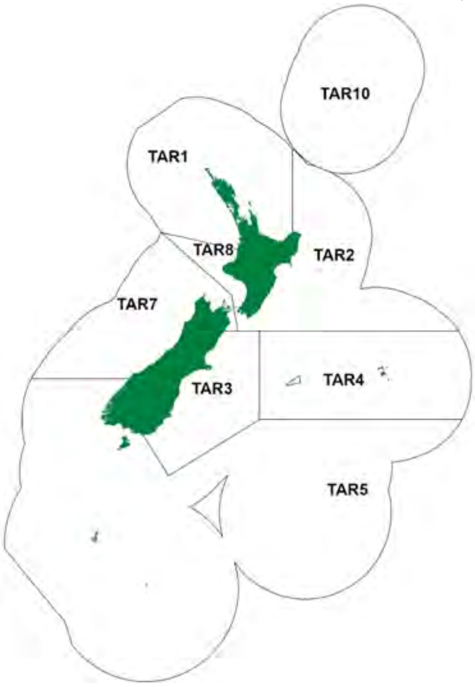
TARAKIHI (TAR)

(*Nemadactylus macropterus, Nemadactylus* sp.)
Tarakihi, King tarakihi



1. FISHERY SUMMARY

1.1 Commercial fisheries

Tarakihi are caught in the coastal waters of the North and South Islands, Stewart Island and the Chatham Islands, down to depths of about 250 m. The fishery for tarakihi developed with the introduction of steam trawlers in the 1890s, and by the mid-1930s annual catches had increased to reach about 2000 t. Annual catches increased substantially from the mid-1940s, until stabilising at about 5000–6000 t per annum during 1950–1981 (Table 1).

Figure 1 shows the historical landings and TACC values for the main tarakihi stocks. Since the introduction of the QMS in 1986, total landings increased from 4446 t to 6119 t in 2001–02 and remained at around 5000–6000 t until 2018–19, declining to around 4400 t in 2019–20 (Table 3).

Table 1: Reported total landings (t) of tarakihi from 1968 to 1982–83.

Year	Landings	Year	Landings	Year	Landings
1968	5 683	1974	5 294	1980–81*	4 990
1969	4 082	1975	4 941	1981–82*	5 193
1970	5 649	1976	4 689	1982–83*	4 666
1971	5 702	1977	6 444		
1972	5 430	1978–79*	4 427		
1973	4 439	1979–80*	4 344		

Source - MAF data.
* Sums of domestic catch for calendar years 1978 to 1982, and foreign and chartered vessel catch for fishing year April 1 to March 31.

In October 2001, the TAR 7 TACC was increased slightly to 1088 t although no allocations were made for recreational, customary, or other sources of fishing mortality. In October 2004, the TACCs for TAR 2 and TAR 3 were increased to 1796 t and 1403 t respectively. From 1 October 2007, the TAC for TAR 1 was increased to 2029 t and the TACC was increased from 1399 to 1447 t. For the fishing year 2018–19, TAR 1, 2, 3 and 7 TACCs were lowered to 1097 t, 1500 t, 1040 t and 1042 t respectively. The TACCS were further reduced in 2019–20 to 1045 t, 1350 t, 936 t and 1024 t respectively.

TAR 4, 5, 8, and 10 have never been assessed and after some initial adjustments undertaken during the late 1980s their TACCs and TACs remained unchanged.

In most years, the annual catch from TAR 4 has been well below the level of the TACC.

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

Year	TAR 1	TAR 2	TAR 3	TAR 4	TAR 5	TAR 7	TAR 8
1931–32	1 146	123	0	0	0	4	2
1932–33	588	481	0	0	0	424	2
1933–34	534	415	152	0	0	215	1
1934–35	691	672	127	0	0	306	2
1935–36	854	969	284	0	0	475	2
1936–37	1 165	673	283	0	0	555	0
1937–38	1 130	758	208	0	0	480	0
1938–39	1 044	788	445	0	27	412	0
1939–40	990	780	239	0	0	480	0
1940–41	637	674	624	0	31	316	0
1941–42	611	779	594	0	26	220	0
1942–43	791	691	491	0	15	87	0
1943–44	573	477	391	0	17	24	0
1944	923	837	466	0	16	29	0
1945	1 189	1 340	269	0	1	432	0
1946	1 410	1 618	383	0	0	545	2
1947	1 162	1 831	970	0	51	643	2
1948	1 075	2 129	793	0	43	688	9
1949	1 575	2 157	973	0	49	873	13
1950	1 925	2 011	743	0	35	803	8
1951	1 948	2 097	772	0	42	747	7
1952	1 990	2 090	948	0	44	949	8
1953	2 066	2 045	809	0	30	896	20
1954	1 697	1 529	578	0	1	470	72
1955	2 124	2 039	599	0	0	833	84
1956	1 850	2 312	384	0	0	699	28
1957	1 423	2 200	1 150	0	12	735	18
1958	1 300	1 952	1 400	0	8	625	20
1959	1 697	2 464	1 315	0	7	666	17
1960	1 489	2 867	862	0	10	732	15
1961	1 456	2 864	1 002	0	15	573	23
1962	1 266	3 126	1 073	0	6	759	52
1963	1 417	2 632	968	0	8	630	43
1964	1 304	2 656	1 250	0	7	593	61
1965	1 324	3 027	1 122	0	11	470	58
1966	1 100	2 964	1 539	0	24	549	64
1967	1 066	2 548	657	0	2	1 981	73
1968	888	1 907	837	0	8	1 941	100
1969	863	1 727	720	0	8	592	173
1970	1 129	1 932	1 120	0	19	1 293	154
1971	1 125	2 006	1 153	0	25	1 192	202
1972	996	1 912	2 169	12	15	741	279
1973	804	1 568	1 455	0	27	747	190
1974	687	1 889	1 913	24	31	1 234	192
1975	584	1 743	1 106	10	482	887	237
1976	620	1 645	1 927	21	143	936	287
1977	849	1 994	1 648	835	53	1 337	465
1978	1 059	1 718	373	6	54	1 021	225
1979	1 236	1 375	717	362	89	1 125	109
1980	1 506	1 391	1 098	246	107	748	109
1981	1 213	1 339	1 242	137	137	1 174	167
1982	1 210	1 277	953	72	117	813	151

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. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Tarakihi are caught by commercial vessels in all areas of New Zealand from the Three Kings Islands in the north to Stewart Island in the south. The main fishing method is bottom trawling. The major fishing grounds are east and west Northland (FMAs 1 and 9), the western Bay of Plenty to Cape Turnagain (FMAs 1 and 2), Cook Strait to the Canterbury Bight (mainly QMA 3), and Jackson Head to Cape Foulwind (QMA 7). The depth distribution of the tarakihi catch tends to increase northwards; most of the catch from the Canterbury Bight is taken within 50–120 m compared to 130–220 m in the east Northland fishery.

During the early 1990s, annual catches of TAR 1 increased to about the level of the TACC and remained at that level during 1991–92 to 2005–06. Annual catches fluctuated over the subsequent years with lower catches in 2006–07 to 2007–08 and 2011–12 to 2012–13 and 2015–16, while annual catches approached the TACC level in 2008–09 to 2010–11 and 2013–14 to 2014–15 and 2016–17. The TACC for TAR 1 was reduced in 2018–19 and 2019–20 with the reductions applied to the eastern area of TAR 1. Annual catches from TAR 1 reduced accordingly and were below the TACC in both years.

The distribution of catch between the main areas of TAR 1 has been variable over the last decade. The annual catches from Bay of Plenty declined during 2010–11 to 2019–20 (35% of the TAR 1 catch in 2018–19 to 2019–20), while catches from east Northland increased in 2013–14 to 2017–18 and declined considerably in 2018–19 to 2019–20 (18% of the TAR 1 catch). In recent years, an increasing proportion of the TAR 1 catch has been taken from the west coast of the North Island (48% of the TAR 1 catch in 2018–19 to 2019–20).

The target trawl fishery accounts for about 60% of the annual catch from each of these three areas. Most of the remainder of the catch is taken as a bycatch from other inshore trawl fisheries.

During 2004–05 to 2017–18, annual catches from TAR 2 were at about the level of the TACC (1796 t). Annual catches declined considerably in 2018–19 and 2019–20 following the reductions in the TAR 2 TACC. Most of the catch from TAR 2 was taken by the target single bottom trawl fishery.

During 2004–05 to 2013–14, annual catches from TAR 3 were maintained at about 70% of the TACC (1403 t). Catches increased to approach the level of the TACC in 2015–16 to 2016–17 and subsequently declined following reductions in the TAR 3 TACC in 2018–19 and 2019–20. During 1989–90 to 2019–20, most of the catch was taken by the trawl method either targeting tarakihi (34% of total catch) or as a bycatch from the main inshore trawl fisheries, principally red cod (17%) and barracouta (11%). The tarakihi target set net fishery off Kaikoura accounted for 21% of the total TAR 3 catch.

Prior to 2010–11, the total catch from TAR 5 was well below the TACC of 150 t. The annual catches increased to about the level of the TACC in 2011–12 and remained at that level over the subsequent years. Tarakihi are predominantly caught by the inshore bottom trawl fisheries in TAR 5, principally as a bycatch of the stargazer trawl fishery and, more recently, from a target trawl fishery.

Catches from TAR 7 remained at about the level of the TACC of 1088 t during 2000–01 to 2017–18. Catches declined in 2018–19 and 2019–20 corresponding to relatively small reductions in the TAR 7 TACC. The TAR 7 fishstock encompasses the area off the west coast of the South Island and extends through Cook Strait. The eastern portion of TAR 7 is considered to be a component of the eastern stock of tarakihi. From 2007–08, the eastern portion of TAR 7 (017 and part of 018) accounted for about 30% of the annual TAR 7 catch. Catches from TAR 7 are dominated by the target bottom trawl fishery.

The total catch from TAR 8 increased during the 1990s and has remained at about the level of the TACC (225 t) from 1998–99. Since then, most (about 70%) of the annual TAR 8 catch has been taken by the target trawl fishery.

Table 3: Reported landings (t) of tarakihi by Fishstock from 1983–84 to present and TACCs (t) from 1986–87 to present. QMS data from 1986–present. [Continued on next page]

Fishstock		TAR 1		TAR 2		TAR 3		TAR 4		TAR 5
FMA (s)		1 & 9		2		3		4		5 & 6
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	1 326	-	1 118	-	902	-	287	-	115	-
1984–85*	1 022	-	1 129	-	1 283	-	132	-	100	-
1985–86*	1 038	-	1 318	-	1 147	-	173	-	48	-
1986–87	912	1 210	1 382	1 410	938	970	83	300	42	140
1987–88	1 093	1 286	1 386	1 568	1 024	1 036	227	314	88	142
1988–89	940	1 328	1 412	1 611	758	1 061	182	314	47	147
1989–90	973	1 387	1 374	1 627	1 007	1 107	190	315	60	150
1990–91	1 125	1 387	1 729	1 627	1 070	1 148	367	316	35	153
1991–92	1 415	1 387	1 700	1 627	1 132	1 148	213	316	55	153
1992–93	1 477	1 397	1 654	1 633	813	1 168	45	316	51	153
1993–94	1 431	1 397	1 594	1 633	735	1 169	82	316	65	153
1994–95	1 390	1 398	1 580	1 633	849	1 169	71	316	90	153
1995–96	1 422	1 398	1 551	1 633	1 125	1 169	209	316	73	153
1996–97	1 425	1 398	1 639	1 633	1 088	1 169	133	316	81	153
1997–98	1 509	1 398	1 678	1 633	1 026	1 169	202	316	21	153

Table 3 [Continued]

Fishstock	TAR 1		TAR 2		TAR 3		TAR 4		TAR 5	
FMA (s)	1 & 9		2		3		4		5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1998–99	1 436	1 398	1 594	1 633	1 097	1 169	104	316	51	153
1999–00	1 387	1 398	1 741	1 633	1 260	1 169	98	316	80	153
2000–01	1 403	1 398	1 658	1 633	1 218	1 169	242	316	58	153
2001–02	1 480	1 399	1 742	1 633	1 244	1 169	383	316	75	153
2002–03	1 517	1 399	1 745	1 633	1 156	1 169	218	316	92	153
2003–04	1 541	1 399	1 638	1 633	1 089	1 169	169	316	53	153
2004–05	1 527	1 399	1 692	1 796	905	1 403	262	316	57	153
2005–06	1 409	1 399	1 986	1 796	1 010	1 403	339	316	62	153
2006–07	1 193	1 399	1 729	1 796	1 080	1 403	263	316	94	153
2007–08	1 286	1 447	1 715	1 796	843	1 403	348	316	50	153
2008–09	1 398	1 447	1 901	1 796	1 017	1 403	77	316	45	153
2009–10	1 332	1 447	1 858	1 796	757	1 403	138	316	81	153
2010–11	1 349	1 447	1 660	1 796	1 207	1 403	180	316	135	153
2011–12	1 134	1 447	1 702	1 796	897	1 403	54	316	151	153
2012–13	1 184	1 447	1 900	1 796	1 026	1 403	31	316	144	153
2013–14	1 425	1 447	1 816	1 796	991	1 403	179	316	126	153
2014–15	1 463	1 447	1 947	1 796	1 112	1 403	154	316	136	153
2015–16	1 229	1 447	1 820	1 796	1 262	1 403	59	316	158	153
2016–17	1 390	1 447	1 967	1 796	1 287	1 403	193	316	151	153
2017–18	1 258	1 447	1 896	1 796	1 144	1 403	51	316	123	153
2018–19	950	1 097	1 563	1 500	1 025	1 040	198	316	122	153
2019–20	826	1 045	1 335	1 350	882	936	96	316	148	153

	TAR 7		TAR 8		TAR 10			
FMA (s)	7		8		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings§	TACC
1983–84*	896	-	109	-	0	-	5 430	-
1984–85*	609	-	102	-	0	-	4 816	-
1985–86*	519	-	122	-	0	-	5 051	-
1986–87	904	930	185	190	0	10	4 446	5 160
1987–88	840	1 046	197	196	0	10	4 855	5 598
1988–89	630	1 059	121	197	0	10	4 090	5 727
1989–90	793	1 069	114	208	0	10	4 473	5 873
1991–92	710	1 087	190	225	2	10	5 417	5 953
1992–93	929	1 087	189	225	0	10	5 158	5 989
1990–91	629	1 087	131	225	< 1	10	5 086	5 953
1993–94	780	1 087	191	225	0	10	4 878	5 990
1994–95	978	1 087	171	225	0	10	5 129	5 991
1995–96	890	1 087	105	225	0	10	5 375	5 991
1996–97	1 013	1 087	133	225	0	10	5 512	5 991
1997–98	685	1 087	153	225	0	10	5 287	5 991
1998–99	1 041	1 087	175	225	0	10	5 501	5 991
1999–00	964	1 087	189	225	0	10	5 719	5 991
2000–01	1 178	1 087	178	225	0	10	5 935	5 991
2001–02	1 000	1 088	223	225	0	10	6 119	5 993
2002–03	1 069	1 088	211	225	0	10	6 008	5 993
2003–04	1 116	1 088	197	225	0	10	5 723	5 993
2004–05	1 056	1 088	184	225	0	10	5 683	6 390
2005–06	1 114	1 088	285	225	0	10	6 205	6 390
2006–07	1 116	1 088	254	225	0	10	5 729	6 390
2007–08	990	1 088	196	225	0	10	5 428	6 438
2008–09	977	1 088	169	225	0	10	5 584	6 438
2009–10	1 162	1 088	226	225	0	10	5 553	6 438
2010–11	983	1 088	194	225	0	10	5 708	6 439
2011–12	1 173	1 088	235	225	0	10	5 346	6 439
2012–13	1 058	1 088	209	225	0	10	5 552	6 439
2013–14	1 073	1 088	248	225	0	10	5 857	6 439
2014–15	1 002	1 088	224	225	0	10	6 038	6 439
2015–16	1 105	1 088	238	225	0	10	5 870	6 439
2016–17	1 139	1 088	210	225	0	10	6 337	6 439
2017–18	1 054	1 088	215	225	0	10	5 742	6 439
2018–19	1 049	1 042	243	225	0	10	5 150	5 383
2019–20	899	1 024	207	225	0	10	4 392	5 059

* FSU data. § Includes landings from unknown areas before 1986–87.

