DREDGE OYSTER (OYU 5)-Foveaux Strait

(*Ostrea chilensis*)

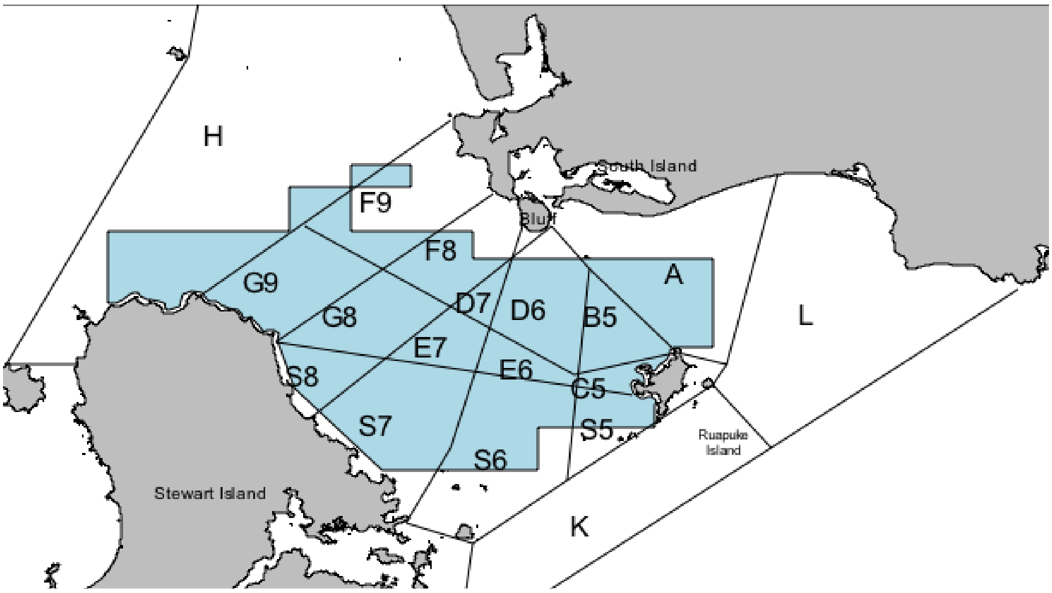


Figure 1: Foveaux Strait (OYU 5) stock boundary and oyster fishery statistical reporting areas, and the outer boundary of the 2007 stock assessment survey area (blue shade) encompassing almost all the commercial fishery.

1. FISHERY SUMMARY

The Foveaux Strait oyster fishery OYU 5 was introduced into the Quota Management System in 1998, with a TAC of 20 300 000 million oysters (Table 1).

Table 1: Total Allowable Catch (TAC) in numbers of oysters, and allocations for customary and recreational catch, for OYU 5 since the stock's introduction into the QMS in 1998. There were no estimates of other mortality (–).

Year	TAC	Customary	Recreational	Other Mortality	TACC
1998 – present	20 300 000	144 000[1]	430 000[1]	–	14 950 000

[1] Dunn, A. (2005)

1.1 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 established 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 boundaries and statistical reporting areas are shown in Figure 1.

Catch limits were introduced in 1963. In 1970, vessel numbers were limited to 23 by regulation. The catch limits were evenly divided between the 23 vessels. Before 1992, landings and catch limits in this fishery were recorded in sacks. Sacks contained an average of 774 oysters and weighed about 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. Reported landings for the period 1907–1962 are shown in Table 2. Catch limits and total landings for 1963–92 are shown in Table 3.

Table 2: Reported landings of Foveaux Strait oysters 1907–1962 (millions of oysters; sacks converted to numbers using a conversion rate of 774 oysters per sack). (Data summarised by Dunn, (2005) 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 3: Reported landings and catch limits for the Foveaux Strait dredge oyster fishery from 1963–1992 (millions of oysters; sacks converted to numbers using a conversion rate of 774 oysters per sack). Catch rate shown in sacks per hour. (Data summarised by Dunn, (2005) from Marine Department Annual Reports).

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	4	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	5	36	5.8
1977	92	2	89	15.9	1992	5	6	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 Catch limit reduced by the proportion of the fishery area with oysters infected by *B. exitiosa* and closed.
5 Landings include catch given as an incentive to fish a 'firebreak' to stop the spread of *B. exitiosa*.
6 Fishing only permitted in outer areas of fishery.

In 1986, *Bonamia exitiosa* (bonamia) was identified as the cause of high mortality in the oyster population and the epizootic reduced oyster density, and the size and number of commercial fishery areas over the next six years (see Cranfield et al. 2005, Doonan et al. 1994). Over that period, management of the fishery used changes to catch limits (Table 3) and spatial fishing strategies to minimize the effects of disease mortality and the spread of infection. In 1993 the oyster fishery was closed to allow the population to recover. The fishery was reopened 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. From 1996, catches were recorded as numbers of oysters. Catch limits and total landings for 1996 to the present are shown in Table 4. Another *B. exitiosa* epizootic confirmed in March 2000 caused a decline in the oyster population and further reduced landings from 2003 (Table 4). Between 2003 and 2008, the Bluff Oyster Management Company (BOMC) shelved half of the TACC, harvesting about 7.5 million oysters annually. In 2011, the population size was continuing to increase and BOMC began to slowly reduce the level of shelving.

The Bluff Oyster Enhancement Company Ltd (BOEC) was established in 1992 to facilitate an oyster enhancement programme in attempts to rebuild the OYU 5 stock back to its pre-1985 level. In 1997, BOEC was renamed the Bluff Oyster Management Company Limited (BOMC), which became a commercial stakeholder organisation (CSO) to represent the combined interests of owners of individual transferable quota (ITQ) shares in the Bluff Oyster fishery (OYU 5). In April 1997, individual quotas were granted, and quota holders were permitted to fish their entire quota on one vessel. The quota shares were evenly allocated based on the 23 vessel licences. Soon after, the numbers of vessels in the fleet declined from 23 to 11. At the same time, the Crown purchased 20% of the available quota from quota holders by tender from willing sellers and transferred it to the Waitangi Fisheries Commission.

The commercial fishing year for the oyster fishery is from 1 October to 30 September however, oysters have been traditionally harvested over a six-month season, 1 March to 31 August. Commercial and recreational fishery data is reported by calendar year and customary fishing by fishing year (1 October to 30 September) as customary permits are issued out of season.

Table 4: Reported landings and catch limits for the Foveaux Strait dredge oyster fishery from 1996–to present. TACC was 14.95 million oysters over this period. Landings and catch limits reported in numbers (millions) of oysters. 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 (774 oysters per sack). Catch rate does not include oysters taken by crew as recreational catch. The numbers of oysters per sack can vary considerably (720–800 per sack, industry data) depending on the fishery areas from which they were caught, the sizes of oysters in these areas, and, and epifauna attached. Some oysters are landed in bins, and bins converted to sacks using a conversion factor of 0.5. Since 2009, fishers have been paid to high-grade the catch and they fish in areas where oyster meat quality is high, but catch rates are lower than for other areas with higher oyster densities, but with lower meat quality. CPUE from 2009 underestimates relative abundance. **[Continued on next page]**

Year	Reported landings	Catch limit including voluntary Catch limits from 2003	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	7.475 [1]	2.3	2.6
2004	7.48	7.475 [1]	2.2	2.5
2005	7.57	7.475 [1]	1.7	1.8
2006	7.44	7.475 [1]	1.9	1.9
2007	7.37	7.475 [1]	2.2	2.4
2008	7.49	7.475 [1]	3.3 [2]	3.3

Table 4 [Continued]:

2009	8.22	8.22 [3]	3.9 [2,4]	3.0
2010	9.54	9.53	4.2 [2,4]	4.2
2011	10.6[5]	10.6[5]	4.2 [2,4]	4.1
2012	11.6	11.6	4.2 [2,4]	4.1
2013	13.2	13.2	5.5 [2,4]	5.5

1 Fifty percent of the TACC was shelved for the season
2 Fishers given incentive to sort above MSL to increase market value, and changes in sorting potentially result in lower catch rates compared to previous years.
3 BOMC unshelved 10% of their shelved quota.
4 Catch reported in bins and sacks, bins converted to sacks by a conversion factor of 0.5.
*5 Landings d*ata for 2011 includes 1.0 million oysters caught under a special permit for the Rugby World Cup.

