MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

ISSN 1175-1584

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Elizabeth Bradford

New Zealand Fisheries Assessment Report 2001/5
February 2001

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EXECUTIVE SUMMARY

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This report extends previous work investigating the feasibility of sampling the recreational fishery to monitor the kahawai stock. The aim of the project was to design a program to monitor the length and age structure of the recreational catch of kahawai, including an estimation of how well various relevant quantities could be measured and the cost of such a project. The work was carried out under Ministry of Fisheries project MOF1999/04I.

The precision with which length or age class proportions can be determined was tabulated for several sample sizes and class proportions between about 0.05 and 0.25 and was low unless the sample size became large. For example, with a sample size of 1500 a proportion cannot be shown to be different from 0.25 if it lies within (0.193, 0.315) with 95% confidence or different from 0.10 if it lies within (0.061, 0.146). It is clear that sample sizes below about 500 would be too small to give useful results.

The available age-length information is known to contain biases and to have inadequate age information for small and large kahawai. The mean and standard deviation of the age at a given length were used to provide a way of simulating ageing of kahawai of a given length.

Calculations were based on data from previous surveys for the regions: Bay of Plenty, Hauraki Gulf, East Northland, KAH 9, KAH 3, and KAH 2.

Previous survey data were used to estimate the likely numbers of kahawai to be available for ageing from a survey session at a ramp during summer weekends and holidays. The numbers are low at most ramps. This information was used to estimate the number of sessions needed to provide 500 kahawai heads. The willingness of fishers to sacrifice kahawai heads is unknown.

The cost estimate for a survey covering the whole country is $650 000–950 000 per year, with the cost of the regional surveys varying between about $90 000 and $180 000. The cost of ageing 500 kahawai is a relatively small part of this.

It is not recommended that the suggested survey be undertaken. However, if a further feasibility study is required, a survey should be carried out in either KAH 9 or the Bay of Plenty.

It is recommended that a North region survey, run between the national surveys, be investigated. Boat ramp surveys could form part of each of these surveys and would give size distributions for kahawai. Harvest estimates would probably come from a diary survey. Changes in the kahawai stock could be followed reasonably well over time through changes in the recreational catch and the size distribution. It is further recommended that the Ministry investigates what other information, such as age data, might be collected during recreational boat ramp surveys.

1. INTRODUCTION

One method suggested for monitoring the kahawai stock in New Zealand waters is to age the recreational catch. For this purpose, Bradford (2000) recommended that a programme of annual boat ramp surveys of the recreational kahawai catch take place in all parts of the country where kahawai are caught. The programme outline follows.

- Surveying should take place over the main summer recreational fishing period.
- Surveying should take place on weekends and holidays. This is unlikely to result in frequent counts of large numbers of kahawai at a given ramp on a given day which could lead to the final size and age distributions being unrepresentative of the recreational catch. Concentrating the surveying on competition days is not recommended.
- As many as possible of the kahawai caught should be measured for length, and heads (otoliths) taken where possible.
- The kahawai should also be weighed, at least during one survey.
- Sexing the kahawai would be desirable but would not be essential.
- Harvest rate data should be collected for those trips where kahawai was a specific target fish, and at a lower priority otherwise.

In the North region, few kahawai are caught by recreational fishers targeting kahawai, and it may be preferable not to use otoliths from targeted kahawai to remove a potential selectivity bias. Most fishers appear to target kahawai when they see a school and schools normally contain fish with a small size range.

Though the recreational fishery samples the kahawai population more randomly and representatively than the commercial purseseine fishery (Bradford 2000), any samples obtained may not be sufficiently random and/or representative of the stock, and kahawai movement may mean that the samples are not comparable from year to year. The sampling is of the recreational catch.

The members of the Pelagic Working Group were concerned about the usefulness and quality of the information that would be collected by such a survey. For example, little is known about recreational gear and preference selectivities in this fishery. Bradford (2000) suggested that the recreational fishery may be sampling the smaller age classes reasonably well, but 3 year olds appear to be under-represented in the recreational catch.

A major concern is the cost of running a boat ramp survey on the scale required to get sufficient otoliths to give a well-determined age distribution. The Pelagic Working Group suggested that the ageing be done every three years.

The Ministry of Fisheries requested a design for a programme to monitor the length and age structure of the recreational catch of kahawai. They wanted to know the power of the data collected to indicate changes in parameters over time. NIWA argued that there were too many unknowns in how kahawai age and size distributions changed for any realistic power calculations to be undertaken. Instead we suggested investigating how accurately the age structure of the catch could be measured. That is the subject of the first part of this report. A survey design is then outlined and costed.

This work was undertaken under project MOF1999/04I.

2. LENGTH PROPORTIONS

2.1 Definitions

The mean length and its standard error are defined by the usual formula. For a given length frequency distribution, the estimated proportion of lengths greater than L_0 is

$$\mathrm{E}[\Pr(L > L_0)] = \hat{p}_0 = r / n,$$

where n is the number of length measurements made and r of them satisfy the criterion $L > L_0$. The standard error of $\hat{p}_0$ is

$$s.e.(\hat{p}_0) = \sqrt{\frac{\hat{p}_0(1-\hat{p}_0)}{n}} = \sqrt{\frac{r/n\left(1 - r/n\right)}{n}}. \tag{1}$$

The corresponding 100(1-α)% confidence interval for $\hat{p}_0$ is (assuming a normal approximation that is valid when n is large and $n\hat{p}_0 = r$, is not too small)

$$\left(\frac{r}{n} - z_{1-\alpha/2}\sqrt{\frac{r/n\left(1 - r/n\right)}{n}}\right), \left(\frac{r}{n} + z_{1-\alpha/2}\sqrt{\frac{r/n\left(1 - r/n\right)}{n}}\right) \tag{2}$$

where $z_{1-\alpha/2}$ is the 1-α/2 percentile of the normal distribution. This confidence interval can give lower values that are less than 0 or upper values that are greater than 1. Such values are unrealistic since the proportions, as defined, must lie between 0 and 1. These formulae are given in most elementary statistical text books, for example, Larsen & Marx (1986).

An exact confidence interval can be defined using percentiles of the F distribution. Let $F_1 = F_{(1-\alpha/2)}(2n-2r+2, 2r)$ and $F_2 = F_{(1-\alpha/2)}(2r+2, 2n-2r)$ be (1-α/2) percentiles of the F distribution with degrees of freedom as indicated. Then the 100(1-α)% confidence interval for $\hat{p}_0$ is (Johnson *et al.* 1992, Alistair Dunn, NIWA, pers. comm.)

$$\left(\frac{r}{(r+(n-r+1)F_1}, \frac{(r+1)}{(r+1+(n-r)/F_2}\right). \tag{3}$$

The limits of this confidence interval are greater than or equal to 0 and less than or equal to 1.

