New Zealand Fisheries Assessment Research Document 92/2

Kahawai fishery assessment for the 1992–93 fishing year

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

1. INTRODUCTION

1.1 Overview

This document revises the information presented in the 1988 and 1989 kahawai Fisheries Assessment Research Documents (Kilner 1988, Sylvester 1989). It provides a brief description of the fishery, a review of the information available in the literature, and reviews previous yield estimates.

Use is made of the length-frequency data collected during market sampling from QMAs 1, 3, and 9 during 1991-92 to estimate values for Z (instantaneous mortality).

A short term status quo forecast of catch levels for kahawai is calculated using the SHOT method of Shepherd (1991). This method provides an estimate of the level of landings which will maintain the exploitation rate at the status quo level.

1.2 Description of the fishery

Kahawai (*Arripis trutta*) are a schooling pelagic marine species belonging to the family Arripidae. 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 rivers (McDowall 1978). Sherrin (1886) reported kahawai 50-60 km up the Waikato River. There are unconfirmed reports of a second species occurring at the Kermadecs and around Northland. Both *A. trutta* and *A. esper* occur in Australia where they are collectively known as "Australian salmon".

Kahawai are an important traditional food fish for Maori (Best 1986). It is also one of the fish species most frequently caught by recreational fishers (Teirney and McKinnon 1991). The recreational catch has been estimated to be in thousands of tonnes (McKoy 1988, Sylvester 1989, Feldman 1991) though actual amounts are not available. Recreational and Maori groups have become increasingly concerned about the state of kahawai stocks. There is a widely held perception, repeatedly reinforced by media articles, that kahawai are becoming scarce and smaller in size due to excessive purse-seine catches (e.g., Owen 1983). Evidence to support or refute this assertion is not available.

Kahawai also form an important commercial fishery. Commercial fishers take kahawai by a variety of methods, though 72 to 90 % of the catch in recent years is taken by seven purse-seine vessels. Significant quantities are also taken in set-net and trawl fisheries, usually as bycatch. Up until the early 1980s kahawai were often dumped at sea or landed as "MIX" or "FELIX", and often used as bait or in other ways not reported. Reliable estimates of unreported catch before 1983 are not available, but the quantities are believed to have been large in some years. From 1983 the method of gathering statistics was improved.

Though kahawai are a relatively low-value species, the fishery is of importance to the purse-seine fleet. It is difficult to understand the kahawai purse-seine fishery in isolation from the other species which these vessels attempt to target. For about five months of the year (December to May) the northern fleet, based in Tauranga, tends to target exclusively for skipjack tuna (*Katsuwonus pelamis*) and takes very little bycatch. Outside the skipjack season the fleet fishes for a mix of species including kahawai, jack mackerels (*Trachurus spp.*), and blue mackerel (*Scomber australasicus*). These are caught 'on demand' as export orders are received (to reduce product storage costs). The southern fleet, based in Nelson, fish exclusively for the mackerels and kahawai. Since the mackerels and kahawai often school together, attempts to target either of the mackerels will often result in a substantial bycatch of kahawai.

Kahawai is a non-QMS species, managed by permit with a restriction on entry. Kahawai are presently managed as five separate Fishstocks: KAH1 (QMA1), KAH2 (QMA2), KAH3 (QMAs 3,4,5,6,7, and 8), KAH9 (QMA9) and KAH10 (QMA10). In March 1991, the Minister of Fisheries announced his decision on the management of kahawai for the 1990-91 fishing year. The total commercial catch limit for kahawai was set at 6500 tonnes, with 10% allocated to Maori, and 4856 tonnes allocated for purseseining. The competitive catch limits for purse seining were divided as follows: 1666 tonnes from KAH1; 851 tonnes from KAH2; and 2339 tonnes from KAH3 (Fig. 1).(Note: purse-seine vessels do not target kahawai from KAH9 (QMA9).) This total commercial catch limit was rolled over for the 1991-92 fishing year.

1.3 Literature review

From morphometric measurements, Fairbridge (1951) and Malcolm (1959) split the Australian population of *Arripis trutta* into two subspecies. MacDonald (1983) used electrophoretic techniques to show that the two populations were separate species. The western *A. esper* was genetically distinct from the eastern *A. trutta*, even though their distributions overlapped, and the New Zealand *A. trutta* could not be distinguished from the eastern Australian species.

Thompson (1892), Graham (1956), and Baker (1971) have described feeding of kahawai in New Zealand and Malcolm (1959) described feeding of *A. trutta* in Australia. Kahawai feed mainly on fishes but also on pelagic crustaceans, especially krill (*Nyctiphanes australis*). The feeding behaviour of *A. trutta* in locating and capturing *N. australis* was described by Morgan and Ritz (1983, 1984). Kahawai smaller than 100 mm eat mainly copepods. Though kahawai are principally pelagic feeders they will take food from the sea bed.

The reproductive biology of Australian *A. trutta* was described by Stanley and Malcolm (1977). It is not known where kahawai spawn (either in Australia or New Zealand), but there are unconfirmed reports that it is on the sea bed in open water. The pelagic eggs of kahawai have been described by Robertson (1975). Crossland (1982)collected eggs in February from the outer Hauraki Gulf.

Robertson (1982) described feeding of juvenile fish (0+ year class) caught in shallow water over eel grass meadows (*Zostera*). Juvenile fish also occur in New Zealand estuaries (Jones and Hadfield 1985).

Age and growth of *A. trutta* in Australia were derived from back-calculation of scale readings by Nicholls (1973). Using this (unvalidated) technique the eastern "subspecies" *A. trutta* was found to have a maximum age of 7 years, while the western "subspecies" *A. esper* had a maximum age of 9 years. However, in New Zealand, Eggleston (1975) compared scale and otolith readings and decided that scales were unsuitable for ageing kahawai older than 5 "years". He used otoliths to age adult kahawai to a maximum of 22 "years". Wood et al. (1990) used the same technique and they recorded a maximum age of 24 "years". The otolith technique has not been validated for kahawai older than 3 years. Jones and Hadfield (1985) show growth of 1 and 2 year old kahawai by following length-frequency modes over a 12 month period in Porirua and Pauatahanui estuaries.

The results of an extensive Australian tagging programme were described in a series of papers by Stanley (1978, 1980, 1983, 1988a 1988b, 1988c). From the tag returns Stanley (1978) calculated an instantaneous mortality rate (Z) of 1.4 ± 0.1 for the Australian fishery. Estimates of Australian tag shedding rates were provided by Kirkwood and Walker (1984). The New Zealand tagging programme was described by Wood et al. (1990) and brief results in James et al (1982) and Anon. (1983).

The sizes and distribution of kahawai schools, based on aerial sightings, were given by Clement (1978) and Habib et al. (1981a, 1981b, 1982). Due to omissions and other errors in the aerial sightings database at that time, the reports issued before 1987 should not be used for inferences about trends in abundance.

Following complaints of "dumping" the Western Australian Fisheries Department in 1985 commissioned a study on the effects of imports of New Zealand canned kahawai on the Australian industry. The report found that New Zealand exports of canned "Australian salmon" amounted to about 25% of the total Australian consumption. It also found that profits on exports from New Zealand were probably dependent on the differential between the exchange rates of the two countries, and when the Australian dollar fell pressure from imports of New Zealand canned kahawai would reduce (Anon. 1986).

Totally irrelevant to stock assessment, but included for completeness, are a number of food technology studies involving kahawai. Boyd et al. (1984) studied the onset of rigor after death in kahawai. Vlieg (1985) published a proximate analysis of kahawai. Spoilage of kahawai was described by Len (1987), and scombroid food poisoning from smoked kahawai by Foo (1975).

