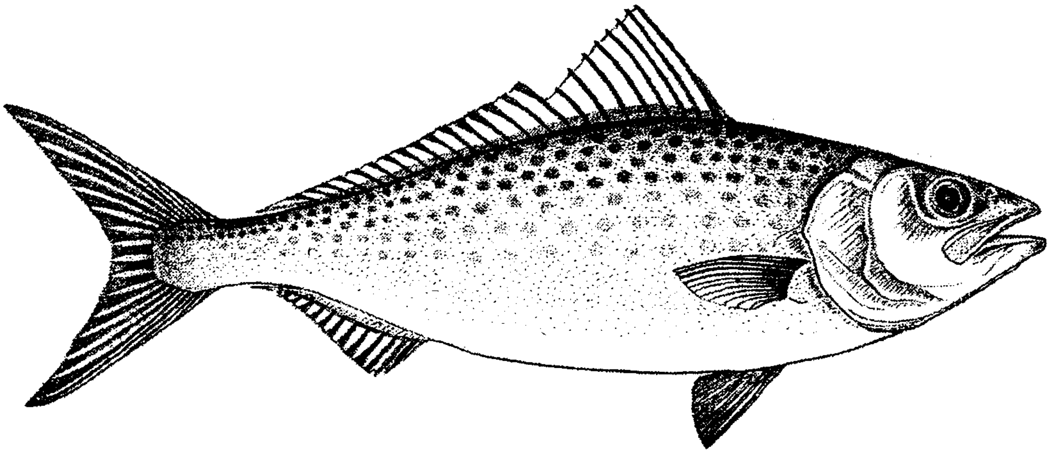
Unified kahawai growth parameters

Elizabeth Bradford



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Contents

Abstract

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For this report, growth parameters are interpreted in a wide sense and include the parameters in the weight-length relation and the natural mortality, as well as the parameters in the von Bertalanffy growth equation. The data used come from the kahawai catch sampling programmes carried out in the Central and North regions during 1990 to 1993. The purpose of this report is to combine the data as far as practicable to give parameters that will be useful for the kahawai stock assessment model which currently treats kahawai as a single national stock.

The length and weight data came mainly from fish caught by purseseine and most of the measured fish were adult (40 cm or larger). Several relations are derived and these should be used with data similar to that for which they were derived. The weight-length relations derived do not appear to differ by sex; they do differ by gonad state.

The parameters in the von Bertalanffy growth equation are estimated for successively larger data sets obtained by grouping the available data from different fishing years and different areas. The parameter estimates so obtained may be biased as the data from age-length keys (tabulated in Appendix 1) are used. The same procedure for ageing the kahawai was used throughout. However, ring counts were assigned to ages slightly differently for fish collected in the north to those collected in central New Zealand leading to a difference comparable to the between reader errors usually associated with ageing work. Juvenile kahawai may grow faster in the north than in other parts of New Zealand. There may be differences in the growth parameters for males and females, but combining the sexes should be adequate for modelling.

The natural mortality was estimated using an estimator developed by Chapman & Robson for three of the age-length data sets available. These results are unreliable because of the selectivities involved in the purseseine fishery, though they do suggest that the natural mortality is close to 0.2 as currently assumed.

Introduction

A strategic research plan for kahawai was developed in 1991 by (the then) MAF Fisheries and kahawai research was actively pursued until 1993. The work included a major tagging study which was used primarily to validate the kahawai ageing technique. The kahawai were tagged and injected with tetracycline which produces a check in the otoliths which could usually be detected in the returned fish. Stevens & Kalish (1998) described the validation of kahawai ages. Griggs *et al.* (1998) analysed the growth and movement of the tagged kahawai.

This report re-examines the data collected during the kahawai catch sampling programmes in 1990–93, and brings together results from sampling in the North and Central regions, in particular, the weight-length and age-length data. The data have been published by Jones *et al.* (1992), McKenzie *et al.*, (1992), Drummond & Wilson (1993), and Drummond (1994, 1995), or are yet to be published (McKenzie & Trusewich, unpubl. data). Some of the previously published ageing data have been revised (Stevens & Kalish 1998). Figure 1 shows the locations of the kahawai Fishstocks, KAH 1, KAH 2, KAH 3, and KAH 9 from which the data were obtained.

The results from these studies enabled the development of a simple stock assessment model for kahawai assumed to be a single stock (Bradford 1996, 1997). The main aim of the work presented in this report was to develop unified growth parameters which could be used in this model. These parameters give a guide to suitable base case parameters in the model. The variation noted in the various intermediate parameters indicates the sensitivity runs which should be done in association with the base case model estimate.

Funding for this project (PIKA02) was provided by the Ministry of Fisheries.

Programme objective

1. To estimate biomass, recruitment variability, and sustainable yields of kahawai.

Objectives for 1996–97

1. To update the stock assessment for kahawai.
2. To determine the feasibility of estimating the relative year class strength of juvenile kahawai from selected areas to provide recruitment indices.
3. To determine the feasibility of using otolith microchemistry to describe stock structure.

This work was carried out under the first of the 1996–97 objectives. Bradford (1997) updated the stock assessment.

Weight-length relation

Kahawai fork lengths (FL) and weights were measured in KAH 3 (Drummond & Wilson 1993, Drummond 1994) and KAH 1 (McKenzie & Trusewich, unpubl. data). Relations given in these reports and below show that the weight and length data are not all related in the same way. Juvenile kahawai appear to grow so that their weight is roughly proportional to their length cubed. Once kahawai reach maturity at about 40 cm length, they seem to have difficulty in maintaining their weight and groups of kahawai caught at different times and places can have weights which are proportional to a power of length between 2 and 3.

Table 1 lists the coefficients (a, b) in several weight-length relations using the data from the references above. Relations for both sexes combined are given as there appears to be no significant difference by sex (sex was found to be marginally significant in the small data set from a purseseine catch in Tasman Bay). The minimum, maximum, and median, or the end points and middle of the range of lengths of each data set (L_{min}, L_{max}, and L_{med}), its size (n), and the fraction of the variation explained in the regression (R^2) are included in Table 1. Figures 2–7 show several of the length-weight data sets with regression relations imposed.

The relations described as "Purseseine 91/92" and "SI purseseine, set net" correspond to the relations given in Annala & Sullivan (1996) for males and females separately. McKenzie & Trusewich (unpubl. data) expected the weight-length relation for mature kahawai to be different from that for immature and resting kahawai and noted the gonad state of the fish selected for weight measurements. Drummond (1994) and Drummond & Wilson (1993) measured the gonad weight. Only kahawai from the west coast were mature or nearly mature in the South Island samples. I have removed kahawai caught in KAH 3 with a gonad weight greater than 50 g from any regressions meant to involve immature and resting fish.

The weight-length relations appear to depend upon the location of the catch and the time of the catch (Kim Drummond, MFish, Nelson and Jeremy McKenzie, NIWA, Auckland, pers. comm.). The purseseine-caught kahawai in KAH 3 could be grouped into those caught in summer and those caught in winter. Those caught in winter were in poorer condition. The same seasonal pattern did not apply to the set net caught kahawai in KAH 3, but there were significant differences between the samples. Jones *et al.* (1992) quoted the relation $W = 0.0026L^{2.23}$ for 307 kahawai caught by trolling in Wellington Harbour with mean length 46.3 cm and mean weight 1.4 kg. This relation has a low exponent and has been excluded from Table 1 as the data set has not been located and checked.

Two combined relations are given: the first combines the immature and resting kahawai caught by purseseine in KAH 1 and purseseine and set net in KAH 3; the second uses the purseseine data from KAH 1 and KAH 3. The first relation covers more of the length range.

The upper part of Figures 2–7 shows weight plotted against length and several fits. The lower plots the (raw) residual weights against length. The dotted line on the residual plots is a lowess smoothed line and is included to indicate any bias in the residuals. The residual plots are expected to be fan-shaped: the fits are performed by regressing $\log(W)$ against $\log(L)$. The fits covering all, or most, of the length range show trends in these residual plots. In particular, there is a general tendency for the largest fish to have negative residuals.

The two combined relations (All 1 and All 2), the relation derived by Drummond & Wilson (SI PS), and that derived by McKenzie & Trusewich (NI) are for immature or resting kahawai. The relation derived by Drummond (1994) (SI sum) is distinct from the others and appears to be suitable for well conditioned kahawai. The other relations lead to noticeable residual bias when adult and juvenile fish are combined, suggesting that a single weight-length relation may not be appropriate for kahawai.

The relation derived by combining the KAH 1 and KAH 3 purseseine data and the KAH 3 set net data covers more of the length range, has a higher R^2, and has more residual bias than the relation derived by combining the KAH 1 and KAH 3 purseseine data (*see* Table 1 and Figures 5 and 6).

Combining data collected by different methods was thought to be ill-advised by the Pelagic Working Group. The relation preferred by the Group was that derived from purseseine caught fish in summer in KAH 3. This relation seems to me to be highly selective and not necessarily representative of the kahawai population. At this stage, we do not have a useful general purpose weight-length relation for kahawai, nor do we have a fishing method which will sample the kahawai population uniformly over the whole length range (*see* below). There are several relations available, from which the most suitable for the purpose can be selected. The simplicity of the kahawai assessment model means that errors introduced by slightly wrong growth parameters are swamped by the structural errors of the model and any weight-length relation (provided it has not been derived from a biased sample) will be suitable, so the relation preferred by the Pelagic Working Group has been used. More problematic is selecting a suitable relation to determine the mean weight of the recreational harvest in an area. At some stage, both weight and length of recreationally caught kahawai will need to be measured during a boat ramp survey.

Data problems

There are several difficulties involved in obtaining a representative length and weight data set for kahawai. Appendix 2 contains a discussion of the problems involved in using purseseine catch samples to represent the total population.

An essential difficulty lies in finding data in which the whole length range is well represented. There are few measured kahawai below 25 cm length and between 35 and 40 cm. Nearly all the kahawai from KAH 1 were adults. Juvenile kahawai were measured in KAH 3 by sampling from the occasional schools of juveniles caught by purseseine and by sampling the set net catch. There are technical difficulties in fitting data over short length ranges. For example, the best fitting linear, quadratic, and cubic relations are little different for adult fish, but differ for juvenile fish.

Kahawai start maturing at about 40 cm FL and the weight-length relation might change at that point. The data suggest adult kahawai are more prone to deconditioning than juveniles. As far as is known, juvenile kahawai remain close to their nursery areas, for example, Tasman and Golden Bays (Drummond 1994). The deconditioning of adult kahawai could be explained by the fish using their energy sources in moving large distances (between feeding), competing for food, or chanelling energy into reproductive rather than somatic growth. As mature kahawai appear more deconditioned than resting ones, mature fish do appear to be chanelling energy into reproductive growth.

Even the recreational fishery using mixed methods is unlikely to give a uniform random sample of lengths. Much of the target kahawai recreational fishery depends upon first sighting kahawai schools, and then targeting bigger fish. In KAH 1, over half of the kahawai caught by the recreational fishery are a bycatch of the recreational snapper and “general” fisheries, that is, are caught near the bottom (Bradford, unpubl. data). These bycatch kahawai are still selectively caught as the snapper fishers are fishing where they believe snapper to be; these areas are not necessarily where the kahawai are representative of the kahawai population.

Growth parameters from age-length keys

Kahawai age-length data from 1991 to 1993 were collected and some new combined relations fitted. Ages in some of the data sets were checked. There is a potential problem in combining age-length data from the North and Central regions as the ring counts were assigned to ages differently. For the data from the North, ages were assigned from the ring counts by assuming a spawning date of 1 February and that the dark band of the otolith (the ring) was laid down on 1 June. The ages for the fish caught in the Central region were assumed to be equal to the ring count. These different methods lead to an error similar to the between-reader errors normally found in reading otoliths. The procedure for counting rings was the same.

The growth parameters have been estimated from the von Bertalanffy equation:

$$L = L_{\infty}(1 - exp(-k(A - t_0)))$$

where L is the length, A the age, and L_{∞}, k, and t_0 the von Bertalanffy parameters. New estimates of growth parameters using various combinations of the data are given (with asymptotic 95% confidence intervals for the estimates) in Table 3 for females, males, and all fish. Included in Table 3 are estimates where the ages have been verified since the original publication and these may differ slightly from the values given in the original sources. Previously published values are repeated in Table 4 for comparison. McKenzie & Trusewich (unpubl. data) do not give growth equations for each sex separately; their relations supersede others published for the North region (Jones *et al.* 1992, McKenzie *et al.* 1992).

The age-length data are tabulated in Appendix 1. Table A1 gives a brief description of where and when each data set was collected and assigns a code to each data set. These codes are used below, together with codes for the combined data sets, also defined in Table A1.

McKenzie & Trusewich (unpubl. data) pointed out that the lengths at age in the age-length key data being used to estimate the growth parameters are biased, particularly for the younger ages. An essential problem with the kahawai ageing data is that most of the otoliths have been taken from fish over 40 cm in length and fish with lengths less than this are not fully represented in the samples. Consequently the growth parameters determined from the age-length keys directly will be biased. McKenzie & Trusewich (unpubl. data) have taken care to present growth parameters which are as unbiased as possible. To do this, they have produced relations valid for the older kahawai by dropping the data for the younger ages. This approach is entirely valid, but the results will not always be useful. For example, because young kahawai are fished by all sectors, any model involving the total exploitation of the kahawai stock needs to include the younger ages in the growth equation.

The new estimations which combine the available data sets are presented in the hope that the age-length data will become less biased as the database size increases.

Age-length data from catch sampling in KAH 2 and 3

The ages for two data sets collected in the 1992–93 fishing year (*see* tables 6, 8, and 9 in Drummond (1995)) from the west coast of the South Island (WCSI23) and the east coast of the South Island (ECSI23) were checked and growth parameters re-estimated (*see* Table 3). The east coast South Island sample contained several large (over 60 cm FL) and old (over 20 years) kahawai, and the youngest kahawai in the sample were aged 5 years. There is little length change with age shown in this sample which is reflected in the low values of k and t_0. Growth parameters from Drummond & Wilson (1993) for data collected east (WCSI02e) and west (WCSI02w) of D'Urville Island and on the east coast of the North Island (ECNI23) in 1990–92 and November 1992, respectively, are given in Table 4.

The west coast South Island data (WCSI23) and the data from east (WCSI02e) and west (WCSI02w) of D'Urville Island are combined to give an overall west coast South Island set of growth parameters. These data sets, together with the east coast South Island (ECSI23) and east coast North Island (ECNI23) data, are combined to give a KAH 2 & 3 set (KAH23) of growth parameters.

It is difficult to tell from the smaller data sets whether there are any differences in the growth parameters for male and female kahawai. When the data sets are combined, it appears that female kahawai have a lower growth rate, k, but grow to a greater size (have a greater L_∞) (*see* the growth parameters labelled west coast South Island combined and KAH23 (KAH 2 and KAH 3 combined) in Table 3).

Diagnostic plots

Venables & Ripley (1994) described some diagnostics which can be used to determine the goodness of fit of non-linear regression models. These diagnostics were applied to the west coast South Island (WCSI23) data set from 1992–93 and the combined west coast South Island data set from 1990 to 1993. The data for kahawai of both sexes were used.

First, the data and the fit are plotted and then the length residuals are plotted against the fitted values of mean length (Figure 8). A lowess line is included on the residual plots to indicate trends in the residuals. There does appear to be some trend in the residuals for lengths below 50 cm. In this range the age probably needs to be specified with greater accuracy than to the nearest year and variations in growth rate of individual kahawai (which seem to exist) will have greater influence.

The estimates of the two measures of curvature described in Venables & Ripley (1994) show that the parameter effects curvature is greater than the prescribed limit of 0.3 suggesting that the parametrisation of the von Bertalanffy equation might not be optimal. The intrinsic effects curvature is adequately small.

Profile plots are given in Figure 9 for both these data sets where the estimated τ (called tau on the plots) for the three parameters in the von Bertalanffy equation are shown. (All the von Bertalanffy parameters are calculated as non-linear parameters, though some are linear parameters. The plots show a very slight curvature, but the parameter estimates are probably satisfactory although they have a small intrinsic effects curvature.