A test for the difference of two proportions ($p_1 = r/n$ and $p_2 = s/m$) is available under the same assumptions that Equations (1) and (2) are valid and the hypothesis that $p_1 = p_2$ can be rejected whenever (Larsen & Marx 1986)

$$\frac{\frac{r}{n} - \frac{s}{m}}{\sqrt{\frac{\left(\frac{r+s}{n+m}\right)\left(1 - \frac{r+s}{n+m}\right)(n+m)}{nm}}} \text{ is either } \begin{cases} \leq -z_{1-\alpha/2} \\ \text{or} \\ \geq +z_{1-\alpha/2} \end{cases} \tag{4}$$

2.2 Estimates of length proportions for the kahawai size distributions

The kahawai lengths measured in the 1991 and 1994 North region, 1992–93 Central region, and the 1996 national boat ramp surveys of recreational fishers were combined for the regions Bay of Plenty, Hauraki Gulf, east Northland, KAH 9, KAH 3, and KAH 2 (defined in Table 1). These estimates of recreational catch length distributions vary amongst the areas (Figure 1).

Equation (1) is used to estimate the c.v. of several length proportions that might be of interest in the kahawai size distributions (Table 2). In this case, the sample sizes are larger than are likely in any individual survey; the c.v.s increase as the estimates of proportion decrease, most noticeably in the KAH 3 sample where the sample size is relatively small and there are few large fish. The mean length is always well determined.

The values of length class proportions, P, likely to be of most interest lie between 0.05 and 0.25. Confidence intervals were calculated for a range of values of proportion and a range of sample sizes, N, that might be encountered in a survey. Both Equations (2) and (3) were used (Table 3). The agreement between the approximate and the exact confidence intervals is good when the sample size and proportion are large. As N and P become smaller, the approximate and exact confidence intervals begin to differ; the exact confidence intervals are wider than the approximate ones and are not symmetric. Length frequency distributions of interest are likely to come from more than 500 fish and any standard tests should not involve proportions much less than 0.05, so the approximate confidence intervals (or c.v.s) will be adequate.

When comparing size distributions, we need to know how much a length class proportion has to change before we can detect a difference. The test to decide whether proportions are equal, Equation (4), was used to determine the values when it will just fail for ranges of N and P chosen so that the assumptions underlying the test hold (Table 4). These results were obtained by simulation. For a given P_0 and an arbitrary P, 1000 random samples of size N were drawn from the appropriate binomial distribution. The probability of rejection was calculated using Equation (4) and lower and upper Ps that gave 95% probability of rejection of the hypothesis that $P = P_0$ were found. Proportions have to change by quite large amounts for the change to be detectable, especially with small sample sizes. For example, with a sample size of 1500 a proportion cannot be shown to be different from 0.25 if it lies within (0.193, 0.315) with 95% confidence or different from 0.10 if it lies within (0.061, 0.146). It is clear that sample sizes below about 500 would be too small to give useful results.

The results in Tables 3 and 4 also apply to age class proportions.

3. AGE AND LENGTH DATA

The kahawai age-length data come mainly from the commercial catch together with some small fish caught during a trawl survey. Bradford (2000) showed that applying an age-length key that combines several years' data to recreational length frequencies led to bias caused by a large year class of 11 year old kahawai in one of the samples. Kahawai ages are available for fish lengths between 26 and 61 cm but recreational fishers land kahawai that are both smaller and larger. The mean ages, $\overline{a}_l$, and mean variances, $\overline{\sigma}_l^2$, at length were determined from the measured data. Measured values at 60 and 61 cm were adjusted to be more consistent with the general pattern. The values of mean and standard deviation were extrapolated to 15 cm at the lower end (small fish can be aged reasonably accurately directly from the length) and were initially assumed constant from 61 to 75 cm (Table 1). The latter assumption is unlikely to be realistic but will not influence the results in any material way. The lowess smoother in S© was applied to the values of $\overline{a}_l$ and $\sqrt{\overline{\sigma}_l^2}$, lightly smoothing $\overline{a}_l$ and more heavily smoothing $\sqrt{\overline{\sigma}_l^2}$ (Figure 2, Table 5).

In what follows, age distributions were simulated by randomly selecting a value from the normal distribution $N(\overline{a}_l, \overline{\sigma}_l^2)$ for each fish length and rounding to the nearest integer.

4. SELECTING A RANDOM SAMPLE OF FISH TO AGE

4.1 Ageing process

As described above, there are no good age-length keys for determining the ages of kahawai caught by recreational fishers. Age distributions were therefore simulated.

Ages were assigned to all lengths from each region 1000 times. The precision of several statistics was determined to give an indication of the sampling variability that might be introduced at various sample sizes. The age statistics computed were the mean age, the proportions of 3, 4, and 5 year olds (separately) and the proportions of fish greater than 10, greater than 12, and greater than 14 years old (Table 6). These statistics were chosen to cover the range of quantities likely to be of interest.

4.2 Selecting a random age sample

In the first simulation, all the random sample of fish were aged. The steps used were as follows.

1. Select a sample of 1000 with replacement from the appropriate measured recreational length frequency.
2. For each fish, select an age (rounded to the nearest integer) from the normal distribution, $N(\overline{a}_l, \overline{\sigma}_l^2)$, where l is the length.
3. Calculate the required statistics of the age distribution.
4. Repeat steps, 1–3 1000 times.
5. Estimate of the c.v. of the statistics.
6. Repeat steps 1–5 for sample of size 500, 400, 300, 200, and 100.
7. Repeat steps 1–6 for the 6 length frequency distributions.

Table 7 contains the results. The mean values show no substantial bias, regardless of sample size. The precision with which any value can be determined decreased with sample size (as might be expected from the results presented for the precision with which length proportions can be obtained). The c.v.s when 400 or 500 fish were aged are less than 10% when the proportion of interest is greater than 0.2, and about 15% when the proportion is around 0.1.

Obtaining otoliths from more than 400 to 500 recreationally caught kahawai in any one region and year is likely to be impracticable. Smaller sample sizes will give estimates that are too imprecise.

4.3 Selecting a random sample of fish lengths and a subset of fish to age

The simulation in Section 4.2 suggested that 400 or 500 fish need to be aged. The next simulation follows the process likely to occur in practice. Recreational fishers are generally happy to have their landed fish measured, but nothing is known about their willingness to have otoliths removed, or to having the heads taken for subsequent removal of otoliths.

