known; however, current biomass (of cockles 30 mm or more shell length) is 34% of B_0 (792/2340 t).

Table 4: Estimates of biomass (t) of cockles on Snake Bank for surveys (*n*, number of sites) between 1982 and 2006. Biomass estimates marked with an asterisk (*) were made using length frequency distributions and length-weight regressions, others by direct weighing of samples sorted into three size classes. Two alternative biomass estimates are presented for 1988 because the survey was abandoned part-way through, “a” assuming the distribution of biomass in 1988 was the same as in 1991, and “b” assuming the distribution in 1988 was the same as in 1985. The 2001 result comes from the second of two surveys, the first having produced unacceptably imprecise results.

Year	***n***	**Total**		**< 30 mm SL**		**≥ 30 mm SL**		**≥ 35 mm SL**	
		Biomass	***c.v.***	**Biomass**	***c.v.***	**Biomass**	***c.v.***	**Biomass**	***c.v.***
1982	199	2 556	–	*216	–	*2 340	–	1 825	~ 0.10
1983	187	2 509	–	*321	–	*2 188	–	1 700	~ 0.10
1985	136	2 009	0.08	*347	~0.10	1 662	0.08	1 174	~ 0.10
1988 a	53	–	–	–	–	1 140	> 0.15	–	–
1988 b	53	–	–	–	–	744	> 0.15	–	–
1991	158	1 447	0.09	686	0.10	761	0.10	197	0.12
1992	191	1 642	0.08	862	0.10	780	0.08	172	0.11
1995	181	2 480	0.07	1 002	0.09	1 478	0.07	317	0.12
1996	193	1 755	0.07	959	0.09	796	0.08	157	0.11
1998	53	2 401	0.18	1 520	0.20	880	0.17	114	0.20
1999	47	3 486	0.12	2 165	0.12	1 321	0.14	194	0.32
2000	50	1 906	0.23	1 336	0.24	570	0.25	89	0.32
2001	51	1 405	0.17	970	0.18	435	0.17	40	0.29
2002	53	1 618	0.14	1 152	0.15	466	0.19	44	0.29
2003	60	2 597	0.11	1 567	0.15	1 030	0.12	121	0.14
2004	65	1 910	0.15	1 364	0.17	546	0.14	59	0.22
2005	57	2 592	0.18	1 625	0.18	967	0.20	111	0.20
2006	57	2 412	0.13	1 620	0.15	792	0.13	103	0.20

Table 5: Biomass estimates (t) and approximate *c.v.*s by shell length size classes for cockles on MacDonald Bank. *n* = the number of samples in the survey.

Year	***n***	**Total**		**< 30 mm SL**		**≥ 30 mm SL**		**≥ 35 mm SL**	
		Biomass	***c.v.***	**Biomass**	***c.v.***	**Biomass**	***c.v.***	**Biomass**	***c.v.***
1998	33	6 939	0.19	5 261	0.18	1 678	0.31	128	0.41
2000	30	6 037	0.28	4 899	0.29	1 137	0.30	34	0.37
2002	24	2 548	0.12	2 010	0.14	538	0.36	61	0.46

(c) Estimation of Maximum Constant Yield (MCY)

As estimates of B_{beg} are available, CAY results are presented in preference to MCY.

(d) Estimation of Current Annual Yield (CAY)

CAY can be estimated for the current year based on a survey conducted in 2006. As fishing is conducted year round on Snake Bank, the full version of the Baranov catch equation is appropriate (Method 1, Sullivan et al., 2005), where:

Using $F_{0.1}$,

$$\text{CAY} = F_{0.1} / (F_{0.1}+M) \times (1 - e^{-(F0.1+M)}) \times B_{beg}$$
$$= 0.41 / 0.71 \times 0.5084 \times 792$$
$$= 232 \text{ t}$$

Using F_{max}, $\text{CAY} = F_{max} / (F_{max}+\text{M}) \times (1 - e^{-(Fmax+M)}) \times B_{beg}$
$= 0.62 / 0.92 \times 0.6015 \times 792$
$= 321$ t

This includes non-commercial catch. A range of sizes is taken commercially, starting from about 25 mm and averaging 29.5 mm; CAY estimates are sensitive to the assumed size at recruitment to the fishery (Table 6). The level of risk to the stock by harvesting the population at the estimated CAY value cannot be determined.

Table 6: Sensitivity of biomass and CAY estimates to shell length at recruitment (L_{recr}) for Snake Bank cockles.

L_{recr} (mm)	B_{beg} (2006) (t)	M	$F_{0.1}$	CAY (t)
20	1 779	0.3	0.30	401
25	1 584	0.3	0.34	398
28	1 194	0.3	0.38	329
30	792	0.3	0.41	232
35	103	0.3	1.00	58

(e) Other factors

Biomass and yield estimates will differ for different sizes of recruitment. Maori and recreational fishers prefer cockles of 30 mm shell length and greater whereas commercial fishers currently prefer cockles of 25 mm and greater. Therefore, yield has been estimated for sizes of recruitment between 25 and 30 mm. As cockles become sexually mature at around 18 mm, using a size of recruitment between 25 mm and 30 mm should provide some protection against egg overfishing under most circumstances. However, using the smaller size of recruitment to estimate yield will confer a greater risk of overfishing.

As the Snake Bank cockle population may receive spat from spawnings in other parts of Whangarei Harbour, it may not be realistic to assume that the Snake Bank stock is discrete and that reduced egg production (as a result of heavy fishing mortality on medium and large sized individuals) would necessarily lead to recruitment overfishing. Spawning stock biomass per recruit (SSBPR) analysis suggests that $F_{50\%} > F_{max} > F_{0.1}$ ($F_{50\%}$ is that fishing mortality which would lead to egg production from the population at equilibrium being half of egg production from the virgin stock), except where the size at recruitment is reduced to 25 mm. Substantial reduction of egg production is therefore unlikely if fishing mortality is restrained to within $F_{0.1}$ or F_{max}, and the fishery concentrates on cockles >30 mm in length.