Age-length data from catch sampling in KAH 1 and 9

McKenzie & Trusewich's estimates

McKenzie & Trusewich (unpubl. data) produced new values of the von Bertalanffy growth parameters for KAH 1 and KAH 9 which replace the parameters given in McKenzie *et al.* (1992) and Jones *et al.* (1992). They also produced a combined KAH 1 and KAH 9 relation (Table 4). Weighted regressions have been used over limited ranges of the data. For the KAH 1 data the recreational length frequency (MFish, unpubl. data) was assumed to give lengths which are representative of the population. These data were used to assign the weights used in estimating the weighted mean length at age for data collected in the 1990–91 fishing year (when the recreational data were collected). For the KAH 9 data which came from the trawl bycatch fishery, the kahawai with lengths between 40 and 58 cm were used and the associated length distributions gave the weights used in estimating weighted mean lengths at age. Growth parameters are given using data collected in the 1990–91 and 1992–93 fishing years (Table 4). McKenzie & Trusewich (unpubl. data) should be consulted for more details on the method they used to estimate the kahawai growth parameters.

The method adopted by McKenzie & Trusewich (unpubl. data) should lead to more reliable estimates of growth parameters for the ranges of ages and lengths fitted. It also leads to wider 95% confidence intervals then can be obtained by the conventional method of using unweighted age-length key data (which was used previously and elsewhere in this report). These wider confidence intervals will give a realistic representation of the uncertainty in the estimates.

Estimates developed in this report

A combined KAH 1 and KAH 9 data set (KAH19 formed from BOP01, BOP12, WCNI01, and WCNI23) was used to derive the growth parameters given in Table 4. The data came from the 1990–91 and 1991–92 Bay of Plenty purseseine catch sampling and the 1990–91 and 1992–93 trawl bycatch sampling in KAH 9. Data for the younger fish are included. The male and female growth parameters are different but less different than the sex difference seen in the KAH 2 and KAH 3 data. The growth parameters, k, from the KAH 1 and KAH 9 combined relation are less than the ks from the KAH 2 and KAH 3 (KAH23) combined relation. The L_∞ values are comparable.

Tagging data from the age validation study

The growth parameters obtained from the age-length data from the Bay of Plenty age validation study are given in Table 4 (Stevens & Kalish 1998) for some fish caught about a year after tagging. The growth parameters for males and females are the same within the confidence limits. The sample sizes are small, and the data do not cover all age classes, for example, there are no 4 year old females. The length distribution of the 5 year old females is skewed towards the smaller sizes. However, removing the smallest female from the sample made no substantive difference to the results. The stress of tagging may have changed the growth rates of some of the fish, particularly the smaller or weaker ones, and the growth parameters derived from these data may not describe normal growth.

These fits were poor. The profile plots, which should be linear in the vicinity of the estimated parameters from the non-linear fit, were noticeably curved, partly because of the small data set. Simple variations of the growth equation were tried (Schnute 1981, Francis 1995) without any noticeable improvement in fit.

No attempt was made to fit growth curves to kahawai recovered from the Tasman Bay tagging as most of the fish belonged to two age classes so there were not enough data to fit a three parameter curve. These fish could be used to increase the sample size of young fish as they were generally smaller than 40 cm (Griggs *et al.* 1998) if the age back-calculated to the time of tagging was estimated. The growth of many these fish was retarded during the period after tagging (Griggs *et al.* 1998).

Combined North and Central regions age-length data

Knowing that there are likely to be incompatibilities between the data sets from the North and Central regions, I have nevertheless calculated growth parameters for combined data. First, I added the KAH 2 data (ECNI23) to the KAH 1 and KAH 9 data (KAH19) and then I added the KAH 3 data as well giving the data sets KAH192 and KAHall (*see* Table 3).

The values of k appear to be generally lower for kahawai caught in the North region than for those from the Central region. The paucity of 1 and 2 year old fish in the samples will bias the estimated values of k. It is uncertain whether the overall k (0.25 for all fish) is a reasonably unbiased estimate. A sex difference in the k values may be present, but given the other uncertainties a combined sex model appears to be adequate for simple stock reduction modelling. L_∞ is always about 55 cm.

Estimation of natural mortality, M

Jones *et al.* (1992) gave the kahawai natural mortality, M, as 0.18 based on one kahawai taken off the east coast of the North Island in the mid 1970s and aged at 26 years by Eggleston. M was estimated using the formula (Hoenig 1983):

$$M = -\ln(p)/A$$

where p is the proportion that reaches age A (or older in an unexploited stock); p is often set to 0.01, when A is the "maximum age" observed. Other values of p may be chosen according to the fishing history of the stock; for example, in an exploited stock the maximum observed age may correspond to a value of 0.05 or higher (Annala & Sullivan 1997).

The original estimate of M for kahawai was made using $p = 0.01$. As the kahawai was captured at a time when the stock was lightly exploited, this value may be reasonable. The value of M was revised to 0.2 by the Pelagic Working Group for the kahawai stock assessment in 1996 on the assumption that 0.2 better represented the accuracy with which the maximum age of kahawai is known.

Estimating the proportion of fish at a given age or older has all the problems of estimating total mortality from catch curve analysis, and other problems due to the necessarily small sample size of the oldest fish. Here, data on the numbers at age from the kahawai catch sampling between 1990 and 1993 are investigated to see if an improved estimate of M can be obtained using the Chapman-Robson estimator (Chapman & Robson 1960). This estimator is also essentially based on catch sampling theory, and will suffer from the same problems.

Data summary

Table 5 gives the numbers at age from catch samples taken in 1990–91 from west and east of D'Urville Island (Drummond & Wilson 1993) and labelled as WCSI02w and WCSI02e. The younger fish from east of D'Urville Island came from an untypical catch for the area (Drummond & Wilson 1993): one 71 cm, age 11, male kahawai was in the sample. Table 5 also gives the numbers at age from catch samples taken in 1992–93 from the west coast South Island (WCSI23), east coast South Island (ECSI23), and the east coast North Island (ECNI23) (Drummond 1995). The ages for the WCSI23 and ECSI23 samples have been verified (Stevens & Kalish 1998) and the numbers at age may differ slightly from those in Drummond (1995). At least some kahawai reach ages of 23 or 24 years. The full age length keys are given in Appendix 1.

Table 6 gives the numbers at age from the Auckland catch sampling in 1991–93. Data from catch sampling in the Bay of Plenty in 1992–93 have been omitted as they are not consistent with other data for older fish. The full age length keys are given in Appendix 1.

The age structure appears to be area dependent, with kahawai over 15 or 16 years being found only around the South Island in substantial numbers. Growth may also be area dependent (Drummond 1995) and the previous section of this report.

The presence of some fish with ages 21–24 is consistent with a natural mortality of about 0.2 calculated from the Hoenig (1983) equation.

Chapman-Robson estimator for natural mortality

The natural mortality, M, was estimated using the Chapman-Robson estimator (Chapman & Robson 1960) and follows Doonan (1994) who used this estimator for orange roughy. Doonan used data from randomised trawl surveys and was also able to estimate a variance for M.

For kahawai, most of the data come from sampling the purseseine catch. The purseseine fishery is highly selective in its catches and catch sampling does not give a random sample of lengths or ages from the population. Part of the selectivity is imposed by the fishing operation where, at least in some areas, particular size classes of kahawai are targeted. Another selectivity is imposed by the fish in that we have no way of knowing what causes the kahawai to come to the surface. We cannot think of the surface schools as a random sample of the population, nor can we assume that the schools on the surface at any time form a constant fraction of the population. The surface abundance can vary from 0% to 100% (or nearly so) of the population. In the large accumulations of kahawai observed off Kaikoura in the early 1980s and of jack mackerel in the Bay of Plenty in the mid 1970s, all (or nearly all) the fish in the area were on the surface. Doonan's method for estimating the variance does not carry over in a simple way to kahawai catch sampling data.

In the simple Chapman-Robson estimator ($\hat{M}$), the fish are assumed to be fully recruited and available to sampling after age T_c, and the age structure results from constant recruitment and a constant natural mortality. The estimator is:

$$\hat{M} = \log\left(\frac{1 + \bar{A} - T_c}{\bar{A} - T_c}\right)$$

where $\bar{A}$ is the mean age of the fish with ages greater than T_c.

A further source of error, which is likely for kahawai, could be introduced by migration of (part of) the population. The Australian members of the Arripidae migrate long distances around the Australian coastline (*see*, for example, Stanley 1978). Tagging studies have shown that at least some of the kahawai population moves throughout the whole geographical range of kahawai in New Zealand (Wood *et al.* 1990, Griggs *et al.* 1998).

I have applied the Chapman-Robson estimator to individual strata of the kahawai catch samples from the west coast North Island pair trawl bycatch fishery in the 1993–93 fishing year, the east coast North Island data collected in November 1992, and the east coast South Island data collected between November 1992 and January 1993. The data are restricted to cover the time periods when otoliths were collected to provide the age-length keys. Strata where the samples were very small or which consisted mainly of fish which were younger than the value of T_c for the area were ignored. Some landings were stratified either by size class or by the area where the fish were caught and the strata have been considered the basic sampling unit. The weighted mean values of M were obtained using the landed weights in the stratum as the weights in the estimation of the mean (Table 7). The proportions at age for the sampled landings used in this analysis are plotted in Figure 10.

Table 7 suggests that M lies between 0.19 and 0.23, but how reliable and representative are these figures?

Examination of Figure 10 shows that the apparent age of recruitment to the fishery varies from area to area. Different values of T_c were used in the calculations though these differences have to be considered artificial. Only the pair trawl bycatch kahawai fishery off the North Island west coast samples the kahawai population approximately randomly. Even in this fishery, there is a general drop off in the numbers of fish older than about 11 years. The purseseine fisheries seem to selectively catch particular size classes (and a few smaller fish). Strong and weak year classes are apparently present.

The Kaikoura data, and other samples taken between the Nelson area and Kaikoura, have led to the hypothesis that kahawai have, on average, a slow migration around the north of the South Island during their lifetime (Kim Drummond, MFish, Nelson, unpubl. result). The congregation of larger kahawai off Kaikoura and down the east coast of the South Island was noticed in the 1998–84 kahawai tagging study (Wood *et al.* 1990).

The length frequency distribution of the recreational catch measured at three boat ramp sites in Hawke's Bay from December 1992 to April 1993 suggests that the 1992 east coast North Island (KAH 2) purseseine catch was not representative of the kahawai in the area (figure 11 in Drummond 1995). The recreational length frequency includes more small fish, but also has a mode which is *higher* than that seen in the purseseine catch. Many recreational fishers selectively target larger kahawai. The Central region purseseine fishery claims not to target particular size classes, but it does seem that 6–9 year old kahawai were predominant in the surface schools in November 1992. One hypothesis is that (some of) these schools were migrating through the area at that time and thus changing the representation of age classes in the area at the time.

The west coast North Island data form the best sample in a statistical sense and the value of $M = 0.19$ is likely to be the most reliable of the values given in Table 7, but M may be biased by variable year class strengths.

The kahawai off Kaikoura are probably older and could be expected to give information about the parts of the population that have been fished over the longest time. Apparent stronger year classes at ages 16 and 18 may arise from bias in the age-length key.

The value of $M = 0.23$ from the east coast of the North Island is unlikely to be reliable as the sample comes from schools of kahawai which appear not to be representative of the kahawai in that area over the 1992–93 summer.

This analysis has confirmed that M is about 0.2. It does not seem possible to disentangle the effects of all possible biases. The existence of fish older than 20 years suggests that M is unlikely to be much larger than 0.2.

One hypothesis consistent with the data is that some kahawai schools move considerable distances around the New Zealand coastline. If this is so, the whole population may belong to one stock, but the kahawai movement patterns are needed to adequately describe the stock. Results from the tagging studies (Wood *et al.* 1990, Griggs *et al.* 1998) suggest that at least some of the kahawai stock moves through the whole New Zealand kahawai habitat. The small numbers of fish involved and various other confounding factors mean that we can not make a reliable estimate of the probability of movement from the tagging studies. Tags damage kahawai causing a fever reaction and tagged fish probably behave as sick fish rather than normal fish (Griggs *et al.* 1998).

Discussion

This report estimates the growth parameters for a New Zealand kahawai stock. There do seem to be regional differences, but possibly not significant differences by sex. However, nearly all the data used came from kahawai caught in the purseseine fishery and this fishery almost certainly takes a biased sample of the population. No attempt to remove this bias has been made. It is thus very unlikely that any of the growth parameters have been accurately determined.

One substantive problem comes from the lack of data in parts of the length range under 40 cm. Kahawai start to mature when they reach about 40 cm (McKenzie & Trusewich, unpubl. data) and they also increase their habitat range and may move to deeper water (Drummond 1994, Jones 1995) when they reach about this size. There are indications in the data that the growth parameters change when kahawai reach maturity.

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Table 1: Examples of coefficients, a and b, and R^2 obtained in the kahawai weight-length relation: $W = aL^b$ (weight W is in grams and fork length L is in centimetres) n, L_{min}, L_{max}, and L_{med} are the number of points, the minimum, maximum, and median lengths in each data set. DW93, Drummond & Wilson (1993); D94, Drummond (1994); and MT97, McKenzie & Trusewich (unpubl. data) refer to the data source. The code names for the data sets given in brackets are defined in Table 2

Data description	a	b	n	R^2	L_{min}	L_{med}	L_{max}	Ref
KAH 3								
Purseseine 91/92 (SI PS)	0.0400	2.76	571	0.967	26	49	60	DW93
Purseseine summer	0.0235	2.91	388	0.982	26	46	60	DW93
Purseseine winter	0.9386	1.94	183	0.704	41	51	58	DW93
Purseseine Tasman Bay	0.0180	2.98	126	0.985	26	38	50	DW93
Set net, Waimea Estuary	0.0195	2.94	488	0.919	18	27	45	D94
Purseseine, Dec Feb	0.0138	3.06	286	0.986	26	40	58	D94
SI purseseine, set net (SI sum)	0.0103	3.14	774	0.984	18	28	58	D94
KAH 1								
KAH 1 resting (NI)	0.0818	2.56	937	0.921	36	50	60	MT97
KAH 1 mature (NI mature)	0.7442	2.02	319	0.848	41	49	59	MT97
Combined								
Purseseine & set net (All 1)	0.0249	2.87	1 932	0.988	18	47	60	
All purseseine (All 2)	0.0607	2.64	1 444	0.959	26	50	60	

Table 2: Definitions of the code names given to the data sets and where the data are plotted

Code	Data set
SI PS	KAH 3 purseseine catches between April 1991 and February 1992 from Drummond & Wilson (1993) (Figure 2)
SI sum	KAH 3 data from Drummond (1994) collected during summer months (Figure 3)
NI	KAH 1 data from immature and resting fish from McKenzie & Trusewich (unpubl. data) (Figure 4)
All 2	Combined data from data sets SI sum (minus data for kahawai with gonad weight > 50 g) & NI (Figure 5)
All 1	Combined data from SI PS (minus data for kahawai with gonad weight > 50 g) & NI (Figure 6)
NI mature	KAH 1 data for mature kahawai from McKenzie & Trusewich (unpubl.) (Figure 7)

Table 3: Von Bertalanffy parameters (with 95% confidence intervals) for kahawai using various data combinations. The data sets used are identified by the codes given in Table A1. These are new estimations of parameters

