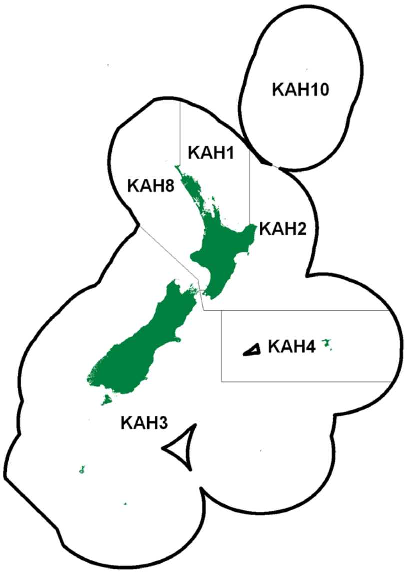
KAHAWAI (KAH)

(Arripis trutta and Arripis xylabion)
Kahawai



1. FISHERY SUMMARY

Kahawai (*Arripis trutta*) and Kermadec kahawai (*Arripis xylabion*) were introduced into the QMS on 1 October 2004 under a single species code, KAH. Within the QMS, kahawai management is based on six QMAs (KAH 1, KAH 2, KAH 3, KAH 4, KAH 8, and KAH 10).

These QMAs differ from the management areas used before kahawai were introduced into the QMS. The definitions of KAH 1, KAH 2, and KAH 10 remain unchanged, but KAH 4 was formerly part of KAH 3, as was the part of KAH 8 south of Tirua Point. The area of KAH 8 north of Tirua point was formerly called KAH 9.

TACs totalling 7612 t were set on introduction into the QMS. These TACs were based on a 15% reduction from both the level of commercial catch and assumed recreational use prior to introducing kahawai into the QMS. The Minister reviewed the TACs for kahawai for the 2005–06 fishing year. Subsequently, he decided to reduce TACs, TACCs, and allowances by a further 10% as shown in Table 1.

Table 1: Recreational and Customary non-commercial allowances, other mortality, TACCs, and TACs (t) for kahawai by Fishstock.

Fishstock	Recreational allowance	Customary Non-commercial allowance	Other sources of mortality	TACC	TAC
KAH 1	900	200	45	1 075	2 200
KAH 2	610	185	30	705	1 530
KAH 3	390	115	20	410	935
KAH 4	4	1	0	9	14
KAH 8	385	115	20	520	1 040
KAH 10	4	1	0	9	14

1.1 Commercial fisheries

Commercial fishers take kahawai by a variety of methods. Purse seine vessels take most of the catch; however, substantial quantities are also taken seasonally in set net fisheries and as a bycatch in surface longline and trawl fisheries.

The kahawai purse seine fishery cannot be understood without taking into account the other species that the vessels target. The fleet, which is based in Tauranga, preferentially targets skipjack tuna (*Katsuwonus pelamis*) between December and May, with very little bycatch. When skipjack are not available, usually from June to November, the fleet fishes for a mix of species including kahawai, jack mackerels (*Trachurus* spp.), trevally (*Pseudocaranx dentex*), and blue mackerel (*Scomber australasicus*). These are caught 'on demand' as export orders are received (to reduce product storage costs). However, since the mackerels and kahawai school together there is often a bycatch of kahawai resulting from targeting of mackerels. Historical estimated kahawai landings are shown in Table 2, from 1931 to 1982. Reported landings, predominantly of *A. trutta*, are shown for 1962 up to and including 1982 in Table 3 by calendar year for all areas combined, and from 1983–84 onwards by fishing year and by historic management areas in Table 4 and by QMAs in Table 5. The historical landings and TACC for the main KAH stocks are depicted in Figure 1.

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

Year	KAH 1	KAH 2	KAH 3	KAH 4	KAH 8	Year	KAH 1	KAH 2	KAH 3	KAH 4
1931–32	1	0	0	0	0	1957	25	6	0	0
1932–33	1	0	0	0	0	1958	33	13	0	0
1933–34	0	0	1	0	0	1959	31	2	0	0
1934–35	0	0	0	0	3	1960	40	1	0	0
1935–36	0	0	0	0	0	1961	40	0	0	0
1936–37	0	0	0	0	0	1962	54	7	0	0
1937–38	2	1	1	0	0	1963	60	11	0	0
1938–39	2	2	1	0	0	1964	75	4	1	0
1939–40	1	1	1	0	0	1965	85	13	0	0
1940–41	1	4	2	0	1	1966	143	106	0	0
1941–42	2	1	1	0	0	1967	147	303	0	0
1942–43	21	1	2	0	0	1968	107	159	29	0
1943–44	58	3	4	0	3	1969	163	29	12	0
1944	90	7	4	0	6	1970	141	59	22	0
1945	102	2	3	0	1	1971	185	258	10	0
1946	94	0	4	0	9	1972	168	151	22	0
1947	54	0	4	0	1	1973	295	132	13	0
1948	58	2	1	0	1	1974	357	206	17	0
1949	23	3	0	0	1	1975	140	28	18	0
1950	34	2	1	0	1	1976	401	108	30	0
1951	22	1	0	0	2	1977	631	385	218	0
1952	27	2	0	0	3	1978	1 237	487	279	0
1953	14	1	0	0	4	1979	1 642	552	608	0
1954	18	2	0	0	2	1980	1 213	885	810	0
1955	19	6	0	0	7	1981	659	625	1301	0
1956	16	3	0	0	7	1982	1 133	639	980	0

Notes:
The 1931–1943 years are April–March but from 1944 onwards are calendar years.
Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.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.

Table 3: Reported total landings (t) of kahawai from 1970 to 1982. Note that these data include estimates of kahawai from data where kahawai were reported within a general category of 'mixed fish' rather than separately as kahawai.

Year	Landings	Year	Landings	Year	Landings
1962	76	1969	234	1976	729
1963	81	1970	294	1977	1 461
1964	86	1971	572	1978	2 228
1965	102	1972	394	1979	3 782
1966	254	1973	586	1980	5 101
1967	457	1974	812	1981	3 794
1968	305	1975	345	1982	5 398

Source: 1962 to 1969, Watkinson & Smith (1972); 1970 to 1982, Sylvester (1989).

Before 1988 there were no restrictions in place for the purse seine fishery.

A total commercial catch limit for kahawai was set at 6500 t for the 1990–91 fishing year, with 4856 t set aside for those harvesting kahawai by purse seine (Table 6). Before the 2002–03 fishing year a high proportion of the purse seine catch was targeted, but in recent years approximately half of the landed catch has been reported as bycatch while targeting other species with purse seine gear.

Table 4: Reported landings (t) of kahawai by management areas as defined prior to 2004, from 1983–84 to 2003–04. Estimates of fish landed as bait or as 'mixed fish' are not included. Data for the distribution of catches among management areas and total catch are from the FSU database up to 1987–88 and from the CELR database after that date. Total LFRR or MHR values are the landings reported by Licensed Fish Receivers (to 2000–01) or on Monthly Harvest returns (to 2003–04).

Fishstock	KAH 1	KAH 2	KAH 3	KAH 8	KAH 10	Unknown Area	Total Catch	Total LFRR/MHR
FMA(s)	1	2	3–7	8, 9	10			
1983–84	1 941	919	813	547	0	46	4 266	–
1984–85	1 517	697	1 669	299	0	441	4 623	–
1985–86	1 597	280	1 589	329	0	621	4 416	–
1986–87	1 890	212	3 969	253	0	1 301	7 525	6 481
1987–88	4 292	1 655	2 947	135	0	581	9 610	9 218
1988–89	2 170	779	4 301	179	0	–	7431	7 377
1989–90	2 049	534	5 711	156	0	16	8 466	8 696
1990–91	1 617	872	2 950	242	0	4	5 687	5 780
1991–92	2 190	807	1 900	199	< 1	7	5 104	5 071
1992–93	2 738	1 132	1 930	832	2	0	6 639	6 966
1993–94	2 054	1 136	1 861	98	15	0	5 164	4 964
1994–95	1 918	1 079	1 290	168	0	24	4479	4 532
1995–96	1 904	760	1 548	237	7	46	4 502	4 648
1996–97	2 214	808	938	194	1	3	4 158	3 763
1997–98	1 601	291	525	264	0	19	2 700	2 823
1998–99	1 833	922	1 209	468	0	3	4 435	4 298
1999–00	1 616	1 138	718	440	0	< 1	3 912	3 941
2000–01	1 746	886	925	272	0	1	3 829	3 668
2001–02	1 354	816	377	271	0	< 1	2 819	2 796
2002–03	933	915	933	221	0	< 1	3 001	2 964
2003–04	1 624	807	109	205	0	0	2 745	2 754

In KAH 1, a voluntary moratorium was placed on targeting kahawai by purse seine in the Bay of Plenty from 1 December 1990 to 31 March 1991; this was extended from 1 December to the Tuesday after Easter in subsequent years. Although total landings decreased in 1991–92, landings in KAH 1 increased, and in 1993–94 the competitive catch limit for purse seining in KAH 1 was reduced from 1666 t to 1200 t. Purse seine catches reported for KAH 9 were also included in this reduced catch limit, although seining for kahawai off the west coast of the North Island ceased after the reduction in the KAH 1 purse seine limit. Purse seine catch limits were reached in KAH 1 between 1998–99 and 2000–01 and in 2003–04.

Prior to the introduction to the QMS, no change was made to the purse seine limit of 851 t for KAH 2. The KAH 2 purse seine fishery was closed early due to the catch limit being reached before the end of the season in each year between 1991–92 and 1995–96 and in 2000–01 and 2001–02.

Within KAH 3, the kahawai purse seine fleet has voluntarily agreed, since 1991–92, not to fish in a number of near-shore areas around Tasman Bay and Golden Bay, the Marlborough Sounds, Cloudy Bay, and Kaikoura. The main purpose of this agreement is to minimise local depletion of schools of kahawai found in areas where recreational fisheries occur, and to minimise catches of juveniles. The purse seine catch limit for KAH 3 was reduced from 2339 to 1500 tonnes from 1995–96. Purse seine catch limits have never been reached in KAH 3.

Since kahawai entered the Quota Management System on 1 October 2004, the purse seine catch limits no longer apply, and landings (regardless of fishing method) are now restricted by quota availability and fishing company policies. KAH 1 landings have ranged between 903 t and 1095 t since the introduction of the current TACC of 1075 t in 2005 (Figure 1). Landings in KAH 2 have been more variable, falling to just 128 t in 2019–20 and 152 t in 2023–24, but exceeding the TACC of 705 t in 2008–09, 2010–11, and 2017–18. KAH 3 landings have been well below the TACC since 2014–15, with just 41 t landed in 2018–19, but increasing to 233 t by 2022–23. KAH 8 landings exceeded the TACC of 520 t in 2007–08 and 2014–15, but have recently declined, ranging between 250 t and 361 t between 2016–17 to 2023–24.

