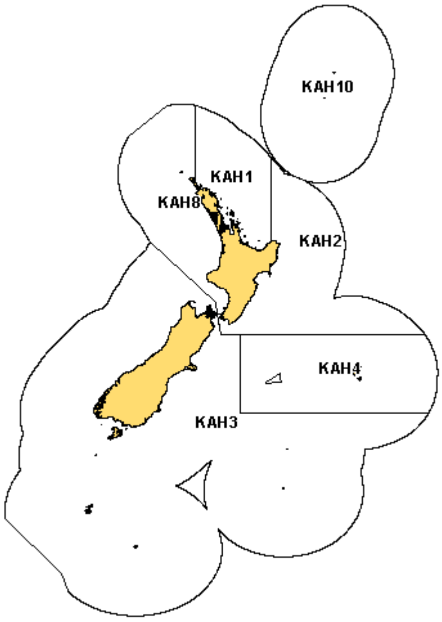
KAHAWAI (KAH)

(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 that part of KAH 8 which is south of Tirua Point. The area of KAH 8 which is 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 follows:

Table 1: KAH allowances, TACCs, and TACs, 1 October 2005.

Fishstock	Recreational Allowance	Customary Non-Commercial Allowance	Other mortality	TACC	TAC
KAH 1	1680	495	65	1 075	3 315
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 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 June through 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. Reported landings, predominantly of *A. trutta*, are shown for 1962 up to and including 1982 in Table 2 by calendar year for all areas combined, and from 1983–84 onwards by fishing year and by historic management areas in Table 3 and by QMAs in Table 4.

Table 2: 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.

Table 3: 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 through 1987–88 and from the CELR database after that date. Total LFRR or MHR values are the landings reported by Licensed Fish Receivers or Monthly Harvest returns.

Fishstock	KAH 1	KAH 2	KAH 3	KAH 9	KAH 10	Unknown Area	Total Catch	Total LFRR/MHR
FMA(s)	1	2	3–8	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	4532
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

 # MHR Data.

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 5). Commercial landings for kahawai have decreased in almost every year since 1998–99 (from 4444 to 2013 t in 2005–06), but increased again in 2006-07 (2 500 t). In 2006–07 commercial catches were within 5% of the TACC in KAH 1, 2, and 3 and 23% under in KAH 8. 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 a bycatch in the other purse seine fisheries described above.

Table 4: Prorated landings (t) of kahawai by the Fishstocks defined in 2004 for the fishing years between 1998–99 and 2006–07. 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.

	KAH1		KAH2		KAH3		KAH4		KAH8	
	1		2		3, 5, & 7		4		8 & 9	
	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC
1998–99	1 652		975		697		0		1 120	
1999–00	1 677		973		499		0		768	
2000–01	1 678		922		425		0		581	
2001–02	1 326		857		156		0		489	
2002–03	869		855		650		0		542	
2003–04	1 641		806		33		0		342	
2004–05	1 147	1 195	708	785	129	455	< 1	10	544	580
2005–06	903	1 075	530	705	233	410	0	9	346	520
2006–07	1 043	1 075	672	705	382	410	< 1	9	403	520

	KAH10			
	10		Total	
	Catch	TACC	Catch	TACC
1998–99	0		4 444	
1999–00	0		3 917	
2000–01	0		3 606	
2001–02	0		2 831	
2002–03	0		2 916	
2003–04	0		2 822	
2004–05	0	10	2 529	3 025
2005–06	0	9	2 013	2 728
2006–07	0	9	2 500	2 728

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, which was extended from 1 December to the Tuesday after Easter in subsequent years. While 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 on 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 between 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 and Golden Bays, the Marlborough Sounds, Cloudy Bay, and Kaikoura. The main purpose of this agreement is to minimise local depletion of schools of kahawai found inshore, and the 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.

Table 5: 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 9		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
2002–02	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. As the catch already exceeded 2339 t before the Minister's decision was announced, an extra 500 t was allocated to cover kahawai bycatch only.
§ Combined landings from KAH 9 and KAH 1 were limited to 1200 t.
* Purse seine fishery for kahawai closed.

1.2 Recreational fisheries

Kahawai are highly prized by some recreational fishers, who employ a range of shore and boat based fishing methods to target and/or catch the species. The only regulatory restrictions on recreational fishing for kahawai are a multi-species bag limit of 20 fish and a minimum set net mesh size of 90 mm. 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. Historical kahawai recreational catches are poorly known

1.2.1 Harvest estimates

The first recreational harvest estimates were obtained from regional telephone diary surveys undertaken in 1991–92 in the South Region, 1992–93 in the Central Region and in 1993–94 in the North Region. National telephone diary surveys were undertaken in 1996 and 2000, with a follow up survey in 2001 (i.e., the 2000 and 2001 estimates are not independent). Combined aerial overflight / boat ramp surveys, focusing on snapper, have provided kahawai harvest estimates in 2004 (Hauraki Gulf only) and 2005 (FMA 1 only).