A random sample of fish is measured and a subset of these fish is aged leading to an age-length key that can be applied to the full sample of measured fish. Because the likely numbers of small and large fish in the recreational catch are small, some lengths may not appear in the aged sample. The number of length classes with no associated age, and the number of lengths with no age, are tallied at each step of the simulation.

1. Select a length sample of size N_l with replacement from the appropriate measured recreational length frequency.
2. Select fish for ageing, with probability N_a/N_l (N_a fish to be aged) using a random permutation of N_a 1s and (N_l - N_a) 0s. The length of these fish will be known.
3. Select an age (rounded to the nearest integer) from the normal distribution, $\mathrm{N}(\overline{a}_l, \overline{\sigma}_l^2)$, where l is the length of the fish to be aged.
4. Apply the age-length key so obtained to the whole length sample.
5. Calculate the required statistics.
6. Repeat steps 1–5 1000 times so that estimates of the c.v.s of the statistics can be found.
7. Repeat steps 1–6 for different values of N_l and N_a. The values of N_l used were 500, 1000, 1500, and 2000 and the values of N_a were 400 and 500.
8. Repeat for the other length frequencies.

Table 8 contains the results of this simulation. The numbers of length classes (and individual fish) that might not be aged can be large. The failure to age some of the older and larger kahawai introduces some (negative) bias particularly into the proportions of kahawai older than 14 years.

The ages of kahawai less than 25 cm can be guessed with reasonable accuracy from the fish length, so failing to age small fish is not of major consequence. Any kahawai with lengths between 25 and about 58 cm could be aged using the ages of fish with nearby lengths. The lack of age information for large fish is of greater importance, because recreational fishers tend to be concerned about the lack of large/old fish. The scanty evidence that is available suggests that the largest kahawai are quite young: one 71 cm kahawai caught off Kaikoura and included in the 1990–92 commercial catch sampling data was 11 years old; a few similar instances are known. In contrast, the oldest known kahawai was 26 years old, 61 cm FL, and caught by *Marine Countess* on 29 November 1973 in the Gisborne area (paper files of data collected by Dave Eggleston, Fisheries Research Division).

5. DISCUSSION

The results of the previous sections confirm the conclusion reached by Bradford (2000) based on a result derived by Thompson (1987) that 400–500 otoliths would need to be aged in each region of interest. Even so, such a sample size is marginal for estimating the changes in proportions of fish in an age class that might be of interest.

It is likely that considerably more kahawai will be available for length measurement than for otolith removal, so estimates of length proportions will be more precise.

All the statistics investigated will vary from year to year in any area through variations in fishing pressure, kahawai migrations, and variations in year class strength. So, although heavy fishing pressure usually reduces the mean age and length of a stock, these quantities can also decrease if a large cohort of young fish enters the fishery, or young fish move into an area from elsewhere. Conversely, either light fishing or a period of weak recruitment can lead to increasing mean age and length. Few large kahawai (over 60 cm) have been aged but there are indications that the largest fish may sometimes be relatively young (10–12 years, say) whereas most kahawai over 20 years tend to be close to $l_\infty \approx 55\,\mathrm{cm}$, indicating a wide spread in growth rates.

Hence, changes in individual age or length classes may not be of importance. Estimates of whether the whole size or age distribution has changed, how the change has occurred, and whether the change is in the same direction from year to year are needed. Such estimates are usually made using the Kolmogorov-Smirnov test for differences in the cumulative distribution functions (Stuart & Ord

1991). This test nearly always gives a significant result for fish size distributions whether or not the change is important from a stock dynamics view point. Possibly the best approach is to examine the differences in cumulative distribution function by eye as was done, for example, by Bradford (1999) when comparing various kahawai size distributions.

In the end, devising an appropriate test depends upon the question being asked. In this case, the aim is to monitor the kahawai stock, which can be interpreted to mean looking for signals of deleterious change in a population. Such signals are likely to be sustained low levels of catch and reductions in older age classes in the catch.

Kahawai have apparently been in lower numbers around much of the South Island during most of the 1990s than they were in the early 1980s. It is unclear whether this is due to fishing pressure or to environmental changes. Local abundance of kahawai has almost certainly dropped in areas such as the Motu River mouth, but such changes may have arisen because the conditions in the area may no longer be suitable to support kahawai.

6. SURVEY DESIGN AND COST

The details of the design parameters and costing of the boat ramp surveys required in each region are given in Appendices A and B.

As many as possible of the kahawai landed should be measured for length, and if possible, weighed. If the fisher is willing, the kahawai heads should be removed. Otoliths would be removed later while the head is suitably constrained (removing kahawai otoliths is, apparently, a somewhat messy operation). Sexing the kahawai would be desirable but not essential as kahawai growth shows little sex dependence (Bradford 1998). The survey forms should allow for the collection of harvest rate information, though measuring and head removal should have higher priority.

To collect less than about 500 fish heads per region would lead to data of little use. If the survey were to be reduced in size, it should be carried out in a limited number of areas. Some factors that might be considered and a suggested priority (highest = 1) are given below. The factors and priorities indicate a personal bias and are not necessarily those of the Pelagic Working Group or the Ministry of Fisheries.

Region	Factors	Priority
KAH 9	Lower cost area; indications of considerable kahawai movement in this area (Bradford 1998) and variable size distributions (Bradford 2000); most recreation fishing is in the harbours and the adult population may be poorly sampled; interviewers likely to be easily available.	1
Bay of Plenty	Lower cost area; important kahawai area; population appears stable in recent years but kahawai density changes; interviewers probably available.	2
KAH 3	High cost area; possible reductions in abundance in southern parts of the area; Tasman and Golden Bays appear to be nursery areas; important to monitor this area, but difficult to survey adequately; large size; interviewers hard to obtain in parts of the area.	3
East Northland	Moderate cost area; probably an area with considerable kahawai movement; interviewers more difficult to obtain.	4
Hauraki Gulf	Higher cost area; mainly small kahawai; low kahawai density in the area; large number of recreational fishers; interviewers likely to be available.	5
KAH 2	Lower cost area if long interview periods used; little recent information, but fishery appears to be healthy; finding suitable interviewers could be difficult.	6

The cost estimate for a survey covering the whole country is $650 000–950 000 per year with the regional surveys varying between $90 000 and $180 000.

The cost of preparing and analysing 500 otoliths is $8000–14 000 per region and is a relatively minor part of the cost. The Pelagic Working Group suggested that otoliths be collected every three years with lengths measured annually. The small marginal cost of the ageing shows there is little point in setting up a boat ramp survey to measure the kahawai lengths without also measuring the age. Further, if ages are not measured annually, any information about the progression of year classes though the recreational catch would be severely downgraded. It is an open question whether the age information collected by ageing at three-year intervals would be any more reliable than the ageing method used in this report. (While searching through Dave Eggleston's files for the details of the oldest kahawai known, it was noticed that the commercial catches in the mid1970s contained more small kahawai than at present. As many of these fish were aged, the age-length information for smaller kahawai could be improved by the addition of some of these data.)