However, it has been demonstrated for this bank that recruitment of juvenile cockles can be reduced by the removal of a large proportion of adult cockles from a given area of substrate. Conversely, there did not seem to be heavy recruitment to the population during the years when adult biomass was close to virgin (1982–85). This would suggest that there is some optimal level of adult biomass to facilitate recruitment, although its value is not known. It would appear prudent, therefore, to exercise some caution in reducing the biomass of adult cockles. If adult biomass is driven too low, then recruitment overfishing of this population could still occur despite high levels of egg production. In addition, sporadic recruitment of juveniles will probably lead to a fluctuating biomass, suggesting that a CAY approach may be more appropriate than a constant catch approach.

The stock assessment is based on a model which assumes equilibrium conditions and the fishing mortality rates calculated by this model are applied in a manner which assumes that the biomass is in equilibrium. These assumptions are very unlikely to be met and this form of management will lead to overharvest if the stock is below optimum level and will lead to underharvest when it is above optimum level. It may be possible to model these populations dynamically using a length-based approach; and that such models should lead to much more robust estimates of available yield.

A length-based stock assessment model developed in 2000 (Breen 2000) allowed for more of the natural variability of the system to be incorporated in the stock assessment. This first model did not adequately capture the detail of cockle dynamics. Further work in 2002 (McKenzie et al. 2003) did not resolve all of these problems and substantial conflict remained in the model.

Additional information on growth and the length frequency of cockles taken by the fishery was collected in 2003 and 2004 and updated in the model. Several additions and enhancements to the model were also made in an attempt to resolve the above-mentioned conflict (Cryer et al. 2004, Watson et al. 2004). As a result, the model showed an improved fit to the observed data. However, there still remained some conflict, primarily relating to annual variability in the growth increment data, in which only two years of observations were available (2002 and 2004). This was thought to be due to the existence of annual variability in recruitment, and possibly mortality, which are presently not explicitly modelled. Watson et al. (2004) therefore concluded that no further development of the model should be undertaken for 3–5 years, and that resources be concentrated more on data collection, and in particular, growth and recruitment data. Consequently, a tag-recapture experiment was started in March 2005, and another large sample of cockles was notch-tagged and released in March 2006. Tagged individuals are being recovered and measured on a quarterly basis, and preliminary results suggest there may be strong seasonal variability in growth.

Although the Shellfish Working Group considered that the development of a length-based stock assessment model would be of considerable benefit to the stock assessment, the problems with the model were such that the current approach used to estimate yield for this fishery that had been agreed to by the Shellfish Fishery Assessment Working Group since 1992 would remain.

4. STATUS OF THE STOCKS

The absolute recruited biomass of cockles (>30 mm shell length) on Snake Bank declined from over 2000 t in the early 1980s to about 700 t in the early 1990s. It has since fluctuated between about 500 and 1500 t without apparent trend, falling to particularly low levels (<500 t) in 2001 and 2002. The recruited biomass in 2006 was 792 t, and length frequency distributions suggest that recent recruitment has been above average. The current TACC is higher than the estimated CAY (232 t) unless a very small size at recruitment is assumed, suggesting that fishing at the level of the current TACC is not likely to be sustainable in the long term. However, current reported landings (151 t) are less than both the TACC and the estimated CAY. Annual surveys are being used to monitor the stock closely, but it is not known if current catch limits will allow the stock to move towards a size that will support the MSY.

Table 7: Summary of yields, catch limits, and reported landings (t) of Snake Bank cockles for the most recent fishing year.

Fishstock	CAY	2004–2005 Actual TACC	2004–2005 Reported Landings
COC 1A	232	346	151

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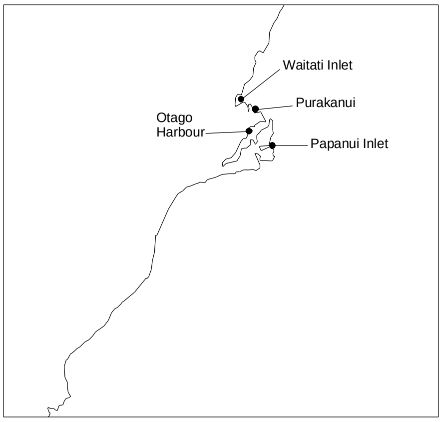
COCKLES (COC 3A) Otago Peninsula

(*Austrovenus stutchburyi*)



1. FISHERY SUMMARY

Cockles are fished commercially only in Papanui and Waitati Inlets, but they are present in other places around the Otago Peninsula. Commercial landings from Papanui and Waitati Inlets are shown in Table 1. A limit of 104 t was in effect for Papanui and Waitati Inlets combined from 1986–87 through 1991–92. From 1992–93 to 1998–99, the catch limits were 90 t for Papanui Inlet and 252 t for Waitati Inlet. In April 2000, the catch limits were increased to 427 t for Papanui Inlet and 746 t for Waitati Inlet.

Table 1: Reported landings (t) of cockles from Papanui and Waitati Inlets, Otago, combined (FMA 3), from 1986–87 to 2004-05 based on Licensed Fish Receiver Returns (LFRR). Catch split provided by Southern Clams Ltd (Stewart 2005).

Year	Papanui (t)	Waitati (t)	Total (t)
1986–87	14		14
1987–88	8		8
1988–89	5		5
1989–90	25		25
1990–91	90	16	106
1991–92	90	14	104
1992–93	90	92	182
1993–94	90	109	199
1994–95	90	252	342
1995–96	90	252	342
1996–97	90	252	342
1997–98	90	252	342
1998–99	90	293	383
1999–00	118	434	552
2000–01	90	606	696
2001–02	49	591	640
2002-03	52	717	767
2003-04	73	689	762
2004-05	91	709	800

Commercial fishing in Papanui and Waitati Inlets began in 1983. There has been no size limit. In 1992, 35 mm shell length was the minimum size for commercial cockles; however, commercial fishers currently target ≥30 mm cockles, therefore 30 mm is used as the effective minimum size in yield calculations. CPUE data are available for this fishery. COC 3A was introduced to the Quota Management System in October 2002 with a TAC of 1,500 t; comprising a customary allowance of 10 t, a recreational allowance of 10 t, an allowance for other fishing related mortality of 10 t, and a TACC of 1,470 t.

