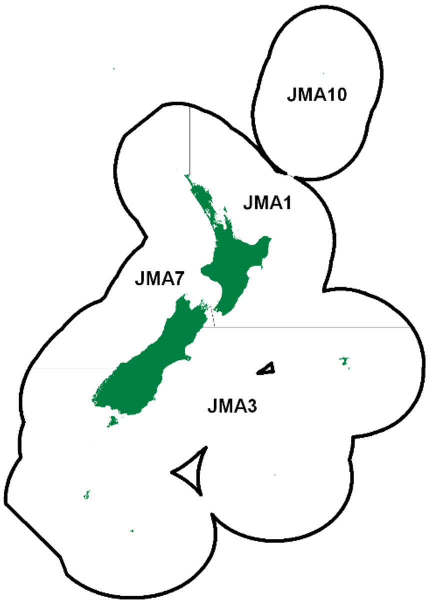
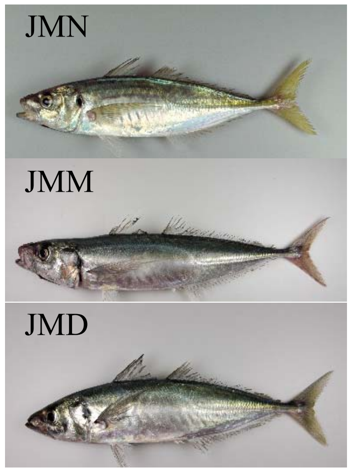
JACK MACKERELS (JMA)

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





1. FISHERY SUMMARY

The jack mackerel fisheries catch three species; two New Zealand 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. 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 the trawl fishery. 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, 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 Kaikoura Peninsula, which peaked at 4 400 t in 1992–93 and averaged more than 3 000 t between 1989–90 and 1993–94. Purse seine catches have shown a steady decline since, dropping from 1 000 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 8 000 t and 9 000 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 5 970 t and 2 700 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 8 780 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, while 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 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 includes both foreign and domestic landings.

Table 3: Reported landings (t) of jack mackerel by Fishstock from 1983–84 to 2016–17 and actual TACCs (t) for 1986–87 to 2016–17. QMS data from 1986–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

* 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 5 970 t (Table 3), with the maximum in 1986–87 only slightly above 4 000 t. Landings increased to 7 529 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 8 000 t set for that year. In 1994–95 reported landings (7 832 t) were half those of 1993–94. Landings from 1994–95 to 1997–98 were around 7 000 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 8 000–10 000 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. At 5553 t, the 2017-18 JMA1 landings were the lowest since 2006-07.

Estimates of the species composition of the JMA 1 purse seine catches are available from 1989–90 to 2017–18 (Figure 2). 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 2 000–5 000 t during the 1990s to an average of 8 150 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). *T. novaezelandiae* annual catches dominated the JMA 1 purse seine fishery from 2014–15 to 2016–17, ranging from 6488 t to 8 858 t, but dropped to 2 432 t and 52% of the catch in 2017-18. The 2017-18 catch of *T. declivis* increased to 2 156 t.