2. REVIEW OF THE FISHERY

2.1 Catch, landings and effort

Kahawai is taken commercially in all QMAs. The reported landings of kahawai for the past eight fishing seasons are shown in Table 1. The landings by method are shown in Table 2. Catches of the main purse-seine target species are shown in Table 3.

2.1.1 Purse-seine catches

Most of the kahawai caught between 1983 and 1990 were taken by purse-seine (72-90 %). Purse-seine catches increased between 1983 and 1989 with a peak tonnage in 1987-88 of 8555 t. In QMA1 kahawai are generally caught in autumn, winter, and spring, with peak catches between September and December. During the summer months skipjack is taken in QMA1 and QMA2 and kahawai are not caught. In QMA3 kahawai is taken throughout the year, although tonnages also peak during October to December. Purse-seine vessels do not fish for kahawai in QMA9 or QMA10.

During the 1983-1990 period the Bay of Plenty (QMA1) purse-seine fishery has remained relatively constant, except for 1987-88. The fishery in QMA2 has been more variable reflecting changes in fishing effort. Catches in the southern fishery (QMA3) have steadily increased from 1983-84 until catch limits were imposed in 1990.

2.1.2 Other methods

Total annual non-purse-seine kahawai catches remained stable at about 1000 t between 1983 and 1990 (see Table 2). The main components are: a bycatch fishery by trawlers, mainly on the west Auckland coast, Bay of Plenty, and Hawke Bay; a target set-net fishery concentrated in North Island west coast harbours, Firth of Thames, and Pegasus Bay; and as a bycatch of the bottom longline fishery, mainly in QMA1.

The west Auckland (QMA9) pair trawl kahawai fishery is highly seasonal: the bulk of catch is taken between February and April. Kahawai are caught largely as a bycatch of trevally and snapper. Since 1986, this annual kahawai bycatch tonnage has remained consistent (150 - 200 t), with the catch per landing ranging between 0.1 and 5 tonnes.

The Bay of Plenty single trawl fishery (QMA1) also targets trevally with a kahawai bycatch.

2.2 Recreational, traditional, and Maori fisheries

Kahawai are a traditional food source for Maori and continue to have cultural significance to many tribes. The fishery at the Motu River mouth is of regional importance (Rowe 1983), especially to Maori, but fisheries exist at the mouths of most major North Island and east coast South Island rivers (Pierce 1987).

Schools of kahawai often occur in the surf zone, around wharves, and in estuaries and are therefore accessible to recreational fishers. They have a very high public profile as a sport and food fish. Kahawai are used as bait by the big game sports fishing industry in Northland and the Bay of Plenty, but are also considered a game fish in their own right. Line records for kahawai are kept by the International Game Fish Association.

The National Marine Recreational Fishing Survey conducted by the Department of Statistics in 1987 indicates that kahawai was the second most dominant species after snapper (*Pagrus auratus*) in the non-commercial finfish catch. An estimated 206 000 people catch kahawai annually (Teirney and McKinnon 1991). Kilner (1988) estimated a recreational catch tonnage as follows: If 206 000 people each caught one kahawai weighing 1.25 kg (the best available estimate of the average size of kahawai caught by recreational fishers nationally) this gives an annual non-commercial catch of 257 t. For an average of 50 fish each the annual catch would be 12 875 t. Sylvester (1989) suggested that a more reasonable estimate of the non-commercial catch is 5-10 kahawai per person per year. The annual catch would then be 1287-2575 t.

From the 1981-84 tagging programme, 57 % (640 tags) of the returns were from amateur fishers and of these amateur returns 37% (235) were caught in set nets.

3. RESEARCH

3.1 Stock structure

Kahawai are considered to form one New Zealand wide stock but stock structure has not been resolved. Results from tagging programmes show that most tagged kahawai are recaptured relatively close (within 50 nautical miles) to the site of tagging, but that some fish move long distances (Fig. 2). From provisional analysis of recapture data from the 1981-84 tagging programme, Kilner (1988) suggested that "limited" movement occurs between three areas: east coast North Island; South Island; west coast North Island.

In December 1991, over 150 tagged kahawai were recaptured by a purse-seiner fishing in Inner Tasman Bay close to the March 1991 release site. This indicates that tagged kahawai are very slow to disperse into the total population. None of the fish tagged in Inner Tasman Bay (140 (5 recaptured) in 1981; 5000 (450 recaptured) in 1991) have yet been recaptured outside the bay, suggesting that local groupings of kahawai may exist. There is also some evidence from the 1991 tagging programme that the catchability of tagged fish may be higher than for untagged fish, since tagged fish do not appear to mix randomly with untagged fish but move inshore. High numbers of tagged kahawai have been caught by a mullet setnetter in Tasman Bay who previously caught few kahawai. This behavioural change was also noted in Australian kahawai (Stanley 1983).

3.2 Resource surveys

There have been no resource surveys specifically for kahawai. The aerial sightings database is the most comprehensive data set available to MAF Fisheries on kahawai occurrence. These data are being evaluated for their use in estimating relative abundance indices for kahawai.

3.3 Growth estimates for kahawai

Morphometric data from Wellington Harbour, and von Bertalanffy growth parameters for kahawai in QMA9 are shown in Tables 4, 5, and Fig. 3.

3.4 Estimation of mortality coefficients

Natural mortality (*M*) was estimated from the equation $M = \log_e 100/$ maximum age, where the maximum age is the age to which 1% of the population survives in an unexploited stock (Hoenig 1983). For kahawai, with a maximum age of 26, this gives an *M* of 0.18.

a) Estimate of instantaneous mortality (Z) derived from catch curves

Bay of Plenty single Trawl fishery (QMA1)

Five landings were sampled in February and March 1991. Samples were combined and scaled by the total tonnage landed to calculate a final weighted length-frequency distribution; 174 kahawai were aged from otoliths to derive an age/length key from which a catch-age frequency distribution was obtained.

Analysis of the catch curve resulted in an estimate of instantaneous total mortality (*Z*) of 0. 05 (Fig. 4). However, the poor fit of the line to the points gives little confidence in this estimate of Z.

The Central region Purse-seine fishery (QMA3):

Kahawai are thought to migrate up and down the east coast of the South Island during the year. The assumption for this analysis is that no exchange of kahawai takes place within a month within a particular sub-area. The three chosen sub-areas were: Outer Marlborough Sounds; Cloudy Bay/Cape Campbell; Kaikoura. For each sub-area the month in which the greatest purse-seine catch was made during 1990-91 was chosen. The length-frequency of the total catch for that month in each sub-area was obtained from catch sampling. Numbers at length were converted to numbers at age using an age/length key obtained by reading otoliths of kahawai from the 3 sub-areas during 1990-91. The age frequency distributions for the three areas are shown in Figs. 5-7. Age classes to the left of the modal peak were assumed not to be fully recruited to the fishery and were excluded from the analysis. The catch curves used to obtain the estimates of Z are shown in Figs. 5-7. The Z values obtained are as follows:

Marlborough Sounds (Nov 1990)	$Z = 0.270$
Cloudy Bay/ Cape Campbell (Feb 1991)	$Z = 0.167$
Kaikoura (Jan 1991)	$Z = 0.196$

West Auckland pair trawl fishery (QMA9)

The west Auckland pair trawl fishery targets trevally with a bycatch of kahawai. Kahawai from twelve landings were measured between 6 February and 15 March 1991. Between 6 and 30 fish bins from each landing (about 10% of each landing) were measured from a total weight of 44.501 tonnes, representing a total of 3979 kahawai measured. These were combined to calculate a final weighted length frequency distribution (based on total kahawai tonnage for each landing). A total of 136 male and 123 female kahawai between 25 and 58 cm long were aged from otoliths to derive an age/length key from which a catch-age frequency distribution was obtained.

