DREDGE OYSTER (OYU 5)-Foveaux Strait

(*Ostrea chilensis*)

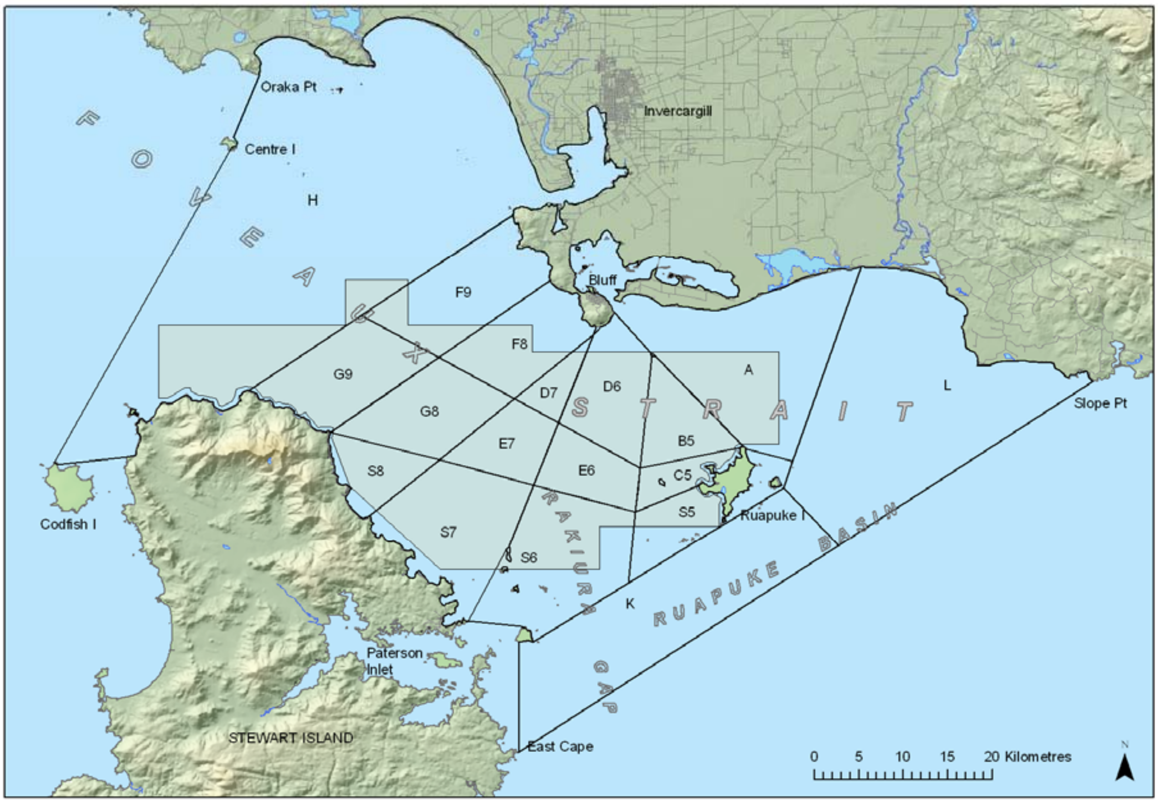

Figure 1: Foveaux Strait (OYU 5) stock boundary and outer boundary of the 1999 dredge survey area encompassing almost all the commercial fishery.

1. FISHERY SUMMARY

(a) Commercial fishery

The Foveaux Strait dredge oyster fishery has been fished for over 140 years. From the late 1880s to 1962 the fishery was managed by limiting the number of vessels licensed to fish. During this period vessel numbers varied between 5 and 12. The fishery was de-licensed in 1962 and boat numbers increased to 30 by 1969. Boundaries of statistical areas for recording catch and effort were established in 1960 and the outer boundary of the licensed oyster fishery was promulgated in 1979. The western fishery boundary in Foveaux Strait is a line from Oraka Point to Centre Island to Black Rock Point (Codfish Island) to North Head (Stewart Island). The eastern boundary is from Slope Point, south to East Cape (Stewart Island). The OYU 5 stock boundary and statistical reporting areas are shown in Figure 1.

Catch limits were introduced in 1963–69 and from 1970 vessel numbers were also limited to 23 by regulation. The catch limits were evenly divided between the 23 vessels. In 1979 the oyster fishery was declared a licensed fishery for the 23 vessels, closing a loophole that allowed vessels to fish outside the designated fishery area. Before 1992, landings and catch limits in this fishery were recorded in sacks. Sacks contained an average of 774 oysters and weighed 79 kg. Catch and effort has been traditionally recorded in sacks per hour dredged. Total landings of oysters between the 1880s and 1962 ranged between 15 and 77 million oysters. Total catches for the period 1907–1962 are shown in Table 1. Catch limits and total landings for 1963–92 are shown in Table 2.

In 1986 a *Bonamia exitiosa* epizootic caused major mortality in the oyster population and the fishery was closed half way through the season to minimise disturbance to oysters. Management of the fishery was modified in response to the continuing mortality from *B. exitiosa*. In 1987, the infected area was closed to dredging to reduce disturbance (so as not to exacerbate infection) and the catch limit reduced in proportion to the population of the closed area (Table 1). In 1988 the restriction on fishing in infected areas was seen as inappropriate in the light of new evidence on how the disease was affected by disturbance and the catch limit was increased. In 1989 the catch limit was increased to the pre- 1986 level, with the proviso that it would be modified if catch and effort data, and the distribution of fishing showed that mortality had reduced the population further (through this period, catch and effort data provided the only information on abundance of oysters in the fishery). *B. exitiosa* infection and mortality continued to spread through Foveaux Strait and by 1990 mortality in the area first infected had reduced oyster density below a level that could be fished economically. The quota remained at 89 million oysters for the 1990 season. However, four weeks of fishing showed that mortality from *B. exitiosa* had become widespread and reduced the oyster population over much of Foveaux Strait. The quota was reduced to 36 million oysters. In 1991 an additional 14 million oysters were dredged from a strip in central Foveaux Strait to reduce the density of oysters with the aim of containing infection by *B. exitiosa* to the west. This strategy failed and infection and mortality continued to spread east. The devastated beds in central Foveaux Strait were closed in 1992 and fishing confined to the outer beds. The catch rate was the lowest in the recent history of the fishery and fishers caught less than a third of the catch available. In 1993, Foveaux Strait was closed to commercial fishing to allow the population to recover.

After three years, the population had rebuilt sufficiently for the Minister of Fisheries to reopen the fishery in 1996 with a catch limit of 14.95 million oysters. This catch limit was converted to a catch quota of 1475 t using a conversion factor of 801 oysters per 79 kg sack based on Bluff Oyster Enhancement Company data. The mean number of oysters per sack landed in 1996 was fewer than 801 so that the quota specified by weight was filled before 14.95 million oysters were landed. The number of sacks landed as well as the number of oysters they contained was tabulated from the 1996 Licensed Fish Receivers Reports (LFLR) data and a new conversion factor of 774 oysters per 79 kg sack estimated. Using this conversion factor, the catch quota for 1997–2001 was 1525 t. From 1996, catches were recorded as numbers of oysters, catch limits and total landings for 1996–2007 are shown in Table 3.

Between 1992 and 2000 the Bluff Oyster Enhancement Company Ltd was granted a special permit to catch oysters during the breeding season as part of their study of the viability of enhancing the oyster population, using spat settled on oyster shell. Permit allocations and reported landings are shown in Table 4. No special permit was issued in 1998.

In April 1997, individual quotas were granted and quota holders permitted to fish their entire quota on one vessel. At the same time, the Crown purchased 20% of the available quota from quota holders and transferred it to the Waitangi Fisheries Commission. The oyster fishery entered the Quota Management System in 1998. The number of vessels in the fishery has dropped from 23 in 1996, to 15 in 1997, and to 11 in 2006.

B. exitiosa infection was undetectable in oysters and monitoring ceased in 1995. No heightened mortality was observed in the fishery between 1995 and 2000. A survey in March 2000 confirmed another epizootic. This survey found localised areas of oysters with heavy *B. exitiosa* infection and high recent mortality; and areas with low prevalence but high intensity of infection which were likely to experience some mortality from the disease in the immediate future. This *B. exitiosa* epizootic began at a similar location to the mid 1980s epizootic that then proceeded to spread throughout Foveaux Strait over a period of several years. The 2000 epizootic also spread in a similar manner. Surveys in October 2001, January and March 2002 found all areas with high densities of recruited oysters (including the designated commercial areas) had a high prevalence of infection and some high intensity patches of infected oysters within or near them. The estimated size of the commercial population in March 2002 suggested a reduction to about 40–65% of the estimated population from October 2001. Infection from *B. exitiosa* continued to cause mortality through to 2006 and preliminary tabulation of the 2007 survey results suggest some *B. exitiosa* mortality likely.