Table 4: Total allowable catches (TAC, t) allowance for customary non-commercial fishing, recreational fishing, and other sources of mortality (t), as well as the total allowable commercial catch (TACC, t) for tarakihi.

Fishstock	TAC	TACC	Customary non-commercial	Recreational	Other Mortality
TAR 1 (FMA 1 & 9)	1 390	1 097	73	110	110
TAR 2	1 823	1 500	100	73	150
TAR 3	1 174	1 040	15	15	104
TAR 4	316	316	0	0	0
TAR 5 (FMA 5 & 6)	153	153	0	0	0
TAR 7	1 174	1 042	5	23	104
TAR 8	225	225	0	0	0
TAR 10	10	10	0	0	0

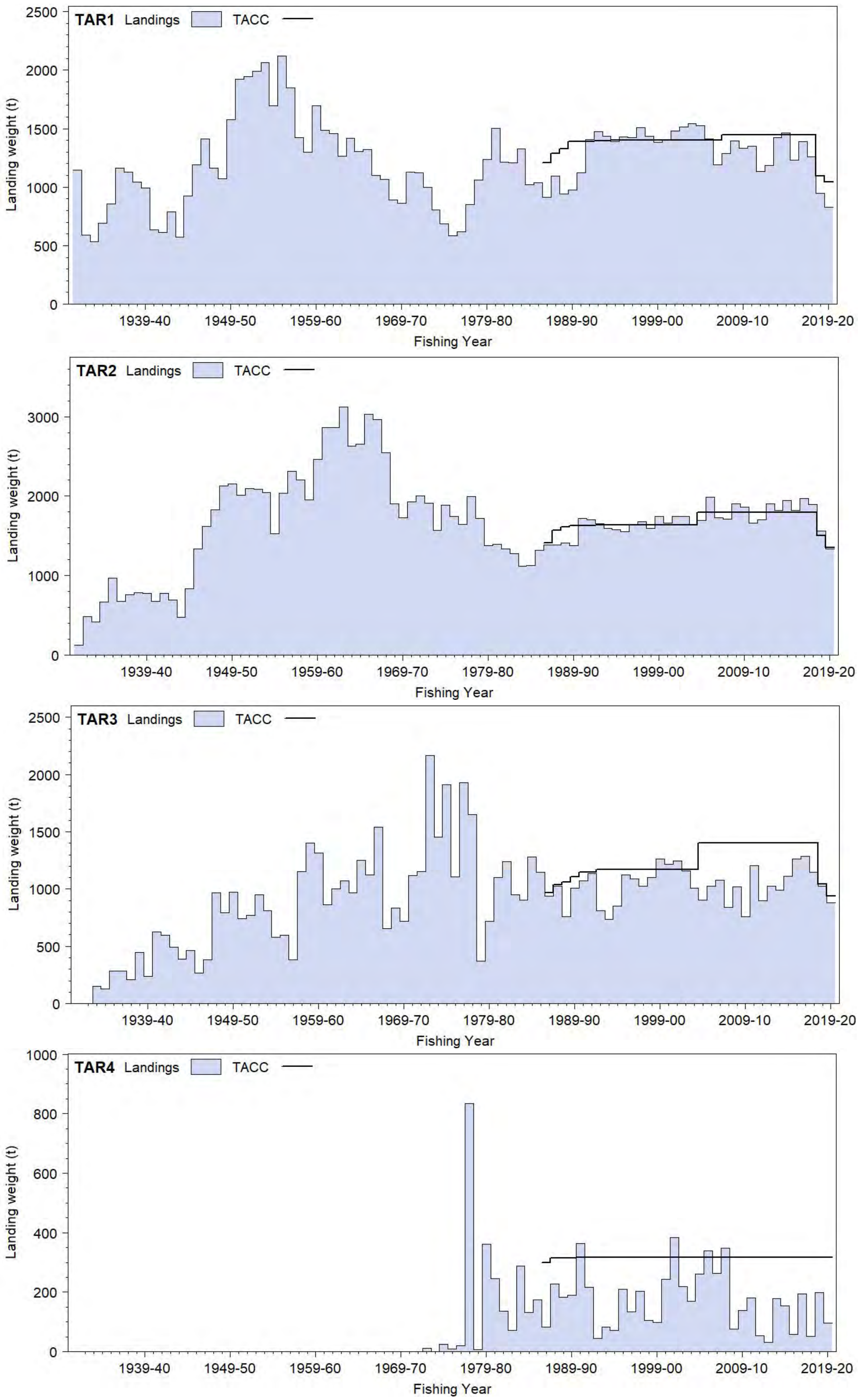


Figure 1: Historical landings and TACCs for the seven main TAR stocks. From top to bottom: TAR 1 (Auckland), TAR 2 (Central East), TAR 3 (South-East Coast) and TAR 4 (Chatham). [Continued on next page].

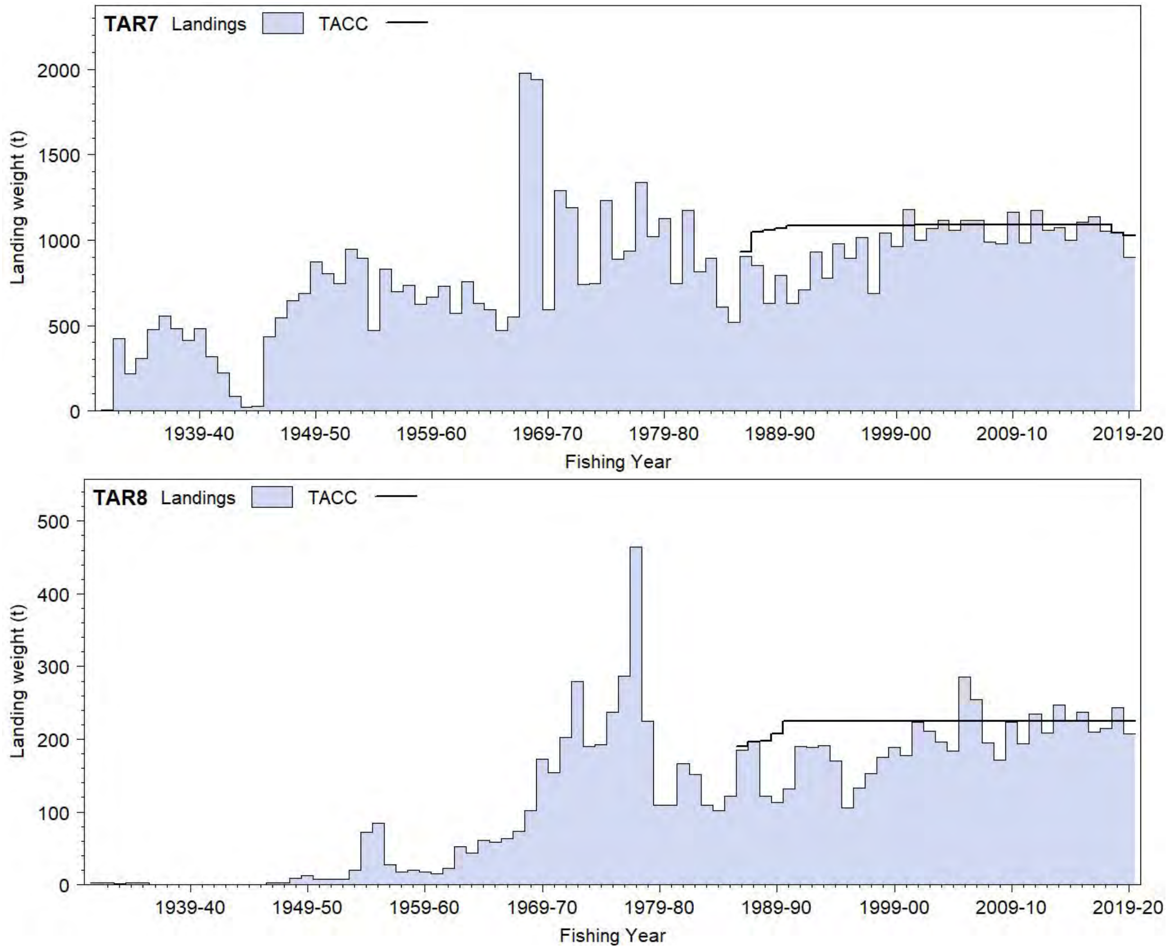


Figure 1 [continued]: Historical landings and TACCs for the seven main TAR stocks. From top to bottom: TAR 7 (Southland Sub-Antarctic) and TAR 8 (Central West).

1.2 Recreational fisheries

Tarakihi are taken by recreational fishers using lines and setnets. They are often taken by fishers targeting snapper and blue cod, particularly around the North Island. The allowances within the TAC for each Fishstock are shown in Table 4.

1.2.1 Management controls

The main methods used to manage recreational harvests of tarakihi are minimum legal size limits (MLS), method restrictions and daily bag limits. Fishers can take up to 20 tarakihi as part of their combined daily bag limit (except in the South-East and Southland fisheries management areas including the Fiordland Marine Area where the limit is 15 within a combined daily bag limit of 30 finfish) and the MLS is 25 cm in all areas.

1.2.2 Estimates of recreational harvest

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for tarakihi were calculated using offsite regional or national telephone-diary surveys (Table 5, Bradford 1998, Boyd & Reilly 2002, Boyd et al 2004). The early telephone-diary method was prone to “soft refusal” bias during recruitment and overstated catches during reporting (Wright et al 2004). Estimates of harvest from the later telephone-diary surveys were found to be implausibly high for many species. None of the harvest estimates from these telephone-diary surveys are now thought reliable.

Onsite surveys provide a more direct means of estimating recreational harvest, but are expensive and suited to relatively few fisheries. Hartill et al (2007a) developed a maximum count aerial-access method to combine data from concurrent creel surveys of recreational fishers returning to key ramps and aerial counts of vessels observed to be fishing. The ratio of the aerial count in a particular area to the number of interviewed parties who claimed to have fished in that area at the time of the overflight is used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. This approach was first used to estimate snapper harvest in the Hauraki Gulf in 2003–04. It was then extended to cover the whole of FMA 1 in 2004–05 and to provide estimates for other species, including tarakihi (FMA 1 only) (Hartill et al 2007b). This survey was repeated in 2011–12 (Hartill et al 2013) and 2017–18 (Hartill et al 2019).

Table 5: Recreational harvest estimates (including catch on amateur charter vessels but excluding catch under customary permits and s111 approvals) for tarakihi stocks (Bradford 1998, Boyd & Reilly 2002, Boyd et al 2004, Hartill et al 2007b, Hartill et al 2013, 2019, Wynne-Jones et al 2014, 2019). The telephone/diary surveys and earlier aerial-access survey ran from December to November but are denoted by the January calendar year. Surveys since 2010 have run through the October to September fishing year but are denoted by the January calendar year. Mean fish weights for offsite surveys were obtained from boat ramp surveys (e.g., Hartill & Davey 2015).

Stock	Year	Method	Number of fish	Total weight (t)	CV
TAR 1	1996	Telephone/diary	498 000	305	0.08
	2000	Telephone/diary	1 035 000	636	0.19
	2001	Telephone/diary	679 000	417	0.16
	2012	Panel survey	166 540	117	0.22
FMA 1 only	2005	Aerial-access*	-	90	0.18
FMA 1 only	2012	Aerial-access*	-	67	0.15
FMA 1 only	2012	Panel survey	160 414	113	0.22
	2012	Panel survey	166 449	117	0.22
FMA 1 only	2018	Aerial-access*	-	46	0.13
FMA 1 only	2018	Panel survey	59 000	50	0.16
	2018	Panel survey	73 289	62	0.14
TAR 2	1996	Telephone/diary	114 000	65	0.14
	2000	Telephone/diary	310 000	191	0.27
	2001	Telephone/diary	484 000	298	0.18
	2012	Panel survey	110 920	72	0.22
	2018	Panel survey	148 159	110	0.22
TAR 3	1996	Telephone/diary	3 000	-	-
	2000	Telephone/diary	25 000	15	0.51
	2001	Telephone/diary	7 000	4	0.37
	2012	Panel survey	4 208	3	0.42
	2018	Panel survey	6 622	5	0.32
TAR 5	1996	Telephone/diary	3 000	-	-
	2000	Telephone/diary	10 000	6	0.57
	2001	Telephone/diary	13 000	7	0.37
	2012	Panel survey	141	<1	0.73
	2018	Panel survey	5 545	4	0.35
TAR 7	1996	Telephone/diary	69 000	24	0.13
	2000	Telephone/diary	87 000	33	0.18
	2001	Telephone/diary	9 000	3	0.15
	2012	Panel survey	48 107	23	0.38
	2018	Panel survey	31 668	21	0.18
TAR 8	1996	Telephone/diary	46 000	28	0.17
	2000	Telephone/diary	66 000	30	0.38
	2001	Telephone/diary	78 000	36	0.28
	2012	Panel survey	31 340	23	0.30
	2018	Panel survey	37 706	22	0.29

* Aerial-access surveys did not include catches from charter vessels whereas these are included in the panel survey estimates. The estimates for FMA 1 in this table are not, therefore, directly comparable. See Edwards & Hartill 2015 for details.

Problems with the earlier offsite telephone-diary surveys led to the development of a rigorously-designed National Panel Survey (NPS) which was first used for the 2011–12 fishing year (Heinemann et al 2015). The 2011–12 NPS used face-to-face interviews of a random sample of 30 390 households to recruit a panel of 7013 fishers and a further sample of 3000 putative non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised computer assisted telephone interviews (CATI). Harvest estimates from the NPS

(Wynne-Jones et al 2014) and the 2011–12 aerial-access survey (Hartill et al 2013) are similar for the FMA 1 portion of TAR 1 (and other key recreational fisheries in FMA 1) and are, therefore, considered to be reasonably accurate and fit for management purposes (Edwards & Hartill 2015). The NPS and a parallel FMA 1 aerial-access survey were repeated for the 2017–18 fishing year and harvest estimates are included in Table 5.

1.3 Customary non-commercial fisheries
No quantitative information on the level of customary non-commercial fishing is available.

1.4 Illegal catch
No quantitative information on the level of illegal tarakihi catch is available.

1.5 Other sources of mortality
No information is available.

2. BIOLOGY

Juvenile tarakihi grow relatively fast, reaching 25 cm fork length (FL) at 4 years of age. Sexual maturity was initially estimated at 25–35 cm FL, and an age of 4–6 years (Annala 1987), but more recent studies indicate 50% maturity is attained at about 33 cm FL and an age of 6 years (Parker & Fu 2011). Growth rates attenuate from an age of 5–6 years (Annala et al 1990).

Growth rates are generally similar for the main tarakihi fishstocks, although recent studies have indicated that the growth rates of tarakihi older than 6 years of age are lower in the Bay of Plenty and east Northland compared to other fishery areas. Tarakihi reach a maximum age of 40+ years (Annala et al 1990).

Tarakihi spawn in summer and autumn. Three main spawning grounds have been identified: Cape Runaway to East Cape, Cape Campbell to Pegasus Bay, and the west coast of the South Island near Jackson Bay. Spawning fish have also been sampled from the Bay of Plenty and east Northland and limited spawning probably occurs throughout the distributional range of tarakihi around New Zealand.

Few larval and post-larval tarakihi have been caught and identified. The post-larvae appear to be pelagic, occur in offshore waters, and are found in surface waters at night. Post-larval metamorphosis to the juvenile stage occurs in spring or early summer when the fish are 7–9 cm FL and 7–12 months old.

