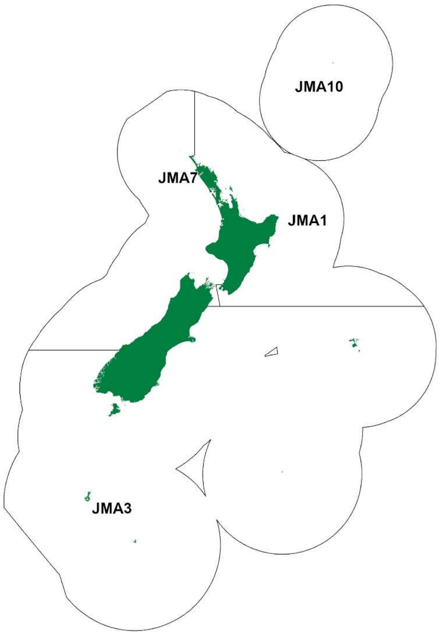
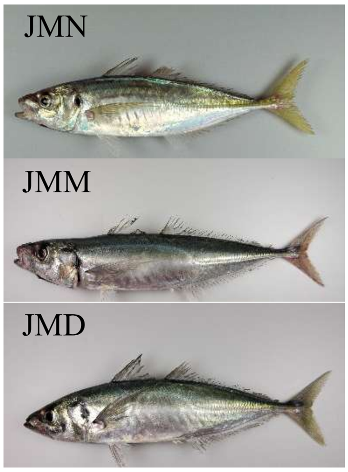
JACK MACKERELS (JMA)

(*Trachurus declivis*, *Trachurus novaezelandiae*, *Trachurus murphyi*)
Hauture





1. FISHERY SUMMARY

The jack mackerel fisheries catch three species: two endemic species, *Trachurus declivis* and *T. novaezelandiae*, and *T. murphyi* which appeared in New Zealand in the 1980s.

Jack mackerels have been included in the QMS since 1 October 1996, with four QMAs. Previously jack mackerels were considered part of the QMS, although ITQs were issued only in JMA 7. In JMA 1 and JMA 3, quota for the fishery was fully allocated as IQs by regulation with the exception of the 20% allocated to customary non-commercial catch. Before the 1995 jack mackerel regulations were issued, catch in JMA 1 taken in the Muriwhenua area north of 36° S to the limit of the Territorial Sea was not covered by the JMA 1 regulations. Allowances for customary non-commercial fishers, recreational fishers, and an allowance for other sources of mortality have only been set in JMA 3 (Table 1).

Table 1: TACs, TACCs, and allowances (t) for jack mackerels by fishstock.

Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
JMA 1	–	10 000	–	–	–
JMA 3	9 000	8 780	20	20	180
JMA 7	–	32 537	–	–	–
JMA 10	–	10	–	–	–

1.1 Commercial fisheries

In JMA 1, the jack mackerel catch is largely taken by the target purse seine fishery operating in the Bay of Plenty in Statistical Area 009 during March–November, with minor catches taken as a bycatch of kahawai and blue mackerel purse seine fisheries, and as a bycatch from trawl fisheries. In most years, relatively small catches were taken from off the east Northland coast (Statistical Areas 002 and 003), although this area accounted for a substantial proportion of the total catch in 1993–94 and 1994–95.

Since 1991–92, jack mackerel targeted landings in JMA 1 have represented more than 80% of total catch. The highest rates of bycatch are from kahawai and blue mackerel targeted operations which each account for about 7% of the total jack mackerel catch. The majority of JMA 1 catch over these years has been taken from Statistical Areas 008 and 009 (Bay of Plenty) between June and November;

considerably less has been taken in Statistical Areas 002 and 003, although high catches were recorded from these areas in 1993–94 and 1994–95.

In JMA 3 little targeting occurred before 1992–93. During the 1990s targeting increased and accounted for the majority of catch (about 50% between 1991–92 and 1996–97), but, after a peak of more than 80% in 1997–98 and 1998–99, the catch has decreased again to about 50–60% in recent years. The balance of the catch in this area comes from trawl bycatch (squid 15–30%, barracouta 15–20%) on the Chatham Rise and in the Southland/Sub-Antarctic region. A purse seine fishery has operated between the Clarence River mouth and the Kaikōura Peninsula, which peaked at 4400 t in 1992–93 and averaged more than 3000 t between 1989–90 and 1993–94. Purse seine catches have shown a steady decline since, dropping from 1000 t in 1994–95, to 100 t in 2001–02 and 2002–03; no catch was recorded for 2003–04, and purse seine catch has subsequently been rare.

Increased availability of jack mackerels caused by the influx of *T. murphyi* resulted in increased quotas in JMA 1 and JMA 3, to 8000 t and 9000 t, respectively, for the 1993–94 fishing year, and a further increase to 10 000 t and 18 000 t, respectively, for the 1994–95 year. The latter increases were made under the proviso that they be accounted for by increased catches of *T. murphyi* only; combined landings of *T. declivis* and *T. novaezelandiae* in JMA 1 and JMA 3 must not exceed the original quotas of 5970 t and 2700 t, respectively. Industry agreed to these limits and voluntarily introduced monitoring programmes to provide the information necessary for them to be met.

For the 2016–17 fishing year, the TACC for JMA 3 was reduced to 8780 t, approximating the 1993–94 TACC level, on the basis that recent catches had been considerably lower than the TACC and that catches of *T. murphyi* were minimal, indicating low abundance of the species in New Zealand waters in recent years.

The three species occur in each of the Fishstocks but have not been individually identified in catch records. Historical estimated and recent reported jack mackerel landings and TACCs are shown in Tables 1 and 2, and Figure 1 shows the historical landings and TACC values for the main JMA stocks. Total annual landings have ranged between 21 059 t and 50 388 t since 1986–87 (Table 3).

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	JMA 1	JMA 3	JMA 7	Year	JMA 1	JMA 3	JMA 7
1931–32	0	0	0	1957	0	0	6
1932–33	0	0	0	1958	0	0	9
1933–34	0	0	0	1959	2	0	0
1934–35	0	0	0	1960	2	0	5
1935–36	0	0	0	1961	1	0	5
1936–37	0	0	0	1962	5	0	5
1937–38	0	0	0	1963	7	2	13
1938–39	0	0	0	1964	5	4	10
1939–40	1	0	0	1965	14	0	8
1940–41	1	1	2	1966	47	0	54
1941–42	0	0	2	1967	213	0	250
1942–43	3	0	2	1968	172	505	4 558
1943–44	0	0	0	1969	128	388	7 065
1944	9	0	0	1970	75	1 029	7 274
1945	7	0	0	1971	473	776	12 684
1946	3	0	6	1972	350	5 450	15 581
1947	14	0	4	1973	395	1 238	14 648
1948	3	0	6	1974	1 236	2 016	16 943
1949	5	0	22	1975	204	3 615	10 043
1950	7	6	3	1976	838	5 690	14 228
1951	4	4	1	1977	1 317	5 228	13 729
1952	1	4	7	1978	1 250	1 547	4 657
1953	0	3	9	1979	2 158	516	4 475
1954	3	0	1	1980	2 504	104	3 533
1955	3	0	12	1981	2 815	110	8 665
1956	1	0	2	1982	1 607	119	8 364

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings.

Table 3: Reported landings (t) of jack mackerel by Fishstock from 1983–84 to present and actual TACCs (t) for 1986–87 to present. QMS data from 1986 to present.

	JMA 1		JMA 3		JMA 7		JMA 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings§	TACC
1983–84*	3 682	–	715	–	12 464	–	0	–	16 861	–
1984–85*	1 857	–	1 223	–	16 013	–	0	–	19 093	–
1985–86*	1 173	–	2 228	–	10 002	–	0	–	13 403	–
1986–87	4 056	5 970	1 638	2 700	19 815	20 000	0	10	25 509	28 680
1987–88	3 108	5 970	1 883	2 700	17 879	22 697	0	10	22 870	31 377
1988–89	2 986	5 970	1 919	2 700	17 403	26 008	0	10	22 308	34 688
1989–90	4 226	5 970	4 013	2 700	21 776	32 027	0	10	30 015	40 707
1990–91	6 472	5 970	6 403	2 700	17 786	32 069	0	10	30 661	40 749
1991–92	7 017	5 970	5 779	2 700	25 880	32 069	0	10	38 676	40 749
1992–93	7 529	5 970	15 399	2 700	24 659	32 537	0	10	47 587	41 216
1993–94‡	14 256	8 000	9 115	9 000	22 377	32 537	0	10	45 748	49 546
1994–95‡	7 832	10 000	11 519	18 000	18 912	32 537	0	10	38 263	60 547
1995–96	6 874	10 000	19 803	18 000	12 270	32 537	0	10	38 947	60 547
1996–97	6 912	10 000	15 687	18 000	12 056	32 537	0	10	34 655	60 547
1997–98	7 695	10 000	15 452	18 000	14 293	32 537	0	10	37 440	60 547
1998–99	5 641	10 000	15 111	18 000	13 629	32 537	0	10	34 381	60 547
1999–00	2 864	10 000	10 306	18 000	7 889	32 537	0	10	21 059	60 547
2000–01	8 360	10 000	2 744	18 000	15 703	32 537	0	10	26 807	60 547
2001–02	5 247	10 000	5 000	18 000	22 338	32 537	0	10	32 585	60 547
2002–03	6 172	10 000	2 225	18 000	26 084	32 537	0	10	34 481	60 547
2003–04	7 396	10 000	705	18 000	28 888	32 537	0	10	36 989	60 547
2004–05	9 418	10 000	716	18 000	36 507	32 537	0	10	46 641	60 547
2005–06	9 924	10 000	5 000	18 000	27 782	32 537	0	10	42 706	60 547
2006–07	5 293	10 000	1 857	18 000	32 039	32 537	0	10	39 189	60 547
2007–08	11 167	10 000	2 629	18 000	34 059	32 537	0	10	47 855	60 547
2008–09	9 791	10 000	1 964	18 000	28 828	32 537	0	10	40 583	60 547
2009–10	9 086	10 000	2 706	18 000	31 152	32 537	0	10	42 944	60 547
2010–11	8 262	10 000	3 592	18 000	28 177	32 537	0	10	40 031	60 547
2011–12	8 911	10 000	3 085	18 000	28 266	32 537	0	10	40 261	60 547
2012–13	8 054	10 000	3 830	18 000	31 776	32 537	0	10	43 659	60 547
2013–14	10 520	10 000	4 693	18 000	35 175	32 537	0	10	50 388	60 547
2014–15	10 177	10 000	4 115	18 000	33 970	32 537	0	10	48 262	60 547
2015–16	6 989	10 000	2 756	18 000	30 875	32 537	0	10	40 621	60 547
2016–17	8 890	10 000	4 665	8 780	33 802	32 537	0	10	47 357	51 327
2017–18	5 553	10 000	5 559	8 780	34 190	32 537	0	10	45 302	51 327
2018–19	4 332	10 000	4 651	8 780	31 752	32 537	0	10	40 735	51 327
2019–20	6 478	10 000	5 355	8 780	31 451	32 537	0	10	43 284	51 327
2020–21	6 777	10 000	5 601	8 780	31 810	32 537	0	10	44 188	51 327

