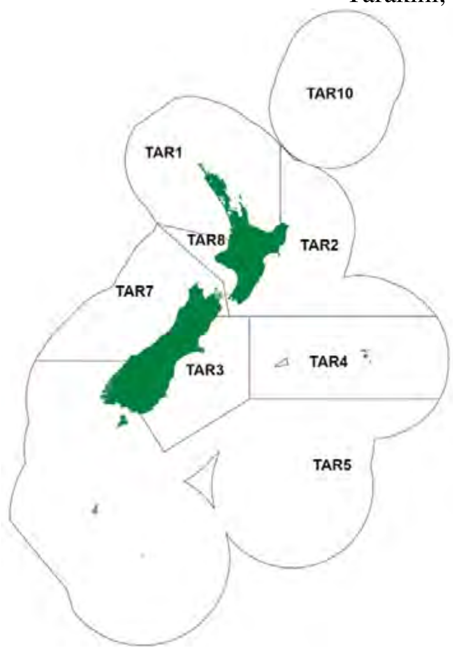
TARAKIHI (TAR)

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



1. FISHERY SUMMARY

1.1 Commercial fisheries

Tarakihi are caught in the coastal waters of the North Island, South Island, 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 1968–1981 (Table 1).

Figure 1 and Table 2 show 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 (

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.

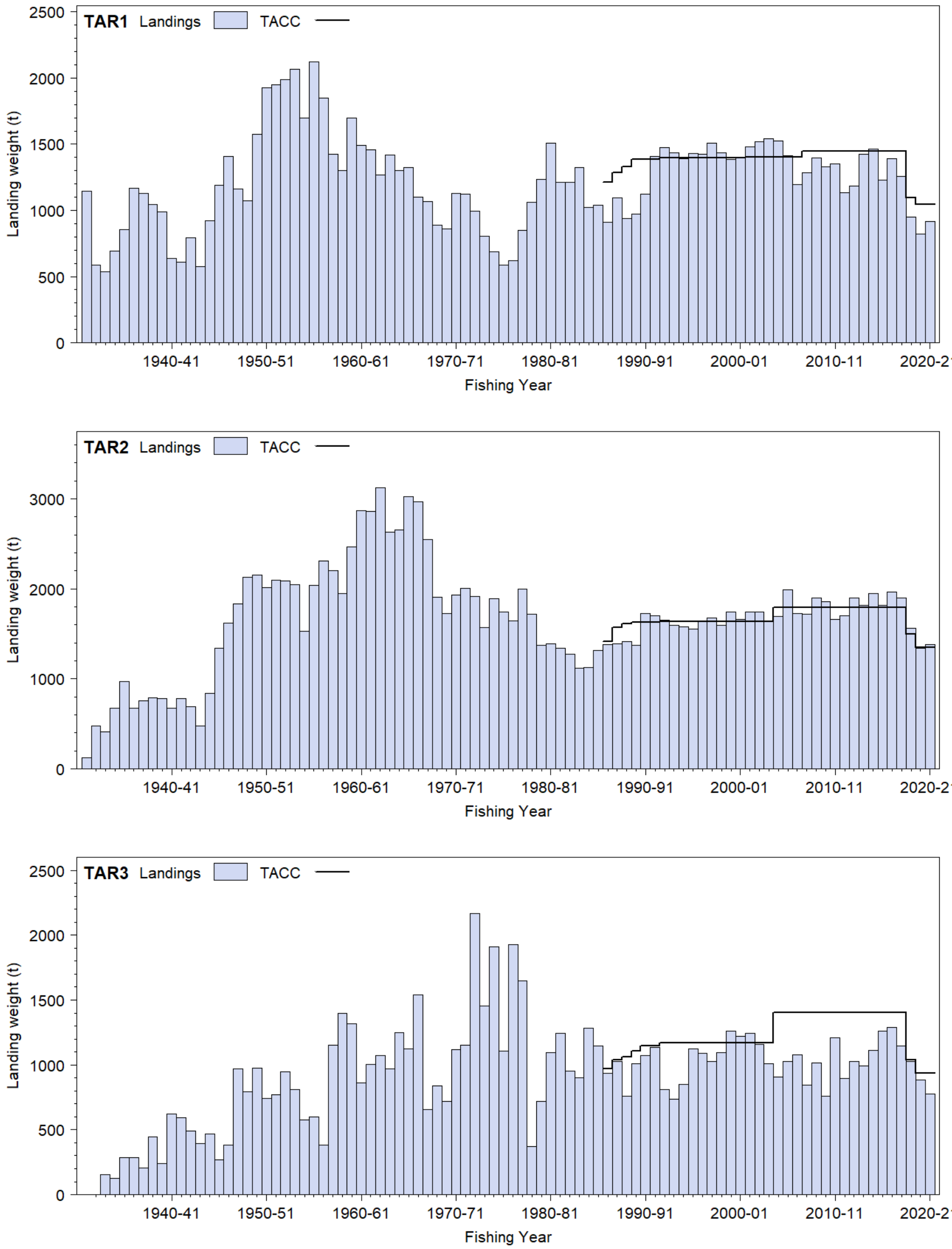


Figure 1: Historical landings and TACCs for the six main TAR stocks. From top to bottom: TAR 1 (Auckland), TAR 2 (Central East), and TAR 3 (South-East Coast). [Continued on next page]

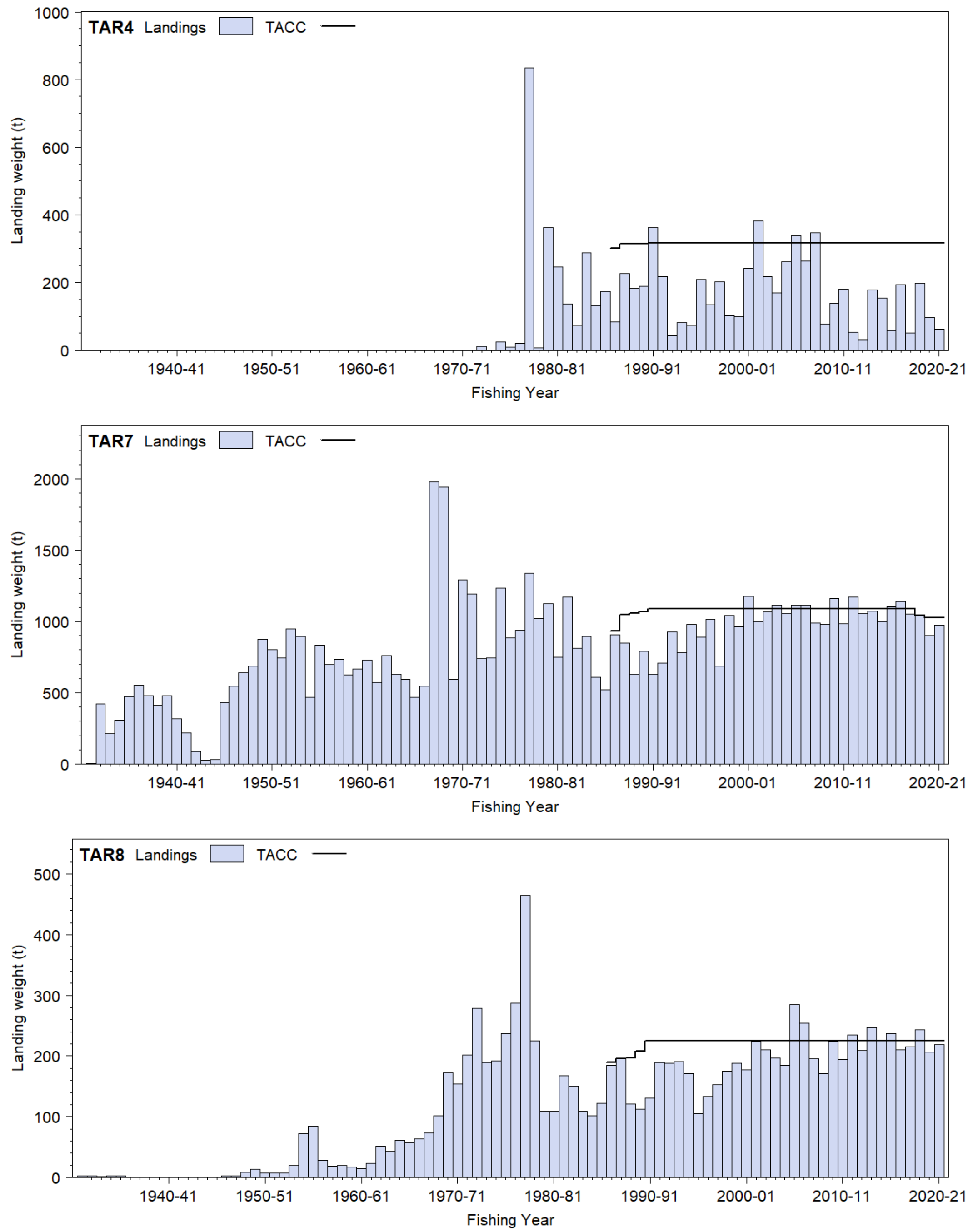


Figure 1: [continued] Historical landings and TACCs for the six main TAR stocks. From top to bottom: TAR 4 (Chatham), TAR 7 (Southland Sub-Antarctic), and TAR 8 (Central West).

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 with 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, 2011–12 to 2012–13, and 2015–16, and annual catches approached the

TACC level in 2008–09 to 2010–11, 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), and 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).

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).

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

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
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	822	1 045	1 339	1 350	882	936	96	316	148	153
2020–21	919	1 045	1 380	1 350	774	936	62	316	171	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
2020–21	976	1 024	219	225	0	10	4 501	5 059

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 Kaikōura 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 153 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 to 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 (Statistical Areas 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.

1.2 Recreational fisheries

Tarakihi are taken by recreational fishers using lines and set nets. 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.

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 from 2019–20.

Fishstock	TAC	TACC	Customary non-commercial	Recreational	Other Mortality
TAR 1 (FMA 1 & 9)	1 333	1 045	73	110	105
TAR 2	1 658	1 350	100	73	135
TAR 3	1 060	936	15	15	94
TAR 4	316	316	0	0	0
TAR 5 (FMA 5 & 6)	153	153	0	0	0
TAR 7	1 154	1 024	5	23	102
TAR 8	225	225	0	0	0
TAR 10	10	10	0	0	0

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 fork length 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 et al 2004, Boyd & Reilly 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.

