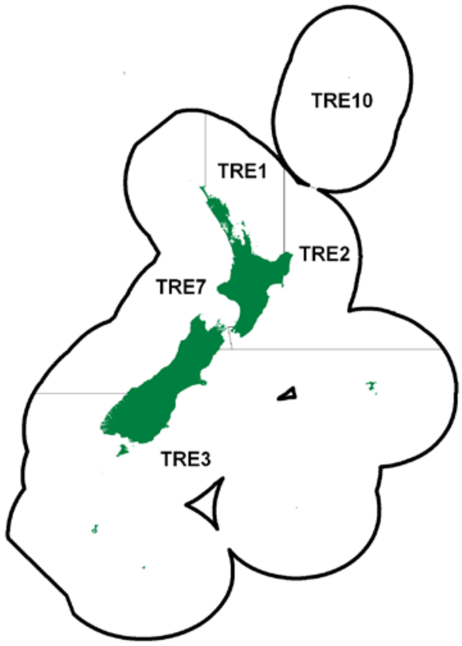
TREVALLY (TRE)

(*Pseudocaranx dentex*)
Arara



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

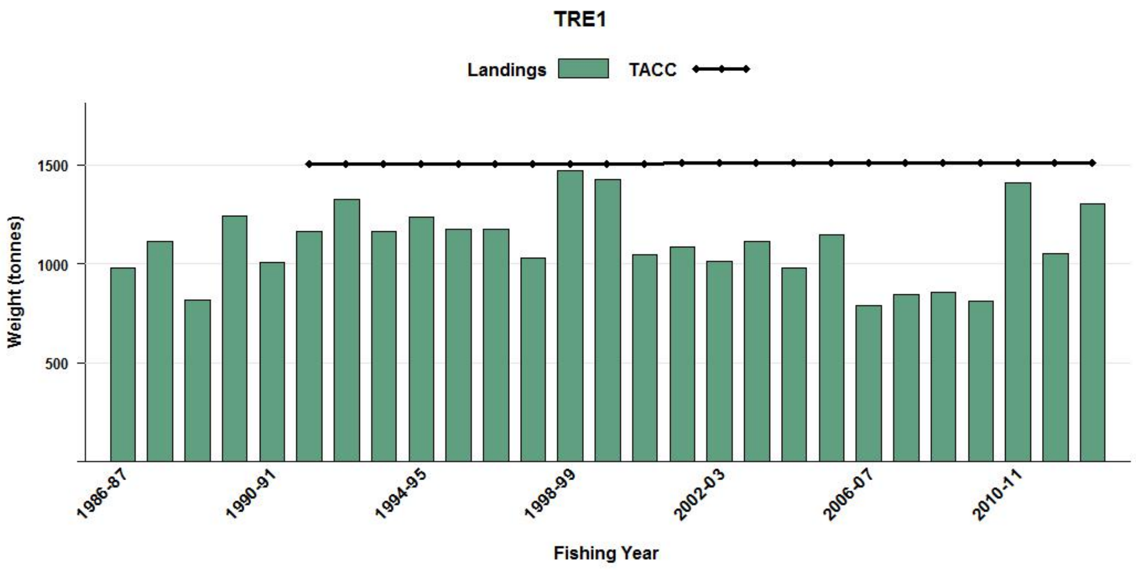
Trevally is caught around the North Island and the north of the South Island, with the main catches from the northern coasts of the North Island. Trevally is taken in the northern coastal mixed trawl fishery, mostly in conjunction with snapper. Since the mid 1970s trevally has been taken by purse seine, mainly in the Bay of Plenty (BoP), in variable but often substantial quantities. Setnet fishermen take modest quantities. Recent reported trevally landings and TACCs are shown in Table 1, while Figure 1 shows the historical landings and TACC values for the main trevally stocks.

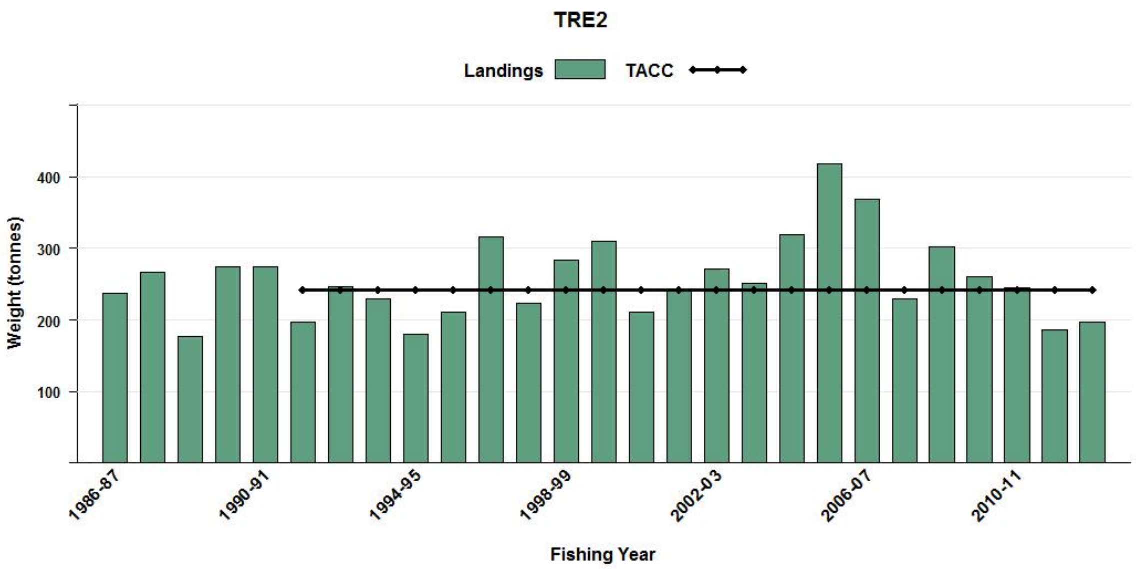
Landings from TRE 1 were 1,301 t (86% TACC), below that of 1,408 t in 2010-11, but higher than any landings of the previous decade. For TRE 2, catches have exceeded the TACC in 12 of the last 17 fishing years. Landings from TRE 7 have been under the TACC for the last nine fishing years.