* FSU data.
§ Includes landings from unknown areas before 1986–87.
‡ JMA 1 & 3 landings are totals from CLR and CELR data.

Landings in JMA 1 before 1989–90 were generally well below the quota of 5970 t (Table 3), with the maximum in 1986–87 only slightly above 4000 t. Landings increased to 7529 t in 1992–93, followed by a substantial increase to the highest recorded value of 14 256 t in 1993–94, which was more than twice the original quota and exceeded the quota of 8000 t set for that year. In 1994–95 reported landings (7832 t) were half those of 1993–94. Landings from 1994–95 to 1997–98 were around 7000 t. Over the period 1997–98 to 2004–05, annual catches from JMA 1 increased to near the level of the TACC (10 000 t) and, until 2014–15, annual catches fluctuated about 8000–10 000 t, with the exception of a considerably lower catch in 2006–07 and a peak catch of 11 200 t in 2007–08. JMA 1 landings since 2015–16 have been consistently less than the TACC of 10 000 t. The 2018–19 JMA 1 landings were the lowest since 1999–00, at 4332 t, but have increased since then to 6777 t in 2020–21.

Estimates of the species composition of the JMA 1 purse seine catches are available from 1989–90 to 2019–20 (Figure 2, Table 4). During 1989–90 and 1990–91, annual catches were dominated by *T. novaezelandiae*, but included a small component of *T. declivis*. The proportion of *T. murphyi* in the catch increased considerably over the following years, accounting for 65% of the total catch in 1993–94 and continued to account for a considerable proportion of the JMA 1 catch during 1994–95 to 1998–99. Since 1999–00, annual catches of *T. murphyi* have been small. From 1999–00 to 2016–17, annual catches from JMA 1 were generally dominated by *T. novaezelandiae.* The annual catch of this species increased from about 2000 t to 5000 t during the 1990s to an average of 8150 t in 2007–08 to 2016–17. Correspondingly, cumulative catches of *T. declivis* and *T. murphyi* were low during this period (7% and 2%, respectively). *Trachurus novaezelandiae* annual catches dominated the JMA 1 purse seine fishery from 2014–15 to 2016–17, ranging from 6488 t to 8858 t, but dropped to 2432 t and 52% of the catch in 2017–18. Catches of *T. declivis* increased in 2017–18 and ranged from 1521 t to 2313 t from 2017–18 to 2019–20.

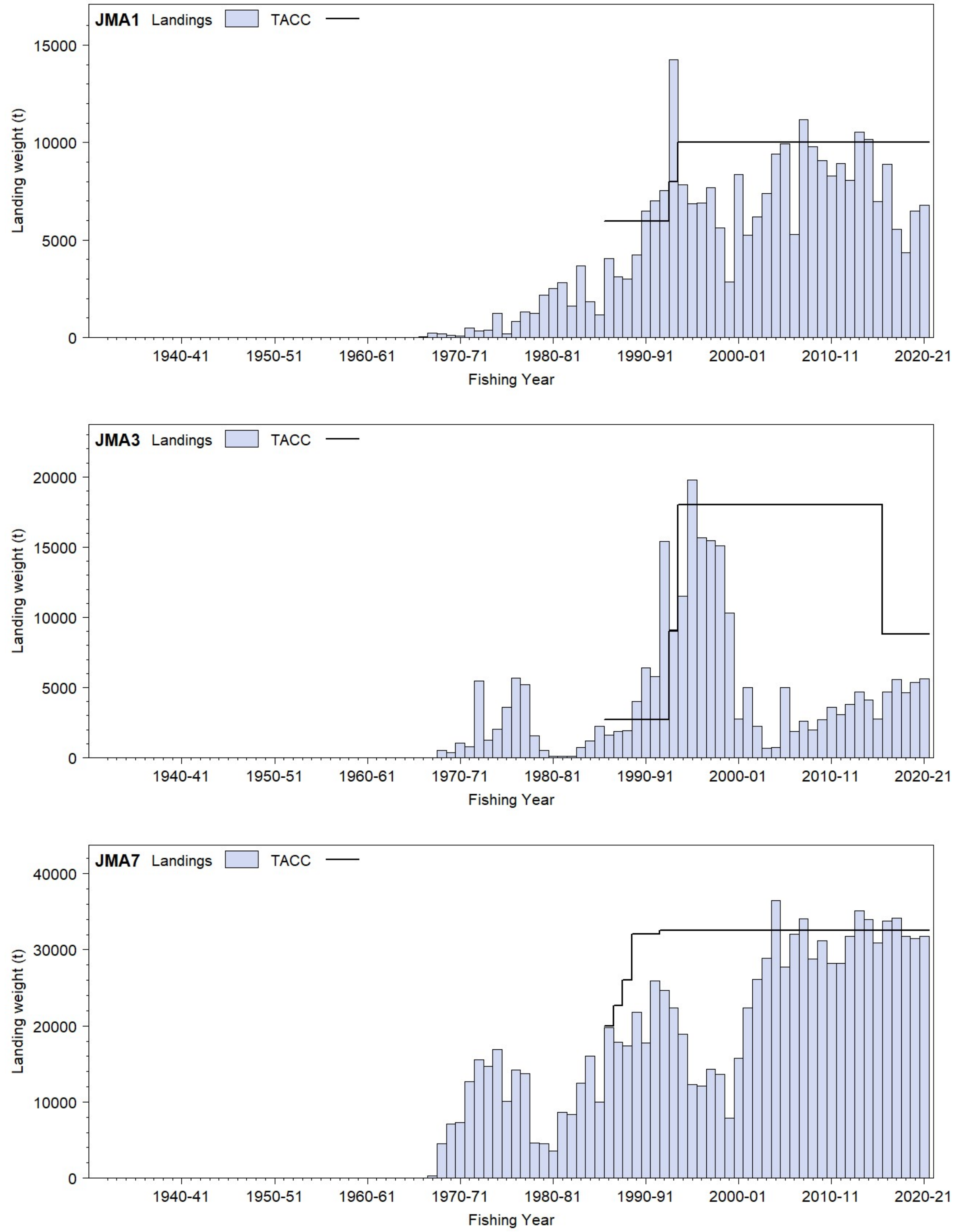


Figure 1: Reported commercial landings and TACC for the three main JMA stocks. From top: JMA 1 (Auckland East, Central East), JMA 3 (South East coast, South East Chatham Rise, Sub-Antarctic, Southland), and JMA 7 (Challenger, Central Egmont, Auckland West).

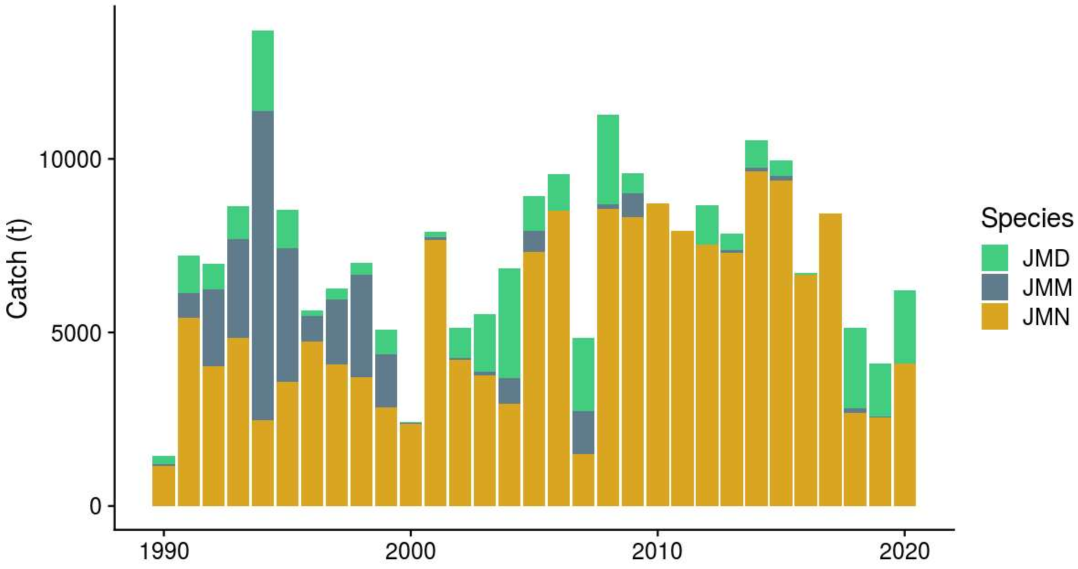


Figure 2: The time series of annual species catch estimates from the JMA 1 purse seine fishery (JMN, *T. novaezelandiae*; JMD, *T. declivis*; JMM, *T. murphyi*).