Table 5: Prorated landings (t) of kahawai by the Fishstocks (and FMA) defined in 2004 for the fishing years from 1998–99 to the present. Distribution of data were derived by linking through the trip code, catch landing data (CLD), statistical areas, and landing points and prorating to CLD totals. Landings since 2004–05 are from QMS MHR data. The TACC is provided for those years since the introduction to the QMS.

	KAH 1		KAH 2		KAH 3		KAH 4		KAH 8		KAH 10			
Fishing	1		2		3, 5, 7		4		8, 9		10		Total	
year	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC
1998–99	1 652	–	975	–	697	–	0	–	1 120	–	0	–	4 444	–
1999–00	1 677	–	973	–	499	–	0	–	768	–	0	–	3 917	–
2000–01	1 678	–	922	–	425	–	0	–	581	–	0	–	3 606	–
2001–02	1 326	–	857	–	156	–	0	–	489	–	0	–	2 831	–
2002–03	869	–	855	–	650	–	0	–	542	–	0	–	2 916	–
2003–04	1 641	–	806	–	33	–	0	–	342	–	0	–	2 822	–
2004–05	1 147	1 195	708	785	129	455	< 1	10	544	580	0	10	2 529	3 025
2005–06	903	1 075	530	705	233	410	0	9	346	520	0	9	2 013	2 728
2006–07	1 046	1 075	672	705	382	410	< 1	9	407	520	0	9	2 507	2 728
2007–08	1 002	1 075	564	705	152	410	0	9	570	520	0	9	2 288	2 728
2008–09	945	1 075	823	705	157	410	0	9	381	520	0	9	2 306	2 728
2009–10	988	1 075	518	705	38	410	< 1	9	451	520	0	9	1 995	2 728
2010–11	1 002	1 075	719	705	46	410	0	9	454	520	0	9	2 221	2 728
2011–12	1 004	1 075	498	705	310	410	0	9	514	520	0	9	2 326	2 728
2012–13	1 095	1 075	502	705	195	410	0	9	468	520	0	9	2 260	2 728
2013–14	1 062	1 075	196	705	372	410	<1	9	472	520	0	9	2 102	2 728
2014–15	992	1 075	523	705	59	410	0	9	607	520	0	9	2 181	2 728
2015–16	1 086	1 075	611	705	44	410	<1	9	481	520	0	9	2 222	2 728
2016–17	1 021	1 075	399	705	58	410	0	9	316	520	0	9	1 794	2 728
2017–18	983	1 075	752	705	59	410	0	9	346	520	0	9	2 139	2 728
2018–19	1 045	1 075	635	705	41	410	0	9	321	520	0	9	2 042	2 728
2019–20	998	1 075	128	705	150	410	0	9	361	520	0	9	1 637	2 728
2020–21	1 017	1 075	670	705	202	410	< 1	9	300	520	0	9	2 188	2 728
2021–22	971	1 075	582	705	210	410	0	9	355	520	0	9	2 118	2 728
2022–23	1 004	1 075	648	705	233	410	0	9	274	520	0	9	2 158	2 728
2023–24	956	1 075	152	705	221	410	0	9	250	520	0	9	1 579	2 728

Table 6: Reported catches (t) by purse seine method and competitive purse seine catch limit (t) from 1990–91 to 2003–04. All data are from weekly reports furnished by permit holders to the Ministry of Fisheries except those for 1993–94 which are from the CELR database. Fishstocks are as defined prior to 2004.

	KAH 1		KAH 2		KAH 3		KAH 8		KAH 10		Total	
Year	Catch	Catch limit	Catch	Catch limit	Catch	Catch limit	Catch	Catch limit	Catch	Catch limit	Catch	Catch limit
1990–91	1 422	1 666	493	851	n/a#	2 839*	0	none	0	none	n/a	5 356
1991–92	1 613	1 666	735*	851	1 714	2 339	0	none	0	none	4 080	4 856
1992–93	1 547	1 666	795*	851	1 808	2 339	140	none	0	none	4 290	4 856
1993–94	1 262	1 200	1 101*	851	1 714	2 339	15	§	0	none	4 092	4 390
1994–95	1 225	1 200	821*	851	1 644	2 339	0	§	0	none	3 690	4 390
1995–96	1 077	1 200	805*	851	1 146	1 500	0	§	0	none	3 028	3 551
1996–97	1 017	1 200	620	851	578	1 500	0	§	0	none	2 784	3 551
1997–98	969	1 200	175	851	153	1 500	0	§	0	none	1 297	3 551
1998–99	1 416*	1 200	134	851	463	1 500	2	§	0	none	2 015	3 551
1999–00	1 371*	1 200	553	851	520	1 500	0	§	0	none	2 444	3 551
2000–01	1 322*	1 200	954*	851	430	1 500	0	§	0	none	2 706	3 551
2001–02	838	1 200	747*	851	221	1 500	0	§	0	none	1 806	3 551
2002–03	514	1 200	819	851	816	1 500	0	§	0	none	2 149	3 551
2003–04	1 203*	1 200	714	851	1	1 500	0	§	0	none	1 918	3 551

By March 1991 when the catch limit was imposed, the purse seine catch had already exceeded 2339 t and the fishery was immediately closed. Because this occurred before the Minister's decision was announced, an extra 500 t was allocated to cover kahawai bycatch only.
* Purse seine fishery for kahawai closed.
§ Combined landings from KAH 9 and KAH 1 were limited to 1200 t.

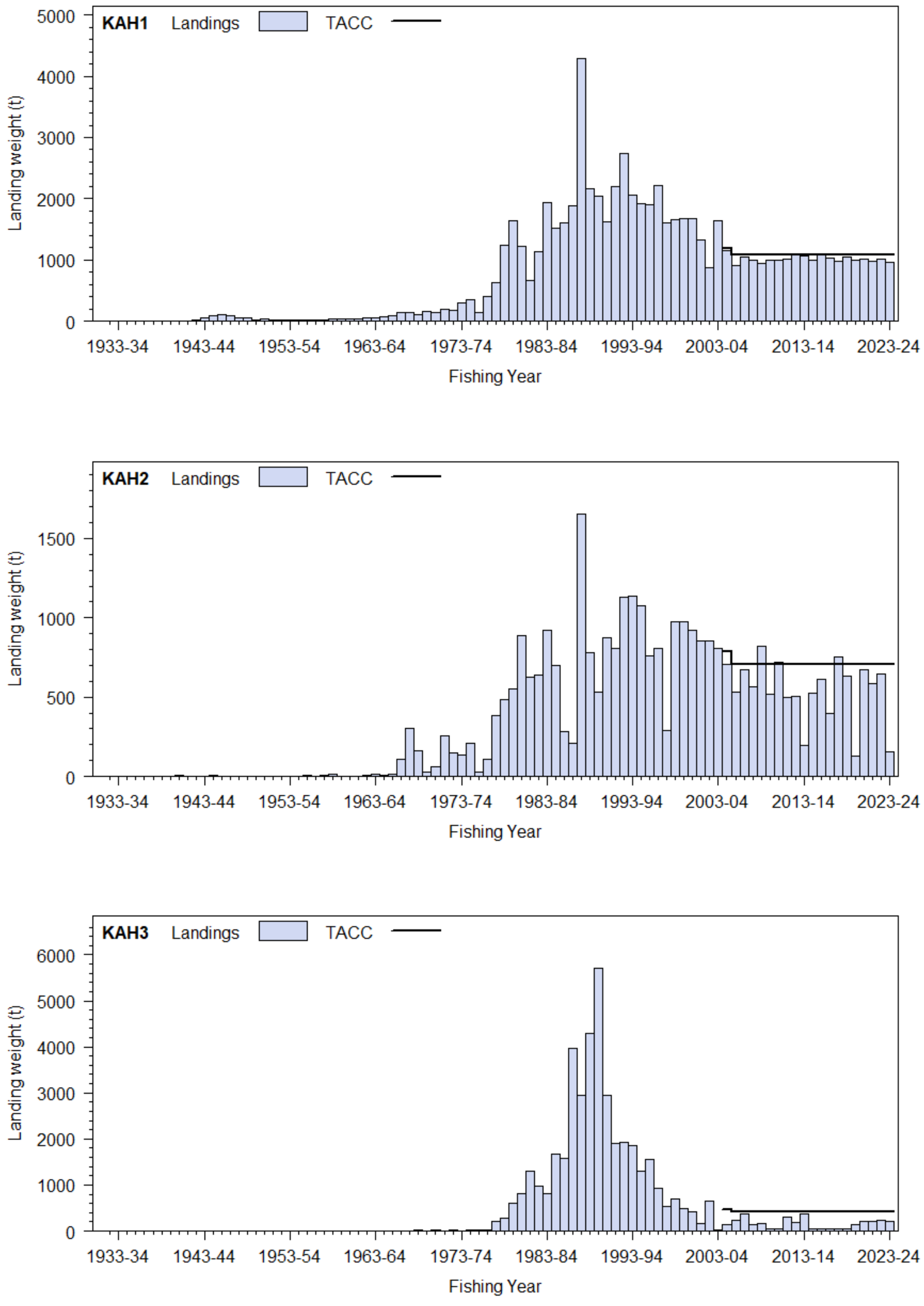


Figure 1: Total commercial landings and TACC for the four main KAH stocks. From top: From top: KAH 1 (Auckland East), KAH 2 (Central East), KAH 3 (South East Coast, South East Chatham Rise, Sub-Antarctic, Southland, Challenger) [Continued on next page]

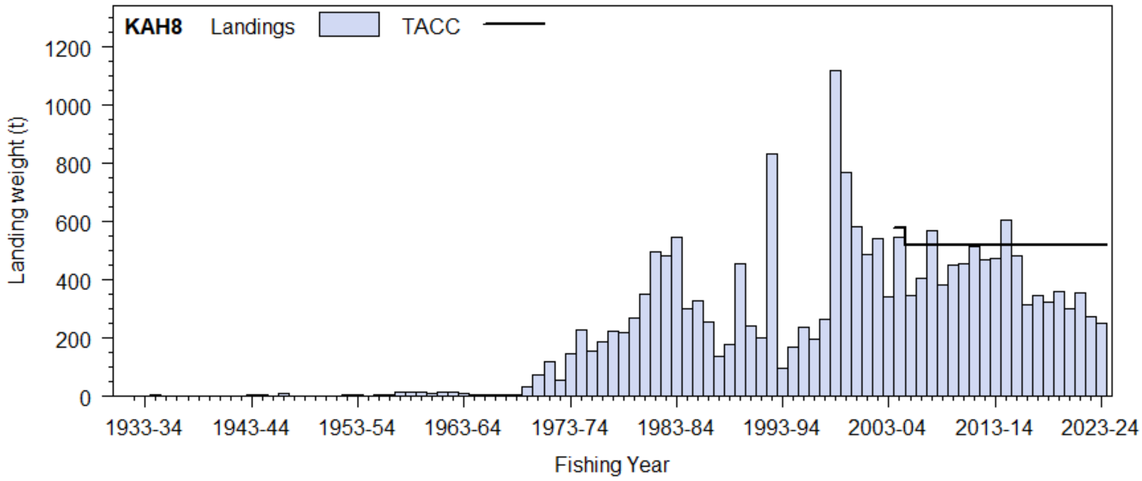


Figure 1 [Continued]: Total commercial landings and TACC for the four main KAH stocks. KAH 8 (Central Egmont, Auckland West).