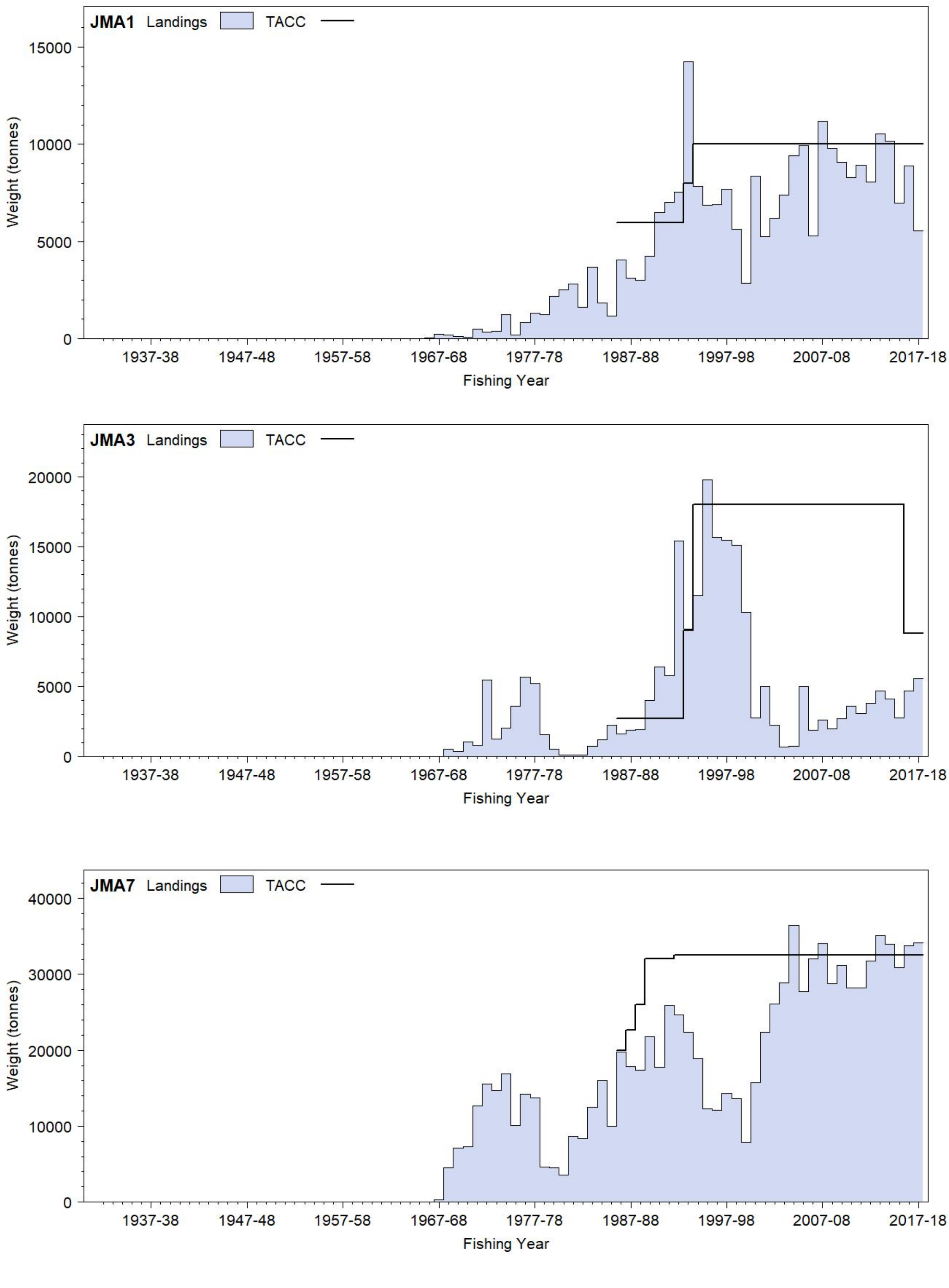


Figure 1: Reported commercial landings and TACC for the three main JMA stocks. From top: JMA 1 (Auckland East, Central East), JMA 3 (South East coast, South East Chatham Rise, Sub-Antarctic, Southland), and JMA 7 (Challenger, Central Egmont, Auckland West).

Total landings in JMA 3 over the period 1984–85 to 1988–89 were relatively constant, at a level below the quota of 2 700 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 5 000 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 2017–18 were 5 559 t.

Landings in JMA 7 represent the greatest proportion of total landings and are mainly taken by deepwater trawlers. Landings fluctuated between 17 403 t and 25 880 t from the mid-1980s through the mid-1990s. The marked decrease to 12 270 t in 1995–96 is attributed to changes in fishing strategies (mid-water trawling between 2 a.m. and 4 a.m. is banned under a code of practice to eliminate dolphin bycatch in JMA 7 that has been operational since 1995–96), the withdrawal of a major company from the fishery for much of the season, and difficulty marketing the relatively low valued *T. murphyi*. From 1995–96 to 1998–99, landings were in the range 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 3 971 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 1 500 t larger than the TACC. In 2008–09 catches decreased below the TACC by nearly 4 000 t but increased again in 2009–10 to 31 152 t, which is within 1 500 t of the quota. JMA 7 landings in 2017–18 were 34 190 t.

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 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 on-board 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 duration and consequently a concentration of fishing effort in the Bay of Plenty in close proximity to the processing facilities in Tauranga, where *T. novaezelandiae* dominate. Market requirements for fish size also affect the jack mackerel species targeted, and consequently the areas fished.

A number of bycatch issues exist in the JMA 7 fishery. A large bycatch fishery for blue mackerel operates for many months of the year and other bycatch species taken in this fishery include barracouta, gurnard, John Dory, kingfish, and snapper. Although non-availability of ACE is unlikely to be constraining in the first three of these additional species, the same is not true of kingfish, blue mackerel, and snapper. Fishing company spokespersons have stated that known hotspots of snapper are avoided.