Table 4: Total JMA 1 purse seine catches and the time series of annual estimates of the species composition of the catch (JMN, *T. novaezelandiae*; JMD, *T. declivis*; JMM, *T. murphyi*) (compiled from various sources, see appendix 5 Langley et al 2016 and Middleton in prep).

Fishing year	Catch (t)	Species proportion		
		JMD	JMM	JMN
1989–90	1 433	0.15	0.04	0.81
1990–91	7 147	0.15	0.10	0.76
1991–92	6 921	0.11	0.32	0.58
1992–93	8 629	0.11	0.33	0.56
1993–94	13 710	0.17	0.65	0.18
1994–95	8 530	0.13	0.45	0.42
1995–96	5 643	0.03	0.13	0.84
1996–97	6 256	0.05	0.30	0.65
1997–98	7 009	0.05	0.42	0.53
1998–99	5 077	0.14	0.30	0.56
1999–00	2 416	0.01	0.01	0.98
2000–01	7 896	0.02	0.01	0.97
2001–02	5 146	0.17	0.01	0.82
2002–03	5 518	0.30	0.02	0.68
2003–04	6 838	0.46	0.11	0.43
2004–05	8 919	0.11	0.07	0.82
2005–06	9 568	0.11	0.00	0.89
2006–07	4 803	0.44	0.26	0.31
2007–08	11 270	0.23	0.01	0.76
2008–09	9 579	0.06	0.07	0.87
2009–10	8 714	0.00	0.00	1.00
2010–11	7 936	0.00	0.00	1.00
2011–12	8 765	0.13	0.00	0.86
2012–13	7 841	0.06	0.01	0.93
2013–14	10 543	0.07	0.01	0.92
2014–15	9 968	0.05	0.01	0.94
2015–16	6 721	0.01	0.00	0.99
2016–17	8 439	0.00	0.00	1.00
2017–18	5 140	0.46	0.03	0.52
2018–19	4 111	0.37	0.01	0.62
2019–20	6 208	0.34	0.00	0.66

Total landings in JMA 3 over the period 1984–85 to 1988–89 were relatively constant, at a level below the quota of 2700 t. Landings increased over subsequent years to peak in 1992–93 at almost three times that of the preceding year and more than five times the quota. Under the first of two consecutive annual increases to the JMA 3 TACC in 1993–94, landings were slightly above the limit set, but dropped well below the higher TACC level in 1994–95. The lower 1994–95 catch relative to that in 1992–93 has been attributed to the delayed implementation of the quota, less targeting of jack mackerel, and low bycatch in the squid trawl fishery. The reduced effort is thought to be a result of marketing difficulties for the relatively lower valued *T. murphyi*. Landings in JMA 3 increased markedly in 1995–96 (19 803 t) to a value exceeding the quota, with catches remaining stable around 15 500 t over three subsequent years. More recently, landings have decreased to levels well below the TACC, fluctuating between 700 t and 5000 t since 2000–01. Declines in landings are attributed to declining abundance of *T. murphyi*, which historically comprised the bulk of JMA 3 landings. JMA 3 landings in 2020–21 were 5601 t.

Landings in JMA 7 represent the greatest proportion of total landings and were mainly taken by bottom trawlers in the early 1990s but are now mainly taken by midwater trawlers. Landings fluctuated between 17 403 t and 25 880 t from 1986–87 to 1994–95. From 1995–96 to 1998–99, landings were in the range of 12 056–14 293 t. Subsequently, landings increased steadily from 15 703 t in 2000–01, to 28 888 t in 2003–04, and to 36 507 t in 2004–05. The 2004–05 landings were 3971 t in excess of the TACC. This increase in JMA 7 landings has been attributed to market demand and a lack of availability of preferred species quota as a result of cuts in quotas for other species and taking the lower-cost option of targeting jack mackerel instead of hoki. The 2007–08 landings were 34 059 t, about 1500 t larger than the TACC. In 2008–09 catches decreased below the TACC by nearly 4000 t but increased again in 2009–10 and have fluctuated around a level very close to the TACC since this time.

A number of factors have been identified that can influence landing volumes in the jack mackerel fisheries. In the purse seine fishery during the 1990s, jack mackerel was often mixed with kahawai. Fishing companies tend to avoid these mixed schools to conserve kahawai quota, particularly at the beginning of the fishing year. When mixing of the two species is prevalent, a low kahawai TACC can result in the targeting of jack mackerel being inhibited. Both skipjack tuna and blue mackerel have been fished in preference to jack mackerel in the purse seine fishery, with the jack mackerel season being influenced by the availability of these species. However, global increases in the market price for jack mackerel have increased its importance in the purse seine fishery to a level similar to that for blue mackerel, and, as a result, the seasonal catch for jack mackerel has broadened considerably in recent years. This has provided fishers with a cost-effective alternative to traditional purse seine targets, particularly skipjack tuna, which incurs higher costs related to onboard storage and handling.

In recent years, there has been a change in the operation of the JMA 1 purse-seine fleet. In response to market requirements, fish are no longer stored in brine on board the vessel. This has resulted in shorter trip durations and consequently a concentration of fishing effort in the Bay of Plenty (where *T. novaezelandiae* dominate) near the processing facilities in Tauranga. Market requirements for fish size also affect the jack mackerel species targeted, and consequently the areas fished.

1.2 Recreational fisheries

Jack mackerels do not rate highly as a recreational target species although they are popular as bait.

Recreational catch in the northern region (JMA 1) was estimated at 333 000 fish (CV 0.13) by a diary survey in 1993–94 (Bradford 1996), 79 000 fish (CV 0.16) in a national recreational survey in 1996 (Bradford 1998), 349 000 fish (CV 39%) in the 2000 survey (Boyd & Reilly 2002) and 295 000 fish (CV 0.2%) in the 2001 survey (Boyd et al 2004). The surveys suggest a harvest of 80–110 t per year for JMA 1, insignificant in the context of the commercial catch. Estimates from other areas are very low (between 500 and 47 000 fish) and are insignificant in the context of the commercial catch

The harvest estimates provided by telephone/diary surveys between 1993 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). 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 nonfishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 5. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 5: Recreational harvest estimates for jack mackerel stocks (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
JMA 1	2011–12	Panel survey	101 076	32.2	0.20
	2017–18	Panel survey	62 710	18.6	0.24
JMA 3	2011–12	Panel survey	50	<1	1.01
	2017–18	Panel survey	0	0	–
JMA 7	2011–12	Panel survey	11 194	10.2	0.57
	2017–18	Panel survey	20 026	6.2	0.51

1.3 Customary non-commercial fisheries
Quantitative information on the current level of Māori customary non-commercial catch is not available.

1.4 Illegal catch
There is no information on illegal activity or catch but it is considered to be insignificant.

1.5 Other sources of mortality
There is no information on other sources of mortality.

2. BIOLOGY

The three species of jack mackerel in New Zealand have different geographical distributions, but their ranges partially overlap. *T. novaezelandiae* predominates in waters shallower than 150 m and warmer than 13 ºC; it is uncommon south of latitude 42º S. *T. declivis* generally occurs in deeper (but less than 300 m) waters cooler than 16 ºC, north of latitude 45º S (Robertson 1978). *T. murphyi* occurs to depths of least 500 m and has a wide latitudinal range (0º S at the Galapagos Islands and coastal Ecuador, to south of 40º S off the Chilean coast) (Kawahara et al 1988).

T. murphyi was first described from New Zealand waters in 1987 (Kawahara et al 1988). Its presence was recorded off the south and east coasts of the South Island. Its distribution expanded to off the west coast of the South Island and the North and South Taranaki bights by the late 1980s, reaching the Bay of Plenty in appreciable quantities by 1992 and becoming common off the east coast of Northland by June 1994. However, this extensive distribution has decreased in more recent years and, since the late 1990s, its presence north of Cook Strait has been sporadic with occasional landings in the JMA 1 purse seine fishery north of East Cape and from the JMA 1 inshore trawl fishery south of East Cape. The total range of *T. murphyi* extends along the west coast of South America, across the South Pacific, to the New Zealand EEZ, and into waters off south-eastern Australia.

All species can be caught by bottom trawl, midwater trawl, or by purse seine nets targeting surface schools.

The vertical and horizontal movement patterns are poorly understood. Jack mackerels are presumed to be generally off the bottom at night, and surface schools can be quite common during the day.

