DREDGE OYSTER (OYU 5) – Foveaux Strait

(*Ostrea chilensis*)

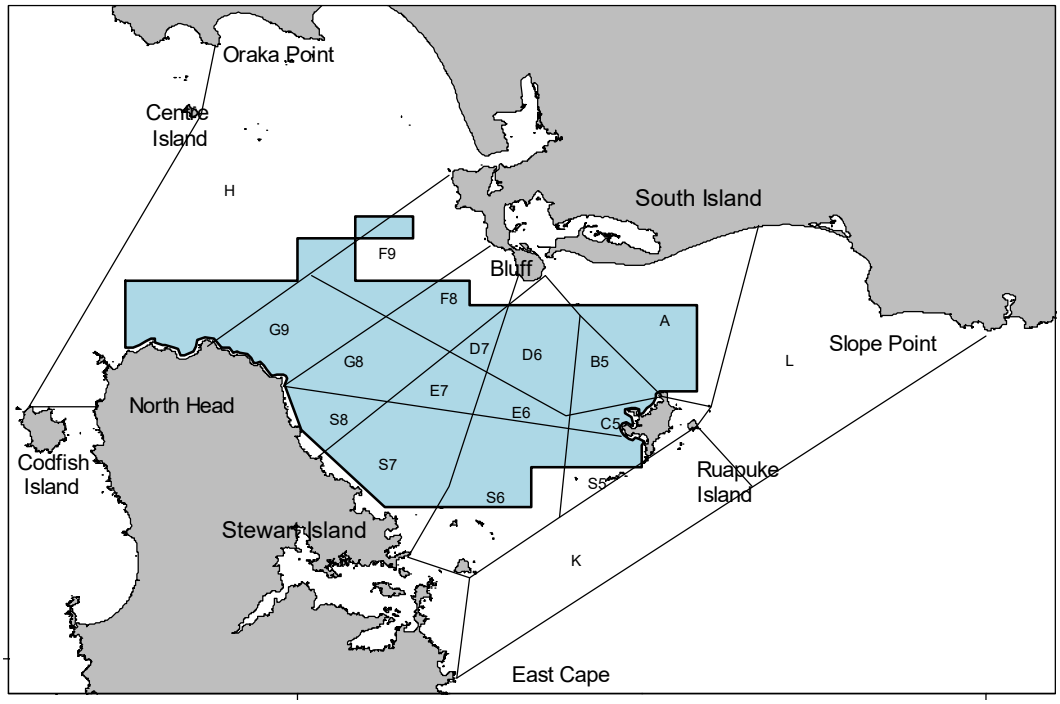


Figure 1: Foveaux Strait (OYU 5) stock boundary and oyster fishery statistical reporting areas 1960–2020, and the 2007–2023 stock assessment survey area (shaded blue) which encompasses the area in which almost all commercial oyster fishing occurs.

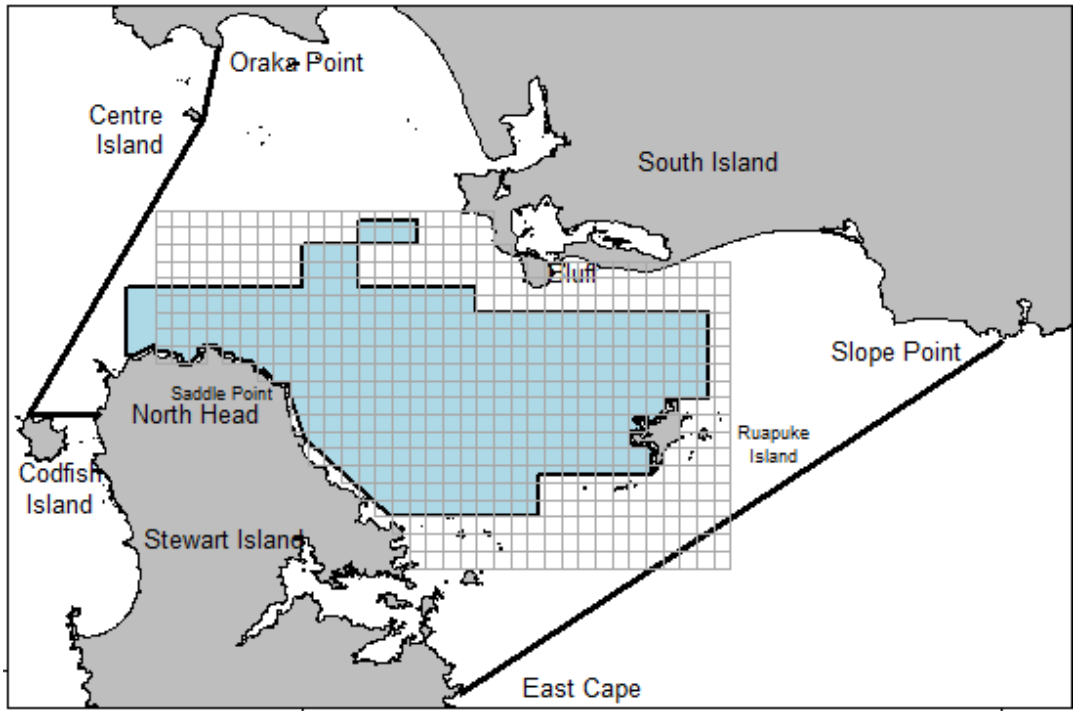


Figure 2: Foveaux Strait (OYU 5) stock boundary and the Integrated Electronic Monitoring and Reporting System (IEMRS) reporting grid established during the 2019 oyster season based on the fishers' one nautical mile square logbook reporting grid first used in 2006. The 2007–2023 stock assessment survey area is shaded blue and encompasses the area in which almost all commercial oyster fishing occurs.

1. FISHERY SUMMARY

The Foveaux Strait oyster fishery OYU 5 was introduced into the Quota Management System (QMS) in 1998, with a Total Allowable Catch (TAC) of 20.3 million oysters (Table 1).

Table 1: Total Allowable Catch (TAC) and Total Allowable Commercial Catch (TACC) in numbers of oysters for OYU 5 since the stock's introduction into the QMS in 1998. There are no allowances for customary and recreational fishing and other sources of mortality (–).

Year	TAC	Customary	Recreational	Other mortality	TACC
1998–present	20 300 000	–	–	–	14 950 000

1.1 Commercial fishery

The Foveaux Strait dredge oyster fishery has been fished for over 150 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. An Integrated Electronic Monitoring and Reporting System (IEMRS) was introduced in 2019 to replace the paper catch and effort landing returns (CELRs). Vessels in the oyster fleet began IEMRS reporting at different times during the 2019 oyster season depending on the quantity of all quota held by the vessel company. IEMRS reporting is based on the fishers' one nautical mile square logbook reporting grid and reporting is at a much finer spatial scale than previously reported by CELRs (Figure 1 and Figure 2). Daily IEMRS reporting for OYU 5 is by logbook grid and not tow-by-tow as for other dredge fisheries.

Catch limits (sacks) 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 1907–62 are given in Table 2. Catch limits and total landings for 1963–92 are given in Table 3.

Table 2: Reported landings of Foveaux Strait oysters 1907–62 (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 to 1992 (millions of oysters; sacks converted to numbers using a conversion rate of 774 oysters per sack). Catch rate given 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 additional approved 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 *Bonamia exitiosa* infection confirmed.
[4] The 1987 season was a shorter season. It closed after the diagnosis of *B. exitiosa* and the catch limit for the overall season was then reduced by the proportion of the fishery area with oysters infected by *B. exitiosa*.
[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, the haplosporid disease *Bonamia exitiosa* (Berthe & Hine 2003, hereafter Bonamia) was identified as the cause of high mortality in the oyster population and the epizootic reduced oyster density, as well as the size and number of commercially fished areas over the next six years (see Doonan et al. 1994, Cranfield et al. 2005). Over that period, management of the fishery used changes to catch limits (Table 3) and spatial fishing strategies to minimise 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 industry (Bluff Oyster Enhancement Company, BOEC) data. From 1996, catches were recorded as numbers of oysters. Catch limits and total landings for 1996 to the present are given 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 Limited (BOMC) shelved half of the TACC, harvesting about 7.5 million oysters annually. Since 2009, fishing 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. From the same time, pre-season catch limits were set by BOMC in consultation with oyster skippers and quota owners, and mid-season adjustments to the catch limits were based on oyster and Bonamia survey data peer-reviewed by the Fisheries New Zealand Shellfish Working Group and based on fishers' information. Following an increasing trend in the population size from about 2005, BOMC began to gradually reduce the level of shelving in 2009. Annual catch limits ranged between 8.22 million oysters and 13.2 million oysters in the period from 2009 to 2020 (Table 4). Catch limits have been reduced to 7.5 million since 2021.

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 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.

Table 4: Reported landings and catch limits for the Foveaux Strait dredge oyster fishery from 1996 to present. TACC has been 14.95 million oysters over this period. Landings and catch limits are reported in numbers (millions) of oysters. Reported catch rates are based on number of sacks landed in CELR data. 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 epifauna attached. Some oysters are landed in bins, and bin numbers are converted to sack numbers using a conversion factor of 0.5. CPUE from 2009 underestimates relative abundance; fishers target beds with large oysters and where oyster meat quality is high, but catch rates are lower than for other areas with higher oyster densities, but with lower meat quality.

Year	Catch limit	Catch limit including voluntary catch limits from 2003	Reported landings	Reported catch rate
1996	14.95	14.95	13.41	5.9
1997	14.95	14.95	14.82	7 0
1998	14.95	14.95	14.85	8.3
1999	14.95	14.95	14.94	7.5
2000	14.95	14.95	14.43	7.2
2001	14.95	14.95	15.11	7.0
2002	14.95	14.95	14.45	3.2
2003	14.95	7.475[1]	7.46	2.3
2004	14.95	7.475[1]	7.48	2.2
2005	14.95	7.475[1]	7.57	1.7
2006	14.95	7.475[1]	7.44	1.9
2007	14.95	7.475[1]	7.37	2.2
2008	14.95	7.475[1]	7.49	3.3[2]
2009	14.95	8.22[3]	8.22	3.9[2, 4]
2010	14.95	9.53	9.54	4.2[2, 4]
2011	14.95	10.6[5]	10.6[5]	4.2[2, 4]
2012	14.95	11.6	11.6	4.2[2, 4]
2013	14.95	13.2	13.3	5.5[2, 4]
2014	14.95	13.2	13.2	4.2[2, 4]
2015	14.95	10.0	10.0	3.5[2, 4]
2016	14.95	10.0	10.0	3.9[2, 4]
2017	14.95	10.0	10.0	3.0[2, 4]
2018	14.95	10.0	9.9	2.3
2019	14.95	10.0	9.5	2.3
2020	14.95	8.33	8.3	2.9
2021	14.95	7.5	7.6	3.0
2022	14.95	7.5	7.7	2.7
2023	14.95	7.5	7.5	2.5
2024	14.95	7.5	5.9	
2025	14.95	7.5	2.4	

[1] 50% of the TACC was shelved for the season.
[2] Fishers given incentive to sort above MLS to increase market value, and changes in sorting potentially result in lower catch rates compared with previous years.
[3] BOMC unshelved 10% of their shelved quota.
[4] Catch reported in bins and sacks, bin numbers converted to sack numbers by a conversion factor of 0.5.
[5] Landings data for 2011 include 1.0 million oysters caught under a special permit for the Rugby World Cup.

