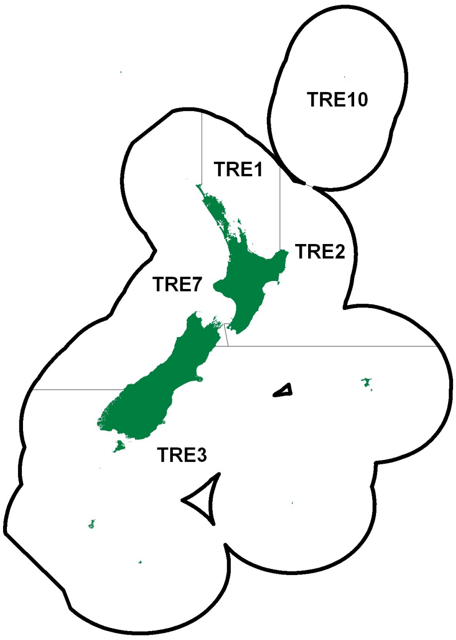
TREVALLY (TRE)

(*Pseudocaranx dentex*)
Araara



1. FISHERY SUMMARY

Trevally was introduced into the QMS in 1986 with five QMAs. A Total Allowable Catch (TAC) was set under the provisions of the 1983 Fisheries Act initially at 3220 t. Since the introduction into the QMS there have been no recreational or customary allocations in TRE 1, 3, 7, or 10; therefore, the total allowable commercial catch (TACC) is the same as the TAC. In 2010, TRE 2 was allocated a 100 t recreational catch, 1 t customary catch, and 7 t for other mortality, combining to make a 350 t TAC.

1.1 Commercial fisheries

Trevally is caught around the North Island and the north of the South Island, with the main catches from the northern coasts of the North Island. Trevally is taken in the northern coastal mixed trawl fishery, mostly with snapper. Since the mid-1970s trevally has been taken by purse seine, mainly in the Bay of Plenty (BoP), in variable but often substantial quantities. Set net fishermen take modest quantities.

Historical estimated and recent reported trevally landings and TACCs are shown in Tables 1 and 2, and Figure 1 shows the historical and recent landings and TACC values for the main trevally stocks.

Trevally landings peaked during the 1970s, with total landings exceeding 6000 t in 1977 and 1978, before declining for all three main trevally stocks: TRE 1, TRE 2, and TRE 7. TRE 1 landings have ranged from 790 t to 1718 t since the introduction of the TACC in 1986–87, with the 2017–18 landings the highest since 1986–87, reducing to 1300 t in 2019–20, and increasing to 1664 t in 2020–21. TRE 2 landings have fluctuated around the TACC of 241 t since it was introduced and have exceeded the TACC in several recent fishing years including 2018–19 when just under 270 t of landings were recorded. Landings from TRE 7 have been under the TACC since 2003–04, and the lowest landings were recorded in 2020–21, at 1147 t.

Table 1: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	TRE 1	TRE 2	TRE 3	TRE 7	Year	TRE 1	TRE 2	TRE 3	TRE 7
1931–32	9	0	0	0	1957	788	235	0	374
1932–33	6	0	0	0	1958	856	197	1	409
1933–34	30	0	0	3	1959	980	175	0	433
1934–35	27	0	0	3	1960	1 141	191	1	686
1935–36	0	0	0	0	1961	1 144	368	0	567
1936–37	0	0	0	0	1962	1 415	431	0	658
1937–38	20	4	0	4	1963	1 284	348	0	769
1938–39	53	10	2	8	1964	1 329	395	2	639
1939–40	17	9	0	6	1965	1 581	344	2	673
1940–41	12	13	0	7	1966	1 568	382	0	1 151
1941–42	17	6	0	4	1967	1 121	472	1	1 512
1942–43	90	1	0	1	1968	1 425	504	0	1 547
1943–44	190	2	0	1	1969	1 428	474	0	1 378
1944	401	2	0	19	1970	2 010	490	0	1 740
1945	307	9	0	23	1971	3 060	779	1	2 109
1946	316	12	2	19	1972	2 738	946	0	2 309
1947	317	8	1	28	1973	1 950	616	0	2 381
1948	432	7	0	34	1974	2 365	687	0	2 077
1949	291	9	0	39	1975	1 470	361	0	1 679
1950	402	39	0	60	1976	2 659	1 026	0	1 994
1951	470	57	0	82	1977	3 749	558	0	2 176
1952	310	73	0	63	1978	3 627	518	1	2 381
1953	376	90	0	136	1979	2 566	449	1	2 658
1954	471	132	0	116	1980	1 471	330	0	2 545
1955	609	120	0	193	1981	1 524	229	0	2 957
1956	556	124	0	179	1982	2 102	135	0	2 548

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns. Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 2: Reported landings (t) of trevally by Fishstock from 1983 to present and TACCs (t) from 1986–87 to present. QMS data from 1986 to present. [Continued on next page]

Fishstock	TRE 1		TRE 2		TRE 3		TRE 7		TRE 10	
FMA (s)	1		2		3, 4, 5, 6		7, 8, 9		10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	1 534	-	77	–	3	–	2 165	–	0	–
1984*	1 798	-	335	–	1	–	1 707	–	0	–
1985*	1 887	-	162	–	1	–	1 843	–	0	–
1986*	1 431	-	161	–	3	–	1 830	–	0	–
1986–87	982	1 210	237	190	< 1	20	1 626	1 800	0	10
1987–88	1 111	1 210	267	219	< 1	20	1 752	1 800	0	10
1988–89	818	1 413	177	235	< 1	20	1 665	2 010	0	10
1989–90	1 240	1 493	275	237	18	20	1 589	2 146	0	10
1990–91	1 011	1 495	273	238	8	22	2 016	2 153	0	10
1991–92	1 169	1 498	197	238	< 1	22	1 367	2 153	< 1	10
1992–93	1 328	1 505	247	241	< 1	22	1 796	2 153	< 1	10
1993–94	1 162	1 506	230	241	< 1	22	2 231	2 153	0	10
1994–95	1 242	1 506	179	241	< 1	22	2 138	2 153	0	10
1995–96	1 175	1 506	211	241	< 1	22	2 019	2 153	0	10
1996–97	1 174	1 506	317	241	< 1	22	1 843	2 153	0	10
1997–98	1 027	1 506	223	241	3	22	2 102	2 153	0	10
1998–99	1 469	1 506	284	241	24	22	2 148	2 153	0	10
1999–00	1 424	1 506	309	241	3	22	2 254	2 153	0	10
2000–01	1 049	1 506	211	241	< 1	22	1 888	2 153	0	10
2001–02	1 085	1 506	243	241	< 1	22	1 856	2 153	0	10
2002–03	1 014	1 507	270	241	< 1	22	2 029	2 153	0	10
2003–04	1 111	1 507	251	241	< 1	22	2 186	2 153	0	10
2004–05	977	1 507	319	241	< 1	22	1 945	2 153	0	10
2005–06	1 149	1 507	417	241	< 1	22	1 957	2 153	0	10
2006–07	790	1 507	368	241	< 1	22	1 739	2 153	0	10
2007–08	847	1 507	230	241	< 1	22	1 797	2 153	0	10
2008–09	855	1 507	302	241	< 1	22	2 018	2 153	0	10
2009–10	814	1 507	261	241	< 1	22	1 966	2 153	0	10
2010–11	1 408	1 507	245	241	< 1	22	1 922	2 153	0	10
2011–12	1 050	1 507	186	241	< 1	22	1 895	2 153	0	10
2012–13	1 301	1 507	197	241	< 1	22	1 842	2 153	0	10
2013–14	1 431	1 507	303	241	< 1	22	1 610	2 153	0	10
2014–15	1 447	1 507	220	241	< 1	22	1 824	2 153	0	10
2015–16	1 576	1 507	285	241	< 1	22	1 949	2 153	0	10
2016–17	1 506	1 507	304	241	< 1	22	1 728	2 153	0	10
2017–18	1 718	1 507	273	241	< 1	22	1 768	2 153	0	10
2018–19	1 394	1 507	269	241	< 1	22	1 427	2 153	0	10
2019–20	1 300	1 507	232	241	< 1	22	1 589	2 153	0	10

Table 2 [Continued]

Fishstock	TRE 1		TRE 2		TRE 3		TRE 7		TRE 10	
FMA (s)	1		2		3, 4, 5, 6		7, 8, 9		10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2020–21	1 664	1 507	240	241	< 1	22	1 147	2 153	0	10

FMA (s)	Total	
	Landings	TACC
1983*	3 779	–
1984*	3 841	–
1985*	3 893	–
1986*	3 425	–
1986–87	2 845	2 230
1987–88	3 131	3 259
1988–89	2 651	3 688
1989–90	3 122	3 906
1990–91	3 308	3 918
1991–92	2 733	3 921
1992–93	3 371	3 931
1993–94	3 624	3 932
1994–95	3 559	3 932
1995–96	3 405	3 932
1996–97	3 333	3 932
1997–98	3 355	3 932
1998–99	3 925	3 932
1999–00	3 989	3 932
2000–01	3 148	3 932
2001–02	3 185	3 933
2002–03	3 313	3 933
2003–04	3 548	3 933
2004–05	3 241	3 933
2005–06	3 524	3 933
2006–07	2 897	3 933
2007–08	2 875	3 933
2008–09	3 175	3 933
2009–10	3 042	3 933
2010–11	3 575	3 933
2011–12	3 131	3 933
2012–13	3 340	3 933
2013–14	3 344	3 933
2014–15	3 521	3 933
2015–16	3 810	3 933
2016–17	3 538	3 933
2017–18	3 759	3 933
2018–19	3 090	3 933
2019–20	3 122	3 933
2020–21	3 051	3 933

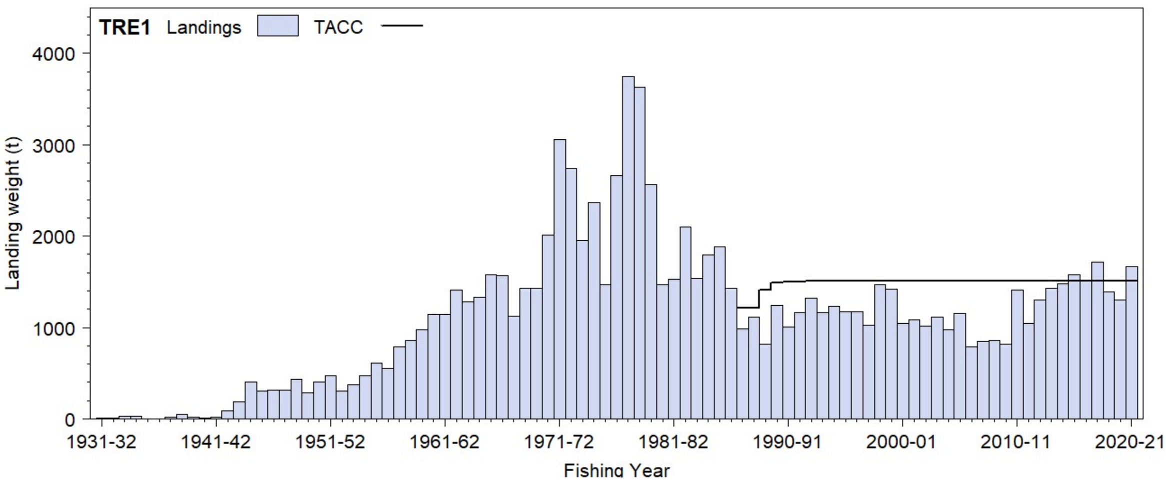


Figure 1: Historical landings and TACCs (t) for the three main TRE stocks. TRE 1 (Auckland). [Continued on next page]