Table 1: Reported landings (t) of trevally by Fishstock from 1983 to 2012–13 and actual TACCs (t) from 1986–87 to 2012–13. QMS data from 1986-present.

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	1842	2153	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	3340	3933





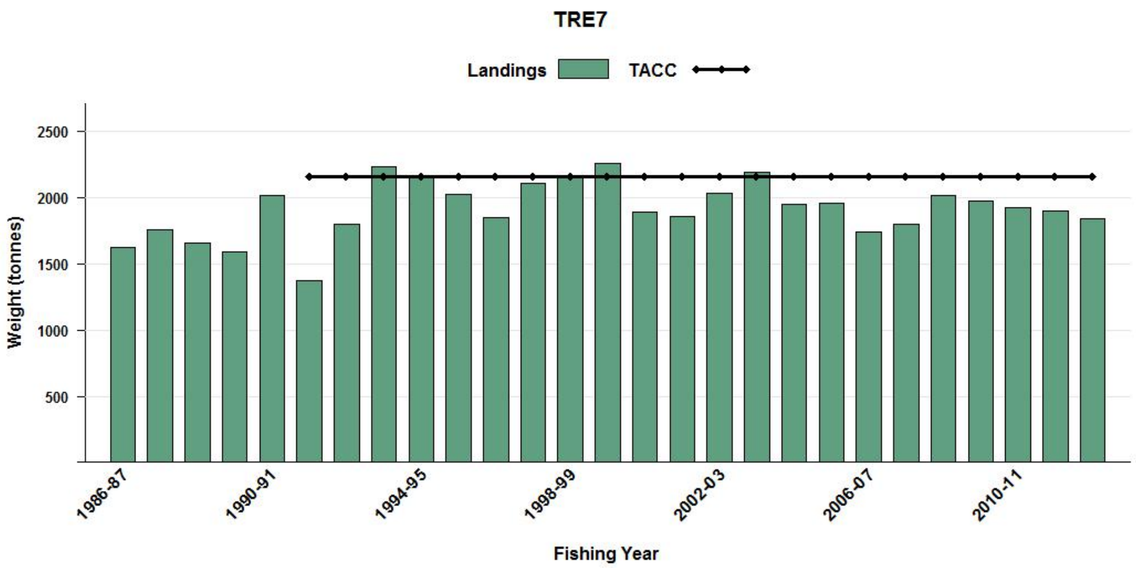


Figure 1: Historical landings and TACCs for the three main TRE stocks. Top: TRE 1 (Auckland), Middle: TRE 2 (Central East), and Lower: TRE 7 (Challenger).

1.2 Recreational fisheries

Recreational fishers catch trevally by setnet and line 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 2. 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 an offsite approach, the offsite regional telephone and diary survey approach. Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2005) and a rolling replacement of diarists in 2001 (Boyd & Reilly 2004 allowed estimates for a further year (population scaling ratios and mean weights were not re-estimated in 2001).

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 under-estimated. 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, which led to the development of an alternative maximum count aerial-access onsite method that provides 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).

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 SNA 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).

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. The panel survey used face-to-face interviews of a random sample of 30, 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews.

The most recent aerial-access survey conducted in QMA 1 in 2011–12 (Hartill et al 2013) provides independent harvest estimates for comparison with those generated from the concurrent national panel survey. Both surveys appear to provide plausible results that corroborate each other TRE 1, and are therefore considered to be broadly reliable (Hartill et al 2013). Note that neither of these estimates includes catch taken on recreational charter vessels, or recreational catch taken under s111 general approvals.

Table 2: Recreational harvest estimates for trevally stocks ((Bradford 1998, Boyd & Reilly 2005, Boyd et al 2004, Hartill et al 2007, Hartill et al 2013, MPI Unpublished data). 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 run through the October to September fishing year but 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	130 227	154	0.11
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	8 866	10	0.25
TRE 3	1996	Telephone/diary	2 000	3#	-
	2000	Telephone/diary	10 000	10	0.45
	2001	Telephone/diary	2 000	12	0.46
	2012	Panel survey	864	1	0.73
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	20 600	29	0.17

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

1.3 Customary non-commercial fisheries

Trevally is an important traditional and customary food fish for Maori. 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 historic illegal catch is incorporated in the TRE 7 stock assessment model catch history (see Table 5).

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 mid-water and on the bottom, and are often associated with reefs and rough substrate. Schools are sometimes mixed with other species such as koheru 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 euphausids. 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 much larger fish of 6–8 kg are occasionally recorded.

Fecundity is relatively low until females reach about 40 cm FL. They appear to be partial 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 3.

Table 3: 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	James (1984)
TRE 1		0.016	3.064	
3. von Bertalanffy growth parameters				
			Both sexes	
	L_∞	k	t_0	
TRE 1	47.55	0.29	-0.13	Walsh et al 1999
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

A stock assessment was attempted for TRE 1, but was not accepted by the Pelagic Working Group as no reliable abundance index was available. The TRE 7 stock assessment was updated in 2009 (Langley & Maunder 2009).