The organisation of the survey, the large number of interview sessions required, and the subsequent data entry are the major survey costs. The first two of these would be about the same if the survey had other objectives, for example, collecting catch rate and length information for recreationally caught snapper. The data entry costs would increase somewhat with other objectives because there would be more interview data to process, but some of the information required would be the same.

6.1 Timing of the survey

The Ministry of Fisheries requested that this work should be completed in time to present the results to the Pelagic Working Group in September 2000. If the Ministry approved the survey, it was then scheduled to start on 1 December 2000. There would be some delay before a contract was let (there are logistical difficulties in meeting this requirement). The science provider then has to carry out the preliminary organisation of the survey including finding and training the interviewers. This would take a minimum elapsed time of 2–3 months.

6.2 Relation to other projects

As suggested above, other objectives could be added for a relatively small marginal increase in cost of the recreational boat ramp surveys.

The work in project REC1999/03 on the feasibility of annual recreational catch estimates for snapper and rock lobster has not yet investigated the feasibility of making a low cost estimate of the recreational fishing effort for snapper each year. Such an estimate of effort would be multiplied by a catch rate estimate from boat ramp surveys to obtain a total catch estimate. However, it is unlikely that a sufficiently accurate measure of effort can be produced at low cost. There is obviously merit in getting an estimate of the size distribution of the recreational snapper catch each year, but such an estimate by itself is unlikely to fulfil the requirements of the Snapper Working Group.

7. RECOMMENDATIONS

We do not recommend a recreational survey solely for estimating the length and age distributions of the kahawai catch because of the cost of running such a survey relative to the information that would be obtained. Estimation of the kahawai age distribution should be undertaken within an overall recreational fishing survey (see below).

If a kahawai survey were to be recommended by the Pelagic Working Group or the Ministry of Fisheries, it can not be undertaken before the summer of 2001–02 because of the organisational work that has to be undertaken before the survey.

The survey costs indicate that the Pelagic Working Group suggestion that ageing be done every three years is not cost effective if lengths are measured annually.

If the Ministry of Fisheries decides that a "feasibility" survey be undertaken, it should take place in one of the regions rather than be of a reduced effort in all regions. The regions with highest priority are KAH 9 (west coast of the North Island) and the Bay of Plenty.

The main aim of widespread marine recreational fishing surveys in New Zealand is to provide estimates of the recreational harvests of those species where the recreational harvest is greater than 10% of the total. These are mainly North region Fishstocks, for example, SNA 1 and 8, CRA 2, and KAH 1 and 9, but include some of the South Island blue cod Fishstocks.

We recommend that the Ministry of Fisheries reconsiders some of its medium term requirements for recreational research and investigates the possibility of a North region survey run between the four yearly national surveys. Boat ramp surveys could form part of each of these surveys and would give size distributions and catch rate data for snapper and kahawai, in particular. Harvest estimates would probably come from a diary survey. Bradford (unpubl. report on project REC1999/03) has estimated the numbers of diarists that would be required to make sufficiently precise estimates of the recreational harvest in SNA 1 and KAH 1 and these numbers mean that the North region surveys should be of about the same size as previously run surveys. Such a survey series would indicate any changes in recreational catch, size distribution, and age distribution (if otoliths were collected) over time and provide some information for monitoring the kahawai stock. The progress of individual year classes through the recreational catch would not be followed in detail.

We further recommend that the Ministry investigates what other information (such as age data) might be collected during recreational boat ramp surveys.

8. ACKNOWLEDGMENTS

I thank Chris Francis (NIWA, Wellington) for advice on how to tackle the question originally posed by the Ministry of Fisheries, Alistair Dunn (NIWA, Wellington) for discussions on confidence intervals for proportions and provision of a routine to calculate the exact confidence intervals, Dave Gilbert (NIWA, Wellington) for useful comments on a draft of this report and his suggestions leading to the calculations in Table 4, and Mike Beardsell (NIWA, Wellington) for editorial comments. This work was funded under Ministry of Fisheries project MOF1999/04I.

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Table 1: Definitions of the regions used.

Code		Definition
BPLE	Bay of Plenty	Cape Runaway to Cape Colville
HAGU	Hauraki Gulf	Cape Colville to Cape Rodney
ENLD	East Northland	Cape Rodney to North Cape, including Mokohinau Is., Little Barrier Is., and Great Barrier Is.
KAH 9	QMA 9	North Cape to Tirau Point
KAH 3	QMAs 3–8	All inshore waters around the South Island and Titahi Bay to Tirau Point
KAH 2	QMA 2	Cape Runaway to Titahi Bay

Table 2: Properties of length distributions. *N*, number of measured lengths; $\bar{L}$, mean length (cm), c.v. is expressed as a percentage.

				Proportion of lengths											
				> 50 cm		> 51 cm		> 52 cm		> 53 cm		> 54 cm		> 55 cm	
Region	*N*	$\bar{L}$	c.v.	*P*	c.v.	*P*	c.v.	*P*	c.v.	*P*	c.v.	*P*	c.v.	*P*	c.v.
BPLE	6 524	43.28	0.3	0.248	2.2	0.204	2.4	0.158	2.9	0.125	3.3	0.087	4.0	0.058	5.0
HAGU	2 633	37.79	0.5	0.122	5.2	0.101	5.8	0.082	6.5	0.070	7.1	0.052	8.3	0.039	9.7
ENLD	2 110	44.48	0.4	0.237	3.9	0.181	4.6	0.133	5.6	0.099	6.6	0.067	8.1	0.050	9.5
KAH 9	6 120	40.40	0.3	0.120	3.5	0.091	4.1	0.064	4.9	0.050	5.6	0.039	6.3	0.025	8.0
KAH 3	928	36.53	0.8	0.080	11.2	0.072	11.2	0.057	13.3	0.045	15.1	0.029	19.0	0.020	22.7
KAH 2	1 503	44.26	0.5	0.321	3.8	0.273	3.8	0.196	5.2	0.128	6.7	0.067	9.7	0.038	13.0

Table 3: 95% confidence intervals for five values of proportion, *P*, calculated for eight values of *N*. Calculations are made using the normal approximation (*A*) and the exact value (*E*).