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 2004, 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.

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).

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 was collected in standardised computer assisted telephone interviews. 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 fish stocks, 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 with 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 Kaikōura, 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 comprised immature fish. Conversely, TAR 3 set net and TAR 2 trawl landed catches comprised mainly mature fish.

The results of tagging experiments carried out near Kaikōura 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, 2021).

An estimate of natural mortality for tarakihi was derived from the age structures of lightly exploited populations sampled from off 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 Kaikōura made during 1987 ranged from 0.12 to 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 Kaikōura 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	$L\infty$	K	t_0	$L\infty$		
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 and Bay of Plenty and east Northland in TAR 1, 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 Tasman Bay/Golden Bay, and low densities of juvenile tarakihi in East Northland, Bay of Plenty, TAR 2, and along the west coasts of both the North and South Islands. 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 Island and North Island. 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 Kaikōura coast to the Wairarapa, East Cape, and Bay of Plenty areas.

The results from previous tagging studies also indicate some connectivity between Kaikōura 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 with the east coast South and North Island fisheries. Further, growth rates of older fish (more than 6 years) 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 (McKenzie et al 2021). The study reaffirmed the similarity in the age structure of the tarakihi populations along the eastern coast of the North Island and South Island. The study also found contrasting pattern in the age structure from the fisheries off the western coast of the North Island and South Island (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 ascertain the stock affinity of tarakihi from Southland (TAR 5), although this area supports a relatively small catch of predominantly young tarakihi.

A recent study of population genetic structure of tarakihi (*N. macropterus*) from samples collected around New Zealand and the Chatham Islands (Papa et al 2021). 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 been 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. This assessment was updated in 2018 and 2019. A new assessment was conducted in 2021 (Langley 2022).

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 and **Error! Reference source not found.**, 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 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 (WCSI) inshore trawl survey

For TAR 7, trawl survey biomass estimates for pre-recruit (less than 25 cm FL) and recruited (at least 25 cm FL) tarakihi were derived for the west coast South Island and Tasman Bay/Golden Bay (TBGB) areas of the WCSI inshore 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 area are relatively stable through the time series, aside from higher than usual estimates in 2005 and 2017 (Figure 2). Off the west coast, most of the survey biomass comprises recruited fish. In contrast, pre-recruited fish make up most of the TBGB survey biomass. 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. Total biomass estimates showed a gradually declining trend until 2003, a sharp increase in 2005 and 2017, followed by a return to levels similar to those seen from 1997 to 2003 (MacGibbon et al 2022). The 2021 biomass of 969 t is below the time series mean. Almost 99% of the biomass was juvenile fish in 2022, while the adult biomass (over 31 cm) was 98% of the total, compared with 81% in 2019. Of the total tarakihi biomass, over 98% was off the west coast (957 t), and 80% (1011 t) of the total was at depths less than 200 m. Juvenile biomass was noticeably lower than in 2019 and was a much smaller proportion of the total biomass compared with other years.

Length frequencies of tarakihi through the time series show smaller fish are more abundant in TBGB than off the west coast.

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, to monitor elephantfish and red gurnard which were officially included in the list of target species in 2012. Six surveys (2007, 2012, 2014, 2016, 2018, and 2021) 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, the biomass has been trending down since 2007 and the 2021 biomass dropped by 45%, the lowest in the time series (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 in 2021 it was 30%. 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 (56–80%) and in 2021 it was the lowest at 56% (Figure 3a). There was virtually no tarakihi caught in the 10–30 m strata in any of the six 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 thirteen ECSI core strata winter trawl surveys were similar and were multi-modal, with smaller modes representing individual cohorts (Beentjes et al in prep). The 0+ and 1+ and sometimes the 2+ cohorts are evident in most surveys. The 0+ and 1+ cohorts were present in the 2021 survey, but there were fewer larger fish over 25 cm than for any previous survey. Overall, tarakihi off the ECSI 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 Bay/Golden Bay, 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. There is considerable variation in the relative abundance of individual age classes amongst surveys, indicating high inter-annual variability in recruitment.

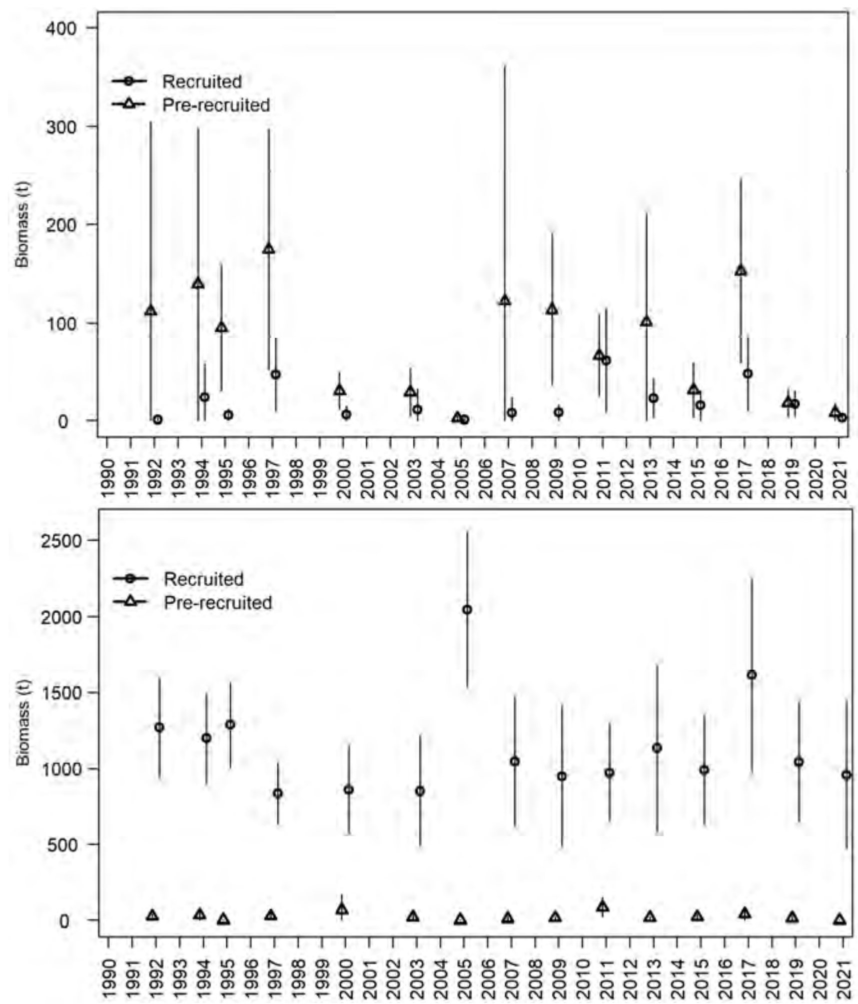


Figure 2: Biomass estimates of pre-recruit (under 25 cm fork length) and recruited (at least 25 cm fork length) for the WCSI inshore trawl survey for Tasman Bay and Golden Bay only (top plot) and west coast South Island only (bottom plot). Error bars are ± two standard deviations.

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 FL).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
Cape	TAR 2	1991	KAH9304	885	27	–	–	–	–	–	–	–	–	–	–
Runaway to		1992	KAH9402	1 128	20	–	–	–	–	–	–	–	–	–	–
Cook Strait		1993	KAH9502	791	23	–	–	–	–	–	–	–	–	–	–
		1994	KAH9602	943	15	–	–	–	–	–	–	–	–	–	–
ECSI (winter)	TAR 3			30–400 m		10–400 m		30–400 m		10–400 m		30–400 m		10–400 m	
		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	–	–	1 522	46	–	–
		1994	KAH9406	1 219	41	–	–	494	31	–	–	725	35	–	–
		1996	KAH9606	1 656	24	–	–	519	30	–	–	1 137	27	–	–
		2007	KAH0705	2 589	24	–	–	822	30	–	–	1 766	24	–	–
		2008	KAH0806	1 863	29	–	–	739	44	–	–	1 123	25	–	–
		2009	KAH0905	1 519	36	–	–	525	42	–	–	994	42	–	–
		2012	KAH1207	1 661	25	–	–	584	34	–	–	1 077	29	–	–
		2014	KAH1402	2 380	23	–	–	818	26	–	–	1 562	26	–	–
		2016	KAH1605	1 462	31	–	–	342	40	–	–	1 121	33	–	–
		2018	KAH1803	1 409	26	–	–	409	28	–	–	1 000	28	–	–
		2021	KAH2104	775	38			236	56			539	33		
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	–	–	–	–	–	–	–	–	–	–
	TAR 7	1992	KAH9204	1 409	14	–	–	–	–	–	–	–	–	–	–
WCSI inshore		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	–	–	–	–	–	–	–	–	–	–
		2021	KAH2103	969	25	–	–	–	–	–	–	–	–	–	–

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

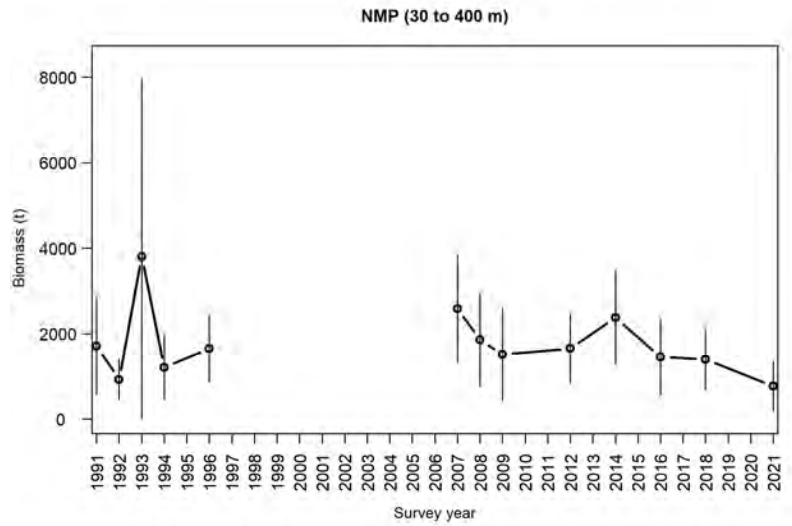


Figure 3: Tarakihi total biomass for the ECSI winter surveys in core strata (30–400 m). Error bars are ± two standard errors.