The landings of oysters from OYU5 (millions of oysters) from 1995–96 to present are shown in Figure 2.

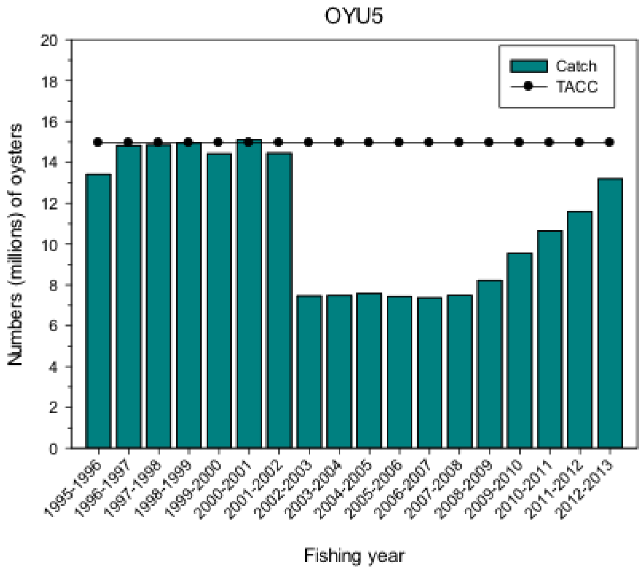


Figure 2: Landings of oysters from OYU 5 (millions of oysters) from 1995–1996 to 2011–2013.

1.2 Recreational fisheries

In 2002, Fisheries Officers estimated that between 70 and 100 recreational vessels were fishing from Bluff and smaller numbers from Riverton and Colac Bay. Recreational fishers may take 50 oysters per day during the open season (March–August). A charter boat fleet (approximately 17 vessels) based at Stewart Island, Bluff, and Riverton also targets oysters during the oyster season.

Four surveys of recreational fishing have been conducted to estimate recreational harvest: the South region 1991–92 survey, the 1996 survey (Bradford 1998), the 1999–2001 survey (MPI Recreational database), and the 2000–01 (MPI Recreational database) 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. The Southland Recreational Marine Fishers Association estimated that the annual recreational catch of oysters in Foveaux Strait in 1995 was about 300 000 oysters.

Table 5: Reported annual recreational catch (numbers of oysters) taken from commercial vessels March to August 2002–present (CELR data) and reported customary catch (numbers of oysters) October to September 1998–present (Tangata taiki data collected by Ngai Tahu).

Year	Recreational catch from commercial vessels els	Customary catch	
1998	N/A	143 940	[1]
1999	N/A	177 360	
2000	N/A	223 332	
2001	N/A	259 243	
2002	236 103	184 335	
2003	282 645	157 980	
2004	146 567	127 708	
2005	190 345	76 464	
2006	139 252	85 312	
2007	90 544	109 260	
2008	141 587	202 952	
2009	182 331	347 390	
2010	179 587	322 498	
2011	219 068	4 020	
2012	219 700	103 110	
2013	227 310	125 260	[2]

1 Customary catch reported for the period 1 July to 31 December only.
[2] Customary catch reported for the period 1 January to 30 September only

The commercial oyster fleet are a major contributor to the level of recreational harvest. Commercial fishers are entitled to 50 oysters each day (subject to approval under s111 of the Fisheries Act 1996), with each commercial vessel's crew potentially taking up to 400 oysters as recreational catch each day. Recreational catches from commercial vessels have, in the past, been reported on Catch and Effort Returns (CELR); and since 2002, have been separately reported on returns and not included in commercial catch effort statistics. Commercial fishers took 227310 oysters under recreational bag limits during the 2013 oyster season. Recreational catch taken on commercial vessels is shown in Table 5.

1.3 Customary non-commercial fisheries

Reporting of Maori customary harvest is specified in the Fisheries (South Island Customary Fisheries) Regulations 1999. Ngai Tahu administers the reporting of customary catch of Foveaux Strait oysters to the Ministry for Primary Industries. Customary catch is reported in the quarter it is summarized, landing dates are not reported for catches under customary permits. A small amount of customary fishing is believed to take place between 31 August and 30 September, and no customary permits are supposed to be issued for the quarter 1 October to 31 December while oysters are spawning. Reported customary catch for 1998 to 2013 is given in Table 5.

1.4 Illegal catch

There are no estimates of illegal catch for OYU 5.

1.5 Other Sources of Mortality

1.5.1 Mortality caused by *Bonamia exitiosa*

Bonamia exitiosa is a haemocritic, haplosporid parasite (infects mainly haemocytes or blood cells) of flat oysters. It is known to infect *Ostrea chilensis* in New Zealand and Chile; *Ostrea angasi* in Australia; *Ostrea puelchana* in Argentina; *Ostrea* (*Ostreola*) *conchaphila* in California, USA; *Ostrea edulis* in Atlantic Spain and probably in the Gulf of Manfredonia (Italy); *Ostrea* *stentina* in Tunisia, and possibly northern New Zealand (this isolate is also similar to *Bonamia. roughleyi*); and *Crassostrea ariakensis* in North Carolina, USA (Mike Hine, pers. comm.). Further, an unknown species of bonamia has been identified in two species of native oysters from Hawaii.

Mortality of oysters from *B. exitiosa* is a recurrent feature of the Foveaux Strait oyster population and the main driver of oyster abundance during epizootics. Large numbers of new clocks (shells of oysters that have died within six months) and oysters in poor condition (both indicative of *B. exitiosa* epizootics), were recorded as long ago as 1906. *B. exitiosa* has been identified in preserved oyster tissues sampled in 1964, at the end of an epizootic that caused a downturn in the fishery (Cranfield et al. 2005) and originally attributed to *Bucephalus longicornutus* (Hine & Jones 1994). A *B. exitiosa* epizootic occurred in the Foveaux Strait oyster fishery in 1986–92 and again in 2000–14. Prevalence of infection between 1996 and 2000 was not sampled, but is thought to be low (almost undetectable) from the low numbers of new clocks that were recorded in biennial oyster population surveys in that period.

The annual cycle of infection is described by Hine (1991). The parasite transmits directly, oyster to oyster, and disease spread is thought to be related to oyster density. Some oysters appear more tolerant of infection than others (Hine 1996). The relationship between the intensity and prevalence of infection in one year, the density of oysters, and the probability of oyster mortality the following year are poorly understood (Sullivan et al. 2005).

It is not known whether other diseases (including an apicomplexan, *Bucephalus* sp., coccidian, and microsporidian) contributed to or caused mortality in oysters during the 1986–92 and 2000–14 epizootics. No direct and immediate effect of oyster dredging on disease status can be determined.

Oyster mortality from bonamia is considerably higher than the commercial catch. Based on the number of oysters sampled with fatal infections during stock assessment surveys, the projected mortality of recruit-sized oysters between the surveys and the oyster seasons have been estimated at 43, 46, 81million oysters for years 2007, 2009, and 2012 respectively. Relatively small bonamia surveys were undertaken in years between stock assessment surveys in key commercial fishery areas, and these surveys did not estimate mortality from the whole population. In 2014, a new series of bonamia surveys began, sampling a core subset of strata which comprised 14 of the 26 stock assessment survey strata from 2012. These 14 strata represent 75% of the recruit-sized oyster population and 46% of the stock assessment survey area.

The 2014 bonamia survey found an overall increase in summer mortality of recruit-sized oysters. Oyster mortality over the summer of 2013–2014 was estimated from the sum of pre-survey mortality estimated from new clocks and gapers, and post survey mortality from the numbers of oysters in the population with fatal, category 3 and higher infections (see Diggles et al. 2003). Pre-survey mortality in core bonamia survey strata was 39.4 million oysters, and a further 44.7 million oysters in the remaining stock assessment strata (background strata). Fatal infections were projected to cause further mortality in 67.1 million oysters in core strata, and 122.4 million oysters for the whole survey area. The number of fatally infected oysters in core strata in 2014 was projected to reduce the recruit-sized oyster population from 538.0 million oysters at the time of the survey (February 2014) to 476.3 million oysters by early in the new oyster season (March 2014), a loss of 11.5%. A further 6.8% of the recruit-sized population died before the survey resulting in an annual summer mortality of 18.3%. This level of mortality is expected to produce a declining trend in the size of the population.