1.2 Recreational fisheries

Kahawai is the second most important recreational species in FMA 1 (after snapper). Kahawai are highly prized by many recreational fishers, who employ a range of shore and boat-based fishing methods to target and/or catch the species. Kahawai is one of the fish species more frequently caught by recreational fishers, and recreational groups continue to express concern about the state of kahawai stocks in some areas. Historical kahawai recreational catches are poorly known. The current allowances within the TAC for each fishstock are shown in Table 1.

Information from the 2017–18 national panel survey (Wynne-Jones et al 2019) show that kahawai were mainly caught by rod or line (95.2%), with just over half of the landed catch taken from trailer boats (50.5%), and a third were taken off land, with very similar percentages seen previously in 2011–12 (Wynne-Jones et al 2014).

1.2.1 Management controls

The main method used to manage recreational harvests of kahawai is the daily bag limit. The current limits for kahawai are: up to 20 kahawai within a multi-species bag limit of 20 fish in the Auckland, Kermadec, Central, and Challenger management areas; up to 15 kahawai within a multi-species bag limit of 30 fish in the South-East, Southland, and Fiordland management areas; and up to 10 kahawai within a multi-species bag limit of 30 fish in the Kaikoura management area. There is no minimum legal size limit for any kahawai stock. A minimum net mesh size applies in all areas (the mesh sizes do vary by management area and net type).

1.2.2 Harvest estimates

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 their fishing location, or at an access point when they return to land after their fishing trip; and offsite methods, where some form of post-event interview and/or diary is used to collect data from fishers.

The first estimates of recreational harvest for kahawai were generated using an offsite regional telephone and diary survey approach in: MAF Fisheries South (1991–92), Central (1992–93), and North (1993–94) regions (Teirney et al 1997). 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 2002) and a rolling replacement of diarists in 2001 (Boyd et al 2004) provided estimates for a further year (mean weights were not re-estimated in 2001). Other than for the 1991–92 MAF Fisheries South survey, the diary method used mean weights of kahawai obtained from fish measured at boat ramps.

The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. This led to the development of an alternative maximum count aerial-access onsite method that provides a more direct means of estimating recreational harvests for boat-based 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 relative 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 (Hartill et al 2007b).

This aerial-access method was first used to estimate the recreational snapper harvest in the Hauraki Gulf in 2003–04 (Hartill et al 2007b), which was subsequently extended to survey the wider SNA 1 fishery in 2004–05 (Hartill et al 2007c). One benefit of this method is that it also provides harvest estimates for other key species, in particular kahawai (Table 7). The Marine Amateur Fisheries Working Group has concluded that this approach generally provides broadly reliable estimates of recreational harvest for KAH 1. It is not, however, possible to reliably quantify shore-based fishing from the air and it is necessary to derive scalars from recent offsite surveys to account for the shore-based kahawai catch. Aerial-access surveys, focusing on snapper, provided kahawai harvest estimates for the Hauraki Gulf in 2003–04 and for all of FMA 1 in 2004–05, 2011–12, and 2017–18. Aerial-access surveys in FMA 1 in 2011–12 and 2017–18 (Hartill et al 2013, 2019) provided independent harvest estimates for comparison with those generated from national panel surveys in those years.

In response to problems with previous telephone-diary surveys and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The two 2011–12 surveys appear to provide plausible results that corroborate each other for KAH 1 and are therefore considered to be broadly reliable (Hartill et al 2013). The panel survey and corroborating aerial-access survey were repeated over the 2017–18 fishing year. A national panel survey was also conducted in 2022–23 (Heinemann & Gray 2024).

Recreational harvest estimates from offsite surveys up to and including 2022–23 are given in Table 8 (from Wynne-Jones et al 2014, 2019, Hartill & Davey 2015, Hartill et al 2019 and Heinemann & Gray 2024), noting that the QMAs do not all match up with the strata used for the older harvest estimates (in particular for KAH 3 and 8).

Table 7: Summary of kahawai harvest estimates (t) derived from an aerial overflight survey of the Hauraki Gulf in 2003–04 (1 December 2003 to 30 November 2004, Hartill et al 2007b) and a similar KAH 1 wide survey conducted in 2004–05 (1 December 2004 to 30 November 2005, Hartill et al 2007c) and in 2011–12 and 2017–18 (1 October to 30 October, Hartill et al 2013, 2019). Values in brackets denote CVs associated with each estimate.

Year	East Northland	Hauraki Gulf	Bay of Plenty	KAH 1
2003–04	–	56 (0.15)	–	–
2004–05	129 (0.14)	98 (0.18)	303 (0.14)	530 (0.09)
2011–12	191 (0.16)	483 (0.13)	268 (0.12)	942 (0.08)
2017–18	312 (0.13)	517 (0.09)	390 (0.11)	1 219 (0.06)

1.2.3 Monitoring harvest

In addition to estimating absolute harvests, a system to provide relative estimates of harvest over time for key fishstocks has been designed and implemented for some key recreational fisheries. The system uses web cameras to continuously monitor trends in trailer boat traffic at key boat ramps complemented by creel surveys that provide estimates of the proportion of observed boats that were used for fishing and the average harvest of snapper and kahawai per boat trip (Hartill et al 2020). These data are combined to provide relative harvest estimates for KAH 1, that have been scaled by concurrent region wide aerial-access harvest estimates, to estimate annual harvest tonnages landed by recreational fishers by substock (Table 9).

Table 8: Recreational catch estimates for kahawai stocks. The surveys ran from October or December to September or November but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey catch estimates). Totals are given in bold.

Stock	Year	Method	Number of fish (thousands)	Mean weight (g) (summer/winter)	Total weight (t)	CV
<u>KAH 1</u>	1994	Telephone/diary	727	[1]	978	–
	1996	Telephone/diary	666		960	0.06
	2000	Telephone/diary	1 860		2 195	0.13
	2001	Telephone/diary	1 905	[2]	2 248	0.13
Hauraki Gulf only	2004	Aerial-access			56	0.15
East Northland	2005	Aerial-access			129	0.14
Hauraki Gulf	2005	Aerial-access			98	0.18
Bay of Plenty	2005	Aerial-access			303	0.14
Total	2005	Aerial-access			530	0.09
East Northland	2012	Aerial-access		1 473/1 220[3]	191	0.16
Hauraki Gulf	2012	Aerial-access		1 565/1 475[3]	483	0.13
Bay of Plenty	2012	Aerial-access		1 477/1 628[3,4]	268	0.12
Total	2012	Aerial-access		[3,4,5]	942	0.08
East Northland	2012	Panel survey	139	1 473/1 220[3]	198	0.14
Hauraki Gulf	2012	Panel survey	245	1 565/1 475[3]	377	0.09
Bay of Plenty	2012	Panel survey	238	1 477/1 628[3,4]	360	0.11
Total	2012	Panel survey	621	[3,4,5]	935	0.07
East Northland	2018	Aerial-access			312	0.13
Hauraki Gulf	2018	Aerial-access			517	0.09
Bay of Plenty	2018	Aerial-access			390	0.11
Total	2018	Aerial-access			1 219	0.06
East Northland	2018	Panel survey	128	1 717	220	0.14
Hauraki Gulf	2018	Panel survey	207	1 702/1 794	357	0.1
Bay of Plenty	2018	Panel survey	211	1 693	357	0.11
Total	2018	Panel survey	546		934	0.07
East Northland	2023	Panel survey	61	1442	88	0.16
Hauraki Gulf	2023	Panel survey	60	1484	90	0.14
Bay of Plenty	2023	Panel survey	109	1705	186	0.12
Total	2023	Panel survey	231	1577	364	0.08
KAH 2	1993	Telephone/diary	195		298	-
	1996	Telephone/diary	142		217	0.09
	2000	Telephone/diary	1 808		2 937	0.74
	2001	Telephone/diary	492	[2]	799	0.20
	2012	Panel survey	145	1 583/1 449[3]	227	0.12
	2018	Panel survey	130	1 698	222	0.14
	2023	Panel survey	66		113	0.36
KAH 3	1992	Telephone/diary	231		210	-
	1994	Telephone/diary	6	[6]	8.4	-
	1996	Telephone/diary	226		137	0.07
	2000	Telephone/diary	413		667	0.16
	2001	Telephone/diary	353	[2]	570	0.18
	2012	Panel survey	104	1 279/2 340[3]	146	0.18
	2018	Panel survey	68	1 056	72	0.15
	2023	Panel survey	52		67	0.22
KAH 8	1994	Telephone/diary	254	[1]	340	-
	1996	Telephone/diary	199		204	0.09
	2000	Telephone/diary	337		441	0.20
	2001	Telephone/diary	466	[2]	609	0.24
	2012	Panel survey	259	1 664/1 318[3]	415	0.12
	2018	Panel survey	229	1 872/1 505	412	0.12
	2023	Panel survey	152		243	0.12

[1] Mean weight obtained from 1992–93 boat ramp sampling.
[2] The 2000 mean weights were used in the 2001 estimates.
[3] Separate mean weight estimates were used for summer (1 October 2011 to 30 April 2012) and for winter (1 May to 30 September 2012).
[4] Separate mean weight estimates were used for the eastern and western Bay of Plenty.
[5] Temporally and spatially separate mean weight estimates used as per notes 3 and 4. [Continued on next page]
[6] No harvest estimate available in the survey report, estimate presented is calculated as average fish weight for all years and areas by the number of fish estimated caught.

Trends inferred from this monitoring programme were initially very similar to that inferred from aerial-access harvest estimates in the Hauraki Gulf in 2004–05, 2006–07, and 2011–12, but the camera/creel kahawai harvest estimate for the Hauraki Gulf in 2017–18 is substantially lower than concurrent aerial-access and national panel surveys estimates for the same year (Table 9 c.f. Table 8). This difference appears to be due to a recent substantial increase in recreational fishing effort and catch around expanding mussel farms in the Firth of Thames, coinciding with a lesser increase in effort in the north-western gulf. Additional creel survey monitoring has been initiated to monitor changes in the recreational fishery in these areas, which had not been adequately monitored from boat ramps in the Auckland metropolitan area up until 2019–20. There is, however, a good correspondence between trends inferred from camera/creel survey based indices and aerial-access survey and/or national panel survey harvest estimates, for recreational harvesting of kahawai for East Northland and the Bay of Plenty. In East Northland, the kahawai catch landed at the two monitored ramps has gone through similar fluctuations, with no apparent long-term trend evident. In the Bay of Plenty the recreational kahawai halved immediately after 2011–12 and remained at this level before spiking up to the highest estimated harvest tonnage in 2017–18, before declining back to the level seen in the years immediately after 2011–12. These estimates show the variability of recreational harvests between years and, in particular, that harvest levels can be driven not only by stock abundance but also by changes in localised availability.