Analysis of the catch curve resulted in an estimate of (Z) of 0.108 (Fig. 8).

If it is assumed that the west Auckland pair trawl fishery is largely unbiased in respect to size selection of adult kahawai, then the derived Z of 0.108 is likely to be a reasonable estimate for the QMA9 kahawai sub-population or stock. If size selective bias occurred in the fishery then younger (smaller) fish, which are more vulnerable to trawling, would have been over-represented in the catch . This would cause Z to be overestimated.

b) Estimate of Z derived from tag return rate

Between 1981 and 1984, just under 14 000 tagged kahawai were released (Wood et al. 1990). Using the tag returns from fish with over 150 days at liberty and plotting $\log_e$ of the number of tags returned in successive 150 day time periods (Fig. 9), annual estimates of Z can be obtained from the slope of the regression line (Stanley 1978). These give estimates of Z for the period up to 1989. Changing the time period or the year used has little effect on the value of Z:

Interval (days)	Year tags released	No. of periods used in regression	Z
150	1982	14	0.827
150	1983	17	0.803
150	1981-84	18	0.767
182	1981-84	18	0.880

There is probably a significant loss of tags, although the loop tags used have lasted remarkably well. Two kahawai have been recaptured in 1991 after 8 years at liberty. However, no double tagging was done during the 1981-84 study. Kirk et al. (1988), using the same type of tags in snapper, recorded a tag loss rate of 10-30% .

It is considered that the regression line representing Z is too steep due to tag loss, incomplete mixing of tags, and possibly some behavioural changes in the tagged fish, and that the Z of about 0.8 derived by this method is unreliable.

However, if $Z = 0.8$) really was the true mortality rate and $M = 0.18$, then F would be <= 0.62. This is unlikely to be so. An F of about 0.62 would indicate an average biomass (B_{av}) over the period 1982-1986 of:

$$\begin{aligned} \text{average catch} &= B_{av}*(F/Z)*\ (1 - e^{-Z}) \\ 5\ 224\ t &= B_{av}*(0.62/0.8)*(\ 1 - 0.571) \\ &= B_{av}*\ 0.332 \\ 15\ 700\ t &= B_{av} \end{aligned}$$

This estimate of biomass is not credible. Aerial sightings have shown more kahawai than that (up to 28 000 t) on a single flight.

3.5 Yield estimates

3.5.1 Previous estimates

Eggleston (1978) provided an initial estimate of the biomass and yield for the kahawai fishery based on aerial sightings, and some major assumptions. In the absence of better data Eggleston's estimated biomass of 100 000 to 150 000 t and a suggested yield of 5000 t was endorsed by James (1983).

For the 1987-88 fishing year no stock size estimate was provided for kahawai (Kilner et al. 1988). In 1988 Kilner (1988) estimated MCY for the kahawai fishery from the equation $MCY = cY_{av}$ where c = 1.0 due to "significant under/misreporting of catches provides an underestimate of fishing mortality"; and Y_{av} = the mean commercial catch over the period

1979-85.

The same equation was used for the stock assessment plenary for the 1989-90 fishing year, with the average catch of the years 1979-1985, but with c = 0.8 "since kahawai has an average life span of around 15 years" (Annala 1989). The following year, Sylvester (1989) derived a national MCY from the same equation where Y_{av} was the average catch from 1983 to 1986: the catch equalled the reported catch plus an estimate for the non-reported "mixed fish" catch from the purse-seiners. The period 1983-86 was taken as a period of reasonably constant effort in the kahawai fishery and because there were likely to have been significant under-reporting problems before 1983. After 1986 it was considered that commercial fishers had increased targeting in anticipation that kahawai would become an ITQ species. c was again set equal to 1.0 because "the kahawai fishery was not fully developed during 1983-86" (Annala 1990).

The 1991 Stock Assessment Plenary could not reach a consensus on the estimation of MCY due to: (1) past under-reporting and misreporting of the catch (this is not a reflection on the fishers. Accurate information was not sought by MAF.); (2) uncertainty over the development and state of the fishery, i.e. whether it is under, fully, or over-exploited; and (3) uncertainty over the extent of recent changes in fishing effort (Annala 1991). All these factors affect the value assigned to c and the period used to estimate Y_{av}.

3.5.2 Estimation of status quo catch - SHOT method

Shepherd (1991) developed a simple method for calculating short-term forecasts of catch, or status quo catch, based on a time-dependent, stock-production model (Appendix 1). The method provides a forecast of the expected catch if fishing mortality remains the same with the same pattern of exploitation.

This method is designed for use where only the most basic fishery data are available. It is not intended to replace the need for full analytical investigation of the fish stock, being based on crude assumptions concerning the state of the stock. The general method is a moving average process which allows for partial recruitment. Where recruitment indices are not available, the SHOT forecast tends from the most recent landings towards the recent average landings.

The SHOT method relies on historical landings and estimates of $\tilde{F}$ (the yield/biomass ratio) based on values of F. Variability in abundance can be incorporated in the analysis if a suitable index (r) is available, but that has not been done here.

The model was run for kahawai using the landings from 1977-78 to 1989-90 and with an index of recruitment set to 1.0 (Table 6). F is unknown for kahawai, but estimates of Z are available from catch curves. All the fisheries for which an estimate has been obtained have Z values between 0.05 (Bay of Plenty trawl fishery) and 0.27 (Marlborough sounds). Thus the parameters in the model were set as $F = Z = 0.27$ and $\tilde{F}$ at 0.2 (from the table in Shepherd (1991).

In the absence of better data, $\tilde{F}$ was kept constant during each run. Since F is relatively low there are many age classes in the population and h (the proportion surviving to the next year) is large. In other words a large proportion of the fish are left to be available for capture in following years, and increases in the population due to recruitment (r) are having little influence. Thus it is reasonable to set the index of recruitment at 1.0.

Because of the uncertainty in the estimate of *F* the model was also run for each Fishstock with $\tilde{F}$ set at 0.05 (corresponding to an *F* of <0.1), 0.1 (corresponding to an *F* of 0.1), and 0.3 (corresponding to an *F* of 0.4). The forecast tonnages forming a status quo catch for each Fishstock using the four values of $\tilde{F}$ are shown in Table 7.

4. MANAGEMENT IMPLICATIONS

In submissions to the 1990 Kahawai Public Discussion Paper (Anon. 1990), recreational fishers were concerned about an apparent decline in the abundance of kahawai in QMA1 and QMA2, and to some extent QMA3. A number of commercial longline fishers in QMA1 also reported a decline in kahawai abundance and a commercial setnetter also reported, in submissions, a decline in the Waikato River area (QMA9) (Sylvester, pers. comm.). Recreational fishers attribute these declines to overfishing by purse-seiners (Feldman 1991).

There has been no significant purse-seine catch of kahawai in QMA9, and purse-seine catches in QMA1 north of the Hauraki Gulf have been minimal (zero in 1983-84; <100 t in 1984-85; <40 t in 1985-86; zero in 1986-87 and 1987-88). For the activities of the purse-seiners to be responsible for any declines in abundance in these areas, there would need to be large movements of kahawai around and between QMAs. However, returns of tagged fish show that most fish are recaptured within 50 nautical miles of the release site, and among those which do travel there is a net movement from the Bay of Plenty to the east, not to Northland or QMA9.

No estimates of current and reference biomass are available.