1.5.2 Incidental mortality caused by heavy dredges

Since 1965, heavy double bit, double ring bag dredges have been used in the Foveaux Strait oyster fishery. These dredges weighed around 410 kg when first introduced. Each oyster skipper fine tunes their dredges and current dredge weights range from 460 kg to 530 kg. These dredges are heavier than the single bit, single ring bag dredges employed between 1913 and 1964.

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 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. Smaller oysters (10–57 mm in length) were less robust (6–8% mortality), 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

Ostrea chilensis is a protandrous hermaphrodite that may breed all year round, but breeding peaks in the spring and summer months. Females produce few large (280–290 μm) yolky eggs, which after fertilisation continue to develop to pediveligers in the inhalant chamber for 18–32 days (depending on temperature). Most larvae are thought to settle immediately on release (at a size of 444–521 μm) and are thought to seldom disperse more than a few centimetres from the parent oyster. Some larvae are released early, at smaller sizes and spend some time in the plankton, and are capable of dispersing widely. Little is known about the timing and proportion of larvae released early in the plankton, and how this strategy may vary spatially and temporally, both within natal populations and the fishery. In Foveaux Strait, spat settlement is primarily during the summer months from December to February. Mean larval production of incubating oysters in Foveaux Strait was determined to be 5.09 $\times 10^4$ larvae, and only 6–18% of the sexually mature oysters spawned as females each year.

Little data are available on recruitment. Stock recruitment relationships for the Foveaux Strait dredge oyster are unknown, but most oysters surviving post settlement, are typically found on live oysters, and to a lesser extent, on oyster shells and on the circular saw *Astraea heliotropium* (Keith Michael, NIWA, pers. comm.). Generally, recruitment of sessile organisms is highly variable and often environmentally and predation driven (Cranfield 1979). About 2% of oyster spat survive the first winter; most mortality appears to result from predation by polychaetes, crabs, and small gastropods. Although settlement predominates on under-surfaces of oysters and shell, most surviving spat are attached to the left (curved and generally uppermost) valve of living oysters. Mean density of six month old oyster spat settled on spat plates at six sites in western and eastern Foveaux Strait over the summer of 1999–2000 was 1 700 m^2 (range 850–2 900 m^2) (Cranfield et al. unpublished data).

Growth rates of oysters varies between years and between areas of Foveaux Strait. Spat generally grow 5 to 10 mm in height by the winter after settlement. Mean height after one year is 18 to 25 mm, 25 to 35 mm after two years, 30 to 51 mm after three years, 40 to 65 mm after four years, and 65 to 75 mm after the fifth year. Oysters recruit to the legal-sized population (a legal-sized oyster will not pass through a 58 mm diameter ring, i.e., it must be at least 58 mm in the smaller of the two dimensions of height or length) at ages of 4–8 years. There is evidence for strong seasonal variation in growth (Dunn et al.1998b).

Dunn et al. (1998b) modelled the growth of a sample of oysters from four areas, grown in cages. Length-based growth parameters from this study are shown in Table 6.

Jeffs & Hickman (2000) estimated measures of maturity from the re-analysis of sectioned oyster gonads sampled at around monthly intervals from four sites in Foveaux Strait from April 1970 to April 1971. Analysis of these samples revealed that oysters were protandrous, maturing first as males at about 20 mm in shell height. Beyond 50 mm, most oysters developed ova while continuing to produce sperm, although oysters did not begin brooding larvae until 60 mm. Considerable quantities of ova were present in oysters throughout the year, but only a very small proportion of oysters spawned ova from July to December with a peak in October. Oysters commonly contained and released sperm throughout the year, although peak spawning was from November to March. The phagocytosis of reproductive material from the follicles of oysters was present in a small proportion of oysters throughout the year. However, it was much more common from January to March amongst both male and female reproductive material, including smaller (less than 50 mm), solely-male oysters.

Table 6: Estimates of biological parameters.

Fishstock	Estimate			Source
1. Natural mortality (*M*)				
OYU 5	0.042			Dunn et al. (1998b)
	Assumed 0.1			Allen (1979)
	Assumed 0.1			Dunn (2007)
2. Length-based growth parameters from Dunn et al. 1998a				
	Length-based growth as estimated from model 3, is presented below. Growth is given for change in diameter.			
	$\Delta l = (L_\infty \quad - l1)(1 - e^{-k_{area + year}(\Delta t + \varphi)}) - \varepsilon$			
	Estimated parameter values (and 95% confidence intervals)			
	L	Area A	92.2 mm (86.7-	
		Bird I.	76.2 mm (73.5-	
		Lee Bay	77.8 mm (73.4-	
		Saddle	81.0 mm (77.3-	
	Estimated parameter values (and 95% confidence intervals)			
	k	1979	(reference year)	
		1980	-0.29 (-0.33– -0.25)	
		1981	0.02 (-0.02 – 0.06)	
		Area A	0.48 (0.41-0.54)	
		Bird I.	0.85 (0.76-0.94)	
		Lee Bay	0.77 (0.68-0.86)	
		Saddle	0.51 (0.50-0.52)	
	φ		-0.03	
3. Size at sexual maturity (Females)				
50 mm diameter (49 mm				Cranfield & Allen (1979)
50 mm in length				Jeffs & Hickman (2000)
4. Percentage of population breeding as females annually				
Foveaux Strait	6-18%			Cranfield & Allen (1979)
Foveaux Strait	~50%			Jeffs & Hickman (2000)

3. STOCKS AND AREAS

The Foveaux Strait oyster fishery has been managed as a single stock, and current stock assessments are undertaken in a fishery area defined by the 2007 survey area. Oyster growth is “plastic” and influenced by habitat. Sub populations within the fishery have different morphological characteristics, but are considered a single genetic stock. There has been considerable translocation of oysters from Foveaux Strait to Fiordland and the Catlins to establish natal populations or supplement existing populations, but no records of reverse translocations.

4. STOCK ASSESSMENT

Surveys of the Foveaux Strait oyster population have been reported since 1906 (Dunn 2005) and see Sullivan et al. (2005) for details since 1960. Early surveys 1906, 1926–1945 are summarised by Sorensen (1968).

4.1 Estimates of fishery parameters and abundance

Estimates of fishery parameters used for stock assessment are given in Fu & Dunn (2009). CPUE data are used unstandardised. Fishery practices have changed from fishing for the highest catch rate to fishing for high meat quality at much lower catch rates to satisfy market requirements. These practices have resulted in more conservative estimates of CPUE and oyster density from catch and effort data. Interannual recruitment to the oyster population can vary markedly (Unpub. data). Oyster spat settle and survive almost exclusively on live oysters in Foveaux Strait.

4.2 Biomass Estimates

Before 2004 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-sized stock abundance from the Foveaux Strait oyster stock assessment model (Dunn 2005, 2007) and projections of future recruit-sized stock abundance under different catch limits and levels of mortality from *B. exitiosa*.

In 2004, Dunn (2005) presented a Bayesian, length-based, single-sex stock assessment model for Foveaux Strait dredge oysters using the general-purpose stock assessment program CASAL (Bull et al. 2005). That model was updated in 2007 (Dunn unpublished) to account for new data available, and a more complex variant of that model was also investigated. For more detailed information on the model structure, data and parameter inputs, sensitivity runs, results and discussion refer to Fu & Dunn (2009). The assessment was updated to include data up to the 2012 fishing year and the abundance indices from the February 2012 stock assessment survey.

The population model partitioned Foveaux Strait oysters into a single sex population, with length (i.e., the anterior-posterior axis) classes from 2 mm to 100 mm, in groups of 2 mm, with the last group defined as oysters at least 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 (including disease mortality), and fishing mortality. The model’s annual cycle was divided into two time steps (Table 7).

Table 7: Annual cycle of the population model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Oct–Feb	Maturation	1.0
		Growth	1.0
		Natural mortality	0.5
		Fishing (summer) mortality	1.0
		B. exitiosa mortality	1.0
	Mar–Sep	Recruitment	1.0
		Natural mortality	0.5
		Fishing (winter) mortality	1.0

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 a mean of 15.5 mm and a CV of 0.4. Relative year class strengths were assumed to be 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 (less than 50 mm minimum diameter) and pre-recruits (oysters between 50 and 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 to be known. Disease mortality is assumed to be zero in the years where there were no reports of unusual mortality, and were 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 of the size-groups) small (less than 50 mm minimum diameter), pre-recruit (at least 50 mm but less than 58 mm minimum diameter), and recruit (at least 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 (amin) 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.