Data	*n*	L_∞	*k*	t_0
West coast South Island – WCSI23, ages 3–19 (preliminary values by Drummond 1995)				
Female	285	55.1 (54.5 – 55.7)	0.39 (0.35 – 0.43)	0.4 (0.2 – 0.7)
Male	288	54.0 (53.4 – 54.6)	0.47 (0.42 – 0.52)	0.8 (0.6 – 1.0)
All	573	54.6 (54.2 – 55.0)	0.43 (0.40 – 0.46)	0.6 (0.4 – 0.8)
East coast South Island – ECSI23, ages 5–23 (preliminary values by Drummond 1995)				
Female	230	59.7 (56.3 – 63.1)	0.10 (0.05 – 0.15)	-10 (-16 – -4)
Male	197	59.9 (53.9 – 65.9)	0.08 (0.02 – 0.14)	-13 (-23 – -3)
All	427	60.3 (56.7 – 63.9)	0.09 (0.05 – 0.13)	-12 (-18 – -6)
West coast South Island combined – WCSI02w, WCSI02e, WCSI23, ages 3–24				
Female	644	55.5 (54.9 – 56.1)	0.28 (0.25 – 0.31)	-0.6 (-1.0 – -0.2)
Male	645	53.4 (52.9 – 53.9)	0.34 (0.31 – 0.37)	-0.05 (-0.3 – 0.4)
All	1 289	54.5 (54.1 – 54.9)	0.30 (0.28 – 0.32)	-0.3 (-0.9 – -0.3)
KAH 2, KAH 3 – KAH23 (ECNI23, WCSI02w, WCSI02e, WCSI23, ECSI23), ages 3–24				
Female	1 203	55.8 (55.4 – 56.2)	0.26 (0.24 – 0.28)	-0.6 (-0.9 – -0.3)
Male	1 147	53.9 (53.5 – 54.3)	0.30 (0.28 – 0.32)	-0.25 (-0.5 – 0.0)
All	2 350	55.0 (54.7 – 55.3)	0.27 (0.26 – 0.28)	-0.5 (-0.7 – -0.3)
KAH 1, KAH 9 – KAH19 (BOP01, BOP12, WCNI01, WCNI23), ages 2–21				
Female	779	57.0 (56.1 – 57.9)	0.22 (0.20 – 0.24)	-0.8 (-1.2 – -0.4)
Male	750	54.9 (54.0 – 55.8)	0.24 (0.22 – 0.26)	-0.9 (-1.3 – -0.5)
All	1 529	56.1 (55.5 – 56.7)	0.23 (0.21 – 0.25)	-0.9 (-1.2 – -0.6)
KAH 1, KAH 9, KAH 2 – KAH192 (KAH19, ECNI23), ages 2–24				
Female	1 108	56.2 (55.6 – 56.8)	0.24 (0.22 – 0.26)	-0.5 (-0.8 – -0.2)
Male	1 055	54.3 (53.7 – 54.9)	0.26 (0.24 – 0.28)	-0.5 (-0.8 – -0.2)
All	2 163	55.4 (54.9 – 55.9)	0.25 (0.23 – 0.27)	-0.5 (-0.7 – -0.3)
KAH 1, KAH 9, KAH 2, KAH 3– KAHall (KAH19, KAH23), ages 2–24				
Female	1 982	56.1 (55.8 – 56.6)	0.25 (0.23 – 0.27)	-0.7 (-0.9 – -0.5)
Male	1 897	54.3 (53.0 – 54.6)	0.27 (0.25 – 0.29)	-0.5 (-0.7 – -0.3)
All	3 879	55.3 (55.0 – 55.6)	0.25 (0.24 – 0.26)	-0.6 (-0.8 – -0.4)

Table 4: Von Bertalanffy parameters (with 95% confidence intervals) for kahawai from the literature and other reports in the process of publication. The data sets (identified by codes from Table A1) are those used by the authors

Data	n	L_∞	k	t_0
East coast North Island – ECNI23, ages 3–21 (Drummond 1995)				
Female	329	54.2 (53.6 – 54.9)	0.33 (0.29 – 0.37)	0.6 (0.3 – 0.9)
Male	305	52.6 (51.8 – 53.3)	0.36 (0.32 – 0.40)	0.6 (0.2 – 1.0)
All	634	53.5 (53.0 – 54.0)	0.34 (0.31 – 0.37)	0.6 (0.3 – 0.9)
East of D'Urville Island – WCSI02e, ages 3–24 (Drummond & Wilson 1993)				
Female	283	55.3 (54.5 – 56.1)	0.30 (0.25 – 0.35)	0.9 (0.1 – 1.7)
Male	278	53.0 (52.3 – 53.7)	0.37 (0.30 – 0.44)	1.3 (0.6 – 2.0)
All	561	54.2 (53.7 – 54.7)	0.33 (0.29 – 0.37)	1.0 (0.4 – 1.6)
West of D'Urville Island – WCSI23w, ages 3–15 (Drummond & Wilson 1993)				
Female	76	54.2 (51.7 – 57.7)	0.39 (0.23 – 0.55)	1.0 (0.0 – 2.0)
Male	79	53.3 (50.1 – 56.5)	0.36 (0.22 – 0.50)	0.6 (-0.5 – 1.7)
All	155	53.7 (51.4 – 56.0)	0.38 (0.27 – 0.49)	0.8 (0.1 – 1.5)
Bay of Plenty age validation data, ages 4–14 (Stevens, in press)				
Female	65	54 (51 – 56)	0.44 (0.24 – 0.64)	1.7 (0.5 – 2.9)
Male	72	53 (50 – 56)	0.31 (0.16 – 0.46)	0.0 (-1.0 – 1.0)
All	137	54 (52 – 56)	0.32 (0.22 – 0.42)	0.4 (-0.8 – 1.6)
KAH 1 1990–91 – BOP01, ages 4–12 (McKenzie & Trusewich, unpubl. data)				
All		57.0 (43.1 – 70.8)	0.11 (-0.04 – 0.26)	-8.1 (-18.5 – 2.2)
KAH 9 1990–91 – WCNI01, ages 5–14 (McKenzie & Trusewich, unpubl. data)				
All		55.4 (50.1 – 60.7)	0.16 (0.04 – 0.27)	-4.6 (-9.7 – 0.5)
KAH 9 1992–93 – WCNI23, ages 5–14 (McKenzie & Trusewich, unpubl. data)				
All		53.7 (51.0 – 56.3)	0.21 (0.09 – 0.32)	-3.7 (-7.6 – 0.2)
KAH 1, BOP01, KAH 9, WCNI01, WCNI23, ages 3–15 (McKenzie & Trusewich, unpubl. data)				
All		55.8 (52.3 – 59.4)	0.14 (0.08 – 0.20)	-6.2 (-9.6 – -2.8)

Table 5: Kahawai: numbers at age. Data are from Drummond & Wilson (1993) from catch sampling in 1990–92 and from Drummond (1995). ECSI23 and WCSI23 ages have been verified (Stevens, in press). Data set codes are defined in Table A1

	WCSI02w			WCSI02e			WCSI23			ECSI23			ECNI23		
Age	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F
3	4	2	2				179	88	91				9	4	5
4	36	17	19	7	4	3	24	17	7				175	92	83
5	29	15	14	24	6	18	37	21	16	8	5	3	66	32	34
6	34	15	19	33	21	12	66	36	30	28	12	16	68	30	38
7	18	12	6	32	17	15	39	12	27	18	7	11	54	23	31
8	12	6	6	36	16	20	25	14	11	18	5	13	53	30	23
9	8	5	3	35	17	18	16	11	5	14	9	5	40	20	20
10	5	1	4	53	29	24	25	13	12	14	5	9	16	8	8
11	1	1		54	27	27	42	23	19	51	28	23	30	11	19
12	4	2	2	57	32	25	24	12	12	26	13	13	28	14	14
13	2	2		51	27	24	28	13	15	40	21	19	23	12	11
14	1	1		34	18	16	32	18	14	37	16	21	27	10	17
15	1		1	47	20	27	19	5	14	39	19	20	16	8	8
16				31	15	16	4	1	3	44	20	24	12	4	8
17				27	16	11	5	2	3	23	11	12	7	4	3
18				16	9	7	6	2	4	37	17	20	4	2	2
19				14	2	12	2		2	14	4	10	5	1	4
20				5	1	4				5	2	3			
21				1		1				6	1	5	1		1
22				1		1				3	1	2			
23				1		1				2	1	1			
24				2	1	1									

Table 6: Kahawai: numbers at age. Data are from McKenzie & Trusewich (unpubl. data). Data set codes are defined in Table A1

	BOP01			BOP12			WCNI01			WCNI23		
Age	Total	M	F	Total	M	F	Total	M	F	Total	M	F
2	1	1		1	1		2	1	1	2	1	1
3	4	4		44	27	17	17	3	14	34	14	20
4	9	6	3	131	61	70	22	8	14	132	68	64
5	13	6	7	107	57	50	11	9	2	92	37	55
6	14	7	7	55	35	20	27	15	12	49	22	27
7	8	5	3	44	23	21	11	7	4	37	21	16
8	12	6	6	22	7	15	11	4	7	45	20	25
9	13	8	5	22	8	14	18	9	9	26	15	11
10	6	3	3	28	11	17	20	7	13	40	22	18
11	14	8	6	32	17	15	16	9	7	28	11	17
12	9	2	7	27	16	11	17	12	5	26	13	13
13	8	3	5	19	11	8	8	5	3	26	16	10
14	5	1	4	19	10	9	6	2	4	21	8	13
15	4	3	1	18	6	12	7	4	3	19	5	14
16	4	1	3	5	4	1	5	3	2	9	5	4
17	1		1	4	3	1	4	2	2	11	3	8
18				7	1	6	1	1		9	3	6
19	1		1	1	1					2	1	1
20				1		1				3	1	1
21				1		1				1		1

Table 7: Mortality estimates from three areas obtained as weighted averages of M estimated from catch samples from individual strata. T_c is the age at which the fish are assumed to be fully recruited

Region	Fishery	Time of sampling	Number of strata	T_c	M
West coast North Island	Pair trawl	Feb-Mar 93	22	4	0.19
East coast North Island	Purseseine	Nov 92	6	6	0.23
Kaikoura	Purseseine	Nov 92–Jan 93	11	11	0.21

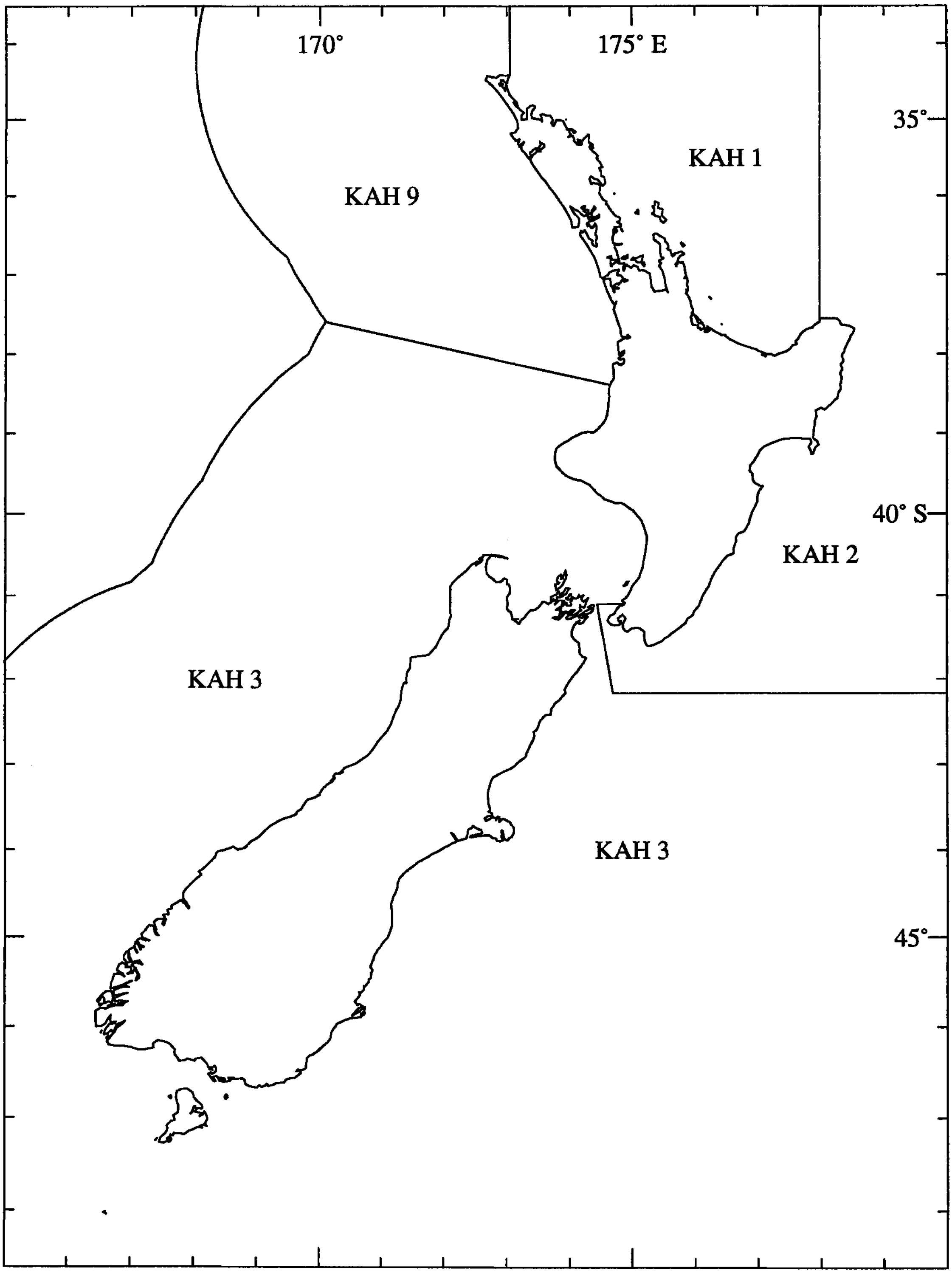
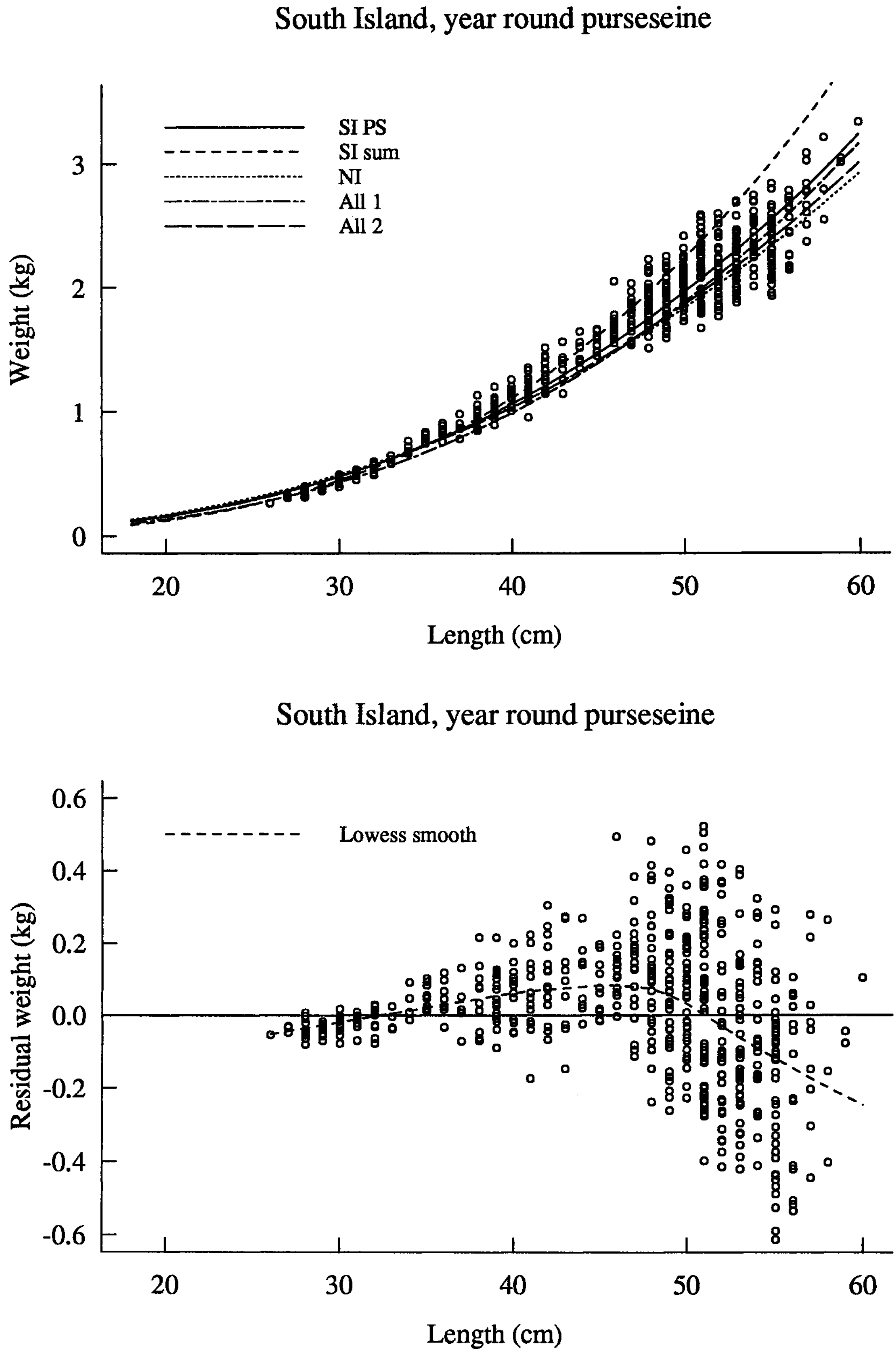
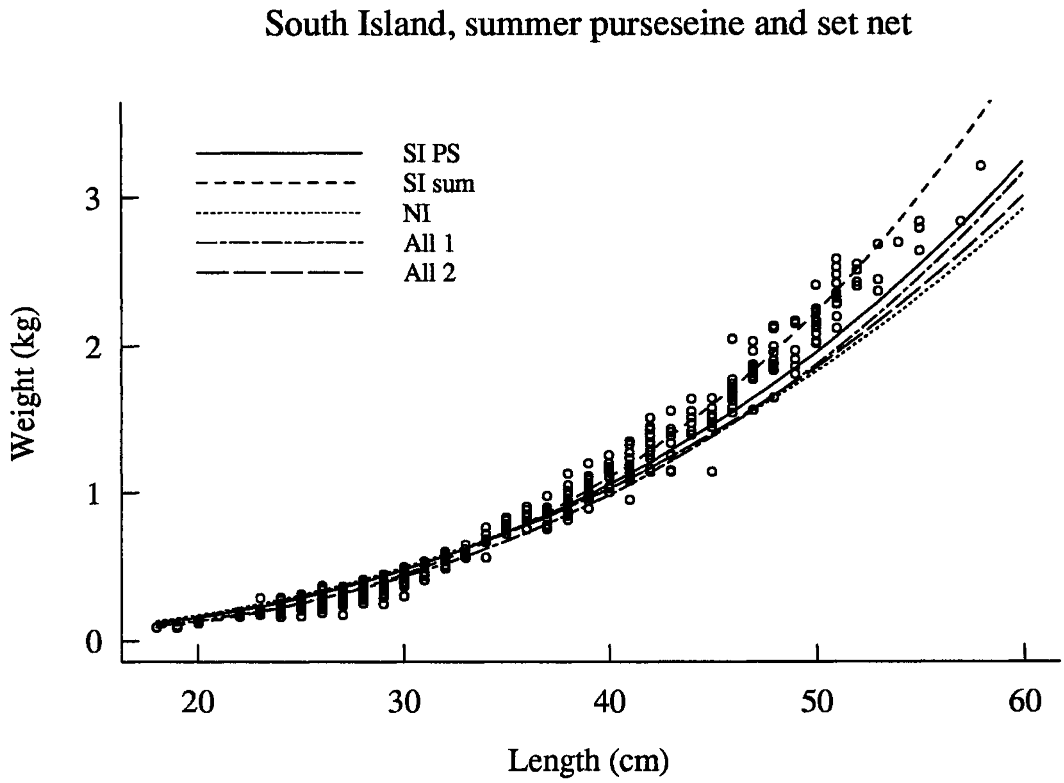