Oysters have been traditionally harvested over a six-month season, 1 March to 31 August (Southland Commercial Fishing Regulations). When the fishery was reopened in 1996, the oyster season started between mid March and early June to avoid disturbing oysters after spawning and reduce the risk of infection by *B. exitiosa*. The oyster season continued to finish on 31 August although many vessels have filled the quota before then. In 2007, the fishery returned to a 1 March start to the oyster season.

Oysters have been commercially harvested from Foveaux Strait since the 1860s, and since the 1870s by dredge. Currently vessels tow two 550 kg, double bit, steel dredges on steel warps. Each dredge is towed off its own derrick, both on the vessel's port side. The dredges are towed along an elliptical track. Once the dredges are shot the vessel drifts down tide under minimal power turning in to the tide to haul the dredge. The dredge contents are emptied on to culching benches and the oysters sorted and sized by hand. Small oysters and bycatch are returned to the sea. Oysters are landed daily, live in the shell.

Table 1: Reported landings of Foveaux Strait oysters 1907–1962 (millions of oysters; sacks converted to numbers assuming a conversion rate of 774 oysters per sack for the years 1907–1992). (Data summarised by Dunn, 2005 from 1907–1962 from Marine Department Annual Reports).

Year	Catch	Year	Catch	Year	Catch	Year	Catch	Year	Catch
1907	18.83	1919	16.56	1931	28.28	1943	56.59	1955	60.84
1908	17.34	1920	20.67	1932	29.01	1944	49.50	1956	58.63
1909	19.19	1921	19.01	1933	32.64	1945	58.85	1957	60.14
1910	18.20	1922	21.11	1934	40.44	1946	69.16	1958	64.44
1911	18.90	1923	22.28	1935	38.48	1947	63.09	1959	77.00
1912	19.00	1924	18.42	1936	49.08	1948	73.10	1960	96.85
1913	26.26	1925	20.01	1937	51.38	1949	75.34	1961	84.30
1914	19.15	1926	21.54	1938	52.05	1950	58.09	1962	53.42
1915	25.42	1927	16.26	1939	58.16	1951	70.15		
1916	22.61	1928	30.03	1940	51.08	1952	72.51		
1917	17.20	1929	30.44	1941	57.86	1953	55.44		
1918	19.36	1930	33.11	1942	56.87	1954	51.29		

Table 2: Reported landings and catch limits for the Foveaux Strait dredge oyster fishery from 1963–92 (millions of oysters; sacks converted to numbers assuming a conversion rate of 774 oysters per sack). Catch rate shown in sacks per hour.

Year	Reported landings		Catch limit	Catch rate	Year	Reported Landings		Catch limit	Catch rate
1963	58		132	6.0	1978	96	2	89	17.1
1964	73		132	6.8	1979	88		89	16.6
1965	95		132	7.9	1980	88		89	15.2
1966	124		132	10.6	1981	89		89	13.4
1967	127		132	9.3	1982	88		89	13.2
1968	114		121	7.7	1983	89		89	12.3
1969	51		94	6.5	1984	89		89	13.8
1970	88		89	7.3	1985	82		89	12.1
1971	89		85	6.9	1986	60	3	89	10.5
1972	77		85	6.7	1987	48		50	10.9
1973	97	1	85	10.0	1988	68		71	10.0
1974	92	1	85	11.5	1989	66		89	10.7
1975	89		89	11.9	1990	36		36	6.4
1976	89		89	13.4	1991	42	4	36	5.8
1977	92	2	89	15.9	1992	5	5	14	3.4

1 Landings include catch given as incentive to explore 'un-fished' areas.
2 Landings include catch given as an incentive to fish Area A.
3 Season closed early after diagnosis of *B. exitiosa* infection confirmed.
4 Landings include catch given as an incentive to fish a 'firebreak' to stop the spread of *B. exitiosa*.
5 Fishing only permitted in outer areas of fishery.

Table 3: Reported landings and catch limit for the Foveaux Strait dredge oyster fishery from 1996–2005. Landings and catch limits reported in numbers (millions) of oysters. Catch rate converted to sacks per hour (774 oysters per sack) to compare with earlier data. Catch rate does not include oysters taken by crew as recreational catch. Reported catch rate based on number of sacks landed in CELR data and revised catch rate based on numbers of oysters landed and converted to sacks.

Year	Reported landings	Catch limit	Reported catch rate	Revised catch rate
1996	13.41	14.95	5.9	5.8
1997	14.82	14.95	7 0	7.0
1998	14.85	14.95	8.3	6.7
1999	14.94	14.95	7.5	6.8
2000	14.43	14.95	7.2	6.4
2001	15.11	14.95	7.0	6.8
2002	14.45	14.95	3.2	3.3
2003	7.46	14.95[1]	2.3	2.6
2004	7.48	14.95[1]	2.2	2.5
2005	7.57	14.95[1]	1.7	1.8
2006	7.44	14.95[1]	1.9	1.9

1 Fifty percent of the TACC shelved for the season.

Table 4: Oyster catches reported from vessels fishing under special permits to the Bluff Oyster Enhancement Company 1992–2000. Fishing took place over the summer breeding season (November–February) rather than the winter season (March–August) of commercial fishing. Reported catch and permit allocations 1992–93 to 1995–96 converted sacks to numbers assuming a rate of 774 oysters per sack.

Summer	Reported catch (millions of oysters)	Permit allocation (millions of oysters)
1992–93	2.43	3.10
1993–94	3.09	3.10
1994–95	3.03	3.10
1995–96	0.93	0.93
1996–97	0.20	0.88
1997–98	0.72	0.72
1998–99	0	0
1999–2000	1.00	1.00

b) <u>Recreational Fishery</u>

In 2002, Fisheries Officers estimated that between 70 and 100 recreational vessels were fishing from Bluff and smaller numbers from Riverton and Colac Bay. Most of these vessels are fitted with GPS and capable of fishing Foveaux Strait with up to four recreational fishers on board. Recreational fishers may take 50 oysters per day during the open season. The charter boat fleet at Stewart Island, Bluff, and Riverton target oysters during the oyster season. Around seventeen include oyster dredging and oyster diving trips as part of their winter programme. Some vessels can have up to 15–20 fishers out for the day (each returning with 50 oysters).

Four surveys of recreational fishing have been conducted to estimate recreational harvest, the South region 1991–92 survey and the 1996 (Bradford, 1998), 1999-001 (Boyd & Reilly, 2004) and 2000-01 (Boyd et al., 2004) national telephone diary surveys. However, the catch of oysters cannot be reliably quantified from these surveys because of the small number of local respondents who reported catches of oysters in their diaries and the identification of oysters as either dredge oysters or generic oysters. The Southland Recreational Marine Fishers Association estimated the annual recreational catch of oysters in Foveaux Strait in 1995 to be about 301 860 oysters. Fisheries Officers believe the recreational catch has increased significantly since (Steve Logie, MFish, Invercargill, pers. comm.).

The commercial oyster fleet are a major contributor to the level of recreational harvest. Commercial fishers are entitled to 50 oysters each fisher each day, with each commercial vessel's crew potentially taking up to 300 oysters as recreational catch each day. Recreational catches from commercial vessels are reported in Catch and Effort Returns as OYS 5 (c/w OYU 5 for commercial landings). Annual catches are shown in Table 5.

Table 5: Reported annual recreational catch of oysters taken from commercial vessels 2002–05 (Allen Frazer, MFish, Dunedin, pers. comm.).

Year	Number of oysters
2002	236 103
2003	282 645
2004	146 567
2005	190 345
2006	139 252

The total recreational catch is about 0.5 million oysters. The reliability of this estimate is not known.

c) Maori customary fisheries

Reporting of Maori customary harvest is specified in the Fisheries (South Island Customary Fisheries) Regulations 1999. Ngai Tahu administers reporting of customary catch of Foveaux Strait oysters to the Ministry of Fisheries quarterly. Reported customary catch for 1998 to 2005 is given in Table 6. Customary catch increased from 0.18 million oysters in 1999 to 0.26 million oysters 2001. Little customary fishing is believed to take place between 31 August and mid November while oysters are spawning.

Table 6: Reported quarterly customary catch (numbers of oysters) 1 July 1998 to 31 December 2005 from Tangata taiki data collected by Ngai Tahu. NA denotes no data available.