Detailed descriptions for the telephone diary approaches used can be found in Teirney *et al*. (1997), Bradford *et al*. (1998) and Reilly (2002). The aerial overflight methodology is described in Hartill *et al*. (2006b). The key difference between the two approaches is that the telephone diary methodology combines unobserved estimates of the number of fishers in an area obtained via a survey of randomly selected individuals from telephone listings, with volunteer diarist data (which is used to estimate the average catch per fisher), whereas the aerial overflight approach combines aerial counts of boats fishing at mid day with dawn to dusk boat ramp interviews describing fishing effort and catch. The aerial overflight survey is, therefore, based on a direct assessment of the fishery while the telephone diary method is indirect, particularly with respect to the estimate of active participants. It is not, however, possible to reliably quantify shore based fishing from the air, and for this reason it was necessary to derive scalars from 2001 diarist data to account for the shore based kahawai catch (28% of the 2001 estimate).

Recreational harvest estimates are given in Tables 6 (telephone diary surveys) and 7 (Aerial overflight surveys).

Table 6: Estimated kahawai harvest by recreational fishers (in numbers and weight) by Fishstock as defined prior to 2004. (Source: Tierney et al. 1997, Bradford 1997, Bradford 1998, Boyd & Reilly 2002, Boyd et al. 2004).

	Survey			KAH 1				KAH 2
Year	Number	CV (%)	Range (t)	Estimate (t)	Number	CV (%)	Range (t)	Estimate (t)
1992–93	-	-	-	-	195 000	-	245–350	298
1993–94	727 000	-	920–1035	978	-	-	-	-
1996	666 000	6	900–1020	960	142 000	9	190–240	217
2000	1 860 000	13	916–2475	2195	1 808 000	74	769–5105	2937
2001	1 905 000	13	-	2248	492 000	20	-	799

	Survey			KAH 3				KAH 9
Year	Number	CV (%)	Range (t)	Estimate (t)	Number	CV (%)	Range (t)	Estimate (t)
1991–92	231 000	-	160–260	210				
1993–94	6000	-	-	8.4#	254 000	-	285–395	340
1996	226 000	7	125–145	137	199 000	9	195–225	204
2000	413 000	16	564–771	667	337 000	20	354–527	441
2001	353 000	18	-	570	466 000	24	-	609

#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.

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.* 2006a) and a similar KAH 1 wide survey conducted in 2004–05 (1 December 2004 to 30 November 2005; Hartill *et al.* 2006b). 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)

The Recreational Technical Working Group (RTWG) concluded that the framework used for the telephone interviews for the 1996 and previous surveys contained a methodological error, resulting in biased eligibility figures. Consequently the harvest estimates derived from these surveys are unreliable.

This group also indicated concerns with some of the harvest estimates from the 2000–01 survey. The following summarises that group's views on the telephone /diary estimates:

"*The RTWG recommends that the harvest estimates from the diary surveys 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 harvest estimates are implausibly high for many important fisheries*."

In 2007, the PELWG made the following conclusions in relation to the recreational harvest estimates for KAH 1 based on their current understanding:

- recreational catches are likely to be variable between years;
- the 2000 and 2001 harvest estimates (2195 and 2248 t) are:
  - possibly overestimated for those years and some PELWG members felt that the estimates were implausibly high;
  - are implausibly high if considered as a long term (back to the early 1990s) average; and
  - likely represent the upper limit of the harvest that may have occurred in any year since the 1990s (after the period of increased commercial landings);
- the aerial overflight estimate for kahawai harvest in 2004–05 of 530 t is:
  - possibly underestimated for that year, and
  - some PELWG members felt that it was implausibly low if considered as a long term average back to the early 1990s;
- the earlier diary survey estimates, although biased, are likely to be at plausible levels for those years, but are still uncertain; and

- the aerial overflight estimates for kahawai be treated with caution due to the limited overlap between the method's sampling technique and the fisheries for kahawai, e.g., the significant proportion of harvest taken by shore-based methods that require auxiliary data to account for.

In 2008, the Northern Inshore Finfish Working Group (NINSWG) made the following conclusions in relation to the recreational harvest estimates for other KAH QMAs based on their conclusions for KAH 1:

- the current KAH QMAs do not match up with the strata used for the historical harvest estimates (KAH 3 and 8);
- recreational catches are likely to be variable between years;
- the 2000 harvest estimate for KAH 2 is implausibly high;
- the 2000 and 2001 harvest estimates for the remaining KAH areas are possibly overestimated.

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.

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 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 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 in open water. 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 early 1990s suggest the onset of sexual maturity in males occurs at around 39 cm 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 aging technique that has been validated (Stevens and Kalish 1998). Kahawai grow rapidly, attaining a length of around 15 cm at the end of their first year, and maturing 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 8. 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).

The maximum recorded age of kahawai is 26 years. The instantaneous rate of natural mortality (*M*) was estimated from the equation $M = \log_e 100/\text{maximum age}$, where maximum age is the age to which 1% of the population survives in an unexploited stock. Based on a maximum age of 26 years, *M* was estimated to equal 0.18. A range of 0.15–0.25 has previously been assumed to reflect the lack of precision in the estimate.

Table 8: Estimates of biological parameters.