		P									
		0.25		0.20		0.15		0.10		0.05	
N		lower	upper	lower	upper	lower	upper	lower	Upper	lower	upper
2 000	*A*	0.231	0.269	0.182	0.218	0.134	0.166	0.087	0.113	0.040	0.060
2 000	*E*	0.231	0.270	0.183	0.218	0.135	0.166	0.087	0.114	0.041	0.060
1 500	*A*	0.228	0.272	0.180	0.220	0.132	0.168	0.085	0.115	0.039	0.061
1 500	*E*	0.228	0.273	0.180	0.221	0.132	0.169	0.085	0.116	0.040	0.062
1 000	*A*	0.223	0.277	0.175	0.225	0.128	0.172	0.081	0.119	0.036	0.064
1 000	*E*	0.223	0.278	0.176	0.226	0.128	0.174	0.082	0.120	0.037	0.065
500	*A*	0.212	0.288	0.165	0.235	0.119	0.181	0.074	0.126	0.031	0.069
500	*E*	0.213	0.290	0.166	0.238	0.120	0.184	0.075	0.130	0.033	0.073
400	*A*	0.208	0.292	0.161	0.239	0.115	0.185	0.071	0.129	0.029	0.071
400	*E*	0.208	0.295	0.162	0.243	0.116	0.189	0.072	0.134	0.031	0.076
300	*A*	0.201	0.299	0.155	0.245	0.110	0.190	0.066	0.134	0.025	0.075
300	*E*	0.202	0.303	0.156	0.250	0.112	0.196	0.068	0.140	0.028	0.081
200	*A*	0.190	0.310	0.145	0.255	0.101	0.199	0.058	0.142	0.020	0.080
200	*E*	0.192	0.316	0.147	0.262	0.104	0.207	0.062	0.150	0.024	0.090
100	*A*	0.165	0.335	0.122	0.278	0.080	0.220	0.041	0.159	0.007	0.093
100	*E*	0.169	0.347	0.127	0.292	0.086	0.235	0.049	0.176	0.016	0.113

Table 4: Detectable differences in proportions. A value of *P* that is less than P_L or greater than P_U has at least a 95% chance of being detected as different from P_0 using a two-sided test. Values obtained by simulation.

N	P_0	P_L	P_U
2 000	0.25	0.197	0.306
1 500	0.25	0.193	0.315
1 000	0.25	0.179	0.331
500	0.25	0.151	0.363
2 000	0.20	0.152	0.252
1 500	0.20	0.146	0.261
1 000	0.20	0.135	0.275
500	0.20	0.089	0.311
2 000	0.15	0.108	0.197
1 500	0.15	0.102	0.204
1 000	0.15	0.094	0.221
500	0.15	0.072	0.246
2 000	0.10	0.065	0.141
1 500	0.10	0.061	0.146
1 000	0.10	0.054	0.160
500	0.10	0.039	0.184
2 000	0.05	0.026	0.081
1 500	0.05	0.023	0.087
1 000	0.05	0.018	0.096
500	0.05	0.010	0.121

Table 5: **Minimum (min.), maximum (max.), median (med.), mean, and standard deviation (s.d.) of the measured ages (A_L) at length (L), including interpolated values, and the values of mean and standard deviation assumed.**

	Measured A_L					Assumed A_L	
L	Min.	Max.	Med.	Mean	s.d.	Mean	s.d.
15						1.400	0.213
16						1.500	0.238
17						1.600	0.262
18						1.700	0.287
19						1.800	0.312
20						1.900	0.337
21						2.000	0.362
22						2.100	0.388
23						2.200	0.414
24						2.300	0.441
25						2.405	0.468
26	2	3	2.5	2.500	0.707	2.581	0.495
27	3	4	3.0	3.333	0.577	3.013	0.523
28	3	4	3.0	3.250	0.500	3.250	0.552
29	3	4	3.0	3.182	0.405	3.261	0.581
30	3	5	4.0	3.714	0.535	3.345	0.611
31	3	4	3.0	3.452	0.506	3.459	0.642
32	3	6	4.0	3.567	0.621	3.530	0.673
33	3	5	3.0	3.489	0.545	3.596	0.705
34	3	6	4.0	3.664	0.658	3.661	0.738
35	3	5	4.0	3.716	0.569	3.742	0.789
36	3	6	4.0	3.803	0.734	3.875	0.847
37	3	7	4.0	3.835	0.764	4.052	0.912
38	3	6	4.0	4.167	0.774	4.234	0.984
39	3	6	5.0	4.540	0.714	4.395	1.063
40	3	7	5.0	4.612	0.717	4.638	1.148
41	4	6	5.0	4.903	0.754	4.894	1.235
42	3	8	5.0	4.795	0.934	5.174	1.324
43	3	9	5.0	5.000	0.965	5.450	1.414
44	4	9	5.0	5.417	0.996	5.726	1.503
45	4	9	6.0	6.000	1.019	6.000	1.592
46	4	12	6.0	6.489	1.521	6.686	1.681
47	5	15	7.0	7.272	2.069	7.385	1.768
48	5	17	8.0	8.028	2.153	8.084	1.856
49	5	18	8.0	8.824	2.530	8.824	1.943
50	5	18	10.0	9.581	2.564	9.619	2.031
51	5	19	10.0	10.382	2.826	10.514	2.119
52	5	19	11.0	11.465	2.931	11.360	2.207
53	6	19	12.0	12.508	2.881	12.336	2.294
54	6	20	13.0	13.050	2.779	13.047	2.380
55	7	23	14.0	14.024	2.767	13.765	2.464
56	9	23	14.0	14.479	2.596	14.488	2.543
57	9	24	15.0	15.218	2.784	15.214	2.592
58	10	21	16.0	16.050	2.580	15.607	2.638
59	10	23	16.0	16.351	3.225	16.027	2.682
60	16	20	18.0	16.800	3.000	16.468	2.723
61	13	20	17.0	17.000	3.000	17.000	2.763
62						17.000	2.801
63						17.000	2.838
64						17.000	2.874
65						17.000	2.909
66						17.000	2.942
67						17.000	2.975
68						17.000	3.006
69						17.000	3.037
70						17.000	3.066
71						17.000	3.094
72						17.000	3.122
73						17.000	3.149
74						17.000	3.174
75						17.000	3.199

Table 6: Properties of age distributions. The length of each fish was assumed known and the age was drawn 100 times from an assumed age at length distribution. The mean and c.v. (%) from the bootstrap distribution are given. $\bar{A}$ is the mean age. The c.v.s represent the variability of age at length and sampling variability. BPLE, Bay of Plenty; HAGU, Hauraki Gulf; ENLD, East Northland.