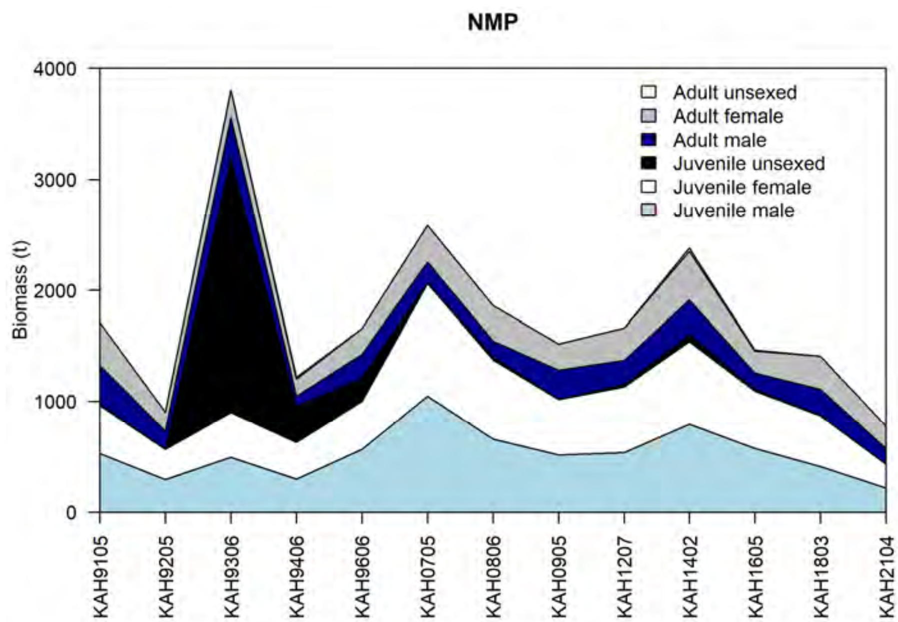


Figure 2a: Tarakihi juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below, and adult is equal to or above, the length at which 50% of fish are mature.

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.

4.2 CPUE analyses

CPUE indices have routinely been derived for tarakihi from the main inshore fisheries in TAR 1, TAR 2, and TAR 3. The 2021 CPUE analysis was extended to include the main tarakihi trawl fisheries from TAR 5, western TAR 7, and TAR 8 (Table 8).

Table 8: Names and descriptions of the tarakihi CPUE series accepted by the Inshore Working Group in 2021. 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	Distributio n
West coast North Island	WCNI-BT	TAR 1	BT	045, 046, 047	TAR	Event	Lognormal
East Northland	ENLD-BT	TAR 1	BT	002, 003	TAR	Event	Weibull
Bay of Plenty and east coast North Island	BPLE-TAR2-BT	TAR 1 TAR 2	BT	008, 009, 010, 011, 012, 013, 014, 015	TAR, SNA, BAR, SKI, WAR, GUR, TRE, JDO	Daily	Lognormal
Area 18 target set net	TAR3-SN	TAR 3	SN	018	TAR	Daily	Lognormal
Eastern Cook Strait	Cook-BT	TAR 7	BT	017, 018	TAR, STA, BAR, WAR, GSH	Daily	Lognormal
West coast South Island	WCSI-BT	TAR 7	BT	033, 034, 035, 036	TAR, RCO, BAR, WAR, GUR	Daily	Lognormal
Taranaki Bight	TAR8-BT	TAR 8	BT	039, 040, 041	TAR	Daily	Lognormal
Southland	TAR5-BT	TAR 5	BT	025, 030	STA, TAR	Daily	Lognormal

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 2019–20 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 and the WCNI-BT and TAR 8 trawl fisheries, the CPUE indices were derived from the lognormal CPUE model of positive tarakihi catch (due to the small proportion of zero catches in the data set).

The CPUE series for the eastern fisheries have been incorporated in the stock assessment of eastern tarakihi. The 2021 CPUE analyses amalgamated the Bay of Plenty and TAR 2 fisheries to derive a single CPUE series, following the amalgamation of these fisheries for the purpose of sampling the age composition of the tarakihi catch. CPUE indices were also developed for the mixed inshore trawl fishery in eastern Cook Strait (Cook-BT) (Statistical Areas 017, 018). The tarakihi fishery in this area catches larger (and older) tarakihi than the trawl fishery in the Pegasus Bay/Canterbury Bight area. A review of the TAR3-BT CPUE analysis highlighted conflicting trends between the CPUE indices and the tarakihi abundance indices from the ESCI inshore trawl survey, with diagnostic analyses indicating that the CPUE analysis was not adequately accounting for large changes in targeting behaviour (from red cod to tarakihi). The TAR3-BT CPUE series was therefore excluded from the 2021 eastern tarakihi stock assessment—the main index of abundance for this area coming from the ECSI trawl survey

The BPLE-TAR2-BT CPUE series reached a peak during 2000–01 to 2004–05 (Figure 4). There were corresponding peaks in the CPUE indices from the ENLD-BT, Cook-BT, and TAR3-SN fisheries at about the same time. More recently, the Cook-BT and TAR3-SN CPUE indices increased considerably from 2015–16 to 2019–20. There was no corresponding increase in the BPLE-TAR2-BT CPUE indices. The ENLD-BT CPUE indices declined considerably during 2008–09 to 2019–20, particularly following higher catches taken in 2013–14 to 2018–19.

The northern WCNI trawl fishery (WCNI-BT) CPUE indices declined considerably from the late 1990s following an increase in the overall level of catch from the fishery.

CPUE indices were developed for the TAR 7 mixed trawl fishery targeting TAR, BAR, WAR, RCO, and STA off the west coast of the South Island (Statistical Areas 033, 034, 035, 036). The indices were evaluated by comparing them with the biomass estimates derived from the *Kaharoa* west coast South Island trawl survey for an area and the length range of fish comparable with that of the commercial catch. The trends in the two sets of 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.

The CPUE indices from the target tarakihi fishery in TAR 8 increased during the late 1990s and 2000s and stabilised at a higher level during 2011–12 to 2019–20. Recent age composition sampling from the TAR 8 fishery revealed that recent catches were composed of a broad range of age classes with evidence of relatively strong recruitment over the last few years (fish aged 4–6 years).

The CPUE indices from the Southland trawl fishery fluctuated during 1989–90 to 2009–10 with peaks in CPUE during 1993–94 to 1996–97 and in 2002–03 and 2004–05. The CPUE indices increased considerably from 2009–10 to 2015–16 and remained at the higher level for the four subsequent years. Recent age composition sampling from the TAR 5 fishery suggest recent catches were predominantly composed of relatively young fish (aged 4–5 years).

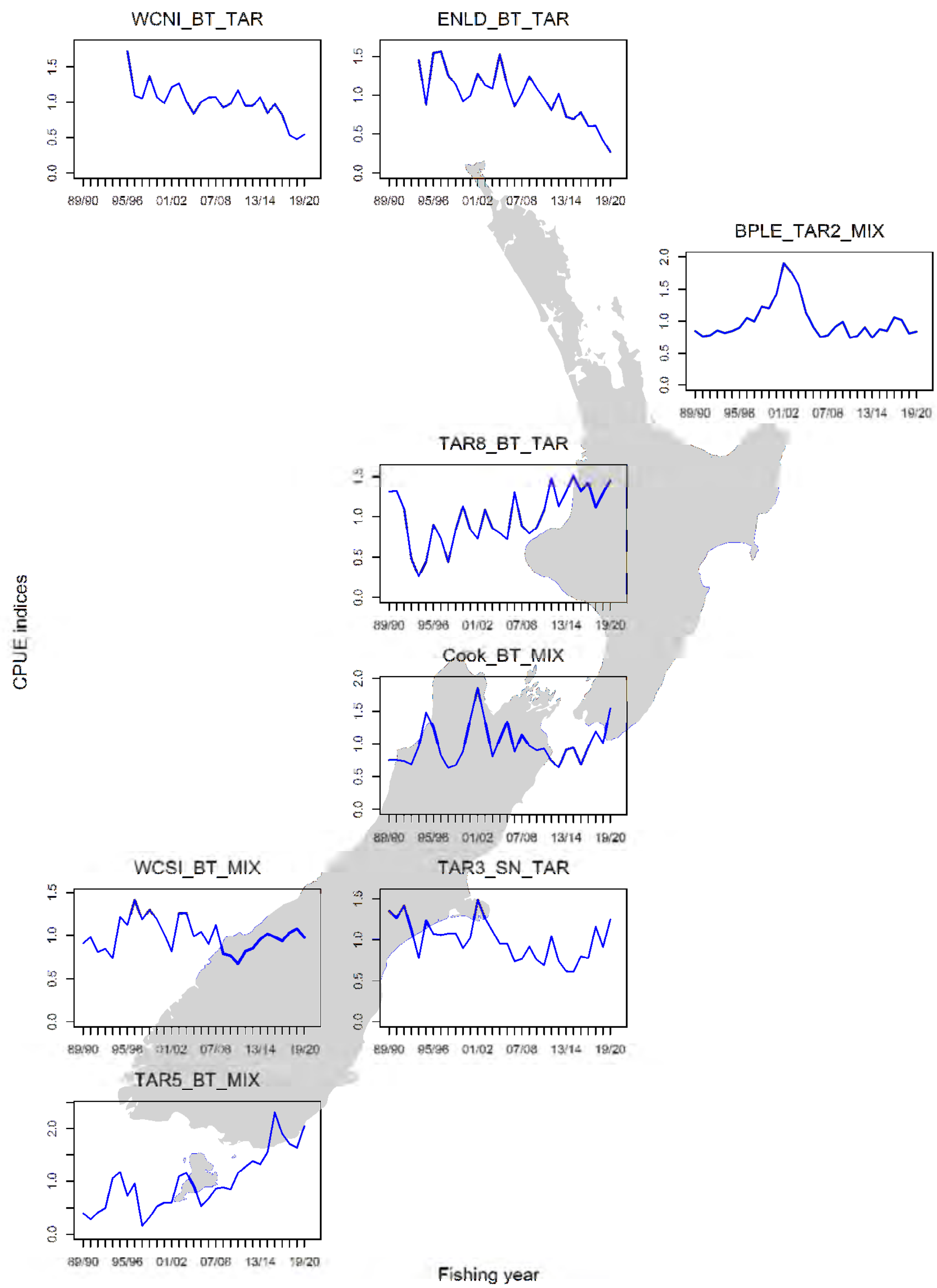


Figure 4: A comparison of the standardised CPUE series from TAR 1, TAR 2, TAR 3, TAR 5, TAR 7, and TAR 8.