The SHOT method does not provide an estimate of the "optimal" level for catches. It makes no assumptions about the state of the stock, i.e. whether it is at, above, or below the optimal exploitation rate. It simply provides a guide to the level of landings which would maintain the stock at the status quo level. Status quo catch estimates for the 1992-93 fishing year for KAH 1 and KAH 2 are slightly greater than recent landings, while they are considerably greater than recent landings for KAH 3. Values of *Z*, which include the effects of commercial and non-commercial fishing, have been calculated for kahawai. Given a value of *M* of around 0.18, these estimates of *Z* (which are uncertain) suggest that the current values of *F* are less than or equal to *M*. Levels of *F* near or below *M* are generally considered sustainable.

In assuming a constant *F* and a constant recruitment, the model attributes variations in the catch to variations in productivity. In practice, economic factors have also been a major cause of variation in purse-seine landings. The model is particularly sensitive to the value of the most recent landings entered. For that reason the 1990-91 landings (which were constrained by quotas) were not included.

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Table 1. Reported landings (t) of kahawai by Fishstock from 1983-84 to 1990-91. Estimates of mislabelled fish, dumped fish, or fish landed as bait are not included. Data for the distribution of catches among QMAs and total catch are from the FSU database to 1987-88 and from the CELR database after that date. Total LFRR values are the landings reported by Licensed Fish Receivers.

Fishing Year	Unknown Area	KAH1	KAH2	KAH3	KAH9	KAH10	Total Catch	Total LFRR
1983-84	46	1941	919	813	547	0	4266	-
1984-85	441	1517	697	1669	299	0	4623	-
1985-86	621	1597	280	1589	329	0	4416	-
1986-87	1301	1890	212	3969	253	0	7525	6481
1987-88	581	4292	1655	2947	135	0	9610	9218
1988-89	0	2170	779	4301	179	0	7431	7377
1989-90	16	2049	534	5711	156	0	8466	8696
1990-91	0	1959	579	2970	0*	1	5510	5777

* Probably incorrect due to errors and omissions in the CELR database.

Table 2. Reported landings (t) of kahawai by method from 1983-84 to 1989-90. Estimates of mislabelled fish, dumped fish, or fish landed as bait are not included. Data are from the FSU database through 1987-88 and from the CELR database after that date. The kahawai catch totalled across methods cannot be reconciled with the totals in Table 1, due to differences in the way the data was compiled. Table 1 is considered to be more reliable.

Fishing Year	BLL	BPT	BS	BT	L	PS	SN	T	OM	Total
1983-84	67	404	33	183	9	3077	588	20	4	4385
1984-85	82	189	33	136	49	3576	594	25	6	4690
1985-86	99	223	21	235	62	3460	484	13	7	4604
1986-87	38	97	93	227	10	6341	754	124	9	7693
1987-88	64	102	56	182	3	8555	698	35	4	9715
1988-89	53	27	10	133	<1	3123	383	9	17	4041
1989-90	67	9	14	72	0	7918	480	54	68	9300

BLL = Bottom longlining
BS = Beach seining/Drag net
L = Lampara
SN = Set net
OM = Other methods
BPT = Bottom pair trawl
BT = Bottom trawl
PS = Purse seine
T = Troll
Total = Total, all methods including "unidentified methods"

Table 3: Reported annual purse-seine catch (t) by major species for all purse-seine vessels combined. Data are from the FSU database through 1987 and from the CELR database after that date. There are errors in the CELR database. Not shown in this table, but extracted as purse-seine catch from the database were 76 t of hake, 32 t of spotties, 0.5 t squid, .013 t white wharehou and 5 southern bluefin tuna each of 1 kg. These are all coding errors.

Year	Sets	KAH	EMA	JMA	SKJ	KIN	TRE	YFN	BAR
1983	439	3609	1869	2115	3653	1.8	544	0	169
1984	519	3609	671	4243	3785	1.9	618	0	31
1985	422	3723	1664	3738	1808	0.7	337	0	33
1986	635	4878	1437	4222	6304	14.7	270	10	20
1987	823	6224	2885	5645	5116	0.2	57	1	50
1988	729	6529	3062	5623	3856	0.1	358	4	39
1989	n.a	4428	5523	6101	5020	0.6	129	0.2	161
1990	n.a	7614	6737	7817	6212	0	462	0	87

KAH = kahawai; EMA = blue mackerel; JMA = jack mackerels; SKJ = skipjack; KIN = kingfish; TRE = trevally; YFN = yellowfin tuna; BAR = barracouta; n.a = not available.

Table 4: Length weight data from kahawai caught by trolling in Wellington Harbour during 1990. s.e. = standard error.

$$weight = a^* \, length^{b}$$

Parameter	Estimate	s.e.	n
a	0.0026	0.00048	307
b	2.233	0.04684	
r^2	93.57		
mean length (cm)	46.3		
mean weight (kg)	1.4		

Table 5: von Bertalanffy growth parameters for male (n= 113) and female (n = 106) kahawai from the west Auckland pair trawl fishery. s.e. = standard error.

Male	K = 0.2770400	s.e = 0.032429
	t_0 = -0.3701887	s.e. = 0.451461
	L_∞ = 53.476	s.e. = 0.779276
	n = 113	
Female	K = 0.2383833	s.e. = 0.028415
	t_0 = -0.623270	s.e. = 0.4051526
	L_∞ = 56.523	s.e. = 1.077398
	n = 106	

Table 6: Reported landings (t) of kahawai by fishing year (1 Oct-30 Sep) by Fishstock used in SHOT calculations. FSU data to 1987-88, then CELR data.

Fishing year	QMA1 (t)	QMA2 (t)	QMA3 (t)	QMA9 (t)
1977-78	1100	400	250	200
1978-79	1400	400	700	200
1979-80	1300	900	200	300
1980-81	1000	400	1400	400
1981-82	1000	500	1200	400
1982-83	1000	600	2500	800
1983-84	1941	919	813	547
1984-85	1517	697	1669	299
1985-86	1597	280	1589	329
1986-87	1890	212	3969	253
1987-88	4292	1655	2947	135
1988-89	2170	779	4301	179
1989-90	2049	534	5711	156

Table 7: Forecast catches (t) using the status quo technique for each Fishstock using four values of $\tilde{F}$

Fishing year	$\tilde{F}$ = 0.05	$\tilde{F}$ = 0.10	$\tilde{F}$ = 0.20	$\tilde{F}$ = 0.30
		KAH1		
1990-91	2100	2100	2100	2000
1991-92	2200	2100	2000	2000
1992-93	2200	2100	2000	1900
		KAH2		
1990-91	600	600	600	600
1991-92	600	600	600	600
1992-93	600	600	600	600
		KAH3		
1990-91	6000	5800	5400	5000
1991-92	6200	5800	5100	4400
1992-93	6300	5700	4700	3900
		KAH9		
1990-91	200	200	200	200
1991-92	200	200	200	200
1992-93	200	200	200	200

Figure 1: New Zealand EEZ showing kahawai Fishstock areas.