				Proportions of ages											
				3 y		4 y		5 y		>10 y		>12 y		>14 y	
	N	$\bar{A}$	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
BPLE	6 524	7.21	0.3	0.142	2.5	0.166	2.5	0.113	3.1	0.224	1.3	0.135	2.1	0.070	3.5
HAGU	2 633	5.37	0.5	0.260	2.9	0.258	3.0	0.118	5.1	0.112	2.9	0.072	4.2	0.040	6.8
ENLD	2 110	7.53	0.5	0.112	5.0	0.135	5.1	0.107	5.8	0.225	2.6	0.123	3.9	0.061	6.2
KAH 9	6 120	6.02	0.3	0.189	2.3	0.193	2.4	0.124	3.2	0.123	2.2	0.064	3.4	0.031	5.4
KAH 3	928	4.89	0.8	0.273	5.0	0.277	5.0	0.119	8.4	0.077	6.0	0.047	9.2	0.025	14.9
KAH 2	1 503	7.67	0.6	0.130	5.7	0.156	5.4	0.103	7.0	0.275	2.6	0.158	4.5	0.069	8.0

Table 7: Properties of age distributions. *N* fish lengths are drawn 1000 times from the length distribution for each region, simulated ages are then assigned to the fish. The mean and c.v. (%) from the bootstrap distribution are given. $\overline{A}$ is the mean age.

			Proportions of ages											
			3 y		4 y		5 y		>10 y		>12 y		>14 y	
N	$\overline{A}$	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
Bay of Plenty														
1 000	7.21	1.8	0.142	7.9	0.166	7.0	0.114	8.6	0.225	5.8	0.136	7.9	0.070	11.2
500	7.21	2.7	0.142	10.8	0.166	9.7	0.114	13.0	0.224	8.9	0.136	11.7	0.070	16.9
400	7.22	2.7	0.141	12.6	0.167	10.8	0.114	14.4	0.226	8.9	0.136	12.2	0.070	18.1
300	7.21	3.2	0.141	13.6	0.167	12.9	0.112	16.4	0.225	10.1	0.136	14.2	0.070	21.4
200	7.19	4.1	0.142	17.3	0.166	15.7	0.114	19.2	0.222	12.9	0.135	18.2	0.069	25.9
100	7.21	5.9	0.141	25.7	0.167	21.8	0.112	27.5	0.224	18.8	0.136	26.4	0.069	37.7
Hauraki Gulf														
1 000	5.37	2.1	0.260	5.4	0.258	5.3	0.118	8.6	0.111	8.8	0.071	11.3	0.040	15.4
500	5.38	2.9	0.260	7.4	0.259	7.5	0.117	11.9	0.112	12.1	0.072	16.1	0.041	22.1
400	5.38	3.4	0.260	8.6	0.258	8.4	0.118	14.1	0.113	14.4	0.072	18.2	0.040	24.0
300	5.38	3.8	0.261	9.4	0.257	9.7	0.117	16.0	0.113	15.4	0.072	20.2	0.040	28.0
200	5.37	4.7	0.261	12.0	0.258	11.9	0.116	18.8	0.112	19.6	0.072	25.4	0.041	34.4
100	5.37	7.1	0.261	17.7	0.261	17.0	0.116	28.5	0.112	29.0	0.071	36.8	0.041	50.2
East Northland														
1 000	7.52	1.7	0.113	9.0	0.135	8.0	0.107	9.1	0.224	5.9	0.123	8.3	0.060	12.5
500	7.52	2.4	0.112	13.0	0.136	11.3	0.108	12.5	0.224	8.6	0.123	12.2	0.060	17.4
400	7.54	2.7	0.114	14.4	0.136	12.8	0.107	14.5	0.226	9.6	0.125	13.4	0.062	19.8
300	7.53	3.0	0.113	16.1	0.136	14.3	0.107	16.5	0.224	10.2	0.123	15.5	0.060	22.7
200	7.53	3.7	0.111	20.2	0.137	18.0	0.108	19.7	0.225	13.1	0.123	19.0	0.061	27.2
100	7.54	5.3	0.113	28.6	0.135	24.1	0.108	28.0	0.227	18.4	0.125	26.3	0.062	38.7
KAH 9														
1 000	6.01	1.9	0.189	6.3	0.193	6.5	0.124	8.8	0.122	8.5	0.064	11.6	0.030	17.2
500	6.02	2.6	0.188	9.1	0.193	9.1	0.123	11.7	0.123	12.3	0.064	17.9	0.031	25.8
400	6.02	2.9	0.189	10.1	0.193	9.8	0.123	13.2	0.124	13.5	0.064	19.1	0.031	27.3
300	6.01	3.5	0.189	12.3	0.193	11.8	0.123	15.1	0.123	15.8	0.064	22.5	0.031	33.8
200	6.02	4.1	0.189	14.2	0.195	14.3	0.122	18.9	0.122	18.5	0.063	27.1	0.031	40.0
100	6.01	5.8	0.189	20.6	0.193	20.3	0.123	27.6	0.123	26.3	0.063	39.0	0.031	55.4
KAH 3														
1 000	4.89	2.0	0.273	5.2	0.276	5.2	0.119	8.6	0.077	10.7	0.047	14.4	0.025	20.1
500	4.90	2.9	0.272	7.1	0.276	7.0	0.119	11.7	0.078	15.6	0.048	20.0	0.025	28.1
400	4.89	3.1	0.273	8.3	0.276	7.9	0.120	13.2	0.077	16.7	0.047	21.5	0.025	31.6
300	4.89	3.8	0.272	9.3	0.277	9.2	0.119	16.4	0.077	21.0	0.048	27.2	0.025	36.7
200	4.89	4.5	0.273	11.7	0.276	11.1	0.118	19.7	0.077	24.1	0.047	31.1	0.024	44.0
100	4.89	6.3	0.273	16.8	0.275	16.7	0.119	26.9	0.076	34.2	0.047	44.2	0.025	62.5
KAH 2														
1 000	7.67	1.7	0.129	8.2	0.156	7.6	0.104	9.3	0.276	5.3	0.158	7.3	0.069	11.4
500	7.67	2.5	0.130	11.4	0.156	10.3	0.104	13.8	0.276	7.3	0.158	10.6	0.069	16.5
400	7.67	2.7	0.130	12.6	0.155	11.8	0.104	15.2	0.276	7.8	0.157	11.4	0.069	17.9
300	7.68	3.2	0.130	14.8	0.156	13.9	0.103	17.4	0.277	9.3	0.158	13.5	0.069	21.8
200	7.68	3.9	0.130	16.9	0.156	16.2	0.104	20.6	0.276	11.7	0.158	16.3	0.069	25.5
100	7.69	5.4	0.129	25.5	0.154	23.7	0.103	29.3	0.278	16.2	0.159	23.0	0.070	36.1

Table 8: Resampling results using a simulated age length key (mean and c.v. (%)). N_L number of fish lengths; N_A number of aged fish; N_{LC-} number of length classes with no age; N_{L-} number of fish not aged; $\overline{L}$ mean of sampled lengths; $\overline{A}$ mean age of sample.