The model was run for the years 1907–2010. Catch data were available for the years 1907–2010, with the catch for 2010 estimated to be 9.5 million oysters. Catches occurred in both time steps with special permit and some customary catch assigned to the first time step (summer fishing mortality), and commercial, recreational, remaining customary, and illegal catch assigned to the second time step (winter fishing mortality).

The priors assumed for most parameters are summarised in Table 8. 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 a mean of 1.0 and a CV of 0.2.

Table 8: 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	–	–	1×10^{-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

4.2.1 Stock assessment results

Model estimates of numbers of oysters were made using the biological parameters and model input parameters described above. A full assessment in 2012 considered two model runs, the basic model and the revised model. The ‘2012 basic model’ updated the basic model used in the 2009 assessment with catch and CPUE data for the 2010, 2011 and 2012 fishing years, the inclusion of the February 2012 biomass survey indices, and an assumed catch of 12.1 million oysters in 2012.

The '2012 revised model' updated the 2009 revised model with similar input data. Table 9 describes the two model runs.

The basic model suggested the virgin equilibrium spawning stock population size to be about 3820 (3440–4290) million oysters, and the current spawning stock size to be 1170 (1060–1290) million oysters (Figure 3). The recruit-sized population was estimated at 1070 (960–1180) million.

Table 9: Model run labels and descriptions.

Model run	Description
2012 basic model	Growth parameters assumed fixed; annual disease rates estimated as independent variables; the disease selectivity was the same as the maturity ogive; Relative catchability *q* for the abundance surveys was fixed to be 1.
2012 revised model	Growth parameters estimated using tag-recapture data; annual disease rates assumed to be cubic-smooth; maturity and disease selectivity ogive decoupled; Estimated relative catchability *q* for the abundance surveys;

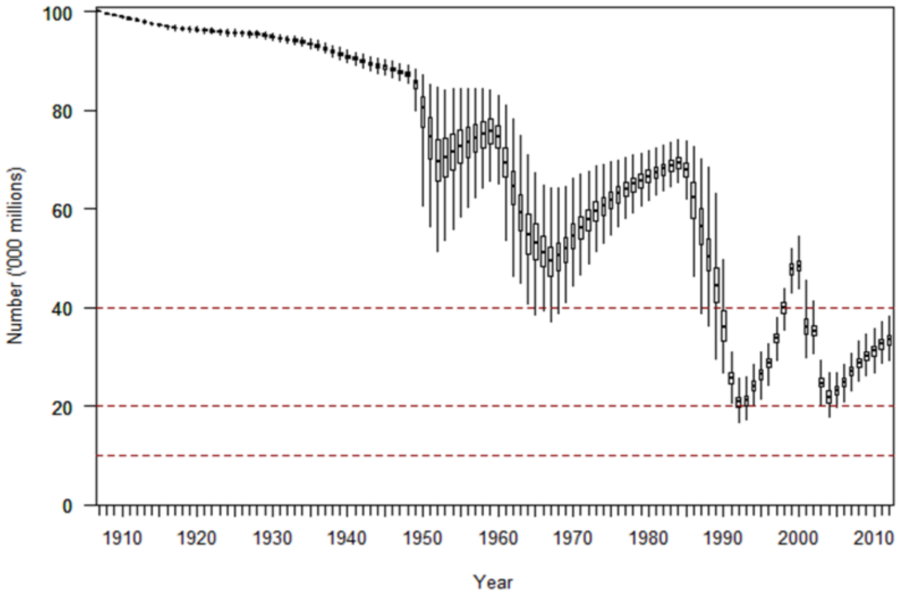


Figure 3: 2012 basic model estimated posterior distributions of SSB (as a percentage of B_0). Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The revised model run suggested a similar stock status as the basic model, with slightly higher productivity resulting from a slightly faster growth rate. The relative estimates of B_0 from these model runs suggested much greater variability in the estimates of the initial population size, but estimates of the current status and recent change in the current status were very similar (see Table 10). Applying a smoothing penalty to the estimated annual disease mortality rates had little impact on the key estimated parameters of the model.

Stock assessments planned every five years from 2012 will update these two models with data on catch history (total landings), unstandardised CPUE, commercial catch sampling for size structure, and abundance indices from population surveys. The new time series of annual bonamia surveys from 2014 (in years between stock assessments), will allow these models to be updated with total landings, catch rate, and catch size structure, and comparable estimates of population size (abundance indices) from the whole survey area.

The 2012 basic model update suggested the virgin equilibrium spawning stock population size to be about 3 510 (3 200−3870) million oysters, and the current spawning stock size to be 1 090 (990−1 210) million oysters (Table 10). The 2012 revised model suggested a similar virgin equilibrium spawning stock population size of 3 670 (3 350−4 050) million oysters, and a current spawning stock size of 1 130 (1 030−1 090) million oysters (Table 10).

Table 10: Bayesian median and 95% credible intervals of B_0 (millions) and SSBs (millions) for 2010 and 2012 from basic and revised models. The 2010 stock assessment partly updated the 2009 assessment with catch rate, total landings, and size structure from catch sampling, but there were no new estimates of population. The 2012 stock assessment updated the 2010 assessment with catch rate, total landings, and size structure from catch sampling, and new estimates of population size from the 2012 stock assessment survey.

Model	B_0	B_{2010}	B_{2012}
2012 basic model	3 510 (3 200−3 870)	1 090 (990−1 210)	1 170 (1 060−1 290)
2012 revised model	3 670 (3 350−4 050)	1 130 (1 030−1 090)	1 200 (1 090−1 330)

Projected stock estimates were made assuming that future recruitment will be log-normally distributed with a mean of 1.0 and standard deviation equal to the standard deviation of the log of recruitment between 1985 and 2010 (i.e., 0.34 with a 95% range of 0.29–0.39). Projections were made assuming no future disease mortality and with future disease mortality assumed to be 0.10 y^{-1} and 0.20 y^{-1}. Three future catch levels were considered each with 912.6 million oysters in 2012 and a future annual commercial catch of either 7.5, 15, or 20 million oysters. Future customary, recreational and illegal catch were assumed equal to levels assumed for 2012. Projected output quantities are summarised in Tables 11–14. The plot of the median expected recruit sized population is given in Figure 4.

Under the assumptions of future disease mortality, model projections of commercial catch at either 7.5, 15, or 20 million showed little difference in expected population size. For example, the projected population size in 2015 with a commercial catch of 7.5 million was less than 2% higher than that with a commercial catch of 20 million oysters. Depending on the level of assumed disease mortality, projected status in 2015 ranged from about 35% more than current levels (assuming no disease mortality) to a level about 34% less than the current level (assuming disease mortality of 0.2 y^{-1}) for the 2012 basic model, and from about 32% more than current levels (assuming no disease mortality) to a level about 24% less than the current level (assuming disease mortality of 0.2 y^{-1}) for the revised 2012 model.

Table 11: 2010 basic model median and 95% credible intervals of current spawning biomass 2012 (B_{2012}), and projected spawning stock biomass for 2013–15 (B_{2013}–B_{2015}) as a percentage of B_0 with an assumption of a future catch of 7.5, 15, or 20 million oysters in 2013–15, and disease mortality of 0.0, 0.1, or 0.2 y^{-1}.

Disease mortality	Catch (millions)	B_{2012} (% B_0)	B_{2013} (% B_0)	B_{2014} (% B_0)	B_{2015} (% B_0)
0	7.5	34.9 (30.6–41.1)	36.2 (29.3–44.4)	40.2 (32.5–50.3)	44.3 (35.6–55.6)
	15	34.9 (30.6–41.1)	36.2 (29.3–44.4)	40.0 (32.4–50.1)	44.0 (35.3–55.3)
	20	34.9 (30.6–41.1)	36.2 (29.3–44.4)	39.9 (32.2–50.0)	43.8 (35.0–55.1)
0.1	7.5	34.9 (30.6–41.1)	35.0 (28.4–43)	34.6 (28.0–43.6)	34.5 (27.4–43.9)
	15	34.9 (30.6–41.1)	35.0 (28.4–43)	34.5 (27.9–43.4)	34.2 (27.2–43.6)
	20	34.9 (30.6–41.1)	35.0 (28.4–43)	34.4 (27.8–43.3)	34.0 (27.0–43.4)
0.2	7.5	34.9 (30.6–41.1)	34.0 (27.6–41.8)	30.0 (24.1–37.9)	27.3 (21.5–35.5)
	15	34.9 (30.6–41.1)	34.0 (27.6–41.8)	29.9 (24.0–37.7)	27.1 (21.3–35.2)
	20	34.9 (30.6–41.1)	34.0 (27.6–41.8)	29.8 (23.9–37.6)	26.9 (21.2–35.1)

Table 12: 2012 basic model median and 95% credible intervals of expected recruit-sized stock abundance for 2012–15 with an assumption of a future catch of 7.5, 15, or 20 million oysters in 2013–15, and disease mortality rates of 0.0, 0.1, or 0.2 y^{-1}.