Year	1 Jan-31 Mar	1 Apr-30 Jun	1 Jul-30 Sep	1 Oct-31 Dec	Total
1998	NA	NA	106 380	37 560	143 940
1999	0	107 520	69 840	0	177 360
2000	63 582	113 634	34 356	11 760	223 332
2001	25 514	136 973	72 996	23 760	259 243
2002	0	117 219	67 116	0	184 335
2003	1 560	85 920	45 840	0	157 980
2004	26 546	9 820	91 342	0	127 708
2005	43 320	25 920	7 224	0	76 464
2006	–	–	–	–	85 312

d) Illegal catch

The Ministry of Fisheries estimated the illegal catch of oysters for the 1998 and 1999 fishing years to be about 10% of the total non-commercial catch, 66 436 oysters. However, because the estimate of illegal catch cannot be verified, the Working Group is not in a position to modify or determine its acceptability.

e) Other Sources of Mortality

i) Mortality caused by *Bonamia exitiosa*

In New Zealand flat oysters, a protozoan (Alveolata, haplosporidia) *Bonamia exitiosa* is an obligate parasite of haemocytes. Mortality of oysters from *B. exitiosa* appears to be a recurrent feature of the Foveaux Strait oyster population dynamics. Large numbers of new clocks (shells of oysters that had died within six months) and oysters in poor condition, both indicative of *B. exitiosa* epizootics, were recorded as long ago as 1906. A *B. exitiosa* epizootic was confirmed in the Foveaux Strait oyster fishery in 1986–92 and again in 2000–06. Prevalence of infection between epizootics is low (almost undetectable), nevertheless, infection appears to be widespread at these low levels throughout the oyster population.

In late winter each year, the parasite occurs at very low levels in apparently healthy oysters. It starts to increase in numbers in November-December, when many oysters are going through the male reproductive cycle. By February, most oysters are in the female cycle and many infected oysters fail to spawn; further proliferation of the parasite after this time results in elevated oyster mortality from

March to May. From May to August *B. exitiosa* enters a late developmental phase, with increasing senescence among the parasite population, leading to an apparent population collapse. The relationship between the intensity and prevalence of infection in one year, the density of oysters, and the probability of an outbreak the following year are poorly understood (see Sullivan et al., 2005).

Mortality from *B. exitiosa* 1986–92 reduced the Foveaux Strait oyster population to below 10% of its pre disease level. A survey in March 2000 of oyster beds in the vicinity of a reported *B. exitiosa* outbreak confirmed the presence of *B. exitiosa* infection and described the extent of the outbreak (Dunn et al., 2000). The survey found heavy infection of *B. exitiosa* and recent mortality in a localised area. The *B. exitiosa* epizootic in the late 1980s began in the same general area, and proceeded to spread throughout Foveaux Strait over a period of several years. It was considered possible that the recent outbreak would also spread in a similar manner. Estimated mortality of recruited oysters (as determined by the proportion of recruit sized new clocks) in 2001 within the focus of infection was about 12% (95% confidence interval 11–13%), with peak mortality of 56% (95% confidence interval 48–64%). A further 10% (95% confidence interval 5–15%) of recruited oysters outside the main focus showed signs of infection. Beyond the focus of infection, recent mortality was 2%, and 2% showed signs of infection. Between 2000 and 2002, infection from *B. exitiosa* caused mortality in 66% of recruited oyster in Foveaux Strait and 72% by 2005. Mortality of oysters in designated commercial fishery areas was 50% by 2002, and oyster density reduced to one third.

It is not known whether other disease agents (including an apicomplexan, *Bucephalus* sp., coccidian, and microsporidian) contributed to or caused mortality in oysters during the 1986–92 and 2000–06 epizootics.

ii) Incidental mortality caused by heavy dredges

Since 1968, heavy double bit double ring bag dredges have been used in the fishery. The dredges weighed 410 kg when first introduced, but were rebuilt more heavily in 1984 and now weigh around 550 kg. These dredges are three and a half times heavier than the single bit single ring bag dredges employed between 1913 and 1968.

Incidental mortality of oysters from dredging with light (320 kg) and heavy (550 kg) dredges was compared experimentally in March 1997 (Cranfield et al., 1997). Oysters in the experiment had only a single encounter with the dredge. Numbers of dead oysters were counted at the end of the experiment, seven days after dredging. The experiment found that mortality was inversely proportional to the size of oysters damaged and that lighter dredges damaged and killed fewer oysters. Recruit size oysters appeared to be quite robust (1–2% mortality) and few were damaged, pre-recruit (10–57 mm in length) less so (6–8%), but spat were very fragile and many were killed especially by the heavy commercial dredge (mortality of spat below 10 mm in height ranged from 19–36%). Incidental mortality from dredging may reduce subsequent recruitment in heavily fished areas but is unlikely to be important once oysters are recruited. The mortality demonstrated experimentally here has not been scaled to the size of the fishery and therefore its importance cannot be assessed.

2. BIOLOGY

The biology of *Ostrea chilensis* has been summarised in previous Shellfish Working Group reports (see Sullivan et al., 2005). Since 2004, stock assessment for OYU 5 has been based on projections from the Foveaux Strait Oyster stock assessment model. The biological inputs, priors, and assumptions are summarised from (Dunn, 2005).

a) Recruitment

Little data are available on recruitment. Relative year class strengths were assumed to average 1.0 over all years of the model, and further, relative year class strengths in the period before 1985 were assumed constant, and defined to be equal to the initial recruitment. Lognormal priors on relative year class strengths were assumed, with mean 1.0 and CV 0.2.

Stock recruitment relationships for the Foveaux Strait dredge oyster are unknown, but most oysters, surviving post settlement, are typically found on live oysters (Keith Michael, NIWA, pers. comm.). Typically, recruitment for sessile organisms is highly variable and often environmentally and predation driven (see Jamieson & Campbell, 1998; Cranfield, 1979). A strong recruitment pulse was observed in the fishery between 1993 and 2000, suggesting that high levels of recruitment are plausible during periods of low abundance. More recently, even at low stock levels, the numbers of small oysters found in population surveys have remained relatively high.

b) Growth

Dunn et al. (1998b) estimated seasonal growth that allowed for areal, yearly, and breakage effects. The complexity of these estimates cannot easily be reproduced within the population model and hence the data were re-fitted using maximum likelihood von Bertalanffy growth model based on the parameterisation of Francis (see Dunn, 2005).

Winter length measurements were ignored, and hence annual growth increment measurements only were considered. The growth parameters at $\alpha = 30$ and $\beta = 55$ were estimated outside the population model, as $g_\alpha = 11.91$ mm and $g_\beta = 3.61$ mm; variation in growth had an estimated CV of c=0.31 and $\sigma_{\min}$=4.45 mm; and estimated measurement error σ_E was 2.12 mm.

c) Maturity

Jeffs & Hickman (2000) estimated measures of maturity from the re-analysis of sectioned oyster gonads. The data for the proportion of oysters with female ova, during the months of October–March, were used to determine the maturity ogive within the model. Figure 2 shows the estimated proportions mature (i.e., proportions of oysters with presence of female ova) by length class, along with exact 95% confidence intervals. Maturity was not considered to be a part of the model partition.

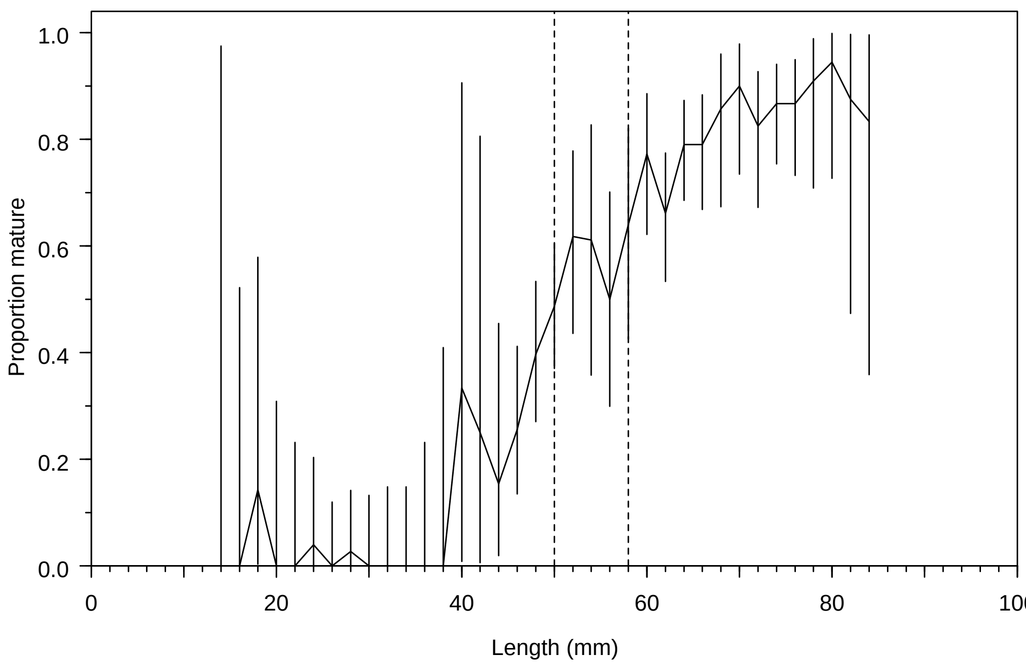

Figure 2: Proportions of mature oysters (defined as the proportion of oysters with female ova) by length (Jeffs & Hickman 2000). Vertical bars give exact 95% confidence intervals, and dashed lines separate the small (<50 mm), pre-recruit (≥ 50 mm and <58 mm), and recruit (≥ 58 mm) size groups.