Table 9: Recreational catch estimates (t) for kahawai in different parts of the KAH 1 stock area calculated from web camera and creel monitoring at key ramps combined with aerial-access estimates for each area in 2004–05 and 2006–07 (Hauraki Gulf only) and 2011–12 and 2017–18 (all areas within KAH 1) (from Hartill et al 2020). Recent estimates, especially for the Hauraki Gulf, are lower than expected but the reasons for this are still being investigated.

Year	East Northland	CV	Hauraki Gulf	CV	Bay of Plenty	CV	Total KAH 1	CV
2004–05	149	0.20	88	0.26	229	0.15	465	0.11
2006–07	–	–	69	0.30	–	–	–	–
2011–12	217	0.18	541	0.19	259	0.21	1017	0.12
2012–13	207	0.22	212	0.20	139	0.21	558	0.12
2013–14	175	0.19	229	0.18	167	0.24	571	0.12
2014–15	86	0.20	191	0.19	107	0.26	384	0.13
2015–16	241	0.17	298	0.18	184	0.17	723	0.10
2016–17	158	0.22	181	0.19	170	0.24	509	0.13
2017–18	275	0.15	260	0.16	404	0.15	938	0.09
2018–19	227	0.16	245	0.17	174	0.16	646	0.10

Web camera and creel monitoring has commenced in other kahawai QMAs but the results have not yet been used to infer trends in those fisheries, although levels of recreational harvesting from these stocks are relatively low.

1.3 Customary non-commercial fisheries

Kahawai is an important traditional and customary food fish for Maori. The level of customary catch has not been quantified and an estimate of the current customary non-commercial catch is not available. Some Maori have expressed concern over the state of their traditional fisheries for kahawai, especially around the river mouths in the eastern Bay of Plenty (Maxwell, 2019).

1.4 Illegal catch

Estimates of illegal catch are not available, but are probably insignificant.

1.5 Other sources of mortality

There is no information on other sources of mortality. Juvenile kahawai may suffer from habitat degradation due to run-off, situation and loss of shelter in estuarine areas.

2. BIOLOGY

Kahawai (*Arripis trutta*) are a schooling pelagic species belonging to the family Arripididae. Kahawai are found around the North Island, the South Island, the Kermadec Islands and Chatham Islands. They occur mainly in coastal seas, harbours, and estuaries and will enter the brackish water sections of rivers. A second species, *A. xylabion*, has been described (Paulin 1993). It is known to occur in the northern EEZ, at the Kermadec Islands and seasonally around Northland.

Kahawai feed mainly on fishes but also on pelagic crustaceans, especially krill (*Nyctiphanes australis*). Kahawai smaller than 100 mm mainly eat copepods. Although kahawai are principally pelagic feeders, they will take food from the seabed.

The spawning habitat of kahawai is unknown but is thought to be associated with the seabed offshore. Schools of females with running ripe ovaries have been caught by bottom trawl in 60–100 m in Hawke Bay (Jones et al 1992). Other females with running ripe ovaries have been observed in east coast purse seine landings sampled in March and April 1992, and between January and April in 1993 (McKenzie, NIWA, unpublished data). Length-maturation data collected from thousands of samples in the early 1990s suggest that the onset of sexual maturity in males occurs at around 39 cm (fork length) and in females at 40 cm (McKenzie, NIWA, unpublished data). This closely matches an estimate of 39 cm used for Australian *A. trutta* (Morton et al 2005). This length roughly corresponds to fish of four years of age in both countries. Eggs have been found in February in the outer Hauraki Gulf. Juvenile fish (0+ year class) can be found in shallow water over eelgrass meadows (*Zostera* spp.) and in estuaries.

Kahawai are usually aged using otoliths, following an ageing technique that has been validated (Stevens & Kalish 1998). Kahawai grow rapidly, attaining a length of around 15 cm at the end of their first year, and mature after 3–5 years at about 35–40 cm, after which their growth rate slows. The longest recorded *A. trutta* had a fork length of 79 cm and was caught by a recreational fisher in the Waitangi Estuary in Hawke Bay in August 1997 (Duffy & Petherick 1999). Northern kahawai, *Arripis xylabion*, grow considerably bigger than kahawai and attain a maximum length of at least 94 cm, but beyond this, little is known about the biology of *A. xylabion*. Male and female von Bertalanffy growth curves appear to be broadly similar, with females attaining a slightly higher value for L_∞, although statistical comparison of sex specific curves using a likelihood ratio test (Kimura 1980) suggests that they are statistically different (Hartill & Walsh 2005). Combined-sex growth curves are probably adequate for modelling purposes and are provided for some areas in Table 10. Sex specific growth parameters given for KAH 1 in previous plenary documents have higher estimates for L_∞ (56.93 for males and 55.61 for females).

Table 10: Estimates of biological parameters.

Fishstock			Estimate	Source
1. Natural mortality (*M*)				
All			0.22	Hartill & Doonan (2022)
2. Weight = a(length)^b (weight in g, length in cm fork length)				
		a	b	
	KAH 1 (resting)	0.0306	2.82	Hartill & Walsh (2005)
	KAH 1 (mature)	0.0103	3.14	Hartill & Walsh (2005)
	KAH 1 & 3 (all)	0.0236	2.89	Hartill & Walsh (2005)
3. von Bertalanffy growth parameters				
	K	t_0	$L\infty$	
KAH 1	0.35	0.13	54.6	Hartill & Bian (2016)
KAH 2	0.34	0.60	53.5	Drummond (1995)
KAH 3	0.30	0.25	54.2	Drummond & Wilson (1993)
KAH 9	0.23	-0.26	55.9	McKenzie, NIWA, unpubl. data

The maximum recorded age of kahawai is 26 years and this age has been previously used to estimate the instantaneous rate of natural mortality (*M*) using the equation M=log$_e$100/maximum age (Jones et al 1992). The resulting estimate of *M* of 0.18 assumes that this maximum observed age equates to that at which 1% of the population would survive in an unexploited stock, but a higher value for *M* is now considered more likely. This is because a re-analysis of purse seine catch-at-age data collected by Eggleston from KAH 2 & 3 between 1973 and 1975 suggested that 1% of the unexploited population would have lived for 20 years, which equates to an *M* of 0.23. A Chapman-Robson estimate of *M* of 0.22 was also derived from these catch-at-age data. Likelihood profiling of *M* undertaken during the 2021 stock assessment also suggested that values around 0.23 were most likely. Estimates of *M* ranging from 0.20 to 0.24 were therefore considered in the 2021 stock assessment and the assumed value used in the base case model was 0.22.

3. STOCKS AND AREAS

Kahawai are presently defined as separate units for the purpose of fisheries management: KAH 1 (FMA 1); KAH 2 (FMA 2); KAH 3 (FMAs 3, 5, 6, & 7); KAH 4 (FMA 4); KAH 8 (FMAs 8 & 9), and KAH 10 (FMA 10).

Returns from tagging programmes do not provide definitive information on the level of potential mixing between KAH QMAs, but tagging returns suggest that most kahawai (*A. trutta*) remain in the same area for several years, but some move throughout the kahawai habitat. The pattern of kahawai movement around New Zealand is poorly understood and there are regional differences in age structure and abundance that are consistent with limited mixing between regions.

Smith et al (2008) compared otolith micro-chemistry (multi-element chemistry and stable isotopes) and meristics (e.g., fin counts) from 0-group kahawai from two regions (Okahu Bay, Waitematā Harbour and Hakahaka Bay, Port Underwood). Two distant sites were chosen to provide the best chance of successful discrimination. Neither meristics nor stable isotopes provided any discrimination, and magnesium and barium concentrations provided only weak discriminatory power.

On balance it seems possible that there are least two stocks of kahawai (*A. trutta*) within New Zealand waters with centres of concentration around the Bay of Plenty and the northern tip of the South Island. These two areas could be assumed to be separate for management purposes. Tagging data show that there is some limited mixing between these areas. Due to the shared QMA boundaries in the lower North Island and South Island, there is likely to be more mixing between the southern KAH QMAs than with the northern QMA (KAH 1).

There is no information about stock structure of *A. xylabion*.

4. STOCK ASSESSMENT

The first age-structured assessment of the KAH 1 stock was first undertaken in 2007 (Hartill 2009), which was updated and revised in 2015 (Hartill & Bian 2016) and then again in 2021 (Hartill & Doonan 2022). Both assessments were undertaken using CASAL (Bull et al 2012). The 2021 assessment is reported below.

There are no accepted assessments for kahawai stocks outside KAH 1, although there are some catch curve estimates of Z from these areas from the early 1990s, which are reported here.

4.1 KAH 1

4.1.1 Estimates of catch, selectivity, and abundance indices

(i) Commercial catch
The commercial catch history used in the assessment is provided in Table 11. Annual catch by method landings statistics up until 1981–82 were provided by Francis & Paul (2013), and Fisheries Statistics Unit data were used to generate landings statistics for 1982–83 to 1988–89. It is noted that catches during these early years are less certain due to reporting issues (e.g., see Table 4 legend).

(ii) Recreational catch
The recreational catch history in KAH 1 is poorly known. Aerial overflight estimates are available for the Hauraki Gulf in 2003–04 (Hartill et al 2007b) and for all three regions of KAH 1 in 2004–05 (Hartill et al 2007c), in 2011–12 (Hartill et al 2013) and in 2017–18 (Hartill et al 2019). Recreational harvest estimates for all three regions of KAH 1 are also available from National Panel Surveys undertaken in 2011–12 and 2017–18 (Wynne-Jones et al 2014, 2019), which were of a broadly similar magnitude to those provided by the aerial-access survey (see Table 8).

Table 11: Commercial catch (t) time series used in the 2021 stock assessment of KAH 1.