Estimates of absolute biomass are not available for any stock. Biomass indices are available from *Kaharoa* trawl surveys of the Hauraki Gulf, BoP, east Northland, and the west coast of the North Island. These relative indices are unlikely to be directly proportional to true stock abundance due to the following factors: (a) the mixed demersal-pelagic nature of trevally; (b) trawl survey gear efficiency is not optimal for the sampling of trevally; and (c) a direct correlation has been found to exist between sea surface temperature during surveys and relative biomass. These factors are most likely to confound any visible trend in the relative abundance indices for trevally produced from past trawl surveys.

In 2012, an index based on aerial sightings was accepted by the NINSWG using data from the MFish database *aer_sight* and the generalised additive model (GAM) to produce standardised annual relative abundance indices (Taylor In Press). This method is referred to as sightings per unit effort (SPUE).

Flights were restricted to those that were exclusive to the BoP (i.e., those having flightpaths that remained within an area defined as the BoP), were flown by pilot #2, and were the first flight of the day (apart from some defined exceptions, e.g., refuelling at the start of the day).

Estimates of relative year effects were obtained using a forward stepwise GAM, where the data were fitted using a two-part model: the chance of a flight with positive sightings was modelled using a binomial regression and the tonnage sighted on positive flights was modelled using a lognormal regression. The data used for the SPUE analyses consisted of aerial sightings of kahawai, trevally, jack mackerel, blue mackerel, and skipjack tuna from 1986–87 to 2010–11 with missing years in 1988–89, from 1994–95 to 1996–97, and in 2006–07. Most of these missing years were the result of no available data. By contrast, 2006–07 was dropped because the working group identified a biasing of the annual index in that year because of the low number of available flights. Similarly, the first year of the original series (1985–86) was dropped by the working group.

A proxy for target comprised purse-seine catches in the BoP; catch data before 1989 were from the *fsu-new* database; and data from 1989 to 2011 were from *warehou*. Target was not recorded in purse-seine catch data before 1998 so this could not be used here.

Table 3a: Standardised SPUE indices for TRE 1 from the binomial-lognormal model fitted to the series 1986–87 to 2010–11 with years of missing data shown.

Fishing year	LNinds	BNinds	CBinds
1986–87	1.30	1.67	2.00
1987–88	1.30	1.90	2.54
1988–89	No data	No data	No data
1989–90	1.62	1.55	2.76
1990–91	1.53	1.10	1.84
1991–92	1.98	1.01	1.54
1992–93	0.94	1.27	1.15
1993–94	1.51	0.82	1.47
1994–95	No data	No data	No data
1995–96	No data	No data	No data
1996–97	No data	No data	No data
1997–98	1.04	0.68	0.44
1998–99	1.26	1.65	1.60
1999–00	0.63	1.26	0.90
2000–01	0.99	1.21	1.01
2001–02	1.23	1.48	1.50
2002–03	1.28	0.90	1.32
2003–04	0.68	1.01	0.95
2004–05	0.69	0.65	0.72
2005–06	0.40	1.19	0.47
2006–07	Insufficient data	Insufficient data	Insufficient data
2007–08	0.84	0.31	0.28
2008–09	0.69	0.62	0.41
2009–10	0.81	0.81	0.76
2010–11	0.75	0.63	0.43

The Working Group concluded that the model of SPUE for trevally probably does reflect, to some degree, the abundance of this species in the BoP and that the SPUE indices should be used for stock assessment, with stock assessment model diagnostics employed to gauge the quality (and appropriate weight) of the abundance indices.

For TRE 1, the combined indices show a declining trend throughout the time series, with the highest value occurring in 1989–90 and the lowest in 2007–08 (Table 3a, Figure 2).

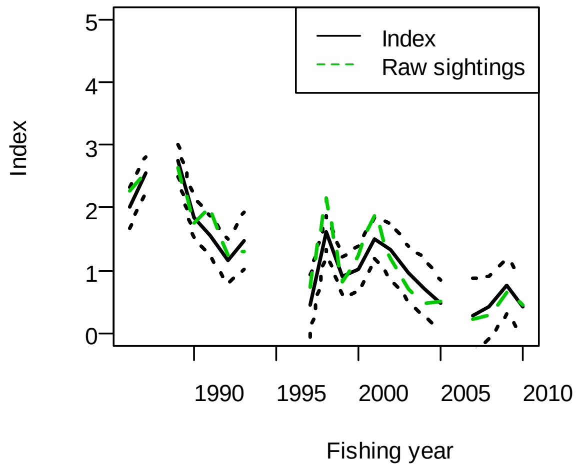


Figure 2: Standardised sightings per unit effort indices for the Bay of Plenty TRE 1 stock, derived as a combination of year effect estimates from a lognormal and a binomial regression; gaps result from missing and insufficient data (see text).

4.1 Challenger, Central West and Auckland West (TRE 7)

4.1.1 CPUE

A standardised CPUE index of abundance was used in the 2009 assessment (Table 4). This was based on positive catches made using single bottom trawls whilst targeting trevally or snapper and covered the period 1989–90 to 2007–08 (Kendrick & Bentley 2009). A second standardised CPUE index - based on data aggregated by month, vessel class and statistical area (Francis et al 1999) was used for an earlier period (1977–78 to 1996–97) in one of the sensitivity runs.

Table 4: Standardised single trawl CPUE indices (relative year effects) with number of vessel days fished from 1989–90 to 2007–08 (Kendrick & Bentley 2009).

Fishing year	Year of relative effect	CPUE index	Fishing year	Year of relative effect	CPUE index
1989–90	1990	5.94	2004–05	2005	2.43
1990–91	1991	3.79	2005–06	2006	3.05
1991–92	1992	3.06	2006–07	2007	2.42
1992–93	1993	2.22	2007–08	2008	2.73
1993–94	1994	2.51			
1994–95	1995	2.29			
1995–96	1996	2.48			
1996–97	1997	2.56			
1997–98	1998	2.36			
1998–99	1999	2.88			
1999–00	2000	2.57			
2000–01	2001	2.34			
2001–02	2002	2.62			
2002–03	2003	3.05			
2003–04	2004	2.86			

4.1.2 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 virgin 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).