Jack mackerels have a protracted spring-summer spawning season. *T. novaezelandiae* probably matures at about 26–30 cm fork length (FL) at an age of 3–4 years, and *T. declivis* matures when about 26–30 cm FL at an age of 2–4 years. Spawning occurs in the North and South Taranaki bights, and probably in other areas as well.

The reproductive biology of *T. murphyi* in New Zealand waters is not well understood. Pre- and post-spawning fish have been recorded from the Chatham Rise, Stewart-Snares shelf, Northland east coast, and off Kaikoura in summer, but it is unknown whether there has been any resulting recruitment in New Zealand waters. A study by Taylor (2002a) showed that older size/age groups become increasingly dominant in catches westward from the South American coast, suggesting that an eastward migration of oceanic spawned larvae and juveniles occurs in the South Pacific Ocean.

Initial ageing of *T. murphyi* taken in New Zealand waters has been completed, but the estimates are yet to be validated. Initial growth is rapid, slowing at 6–7 years, and *T. murphyi* is a moderately long-lived species with a maximum observed age of 32 years. *T. novaezelandiae* and *T. declivis* have moderate initial growth rates that slow after about 6 years. Both species reach a maximum age of 25+ years.

The best available estimate of M for *T. novaezelandiae* and *T. declivis* is 0.18 based on the age-frequency distributions of lightly exploited populations in the Bay of Plenty. Assuming $M = 0.18$, estimates of Z made in 1989 suggest that F is less than 0.05 for both endemic species off the central west coast (the main jack mackerel fishing ground). Biological parameters relevant to the stock assessment are shown in Table 6.

Table 6: Estimates of biological parameters.

Fishstock			**Estimate**	**Source**
1. Natural mortality (M)				
All			0.18	
			Considered best estimate for both endemic species from all areas.	Horn (1991a)
2. Weight = $a(\text{length})^b$ (Weight in g, length in cm fork length)				
			All	
		a	b	
T. declivis		0.023	2.84	Horn (1991a)
T. novaezelandiae		0.028	2.84	Horn (1991a)
3. von Bertalanffy growth parameters				
			All	
	L_∞	k	t_0	
T. declivis	46 cm	0.28	-0.40	Horn (1991a)
T. novaezelandiae	36 cm	0.30	-0.65	Horn (1991a)
T. s. murphyi	51.2 cm	0.155	-1.4	Taylor et al (2002b)

3. STOCKS AND AREAS

There is no new information that would alter the stock boundaries given in previous assessment documents. For assessment purposes the three jack mackerel species are treated separately where possible.

There are two possible hypotheses on the stock structure of *T. murphyi* in New Zealand waters: it is either a separate stock established by fish migrating from South America, or part of a single, extensive trans-Pacific stock. Although successful recruitment in New Zealand waters would indicate the establishment of a separate stock, current evidence favours the latter hypothesis with an extensive stock between latitudes 35–50° S linking the coasts of Chile and New Zealand across what has been described as 'the jack mackerel belt'. Few detailed data are available to document the process of range expansion by *T. murphyi* or indicate the relative abundance of the three species in particular areas. As a requirement of the increased TACCs introduced in 1994–95, improvements to jack mackerel catch monitoring were made to provide adequate data for quantifying species composition and relative abundance in JMA 1 and JMA 3.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the 2022 Fisheries Assessment Plenary based on Fisheries New Zealand data updates for jack mackerel fisheries interaction tables in this section. Fishery interactions are described more fully issue-by-issue in the Aquatic Environment and Biodiversity Annual Review 2021 (Fisheries New Zealand 2021), online at https://www.mpi.govt.nz/dmsdocument/51472-Aquatic-Environment-and-Biodiversity-Annual-Review-AEBAR-2021-A-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment.

4.1 Role in the ecosystem

A study of fish assemblages using research trawls suggested that *Trachurus novaezelandiae* is part of an inshore assemblage that prefers shallow northern waters (centred on about 60 m depth and latitude about 38.7° S). All three species overlap spatially, but *T. declivis* is part of a deeper assemblage around central New Zealand (centred on about 130 m and about 40.1° S), and *T. murphyi* occurs deeper still and further south (centred on about 220 m and about 44.7° S) (Francis et al 2002). *T. novaezelandiae* and *T. declivis* range through the water column from surface to the sea floor. The behaviour of *T. murphyi* in New Zealand is less well known but studies off Chile suggest that this species tends to aggregate at night and that this could reflect nocturnal foraging (Bertrand et al 2004, 2006). The effect on the ecosystem of extracting, for example, between 5000 and 10 000 t of jack mackerels from JMA 1 and about 30 000 t from JMA 3 per year over the past decade is unknown.

4.1.1 Trophic interactions

Stevens et al (2011) reported the diet of *T. novaezelandiae* and *T. declivis* from the Bay of Plenty, Northland, and off the west coast South Island to be predominantly euphausiids with fewer amphipods and fish (see also Hurst 1980). Crustaceans (several groups) were the dominant prey of *T. novaezelandiae* in the Hauraki Gulf, with fewer fish and polychaetes (Godfriaux 1968, 1970). The diet of *T. murphyi* from research trawls on shelf areas around New Zealand, mainly down to 500 m depth, included: crustaceans (55%, mainly euphausiids 38%, amphipods 12%, and *Munida* 6%); salps (36%); and teleosts (11% frequency of occurrence in non-empty stomachs, Stevens et al 2011).

Predators of jack mackerels are likely to include many fishes, seabirds, and marine mammals given the relatively high abundance of jack mackerels. The diet of gemfish from research trawls in Southland included *Trachurus* spp. (6% of total, Stevens et al 2011). *T. declivis* and *T. murphyi* were identified from the stomachs of leafscale gulper shark and Plunket's shark and *T. declivis* from the stomachs of school shark (Dunn et al 2010). The diet of spiny dogfish included scavenged jack mackerel (Dunn et al 2013).

4.2 Bycatch (fish and invertebrates)

Between 2009 and 2011, *T. novaezelandiae* dominated 97% of purse seine landings in JMA 1 (Walsh et al 2012). The estimated proportions by year were 1–17% for *T. declivis*, 0–3% for *T. murphyi*, and 81–99% for *T. novaezelandiae*. There was spatial and temporal heterogeneity in size and abundance; *T. novaezelandiae* dominated landings from the Bay of Plenty throughout the year and large *T. declivis* and *T. murphyi* were common in east Northland during winter (Walsh et al 2016).

Finucci et al (2020) used data from scientific observers and commercial catch-effort returns to estimate the rates and annual levels of fish and invertebrate bycatch and discards in the jack mackerel trawl fisheries, from 2002–03 to 2018–19. Jack mackerel species (*Trachurus* spp.) accounted for 78% of the total estimated catch from trawls targeting jack mackerels between 1 October 2002 and 30 September 2019. The remaining 22% comprised mostly other commercial species, including barracouta (*Thyrsites atun*, 11%), blue mackerel (*Scomber australasicus*, 3.1%), and frostfish (*Lepidopus caudatus*, 3.0%) (Table 7). Over 90% of reported catch was of QMS species, although altogether 370 taxa were identified by observers. Species with notable levels of discards included spiny dogfish (68%), kingfish (50%), porcupine fish (83%), and sunfish (100%).

Table 7: Bycatch and discards from all observer records for the target trawl fishery for jack mackerel from 1 October 2002 to 30 September 2019 for species or species groups with a total catch of 100 kg or more, ordered by decreasing percentage of catch (Finucci et al in 2020).

Species code	Common name	Scientific name	Estimated catch (kg)	% of catch	% discarded
JMA/JDM/JMM/JMN	Jack mackerel	*Trachurus declivis, T. murphyi, T. novaezelandiae*	279 209.8	77.7	0.0
BAR	Barracouta	*Thyrsites atun*	40 004.0	11.1	0.1
EMA	Blue mackerel	*Scomber australasicus*	11 140.8	3.1	0.0
FRO	Frostfish	*Lepidopus caudatus*	10 776.2	3.0	0.3
RBT	Redbait	*Emmelichthys nitidus*	8451.9	2.4	0.5
STU	Slender tuna	*Allothunnus fallai*	1057.6	0.3	3.1
SPD	Spiny dogfish	*Squalus acanthias*	845.6	0.2	68.1
SWA	Silver warehou	*Seriolella punctata*	786.5	0.2	0.0
PIL	Pilchard	*Sardinops sagax*	747.7	0.2	3.6
RBM	Ray's bream	*Brama brama*	698.2	0.2	0.0
KIN	Kingfish	*Seriola lalandi*	682.4	0.2	50.2
WAR	Blue warehou	*Seriolella brama*	525.5	0.1	0.0
SNA	Snapper	*Chrysophrys auratus*	485.4	0.1	0.3
SDO	Silver dory	*Cyttus novaezealandiae*	285.2	0.1	1.2
TRE	Trevally	*Pseudocaranx georgianus*	246.6	0.1	0.0
JDO	John dory	*Zeus faber*	225.9	0.1	0.0
POP	Porcupine fish	*Allomycterus jaculiferus*	219.0	0.1	82.7
HOK	Hoki	*Macruronus novaezelandiae*	193.3	0.1	0.1
GUR	Gurnard	*Chelidonichthys kumu*	178.0	<0.1	0.1
ATT	Kahawai	*Arripis trutta, A. xylabion*	160.2	<0.1	0.0
MAK	Mako shark	*Isurus oxyrinchus*	145.4	<0.1	34.4
NMP	Tarakihi	*Nemadactylus macropterus & N. rex*	144.9	<0.1	0.2
SUN	Sunfish	*Mola mola*	136.5	<0.1	100.0
THR	Thresher shark	*Alopias vulpinus*	129.2	<0.1	100.0

4.3 Incidental capture of protected species (mammals, seabirds, and protected fish)

For protected species, capture estimates presented here include all animals recovered to the deck (alive, injured, or dead) of fishing vessels but do not include any cryptic mortality, e.g., seabirds that are struck by a warp but not brought onboard the vessel (Middleton & Abraham 2007).