	Purse seine	Set net	Bottom trawl	Other	KAH 1		Purse seine	Set net	Bottom trawl	Other	KAH 1
1930–31	–	–	–	–	–	1975–76	140	148	65	48	401
1931–32	–	1	–	–	1	1976–77	271	163	123	74	631
1932–33	–	–	–	–	–	1977–78	432	461	200	145	1 238
1933–34	–	–	–	–	–	1978–79	875	228	380	159	1 642
1934–35	–	–	–	–	–	1979–80	561	270	250	132	1 213
1935–36	–	–	–	–	–	1980–81	292	159	131	76	658
1936–37	–	2	–	–	2	1981–82	440	356	202	135	1 133
1937–38	–	–	–	–	–	1982–83	169	527	105	181	982
1938–39	–	1	–	–	1	1983–84	1 445	321	65	111	1 942
1939–40	–	–	–	–	–	1984–85	882	410	82	141	1 515
1940–41	–	1	–	–	1	1985–86	1 191	263	53	91	1 598
1941–42	–	12	4	4	20	1986–87	1 544	224	45	77	1 890
1942–43	–	35	12	12	59	1987–88	3 964	212	43	72	4 291
1943–44	–	53	18	18	89	1988–89	1 644	340	69	117	2 170
1944–45	–	62	21	21	104	1989–90	1 699	351	70	121	2 241
1945–46	–	55	19	19	93	1990–91	1 563	333	82	62	2 040
1946–47	–	32	11	11	54	1991–92	1 726	322	49	75	2 172
1947–48	–	35	11	11	57	1992–93	2 473	628	176	162	3 439
1948–49	–	14	4	4	22	1993–94	1 162	596	80	137	1 975
1949–50	–	20	7	7	34	1994–95	1 053	436	65	157	1 711
1950–51	–	13	4	4	21	1995–96	1 098	350	127	135	1 710
1951–52	–	16	5	5	26	1996–97	921	691	113	105	1 830
1952–53	–	8	3	3	14	1997–98	712	351	116	72	1 251
1953–54	–	11	4	4	19	1998–99	1 374	217	149	85	1 825
1954–55	–	12	4	4	20	1999–00	1 222	243	106	43	1 614
1955–56	–	9	3	3	15	2000–01	1 393	217	79	57	1 746
1956–57	–	16	5	5	26	2001–02	957	292	59	45	1 353
1957–58	–	20	7	7	34	2002–03	608	236	49	37	930
1958–59	–	19	7	7	33	2003–04	1 361	200	51	25	1 637
1959–60	–	24	8	8	40	2004–05	834	178	48	38	1 098
1960–61	–	24	8	8	40	2005–06	535	216	72	82	905
1961–62	–	33	12	12	57	2006–07	696	267	40	43	1 046
1962–63	–	36	12	12	60	2007–08	668	261	57	36	1 022
1963–64	–	45	15	15	75	2008–09	602	274	31	48	955
1964–65	–	51	17	17	85	2009–10	555	329	60	47	991
1965–66	–	86	28	28	142	2010–11	541	306	58	61	966
1966–67	–	88	29	29	146	2011–12	707	185	68	85	1 045
1967–68	–	64	21	21	106	2012–13	707	232	115	54	1 108
1968–69	–	98	33	33	164	2013–14	645	220	132	66	1 063
1969–70	–	84	28	28	140	2014–15	490	212	106	198	1 006
1970–71	–	111	38	38	187	2015–16	717	184	72	121	1 094
1971–72	–	100	33	33	166	2016–17	667	182	87	86	1 022
1972–73	–	177	58	58	293	2017–18	661	161	59	100	981
1973–74	–	214	71	71	356	2018–19	640	200	111	101	1 052
1974–75	38	64	19	20	141	2019–20	682	161	80	81	1 004

Zero inflated negative binomial (ZINB) generalised linear modelling of observations of the number of kahawai landed per complete hour of interviewing at selected boat ramps surveyed since 1990 was used to reconstruct recreational catch histories for all three regions of KAH 1 from that time onward (Hartill & Doonan 2022). Environmental covariates (wind speed and tidal state) and temporal factors (fishing year, month, and day type) were offered to separate regional models which were used to predict the number of kahawai landed at each of the surveyed ramps since 1990. These predictions were used to calculate estimates of the annual number of kahawai landed across all of the boat ramps that were surveyed in each region, which were then combined with regional annual mean weight estimates. The resulting annual landed weight index was regarded as a relative index, because only a sample of boat ramps were surveyed in each region in each year. These regional relative harvest indices were therefore scaled to aerial-access harvest estimates for each region for 2004–05, 2011–12 and 2017–18, to provide estimates of the total recreational harvest of kahawai taken from each region of KAH 1 (Figure 2).

Estimates of recreational harvest were required back to 1930–31, however, and the harvest at that time was assumed to be 10% of that in 1974–75, which was then ramped up to that value over the intervening years.

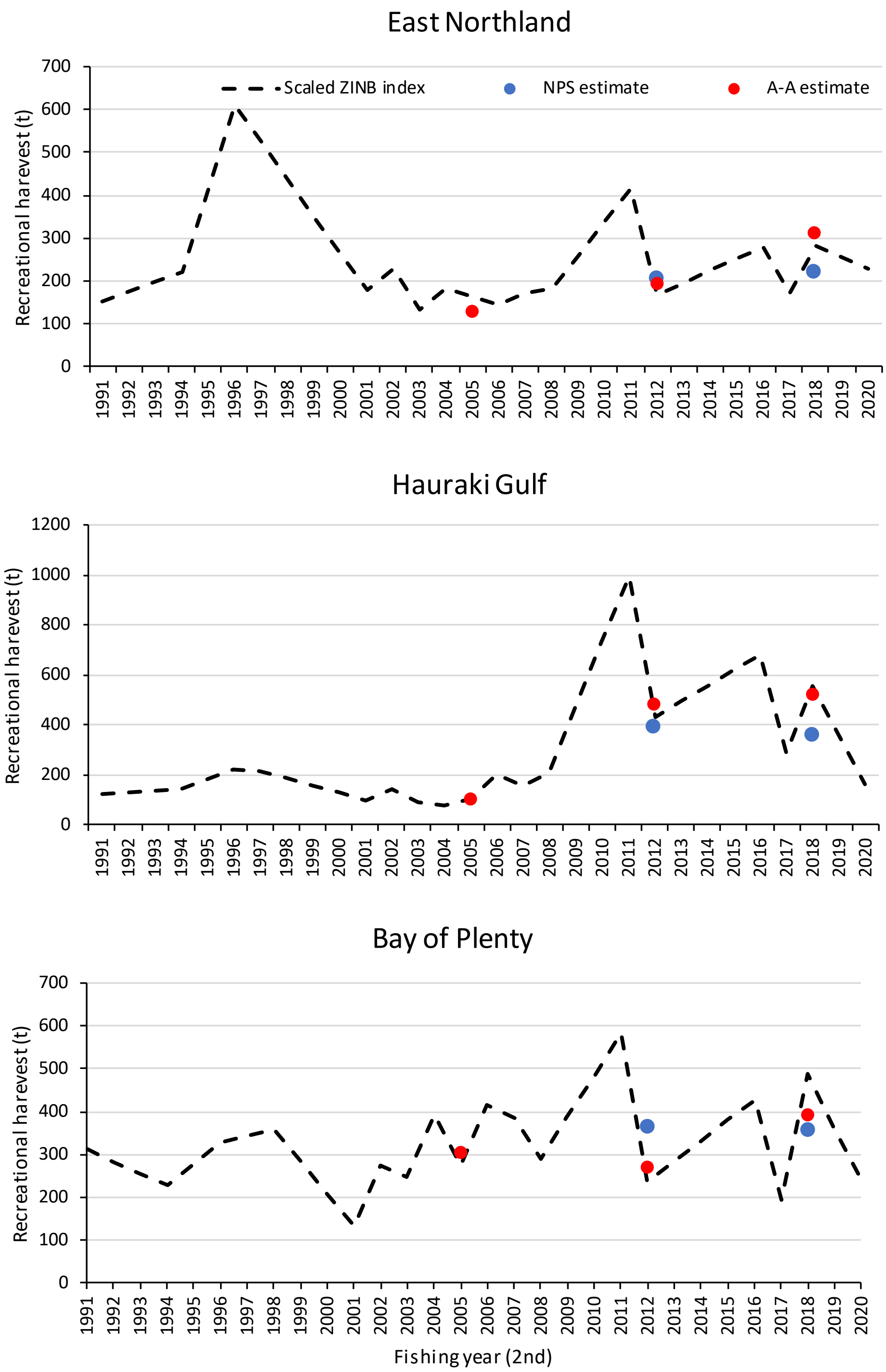


Figure 2: Regional recreational catch histories for KAH 1 based on zero inflated negative binomial modelling of creel survey landings data (kahawai landed per complete creel survey hour). The relative harvest indices generated from regional model predictions were scaled up by regional harvest estimates provided by aerial-access surveys of KAH 1 in 2004–05, 2011–12 and 2017–18, to account for the catch landed by all recreational fishers, at all access points including those which had not been surveyed.

(iii) Catch composition data and selectivity estimates

The earliest catch-at-age data that are available were collected from single trawl and purse seine landings sampled in 1991, 1992, and 1993. Purse seine landings were also sampled in 2005, 2011, and 2012. Catch-at-age data were available from set net landings from the Hauraki Gulf in 2011 and 2012, which were sampled so that the selectivity for this method could be estimated.

Recreational landings sampled during each of 13 years between 2001 and 2018 provided the most consistently sampled source of catch-at-age data used in the assessment (Hartill et al 2007a, 2007d, 2008, Armiger et al 2006, 2009, 2014, 2019). Boat ramp surveys were conducted in East Northland, the Hauraki Gulf, and the Bay of Plenty between January and April in each year, and regional age composition data were fitted in a fleets-as-areas model in 2021. The Hauraki Gulf catch-at-age data were separated out into two time series; an "early" period between 2001 and 2008 when landings were dominated by 3 and 4-year-olds, and a "late" period from 2009 to 2018, when recreational catches of kahawai were dominated by much older fish, which was thought to be due episodic immigration of larger fish from the Bay of Plenty

All age composition data were iteratively reweighted following the Francis method TA1.8 (Francis 2011), which resulted in effective sample sizes being down weighted by a range between 86 and 97% across regions and years for the recreational catch-at-age, 97% for the purse seine catch-at-age data and by 93% for the single trawl data. This process maintained CVs for the abundance indices at the level originally estimated outside of the model.

Logistic selectivity ogives were estimated for the purse seine, East Northland recreational, "late" Hauraki Gulf recreational and Bay of Plenty recreational fisheries, and double-normal selectivities were estimated for the "early" Hauraki Gulf recreational and single trawl fisheries. The single trawl selectivity ogive was also used when accounting for the relatively small tonnage landed by other methods such as bottom longlining and beach seine. A double normal selectivity was estimated from the set net catch-at-age data and subsequently fixed at MPD parameter values.

(iv) Indices of abundance

Four indices of abundance were available for the assessment; three regional recreational CPUE indices and an aerial Sightings per Unit Effort (SPUE) index. Set net CPUE indices used in the 2007 assessment are no longer considered reliable because ring net fishing is often reported as set net fishing.

Recreational CPUE indices

The recreational CPUE indices used in the 2021 model were based on creel survey data collected at boat ramps during surveys conducted intermittently since 1991. Separate standardised indices of the number of kahawai caught per angler trip (rod & line methods only) were calculated for the three regions of KAH 1 (Figure 3) (Hartill & Doonan 2022). Because the catch data used for these standardisations were counts of the number of fish landed per boat trip, and the majority of anglers did not catch kahawai during their trip in any given region or fishing year, negative binomial (NB) and zero inflated negative binomial (ZINB) CPUE generalised linear modelling methods were used to standardise catch rates and generate relative abundance indices.