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 are reported by calendar year and customary fishing by fishing year (1 October to 30 September) because customary permits are issued out of season. The landings of oysters from OYU 5 (millions of oysters) from 1995–96 to present are shown in Figure 3.

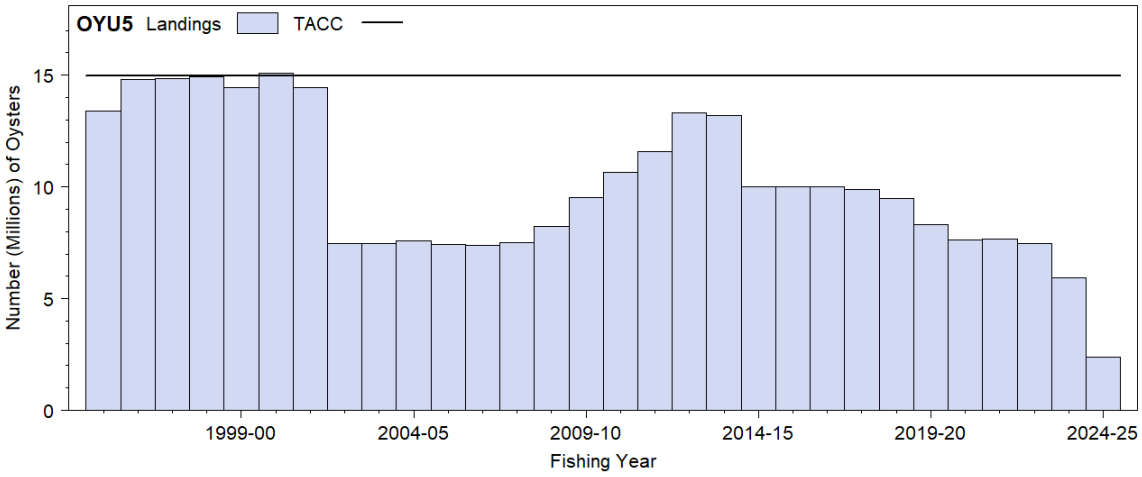


Figure 3: Landings and TACC for oysters from OYU 5 (millions of oysters) from 1995–96 to present.

1.2 Recreational fisheries

Recreational landings comprise mostly recreational catch taken by commercial fishers on oyster vessels (under s111 of the Fisheries Act 1996) and by other recreational fishers. Recreational catch taken by commercial vessels is given in Table 5. The commercial oyster fleet is a major contributor to the level of recreational harvest. Commercial fishers are entitled to 50 oysters each day, 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 (CELRs) and, since 2002, have been separately reported on returns and not included in commercial catch effort statistics.

Table 5: Reported annual recreational catch (numbers of oysters) taken by commercial vessels between March and September since 2002 (CELR data and electronic reporting).

Year	Recreational catch from commercial vessels	Year	Recreational catch from commercial vessels
2002	236 103	2014	224 400
2003	282 345	2015	186 018
2004	69 706	2016	187 382
2005	111 748	2017	216 447
2006	31 090	2018	238 357
2007	90 544	2019	219 336
2008	141 592	2020	156 807
2009	182 331	2021	152 746
2010	194 306	2022	156 878
2011	179 587	2023	154 903
2012	219 068	2024	157 576
2013	257 140	2025	107 188

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

The harvest estimates provided by telephone-diary surveys between 1992 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a national panel survey was conducted for the first time throughout the 2011–12 fishing year (Wynne-Jones et al. 2014, Table 6). The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information was collected in standardised phone interviews. The panel survey was repeated

in 2017–18 and 2022–23 using directly comparable methods (Wynne-Jones et al. 2019, Heinemann & Gray 2024).

Table 6: Estimated numbers of oysters (all species combined) harvested by recreational fishers in OYU 5, excluding charter vessels and s111 approvals. Estimates from telephone-diary surveys in 1991–92, 1996, 1999–2000, and 2000–01, and from the national panel surveys in 2011–12, 2017–18 and 2022–23.

Survey	Numbers	CV	Reference
1991–92	16 000	0.60	Teirney et al. (1997)
1996	106 000	–	Bradford (1998)
1999–2000	38 000	1.02	Boyd & Reilly (2004)
2000–01	129 000	1.15	Boyd et al. (2004)
2011–12	15 337	0.50	Wynne-Jones et al. (2014)
2017–18	48 403	0.49	Wynne-Jones et al. (2019)
2022–23	38 469	0.44	Heinemann & Gray (2024)

1.3 Customary non-commercial fisheries

Reporting of Māori customary harvest is specified in the Fisheries (South Island Customary Fisheries) Regulations 1999. Ngāi Tahu administers the reporting of customary catch of Foveaux Strait oysters to Fisheries New Zealand. Customary catch is reported in the quarter it is summarised; 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 when oysters are spawning. Reported customary catch since 2000–01 is given in Table 7. These numbers are likely to be an underestimate of customary harvest as only the catch approved and harvested in kilograms and numbers are reported in the table.

Table 7: Fisheries New Zealand records of customary harvest of oysters (reported in numbers), 2000–01 to present. – no data and NA whole of fishing year data not currently available.

Fishing year	Approved	Harvested	Fishing year	Approved	Harvested
2000–01	75 792	72 996	2013–14	163 454	162 988
2001–02	215 343	208 095	2014–15	–	–
2002–03	1 800	1 560	2015–16	231 198	221 952
2003–04	–	–	2016–17	102 420	98 490
2004–05	–	–	2017–18	132 334	128 806
2005–06	77 560	75 592	2018–19	9 240	6 684
2006–07	65 400	65 400	2019–20	142 680	141 300
2007–08	192 852	189 572	2020–21	214 426	211 478
2008–09	354 982	347 390	2021–22	33 021	31 831
2009–10	126 120	112 438	2022–23	139 912	139 142
2010–11	336 264	326 526	2023–24	35 680	35 630
2011–12	170 752	170 752	2024–25	NA	NA
2012–13	224 350	223 720			

1.4 Unreported catch

There are no estimates of unreported catch for OYU 5.

1.5 Other sources of mortality

1.5.1 Mortality caused by *Bonamia exitiosa*

Bonamia exitiosa is a haplosporid parasite that infects mainly haemocytes or blood cells (Hine et al. 2001) of several flat oyster species. 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 in the cupped oyster *Crassostrea ariakensis* in North Carolina, USA (Hill-Spanik et al. 2015). Further, an unknown species of *Bonamia* has been identified in two species of native oysters from Hawaii (Hill-Spanik et al. 2015).

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. *Bonamia 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 *Alcicornis longicornutus* (previously *Bucephalus longicornutus*) (Howell 1967, Hine & Jones 1994). Mortality from *B. exitiosa* (1985–92, Doonan et al. 1994) quickly reduced the oyster population to 9% of its pre-disease level. It is likely that this epizootic was either due to a reintroduction of *B. exitiosa* or another pathogen (e.g., APX) comprising a co-infection in the oyster population (Doonan et al. 1994, Hine & Jones 1994, Hine 2002, Cranfield et al. 2005). 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. Two further *B. exitiosa* epizootics (2000–05, Dunn et al. 2000, Michael et al. 2008; and 2012–15, Michael et al. 2020) have shown that mortality from Bonamia is a recurrent feature of the oyster population that prevents oyster densities and population size rebuilding to pre disease levels.

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 (Cranfield et al. 2005). 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, *Alcicornis* sp., coccidian, and microsporidian) contributed to or caused mortality in oysters during the 1985–92, 2000–05, and 2012–15 epizootics (Doonan et al. 1994, Michael et al. 2020). Of oysters sampled in February 2020, 80% had at least one or more pathogens (*Bonamia exitiosa*, Apicomplexan X (APX), *Alcicornis longicornutus*, *Microsporodium rapuae*, Rickettsia-like organisms (RLO), and Endozoicomonas-like organisms (ELO)), and 30–40% had two or more pathogens. Co-infections may be important in Foveaux Strait oysters and may have significant effects on recruitment as well as on oyster mortality. Most recruit-sized oysters and all pre-recruit oysters infected with *A. longicornutus* were castrated. *A. longicornutus* prevalence across the fishery is not known. APX and *B. exitiosa* are thought to severely affect gametogenesis (Diggles & Hine 2002), and thereby recruitment.

No direct and immediate effect of oyster dredging on disease status can be determined. Fishery independent survey data and fishers' logbook data recorded at the spatial scale of 1 nautical mile squares show no relationship between dredging intensity during the winter oyster season and levels of fatal infections of *B. exitiosa* the following summer (Michael 2023a).

Oyster mortality from Bonamia has been considerably higher than the level of mortality from the commercial catch since the onset 1985–1992 Bonamia mortality event. 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 has been estimated at 43, 46, 81, 18 and 19 million oysters for years 2007, 2009, 2012, 2017 and 2023 respectively. Smaller Bonamia surveys are undertaken in years between stock assessment surveys, and these surveys do not estimate mortality from the whole population. In 2014, a new series of Bonamia surveys began, sampling a core subset of strata that comprised 14 of the 26 stock assessment survey strata from 2012 that represented 75% and 69% of the recruit-sized oyster population in 2012 and 2017, respectively, and 46% of the stock assessment survey area.

Mortality in the Bonamia survey area (Figure 4) was high in 2014 and 2015, respectively 116.5 million (18.3%) and 47.9 million (13.1%) recruit-sized oysters (Michael et al. 2015a,b). Bonamia infection levels decreased markedly in 2016 and mortality of recruit-sized

oysters was 16.2 million (4.2%) (Michael et al. 2016), at levels not recorded since 2005. In 2017, Bonamia mortality was similar to that in 2016 (5.1%, 13.5 million recruit-sized oysters; Michael et al. 2019a). Bonamia mortality remained low from 2018 through to 2020 (10.9–18.6 million oysters, 2–3%) (Michael et al. 2019b, Michael et al. 2020, 2021). In 2021, Bonamia mortality started to increase in % and rate, rising from 4.3% (34.7 m) in 2021 to 17.5% (30.6 m) in 2024 (Michael et al. 2022, 2024, Morrison et al. 2025) (note that population size fell over the same time period). In 2025, the mortality rate continued to rise, to 20.3% (23.2 m oysters, Morrison et al., in prep).