Figure 1: Map of New Zealand showing the kahawai Fishstocks referred to in this report.


South Island, year round purseseine

South Island, year round purseseine

Figure 2: Kahawai length weight data taken from purseseine catches between April 1991 and February 1992 in KAH 3 (line labelled SI PS). The other abbreviations used in the legend are defined in Table 2.


South Island, summer purseseine and set net

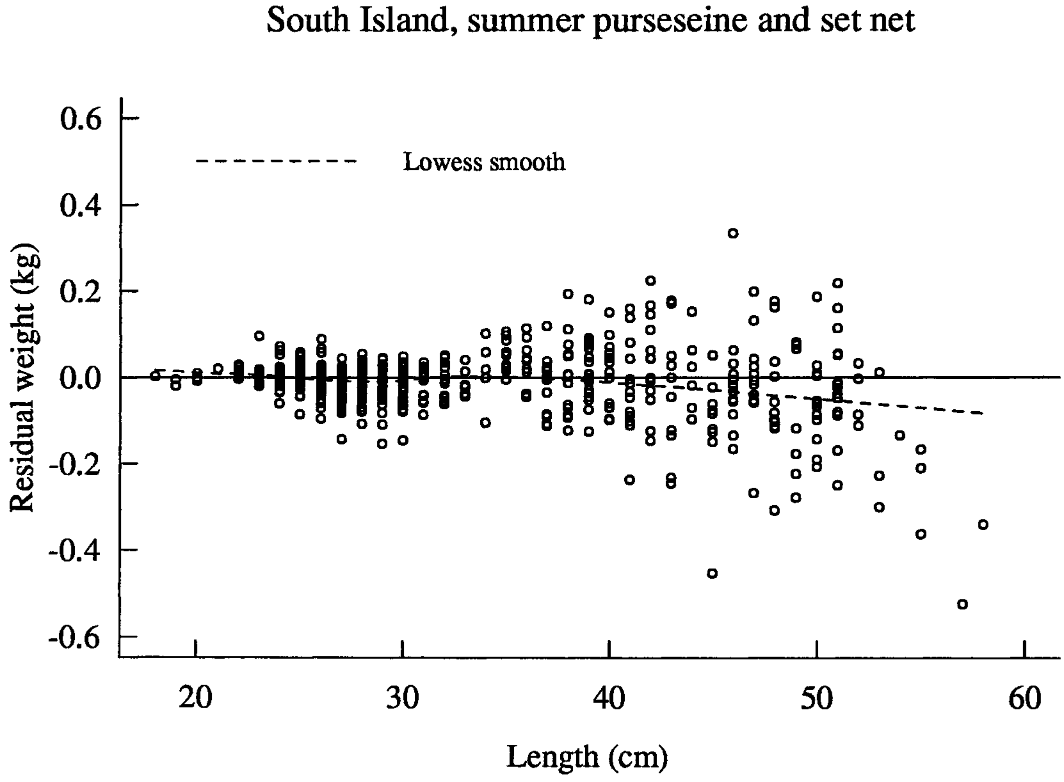

South Island, summer purseseine and set net

Figure 3: **Kahawai length weight data taken from purseseine catches in December 1991 and February 1992 in KAH 3 and from set net catches between April 1991 and February 1992 (line labelled SI sum). The other abbreviations used in the legend are defined in Table 2.**

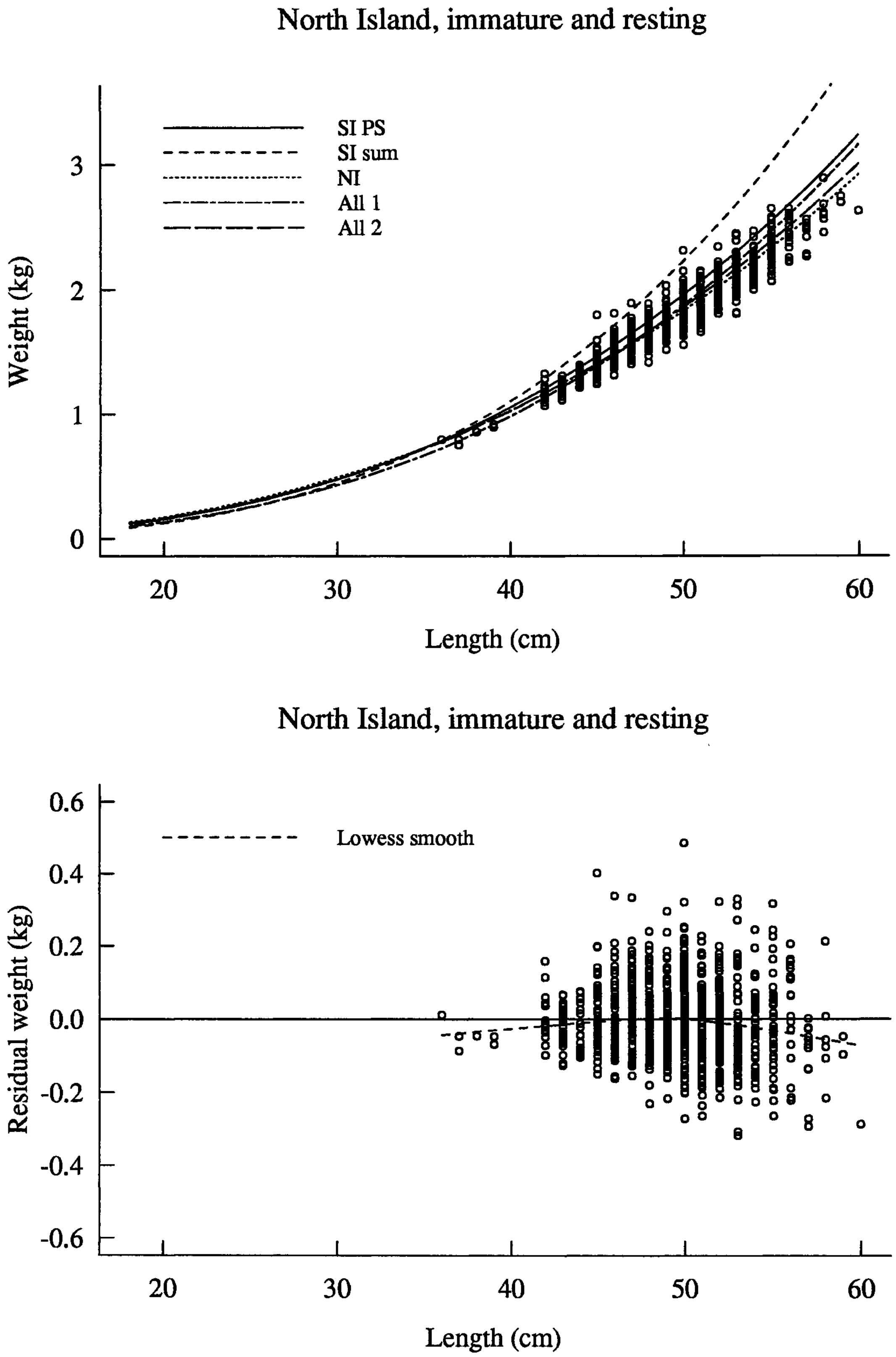


Figure 4: **Kahawai length weight data taken from purseseine catches in 1991 and 1992 in KAH 1 (line labelled NI). The other abbreviations used in the legend are defined in Table 2.**

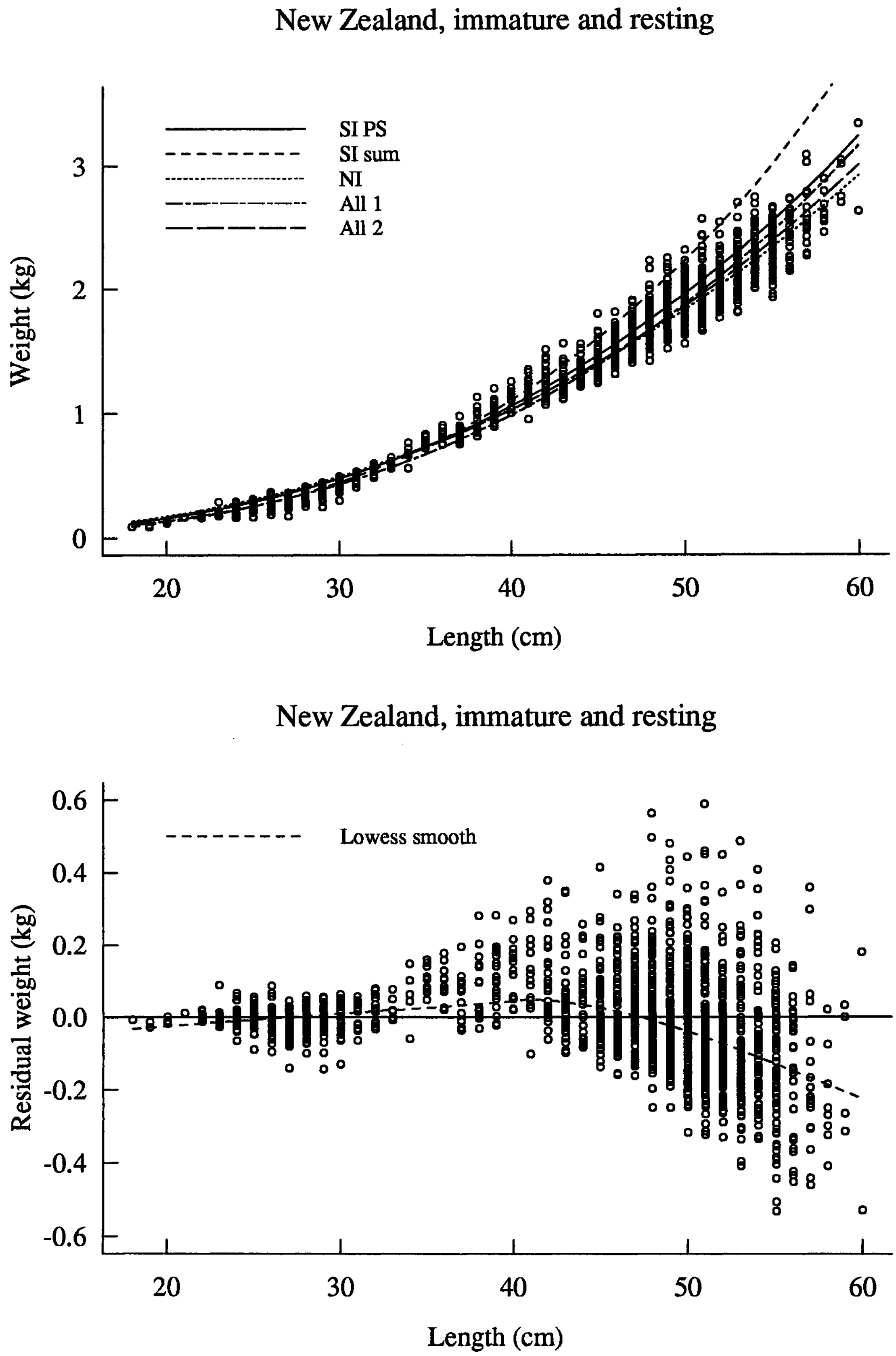
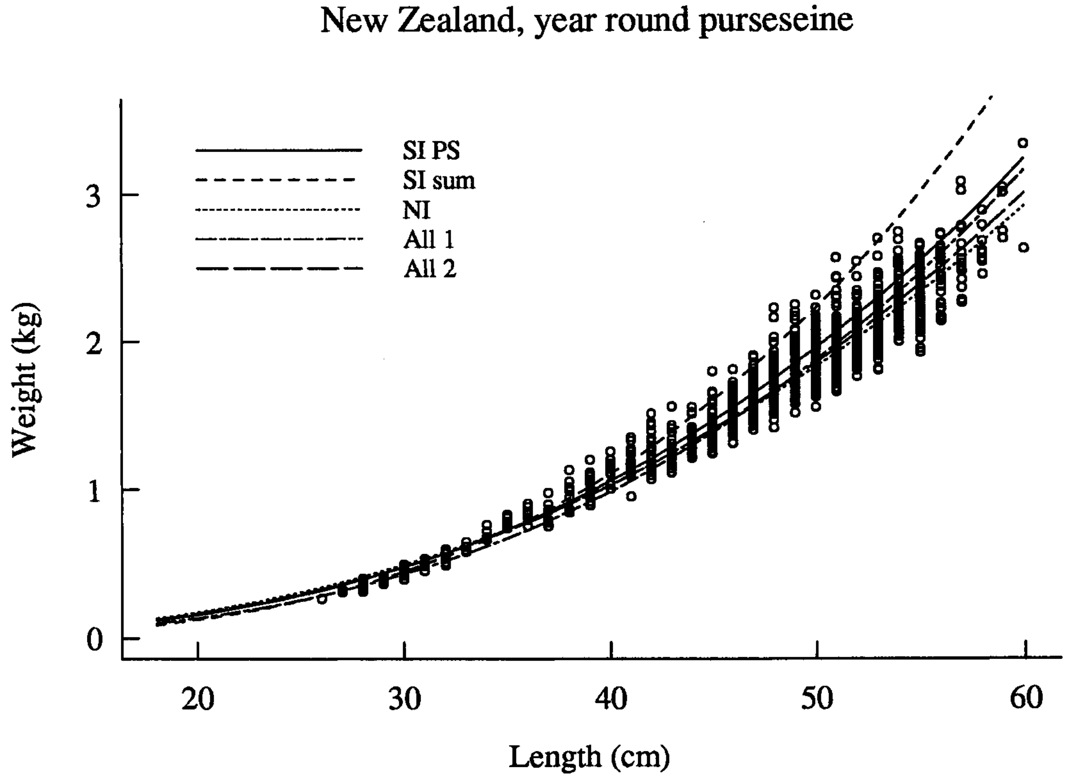


Figure 5: Kahawai length weight data taken from purseseine and set net catches in KAH 3 and purseseine catches in KAH 1 (line labelled All 1). KAH 3 data are from fish with gonad weight 50 g or less and KAH 1 data are from resting or immature fish. The other abbreviations used in the legend are defined in Table 2.