Disease mortality	Catch (millions)	rB_{2012}/rB_{2012}	rB_{2013}/rB_{2012}	rB_{2014}/rB_{2012}	rB_{2015}/rB_{2012}
0	7.5	1.00 (1.00–1.00)	1.05 (0.93–1.15)	1.18 (1.04–1.38)	1.32 (1.13–1.61)
	15	1.00 (1.00–1.00)	1.05 (0.93–1.15)	1.17 (1.03–1.37)	1.31 (1.12–1.59)
	20	1.00 (1.00–1.00)	1.05 (0.93–1.15)	1.17 (1.02–1.37)	1.30 (1.11–1.59)
0.1	7.5	1.00 (1.00–1.00)	0.97 (0.86–1.07)	0.94 (0.83–1.11)	0.94 (0.79–1.15)
	15	1.00 (1.00–1.00)	0.97 (0.86–1.07)	0.94 (0.82–1.11)	0.93 (0.78–1.14)
	20	1.00 (1.00–1.00)	0.97 (0.86–1.07)	0.93 (0.82–1.11)	0.92 (0.78–1.14)
0.2	7.5	1.00 (1.00–1.00)	0.90 (0.80–0.99)	0.97 (0.66–0.90)	0.67 (0.56–0.84)
	15	1.00 (1.00–1.00)	0.90 (0.80–0.99)	0.75 (0.66–0.90)	0.66 (0.55–0.83)
	20	1.00 (1.00–1.00)	0.90 (0.80–0.99)	0.75 (0.65–0.90)	0.66 (0.55–0.83)

Table 13: 2012 revised model median and 95% credible intervals of current spawning biomass 2012 (B_{2012}), and projected spawning stock biomass for 2013–15 (B_{2012}–B_{2015}) as a percentage of B_0 with an assumption of a future catch of 7.5, 15, or 20 million oysters in 2013–15, and disease mortality of 0.0, 0.1, or 0.2 y^{-1}

Disease mortality	Catch (millions)	B_{2012} (% B_0)	B_{2013} (% B_0)	B_{2014} (% B_0)	B_{2015} (% B_0)
0	7.5	34.5 (29.7-41.1)	36.5 (29.6-44.9)	40.6 (33.0-50.6)	44.6 (36-56.6)
	15	34.5 (29.7-41.1)	36.5 (29.6-44.9)	40.4 (32.8-50.5)	44.2 (35.7-56.3)
	20	34.5 (29.7-41.1)	36.5 (29.6-44.9)	40.3 (32.7-50.4)	44.0 (35.5-56.1)
0.1	7.5	34.5 (29.7-41.1)	35.6 (28.9-43.8)	36.1 (29.1-45.4)	36.5 (29.2-46.9)
	15	34.5 (29.7-41.1)	35.6 (28.9-43.8)	35.9 (29.0-45.3)	36.2 (29.0-46.7)
	20	34.5 (29.7-41.1)	35.6 (28.9-43.8)	35.6 (28.9-45.2)	36.0 (28.8-46.5)
0.2	7.5	34.5 (29.7-41.1)	34.7 (28.2-42.8)	32.1 (25.8-40.9)	30.3 (23.8-39.4)
	15	34.5 (29.7-41.1)	34.7 (28.2-42.8)	32.0 (25.7-40.7)	30.1 (23.5-39.2)
	20	34.5 (29.7-41.1)	34.7 (28.2-42.8)	31.9 (25.6-40.6)	30.0 (23.4-39.0)

Table 14: 2012 revised model median and 95% credible intervals of expected recruit-sized stock abundance for 2013–15 with an assumption of a future catch of 7.5, 15, or 20 million oysters in 2011–13, and disease mortality rates of 0.0, 0.1, or 0.2 y^{-1}.

Disease mortality	Catch (millions)	rB_{2012}/rB_{2012}	rB_{2013}/rB_{2012}	rB_{2014}/rB_{2012}	rB_{2015}/rB_{2012}
0	7.5	1.00 (1.00–1.00)	1.07(0.96-1.16)	1.20 (1.05-1.39)	1.35 (1.16-1.62)
	15	1.00 (1.00–1.00)	1.07 (0.96-1.16)	1.19 (1.04-1.39)	1.34 (1.14-1.61)
	20	1.00 (1.00–1.00)	1.07 (0.96-1.16)	1.19 (1.04-1.38)	1.33 (1.13-1.60)
0.1	7.5	1.00 (1.00–1.00)	1.00 (0.90-1.09)	1.00 (0.88-1.17)	1.02 (0.87-1.24)
	15	1.00 (1.00–1.00)	1.00 (0.90-1.09)	1.00 (0.87-1.17)	1.01 (0.86-1.23)
	20	1.00 (1.00–1.00)	1.00 (0.90-1.09)	1.00 (0.87-1.16)	1.00 (0.85-1.22)
0.2	7.5	1.00 (1.00–1.00)	0.94 (0.84-1.03)	0.84 (0.73-0.99)	0.78 (0.65-0.95)
	15	1.00 (1.00–1.00)	0.94 (0.84-1.03)	0.84 (0.73-0.99)	0.77 (0.64-0.94)
	20	1.00 (1.00–1.00)	0.94 (0.84-1.03)	0.83 (0.72-0.98)	0.76 (0.64-0.94)

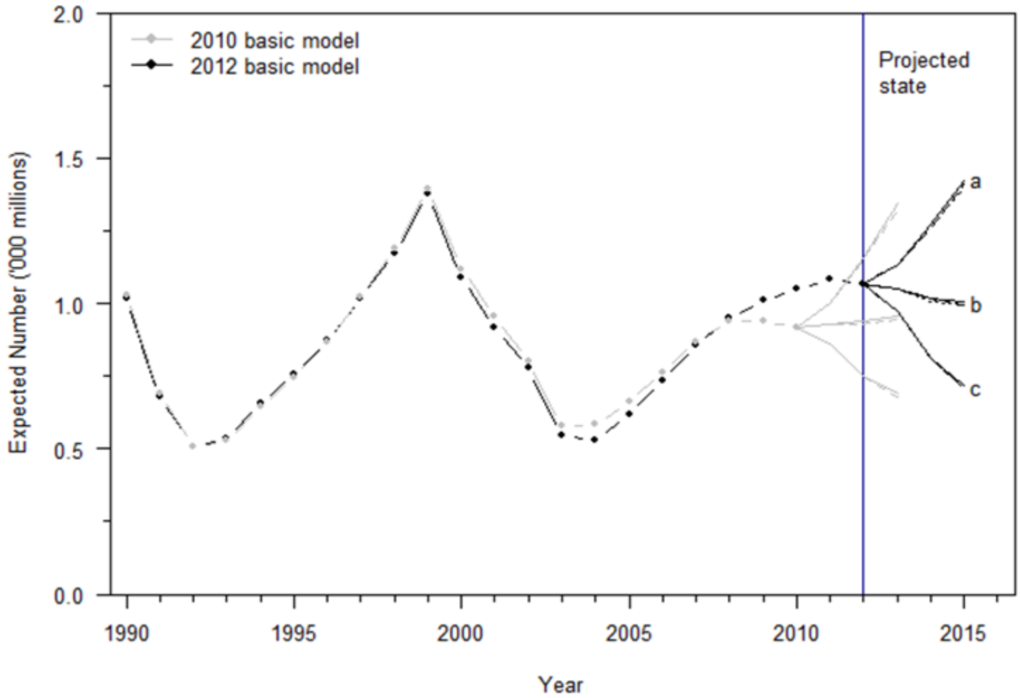


Figure 4: Model estimates of recent recruit-sized stock abundance and projected recruit-sized stock abundance for 2013–15 with catch of 7.5 (solid line), 15 (dash dot), and 20 million oysters (dashed line) under assumptions of (a) no disease mortality, (b) disease mortality of 0.10 y-1, and (c) disease mortality of 0.20 y-1 , for the 2010 and 2012 basic models. (top) and revised models for the same years respectively (bottom). [Continued on next page]