Over the period 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 TRE 7 stock, it is necessary to make allowance for mortality due to discarded fish, recreational catch, customary catch, and non-reported catch. The agreed catch history for the model is given in Table 5.

4.1.3 Catch at age

A time series of age frequency distributions is available from the target TRE 7 single trawl fishery from 1997–98 to 2008–09. There are also some age frequency samples for the pair trawl method. 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 1974–76 and 1978–79 fishing years. These data were incorporated in the assessment, but further exploration is required with respect to the sampling protocols, data validation, and the weighting given to the data.

4.1.4 Estimate of natural mortality (*M*)

Initial model runs fixed the value of natural mortality at 0.10, the value used in previous assessments. A likelihood profile for the parameter indicated that 0.10 was at the upper range of the plausible values for M, given the observational data and the structural assumptions of the model, and two alternative values of M were considered: the most likely value (M = 0.087) and a lower value corresponding to a relative likelihood of 0.05 (M = 0.075) (Langley & Maunder 2009).

Table 5: Catch history (t) for 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
1944	3	2	1	14	15	34
1945	3	2	1	16	15	36
1946	3	2	1	18	15	38
1947	14	7	3	20	15	59
1948	8	4	2	23	15	52
1949	7	4	1	25	15	52
1950	15	8	3	27	15	68
1951	36	18	7	29	15	105
1952	31	16	6	31	15	99
1953	103	52	21	33	15	223
1954	78	39	16	36	15	184
1955	138	69	28	38	15	288
1956	130	65	26	40	15	276
1957	296	148	59	42	15	560
1958	343	172	69	44	15	642
1959	351	176	70	46	15	658
1960	595	128	119	48	10	900
1961	471	101	94	51	10	727
1962	543	116	109	53	10	831
1963	662	142	132	55	10	1 001
1964	534	114	107	57	10	822
1965	544	117	109	59	10	839
1966	1 080	60	216	61	10	1 427
1967	1 493	83	299	64	10	1 949
1968	1 515	84	303	66	10	1 978
1969	1 322	73	264	68	10	1 737
1970	1 682	0	336	70	10	2 098
1971	2 037	0	407	70	10	2 524
1972	2 226	0	445	70	10	2 751
1973	2 320	0	464	70	10	2 864
1974	2 024	0	405	70	10	2 509
1975	1 598	0	320	70	10	1 998
1976	1 894	0	379	70	10	2 353
1977	2 113	0	423	70	10	2 616
1978	2 322	0	464	70	10	2 866
1979	2 600	0	520	70	10	3 200
1980	2 493	0	499	70	12	3 074
1981	2 844	0	569	70	12	3 495
1982	2 497	0	499	70	12	3 078
1983	2 165	0	433	70	12	2 680
1984	1 707	0	341	70	12	2 130
1985	1 843	0	369	70	12	2 294
1986	1 678	0	336	70	12	2 095
1987	1 626	0	163	70	12	1 871
1988	1752	0	158	70	12	1992
1989	1665	0	133	70	12	1880
1990	1589	0	111	70	12	1782
1991	2016	0	121	70	12	2219
1992	1367	0	68	70	12	1517
1993	1796	0	72	70	12	1950
1994	2231	0	67	70	12	2380
1995	2138	0	43	70	12	2263
1996	2019	0	20	70	12	2121
1997	1844	0	18	70	12	1944
1998	2103	0	21	70	12	2206
1999	2148	0	21	70	12	2251
2000	2254	0	23	70	12	2359
2001	1888	0	19	70	12	1989
2002	1810	0	18	70	12	1910
2003	2050	0	21	70	12	2153
2004	2156	0	22	70	12	2260
2005	1945	0	19	70	12	2046
2006	1957	0	20	70	12	2059
2007	1739	0	17	70	12	1838
2008	1739	0	17	70	12	1838

Estimates of current biomass and stock status were highly sensitive to the assumed value of natural mortality. This was due to the lack of contrast in the CPUE indices which allows the model considerable freedom to fit the age frequency data. These data include a relatively large proportion in the accumulated oldest age class. Alternative assumptions regarding M substantially influence the time series of recruitment estimates, particularly over the last 20 years, to attain the best fit to the age frequency distributions.

4.1.5 Model structure

The age structured population model encompasses the 1944–2008 period. The model structure includes two sexes, 1–20 year age classes and an accumulating age class for older fish (20+ 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 equivalent to those used in previous assessments and equivalent for the two sexes (see Table 3). For the initial 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 0.75 and the standard deviation of the natural logarithm of recruitment (σ_R) was fixed at 0.6. Recruitment deviates were estimated for the 1960–2006 years.

Primary differences in the models used in the previous (2005) and current (2009) assessments are as follows:

- Additional data, including three years of catch-at-age and an updated CPUE index.
- Refinement of the assumed level of unreported catch since 1986.
- Change in model software from CASAL to Stock Synthesis. This was demonstrated to have minimal effect on the model results.

- A change in the definition of adult biomass with knife-edge maturity at 5 years old (it was previously assumed that all fish were mature).
- Estimation of separate selectivities for the periods pre and post 1986 to account for an increase in trawl mesh size associated with the introduction of a minimum legal size.

The model was fitted to: (a) a combined (either trevally or snapper targeted) CPUE index for the years 1990 to 2008, (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 2008. A range of sensitivity analyses were conducted to examine the key structural assumptions of the model.

Model projections were conducted with annual catches assumed equivalent to the TAC plus an allowance for customary, recreational, and non-reported commercial catch (of total catch of 2257 t). 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 incorporated using a Markov chain Monte Carlo (MCMC) approach.