Fishstock			Estimate		Source
1. Natural mortality (M)					
All			0.18		Jones *et al.* (1992)
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)
3. von Bertalanffy growth parameters					
		K	t_0	L¥	
KAH 1		0.33	-0.1	54.3	Hartill *et al.* (2007a)
KAH 2		0.34	0.6	53.5	Drummond (1995)
KAH 3		0.3	0.25	54.2	Drummond & Wilson (1993)
KAH 9		0.23	-0.26	55.9	McKenzie, NIWA, unpubl. data

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 (QMA 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.* (2007) 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, Waitemata Harbour and Hakahaka Bay, Port Underwood). Two distant sites were chosen in order 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 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

In 2007 an age-structured stock assessment was undertaken for KAH 1 using CASAL (Bull *et al*. 2004). This assessment is reported below. This replaces the 1997 nation-wide assessment which is no longer considered valid by the PELWG due to the simplistic methods used and its historical nature. Therefore, aside from some catch curve estimates of Z from the early 1990s, there is no longer an accepted stock assessment for areas outside KAH 1.

4.1 KAH 1

4.1.1 Estimates of catch, selectivity and abundance indices

(i) Commercial catch

The commercial catch history assumed in the assessment is provided in Table 9. It is noted that catches in the early years are less certain due to reporting (e.g., see Table 3 legend).

Table 9: Commercial catch time series used in the stock assessment. PS – purse seine, SN – set net, ST – single trawl, OT – other gears.

	East Northland				Hauraki Gulf				Bay of Plenty				KAH 1
Fishing Year	PS	SN	ST	OT	PS	SN	ST	OT	PS	SN	ST	OT	All
1974–75	–	8	1	6	–	27	1	5	12	2	5	2	69
1975–76	–	17	3	13	–	58	2	10	25	4	11	4	146
1976–77	–	33	6	25	–	116	4	21	50	8	21	8	292
1977–78	–	51	9	39	–	176	6	32	77	12	33	12	446
1978–79	–	70	12	53	–	243	9	44	106	16	45	16	614
1979–80	–	74	13	57	–	258	9	47	112	17	48	17	653
1980–81	–	70	12	53	–	244	9	44	106	16	45	16	617
1981–82	–	74	13	56	–	256	9	46	111	17	48	17	647
1982–83	–	112	19	85	–	389	14	70	169	26	72	26	982
1983–84	–	68	12	52	–	237	9	43	1 445	16	44	16	1 941
1984–85	–	87	15	66	–	303	11	55	882	20	56	20	1 517
1985–86	–	56	10	43	–	194	7	35	1 191	13	36	13	1 597
1986–87	–	48	8	36	–	165	6	30	1 544	11	31	11	1 890
1987–88	–	45	8	34	–	157	6	28	3 964	10	29	10	4 292
1988–89	–	72	13	55	–	251	9	45	1 644	17	47	17	2 169
1989–90	1	75	13	57	–	259	9	47	1 698	17	48	17	2 241
1990–91	0	54	10	39	–	189	6	10	1 563	69	65	29	2 035
1991–92	–	68	14	53	3	157	2	21	1 723	65	29	19	2 154
1992–93	199	74	147	93	–	402	14	63	2 326	83	15	53	3 469
1993–94	118	51	19	165	–	278	6	105	1 451	93	55	35	2 377
1994–95	4	103	30	95	–	207	7	73	1 287	67	23	38	1 934
1995–96	1	74	41	71	–	185	4	35	1 368	90	80	39	1 987
1996–97	53	99	63	60	–	120	3	17	989	81	47	34	1 567
1997–98	30	138	40	46	–	144	9	18	682	65	67	22	1 260
1998–99	44	78	28	49	–	110	3	41	1 329	28	115	18	1 843
1999–00	4	74	29	18	–	132	1	25	1 214	31	76	14	1 618
2000–01	34	84	4	27	–	110	–	29	1 359	12	72	15	1 747
2001–02	43	81	5	9	–	195	–	11	949	16	54	37	1 399
2002–03	57	64	12	7	–	173	–	8	551	17	35	29	952
2003–04	52	51	16	11	–	146	–	2	1 311	14	34	24	1 661
2004–05	36	35	11	7	–	101	–	1	905	10	24	16	1 147
2005–06	28	28	9	6	–	80	–	1	713	8	19	13	903

(ii) Recreational catch

The recreational catch history in KAH 1 is poorly known. Estimates are available for the Hauraki Gulf in 2003–04 (Hartill *et al*. 2006a) and for three subregions of KAH 1 in 2004–05 (Hartill *et al*. 2006b) which were derived from aerial overflight surveys. These estimates are used in the model for those years.

Two recreational catch scenarios were ultimately considered in the stock assessment model: a constant harvest of either 800 t or 1865 t, except in 2005 when 530 t was used. The 530 t estimate was considered implausibly low as a long term average from 1975 so an arbitrary value of 800 t was used instead. The arbitrary upper bound of 1865 t is equal to the recreational allowance made when kahawai was introduced to the QMS 1 October 2004. This was based on the 2000 harvest estimate reduced by 15%.

Constant harvest tonnages were used as there was concern that if a catch history with an assumed trend was used this trend could influence the model results, despite being essentially unknown. It was felt that these two scenarios would span the likely impacts of intermediate catch scenarios, even those with a trend.
Data from three recent surveys of recreational fishers were used to apportion the annual harvests across the three subregions (Northland, Hauraki Gulf, and Bay of Plenty). These surveys were the two linked telephone diary surveys conducted in 1999–00 (Boyd & Reilly 2002) and 2000–01 (Boyd *et al*. 2004) and the aerial overflight survey conducted in 2004–05 (Hartill *et al*. 2006b). All three surveys suggest very similar catch split proportions: Northland 22%, the Hauraki Gulf 18%, and the Bay of Plenty 60%.