Several juvenile nursery areas have been identified in shallower, inshore waters, including the southwest coast of the North Island, Tasman Bay, near Kaikoura, northern Pegasus Bay, Canterbury Bight, Otago and the Chatham Islands. Juveniles move out to deeper water at a length of about 25 cm FL at an age of 3–4 years. Recent sampling of the TAR 3 trawl catch revealed that a high proportion of the landed catch is comprised of immature fish. Conversely, TAR 3 set net and TAR 2 trawl landed catches were comprised mainly of mature fish.

The results of tagging experiments carried out near Kaikoura during 1986 and 1987 indicate that some tarakihi are capable of moving long distances. Fish have been recaptured from as far away as the Kaipara Harbour on the west coast of the North Island, south of Whangarei on the east coast of the North Island, and Timaru on the east coast of the South Island. Age composition of commercial bottom trawl and survey catches along the east coast of New Zealand suggest that juvenile tarakihi move progressively northward from the Canterbury Bight to East Northland as they grow older (McKenzie et al 2017).

An estimate of natural mortality for tarakihi was derived from the age structures of lightly exploited populations sampled from the west coast of the South Island in 1971 and 1972. A catch curve analysis yielded total mortality estimates of 0.13 from both samples (Vooren 1973). Estimates of Z for the area near Kaikoura made during 1987 ranged from 0.12–0.16 for fish between 8 and 20 years old (Annala et al. 1990). An approximation of M was derived from the oldest age observed in the Kaikoura sample

(42 years), yielding an estimate of $M = 0.11$. It was concluded that M was no greater than 0.10 and that this value was also the best available estimate of M.

Biological parameters relevant to the stock assessment are shown in Table 6.

Table 6: Estimates of biological parameters of tarakihi.

Fishstock			Estimate				Source
1. Natural mortality (*M*)							
			0.10 considered best estimate for all areas for both sexes				Annala et al (1989, 1990)
2. Weight = a (length)^b (Weight in g, length in cm fork length)							
	Females			Males			
	a		b	a		b	
TAR 3	0.04		2.79	0.0433		2.77	Annala et al (1990)
TAR 4	0.023		2.94	0.017		3.02	Annala et al (1989)
TAR 7	0.015		3.058	0.0141		3.07	Manning et al (2008)
3. von Bertalanffy growth parameters							
	Females			Males			
	K	t_0	L_∞	K	t_0	L_∞	
TAR 3	0.2009	- 1.103	44.6	0.2085	- 1.397	42.1	Annala et al (1990)
TAR 4	0.2205	- 1.026	44.6	0.1666	- 2.479	44.7	Annala et al (1989)
TAR 7	0.234	- 0.57	45.6	0.252	- 0.41	42.7	Manning (2008)

3. STOCKS AND AREAS

The results of tagging experiments have shown that tarakihi are capable of moving large distances around the coasts of the main islands of New Zealand. The long pelagic larval phase of 7–12 months indicates that larvae will also be widely dispersed. Previously these two factors, in addition to the lack of any evidence of genetic isolation, had been used to suggest that tarakihi around the main islands of New Zealand consist of one continuous stock. Further, because of the large distance between the mainland and the Chatham Islands, and the separation of these two areas by water deeper than that which is usually inhabited by adult tarakihi, the tarakihi around the Chatham Islands were considered to be a separate stock.

Trends in CPUE indices and age compositions from the TAR 1, 2 and 3 fisheries were examined to investigate the stock structure of tarakihi along the east coasts of mainland New Zealand. The fisheries in Canterbury Bight/Pegasus Bay are dominated by younger fish and there is a progressive increase in the proportion of older fish in the catches from TAR 2, Bay of Plenty and east Northland, while the relative strength of individual year classes is comparable amongst these areas. Trends in CPUE indices are also comparable among these fisheries, lagged by the relative age of recruitment to the respective fishery.

There are distinct spawning grounds in each of the two main islands (off East Cape in the northern area and off Cape Campbell in the south), while there is a preponderance of juvenile fish in Canterbury Bight/Pegasus Bay and low densities of juvenile tarakihi in East Northland, Bay of Plenty and TAR 2. The long pelagic phase of tarakihi may provide a mechanism for the transfer of larvae to the nursery grounds in Canterbury Bight/Pegasus Bay.

These observations indicate considerable connectivity of tarakihi along the east coast of the South and North Islands. The current stock hypothesis is that the Canterbury Bight/Pegasus Bay area represents the main nursery area for the eastern stock unit. At the onset of maturity, a proportion of the fish migrate northwards to recruit to the East Cape area and, subsequently, the Bay of Plenty and east Northland areas. This hypothesis is further supported by the northward movement of tagged fish from the Kaikoura coast to the Wairarapa, East Cape and Bay of Plenty areas.

The results from previous tagging studies also indicate some connectivity between Kaikoura and the west coast North Island. However, limited data are available from the west coast North Island to elucidate the degree of the linkage between these areas. Recent age composition data from the west coast North Island revealed similarities and differences in the relative strength of individual year classes compared to the east coast South and North Island fisheries. Further, growth rates of older fish (more than 6 yrs) sampled from the west coast North Island differed from east Northland, suggesting a lack of connectivity between the fisheries around the north of the North Island.

A more recent study (2018–19 and 2019–20) conducted age composition sampling of all the main tarakihi fisheries around mainland New Zealand. The study reaffirmed the similarity in the age structure of the tarakihi populations along the eastern coast of the North and South Islands. The study also found contrasting pattern in the age structure from the fisheries off the western coast of the North and South Islands (TAR 7 WCSI, TAR 8 and TAR 1W). The age structure of these fisheries was consistent with the relative strength of individual year classes of juvenile tarakihi sampled from Tasman Bay/Golden Bay. These results support the current stock hypothesis that eastern tarakihi represents a discrete stock unit, while providing strong evidence of a separate western tarakihi stock unit. Limited information is available to assertain the stock affinity of tarakihi from Southland (TAR 5), although this area supports a relatively small catch of tarakihi.

A recent study of population genetic structure of tarakihi (*N. macropterus*) from samples collected around New Zealand and the Chatham Islands (Papa et a. 2020). No clear genetic structure was detected for the overall New Zealand area indicating a panmictic genetic structure. However, the study detected weak genetic breaks between the west and east coasts of South Island and between Hawke’s Bay and East Northland. The latter observation is consistent with an earlier study that detected two successive genetic breaks between East Cape and East Northland (Gauldie & Johnston 1980). These observations may indicate a more complex population structure of tarakihi around northern North Island than currently assumed from the age composition data (and other fisheries data).

Smith et al (1996) used two genetic techniques to determine that king tarakihi from northern New Zealand is a separate species from tarakihi (*N. macropterus*). King tarakihi are caught at the northern extent of the range of tarakihi (North Cape and Three Kings Islands). Due to concerns that some tarakihi catches were being misreported, as from December 2010, king tarakihi was included within the species definition of the tarakihi QMS fishstocks (under Fisheries (Commercial Fishing) Regulations 2001). All subsequent catches of king tarakihi should have be included within the TAR 1 TACC. However, modest commercial catches (20–30 t per annum) of king tarakihi (KTA) were reported from FMA 1 in the 2002–03 to 2004–05 fishing years. No additional annual catches of king tarakihi have been reported separately since then.

The magnitude of king tarakihi catches reported within TAR 1 is considered to be small due to the distribution of the main fisheries relative to the known distribution of king tarakihi. Similarly, the magnitude of tarakihi catch misreported as king tarakihi is also considered to have been small.

4. STOCK ASSESSMENT

An integrated assessment for TAR 7 was conducted in 2008 with data that included the commercial catch, trawl survey biomass and proportions-at-age estimates, CPUE indices, and commercial catch proportions-at-age.

In 2017, a stock assessment was conducted for east coast tarakihi combining eastern TAR 1 (Bay of Plenty and East Northland), TAR 2 and TAR 3.

4.1 Trawl Surveys

4.1.1 Relative abundance

Indices of relative biomass are available from *Kaharoa* trawl surveys in TAR 2, TAR 3 and TAR 7 (Table 7, Figure 2, 3 and 3a). Note that these estimates were revised in 1996 as a result of new doorspread estimates becoming available from SCANMAR measurements. In TAR 2 and TAR 3 no trend is apparent in the biomass estimates. The TAR 2 survey was conducted for four consecutive years: 1993–1996 and then discontinued.

West Coast South Island Inshore Trawl Survey

For TAR 7, trawl survey biomass estimates for pre-recruit (less than 25 cm F.L.) and recruited (≥ 25 cm) tarakihi were derived for the west coast South Island and Tasman Bay/Golden Bay (TBGB) areas of the WCSI trawl survey. The TBGB area is considered to be a primary nursery ground for tarakihi in TAR 7. A substantial proportion of the TAR 7 commercial catch is taken from the west coast portion of the survey area. For comparability with the commercial CPUE indices it is appropriate to partition the trawl survey biomass indices by area and size category.

Biomass estimates for the west coast strata of the survey ground are relatively stable through the time series aside from higher than usual estimates in 2005 and 2017 (Figure 2). The most recent estimate from 2019 is more similar to the time series mean (MacGibbon 2019). Most of the survey biomass is recruited fish. In contrast, more of the survey biomass in TBGB is comprised of pre-recruited fish. Biomass estimates in TBGB fluctuate more than those for the west coast and the CVs for pre-recruited fish are often high. Throughout the time series, total biomass of the west coast has been substantially greater than for TBGB. Similar to the west coast, the 2019 estimates for TBGB are substantially lower than in 2017 and more in line with the time series mean. Most of the fish in TBGB are pre-recruited fish.

East coast South Island Trawl Survey

The ECSI winter surveys from 1991 to 1996 (depth range 30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range; but these were discontinued after the fifth in the annual time series, because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007, and this time included strata in the 10–30 m depth range, in order to monitor elephant fish and red gurnard which were officially included in the list of target species in 2012. Only the 2007, 2012, 2014, 2016 and 2018 surveys provide full coverage of the 10–30 m depth range.

Tarakihi biomass in the core strata peaked in 1993 due to a single large catch off Timaru resulting in a high CV of 55%. Overall, however, there is no trend in the core strata time series, although the 2018 biomass was the third lowest survey estimate, down slightly from the 2016 estimate (Table 7, Figure 3). Pre-recruit core strata biomass was a major but variable component of tarakihi total biomass estimates on all surveys, ranging from 18% to 60% of total biomass, and 29% in 2018. Similarly, juvenile core strata biomass (based on length-at-50% maturity) was also a large component of total biomass, but the proportion was relatively constant over the time series, 60–80%, and in 2018 it was 62% (Figure 4). There was virtually no tarakihi caught in the 10–30 m strata in any of the five surveys, and hence the shallow strata are of no value for monitoring tarakihi. The distribution of tarakihi hotspots varies, but overall this species is consistently well represented over the entire survey area, most commonly from 30 to about 150 m.

The size distributions of tarakihi in each of the twelve ECSI core strata winter trawl surveys were similar and were multi-modal, with smaller modes representing individual cohorts (Beentjes et al 2016). In 2012, 2016 and 2018, the 0+, 1+, 2+, and possibly 3+ cohorts were particularly evident, but were less defined in 2014. Tarakihi on the ECSI, overall, were generally smaller than those from the west coast South Island (Stevenson & MacGibbon 2018) and the east coast North Island (Parker & Fu 2011), suggesting that, like Tasman/Golden Bays, Pegasus Bay and the Canterbury Bight are important nursery grounds for juvenile tarakihi (Beentjes et al 2012, McKenzie et al 2017). The tarakihi sampled by the ECSI trawl surveys are dominated by 2–5 year old fish (MacGibbon et al 2019). There is considerable variation in the relative abundance of individual age classes amongst surveys, indicating high inter-annual variability in recruitment.

North Island Trawl Surveys

Summer surveys in the Bay of Plenty (from Mercury Islands to Cape Runaway) were carried out from 1983 to 1999. These surveys were extended to 250 m, in February 1996 (KAH9601) and 1999 (KAH9902), so that tarakihi depths would be covered. However, the estimates of biomass were low (35 t CV 46% in 1996 and 50 t CV 27% in 1999). Most of the catch in the 1999 survey was taken in depths of 150 to 200 m.

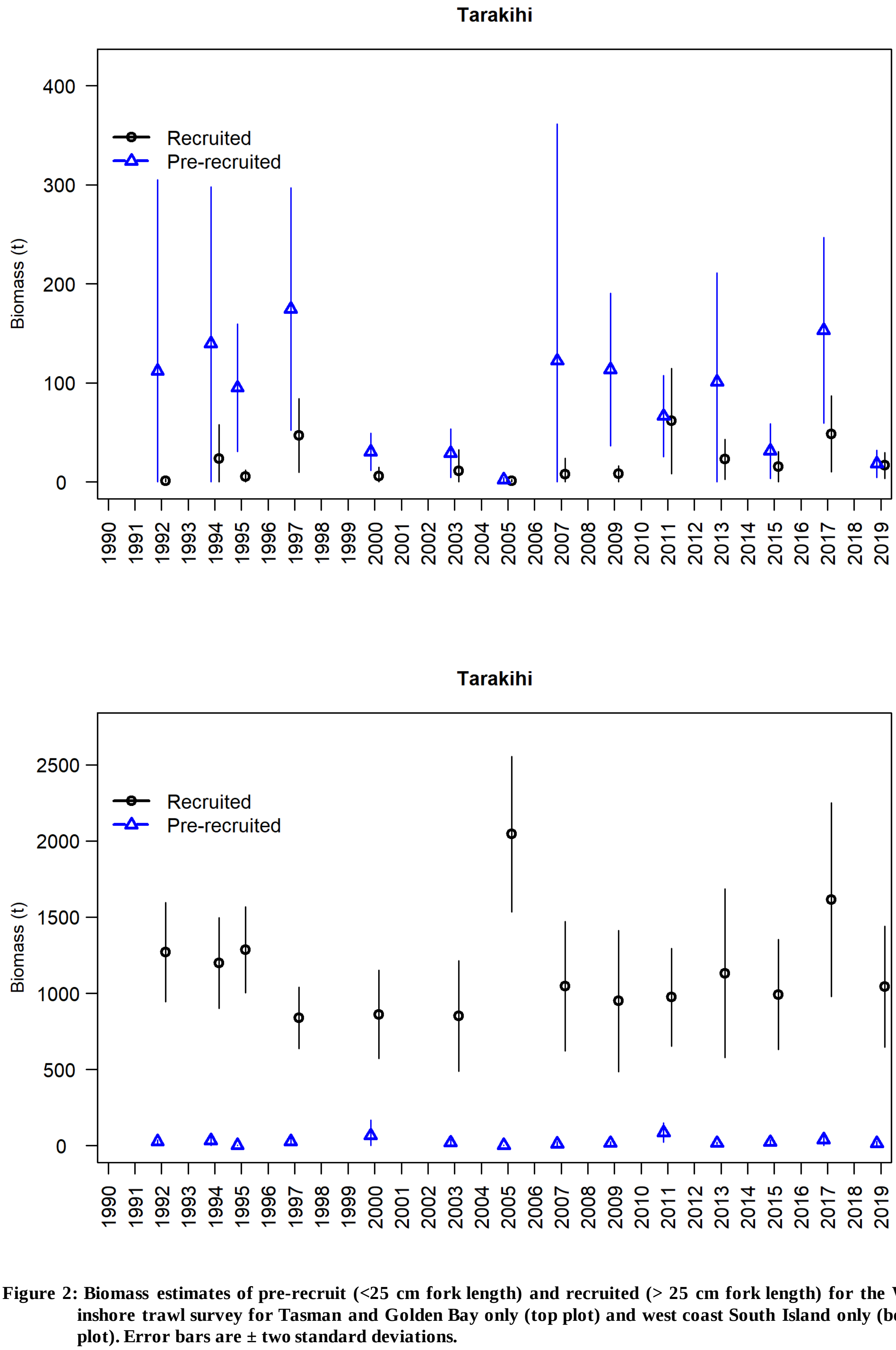


Figure 2: Biomass estimates of pre-recruit (<25 cm fork length) and recruited (> 25 cm fork length) for the WCSI inshore trawl survey for Tasman and Golden Bay only (top plot) and west coast South Island only (bottom plot). Error bars are ± two standard deviations.