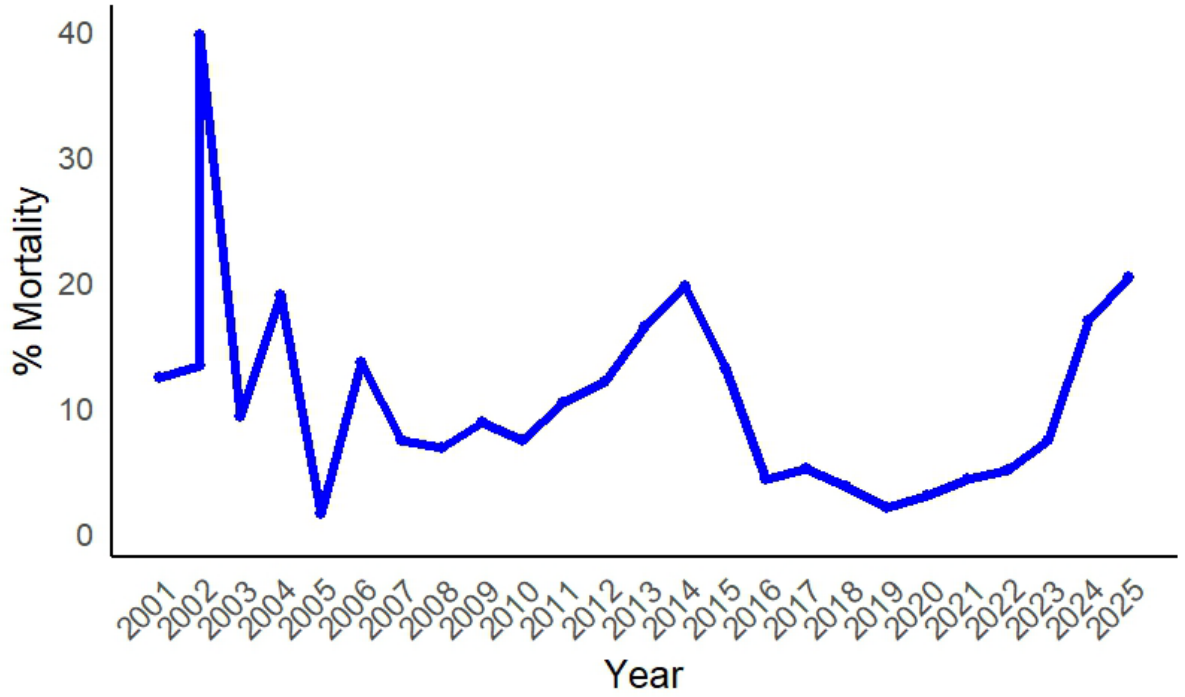


Figure 4: Percentage mortality of the recruit-sized oyster population in the Bonamia survey area since 2001.

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. Oyster skippers fine tune 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 during an experiment 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 both damage and mortality of oysters left behind on the dredge track were inversely related to size. Recruit-sized 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 to 36%). Damage and mortality in both juvenile and adult oysters left on the dredge track did not differ significantly between heavy and light dredges. The mean rate of heavy damage in juvenile oysters (7%) was greater than that in adults (2%) but the difference was not significant. 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 has not been scaled to the size of the fishery and therefore its importance cannot be assessed.

2. BIOLOGY

Ostrea chilensis is a larviparous, protandrous hermaphrodite (Cranfield 1979) that may breed all year round. Females produce large (300–350 μm) yolky eggs, that are spawned from July to December with a peak in October (Jeffs & Hickman 2000). After fertilisation in the inhalant chamber (Hollis 1963, Stead 1971b, Westerkov 1980), brooding ranges from 15 to 38 days (depending on temperature) and larvae develop into pediveligers for 18–32 days (Hollis 1963, Stead 1971a, Westerskov 1980). Most larvae are thought to settle immediately on release (at a size of 448–541 μm, Cranfield & Michael 1989) and are thought to seldom disperse more than a few centimetres from the parent oyster (Cranfield 1979); however, Michael (2019a) showed that the distributions of settlers suggested greater dispersal of larvae. Some larvae are released early, at smaller sizes and spend some time in the plankton (Hickman 2000) and are capable of dispersing widely. But little is known about the timing and proportion of larvae released early in the plankton, and how this strategy may vary spatially and temporally. In Foveaux Strait, spat settlement is primarily during the summer months from November to February (Michael & Shima 2018). Mean larval production of incubating oysters in Foveaux Strait was determined to be 5.09×10^4 larvae (Cranfield 1979), and only 6–18% of the sexually mature oysters spawned as females each year (Stead 1971b, Cranfield & Allen 1979).

The abundance of competent larvae and resultant recruitment to the oyster population can vary substantially between years (Michael et al. 2020). Michael & Shima (2018) showed that factors other than densities of oysters play a major role in the numbers of competent larvae available for settlement, and that the stock recruitment relationships for the Foveaux Strait dredge oyster can be weak in some years. Most oysters surviving post-settlement are typically found on live oysters and, to a lesser extent, on oyster shells and on the gastropod *Astraea heliotropium* (Michael 2019b). 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 (Cranfield 1979). Mean density of six-month-old oyster spat settlement on spat plates at six sites in western and eastern Foveaux Strait over the summer of 1999–2000 was 1700 m^{-2} (range 850–2900 m^{-2}) (Cranfield et al., NIWA, unpublished data).

Spawning stock size is not a reliable predictor of recruitment to the population or the fishery. Low recruitment can persist during periods of high spawning stock size and spawner densities, and high recruitment can occur at times of low spawning stock size and spawner densities (Michael & Shima 2018). The Beverton-Holt stock-recruit relationship does not describe recruitment to OYU 5 well.

Spat monitoring data and the numbers of 0+ oysters landed on the catch of commercial sized oysters provide indices of early recruitment. These two indices are highly correlated over time, with a Pearson correlation of 0.96 ($p < 0.001$) (Keith Michael, NIWA, unpublished data).

Growth rates of oysters vary 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 18–25 mm, 25–35 mm after two years, 30–51 mm after three years, 40–65 mm after four years, and 65–75 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). Two-dimensional growth does not describe the harvestable size of oysters. Depth of shell or ‘cupping’ is the most important dimension and is often associated with high meat volume and quality.

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 given in Table 8.

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 8: Estimates of biological parameters.

Fishstock	Estimate	Source
1. Natural mortality (*M*)		
OYU 5	0.042	Dunn et al. (1998a)
	Assumed 0.1	Cranfield & Allen (1979)
	Assumed 0.1	Dunn (2007)
2. Length-based growth parameters from Dunn et al. (1998b)		
Length-based growth as estimated from model 3, is presented below. Growth is given for change in diameter. $\Delta L = (L_\infty - L_1)\left(1 - e^{-k(\Delta_t+\phi)}\right) - \varepsilon$		
Estimated parameter values (and 95% confidence intervals)		
L_∞	Area A	92.2 mm (86.7–97.9)
	Bird I.	76.2 mm (73.5–78.9)
	Lee Bay	77.8 mm (73.4–81.4)
	Saddle	81.0 mm (77.3–84.9)
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 height)		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

Oyster beds have been commercial exploited in Tasman Bay (OYS 7) until 2017–18, in Cloudy Bay and Clifford Bay (OYS 7C) until 2016–17 and in Foveaux Strait (OYU 5) which are still currently exploited. Beds at the Chatham Islands (OYS 4) have potential for commercial exploitation.

The Foveaux Strait oyster fishery is managed as a single stock. Cranfield & Allen (1979) suggested that this fishery comprised approximately 50 discrete or more dense localised populations, 'oyster beds' (> 4 nautical miles apart), generally separated by extensive areas with low oyster densities. These 'oyster beds' were assumed to be self-recruiting based on the reproductive biology of *O. chilensis*. A study by Michael (2019a) found that oyster spat settlement was widespread, and settlement patterns implied greater dispersal and larval mixing than had been previously reported. The swift currents and variable pelagic larval duration may enhance mixing and connectivity between populations. These data suggest a single stock.

Oyster distribution is patchy, and oysters are concentrated within an area approximately one third of the stock area. Current stock assessments are undertaken in a fishery area defined by the 2007 survey area (Figures 1 and 2).

Oyster growth is 'plastic' and influenced by habitat. Sub-populations within the fishery area have different morphological characteristics but are considered a single genetic stock. Oysters discarded during fishing may be carried considerable distances by the strong tidal currents and provide a greater level of genetic mixing within the fishery. 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. A small fishery in Cloudy and Clifford bays (OYS 7C) was established by translocation of oysters from Foveaux Strait in the early years of the twentieth century (Anon. 1917).

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

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 and Biodiversity Annual Review where the consequences are also discussed (Aquatic environment and biodiversity annual review (AEBAR) | NZ Government (mpi.govt.nz)). The drivers of oyster production in OYU 5 have been summarised by Michael (2023b) and Michael et al. (2023).

4.1 Role in the ecosystem

Dredge oysters (*Ostrea chilensis*) are benthic, epifaunal, bivalve molluscs that have a relatively limited pelagic larval dispersal phase. Once settled, oysters are incapable of moving; however, in Foveaux Strait they may be moved by storms. Discarded oysters are also dispersed by strong tidal currents. Oysters play important roles in the ecosystem, and these roles are system specific. Oysters are considered to be ecosystem engineers because the shells of live and dead oysters provide settlement substrata for other benthic taxa. In the high energy system of Foveaux Strait, as well as in other systems, animals and plants bind the shells of dead oysters and this provides a stable foundation for the colonisation and over colonisation of other benthic taxa (e.g., algae, ascidians, bryozoans, sponges, molluscs) to form biogenic reefs that provide habitats for other mobile benthic taxa (e.g., echinoderms, crustaceans, marine worms, and fish). However, these biogenic reefs do not provide good habitat for oysters. In low energy, sheltered habitats, ecosystem services provided by oysters may include filtering phytoplankton and other suspended particles from the seawater to improve water clarity, and linking primary production with higher trophic levels.

Dredge oysters are patchily distributed around the New Zealand coast on a variety of substrates (rock, gravel, sand, mud) in intertidal to subtidal inshore waters, commonly in depths of up to 60 m or more.

4.1.1 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 brittle stars (*Ophiopsammus maculata*) (Stead 1971b), starfish (*Coscinasterias calamaria* and *Astrostole scabra)* (Cranfield 1979), and flatworms (*Enterogonia orbicularis*) (Handley 2002); and suspected invertebrate predators including octopus (*Pinnoctopus cordiformis*) and shell boring gastropods (*Poirieria zelandica, Xymene ambiguous*, *Xymenella pusillis*) (Brown 2012). Predators of oysters probably vary with oyster size. Most mortality of oyster spat (small juveniles) during their first winter appears to result from predation by polychaetes, crabs, and gastropods.

4.2 Non-target catch of fish and invertebrates

A range of non-target fish and invertebrate species are caught and discarded by dredge fisheries for *O. chilensis*. Few data are available on the level or effect of this non-target catch and discarding by the fisheries. Invertebrate non-target catch data are available from dredge surveys of the oyster stocks, and the non-target catch of the fisheries is likely to be similar to that of the survey tows conducted in areas that support commercial fishing. Fish non-target catch data are generally not recorded on surveys, because fish constitute a small fraction of the total non-target catch.