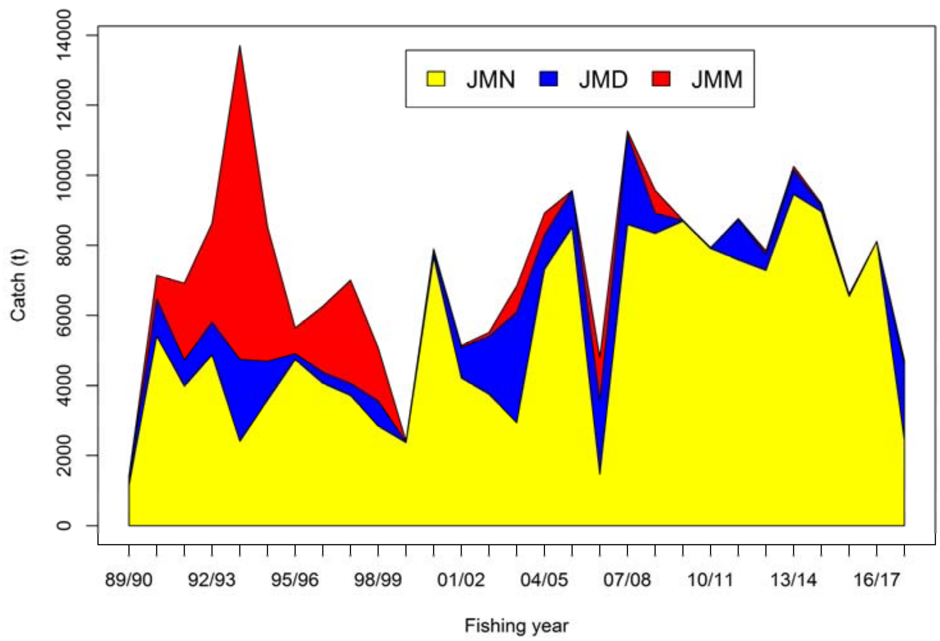


Figure 2: The time series of annual species catch estimates from the JMA 1 purse seine fishery (JMN, *T. novaezelandiae*; JMD, *T. declivis*; JMM, *T. murphyi*).

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 Langley & Middleton 2019).

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	10 260	0.07	0.01	0.92
2014–15	9 094	0.02	0.01	0.97
2015–16	6 555	0.01	0.00	0.99
2016–17	8 115	0.00	0.00	1.00
2017–18	4 710	0.46	0.03	0.52

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 non-fishers 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 Maori 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°C; it is uncommon south of latitude 42°S. *T. declivis* generally occurs in deeper (but less than 300 m) waters less than 16° C, north of latitude 45° S. *T. murphyi* occurs to depths of least 500 m and has a wide latitudinal range (0° S at the Galapagos Islands and coastal Ecuador, to south of 40° S off the Chilean coast).

T. murphyi was first described from New Zealand waters in 1987. Its presence was recorded off the south and east coasts of the South Island. It expanded onto 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 on 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, through to the New Zealand EEZ, and into waters off southeastern Australia.

All species can be caught by bottom trawl, mid-water trawl, or by purse seine 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 recent study showed that older size/age groups become increasingly dominant in catches as one moves westward from the South American coast, suggesting that an eastward migration of oceanic spawned larvae and juveniles occurs in the South Pacific.

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(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. While 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 in order provide adequate data for quantifying species composition and the relative abundance in JMA 1 and JMA 3.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the 2018 Fisheries Assessment Plenary based on reviews of similar chapters by the Aquatic Environment Working Group. This summary is for the jack mackerel fisheries, but a more detailed summary, issue-by-issue, is available in the Aquatic Environment & Biodiversity Annual Review 2017 (MPI 2017): https://www.mpi.govt.nz/dmsdocument/27471-aquatic-environment-and-biodiversity-annual-review-aebar-2017-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, about 10 000 t of jack mackerels from JMA 1 and 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 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 and 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% percentage frequency of occurrence in stomachs with food, 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)

Anderson et al. (2017) 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 2013–14. Jack mackerel species (*Trachurus* spp.) accounted for 75% of the total estimated catch from trawls targeting jack mackerels between 1 October 2002 and 30 September 2014. The remaining 25% comprised mostly other commercial species, including barracouta (*Thyrsites atun*, 13%), blue mackerel (*Scomber australasicus*, 3.4%), and frostfish (*Lepidopus caudatus*, 3.4%) (Table 7). Over 90% of reported catch was of QMS species, although altogether 320 taxa were identified by observers. Species with notable levels of discards included spiny dogfish (66%), porcupine fish (77%), thresher shark (99%), and sunfish (100%).

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.

Table 7: Bycatch and discards from all observer records for the target trawl fishery for jack mackerel from 1 October 2002 to 30 September 2014 for species or species groups with a total catch of 100 t or more, ordered by decreasing percentage of catch.

Species code	Common name	Scientific name	Estimated catch (t)	% of catch	% discarded
JMA	Jack mackerel	*Trachurus declivis, T. murphyi, T.*	88 169	44.03	0
JMD	Greenback jack	*Trachurus declivis*	41 105	20.53	0
BAR	Barracouta	*Thyrsites atun*	25 857	12.91	0
JMN	Yellowtail jack	*Trachurus novaezelandiae*	17 150	8.56	0
EMA	Blue mackerel	*Scomber australasicus*	6 879	3.44	0
FRO	Frostfish	*Lepidopus caudatus*	6 745	3.37	0
RBT	Redbait	*Emmelichthys nitidus*	4 917	2.46	1
JMM	Slender jack	*Trachurus murphyi*	4 061	2.03	0
RBM	Rays bream	*Brama brama*	612	0.31	0
SWA	Silver warehou	*Seriolella punctata*	568	0.28	0
STU	Slender tuna	*Allothunnus fallai*	535	0.27	7
SPD	Spiny dogfish	*Squalus acanthias*	499	0.25	66
SQU	Arrow squid	*Nototodarus sloanii & N. gouldi*	496	0.25	0
SNA	Snapper	*Pagrus auratus*	297	0.15	0
KIN	Kingfish	*Seriola lalandi*	273	0.14	31
SDO	Silver dory	*Cyttus novaezealandiae*	239	0.12	1
PIL	Pilchard	*Sardinops sagax*	228	0.11	0
WAR	Common warehou	*Seriolella brama*	225	0.11	0
JDO	John dory	*Zeus faber*	147	0.07	0
POP	Porcupine fish	*Allomycterus jaculiferus*	137	0.07	77