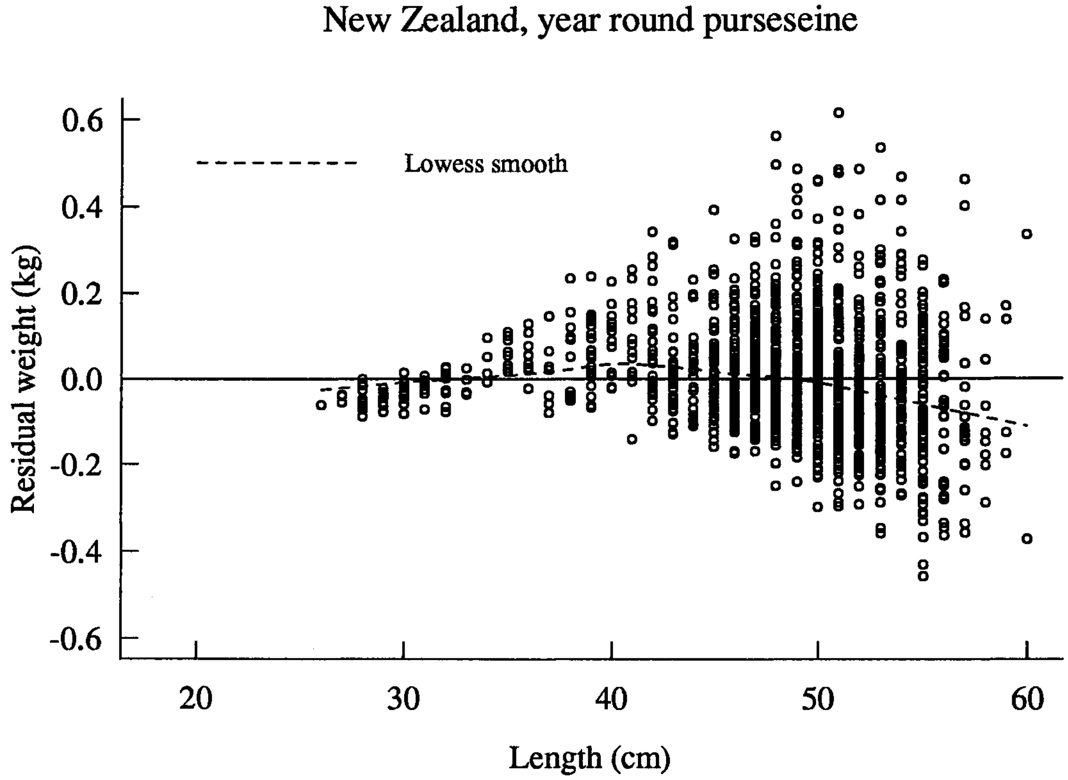


Figure 6: Kahawai length weight data taken from purseseine catches in KAH 3 and KAH 1 (line labelled All 2). KAH 3 data are from fish with gonad weight 50 g or less and KAH 1 data are from resting or immature fish. The other abbreviations used in the legend are defined in Table 2.

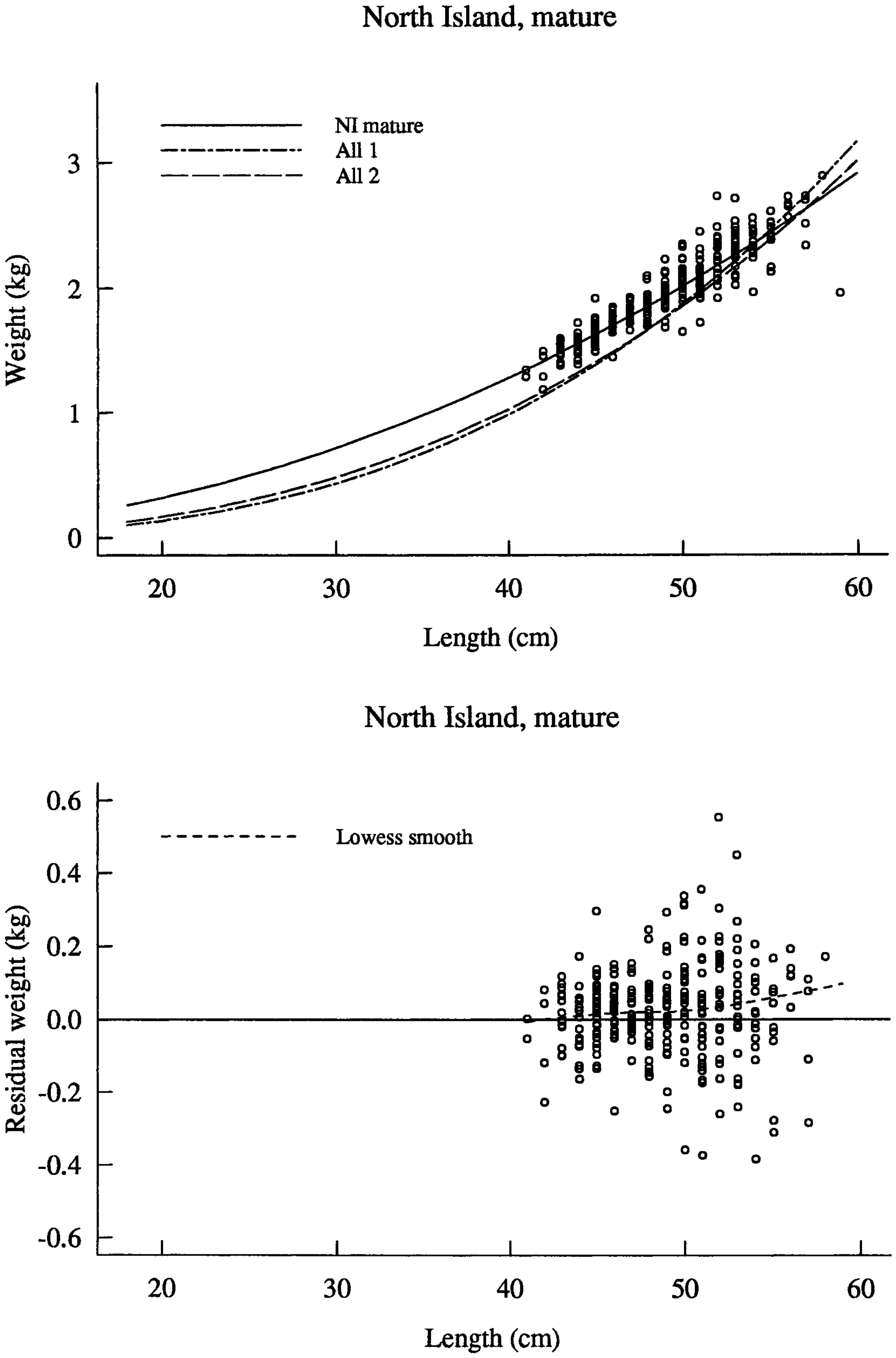


Figure 7: Kahawai length weight data taken from purseseine catches in KAH 1 in 1991 and 1992 (line labelled NI mature). All the fish were mature. The other abbreviations used in the legend and define in Table 1.

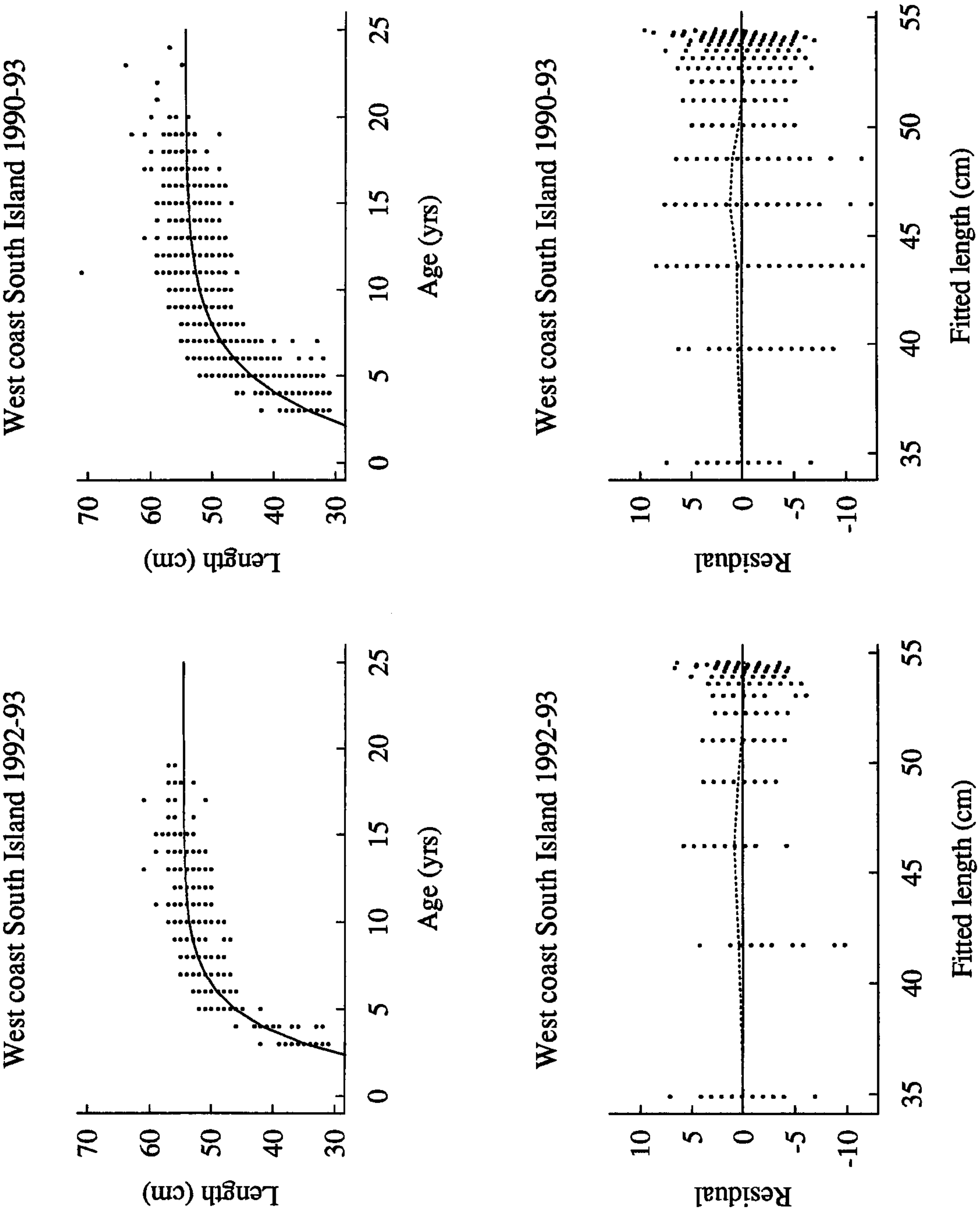


Figure 8: Kahawai age length data from the west coast of the South Island. The upper plots show the data and the fitted von Bertalanffy curve. The lower plots show the residual lengths about the fitted mean lengths at age. Some outlying residuals are not shown. The dotted line on the lower plots is a lowess fit to the data.

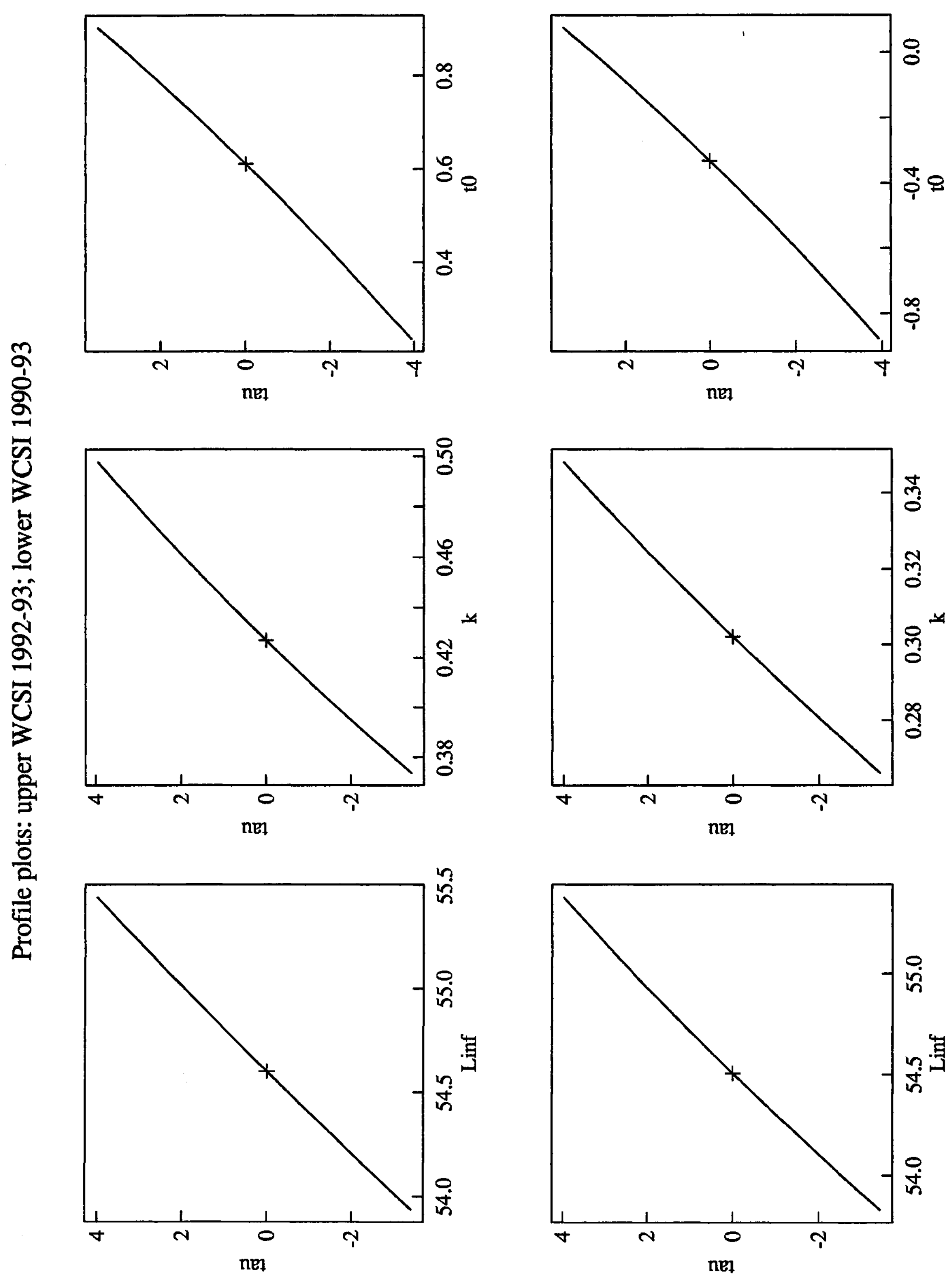
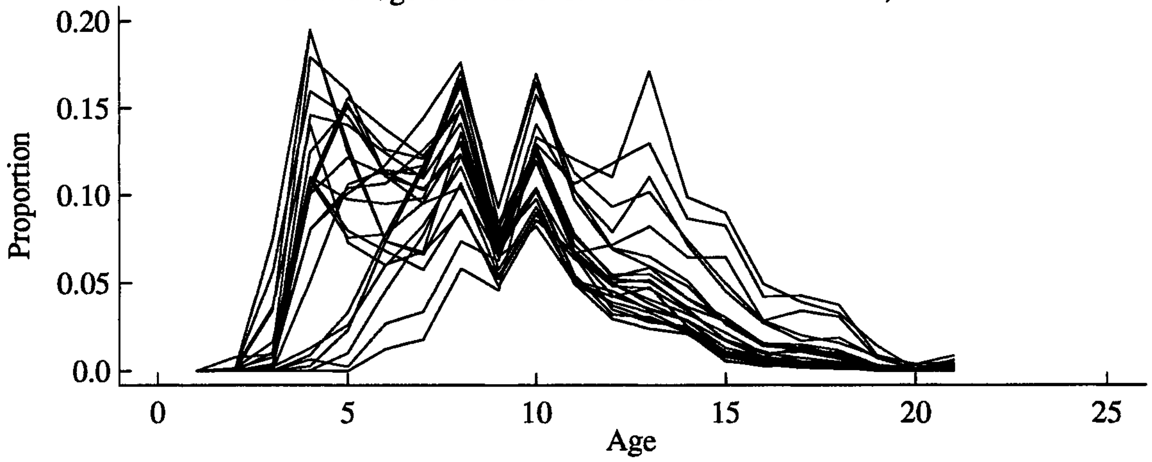
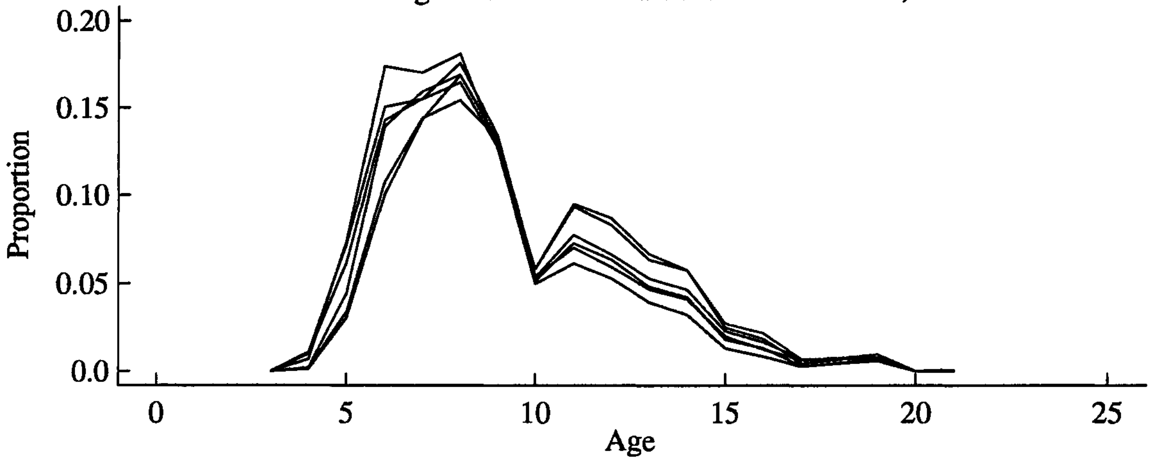