With the ZINB standardisations the same terms were offered to both the left hand (negative binomial) and right hand (additional zero) components of the model. Rootogram diagnostic plots suggested that the ZINB models for East Northland and the Bay of Plenty provided better fits to the data than the NB models, but the ZINB model for the Hauraki Gulf fishery did not converge, and the NB index was used for this region. The Hauraki Gulf CPUE index was truncated at 2008 because CPUE at length analyses suggested that there was a sudden episodic influx of large kahawai into the Gulf sometime after 2008, which could not be explained by the subsequent growth of much smaller 3 and 4 year old fish that dominated recreational landings between 2001 and 2008.

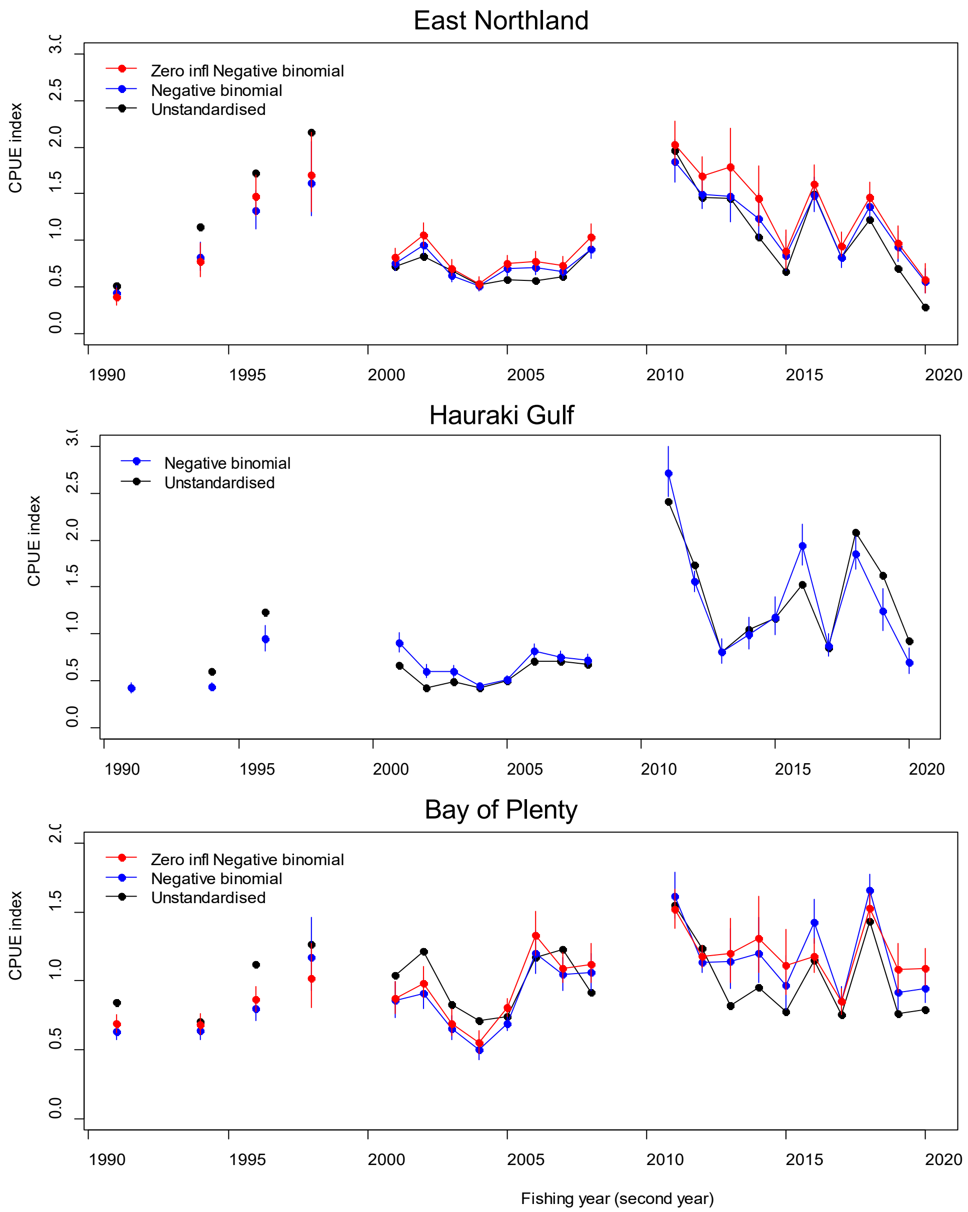


Figure 3: Standardised recreational CPUE (number of fish/angler trip). Vertical lines are bootstrap 95% confidence intervals.

Aerial sightings index

In 2012, an index of abundance [sightings per unit effort (SPUE)] based on commercial aerial sightings data was accepted by the Northern Inshore Working Group. This index was calculated using data from the *aer_sight* database and applying a generalised additive model (GAM) to produce standardised annual relative abundance indices (Taylor 2014).

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

Estimates of relative year effects were obtained using a forward stepwise GAM, where the data were fitted using two models: 1) the probability of a flight having a positive sighting modelled using a binomial regression; and 2) the tonnage sighted on positive flights modelled using a lognormal regression. These two models were combined into a single index. The data used for the SPUE analyses consisted of aerial sightings of kahawai, trevally, jack mackerel, blue mackerel, and skipjack tuna collected over the period 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 there being no available data. By contrast, 2006–07 was dropped because the working group identified a bias in the annual index for that year because of the low number of available flights. The first year of the original series (1985–86) was dropped by the working group for the same reason.

The species with the maximum daily purse seine catch from the vessels that the pilot was working with in the BoP was used as a proxy for target species. Catch data before 1989 were from the *fsu-new* database and data from 1989 to 2013 were from the *warehou* database.

The working group accepted the combined model of SPUE for kahawai as an index of abundance in the BoP. The BoP combined SPUE index for kahawai shows substantial inter-annual variation with an overall gradual declining trend from 1986–87 to 2002–03; thereafter increasing sharply to a peak in 2007–08, and then declining to points above the long-term mean (Figure 4, Table 12).

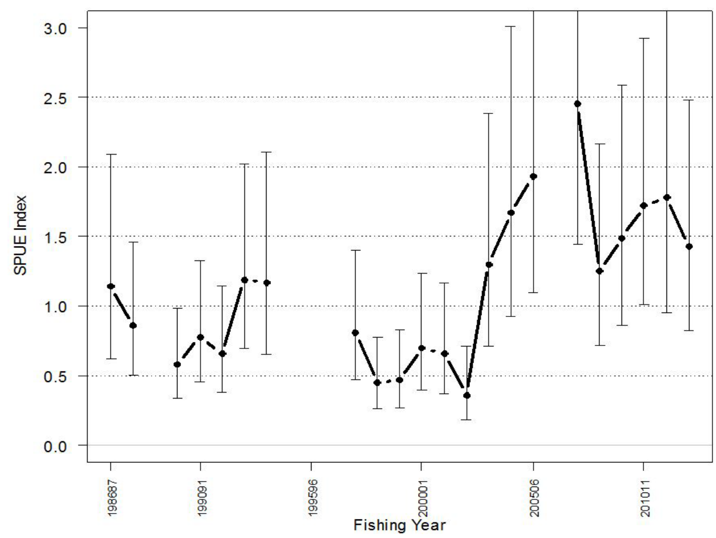


Figure 4: Standardised sightings per unit effort (SPUE) indices for the Bay of Plenty KAH 1 stock, derived as a combination of year effect estimates from a lognormal and a binomial regression. Vertical lines are 95% confidence intervals.

Table 12: Standardised sightings per unit effort (SPUE) indices for the Bay of Plenty KAH 1 stock, derived as a combination of year effect estimates from a lognormal and a binomial regression for 1986–87 to 2012–13.

Fishing year	Combined	CV	Fishing year	Combined	CV
1986–87	1.14	0.31	2001–02	0.66	0.29
1987–88	0.86	0.27	2002–03	0.36	0.29
1988–89	No data	No data	2003–04	1.30	0.35
1989–90	0.58	0.27	2004–05	1.67	0.30
1990–91	0.78	0.27	2005–06	1.93	0.29
1991–92	0.66	0.28	2006–07	Insufficient data	Insufficient data
1992–93	1.19	0.27	2007–08	2.45	0.27
1993–94	1.17	0.30	2008–09	1.25	0.28
1994–95	No data	No data	2009–10	1.49	0.28
1995–96	No data	No data	2010–11	1.72	0.27
1996–97	No data	No data	2011–12	1.78	0.32
1997–98	0.81	0.28	2012–13	1.43	0.28
1998–99	0.45	0.28			
1999–00	0.47	0.54			
2000–01	0.70	0.29			

4.1.2 Model structure

The stock assessment was restricted to KAH 1 because this is the QMA where most of the observational data have been collected. Future assessments may consider a broader stock definition, but improved understanding of the movement dynamics of this species and further development of this model are required before this can be attempted. Even within KAH 1 there is little information on connectivity between the three main areas of the fishery: East Northland, Hauraki Gulf, and the Bay of Plenty. There are few tag data available that can be used to estimate these migration processes, because almost all of the kahawai that have been tagged have been released in the Bay of Plenty. This provides little information about emigration from the Hauraki Gulf and East Northland. Recreational catch-at-age data collected since the 2007 assessment suggests that size-based migration between areas may vary more considerably and unpredictably than previously thought. A fleets-as-areas model structure was therefore used for the 2021 stock assessment for KAH 1, where separate selectivities and catch histories for the three regional recreational fisheries were used to account for the differing impact of these regional fisheries on the combined KAH 1 stock. A single selectivity and catch history was used for each of the commercial method fisheries, as they were either focused on a single region of KAH 1, or their catch histories were relatively small.

The stock assessment model assumes KAH 1 is a single biological stock exploited by several fisheries. Deviations from the spawner-recruitment curve were estimated for those years when there were three or more years of observational catch-at-age data and were constrained to a mean of 1.0 across all years from 1994 to 2020. Year-class strengths were estimated from the recreational landing composition data, because the Working Group concluded that year-class strengths could not be inferred from the limited purse seine, single trawl and set net catch composition data that were available. It is acknowledged that there is a potential mismatch between the recreational CPUE indices and the associated age structure of landed fish, because count data for unlanded catches were also used when generating these CPUE indices. The selectivity of the purse seine fishery appears to vary annually. The more recent purse seine and set net age compositional data that might have influenced the estimation of the 1994 to 2020 year classes were therefore heavily down-weighted so they had little influence on year class strength estimation.

A single annual time step was used, in which ageing was followed by recruitment, maturation, growth, and then mortality (natural and fishing). The relationships between length and age, and length and weight, were both assumed to be constant through time and were based on updated parameter values given in Table 10. Annual abundances of the age classes 1 to 20 were estimated in the model, with 20-year-olds representing all fish older than 19 years. The model was not sex specific. Maturation was knife-edged at four years of age. There is no information on the relationship between stock size and recruitment. The rate of natural mortality is uncertain, although there was evidence to suggest it was higher than previously assumed.