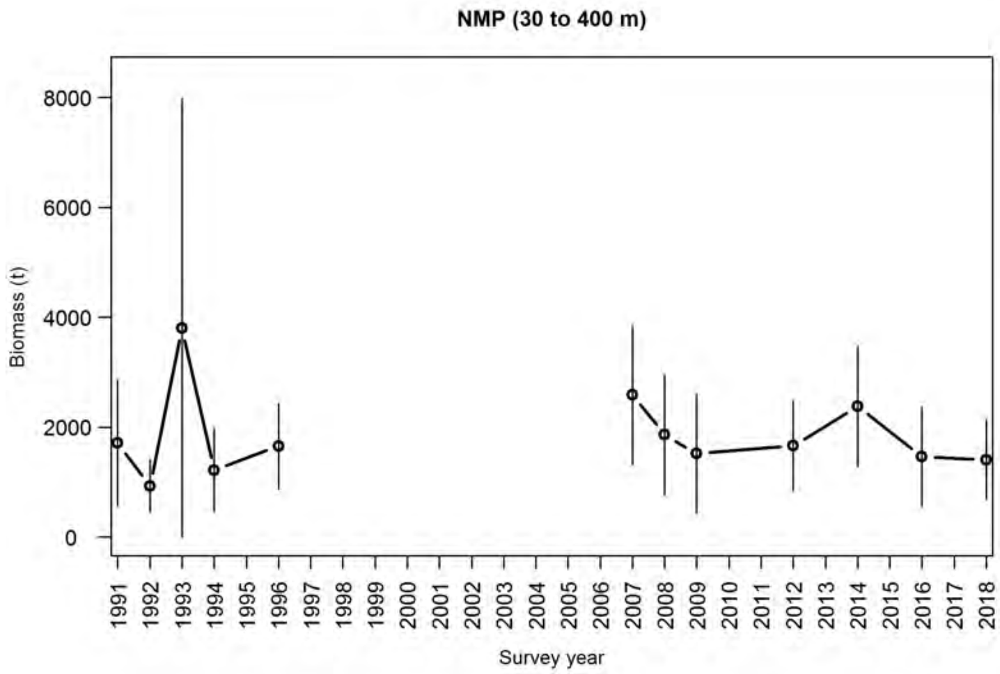


Figure 3: Tarakihi total biomass for the ECSI winter surveys in core strata (30–400 m). Error bars are ± two standard errors.

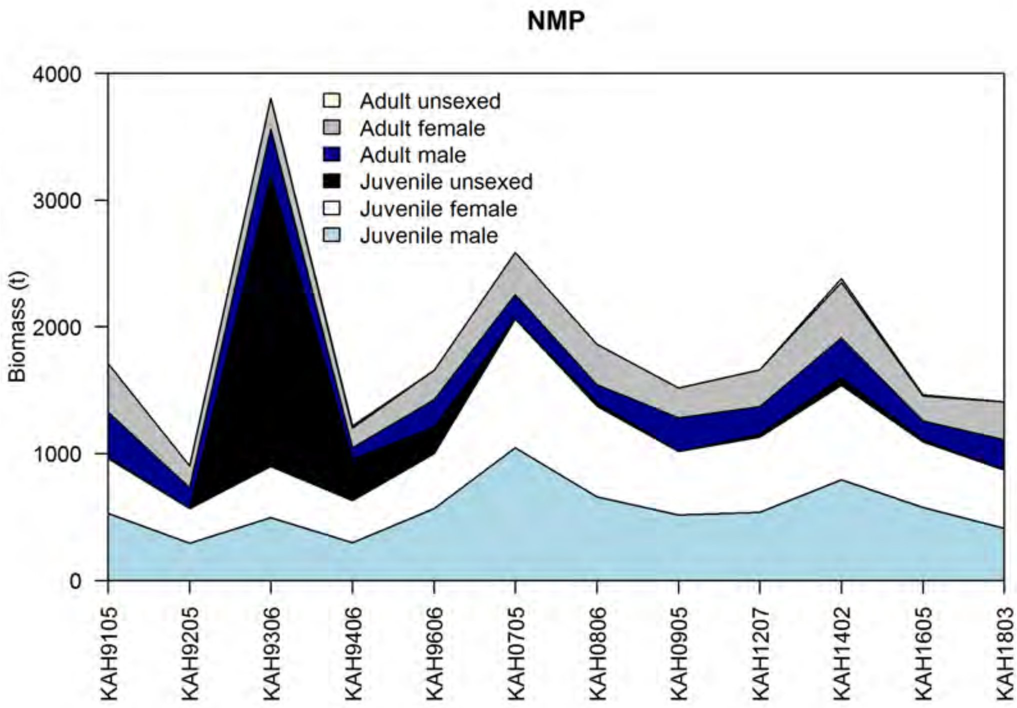


Figure 2a: Tarakihi juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below and adult is equal to or above the length at which 50% of fish are mature.

Table 7: Relative biomass indices (t) and coefficients of variation (CV) for tarakihi for Cape Runaway to Cook Strait, ECSI – summer and winter, and Tasman Bay to Haast survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 and 9 equivalent to current strata 13, 16 and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (25 cm).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
Cape Runaway to Cook Strait	TAR 2	1991	KAH9304	885	27	-	-	-	-	-	-	-	-	-	-
		1992	KAH9402	1 128	20	-	-	-	-	-	-	-	-	-	-
		1993	KAH9502	791	23	-	-	-	-	-	-	-	-	-	-
		1994	KAH9602	943	15	-	-	-	-	-	-	-	-	-	-
ECSI (winter)	TAR 3			30–400 m		10–400m		30–400m		10–400m		30–400m		10–400m	
		1991	KAH9105	1 712	33	-	-	305	38	-	-	1 414	33	-	-
		1992	KAH9205	932	26	-	-	288	26	-	-	614	28	-	-
		1993	KAH9306	3 805	55	-	-	2 282	62	-	-	1522	46	-	-
		1994	KAH9406	1 219	41	-	-	494	31	-	-	725	35	-	-
		1996	KAH9606	1 656	24	-	-	519	30	-	-	1137	27	-	-
		2007	KAH0705	2 589	24	-	-	822	30	-	-	1766	24	-	-
		2008	KAH0806	1 863	29	-	-	739	44	-	-	1123	25	-	-
		2009	KAH0905	1 519	36	-	-	525	42	-	-	994	42	-	-
		2012	KAH1207	1 661	25	-	-	584	34	-	-	1077	29	-	-
		2014	KAH1402	2 380	23	-	-	818	26	-	-	1562	26		
		2016	KAH1605	1 462	31			342	40			1 121	33		
		2018	KAH1803	1 409	26	-	-	409	28	-	-	1000	28	-	-
ECSI (summer)	TAR 3	1996	KAH9618	3 818	21	-	-	-	-	-	-	-	-	-	-
		1997	KAH9704	2 036	24										
		1998	KAH9809	4 277	24	-	-	-	-	-	-	-	-	-	-
		1999	KAH9917	2 606	15	-	-	-	-	-	-	-	-	-	-
		2000	KAH0014	1 510	13	-	-	-	-	-	-	-	-	-	-
Tasman Bay to Haast	TAR 7	1992	KAH9204	1 409	14	-	-	-	-	-	-	-	-	-	-
		1994	KAH9404	1 420	14	-	-	-	-	-	-	-	-	-	-
		1995	KAH9504	1 389	11	-	-	-	-	-	-	-	-	-	-
		1997	KAH9701	1 087	12	-	-	-	-	-	-	-	-	-	-
		2000	KAH0004	964	19	-	-	-	-	-	-	-	-	-	-
		2003	KAH0304	912	20										
		2005	KAH0503	2 050	12	-	-	-	-	-	-	-	-	-	-
		2007	KAH0704	1 089	21	-	-	-	-	-	-	-	-	-	-
		2009	KAH0904	1 088	22	-	-	-	-	-	-	-	-	-	-
		2011	KAH1104	1 188	15	-	-	-	-	-	-	-	-	-	-
		2013	KAH1305	1 272	22	-	-	-	-	-	-	-	-	-	-
		2015	KAH1503	1 058	17	-	-	-	-	-	-	-	-	-	-
		2017	KAH1703	1 857	18	-	-	-	-	-	-	-	-	-	-
		2019	KAH1902	1 094	19										

*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth except for COM9901 and CMP0001. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

4.2 CPUE analyses

4.2.1 East Coast (TAR 1E, TAR 2, TAR 3) and West Coast North Island (TAR 1W) CPUE

CPUE indices have routinely been derived for tarakihi from the main inshore fisheries in TAR 1, TAR 2 and TAR 3. The CPUE indices were updated in 2012 and the Working Group adopted the CPUE indices as the best available indicators of tarakihi abundance for each fishstock. In 2017, the CPUE indices were updated again, with some refinements (Langley 2017). In 2018, the CPUE indices for the TAR 1E, TAR 2, TAR 3 fisheries were updated for inclusion in an update of the eastern stock assessment. The TAR 1W CPUE indices were not updated at that time.

The six sets of CPUE series are defined in Table 8. The individual CPUE data sets either maintained the individual trawl event records or aggregated daily catch and effort data (approximating the CELR data format). Event based catch and effort data were available for the TAR 1 trawl fisheries from 1993–94. These event-based data were utilised for those fisheries where there had been appreciable changes in the spatial distribution of fishing effort which had influenced the catch rates of tarakihi. The daily aggregated catch and effort data were available from 1989–90 to 2016–17 for all fisheries.

For the trawl fisheries, CPUE was modelled as two components: 1) the magnitude of the positive tarakihi catch (assuming either a lognormal or Weibull error distribution) and 2) the presence/absence of tarakihi in the catch (binomial model). Combined annual CPUE indices were derived from the year effects determined from the two models. For the TAR 3 set net fishery, the CPUE indices were derived from the lognormal CPUE model of positive tarakihi catch.

The BPLE-BT, TAR2-BT, TAR3-BT and TAR3-SN CPUE indices derived in 2017 were very similar to the sets of CPUE indices from 2012. In 2017, there were changes in the definition of the CPUE data sets for the WCNI-BT and ENLD-BT fisheries which resulted in considerable differences in the CPUE indices compared to the 2012 analysis.

Table 8: Names and descriptions of the six tarakihi CPUE series accepted by the WG in 2017. Also shown is the error distribution that had the best fit to the distribution of standardised residuals for the positive catch component of the model.

Name	Code	QMA	Method	Statistical areas	Target species	Data format	Distribution
West coast North Island	WCNI-BT	TAR 1	BT	045, 046, 047	TAR, SNA, TRE	Event	Lognormal
East Northland	ENLD-BT	TAR 1	BT	002, 003	TAR	Event	Weibull
Bay of Plenty	BPLE-BT	TAR 1	BT	008, 009, 010	TAR, SNA, TRE, SKI, JDO, GUR	Daily	Weibull
East coast North Island	TAR2-BT	TAR 2	BT	011, 012, 013, 014, 015	TAR, SNA, BAR, SKI, WAR, GUR	Daily	Lognormal
East coast South Island	TAR3-BT	TAR 3	BT	017, 018, 020, 022, 024, 026	TAR, BAR, RCO, WAR, GUR	Daily	Lognormal
Area 18 target setnet	TAR3-SN	TAR 3	SN	018	TAR	Daily	Lognormal

Both the BPLE-BT and TAR2-BT CPUE indices reached a peak during 2000–01 to 2004–05 (Figure 5). There were corresponding peaks in the CPUE indices from the ENLD-BT and TAR3-SN fisheries at about the same time. The increase in the CPUE indices was preceded by a peak in the TAR3-BT CPUE indices during 1999–2000 to 2001–02. More recently, the CPUE indices from the TAR3-BT fishery increased during 2009–10 to 2016–17, while the TAR2-BT CPUE indices also increased during the last five years. This is contrasted by a sharp decline in the CPUE indices from BPLE-BT and ENLD-BT during 2009–10 to 2015–16. For 2016–17, the BPLE-BT increased, while the index from ENLD-BT continued the declining trend. The CPUE indices from the northern WCNI trawl fishery (WCNI-BT) generally declined between 1998–99 to 2003–04 and 2013–14 to 2015–16 (Figure 5).

The CPUE indices (with the exception of WCNI-BT) were used as inputs to the stock assessment of tarakihi off the east coast of the North and South Islands.

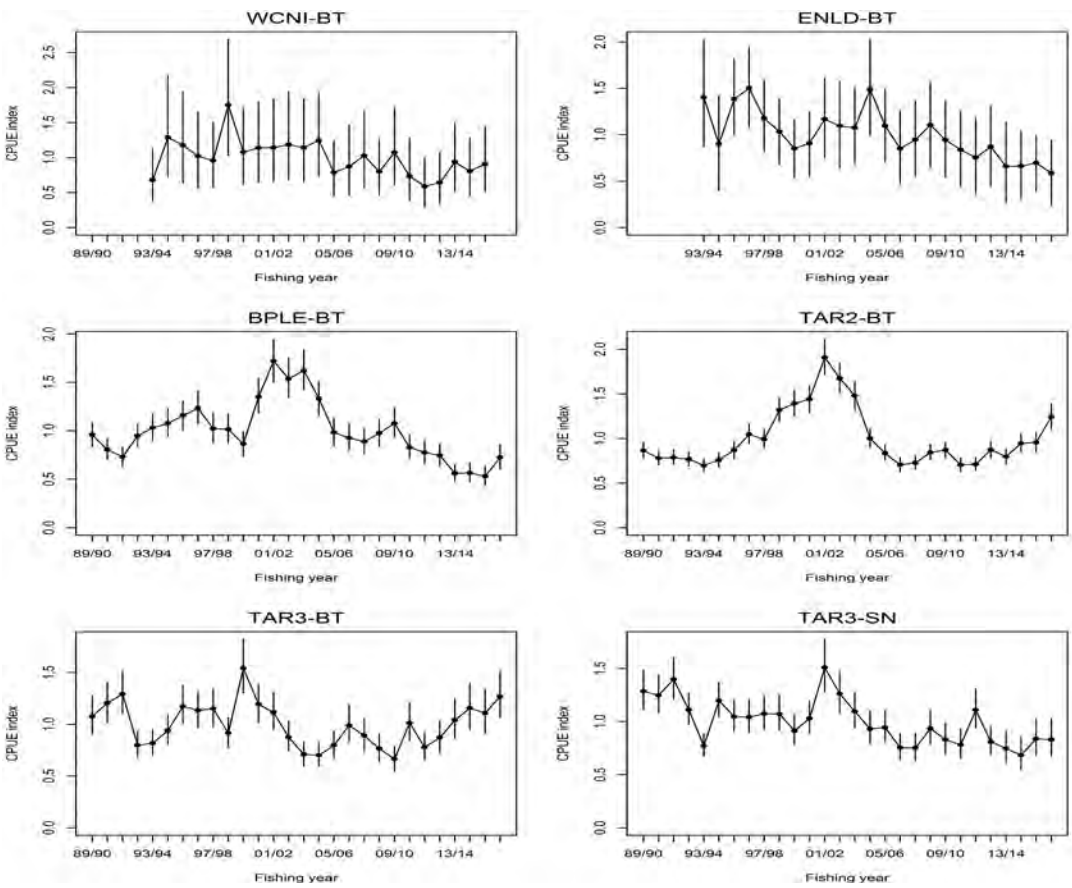


Figure 5. A comparison of the six sets of CPUE indices from TAR 1, TAR 2 and TAR 3 (combined indices, except for TAR3-SN). The error bars represent 95% confidence intervals.