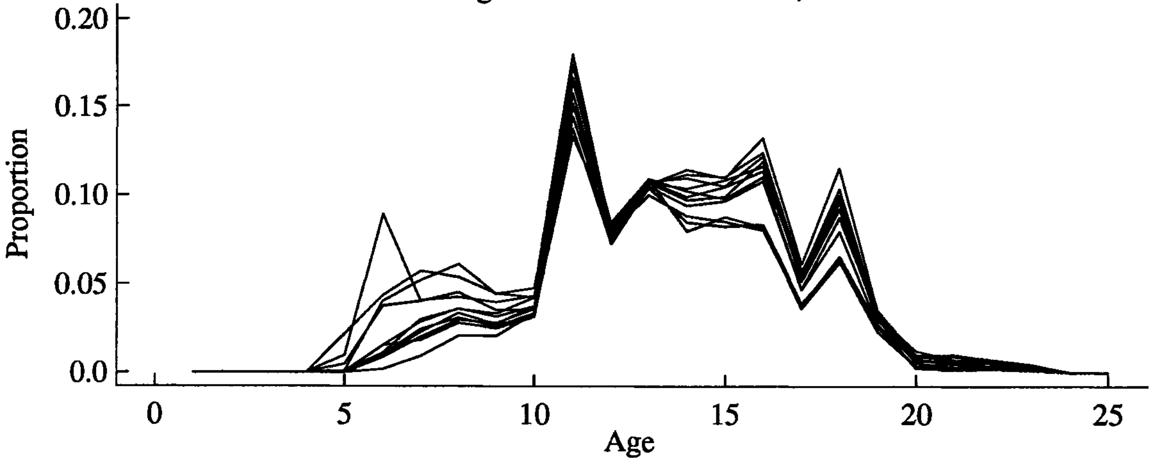
Figure 9: Kahawai age-length data from the west coast of the South Island. Profile plots showing the linearity of the fitted parameters. Tau is the statistic used to define curvature, L_∞ is called Linf on the plots.



Kahawai age distributions: West coast North Island, 1992-93



Kahawai age distributions: East coast North Island, 1992



Kahawai age distributions: Kaikoura, 1992-93

Figure 10: Proportions at age in the kahawai catch sampling landings used in M estimation.

Appendix 1: Kahawai age length keys

The data sets used are described below (Table A1) and given a label which is used in the text to describe the data set.

Table A1: Description of the age length data sets tabulated below and the code used to refer to them in the text. Codes for combined data sets are included

Code	Tables	Where and when collected
WCSI02w	A2–A4	west of D'Urville Island, Golden Bay, Farewell Spit, Tasman Bay. October 1990–February 1992
WCSI02e	A5–A7	east of D'Urville Island, Marlborough Sounds, Cloudy/Clifford Bay, Kaikoura. October 1990–May 1992
WCSI23	A8–A10	north west coast South Island. December 1992
GBAY23	A11	Golden Bay. December 1992
ECSI23	A12–A14	east coast South Island. October 1992–January 1993
ECNI23	A15–A17	east coast North Island. November 1992
WCNI01	A18–A20	west coast North Island. February–March 1991
WCNI23	A21–A23	west coast North Island. February–March 1993
BOP01	A24–A26	Bay of Plenty. May–July 1991
BOP12	A27–A29	Bay of Plenty. January–June 1992
BOP23	A30–A32	Bay of Plenty. October–December 1992
KAH23		ECNI23, WCSI02w, WCSI02e, WCSI23, ECSI23
KAH19		BOP01, BOP12, WCNI01, WCNI23
KAH192		KAH19, ECNI23
KAHall		KAH19, KAH23

The data in Tables A2–A17 are taken from Drummond & Wilson (1993) and Drummond (1995), except that recently verified ages are sometimes used. Thus, Tables A2–A17 contain the data obtained in the Central region catch sampling programme in 1990–93. Catch sampling was of the purseseine catch in KAH 2 (east coast North Island) and various parts of KAH 3 (east coast South Island, and samples from catches taken in and around Tasman and Golden Bays).

The data in Tables A18–A32 were supplied by Jeremy McKenzie (NIWA, Auckland) and contain data that were collected in the North region catch sampling programme in 1990–93. Catch sampling was of the purseseine catch in the Bay of Plenty and of the kahawai bycatch of the pair trawl fishery on the west coast of the North Island.

Table A10: Kahawai age-length data from northwest coast South Island (both sexes). The lengths and otoliths were collected in December 1992

	Age																	
Length	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
62																		
61											1				1			2
60																		
59									1			2	1					4
58													2					2
57								1	2		2	1	4	2	1	3	1	17
56							1	1	2	3	6	9	3	1	2	1	1	30
55					1	3	2	3	7	1	4	11	7			1		40
54					2	2	2	3	12	7	3	4	1					36
53				2	1	1	3	5	7	8	4	3	1	1		1		37
52			2	5	7	3	4	3	8	2	5	1						40
51			2	11	8	5	2	5	2	2	1	1			1			40
50			6	14	9	4		2	1	1	2							39
49			5	13	5	3		1										27
48			7	11	4	4	1	1										28
47			9	9	2		1											21
46		3	4	1														8
45			1															1
44																		
43		4																4
42	1	5	1															7
41		2																2
40		1																1
39	2	1																3
38	13																	13
37	27	4																31
36	28	1																29
35	29																	29
34	31																	31
33	28	1																29
32	17	2																19
31	2																	2
30																		
29																		
28	1																	1
27																		
26																		
25																		
24																		
23																		
Total	179	24	37	66	39	25	16	25	42	24	28	32	19	4	5	6	2	573

Table A11: Kahawai age-length data from Golden Bay. The lengths and otoliths were collected in December 1992

Males

	Age		
Length	3	4	Total
42	1	1	2
41		1	1
40		1	1
39	1		1
38	2		2
37	10	2	12
36	2		2
35	15		15
34	15		15
33	14	1	15
32	5		5
31	1		1
Total	66	6	72

Females

	Age		
Length	3	4	Total
42			
41			
40			
39	1	1	2
38	8		8
37	11	1	12
36	5		5
35	14		14
34	16		16
33	14		14
32	2		2
31			
Total	71	2	73

Both sexes

	Age		
Length	3	4	Total
42	1	1	2
41		1	1
40		1	1
39	2	1	3
38	10		10
37	21	3	24
36	7		7
35	29		29
34	31		31
33	28	1	29
32	7		7
31	1		1
Total	137	8	145

Table A12: Kahawai age-length data from east coast South Island (males). The lengths and otoliths were collected in October 1992 to January 1993

	Age																			
Length	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
62																				
61																1				1
60														2						2
59																				
58											4		1	2	1	1	1			10
57									1	2		1	2	1				1		8
56						1		1	1	2	2	3	1	2	1				1	15
55								2	1	1	1	9	3	3						20
54						1	3	3	4	1	3	1		3	1					20
53					1		4	3	2	6	2	2		1						21
52				1	1	2	3	2	5		2	2	2	3	1					24
51			1	1	2		8		2	1	3	2								20
50			2	1	1		6	1	3				1							15
49		2		1	2	1	3	1	2	1	1									14
48		6	4	1	2					1	1		1							16
47		2					1			1										4
46		2																		2
45	2																			2
44	3																			3
43																				
42																				
41																				
40																				
39																				
38																				
37																				
36																				
35																				
34																				
33																				
32																				
31																				
30																				
29																				
28																				
27																				
26																				
25																				
24																				
23																				
Total	5	12	7	5	9	5	28	13	21	16	19	20	11	17	4	2	1	1	1	197

Table A13: Kahawai age-length data from east coast South Island (females). The lengths and otoliths were collected in October 1992 to January 1993

	Age																			
Length	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
62																	1			1
61																				
60												1	1		1					3
59									1		2	5	1	2	1		1	1	1	15
58									1	2	1	1	3	4	1	1	2			16
57									2	1	3	3	2	2		1	1			15
56							1	1	3	6	3	4		2	2					22
55							2	1	3	3	3	3	1	4	1	1		1		23
54				1			4	2	1	3	3	1	2	4						21
53					1	1	5	1	2	2	2	4	2	2	1					23
52				2	1	4	6	4	1	2	2				2					24
51		1	1	2			2	2	2	2	1	2								15
50			5	1	2	3	2	1	1											15
49		3	4	7					1											15
48		5	1		1	1	1	1	1											11
47		5													1					6
46	1	2																		3
45	1																			1
44	1																			1
43																				
42																				
41																				
40																				
39																				
38																				
37																				
36																				
35																				
34																				
33																				
32																				
31																				
30																				
29																				
28																				
27																				
26																				
25																				
24																				
23																				
Total	3	16	11	13	5	9	23	13	19	21	20	24	12	20	10	3	5	2	1	230

Table A14: Kahawai age-length data from east coast South Island (both sexes). The lengths and otoliths were collected in October 1992 to January 1993

	Age																		
Length	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
62																	1			1
61																1				1
60												1	1	2	1					5
59									1		2	5	1	2	1		1	1	1	15
58									1	2	5	1	4	6	2	2	3			26
57									3	3	3	4	4	3		1	1	1		23
56						1	1	2	4	8	5	7	1	4	3				1	37
55							2	3	4	4	4	12	4	7	1	1		1		43
54				1		1	7	5	5	4	6	2	2	7	1					41
53					2	1	9	4	4	8	4	6	2	3	1					44
52				3	2	6	9	6	6	2	4	2	2	3	3					48
51		1	2	3	2		10	2	4	3	4	4								35
50			7	2	3	3	8	2	4				1							30
49		5	4	8	2	1	3	1	3	1	1									29
48		11	5	1	3	1	1	1	1	1	1		1							27
47		7					1			1					1					10
46	1	4																		5
45	3																			3
44	4																			4
43																				
42																				
41																				
40																				
39																				
38																				
37																				
36																				
35																				
34																				
33																				
32																				
31																				
30																				
29																				
28																				
27																				
26																				
25																				
24																				
23																				
Total	8	28	18	18	14	14	51	26	40	37	39	44	23	37	14	5	6	3	2	427

Table A15: Kahawai age-length data from east coast North Island (males). The lengths and otoliths were collected in November 1992

	Age																		
Length	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																				
61																				
60																				
59																				
58																				
57													1							1
56									1						1					2
55										1		2	1	1						5
54						1			1	1	1		3	1	2					10
53					1			1	3	2	3	2		1	1	1				15
52						2	1		1	3	3	2	2	1						15
51					1			1	1	3	3	3	1				1			14
50					1	3	5	4	2	3	1	1								20
49				1	2	8	3	1	2	1	1					1				20
48				5	4	7	3	1												20
47			2	5	4	3	6													20
46			1	6	7	5	1													20
45		1	6	6	1	1														15
44		1	6	5	2		1													15
43		1	5	1																7
42		2	6	1																9
41		1	1																	2
40		1																		1
39		6	1																	7
38		12	3																	15
37		15																		15
36		14	1																	15
35		15																		15
34		15																		15
33	3	8																		11
32	1																			1
31																				
30																				
29																				
28																				
27																				
26																				
25																				
24																				
23																				
Total	4	92	32	30	23	30	20	8	11	14	12	10	8	4	4	2	1			305

Table A16: Kahawai age-length data from east coast North Island (females). The lengths and otoliths were collected in November 1992

																	Age		
Length	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																				
61																				
60																				
59																				
58																				
57											1	1			1	1				4
56											2	1	2		1	1	1			8
55									2	1	1	4	3	3	1				1	16
54									2	3	1	6		1			2			15
53						1	1	1	2	4	1	1	2	3			1			17
52					1	1	2		4	2	3	3	1	1						18
51						4	3	2	5	4	2	1								21
50				3	5	1	5	2	3											19
49			1	1	9	3	4	1	1											20
48			1	3	4	8	3	1												20
47				10	5	4	1	1												21
46			4	7	3															14
45			7	3	4	1	1													16
44		1	3	10																14
43			3																	3
42		2																		2
41		1	2																	3
40		1	5																	6
39		4	2	1																7
38		6	2																	8
37	1	11	2																	14
36		13	1																	14
35		15																		15
34	1	12	1																	14
33	1	14																		15
32	1	3																		4
31																				
30	1																			1
29																				
28																				
27																				
26																				
25																				
24																				
23																				
Total	5	83	34	38	31	23	20	8	19	14	11	17	8	8	3	2	4		1	329

Table A17: Kahawai age-length data from east coast North Island (both sexes). The lengths and otoliths were collected in November 1992

																	Age		
Length	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																				
61																				
60																				
59																				
58																				
57											1	1	1		1	1				5
56									1		2	1	2		2	1	1			10
55									2	2	1	6	4	4	1				1	21
54						1			3	4	2	6	3	2	2		2			25
53					1	1	1	2	5	6	4	3	2	4	1	1	1			32
52					1	3	3		5	5	6	5	3	2						33
51					1	4	3	3	6	7	5	4	1				1			35
50				3	6	4	10	6	5	3	1	1								39
49			1	2	11	11	7	2	3	1	1					1				40
48			1	8	8	15	6	2												40
47			2	15	9	7	7	1												41
46			5	13	10	5	1													34
45		1	13	9	5	2	1													31
44		2	9	15	2		1													29
43		1	8	1																10
42		4	6	1																11
41		2	3																	5
40		2	5																	7
39		10	3	1																14
38		18	5																	23
37	1	26	2																	29
36		27	2																	29
35		30																		30
34	1	27	1																	29
33	4	22																		26
32	2	3																		5
31																				
30	1																			1
29																				
28																				
27																				
26																				
25																				
24																				
23																				
Total	9	175	66	68	54	53	40	16	30	28	23	27	16	12	7	4	5		1	634