4.3.1 Marine mammal captures

Jack mackerel trawlers occasionally catch marine mammals, primarily common dolphin, long-finned pilot whale, and New Zealand fur seal (which are all classified as 'Not Threatened' under the New Zealand Threat Classification System in 2019 (Baker et al 2019)). Between 2002–03 and 2019–20, there were 198 observed captures of whales and dolphins in jack mackerel trawl fisheries: common dolphin (183), long-finned pilot whale (13), dusky dolphin (1), and long-beaked common dolphin (1). Estimated captures for 2002–03 to 2019–20 are shown in Table 8, and show a strong declining trend. Common dolphins were observed captured off the Taranaki coast or off the west coast of the North Island (Abraham et al 2016, 2021). The 2002–03 to 2017–18 average of the estimated capture rate for common dolphins is 1.5 captures per 100 tows (range 0 to 4.62) in the jack mackerel fishery.

4.3.2 Seabird captures

Annual observed seabird capture rates ranged from 0 to 1.4 per 100 tows in jack mackerel fisheries between 2002–03 and 2019–20 (Abraham & Thompson 2009, Abraham & Thompson 2011, Thompson et al 2013, Abraham et al 2016). Capture rates have fluctuated without obvious trend at this low level (Table 9). Total estimated seabird captures in the jack mackerel trawl fishery varied from 3 to 27 between 2002–03 and 2019–20 (Table 9).

Observed seabird captures since 2002–03 have been mostly prions, shearwaters, and petrels (83 of the 111 observed seabird captures), with 28 observed albatross captures (Table 10). Seabird captures in the jack mackerel fishery have been observed mostly on the Stewart-Snares shelf, off Taranaki, and off the east coast South Island. These numbers should be regarded as only a general guide on the distribution of captures because the numbers are small, and the observer coverage is not uniform across areas and may not be representative.

Table 8: Number of tows by fishing year and observed common dolphin captures in jack mackerel trawl fisheries, 2002–03 to 2019–20. Annual fishing effort (tows), number of observed tows and observer coverage (%) in jack mackerel trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of common dolphin; estimated captures and capture rate of common dolphin (mean and 95% credible interval). Estimates are based on methods described by Abraham et al (2021), available online at https://protectedspeciescaptures.nz/PSCv6/released/. Observed and estimated protected species captures in this table derive from the PSC database version PSCV6.

	Fishing effort			Obs. captures		Est. captures		Est. capture rate	
Fishing year	Tows	No. Obs	% obs	Captures	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	3 067	346	11.3	21	6.07	141	60-259	4.59	1.96-8.44
2003–04	2 383	152	6.4	17	11.18	99	45-181	4.17	1.89-7.6
2004–05	2 509	558	22.2	21	3.76	85	46-139	3.39	1.83-5.54
2005–06	2 809	709	25.2	2	0.28	12	2-33	0.43	0.07-1.17
2006–07	2 711	802	29.6	11	1.37	55	23-102	2.04	0.85-3.76
2007–08	2 652	818	30.8	20	2.44	42	24-70	1.60	0.9-2.64
2008–09	2 169	813	37.5	11	1.35	23	11-43	1.05	0.51-1.98
2009–10	2 406	786	32.7	4	0.51	17	4-42	0.69	0.17-1.75
2010–11	1 882	593	31.5	7	1.18	53	18-108	2.82	0.96-5.74
2011–12	2 032	1 548	76.2	5	0.32	7	5-13	0.32	0.25-0.64
2012–13	2 213	1 940	87.7	15	0.77	16	15-20	0.71	0.68-0.9
2013–14	2 447	2 187	89.4	28	1.28	29	28-35	1.21	1.14-1.43
2014–15	1 750	1 512	86.4	19	1.26	21	19-28	1.21	1.09-1.6
2015–16	1 544	1 383	89.6	2	0.14	3	2-7	0.17	0.13-0.45
2016–17	1 407	1 024	72.8	0	0.00	1	0-5	0.05	0-0.36
2017–18	1 688	1 474	87.3	0	0.00	0	0-4	0.03	0-0.24
2018–19	1 627	1 278	78.5	0	0.00				
2019–20	1 747	1 352	77.4	0	0.00				

Table 9: Number of tows by fishing year and observed seabird captures in jack mackerel trawl fisheries, 2002–03 to 2019–20. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described by Abraham & Richard (2020) and are available online at https://protectedspeciescaptures.nz/PSCv6/released/. Observed and estimated protected species captures in this table derive from the PSC database version PSCV6.

	Fishing effort			Obs. captures		Est. captures		Est. capture rate	
Fishing year	Tows	No. Obs	% obs	Captures	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	3 067	346	11.3	4	1.16	22	10-42	0.72	0.33-1.37
2003–04	2 383	152	6.4	0	0.00	7	1-17	0.29	0.04-0.71
2004–05	2 509	558	22.2	8	1.43	16	9-27	0.63	0.36-1.08
2005–06	2 809	709	25.2	0	0.00	20	5-45	0.70	0.18-1.6
2006–07	2 711	802	29.6	1	0.12	8	2-19	0.31	0.07-0.7
2007–08	2 652	818	30.8	1	0.12	9	2-20	0.32	0.08-0.75
2008–09	2 169	813	37.5	6	0.74	14	7-26	0.63	0.32-1.2
2009–10	2 406	786	32.7	9	1.15	15	9-27	0.63	0.37-1.12
2010–11	1 882	593	31.5	7	1.18	15	8-28	0.78	0.43-1.49
2011–12	2 032	1 548	76.2	6	0.39	9	6-18	0.47	0.3-0.89
2012–13	2 213	1 940	87.7	26	1.34	27	26-31	1.22	1.17-1.4
2013–14	2 447	2 187	89.4	7	0.32	7	6-13	0.30	0.25-0.53
2014–15	1 750	1 512	86.4	12	0.79	14	12-22	0.81	0.69-1.26
2015–16	1 544	1 383	89.6	6	0.43	7	6-12	0.47	0.39-0.78
2016–17	1 407	1 024	72.8	4	0.39	6	4-13	0.45	0.28-0.92
2017–18	1 688	1 474	87.3	10	0.68	11	10-16	0.67	0.59-0.95
2018–19	1 627	1 278	78.5	3	0.23	5	3-10	0.28	0.18-0.61
2019–20	1 747	1 352	77.4	1	0.07	3	1-9	0.16	0.06-0.52

The jack mackerel target trawl fishery contributes to the total risk posed by New Zealand commercial fishing to seabirds (Table 11). The species to which the fishery poses the most risk is Southern Buller's albatross; this target fishery posing 0.002 of PST (Table 11). Southern Buller's albatross was assessed at high risk (Richard et al 2017).

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the jack mackerel trawl fishery. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Department of Internal Affairs 2006). The 2006

Notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling ("paired streamer lines", "bird baffler" or "warp deflector" as defined in the Notice).

Table 10: Number of observed seabird captures in jack mackerel trawl fisheries, 2002–03 to 2019–20, by species and area. Observed protected species captures in this table derive from the PSC database version PSCV6.

Species	Risk category	Taranaki	WCNI	Chatham Rise	Stewart-Snares shelf	ECSI	WCSI	Total
Salvin's albatross	High	0	0	0	0	3	0	3
Southern Buller's albatross	High	0	0	1	3	2	0	6
New Zealand white-capped albatross	Medium	5	0	0	10	4	0	19
Total albatrosses	–	5	0	1	13	9	0	28
Westland petrel	High	0	0	0	0	0	1	1
White-chinned petrel	Negligible	0	0	1	32	5	0	38
Sooty shearwater	Negligible	1	0	0	10	2	0	13
Common diving petrel	Negligible	0	0	0	1	0	1	2
White-faced storm petrels	Negligible	0	3	1	0	0	0	4
Australasian gannet	Negligible	1	0	0	0	0	0	1
Fairy prion	Negligible	5	0	0	1	1	0	7
Cape petrels	–	2	0	0	0	0	1	3
Cook's petrel	–	1	0	0	0	0	0	1
Fulmar prion	–	10	0	0	0	0	0	10
Grey-backed storm petrel	–	1	0	1	0	0	0	2
Large seabird	–	1	0	0	0	0	0	1
Total other birds	–	22	3	3	44	8	3	83

Table 11: Risk ratio of seabirds predicted by the level two risk assessment for the jack mackerel and all fisheries included in the level two risk assessment, 2006–07 to 2016–17, showing seabird species with a risk ratio of at least 0.001 of PST (Richards et al 2020). The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard et al 2017, where full details of the risk assessment approach can be found). The DOC threat classifications are shown (Robertson et al 2017 at http://www.doc.govt.nz/documents/science-and-technical/nztcs19entire.pdf).