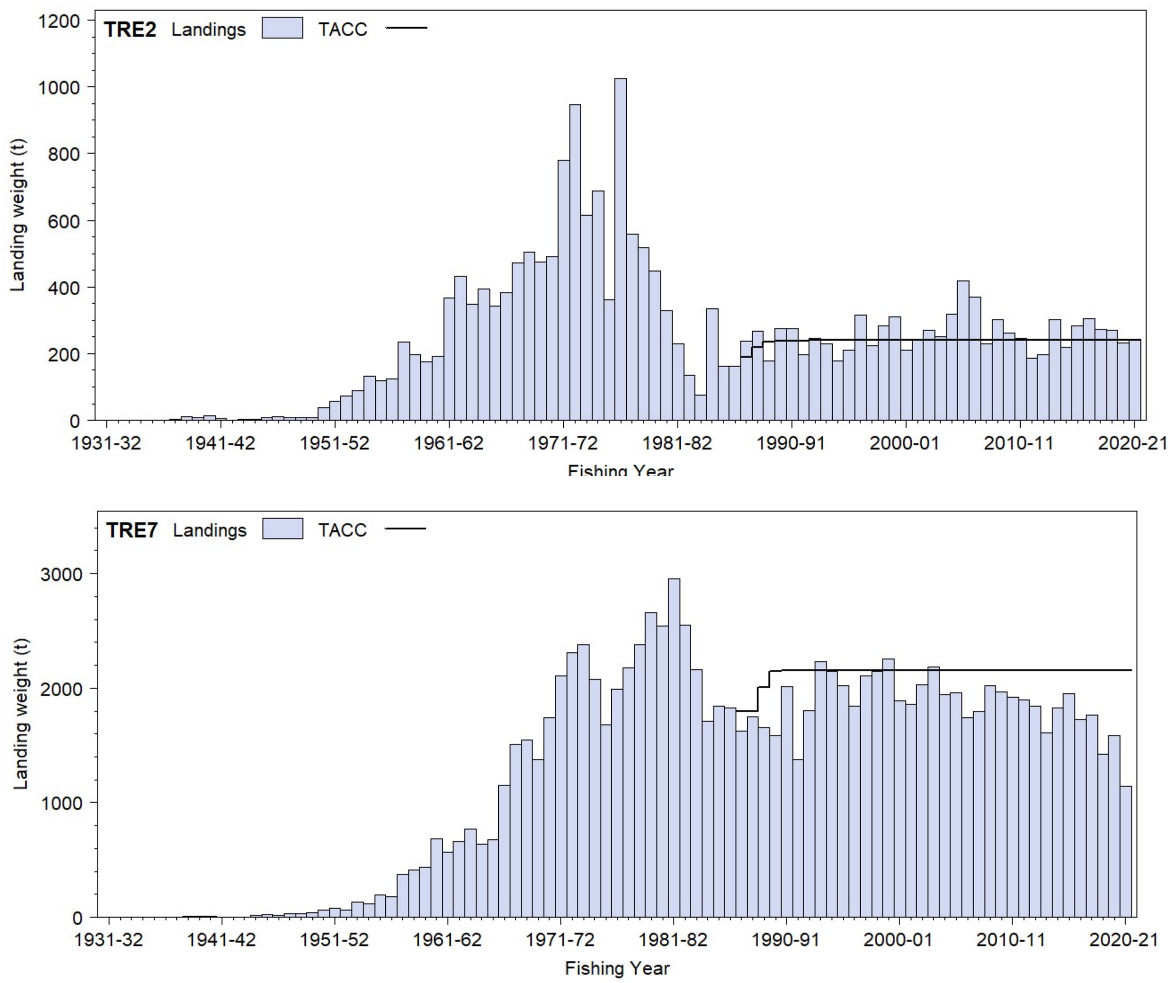


Figure 1 [Continued]: Historical landings and TACCs (t) for the three main TRE stocks. TRE 2 (Central East) and TRE 7 (Challenger).

1.2 Recreational fisheries

Recreational fishers catch trevally by line and set net methods. Although highly regarded as a table fish, some trevally may be used as bait.

1.2.1 Management controls

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

1.2.2 Estimates of recreational harvest

Recreational catch estimates are given in Table 3. 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 trevally were calculated using offsite telephone-diary surveys in 1996 (Bradford 1998), 2000 (Boyd & Reilly 2004), and 2001 (Boyd et al 2004).

The harvest estimates provided by these telephone diary surveys are no longer considered reliable for various reasons. With the early telephone/diary method, fishers were recruited to fill in diaries by way of a telephone survey that also estimates the proportion of the population that is eligible (likely to fish). A 'soft refusal' bias in the eligibility proportion arises if interviewees who do not wish to co-operate falsely state that they never fish. The proportion of eligible fishers in the population (and, hence, the harvest) is thereby underestimated. Pilot studies for the 2000 telephone/diary survey suggested that this effect could occur when recreational fishing was established as the subject of the interview at the outset. Another equally serious cause of bias in telephone/diary surveys was that diarists who did not immediately record their day's catch after a trip sometimes overstated their catch or the number of trips made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys (Wright et al 2004).

The recreational harvest estimates provided by the 2000 and 2001 telephone diary surveys are thought to be implausibly high for many species; therefore an alternative maximum count aerial-access onsite method was developed to provide a more direct means of estimating recreational harvests for suitable fisheries. The maximum count aerial-access approach combines data collected concurrently from two sources: a creel survey of recreational fishers returning to a subsample of ramps throughout the day; and an aerial survey count of vessels observed to be fishing at the approximate time of peak fishing effort on the same day. 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 was used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. The methodology is further described by Hartill et al (2007).

Table 3: Recreational harvest estimates for trevally stocks (Bradford 1998, Boyd & Reilly 2004, Boyd et al 2004, Hartill et al 2007, 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. The surveys since 2010 have been run throughout the October to September fishing year and are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey harvest estimates).

Stock	Year	Method	Number of fish	Total weight (t)	CV
TRE 1	1996	Telephone/diary	194 000	234	0.07
	2000	Telephone/diary	701 000	677	0.13
	2001	Telephone/diary	449 000	434	0.19
	2005	Aerial-access *	–	105	0.18
	2012	Aerial-access *	–	124	0.12
	2012	Panel survey	139 473	165	0.11
	2018	Aerial-access *	–	145	0.09
	2018	Panel survey	95 097	125	0.09
TRE 2	1996	Telephone/diary	9 000	13	0.19
	2000	Telephone/diary	153 000	160	0.60
	2001	Telephone/diary	32 000	339	0.23
	2012	Panel survey	10 308	11	0.24
	2018	Panel survey	10 988	17	0.24
TRE 3	1996	Telephone/diary	2 000	3†	–
	2000	Telephone/diary	10 000	10	0.45
TRE 3	2001	Telephone/diary	2 000	12	0.46
	2012	Panel survey	859	1	0.73
	2018	Panel survey	221	<1	0.59
TRE 7	1996	Telephone/diary	67 000	70	0.11
	2000	Telephone/diary	69 000	81	0.27
	2001	Telephone/diary	107 000	124	0.21
	2012	Panel survey	23 123	32	0.16
	2018	Panel survey	31 879	68	0.17

* 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.

† No harvest estimate available in the survey report; the estimate presented is calculated as average fish weight for all years and areas multiplied by the number of fish estimated caught.

This aerial-access method was first employed and optimised to estimate snapper harvests in the Hauraki Gulf in 2003–04. It was then extended to survey the wider FMA 1 fishery in 2004–05 and to provide estimates for other species, including trevally (Hartill et al 2007). This survey was repeated in 2011–12 (Hartill et al 2013) and 2017–18 (Hartill et al 2019).

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al 2014), repeated for the 2017–18 fishing year (Wynne-Jones et al 2019). The panel surveys used face-to-face interviews of a random sample of about 30 000 New Zealand households to recruit a panel of fishers and non-fishers for a full year. Panel members were contacted regularly about their fishing activities and catch information in standardised phone interviews.

Aerial-access surveys conducted in FMA 1 in 2011–12 (Hartill et al 2013) and 2017–18 (Hartill et al 2019) provide independent harvest estimates for comparison with those generated from the concurrent national panel survey. Both survey types appear to provide plausible results that corroborate each other in TRE 1 and are therefore considered to be broadly reliable (Hartill et al 2013).

1.3 Customary non-commercial fisheries

Trevally is an important traditional and customary food fish for Māori. No quantitative information is available on the current level of customary non-commercial take.

1.4 Illegal catch

No quantitative information is available on the level of illegal trevally catch. An estimate of historical illegal catch is incorporated in the TRE 7 stock assessment model catch history (see Section 4.3.2).

1.5 Other sources of mortality

No quantitative estimates are available regarding the impact of other sources of mortality on trevally stocks. Trevally are known to occur in sheltered harbour and estuarine ecosystems particularly as juveniles. Some of these habitats are known to have suffered substantial environmental degradation.

2. BIOLOGY

Trevally are both pelagic and demersal in behaviour. Juvenile fish up to 2 years old are found in shallow inshore areas including estuaries and harbours. Young fish enter a demersal phase from about 1 year old until they reach sexual maturity. At this stage adult fish move between demersal and pelagic phases. Schools occur at the surface, in midwater and on the bottom, and are often associated with reefs and rough substrate. Schools are sometimes mixed with other species such as kōheru and kahawai. The occurrence of trevally schools at the surface appears to correlate with settled weather conditions rather than with a specific time of year.

Surface schooling trevally feed on planktonic organisms, particularly euphausiids. On the bottom, trevally feed on a wide range of invertebrates.

Trevally are known to reach in excess of 40 years of age. The growth rate is moderate during the first few years, but after sexual maturity at 32 to 37 cm fork length (FL), the growth rate becomes very slow. The largest fish are typically around 60 cm FL and weigh about 4.5 kg; however, larger fish of 6–8 kg are occasionally recorded.

Fecundity is relatively low until females reach about 40 cm FL. They appear to be batch spawners, releasing small batches of eggs over periods of several weeks or months during the summer. Biological parameters relevant to stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters.

Fishstock			**Estimate**	**Source**
1. Natural mortality (M)			See Section 4.1.4	
2. Weight = a(length)^b (Weight in g, length in cm fork length)			Both sexes	
	a		b	
TRE 1	0.016		3.064	James (1984)
TRE 1 (BoP)	0.0291		2.8861	Parsons et al (2021)
3. von Bertalanffy growth parameters			Both sexes	
	L_∞	k	t_0	
TRE 1	47.55	0.29	-0.13	Walsh et al (1999)
TRE 1 (BoP)	43.50	0.36	-0.13	McKenzie (in prep)
TRE 7	46.21	0.28	-0.25	

3. STOCKS AND AREAS

There are no new data that would alter the stock boundaries given in previous assessment documents.

4. STOCK ASSESSMENT

4.1 TRE 1

The TRE 1 QMA is believed to contain two biological stocks: East Northland (EN) to Hauraki Gulf (HG), and Bay of Plenty. Stock assessments for each of these stocks were rejected by the Northern Inshore Working Group in 2015 and 2016. The Bay of Plenty assessment was rejected on account of strong conflict between abundance indices (standardised bottom trawl CPUE and aerial sightings).

The East Northland to Hauraki Gulf assessment was not initially attempted because the abundance index, based on standardised bottom trawl CPUE (there are insufficient aerial sightings data for the East Northland area), showed conflicting trends in the positive-catch and proportion-of-zero-catch models. This conflict was due to a trend of increasing reporting of low catches in a tow. CPUE analysis was therefore conducted on data that had been amalgamated to the trip level, which successfully eliminated conflict between the positive-catch and proportion-of-zero-catch models. The resulting standardised bottom trawl CPUE index was accepted by the working group as an index of abundance (Figure 2), but an assessment was not attempted due to the lack of contrast within the index.

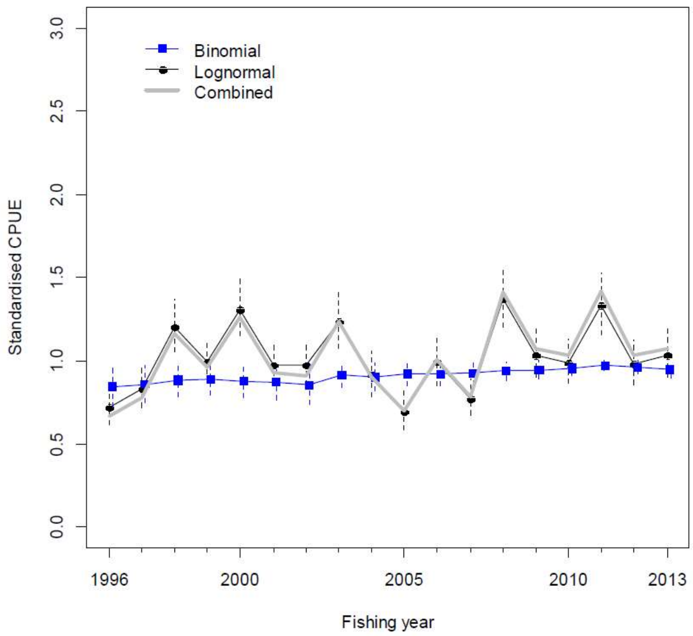


Figure 2: Indices of abundance accepted for the East Northland to Hauraki Gulf stock. Standardised bottom trawl CPUE produced from TCEPR/TCER data forms rolled-up to the trip level. Note that it is the combined index which is accepted as an index of abundance.

Patterns seen in the time series of catch at-age data from TRE 1 suggest that the Bay of Plenty and East Northland regions are likely to constitute two biological sub-stocks (McKenzie et al 2016). An age-based total catch-history assessment model for the Bay of Plenty trevally sub-stock was unable to achieve plausible assessment results when both the aerial sightings and bottom trawl CPUE abundance indices were fitted or when the model was fitted to the aerial sightings index on its own (McKenzie et al 2015). The model was, however, able to achieve plausible estimates for B_0 when the aerial index was excluded, achieving acceptable fits to both the bottom trawl CPUE and the bottom trawl age composition data (McKenzie et al 2015). The working group accepted that the bottom-trawl-index-only model provided a basis for a future assessment of the Bay of Plenty sub-stock; and also recommended that the aerial sightings index should be dropped from future Bay of Plenty assessments due to inconsistency with the other observational data in the model, i.e., catch history, catch-at-age, and bottom trawl CPUE. The working group recommended that assessments for the TRE 1 east Northland and Bay of Plenty sub-stocks should be undertaken, after completion of the next catch-at-age study for TRE 1.