In OYU 5 (Foveaux Strait), oyster density in complex habitats is low (Stead 1971a) and oysters thrive on substrates with little epifauna (Fleming 1952, Cullen 1962, Stead 1971b, Robjohns 1979, Hill et al. 2010). Fleming (1952) sampled the bycatch of oyster dredging (in May 1950). Oysters dominated the dredge contents, followed by *Pyura pachydermatina*, urchins (4 species, including kina), brachiopods, mussels (mytilids), and other bivalves as "secondary characterising species". Bryozoans and sponges were also present, including *Cinctipora elegans*; however, they were not in large enough quantities to be recorded as characterising species. Of the bryozoans, the stomatopora species were the most common encrusting species (Fleming 1952).

More recently, presence-absence data on non-target catch of oyster dredging have been recorded during surveys and in fishers' logbooks (Michael 2007). Fishery-independent bycatch sampling was undertaken in February 2020, 2021, and 2022 to satisfy requirements for the Integrated Electronic Monitoring and Reporting System regulations. The frequency of dredge tows does not allow for tow-by-tow reporting of bycatch and oyster discards. These surveys described bycatch and oyster discards from fishery areas with high, moderate, and low or no fishing effort during the 2019, 2020, 2021, and 2022 oyster seasons (Michael 2022a, 2022b, 2023a).

In a specific study of the benthic macrofauna non-target catch of the 2001 stratified random 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 (Table 9) caught as non-target catch 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 non-target catch species were brittle stars *Ophiopsammus maculata* (90% occurrence), circular saw shells (gastropods) *Astraea heliotropium* (80%), hermit crabs *Pagurus novaezelandiae* (80%), eight-armed starfish *Coscinasterias muricata* (63%), and brown dipple starfish *Pentagonaster pulchellus* (54%). Presence-absence data for common non-target species caught during oyster dredge surveys in Foveaux Strait were also reported by Michael (2007) (Table 9) and during commercial fishing activity in fishers' logbooks (Michael 2007).

Bycatch sampling in 2020 (Michael 2022a) found that live bycatch generally accounted for a small percentage of the dredge contents, 4.0% of all the catch (including oysters) by weight. Median bycatch weight of all live bycatch species for all tows was 3.0 kg per tow. Of the weight of live bycatch combined, 83.2% was non-fish non-QMS species. Four species accounted for 60.1% of live bycatch: *Astraea heliotropium*, *Ophiopsammus maculata*, *Pyura pachydermatina*, and *Modiolus areolatus*. Relatively high catches of *P. pachydermatina* and *M. areolatus* were recorded from individual tows. Catches of QMS fish species, QMSR_ONG (Sponges), and QMSR_COZ (Bryozoans) were low, regardless of region and fishing effort. Bycatch sampling in 2021 (Michael 2022b) found the same non-fish non-QMS species accounting for 61.4% of bycatch by weight and the bryozoan *Cinctipora elegans* accounted for a further 29.1% of bycatch, mainly from one station. QMS species represented an additional 5.2%, mostly kina (*Evechinus chloroticus*, 4.89%) and sea cucumbers (*Australostichopus mollis*, < 0.1%). Bycatch was less diverse in 2022 than in previous surveys, and no large catches of sponges, bryozoans, or stalked ascidians were taken. Live bycatch was on average 4.0% of the total

unsorted catch. The top ten species ranked by weight (86.2% of bycatch in 2022) were non-fish non-QMS species that are ubiquitous throughout the fishery area. Two of these species, *Astraea heliotropium* and *Modiolus areolatus,* accounted for 51.1% of all bycatch. QMS species accounted for 11.4%; kina (*Evechinus chloroticus*) accounted for 10.9%. Bycatch of bryozoans and porifera combined accounted for a further 2.4% of all bycatch. The bushy bryozoan *Othoscuticella fusiformis* accounted for most of this bycatch. Bycatch by each region and fishing effort were mostly similar and generally comprised mobile species *A. heliotropium*, *Ophiopsammus maculata*, *E. chloroticus*, and *Pagurus novaezealandie*, and the sessile species *M. areolatus* accounted for the highest catches across all effort strata and regions (Michael 2023a).

Table 9: Invertebrate species commonly caught as non-target catch in dredge surveys of oysters (*O. chilensis*) in Foveaux Strait (Michael 2007).

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)
Starfish, brittlestars, and holothurians	*Coscinasterias muricata* (eight-armed starfish), *Pentagonaster pulchellus* (brown dipple starfish), *Ophiosammus maculata* (snaketail brittle star), *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)

4.2.1 Non-target catch in other oyster stocks

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

In OYS 7C (Cloudy Bay/Clifford Bay), a dredge survey of oysters in Cloudy Bay and Clifford Bay was conducted in 2006, and the survey skipper recorded qualitative comments about the non-target catch of each tow, which included "coral", "sticks and seaweed", shells, volutes, "red weed", horse mussels, shell with worm, small crabs, mussels, and scallops (Brown & Horn 2006).

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

4.3 Incidental catch of seabirds, mammals, and protected fish

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

4.4 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 Bay/Clifford Bay, and the Chatham Islands) or on fine sediment 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 they 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. (1999, 2001, 2003) suggested that epifaunal reefs are oyster habitat, but Michael (2007, 2010) noted 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 Bay/Clifford Bay and the Chatham Islands fisheries areas have not been defined. The benthic habitat within the Tasman Bay oyster fishery area is predominantly 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 gear such as dredges has impacts on benthic populations, communities, and their habitats (e.g., Kaiser et al. 2006, Rice 2006). The effects are not uniform but depend on at least: "*the specific features of the seafloor habitats, including the natural disturbance regime; the species present; the type of gear used, the methods and timing of deployment of the gear, and the frequency with which a site is impacted by specific gears; and the history of human activities, especially past fishing, in the area of concern*" (Department of Fisheries and Oceans 2006). In New Zealand, the effects of oyster dredging on the benthos have been studied in Foveaux Strait (OYU 5) (Cranfield et al. 1999, 2001, 2003, Michael 2007) and Tasman Bay/Golden Bay (OYS 7) (Tuck et al. 2017). The results of these studies are summarised by the Aquatic Environment & Biodiversity Annual Review 2021 (Fisheries New Zealand 2022) 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 (Fisheries New Zealand 2022) may be more severe in sheltered areas (e.g., Tasman Bay) than in exposed areas (e.g., Foveaux Strait, Cloudy Bay/Clifford Bay, 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 differs (Fisheries New Zealand 2022). Cranfield et al. (1999, 2001, 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, and that the previous conclusions cannot be supported. Some of the findings of a review of the drivers of long-term change in the Foveaux Strait oyster fishery (Michael 2023b) are given below.

- The extent of the oyster fishery area described in 1906 has not been reduced by fishing.
- The spatial distribution and locations of 'oyster beds' have remained constant through time, and oyster densities within them wax and wane.
- The principal driver of oyster availability to the commercial fishery, i.e., large numbers of oyster beds with high densities of commercial-sized oysters, is mortality from *B. exitiosa*.
- Fishery and logbook data recorded at the spatial scale of 1 nautical mile squares show no relationship between dredging intensity during the winter oyster season and levels of fatal infections of *B. exitiosa* the following summer.
- Regular high recruitment to the oyster population shows productivity of the oyster fishery is high and is not likely to have changed substantially over time.

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 (potting) 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 within three years. Bottom trawling also occurs within the OYU 5 area, but there is little overlap with the main areas fished for oysters.

Studies of the effects of oyster dredging, and of the effects of other bottom contact fishing gears, generally do not consider the effects of storms. The distributions of maerl beds are strongly influenced by storm waves, even in depths greater than 100 m; maerl is present at the periphery of wave induced sediment transport (Joshi et al. 2017). Callaway et al. (2020) showed that ecosystems driven by strong hydrodynamic regimes such as storms in Foveaux Strait can be relatively resistant to anthropogenic effects. Generally, the taxa in highly energy environments are likely to be more resilient to disturbance.

4.5 Other considerations

4.5.1 Spawning disruption

Fishing during spawning may disrupt spawning activity or success. Fishing-induced damage to oysters that is 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. In the Foveaux Strait fishery, the traditional harvesting period (1 March to 31August) occurs after the main spring and summer peaks in oyster spawning activity (Jeffs & Hickman 2000).

4.5.2 Habitat of particular significance for fisheries management

Essential habitat to maintain oyster production is characterised by low complexity habitat that comprises mainly stable sediments of pea gravel and coarse calcareous sand, and the shells of bivalves. This is consistent with the earliest descriptions of commercially fished areas in the early 1950s.

5. ANNUAL ABUNDANCE AND BONAMIA SURVEYS

Surveys of the Foveaux Strait oyster population have been reported since 1906 (Dunn 2005). Early surveys (1906, 1926–45) are summarised by Sorensen (1968) and see Sullivan et al. (2005) for details since 1960.

OYU 5 stock assessments, oyster, and Bonamia surveys since 1999 are summarised by Michael et al. (2020). These surveys have consistently sampled the 1999 survey area (1054 km^2). An additional stratum (B1a, 16 km^2) was introduced by oyster skippers in 2007. Since then, the size of the Foveaux Strait oyster survey area has remained at 1070 km^2. The 1999 stratum boundaries have also remained similar; however, some of the original strata have been subdivided at various times to better define the areas with commercial densities of oysters. Since 2012, 26 survey strata have been sampled for stock assessments, and smaller Bonamia surveys have sampled 15 strata (Michael et al. 2015a). The introduction of five-yearly stock assessments in 2012 has placed greater onus on the annual Bonamia surveys to monitor changes in the oyster population in commercial fishery areas, as well as the status of Bonamia, the prevalence and intensity of infection, and short-term (summer) mortality.

OYU 5 surveys incorporate a fully randomised, two-phase sampling design aimed at better estimating oyster densities and population sizes of oysters and new clocks. A standard Bonamia survey area was established in 2014 to ensure comparability between surveys from year to year. This area represents the core commercial fishery that has been consistent throughout the fluctuations in oyster abundance driven by Bonamia mortality. Bonamia survey strata make up 14 of the 26 stock assessment survey strata. The remaining twelve strata are combined into a single (15^{th}) background stratum (BK). The Bonamia survey area is 46% of the stock assessment survey area and represented 75%, 69%, and 67% of the recruit-sized oyster population in 2012, 2017, and 2023, respectively. Some limited sampling in the background stratum was also undertaken to allow data from these surveys to be comparable from year to year and to be incorporated into stock assessments. This survey design and sampling effort predicts a coefficient of variation (CV) for survey estimates of about 11%.

Since 2019, survey estimates of oyster density and population size have been reported by four size groups: extra-large (called ‘commercial’ until 2024) oysters unable to pass through a 65-mm internal diameter ring; large (called ‘recruits’ until 2024), able to pass through a 65-mm internal diameter ring and unable to pass through a 58-mm internal diameter ring; medium (called ‘pre-recruits’ until 2024), able to pass through a 58-mm internal diameter ring, but unable to pass through a 50-mm ring; and small oysters, able to pass through a 50-mm internal diameter ring and down to 10 mm length. These surveys also estimate medium and small, new and old clocks (see Michael et al. 2020 for definitions).