Species name	PST (mean)	Risk ratio: MAC risk ratio	Risk ratio: Total	Risk category	DOC Threat Classification
Southern Buller's albatross	1 368.4	0.002	0.392	High	At Risk: Naturally Uncommon
New Zealand white-capped albatross	10 900.3	0.001	0.353	High	At Risk: Declining

4.3.3 Protected fish species captures

Mobulid rays (spinetail devilrays, *Mobula mobular*, and manta rays, *Mobula birostris,* both protected since 2010 under the Wildlife Act 1953) occur mainly in north-eastern North Island waters during summer and could potentially be caught in purse seine nets along the north-east coast of North Island. However, observers monitoring mackerel purse seine fisheries (coverage 0–17.8% per year, 2002–18) have not reported any captures of mobulid rays to date.

4.4 Benthic interactions

Jack mackerel are taken using trawls that are sometimes fished on or near the seabed. The spatial extent of seabed contact by trawl fishing gear in New Zealand's EEZ and Territorial Sea has been estimated and mapped in numerous studies for trawl fisheries targeting deepwater species (Baird et al 2011, Black et al 2013, Black & Tilney 2015, Black & Tilney 2017, Baird & Wood 2018, and Baird & Mules 2019, 2021a, 2021b), species in waters shallower than 250 m (Baird et al. 2015, Baird & Mules 2021a, 2021b), and all trawl fisheries combined (Baird & Mules 2021a, 2021b). The most recent assessment of the deepwater trawl footprint was for the period 1989–90 to 2018–19 (Baird & Mules 2021b).

During 1989–90 to 2018–19, about 55 100 bottom-contacting jack mackerel trawls were reported on TCEPRs and ERS (Baird & Mules 2021b); this represents about 1200–3300 tows in most years up to 2013–14 and an average of 880 tows per year from 2014–15 to 2018–19. The total footprint generated from these tows was estimated at about 46 697 km^2. This footprint represented coverage of 1.1% of the seafloor of the combined EEZ and the Territorial Sea areas; 3.4% of the 'fishable area', that is, the seafloor area open to trawling, in depths of less than 1600 m. For the 2018–19 fishing year, 870 jack mackerel bottom-contacting tows had an estimated footprint of 2825 km^2 which represented coverage of 0.1% of the EEZ and Territorial Sea and 0.2% of the fishable area (Baird & Mules 2021b).

The overall trawl footprint for jack mackerel (1989–90 to 2018–19) covered 16% of the seafloor in < 200 m, 6% of 200–400 m seafloor, and < 0.05% of the 400–600 m seafloor (Baird & Mules 2021b). The jack mackerel footprint contacted 1%, 0.1%, and < 0.01% of those depth ranges, respectively, in 2018–19 (Baird & Mules 2021b). The BOMEC class C (off the west coast of the North Island) had the highest proportion of area covered by the jack mackerel footprint in 2018–19 (4%), with the remainder of the footprint covering about 0.3% of the 61 000 km^2 of class E (Stewart-Snares shelf) and 0.2% of the 138 550 km^2 of class H (Chatham Rise) (Baird & Mules 2021b).

Trawling for jack mackerel with some or all of the gear contacting the bottom, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., Rice 2006) and there may be consequences for benthic productivity (e.g., Jennings et al 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review 2021 (Fisheries New Zealand 2021).

4.5 Other considerations

4.5.1 Spawning disruption

Fishing may disrupt spawning activity or success. Canadian research carried out on Atlantic cod (*Gadus morhua*) concluded that "Cod exposed to a chronic stressor are able to spawn successfully, but there appears to be a negative impact of this stress on their reproductive output, particularly through the production of abnormal larvae" (Morgan et al 1999). Morgan et al (1997) also reported disruption of a spawning shoal of Atlantic cod: "Following passage of the trawl, a 300-m-wide "hole" in the aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl." There have been no specific studies for jack mackerel in New Zealand waters, but information on the timing and location of spawning and fishing exists. *T. declivis* and *T. novaezelandiae* are serial spawners with a protracted spring-summer spawning season (Hurst et al 2000). *T. murphyi* appears to spawn from late winter through to summer (Horn 1991b, Hurst et al 2000). The JMA 7 trawl fishery has peaks of catch and effort in spring-summer (October–March) and in winter (April–September) (McKenzie 2008), the former overlapping with spawning. Most of the purse seine catch from the Bay of Plenty is taken in September–October, but an increasing proportion has been caught in November–December since 2005–06 (Walsh et al 2012), also overlapping the spring-summer spawning.

4.5.2 Habitat of particular significance to fisheries management

Habitat of particular significance for fisheries management (HPSFM) does not have a policy definition (Ministry for Primary Industries 2016), although work is underway to generate one. Studies of potential relevance have identified areas of importance for spawning and juveniles (Hurst et al 2000). *T. declivis* spawning was found to be common on the southwest and northwest North Island outer shelf, and moderate to high abundance of juveniles was recorded from northwest North Island, Hauraki Gulf, and Bay of Plenty outer shelf. *T. novaezelandiae* spawning was found to be common on the southwest and northwest inner and outer shelf of the North Island, and moderate to high abundance of juveniles was recorded from Hauraki Gulf and Bay of Plenty inner and outer shelf, East Cape inner shelf, and Tasman Bay/Golden Bay. *T. murphyi* spawning was found to be common on the southwest outer shelf and only low abundance of juveniles was recorded from the outer Southland shelf and at 300–600 m on the Chatham Rise.

4.5.3 Genetic effects
Fishing and environmental changes, including those caused by climate change or pollution, could alter the genetic composition or diversity of a species. There are no known studies of the genetic diversity of jack mackerels in New Zealand.

4.5.4 Marine heatwave
The effects of the marine heatwave on jack mackerel fisheries that was experienced in New Zealand waters in the summer months of 2017–18 are unknown.

5. STOCK ASSESSMENT

Stock assessments for jack mackerel are complicated by the reporting and management of three species under a single code.

Preliminary stock assessments for *T. declivis* and *T. novaezealandiae* in JMA 7 were undertaken in 2007 based on outputs from a Bayesian analysis for splitting the recorded commercial catch into *T. declivis*, *T. novaezealandiae*, and *T. murphyi* components. This analysis was based on species proportions sampled by fishery observers and was used to derive CPUE indices and a catch history for the *T. declivis* fishery in JMA 7, which were incorporated along with a proportions-at-age series into stock assessments. However, work in 2020 concluded that the observer data (stored in the Centralised Observer Database *cod*) were inadequate for deriving species splits in JMA 7 (Webber & Starr 2022) rendering the previous analyses unusable.

5.1 Challenger, Central West, and Auckland West (JMA 7)

Species proportion estimates
Previously a species proportion model fitted to observer data was used to estimate the proportion of *T. declivis* in the reported (TCEPR) catch for the JMA 7 fishery from 1989–90 to 2004–05 (Rohan et al 2006). In the model the species proportions are estimated for six strata each year (1989–90 to 2004–05). However, work in 2020 concluded that the *cod* data were inadequate for deriving species splits in JMA 7 (Webber & Starr 2022) rendering this analysis unusable. Currently, there do not appear to be any alternative data for estimating species proportions in JMA 7. The main issue with the observer data is the representativeness of samples. Samples will often be unrepresentative of the entire catch in a tow because observers will usually take a single sample (i.e., a few bins of fish) at the beginning of unloading the tow. Because JMA, both within and between species, are not homogeneously mixed within a tow, such a sample is likely to be unrepresentative of the entire tow.

CPUE
Although the species proportion model could not be used, a set of CPUE standardisations of all three species combined was done for positive catches of JMA only (i.e., the CPUE series could be assumed to track the abundance of all three species). This was done because 98% of observed targeted JMA tows caught JMA. Three different series were produced: a bottom trawl (BT) series from 1990–2002 based on the Electronic Data Warehouse (EDW), a midwater (MW) series 2001–19 also based on the EDW, and a MW series 2007–19 based on the *cod* database (Figure 3, Table 12). The earlier BT series seems to fluctuate more from year to year when compared with the two MW trawl series. The two MW trawl series, based on different data sets, align reasonably well, lending some credibility to these series. All three series suggest a generally increasing trend in CPUE over the past 30 years.