4.1.6 Results

The assessment indicated 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. In the MPD runs, the spawning biomass trajectory from the early 1980s was sensitive to the assumed value of *M*, but was relatively insensitive to the range of other alternative structural assumptions investigated.

An MCMC approach was applied to estimate model uncertainty for the models with different values of natural mortality (tables 6 and 7). Reasonable results were attained for the two higher values of natural mortality (0.087 and 0.10); however, problems were encountered for the lower value of natural mortality (0.075) with MCMC parameter values being constrained by the bounds of key parameters (particularly selectivity parameters), thereby, resulting in biased estimates of stock status. On this basis, the MCMC results for the lower value of natural mortality were rejected and it was concluded that the lower value of natural mortality was less plausible than the other two values. The female spawning biomass trajectories for runs with *M* = 0.1 and *M* = 0.087 are presented in Figures 3 and 4 respectively. Female spawning biomass is predicted to have remained stable (*M* = 0.087) or to have increased (*M* = 0.1) since the 1980s, with moderate-high probability that the current biomass is above the B_{MSY} level (61% and 100%, respectively).

Table 6: Probability (*Pr*) of the TRE 7 stock falling below key reference points in 2008, using model runs with the two plausible estimates of M. B_{2008} is the mid-year female spawning biomass in 2008. Estimates are derived from MCMC analysis.

	Pr (B_{2008}<B_{MSY})	*Pr* (B_{2008}<0.2B_0)	*Pr* (B_{2008}<0.1B_0)
M = 0.10	0	0	0
M = 0.087	0.39	0.05	0

Table 7: Biomass estimates (medians, with 95% confidence intervals in parentheses) for model runs with the two plausible estimates of *M*. B_{2008} is the mid-year female spawning biomass in 2008. Estimates are derived from MCMC analysis.

	B_0	B_{2008}	B_{MSY}	*MSY*	B_{MSY}/ B_0	B_{2008}/ B_0	B_{2008}/ B_{MSY}
M = 0.10	31 968	16 889	8 956	2 461	0.280	0.53	1.87
	(29 177–38 119)	(11 067–24 506)	(8 172–10 683)	(2 246–2 924)	(0.279–0.281)	(0.38–0.67)	(1.34–2.38)
M = 0.087	30 729	9 171	8 619	2 106	0.280	0.30	1.07
	(28 223–33 736)	(5 121–14 613)	(7 914– 9 468)	(1 932–2 309)	(0.279–0.281)	(0.18–0.44)	(0.64–1.55)

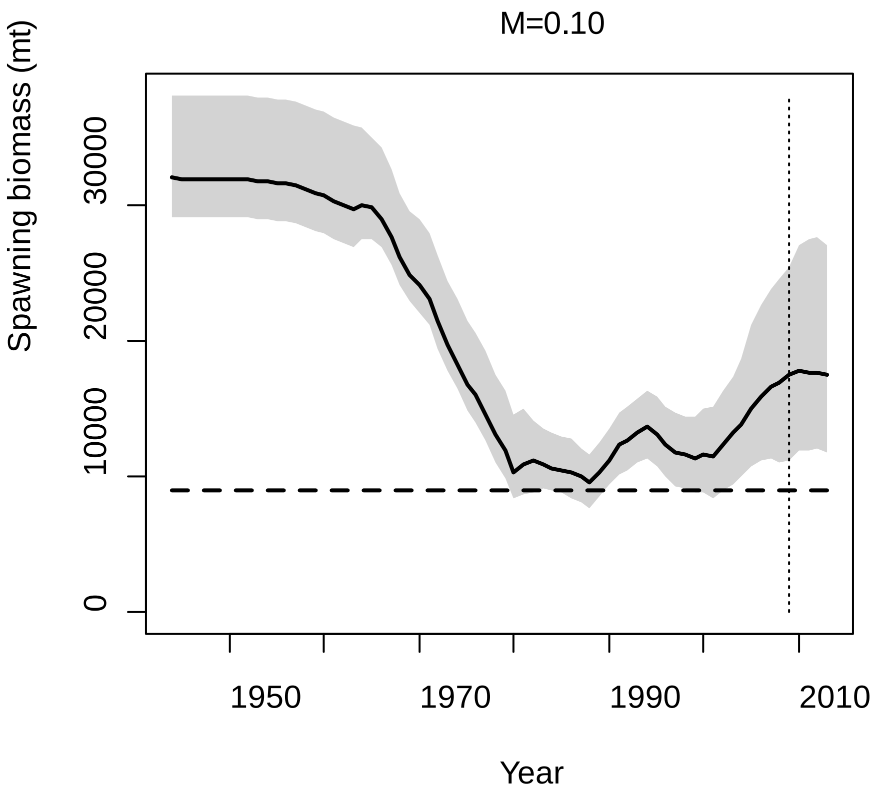


Figure 3: Spawning biomass (female only) trajectory (median of MCMCs) for the model run with natural mortality at 0.10. 95% confidence intervals were derived from MCMC. The horizontal line represents the B_{MSY} and dashed vertical line represents the first year of the projection period (2009).