d) Natural Mortality

A constant value for natural mortality of 0.1 y^{-1} was assumed, implying a maximum age (at which 1% survive) of 46 years. This assumption was based on estimates of *M* from Dunn (1998) and two oysters tagged at recruit size (one from 1973 and one from 1976 or 1977) and recaptured (live) in early 2003 (K.P. Michael, NIWA, pers. comm.). These data suggest the value of *M* plus *F* was not high, as at least two oysters lived to recruit size and survived a further 26–29 years.

e) Disease Mortality

Data on disease mortality events are limited. Anecdotal reports exist of a mortality events indicated by large numbers of “clocks” (the articulated shells of recently-dead oysters with the ligament attaching the two valves intact) from the late 1940’s to 1960–63. The reported proportions of clocks to live oysters are similar to those found in abundance surveys during the *B. exitiosa* epidemics in the early 1990s and early 2000s. Hine (1996) later noted that the most likely cause of the mortality during the 1960s was *B. exitiosa*.

The *B. exitiosa* outbreak in the late 1980s was thought to have started in 1985–86, with evidence of continued *B. exitiosa* mortality up until March 1995. No further evidence of unusual mortality was found in the fishery until the summer of 2000. Disease mortality is set to zero for the years 1907–1948 (the period before any abundance estimates); 1952–1959 (to allow for disease mortality in the late 1940s); 1967–1984 (to allow for disease mortality in the early 1960s); and 1996–1999 (to allow for the epizootic in the late 1980s and the subsequent epizootic in 2000). Where disease mortality was estimated, a normal prior with mean -0.2 (sic), standard deviation 0.2, and bounds [0.0, 0.8] were used.

Dunn (2005) assumed that the relationship between disease mortality, oyster length, or oyster maturity was the same as the maturity ogive. B. Diggles (unpublished results) analysed 500 oysters from a survey on January 2004 for *B. exitiosa* infection, sex, and maturity with lengths between 24 and 81 mm. These data provide information on the disease selectivity of oysters, and can be used to determine a length-based selectivity of *B. exitiosa* (Figure 3).

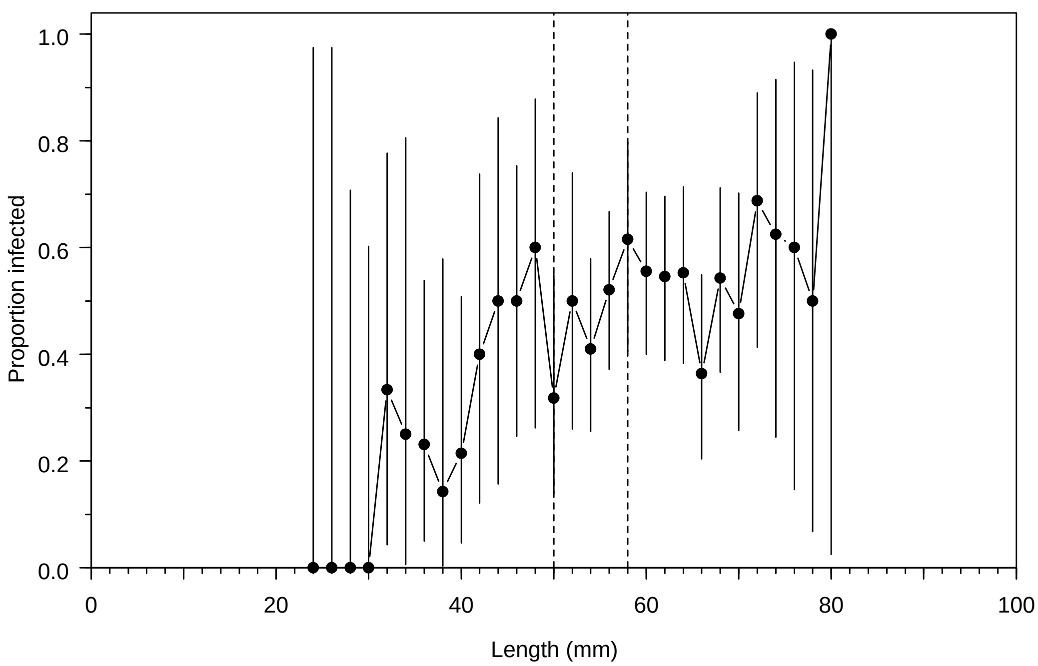

Figure 3: Proportions of oysters (and 95% confidence intervals) with a *B. exitiosa* infection of level 1+ from *B. exitiosa* histological sampling from the January 2004 surveys by length (B. Diggles, unpublished results). Dashed lines separate the small (<50 mm), pre-recruit (≥ 50 mm and <58 mm), and recruit (≥ 58 mm) size groups.

3. STOCKS AND AREAS

The population of oysters in Foveaux Strait in 1975 consisted of a number of discrete small dense patches generally separated by extensive areas of barren ground. Oyster-bearing ground covered some 1200 km^2 of Foveaux Strait. In 1975, ninety one percent of the total oyster population was located in about 50 small dense patches of oysters that together covered only 12 km^2 of the seafloor. Throughout the years, high catches of oysters have been confined to the same locations suggesting that these localised patches of oysters have remained stable in position over the history of the fishery. Between 1986 and 1992, mortality from *B. exitiosa* progressively destroyed most of the dense patches of oysters. This catastrophic mortality in the established fishery area (the 1975–76 survey area) forced fishers to expand the area fished ahead of the wave of mortality (Doonan et al., 1994).

Grid surveys between 1990 and 1993 sampled on a wider scale (1–2 nautical mile spacing between stations) than a survey in 1975 (0.3 nautical mile spacing) and were not able to delineate small dense patches (Cranfield et al., 1999). Stratified random surveys in 1995, 1997, and 1999 were aimed at estimating population size in the entire fishery area. Although data from these surveys can by used to look at macro scale distribution of oysters (areas where mean density was above a density of 400 oysters per survey tow, equivalent to 6–8 sacks per hour in commercial fishing), the distribution of sampling could not delineate small patches. Recent surveys in 1999, 2001, 2002, 2005, and 2007 have focused sampling effort on commercial areas designated by fishers and their logbook data, to primarily estimate the size of the commercial population. Logbook data were aimed at recording commercial patches of recruited oysters down to 0.3 nautical miles and to identify areas of low oyster density from prospecting tows. In 2006, fishers' logbooks were reformatted to record data on catch and effort, bycatch, size structure, and estimates of new clocks to estimate disease mortality in nautical mile squared grids. All fishing events from all vessels in the oyster fleet were recorded for the 2006 oyster season.

Mortality from *B. exitiosa* infection has reduced recruited oyster density to low levels throughout the commercial oyster fishery area. There is insufficient information from either surveys or logbooks to describe the distribution of oysters at a fine spatial scale.

4. STOCK ASSESSMENT

a) Population estimates

Surveys of the Foveaux Strait oyster population have been reported since 1906, see Table 7 for estimates since 1960 and Sullivan et al. (2005) and Dunn (2005) for details. Early surveys 1906, 1926–1945 are summarised by Sorensen (1968). Two large surveys to map oyster density were carried out in 1960–62 by Stead (1971), and again in 1975 and 1976 by Cranfield & Allen (1979). The efficiency of the small dredge used in 1975 and 1976 was poorly estimated at that time and the population estimate from that survey was too inaccurate for use in management. The efficiency of that survey dredge was better estimated during the surveys of 1990 and this new estimate of efficiency for the dredge was used to re-estimate the oyster population in 1975–76 to give a more accurate estimate that is comparable with recent surveys (Doonan et al., 1994).