4.2.2 Eastern Cook Strait (TAR 7)

CPUE indices of abundance were developed for the mixed trawl fishery targeting TAR, BAR, WAR, GSH, STA off the northeastern coast of the South Island (Statistical Areas 017, 018). A GLM approach was used to model the probability of catching tarakihi during a fishing day (binomial model) and the magnitude of the positive catch of tarakihi (lognormal model). The main explanatory variables included in both models were fishing year, target species, month, vessel and fishing duration. The annual coefficients from both models were combined to derive the CPUE indices (delta-lognormal indices).

The CPUE indices fluctuate over the time series with peaks in CPUE during 1993–94 to 1995–96 and 2000–01 to 2002–03. For the last decade, CPUE indices were relatively stable, at about the average for the series (Figure 6).

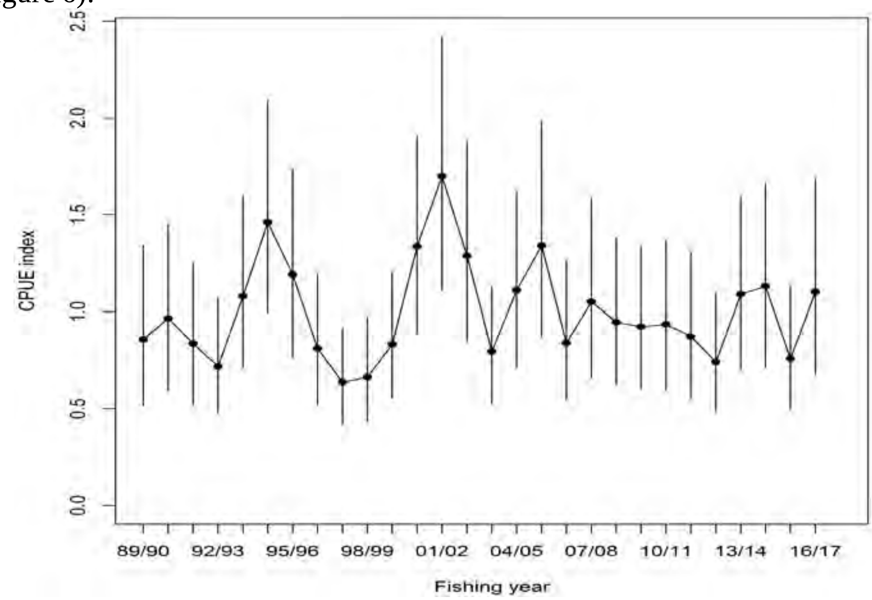


Figure 6: CPUE indices from the eastern Cook Strait mixed inshore trawl fishery.

4.2.3 West coast South Island (TAR 7)

Previously, CPUE indices were developed for the mixed trawl fishery targeting TAR, BAR, WAR, RCO, STA off the west coast of the South Island (Statistical Areas 033, 034, 035, 036). The CPUE indices were updated in 2018. The indices were evaluated by comparing them with the biomass estimates derived from the *Kaharoa* west coast South Island trawl survey for a comparable area and the length range of fish comparable to the commercial catch. The trends in the two sets of indices were comparable during 2006–07 to 2016–17; however, the indices deviated markedly during 1989–90 to 2003–04 and, on that basis, the entire time series of CPUE indices was rejected as an index of stock abundance.

4.2 Stock Assessment Models

East coast North and South Islands (TAR 1E, 2, 3 and eastern TAR 7)

In 2017, an assessment of the east coast mainland New Zealand tarakihi stock was conducted. The assessment was based on the hypothesis of a single east coast stock of tarakihi, as described in Section 3. The area included within the assessment encompasses the east coast of the South Island (TAR 3), eastern Cook Strait (including a portion of TAR 7), the central east coast of the North Island (TAR 2), Bay of Plenty (TAR 1) and east Northland (TAR 1).

The assessment was conducted using an integrated age structured population model implemented in Stock Synthesis. The assessment models incorporated the available catch, CPUE indices, trawl survey biomass estimates and age/length frequency distributions, and recent commercial age composition data.

The current stock hypothesis assumes a relatively complex spatial structure for the east coast tarakihi population: juvenile tarakihi reside predominately in the Canterbury Bight/Pegasus Bay area and, coinciding with the onset of sexual maturity, a proportion of the population migrates along the east coast, extending progressively northwards with increased age and terminating in the East Northland area. During the model development phase, a range of options were investigated to determine the appropriate degree of spatial stratification for the assessment model, given the spatial scale and information content of the various input data sets. The final model options structured the input data into three model regions: east coast South Island (including eastern Cook Strait), central east coast North Island and Bay of Plenty combined (BPLE-TAR2), and East Northland. The east coast South Island region included three commercial fisheries: the Canterbury Bight/Pegasus Bay trawl fishery (TAR3-BT), Kaikoura set net fishery (TAR3-SN) and the eastern Cook Strait trawl fishery (CS-BT). The other two regions each included a commercial trawl fishery and a relatively small non-commercial fishery.

The main input data sets included in the assessment model(s) are as follows:

- Fishery specific annual catches 1932–2016 (2016 = 2015–16 fishing year), including an allowance for unreported catch (an additional 20% of the reported catch prior to the introduction of the QMS in 1986 and an additional 10% of the unreported catch from 1986 onwards) (Figure 7).
- Recent CPUE indices: TAR3-BT, TAR3-SN, combined TAR2-BT and BPLE-BT, ENLD-BT.
- Historical CPUE indices: East Cape (BPLE-TAR2 region) 1961–1970, Canterbury Bight (ECSI region) 1963–1973 (only included in full catch history models).
- Kaharoa inshore ECSI trawl survey biomass estimates and age/length compositions (both winter (n=11) and summer (n=5) time-series).
- Kaharoa inshore ECNI trawl survey biomass estimates and length compositions (n = 3).
- Recent commercial age composition data: TAR3-BT (n=4), TAR3-SN (n=4), CS-BT (n=1), combined TAR2-BT and BPLE-BT combined (n=5), and ENLD-BT (n=2).
- Age composition derived from the James Cook trawl survey of Pegasus Bay-Cape Campbell in 1987.

In addition, a number of age compositions from early trawl surveys were considered in the model development phase. These data were uninformative and were excluded from the final model options.

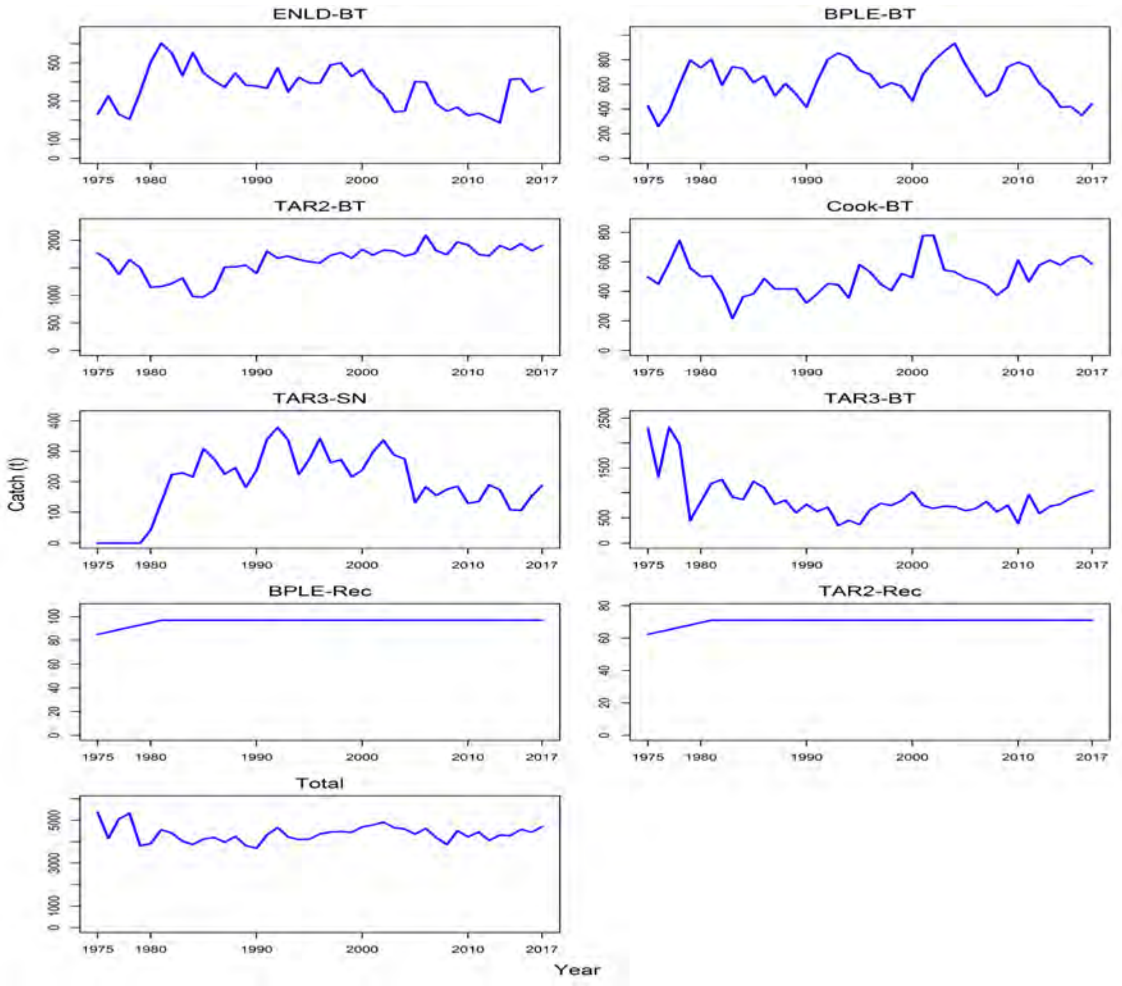


Figure 7: Annual catches of tarakihi by fishery and total included in the base eastern tarakihi stock assessment (1975–2016 and updated to include 2017). The specific commercial fisheries are: TAR3-BT (TAR 3), TAR3-SN (TAR 3), Cook-BT (includes catch from TAR 2 and eastern TAR7), TAR2-BT (TAR 2) and BPLE-BT (TAR 1), ENLD-BT (TAR 1).

The assessment models were structured to include 40 age classes combining both sexes. The key biological parameters are presented in Table 9.

Table 9: Biological parameters included in the east coast tarakihi assessment model for the base model.

Parameter	Value (fixed)
Natural mortality	0.10 y^{-1}
Growth parameters	Length Age 1 = 15.37, k = 0.2009, Linf = 44.6
Proportion mature	Age based
	Ages 1-3 0, Age 4 0.25, Age 5 0.5, Ages 6+ 1.0
SRR steepness	0.9
SigmaR	0.6

For the final model options, two contrasting models were configured: a three region, spatially disaggregated model and a single region, spatially aggregated model (Table 10). The three region model was configured to approximate the stock hypothesis; i.e., each region included a discrete population with recruitment in the southern (ECSI) region only and age-specific movement of fish northwards between adjacent regions. Within each region, the oldest age classes in the population were assumed to be fully vulnerable to the key fisheries (TAR3-BT, CS-BT, TAR2BPLE-BT and ENLD-BT). Fishery catches were taken from the population in each respective region and the abundance indices (CPUE and trawl survey) were taken to represent trends in relative abundance in that region.

In contrast, the single region model comprised a single population. The age composition of the catch from each fishery was mediated by the selectivity of the individual fisheries. For the ENLD-BT fishery, the oldest age classes were assumed to be fully vulnerable (logistic selectivity) based on the high proportion of older age classes observed in the fishery age composition compared to the other fisheries. The selectivity of these other fisheries (and surveys) was parameterised using a double normal function, allowing for lower vulnerability of the older age classes. Thus, all sets of CPUE indices and surveys monitored the relative abundance of the single population mediated by the selectivity.

Annual recruitment was derived from a Beverton-Holt spawner-recruit relationship (SRR). The base model options assumed a high value for steepness (h = 0.9) on the basis that recruitment was considered to be most strongly influenced by the prevailing oceanographic conditions during the long pelagic phase of post larval tarakihi. Inter-annual variability in recruitment was estimated as deviates from the SRR for the period that was informed by the age composition data and recent abundance indices (i.e. 1980–2015). Recruitment deviates were assumed to have a relatively high degree of variability (*sigmaR* = 0.6).

The relative weightings applied to the main data sets were equivalent for the final range of model options, allowing a direct comparison of the model fits (likelihood components) among the individual models. For the recent CPUE indices, each series was assigned a coefficient of variation (CV) of 20%, while the individual trawl survey biomass estimates were weighted by the CV from the individual survey. Most of the recent commercial age composition data sets were assigned a moderate weighting (Effective Sample Sizes of 30). Substantial changes in the relative weightings of individual data sets did not substantially change the model results, indicating broad consistency amongst the key input data sets.

Initial model options included the entire catch history from 1932 and estimated initial levels of fishing mortality for the two fisheries that caught modest quantities of tarakihi during the early 1930s. However, for the three region model, the fits to the CPUE and age composition data from the East Northland model were very poor and the model estimated an implausibly large biomass for the East Northland region. These issues could not be resolved within the modelling framework and appeared to be attributable to the large catches allocated to the East Northland fishery prior to 1965. For this period, the allocation of catches to each region was based on port of landing and all landings in Auckland were attributed to East Northland. This assumption is likely to be incorrect, although no other information is available to apportion the early catch amongst the East Northland and Bay of Plenty fisheries. On that basis, the full catch history, three region model was rejected. In contrast, the full catch history, single region model yielded credible results, including a good fit to the East Northland CPUE and age composition data. It appears that the constraints imposed by the spatial structure of the three region model resulted in conflict between the distribution of catch (and therefore biomass) and the other data sets. These constraints do not exist in the single region model (*1Region_Start1932*).

The regional distribution of catch is considered to be more reliable from about 1965 onwards. Additional model options were configured that were initialised in 1975 (*1Region_Start1975* and *3Region_Start1975*). Initial (1975) conditions were determined by estimating (five) fishery specific levels of fishing mortality (Initial Fs) that were informed by an assumed equilibrium level of catch in the initialisation period. The fishery specific levels of equilibrium catch were set at the average fishery catch from the preceding 10 years (i.e. 1965–1974). For the main model options, equilibrium catches were assumed to be known with a high level of precision. The influence of these assumptions was investigated by increasing the uncertainty associated with the values of the equilibrium catches (model sensitivity InitialCatchVar).

Table 10: The number of estimated parameters included in each of the main model options.

Parameter	Model option		
	1Region_Start1932	1Region_Start1975	3Region_Start1975
Ln R0	1	1	1
RecDevs	37	37	37
Selectivity	28	28	18
Initial F	2	5	5
Movement	0	0	4
Total	68	71	65

Overall, the model options that commenced in 1975 yielded very similar results to the full catch history model (*1Region_Start1932*) in terms of the biomass trajectory from 1985–2016 and the estimate of equilibrium, unexploited biomass (SB_0) (Figure 8). Some differences existed between the three region model and the single region models following the initialisation of the population(s) although the biomass trajectories converged during the subsequent period. The comparative model options both had a relatively poor fit to the CPUE indices from ENLD-BT and TAR2BPLE-BT during the early 1990s although the lack of fit was more pronounced for the three region model. Overall fits to some of the other abundance indices (CPUE and survey) were also somewhat worse for the three region model. The fits to the age composition data sets were also considerably worse for the three region model. The greater flexibility of the parameterisation of the selectivity functions (Table 10) for the single region model appears to be the main reason for the improved fit to the two main data components.