A new assessment for TRE 1 Bay of Plenty was conducted in 2022, with the aerial sightings index dropped, and incorporating updated bottom trawl CPUE and new age composition data.

4.1.1 CPUE

Bay of Plenty

A standardised CPUE index of abundance was used in the 2022 assessment (Table 5, Figure 3). The CPUE data set comprised catch and effort records from the bottom trawl fishery targeting trevally, snapper, tarakihi, John dory, or red gurnard within Bay of Plenty during 1989–90 to 2020–21. Fishing effort records were aggregated by vessel fishing day in a format consistent with the CELR reporting format.

Table 5: Standardised single trawl CPUE indices (relative year effects) for Bay of Plenty from 1989–90 to 2020–21.

Fishing year	CPUE index	Fishing year	CPUE index
1989–90	0.893	2005–06	1.081
1990–91	0.731	2006–07	0.695
1991–92	0.317	2007–08	1.481
1992–93	0.725	2008–09	0.954
1993–94	0.920	2009–10	1.138
1994–95	0.596	2010–11	1.462
1995–96	0.735	2011–12	1.113
1996–97	0.945	2012–13	0.950
1997–98	0.502	2013–14	0.925
1998–99	1.258	2014–15	0.817
1999–00	1.284	2015–16	1.381
2000–01	1.006	2016–17	1.585
2001–02	0.994	2017–18	1.485
2002–03	0.657	2018–19	1.035
2003–04	0.633	2019–20	1.365
2004–05	1.051	2020–21	2.138

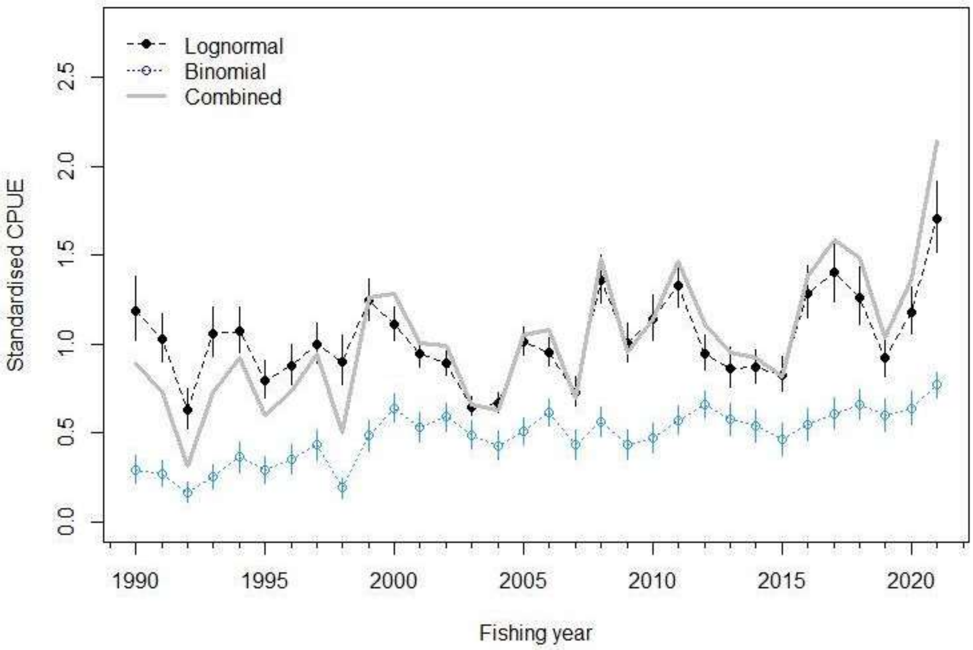


Figure 3: Indices of abundance accepted for the Bay of Plenty stock. Standardised bottom trawl CPUE produced from TCEPR/TCER data aggregated by vessel fishing day. Note that it is the combined index which is accepted as an index of abundance.

The standardised CPUE analysis included two components: a positive trevally catch component modelled assuming a lognormal error structure and a binomial model of the presence/absence of trevally in the vessel daily catch. The CPUE final index multiplied the annual indices from the separate models to derive a combined index.

From 1989–90 to 2020–21, the CPUE indices have an irregular but upward trend, with an approximate doubling over the period.

4.1.2 Catch history

Commercial catch records for TRE 1 Bay of Plenty date back to 1931. Before that time the stock is assumed to have been lightly exploited and close to its unexploited state. It is likely that reported catches prior to 1970 are underestimates of the true catch due to large-scale discarding of fish (James 1984). Since 1931, allowances have been made in the catch history for recreational, illegal catch, and discards. A small amount of catch is assigned to bottom trawl from methods that are not bottom trawl, purse seine, or recreational (e.g., PSH, bottom longline, bottom pair trawl). The final catch history in the assessment model is presented in Figure 4.

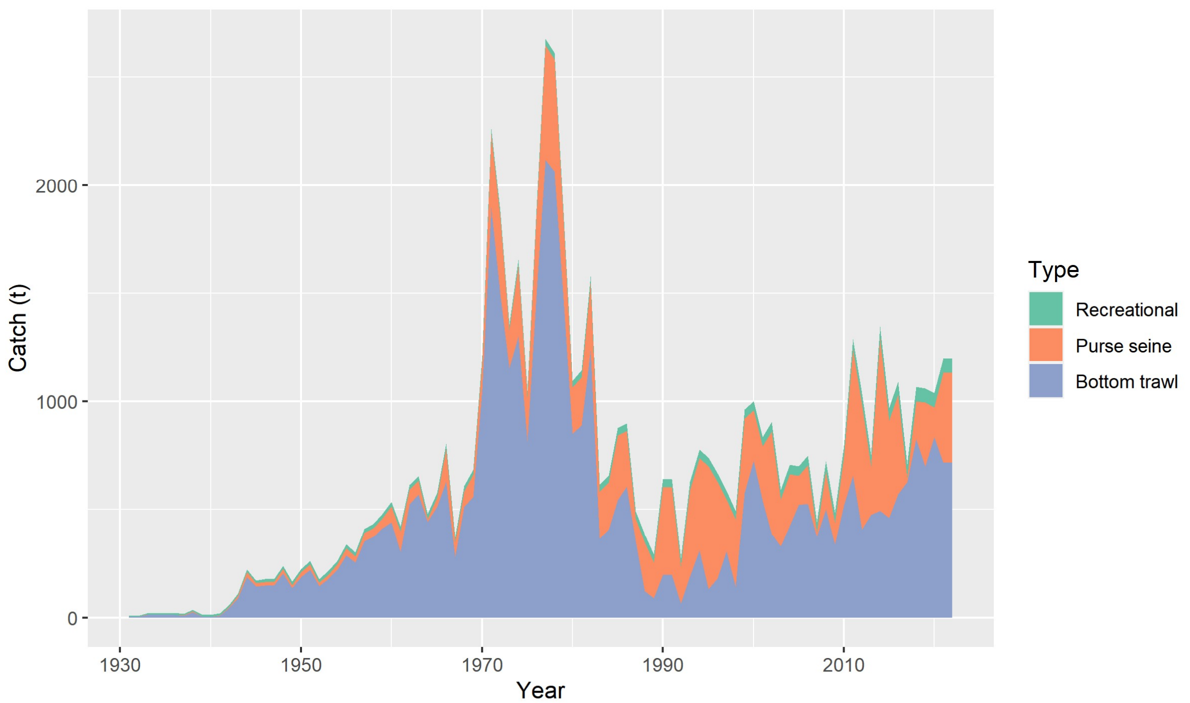


Figure 4: Catch history for the Bay of Plenty area of the TRE 1 fishery including total annual reported commercial catch, estimated discards, illegal catch, and recreational catch.

4.1.3 Catch at age

A time series of age frequency distributions is available from the bottom trawl fishery within Bay of Plenty from 1997–98 to 2019–20 (8 observations). There is also a time series from the purse seine fishery from 1997–98 to 2012–13 (9 observations), which exhibited considerable variability and were down-weighted in the assessment model.

4.1.4 Estimates of natural mortality

Following previous assessments, natural mortality was assumed to be 0.10 based on an observed maximum age of about 45 years (estimated using the equation $M = \log_e 100$/maximum age, where maximum age is the age to which 1% of the population survives in an exploited stock). Estimates of stock status were sensitive to the value of natural mortality and the final mode of the posterior distribution (MPD) model runs included sensitivity runs using a lower value of 0.075 and a higher value of 0.125.

4.1.5 Model structure

The age structured population model encompasses the 1931–2022 period. The model structure is non-sexed with 1–30 year age classes, including an accumulating age class for older fish (30+ years). The age structure of the population at the start of the model is assumed to be in an unexploited, equilibrium state.

The biological parameter for natural mortality is the same as that used in previous trevally assessments, with Bay of Plenty specific estimates for growth and weight-length (see Table 6). For the base model, natural mortality was invariant with age at a value of 0.10. A Beverton-Holt spawning stock recruitment relationship (SRR) was assumed with steepness (h) fixed at 0.85 and the standard deviation of the natural logarithm of recruitment (σ_R) was fixed at 0.6. Recruitment deviates were estimated for the 1970–2015 years.

Table 6: Biological parameters for the Bay of Plenty area in TRE 1.

Fishstock			Estimate	Source
1. Natural mortality (*M*)			See Section 4.1.4	
2. Weight = a(length)^b (Weight in g, length in cm fork length).				
			Both sexes	
		a	b	
		0.0291	2.8861	Parsons et al (2021)
3. von Bertalanffy growth parameters				
			Both sexes	
	L_∞	k	t_0	
	43.5	0.36	-0.13	McKenzie (in prep)

Separate fishery selectivities were estimated for the main bottom trawl fishery (double normal parameterisation) and the purse seine fishery (double normal parameterisation), and a double normal selectivity was estimated outside the assessment model for the recreational fishery. The CPUE indices were linked to the vulnerable biomass of the main bottom trawl fishery.

The model was fitted to: (a) a bottom trawl CPUE index for the years 1990 to 2021, (b) a commercial proportions-at-age series for 1998 to 2020. The weighting of the individual data sets followed the approach of Francis (2011). The final assessment model adopted a CV of 27% for the time series of CPUE indices. The highly variable purse seine age composition data were assigned a low weighting in the likelihood (effective sample size of one).

During model development, a range of options was investigated to examine the key structural assumptions of the model. The most influential assumption was the value of natural mortality (0.10), and the MPD final model runs included sensitivity runs using a lower value of 0.075 and a higher value of 0.125. Other MPD final model run sensitivities were: (a) including the northern part of TRE 2 as part of the stock, and (b) starting the model in a non-equilibrium state in 1983 and dropping the uncertain catch history before then. Sensitivities were undertaken as MPDs, with the base model run taken through a Markov chain Monte Carlo (MCMC) analysis. The right-hand limbs of the trawl and purse seine selectivities were estimated to be flat in the MPD and were fixed at these values for the MCMC runs.

Model projections for a five-year period (2023–27) were conducted. These projections were conducted with catch assumed to be either at the 2022 level, or twenty percent higher. In the projection period, recruitment variation was incorporated in the model with the recruitment deviates resampled from the last ten years (2012–2021), or over the whole period (1970–2021). Parameter uncertainty was determined using an MCMC approach.

4.1.6 Results

The base assessment model indicates that the spawning biomass declined in the 1970s consistent with the high catch taken during this period (Figure 5). From the mid-1980s the spawning biomass increased to 66.4% B_0 (45.2, 95.2) in 2022 (median and 95% credible interval) (Table 7). Recruitment is highly uncertain, but is estimated to have decreased from 1970 to the early 1990s, and subsequently increased to higher but variable levels (Figure 6). Fishing intensity was highest from 1970 to 1985, following the increase in landings over this period (Figure 7).

Of the MPD sensitivities investigated, the most influential was the value of natural mortality (0.10 in the base model). The estimated current status of the stock can vary from 46% B_0 to 84% B_0 depending on the value of natural mortality assumed (0.075 or 0.125, respectively) (Table 8). Incorporating the northern part of TRE 2 into the assessment resulted in little difference to the estimated status of the stock, as did using a non-equilibrium model starting in 1983.