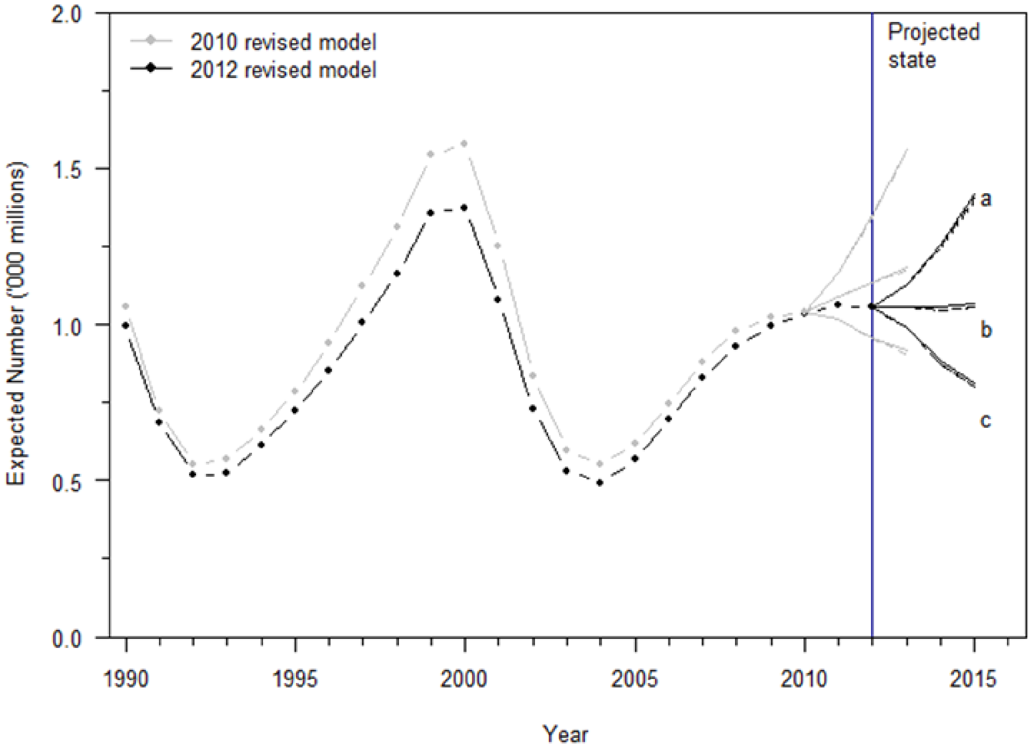


Figure 4 [Continued]: Model estimates of recent recruit-sized stock abundance and projected recruit-sized stock abundance for 2013–15 with catch of 7.5 (solid line), 15 (dash dot), and 20 million oysters (dashed line) under assumptions of (a) no disease mortality, (b) disease mortality of 0.10 y-1, and (c) disease mortality of 0.20 y-1 , for the 2010 and 2012 basic models. (top) and revised models for the same years respectively (bottom).

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was reviewed by the Aquatic Environment Working Group for inclusion in the Fishery Assessment Plenary November 2014. A broader summary of information on a range of issues related to the environmental effects of fishing and aspects of the marine environment and biodiversity of relevance to fish and fisheries is available in the Aquatic Environment & Biodiversity Annual Review (Ministry for Primary Industries 2013a).

5.1 Role in the ecosystem

Dredge oysters (*Ostrea chilensis*) are benthic, epifaunal, sessile bivalve molluscs that have a relatively limited pelagic larval dispersal phase. They are patchily distributed around the New Zealand coast on a variety of substrates (biogenic reef, gravel, sand, mud) in intertidal to subtidal inshore waters, commonly in depths of up to 60 m or more. Commercially exploited beds of oysters occur in Foveaux Strait (OYU 5), Tasman Bay (OYS 7), and Cloudy and Clifford Bays (OYS 7C). Beds at the Chatham Islands (OYS 4) have potential for commercial exploitation. Oysters play important roles in the ecosystem that include influencing water quality by filtering phytoplankton and other suspended particles from the seawater, linking primary production with higher trophic levels, and acting as ecosystem engineers by stabilising sediments and providing structural habitat (biogenic reef) for other taxa (e.g., algae, ascidians, bryozoans, sponges, echinoderms, worms, molluscs, crustaceans, fish).

5.1.1 Trophic interactions

Oysters are active suspension feeders, consuming phytoplankton suspended in the water column. Their diet is the same as or similar to that of many other suspension feeding taxa, including other bivalves such as scallops, clams, and mussels. Oysters are probably prey for a wide range of invertebrate and fish predators, but published records of known or suspected predators are limited. Reported invertebrate predators of *O. chilensis* include brittlestars (*Ophiopsammus maculata*) (Stead 1971), starfish (*Coscinasterias calamaria* and *Astrostole scabra*) (Cranfield 1979) and flatworms (*Enterogonia orbicularis*) (Handley 2002); suspected invertebrate predators include octopus (*Pinnoctopus cordiformis*) and shell boring gastropods (*Poirieria zelandica*, *Xymeme ambiguous*, and *Xymenella pusillis*) (Brown 2012). Predators of oysters probably change with oyster size. Most mortality of oyster spat (small juveniles) during their first winter appears to result from predation by polychaetes, crabs, and gastropods (Ministry for Primary Industries 2013b).

5.2 Incidental catch (fish and invertebrates)

A range of non-target fish and invertebrate species are caught and discarded by dredge fisheries for *O. chilensis*. No data are available on the level or effect of this incidental catch (bycatch) and discarding by the fisheries. Invertebrate bycatch data are available from dredge surveys of the oyster stocks, and the bycatch of the fisheries is likely to be similar to that of the survey tows conducted in areas that support commercial fishing. Fish bycatch data are generally not recorded on surveys, presumably because fish constitute a small fraction of the total bycatch.

In OYU 5 (Foveaux Strait), Cranfield et al. (1999) summarised the results of Fleming (1952) who sampled the macrofaunal bycatch of oyster fishing in a 'near virgin' area of the fishery in 1950; the bycatch was dominated by the frame-building bryozoan *Cinctipora elegans* (and oysters *O. chilensis*) and included a diverse range of other epifaunal organisms. More recently, presence-absence data on the bycatch of oyster dredging have been recorded during surveys and in fishers' logbooks (Michael 2007). In a specific study of the benthic macrofauna bycatch of the 2001 oyster dredge survey in Foveaux Strait, Rowden et al. (2007) identified at least 190 putative species representing 82 families and 12 phyla; 'Commercial' survey strata were principally characterised by the families Balanidae (barnacles), Mytilidae (mussels), Ophiodermatidae (brittle stars), Ostreidae (oysters), and Pyuridae (tunicates). For the 2007 survey of OYU 5, Michael (2007) listed the percentage occurrence of sessile and motile species caught as bycatch in the survey dredge tows. The five most commonly caught sessile species (excluding oysters) were hairy mussels *Modiolus areolatus* (80% occurrence), barnacles *Balanus* sp. (61%), kina *Evechinus chloroticus* (61%), nesting mussels *Modiolarca impacta* (53%), and ascidians *Pyura pulla* (51%). The five most commonly occurring motile bycatch species were brittlestars *Ophiopsammus maculata* (90% occurrence), circular saw shells (gastropods) *Astraea heliotropium* (80%), hermit crabs *Pagurus novizelandiae* (80%), eight armed starfish *Coscinasterias muricata* (63%), and brown dipple starfish *Pentagonaster pulchellus* (54%). Common bycatch species of oyster dredge surveys in Foveaux Strait were reported by Michael (2007) and are listed below in Table 15.