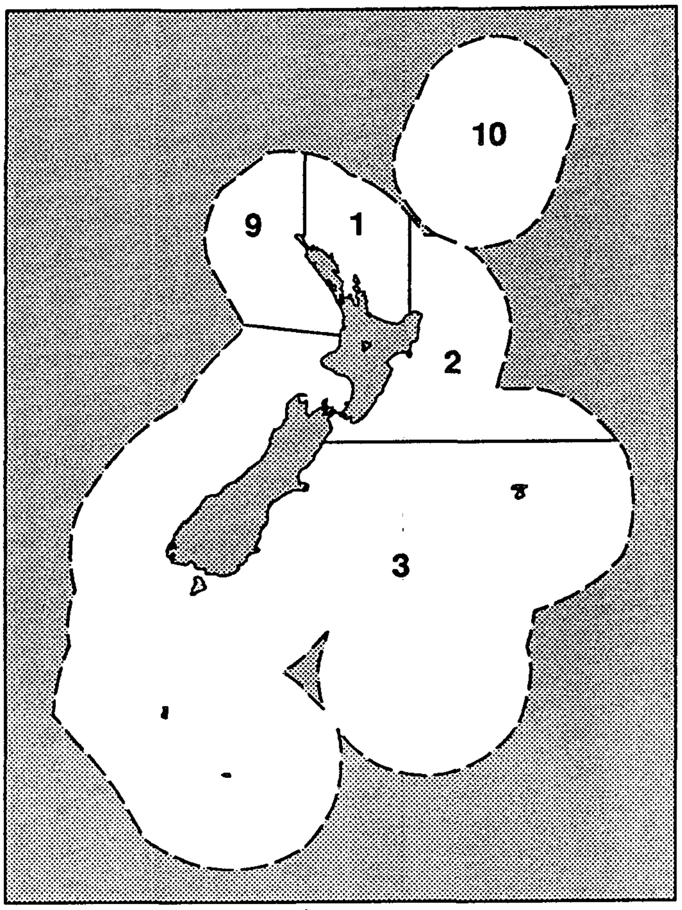


Figure 2: Tagging data from 1981 to 1984 for kahawai. Plot of days at liberty against distance travelled (nautical miles, by shortest sea route), all areas combined. Days at liberty ≤ 150 excluded from plot.

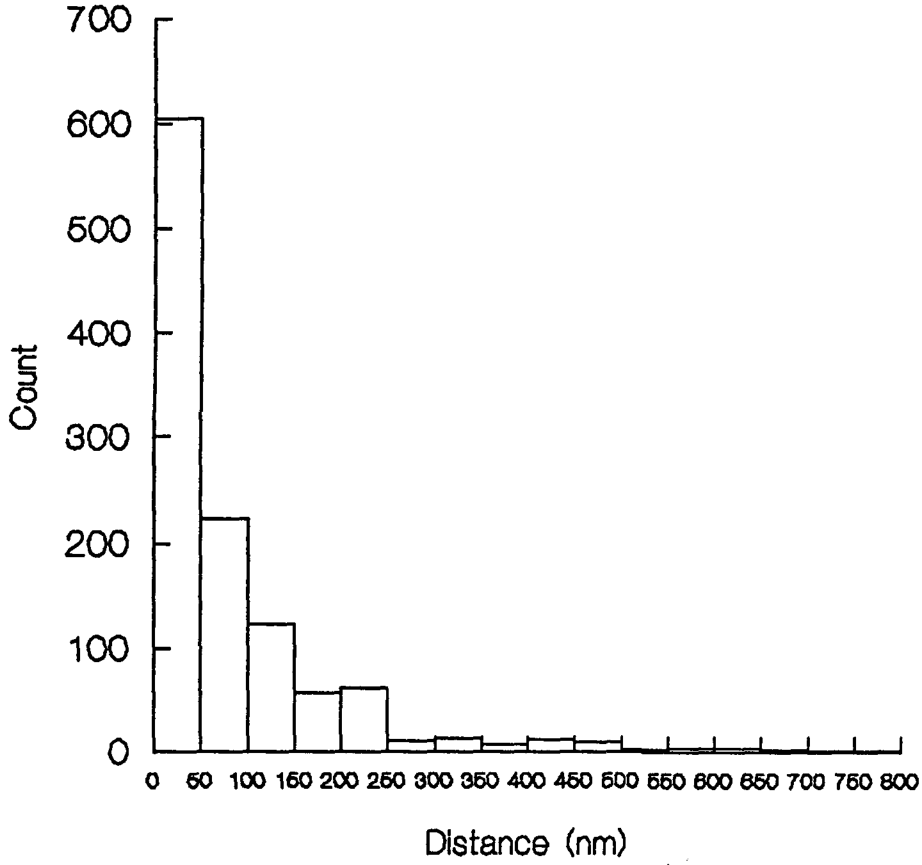


Figure 3: The relationship between age and fork length for male (n=113) and female (n=106) kahawai. von Bertalanffy curves fitted for each sex are also shown.

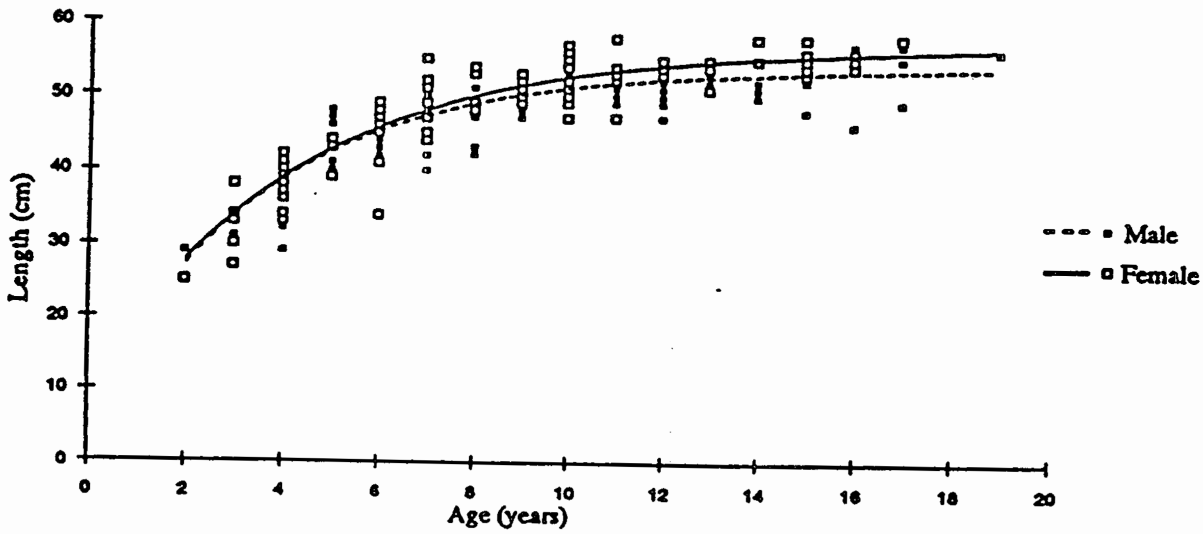


Figure 4: Catch curve derived from the Bay of Plenty kahawai trawl bycatch fishery.