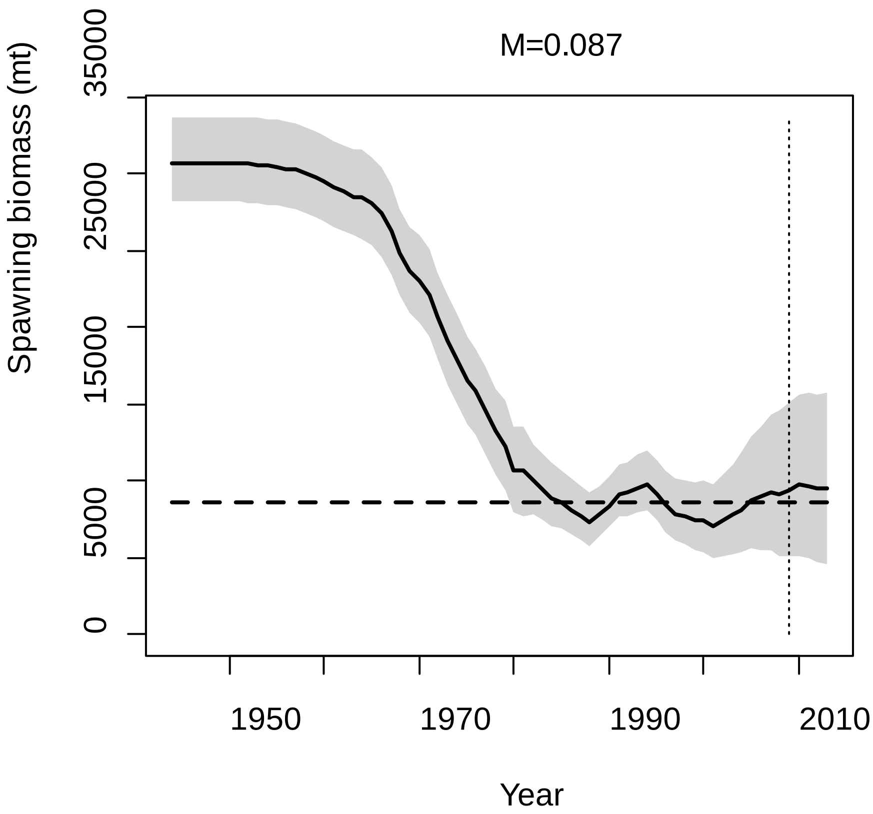


Figure 4: Spawning biomass (female only) trajectory (median of MCMCs) for the model run with natural mortality at 0.087. 95% confidence intervals were derived from MCMC. The horizontal line represents the B_{MSY} and dashed vertical line represents the first year of the projection period (2009).

Stock projections, for a five-year period, were conducted for the two accepted models (*M* = 0.087 and *M* = 0.10). The projections assumed a constant catch based on the TAC and an allowance for recreational and customary catch. For both models, the stock size is predicted to remain at about the current level over the next five years, and remain at or above the B_{MSY} level (probability of 61% and 100% for natural mortality of 0.087 and 0.10, respectively) with a high probability (95% and 100%, respectively) that the biomass will remain above 20% of the unexploited level (B_0). For both models the stock was virtually certain to remain above 10% of B_0 (Probability of 100% in both cases).

Table 8: Biomass estimates (medians, with 95% confidence intervals in parentheses) for model runs with the two plausible estimates of *M*. B_{2013} is the mid-year female spawning biomass in 2013. Estimates are derived from MCMC analysis. Probability (*Pr*) of the spawning biomass remaining above default reference points is also given.

	B_{2013}/B_{MSY}	B_{2013}/B_0	$Pr\ (B_{2013}>B_{MSY})$	$Pr\ (B_{2013}>0.2B_0)$	$Pr\ (B_{2013}>0.1B_0)$
M = 0.10	1.95 (1.43–2.60)	0.55 (0.40–0.73)	1.00	1.00	1.00
M = 0.087	1.08 (0.55–1.68)	0.31 (0.15–0.47)	0.61	0.95	1.00

4.2 Yield estimates and projection

There are no new data that would alter the yield estimates given in the 1999 Plenary Report for TRE 1, 2, and 3. The TRE 1 yield estimates are based on commercial landings data and the results of a historical stock reduction analysis. Yield estimates for TRE 2 and TRE 3 were derived from commercial landings data.

Estimation of Maximum Constant Yield (*MCY*)

The estimates of *MCY* are summarised in Table 8 and detailed in the following sections for each stock. The level of risk to the stock by harvesting the population at the estimated *MCY* value has not been determined.

TRE 1

An estimate of current surplus production (CSP) is available from a stock reduction analysis of the BoP fishery using data from 1973 to 1983. The stock was estimated to have fallen to between 0.3 and 0.7 of its initial size in the period. Using a modified estimate of absolute stock size from a tagging experiment in 1977 and conservative net stock productivity values (0.02-0.06 y^{-1}) the estimate for CSP in 1984 was 600 t. No new information has become available to permit updating the stock reduction analysis estimate of CSP made in 1984. Although not an estimate of equilibrium surplus production, this value for CSP was used to estimate *MCY* using the equation *MCY* = 2/3 CSP (Method 3). This is believed to be a conservative estimate of *MCY*.

$$MCY = 2/3 * 600 \text{ t} = 400 \text{ t}.$$

MCY was estimated using the equation $MCY = cY_{AV}$ (Method 4) for the Hauraki Gulf and North east coast sub-areas. Y_{AV} was set equal to the mean annual commercial landings for the decade 1977–86 and equalled 924 t. Based on an estimate of *M* = 0.1, c was set equal to 0.9.

$$MCY = 0.9 * 924 \text{ t} = 830 \text{ t}.$$

These *MCY* values were combined to provide the overall *MCY* estimate for TRE 1 of 1230 t. This estimate of *MCY* has not changed since the 1992 Plenary Report.

TRE 2 and TRE 3

MCY estimates using the equation $MCY = cY_{AV}$ (Method 4) with mean annual commercial landings for the decade 1977–86 and the natural variability factor c, set equal to 0.9 for these areas, has not changed since the 1989 Plenary Report.

Other yield estimates and stock assessment results

TRE 7

Estimates of *MSY* derived from the 2009 TRE 7 assessment were 2461 t (2246-2924) for $M = 0.1$ and 2106 t (1932–2309) for $M = 0.087$. The current commercial allowance is 2153 t.