4.3 Stock assessment models

East coast North and South Islands (TAR 1E, 2, 3, and TAR 7E)
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). For 2021, the 2017 base case (single area) assessment model was updated, and a more complex three-region spatially structured model was developed as an alternative.

The 2021 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 predominantly 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. The 2021 assessment used a similar fishery configuration to the 2017 assessment, reflecting the spatial scale and information content of the various input data sets. The model options structured the input data into three main model regions: east coast South Island (including eastern Cook Strait), Bay of Plenty and central east coast North Island combined (TAR2-BPLE), and East Northland. The east coast South Island region included three commercial fisheries: the Canterbury Bight/Pegasus Bay trawl fishery (TAR3-BT), Kaikōura 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 1932–2020 (2020 = 2019–20 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 5).
- Recent CPUE indices: TAR3-SN, Cook-BT, combined TAR2-BPLE-BT, and ENLD-BT.
- *Kaharoa* inshore ECSI trawl survey biomass estimates and age/length compositions (both winter (n = 13) and summer (n = 5) time series).
- *Kaharoa* inshore ECSI winter trawl survey juvenile (2 year) abundance indices (n = 8).
- *Kaharoa* inshore ECNI trawl survey biomass estimates and length compositions (n = 3).
- Recent commercial age composition data: TAR3-BT (n = 6), TAR3-SN (n = 4), CS-BT (n = 3), TAR2-BT and BPLE-BT combined (n = 7), and ENLD-BT (n = 4).
- 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 2017 model development phase. These data were uninformative and were not included in the 2021 assessment.

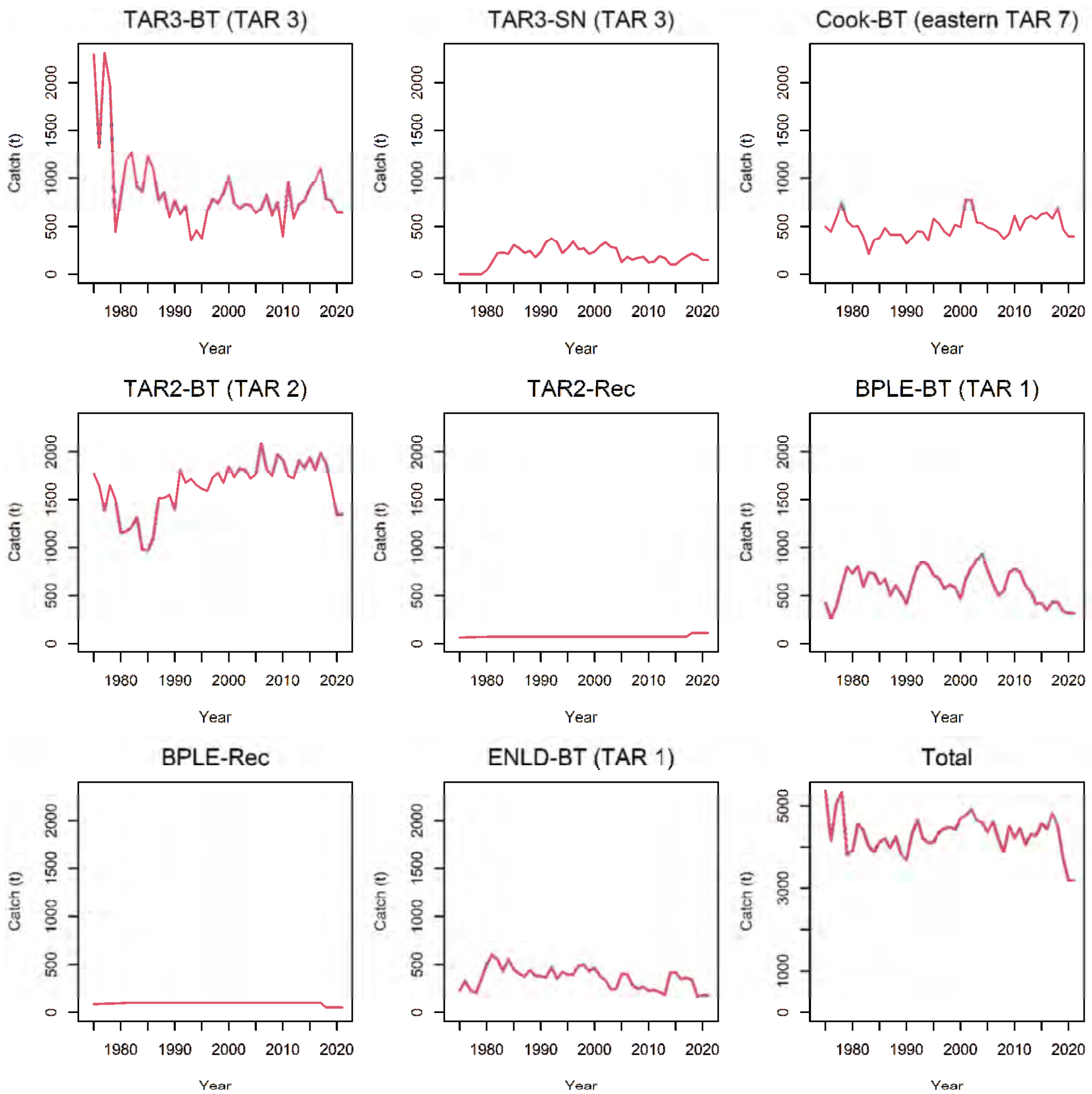


Figure 5: Annual catches of tarakihi by fishery included in the base eastern tarakihi stock assessment. The specific commercial fisheries are: TAR3-BT (TAR 3), TAR3-SN (TAR 3), Cook-BT (includes catch from TAR 2 and eastern TAR7), TAR2-BT (TAR 2), and BPLE-BT (TAR 1), ENLD-BT (TAR 1). Rec is recreational fishery.

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 2021 assessment two contrasting sets of models were configured: a single region, spatially aggregated model and a three-region, spatially structured model (Table 10). The single region model is comparable with the base case model from the 2017 stock assessment. The single region model was structured as 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 higher proportion of older fish observed in the fishery age composition compared with the other fisheries. The selectivity of the 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 fishery-specific selectivity.

The three-region spatial 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. The movement rate of tarakihi from TAR 3 to TAR2-BPLE was allowed to vary annually (during 1990–2019) to enable the model to fit to different trends in the recent CPUE indices from the two regions. Within each region, the oldest age classes in the population were assumed to be fully vulnerable to the key fisheries (Cook-BT, TAR2-BPLE-BT, and ENLD-BT), whereas other fisheries and surveys were parameterised using a double normal function. Fishery catches were taken from the population in each respective region and the abundance indices (CPUE and/or trawl survey) were taken to represent trends in relative abundance in that region.

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., 1980–2020). 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%, whereas 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.

For the 2017 assessment, preliminary modelling included the entire catch history from 1932. However, for the spatially structured models, the fits to the CPUE and age composition data from the East Northland model were 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.

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

Parameter	**Model option**	
	Single region	**Three region**
Ln R_0	1	1
RecDevs	41	41
Selectivity	33	27
Initial *F*	5	5
Movement	0	34
Total	80	108

The regional distribution of catch is considered to be more reliable from about 1965 onwards. For the 2017 assessment, the main model options included two models that were initialised in 1975. Initial (1975) conditions were determined by estimating (five) fishery specific levels of fishing mortality (Initial *F*s) 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 current (2021) assessment, the two main sets of model options (single region and three-region spatially structured model) were initialised in 1975, and model sensitivities incorporated uncertainty in the initial equilibrium catch levels or included the entire catch history (unexploited population initialised in 1932).

Overall, the single region and spatially structured models yielded very similar biomass trajectories and estimates of reference (SB_0) and current biomass (Figure 6). The model results were very similar regardless of whether the models were initialised in 1975 or 1932. Likelihood profiles of the R_0 parameter determining overall stock size revealed that the lower bound of the parameter estimate was informed by the overall magnitude of historical catch and the age composition data from the TAR3-BT and TAR3-SN fisheries and the upper bound of the parameter was informed by age composition data from the ENLD-BT fishery and CPUE indices from ENLD-BT and TAR2-BPLE-BT fisheries.

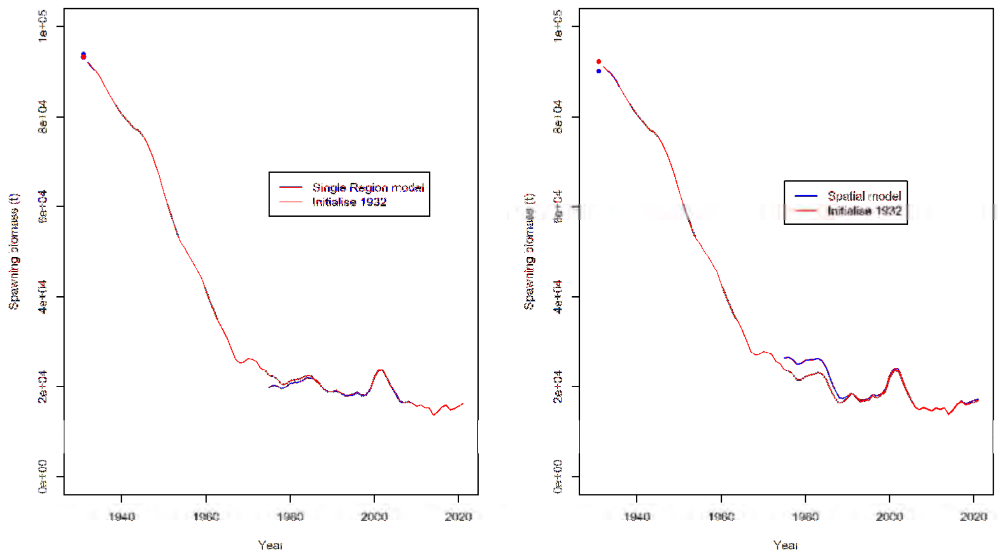


Figure 6: A comparison of the biomass trajectories (median of MCMCs) from the single region model (left) and spatially structured model (right) initialised at 1975 (blue line) or 1932 (red line). The corresponding estimates of the equilibrium, unexploited biomass SB_0 (points) are plotted (arbitrarily) at 1931.