Table 15: Invertebrate species commonly caught as bycatch in dredge surveys of oysters (*O. chilensis*) in Foveaux Strait. Sourced from Michael (2007). [Continued on next page]

Type	Species
Infaunal bivalves	*Glycymeris modesta* (small dog cockle), *Tawera spissa* (morning star shell), *Tucetona laticostata* (large dog cockle), *Pseudoxyperas elongata* ('tuatua'), *Venericardia purpurata* (purple cockle)
Epifaunal bivalves	*Modioilus areolatus* hairy mussel), *Modiolarca impacta* (nesting mussel), *Aulacomya atra maoriana* (ribbed mussel), *Barbatia novaezelandiae* (ark shell), *Pecten novaezelandiae* (scallop), *Chlamys zelandiae* (lions paw scallop), *Neothyris lenticularis* (large lantern shell), *N. compressa* (compressed lantern shell)
Sponges	*Chondropsis* topsentii (cream sponge), *Crella incrustans* (red-orange sponge), *Dactylia palmata* (finger sponge)
Ascidians	*Pyura pachydermatina* (kaeo), *P. pulla*
Algae	Red algae spp.
Bryozoans	*Celleporaria agglutinans* (hard/plate coral), *Cinctipora elegans (reef-building bryozoan), Horera foliacea* (lace coral), *Hippomenella vellicata* (paper coral), *Tetrocycloecia neozelanica* (staghorn coral), *Orthoscuticella fusiformis* (soft orange bryozoan)
Barnacles and chitons	*Balanus decorus* (large pink barnacle), *Cryptochonchus porosus* (butterfly chiton), *Eudoxochiton nobilis* (noble chiton), *Rhyssoplax canaliculata* (pink chiton)

Table 15 [Continued]:

Starfish, brittlestars, and holothurians	*Coscinasterias muricata* (eight armed starfish), *Pentagonaster pulchellus* (brown dipple starfish), *Ophiosammus maculata* (snaketail brittlestar), *Australostichopus mollis* (sea cucumber)
Crabs	*Pagurus novaezelandiae* (hermit crab), *Eurynolambrus australis* (triangle crab), *Metacarcinus novaezelandiae* (cancer crab), *Nectocarcinus* sp. (red crab)
Urchins	*Evechinus chloroticus* (kina), *Apatopygus recens* (heart urchin), *Goniocidaris umbraculum* (coarse-spined urchin), *Pseudechinus novaezelandiae* (green urchin), *P. huttoni* (white urchin), *P. albocinctus* (red urchin)
Gastropods	*Astraea heliotropium* (circular saw shell), *Alcithoe arabica* (volute), *Argobuccinum pustulosum tumidum, Turbo granosus, Cabestana spengleri, Charonia lampras*
Octopuses	*Pinnoctopus cordiformis* (common octopus), *Octopus huttoni* (small octopus)

In OYS 7 (Tasman/Golden Bays), data on the bycatch of the 1994–2014 dredge surveys have been collected but not analysed, except for preliminary estimation of the 1998–2013 bycatch trajectories (Williams et al. 2014b). The surveys record the bycatch of other target species of scallops (*Pecten novaezelandiae*) and green-lipped mussels (*Perna canaliculus*), and various other non-target bycatch in nine categories (Williams et al. 2014b). Observation of the 2014 survey sampling identified a problem with the way these categorical bycatch data have been recorded which limits their utility (Williams et al. 2014a).

In OYS 7C, a dredge survey of oysters in Cloudy and Clifford Bays was conducted in 2006, and the survey skipper recorded qualitative comments on the bycatch of each tow, which included 'coral', 'sticks and seaweed', shells, volutes, 'red weed', horse mussels, shell with worm, small crabs, mussels, and scallop (Brown & Horn 2006).

In OYS 4 (Chatham Islands), data on the bycatch of a 2013 dredge survey of oysters off the north coast of Chatham Island were recorded (as estimated volumes of different bycatch categories) but not analysed (Williams et al. 2013).

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

There is no known bycatch of seabirds, mammals or protected fish species from *O. chilensis* oyster fisheries.

5.4 Benthic interactions

There are a variety of benthic habitats in the different oyster fisheries areas, which generally occur either on coarse substrates usually found in areas of high natural disturbance (Foveaux Strait, Cloudy/Clifford Bays and the Chatham Islands) or on fine substrates typical of sheltered areas (Tasman Bay). Benthic habitats within the Foveaux Strait oyster fishery area were classified by Michael (2007) and comprise a variety of sand/gravel/shell flats and waves, rocky patch reef, and biogenic areas. Cranfield et al. (1999) referred to the latter as epifaunal reefs that he defined as "tidally-oriented, linear aggregations of patch reefs formed by the bryozoan *Cinctipora elegans*, cemented by encrusting bryozoans, ascidians, sponges and polychaetes". Cranfield et al.'s papers (Cranfield et al. 1999, Cranfield et al. 2001, Cranfield et al. 2003) suggested that epifaunal reefs are oyster habitat, but Michael's reports (Michael 2007, 2010) state that commercial fishing for oysters is mainly based on sand, gravel, and shell habitats with little epifauna. In Foveaux Strait, commercial oyster dredging occurs within an area of about 1000 km^2 (although only a portion of this is dredged each year), which is about one-third of the overall OYU 5 stock area (Michael 2010). Habitats within the Cloudy/Clifford Bays and the Chatham Islands fisheries areas have not been defined. The benthic habitat within the Tasman Bay oyster fishery area is predominately mud, although to some extent this may have been affected by land-based sedimentation into the bay and homogenisation of the substrate by dredging and trawling (Brown 2012).

It is well known that fishing with mobile bottom contact gears such as dredges has impacts on benthic populations, communities, and their habitats (e.g., see Kaiser et al. 2006, Rice 2006). The effects are not uniform, but depend on at least: "the specific features of the seafloor habitats, including the natural disturbance regime; the species present; the type of gear used, the methods and timing of deployment of the gear, and the frequency with which a site is impacted by specific gears; and the history of human activities, especially past fishing, in the area of concern" (Department of Fisheries and Oceans 2006). In New Zealand, the effects of oyster dredging on the benthos have been studied in Foveaux Strait (OYU 5) (Cranfield et al. 1999, Cranfield et al. 2001, Cranfield et al. 2003, Michael 2007) and Tasman/Golden Bays (OYS 7) (Tuck et al. 2011). The results of these studies are summarised in the Aquatic Environment & Biodiversity Annual Review (Ministry for Primary Industries 2013a), and are consistent with the global literature: generally, with increasing fishing intensity there are decreases in the density and diversity of benthic communities and, especially, the density of emergent epifauna that provide structured habitat for other fauna.

The effects of dredging (Ministry for Primary Industries 2013a) may be more severe in sheltered areas (e.g., Tasman Bay) than in exposed areas (e.g., Foveaux Strait, Cloudy/Clifford Bays, Chatham Islands). Dredging damages epifauna, and erect, structured habitats, such as biogenic/epifaunal reefs, are the most sensitive to dredging disturbance. Dredging destabilises sediment/shell substrates, suspends sediments and increases water turbidity; the sensitivity of habitats to suspended sediments and their deposition probably varies depending on the prevailing natural flow regime, being greater in muddy sheltered areas than in high flow environments. Habitats disturbed by dredging tend to become simpler, more homogenous areas typically dominated by opportunistic species. Dredging generally results in reduced habitat structure and the loss of long-lived species.

For studies of the effects of oyster dredging in Foveaux Strait, interpretation of the authors differ (Ministry for Primary Industries 2013a): "Cranfield et al's papers (Cranfield et al. 1999, Cranfield et al. 2001, Cranfield et al. 2003) concluded that dredging biogenic reefs for their oysters damages their structure, removes epifauna, and exposes associated sediments to resuspension such that, by 1998, none of the original bryozoan reefs remained. Michael (2007) concluded that there are no experimental estimates of the effect of dredging in the strait or on the cumulative effects of fishing or regeneration, that environmental drivers should be included in any assessment, and that the previous conclusions cannot be supported. The authors agree that biogenic bycatch in the fishery has declined over time in regularly-fished areas, that there may have been a reduction in biogenic reefs in the strait since the 1970s, and that simple biogenic reefs appear able to regenerate in areas that are no longer fished (dominated by byssally attached mussels or reef-building bryozoans). There is no consensus that reefs in Foveaux Strait were (or were not) extensive or dominated by the bryozoan *Cinctipora*."

Some areas of the Foveaux Strait (OYU 5) oyster fishery are also commercially fished (potted) for blue cod (*Parapercis colias*), and Cranfield et al. (2001) presented some evidence to suggest that dredged benthic habitats and blue cod densities regenerated in the absence of oyster dredging. Bottom trawling also occurs within the OYU 5 area, but there is little overlap with the main areas fished for oysters. In OYS 7, other benthic fisheries (e.g. bottom trawl, scallop, green-lipped mussel) occur and probably also interact with oysters and their habitats.