4.3 Other factors

Trevally are caught by trawling, together with other species such as snapper, red gurnard and John dory. Mismatches between the proportions of quota held for these species in any year for individual quota holders may affect landings in any one year. As a result of the interaction between snapper and trevally in the TRE 7 trawl fishery, the trevally catch is sometimes constrained by the availability of snapper quota.

Catch sampling of the TRE 1 purse seine catch was carried out annually from 1997–98 to 2002–03. Catch-at-age sampling of TRE 1 caught by single trawl gear was reinstated during the 2006–07 fishing year (Walsh et al 2010). Prior to this the TRE 1 single trawl fishery was last sampled in 1999–2000. The 1999–2000 single trawl samples had a broad range of age classes and a relatively strong 20+ aggregate year class (mean age 8.4 years). There were proportionally fewer older age classes in the 2006–07 single trawl samples and the 20+ aggregate year class was significantly smaller (mean age 6.9 years). In contrast, the age composition of TRE 1 purse seine catches sampled in 1999–00 and 2006–07 showed very little difference in age distribution (mean age 1999–00 9.6 years; mean age 2006–07 10.4 years). The purse seine method appears to select a narrow range of lengths and ages while single trawl catch probably provides better representation of the “true” age structure of the stock (Walsh et al 2010).

The 2006–07 TRE 7 catch-at-age study sampled catches from three spatial areas (90 Mile Beach; Kaipara Manukau; South Taranaki Bight). This was the first time area specific age information had been collected from TRE 7. Strong evidence of spatial heterogeneity in age structure was seen in the catch sampling results. Both 90 Mile Beach and Kaipara-Manukau sub-areas had a broad range of age classes but 90 Mile Beach was unique in having relatively high numbers of 3 and 4 year old fish. The Southern Taranaki Bight age composition differed markedly from the two northern areas having a very large proportion of fish older than 20 years and very few fish aged 3 and 4 years (Walsh et al 2010). This pattern may have implications for stock assessment (if it is observed to be persistent) and is currently being investigated with additional catch-at-age programmes and CPUE analysis.

5. STATUS OF THE STOCKS

- **TRE 1**

The assessment for TRE 1 undertaken in 2006 was not accepted by the Pelagic Working Group due to the lack of a reliable abundance index. Recent catches reported for TRE 1 are less than the estimated *MCY* levels and below the TACC. Reduced proportions of older age classes in the single bottom trawl catch between 1999–00 and 2006–07 combined with the strong drops in landings in 2006–07 and 2007–08 may indicate that stock abundance is declining at current catch levels.

- **TRE 2**

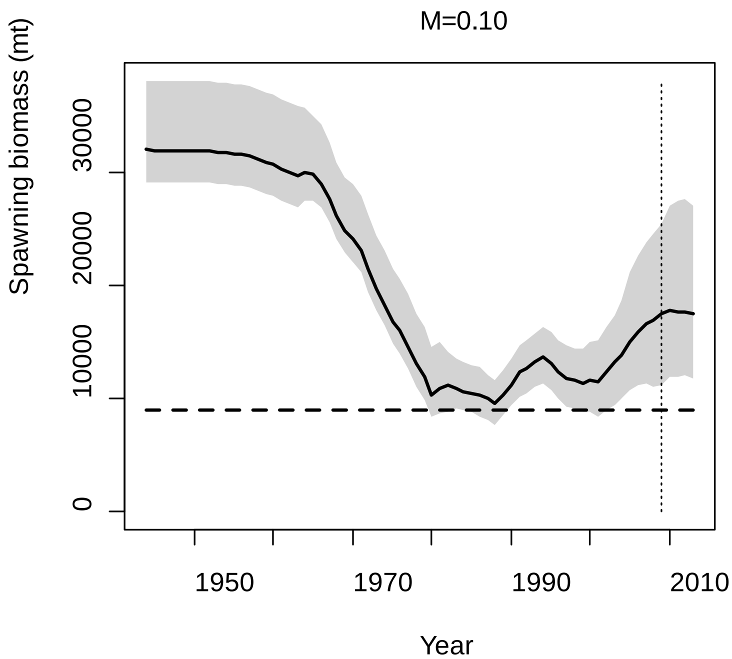
From 2002–03 to 2006–07 reported catches for TRE 2 were substantially larger (average 325 t) than the TACC (241 t) but fell to the level of the TACC in 2007–08. It is not known if these recent catches are sustainable.