The latest survey in February 2025 (Morrison et al. in prep) was a Bonamia area assessment survey that sampled 55 random stations; see Figure 5 for survey and stratum boundaries and survey stations.

Mean population estimates and bootstrapped 95% confidence intervals from stock assessment surveys 1999–2025 are shown in Figure 6. Population estimates bootstrapped 95% confidence intervals, and percentage change of the four size groups of oysters in the Bonamia survey area for 2012 and 2014–25 are shown in Figure 7.

Figure 5: Location of station tows for the February 2025 Bonamia area survey. Each of the blue shaded polygons is an individual stratum, while the surrounding unshaded polygons are treated as one large stratum.

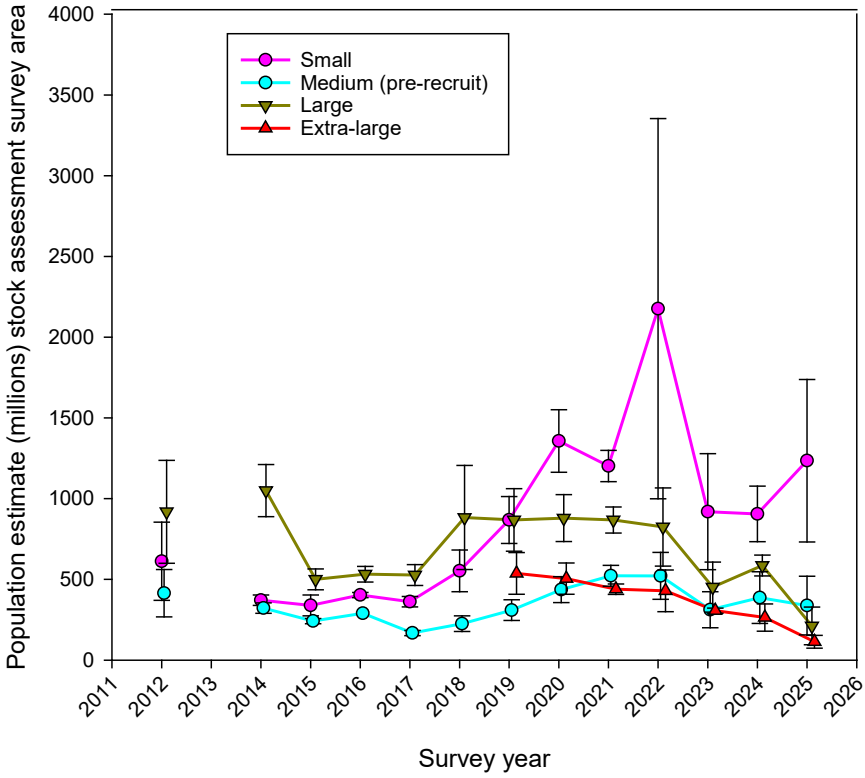


Figure 6: Mean population sizes and 95% confidence intervals for extra-large, large, medium, and small oysters in the 2007 stock assessment survey area between 2012 and 2025. There are no data for the stock area for 2013. Estimates for the stock area from Bonamia surveys should be used with caution because the outer 12 survey strata, combined as stratum BK in Bonamia surveys were allocated only five survey tows. The trends in mean population sizes between 2014 and 2025 are shown as lines.

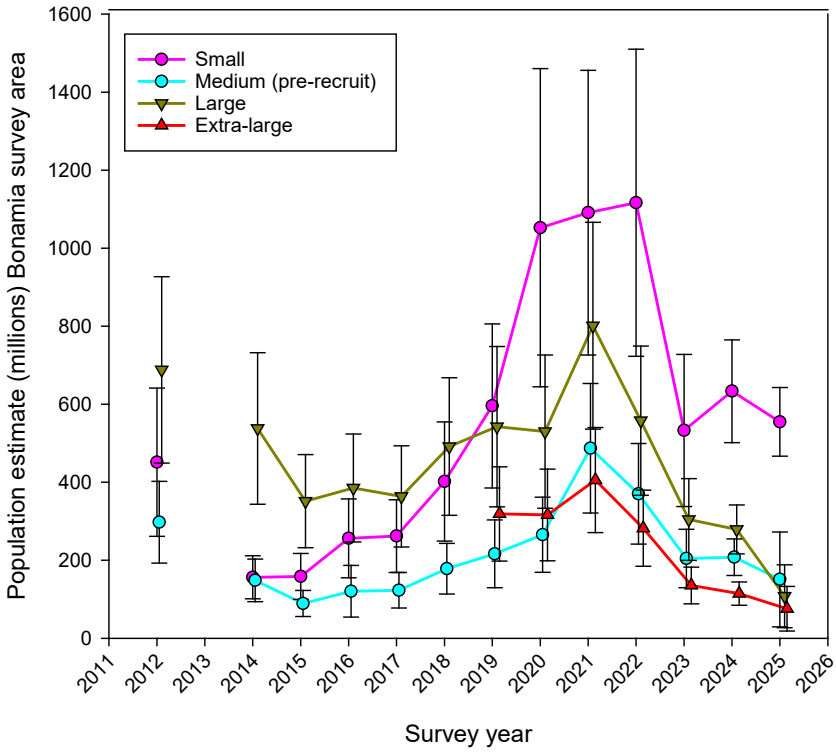


Figure 7: Mean population sizes and 95% confidence intervals for extra-large, large, medium, and small oysters in the Bonamia survey area between 2012 and 2025. The survey data for February 2013 are not included (sampling does not cover all the Bonamia survey area). The trends in mean population sizes between 2014 and 2025 are shown as lines.

Mean population estimates and bootstrapped 95% confidence intervals from stock assessment surveys 2012, 2017, and 2023 are given in Table 10 and for the Bonamia survey area for 2012–2014 to 2022–2025 in Table 11.

Table 10: Survey estimates of oyster density, population size, and percentage changes in the population size of recruit-sized, pre-recruit, and small oysters in the stock assessment area are recalculated for 2012, 2017, and 2023. The mean oyster density per square metre (Density) that determines catch rate (sacks per hour), coefficient of variation (CV) of the density estimate, mean population size in millions of oysters (Pop.n), bootstrapped upper and lower 95% confidence intervals (L 95%CI and U 95%CI) in millions of oysters that reflect the variability in the catches, period that covers the measure of change, and the percentage change in the mean population size. Population increases of greater than 10% are shaded green and decreases by more than 10% are shaded tan.

Year	Size	Density	CV	Pop.n	L 95%CI	U 95%CI	Period	Percent
2012	XL + Large	0.86	0.08	918.4	600.1	0.86		–
2017	XL + Large	0.49	0.09	527.4	343.1	0.49	2012–2017	-42.6
2023	XL + Large	0.42	0.08	452.2	297.3	0.42	2017–2023	-14.3

Year	Size	Density	CV	Pop.n	L 95%CI	U 95%CI	Period	Percent
2012	Medium	0.39	0.10	414.3	267.8	629.0		–
2017	Medium	0.16	0.10	168.2	108.9	253.4	2012–2017	-59.4
2023	Medium	0.29	0.10	311.9	200.1	476.5	2017–2023	+85.4

Year	Size	Density	CV	Pop.n	L 95%CI	U 95%CI	Period	Percent
2012	Small	0.57	0.14	612.2	370.3	967.9		–
2017	Small	0.34	0.09	361.6	234.9	546.9	2012–2017	-40.9
2023	Small	0.86	0.14	919.3	560.3	1443.7	2017–2023	+154.2

Table 11: A standard Bonamia survey area was established in 2014. Survey estimates of oyster density, population size, and percentage changes in the population size of extra-large, large, medium, and small oysters in the Bonamia survey area are recalculated for 2012 and for 2014–2025. The mean oyster density per square metre (Density) that determines catch rate (sacks per hour), coefficient of variation (CV) of the density estimate, mean population size in millions of oysters (Pop.n), bootstrapped upper and lower 95% confidence intervals (L 95%CI and U 95%CI) in millions of oysters that reflect the variability in the catches, period that covers the measure of change, and the percentage change in the mean population size. Population increases greater than 10% are shaded green and decreases of more than 10% are shaded tan.

Year	Size	Density	CV	Pop.n	L 95%CI	U 95%CI	Period	Percent
2019	Extra-large	0.65	0.13	318.7	198.0	500.1	2018–2019	–
2020	Extra-large	0.64	0.12	316.1	198.8	492.5	2019–2020	-0.8
2021	Extra-large	0.82	0.07	405.6	271.0	606.6	2020–2021	+28.3
2022	Extra-large	0.57	0.09	282.1	184.5	428.3	2021–2022	-30.4
2023	Extra-large	0.28	0.09	135.4	88.4	206.0	2022–2023	-52.0
2024	Extra-large	0.25	0.13	114.5	85.2	143.8	2023–2024	-15.5
2025	Extra-large	0.17	0.06	75.9	57.2	94.6	2024–2025	-33.7

Year	Size	Density	CV	Pop.n	L 95%CI	U 95%CI	Period	Percent
2012	Large	1.40	0.09	688.1	449.2	1 046.7	–	–
2014	Large	1.09	0.11	538.0	343.6	832.2	2012–2014	-21.8
2015	Large	0.71	0.08	351.4	232.1	528.8	2014–2015	-34.7
2016	Large	0.78	0.09	385.2	246.9	593.8	2015–2016	+9.6
2017	Large	0.74	0.11	363.6	233.9	559.1	2016–2017	-5.6
2018	Large	1.00	0.11	494.1	315.0	764.9	2017–2018	+35.9
2019	Large	1.10	0.13	542.5	337.0	851.0	2018–2019	+9.8
2020	Large	1.08	0.12	529.9	333.2	825.7	2019–2020	-2.3
2021	Large	1.63	0.06	801.4	536.2	1 196.7	2020–2021	+51.2
2022	Large	1.13	0.09	557.9	366.6	842.9	2021–2022	-30.4
2023	Large	0.62	0.09	304.5	199.6	461.2	2022–2023	-45.4
2024	Large	0.62	0.11	279.0	216.4	341.6	2023–2024	-8.4
2025	Large	0.24	0.07	107.9	80.6	134.9	2024–2025	-61.3

Year	Size	Density	CV	Pop.n	L 95%CI	U 95%CI	Period	Percent
2012	Medium	0.60	0.10	297.4	192.6	454.4	–	–
2014	Medium	0.30	0.12	148.4	93.7	230.7	2012–2014	-50.1
2015	Medium	0.18	0.12	89.2	55.8	139.2	2014–2015	-39.9
2016	Medium	0.25	0.03	120.5	186.7	491.8	2015–2016	+35.1
2017	Medium	0.25	0.12	123.1	77.5	191.7	2016–2017	+2.2
2018	Medium	0.36	0.11	178.4	113.5	276.5	2017–2018	+44.9
2019	Medium	0.44	0.15	216.5	129.6	346.1	2018–2019	+21.4
2020	Medium	0.54	0.11	265.3	169.1	410.7	2019–2020	+22.5
2021	Medium	0.99	0.08	487.0	320.9	733.6	2020–2021	+83.6