(b) Recreational fisheries

Cockles are taken by recreational fishers in many areas of New Zealand. The recreational fishery is harvested entirely by hand digging. Relatively large cockles are preferred, but ≥30 mm cockles are taken.

Amateur harvest levels in FMA 3 were estimated by telephone and diary surveys in 1993–94 (Teirney et al., 1997), 1996 (Bradford, 1998) and 2000 (Boyd & Reilly 2004), Table 2. COC3A is a smaller area within MA 3. Harvest weights are estimated using an assumed mean weight of 25 g (for cockles >30 mm). The estimates for 1993-94 and 1996 are considerably less than the 2000 estimate and are considered to substantially underestimate the recreational harvest. The 2000 estimate is considered to be a more reliable estimate of absolute harvest.

Table 2: Estimated numbers of cockles harvested by recreational fishers in FMA 3, and the corresponding harvest tonnage. Figures were extracted from a telephone and diary survey in 1993–94, and the national recreational diary surveys in 1996 and 2000.

Fishstock	Survey	Harvest (N)	% c.v.	Harvest (t)
1993–94				
FMA 3	South	106 000	51	2.7
1996				
FMA 3		144 000	–	3.6
2000				
FMA3		1476000	45	36.9

(c) Maori customary fisheries

Many intertidal bivalves, including cockles, are very important to Maori as traditional food, particularly to Huirapa and Otakou Maori in the Otago area. Tangata tiaki issue customary harvest permits for cockles in Otago. The number of cockles harvested under customary permits is given in Table 3.

Table 3: Number of cockles harvest under customary fishing permits

Year	Number of cockles
1998	750
1999	0
2000	1 109
2001	1 090
2002	0
2003	2 750
2004	4 390
2005	5 699

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(d) Illegal catch

No quantitative information is available on the magnitude of illegal catch but it is thought to be insignificant.

(e) Other sources of mortality

No quantitative information is available on the magnitude of other sources of mortality. It has been suggested that some harvesting implements, such as brooms, rakes, “hand-sorters”, bedsprings and “quick-feeds” cause some incidental mortality, particularly of small cockles, but this proposition has not been scientifically investigated. The incidental mortality from mechanical digging is thought to be relatively small. High-grading of cockles is also practised, with smaller sized cockles being returned to the beds. The mortality from this activity is unknown, but is likely to be low.

2. STOCKS AND AREAS

Little is known of the stock boundaries of cockles. No specific studies of stock structure in cockles are available. Recent assessments have considered the commercially fished areas to be “discrete populations”.

Cockles have larvae that spend about three weeks in the plankton. As in similar marine invertebrates that are essentially sessile after settlement, the planktonic phase may function as a dispersal mechanism. Populations such as those surveyed near Dunedin may receive spat from other nearby populations and may, in turn, provide spat for other areas.

3. STOCK ASSESSMENT

Stock assessments for Papanui Inlet and Waitati Inlet have been conducted using absolute biomass surveys, yield-per-recruit analyses, and Method 1 for estimating CAY (Annala et al., 2002). Breen et al (1999) also estimated biomasses and yields for Otago Harbour and Purakanui.

(a) Estimates of fishery parameters and abundance

A project to estimate growth and mortality in Papanui and Waitati Inlets, Purakanui and Otago Harbour (Bed 1) was undertaken in the late 1990s. Notched clams did not exhibit significant growth when recovered after one year, and modes in the length frequency distributions did not shift when measured over four sampling periods within a year (Breen et al., 1999).

In 2004 yield-per-recruit modelling was conducted for Papanui and Waitati inlets separately (Stewart 2005). For this the parameters L_∞ = 40.296 mm, K = 0.311/yr, t_0 = 0.0 mm, M = 0.30/yr, size at recruitment = 30 mm, a = 0.00023172, b = 3.1375, as used by Wing *et al.* (2002), were used again. For both inlets, $F_{0.1}$ was estimated for M = 0.1, 0.2 and 0.3/yr respectively.

(b) Biomass estimates

Biomass surveys have been undertaken periodically in COC 3 since 1984. A major difference in methods used to extract biomass values for different size classes exists between previous surveys. Wildish (1984) and Stewart et al. (1992) separated cockles by sieving into three size classes. Breen *et al.* (1999) measured random samples of cockles from each inlet to calculate length-weight relationships. The first method only allows estimation of biomass from predetermined size classes. By calculating size structure of populations using length to weight data a more flexible approach is allowed where data can be matched to current commercial needs as well as to future survey results. The 1998 survey used random samples from each inlet to calculate length to weight relationships (Breen *et al.* 1999). This method was once again used in the 2002 survey (Wing *et al.,* 2002). In the 2004 survey random samples from each shellfish bed were weighed and their longest axis measured (Stewart 2005). These data were then used to generate length to weight relationships.

In Table 4, estimates of biomass from previous surveys are compared with the 2004 survey (Stewart 2005). In Papanui Inlet the biomass of juvenile cockles (>2–18 mm) has declined from the 1992 survey to 2002, but has since risen to above 2002 figures. The biomass of adults (19–34 mm) has declined from 3435 t in 1998 to 2414 t in 2004. The biomass of cockles ≥30 mm in 2002 was similar to that estimated in 1998 and remains similar at 3676 t in 2004. The biomass of the largest adults (≥35 mm) has decreased only slightly since 2002. In Waitati inlet the biomass of juveniles (256 t) in 2004 remains well below the 1210 t figure from the 1992 survey. The 2004 biomass of adults (19–34 mm) was higher than in 2002 but less than the 1998 figure. The biomass of larger-sized adults (i.e., the ≥30) was higher than previous surveys, but the ≥35 mm size class has remained about the same.