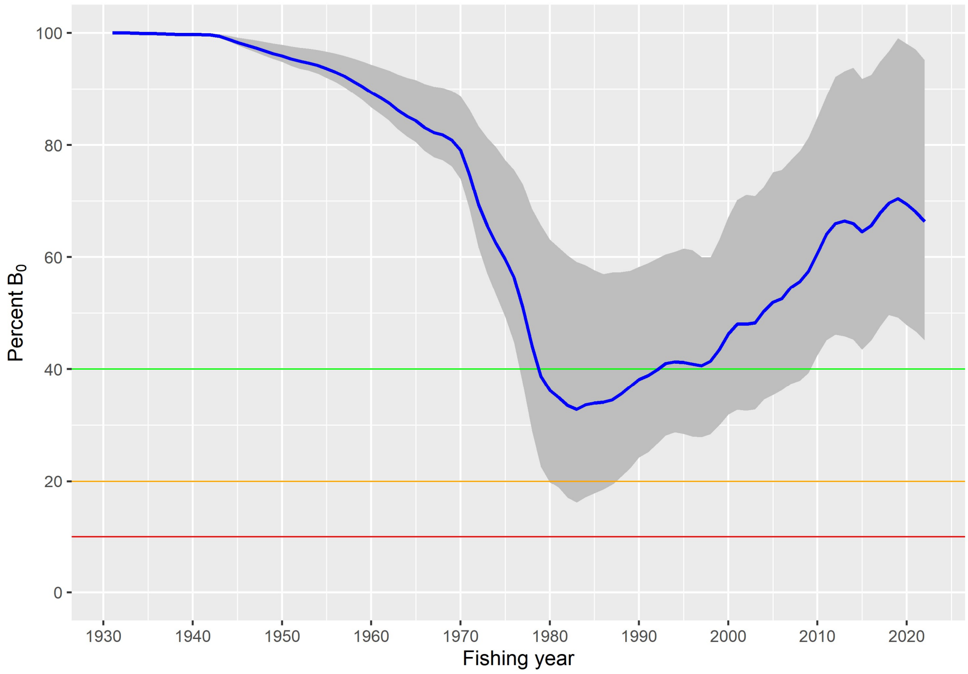


Figure 5: Spawning stock biomass from the MCMC model fits for the base model, with 95% credible interval. Horizontal lines are the 40% target (green), soft limit (20% B_0), and hard limit (10% B_0).

Table 7: Virgin biomass (B_0) and current stock status (% B_0) for the base model with medians and 95% credible intervals. Estimates are derived from MCMC analysis.

Model	B_0 (thousands of tonnes)	B_{2022}(% B_0)
Base	27.1 (21.7, 49.1)	66.4 (45.2, 95.2)

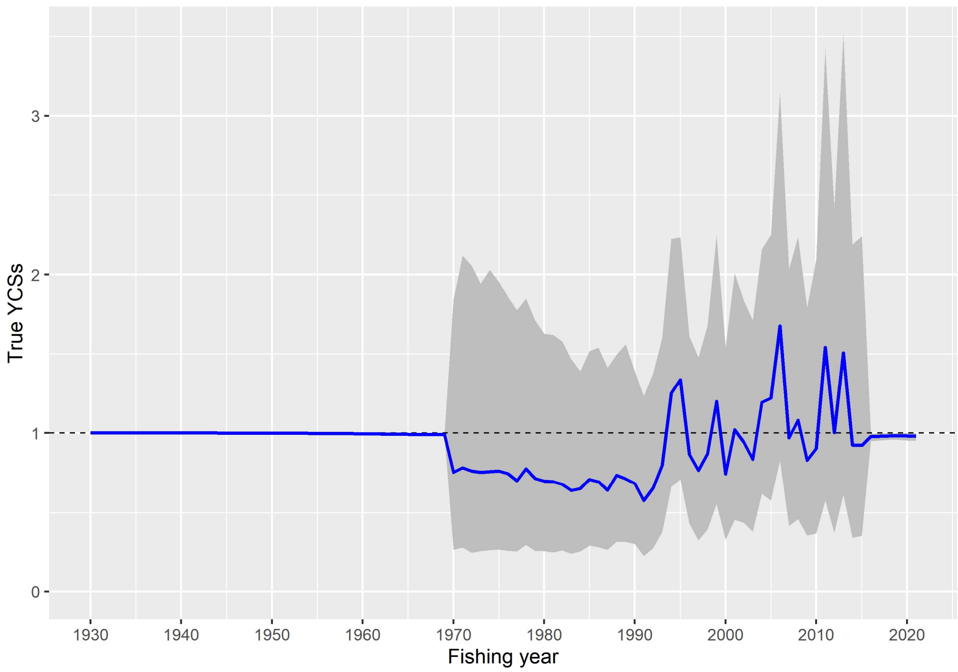


Figure 6: True year class strengths (YCSs) from the MCMC model fits for the base model, with 95% credible interval.

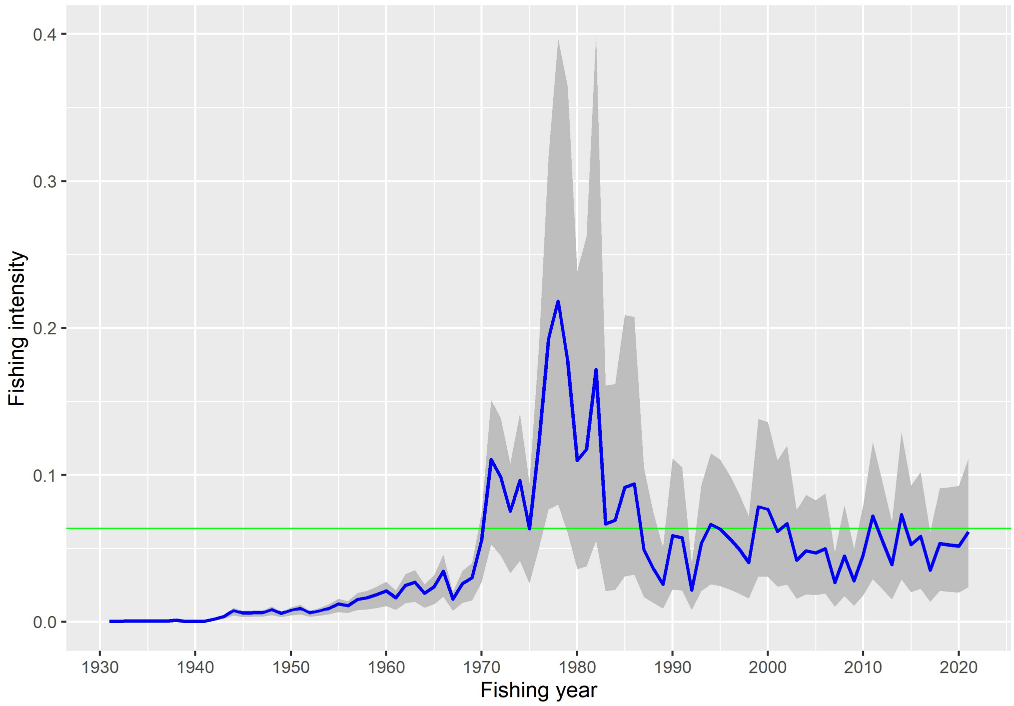


Figure 7: Fishing intensity (total annual landing divided by *SSB*), with 95% credible interval. The horizontal green line is the target fishing intensity corresponding to the 40% B_0 target (MPD calculation).

Table 8: Virgin biomass (B_0) and current stock status (% B_0) for the base model and sensitivities on the natural mortality. Estimates are derived from MPD analysis.

Model	B_0 (thousands of tonnes)	B_{2022}(% B_0)
Base (M = 0.10)	24.0	65
M = 0.075	25.0	46
M = 0.125	26.9	84

4.1.7 Yield estimates and projections

Stock projections, for a five-year period, were conducted for the base model. The projections used either the current assumed 2021–22 catch, or the current catch plus twenty percent. YCSs were sampled from either the last 10 years (2012–2021), or from the start of when YCSs were estimated (1970–2021). For all projection scenarios, there is a low probability that the target biomass will decline below the target level (Table 9, Figure 8).

Table 9: Stock status in the last year (2027) of the five-year forecast period for the base model using either the assumed current catch in 2021–22, or the current catch plus twenty percent. Recruitment was resampled from recent estimates (2012–2021) or long-term estimates (1970–2021).

Projection	Pr(SB_{2027} > X% SB_0)		
	10%	20%	40%
current catch, recent recruitment	1	1	0.966
catch plus 20%, recent recruitment	1	1	0.904
current catch, long-term recruitment	1	1	0.955
catch plus 20%, long-term recruitment	1	1	0.905

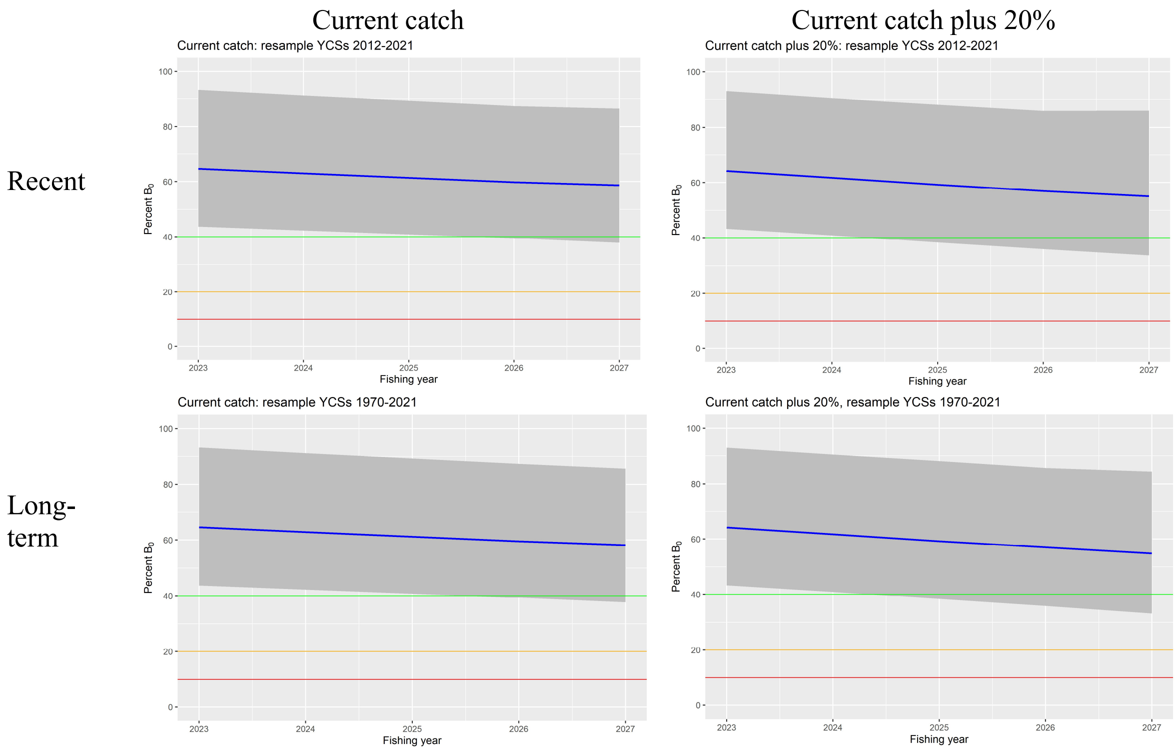


Figure 8: Spawning stock biomass with 95% credible interval during the five-year forecast period for the base model using either the assumed current catch in 2021–22, or the current catch plus twenty percent. Recruitment was resampled from recent estimates (2012–2021) or long-term estimates (1970–2021).

4.1.8 Future Research Considerations

- Undertake simultaneous catch sampling in TRE 1 and TRE 2 to resolve stock relationships and to validate years of recent strong recruitment estimated by the model.
- Further explore CPUE standardisation, including the incorporation of appropriate environmental covariates, sensitivity to the inclusion of key vessels, and potential influences of efficiency creep.
- Explore alternative parameterisation of growth and associated assessment model sensitivities

4.2 TRE 2

High annual variability in standardised CPUE indices, and narrow confidence intervals led the Northern Inshore Working Group to conclude that trevally in TRE 2 are probably part of the TRE 1 biological stock in the Bay of Plenty, with abundance in TRE 2 fluctuating markedly according to the movement of fish into and out of this QMA. Stock assessments for TRE 2 will in future be done in conjunction with TRE 1.

A new CPUE analysis for TRE 2 was conducted in 2018 (Schofield et al 2018). Combined (binomial/Weibull) indices were produced for 1989–90 to 2016–17 using data aggregated to vessel-day resolution, and for 2006–07 to 2016–17 using tow resolution data. There was good correspondence between the two indices for the overlapping period.

Comparison of CPUE trends between the TRE 2 combined series and the TRE 1 BoP index (Figure 9) showed good correspondence between 1989–90 and 2006–07, but a poor relationship thereafter.

For TRE 2, the working group considered that the large variations in the early part of the series, over relatively short time periods, suggest that factors in addition to changes in abundance may be influencing the index.