Table A18: Kahawai age-length data from the west coast of the North Island (males). The lengths and otoliths were collected in February and March 1991

																Age		
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
62																		
61																		
60																		
59																		
58																		
57															1	1		2
56																	1	1
55									1		3	1		1		1		7
54										1					1			2
53								1	1		1	3		1				7
52						1			2	1	2	1		2				9
51								2	2	1	2		1					8
50						1		2	1	2	2		1					9
49							1	1		2	1							5
48				1	1	1		1										4
47				1	2		2	1		2	1							9
46				1	1	1									1			4
45					1													1
44				1	3	1												5
43					4			1										5
42			1		1	2	1											5
41				2	1													3
40			2	1	1													4
39				1														1
38			1															1
37				1														1
36																		
35																		
34		1	1															2
33		1																1
32			2															2
31																		
30		1																1
29	1		1															2
28																		
27																		
26																		
25																		
24																		
23																		
Total	1	3	8	9	15	7	4	9	7	9	12	5	2	4	3	2	1	101

Table A19: Kahawai age-length data from the west coast of the North Island (females). The lengths and otoliths were collected in February and March 1991

																Age		
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
62																		
61																		
60																		
59																		
58										1			1	1		1		4
57									1									1
56																1		1
55									1		1	1	1	1	1			6
54							1		4	1	3	1	2		1			13
53							1	3		2	1			1				8
52							1	1	2	2								6
51					1			2	1			1						5
50								1	1									2
49					1	1	2	1	2									7
48					1		1											2
47					2			1	1	1								5
46					2	1												3
45					2	1												3
44				1	1	1	1											4
43				1														1
42			1															1
41			1		1													2
40			1															1
39			2															2
38		2	2															4
37			1															1
36			2															2
35																		
34		3	2		1													6
33		6	2															8
32		1																1
31																		
30		1																1
29																		
28																		
27		1																1
26																		
25	1																	1
24																		
23																		
Total	1	14	14	2	12	4	7	9	13	7	5	3	4	3	2	2		102

Table A20: Kahawai age-length data from the west coast of the North Island (both sexes). The lengths and otoliths were collected in February and March 1991

																Age		
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
62																		
61																		
60																		
59																		
58										1			1	1		1		4
57									1						1	1		3
56																1	1	2
55									2		4	2	1	2	1	1		13
54							1		4	2	3	1	2		2			15
53							1	4	1	2	2	3		2				15
52						1	1	1	4	3	2	1		2				15
51					1			4	3	1	2	1	1					13
50						1		3	2	2	2		1					11
49					1	1	3	2	2	2	1							12
48				1	2	1	1	1										6
47				1	4		2	2	1	3	1							14
46				1	3	2									1			7
45					3	1												4
44				2	4	2	1											9
43				1	4			1										6
42			2		1	2	1											6
41			1	2	2													5
40			3	1	1													5
39			2	1														3
38		2	3															5
37			1	1														2
36			2															2
35																		
34		4	3		1													8
33		7	2															9
32		1	2															3
31																		
30		2																2
29	1		1															2
28																		
27		1																1
26																		
25	1																	1
24																		
23																		
Total	2	17	22	11	27	11	11	18	20	16	17	8	6	7	5	4	1	203

Table A21: Kahawai age-length data from the west coast of the North Island (males). The lengths and otoliths were collected in February and March 1993

																			Age	
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																					
60																					
59									1												1
58																					
57								1		1	1	1	1				1				6
56												2		1	1	1	2				7
55								1		1	2	3	2		1				1		11
54							1		1		1	5		1	1			1			11
53									2	1	2	1		2	1	1					10
52								1	2	2			2	1	1	1					10
51						1		3	2	2	4	2	1								15
50					1	2		2	5	3		1	1								15
49					2		7		4			1	1								15
48				2		6	4	2	3	1											18
47					2	4	1	4	1		3										15
46				6	4	2	5		1												18
45				4	4	5	2														15
44			6	9	1	1		1													18
43			7	3																	10
42			8	1	1																10
41			5	1	4																10
40			7	3	1																11
39		1	6	2	1																10
38			8	2																	10
37		4	5		1																10
36		4	5	1																	10
35			4	2																	6
34		1	1	1																	3
33		1																			1
32		3																			3
31			2																		2
30			2																		2
29																					
28			1																		1
27			1																		1
26																					
25																					
24																					
23	1																				1
Total	1	14	68	37	22	21	20	15	22	11	13	16	8	5	5	3	3	1	1		286

Table A22: Kahawai age-length data from the west coast of the North Island (females). The lengths and otoliths were collected in February and March 1993

																			Age		
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																1					1
60																	1		1		2
59										1				2	1	2	1		1	1	9
58											1		3	2	1	1	1	1			10
57										1	2		2	4	1	2					12
56											2	1	2	3		2	1				11
55									1	1	2	1	1	2	1		1				10
54										3		3	3								9
53							1	1	2	2	1	2					1				10
52							1		4	1	2	1		1							10
51					2	2	3	2	3	2	2		1								17
50					1	3	6	2	2	1											15
49					3	2	9	1	1	1			1								18
48					1	5	1	2	3	3	1										16
47				3	5	2	2	1	1			2									16
46				3	7	2		2	1	1											16
45			1	8	5		1														15
44			6	9	2		1														18
43			6	4																	10
42			10	1																	11
41			3	6	1																10
40			9	1																	10
39			1	10																	11
38		3	3	4																	10
37		5	5																		10
36		4	3	3																	10
35		3	3	1																	7
34		1	2	1																	4
33			1																		1
32		1	4																		5
31			1																		1
30			6	1																	7
29	1	3																			4
28																					
27																					
26																					
25																					
24																					
23																					
Total	1	20	64	55	27	16	25	11	18	17	13	10	13	14	4	8	6	1	2	1	326

Table A23: Kahawai age-length data from the west coast of the North Island (both sexes). The lengths and otoliths were collected in February and March 1993

																			Age		
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
61																1					1
60																	1		1		2
59									1	1				2	1	2	1		1	1	10
58											1		3	2	1	1	1	1			10
57								1		2	3	1	3	4	1	2	1				18
56											2	3	2	4	1	3	3				18
55								1	1	2	4	4	3	2	2		1			1	21
54							1		1	3	1	8	3	1	1			1			20
53							1	1	4	3	3	3		2	1	1	1				20
52							1	1	6	3	2	1	2	2	1	1					20
51					2	3	3	5	5	4	6	2	2								32
50					2	5	6	4	7	4		1	1								30
49					5	2	16	1	5	1		1	2								33
48				2	1	11	5	4	6	4	1										34
47				3	7	6	3	5	2		3	2									31
46				9	11	4	5	2	2	1											34
45			1	12	9	5	3														30
44			12	18	3	1	1	1													36
43			13	7																	20
42			18	2	1																21
41			8	7	5																20
40			16	4	1																21
39		1	7	12	1																21
38		3	11	6																	20
37		9	10		1																20
36		8	8	4																	20
35		3	7	3																	13
34		2	3	2																	7
33		1	1																		2
32		4	4																		8
31			3																		3
30			8	1																	9
29	1	3																			4
28			1																		1
27			1																		1
26																					
25																					
24																					
23	1																				1
Total	2	34	132	92	49	37	45	26	40	28	26	26	21	19	9	11	9	2	3	1	612

Table A24: Kahawai age-length data from the Bay of Plenty (males). The lengths and otoliths were collected in May to July 1991

	Age																				
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																					
60																					
59																					
58																					
57																					
56																					
55																					
54												1		1							2
53																					
52										1		1		1							3
51							1			3	1		1		1						7
50							1		1	3		1									6
49							1	5	1		1			1							9
48					2	1	1	2		1											7
47				1	2	3	1														7
46								1	1												2
45			1		3	1	1														6
44				1																	1
43		1	1	4																	6
42			3																		3
41																					
40		1																			1
39																					
38			1																		1
37																					
36		1																			1
35																					
34	1																				1
33																					
32		1																			1
31																					
30																					
29																					
28																					
27																					
26																					
25																					
24																					
23																					
Total	1	4	6	6	7	5	6	8	3	8	2	3	1	3	1						64

Table A25: Kahawai age-length data from the Bay of Plenty (females). The lengths and otoliths were collected in May to July 1991

	Age																				
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																					
60																					
59																					
58												1									1
57																					
56													1								1
55																		1			1
54										1		1		1	2	1					6
53											1		1								2
52							3	1	1	1	3	3	2		1						15
51							1	1	1	3											6
50								1	1	1											3
49					1	2	1				1										5
48					4			1			1										6
47				2	1	1	1														5
46			2	1				1			1										5
45																					
44																					
43				1																	1
42			1	1																	2
41					1																1
40				2																	2
39																					
38																					
37																					
36																					
35																					
34																					
33																					
32																					
31																					
30																					
29																					
28																					
27																					
26																					
25																					
24																					
23																					
Total			3	7	7	3	6	5	3	6	7	5	4	1	3	1		1			62

Table A26: Kahawai age-length data from the Bay of Plenty (both sexes). The lengths and otoliths were collected in May to July 1991

	Age																				
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																					
60																					
59																					
58												1									1
57																					
56													1								1
55																		1			1
54										1		2		2	2	1					8
53											1		1								2
52							3	1	1	2	3	4	2	1	1						18
51							2	1	1	6	1		1		1						13
50							1	1	2	4		1									9
49					1	2	2	5	1		2			1							14
48					6	1	1	3		1	1										13
47				3	3	4	2														12
46			2	1				2	1		1										7
45			1		3	1	1														6
44				1																	1
43		1	1	5																	7
42			4	1																	5
41					1																1
40		1		2																	3
39																					
38			1																		1
37																					
36		1																			1
35																					
34	1																				1
33																					
32		1																			1
31																					
30																					
29																					
28																					
27																					
26																					
25																					
24																					
23																					
Total	1	4	9	13	14	8	12	13	6	14	9	8	5	4	4	1		1			126

Table A27: Kahawai age-length data from the Bay of Plenty (males). The lengths and otoliths were collected in January to June 1992

	Age																				
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																					
60																					
59																					
58													1								1
57													1	1	2			1			5
56								1				3	2	2	1						9
55										3	4	2	2		1	1					13
54								2	1	1	1	2	1	1		1	1				11
53						1	1		1	3	2	2	1	1							12
52								1	2	2	1	1	1	1		1					10
51						3			2	2	2	1									10
50					2	1		1	1	2	2		1								10
49					1	2	1	1	2	1	2										10
48					2	3	2	2	2	2	2										15
47					5	4	2														11
46				2	5	3	1			1											12
45					5	5															10
44				5	5																10
43				7	2	1															10
42			2	6	2																10
41			1	9	3																13
40			3	7																	10
39			3	6	1																10
38				10	1																11
37			6	3	1																10
36		1	8	1																	10
35		1	9																		10
34		3	6	1																	10
33		5	5																		10
32		3	7																		10
31		8	4																		12
30	1	4	6																		11
29		2	1																		3
28																					
27																					
26																					
25																					
24																					
23																					
Total	1	27	61	57	35	23	7	8	11	17	16	11	10	6	4	3	1	1			299

Table A28: Kahawai age-length data from the Bay of Plenty (females). The lengths and otoliths were collected in January to June 1992

																			Age		
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																					
60																			1		1
59													1	1			1				3
58									1			2		2	1		2				8
57									1		2	2	1	4							10
56								1	1	1	2		1	1		1	2			1	11
55								1		3	2	1	1	2			1				11
54						1		2	2	2		1	2								10
53						1			4	2	1	1		1							10
52						1	3	1	2	2			1	1							11
51					1	2	2	3	1	2	2		1								14
50						2	2	2		1	2	1									10
49					1	4	1	1		2			1								10
48						2	3	1	4												10
47				1	1	3	2	1	1												9
46				2	4	2	1	1													10
45				1	7	2	1														11
44			1	7	3																11
43			1	8		1															10
42				10	1																11
41			5	4	1																10
40			3	7																	10
39			5	4	1																10
38			1	4																	5
37			6	1																	7
36		1	8	1																	10
35		2	8																		10
34		3	7																		10
33		4	6																		10
32		1	9																		10
31		6	6																		12
30			4																		4
29																					
28																					
27																					
26																					
25																					
24																					
23																					
Total		17	70	50	20	21	15	14	17	15	11	8	9	12	1	1	6		1	1	289

Table A29: Kahawai age-length data from the Bay of Plenty (both sexes). The lengths and otoliths were collected in January to June 1992

																			Age		
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																					
60																			1		1
59													1	1			1				3
58									1			2	1	2	1		2				9
57									1		2	2	2	5	2			1			15
56								2	1	1	2	3	3	3	1	1	2			1	20
55								1		6	6	3	3	2	1	1	1				24
54						1		4	3	3	1	3	3	1		1	1				21
53						2	1		5	5	3	3	1	2							22
52						1	3	2	4	4	1	1	2	2		1					21
51					1	5	2	3	3	4	4	1	1								24
50					2	3	2	3	1	3	4	1	1								20
49					2	6	2	2	2	3	2		1								20
48					2	5	5	3	6	2	2										25
47				1	6	7	4	1	1												20
46				4	9	5	2	1		1											22
45				1	12	7	1														21
44			1	12	8																21
43			1	15	2	2															20
42			2	16	3																21
41			6	13	4																23
40			6	14																	20
39			8	10	2																20
38			1	14	1																16
37			12	4	1																17
36		2	16	2																	20
35		3	17																		20
34		6	13	1																	20
33		9	11																		20
32		4	16																		20
31		14	10																		24
30	1	4	10																		15
29		2	1																		3
28																					
27																					
26																					
25																					
24																					
23																					
Total	1	44	131	107	55	44	22	22	28	32	27	19	19	18	5	4	7	1	1	1	588

Table A30: Kahawai age-length data from the Bay of Plenty (males). The lengths and otoliths were collected in October to December 1992

																			Age		
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																					
60																					
59																					
58												1									1
57									1	1	1	1									4
56						1	1	1	1			1									5
55								1	1	2	1	1									6
54						1	2	2	2	3											10
53						2	1	2	2	2		1									10
52					2	1	2	1		2	1				1						10
51				1		2	4	1	2	5		1									16
50					2	3	5	1	2	2	1										16
49				2	9	8		1	1												21
48				3	13	2		1	1												20
47				8	7	5	1														21
46				11	4																15
45				10																	10
44			2	7	1																10
43			2	8																	10
42			10	9																	19
41			7																		7
40			2																		2
39		1	3																		4
38		6	4																		10
37		8	2																		10
36		10																			10
35		10																			10
34		10																			10
33		9																			9
32																					
31																					
30																					
29																					
28																					
27																					
26																					
25																					
24																					
23																					
Total		54	32	59	38	25	16	11	13	17	4	6			1						276

Table A31: Kahawai age-length data from the Bay of Plenty (females). The lengths and otoliths were collected in October to December 1992

																			Age		
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																					
60									1				1		1						3
59									1	1	1		1				1				5
58										1	2		1	1	1						6
57							1	1	5	2						1					10
56						1		2	2	2	1	1	1								10
55						3	2	4		1		1									11
54							4	2	1		1	2		1							11
53							3		3	1	3										10
52					1	1	2	3	1	2											10
51					1	1	3	2	2	1											10
50				1	4	6															11
49				4	6	3	2														15
48				5	2	3															10
47			2	7	2																11
46			1	7	2																10
45			1	8	2																11
44			1	9	1																11
43			5	4																	9
42			4	5																	9
41			6																		6
40		2	8																		10
39		2	8																		10
38		6	5																		11
37		8	2																		10
36		9	1																		10
35		10																			10
34		9	2																		11
33		2																			2
32		2																			2
31		1																			1
30																					
29																					
28																					
27																					
26																					
25																					
24																					
23																					
Total		51	46	50	21	18	17	14	16	11	8	4	4	2	2	1	1				266

Table A32: Kahawai age-length data from the Bay of Plenty (both sexes). The lengths and otoliths were collected in October to December 1992