Table 4: Current (±95% CI) and previous biomass estimates from Papanui Inlet and Waitati Inlet (Wildish, 1984; Stewart *et al*., 1992; Breen *et al*., 1999; Wing *et al.*, 2002; Stewart 2005). Area of current commercial beds, Papanui Inlet = 815,811 m^2

Papanui Inlet

Size Class	**1984**	**1992**	**1998**	**2002**	**2004** Total inlet	**2004** Commercial area
>2 to 18mm (juveniles)	65	139	33	16.9 ± 1.7	36.01±2.16	13.25±1.25
19 to 34mm (adults)	3705	3721	3435	1969.6 ± 191.6	2414.89±150.7	824.75±87.91
≥35mm	2370	1706	2231	2578.8 ± 252.1	2301.23±271.89	1847.14±208.4
≥30mm			3990.2	3859.7 ± 364.6	3676.81±367.4	2419.61±271.29
Total (t)	6140	5567	5699	4565.4 ± 423.8	4752.13±424.76	2685.14±297.59

Waitati Inlet. Area of current commercial beds, Waitati Inlet = 943,986 m^2

Size Class	**1984**	**1992**	**1998**	**2002**	**2004** Total inlet	**2004** Commercial area
>2 to 18mm (juveniles)	619	1210	304	153.1 ± 20.4	256.96±13.56	77.43±4.24
19 to 34mm (adults)	7614	5198	8519	6652.6 ± 651.9	7272.4±403.43	2735.16±128.92
≥35mm	3844	4620	4381	4297.5 ± 297.9	4534.7±507.85	3872.43±383.77
≥30mm			7235	7183.1 ± 462.7	7992.64±720.47	5612.2±6.81
Total (t)	12080	11027	13204	11103.1 ± 847.8	12064.1±924.86	6685.02±516.93

(c) Estimates of Maximum Constant Yield (MCY)

Although estimates of B_{beg} are available, MCY results for Papanui and Waitati Inlets are also presented here (Table 5). MCY was estimated using Method 1 ($MCY = 0.25\ F_{0.1}\ B_0$) of Annala *et al.* (2002) and the 2004 biomass estimates. For each of these locations MCY was estimated for both the entire inlet area and a subset area where the commercial fishery has been operating for the past several years.

Table 5: MCY estimates (±95% CI) for COC 3 cockles ³30 mm shell length.

Papanui whole inlet
B_0 = 4119.38

M	**F0.1**	**MCY**	**Lower**	**Upper**
0.2	0.2321	213.35	192.03	234.67
0.3	0.3412	313.63	282.29	344.97
0.4	0.4767	438.18	394.40	481.97

Papanui current commercial area
B_0 = 2453.62

M	**F0.1**	**MCY**	**Lower**	**Upper**
0.2	0.2321	140.40	124.66	156.14
0.3	0.3412	206.39	183.25	229.53
0.4	0.4767	288.36	256.03	320.69

Waitati whole inlet
B_0 = 9399.11

M	**F0.1**	**MCY**	**Lower**	**Upper**
0.2	0.2321	463.77	421.97	505.58
0.3	0.3412	681.77	620.32	743.23
0.4	0.4767	952.52	866.66	1038.38

Waitati current commercial area
B_0 = 6080.69

M	**F0.1**	**MCY**	**Lower**	**upper**
0.2	0.2321	325.65	298.36	352.93
0.3	0.3412	478.72	438.61	518.83
0.4	0.4767	668.83	612.79	724.88

(d) Estimates of Current Annual Yield (CAY)

For both Papanui Inlet and Waitati Inlet, CAY (Table 5) was estimated using Method 1 ($CAY = (F_{0.1}/Z)\ (1\text{-}exp(\text{-}Z))B_{beg}$) (Annala *et al.*, 2002) and the 2004 biomass estimates. For each of these locations CAY was estimated for both the entire inlet area and a subset area where the commercial fishery has been operating for the past several years.

Table 6: CAY estimates (±95% CI) for COC 3 cockles ³30 mm shell length.

Papanui whole inlet
B_{beg} = 4119.38

M	F0.1	CAY	Lower	Upper
0.2	0.2321	776.34	705.68	847.00
0.3	0.3412	1037.58	943.14	1132.01
0.4	0.4767	1307.75	1188.73	1426.77

Papanui current commercial area
B_{beg} = 2453.62

M	F0.1	CAY	Lower	Upper
0.2	0.2321	462.41	410.24	514.58
0.3	0.3412	618.01	548.29	687.74
0.4	0.4767	778.93	691.05	866.81

Waitati whole inlet
B_{beg} = 9399.11

M	F0.1	CAY	Lower	Upper
0.2	0.2321	1771.36	1632.73	1909.99
0.3	0.3412	2367.42	2182.14	2552.70
0.4	0.4767	2983.87	2750.34	3217.39

Waitati current commercial area
B_{beg} = 6080.69

M	F0.1	CAY	Lower	Upper
0.2	0.2321	1145.97	1055.52	1236.39
0.3	0.3412	1531.59	1410.71	1652.46
0.4	0.4767	1930.39	1778.04	2082.71

The level of risk to the stock of using the CAY estimates above has not been determined. The Shellfish Working group notes that the CAYs do not take into account the different productivity between inlets. Estimates of productivity should be made in future surveys based on survey biomass estimates and catch data.

(e) <u>Other factors</u>

Commercial, customary and recreational fishers target different sized cockles. Biomass and yield estimates will differ for different sizes of recruitment to the fishery. Maori and recreational fishers prefer larger cockles (>45 mm shell length and greater) whereas commercial fishers currently prefer cockles of around 28-34 mm. Estimates of yields have been estimated for size of recruitment at ≥30 mm; however, these estimates do not consider multiple fisheries preferring different sized cockles. Depending on the management approach taken in the future in COC 3, the appropriateness of the current methods to estimate yield may need to be reviewed.

The yield estimates use information from yield-per-recruit analyses that assume constant recruitment, and constant growth and mortality rates. Yield estimates will be improved when growth, mortality and recruitment variation are better known.

As cockles become sexually mature at around 18 mm, using a size of recruitment of 30 mm should provide some protection against egg overfishing under most circumstances. Certainly the increase in the biomass of small cockles (<2->19mm) seen in both inlets in 2004 suggests that the very poor recruitment observed by Wing *et al* (2002) may have been due to natural variability, and supports the conjecture that significant recruitment might occur only sporadically in the Otago fishery, as suggested by John Jillett (pers. comm.) and Breen *et al.* (1999). The possibility that fishing has an effect on recruitment remains an unknown.