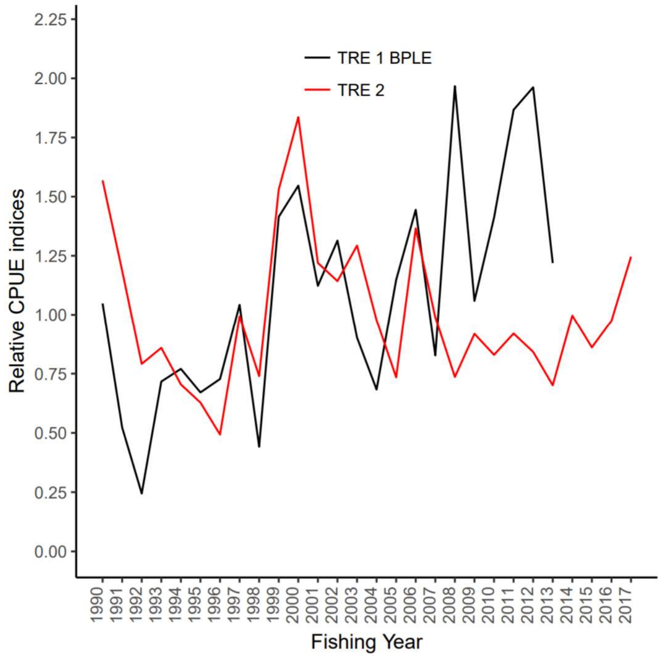


Figure 9: Standardised CPUE for TRE 2 (Schofield et al 2018) and TRE 1 Bay of Plenty (BoP, McKenzie et al 2016).

Data were further analysed in 2022 (McKenzie in prep.) and an attempt was made to develop a stock assessment linking BoP trevally and TRE 2(N), but this was unsuccessful.

4.3 TRE 7

The TRE 7 stock assessment was revised and updated in 2015 (Langley 2015). Recent analyses have revealed considerable differences in TRE 7 age composition data and trends in CPUE indices among the three main fishing areas within the TRE 7 Fishstock; i.e., Ninety Mile Beach (NMB), South Taranaki Bight (STB), and the core area of the fishery between North Taranaki Bight and Tauroa Point (KMNTB). The apparent spatial heterogeneity within TRE 7 indicated that the assumption of a single stock was not appropriate. Attempts to incorporate spatial structure within the TRE 7 assessment model were not successful due to inadequate historical catch-at-age data from the STB and NMB areas (Langley 2015). The final 2015 stock assessment was limited to the core area of the fishery (KMNTB) only. This area accounted for 60% of the total TRE 7 commercial catch from 1944 to 2012–13 and 70% of the catch from recent years (2010–2011 to 2012–13).

4.3.1 CPUE

A standardised CPUE index of abundance was used in the 2015 assessment (Table 10). The CPUE data set comprised catch and effort records from the single bottom trawl fishery targeting trevally or snapper within the core area of the fishery (KMNTB area) during 1990–91 to 2012–13. Fishing effort records were aggregated by vessel fishing day in a format consistent with the CELR reporting format. The final data set excluded one of the vessels that dominated the fishery in recent years. The trend in catch rate of trevally for this vessel differed considerably from the remainder of the fleet and there were also marked differences in the overall age composition of the trevally catches taken by this vessel (Langley 2015).

The standardised CPUE analysis included two components: a positive trevally catch component modelled assuming a Weibull error structure and a binomial model of the presence/absence of trevally in the vessel daily catch. The CPUE final index multiplied the annual indices from the separate models to derive a combined index.

The CPUE indices increase markedly after 2007–08. There were considerable changes in the operation of the fishery during that period related to an increased degree of targeting trevally following the reduction in the TACC for snapper in 2005–06. The CPUE standardisation accounts for a component of the change in the operation of the fishery, although it is unknown whether the shift in targeting is fully accounted for in the final CPUE indices.

Table 10: Standardised single trawl CPUE indices (relative year effects) from 1990–90 to 2012–13 (Langley 2015).

Fishing year	CPUE index	Fishing year	CPUE index
1989–90	–	2001–02	0.805
1990–91	1.291	2002–03	0.882
1991–92	1.202	2003–04	0.783
1992–93	0.862	2004–05	0.620
1993–94	1.181	2005–06	0.855
1994–95	0.980	2006–07	0.685
1995–96	0.888	2007–08	0.920
1996–97	0.830	2008–09	0.819
1997–98	0.782	2009–10	0.828
1998–99	0.992	2010–11	1.209
1999–00	0.764	2011–12	1.055
2000–01	0.678	2012–13	1.023

4.3.2 Catch history

Commercial catch records for TRE 7 date back to 1944. Before that time the stock is assumed to have been lightly exploited and close to its unexploited state. It is likely that reported catches prior to 1970 are underestimates of the true catch due to large-scale discarding of fish (James 1984). Total annual TRE 7 catches were apportioned by fishery area and fishing method (single and pair bottom trawl) (Figure 10). The base assessment model included annual catches from the KMNTB area only. A separate fishery was configured to account for the catch by the single dominant vessel operating in the bottom trawl fishery in recent years.

Since 1944, there has also been a recreational and customary catch as well as an illegal or non-reported catch. For the purposes of modelling the KMNTB component of the TRE 7 stock, it is necessary to make allowance for mortality due to discarded fish, recreational catch, customary catch, and non-reported catch. The final catch history included in the assessment model is presented in Table 11.

4.3.3 Catch at age

A time series of age frequency distributions is available from the target TRE 7 single trawl fishery within KMNTB from 1997–98 to 2012–13 (nine observations). The age sampling data from the dominant single trawl vessel were excluded from the age frequency samples for 2009–10 and 2012–13. There are also some age frequency samples for the pair trawl method from the late 1990s and early 2000s (three observations). Previous comparisons found no significant difference between the age composition of catches made by pair and single trawl methods (Hanchet 1999).

In addition, two sources of age frequency data are available from the 1970s: (1) a series covering the years 1971–74 derived from research sampling carried out by the vessel *James Cook*, and (2) a series derived from market sampling carried out in the 1974–1976 and 1978–1979 fishing years (five observations). There is considerable variability amongst the latter series with the result that these data were relatively uninformative in the assessment modelling and, hence, were down-weighted in the final model options.

4.3.4 Estimate of natural mortality (*M*)

Following previous assessments, natural mortality was assumed to be 0.10 based on an observed maximum age of about 40 years (using the regression method of Hoenig 1983). Estimates of stock status were sensitive to the value of natural mortality and the final model runs included a sensitivity run using a lower value of 0.083, corresponding to an assumed maximum age of 50 years.

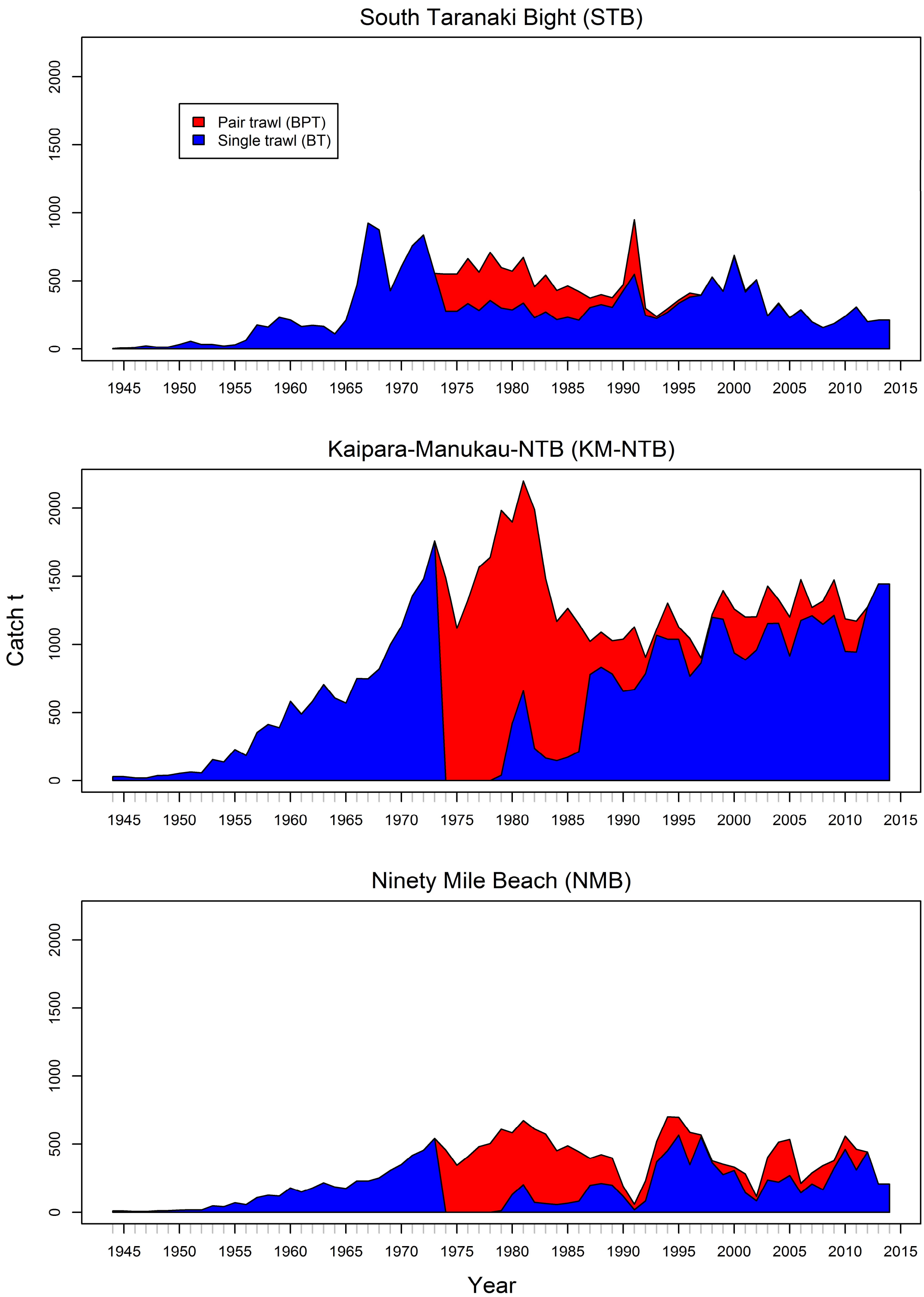


Figure 10: Total TRE 7 commercial catch history formulated for the stock assessment, apportioned by fishing method and sub-area of TRE 7.

Table 11: Catch history (t) for the KMNTB area of the TRE 7 fishery including total annual reported commercial catch, estimated discarded (D) commercial catch, estimated non-reported commercial catch, recreational catch, and customary catch. (The year denotes the year at the end of the fishing year.)

Year	Reported landings	D	Under-reported catch	Rec. catch	Cust. catch	Total	Year	Reported landings	D	Under-reported catch	Rec. catch	Cust. catch	Total
1944	14	9	5	14	15	57	1980	1 582	0	317	70	12	1 981
1945	15	10	5	16	15	60	1981	1 833	0	367	70	12	2 282
1946	10	7	3	18	15	53	1982	1 659	0	331	70	12	2 072
1947	11	5	2	20	15	53	1983	1 237	0	247	70	12	1 566
1948	21	10	5	23	15	74	1984	975	0	195	70	12	1 252
1949	23	13	3	25	15	79	1985	1 053	0	211	70	12	1 346
1950	31	16	6	27	15	95	1986	959	0	192	70	12	1 233
1951	37	19	7	29	15	107	1987	929	0	93	70	12	1 104
1952	33	17	6	31	15	102	1988	1 001	0	90	70	12	1 173
1953	90	45	18	33	15	201	1989	951	0	76	70	12	1 109
1954	79	40	16	36	15	186	1990	971	0	68	70	12	1 121
1955	134	67	27	38	15	281	1991	1 065	0	64	70	12	1 211
1956	108	54	22	40	15	238	1992	863	0	43	70	12	988
1957	207		41	42	15	409	1993	1 070	0	43	70	12	1 195
1958	241		49	44	15	470	1994	1 264	0	38	70	12	1 384
1959	228		45	46	15	449	1995	1 106	0	22	70	12	1 210
1960	411	88	82	48	10	639	1996	1 034	0	10	70	12	1 126
1961	346	74	69	51	10	550	1997	892	0	9	70	12	983
1962	411	88	82	53	10	644	1998	1 208	0	12	70	12	1 302
1963	499		99	55	10	770	1999	1 382	0	14	70	12	1 478
1964	429	92	86	57	10	673	2000	1 246	0	13	70	12	1 341
1965	402	86	81	59	10	638	2001	1 189	0	12	70	12	1 283
1966	597	33	119	61	10	820	2002	1 192	0	12	70	12	1 286
1967	595	33	119	64	10	821	2003	1 414	0	14	70	12	1 510
1968	652	36	130	66	10	894	2004	1 314	0	13	70	12	1 409
1969	795	44	159	68	10	1 076	2005	1 190	0	12	70	12	1 284
1970	945	0	189	70	10	1 214	2006	1 461	0	15	70	12	1 558
1971	1 130	0	226	70	10	1 436	2007	1 259	0	12	70	12	1 353
1972	1 233	0	247	70	10	1 560	2008	1 305	0	12	70	12	1 399
1973	1 468	0	294	70	10	1 841	2009	1 460	0	14	70	12	1 556
1974	1 239	0	248	70	10	1 567	2010	1 177	0	12	70	12	1 271
1975	933	0	187	70	10	1 200	2011	1 161	0	11	70	12	1 254
1976	1 102	0	221	70	10	1 403	2012	1 260	0	13	70	12	1 355
1977	1 306	0	261	70	10	1 647	2013	1 429	0	14	70	12	1 525
1978	1 367	0	273	70	10	1 720	2014	1 429	0	14	70	12	1 525
1979	1 653	0	331	70	10	2 064							

4.3.5 Model structure

The age structured population model encompasses the 1944–2014 period. The model structure includes two sexes and 1–40 year age classes, including an accumulating age class for older fish (40+ years). The age structure of the population at the start of the model is assumed to be in an unexploited, equilibrium state. The biological parameters are those used in previous assessments and equivalent for the two sexes (see Table 4). For the base model, natural mortality was invariant with age at a value of 0.1. A Beverton-Holt spawning stock recruitment relationship (SRR) was assumed with steepness (h) fixed at 0.85 and the standard deviation of the natural logarithm of recruitment (σ_R) was fixed at 0.6. Recruitment deviates were estimated for the 1970–2008 years.