Both sets of models provide a good fit to the age composition data from the fisheries and ECSI trawl survey. The models also provide a good fit to the ECSI trawl survey abundance indices (all biomass and 2 year age-based indices). The increased parameterisation of the three-region spatially structured model results in a considerable overall improvement in the fit to the range of CPUE indices compared with the single-region model, particularly for the last 3–4 years (Figure 7). The single-region model is unable to accommodate the contradictory trends between the increasing CPUE indices from the TAR3-SN and Cook-BT fisheries with the sharp decline in the CPUE indices from ENLD-BT, while CPUE from TAR2-BPLE-BT remained relatively stable (Figure 7). In contrast, the three-region spatially structured model has the capacity to account for variability in regional abundance due to regional-scale differences in exploitation rates; for example, the recent decline in the ENLD-BT CPUE indices followed a period of higher catch from that area. The three-region spatial model also has considerable flexibility to fit to the differential trends in the CPUE indices via inter-annual variation in movement of fish from TAR 3 to TAR2-BPLE regions.

There are limited observations available to strongly inform the movement parameters of the spatial model. The increased number of parameters may be accounting for inter-annual variation in the movement of mature tarakihi and/or variation in the distribution of recruitment between the regions or other spatial dynamics not accounted for explicitly within the assessment model. Additionally, the movement parameters may simply be accounting for sampling error in the individual sets of CPUE indices (i.e., nuisance parameters). On balance, the Plenary selected the three-region spatial model as the preferred model option (‘base case’) and the single-region model was retained as a credible alternative model option. The final set of model sensitivities were conducted for the three-region ‘base case’ model.

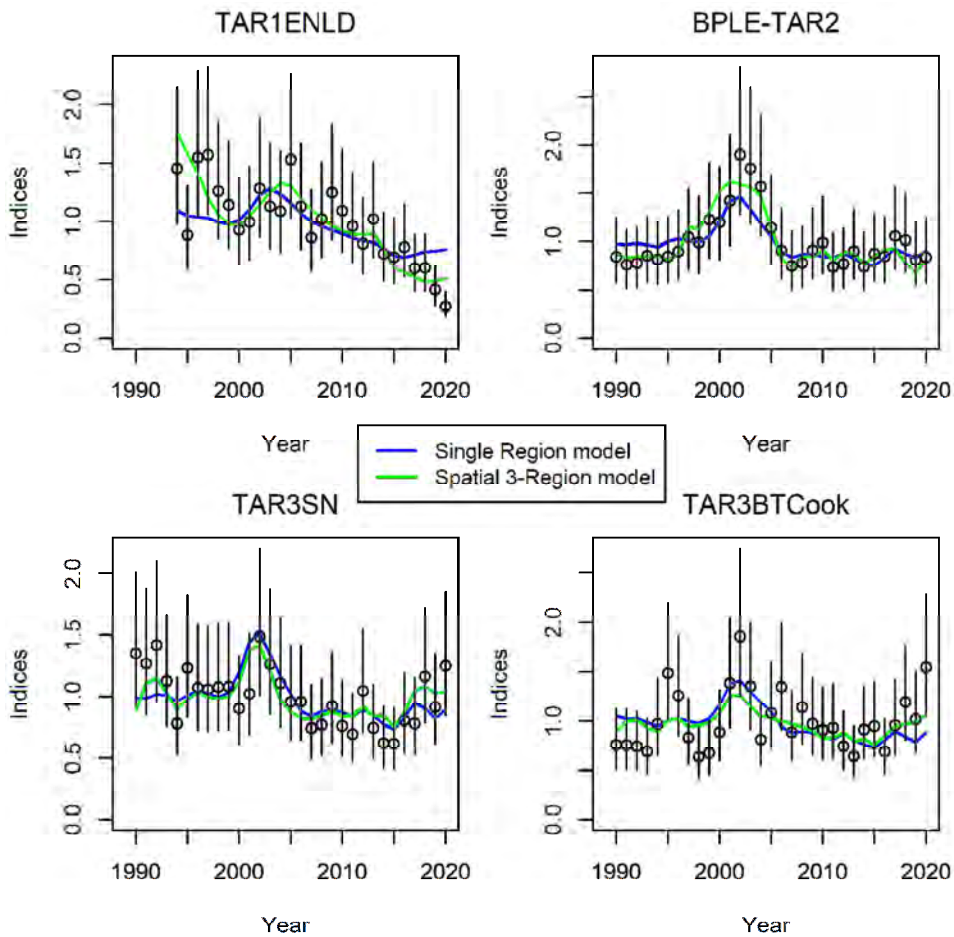


Figure 7: The fit to the individual sets of CPUE indices from the single-region model and three-region spatial model ('base case').

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 per annum) 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 (R_0) and, hence, equilibrium, unexploited biomass (SB_0). The overall levels of depletion are linked to the estimates of Initial F (in 1975) informed by the assumed level of initial equilibrium catches.

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 (three-region spatially structured model) to investigate the influence of five key assumptions (Table 11). Current stock status was defined as the mid-year spawning biomass (male and female fish) in 2020–21 relative to equilibrium, unexploited biomass (SB_{2021}/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., $F_{2021}/F_{SB40\%}$).

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
Start1932	Entire catch history, unexploited equilibrium conditions in 1932.

Spawning biomass is estimated to have declined to about 20–30% 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, moderated by variation in recruitment, especially a period of higher recruitment during the mid-late 1990s. Spawning biomass is estimated to have been below the default soft limit since the mid-2000s, and current spawning biomass (2021) is estimated to be at 19% (three-region spatially structured model) and 17% (single-region model) of the unexploited, equilibrium biomass level (SB_{2021}/SB_0 = 0.193 or 0.171) (Table 12). Spawning biomass increased slightly from the lowest level in 2014 (Figure 8a and Figure 8b), following above average recruitment in 2011–2012 (Figure 9a and Figure 9b) and recent reductions in TACC and catch. Recruitment was estimated to be below average in 2017 and 2018, while the most recent year classes (2019 and 2020) were estimated to be at about the average level.

The stock status is similar for the range of model options and sensitivities, although the stock status is more pessimistic for the model sensitivities with lower productivity parameters. For the base case parameterisation, the singe-area and three area models estimate a high probability (60% three-region spatial model or 86% single-region model) that the spawning biomass is below the soft limit, and a very low probability (< 1%) of being below the hard limit of 10% SB_0 (Table 12).

Table 12: Estimates of current (SB_{2021} 2020–21) 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 for the three-region base case model and associated sensitivities and the single-region model.

Model option	SB_0 (t)	SB_{2021} (t)	SB_{2021}/SB_0	Pr (SB_{2021} > X%SB0)		
				40%	20%	10%
Base	**88 256**	**17 009**	**0.193**	**0.000**	**0.421**	**0.999**
Three-region, spatial	**(84 776–92 076)**	**(11 246–22 596)**	**(0.128–0.252)**			
InitialCatchVar	85 123	15 675	0.184	0.000	0.305	0.997
	(80 298–89 833)	(9914–20 907)	(0.119–0.243)			
LowM	103 724	16 322	0.157	0.000	0.048	0.954
	(99 242–108 383)	(9167–21 624)	(0.089–0.21)			
Maturity	71 847	10 187	0.142	0.000	0.018	0.924
	(69 006–75 119)	(6232–14 249)	(0.087–0.196)			
Start1932	91 580	16 699	0.183	0.000	0.281	0.995
	(89 227–94 136)	(10 700–21 520)	(0.117–0.236)			
Steepness 0.8	95 243	17 633	0.185	0.000	0.337	0.982
	(91 082–99 834)	(10 032–24 095)	(0.108–0.253)			
Single Region	**93 785**	**16 123**	**0.171**	**0.000**	**0.144**	**0.991**
	(88 756–98 577)	**(10 391–21 223)**	**(0.114–0.223)**			

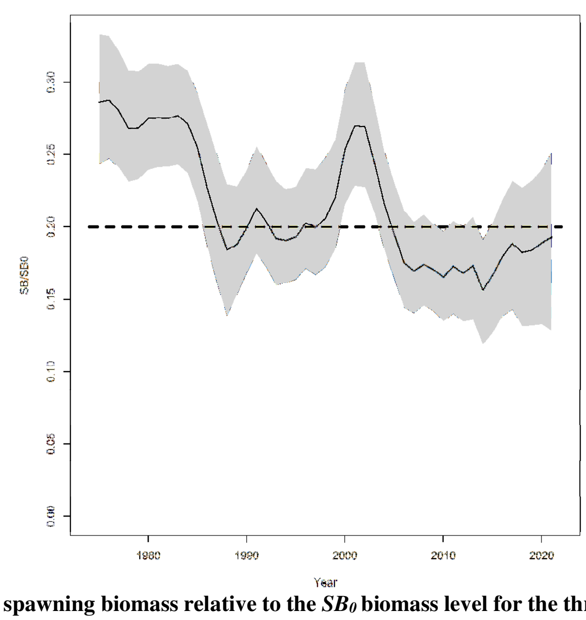


Figure 8a: Annual trend in spawning biomass relative to the SB_0 biomass level for the three-region spatial model (base model), including the 20% SB_0 soft limit. The line represents the median and the shaded area represents the 95% confidence interval.