In other cockle fisheries it has been shown that recruitment of juvenile cockles can be reduced by the removal of a large proportion of adult cockles from a given area of substrate. This would suggest that there is some optimal level of adult biomass to facilitate recruitment, although its value is not known. To date it has not been determined whether the cockles being targeted by commercial harvesting in the Otago fishery comprise the bulk of the spawning stock or if disturbance of the cockle beds is influencing settlement.

The distribution of very small size classes (2-10mm) across the various beds is variable. The fact that very small shellfish are notably absent, or present in only low numbers, on Beds C and E+ in Papanui Inlet and on Bed G in Waitati suggests that heavily fished beds may have low numbers of recruits. This is, however, by no means consistent, with other commercial beds having reasonably high numbers of recruits that are comparable with non-commercially harvested beds. A comparison of the size/frequency histograms with fishing history for each bed would be a worthwhile exercise and may reveal more. The fact that the relationship between spawning stock and recruitment in this fishery is poorly understood remains a concern.

The possibility that fishing has an effect on recruitment does, however, remain an unknown. To date it has not been determined whether the cockles being targeted by commercial harvesting comprise the bulk of the spawning stock or if disturbance of the cockle beds is influencing settlement.

The increase in biomass recorded in the current survey suggests that the current level of harvest is sustainable or may tolerate a slight increase. What is not known is if the increase in biomass is a long-term trend or simply the result of natural variability, possibly linked to sporadic recruitment.

The impacts of the illegal catch, the Maori traditional catch and incidental handling mortality are unknown, although illegal catch is thought to be insignificant. The impacts of the recreational fishery are probably minor compared with those from the commercial fishery.

4. STATUS OF THE STOCKS

In Papanui Inlet the biomass of juvenile (>2–18 mm) cockles has more than doubled relative to 2002 numbers. The biomass of adult (19–34 mm) cockles has also increased over 2002 figures but lies below 1992 and 1998 levels. The biomass of large cockles (≥30mm class and ≥35mm class) has decreased from 2002. There is, however, a new cohort of relatively small (<10 mm) cockles evident across most of the beds in Papanui.

In Waitati Inlet the biomass of juvenile cockles (>2–18 mm) has increased from 2002 levels but remains well below figures for 1992. The biomass of adult (19–34 mm) cockles has increased over 2002 levels but is lower than that recorded in 1998. The biomass of large adult (≥35 mm) cockles has remained at a similar level since 1992, but the biomass of cockles ≥30 mm has risen through time.

No size limit has been set for COC 3; however, commercial fishers currently target 28-34 mm cockles and >38 mm. In both inlets, the estimates of CAY for this size category are above current catch levels and recent reported landings. Furthermore, CAY estimates for the areas of both inlets where commercial fishing currently occurs are also above current catch levels and recent reported landings. Catch levels higher than recent reported landings would be required to move the stocks in these two inlets towards a size that will support the maximum sustainable yield. The Shellfish Working Group noted that current catch is within the MCY for 2005.

Cockles recruit to the spawning stocks in the Otago area at a length of about 18 mm shell length. The harvested beds may receive spat from other areas. For these reasons, and because of the low harvesting levels, the risk of recruitment overfishing is probably low.

Table 7: Summary of yields (t) and reported landings for the most recent fishing year.

Area	2005 MCY	2005 CAY	2001–2002 Catch limit	2001–2002 Reported landings	2002-2003 Reported landings	2003-2004 Reported landings	2004-2005 Reported landings
Whole of Papanui Inlet	213-438	692-1167	427	49	52	72	
Whole of Waitati Inlet	463-952	1506-2537	746	591	717	687	

5. FOR FURTHER INFORMATION

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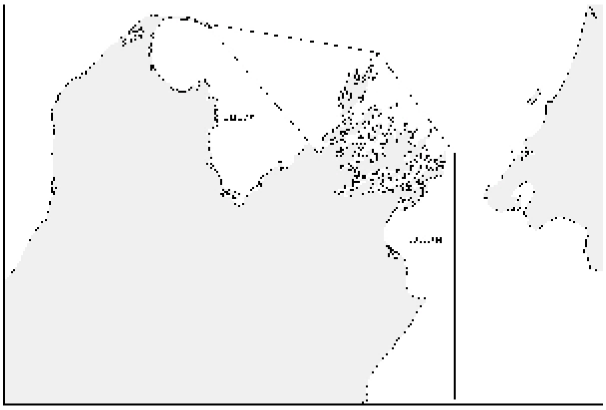
COCKLES (COC 7A/7B) Nelson/Marlborough

(*Austrovenus stutchburyi*)



1. FISHERY SUMMARY

COC 7A was introduced to the Quota Management System in October 2002 with a TAC of 1510 t; comprising a customary allowance of 25 t, a recreational allowance of 85 t, an allowance for other fishing related mortality of 10 t, and a TACC of 1390 t.

COC 7B was introduced to the Quota Management System in October 2002 with a TAC of 10 t; comprising a customary allowance of 5 t, a recreational allowance of 5 t.

(a) Commercial fisheries

Commercial harvesting at Pakawau Beach in Golden Bay began in 1984, but with significant landings taken only since 1986. Harvesting at Pakawau Beach has occurred every year since 1984. Cockles have also been taken commercially from Tapu Bay-Riwaka (in Tasman Bay) since 1992–93, and Ferry Point (in Golden Bay) since 1998–99. Catch statistics (Table 1) are derived from company records and QMS returns. All commercial landings have been taken by mechanical harvester.

Table 1: Reported landings (t) of cockles from all commercially harvested areas in COC 7A/7B. Landings from 1983–84 to 1991–92 are based on company records.

Fishing Year	Total Landings	Catch Limit
1983–84	2	225
1984–85	38	225
1985–86	174	225
1986–87	230	225
1987–88	224	225
1988–89	265	300
1989–90	368	300
1990–91	535	300
1991–92	298	300
1992–93	300	336
1993–94	440	336
1994–95	326	336
1995–96	329	336
1996–97	325	336
1997–98	513	949
1998–99	552	1 130
1999–00	752	1 130
2000–01	731	1 134
2001–02	556	1 134
2002-03	569	1 390
2003-04	553	1 390
2004-05	428	1 390

At Pakawau Beach, the fishery operated up to October 1988 under a special permit constraining annual landings to 225 t. From 1988–89 to 1997–98, the fishery operated under a commercial permit allowing an annual catch of 300 t. In 1997–98, the fishery was re-assessed and a catch limit of 913 t was set based on a CAY harvest strategy. This level of harvest was changed to 760 t from the 1998–99 fishing year, and then 764 t for the 2000–01 fishing year. The harvest is taken from an area of about 500 ha.