The time series of catches used was assumed to cover both recreational and non-commercial customary catch.

(iii) Catch composition data and selectivity estimates

The earliest catch-at-age data that are available were collected from commercial fisheries in 1991, 1992 and 1993. Landings were sampled from the East Northland purse seine fishery and from the Bay of Plenty single trawl and purse seine fisheries. These age distributions were included in the model with the exception of the 1993 Bay of Plenty purse seine data, which were dropped because they were shown to be unrepresentative of the landings. Age compositions for purse seine landings from east Northland and the Bay of Plenty were available for 2005 and included in the model. Age and length samples from the recreational fisheries in three regions of KAH 1 were available since 2001, and were also included in the model (Armiger *et al*. 2006, Hartill *et al*. 2007a, 2007b).

Selectivity ogives are estimated for each of the six fisheries (i.e., the three regional recreational fisheries, two regional purse seine fisheries, and a single trawl fishery), accounting for a high proportion of the KAH 1 landings in each year. A double normal selectivity ogive was used to describe the set net fishery, which, although it has relatively low landings (200–300 t in most years) compared to the purse seine fishery, has been included so that the associated indices of abundance can be used in the model. No landings have been sampled from this fishery, so the selectivities were not informed by any data.

(iv) Catch-curve analysis results

Annual estimates of total mortality (*Z*) have been derived from recreation catch data sampled in East Northland and the Bay of Plenty. They were calculated using a Chapman Robson estimator independently from the stock assessment model (Table 10). These estimates were calculated using a range of assumed ages for full recruitment to demonstrate the sensitivity of the results to this assumption.

Table 10: Estimates of Z derived from recreational catch sampling in KAH 1, by survey year by assumed age at recruitment.

East Northland Age at recruitment	2001	2002	2003	2004	2005	2006
3	0.33	0.33	0.32	0.28	0.24	0.23
4	0.34	0.38	0.35	0.31	0.28	0.26
5	0.30	0.37	0.39	0.33	0.33	0.32
6	0.30	0.40	0.41	0.38	0.36	0.36

Bay of Plenty	2001	2002	2003	2004	2005	2006
3	0.23	0.25	0.28	0.20	0.27	0.25
4	0.26	0.30	0.32	0.23	0.29	0.30
5	0.28	0.33	0.34	0.26	0.30	0.31
6	0.30	0.36	0.38	0.32	0.30	0.32

(v) Indices of abundance

Regional indices of abundance were available from two sources: recreational fisheries and set net fisheries (Figure 1). Two other indices of abundance were also initially considered from the Bay of Plenty, but dropped: an aerial sightings index, and one based on commercial trawl catch rate data. The former was considered underdeveloped and the latter was based on poor measures of catch and effort.

Boat ramp surveys have been conducted in KAH 1 since 1991, and these data have been used to generate standardised CPUE indices for three regional fisheries: East Northland, Hauraki Gulf and Bay of Plenty (Hartill & Walsh 2005). These indices were derived from Poisson-based generalised linear models of the number of kahawai caught in a trip (including those released) given the time spent fishing and other explanatory variables. Poisson-based modelling accommodates a high proportion of zero catches in the data, and posterior statistical tests suggested that the level of dispersion was close to one. Boat ramp data suggest that approximately 80% of the recreational catch is landed (Hartill & Walsh 2005).

Standardised indices of abundance were also derived from commercial set net data reported on CELR forms since 1990 (Figure 1). Generalised log-linear models were used to derive indices for each of the three sub-regions of KAH 1 (McKenzie *et al*. 2007). There were insufficient data available from the Bay of Plenty to provide reliable indices for 2003–04 and 2004–05 so these years were not included in the model. Some PELWG members expressed their concerns at the utility of the set net indices, given the low catches taken by this method, the lack of an appropriate selectivity ogive, the potential for non-reporting of catch; and given that kahawai were not in the QMS for most of the series; and that it is only mandatory to report the top five species in a fishing event.

There is no consistent pattern in catch rates when comparisons are made across and within regions. Recreational catch rates in East Northland increased in the early 1990s, and then declined in recent years, whereas the reverse trend is evident in the set net index. Both indices exhibit interannual variability in the Hauraki Gulf and little trend is apparent. In the Bay of Plenty there is no trend in the recreational index, but a clear decline is evident in the set net index

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. Annual sampling of recreational catches, which has taken place in all three areas since 2001 (and intermittently since 1991), suggests that there are consistent regional differences in the length and age compositions of kahawai among these regions. For example, in the Hauraki Gulf, recreational landings of kahawai are regularly dominated by three year olds, with low proportions of fish older than five years. It is improbable that these regional differences in age structure can be attributed to relative fishing pressure alone, which suggests that some form of movement between areas is highly likely. 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 from East Northland. For this reason it was not possible to partition the model into three interconnected sub-stocks, as their connectivity is inestimable. Area specific observational data were combined into a single stock model which includes most of the currently available data.

In the stock assessment model it is assumed that 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 fishing years from 1974–75 to 2005–06.

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 the parameter values given in Table 8. 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, and the rate of natural mortality is uncertain. Sensitivity to these parameters is discussed in the next section.