Table 11 [Continued]:

Year	Size	Density	CV	Pop.n	L 95%CI	U 95%CI	Period	Percent
2022	Medium	0.75	0.09	370.3	241.5	563.8	2021–2022	-24.0
2023	Medium	0.42	0.12	204.5	129.6	317.4	2022–2023	-44.8
2024	Medium	0.46	0.11	207.6	160.9	254.3	2023–2024	+1.5
2025	Medium	0.34	0.05	150.9	121.6	180.2	2024–2025	-27.3

Year	Size	Density	CV	Pop.n	L 95%CI	U 95%CI	Period	Percent
2012	Small	0.92	0.16	451.3	261.5	731.7	–	–
2014	Small	0.32	0.10	156.3	101.1	239.4	2012–2014	-65.4
2015	Small	0.32	0.12	158.5	99.6	247.1	2014–2015	+1.4
2016	Small	0.52	0.07	256.1	155.0	407.3	2015–2016	+61.6
2017	Small	0.53	0.10	261.9	168.8	401.6	2016–2017	+2.3
2018	Small	0.82	0.13	401.8	249.2	631.2	2017–2018	+53.4
2019	Small	1.21	0.10	595.8	385.4	912.5	2018–2019	+48.3
2020	Small	2.14	0.14	1 052.4	644.4	1 665.9	2019–2020	+76.6
2021	Small	2.22	0.07	1 091.2	726.3	1 637.0	2020–2021	+3.7
2022	Small	2.27	0.10	1 116.6	723.1	1 709.9	2021–2022	+2.3
2023	Small	1.08	0.12	532.8	337.6	827.2	2022–2023	-52.3
2024	Small	1.41	0.10	633.3	501.5	765.1	2023–2024	+18.8
2025	Small	1.24	0.04	554.6	466.6	642.5	2024–2025	-12.4

5.1 Distribution of oysters

Stratified random survey designs used for oyster surveys do not describe the distribution of oyster density well. Fishers' logbooks record fine spatial scale data on catch and effort; however, these data reflect fisher behaviour rather than the distribution of oyster density. Stock assessment and Bonamia survey data show no contraction of the fishery area compared to that described by Sorensen (1968) from

1906. The distribution of oyster density within the fishery area is determined by Bonamia mortality and recruitment. The highest densities occur in the core survey strata. The density of medium-sized oysters from the 2025 survey is shown in Figure 8.

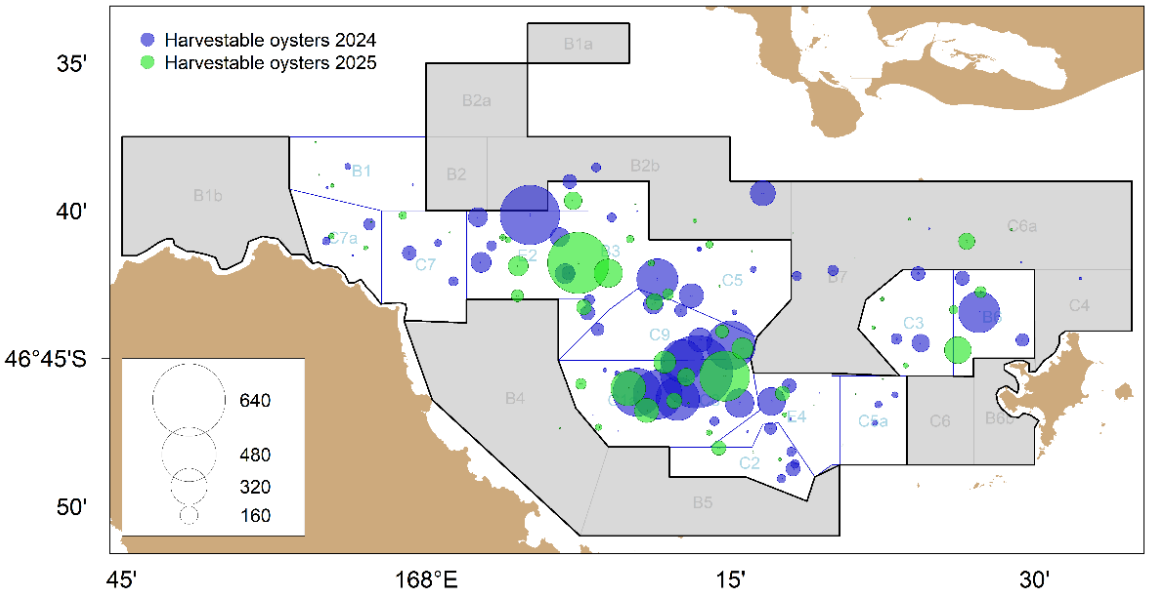


Figure 8: Density (numbers of oysters per standard tow representing an area swept of 1221 m^2) of medium-sized oysters sampled during the February 2025 survey.

6. STOCK ASSESSMENT

Stock assessments are conducted every five years, based on abundance, and Bonamia surveys are carried out in the years between stock assessments.

6.1 Estimates of fishery parameters and abundance

Estimates of fishery parameters used for stock assessment are given by Fu & Dunn (2009). CPUE data are unstandardised. These practices have resulted in more conservative estimates of CPUE and oyster density from catch and effort data. Inter-annual recruitment to the oyster population can vary markedly (unpublished data).

6.2 Biomass estimates

Before 2004 the Foveaux Strait oyster fishery was managed by current annual yield (*CAY*, Method 1, see the Introductory section of this Plenary report) 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, Fu & Dunn 2009, Fu 2013, Large et al. 2021) 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 to account for new data available, and a more complicated 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) and Fu (2013). The assessment was updated to include data up to the 2016 fishing year and the abundance indices from the February 2017 stock assessment survey (Large et al. 2021).

In 2023 Doonan et al. (2024) presented a new stock assessment model using Casal2 (Doonan et al., 2016). The new model was based on the basic model from the 2017 assessment (Large et al. 2021) and

added a smoother to the disease rate. It also changed the disease process from an instantaneous rate into an exploitation rate and incorporated a disease sub-model that fitted to historical disease mortality data through abundance of old clocks and subdivided the oyster population into the following partitions: oysters, diseased, new clocks, and old clocks. The assessment included data up to the 2023 fishing year (including abundance of old clocks) and the abundance indices from the February 2023 stock assessment survey (Doonan et al. 2024).

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 2-mm groups, with the last group defined as oysters of at least 100 mm. The stock was assumed to reside in a single, homogeneous area. The partition accounted for numbers of oysters by length class within an annual cycle, where transition between length classes was determined by the growth parameters. Oysters entered the partition following spawning and were removed by natural mortality, fishing mortality and disease mortality (the latter transitioning them to diseased, then to new clocks, then to old clocks, before removing them from the model). The model's annual cycle was divided into two time steps (Table 12).

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 was assumed to be zero in the years when there were no reports of unusual mortality and was otherwise estimated. Disease mortality estimation was informed by using old clocks abundance.

Table 12: 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	Summer (Oct–Feb)	Growth	1.0
		Natural mortality	0.5
		Fishing (summer) mortality	1.0
		Oysters → diseased transition	1.0
		Diseased → new clocks transition	1.0
2	Winter (Mar–Sep)	Recruitment	1.0
		Natural mortality	0.5
		Fishing (winter) mortality	1.0
		Diseased → old clocks transition	1.0
		New clocks → old clocks transition	1.0
		Old clocks removal	1.0

The models used eight selectivity ogives: the commercial fishing selectivity (split into two, up to 2009 and from 2009 onwards, to account for the change in fishing behaviour, and assumed constant over all time steps of the fishery, aside from changes in the definition of legal size); an overall survey selectivity, which was partitioned into three additional selectivities (one for each of the size-groups)—small, pre-recruit, 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 (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.

The model was run for the years 1907–2023. Catch data were available for the years 1907–2022, with the catch for 2022 estimated to be 7.6 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 unreported catch assigned to the second time step (winter fishing mortality).

The priors assumed for most parameters are summarised in Table 13. 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 13: 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	0.6	0.3	0.15	0.95
Mark-recapture survey q	Lognormal	0.6	0.3	0.10	0.90
YCS	Lognormal	1.0	1.0	0.01	100.0
Disease mortality	Normal	-10	1.873	$1x10^{-12}$	0.90

The new OYU 5 stock assessment model uses historical abundance data series as observations of the trajectory of the population and balances unaccounted for losses or increases to the stock between surveys by estimating disease mortality and recruitment within the model. A disease sub-model has been developed to provide projections of future disease mortality (by sampling values for time to next disease event, magnitude of disease event and duration of disease event), and thereby improved projections of future stock status. The data informing disease mortality include summertime old clocks abundance for pre-recruits and recruits. A model was also tested including abundance of new clocks and Bonamia prevalence, although the results from this were considered less reliable. The use of empirical data on recruitment could further improve the model, along with better estimates of numbers at length (year class strengths) from improved selectivity ogives.

6.2.1 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 2023 (Doonan et al. 2024) considered three model runs, the ‘no disease data’ model, the ‘old clocks only’ model and the ‘all disease data’ model. The ‘no disease data’ model updated the data used in the 2017 assessment with catch, CPUE, and commercial catch length frequency data for the 2017, 2018, 2019, 2020, 2021 and 2022 fishing years; the inclusion of the February 2017, 2018, 2019, 2020, 2021, 2022 and 2023 biomass survey indices; and an assumed catch of 8.54 million oysters for the 2023 fishing year. The ‘old clocks only’ model also included abundance of old clocks for pre-recruits and recruits, while the ‘all disease data’ model additionally included abundance of new clocks and Bonamia fatal (3+) prevalence. The working group took the base case to be the ‘old clocks only’ model. Table 14 describes the three model runs.

Table 14: Model run labels and descriptions.

Model run	Description
2023 no disease data	Uses only standard data up to 2023 (catch, CPUE, catch length frequency and biomass survey)
2023 old clocks only	Additionally uses summertime abundance of old clocks for pre-recruits and recruits
2023 all disease data	Additionally uses summertime abundance of new clocks for pre-recruit and recruits, and Bonamia fatal (3+) abundance for recruits

All three models produce similar stock structures and fits to the data. 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 (Table 15).

The 2023 'old clocks only' model suggested a virgin equilibrium spawning stock population size of 2886 (2672–3141) million oysters and a current recruit-sized stock abundance of 941 (843–1048) million oysters (Table 15). The 2023 'no disease data' model suggested the virgin equilibrium spawning stock population size to be about 2863 (2649−3103) million oysters, and the current recruit-sized stock abundance to be 970 (862–1093) million oysters (Table 15). The 2023 'all disease data' model suggested a virgin equilibrium spawning stock population size of 2737 (2536–2958) million oysters and a current recruit-sized stock abundance of 1106 (997–1231) million oysters (Table 15).