The absolute population size was estimated in 1990 using a stratified random dive survey. The efficiency of the small survey dredge and of commercial dredges was estimated by comparing oyster density in the same areas using these dredges with the density from the dive survey. In 1992 and 1993 the population was estimated from grid pattern dredge surveys. The population was estimated from stratified random surveys in March and October 1995, and in October 1997, 1999, 2001, 2002, January 2005, and in February 2007. Surveys of the Foveaux Strait oyster population have been traditionally in October after the commercial oyster season had finished, when the seasonal mortality from *B. exitiosa* was at its lowest, and to allow sufficient time for the stock assessment process to be completed before the next oyster season began the following March. Population estimates from surveys in 1990–1997 used an estimate of dredge efficiency (0.164) and surveyed the whole fishery area with a two-phase random stratified design. Population estimates for these surveys are shown in Table 7. The 1999–2007 population surveys used a revised estimate of dredge efficiency (0.166) and used information from commercial, exploratory and background areas designated by fishers to stratify the surveys.

A Bayesian length-based, single sex population model for Foveaux Strait oysters that incorporates disease mortality from *B. exitiosa* has been used for the stock assessment of Foveaux Strait oysters since the 2004. Projections of recruit-sized stock abundance based on harvest levels of 15 million oysters and no catch, and levels of *B. exitiosa* mortality ranging from 0–0.4 y^{-1} have been updated for the 2005, 2006, and 2007 oyster stock assessments (Dunn, 2005, 2006, 2007). This model assumes a single stock within the stock boundaries. A spatially explicit epidemiological model of *B. exitiosa* (Gilbert & Michael, 2006) may incorporate the stock assessment model in the future to provide stock assessment on sub areas of the fishery.

Table 7: Summary of Foveaux Strait dredge oyster survey data 1960–2007 with recruited, pre-recruit, and small oyster population size estimates (millions of oysters) and CVs. For longer and more detailed data 1960–2007 see Dunn (2007). '–' indicates unknown.

Date	Design[1]	Area (km^2)	Stations	Type[2]	Category	Live	CV	Reference
1960–64	Grid	ca. 1800	542	E	Recruit	~1 000	–	Stead (1971b)
		1055	310	E*	Recruit	3 059	0.21	Dunn (2005)
1962	Specific	–	36	Dive	Recruit	–	–	Stead 1971b)
1965–1971	Specific	374	6	C	–	–	–	Street & Crowther (1973)
1973	Grid	–	150	F	Recruit	–	–	Allen & Cranfield (1979)
Apr–Aug 1974	MR	374	–	C	Recruit	~1 800	0.20	Cranfield & Allen (1979)
Apr–Aug 1975	MR	374	–	C	Recruit	~1 500	0.11	Cranfield & Allen (1979)
1975–76	Grid	374	929	F	Recruit	1 140	0.15	Allen & Cranfield (1979)
Sep 1986	Specific	–	27	F	Recruit	–	–	Dinamani et al. (1987)
Jan 1987	Specific	–	67	F	Recruit	–	–	Dinamani et al. (1987)
Jul 1990	Grid	1116	293	D*	Recruit	771	0.14*	Cranfield et al. (1991)
		1055	293	D*	Recruit	707	0.11	Dunn (2005)
Oct 1990	SR	646	83	Dive	Recruit	–	–	Cranfield et al. (1991)
		646	83	Dive	Pre-recruit	–	–	Cranfield et al. (1991)
		646	83	Dive	Small	–	–	Cranfield et al. (1991)
Oct 1990	SR	646	116	F	Recruit	607	0.11	Cranfield et al. (1991)
		1055	116	F*	Recruit	623	0.12	Dunn (2005)
Mar 1992	Grid	1229	370	D*	Recruit	319	0.18	Doonan & Cranfield (1992)
		1055	293	D*	Recruit	285	0.12	Dunn (2005)
Oct 1993	Grid	875	177	D*	Recruit	372	0.21	Cranfield et al. (1993)
		1055	177	D*	Recruit	397	0.10	Dunn (2005)
		1055	177	D*	Pre-recruit	383	0.11	Dunn (2005)
		1055	177	D*	Small	1 004	0.10	Dunn (2005)
Mar 1995	SR	680	50	D*	Recruit	543	0.30	Cranfield et al. (1995)
		680	50	D*	Pre-recruit	–	–	Cranfield et al. (1995)
		1055	49	D*	Recruit	576	0.25	Dunn (2005)
		1055	49	D*	Pre-recruit	401	0.28	Dunn (2005)
		1055	49	D*	Small	402	0.25	Dunn (2005)
Oct 1995	SR	680	154	D*	Recruit	639	0.19	Cranfield et al. (1996)
		1055	154	D*	Recruit	782	0.11	Dunn (2005)
		1055	154	D*	Pre-recruit	380	0.10	Dunn (2005)
		1055	154	D*	Small	718	0.21	Dunn (2005)
Oct 1997	SR	693	107	D*	Recruit	630	0.21	Cranfield et al. (1998)
		1055	107	D*	Recruit	660	0.14	Dunn (2005)
		1055	107	D*	Pre-recruit	727	0.14	Dunn (2005)
		1055	107	D*	Small	918	0.14	Dunn (2005)
Jan 1998	Specific	–	–	D*	Recruit	–	–	Cranfield (1998)
		–	–	D*	Pre-recruit	–	–	Cranfield (1998)
Oct 1999	SR	1055	199	D*	Recruit	1 461	0.16	Michael et al. (2001)
		1055	199	D*	Recruit	1 453	0.16	Dunn (2005)
		1055	199	D*	Pre-recruit	896	0.12	Dunn (2005)
		1055	199	D*	Small	1 364	0.11	Dunn (2005)
Mar 2000	Specific	–	35	D*	Recruit	–	–	Dunn et al. (2000)
Oct 2001	SR	1055	192	G*	Recruit	995	0.11	Michael et al. (2004b)
		1055	192	G*	Pre-recruit	872	0.12	Michael et al. (2004b)
		1055	192	G*	Small	1 410	0.12	Michael et al. (2004b)
Jan 2002	Specific	–	35	G*	Recruit	–	–	Dunn et al. (2002b)
Mar 2002	Specific	–	35	G*	Recruit	–	–	Dunn et al. (2002a)
Oct 2002	SR	1055	155	G*	Recruit	502	0.14	Michael et al. (2004a)
		1055	155	G*	Pre-recruit	520	0.11	Michael et al. (2004a)
		1055	155	G*	Small	1 243	0.10	Michael et al. (2004a)
Feb 2003	Specific	–	16	G*	Recruit	–	–	Dunn et al. (2003)
Jan 2004	Specific	–	40	G*	Recruit	–	–	Michael (unpub.)
Jan 2005	SR	1055	80	G*	Recruit	408	0.13	Michael et al. (2006)
		1055	80	G*	Pre-recruit	415	0.15	Michael et al. (2006)
		1055	80	G*	Small	1 345	0.12	Michael et al. (2006)
Feb 2006	Specific	407	44	G*	Recruit	242	0.14	Michael (unpub.)
		407	44	G*	Pre-recruit	257	0.17	Michael (unpub.)
		407	44	G*	Small	622	0.13	Michael (unpub.)

Table 7 (continued): Summary of Foveaux Strait dredge oyster survey data 1960–2007 with recruited, pre-recruit, and small oyster population size estimates (millions of oysters) and CVs. '–' indicates unknown.

Date	Design[1]	Area (km^2)	Stations	Type[2]	Category	Live	CV	Reference
Feb 2007[4]	SR	1070	104	G*	Recruit	665	0.11	Michael (unpub.)
		1070	104	G*	Pre-recruit	488	0.12	Michael (unpub.)
		1070	104	G*	Small	885	0.10	Michael (unpub.)
		1055	101	G*	Recruit[3]	663	0.11	Dunn (2007)
		1055	101	G*	Pre-recruit[3]	486	0.12	Dunn (2007)
		1055	101	G*	Small[3]	879	0.10	Dunn (2007)

1. Survey designs either circumscribed the known oyster beds (CD), sampled specific stations non-randomly (specific), followed a grid pattern (grid), were stratified random (SR), or were mark-recapture surveys (MR).
2. Indicates a calibrated estimate. A–F indicates the type of dredge, while 'Dive' indicates a dive survey. The dredges are: (A) Light, hand-hauled commercial dredge about 1 m-wide, used up to 1913; (B) Commercial dredge, about 3.35 m-wide with single-bit and single ring bag, weighing ~150 kg and used up to 1968; (C) Commercial dredge, about 3.35 m-wide, introduced in 1968 with double-bit and double ring bag and weighing about 400 kg; (D) The 1968 commercial dredge, about 3.35 m-wide, modified in 1984 increasing weight to about 530 kg; (E) 0.91 m-wide light survey dredge with a rigid mesh catch bag; (F) 1.25 m-wide survey dredge, designed to be a smaller version of 1968 commercial dredge with double-bit and double flexible ring bag; (G) 3.32 m-wide commercial dredge similar to the 3.35 m-wide dredge introduced in 1968 with double-bit and double ring bag, and weighing 400 kg.
3. The February 2007 included an additional stratum in the north Foveaux Strait. Re-analysed estimates ignore this stratum, and hence are estimates of abundance over an area comparable to earlier surveys.
4. Two errors in the length of tows resulted in a revised estimate of the number of recruits and small oysters for the February 2007 survey. Model runs presented below used values of 661 recruits and 877 smalls for the February 2007 abundance indices, instead of the corrected values of 663 and 879 respectively.

b) Estimate of the commercial population and yield

Since 1996, yield was estimated for the commercial population (the part of Foveaux Strait likely to be fished), to prevent recruitment over fishing in areas where oyster populations were rebuilding after *B. exitiosa* mortality. Estimates of commercial population size between 1996 and 1999 used the portion of the population over 400 oysters per tow (roughly equivalent to a commercial catch rate of 6–8 sacks per hour considered economic by fishers in the 1970s and early 1980s) from the entire Foveaux Strait fishery area. From 2000, estimates of commercial population size were based on estimates of the entire recruited oyster population in areas designated as 'commercial' by fishers (Michael et al., 2004), commercial fishery areas since 2002 are shown in Figure 4.