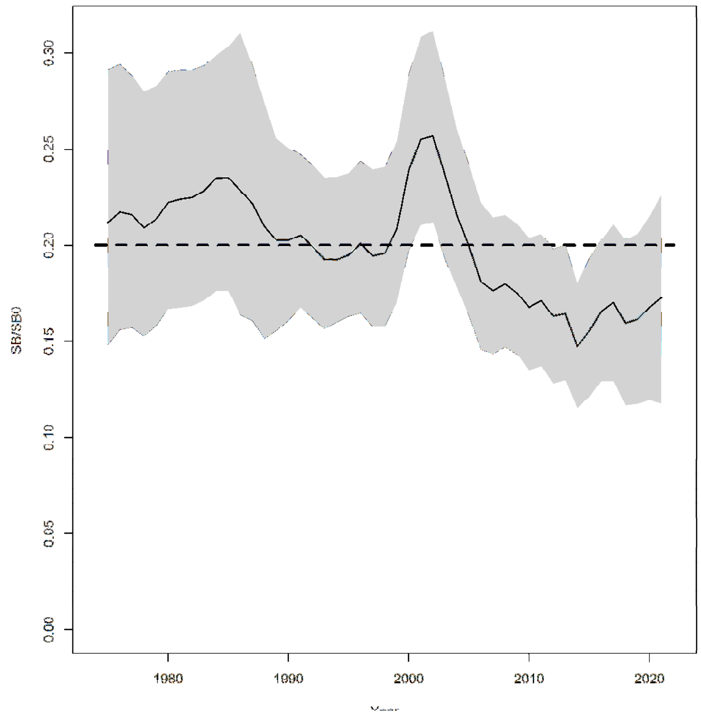


Figure 8b: Annual trend in spawning biomass relative to the SB_0 biomass level for the single-region model, including the 20% SB_0 soft limit. The line represents the median and the shaded area represents the 95% confidence interval.

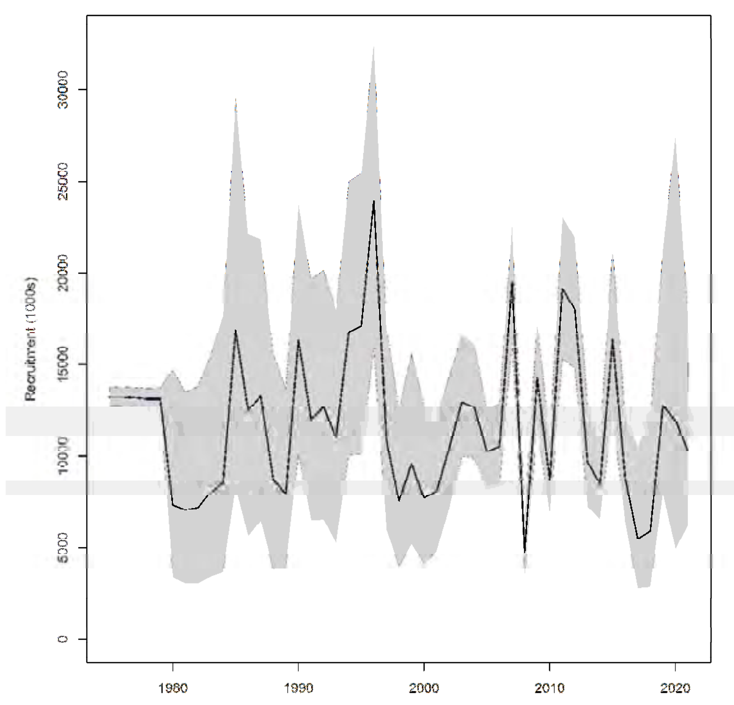


Figure 9a: Annual recruitments from the three-region spatial model (base model). The line represents the median and the shaded area represents the 95% confidence interval.

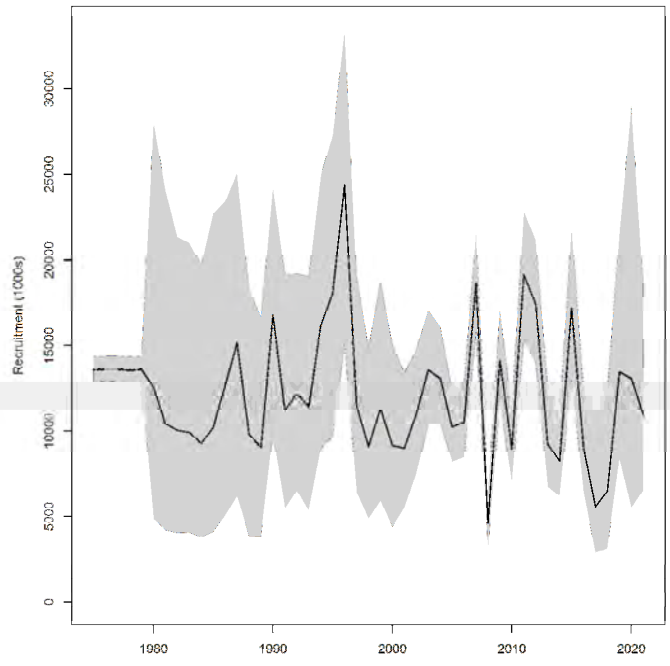


Figure 9b: Annual recruitments from the single region model. The line represents the median and the shaded area represents the 95% confidence interval.

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 10a and Figure 10b). From 2000, fishing mortality rates are estimated to have increased steadily to a maximum level in 2017. Fishing mortality rates declined considerably in 2019 and 2020, following the reductions in TACC, although current fishing mortality rates are estimated to remain well above the reference level (i.e., $F_{2021}/F_{SB40\%}$ = 1.62 three-region model; 1.89 single-region model) (Table 13). The estimates of current fishing mortality rates are similar for the range of model options and sensitivities. Equilibrium yields at the target biomass level are estimated to be about 4100–4300 t compared with current total 2019–20 model catches of 3191 t (including 10% unreported catch).

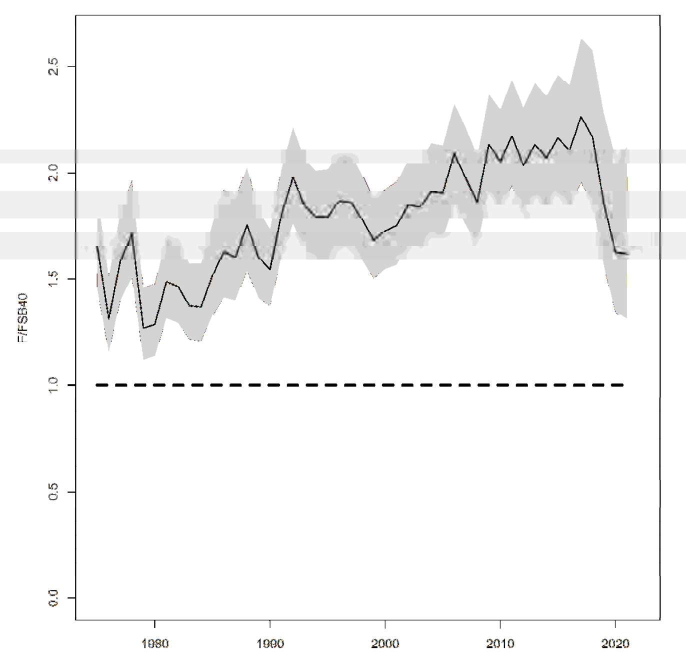


Figure 10a: Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the three-region spatial model (base model). The line represents the median and the shaded area represents the 95% credible interval.

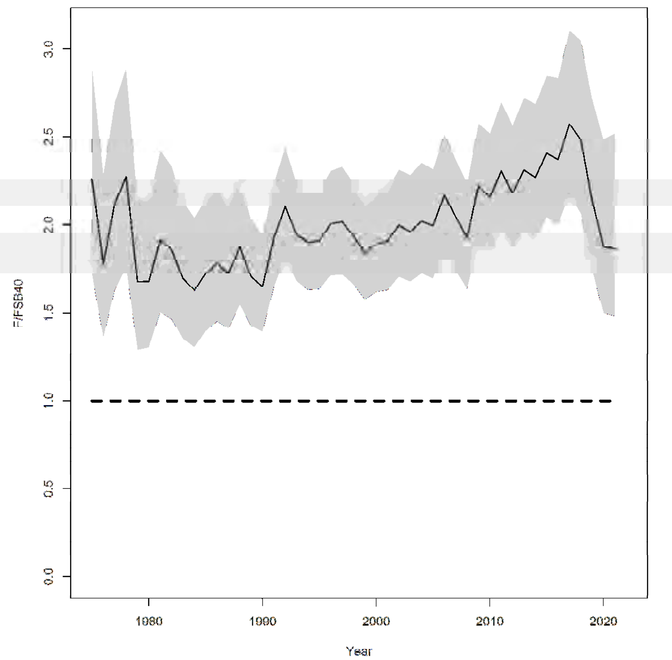


Figure 10b: Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the single-region model. The line represents the median and the shaded area represents the 95% credible interval.

Table 13: Estimates of current (F_{2021} 2020–21) 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 for the three-region base case model and associated sensitivities and the single-region model with base case parameters. The associated levels of $F_{SB40\%}$ equilibrium yield (t) are also presented.

Model option	$F_{SB40\%}$	$F_{2021}/F_{SB40\%}$	Pr(F_{2021}<$F_{SB40\%}$)	$F_{SB40\%}$ *Yield*
Base	**0.093**	**1.619**	**0.000**	**4 213**
Three-region, spatial		**(1.312–2.122)**		**(4 007–4 482)**
InitialCatchVar	0.093	1.744	0.000	4 094
		(1.384–2.306)		(3 845–4 355)
LowM	0.079	2.007	0.000	4 268
		(1.619–2.74)		(4 017–4 647)
Maturity	0.078	1.996	0.000	4 065
		(1.568–2.698)		(3 848–4 347)
Start1932	0.093	1.625	0.000	4 378
		(1.326–2.159)		(4 211–4 679)
Steepness 0.8	0.086	1.724	0.000	4 223
		(1.325–2.444)		(4 003–4 514)
Single-Region	**0.82**	**1.885**	**0.000**	**4 059**
		(1.507–2.571)		**(3 850–4 274)**

Projections

For each model option, stock projections (Table 14) were conducted for the 5-year period following the terminal year of the model (i.e., 2021–22 to 2025–26). During the projection period, recruitment was derived from the SRR with deviates sampled from the normal distribution (standard deviation *sigmaR* =0.6). Recent (10 year and 20 year) model estimates of recruitment were equivalent to the SRR recruitment average level (i.e., average recruitment deviates ~ 0).

Stock projections were based on the status quo (2019–20) commercial and recreational catches, including the 10% allowance for unreported catch. The 2019–20 annual catch for TAR 3 was ~10% less than the TACC.

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 2026 (5 years) from catch based projections for the three-region base case and associated sensitivities and for the single-region model with base case parameters.