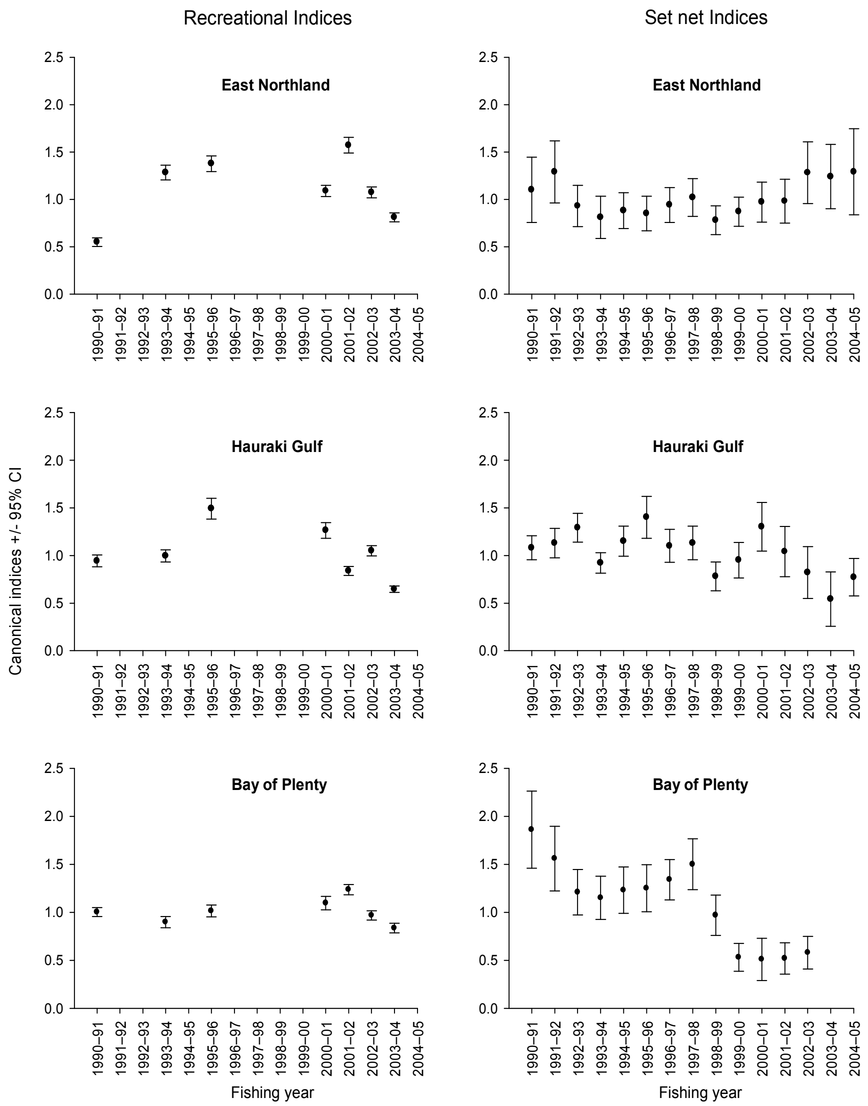


Figure 1: Standardised regional catch rate indices considered in the KAH 1 stock assessment model. Indices derived from recreational fishers using baited hooks and/or jigs since 1991 are given in the left hand panels, and those derived from commercial set net CELR data are given in the right hand panels.

It was assumed that the population was at an unfished equilibrium state (B_0) in 1975. Key model outputs are probably robust to this assumption as commercial landings 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 (combinations of method and region) according to observed catches and estimated selectivities. Method specific annual landings from five fishing methods were considered: recreational, purse seine, single trawl, set net, and other minor commercial fisheries. Landings by method are further divided into regional catch histories, as the catch-at-age data were collected at this spatial scale. Purse seine fisheries only occur in East Northland and the Bay of Plenty and share a common estimated selectivity. Separate selectivities were fitted to each of the three regional recreational fisheries.

4.1.3 Evaluation of uncertainty

A common approach in the assessment of fish stocks is to select a 'base' or 'reference' model which represents the most likely situation and then to evaluate uncertainty by selecting a number of analyses which vary key assumptions relative to the base case model. Frequently the more important sets of runs are evaluated using Bayesian methods to characterise the uncertainty in the estimated and derived parameters.

In the assessment for KAH 1 there was uncertainty in some important model inputs (e.g., recreational catch history and abundance indices) and some influential biological parameters could not be estimated within the model (e.g., natural mortality and steepness).

The approach taken to represent uncertainty was to determine the four main factors for which uncertainty was likely to have an impact on key model outputs (referred to as the 'axes of uncertainty') and then to select a limited number of plausible options across each axis. Model runs were then undertaken for all possible combinations of options across each axis – this set of options was referred to as the 'grid'. The selected grid axes are provided in Table 11. Overall, the grid comprised 36 model runs which in totality were thought to be a realistic reflection of the extent of uncertainty in the KAH 1 assessment.

Table 11. Axes of uncertainty and options chosen on grid. N is the number of levels on the axis.