5.5 Other considerations

5.5.1 Spawning disruption

Fishing during spawning may disrupt spawning activity or success. In the Foveaux Strait fishery, the traditional harvesting period (1 March to 31 August) occurs after the main spring and summer peaks in oyster spawning activity (Jeffs & Hickman 2000). Fishing-induced damage to oysters incurred during the period before spawning could interrupt gamete maturation. Oyster fishing also targets high-density beds of oysters, which are disproportionately more important for fertilisation success during spawning.

5.5.2 Habitat of particular significance for fisheries management

None currently identified.

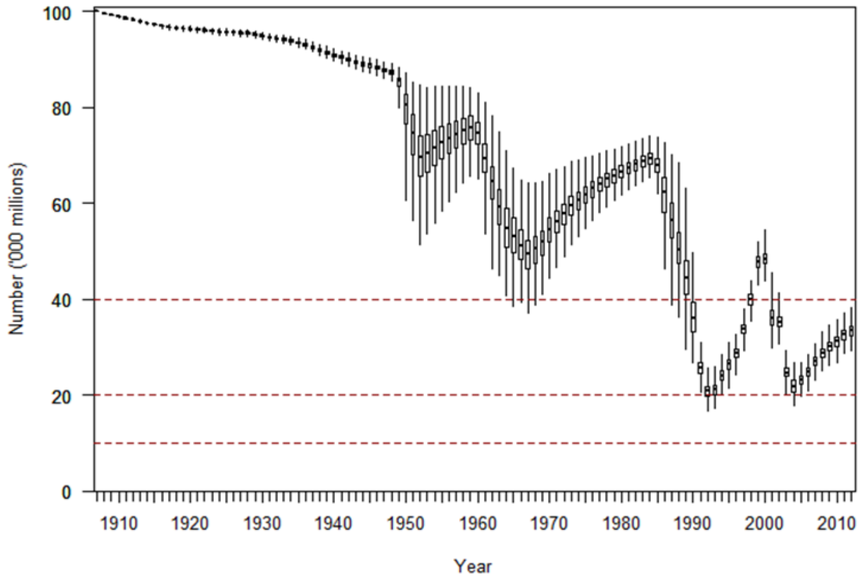
6. STATUS OF THE STOCKS

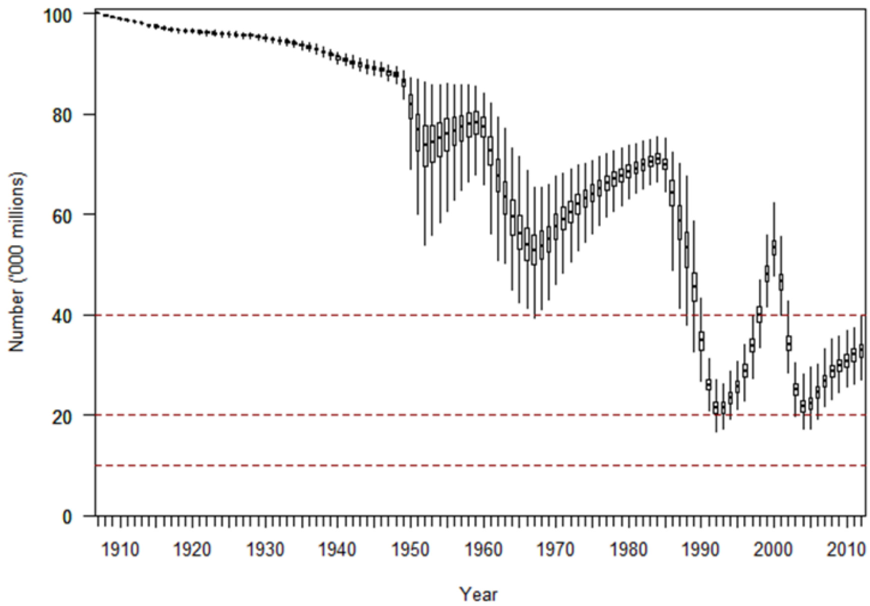
Stock Structure Assumptions
OYU 5 is assessed as a single stock defined by the survey boundaries.

Foveaux Strait Oysters OYU 5

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Basic model (absolute biomass) and revised model (relative biomass)
Reference Points	Target(s): 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unlikely (< 40%) to be at or above the target.
Status in relation to Limits	Model / B_0 / B_{2012} / $\%B_0$ 2012 basic / 3 510 / 1 090 / 31.1% 2012 revised / 3 670 / 1 130 / 30.1% Unlikely (< 40%) to be below the Soft Limit Very Unlikely (< 10%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status





2012 basic model (top) and revised model (bottom) estimated posterior distributions of Spawning Stock Biomass (as a percentage of B_0). Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median. Significant declines in population size are attributed to epizootics of *Bonamia exitisoa.*

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Stock size reached a low point in 2005, which is near the historical minimum, but had increased until 2012. The 2014 Bonamia survey suggests a decline in the recruit-sized population. Commercial catch rates have remained relatively high.
Recent Trend in Fishing Mortality or Proxy	The TACC has been 14.95 million oysters since 1996. Bluff oyster management company shelved 50% of the ACE from 2003−2008, and since 2009 have progressively unshelved part of the 50% originally shelved. Landings have increased from 7.5 million oysters to 13.2 million in 2013.
Other Abundance Indices	Unstandardised catch and effort data are a good proxy for oyster density and reflect the status of commercial fishery areas. Commercial catch rates have been increasing since 2005 from annual means of 1.8 sacks per hour to 4.2 sacks per hour in 2012, and have increased further to 5.5 sacks per hour in 2013. The practice of high grading since 2009 has probably resulted in more conservative estimates of catch and effort that for the period before 2009.
Trends in Other Relevant Indicators or Variables	Since 2005, mortality from bonamia has been relatively low (less than10% of recruited oysters) recruitment to the fishery has exceeded *B. exitiosa* mortality, and the population size of recruited oysters had continued to increase until 2013. In 2014, bonamia infection was still widespread, but patchily distributed in the fishery area. Post survey mortality (11.5%) in February 2014 was markedly higher than the levels between 2008 and 2013: 6.9%, 3.3%, 6.3%, 6.6%, 6.7% and 8.8% respectively. Summer mortality in 2014 was 18.3%, and with recruitment to the population being lower than the long-term average, the recruit-sized oyster population is expected to decline in the short-term.
Projections and Prognosis	
Stock Projections or Prognosis	The 2012 stock assessment suggested that recruit-sized stock abundance was about 30% (26–34%) of B_0. By 2012, the trajectory of the future

	stock size was already starting to flatten due to the continuing low level of mortality from bonamia and reduced recruitment to the population since 2009. Bonamia mortality ranged from between 8% and 12% between 2007 and 2012. The population size of recruit-sized oysters in core strata declined by 21.8% over the two years between 2012 and 2014, and fatally infected oysters were expected to further reduce the population by 11.5% within one to two months. This level of bonamia mortality is expected to cause a downward trend in the oyster population, consistent with projection "c". A significant increase in recruitment could have a major restorative effect, but there will be a 4–6 year lag before any heightened recruitment to the population translates to recruitment to the fishery.	
Probability of Current Catch or TACC causing decline below Limits	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 negative effect on future stock levels.	
Assessment Methodology		
Assessment Type	Full five yearly, quantitative stock assessment with annual surveys.	
Assessment Method	Bayesian length based stock assessment model	
Assessment Dates	Latest assessment: Full in 2012	Next full assessment: 2017
Overall Assessment Quality (rank)	1 – High Quality	
Main data inputs (rank)	- catch history (total landings) - unstandardised CPUE - commercial catch length frequency sampling - abundance indices from population surveys	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Changes to Model Structure and Assumptions	The model may be reviewed in the future	
Major Sources of Uncertainty	Stock size is highly dependent on the levels of mortality from bonamia and continued recruitment around the long-term average. Interannual and spatial variabilty in oyster growth rates may affect transitions of pre-recruit oysters to the recruited oyster population.	

Qualifying Comments
In the absence of disease mortality, the fishery has shown an ability to rebuild quickly at the level of the TACC. Reduced levels of recruitment to the oyster population believed to be environmentally driven may slow any rebuilding in the short-term.
Fishery Interactions
There is some overlap between oyster dredging and bottom trawling. Bycatch data are recorded from population and bonamia surveys, and in fishers' logbooks.

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