Model option	SB_{2020}/SB_0	Pr (SB_{2026} > X%SB_0)		
		10%	20%	40%
Base Three-region	**0.206** **(0.108–0.313)**	**0.987**	**0.542**	**0.001**
InitialCatchVar	0.171 (0.086–0.29)	0.935	0.302	0.000
LowM	0.145 (0.069–0.23)	0.848	0.092	0.000
Maturity	0.146 (0.073–0.228)	0.865	0.099	0.001
Start1932	0.211 (0.122–0.329)	0.995	0.591	0.003
Steepness 0.8	0.160 (0.069–0.273)	0.879	0.221	0.001
Single-Region	**0.192** **(0.105–0.312)**	**0.981**	**0.441**	**0.001**

Qualifying Comments

The stock assessment is strongly dependent on the CPUE series 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. A comparison between the trends in abundance from the ECSI trawl survey and the corresponding fishery (TAR3-BT) revealed that the CPUE standardisation procedures were not adequate to account for large-scale changes in the operation of the fishery (in the absence of trawl resolution data). The reliability of other CPUE indices may be reduced by recent changes in the operation of the fisheries in response to the recent reductions in TACCs.

The relationship between TAR 5 (Southland) and the eastern tarakihi stock is unclear. The limited age composition data available from the TAR 5 fishery are consistent with the corresponding data from TAR3-BT fishery. However, the increasing trend in CPUE from TAR5-BT is not consistent with recent trends in TAR3-BT CPUE indices and ECSI trawl survey biomass indices. Consequently, the 2021 assessment does not include the TAR 5 Fishstock.

Future research considerations

- Continue and possibly intensify catch sampling monitoring of the stock in all areas as 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. Additional sampling of the age composition of the eastern Cook Strait fishery (Cook-BT) would also be beneficial because limited data are currently available from this area.
- Investigate the distribution of juvenile tarakihi along the eastern coasts of the North Island and South Island, including Southland (TAR 5), to evaluate the reliability of the estimates of year class strength from the *Kaharoa* ECSI trawl surveys.
- Improve understanding of the spatial structure of the length/age composition of the tarakihi population from analysis of available catch sampling data.
- Reinstate the *Kaharoa* ECNI trawl survey (FMA 2) to derive further fisheries-independent indices of abundance for tarakihi. The abundance indices and age compositions derived from the reinstated trawl survey should be compared with the previous trawl surveys conducted in the early 1990s (archived otoliths are available from those surveys).
- Consider conducting more tagging studies to obtain better information about fish movements.
- Take changes in fishing technology and operation into account when designing catch sampling schemes and analysing CPUE data. Alternatively, consider adding a parameter (estimated or fixed) that defines a (linear) increase in catchability through time. Improve understanding of fishing behaviour related to targeting or avoiding tarakihi.

- Improve monitoring of the abundance of tarakihi within the ENLD fishery area to verify the recent decline in the CPUE indices from this fishery.
- 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 incidental mortality of tarakihi in FMAs 3 and 7, which have 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 FMA 3 receives most of the recruitment.
- Develop a stock assessment for western tarakihi, incorporating the data available from the west coast of the South Island (catch, trawl surveys, CPUE indices, and age compositions), Tasman Bay/Golden Bay (trawl surveys), and the west coast of the North Island (catch, CPUE indices and age compositions).
- Conduct regular (annual or biennial) updates of the base case assessment model to monitor the performance of the stock rebuild strategy. The model updates would incorporate additional catches, CPUE indices, trawl survey biomass indices, and length/age compositions.
- Investigate the magnitude of unreported tarakihi catches from the main fisheries before and after the introduction of the QMS.

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 (1992–2007), survey proportions-at-age data (1995–2007), 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 Bay, and Golden Bay, 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 15. 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 fitted 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 16). 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 15: 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 16: **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; Qi, ith quantile. The interval ($Q_{0.025}$, $Q_{0.975}$) is a Bayesian credible 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

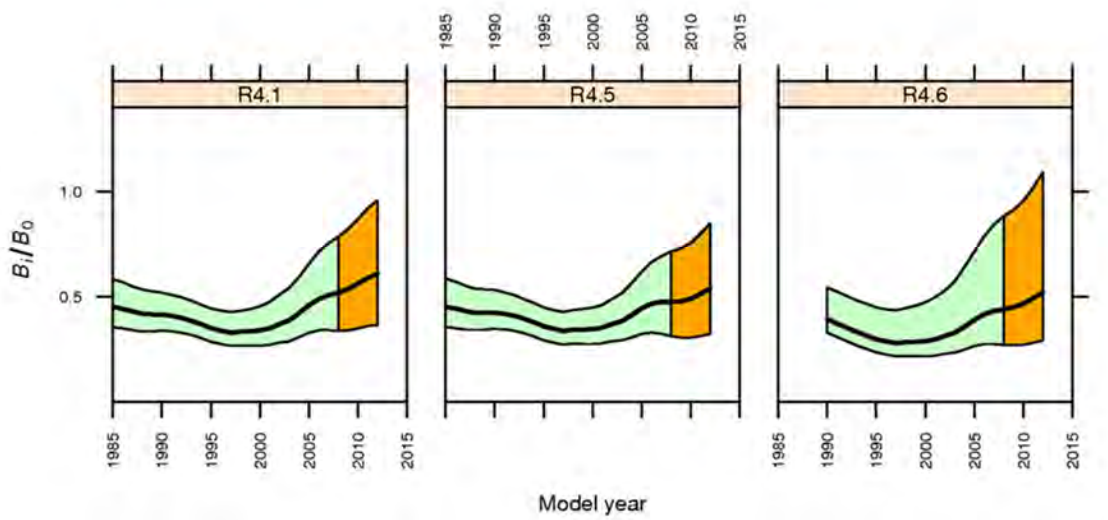


Figure 11: Relative *SSB* trajectories (green) and projected status assuming a future constant catch equal to the current catch (orange) calculated from the MCMC runs for model runs 4.1, 4.5, and 4.6 in the quantitative stock assessment of TAR 7. The shaded region indicates the 95% credibility region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

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 4, 5, 8

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

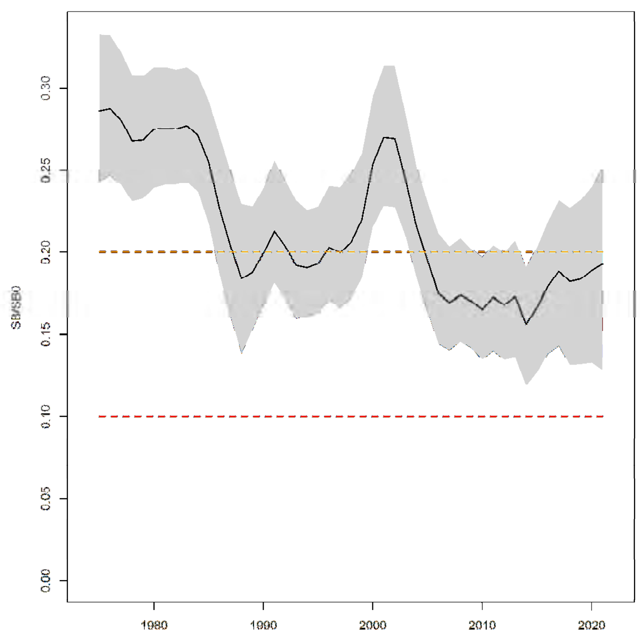
5. STATUS OF THE STOCKS

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

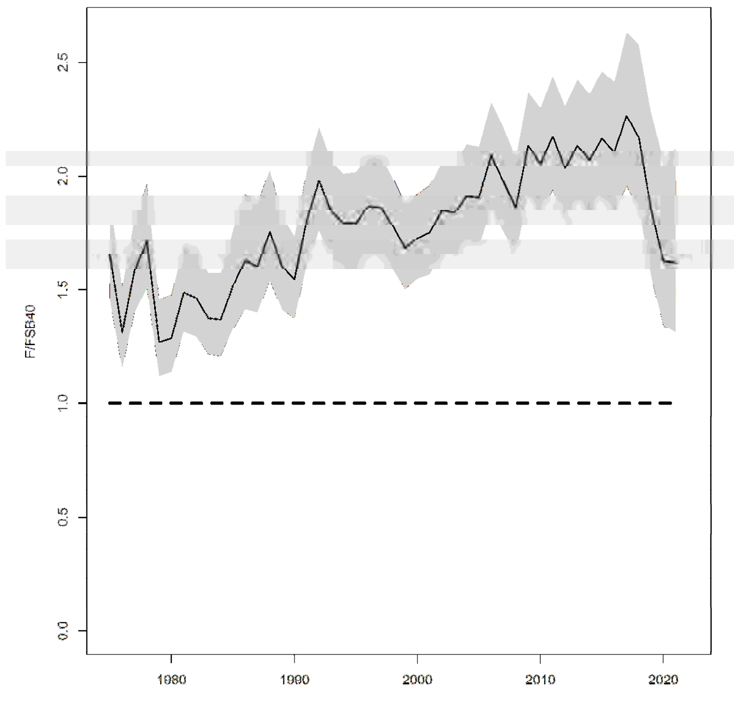
Tarakihi off the east coast of the North Island and South Island are considered to represent a single stock. The spatial domain of the stock assessment encompasses the area from North Cape to Slope Point (southern boundary of TAR 3), including the eastern approaches to Cook Strait (within TAR 7 and TAR 2).