The two single region model options yielded very similar estimates of stock biomass (Figure 8). The two model options yielded very similar fits to the individual data sets, excluding the two additional sets of CPUE indices from the 1960s and early 1970s that were only included in the full catch history model. The *1Region_Start1975* model was selected as the base model option as the model was most directly comparable to the *3Region_Start1975* model, while yielding results that were not substantively different from the *1Region_Start1932* model.

Overall, the model results indicate the stock has been in a depleted state since the mid-1970s. This followed a period of relatively high catches (5000–7000 t) during the 1950s and early 1960s. The recent CPUE indices and the associated levels of catch are highly influential in determining the estimate of average recruitment (*R0*) and, hence, equilibrium, unexploited biomass (SB_0). The overall levels of depletion are strongly influenced by the cumulative catch from the earlier period of the model (*1Region_Start1932*) or the estimates of Initial F informed by the assumed level of initial equilibrium catch (*1Region_Start1975* and *1Region_Start1932*).

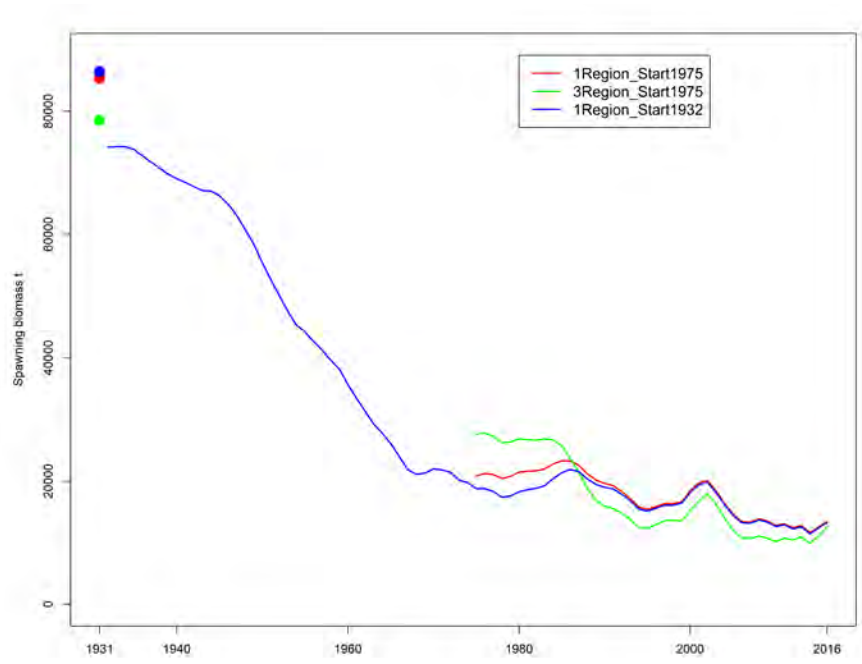


Figure 8: A comparison of the biomass trajectories from the three main model options and the corresponding estimates of the equilibrium, unexploited biomass SB_0 (points) plotted (arbitrarily) at 1931.

Estimates of stock status were determined for each model option using an MCMC approach (sampling from 1 million MCMC draws at an interval of 1000). Model sensitivities were conducted for the base model option (*1Region_Start1975*) to investigate the influence of four key assumptions (Table 11). Current stock status was defined as the mid-year spawning biomass (male and female fish) in 2015–16 relative to equilibrium, unexploited biomass (SB_{2016}/SB_0). Current fishing mortality was estimated relative to a reference fishing mortality that corresponds to the default target biomass of 40% of SB_0 (i.e., $F_{2016}/F_{SB40\%}$).

Table 11: Description of model sensitivities

Sensitivity	Description
InitialCatchVar	Uncertainty associated with Initial Equilibrium Catches SE of ln(Catch) = 1.0
LowM	$M = 0.08$
Maturity	Length based maturity OGIVE Logistic function parameters Mat50 = 33.56, Matslp = -0.45
Steepness 0.8	$h = 0.8$

Spawning biomass is estimated to have declined to about the default soft limit of 20% SB_0 by the initial period of the assessment model in 1975 (Table 12). Spawning biomass tended to decline over the subsequent years, following an increase in total catches during the 1990s and moderated by variation in recruitment, especially a period of higher recruitment during the mid-late 1990s. Since the mid-2000s, spawning biomass is estimated to have been below the default soft limit and, for the base model, current spawning biomass is estimated to be at 17% of the unexploited, equilibrium biomass level (SB_{2016}/SB_0 = 0.170) (Table 12). Spawning biomass increased slightly from the lowest level in 2014, following above average recruitment in 2011–2012 (Figure 9).

The stock status is similar for the range of model options, although the stock status is slightly more pessimistic for the model sensitivities with lower productivity parameters. For the base case, the model estimates a high probability (89%) that the spawning biomass is below the soft limit, and a low probability (0.3%) of being below the hard limit of 10% SB_0 (Table 12).

Table 12: Estimates of current (SB_{2016} 2015–16) and equilibrium, unexploited spawning biomass (SB_0) (median and the 95% confidence interval from the MCMCs) and probabilities of current biomass being above specified levels.

Model option	SB_0	SB_{2016}	SB_{2016}/SB_0	Pr ($SB_{2016} > X\%SB0$)		
				40%	20%	10%
Base Region1_Start1975	86 321 (81 977–91 907)	14 620 (10 685–19 413)	0.170 (0.126–0.219)	0.000	0.112	0.997
Region3_Start1975	79 796 (77 016–82 957)	14 170 (10 281–17 850)	0.178 (0.131–0.222)	0.000	0.163	0.998
Region1_Start1932	86 988 (83 194–91 140)	14 614 (11 021–19 283)	0.168 (0.127–0.218)	0.000	0.102	0.999
InitialCatchVar	84 281 (78 864–90 153)	14 172 (10 314–18 749)	0.169 (0.125–0.22)	0.000	0.096	0.999
LowM	102 094 (97 065–107 398)	12 832 (8 295–16 878)	0.126 (0.081–0.166)	0.000	0.000	0.890
Maturity	73 392 (70 030–77 494)	10 350 (7 062–13 780)	0.14 (0.099–0.184)	0.000	0.001	0.970
Steepness 0.8	93 638 (88 334–99 012)	14 464 (8 907–19 488)	0.156 (0.097–0.205)	0.000	0.040	0.969

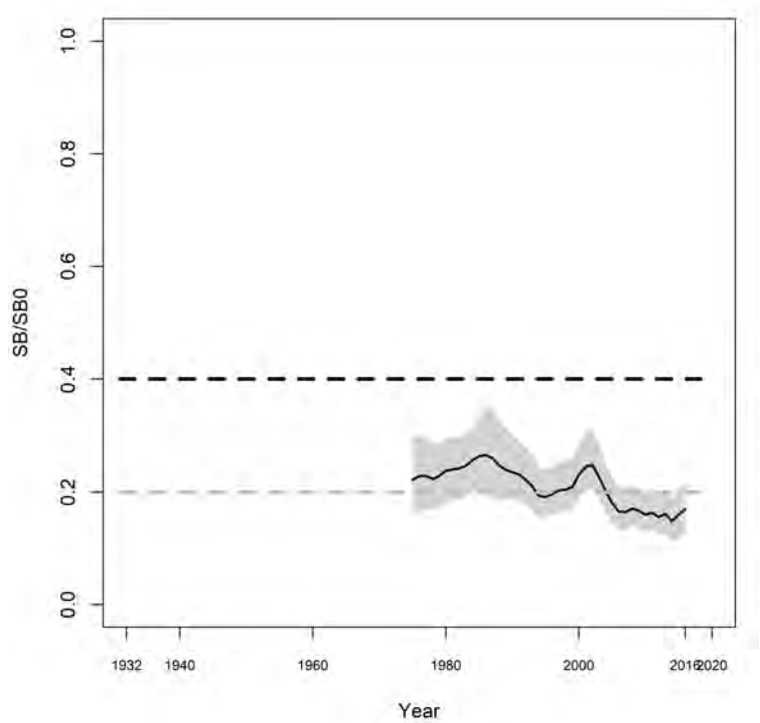


Figure 9: Annual trend in spawning biomass relative to the 40% SB_0 interim target biomass level and 20% SB_0 soft limit for the base model. The line represents the median and the shaded area represents the 95% confidence interval.

Annual fishing mortality rates are estimated to have exceeded the level of fishing mortality that corresponds to default target biomass level (i.e. $F_{SB40\%}$) throughout the model period (from 1975) (Figure 10). From 2000, fishing mortality rates are estimated to have increased steadily and for the base model current fishing mortality rates are estimated to be more than double the reference level (i.e. $F_{2016}/F_{SB40\%}$ = 2.23) (Table 13). The estimates of current fishing mortality rates are similar for the range of model options.

Equilibrium yields at the target biomass level are estimated to be about 4100 t. Fishing at the $F_{SB40\%}$ level of fishing mortality would have yielded considerably lower levels of catch in 2016. However, estimates of recent potential yields are relatively uncertain due to the uncertainty associated with estimates of recent recruitment.

Table 13. Estimates of current (F_{2016} 2015–16) and reference levels of fishing mortality ($F_{SB40\%}$) (median and the 95% confidence interval from the MCMCs) and the probability of fishing mortality being below the level of fishing mortality associated with the interim target biomass level. The associated levels of $F_{SB40\%}$ equilibrium yield and 2016 yield at $F_{SB40\%}$ are also presented.

Model option	$F_{SB40\%}$	$F_{2016}/F_{SB40\%}$	Pr(F_{2016}<$F_{SB40\%}$)	$F_{SB40\%}$ *Yield*	Yield 2016
Base	0.0839	2.231	0.00	4 175	2 448
(Region1_Start1975)	(0.0801–0.0877)	(1.791–2.785)		(3 979–4 379)	(1 819–3 216)
Region3_Start1975	0.0924	2.055	0.00	4 166	2 616
	(0.0896–0.0946)	(1.72–2.629)		(4 003–4 340)	(1 889–3 318)
Region1_Start1932	0.0839	2.231	0.00	4 202	2 451
	(0.0802–0.0873)	(1.816–2.741)		(4 068–4 355)	(1 839–3 201)
InitialCatchVar	0.0838	2.293	0.00	4 072	2 371
	(0.0799–0.0871)	(1.851–2.906)		(3 825–4 319)	(1 730–3 163)
LowM	0.0722	2.905	0.00	4 186	1 842
	(0.0687–0.0752)	(2.37–3.866)		(3 979–4 408)	(1 217–2 411)
Maturity	0.076	2.504	0.00	4 055	1 569
	(0.0732–0.0784)	(2.034–3.166)		(3 855–4 250)	(1 096–2 078)
Steepness 0.8	0.0781	2.451	0.00	4 187	2 264
	(0.0747–0.0811)	(1.918–3.449)		(3 978–4 406)	(1 412–3 034)

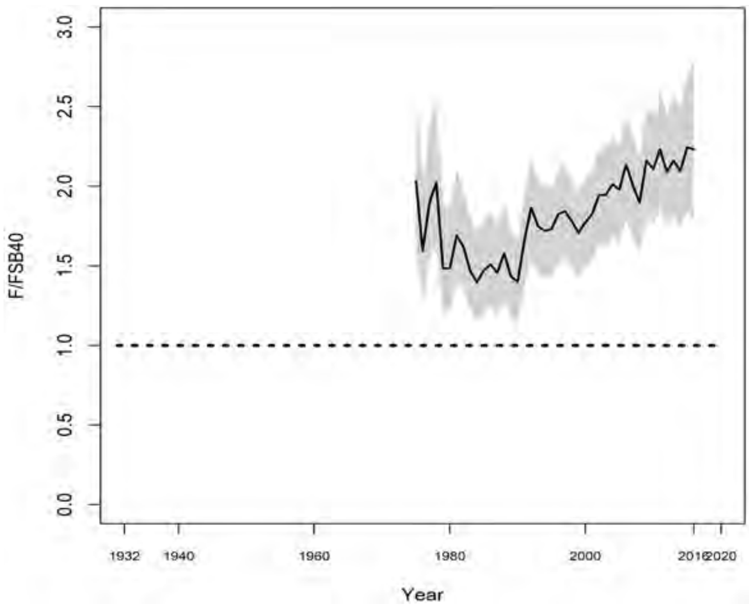


Figure 10: Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval.

Projections

For the base model option, stock projections were conducted for the 10-year period following the terminal year of the model (i.e. 2017–2026). During the projection period, recruitments were generated from the lognormal distribution around the geometric mean of the estimated recruitments.

Stock projections were based on multiples of the status quo (2016) commercial and recreational catches: i.e., 40%, 60%, 80% and 100% of the total 2016 catch of 4442 t, including the 10% allowance for unreported catch. The minimum period required to rebuild the stock to the target biomass level (*Tmin*) was determined from a stock projection with no catch. *Tmin* was estimated to be 4 years for a target biomass of 35% SB_0 and 5 years for a target biomass of 40% SB_0. Projections were also conducted at specified levels of fishing mortality levels: $F_{SB35\%}$, $F_{SB40\%}$, and the level of fishing mortality required to rebuild the stock to the target biomass level by twice *Tmin* (i.e., 8 years for 35% SB_0 and 10 years for 40% SB_0).

The projections indicate that a catch reduction of at least 20% is required to reduce the risk of the stock falling below the hard limit (10% SB_0) during the next 10 years and increase the probability that the stock will rebuild to above the soft limit (20% SB_0) (Table 14). However, substantially larger reductions in catch (approaching a reduction of 60%) are required to rebuild the stock to the 40% SB_0 default target level within the 10-year projection period.

Table 14: Estimated stock status (and 95% confidence intervals) and the probabilities of the spawning biomass being above default biomass limits and interim target level in 2021 (5 years) and 2026 (10 years) from catch based projections for the base case.

Percent of 2016 catch	SB_{2021}/SB_0	Pr (SB_{2021} > X%SB_0)			
		10%	20%	35%	40%
100%	0.149 (0.062–0.277)	0.850	0.206	0.002	0.001
80%	0.201 (0.117–0.331)	0.988	0.504	0.014	0.002
60%	0.253 (0.169–0.383)	1.000	0.859	0.062	0.014
40%	0.304 (0.220–0.433)	1.000	0.994	0.220	0.063
	SB_{2026}/SB_0	Pr (SB_{2026} > X%SB_0)			
		10%	20%	35%	40%
100%	0.148 (0.0–0.399)	0.681	0.290	0.041	0.026
80%	0.253 (0.089–0.477)	0.966	0.700	0.156	0.084
60%	0.347 (0.192–0.574)	1.000	0.963	0.482	0.278
40%	0.436 (0.279–0.669)	1.000	1.000	0.828	0.632

Projections that reduced the level of fishing mortality to $F_{SB35\%}$ or $F_{SB40\%}$ from 2017 onwards resulted in a very high probability of the stock rebuilding to above the soft limit within 5 years (Table 15) due to a large initial reduction in catch (approx. 40–50% reduction). Under the constant fishing mortality scenarios, annual catches increased as the biomass increased and the rate of rebuild attenuated as the biomass approached the corresponding target level (35% SB_0 or 40% SB_0). Consequently, target biomass levels were not achieved within the 10-year projection period (Table 15). To attain the target biomass levels within a period of twice *Tmin* a larger reduction in fishing mortality was required, equating to a reduction in fishing mortality to approximately 25% of the F_{2016} level.

Table 15: Estimated stock status (and 95% confidence intervals) and the probabilities of the spawning biomass being above default biomass limits and interim target level in 2021 (5 years) and 2026 (10 years) from fishing mortality based projections for the base case.