4.3 Incidental Capture of Protected Species (seabirds, mammals, 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 struck by a warp but not brought onboard the vessel (Middleton & Abraham, 2007).

4.3.1 Marine mammal interactions

Jack mackerel trawlers occasionally catch marine mammals, primarily common dolphin, long-finned pilot whale, and NZ fur seal (which were all classified as “Not Threatened” under the NZ Threat Classification System in 2013, Baker et al 2016).

Between 2002–03 and 2016–17, there were 197 observed captures of whales and dolphins in jack mackerel trawl fisheries. Observed captures were common dolphin (183), long-finned pilot whale (13), and dusky dolphin (1). In the 2015–16 and 2016–17 fishing years there were 2 and 0 observed captures of common dolphins in jack mackerel trawl fisheries, respectively (Table 8). Estimated captures for 2002–03 to 2014–15 are shown in Table 8. Common dolphins were observed captured off the Taranaki coast or off the west coast of the North Island (Abraham et al 2016). Modifications to the captures estimation model are currently being evaluated via the Aquatic Environment Working Group, reflecting structural changes in fisheries operations in recent years; for this reason captures estimates are not currently available for the 2015–16 fishing year onwards. The fifteen year average of the rate of capture for common dolphins is 2.1 captures per 100 tows (range 0 to 11.2) in the jack mackerel fishery.

Table 8: Number of tows by fishing year and observed and model-estimated total common dolphin captures in jack mackerel trawl fisheries, 2002–03 to 2016–17. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Abraham et al (2016) and available via https://data.dragonfly.co.nz/psc. Estimates for 2002–03 to 2014–15 are based on data version 2018v1.

		Observed				Estimated	
	Tows	No.ob	%ob	Capture	Rate	Captures	95%c.i.
2002–03	3 067	346	11.3	21	6.07	128	54-243
2003–04	2 383	152	6.4	17	11.18	105	46-196
2004–05	2 510	558	22.2	21	3.76	82	43-135
2005–06	2 808	709	25.2	2	0.28	10	2-29
2006–07	2 711	802	29.6	11	1.37	50	20-94
2007–08	2 653	818	30.8	20	2.44	41	23-68
2008–09	2 169	813	37.5	11	1.35	26	13-49
2009–10	2 406	786	32.7	4	0.51	23	6-55
2010–11	1 881	593	31.5	7	1.18	63	24-120
2011–12	2 031	1 549	76.3	5	0.32	7	5-14
2012–13	2 215	1 941	87.6	15	0.77	16	15-20
2013–14	2 453	2 193	89.4	28	1.28	30	28-36
2014–15	1 752	1 515	86.5	19	1.25	21	19-28
2015–16	1 544	1 382	89.5	2	0.14		
2016–17	1 405	1 022	72.7	0	0.00		

4.3.2 Seabird interactions

Annual observed seabird capture rates ranged from 0 to 1.4 per 100 tows in jack mackerel fisheries between 2002–03 and 2016–17 (Abraham & Thompson 2009, Abraham et al 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). In the 2015–16 fishing year there were 6 observed captures of birds in the jack mackerel trawl fishery, and 4 in the 2016–17 fishing year, at a rate of 0.4 birds per 100 observed tows. Total estimated seabird captures in the jack mackerel trawl fishery varied from 7 to 26 between 2002–03 and 2015–16 (Table 9).

Table 9: Number of tows by fishing year and observed seabird captures in jack mackerel trawl fisheries, 2002–03 to 2016–17. 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 in Abraham et al (2016) and Abraham & Richard (2017, 2018) and are available via https://data.dragonfly.co.nz/psc. Estimates for 2002–03 to 2016–17 are based on data version 2018v1.