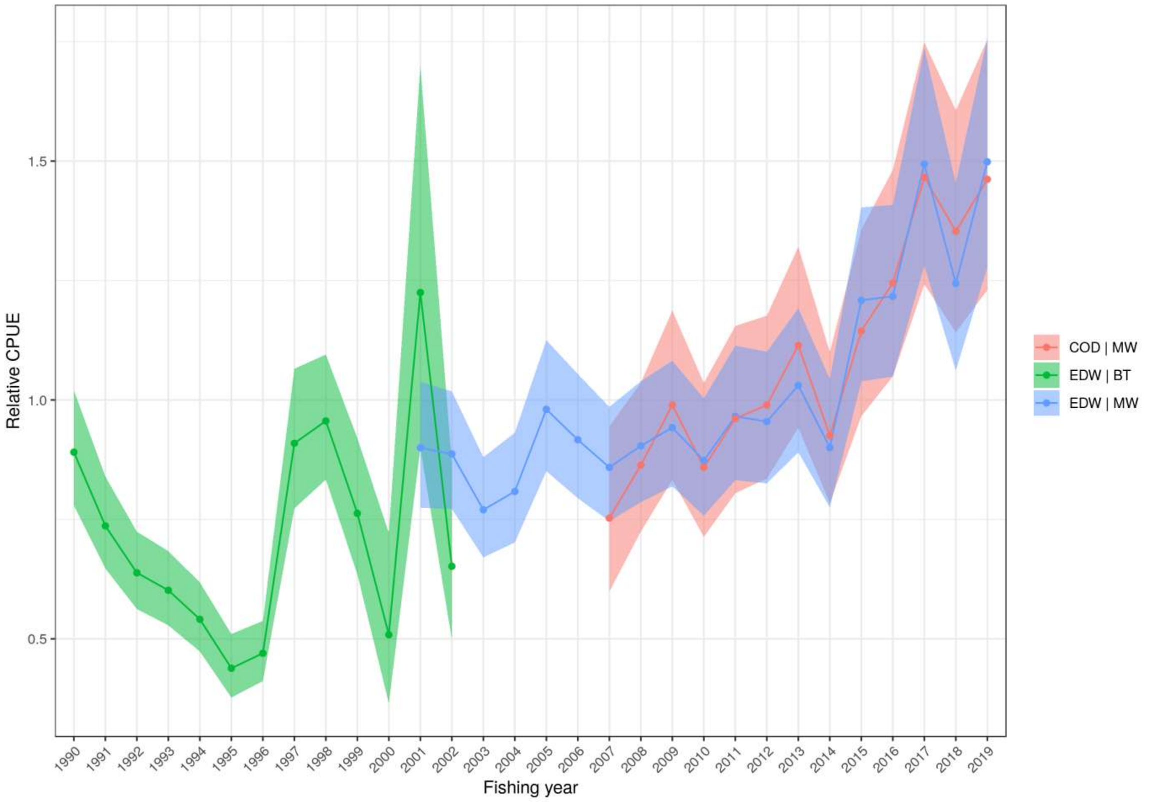


Figure 3: Standardised catch per unit effort (CPUE) indices of all three JMA species combined (i.e., JMD, JMM, and JMN) in JMA 7 from 1990-2019. Three series are presented: a bottom trawl (BT) series from 1990–2002 based on data held in the Electronic Data Warehouse (EDW); a midwater (MW) series from 2001–19 also based on EDW data; and a MW series from 2007–19 based on data held in the Centralised Observer Database *cod*). Points represent the median, and shaded region represents the 95% credible interval. The MW EDW series is scaled to have a geometric mean of 1, and the MW COD and BT EDW series are scaled to have the same geometric mean as the MW EDW series for the overlapping years. Data plotted as first year (i.e., 1990–91 plotted as 1990).

Table 12: Standardised CPUE indices (i.e., relative year effects, each series is rescaled to have a geometric mean of 1) from 1990–91 to 2019–20. The mean and CV for each series are provided. [Continued on next page]

	EDW BT		EDW MW		COD MW	
Fishing year	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**
1990–91	1.2925	0.069	–	–	–	–
1991–92	1.0691	0.067	–	–	–	–
1992–93	0.9256	0.065	–	–	–	–
1993–94	0.8735	0.066	–	–	–	–
1994–95	0.7855	0.067	–	–	–	–
1995–96	0.6372	0.078	–	–	–	–
1996–97	0.6818	0.068	–	–	–	–
1997–98	1.3209	0.082	–	–	–	–
1998–99	1.3870	0.070	–	–	–	–
1999–00	1.1105	0.095	–	–	–	–
2000–01	0.7498	0.176	–	–	–	–
2001–02	1.8005	0.166	0.899	0.073	–	–
2002–03	0.9550	0.141	0.886	0.072	–	–
2003–04	–	–	0.770	0.070	–	–
2004–05	–	–	0.809	0.072	–	–
2005–06	–	–	0.980	0.072	–	–
2006–07	–	–	0.917	0.072	–	–
2007–08	–	–	0.859	0.071	0.708	0.115
2008–09	–	–	0.904	0.071	0.812	0.092
2009–10	–	–	0.942	0.072	0.931	0.089
2010–11	–	–	0.874	0.072	0.807	0.094
2011–12	–	–	0.966	0.074	0.905	0.093
2012–13	–	–	0.955	0.074	0.929	0.087
2013–14	–	–	1.031	0.074	1.046	0.086
2014–15	–	–	0.900	0.075	0.870	0.085

Table 12: [Continued]

	EDW BT		EDW MW		COD MW	
Fishing year	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**
2015–16	–	–	1.209	0.076	1.075	0.086
2016–17	–	–	1.218	0.076	1.169	0.087
2017–18	–	–	1.495	0.078	1.379	0.088
2018–19	–	–	1.244	0.080	1.272	0.087
2019–20	–	–	1.498	0.082	1.374	0.090

Catch History
Catch records for jack mackerel extend back to 1946, although landings are small until the mid-1960s. Recreational catch, illegal catch, and customary non-commercial catch are not well known, though are small relative to the commercial catch, so no components are included for these in the catch history.

Catch at Age
Catch-at-age data were used from the commercial fishery in the years 1989–90, 1990–91, 1995–96, 2004–05, and 2005–06 to 2016–17, but proportions have been scaled on the discredited species proportions in 2020.

5.2 Biomass estimates
Estimates of current biomass are not available.

5.3 Other yield estimates and stock assessment results
For *T. declivis* and *T. novaezelandiae* catch-at-age proportions are available for the years 2006–07 to 2008–09 in JMA 7. These were used to estimate instantaneous total mortality *Z* values by the Chapman-Robson maximum likelihood method (Chapman & Robson 1960). As a sensitivity analysis, the assumed age of recruitment was varied between 3 and 6 years (Smith 2011).

For *T. declivis* estimates of *Z* varied between 0.17 y^{-1} and 0.23 y^{-1}. For *T. novaezelandiae*, *Z* varied between 0.23 $y^{-1}$and 0.43 y^{-1}. Estimates were lowest in the 2008–09 fishing year for both species. The accepted value of natural mortality for both species is 0.18 y^{-1}, indicating that estimates of average instantaneous fishing mortality (*F*) were well below *M* for *T. declivis* and about equal to *M* for *T. novaezelandiae*.

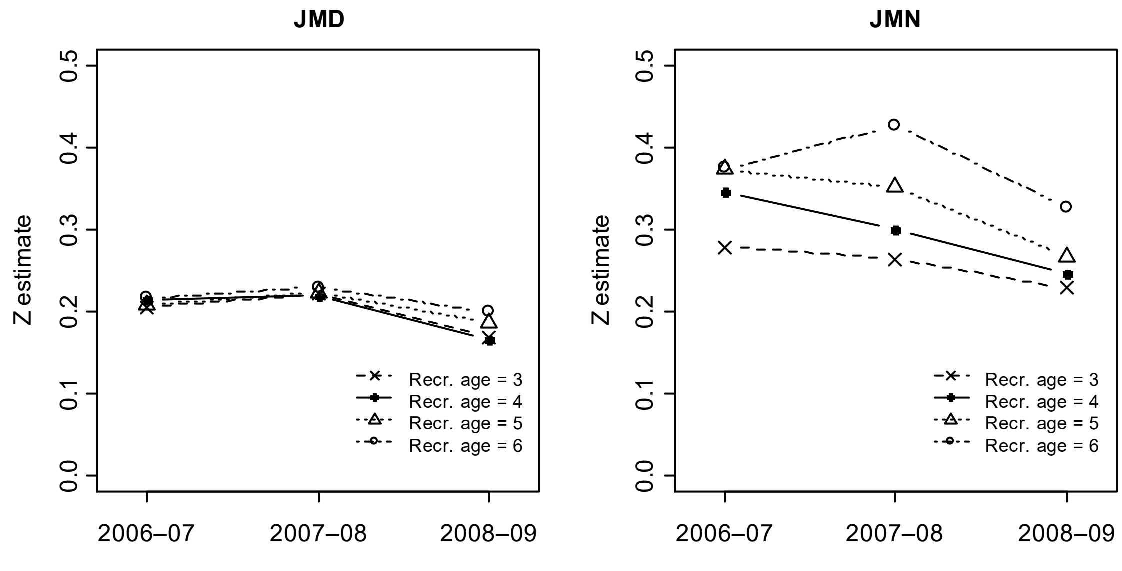


Figure 4: Estimates of instantaneous total mortality (*Z*) by year for *T. declivis* and *T. novaezelandiae* in JMA 7.

5.4 Other factors
T. murphyi has been known at times to comprise a substantial proportion of the purse seine catches in the area between Cook Strait and Kaikoura, in the Bay of Plenty, and off the east Northland coast, although the proportion of this component has declined considerably since the late 1990s. *T. murphyi* has also been an important component of the west coast North Island jack mackerel trawl fishery but

has declined in recent years. Thus, there has been a contraction in the range of this species in New Zealand waters, although it is unknown yet whether this represents a decrease in its overall abundance here. The effect of *T. murphyi* on the range and abundance of the other two species is unknown.

Aerial sightings data were used to produce a time series of relative abundance indices for jack mackerel. The time series covered the period from the beginning of the purse seine fishery in 1976 to 1993. It indicated an increase in abundance in JMA 1 from the early 1990s, and, although the result is not as clear, a similar trend in JMA 3 and JMA 7. These increases were attributed to the invasion of *T. murphyi.*

The validity of this early aerial sightings abundance index is uncertain. Further analysis of these data has been the focus of considerable effort in recent years and the Northern Inshore Working Group has not yet accepted revised abundance indices due to data and model concerns.

The stipulation that catches in JMA 1 and JMA 3 above the original TACs (5970 t and 2700 t, respectively) be accounted for by increases in *T. murphyi* only, is a method of managing this species independently of the other two. This approach was introduced as a means of maintaining stocks of the endemic species while allowing exploitation of increased stocks of *T. murphyi* resulting from its invasion.