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Base case three-region model
Reference Points	Target: Interim target of 40% SB_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Interim overfishing threshold: $F_{SB40\%}$
Status in relation to Target	$SB_{2020–21}$ was estimated to be 19% SB_0; Exceptionally Unlikely (< 1%) to be at or above the target
Status in relation to Limits	Soft Limit: Likely (> 60%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing threshold: Virtually Certain (> 99%) that overfishing is occurring

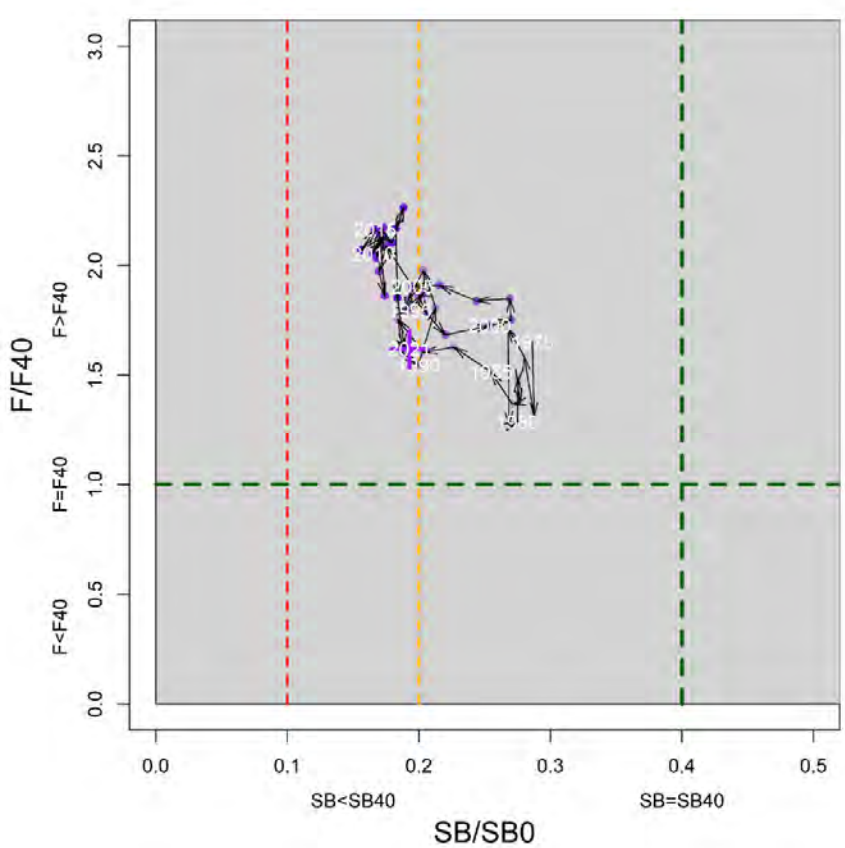
Historical Stock Status Trajectory and Current Status



Annual trend in spawning biomass relative to the 20% SB_0 soft limit and 10% SB_0 hard limit for the updated base model. The line represents the median and the shaded area represents the 95% credible interval.



Annual trend in fishing mortality relative to the $F_{SB40\%}$ 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 $SB_{40\%}$ 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 increased during 2000–2017 and then declined in 2018–19 and 2019–20 following TACC reductions. For the base model, current fishing mortality rate is estimated to be 1.62 times the level of fishing mortality that corresponds to the interim target biomass level ($F_{SB40\%}$).
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections were conducted for a 5-year period assuming the current (2019–20) level of catch across fisheries. Spawning biomass was projected to increase slightly over the next 5 years 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: About as Likely as Not (40–60%) to remain below Hard Limit: Very Unlikely (< 10%) 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	Fishing mortality is projected to decline at current (2019–20) catch levels but is Likely (> 60%) to remain above the reference level over the next 5 years.

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: 2022	Next assessment: 2026
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 - *Kaharoa* trawl survey 2 year abundance estimates	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Development of three-region spatially structured model - Refinement to CPUE indices incorporated in the assessment model, including combining BPLE and TAR2 CPUE indices - Inclusion of trawl CPUE indices from eastern Cook Strait - Inclusion of *Kaharoa* trawl survey 2 year abundance estimates - Exclusion of TAR3-BT CPUE indices	
Major Sources of Uncertainty	- Uncertainty in the stock structure and movement dynamics - Limited catch and effort data from the ENLD fishery may reduce the reliability of the indices for the last 2–3 years - Uncertainty in the maturity ogive	

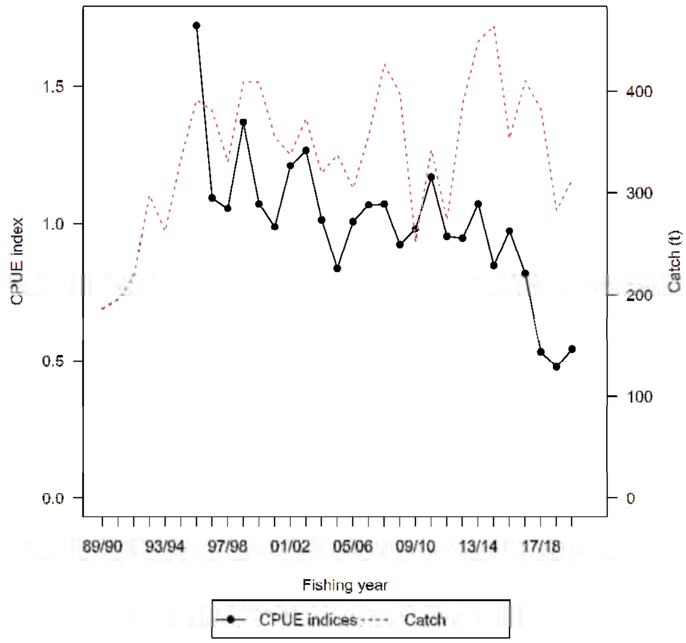
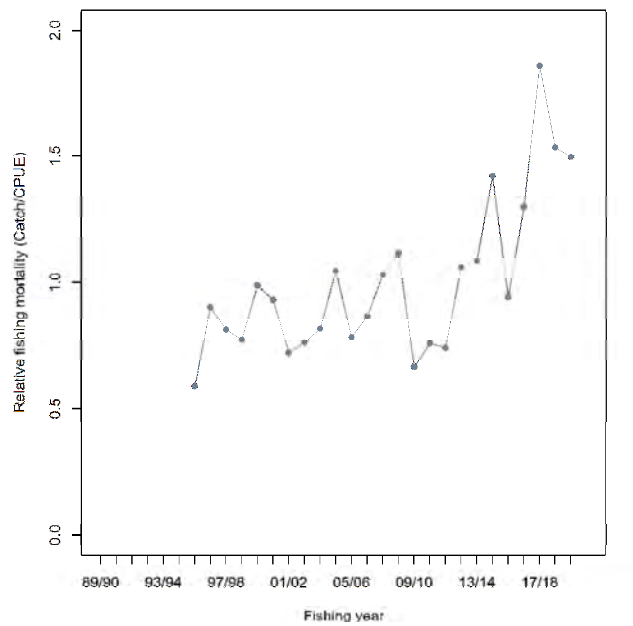
Qualifying Comments
The three-region spatial model was formulated to account for differences in the trends in recent CPUE indices. The estimates of stock status from the base case model (three-region) were comparable with estimates of stock status from a less complex single-region model. Projections 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 1E. 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. TAR 2. This is mostly (80%) a TAR target fishery. The main fishing method is trawling. The following species are the main fish bycatch in this fishery: red gurnard, gemfish, and blue warehou. TAR 3. The main fishing method is trawling. The following species are the main fish bycatch in this fishery: red cod, barracouta, and flatfish. The tarakihi target set net fishery bycatch includes very small amounts of ling and spiny dogfish. TAR 7E. The main fishing method is trawling. The following species are the main fish bycatch in this fishery: red cod, barracouta, and ghost shark.

- **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 2006–07 to 2017–18 and increased to 60% in 2019–20 (following reductions in TACC applied to the eastern area of TAR1).

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	Standardised lognormal CPUE indices derived from trawls targeting tarakihi in the northern area of TAR 1W (Statistical Areas 045–047), 1993–94 to 2019–20
Reference Points	Target: B_{MSY} (value to be determined) Soft Limit: 20% B_0 Hard Limit: 10% B_0 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 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 TAR 1W fishery.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE indices declined by about 25% from the period 1996–97 to 1999–2000 compared with 2014–15 to 2016–17 (by 25%) and were substantially lower in 2017–18 to 2019–20 (45% of the 1996–97 to 1999–2000 level).
Recent Trend in Fishing Intensity or Proxy	Relative fishing intensity increased (by 85%) from the period 2000–01 to 2013–14 compared with 2017–18 to 2019–20.
Other Abundance Indices	- WCNI trawl survey catch rates were consistent with the CPUE series for the equivalent area.
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	Unknown

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: 2021	Next assessment: 2024
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	- CPUE analysis limited to target tarakihi trawls (excluding SNA and TRE)	
Major Sources of Uncertainty	- Only part of the west coast TAR stock is monitored by this series - Relative abundance prior to 1994–95	

Qualifying Comments
The CPUE indices were derived for the northern area of the fishery only (Statistical 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. The catch of TAR from Statistical Areas 045–047 consisted largely of adult fish with the highest proportion of fish >15 years of all west coast fisheries. Declining abundance therefore suggests a decline in spawner biomass on the west coast. 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, and a west coast TAR full quantitative stock assessment is scheduled for 2024.

Fishery Interactions
The main fishing method is trawling. Target tarakihi trawls catch snapper and trevally as bycatch.

- **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.

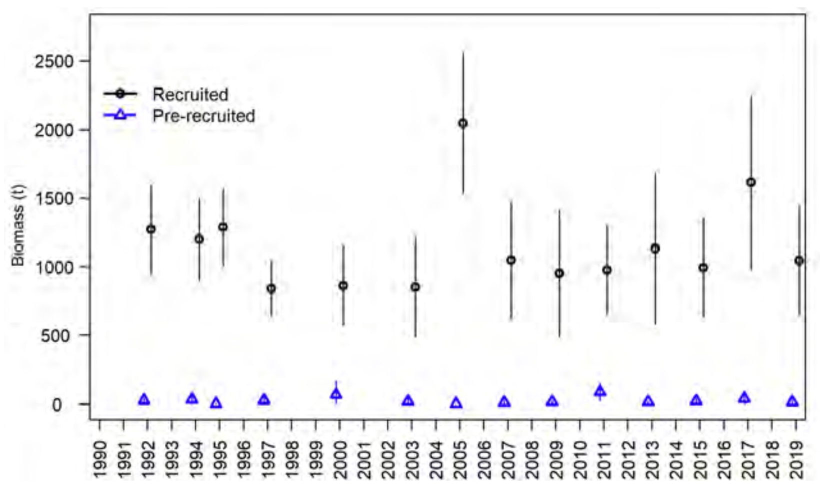
- **TAR 7**

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: 2019	Next assessment: Unknown
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 because it was not considered to represent a reliable index of stock abundance, at least during 1989–90 to 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 also taken as a bycatch at other depths. 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.

- **TAR 8**

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

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