Axis	N	Range
M	3	0.12, 0.18, 0.24,
h	2	0.75, 1
Non-commercial catch	2	Constant 800, 1865t
Abundance indices	3	All, no set net, no recreational

In relation to the selected grid chosen, it was noted that:

- with additional time and resources the number of axes and/or levels in the grid could be increased;
- model diagnostics were not examined for all grid runs;
- the lower and higher values of *M* used in the grid (0.12 and 0.24) were probably at the limit of what would be considered plausible values;
- if this approach were to be developed further, it would be useful to weight each grid cell based on the plausibility of the cell components. This was not done for this exercise; and
- the range of values selected for recreational catch may not span the plausible range – a lower plausible value was not included in the grid because it was not likely to lead to qualitatively different conclusions.

4.1.4 Results

A grid search of the four axes of uncertainty suggested that there were differences in the magnitude and manner of their influence on the model. The model was largely insensitive to the indices of abundance offered, which is to be expected given the contradictory nature of these indices. The assumed steepness of the stock recruitment relationship also had only small influence on estimates of fishing mortality and yield.

Natural mortality had the most influence on the results. As mentioned in the previous section, both the lower value of 0.12 and the upper value of 0.24 were regarded as being at the limit of plausible values. Lower values of natural mortality resulted in higher levels of estimated fishing mortality, lower yields, and lower current biomass, although there was little contrast in estimates of virgin biomass (Figure 2 and 3, Table 12). Increased levels of natural mortality were offset by estimated selectivity ogives which were shifted to the right, resulting in reduced fishing mortality. The model essentially operated as an integrated catch curve, in which the slope of the right hand limb of the age distributions was approximated by the model parameters and dynamics.

Table 12. Model outputs for different values of *M* and assumed non-commercial catches. Values represent the median of the six model runs in each stratum (abundance index and steepness choice). All biomass estimates are in terms of spawning biomass.

		B_0 (t)	B_{06} (t)	B_{06}/B_0	B_{06}/B_{MSY}	MSY (t)
	0.12	41 690	11 260	0.27	1.22	2 130
800 t	0.18	38 762	17 582	0.45	1.84	2 822
	0.24	43 216	27 228	0.62	2.12	4 007
	0.12	59 453	14 518	0.24	1.11	3 042
1865 t	0.18	54 614	22 562	0.43	1.78	4 004
	0.24	60 082	35 882	0.59	2.06	5 564

The second most influential axis of uncertainty was the axis relating to the assumed recreational catch history (Figure 2 and 3, Table 12). The assumed recreational catch history had little influence on the predicted stock status (B_{06}/B_{MSY}), but did affect the estimate of total available yield.

Estimates of B_{MSY} as a proportion of B_0 varied across model runs (18.3–31% B_0). Lower percentages were associated with higher values of steepness.

Based on the scenarios examined, it is likely that current spawning biomass is greater than B_{MSY}, but it is uncertain how far above.

4.1.5 Yields

A modified yield per recruit analysis (incorporating the impact of the stock recruitment relationship) was carried out for each scenario to calculate the equilibrium yield estimates within each grid cell. It was assumed that the maximum sustainable yield (MSY) occurs at the maximum yield per recruit ($F=F_{max}$). B_{MSY} was defined as the start of the year biomass producing the maximum yield with fixed selectivities for each method and fixed proportions of the catch for each method based on the catch distribution in 2005–06. Results are expressed relative to virgin start of year biomass (B_0; which is sensitive to the assumed recreational catch history). The yield per recruit and its maximum will vary depending on the allocation of total catch amongst the fishing methods, because yield is mediated through the selectivity curves and these differ among the fisheries.

Estimates of MSY(t) derived from differing combinations of M and assumed recreational catch history are given in Table 12 and Figure 4. Differences in the range of MSY tonnages associated with the two recreational catch history scenarios (Figure 4) are almost solely due to the size of the associated estimates of B_0. That is, the ratio between MSY and B_0 is approximately constant across the range of recreational harvest estimates. For this reason, the yield estimates are only valid for each matched recreational harvest estimate. The assumed natural mortality rate also influences the yield estimate, both in an absolute sense, and relative to B_0.

Current assumed removals are lower than almost all estimates of deterministic MSY. Combining this with the result that most estimates of B_{06} are well above B_{MSY} it is unlikely that the stock will decline below B_{MSY} at current assumed catch levels, given the model recruitment assumptions.

The current TAC for KAH 1 is 3315 t with a TACC and allowances outlined in Table 1. The estimates of deterministic MSY depend on model assumptions, in particular the assumed natural mortality and time series of non-commercial catches. When non-commercial harvests are assumed to have been 800 t per year, median MSY estimates from grid strata range from 2130 to 4007 t. When non-commercial harvests are assumed to have been 1865 t per year, median MSY estimates from grid strata range from 3042 to 5564 t.