Projected stock estimates were made assuming that future recruitment values were randomly sampled from estimates between 2013 and 2022. A sensitivity run was also explored where recruitment values were sampled from the entire estimation period (1986 – 2022). Projections were made assuming the new disease sub-model predicting future disease events. A sensitivity run also allowed for future disease mortality assumed to be fixed at 0 y^{-1}, 0.10 y^{-1} and 0.20 y^{-1} for all projected years. Future annual commercial catches were considered to remain at 2023 levels of 8.54 million oysters. Future customary, recreational, and unreported catches were assumed equal to levels assumed for 2023. Projected output quantities are summarised in Tables 16 and 17. The plot of the median expected recruit-sized population using the disease sub-model is shown in Figure 9. The plot for the sensitivity run for different fixed disease rates in shown in Figure 10. An additional projection increasing harvest to the TACC was explored for the base case (Figure 11), suggesting that current levels of harvest have minimal effect on stock status (results not tabulated).

Table 15: Median and 95% credible intervals of B_0 (millions), spawning stock biomass (millions) and spawning stock biomass % B_0 for 2017 and 2023 from the 2017 basic and 2023 'old clocks only', 'no disease data' and 'all disease data' models. The 2023 stock assessments updated the 2017 assessment with a disease rate smoother, plus catch rate, total landings, and size structure from catch sampling up to 2022, and new estimates of population size from the 2023 stock assessment survey. For the latter two models data from old clocks, new clocks and Bonamia fatal (3+) prevalence were also used.

Model	B_0	B_{2023}	B_{2023} (% B_0)	B_{2017}	B_{2017} (% B_0)
2017 Basic	4 191 (3 053–5 503)	-	-	703 (511–923)	
2017 Revised	3 581 (3 008–3 593)	-	-	631 (567–704)	
2023 Old clocks only	2 886 (2 672–3 141)	941 (843–1 048)	32.6 (29.3–35.9)	799 (724–877)	27.6 (25.1–30.4)
2023 No disease data	2 863 (2 640–3 103)	970 (862–1 093)	33.9 (30.2–37.8)	763 (692–842)	26.7 (24.0–29.5)
2023 All disease data	2 737 (2 536–2 958)	1 106 (997–1 231)	40.4 (36.4–44.5)	773 (712–840)	28.2 (25.8–30.7)

Table 16: 2023 model medians and 95% credible intervals of current spawning stock biomass 2023 (B_{2023}) and projected spawning stock abundance for 2024–28 (B_{2024}–B_{2028}) as a percentage of B_0, with an assumption of a future catch of 8.54 million oysters in 2024–28, different model runs and disease mortality taken from the disease sub-model (sampling disease event characteristics), or fixed at 0.0, 0.1, or 0.2 y^{-1} (for the old clocks only model).

Model	Disease mortality	B_{2023} (% B_0)	B_{2024} (% B_0)	B_{2025} (% B_0)	B_{2026} (% B_0)	B_{2027} (% B_0)	B_{2028} (% B_0)
Old clocks only	Disease model	32.6 (29.3–35.9)	26.1 (22.2–30.5)	25.0 (20.0–30.9)	25.5 (19.3–33.8)	27.7 (19.7–38.4)	31.3 (21.6–43.1)
No disease data	Disease model	33.9 (30.2–37.8)	26.9 (22.9–31.9)	25.8 (20.6–32.6)	26.2 (19.9–35.9)	28.4 (20.3–40.5)	32.0 (21.9–45.0)
All disease data	Disease model	40.4 (36.4–44.5)	39.0 (33.6–46.0)	35.3 (27.0–49.0)	32.4 (23.2–52.3)	31.6 (21.6–55.2)	33.2 (21.5–56.9)
Old clocks only	0 yr^{-1}	32.6 (29.3–35.9)	29.2 (25.2–33.8)	33.8 (29.3–39.1)	38.4 (33.2–44.4)	42.6 (36.6–49.6)	46.6 (39.9–54.3)
Old clocks only	0.1 yr^{-1}	32.6 (29.3–35.9)	28.4 (24.5–32.9)	31.3 (27.1–36.1)	33.8 (29.3–39.3)	36.1 (30.9–42.2)	38.0 (32.3–44.5)
Old clocks only	0.2 yr^{-1}	32.6 (29.3–35.9)	27.6 (23.9–32.0)	29.0 (25.2–33.6)	30.1 (26.0–35.1)	31.0 (26.5–36.4)	31.7 (26.7–37.4)

Table 17: 2023 model percentage of projections (i) above 40% B_0, (ii) below 20% B_0 and (iii) below 10% B_0.

Metric	Model	2023	2024	2025	2026	2027	2028
% above 40% B_0	**Old clocks only**	0	0	0	0.1	1.3	7.2
	No disease data	0.1	0	0	0.5	3	10.7
	All disease data	58.1	39.5	22.9	15.1	15.5	21.3
% below 20% B_0	**Old clocks only**	0	0.1	2.6	4.5	3	1
	No disease data	0	0	1.3	2.8	2.1	0.9
	All disease data	0	0	0	0.2	0.9	1.2
% below 10% B_0	**Old clocks only**	0	0	0	0	0	0
	No disease data	0	0	0	0	0	0
	All disease data	0	0	0	0	0	0

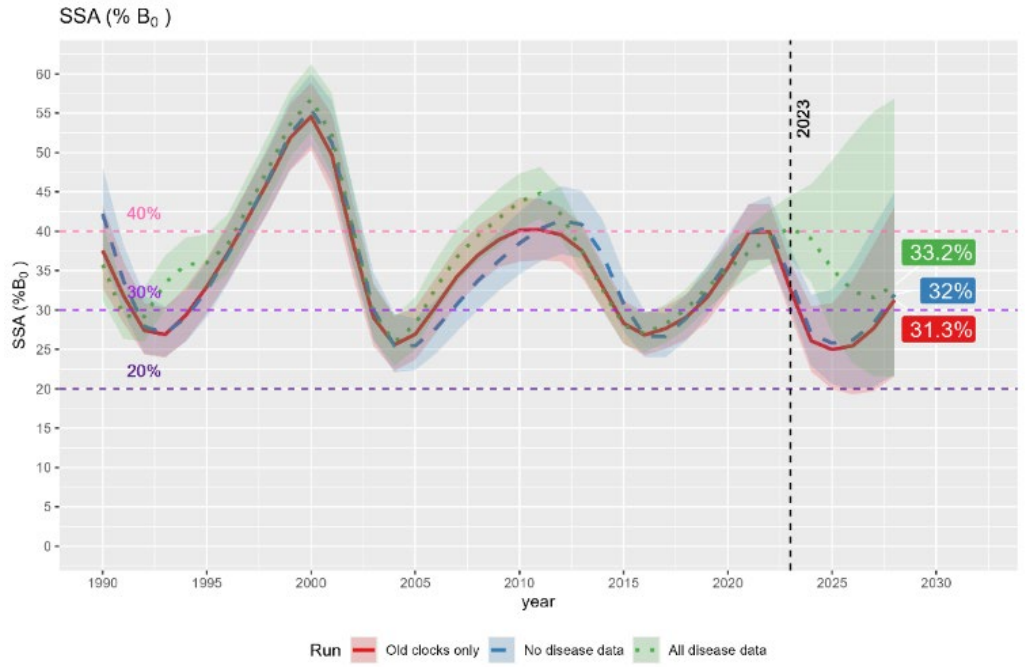


Figure 9: Model estimates of recent spawning stock abundance and projected spawning stock abundance (% B_0) for 2024–28 using the 'old clocks only' model (red solid line), 'no disease data' model (blue dashed line) and 'all disease data' model (green dotted line). The disease model is used for future disease rate projections.

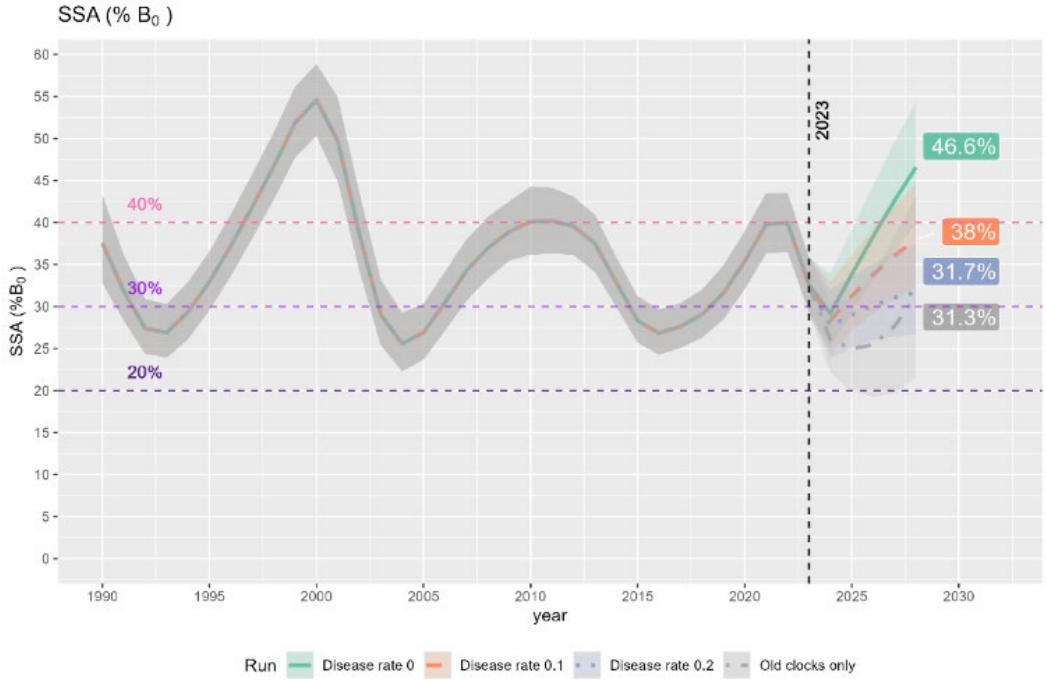


Figure 10: Model estimates of recent spawning stock abundance and projected spawning stock abundance (% B_0) for 2024–28 using the 'old clocks only' model, using the following future disease rates: 0 yr^{-1} (green solid line), 0.1 yr^{-1} (orange dashed line), 0.2 yr^{-1} (blue dotted line), and new disease model (grey dot-dash line).