It was assumed that the population was at an unfished equilibrium state (B_0) in 1930, as reported commercial landings between 1930 and 1940 were only in the order of 1 to 2 tonnes per year. Key model outputs are probably robust to this assumption because commercial landings before the early 1970s were only of the order of a few hundred tonnes and recreational landings were assumed to be low relative to stock size prior to this time. Total fishing mortality was apportioned between fisheries according to observed catches and estimated selectivities. Method specific annual landings from seven fishing methods were considered: purse seine, single trawl, set net, other minor commercial fishing methods, and for the three regional recreational fisheries.

4.1.3 Evaluation of uncertainty

Evaluations of preliminary models focused on the assumed value for natural mortality (M). An M of 0.22 was assumed for the base case model. Two sensitivity models were also considered for two alternative values for M: 0.20 and 0.24.

MCMCs were run for all three of these models, with three concatenated chains of 1 million iterations that had been burnt in for half a million iterations. MCMC traces for some of the selectivity parameters for the $M = 0.20$ and 0.24 sensitivities fluctuated markedly, with the best diagnostics achieved by the base case ($M = 0.22$) model.

The base case model was projected for a five-year period (2021–22 to 2025–26), with future catches for these years and the recently completed 2020–21 fishing year all being set to the average annual catch by fishery for the three year period from 2017–18 to 2019–20. Year-class strengths were drawn from the 10-year period, 2005–2014.

4.1.4 Results

The trajectory of the spawning stock biomass estimated by the base case model broadly followed the abundance indices offered to the model, given the extent of interannual variability (Figure 5). All models suggest that the stock was gradually fished down until the late 1970s, followed by a steeper decline that coincided with the development of the purse seine fishery during the 1980s (Figure 6). These models suggest that the biomass of the KAH 1 stock started to rebuild during the early 2000s, followed by a decline in abundance in recent years due to lower levels of recruitment. Higher assumed values for *M* produced higher estimates of stock abundance and stock status.

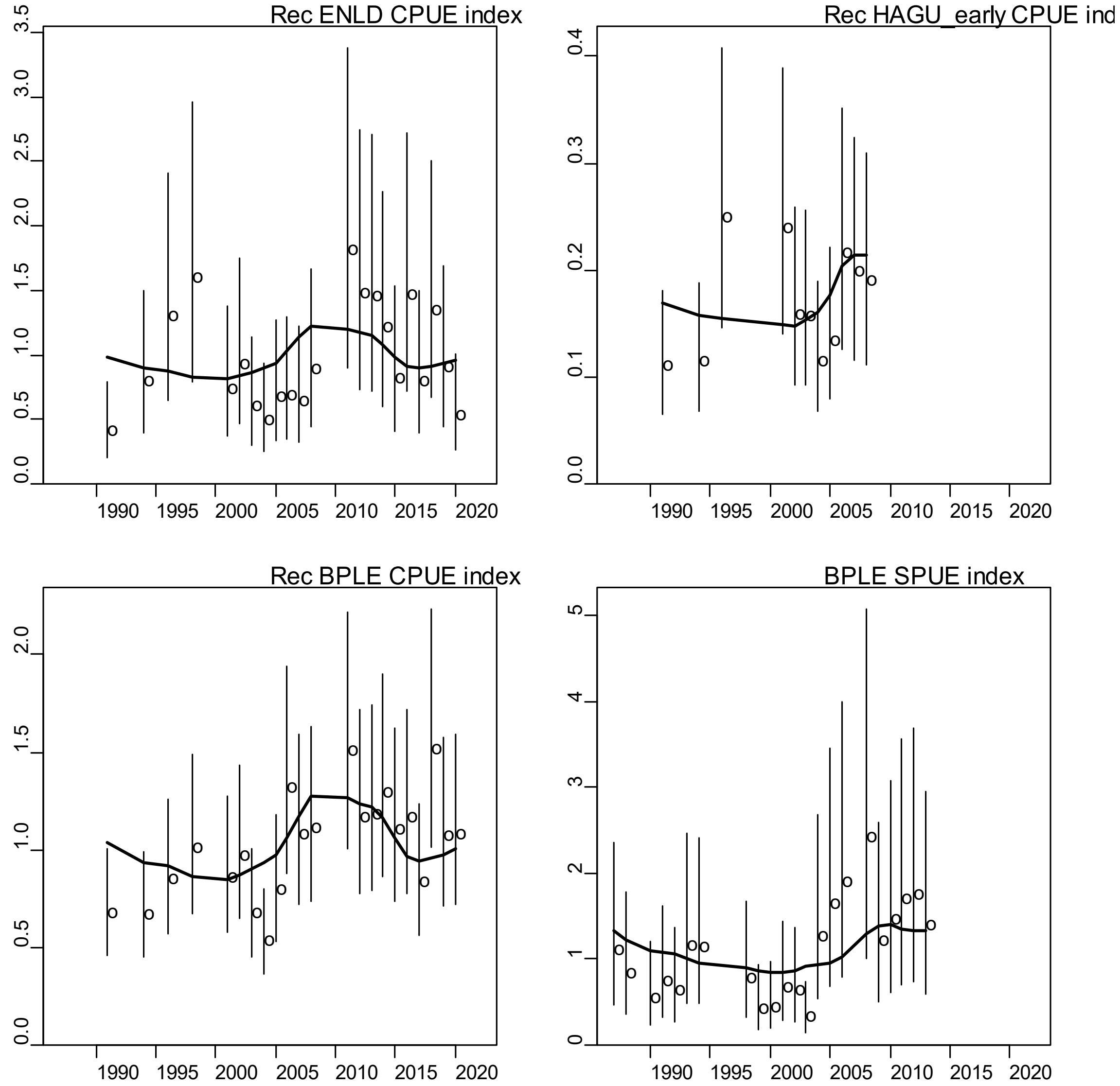


Figure 5: Base case model fits to the three regional recreational CPUE abundance indices (number of fish caught per boat trip - see Figure 4) and a western Bay of Plenty aerial Sightings Per Unit Effort index (total school tonnage observed per flight - see Figure 5).

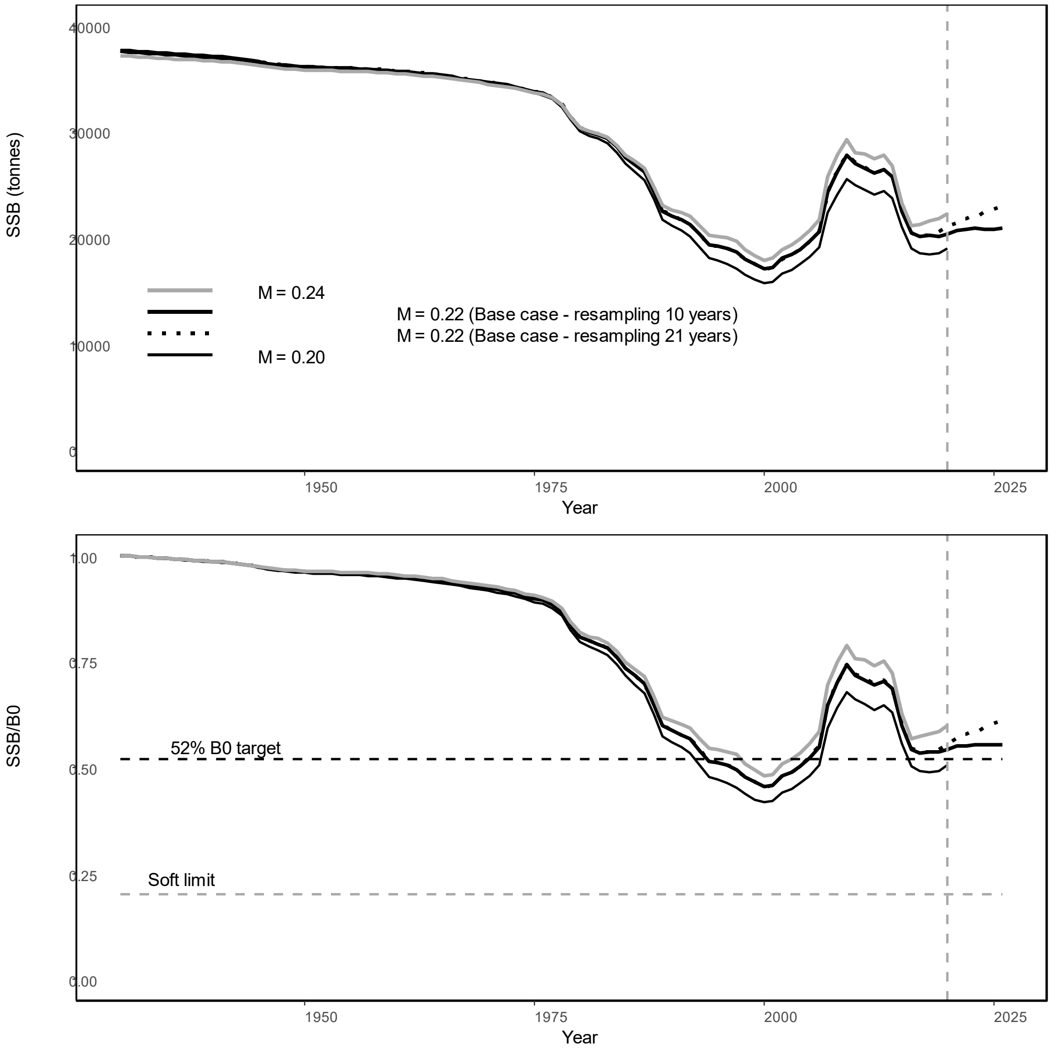


Figure 6: Comparison of spawning stock biomass (upper panel) and stock status trajectories (lower panel) for the base case (where *M* was assumed to be 0.22) and for two model sensitivities where higher and lower values for M were assumed. Two projections are shown for the base case; where most recent estimated year classes were resampled empirically, and where all of the estimated year classes were resampled. The vertical dashed line denotes first year of the projection period (2020–21). The spawning stock biomass estimates shown are MCMC medians.

The median MCMC estimate for $\%B_0$ in 2020 was estimated to be 56% for the base case, 50% when a lower *M* of 0.20 was assumed, and 60% when *M* was 0.24 (Table 13). In 2010 the Minister of Fisheries set a target reference point of 52% B_0 for this shared fishery, and although two of the sensitivity runs suggest that the KAH 1 stock biomass has fallen below this level at times, there is a high probability that the current biomass predicted by each model is close to or above this level (Tables 13 & 14).