The Ferry Point fishery, initiated in 1998–99, has an annual allowable catch of 334 t based on an MCY harvest strategy. The harvested area is about 400 ha. The Tapu Bay-Riwaka fishery, which was developed in 1990–91, has operated under a commercial permit limiting catches to 36 t annually. This fishery has been only lightly harvested owing largely to water quality issues, and the area from which catches have been taken is probably less than 100 ha.

COC 7A (Tasman and Golden Bays) and COC 7B (Marlborough) were introduced into the QMS on 1 October 2002, with COC 7A effective from 1 October 2003. For COC 7A a TAC was set at 1,510 t; comprising a customary allowance of 25 t, a recreational allowance of 85 t, and a TACC of 1 390 t. For COC 7B a TAC was set at 10 t; comprising a customary allowance of 5 t, a recreational allowance of 5 t and a TCC of 0 t.

(b) Recreational fisheries

Cockles are taken by recreational fishers, generally using hand digging. The catch limit is currently 150 cockles per person per day. Relatively large cockles (i.e., shell length > 30 mm) are generally preferred.

Estimates of the amateur cockle harvest from QMA 7 are available (Table 2) from a telephone and diary survey in 1992–93 (Tierney et al., 1997) and from national diary surveys in 1996 (Bradford, 1998) and 2000 (Boyd & Reilly 2004). Harvest weights were estimated assuming a mean weight of 25 g per cockle. The 1992-93 and 1996 estimates are very uncertain and probably under-estimate actual recreational catch. The 2000 survey is considered to be a more reliable estimate of recreational harvest.

Table 2: Estimated numbers of cockles harvested by recreational fishers in QMA 7, and the corresponding harvest tonnage. Data from both surveys were not sufficiently reliable to allow estimates of CVs.

Year	QMA 7 harvest (number)	(t)
1992–93	166 000	4
1996	325 000	8
2000	499 000	12.5

(c) Maori customary fisheries

Cockles are an important Maori traditional food, but no quantitative information on the level of customary take in COC 7A/7B is available. However, Kaitiaki are now in place in many areas and estimates of customary harvest can be expected in the near future.

(d) Illegal catch

No quantitative information on the level of illegal catch is available.

(e) Other sources of mortality

The extent of any other sources of mortality is unknown. Incidences of unexplained large-scale die-off in localised areas have been noted (e.g., at Pakawau Beach in 1999). Mortality of unrecruited cockles during the mechanical harvesting process was found to be very low (Bull, 1984), and disturbance and mortality of other invertebrates in the harvested areas is slight (Wilson et al., 1988). Cockles (particularly those smaller than 25 mm, which are not taken by the mechanical harvester) are vulnerable to predation by birds and may be important in the diet of some species (Wilson et al., 1988).

2. BIOLOGY

All references to "shell length" in this report refer to the maximum linear dimension of the shell (in an anterior-posterior axis). General cockle biology has been summarised earlier in this Plenary report. Some aspects of biology with particular relevance to COC 7A/7B follow.

Estimates of growth and mortality have been made for cockles from Pakawau Beach (Osborne 1992, 1999), and are summarised in Table 3. The 1992 investigation used a Walford plot of tag recapture data (Bull 1984), and measured growth after about 18 months on translocated cockles, to produce the growth parameters. A MIX analysis of the scaled length-frequency distribution from the 1992 survey enabled calculation of the proportional reduction of the 4+ and 5+ age classes to produce estimates of instantaneous natural mortality, M (after removal of estimated fishing mortality, F).

The 1999 investigation used a MIX analysis of length-frequency data from two strata in comparable surveys in 1997, 1998 and 1999 to estimate mean lengths (and proportion in the population) of the first 8 year classes. Von Bertalanffy parameters were estimated for each survey. Mean natural mortality rates were estimated (for age classes 4–7) between 1997 and 1998, and 1998 and 1999.

It was acknowledged that none of the MIX analyses converged, but the results presented were the best available fits (Osborne 1992, 1999). However, all four analyses produced very similar von Bertalanffy parameters. There is a trend of a reducing L_∞ and increasing K over the period 1992–1999, which might be expected as a result of fishing.

Table 3: Estimates of biological parameters.

Population & years	Estimate			Source
1. Natural mortality (M)				
Pakawau Beach (1992)	0.45 for 4+; 0.30 for 5+			Osborne (1992, 1999)
Pakawau Beach (1998)	0.40			Osborne (1999)
Pakawau Beach (1999)	0.52			Osborne (1999)
2. Weight = a (shell length)^b (weight in g, shell length in mm)				
Pakawau Beach (1992)	a = 0.000017	b = 3.78		Osborne (1992)
Ferry Point (1996)	a = 0.000205	b = 3.153		Forrest & Asher (1997)
Tapu Bay-Riwaka (1991)	a = 0.000150	b = 3.249		Stark & Asher (1991)
3. von Bertalanffy growth parameters				
	K	**t_0**	**L_∞**	
Pakawau Beach (1984–92)	0.36	0.30	49.0	Osborne (1992)
Pakawau Beach (1997)	0.38	0.68	48.3	Osborne (1999)
Pakawau Beach (1998)	0.40	0.68	47.4	Osborne (1999)
Pakawau Beach (1999)	0.41	0.66	47.0	Osborne (1999)

3. STOCKS AND AREAS

Little is known of the stock boundaries of cockles. The planktonic larval phase of this shellfish has a duration of about 3 weeks, so dispersal of larvae to and from a particular site could be considerable. Cockles are known to be abundant and widely distributed throughout Golden and Tasman Bays, and although nothing is known about larval dispersion patterns, cockles in these areas are likely to comprise a single stock. However, in the absence of any detailed information on stocks, the three currently fished sites in COC 7A/7B are all managed separately.

It should be noted that COC 7A/7B includes all the waters in QMA 7 (i.e., from Awarua Point on the West Coast, around the northern South Island to the Clarence River mouth).