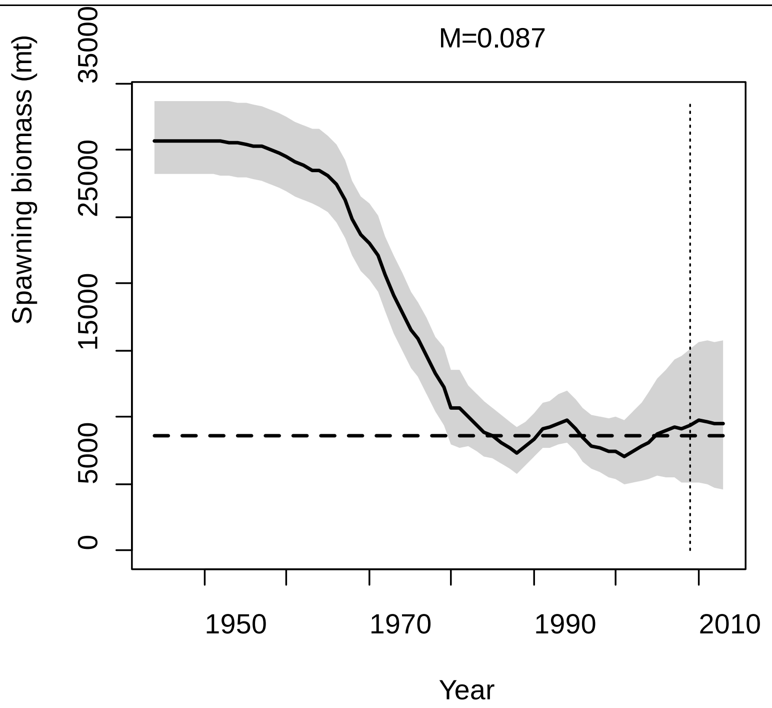
- **TRE 7**

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	2009
Assessment Runs Presented	Two alternate model runs, one with *M* = 0.1 and the other with *M* = 0.087, were used to evaluate TRE 7 status.
Reference Points[3] (Note: These have not actually been set by fisheries managers yet)	Target: Not established but B_{MSY} (28% B_0) assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	<u>Model run *M* = 0.1:</u> B_{2008} estimated to be 38% – 67% B_0 (median = 53% B_0); Very Likely (> 90%) to be at or above the target <u>Model Run *M* = 0.087</u>: B_{2008} estimated to be 18% – 44% B_0 (median = 30% B_0); Likely (> 60%) to be at or above the target
Status in relation to Limits	<u>Model Run *M* = 0.1</u>: B_{2008} Very Unlikely (< 10%) to be below the Soft and Hard Limits <u>Model Run 0.087</u> B_{2008} Very Unlikely (< 10%) to be below the Soft Limit and Hard Limits

Historical Stock Status Trajectory and Current Status





Spawning biomass (female only) trajectories (median of MCMCs) for the model runs with natural mortality at 0.10 and 0.087. 95% confidence intervals were derived from MCMC. The horizontal line represents the B_{MSY} and dashed vertical line represents the first year of the projection period (2009).

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 in the 1960s and 1970s consistent with the increase in the total annual catch. Since 1980 spawning biomass appears to have remained fairly stable (*M* = 0.087), or to have increased to 2008 (*M* = 0.1).
Recent Trend in Fishing Mortality or Proxy	- Relatively large proportions of fish > 10 years, including a healthy 20+ age group (as evidenced by the age structure of the commercial catch) suggest that TRE 7 have not been heavily exploited.
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 stock is About as Likely as Not (40–60%) to remain stable over the next 5 years and the probability of the stock going below B_{MSY} in 2013 is estimated at 0% (*M* = 0.1) and 38% (*M* = 0.087).
Probability of Current Catch or TACC causing decline below Limits (5 years)	Model Run *M* = 0.1: B_{2013} Very Unlikely (< 10%) to decline below Soft and Hard Limits. Model Run 0.087: B_{2013} Very Unlikely (< 10%) to decline below Soft Limit and Very Unlikely (< 10%) to decline below Hard Limit.

Assessment Methodology	
Assessment Type	Level 1 – Full Quantitative Stock Assessment
Assessment Method	Age-structured Stock Synthesis model with Bayesian estimation of posterior distributions.
Main data inputs	- Proportions at age data from the commercial fisheries and historic trawl surveys. - Estimates of biological parameters.

	- Standardised CPUE index of abundance	
Period of Assessment	Latest assessment: 2009	Next assessment: 2014
Changes to Model Structure and Assumptions[10]	Primary differences in the models used in the previous (2005) and current (2009) assessments are as follows: - Additional data, including three years catch-at-age and an updated CPUE index - Refinement of the assumed level of unreported catch since 1986. - Change in model software from CASAL to Stock Synthesis. This was demonstrated to have minimal effect on the model results. - A change in the definition of adult biomass with knife-edge maturity at 5 years old (it was previously assumed that all fish were mature) - Estimation of separate selectivities for the periods pre and post 1986 to account for an increase in trawl mesh size associated with the introduction of a minimum legal size	
Major Sources of Uncertainty	The model allows only a narrow range of plausible values of *M*, which does not reflect real uncertainty in this parameter.	

Qualifying Comments
Analysis of the age structure of commercial bottom trawl catches in 2006–07 suggests that there may be some spatial structure within TRE 7 stock. Future TRE 7 assessments may need to be spatially structured.

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

Yield estimates, TACCs and reported landings by Fishstock are summarised in Table 9.

Table 9: Summary of yields (t), TACCs (t) and reported landings (t) of trevally for the most recent fishing year.

Fishstock	QMA	FMAs	*MCY*	2012–13 Actual TACC	2012–13 Commercial landings
TRE 1	Auckland (East)	1	1 230	1 507	1 301
TRE 2	Central (East)	2	310	241	197
TRE 3	South-East, Chatham, Southland and Sub-Antarctic	3, 4, 5, 6	5	22	< 1
TRE 7	Auckland (West), Central (West), Challenger	7, 8, 9	*see assessment	2 153	1 842
TRE 10	Kermadec	10	0	10	0
Total				3 933	3 340

6. FOR FURTHER INFORMATION

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

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.)

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.)

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 National marine recreational fishing survey: diary results and harvest estimates. Draft New Zealand Fisheries Assessment Report. (Unpublished report held by Ministry for Primary Industries.)

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Draft New Zealand Fisheries Assessment Report for Ministry of Fisheries project REC1998-03 obj. 2. (Unpublished report held by Ministry for Primary Industries.)

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.)

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.)

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 (Draft) Review of methods used to estimate recreational harvests. Draft report held by MPI. Project code: REC2004-06.

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.

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; 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.*

Taylor, P R (In Press) Developing indices of relative abundance from observational aerial sightings of inshore pelagic finfish; step 1, exploring the data. Draft New Zealand Fisheries Assessment Report. 66 p. Draft report held by MPI.

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.*

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.