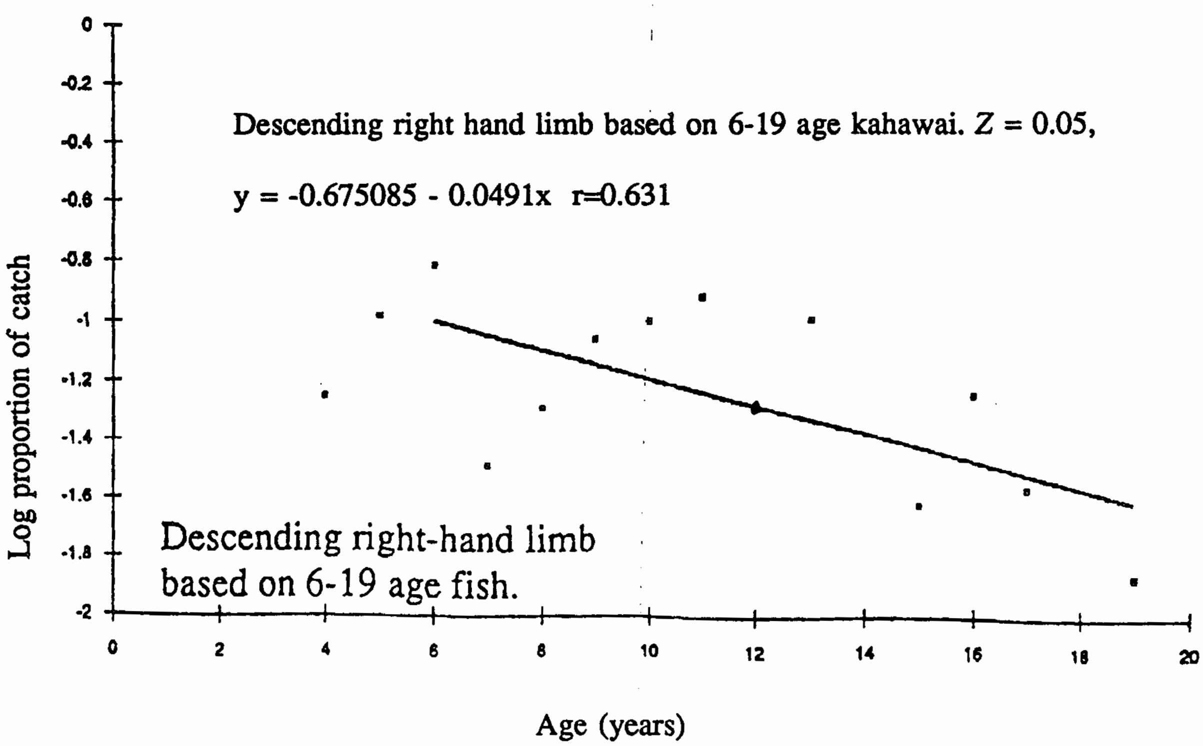


Figure 5: a) Age/length frequency for Marlborough Sounds kahawai, total purse-seine landings November 1990. b) Catch curve for same fish, slope = -0.270, s.e.= 0.041, r^2= 0.783.

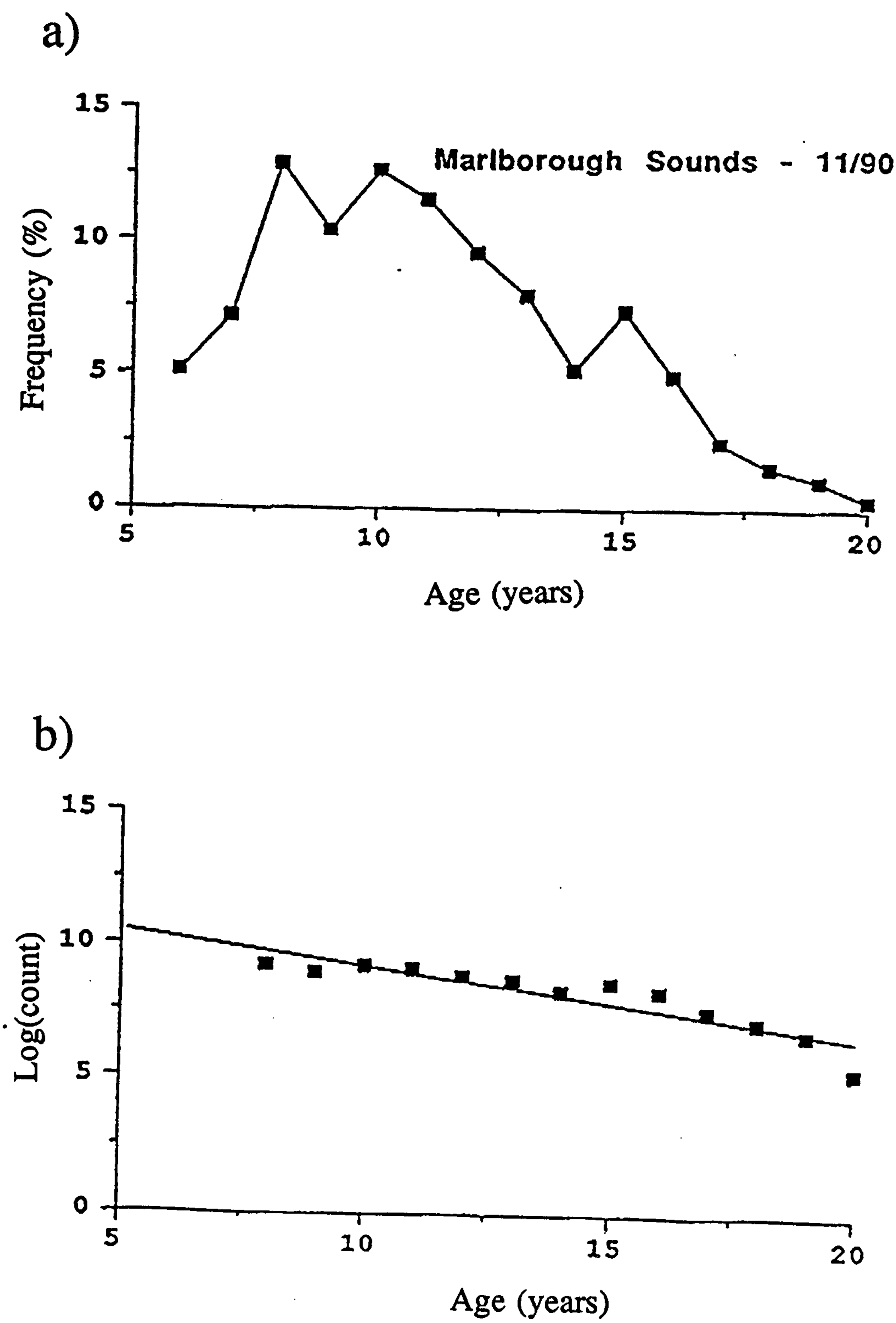


Figure 6: a) Age length frequency for Cloudy Bay/Cape Campbell kahawai, total purse-seine landings February 1991. b) Catch curve for same fish, slope = -0.167, s.e.= 0.034, r^2= 0.726.