Separate fishery selectivities were estimated for the main bottom trawl fishery (double normal parameterisation) and the pair trawl fishery (logistic), and a double normal selectivity was estimated for the *James Cook* research trawl age samples. The CPUE indices were linked to the vulnerable biomass of the main bottom trawl fishery.

The model was fitted to: (a) a combined (either trevally or snapper targeted) bottom trawl CPUE index for the years 1990 to 2013, (b) a research sampling proportions-at-age series for 1971 to 1974, (c) a market sampling proportions-at-age series covering 1974 to 1976 and 1978 to 1979, (d) a commercial proportions-at-age series for 1997 to 2013. The weighting of the individual data sets followed the approach of Francis (2011). The final assessment model adopted a CV of 16% for the time series of CPUE indices. The recent bottom trawl age composition data were assigned a moderately high weighting in the likelihood (ESS of about 50).

During model development, a range of options was investigated to examine the key structural assumptions of the model. The most influential assumption was the value of natural mortality, and a lower value of natural mortality (0.083) was used as a key model sensitivity. An additional sensitivity run was conducted assuming a lower value of steepness for the SRR (0.7 compared with 0.85), and with M=0.1).

The base model estimates a low selectivity of older fish for the bottom trawl (BT) fishery. The age composition data appear to be uninformative regarding the selectivity of the oldest age classes and, hence, the selectivity was sensitive to the prior for the associated parameters. An additional selectivity was conducted that assumed a prior value which corresponded to a high selectivity of the older age classes (0.8 for the oldest age class) (*BTselect*).

The base model encompassed the KMNTB area only. The spatial stratification of the TRE 7 Fishstock was primarily based on differences in the age composition of trevally amongst sub-areas of TRE 7. However, limited sampling has been conducted in the other areas and, although some differences in age structure of the catch are apparent among areas, there are some similarities in the age structures from the three areas. Spatial differences in age composition could be attributable to differences in fishery selectivity and/or variability in the sampled component of the catch. On that basis, an alternative model was formulated based on a single stock hypothesis, including the entire catch from TRE 7 within the framework of the KMNTB model (*AllCatch*). The *AllCatch* model provides estimates of yield that are consistent with the total TRE 7 catch and the TACC.

Further model runs were undertaken to explore the influence of two key data sets in the assessment: the recent (2007–2013) CPUE indices and the 1998–2001 bottom pair trawl (BPT) age composition data.

Model projections for a five year period (2015–2019) were conducted using the *AllCatch* model. These projections were conducted with annual commercial catch assumed to be either at the level of the TACC or equivalent to the annual catch from the 2012–13 fishing year and included additional allowances for customary and recreational catch. In the projection period, recruitment variation was incorporated in the model with the recruitment deviates simply constrained by the assumed variation in the deviates (σ_R = 0.60). Parameter uncertainty was determined using a Markov chain Monte Carlo (MCMC) approach.

4.3.6 Results

The assessment models indicate that the spawning biomass gradually declined during the 1940s and 1950s. The rate of decline increased in the 1960s and 1970s consistent with the increase in the total annual catch. The extent of the reduction in the spawning biomass during the 1970s was informed by the 1998–2001 age composition data from the BPT fishery. The proportion of older fish included in the age composition provide information regarding the level of fishing mortality in the preceding period. Thus, the estimation of the level of depletion will also be influenced by the assumed value of M (i.e., higher depletion with lower M). The spawning biomass remained relatively stable during the late 1990s and 2000s.

The stock status of the KMNTB component of TRE 7 has been assessed relative to a default target biomass level of 40% SB_0 and associated soft limit and hard limits of 20% and 10% SB_0 (Ministry of Fisheries 2008). Stock status conclusions are specific to the area encompassed by the base assessment model (i.e., KMNTB). For the base model, spawning biomass was maintained at about 50% SB_0 during the late 1990s and 2000s and there is a very low probability that the biomass declined below the target biomass during that period (Figure 11). The spawning biomass is estimated to have increased from 2010 to 2014 and the base model estimates that current biomass (SB_{2014}) is above the target biomass level (Tables 12 and 13).

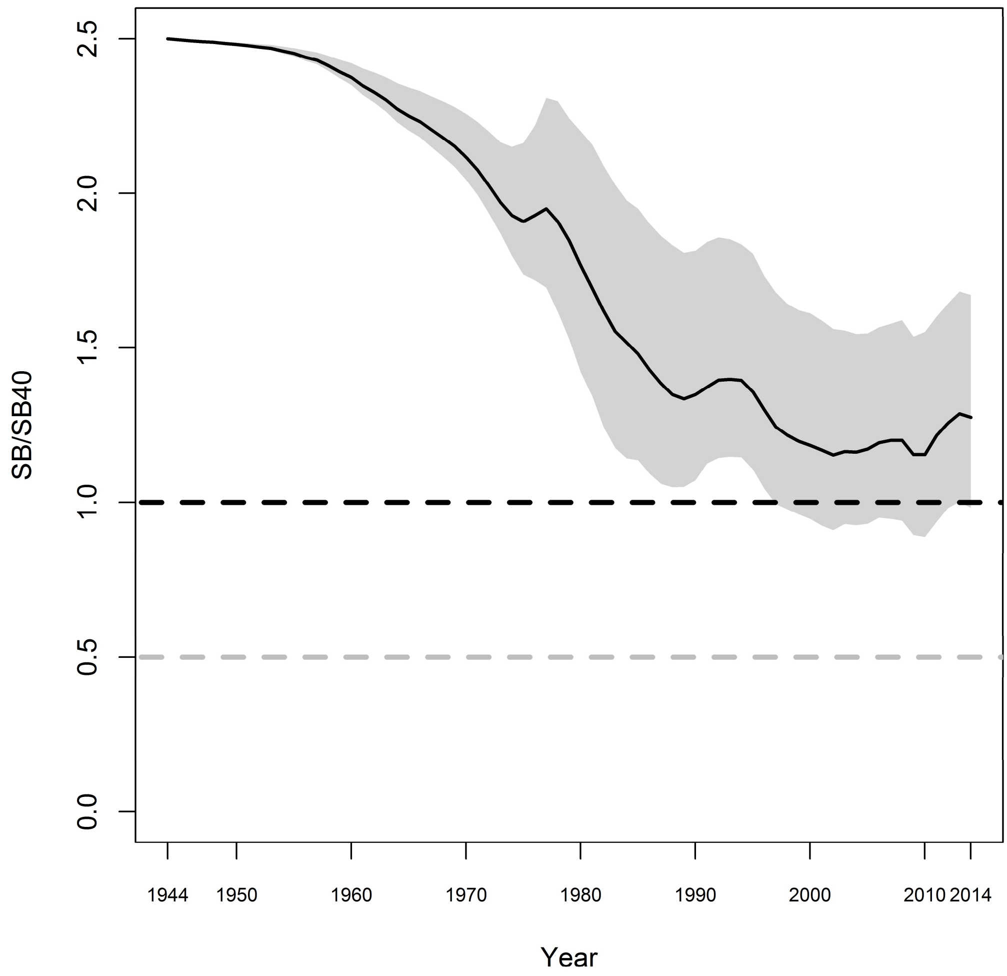


Figure 11: Spawning biomass (female only) trajectory from MCMC model fits for the base model, with 95% credible intervals.

Table 12: Biomass and yield estimates (medians, with 95% confidence intervals in parentheses) for the base model and sensitivities. Estimates are derived from MCMC analysis. Model results are limited to the KMNTB area of TRE 7, except for the *AllCatch* sensitivity which represents the entire TRE 7 area.

Model option	SB_0	SB_{2014}	$SB_{40\%}$	SB_{2014}/SB_0	$SB_{2014}/SB_{40\%}$
Base	22 339	11 526	8 935	0.510	1.275
	(18 493–36 213)	(73 84–23 808)	(7 397–14 485)	(0.393–0.669)	(0.982–1.672)
M low	21 026	8 399	8 410	0.399	0.998
	(18 692–26 268)	(5 774–13 446)	(7 477–10 507)	(0.305–0.525)	(0.762–1.313)
Steep70	23 557	11 483	9 423	0.489	1.224
	(19 723–39 933)	(7 384–26 688)	(7 889–15 973)	(0.368–0.682)	(0.92–1.704)
BTselect	20 436	9 698	8 174	0.474	1.184
	(17 787–27 121)	(6 708–16 116)	(7 115–10 848)	(0.371–0.619)	(0.927–1.549)
AllCatch	34 363	16 873	13 745	0.49	1.226
	(29 348–50 375)	(11 247–32 361)	(11 739–20 150)	(0.381–0.66)	(0.951–1.649)

Table 13: Estimates of target fishing mortality ($F_{SB40\%}$) and current fishing mortality (F_{2014}) relative to the target level (medians, with 95% confidence intervals in parentheses) for the base model and sensitivities. Estimates are derived from MCMC analysis. Model results are limited to the KMNTB area of TRE 7, except for the *AllCatch* sensitivity which represents the entire TRE 7 area.

Model option	$F_{SB40\%}$	$F_{2014}/F_{SB40\%}$	$Pr(F_{2014}<F_{SB40\%})$
Base	0.0877 (0.0844-0.0904)	0.678 (0.338-1.024)	0.969
M low	0.0768 (0.0742-0.079)	1.067 (0.69-1.517)	0.365
Steep70	0.077 (0.0741-0.0795)	0.776 (0.351-1.183)	0.851
BTselect	0.0885 (0.0855-0.0908)	0.796 (0.49-1.12)	0.902
AllCatch	0.0872 (0.0843-0.0896)	0.591 (0.319-0.862)	0.999

Current levels of fishing mortality are estimated to be below the $F_{SB40\%}$ level for all model options with the base level of natural mortality (*M*=0.1). The model sensitivity with the lower *M* estimated current fishing mortality to be at about the $F_{SB40\%}$ level (Table 13 and Figure 12).

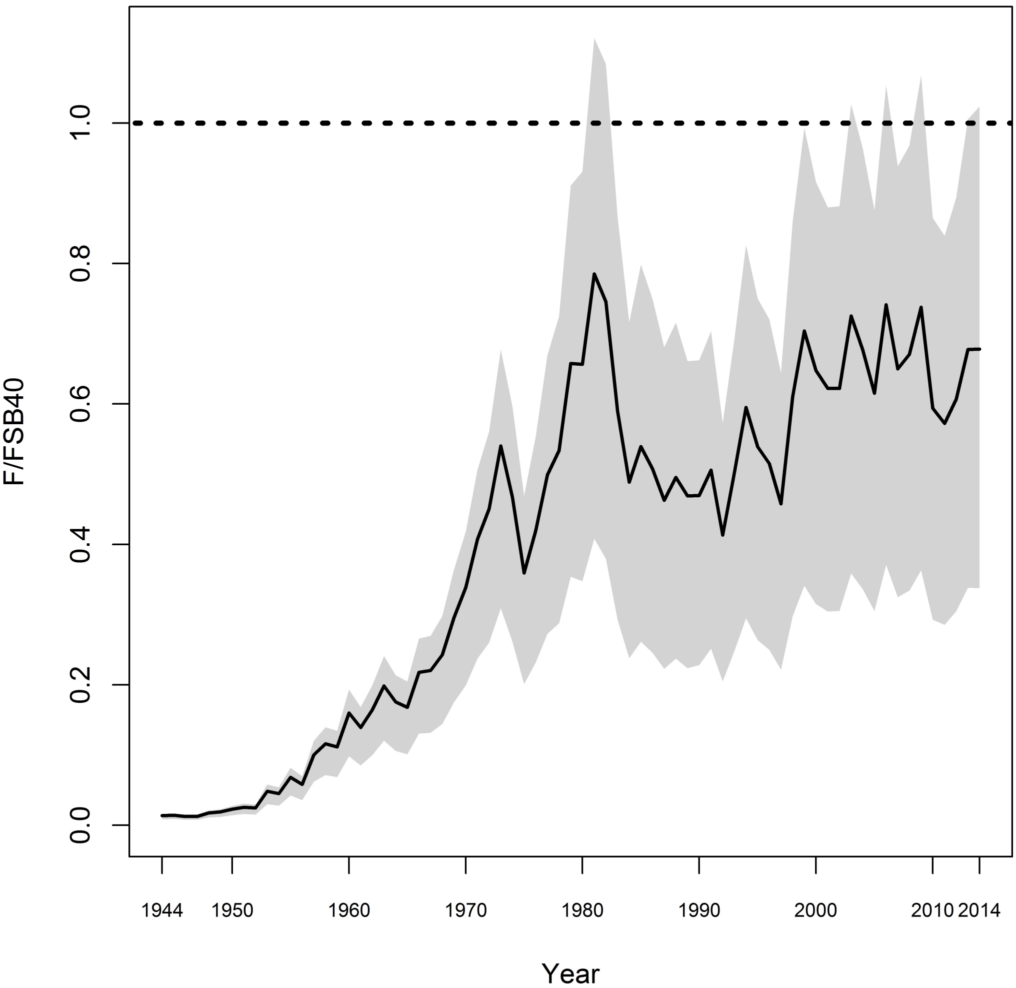


Figure 12: Fishing mortality (female only) relative to the overfishing threshold ($F_{SB40\%}$) (median of MCMCs) for the base model run. 95% credible intervals were derived from MCMC. The dashed, black horizontal line represents the default overfishing threshold.