4. STOCK ASSESSMENT

This report summarizes estimates of absolute biomass and yields for exploited and unexploited cockle populations in Tasman and Golden Bays. Stock assessments have been conducted using absolute biomass surveys, yield-per-recruit analyses, Methods 1 and 2 for estimating MCY, and Method 1 for estimating CAY (Annala et al., 2001).

Recruited cockles are considered to be those with a shell length of 35 mm or greater. This is the minimum size of cockles generally retained by the mechanical harvesters used in the COC 7A/7B fishery. Where possible, estimates of yields from surveys are based on recruited biomass not occurring in areas of eel grass (*Zostera*), as the disturbance of these *Zostera* beds by mechanical harvesters has detrimental effects on intertidal ecology.

(a) Estimates of fishery parameters and abundance

Biomass estimates from surveys are available for the three commercially fished areas and three other sites.
On Pakawau Beach, the surveys done in 1992 and 1997–2001 used a stratified random approach (Table 4). An additional southern stratum was added to the survey area in 1997, accounting for the greater survey area relative to 1992. The surveys in 1988 and 1984 covered smaller areas still. There is no apparent decline in biomass per unit area throughout the entire series of surveys. The six comparable surveys show total and recruited biomass to have fluctuated, but with no consistent trend. Because harvesting is not permitted in areas of *Zostera*, additional estimates of recruited biomass available to harvesters are presented (Table 4).

Estimates of biomass are available for Tapu Bay-Riwaka in 1991 using a fixed transect approach (Stark & Asher, 1991) and Ferry Point in 1996 using a stratified random approach (Forrest & Asher, 1997). Both these surveys were conducted about two years prior to the commencement of commercial harvesting in those areas. The cockle resource on three other beaches in Golden Bay was assessed using stratified random surveys in 1993 (Osborne & Seager, 1994). Results from all these surveys are listed in Table 5.

Table 4: Estimates of biomass (t) with 95% confidence intervals (CI) where available, and mean density (kg/m^2) for cockles on Pakawau Beach. Values are given for the total and recruited (³ 35 mm) biomass. Available biomass is recruited biomass not occurring in areas of *Zostera*. *n* = number of samples in the survey. Lines of data in italics represent results from the 1997–1999 surveys, but using only those strata surveyed in 1992.

Date	Area	*n*	Total biomass			Recruited biomass			Available biomass	
	(ha)		t	CI	kg/m^2	t	CI	kg/m^2	t	CI
1984	326	–	4 604	1562	1.41	–	–	–	–	–
1988	510	–	5 640	–	1.11	–	–	–	–	–
Nov 1992	588	313	6 784	929	1.15	5521	852	0.94	3 407	–
May 1997	*588*	*257*	*8 979*	*528*	*1.53*	–	–	–	–	–
Jun 1998	*588*	*265*	*7 970*	*1 326*	*1.36*	–	–	–	–	–
Apr 1999	*588*	*262*	*8 196*	*1 339*	*1.39*	–	–	–	–	–
May 1997	642	264	9 279	550	1.45	7796	515	1.21	5 888	643
Jun 1998	642	272	8 269	1 360	1.29	6915	1224	1.08	3 604	842
Apr 1999	642	269	8 666	1 425	1.35	7183	1324	1.12	3 645	869
Mar 2000	642		7878	1 302	1.23					
Mar 2001#	642	231	10 252	1 629	1.60	9117	1519	1.42	3 613	764
Feb 2004	642	312	10 185	1 238	1.59	9421	1195	1.47	6 191	945

\# Recruited and available biomass were calculated in 2001 using a recruited size of ≥ 30 mm shell length.

Table 5: Estimates of biomass (t) with 95% confidence intervals (CI) where available, and mean density (kg/m^2) for cockles at various sites in Golden and Tasman Bays. Where possible, values are given for the total and recruited (³ 35 mm) populations. *n* = number of samples in the survey.

Site	Date	Area	*n*	Total biomass			Recruited biomass		
		(ha)		t	CI	kg/m^2	t	CI	kg/m^2
Tapu Bay-Riwaka	Mar 1991	306	321	~3 900	–	1.28	–	–	–
Tapu Bay	Feb 2004	122.7	144	1 423	269	1.16	1 076	235.6	0.88
Riwaka (excl. Tapu Bay)*	Mar 1991	–	–	–	–	–	1 880	450	–
Ferry Point	Dec 1996	436	552	2 617	190	5.99	#2 442	191	5.60
Ferry Point	Feb 2004	40	126	646	99.8	1.63	443	79	1.12
Collingwood Beach	Mar 1993	176	70	334	148	0.19	292	139	0.17
Takaka Beach	Mar 1993	338	107	1 850	671	0.55	796	395	0.24
Rangihaeata Beach	Mar 1993	197	75	473	345	0.24	438	320	0.22

* Recalculated by Breen (1996) from data in Stark & Asher (1991).
\# Recruited biomass includes cockles ≥ 30 mm shell length.

Surveys reporting on cockle abundance have also been produced for Motupipi, Golden Bay, in June 1995 (transect survey, 50 ha, 30 samples, mean density of 87 cockles per m^2, no sizes or weights recorded), and at various sites in the Marlborough Sounds in August 1986 (diver survey below mean low water only, 9 sites, main densities in Kenepuru and inner Pelorus Sounds).

(b) Biomass estimates

Absolute virgin biomasses, B_0, are assumed to be equal to estimated biomass of cockles ≥ 35 mm shell length from surveys conducted before, or in the early stages of, any commercial fishing. These are listed above in Tables 4 and 5. Absolute current biomass can be estimated similarly from current surveys.

The biomass that will support the maximum sustainable yield (B_{MSY}) is not known for any of the areas fished in COC 7A/7B.

(c) Estimation of Maximum Constant Yield (MCY)

Estimates of MCY have been made for populations of cockles in various areas, and at various times, using the equation MCY = 0.25 * F_{ref} * B_0 (Method 1), where F_{ref} is either $F_{0.1}$ or F_{max}. This method applies to new fisheries, or to those with only very low past levels of exploitation. The value of F_{ref} is dependent on M, so owing to the uncertainty of M a range of MCY estimates have been given for each stock (Table 6). For all estimates in Table 6, B_0 was taken as recruited biomass available for fishing (i.e., not in *Zostera* beds) in the survey area.