Bay of Plenty

		N_{CL-}		N_{L-}		$\overline{L}$		$\overline{A}$	
N_L	N_A	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
500	500	0.00		0.00		43.29	0.9	7.21	2.5
500	400	1.14	87.8	1.27	93.3	43.25	1.0	7.19	2.7
1 000	500	3.63	48.3	5.24	59.1	43.28	0.7	7.20	2.0
1 000	400	4.65	39.6	7.74	52.8	43.27	0.7	7.19	2.1
1 500	500	5.53	35.5	10.19	47.5	43.27	0.5	7.20	1.7
1 500	400	6.71	31.5	14.30	46.0	43.28	0.5	7.19	1.9
2 000	500	6.94	30.8	15.19	44.8	43.28	0.5	7.20	1.6
2 000	400	8.14	26.9	21.05	45.0	43.28	0.4	7.19	1.8

		Proportion of ages											
		3 y		4 y		5 y		>10 y		>12 y		>14 y	
N_L	N_A	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
500	500	0.142	11.2	0.166	9.7	0.113	12.8	0.224	8.1	0.136	11.1	0.070	16.1
500	400	0.142	12.0	0.167	11.2	0.114	13.7	0.223	9.0	0.134	12.4	0.068	17.6
1 000	500	0.142	10.0	0.166	9.6	0.115	12.2	0.223	7.1	0.134	10.0	0.068	15.0
1 000	400	0.142	11.3	0.168	10.8	0.115	13.7	0.222	7.6	0.133	11.1	0.068	17.2
1 500	500	0.142	10.2	0.167	9.3	0.113	12.1	0.222	6.4	0.134	9.3	0.068	15.0
1 500	400	0.142	11.2	0.168	10.8	0.114	13.3	0.222	7.2	0.133	10.6	0.067	17.4
2 000	500	0.142	10.4	0.167	9.1	0.115	11.5	0.223	6.1	0.133	8.7	0.068	14.5
2 000	400	0.143	11.9	0.168	10.6	0.115	13.2	0.222	6.8	0.132	10.7	0.067	16.6

Hauraki Gulf

		N_{CL-}		N_{L-}		$\overline{L}$		$\overline{A}$	
N_L	N_A	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
500	500	0.00		0.00		37.78	1.1	5.37	3.0
500	400	1.25	85.4	1.42	91.4	37.76	1.1	5.35	3.1
1 000	500	3.98	43.7	5.96	55.0	37.79	0.8	5.34	2.3
1 000	400	5.24	36.2	9.03	48.5	37.78	0.8	5.32	2.6
1 500	500	5.99	32.3	11.65	44.7	37.79	0.6	5.34	2.1
1 500	400	7.15	29.8	16.08	45.6	37.78	0.6	5.32	2.1
2 000	500	7.17	27.6	17.33	43.6	37.81	0.5	5.34	1.9
2 000	400	8.45	25.6	23.95	41.3	37.80	0.6	5.32	2.2

		Proportion of ages											
		3 y		4 y		5 y		>10 y		>12 y		>14 y	
N_L	N_A	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
500	500	0.261	7.4	0.258	7.7	0.118	12.6	0.112	12.5	0.071	16.2	0.040	21.7
500	400	0.261	8.1	0.258	8.3	0.118	13.4	0.110	13.5	0.070	17.5	0.039	23.3
1 000	500	0.262	7.1	0.259	7.4	0.119	11.7	0.110	10.7	0.069	14.3	0.038	20.7
1 000	400	0.263	8.0	0.259	8.0	0.119	13.0	0.108	11.4	0.067	16.2	0.037	24.3
1 500	500	0.263	6.9	0.259	7.4	0.118	11.7	0.109	10.1	0.068	13.9	0.037	20.5
1 500	400	0.262	7.9	0.261	8.5	0.120	13.7	0.107	10.9	0.067	15.6	0.036	23.6
2 000	500	0.262	7.1	0.260	7.3	0.119	12.1	0.109	9.1	0.068	13.5	0.037	19.3
2 000	400	0.263	7.9	0.261	8.1	0.119	13.8	0.107	10.8	0.066	15.3	0.035	23.8

Table 8 — continued

East Northland

N_L	N_A	N_{CL-} mean	N_{CL-} c.v.	N_{L-} mean	N_{L-} c.v.	$\bar{L}$ mean	$\bar{L}$ c.v.	$\bar{A}$ mean	$\bar{A}$ c.v.
500	500	0.00		0.00		44.49	0.8	7.53	2.2
500	400	1.01	96.9	1.16	103.1	44.45	0.8	7.51	2.5
1 000	500	2.75	52.7	4.49	65.5	44.49	0.6	7.52	1.9
1 000	400	3.77	43.3	7.22	57.7	44.48	0.6	7.51	2.0
1 500	500	3.96	42.2	8.82	57.0	44.49	0.5	7.52	1.8
1 500	400	4.94	35.8	13.04	54.7	44.48	0.5	7.50	1.8
2 000	500	4.69	36.4	13.59	53.4	44.48	0.4	7.51	1.5
2 000	400	5.68	32.0	19.21	53.7	44.48	0.4	7.51	1.7

		Proportion of ages											
		3 y		4 y		5 y		>10 y		>12 y		>14 y	
N_L	N_A	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
500	500	0.113	12.7	0.135	11.0	0.107	13.2	0.225	8.0	0.124	11.8	0.061	17.0
500	400	0.114	14.0	0.137	12.4	0.108	14.0	0.224	9.1	0.122	13.0	0.059	19.5
1 000	500	0.112	12.1	0.136	11.0	0.109	12.9	0.224	7.0	0.122	10.9	0.059	17.1
1 000	400	0.112	13.7	0.137	12.1	0.108	13.8	0.224	7.7	0.121	11.8	0.058	18.7
1 500	500	0.113	12.2	0.136	11.1	0.108	12.7	0.224	6.9	0.121	10.7	0.059	16.3
1 500	400	0.113	12.8	0.137	12.4	0.108	13.9	0.223	7.4	0.120	11.2	0.058	18.5
2 000	500	0.113	12.1	0.136	10.7	0.109	12.1	0.223	6.4	0.121	10.0	0.059	16.0
2 000	400	0.112	12.7	0.138	11.4	0.109	13.8	0.222	7.2	0.120	10.9	0.058	17.5