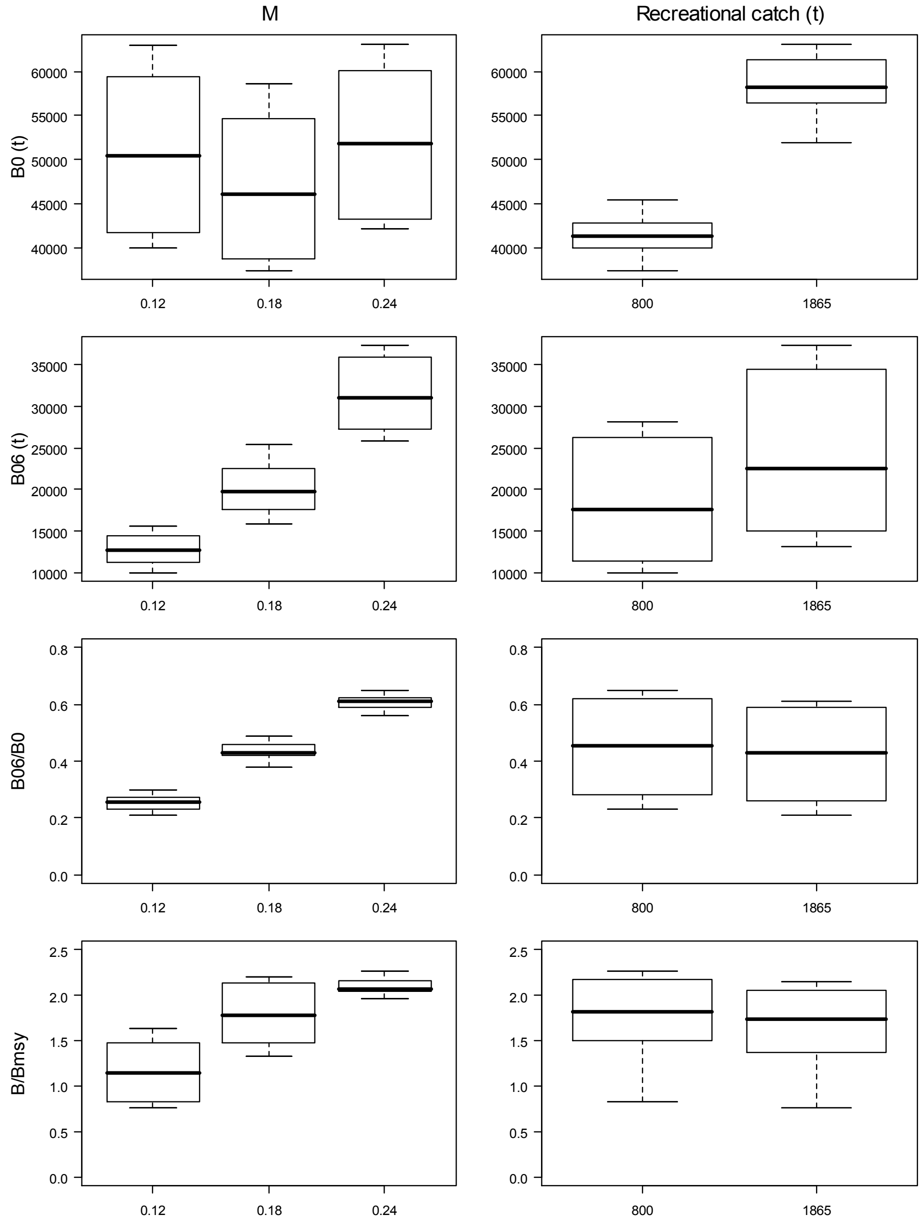


Figure 2. Boxplot showing the distribution of model results for the two key axes in the grid: natural mortality (left) and non-commercial catches (right). Each boxplot summarises 12 and 18 model runs for natural mortality and non-commercial catches respectively.

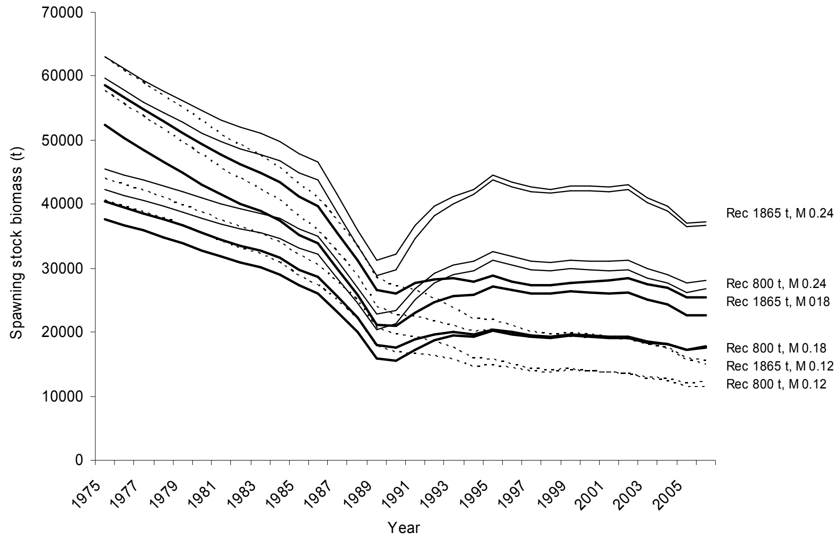


Figure 3: Biomass trajectories for differing assumed values for natural mortality (*M*), stock recruitment steepness (h) and assumed recreational catch history. For a given *M*, the upper pair of trajectories relate to a recreational catch of 1865 tonnes per annum, and the lower pair 800 tonnes. For each pair of trajectories, the upper is based on a steepness of 0.75 and the lower an assumed value of 1.0. The model did not appear to be sensitive the indices of abundance used, and both the set net and recreational indices of abundance are included in these runs.