The mean commercial population size in February 2007 196 million oysters (95% C.I.s 124–300) has increased from 144 million (95% C.I.s 93–216 million) in October 2002. The area of the designated commercial areas increased from 173 km2 in 2002 to 367 km^2 in 2005, and remained the same in 2007. Oyster density was halved from 0.83 oysters/m^2 to 0.44/m^2 in 2005, but slightly increased to 0.53 /m^2 in 2007.

A commercial catch rate of 6–8 sacks per hour provided a reasonable economic return to fishers' (paid by how much they catch) in the 1970s and 1980s and this rate corresponds to 400 oysters per standard survey tow. Although it has no biological basis, it has been used as an indicator of commercial densities. Estimates of the proportion of oysters above 400 oysters per standard survey tow over the entire fishery area 2001–07 are given in Table 8.

Table 8: Estimates of the proportion of oysters above 400 oysters per standard survey tow over the entire fishery area 2001–07; the number of stations sampled (No. stations), the mean oyster density per m^2 (Mean density), standard deviation (s.d.) of the density estimate, coefficient of variation (CV) of the population estimate, mean population size (Mean population with upper and lower 95 % confidence intervals in parenthesis), and the area of each survey (Area).

Year	No. stations	Mean density	s.d.	CV.	Mean	population 95% CI	Area km^2
2001	192	0.59	0.10	0.17	624	(359–1012)	1054
2002	155	0.17	0.06	0.33	178	(57–331)	1054
2005	80	0.03	0.02	0.58	33	(0–78)	1054
2007	104	0.19	0.07	0.36	204	(60–403)	1070

Before the 2004 OYU 5 stock assessment, the Foveaux Strait oyster fishery was managed by current annual yield (CAY, Method 1, see Sullivan et al., 2005) based on survey estimates of the population in designated commercial fishery areas. Since 2004, the TACC has been based on estimates of recruit size stock abundance from the Foveaux Strait oyster stock assessment model (Dunn, 2007) and projections of future recruit size stock abundance under different catch limits and heightened mortality from *B. exitiosa*.

A possible and significant source of error in the estimate of yield could be the estimate of dredge efficiency and its' impact on the estimate of commercial population size. Dredge efficiency was last calculated in 1990. The distribution of oysters, the structure of commercial fishery areas, the substrate and epifauna, and the number of clocks (shells of dead oysters) are likely to have changed since then and may effect dredge efficiency.

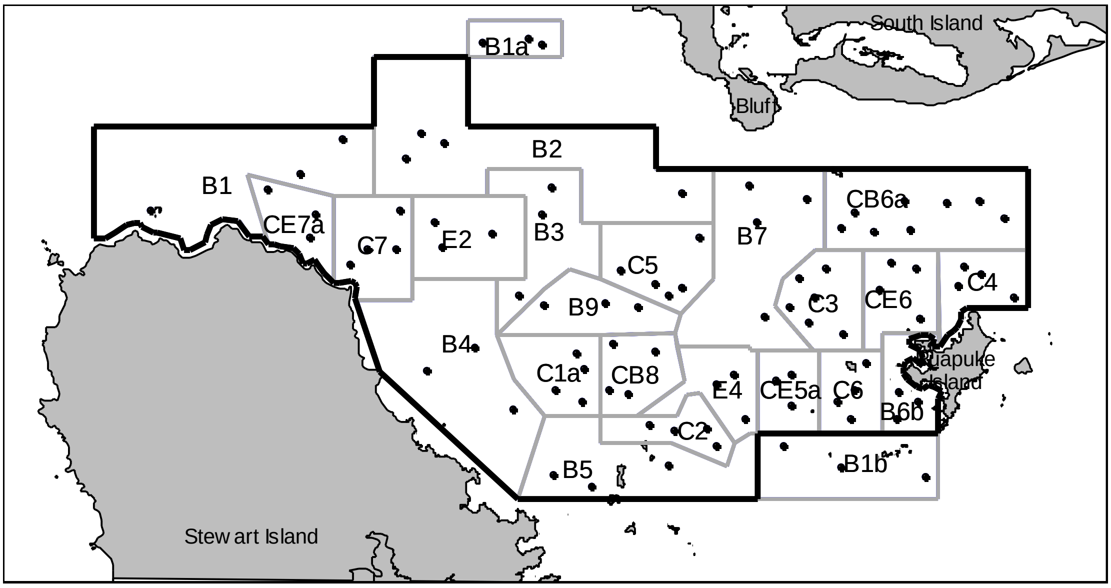

Figure 4: The 1999 survey area, and strata surveyed and the first-phase station allocation (points) used in the February 2007 survey. Strata designated commercial by oyster boat skippers are those with a "C" prefix. Exploratory strata are those designated by an "E" prefix, and background strata by "B" prefix. New strata are B1a, B1b, and CE7a.

c) Estimates of recruit size stock abundance

In 2004, Dunn (2005) presented a Bayesian, length-based single-sex, stock assessment model for Foveaux Strait dredge oysters. The base case from that assessment was updated to include data from the 2005–06 fishing year and the abundance indices from the February 2006 survey. The stock assessment was implemented using Bayesian estimation with the general-purpose stock assessment program CASAL (Bull et al., 2005).

The population model partitioned Foveaux Strait oysters into a single sex population, with length (i.e., the anterior-posterior axis) classes 2 mm to 100 mm, in groups of 2 mm (i.e., from 2 to <4 mm, 4 mm to <6 mm, etc.), with the last group defined as oysters ≥ 100 mm. The stock was assumed to reside in a single, homogeneous area. The partition accounted for numbers of oyster by length class within an annual cycle, where movement between length classes was determined by the growth parameters. Oysters entered the partition following recruitment and were removed by natural mortality, disease mortality, and fishing mortality. The models annual cycle was based on the fishing year, divided into two time steps

The model was run for the years 1907–2007. Catch data were available for the years 1907–2006, with the catch for 2007 assumed to be 7.5 million oysters. Catches occurred in both time steps — with special permit and some customary catch assigned to the 1st time step (summer fishing mortality), and commercial, recreational, remaining customary, and illegal catch assigned to the 2nd time step (winter fishing mortality).

Oysters were assumed to recruit at age 1+, with a Beverton-Holt stock recruitment relationship (with steepness 0.9) and length at recruitment defined by a normal distribution with mean 15.5 mm and CV

0.4. Recruitment was assumed to take place at the beginning of the 2nd time step (i.e., the time step immediately following summer spawning). Relative year class strengths were assumed known and equal to initial recruitment for the years up to 1984 — nine years before the first available length and abundance data on small (oysters <50 mm minimum diameter) and pre-recruits (oysters between ≥ 50 to <58 mm minimum diameter) were available; otherwise relative year class strengths were assumed to average 1.0. Growth rates and natural mortality (*M*) were assumed known. Disease mortality is assumed to be zero in the years where there were no reports of unusual mortality, and otherwise estimated.

The models used seven selectivity ogives: the commercial fishing selectivity (assumed constant over all years and time steps of the fishery, aside from changes in the definition of legal size); a survey selectivity, which was then partitioned into three selectivities (one for each for each of the size-groups) — small (<50 mm minimum diameter), pre-recruit (≥ 50 mm and <58 mm minimum diameter), and recruit (≥ 58 mm minimum diameter); maturity ogive; and disease selectivity — assumed to follow a logistic curve equal to the maturity ogive. The selectivity ogives for fishing selectivity, maturity, and disease mortality were all assumed to be logistic. The survey selectivity ogives were assumed to be compound logistic with an additional parameter a_{min}, that describes the minimum possible value of the logistic curve. Selectivity functions were fitted to length data from the survey proportions-at-length (survey selectivities), and to the commercial catch proportions-at-length (fishing selectivity).