	Fishing effort			Observed captures		Estimated captures	
	Tows	No. Obs	% obs	Captures	Rate	Mean	95% c.i.
2002–03	3 067	346	11.3	4	1.16	22	10-40
2003–04	2 383	152	6.4	0	0.00	7	1-17
2004–05	2 510	558	22.2	8	1.43	16	10-27
2005–06	2 808	709	25.2	0	0.00	17	6-38
2006–07	2 711	802	29.6	1	0.12	8	2-18
2007–08	2 653	818	30.8	1	0.12	9	3-19
2008–09	2 169	813	37.5	6	0.74	14	7-25
2009–10	2 406	786	32.7	9	1.15	17	10-28
2010–11	1 881	593	31.5	7	1.18	14	8-27
2011–12	2 031	1 549	76.3	5	0.32	9	5-15
2012–13	2 215	1 941	87.6	24	1.24	26	25-29
2013–14	2 453	2 193	89.4	6	0.27	7	6-12
2014–15	1 752	1 515	86.5	11	0.73	14	12-21
2015–16	1 544	1 382	89.5	6	0.43	7	6-12
2016–17	1 405	1 022	72.7	4	0.39	6	4-12

Observed seabird captures since 2002–03 have been mostly prions, shearwaters, and petrels (65 of the 95 observed seabird captures), with 25 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 10: Number of observed seabird captures in jack mackerel trawl fisheries, 2002–03 to 2016–17, by species and area. The risk category 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). It is not an estimate of the risk posed by fishing for jack mackerel. Data based on version 2017v1.

Species	Risk Category	Taranaki	West Coast North Island	Chatham Rise	Stewart Snares Shelf	East Coast South Island	West Coast South Island	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	High	3	0	0	9	4	0	16
Total albatrosses	-	3	0	1	12	9	0	25
Westland petrel	High	0	0	0	0	0	1	1
White-chinned petrel	Negligible	0	0	0	25	5	0	30
Sooty shearwater	Negligible	1	0	0	6	2	0	9
Common diving petrel	Negligible	0	0	0	1	0	1	2
White-faced storm petrels	Negligible	0	3	0	0	0	0	3
Australasian gannet	Negligible	1	0	0	0	0	0	1
Fairy prion	Negligible	5	0	0	2	1	0	8
Cape petrels	-	1	0	0	0	0	1	2
Fulmar prion	-	9	0	0	0	0	0	9
Grey-backed storm petrel	-	0	0	1	0	0	0	1
Total other birds	-	16	3	1	34	8	3	65

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

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. 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

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).

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 and Tilney 2015, Black and Tilney 2017, and Baird and Wood 2018) and species in waters shallower than 250m (Baird et al 2015).

Target jack mackerel tows accounted for about 3.5% of all tows reported on TCEPR forms that fished on or close to the bottom between 1989–90 and 2004–05 (Baird et al 2011). These tows were located in Benthic-optimised Marine Environment Classification (BOMEC, Leathwick et al 2012) classes C, E (shelf), H (upper slope), and J (mid-slope) (Baird & Wood 2012), and 91% were in water shallower than 200 m (Baird et al 2011).

During 1989–90 to 2015–16, about 50 100 bottom-contacting jack mackerel trawls were reported on TCEPRs (Baird & Wood 2018); this represents about 1200–3300 tows in most years up to 2013–14 and about 850 tows each for 2014–15 and 2015–16. The total footprint generated from these tows was estimated at about 44 430 km². This footprint represented coverage of 1.1% of the seafloor of the combined EEZ and the Territorial Sea areas; 3.2% of the 'fishable area', that is, the seafloor area open to trawling, in depths of less than 1600 m. For the 2016–17 fishing year, 784 jack mackerel bottom-contacting tows had an estimated footprint of 3796 km² which represented coverage of 0.1% of the EEZ and Territorial Sea and 0.3% of the fishable area (Baird & Mules in prep.).

The overall trawl footprint for jack mackerel (1989–90 to 2015–16) covered 14% of the seafloor in < 200 m, 6% of 200–400 m seafloor, and <0.05% of the 400–1600 m seafloor (Baird & Wood 2018). In 2016–17, the jack mackerel footprint contacted 1%, 0.1%, and < 0.01% of those depth ranges, respectively (Baird & Mules in prep.). 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 2016–17 (4%), with the remainder of the footprint covering about 0.3% of the 61 000 km² of class E (Stewart-Snares shelf) and 138 550 km2 of class H (Chatham Rise) (Baird & Mules in prep.).

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 2017 Aquatic Environment and Biodiversity Annual Review (MPI 2017).

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 1990, 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 taken from the Bay of Plenty is 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 (MPI, 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 outer shelf North Island, 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 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/Golden Bays. *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 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 data from a new Bayesian analysis for splitting the recorded commercial catch into *T. declivis*, *T. novaezealandiae*, and *T. murphyi* components. This analysis 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 the assessments.

The assessment for *T. declivis* is described below, but the assessment for *T. novaezealandiae* is not included because of convergence problems with the assessment model which led to its rejection by the working group.

Otherwise, there are no new data that would alter the yield estimates given in the 1996 Plenary Report. Estimates of *MCY* for JMA 1 and JMA 3 have not changed since the 1993 Plenary Report. Other yield estimates have not changed since the 1991 Plenary Report. The yield estimates are based on biomass estimates from a stock reduction analysis and aerial sightings data.