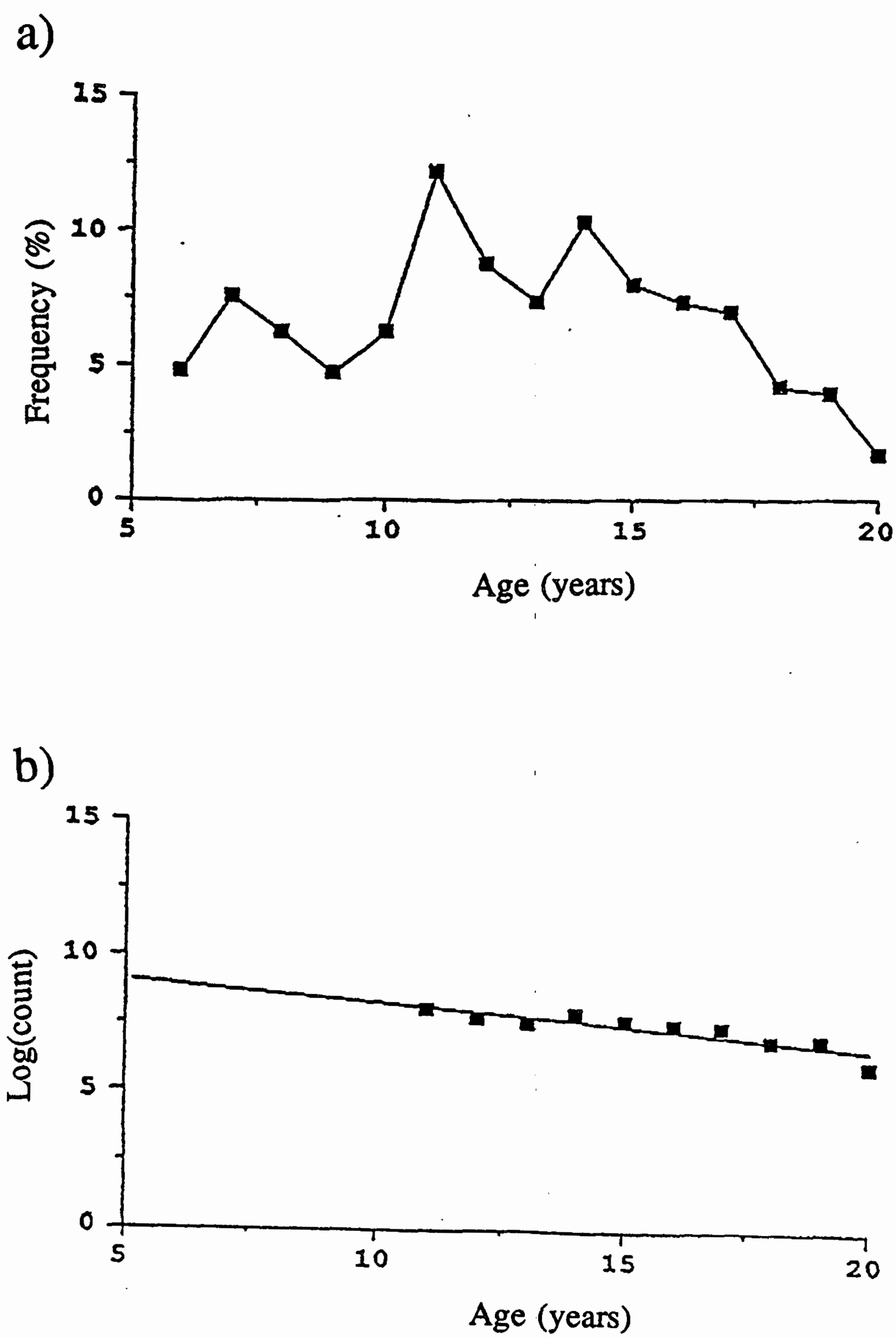
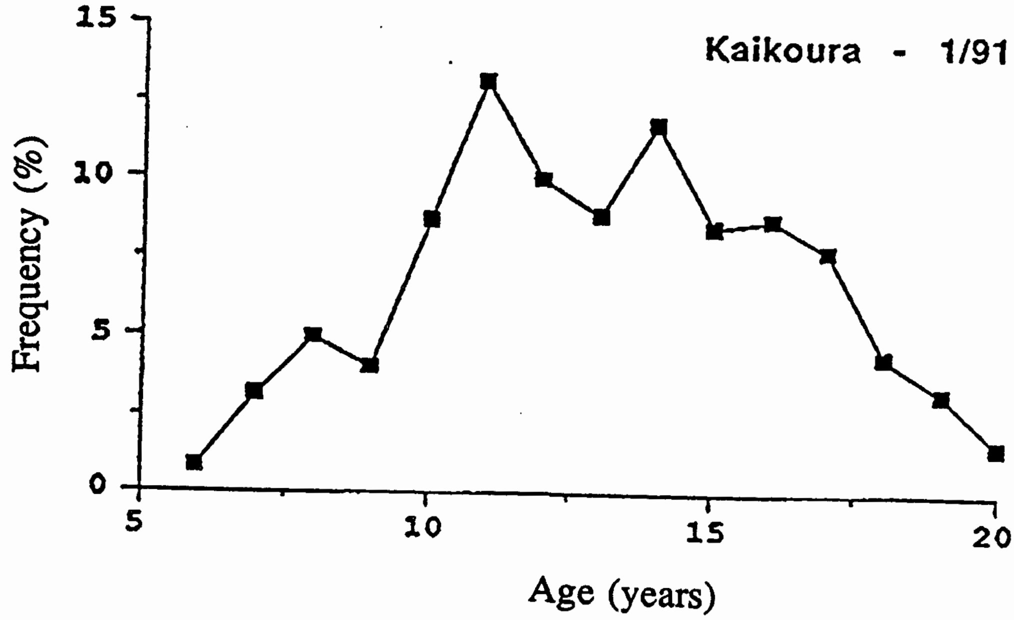


Figure 7: a) Age length frequency for Kaikoura kahawai, total purse-seine landings January 1991. b) Catch curve for same fish, slope = -0.196, s.e.= 0.036, r^2= 0.742.

a)



b)

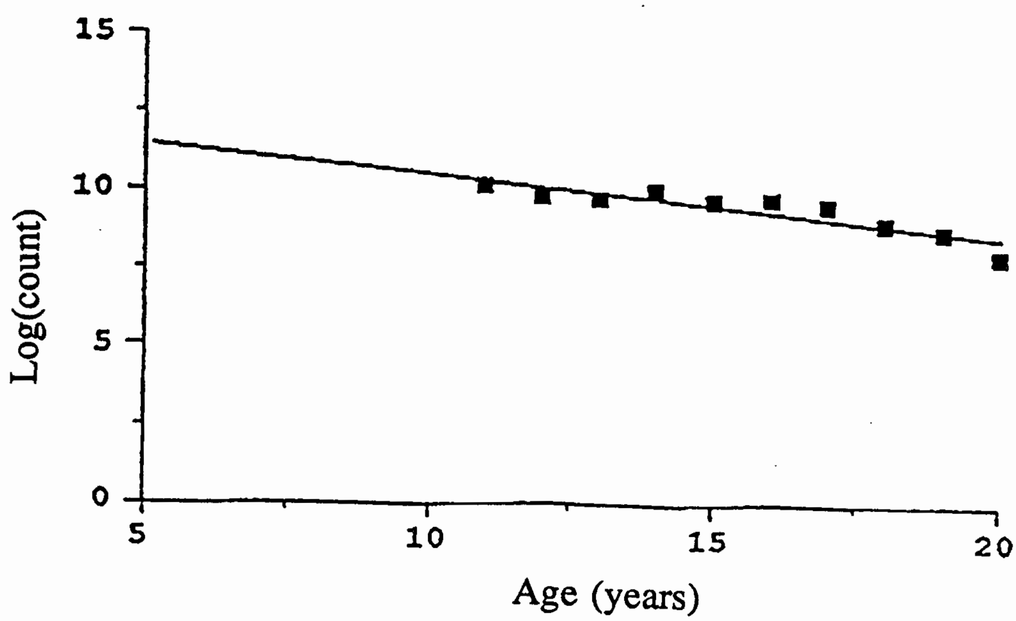


Figure 8: Catch curve derived from the west Auckland kahawai trawl bycatch fishery.