The maximum exploitation rate (i.e., the ratio of the maximum catch to vulnerable numbers of oysters in any year) was assumed to be relatively high, and was set at 0.5. No data are available on the maximum exploitation rate, but the choice of this value can have the effect of determining the minimum possible virgin stock size (B_0) allowed by the model.

Model estimates of numbers of oysters were made using the biological parameters and model input parameters described above. The priors assumed for most parameters are summarised in Table 9. In general, ogive priors were chosen to be non-informative and were uniform across wide bounds. The prior for disease mortality was defined so that estimates of disease mortality were encouraged to be low. An informed prior was used when estimating the survey catchability, where a reasonably strong lognormal prior was used, with mean 1.0 and CV 0.2.

Table 9: The priors assumed for key parameters. The parameters are mean and CV for lognormal (in natural space); and mean and s.d. for normal.

Parameter	Distribution	Parameters		Bounds	
CPUE *q*	Uniform-log	–	–	$1x10^{-8}$	0.1
1976 survey *q*	Lognormal	0.5	0.3	0.15	0.95
Mark-recapture survey *q*	Lognormal	0.5	0.3	0.10	0.90
YCS	Lognormal	1.0	1.0	0.01	100.0
Disease mortality	Normal	-0.2	0.2	0.00	0.80

A single Monte-Carlo Markov Chain (MCMC) was run on the model, with length $6x10^6$ iterations including a burn-in of $1x10^6$. Final posterior distributions were derived from systematic sub-sampling (“thinning”) of the chain, excluding the burn-in, to 1000 samples. Convergence diagnostics for all parameters the model were not formally investigated, but the trace plots indicated reasonable evidence for convergence (not shown).

Model fits to recruit sized and pre-recruit sized dredge survey length frequencies, maturity data, and fishing length frequencies were adequate, although there was some evidence of over-fitting to the recruit sized length frequencies. Diagnostic plots of the combined fits to recruit, pre-recruit, and small dredge survey selectivities suggested that the parameterisation of selectivities for the three size groups (recruit, pre-recruit, and small) was adequate. Estimated CPUE *q*’s showed an increase in relative catchability from series A and B to series C, possibly corresponding with improved technology and dredge size. The 1975–76 and mark-recapture abundance data contribute little to the model fits, as these series are short and are unrelated to other abundance data in the model — their *q*’s are probably more a reflection of how the model interprets the estimates to be consistent with other abundance information from longer time series, i.e., about 30–50% of the total abundance available at that time (both of these survey data represent abundance within a smaller survey region than that was covered in subsequent surveys). However, posterior distributions for all the catchability constants were relatively narrow. MPD model fits to abundance indices showed no strong evidence of poor fit to the data. However, most of the historical data provided to the model were derived from the catch-effort indices and it is not known how well these index abundance (although comparisons with survey data suggest that these are broadly informative).

The model suggested the virgin equilibrium spawning stock population size to be about 5330 (4660–6190) million oysters, and the current spawning stock size to be 1070 (910–1280) million oysters. The recruit-sized population was estimated as 740 (630–880) million (see Figure 5).

Estimates of the disease mortality rate ranged from 0.0 up to a maximum of 0.80 y^{-1} (the upper bound) in the mid-1980s and early 2000s, and accounted for the dramatic declines in the abundance of oysters during periods of epidemic.

Estimates of relative year class strength were uncertain and variable, but suggest that there may have been a pulse of strong recruitment during the mid to late-1990s. Recent recruitment was estimated to be lower than average. However, without other, better, data on historical levels of recruitment, these estimates could not be validated.

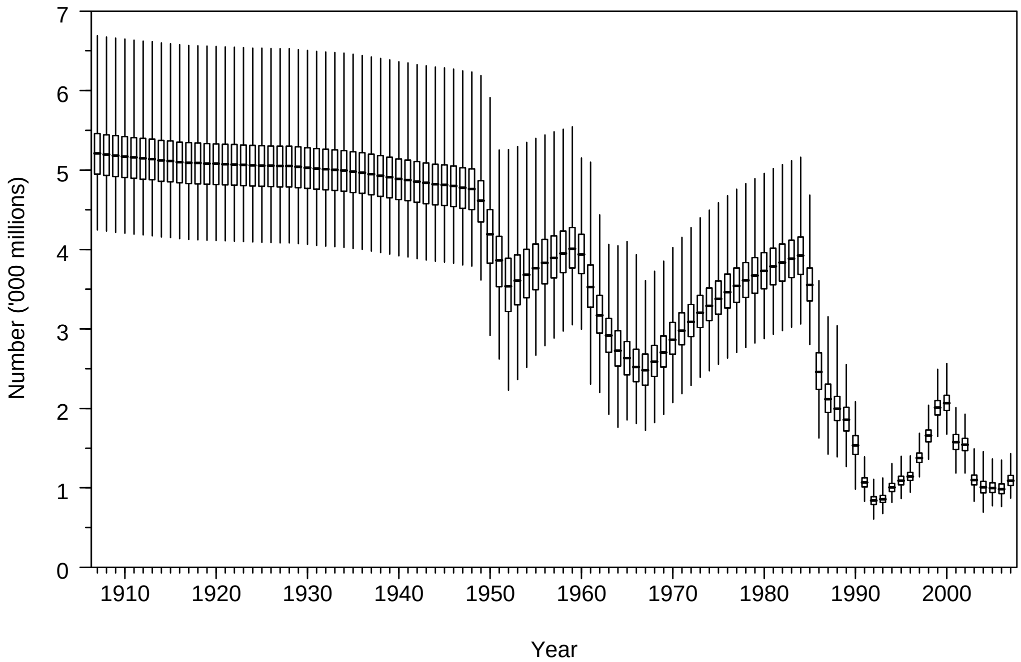

Figure 5: Estimated posterior distributions of SSBs. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

Projected stock estimates were made assuming that future recruitment will be log-normally distributed with mean 1.0 and standard deviation equal to the standard deviation of log of recruitment between 1985 and 2004 (i.e., 0.34 with 95% range 0.29–0.39). Projections were made assuming no future disease mortality and with future disease mortality assumed to be 0.0 y^{-1}, 0.10 y^{-1}, and 0.20 y^{-1}. Two future catch levels were considered each with 7.5 million oysters in 2007, and a future annual commercial catch of either 7.5 or 15 million oysters. Future customary, recreational, and illegal catch were assumed equal to levels assumed for 2007. Projected output quantities are summarised in Table 10 and Table 11.

Under the assumptions of future disease mortality, model projections of commercial catch at either 7.5 or 15 million showed little difference in expected population size For example, the projected population size in 2010 with a commercial catch of 7.5 million was less than 2% higher than that with a commercial catch of 15 million oysters. Depending on the level of assumed disease mortality, projected status in 2010 ranged from about 60% more than current levels (assuming no disease mortality) to a level similar to the current level (assuming disease mortality of 0.2 y^{-1}). Plots of the median expected recruit sized population are given in Figure 6.

Table 10: Median and 95% credible intervals of current spawning stock biomass 2007 (B_{2007}), and projected spawning stock biomass for 2008–2010 (B_{2008}–B_{2010}) as a percentage of B_0 with an assumption of a future catch of 7.5 million oysters in 2007 and 7.5 or 15 million oysters in 2008–2010, and disease mortality rate of 0.0, 0.1, or 0.2 y^{-1}.

Disease mortality	Catch (millions)	B_{2007} (% B_0)	B_{2008} (% B_0)	B_{2009} (% B_0)	B_{2010} (% B_0)
0.00	7.5	21.2 (18.0–24.7)	24.1 (19.4–29.6)	28.9 (23.3–35.8)	33.6 (27.5–42.0)
	15.0	21.2 (18.0–24.7)	24.1 (19.4–29.6)	28.8 (23.2–35.7)	33.4 (27.3–41.8)
0.10	7.5	21.2 (18.0–24.7)	23.4 (18.8–28.7)	25.5 (20.5–31.6)	27.2 (22.1–34.0)
	15.0	21.2 (18.0–24.7)	23.4 (18.8–28.7)	24.5 (20.4–31.5)	27.0 (22.0–33.9)
0.20	7.5	21.2 (18.0–24.7)	22.8 (18.4–28.0)	22.0 (18.0–28.1)	21.2 (18.0–28.1)
	15.0	21.2 (18.0–24.7)	22.8 (18.4–28.0)	22.4 (18.1–27.9)	21.1 (17.9–27.9)

Table 11: Median and 95% credible intervals of expected recruit-sized stock abundance for 2007–2010 with an assumption of a future catch of 7.5 million oysters in 2007 and 7.5 or 15 million oysters in 2008–2010, and disease mortality rate of 0.0, 0.1, or 0.2 y^{-1}.