Table 13: Biomass (t) and stock status estimates derived from MCMC runs for the base model (three chains combined) and two sensitivity models (medians with 95% credible intervals in parentheses). [Continued on next page]

Model	SSB0	SSB2020	SSB52%	SSB2020/SSB0	SSB2020/SSB52%
M = 0.22	37 549	20 880	19 524	0.556	1.069
(Base case)	(34 151–43 205)	(17 050–26 796)	(17 759–22 467)	(0.499–0.620)	(0.960–1.193)
M = 0.20	37 665	18 975	19 586	0.504	0.969
	(34 873–41 824)	(15 533–23 661)	(18 134–21 748)	(0.445–0.566)	(0.857–1.088)
M = 0.24	37 131	22 299	19 319	0.600	1.154
	(33 583–43 599)	(18 115–29 016)	(17 463–22 671)	(0.534–0.666)	(1.037–1.278)

Table 14: Probability of the KAH 1 stock in 2020 being below soft and hard limits and being at or above the target reference point. The target reference point of 52% B_0 was set by the Minister of Fisheries for this stock in 2010. Probabilities are calculated from the distribution of MCMC estimates calculated from each model.

Model	Pr (SSB_{2020}<10% SSB_0)	Pr (SSB_{2020}<20% SSB_0)	Pr (SSB_{2020}>52% SSB_0)
M = 0.22 (Base case)	0.000	0.000	0.854
M = 0.20	0.000	0.000	0.303
M = 0.24	0.000	0.000	0.985

4.1.5 Projections and yield estimates

The base and sensitivity models were projected forward five years, with empirical resampling from both the 10 most recently estimated year classes (2005–2014) and the full time series (1994–2014), using the average catch taken by each fishery annually over the three-year period from 2017–18 to 2019–20. These projections suggest that current stock status is likely to improve over the projected period (Table 15, Figure 7). The probability of the stock being at or above 52% B_0 in 2026 is 0.654 when the 10 most recently estimated year classes were resampled, and 0.839 when all 21 estimated year classes were resampled.

Table 15: Probability of the KAH 1 stock in 2026 falling below soft and hard limits and being at or above the target reference point. The target reference point of 52% B_0 was set by the Minister of Fisheries for this stock in 2010. Probabilities are calculated from the distribution of MCMC estimates calculated from each model (three chains combined for the base model).

Model	SSB2026/SSB0	Pr (SSB2026<10% SSB0)	Pr (SSB2026<20% SSB0)	Pr (SSB2026>52% SSB0)
M = 0.22 (21 YCSs resampled)	0.608 (0.460–0.728)	0.000	0.000	0.840
M = 0.22 (10 YCSs resampled)	0.556 (0.401–0.682)	0.000	0.987	0.646

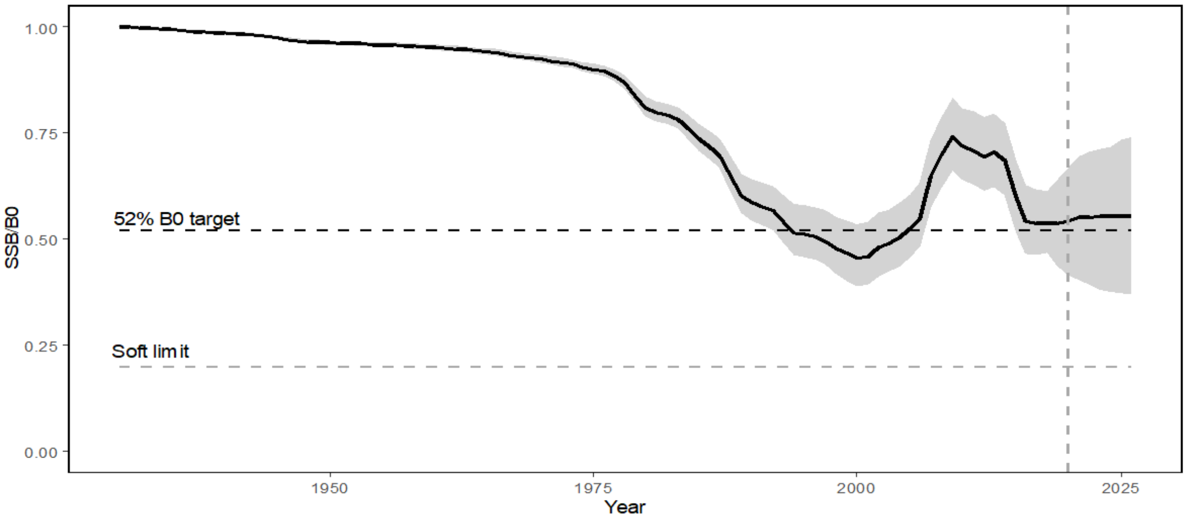


Figure 7: Spawning stock biomass relative to B_0 for the base model (M = 0.22; three chains combined). The 52% B_0 target set by the Minister of Fisheries in 2010 is denoted by a black dashed line and the 20% B_0 soft limit is denoted by the grey dashed line. The grey shaded area denotes 95% credible intervals derived from the MCMC model run and the black line denotes the median estimate for each year. The projection shown here is based on empirical resampling of the 10 most recently estimated year class strengths. The vertical dashed line denotes the first year of the projection period (2021). These projections are based on resampling of the 10 most recent years for which year class strengths were estimated.

The deterministic yield corresponding to 52% B_0 from the base case model is 2785 t.

4.1.7 Future research considerations

- Examine the sensitivity of model outputs and perception of stock status to potential underestimation of historical catch data.
- Incorporate uncertainty in the recreational catch history (mean weight, estimated numbers caught per year, aerial access estimates).
- Further explore the standardisation of recreational fishery CPUE indices for inclusion within the stock assessment model.
- Investigate patterns in recreational selectivity and address the potential mismatch between recreational CPUE and the age composition of landed catch (e.g., sensitivity using only landed catch for the recreational CPUE series, consider fitting the model to age 4 and older, split discards as a separate fishery with its own selectivity). Gather a better understanding of the size of released kahawai, and those used for bait.
- A spatial model should be considered if there are data to inform it on movements of different age/size classes between sub-areas. This may reduce the patterns in residuals for model fits to recreational catch at age.
- Research is required to better understand movement and stock structure.

5. STATUS OF THE STOCKS

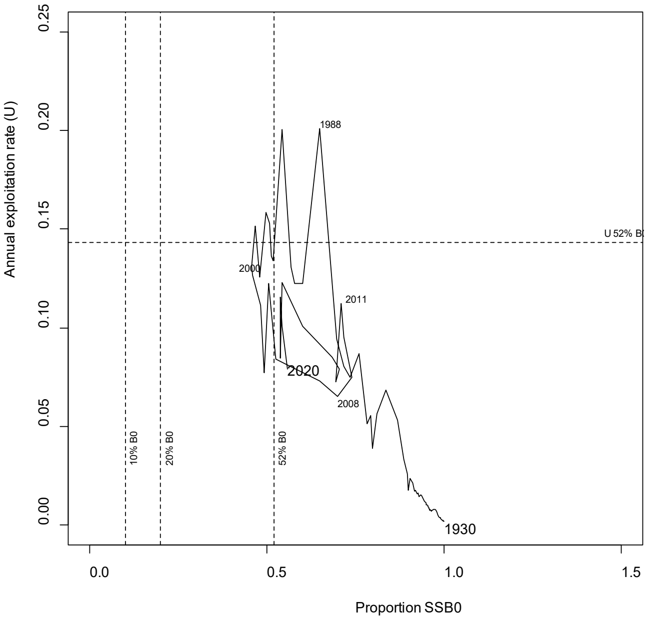
KAH 1

Stock Structure Assumptions

Two stocks of kahawai (*A. trutta*) are assumed to exist within New Zealand waters with centres of concentration around the Bay of Plenty (KAH 1) and the northern tip of the South Island. Tagging data show that there is limited mixing between these areas.

Stock Status		
Most Recent Assessment Plenary Publication Year	2021	
Intrinsic Productivity Level	Medium	
Catch in most recent year of assessment	Year: 2019–20	Catch: 998 t
Assessment Runs Presented	Base case model with M=0.22	
Reference Points	Target: 52% B_0 (set by Minister of Fisheries in 2010) Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{52\%B0}$	
Status in relation to Target	About As Likely as Not (40–60%) to be at or above	
Status in relation to Limits	Soft Limit: Exceptionally Unlikely (< 1%) 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



Trajectory of spawning stock biomass relative to B_0 for the base model (M = 0.22) and annual fishing intensity. The 52% B_0 target set by the Minister of Fisheries in 2010 is denoted by a black dashed line and the 20% B_0 soft limit and 10% B_0 hard limit are denoted by the grey dashed lines. Annual exploitation rates where calculated as the total tonnage of all fish four years and older divided by the biomass of all fish four years and older in each year.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Little change in stock biomass since 2016
Recent Trend in Fishing Mortality or Proxy	The exploitation rate has fluctuated without trend since 2009 and remains well below the overfishing threshold.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The KAH 1 stock is likely to increase slightly over the next five years at recent catch levels.
Probability of Current Catch or TAC causing biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of current catch or TAC causing overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Statistical catch at age model implemented under CASAL	
Assessment Dates	Latest assessment Plenary publication year: 2021	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	

Main data inputs (rank)	- Proportions-at-age from purse seine, single trawl, set net and recreational fisheries - Standardised recreational CPUE indices - Estimates of biological parameters (e.g. growth, age-at-maturity, length/weight) - Estimates of recreational harvest - Commercial catch - Aerial SPUE index	1 – High Quality 2 – Medium or Mixed Quality: variable catchability and availability 1 – High Quality 1 – High Quality 1 – High Quality 2 – Medium or Mixed Quality: only covers western Bay of Plenty
Data not used (rank)	- Set net CPUE indices	3 – Low Quality: confusion between set net and ring net fishing reporting
Changes to Model Structure and Assumptions	- Change to a fleets-as-areas model structure - Change to standardised recreational CPUE indices for each region of KAH 1 - Regional recreational catch histories were modelled for the period 1991 to 2020 based on creel survey data collected in most years and aerial-access harvest estimates provided by three aerial access surveys - Changed default *M* from 0.20 to 0.22 - Year class strengths only estimated 1994 to 2014, based solely on recreational catch at age data	
Major Sources of Uncertainty	- Recreational catch history, especially prior to 1990 - Recreational CPUE may be affected by availability because of limited spatial coverage by the recreational fishery - The degree of exchange between the KAH 1 and other stocks is essentially unknown - Spatial complexity in the movement of different sizes/ages of kahawai - Age composition data from the purse seine fishery might not reflect removals. - There is a conflict between age data and CPUE indices in the current model	

Qualifying Comments
- The assessment model has some structural inconsistencies, but none of the indices suggest a cause for concern. The relatively high target level also provides a buffer against poor stock status.

Fishery Interactions
Commercial catches of KAH 1 are primarily taken by purse-seine in association with jack mackerel, blue mackerel and trevally.

All other KAH regions

No accepted assessment is available that covers these regions. It is not known if the current catches, allowances or TACCs are sustainable. The status of KAH 2, 3 and 8 relative to B_{MSY} is unknown.

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