Estimates of MCY for Pakawau Beach have also been produced from MCY = 0.5 * F_{ref} * B_{av} (Method 2), using F_{max}, and with B_{av} being 3582 t (the average of the available recruited biomass from the five comparable surveys in 1997–2001). For a range of M values, MCY is as follows:

M	0.2	0.3	0.4
MCY	1182	2418	4658

Table 6: Estimates of MCY (t, using 0.25 * F_{ref} * B_0) for various cockle stocks in Tasman and Golden Bays, assuming a range of values for M.

Site	Date	F_{ref}				M
			0.2	0.3	0.4	0.5
Pakawau Beach	1992	$F_{0.1}$	230	324	434	554
Pakawau Beach	1997	$F_{0.1}$	397	559	751	957
Ferry Point	1996	$F_{0.1}$	127	170	223	284
Ferry Point	1996	F_{max}	264	453	789	1493
Riwaka	1991	$F_{0.1}$	167	224	286	–
Collingwood Beach	1993	$F_{0.1}$	20	28	37	48
Takaka Beach	1993	$F_{0.1}$	53	74	100	127
Rangihaeata Beach	1993	$F_{0.1}$	23	32	43	55

The level of risk by harvesting the populations at the estimated MCY levels cannot be determined for any of the surveyed areas. However, yield estimates are substantially higher when based on F_{max} rather than $F_{0.1}$, so risk would be greater at MCYs based on F_{max}.

(d) Estimation of Current Annual Yield (CAY)

Estimates of CAY have been made in the past for cockle stocks at Pakawau Beach, Ferry Point and Riwaka, using CAY = $F_{ref}/(F_{ref} + M) * (1 - e^{-(Fref + M)}) * B_{beg}$ (Method 1), where beginning of season biomass (B_{beg}) is current recruited biomass available to the fishery, and F_{ref} is either $F_{0.1}$ or F_{max}. However, estimates of current biomass that would allow updated calculations are available only for Pakawau Beach. The most recent estimates of CAY available for all stocks are listed in Table 7.

Table 7: Estimates of CAY (t) for various cockle stocks in Tasman and Golden Bays, assuming a range of values for M.

Site	Date	F_{ref}	M			
			0.2	**0.3**	**0.4**	**0.5**
Pakawau Beach	2001	$F_{0.1}$	778	996	1 210	1 396
Pakawau Beach #	2001	$F_{0.1}$	1 964	2 514	3 053	3 522
Pakawau Beach	2001	F_{max}	1 599	2 388	2 975	–
Ferry Point	1996	$F_{0.1}$	407	501	600	696
Ferry Point	1996	F_{max}	748	1050	1 369	1 650
Riwaka	1993	$F_{0.1}$	507	615	708	

\# Calculations using total recruited biomass, rather than available recruited biomass.

(e) Other yield estimates and stock assessment results

$F_{0.1}$ and F_{max} were estimated from a yield per recruit (YPR) analysis using the age and length-weight parameters for Pakawau Beach cockles from Osborne (1992), and assuming size at recruitment to the fishery of either 30 or 35 mm shell length. A range of M values was used to produce the estimates in Table 8.

Table 8: Estimates of $F_{0.1}$ and F_{max} using a range of M values and two minimum harvest sizes (MHS).

F_{ref}	MHS (mm)	M			
		0.2	**0.3**	**0.4**	**0.5**
$F_{0.1}$	35	0.27	0.38	0.51	0.65
$F_{0.1}$	30	0.26	0.34	0.45	0.57
F_{max}	35	0.66	1.35	2.60	–
F_{max}	30	0.53	0.91	1.59	3.01

(f) Other factors

The areas of Golden Bay and Tasman Bay currently commercially fished for cockles are very small with respect to the total resource. Recruitment overfishing is unlikely owing to the extent of the resource protected from the fishery in *Zostera* beds, in sub-tidal areas, and in the protected areas adjacent to Farewell Spit and in other areas of Golden Bay. Cockle larvae are planktonic for about 3 weeks, so areas like Golden Bay and Tasman Bay probably constitute single larval pools. Consequently, fisheries in relatively small areas (like Pakawau Beach) are likely to have little effect on recruitment. It is noted, however, that recruitment of juvenile cockles can be reduced by the removal of a large proportion of adult cockles from the area (i.e., successful settlement occurs only in areas containing a population of adult cockles).

It is also likely that growth and mortality of cockles are density-dependent. A reduction in density due to fishing could enhance the growth and survival of remaining cockles.

Because cockles begin to spawn at a shell length of about 18 mm, and the larval pools in Tasman and Golden Bays are probably massive and derive from a wide area (most of which is closed to commercial fishing), there is a low risk of recruitment overfishing at any of the exploited sites.

5. STATUS OF THE STOCKS

Estimates of reference biomass and reference fishing mortality rates are available, and there are estimates of current biomass for each area.

At Pakawau Beach, the biomass of cockles does not appear to have declined since the start of the commercial fishery in 1983, and has probably increased owing to exceptional recruitment in 2000. At Ferry Point, the size and abundance of cockles has declined markedly since 1996. A CAY strategy and more frequent surveys may allow this stock to rebuild or at least indicate a long-term average biomass for the area. At Riwaka-Tapu Bay, size and abundance has also declined. A MCY strategy is possible for this stock without on-going surveys, or a CAY strategy with more frequent surveys, which would give better information on the long-term average biomass for the area.
Because of the uncertainty over the relationship between $B_{current}$ and B_{msy}, it is not known if recent catches and current catch limits will allow the COC 7A stock to move towards a size that will support the MSY.

Summary of yields (t) and reported landings for the most recent fishing year.

Area	MCY	CAY	2002–2003 TACC	2003–2004 Reported landings	2004–2005 Reported landings
Pakawau Beach	230–957	778–3522	-	–	
Ferry Point	127–1493	–	-	–	
Riwaka – Tapu Bay	167–286	–	–		
Fishstock					
COC 7A			1134	553	428

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