Stock status from the model sensitivities is comparable to the base model, although the status is less optimistic for the *Low M* sensitivity (Tables 12–14 and Figure 13). For the *Low M* sensitivity, current biomass was estimated to be at about the target biomass level with no associated risk that the stock biomass has approached the biomass limit reference points. The stock status from the *AllCatch* model, that includes all the TRE 7 catch, is very similar to the base model, although the estimate of equilibrium yield is considerably higher, which is consistent with the magnitude of catch included in the *AllCatch* model.

Table 14: Probability (*Pr*) of the KMNTB component of the TRE 7 stock being above key reference points in 2014. Estimates are derived from MCMC analysis.

	Pr **(B_{2014}>0.1B_0)**	***Pr*** **(B_{2014}>0.2B_0)**	***Pr*** **(B_{2014}>0.4B_0)**
Base	1.000	1.000	0.961
M low	1.000	1.000	0.492
Steep70	1.000	1.000	0.899
BTselect	1.000	1.000	0.909
AllCatch	1.000	1.000	0.931

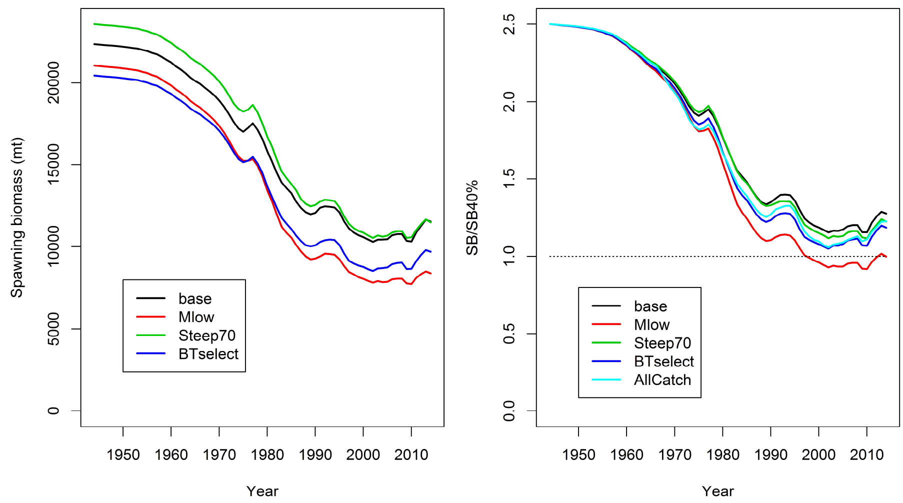


Figure 13: Median spawning biomass (female only) trajectories from MCMC model fits for the base model and sensitivities. The horizontal line in the right panel represents the target biomass level.

Further model runs were undertaken to explore the influence of two key data sets in the assessment. There is some concern regarding the reliability of the recent (2007–2013) CPUE indices due to changes in the targeting behaviour of the trawl fleet. A model trial was conducted that down-weighted the later indices (by increasing the CV to 30%). The BPT age composition data from 1998–2001 are influential in determining the extent of the stock depletion during the preceding period. A model trial was conducted that assigned a high weight (ESS 200) to these BPT age data to ensure that the estimated levels of fishing mortality were entirely consistent with the age composition data (i.e., to ensure a good fit to the 'plus group' in the age composition). Both model trials resulted in a reduction in the current stock status relative to SB_0 compared with the base model (by approximately 10%), although in both the current stock status was estimated to be above the target biomass level. On that basis, it was concluded that the overall conclusions of the assessment were not overly sensitive to either set of data.

4.3.7 Yield estimates and projections

Stock projections, for a five-year period, were conducted for the *AllCatch* model. The projections used either the TACC or a constant catch equivalent to the 2013 catch level; i.e., 2153 t for the TACC projection and 1952 t for the 2013 catch projection. For the TACC projection, the spawning biomass is projected to decline slightly (by 3%) during the projection period, although there is a low probability that the biomass will decline below the target biomass level (Table 15). For the constant catch projection, projected biomass is maintained at the current (2014) level. The $F_{40\%B0}$ yield at the 2014 biomass level is 2949 t (1987–5557 t) for the *AllCatch* model that includes the entire TRE 7 catch. The current TACC is 2153 t.

Table 15: Stock status in the terminal year (2019) of the five-year forecast period for the *AllCatch* model using either the current TACC or the 2013 catch in the projections.

Model option	SB_{2019}/SB_0	Pr(SB_{2019} > X%SB_0)		
		10%	20%	40%
AllCatch (with TACC projection)	0.478 (0.355–0.659)	1.000	1.000	0.863
AllCatch (with 2013 catch projection)	0.494 (0.374–0.671)	1.000	1.000	0.924

5. STATUS OF THE STOCKS

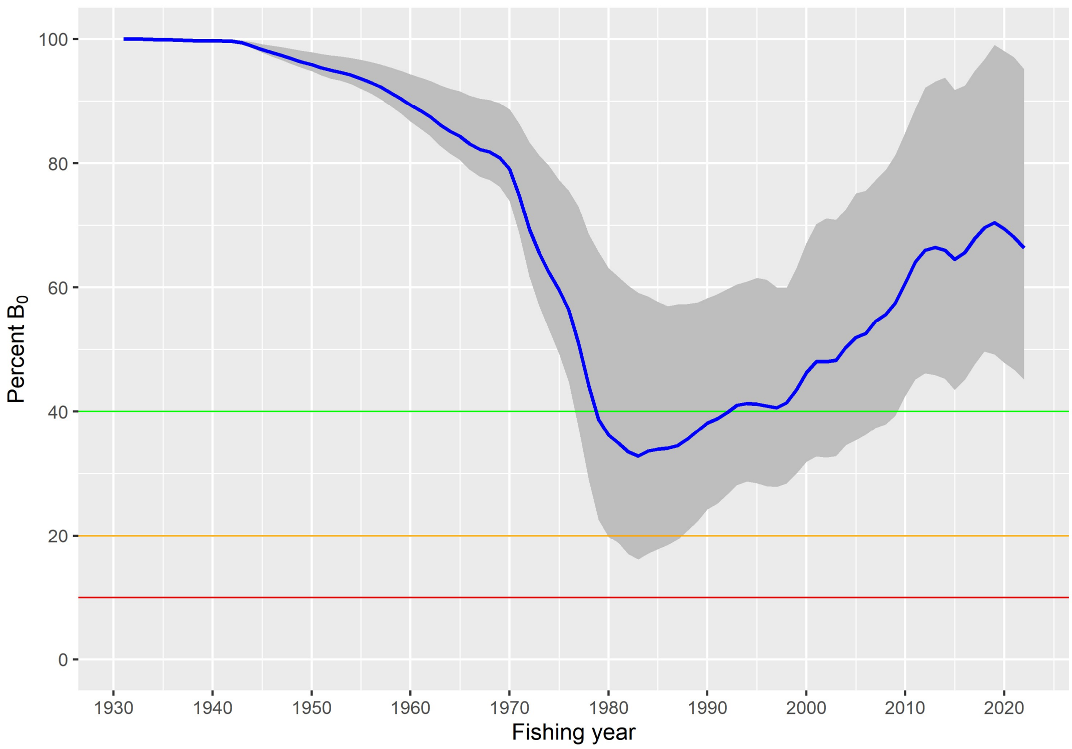
- **TRE 1**

Stock Structure Assumptions
Trevally occurring along the east coast of the North Island are believed to comprise two stocks: (i) east Northland and Hauraki Gulf, and (ii) Bay of Plenty.

Bay of Plenty

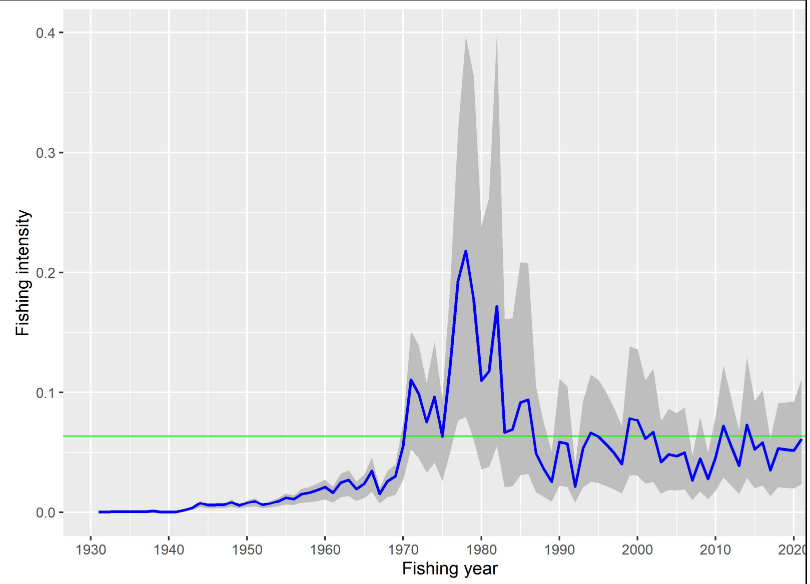
Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Base model run
Reference Points	Interim Target: 40% SB_0 Soft Limit: 20% SB_0 Hard Limit: 10% SB_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Likely (> 60%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Exceptionally Unlikely (< 1%) to be below
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status



Spawning stock biomass from the MCMC for the base model, with 95% credible interval. Horizontal lines are the 40% target (green), soft limit (orange), and hard limit (red).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning biomass has declined slightly from a peak in 2018.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been increasing slightly over the last 5 years.



Fishing intensity (total annual landing divided by SSB), with 95% credible interval. The horizontal green line is the target fishing intensity corresponding to the 40%B0 target (MPD calculation).

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	

Projections and Prognosis	
Stock Projections or Prognosis	Model projections indicate that the biomass will decline slightly, but with low probability of dropping below 40% SB_0 by 2027.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits (5 years)	Very Unlikely (< 10%) to decline below Soft and Hard Limits at current catch.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) at current catch

Assessment Methodology and Evaluation		
Assessment Type	Level 1 – Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2022	Next assessment: 2027
Overall assessment quality rank	1 – High Quality	

Main data inputs (rank)	- Standardised CPUE index of abundance - Proportions at age data from the commercial fisheries	1 – High Quality 1 – High Quality
Data not used (rank)	BoP trawl survey Aerial sightings index	3 – Low Quality: Not reliable for trevally 3 – Low Quality: Not reliable for trevally
Changes to Model Structure and Assumptions	- No previously accepted assessment	
Major Sources of Uncertainty	- Annual variability in BT CPUE index, possible resulting from varying catchability as this species is semi-pelagic.	

Qualifying Comments
- There is no corroborating information (outside the model) supporting estimated recent high recruitment, or fishery independent support for the strong increase in biomass. - The stock relationship between the Bay of Plenty and TRE 2(N) is unknown.

Fishery Interactions
Main QMS bycatch species are snapper, red gurnard, John dory, and tarakihi.

East Northland and the Hauraki Gulf
Preliminary assessments have previously been undertaken for the EN/HG stock, using abundance indices derived from standardised CPUE analyses, bottom trawl catch-at-age data, and catch history. There is currently no accepted index of abundance for the EN/HG stock, and no assessment.