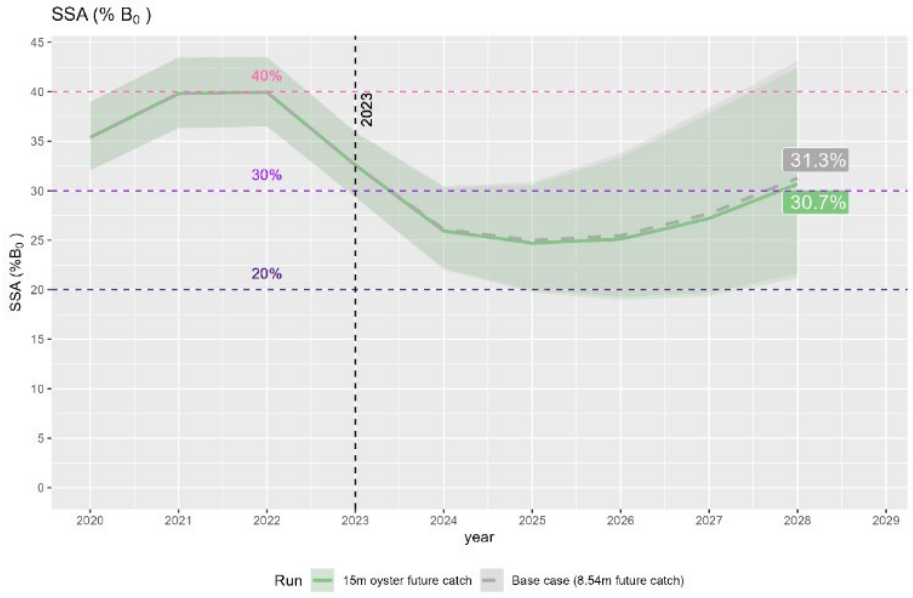


Figure 11: Model estimates of recent spawning stock abundance and projected spawning stock abundance (% B_0) for 2024–28 using the base case model with future catches of 8.54 m (dashed grey line) or 15 m (solid green line) oysters.

7. FUTURE RESEARCH CONSIDERATIONS

- Re-examine length frequencies from the landings sampling, and if considered appropriate explore the use of scaled length frequency distributions of landings to remove harvested individuals from the partition rather than applying an estimated selectivity.
- Review broader information on the environmental drivers on oyster condition, growth and disease (New Zealand and overseas), and temporal dynamics of disease outbreaks in oysters from overseas studies, to inform further development of the disease sub-model.
- Review the assumptions for growth, *M* and dredge efficiency, sensitivity to these, and implications for the assessment model's ability to fit the small oyster survey index.
- Consider experimental approaches or available data to inform the breakdown and catchability of old clocks.
- Explore further development of the "all disease data" model.
- Explore the utility of the spat index within the assessment model.
- Investigate data on size-disaggregated disease mortality and de-couple maturity and disease selectivity within the assessment model.

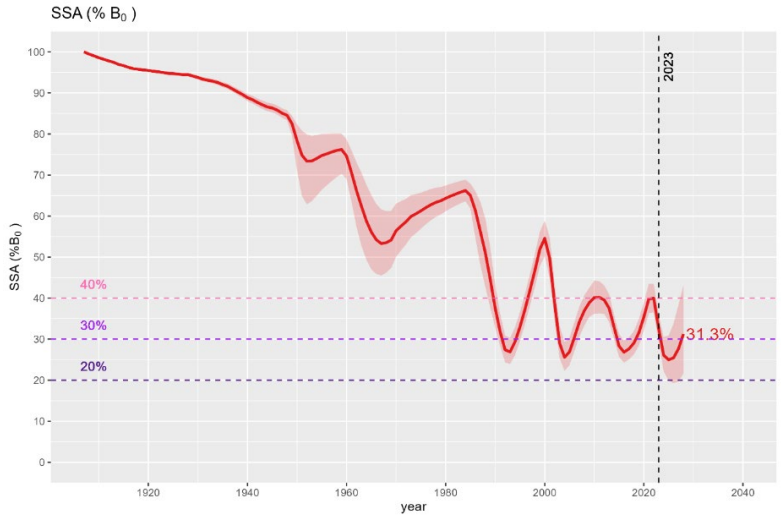
8. STATUS OF THE STOCK

Stock structure assumptions
OYU 5 is assessed as a single stock defined by the survey boundaries.

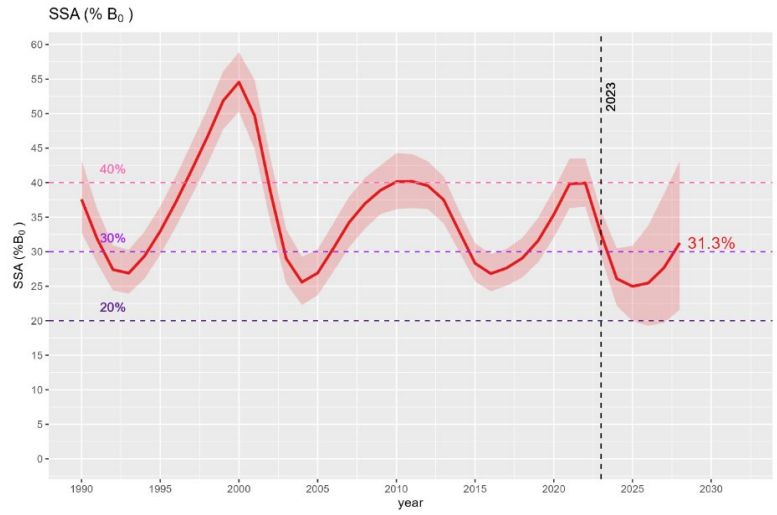
Stock Status		
Most Recent Assessment Plenary Publication Year	2024	
Intrinsic productivity level	Low	
Catch in most recent year of assessment	Year: 2023	Catch: 7.5 million oysters
Assessment Runs Presented	'Old clocks only' model (considered base case)	

Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	2023: B_{2023} is Unlikely (< 40%) to be at or above the target
Status in relation to Limits	2023: Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit
Status in relation to Overfishing	2023: Unknown, but at a TACC of 15 million oysters, fishing is expected to have only very minor effects. Future stock size is determined by levels of disease mortality and recruitment.

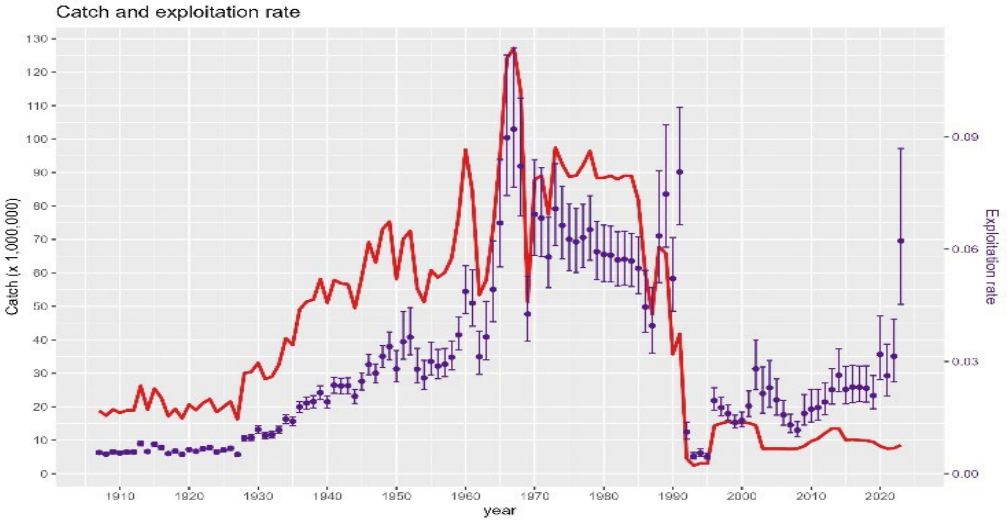
Historical Stock Status Trajectory and Current Status



2023 'old clocks only' model estimated posterior distributions of spawning stock biomass (rB_{year}) as a percentage of B_0 (full series). Shaded area shows the marginal posterior distribution, with solid line indicating the median (predicted to be 31.3% in 2023). Significant declines in population size are attributed to epizootics of *Bonamia exitiosa*.



2023 'old clocks only' model estimated posterior distributions of spawning stock biomass (rB_{year}) as a percentage of B_0 since 1990. Shaded area shows the marginal posterior distribution, with solid line indicating the median (predicted to be 31.3% in 2023). Significant declines in population size are attributed to epizootics of *Bonamia exitiosa*.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The Bonamia survey area is 46% of the stock assessment survey area and represented 75%, 69% and 67% of the recruit-sized oyster population in 2012, 2017, and 2023 respectively. Recruit, pre-recruit, and small oysters in the Bonamia survey area have shown substantial increases since the last stock assessment in 2017, reversing the declines between 2012 and 2017; however, between 2021 and 2023, recruit and pre-recruit oysters showed 75.9% and 68.8% declines, respectively, in some part probably due to changes in the timing of Bonamia mortality, and catchability rather than changes in oyster densities.
Recent Trend in Fishing Mortality or Proxy  **Catch (red line) and exploitation rate (purple points, median ± 95% credible interval).** While the harvest has declined slightly since 2017, exploitation rate fluctuated around 0.03 after 2000, increasing to 0.06 in 2023, related to the reduction in vulnerable biomass associated with the current Bonamia event.	
Other Abundance Indices	A spat index is not currently used within the assessment.
Trends in Other Relevant Indicators or Variables	From 2005 to 2011, mortality from Bonamia was relatively low (about 10% of recruited oysters), recruitment to the fishery exceeded *B. exitiosa* mortality, and the population size of recruited oysters increased. A third cycle of high *B. exitiosa* mortality between 2012 to 2015 reduced the stock by half. Summer mortality in 2017 was relatively low (about 5%) and remained low until 2021. Low mortality together with higher recruitment since 2016 has enabled the oyster population to rebuild. Since 2021, annual mortality has increased to above 10%.

Projections and Prognosis	
Stock Projections or Prognosis	Projections from the 'old clocks only' 2023 stock assessment model suggested that recruit-sized stock abundance in 2028, with *B. exitiosa* mortality from the disease model and a catch level of 8.54 million oysters, would increase to about 31.3% B_0.

Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Although 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.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	1 – Full Quantitative Stock assessment	
Assessment Method	Bayesian length-based stock assessment model	
Assessment Dates	Latest assessment Plenary publication year: 2024	Next full assessment: 2029
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 - abundance indices for old clocks	1 – High Quality (all)
Data not used (rank)	- Bonamia incidence from surveys - New clock abundance from surveys	2 – Medium or mixed quality for both (data conflicts introduced with current parameterisation)
Changes to Model Structure and Assumptions	- Model partition expanded to include diseased oysters, new clocks, and old clocks - Fitted old clocks abundance - Disease modelled as exploitation rate rather than instantaneous rate - Total landings, catch rates, and catch size structure updated - New estimates of population size from the 2018–23 surveys included - New disease projection model applied	
Major Sources of Uncertainty	- Stock size is highly dependent on the levels of mortality from Bonamia and continued recruitment around the long-term average - Dredge efficiency - Interannual and spatial variability in oyster growth rates may affect transitions of pre-recruit oysters to the recruited oyster population - The processes that generate data on prevalence of disease and new clocks are not fully known and, to a lesser extent, the same applies for old clocks - The projected periodicity and intensity of disease events is unknown	

Qualifying Comments
Stock status is influenced largely by disease dynamics, and less so by fishing.

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