5.1 *T. declivis* in Challenger, Central West and Auckland West (JMA 7)

Species Proportion Estimates

A Bayesian species proportions model was used to estimate the proportion of *T. declivis* in the reported (TCEPR) catch for the JMA 7 fishery from 1989–90 through to 2004–05. Six spatial-temporal strata were used in the model: three spatial strata in combination with two temporal strata. The three spatial strata consisted of three regions with differing patterns in the relative proportions of the three jack mackerel species. The two temporal strata are a summer fishery (October–March) and a winter fishery (April–September). In the model the species proportions are estimated for each year (1989–90 to 2004–05), and the six strata for that year.

CPUE

The Bayesian species proportions model was used to estimate the *T. declivis* catch for each TCEPR tow, and the derived catch-effort data used in a standardised CPUE analysis. Based on changes in jack mackerel fishery practice, and changes in vessel composition over time, the CPUE analysis was split into two time periods: an early period covering the years 1989–90 to 1995–96, and a late period covering 1996–97 to 2004–05 (Table 12).

Table 12: Standardised CPUE indices (relative year effects) with number of tows from 1989–90 to 2004–05.

	Year	CPUE index	CV	Number of tows
1989–90	1990	2.07	0.1	716
1990–91	1991	2.05	0.1	688
1991–92	1992	1.9	0.1	947
1992–93	1993	1.56	0.09	1 088
1993–94	1994	1.37	0.09	1 444
1994–95	1995	1.28	0.09	597
1995–96	1996	0.89	0.1	502
1996–97	1997	1.69	0.13	160
1997–98	1998	0.92	0.11	252
1998–99	1999	2.7	0.08	712
1999–00	2000	2.15	0.08	717
2000–01	2001	2.67	0.07	1 240
2001–02	2002	2.85	0.07	1 760
2002–03	2003	2.38	0.06	2 272
2003–04	2004	2.59	0.07	2 055
2004–05	2005	3.23	0.07	2 002

Catch History

Catch records for jack mackerel extend back to 1946, although landings are small until the mid-1960s. The Bayesian model annual species proportions were used to estimate the *T. declivis* landings from 1991–92 to 2004–05, while previous species proportions were used to estimate landings for the earlier years (Table 13). 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, and 2004–05.

Table 13: Catch history (t) for T. declivis in the JMA 7 fishery. The year denotes the calendar year at the end of the fishing year.

Year	Estimated catch	Year	Estimated catch	Year	Estimated catch
1946	3	1967	3 326	1988	10 340
1947	1	1968	3 326	1989	10 963
1948	2	1969	3 326	1990	6 315
1949	8	1970	2 787	1991	6 759
1950	0	1971	4 634	1992	12 422
1951	0	1972	6 405	1993	7 925
1952	3	1973	5 284	1994	10 741
1953	4	1974	6 423	1995	6 809
1954	0	1975	4 591	1996	5 276
1955	5	1976	5 518	1997	4 702
1956	1	1977	6 151	1998	5 002
1957	3	1978	2 197	1999	10 045
1958	4	1979	2 524	2000	4 339
1959	0	1980	1 522	2001	6 595
1960	2	1981	3 547	2002	13 403
1961	2	1982	3 372	2003	12 781
1962	2	1983	5 540	2004	16 752
1963	5	1984	6 980	2005	17 154
1964	4	1985	8 967	2006	–
1965	3	1986	6 801	2007	–
1966	23	1987	11 493	2008	–

Model Structure

In 2007, the observational data were incorporated into an age-based Bayesian stock assessment to estimate stock size. The stock was considered to reside in a single area, with no partition by sex or maturity. In the model age groups were 1–25 years, with a plus group of 25+. The model covered the period 1965–2005 (estimated catch was insignificant before 1965).

There was a single time step in the model, in which the order of processes is ageing, recruitment, and mortality (natural and fishing). Recruitment numbers followed a Beverton-Holt relationship with steepness of 0.924 derived from a mean value over a number of species similar to jack mackerel. Maturation was not explicitly modeled; instead a maturity-at-age logistic ogive was used with an a_{50} of 3 and an a_{to95} of 9 years. Growth was assumed to follow a von Bertalanffy curve.

The model was fitted to: (a) an early CPUE series covering the years 1990 to 1996, (b) a late CPUE series covering the years 1997 through to 2005, (c) and a commercial proportions-at-age series for 1990, 1991, 1996, and 2005. A research trawl proportions-at-age for 1981 was not entered into the model, but the fit to it was evaluated outside the model assuming that the research trawl selectivity is the same as the commercial trawl selectivity. A double half normal curve was used to model the commercial trawl selectivity.

The relative influence of the different data series in the model was evaluated by dropping the early CPUE series, dropping the late CPUE series, and putting more weight on the proportions-at-age data by increasing their effective sample size.

Results

For the base model in this preliminary assessment it was estimated that current biomass is at 53% of virgin biomass (B_0). The biomass trajectory indicates a decline in biomass until the mid-1990s, followed by an increase in biomass until 2002, subsequently followed by a slight decline (Figure 3).

Dropping the early CPUE series put the estimate of current biomass at 76% B_0, in contrast dropping the late CPUE series put the current biomass at only 30% B_0. Doubling the effective sample sizes for all the proportions-at-age data put the estimate of current biomass at 66% B_0.