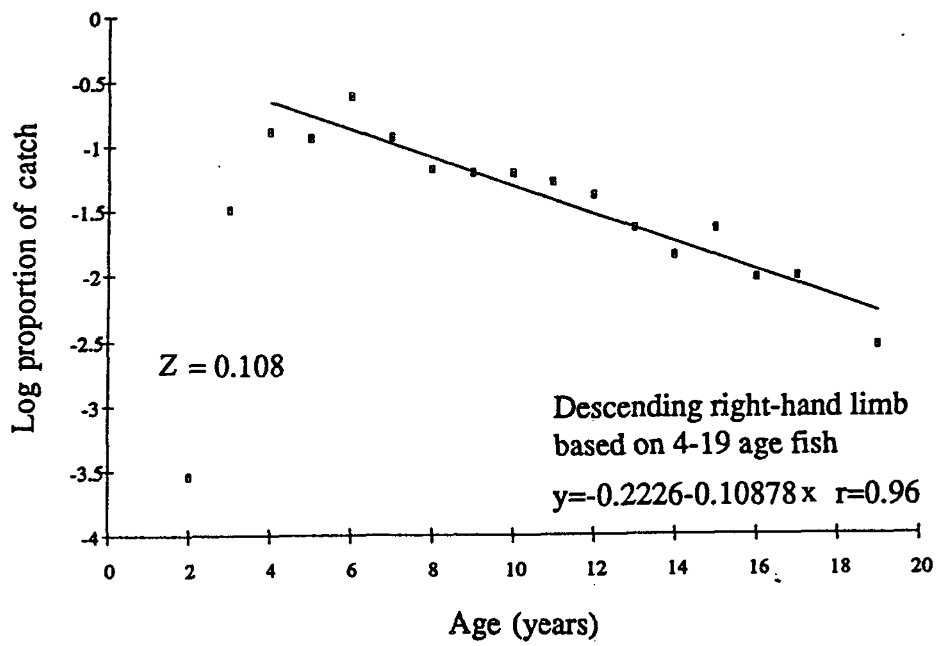
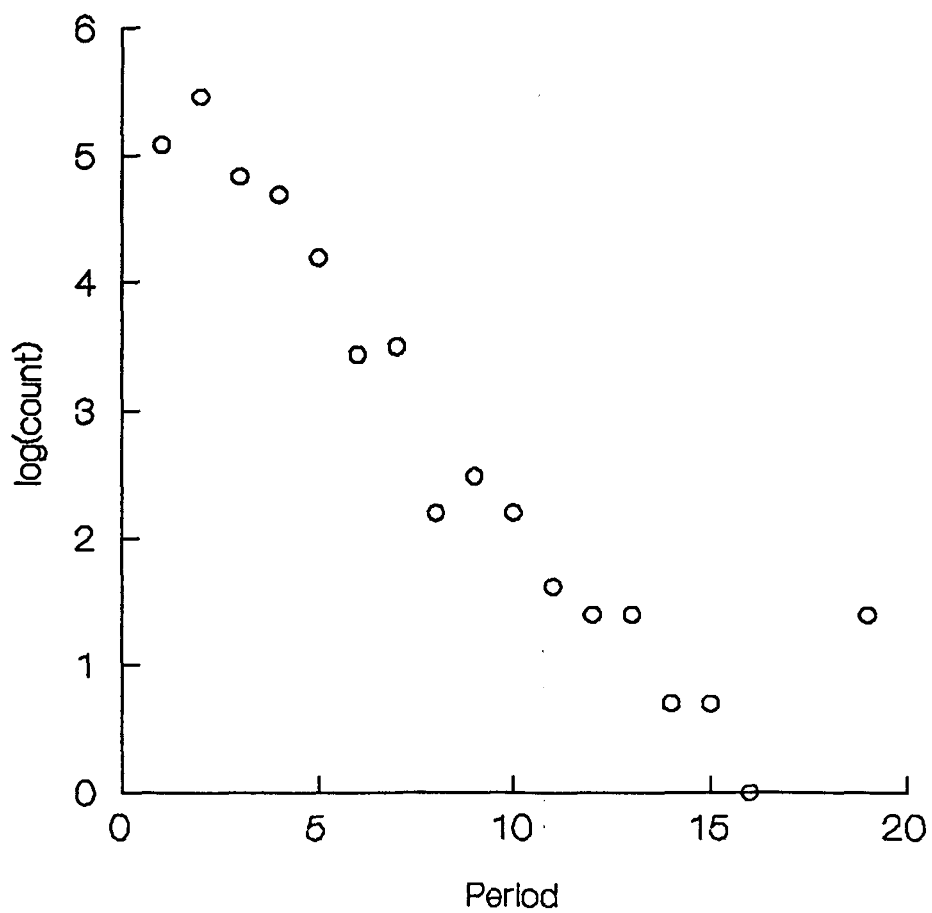


Figure 9: Tagging data from 1981 to 1984 for kahawai. Plot of log-counts of tag returns in each period of 150 days. Tags returned within first 150 days not included.



APPENDIX 1: The SHOT equations

Shepherd (1991) gave a detailed explanation for the derivation of the SHOT method. A brief outline is provided here:

The yield equation used by Shepherd is derived from:

$$Y_{(y+1)} = h_{(y)} Y_{(y)} + \tilde{\tilde{F}}_{(y)} P_{(y+1)}$$

Where $Y_{(y+1)}$ is the yield (catch) expected in year y+1 if the fishing rate is the same during year y+1 as in year y. $P_{(y+1)}$ is the annual production (recruitment to the fishery in weight); and $h_{(y)}$ is the "hang-over" factor representing the proportion (in weight) of the exploited stock which survives until the following year.

Note that it is not necessary to know B, the biomass. The equation used to produce the SHOT forecast is a re-indexed form of this yield equation, i.e.

$$Y_{(y)} = h_{(y-1)} Y_{(y-1)} + \tilde{\tilde{F}}_{(y-1)} \hat{P}_{(y)}$$

where, if there is no recruit index, i.e. recruit index (r) is set to 1.0, then:

$$\hat{P}_{(y)} = \overline{P}$$

The averages (indicated by the overbar) are taken over all available previous values of P, with a minimum of three values in the average. P, the estimate of production, needs to be calculated for each available year, in order to obtain the average.

..... P is obtained from:

$$P_{(y)} = \frac{Y_{(y)}}{\tilde{\tilde{F}}_{(y)}} - \frac{h_{(y-1)} Y_{(y-1)}}{\tilde{\tilde{F}}_{(y-1)}}$$

$\tilde{\tilde{F}}$ is defined as:

$$\tilde{\tilde{F}} = F\{1 - \exp(G-Z)\} / (Z-G)$$

..... and G is the logarithm of the weight ratio of successive age groups.

An example of a SHOT spreadsheet for kahawai is provided below. For an explanation of the columns, refer to Shepherd (1991). The status quo catch is shown in the column "Est'd Landings".

Kahawai QMA 1 SHOT spreadsheet

Running recruitment weights

older	0.00	G-M =	0.00
central	1.00	exp(d)	1.00
younger	0.00	exp(d/2)	1.00

Year	Landings	Recrt Index	W'td Index	Y/B Ratio	Hangover	Act'l Prodn	Est'd prodn	Est'd SQC	Act'l Expl Biom	Est'd Expl Biom	Est'd Landings
77/78	1100	1.00		0.20	0.80						
78/79	1400	1.00	1.00	0.20	0.80	2600			7000		
79/80	1300	1.00	1.00	0.20	0.80	900			6500		
80/81	1000	1.00	1.00	0.20	0.80	-200			5000		
81/82	1000	1.00	1.00	0.20	0.80	1000	1100	1020	5000	5100.00	1020
82/83	1000	1.00	1.00	0.20	0.80	1000	1075	1015	5000	5075.00	1015
83/84	1941	1.00	1.00	0.20	0.80	5705	1060	1012	9705	5060.00	1012
84/85	1517	1.00	1.00	0.20	0.80	-179	1834	1920	7585	9598.17	1920
85/86	1597	1.00	1.00	0.20	0.80	1917	1547	1523	7985	7614.57	1523
86/87	1890	1.00	1.00	0.20	0.80	3062	1593	1596	9450	7980.88	1596
87/88	4292	1.00	1.00	0.20	0.80	13900	1756	1863	21460	9316.11	1863
88/89	2170	1.00	1.00	0.20	0.80	-6318	2971	4028	10850	20138.50	4028
89/90	2049	1.00	1.00	0.20	0.80	1565	2126	2161	10245	10806.09	2161
90/91		1.00	1.00	0.20	0.80		2079	2055		10275.33	2055
91/92		1.00	1.00	0.20	0.80		1919	2028		10139.65	2028
92/93		1.00	1.00	0.20	0.80		1782	1979		9894.01	1979