	Age																				
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
62																					
61																					
60									1				1		1						3
59									1	1	1		1				1				5
58										1	2	1	1	1	1						7
57							1	1	6	3	1	1				1					14
56						2	1	3	3	2	1	2	1								15
55						3	2	5	1	3	1	2									17
54						1	6	4	3	3	1	2		1							21
53						2	4	2	5	3	3	1									20
52					3	2	4	4	1	4	1				1						20
51				1	1	3	7	3	4	6		1									26
50				1	6	9	5	1	2	2	1										27
49				6	15	11	2	1	1												36
48				8	15	5		1	1												30
47			2	15	9	5	1														32
46			1	18	6																25
45			1	18	2																21
44			3	16	2																21
43			7	12																	19
42			14	14																	28
41			13																		13
40		2	10																		12
39		3	11																		14
38		12	9																		21
37		16	4																		20
36		19	1																		20
35		20																			20
34		19	2																		21
33		11																			11
32		2																			2
31		1																			1
30																					
29																					
28																					
27																					
26																					
25																					
24																					
23																					
Total		105	78	109	59	43	33	25	29	28	12	10	4	2	3	1	1				542

Table A2: Kahawai age-length data from west of D'Urville Island: Golden Bay, Farewell Spit, Tasman Bay (males). The lengths and otoliths were collected between October 1990 and February 1992

	Age													
Length	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
62														
61														
60														
59														
58														
57							1							1
56														
55														
54				1			1							2
53							1					1		2
52					1				1		1			3
51				2	1	2				2				7
50				1	1		2							4
49				3	2	1		1						7
48				2	2	2					1			7
47			1	2	2									5
46			1	3										4
45					1	1								2
44			2		1									3
43					1									1
42		1	3	1										5
41		3	1											4
40		2	2											4
39														
38			1											1
37		1	2											3
36	2	1	1											4
35		2	1											3
34		6												6
33														
32														
31		1												1
30														
29														
28														
27														
26														
25														
24														
23														
Total	2	17	15	15	12	6	5	1	1	2	2	1		79

Table A3: Kahawai age-length data from west of D'Urville Island: Golden Bay, Farewell Spit, Tasman Bay (females). The lengths and otoliths were collected between October 1990 and February 1992

	Age													
Length	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
62														
61														
60														
59														
58														
57														
56										1				1
55							1							1
54														
53							1	1						2
52				2	1	1		1					1	6
51			1	3	2	2		1		1				10
50				3	1	2								6
49						1	1	1						3
48				4	1									5
47			3	1										4
46			1	1	1									3
45		1	1	1										3
44			1											1
43			2											2
42			1	2										3
41		2	1	1										4
40		1		1										2
39														
38		1	1											2
37		1												1
36	1	3												4
35		4	1											5
34	1	1												2
33		4	1											5
32		1												1
31														
30														
29														
28														
27														
26														
25														
24														
23														
Total	2	19	14	19	6	6	3	4		2			1	76

Table A4: Kahawai age-length data from west of D'Urville Island: Golden Bay, Farewell Spit, Tasman Bay (both sexes). The lengths and otoliths were collected between October 1990 and February 1992

	Age													
Length	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
62														
61														
60														
59														
58														
57							1							1
56										1				1
55							1							1
54				1			1							2
53							2	1				1		4
52				2	2	1		1	1		1		1	9
51			1	5	3	4		1		3				17
50				4	2	2	2							10
49				3	2	2	1	2						10
48				6	3	2					1			12
47			4	3	2									9
46			2	4	1									7
45		1	1	1	1	1								5
44			3		1									4
43			2		1									3
42		1	4	3										8
41		5	2	1										8
40		3	2	1										6
39														
38		1	2											3
37		2	2											4
36	3	4	1											8
35		6	2											8
34	1	7												8
33		4	1											5
32		1												1
31		1												1
30														
29														
28														
27														
26														
25														
24														
23														
Total	4	36	29	34	18	12	8	5	1	4	2	1	1	155

Table A5: Kahawai age-length data from east of D'Urville Island: Marlborough Sounds, Cloudy/Clifford Bay, Kaikoura (males). The lengths and otoliths were collected between October 1990 and May 1992

	Age																					
Length	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
71								1														1
70																						
69																						
68																						
67																						
66																						
65																						
64																						
63																						
62																						
61																						
60																						
59																						
58																						
57										1	1	1		3	1	1						8
56						1		1	3		1	1	1	1								9
55						1	2	1	1	1	3	1	2	4	2						1	19
54						1	2	2	3	1	2	3	1	1	2		1					19
53					1		5	2	3	3	3	4	5	3	3	1						33
52				1	1	1	2	1	4	4	3	2	2	1								22
51				2	4	2	6		2	6	1	3	2	1	1							30
50				1	1	3	10	13	6	6	3	2	1									46
49			1	3	4	4		6	7	3	1	1		2								32
48					4	3	2		3	2			1									15
47			3	2		1						2										8
46			4	2	1																	7
45			2	1																		3
44			2	1																		3
43		1	1	1																		3
42			1	2																		3
41		1	2																			3
40			2	1																		3
39			1																			1
38		1																				1
37	1	2																				3
36	1		1																			2
35		1																				1
34	1																					1
33																						
32	1		1																			2
Total	4	6	21	17	16	17	29	27	32	27	18	20	15	16	9	2	1				1	278

Table A6: Kahawai age-length data from east of D'Urville Island: Marlborough Sounds, Cloudy/Clifford Bay, Kaikoura (females). The lengths and otoliths were collected between October 1990 and May 1992

	Age																				
Length	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
71																						
70																						
69																						
68																						
67																						
66																						
65																						
64																				1		1
63																1						1
62																						
61																1						1
60														1	1		1					3
59									1	1		1						1	1			5
58								1	1				2	1	1	2						8
57									1	2	1		2		1	1	2				1	11
56								5	1		3	3	1	1	1		1					16
55							1	1	3	2	3	6	3	3	1	2						25
54							1	5	4	4	3	6	2	3	1	2						31
53				2	4	2	4	2	6	1	3	4	1	1	1	2						33
52			1		3	2	7	3	2	4	1		4	1								28
51				4	2	4	7	5	2	8	1	3										36
50					3	2	1	1	1	1		4										13
49			2	3	5	3	1	2	2	1	1		1			1						22
48			1	2	2	4	1	1														11
47					1	1	1		1													4
46			1	1				1														3
45		1	2																			3
44		1																				1
43				1																		1
42		1																				1
41		3	2																			5
40		1																				1
39		1																				1
38		2																				2
37	1	1		1																		3
36		4	2																			6
35	1																					1
34	1	1	1																			3
33		1		1																		2
32		1																				1
Total	3	18	12	15	20	18	24	27	25	24	16	27	16	11	7	12	4	1	1	1	1	283

Table A7: Kahawai age-length data from east of D'Urville Island: Marlborough Sounds, Cloudy/Clifford Bay, Kaikoura (both sexes). The lengths and otoliths were collected between October 1990 and May 1992

	Age																				
Length	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
71								1														1
70																						
69																						
68																						
67																						
66																						
65																						
64																				1		1
63																1						1
62																						
61																1						1
60														1	1		1					3
59									1	1		1						1	1			5
58								1	1				2	1	1	2						8
57									1	3	2	1	2	3	2	2	2				1	19
56						1		6	4		4	4	2	2	1		1					25
55						1	3	2	4	3	6	7	5	7	3	2				1		44
54						1	3	7	7	5	5	9	3	4	3	2	1					50
53				2	5	2	9	4	9	4	6	8	6	4	4	3						66
52			1	1	4	3	9	4	6	8	4	2	6	2								50
51				6	6	6	13	5	4	14	2	6	2	1	1							66
50				1	4	5	11	14	7	7	3	6	1									59
49			3	6	9	7	1	8	9	4	2	1	1	2		1						54
48			1	2	6	7	3	1	3	2			1									26
47			3	2	1	2	1		1			2										12
46			5	3	1			1														10
45		1	4	1																		6
44		1	2	1																		4
43		1	1	2																		4
42		1	1	2																		4
41		4	4																			8
40		1	2	1																		4
39		1	1																			2
38		3																				3
37	2	3		1																		6
36	1	4	3																			8
35	1	1																				2
34	2	1	1																			4
33		1		1																		2
32	1	1	1																			3
Total	7	24	33	32	36	35	53	54	57	51	34	47	31	27	16	14	5	1	1	1	2	561

Table A8: Kahawai age-length data from northwest coast South Island (males). The lengths and otoliths were collected in December 1992

																Age		
Length	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
62																		
61															1			1
60																		
59												1						1
58																		
57								1	1			1						3
56							1	1		1	3	5	2		1	1		15
55					1	2	2	1	4	1		6	2			1		20
54								1	9	3	2	2	1					18
53				2			3	3	2	5	1	2		1				19
52			1	2	1	1	2	1	5	2	5							20
51			1	5	3	3	1	3	1		1	1						19
50			4	8	3	3			1		1							20
49			2	6	2	3		1										14
48			3	7	1	2	1	1										15
47			6	5	1		1											13
46		3	3	1														7
45			1															1
44																		
43		3																3
42	1	4																5
41		1																1
40		1																1
39	1																	1
38	2																	2
37	13	3																16
36	13	1																14
35	15																	15
34	15																	15
33	14	1																15
32	11																	11
31	2																	2
30																		
29																		
28	1																	1
27																		
26																		
25																		
24																		
23																		
Total	88	17	21	36	12	14	11	13	23	12	13	18	5	1	2	2		288

Table A9: Kahawai age-length data from northwest coast South Island (females). The lengths and otoliths were collected in December 1992

																Age		
Length	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
62																		
61											1							1
60																		
59									1			1	1					3
58													2					2
57									1		2		4	2	1	3	1	14
56									2	2	3	4	1	1	1		1	15
55						1		2	3		4	5	5					20
54					2	2	2	2	3	4	1	2						18
53					1	1		2	5	3	3	1	1			1		18
52			1	3	6	2	2	2	3			1						20
51			1	6	5	2	1	2	1	2					1			21
50			2	6	6	1		2		1	1							19
49			3	7	3													13
48			4	4	3	2												13
47			3	4	1													8
46			1															1
45																		
44																		
43		1																1
42		1	1															2
41		1																1
40																		
39	1	1																2
38	11																	11
37	14	1																15
36	15																	15
35	14																	14
34	16																	16
33	14																	14
32	6	2																8
31																		
30																		
29																		
28																		
27																		
26																		
25																		
24																		
23																		
Total	91	7	16	30	27	11	5	12	19	12	15	14	14	3	3	4	2	285

Appendix 2: Some sampling problems with schooling pelagic fish

The work described in this Appendix was done as part of a tender for the Ministry of Fisheries contract KAH9701. One objective was to design a further catch sampling of the kahawai purseseine catch in the Bay of Plenty, Tasman and Golden Bays, and Kaikoura so that the mean age weighted coefficient of variation (*c.v.*) on the age distribution in each area was 20%. This work led to the recommendation and subsequent decision by the Ministry of Fisheries that this objective not be included in the project.

The discussion is included here because the sampling problems encountered will apply to any sampling of schooling pelagic fish.

The proposal in the Ministry call for tenders was to randomly sample the kahawai landings to obtain an age distribution, rather than to randomly sample for length and then sub-sample to collect otoliths for an age-length key which was the method used in the work discussed in this report.

First, the number of landings needed to get the required mean weighted *c.v.* was estimated using data from the 1991–93 catch sampling in the Bay of Plenty, Tasman and Golden Bays (area 38), and Kaikoura (area 18).

When sampling directly for age, the mean age weighted *c.v.* (C) for unstratified landings is given by:

$$C = \frac{1}{\sqrt{n}m} \sum_{\alpha} \nu_{\alpha}$$

where n is the number of landings sampled, m is the mean number of fish in a landing and $\nu_{\alpha} = (n/N^2)var(\hat{N}_{\alpha})$ is the variance of the numbers at age a, N is the total number of landings, and $\hat{N}_{\alpha}$ is an estimator of the number at age (D. J. Gilbert, NIWA, Wellington, unpubl. results). The number of landings required to achieve the target weighted *c.v.*, $C_{.2}$, is given by:

$$n^* = \frac{1}{C_{.2}m^2} \left(\sum_{\alpha} \nu_{\alpha} \right)^2$$

An age-length key for each area derived from the previous samplings (Drummond & Wilson 1993, Drummond 1995, McKenzie and Trusewich, unpubl., and data in this report) was used to convert the numbers at length in the samples to numbers at age and so obtain estimates of ν_{α} and $\hat{m}$, the estimated average number of fish in a landing. The predicted values of n^* are given in Table A33.

The area 18 (Kaikoura) and Bay of Plenty samplings are considered in the separate fishing years they were sampled and with lumped data. The few landings sampled in area 38 (Tasman and Golden Bays) are treated together. The size class strata used in the Bay of Plenty were taken as separate landings. These estimates for n^* are approximate and subject to various errors, including errors in the age-length key used for the Bay of Plenty. The estimates $\hat{m}$ are included to give an indication of the size of the landings.

Table A33: Sample sizes from previous catch samplings, n, the estimated mean number of fish in a landing and the estimated number of landings, n^*, required to give a mean weighted $c.v.$ on the age distribution of 20%

	$\hat{m}$	n	n^*
Area 18: All data	19 600	52	18
Area 18: 1990–91	19 264	30	18
Area 18: 1991–92	22 991	13	12
Area 18: 1992–93	15 825	9	32
Area 38: All data	63 437	9	39
Bay of Plenty: All data	27 615	34	112
Bay of Plenty: 1990–91	21 442	9	56
Bay of Plenty: 1991–92	37 891	13	103
Bay of Plenty: 1992–93	21 111	12	80

The between-landings variability in Bay of Plenty and Tasman and Golden Bays is immediately obvious. The values of n^* given in Table A34 suggest the number of landings which would have to be sampled to get an estimate of the population age distribution.

Table A34: Estimates of the expected number of kahawai landings that would be available for sampling

Area	**Expected number of landings**
Kaikoura	0–6 Based on full boat loads when fishing far from the base port
Tasman/Golden Bay	6–10 Based on landings averaging half-full boats and 1000 t coming from this area
Bay of Plenty	6–10 Based on landings averaging half-full boats and 1000 t coming from the target purseseine fishery

Next, an estimate was made of the likely number of landings in each of the three areas in a current fishing year given the changes that have taken place since the 1991–93 catch sampling (Table A34). Purseseine boats have a hold capacity of between 250 and 300 t and several of the landings are from full boats. The purseseine catch limits are 1200 t in KAH 1 and 1500 t in KAH 3.

Thus it should be clear that to monitor the age distribution of the kahawai population to within the specified criterion, we would need to sample several times the number of available landings. Although there are many approximations in the above estimates, nothing is likely to change this conclusion substantially.

The sampling fraction was ignored in the above estimates; its inclusion will enable the design criteria to be met for the catch in a given year, if nearly all the landings are sampled. When the sampling fraction n/N is included, the mean weighted $c.v.$, C, for unstratified landings is given by (Gilbert, unpubl. results):

$$C = \sqrt{1 - \frac{n}{N}} \frac{1}{\sqrt{nm}} \sum_{\alpha} \sqrt{\nu_\alpha}$$

which is similar to the preceding expression with an additional term. Obviously, C can be reduced to the required level by making the number of landings sampled, n, a large part of the total landings, N. The expressions for the mean weighted variance when the landings are stratified will have multiplying constants of similar form.

Thus, the conclusion is that catch sampling data for schooling pelagic fish taken by purseseine may tell us little about the fish population since whole schools are taken and the population may be inadequately sampled by the catch.

Difficulties with sampling purseseine caught kahawai

Adequate sampling of the kahawai purseseine catch to monitor the population age distribution is almost impossible. Some of the difficulties are itemised below.

1. There appears to be some targeting of particular schools so the age distribution will be strictly for the catch and not give useful information about the population. The mean weighted *c.v.* of the age distribution can be achieved only by assuming a large sampling fraction. The age distributions in successive years already available from the Bay of Plenty appear different and inconsistent.
2. A rule of thumb estimate suggests that about 10% (but varying between 0 to perhaps 100%) of the kahawai population will be schooling on the surface at any one time, and thus accessible to the purseseine fishery. This was first suggested by Eggleston (1978) and is consistent with the size of kahawai schools estimated by aerial sighting (Bradford & Taylor 1995). The surface population may not form a random sample from the population and the size/age composition may vary over time and space. For example, the apparent differences in age composition of the catch alluded to above may be due to the different times of year when the kahawai were sampled.
3. The kahawai are bulk handled and the catches from several schools are combined. Even to monitor the catch properly, one needs a small sample from each school as it is caught at sea. This is not practical.