Disease mortality	Catch (millions)	rB_{2007}/rB_{2007}	rB_{2008}/rB_{2007}	rB_{2009}/rB_{2007}	rB_{2010}/rB_{2007}
0.00	7.5	1.00 (1.00–1.00)	1.15 (0.96–1.27)	1.37 (1.15–1.58)	1.59 (1.34–1.89)
	15.0	1.00 (1.00–1.00)	1.15 (0.96–1.27)	1.36 (1.15–1.57)	1.58 (1.33–1.88)
0.10	7.5	1.00 (1.00–1.00)	1.16 (1.01–1.28)	1.31 (1.14–1.55)	1.44 (1.20–1.80)
	15.0	1.00 (1.00–1.00)	1.16 (1.01–1.28)	1.30 (1.13–1.54)	1.43 (1.19–1.78)
0.20	7.5	1.00 (1.00–1.00)	1.08 (0.94–1.19)	1.07 (0.92–1.27)	1.05 (0.87–1.33)
	15.0	1.00 (1.00–1.00)	1.08 (0.94–1.19)	1.06 (0.91–1.26)	1.04 (0.86–1.31)

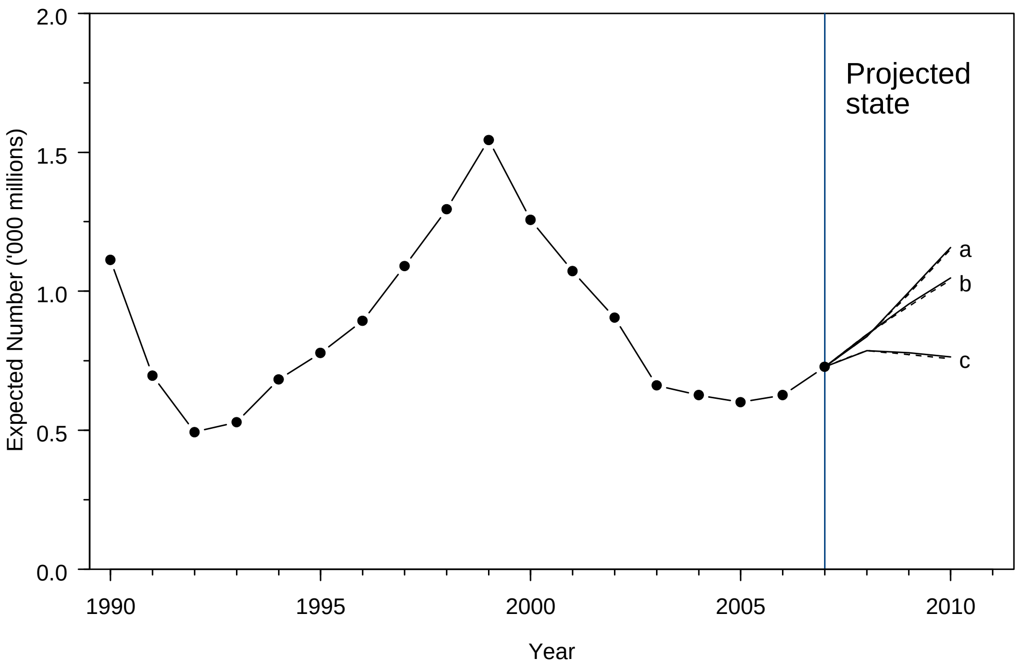

Figure 6: Estimates of recent recruit-sized stock abundance and projected recruit-sized stock abundance for 2008–2010 with catch of 7.5 (black) and 15 million oysters (grey), under assumptions of (a) no disease mortality, (b) disease mortality of 0.10 y^{-1}, and (c) disease mortality of 0.20 y^{-1}.

5. FACTORS MODIFYING YIELD ESTIMATES

a) Continuing mortality from *Bonamia exitiosa*

Since the present *Bonamia exitiosa* epizootic began in 2000, surveys of the oyster population found all areas with high densities of recruited oysters including the designated commercial areas had a high prevalence of infection, and all areas had some high intensity patches of infected oysters within or near them. By October 2002, mortality from *B. exitiosa* infection had reduced both the numbers of commercial fishery areas and the oyster densities within them. Mortality of oysters from 1999–2002 has reduced the oyster population in designated commercial fishery areas to one-third of the population in 1999. Between October 2002 and January 2005, large numbers of pre-recruit oysters entering the fishery have exceeded mortality from *B. exitiosa* infection. In 2007, may of these appear to have recruited to the fishery increasing the population size of recruited oysters by about 63% since 2005. Strong rebuilding was recorded in the area where *B. exitiosa* infection was first detected in 1999 and 2000.

Infection by *B. exitiosa* in oysters sampled at 40 stations in February 2006 showed the distribution of infection was widespread, from localised patches in the eastern fishery in January 2005 to infection spread across the fishery areas in February 2006. Fishing effort over this period was almost exclusively in the eastern fishery. Although prevalence (the percentage of infected oysters in a sample) of infection was similar to January 2005, intensity of infection (in infected oysters only) had increased. Mortality based on the number of oysters sampled with category 3+ infections and oyster densities estimated from limited sampling in commercial strata in February 2006 was expected to reduce the recruited oyster population from 242 million oysters (95% CI 145–377) to 228.2 million (135–357) by the beginning of the 2006 oyster season. Preliminary exploration of the 2007 data from 104 random stations show 51% of stations with some infection detected and about 11% of all oysters sampled. Prevalence ranged from 4–52% in samples. Some 65% of infected oysters had category 3+ infections.

Examination of qualitative data on fishing patterns and the spread of prevalence and intensity of infection suggest no direct link between fishing, infection, and disease mortality; and the factors that influence infection are global and possibly environmentally driven. These will be better investigated shortly using the 2006 fishers' logbook data providing good coverage of the fleet fishing effort and the 2007 infection data.

6. STATUS OF THE STOCKS

The Foveaux Strait oyster fishery has been fished for 140 years and is considered a single stock. In the 1970s and early 1980s, catch limits were set at about 89 million oysters (then as 115 000 sacks). A *B. exitiosa* epizootic in 1986 reduced the recruited oyster population to below 10% of its pre disease level by 1992. The fishery was closed in 1993 and reopen after a rapid rebuild in 1996 with a catch limit (TACC) of 14.95 million oyster to allow the fishery to rebuild. Another *B. exitiosa* epizootic in 2000 further reduced the population to low levels, and the fishery is currently beginning another rebuilding phase.

Mortality from infection by *B. exitiosa* is the principal driver of oyster population dynamics in Foveaux Strait. Infection by *B. exitiosa* was widespread in the fishery area in February 2006. Results from a survey in February 2007 that investigated the status of infection will be available from June 2007.

Since 2004, model projections of recruit-sized stock abundance under different catch limits and mortality levels (from *B. exitiosa*) have been used for the Foveaux Strait oyster stock assessment. In 2007, model estimates of population size were similar to those projections from the 2005 stock assessment. While uncertainty exists in levels of future recruitment and continued *B. exitiosa* related mortality, projections from the Foveaux Strait oyster stock assessment model indicate that current catch limits are unlikely to have any significant impact on future stock levels. Instead, future disease mortality will determine future stock status. Depending on the level of assumed disease mortality, the median projected status in 2010 ranged from about 60% more than the current level (with nil disease mortality) to about the same as the current level (assuming disease mortality of 0.2 y^{-1}). The model trajectories showed continued rebuilding of the fishery.

The recent survey indicated that the central and western areas have been rebuilding and eastern areas have been further reduced by bonamia mortality. This temporal pattern of the distribution of oyster density is similar to that observed between 1986 and 1999. There was no sampling for bonamia infection between October 1995 and 1999, and it is not know whether low levels of bonamia mortality were present in the fishery 1995–1999, but not causing mortality while oyster populations were rebuilding.

Few fishery specific data are available to assess the direct and indirect effects of oyster dredging on recruitment, growth, and mortality of oysters. Oyster dredging has been shown to increase the mortality of spat settled the previous summer; 36% of spat < 10 mm in length, in a single pass of a commercial dredge. A natural mortality of this size class, up to 90%, has been recorded for spat settled on artificial collectors and in the absence of dredging. Fishing effort has decreased from the 1960s to 1980s.

Reported landings and catch limits for the 2005/06 fishing year are summarised in Table 12.

Table 12: Catch limits and reported landings for the 2005/06 fishing year.

Fishstock	Catch limit	Reported landings 2005-06
OYU 5	14.95	7.44

7. FOR FURTHER INFORMATION

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