Fishing mortality	SB_{2021}/SB_0	Pr (SB_{2021} > X% SB_0)			
		10%	20%	35%	40%
$F_{SB35\%}$	0.246 (0.191–0.34)	1.000	0.942	0.020	0.003
$F_{SB40\%}$	0.264 (0.206–0.364)	1.000	0.983	0.042	0.007
25% of F_{2016}	0.304 (0.238–0.417)	1.000	0.999	0.159	0.036
	SB_{2026}/SB_0	Pr (SB_{2026} > X% SB_0)			
		10%	20%	35%	40%
$F_{SB35\%}$	0.283 (0.156–0.52)	1.000	0.870	0.240	0.129
$F_{SB40\%}$	0.311 (0.188–0.553)	1.000	0.953	0.347	0.202
25% of F_{2016}	0.384 (0.25–0.638)	1.000	0.998	0.658	0.431

The stock assessment is strongly dependent on CPUE indices as the primary indices of stock abundance. Fishery independent surveys are conducted within the ECSI area only and principally monitor the abundance of juvenile tarakihi. Consequently, the CPUE indices and trawl survey data are not directly comparable. Nevertheless, the assessment model indicates that the trends in the various sets of CPUE indices are generally consistent with the data from the trawl surveys (biomass and age/length compositions) and commercial age composition data. This indicates that the various sets of CPUE indices probably provide a reasonable index of stock abundance in each of the fishery areas.

There is sufficient information available to support the current hypothesis that tarakihi along the east coast of the North and South Island belong to a single stock. However, the broader stock structure around mainland New Zealand, including the west coast of the North and South Islands, is poorly understood. There is evidence from tagging studies that some tarakihi migrate from the ECSI to the west coast of the North Island. In addition, there is the possibility that tarakihi off the west coast of the North and South Islands could contribute recruits to the ECSI nursery grounds, contributing to the abundance of tarakihi in the area.

The current stock assessment assumes that east coast tarakihi represents a discrete stock. The level of recruitment estimated for the stock determines the overall level of reference biomass (SB_0) and stock status. Biases in the estimation of recruitment due to the misspecification of recruitment processes could influence the estimates of stock status for east coast tarakihi. Some preliminary modelling was conducted to investigate the sensitivity of the model results to more complex stock relationships. However, these issues were not fully investigated due to limitations in the data available from the other (west coast) areas and the scope of the assessment project.

Stock assessment update 2018

In 2018, the base assessment model (Region1_Start1975) was updated to include catches and CPUE indices for 2017 (2016–17 fishing year). There were no other changes to the model configuration or treatment of the data sets (i.e. equivalent data weightings). The updated model yielded virtually identical estimates of stock status for the 2016 year (SB_{2016}/SB_0 = 0.167 CI 0.126–0.211) compared to the 2017 assessment. For the updated model, stock status in 2017 was estimated to be SB_{2017}/SB_0 = 0.173 (CI 0.130–0.223) (Table 16).

Table 16: Estimates of current (SB_{2017} 2016–17) and equilibrium, unexploited spawning biomass (SB_0) (median and the 95% confidence interval from the MCMCs), probabilities of current biomass being above specified levels, and current fishing mortality relative to the reference level from the 2018 update of the base assessment model.

SB_0	SB_{2017}	SB_{2017}/SB_0	Pr (SB_{2017} > X%SB0)			$F_{2017}/F_{SB40\%}$
			40%	20%	10%	
86 663	15 054	0.173	0.000	0.126	1.000	2.303
(82 361–91 337)	(11 163–19 789)	(0.130–0.223)				(1.851–2.836)

The updated assessment model was used to conduct stock projections to 2027–28 (10+1 years) at various levels of catch (Table 17). The baseline level of catch from the constituent model fisheries represented a total catch of 4619 t (including a 10% allowance for unreported commercial catch) based on recent catches and/or current (2017–18) TACCs. Recreational and customary catches were held constant at current levels in the projections.

Table 17: Estimated stock status (median) and the probabilities of the spawning biomass being above default biomass limits and interim target level in 2028 (10+1 years) from catch based projections for the base case.

Percent of baseline commercial catch	Projected catch (t)	SB_{2028}/SB_0	Pr (SB_{2028} > X%SB_0)			
			10%	20%	30%	40%
100%	4 619	0.136	0.623	0.295	0.101	0.026
80%	3 728	0.237	0.924	0.642	0.912	0.094
60%	2,838	0.333	0.999	0.920	0.626	0.282
40%	1,949	0.425	1.000	0.998	0.912	0.592

Future research considerations

- Continue and possibly intensify monitoring of the stock while it rebuilds. Increased emphasis should be on the collection of data from the East Northland fishery to ensure monitoring of the full age structure of the population.
- Improve the understanding of the stock relationships of tarakihi around mainland New Zealand. This could be progressed by extending the current model to develop a whole of New Zealand stock assessment model, including several plausible stock structure and migration hypotheses. Such a model would integrate the data available from west coast South Island (catch, trawl surveys, CPUE indices and age compositions), Tasman Bay/Golden Bay (trawl surveys) and west coast North Island (catch, CPUE indices and age compositions). This would provide a framework to evaluate the extent of variation in recruitment dynamics amongst regions and, thereby provide an indication of the potential stock linkages between the east coast and other regions. The study would also highlight limitations of the data currently available from the other main fishery areas.
- Investigate the potential utility of a WCNI or ECNI trawl survey for obtaining further fisheries-independent indices for tarakihi.
- Consider conducting more tagging studies to obtain better information about stock movements.
- Expand the catch sampling programme to obtain fish ages for more parts of the distribution of the species:
    - Investigate the utility of ageing existing samples from the fisheries and trawl surveys to augment the number of aged fish, especially from important areas or those with poor representation.
    - Request that observers on the west coast of the North Island start collecting otoliths.
    - Additional sampling of the age composition of the eastern Cook Strait fishery (Cook-BT) would also be beneficial as limited data are currently available from this area.
- Take changing fishing technology into account when designing catch sampling schemes and analysing CPUE.
- Increase biological sampling during the spawning season and examine gonads to obtain better staging information to inform the maturity ogive.
- Investigate mechanisms for estimating the discard rate and/or level of return to the sea of sub-MLS fish in Area 3, which has a relatively large number of small tarakihi.

- Investigate the potential of currents and gyres (especially the one off ECNI) to act as dispersal or retention mechanisms for larval and juvenile tarakihi, especially in terms of the observation that Area 3 receives most of the recruitment.

TAR 7

An integrated statistical catch-at-age stock assessment for TAR 7 was carried out in 2008 for data up to the end of the 2006–07 fishing year (Manning 2008). The model partitioned by age (0–45 years) and sex was fitted to the trawl survey relative abundance indices (1992–07), survey proportions-at-age data (1995–07), and WCSI fishery catch-at-age data (2005–2007). The stock boundary assumed in the model included the west coast of the South Island, Tasman and Golden Bays, but not eastern Cook Strait (a catch history was compiled for the model stock that excluded eastern Cook Strait). A summary of the model's annual cycle is given in Table 18. The base case model (R4.1) was fit to trawl survey biomass indices (lognormal likelihood) and proportion at age data (multinomial likelihood), U_{max} was set at 0.8, steepness was assumed to be 0.75, and M was fixed at 0.1. The base case model assumed an equilibrium biomass at the beginning of the population reconstruction in 1940. One sensitivity R4.5 was the same as R4.1 but was also fit to the CPUE data (lognormal likelihood). The other sensitivity (R4.6) also included the CPUE data; however, the model was started in 1985 from a non-equilibrium start. Model run 4.5 was very similar to the base case (4.1) in terms of biomass trajectory and stock status, but sensitivity 4.6 was more pessimistic in terms of stock status (Table 19). None of the three estimated a mean or median stock status that is below B_{MSY} and the stock is expected to rebuild, on average, for all three runs under current levels of removals and with average recruitment (Figure 11).

Table 18: The TAR 7 model's annual cycle (Manning 2008). Processes within each time step are listed in the time step in which they occur in particular order (e.g., in time step 3, new recruits enter the model partition first followed by the application of natural and fishing mortality to the partition). *M*, the proportion of natural mortality assumed during each time step. *F*, the nominal amount of fishing mortality assumed during each time step as a proportion of the total catch in the stock area. Age, the proportion of fish growth that occurs during each time step in each model year.

			Proportions			
Time step	**Duration**	**Process applied**	***M***	***F***	**Age**	**Observations**
1	Oct–Apr	Mortality (*M*, *F*)	0.58	0.74	0.90	Survey relative biomass (KAH) Survey proportions-at-age (KAH) Survey proportions-at-age (JCO) Survey proportions-at-length (KAH) Fishery catch-at-age Fishery relative abundance (CPUE)
2	May (instantaneous)	Spawning Age incrementation	0.00	0.00	0.00	NIL
3	May–Sept	Recruitment Mortality (*M*, *F*)	0.42	0.26	0.10	Fishery catch-at-age

Table 19: **MCMC initial and current biomass estimates for the TAR 7 model runs R4.1, 4.5, and 4.6. B_0, virgin or unfished biomass; B_{2007}, mid-year biomass in 2007 (current biomass); (B_{2007} / B_0) %, B_0 as a percentage of B_{2007}; Min, minimum; Max, maximum; *Q*i, ith quantile. The interval ($Q_{0.025}$, $Q_{0.975}$) is a Bayesian credibility interval (a Bayesian analogue of frequentist confidence intervals).**

	R4.1			R4.5		
	B_0	B_{2007}	(B_{2007} / B_0) %	B_0	B_{2007}	(B_{2007} / B_0) %
Min	13 010	4 340	33.4	12 810	4 180	32.6
$Q_{0.025}$	14 290	6 060	42.3	13 780	5 350	39.1
Median	16 440	9 010	54.7	15 640	7 880	50.4
Mean	16 570	9 180	54.9	15 730	8 020	50.6
$Q_{0.975}$	19 630	13 410	68.3	18 310	11 500	63.0
Max	22 030	16 510	75.0	21 430	15 420	72.0
		R4.6				
Min	14 660	4 150	28.3			
$Q_{0.025}$	18 350	6 490	34.7			
Median	24 540	10 190	41.6			
Mean	25 680	10 940	41.9			
$Q_{0.975}$	40 600	19 890	50.5			
Max	63 300	34 700	58.3			

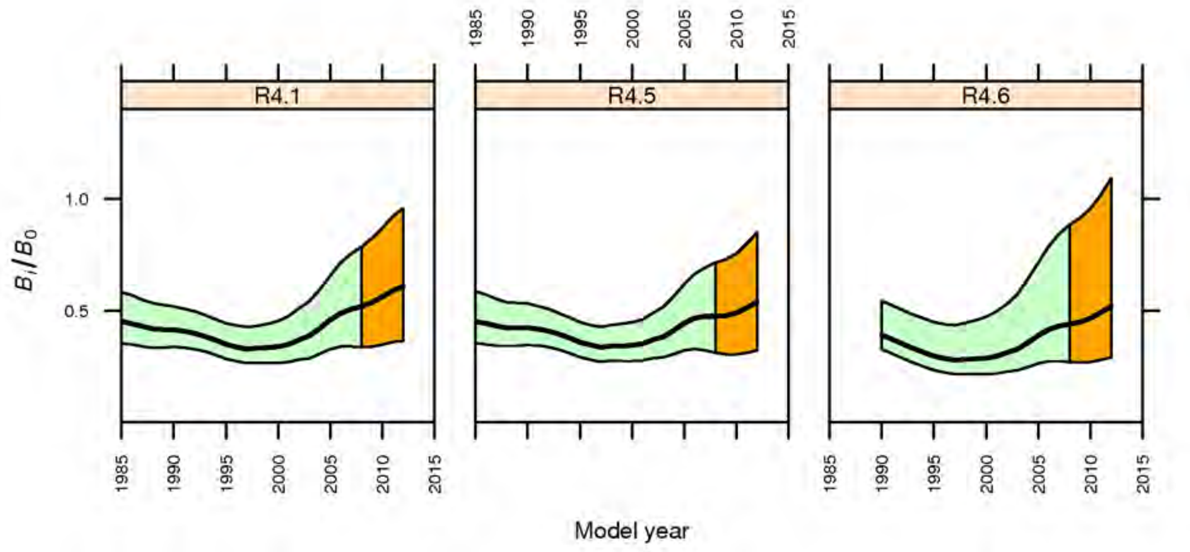


Figure 11: **Relative SSB trajectories (green) and projected status assuming a future constant catch equal to the current catch (orange) calculated from the MCMC runs for model runs 4.1, 4.5, and 4.6 in the quantitative stock assessment of TAR 7. The shaded region indicates the 95% credibility region about median SSB (dotted lines) calculated from each model's SSB posterior distribution.**

The east coast stock assessment includes the eastern area of the TAR 1 fishstock (QMA 1) but does not include the western area of TAR 1 (QMA 9).

B_{MSY} proxy

Tarakihi is classified as a Low Productivity stock which, according to the Operational Guidelines for the Harvest Strategy Standard for New Zealand Fisheries, corresponds to a B_{MSY} proxy of 40% B_0. This decision was made taking all factors into account, but with greatest emphasis on the HSS Operational Guidelines, and considering the three Low Productivity parameters for TAR were attributed greater weight than the two Medium Productivity parameters for determining productivity.

TAR 1W, 4, 5, 8

Estimates of current absolute biomass for TAR 4, 5, 8 are not available.

5. STATUS OF THE STOCKS

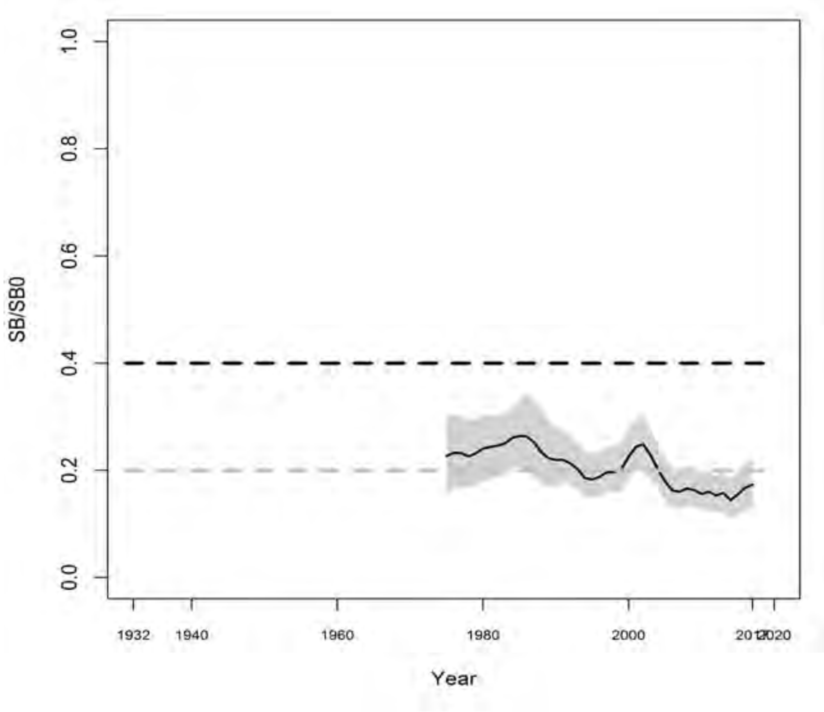
- **TAR 1E, TAR 2, TAR 3, TAR 7 (Eastern Cook Strait)**

Tarakihi off the east coast of the North and South Islands are considered to represent a single stock. The eastern area of TAR 1 accounted for approximately 60% of the annual TAR 1 catch in recent years.