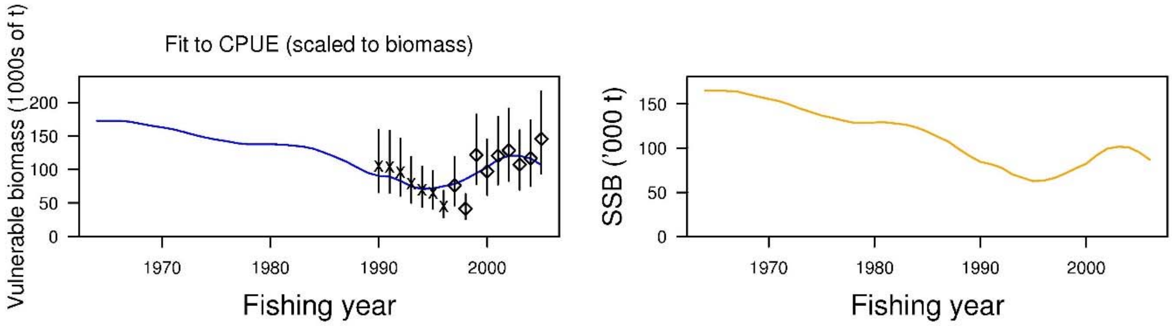


Figure 3: Biomass trajectories for the base case. The left-hand graph shows the fit of the CPUE indices to the vulnerable biomass; the right-hand graph shows the mature biomass trajectory. The year denotes the calendar year at the end of the fishing year.

5.2 Estimates of fishery parameters and abundance

Estimates of fishery parameters are given in Table 14.

Table 14: Estimates of fishery parameters.

Parameter	Fishstock	Estimate	Species	Source
$F_{0.1}$	JMA 7	0.23	*T. declivis*	Horn (1991a)
		0.33	*T. novaezelandiae*	Horn (1991a)

5.3 Biomass estimates

Biomass estimates are discussed in the section on estimation of *MCY*. Estimates of current biomass are not available.

5.4 Yield estimates and projections

The 2007 assessment for *T. declivis* did not include yield estimates so there is no information to update the historical estimates described below.

(i) Challenger, Central (West) and part of Auckland (West) (FMAs 7, 8, and part of 9)

MCY was estimated in the early 1990s for the two endemic jack mackerel species separately using the equation *MCY* = 2/3 *MSY* (Method 3). The deterministic *MSY* values (8.8% and 14.7% of B_0 for *T. declivis* and *T. novaezelandiae* respectively) were calculated using a yield per recruit analysis and a Beverton and Holt stock-recruitment relationship with an assumed steepness of 0.95. B_0 was estimated using a backward projection of a stock reduction analysis that produced biomass trajectories over the period 1970–90.

For *Trachurus declivis*, B_0 = 200 000 t,

$$\begin{aligned} MCY &= 2/3 \times (0.088 * 200\,000 \text{ t}) \\ &= 11\,800 \text{ t} \end{aligned}$$

For *Trachurus novaezelandiae*, B_0 = 100 000 t,

$$\begin{aligned} MCY &= 2/3 \times (0.147 * 100\,000 \text{ t}) \\ &= 9\,800 \text{ t} \end{aligned}$$

Because these yield estimates are based on an assumed stock-recruitment relationship, they are highly uncertain.

(ii) Northland, Bay of Plenty, east coast North Island (FMAs 1 and 2)

Annual landings before 1990–91 ranged from 1 173 t to less than 5 000 t. Landings subsequently increased markedly as a result of the increased availability of *T. murphyi* to a maximum in excess of 14 000 t in 1993–94. Concerns about the assumptions used to produce the original yield estimate and the production of time series abundance indices from aerial sightings data resulted in a revised yield estimate in the mid 1990s. The aerial sightings indices showed little change in jack mackerel abundance estimates in JMA 1 between 1976 and 1990.

MCY was estimated in 1993 using the equation $MCY = cY_{AV}$ (method 4) incorporating the mean of removals from 1983–84 to 1989–90, before the *T. murphyi* invasion influenced total catches. It is assumed that this represents a period when fishing effort was relatively stable, thus satisfying the criterion for the use of method 4. The calculated *MCY* applies only to *T. declivis* and *T. novaezelandiae*.

Using M = 0.18 and therefore c = 0.8,

$$\begin{aligned} MCY &= 0.8 \times 3\,013 \text{ t} \\ &= 2\,410 \text{ t (rounded to 2400 t)} \end{aligned}$$

(iii) Rest of the EEZ (QMAs 3–6)

Trawl surveys in QMAs 3–6 are not considered to be a suitable means to estimate biomass of jack mackerels, due primarily to the slow towing speed. Landings from JMA 3 have fluctuated widely since 1983–84, and were relatively high in the 1990s due probably to an increased abundance of *T. murphyi*.