- **TRE 2**

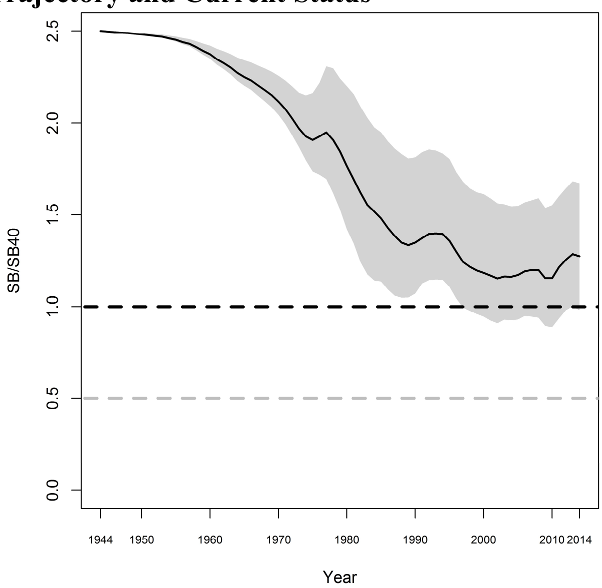
There is no accepted stock assessment for TRE 2. Trevally in TRE 2 are thought to be part of the biological stock located in the Bay of Plenty (TRE 1); therefore, future assessments for TRE 2 will be undertaken in conjunction with TRE 1.

- **TRE 7**

Stock Structure Assumptions
Trevally occurring along the west coast of the North Island are believed to comprise a single stock.

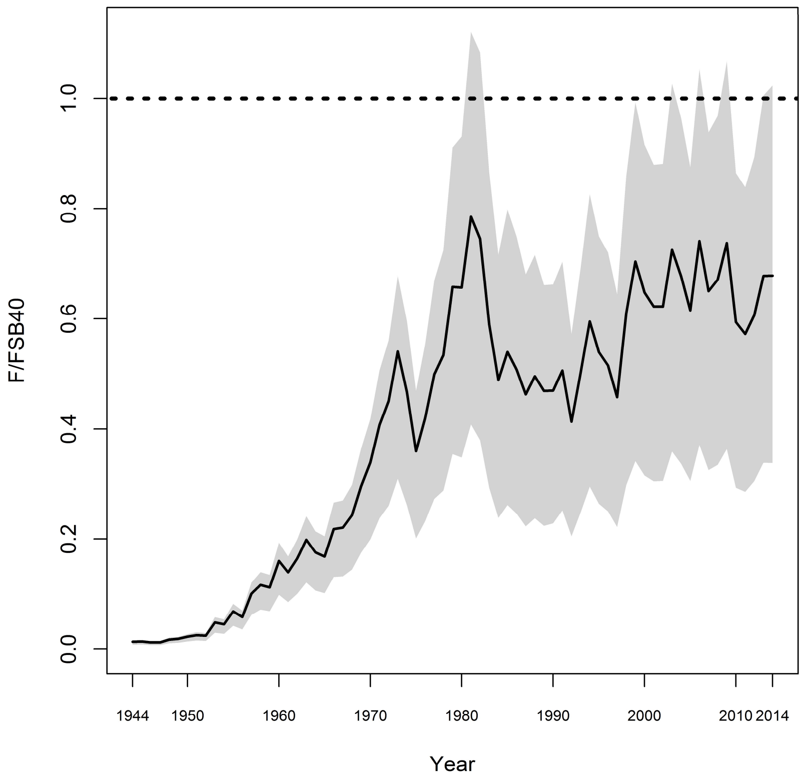
Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	A base case model based on the main fishery area only (Kaipara-Manukau-Northern Taranaki Bight; KMNTB); this represents about 70% of recent (2010–11 to 2012–13) TRE 7 catches
Reference Points	Interim Target: 40% SB_0 Soft Limit: 20% SB_0 Hard Limit: 10% SB_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Exceptionally Unlikely (< 1%) to be below
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Spawning biomass (female only) relative to the interim target biomass ($SB_{40\%}$) (median of MCMC samples) for the base model run. 95% credible intervals were derived from MCMC samples. The dashed, black horizontal line represents the default target biomass level and the grey line represents the default soft limit (20% SB_0).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning biomass is estimated to have declined gradually during the 1940s and 1950s. The rate of decline increased from the 1960s to the mid-1980s consistent with the increase in the total annual catch. Since the mid-1990s spawning biomass has remained relatively stable.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality rates are estimated to have been relatively stable since the late 1990s, at a level below $F_{SB40\%}$.



Annual fishing mortality relative to the level of fishing mortality that corresponds to the default target spawning biomass from the KMNTB base assessment model. The solid line represents the median of the MCMC samples and the shaded area represents the 95% credible interval.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Model projections indicate that the biomass of TRE 7 is About as Likely as Not (40–60%) to decline over the next 5 years (to 2019), but with low probability of dropping below 40% SB_0 by 2019.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits (5 years)	Exceptionally Unlikely (< 1%) to decline below Soft and Hard Limits
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured Stock Synthesis model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2015	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	

Main data inputs (rank)	- Standardised CPUE index of abundance - Proportions at age data from the commercial fisheries and trawl surveys	1 – High Quality 1 – High Quality
Data not used (rank)	- Bottom pair trawl CPUE, 1973–74 to 1984–85	3 – Low Quality: does not index abundance
Changes to Model Structure and Assumptions	- The stock assessment was based on data from KMNTB only. The fishery catch, CPUE, and age composition data sets were reconfigured accordingly. The model was re-run with the total TRE 7 catch to calculate the total expected yield at $F_{SB40\%}$. Projections were based on the model for the entire area, using both the 2014 catch and the 2014 TACC.	
Major Sources of Uncertainty	- Reliability of CPUE as an index of stock abundance as a result of recent increases in the degree of targeting of trevally - Whether results for the KMNTB sub-area reflect changes in biomass in the other two sub-areas within TRE 7 - Reliability of the pair trawl age composition data (1998–2001), which strongly influence estimates of B_0 and exploitation rates during the period of peak catch	

Qualifying Comments
- The stock assessment was based on the KMNTB sub-area only, and the extent to which it is reflective of the other two (smaller) sub-areas is unknown.

Fishery Interactions
Main QMS bycatch species are snapper, red gurnard, John dory, and tarakihi.

6. FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J; O'Brien, C J (1999) Report from the Fishery Assessment Plenary, April 1999: stock assessments and yield estimates. 430 p. (Unpublished report held in NIWA library, Wellington).

Annala, J H et al (Comps.) (2004) Report from the Fishery Assessment Plenary, May 2004: stock assessment and yield estimates. (Unpublished report held in NIWA library, Wellington.)

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. (Unpublished draft New Zealand Fisheries Assessment Report for the Ministry of Fisheries project REC2000-03, held by Fisheries New Zealand.) 92 p.

Boyd, R O; Reilly, J L (2004) 1999–2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished draft New Zealand Fisheries Assessment Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand.) 28 p.

Bradford, E (1997) Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993–94. New Zealand Fisheries Assessment Research Document 1997/7. 16 p. (Unpublished report held in NIWA library, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished report held in NIWA library, Wellington.)

Edwards, C T T; Hartill, B (2015) Calibrating between offsite and onsite amateur harvest estimates. *New Zealand Fisheries Assessment Report 2015/49*. 23 p.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* 68: 15.

Francis, M P; Bradford, E; Paul, L J (1999) Trevally catch per unit effort in TRE 7. New Zealand Fisheries Assessment Research Document 1999/13. 27 p. (Unpublished report held in NIWA library, Wellington.)

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

Gilbert, D J (1988) Trevally. New Zealand Fisheries Assessment Research Document 1988/29. 28 p. (Unpublished report held by NIWA library.)

Hanchet, S M (1999) Stock assessment of Trevally (*Caranx georgianus*) in TRE 7. New Zealand Fisheries Assessment Research Document 1999/55. 20 p. (Unpublished report held by NIWA library, Wellington.)

Hartill, B; Bian, R; Armiger, H; Vaughan, M; Rush, N (2007) Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004–05. *New Zealand Fisheries Assessment Report 2007/26*. 44 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2013) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2011–12. *New Zealand Fisheries Assessment Report 2013/70*. 44 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2019). Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2017–18. *New Zealand Fisheries Assessment Report 2019/23*. 39 p.

Hoenig, J M (1983) Empirical use of longevity data to estimate mortality rates. *Fisheries Bulletin* 81: 899–903.

James, G D (1980) Tagging experiments on trawl-caught trevally, *Caranx georgianus*, off north-east New Zealand. *New Zealand Journal of Marine and Freshwater Research 14 (3)*: 249–254.

James, G D (1984) Trevally. *Caranx georgianus*: age determination, population biology and fishery. Ministry of Agriculture and Fisheries. *Fisheries Research Bulletin 25*. 51 p.

Kendrick, T H; Bentley, N (2010) Fishery characterisation and catch-per-unit-effort indices for trevally in TRE 7; 1989–90 to 2007–08. *New Zealand Fisheries Assessment Report 2010/41.*

Langley, A D (2001) Length and age composition of trevally in commercial landings from TRE 1 and TRE 7, 1999–2000. *New Zealand Fisheries Assessment Report 2001/42*. 32 p.

Langley, A D (2002a) Length and age composition of trevally in commercial landings from TRE 1 and TRE 7, 2000–01. *New Zealand Fisheries Assessment Report 2002/19*. 34 p.

Langley, A D (2002b) Analysis of catch and effort data from the TRE 7 fishery. *New Zealand Fisheries Assessment Report 2002/32*. 28 p.

Langley, A D (2003) Length and age composition of trevally in commercial landings from TRE 1, 2001–02. *New Zealand Fisheries Assessment Report 2003/48*. 18 p

Langley, A D (2004) Length and age composition of trevally (*Pseudocaranx dentex*) in commercial landings from the TRE 1 purse-seine fishery, 2002–03. *New Zealand Fisheries Assessment Report 2004/39*. 17 p.

Langley, A D (2015) Stock assessment of TRE 7. *New Zealand Fisheries Assessment Report 2015/45*. 76 p.

Langley, A D; Maunder, M (2009) Stock assessment of TRE 7. *New Zealand Fisheries Assessment Report 2009/49.* 42 p.

Maunder, M N; Langley, A D (2004) Integrating the standardisation of catch-per-unit-effort into stock assessment models: testing a population dynamics model and using multiple data types. *Fisheries Research 70 (2–3)*: 389–395.

McKenzie, A (2008) Standardised CPUE analysis and stock assessment of the west coast trevally fishery (TRE 7). *New Zealand Fisheries Assessment Report 2008/44.*

McKenzie, A (in prep) Stock assessment of Bay of Plenty trevally (TRE 1) for 2021–22. New Zealand Fisheries Assessment Report.

McKenzie, J R; Parsons, D M; Bian, R; Doonan, I (2016) Assessment of the TRE 1 stocks in 2015. *New Zealand Fisheries Assessment Report 2016/48*. 98 p.

Ministry of Fisheries (2008) Harvest Strategy Standard for New Zealand fisheries. 25 p. Available at http://fs.fish.govt.nz/Page.aspx?pk=61&tk=208&se=&sd=Asc&filSC=&filAny=False&filSrc=False&filLoaded=False&filDCG=9&filDC=0&filST=&filYr=0&filAutoRun=1.

Parsons, D M; Bian, R; Parkinson, D; MacGibbon, D J (2021) Trawl surveys of the Hauraki Gulf and Bay of Plenty in 2019 and 2020 to estimate the abundance of juvenile snapper. *New Zealand Fisheries Assessment Report 2021/08*. 127 p.

Schofield, M I; Langley, A D; Middleton, D A J (2018) Characterisation and catch-per unit-effort (CPUE) analyses for FMA 2 trevally (TRE 2). (Draft New Zealand Fisheries Assessment Report held by Fisheries New Zealand.)

Taylor, P R (2011) Developing indices of relative abundance from observational aerial sightings of inshore pelagic finfish; step 1, exploring that data. *New Zealand Fisheries Assessment Report 2014/34*. 66 p.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Walsh, C; McKenzie, J M (2010) Review of length and age sampling for trevally in TRE 1 and TRE 7. *New Zealand Fisheries Assessment Report 2010/09*. 27 p.

Walsh, C; McKenzie, J M; Ó Maolagáin, C; Buckthought, D; Blackwell, R; James, G D; Rush, N (2010) Length and age composition of commercial trevally landings in TRE 1 and TRE 7, 2006–07. *New Zealand Fisheries Assessment Report 2010/9.* 62 p.

Walsh, C; McKenzie, J; Ó Maolagáin, C; Stevens, D (1999) Length and age composition of trevally in commercial landings from TRE 1 and TRE 7, 1997–98. *NIWA Technical Report 66*.

Wright, P; McClary, D; Boyd, R O (2004) 2000/2001 National Marine Recreational Fishing Survey: direct questioning of fishers compared with reported diary data. (Unpublished Final Research Report for Ministry of Fisheries Project REC2000–01: Objective 2, held by Fisheries New Zealand.) Available at http//fs.fish.govt.nz.

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/2*4. 104 p.

Wynne-Jones,J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.