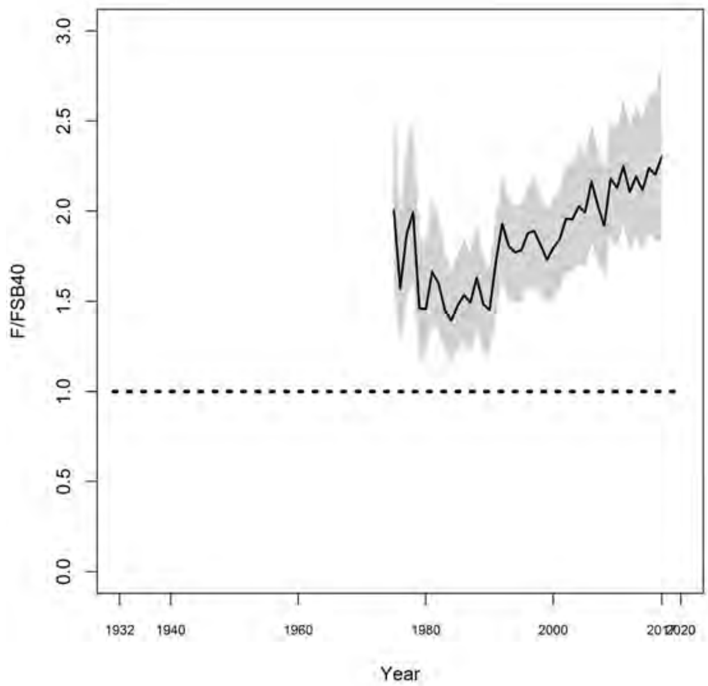
Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Base case model
Reference Points	Target: Interim target 40% SB_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Interim overfishing threshold: $F_{SB40\%}$
Status in relation to Target	$SB_{2016–17}$ was estimated to be 17.3% SB_0; Exceptionally Unlikely (< 1%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Likely (> 90%) to be below Hard Limit: Very Unlikely (< 10%) to be below

Status in relation to Overfishing	Interim overfishing threshold: Virtually Certain (> 99%) that overfishing is occurring

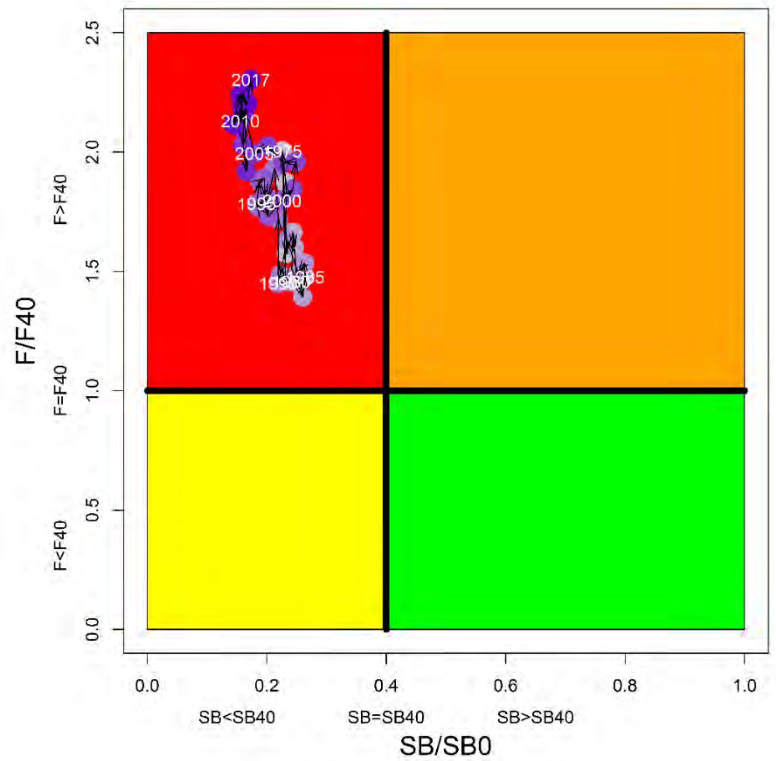
Historical Stock Status Trajectory and Current Status



Annual trend in spawning biomass relative to the 40% *SB0* interim target biomass level and 20% *SB0* soft limit for the updated base model. The line represents the median and the shaded area represents the 95% confidence interval.



Annual trend in fishing mortality relative to the *FSB40%* interim target biomass level for the updated base model. The line represents the median and the shaded area represents the 95% credible interval.



Annual spawning biomass and fishing mortality compared to the *SB40%* interim target biomass level and corresponding fishing mortality reference for the updated base model (median values from MCMCs).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	There has been a general decline in spawning biomass since the late 1980s, moderated by fluctuations in recruitment. Spawning biomass is estimated to have been below the soft limit (20% SB_0) since the early 2000s.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality rates have increased since 2000. For the base model, current fishing mortality rates are estimated to be 2.30 times the level of fishing mortality that corresponds to the interim target biomass level ($F_{SB40\%}$).
Other Abundance Indices	- Trawl CPUE indices from eastern Cook Strait
Trends in Other Relevant Indicators or Variables	The trend in CPUE indices from eastern Cook Strait are consistent with the trends in vulnerable biomass for the Cook Strait fishery derived from the eastern stock assessment.

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections were conducted for a 10-year period assuming multiples of the current level and distribution of catch across fisheries. Spawning biomass was projected to decline slightly at the current level of catch.
Probability of Current Catch or TACC causing decline biomass to remain below or to decline below Limits	Current Catch Soft Limit: Very Likely (> 90%) to remain below Hard Limit: Unlikely (< 40%) to decline below TACC Not included because the assessed stock boundaries do not match QMA boundaries.
Probability of Current Catch or TACC causing overfishing to continue or to increase	Virtually Certain (> 99%) that current catch levels will cause overfishing to continue or increase

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured Stock Synthesis model with MCMC estimation	
Assessment Dates	Latest assessment: 2018	Next assessment: 2022
Overall assessment of quality rank	1 – High Quality	
Main data inputs (rank)	- Commercial catch history - CPUE indices - Recent commercial age frequency - Kaharoa trawl survey abundance estimates and age/length frequencies	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- James Cook survey age compositions	3 – Low Quality: Not representative
Changes to Model Structure and Assumptions	- New assessment. Previous assessments of individual fishery areas based on trends in CPUE indices - Refinement to CPUE indices incorporated in the assessment model	
Major Sources of Uncertainty	- Uncertainty in the stock structure	

Qualifying Comments
Projections are based on the distribution of catch across fisheries remaining constant. If the ratio of catch across fisheries changes, the projections will change. There is a poor match between the assessed stock area, and the TAR QMAs.

Fishery Interactions
TAR 1. The main fishing method is trawling. Target tarakihi trawls catch snapper, John dory, gemfish and trevally in East northland; and snapper, trevally and gemfish in the Bay of Plenty. Incidental captures of seabirds occur in the bottom longline and setnet fisheries, including black petrel which is ranked as at very high risk in the Seabird Risk Assessment. [1] TAR 2. This is mostly (83%) a TAR target fishery. The main fishing method is trawling. The following species are the main fish bycatch in this fishery: GUR, SKI and WAR. Interactions with other species are currently being characterised. TAR 3. The main fishing method is trawling. The following species are the main fish bycatch in this fishery: RCO, BAR and FLA. The tarakihi target setnet fishery bycatch includes very small amounts of LIN and SPD. Interactions with other species are currently being characterised.

- **TAR 1W western stock**

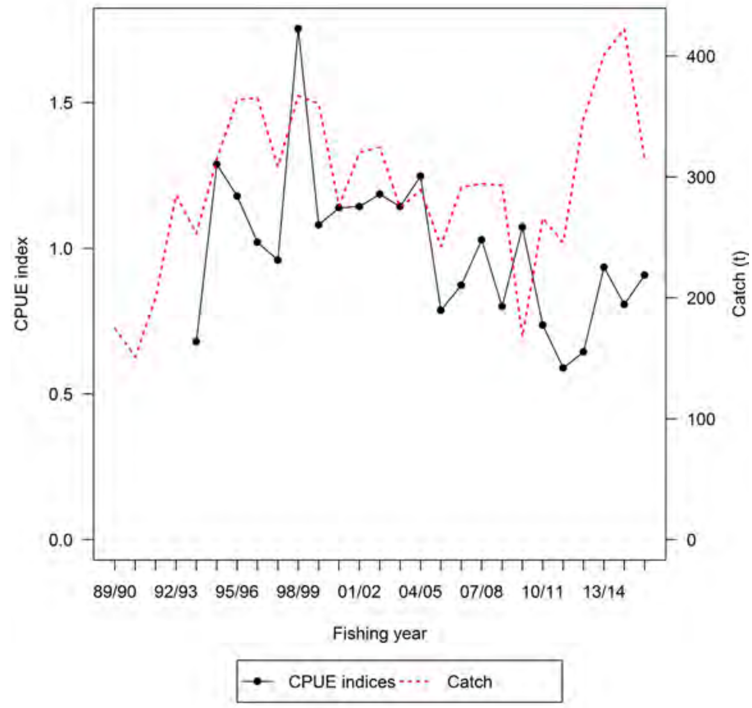
The eastern area of TAR 1 is included within the east coast stock assessment. The western area of TAR 1 accounted for approximately 40% of the annual TAR 1 catch in recent years.

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Standardised delta-lognormal CPUE indices derived from trawls targeting tarakihi, snapper or trevally in the northern area of TAR 1W (Stat Areas 045–047), 1993/94–2015/16
Reference Points	Target: B_{MSY} (value to be determined) Soft Limit: 20% B_0 Hard Limit: 10% B_0

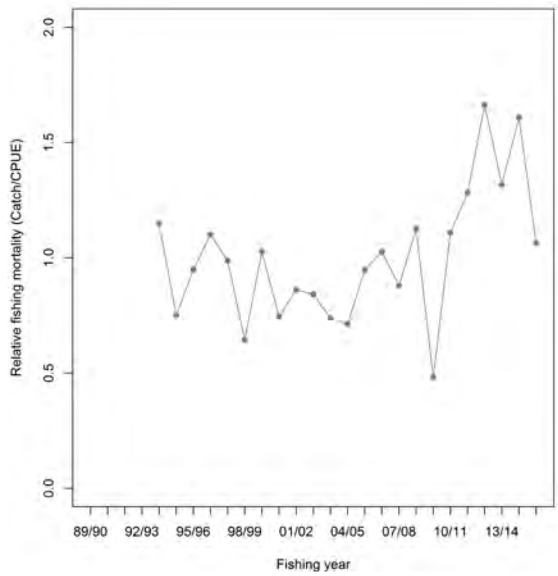
[1] The risk was defined as the ratio of the estimated annual number of fatalities of birds due to bycatch in fisheries to the Potential Biological Removal (PBR), which is an estimate of the number of seabirds that may be killed without causing the population to decline below half the carrying capacity. Richard & Abraham (2013).

	Overfishing threshold: F_{MSY} (value to be determined)
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised delta-lognormal CPUE indices for the northern area of TAR 1W and the annual tarakihi catch from the corresponding area.



Fishing intensity (catch/CPUE) for the northern WCNI tarakihi fishery.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE indices generally declined from 2000/01-2004/05 to 2013/14-2015/16 (by 25%).
Recent Trend in Fishing Intensity or Proxy	Fishing mortality increased (by 70%) from 2000/01-2004/05 to 2011/12-2015/16.
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 decline 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 increase	-

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	CPUE analysis of trawl catch and effort data	
Assessment Dates	Latest assessment: 2017	Next assessment: 2022
Overall assessment of quality rank	1 – High Quality	
Main data inputs (rank)	- Bottom trawl catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Change to trawl event-based data set from trip stratum roll-up - Delta-lognormal CPUE models, including zero catches - Restriction of CPUE analysis to the northern area of the fishery	
Major Sources of Uncertainty	- Uncertainty in the stock structure - Relative abundance prior to 1993–95	

Qualifying Comments
The CPUE indices were derived for the northern area of the fishery only (Stat Areas 045–047). This area accounted for most of the TAR 1W catch. Since the mid-1990s, a target trawl fishery has developed in the North Taranaki Bight in the southern area of TAR 1W. CPUE trends from this area differed markedly from the northern area of the fishery. Thus, the CPUE indices represent the trends in abundance for the northern area of the fishery and do not represent the overall trends in tarakihi abundance in TAR 1W. Reference points based on CPUE were not determined because, based on the east coast TAR stock assessment, biomass may have declined substantially before the start of the series.

Fishery Interactions
The main fishing method is trawling. Target tarakihi trawls catch snapper and trevally as bycatch. Interactions with other species are currently being characterised.

- **TAR 4**

For TAR 4, the fishery around the Chatham Islands appears to have been lightly fished for several years.

- **TAR 5**

Insufficient information is available to determine the status of TAR 5.

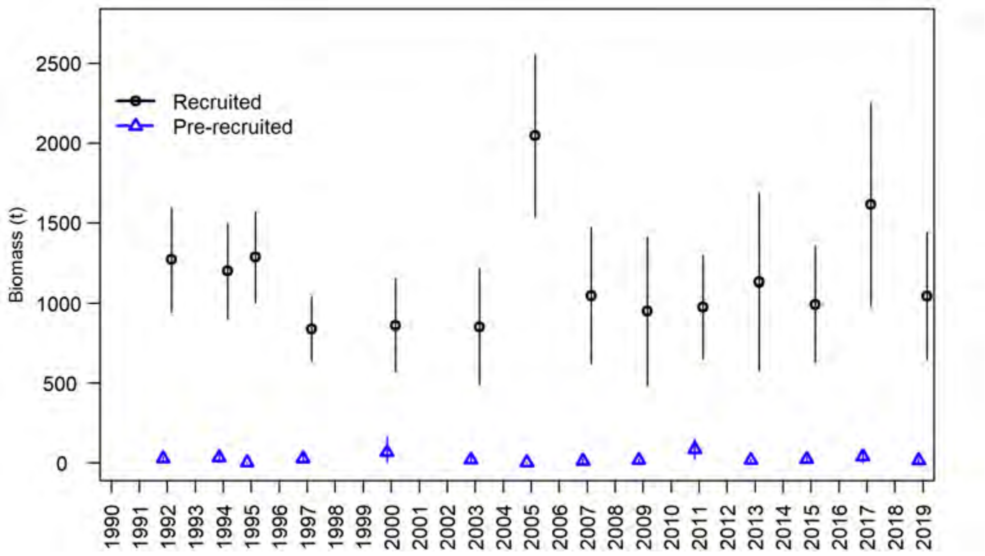
- **TAR 7**

Stock Structure Assumptions

For the purpose of this assessment the west coast South Island and Tasman Bay areas of TAR 7 are assumed to be a discrete stock. The eastern Cook Strait area of TAR 7 is considered to be part of the eastern stock of tarakihi.

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Time series of WCSI trawl survey biomass, most recent survey 2019
Reference Points	Target: Not established but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	In 2007 the range of model results for TAR 7 estimated that the stock was Likely (> 60%) to be at or above B_{MSY} (40% B_0). Trawl survey recruited biomass index for WCSI 2017 was higher than in 2007, suggesting the stock is still Likely (> 60%) to be above B_{MSY} level.
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Trawl survey biomass estimates from the west coast South Island area of TAR 7 (excluding Tasman Bay/Golden Bay).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The WCSI trawl survey biomass index has remained stable since 2006/07.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Biomass (WCSI) is expected to stay steady over the next 3–5 years assuming current (2012/13) catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) for current catch and TACC Hard Limit: Very Unlikely (< 10%) for current catch and TACC
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	-West coast South Island trawl survey biomass	
Assessment Dates	Latest assessment: 2018	Next assessment: 2020?
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Survey biomass and length frequency	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- The time-series of CPUE indices from the TAR 7 WCSI fishery is no longer used as it was considered not to represent a reliable index of stock abundance, at least during 1989/90-2006/07.	
Major Sources of Uncertainty	- Stock structure is currently uncertain. The eastern Cook Strait area of the TAR 7 fish stock is considered to be part of the eastern stock of tarakihi, although the extent of the interaction between tarakihi around coastal New Zealand is unknown.	

Qualifying Comments
-

Fishery Interactions
The main fishing method is trawling. The major target trawl fisheries occur at depths of 100–200 m and tarakihi are taken as a bycatch at other depths as well. TAR 7 is reported as bycatch in target barracouta and red cod bottom trawl fisheries. Smooth skates are caught as a bycatch in this fishery. Interactions with other species are currently being characterised.

- **TAR 8**

Insufficient information is available to determine the status of TAR 8.

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