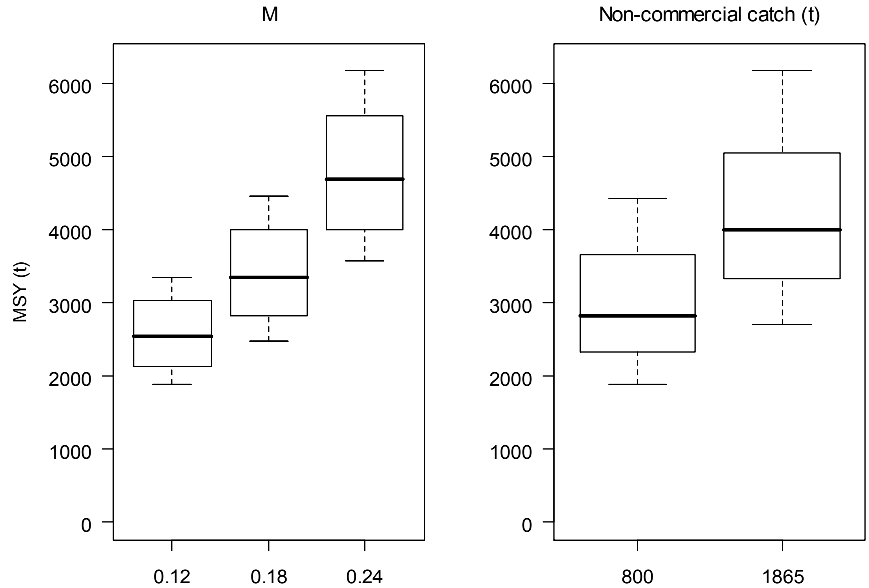


Figure 4. Boxplot showing the distribution of MSY estimates for the two key axes in the grid: natural mortality (left) and non-commercial catches (right). Each boxplot summarises 12 and 18 model runs for natural mortality and non-commercial catches respectively.

4.2 Assessment for other KAH areas
4.3

Historic estimates of total mortality (*Z*) derived from the age composition of commercial catch data collected in the early 1990s for areas outside KAH 1 are given in Table 13.

Table 13: Estimates of Z derived from commercial fisheries catch sampling data.

Fishstock	Estimate	Time sampled	Source
KAH 2	0.24	Nov 92	Drummond (1995)
KAH 3 (Marlborough Sounds)	0.22–0.35	Nov 90–Mar 91	Drummond & Wilson (1993)
KAH 3 (Cloudy/Clifford Bays)	0.19–0.27	Nov 90–Jun 91	Drummond & Wilson (1993)
KAH 3 (Kaikoura)	0.23–0.30	Nov 90–May 91	Drummond & Wilson (1993)
KAH 9	0.11	Feb 91– Mar 91	Jones *et al.* (1992)

The interpretation of catch curve analyses is difficult for schooling pelagic species for several reasons which include: (a) difficulties in obtaining a representative sample of sufficient size to describe the age distribution of the population because of the schooling behaviour of kahawai; (b) uncertainty in the value of *M*; and (c) lack of contrast in the data if exploitation rates are not changing.

5. STATUS OF THE STOCKS

KAH 1

An assessment was undertaken for KAH 1 in 2007. In the assessment for KAH 1 there was uncertainty in some important model inputs (e.g., recreational catch history and abundance indices) and some influential biological parameters could not be estimated within the model (e.g., natural mortality and the spawner recruitment relationship).

The approach taken to represent uncertainty was to determine the four main factors for which uncertainty was likely to have an impact on key model outputs (referred to as the ‘axes of uncertainty’) and then to select a limited number of plausible options across each axis. Model runs were then undertaken for all possible combinations of options across each axis – this set of options was referred to as the ‘grid’. Overall, the grid comprised 36 model runs which in totality were thought to be a realistic reflection of the extent of uncertainty in the KAH 1 assessment.

Based on the scenarios examined, it is likely that current spawning biomass is above B_{MSY}, but it is uncertain how far above.

Current assumed removals are lower than almost all estimates of deterministic MSY. Combining this with the result that most estimates of current biomass are well above B_{MSY} it is unlikely that the stock will decline below B_{MSY} at current assumed catch levels, given the model recruitment assumptions.

The current TAC for KAH 1 is 3315 t with a TACC and allowances outlined in Table 1. The estimates of deterministic MSY depend on model assumptions, in particular the assumed natural mortality and time series of non-commercial catches. When non-commercial harvests are assumed to have been 800 t per year, median MSY estimates from grid strata range from 2130 to 4007 t. When non-commercial harvests are assumed to have been 1865 t per year, median MSY estimates from grid strata range from 3042 to 5564 t.

Within the range of non-commercial catches investigated, estimates of stock status are relatively insensitive to the absolute level of the non-commercial catch, provided that these catches are assumed to be constant over the model period.

Deterministic projections assuming M=0.18 and including all abundance indices were undertaken in 2008 based on the 2007 assessment and the current TACC and assumed non-commercial removals. These indicated that biomass was predicted to increase over the next five years for both steepness and non-commercial catch scenarios.

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, or at a level that will allow the stock to move towards a size that will support the MSY.

Table 14: Summary of reported landings (t) and TACCs by QMA for the most recent fishing year.

Fishstock	FMA	2006–07 TACC	2006–07 Reported landings
KAH 1	1	1 075	1 043
KAH 2	2	705	672
KAH 3	3, 5, & 7	410	383
KAH 4	4	9	< 1
KAH 8	8 & 9	520	403
KAH 10	10	9	0
TOTAL		2 728	2 500

6. FOR FURTHER INFORMATION

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