For JMA 3 there are no available estimates of biomass and no series of catch data from a period of relatively constant fishing mortality. Therefore, it is not possible to estimate *MCY* for this Fishstock.

The level of risk to the stock by harvesting the population at the estimated *MCY* value cannot be determined.

Estimates of current biomass are not available for any jack mackerel stock, so *CAY* cannot be estimated. Yield estimates for *T. declivis* and *T. novaezelandiae* are shown in Table 15.

Table 15: Yield estimates for *T. declivis* and *T. novaezelandiae* (t).

Parameter	Fishstock	Estimate
MCY	JMA 1	2 400
	JMA 3	Cannot be determined
	JMA 7	21 600
CAY	All	Cannot be determined

5.5 Other yield estimates and stock assessment results

For *T. declivis* and *T. novaezelandiae* catch-at-age proportions are available for the years 2006–07 through 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 three and six 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 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*.

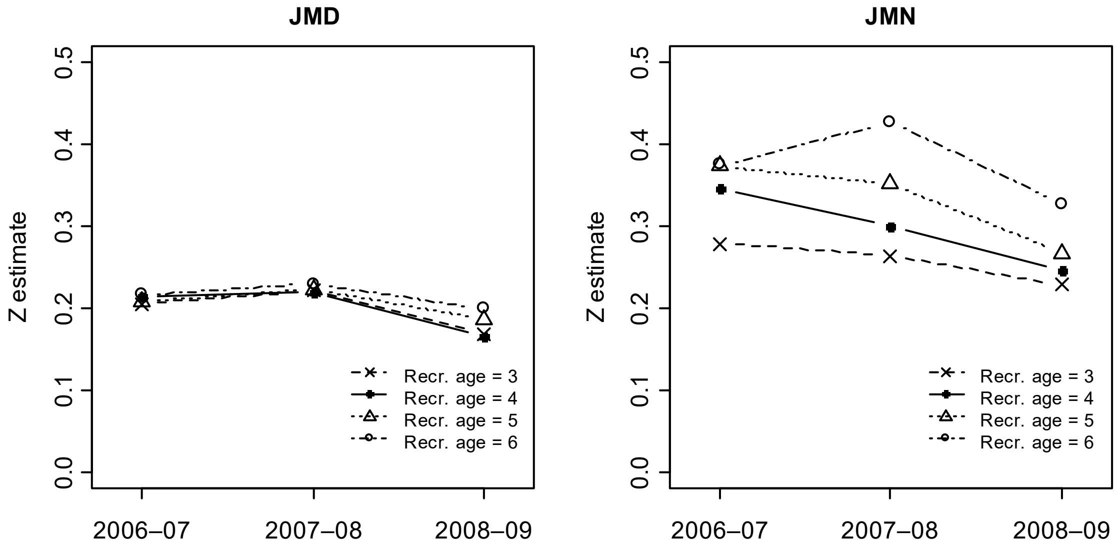


Figure 4: Estimates of instantaneous total mortality (*Z*) by year for *T. declivis* and *T. novaezelandiae* in JMA 7.

5.6 Other factors

The estimates of *MCY* given above are likely to be conservative as they do not take into account the presence of the third species, *T. murphyi*, which 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 on 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 have been the focus of considerable effort in recent years and the Northern Inshore Working Group had 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 2006/07–2008/09, 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 2006/07–2008/09, 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.

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	1993: $MCY = cY_{AV}$
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: 1993	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)	Species proportions estimates	
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 and have comprised a high percentage of *T. murphyi* in some years. Interactions with other species are currently being characterised.

- **JMA 7**

Stock Status	
Year of Most Recent Assessment	2011
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	Estimates of total mortality for *T. declivis* (JMD) and *T. novaezelandiae* (JMN) from catch curve analyses in 2011 suggest that fishing mortality was well below *M* for JMD and about equal to *M* for JMN; i.e. it is Unlikely (< 40%) that overfishing is occurring.
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	-	
Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Catch curve analysis	
Assessment Dates	Latest assessment: 2011	Next assessment: 2018
Overall assessment quality rank	-	
Main data inputs (rank)	-	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	No abundance indices are available. The analyses (catch curves) may not provide accurate values of average fishing mortality.	

Qualifying Comments
-

Fishery Interactions
JMA 7 catches are primarily taken by targeted 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. Interactions with other species are currently being characterised.

Yield estimates, TACCs and reported landings for the 2017–18 fishing year are summarised in Table 16.

Table 16: Summary of TACCs (t) and reported landings (t) for all three species in the most recent fishing year.

Fishstock		FMAs	2017–18 Actual TAC	2017–18 Reported landings
JMA 1	Auckland (East)/ Central (East)	1, 2	10 000	5 553
JMA 3	South-East/Southland/Sub-Antarctic	3, 4, 5, 6	8 780	5 559
JMA 7	Challenger/Central (West)/Auckland (West)	7, 8, 9	32 537	34 190
JMA 10	Kermadec	10	10	0
Total			51 327	45 302

7. FOR FURTHER INFORMATION

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