The increase in *T. novaezelandiae* catch has predominantly occurred within the Bay of Plenty fishery area. There has been a small decrease in the length of fish caught from the fishery since 2006–07 to 2008–09, although it is unknown whether the decline in fish size is attributable to an increase in fishing mortality rates, changes in fishing operation, or variation in annual recruitment. Age composition data are available for the *T. novaezelandiae* catch from 2006–07 to 2008–09, but age-based sampling was discontinued due to the relatively high inter-annual variability in the age compositions, with the fishery targeting size classes based on market demand.

Future Research Considerations

- Develop and implement new sampling and data recording protocols to enable the Fisheries New Zealand observer programme to adequately sample and record the species composition of the JMA complex from commercial catches in the main JMA fisheries. The current practice of taking a sample of JMA from the beginning of a bag is not adequate because species are not homogeneously mixed within a tow. Instead, samples need to be collected throughout a bag all the way to the cod-end.
- The utility of shed sampling for some of the JMA fisheries should be explored. Although shed sampling would not help split the catch on a tow-by-tow basis, it could help determine the proportion of each species on a trip-by-trip basis and could be applicable to observed and unobserved trips. If done after observed trips, the observer sampling could be confirmed.
- Develop a custom stock assessment model to overcome the lack of historic species split information. This should model all three species combined and be fitted to combined data for those years without known species-splits, and to standard data for the remaining years. A simulation model to ensure that the ‘custom model’ is capable of producing outputs useful to management may also be required.
- A simpler, alternative approach to the ‘custom’ assessment described above, would be to use a standard assessment model and test a wide variety of assumed historical catch histories for the three species. The historical species split may be informed by Australian catch information for JMM (assuming that this will also reflect the same timing of influxes into New Zealand waters) and/or from historical New Zealand sales data where price or market differences by species may have existed.

6. STATUS OF THE STOCKS

Assessment of the status of JMA is complicated by the reporting and management of three species under a single code. This is further complicated by the uncertain 'status' of *T. murphyi*. The effect of the *T. murphyi* invasion on stocks of the New Zealand jack mackerels is unknown.

Stock Structure Assumptions
The three species have different levels of mobility and different spatial distributions within New Zealand. *T. murphyi* has been extremely mobile, with a widespread distribution throughout New Zealand during the 1990s but is now rarely seen in areas where once it was common. The degree to which its biomass has actually declined is difficult to determine and there are no recent reliable estimates of its current spatial distribution. There are reports from hoki surveys in Cook Strait of aggregations of *T. murphyi* lying in deeper water.

T. declivis is also believed to be highly mobile within New Zealand. Because of this, a single biological stock is assumed, but this has not yet been reliably determined. The mobility of *T. novaezelandiae* is assumed to be lower, given that it is a smaller animal with a more northerly and inshore distribution than *T. declivis*. Consequently, there is a higher probability of multiple independent breeding populations for *T. novaezelandiae*.

- **JMA 1**

Stock Status	
Year of Most Recent Assessment	-
Reference Points	Target(s): Not established but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not established
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	-
Historical Stock Status Trajectory and Current Status	
-	
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	An index for JMA 1 is not available at this time. Recent work and discussions concerning the use of aerial sightings data for annual relative abundance indices concluded that the inter-annual variation was too great for these data to provide a reliable index.
Recent Trend in Fishing Mortality or Proxy	-
Trends in other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	It is not known whether catches at the level of the current TACCs or recent catch levels are sustainable in the long-term.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology and Evaluation		
Assessment Type	Level 3 — Qualitative Evaluation: Fishery characterisation with evaluation of fishery trends (e.g., catch, effort and nominal CPUE, length-frequency information) - there is no agreed index of abundance	
Assessment Method	-	
Assessment Dates	Latest assessment:	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Species proportions estimates	
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
-

Fishery Interactions
JMA 1 catches are primarily taken by targeted purse seine. Because jack mackerel often occur in mixed schools with kahawai, particularly towards the end of the fishing year, this can inhibit jack mackerel targeting in this fishery at this time. Interactions with other species are currently being characterised.

- **JMA 3**

Stock Status	
Year of Most Recent Assessment	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not established
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	-

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	-
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	It is not known whether catches at the level of the current TACCs or recent catch levels are sustainable in the long-term.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology and Evaluation		
Assessment Type	Level 4: Low information evaluation — there are only data on catch and TACC, with no other fishery indicators. Catch is qualified with species proportions estimates from MPI observer data. Some length-frequency information is available.	
Assessment Method	-	
Assessment Dates	Latest assessment: -	Next assessment: -
Overall assessment quality rank		
Main data inputs (rank)	-	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

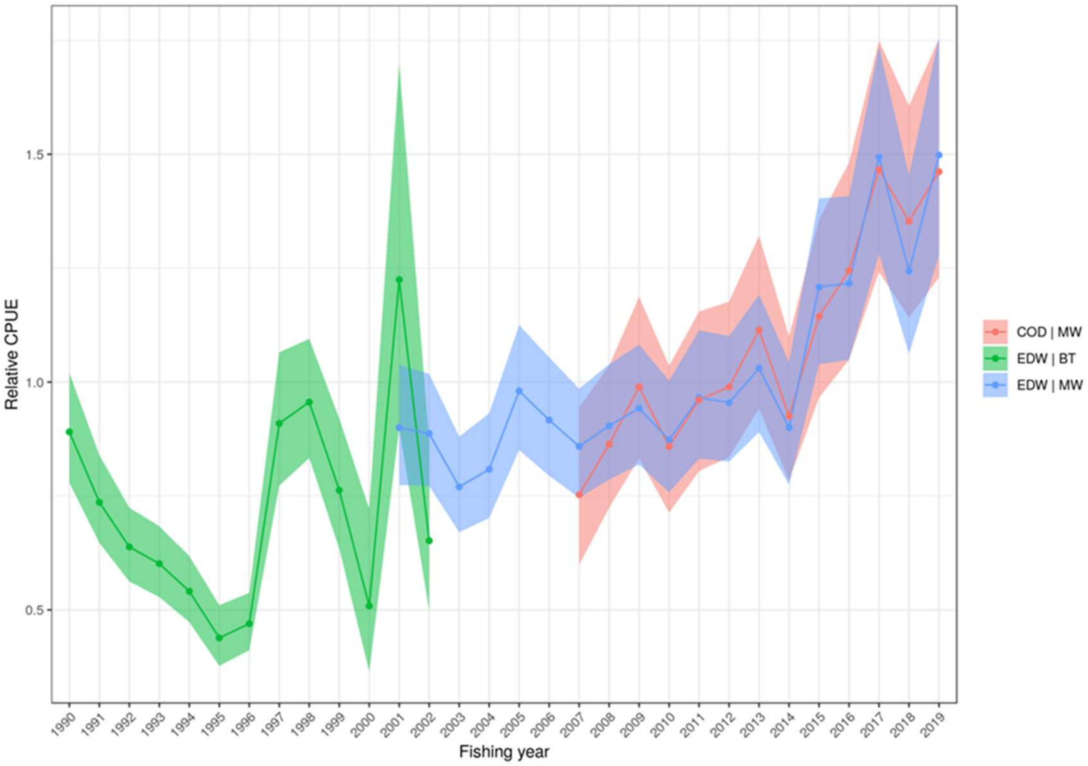
Qualifying Comments
-

Fishery Interactions
JMA 3 catches are primarily taken by midwater trawl. Non-target species captured in this fishery include barracouta and redbait. Incidental captures of protected species have been recorded for New Zealand fur seals and cetaceans. Trawls on or near the seabed interact with benthic habitats.

- **JMA 7**

Stock Status	
Year of Most Recent Assessment	2020
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\% B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised catch per unit effort (CPUE) indices of all three JMA species combined (i.e., JMD, JMM, and JMN) in JMA 7 from 1990-2019. Three series are presented: a bottom trawl (BT) series from 1990–2002 based on data held in the Electronic Data Warehouse (EDW); a midwater (MW) series from 2001–19 also based on EDW data; and a MW series from 2007–19 based on data held in the Centralised Observer Database *cod*). Points represent the median, and shaded region represents the 95% credible interval. The MW EDW series is scaled to have a geometric mean of 1, and the MW COD and BT EDW series are scaled to have the same geometric mean as the MW EDW series for the overlapping years. Data plotted as first year (i.e., 1990–91 plotted as 1990).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE for all 3 species combined has shown a long-term increase.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	CPUE analysis	
Assessment Dates	Latest assessment: 2020	Next assessment: 2022
Overall assessment quality rank	2 – Medium or mixed quality: combined index for 3 species	
Main data inputs (rank)	- combined CPUE - age frequency - length frequency	1 – High Quality 1 – High Quality 1 – High Quality

Data not used (rank)	- species split data	3 – Low Quality: representativeness of data are questionable
Changes to Model Structure and Assumptions	- Catch curve analysis replaced with CPUE analyses	
Major Sources of Uncertainty	- The catch split between the 3 species cannot be reliably estimated.	

Qualifying Comments
- Although abundance indices are available for the 3 species combined, it is not possible to undertake a full stock assessment with the current sources of data.

Fishery Interactions
JMA 7 catches are primarily taken by midwater trawl. A number of bycatch issues exist with blue mackerel, an important component of this fishery, and the non-availability of ACE for kingfish, blue mackerel, and snapper potentially influences targeting in some sub-areas. Incidental captures of protected species have been recorded for New Zealand fur seals and cetaceans. Trawls on or near the seabed interact with benthic habitats.

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