KAH 9

N_L	N_A	N_{CL-} mean	N_{CL-} c.v.	N_{L-} mean	N_{L-} c.v.	$\bar{L}$ mean	$\bar{L}$ c.v.	$\bar{A}$ mean	$\bar{A}$ c.v.
500	500	0.00		0.00		40.38	1.0	6.01	2.7
500	400	1.03	94.6	1.17	101.0	40.38	1.0	6.00	2.6
1 000	500	3.03	53.2	4.55	66.2	40.40	0.7	5.99	2.1
1 000	400	3.98	45.2	6.91	59.8	40.39	0.7	5.98	2.1
1 500	500	4.57	40.1	8.86	58.0	40.39	0.6	5.98	1.8
1 500	400	5.65	34.2	13.18	52.5	40.41	0.6	5.98	1.9
2 000	500	5.81	32.1	13.75	50.3	40.38	0.5	5.98	1.7
2 000	400	6.94	28.8	18.78	47.5	40.39	0.5	5.97	1.8

		Proportion of ages											
		3 y		4 y		5 y		>10 y		>12 y		>14 y	
N_L	N_A	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
500	500	0.189	9.3	0.192	9.1	0.124	11.8	0.122	12.1	0.064	17.1	0.031	25.0
500	400	0.190	9.8	0.194	9.6	0.123	13.8	0.121	12.5	0.063	18.6	0.030	28.0
1 000	500	0.189	9.1	0.194	8.6	0.124	11.7	0.120	10.4	0.061	15.9	0.029	24.6
1 000	400	0.190	10.1	0.194	9.9	0.125	13.0	0.119	11.6	0.061	17.2	0.028	26.8
1 500	500	0.190	8.8	0.194	8.5	0.124	11.5	0.120	9.9	0.061	15.1	0.029	24.0
1 500	400	0.189	9.6	0.195	9.4	0.125	13.3	0.119	10.7	0.060	16.3	0.027	26.5
2 000	500	0.190	8.1	0.195	8.9	0.124	11.1	0.119	9.5	0.061	14.6	0.028	23.8
2 000	400	0.190	9.6	0.196	9.4	0.124	13.4	0.118	10.5	0.059	16.0	0.027	27.9

Table 8 — continued

KAH 3

N_L	N_A	N_{CL} mean	N_{CL} c.v.	N_L mean	N_L c.v.	$\bar{L}$ mean	$\bar{L}$ c.v.	$\bar{A}$ mean	$\bar{A}$ c.v.
500	500	0.00			0.00	36.55	1.0	4.90	2.9
500	400	0.76	115.3	0.89	125.5	36.52	1.1	4.87	3.0
1 000	500	1.99	61.6	3.29	78.6	36.53	0.7	4.86	2.3
1 000	400	2.79	50.7	5.86	69.8	36.52	0.8	4.85	2.5
1 500	500	2.82	48.1	6.69	71.4	36.54	0.6	4.86	2.0
1 500	400	3.65	41.1	10.21	64.5	36.53	0.6	4.84	2.2
2 000	500	3.32	42.8	10.09	69.0	36.54	0.5	4.85	1.9
2 000	400	4.04	36.4	14.70	62.9	36.53	0.5	4.84	2.0

		Proportion of ages											
		3 y		4 y		5 y		>10 y		>12 y		>14 y	
N_L	N_A	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
500	500	0.273	7.3	0.275	7.3	0.118	12.5	0.078	15.7	0.048	20.8	0.025	27.2
500	400	0.273	8.2	0.277	8.1	0.119	13.4	0.076	16.9	0.046	21.9	0.024	31.9
1 000	500	0.273	6.8	0.277	7.0	0.119	11.9	0.075	13.4	0.045	18.0	0.023	27.9
1 000	400	0.275	7.9	0.279	7.9	0.119	13.5	0.073	14.8	0.044	20.3	0.022	30.3
1 500	500	0.274	7.1	0.277	6.9	0.120	11.4	0.074	12.8	0.044	18.2	0.022	26.9
1 500	400	0.275	7.9	0.278	7.6	0.119	13.3	0.072	13.9	0.043	20.0	0.021	32.3
2 000	500	0.275	6.7	0.277	6.9	0.119	11.7	0.074	11.9	0.044	16.7	0.022	27.3
2 000	400	0.275	7.8	0.278	7.8	0.120	13.5	0.073	13.2	0.044	19.0	0.022	30.2

KAH 2

N_L	N_A	N_{CL} mean	N_{CL} c.v.	N_L mean	N_L c.v.	$\bar{L}$ mean	$\bar{L}$ c.v.	$\bar{A}$ mean	$\bar{A}$ c.v.
500	500	0.00		0.00		44.25	0.9	7.67	2.5
500	400	0.60	129.0	0.67	137.0	44.27	0.9	7.67	2.5
1 000	500	1.99	64.7	2.93	78.5	44.26	0.6	7.66	1.9
1 000	400	2.83	48.6	4.64	64.3	44.28	0.6	7.67	2.0
1 500	500	3.17	45.4	6.06	67.2	44.26	0.5	7.66	1.6
1 500	400	3.85	39.2	8.11	60.7	44.27	0.5	7.66	1.8
2 000	500	3.93	39.6	8.98	63.9	44.26	0.4	7.66	1.6
2 000	400	4.54	35.3	11.89	57.1	44.25	0.4	7.65	1.6

		Proportion of ages											
		3 y		4 y		5 y		>10 y		>12 y		>14 y	
N_L	N_A	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
500	500	0.130	11.7	0.156	10.4	0.104	13.2	0.276	7.4	0.158	10.5	0.069	16.1
500	400	0.130	12.5	0.155	11.9	0.104	14.9	0.276	7.6	0.157	10.9	0.069	18.0
1 000	500	0.130	10.7	0.156	9.7	0.104	12.9	0.275	6.0	0.156	9.0	0.068	15.5
1 000	400	0.129	11.9	0.156	10.9	0.104	14.4	0.275	6.7	0.157	10.4	0.067	18.1
1 500	500	0.129	11.1	0.156	9.8	0.104	12.9	0.275	5.7	0.157	9.1	0.067	15.3
1 500	400	0.130	12.2	0.156	11.2	0.105	14.6	0.275	6.1	0.156	10.0	0.067	17.2
2 000	500	0.130	10.4	0.157	9.4	0.104	13.0	0.274	5.3	0.155	8.4	0.067	15.5
2 000	400	0.129	11.8	0.157	11.4	0.104	13.9	0.273	6.1	0.154	9.3	0.066	16.9

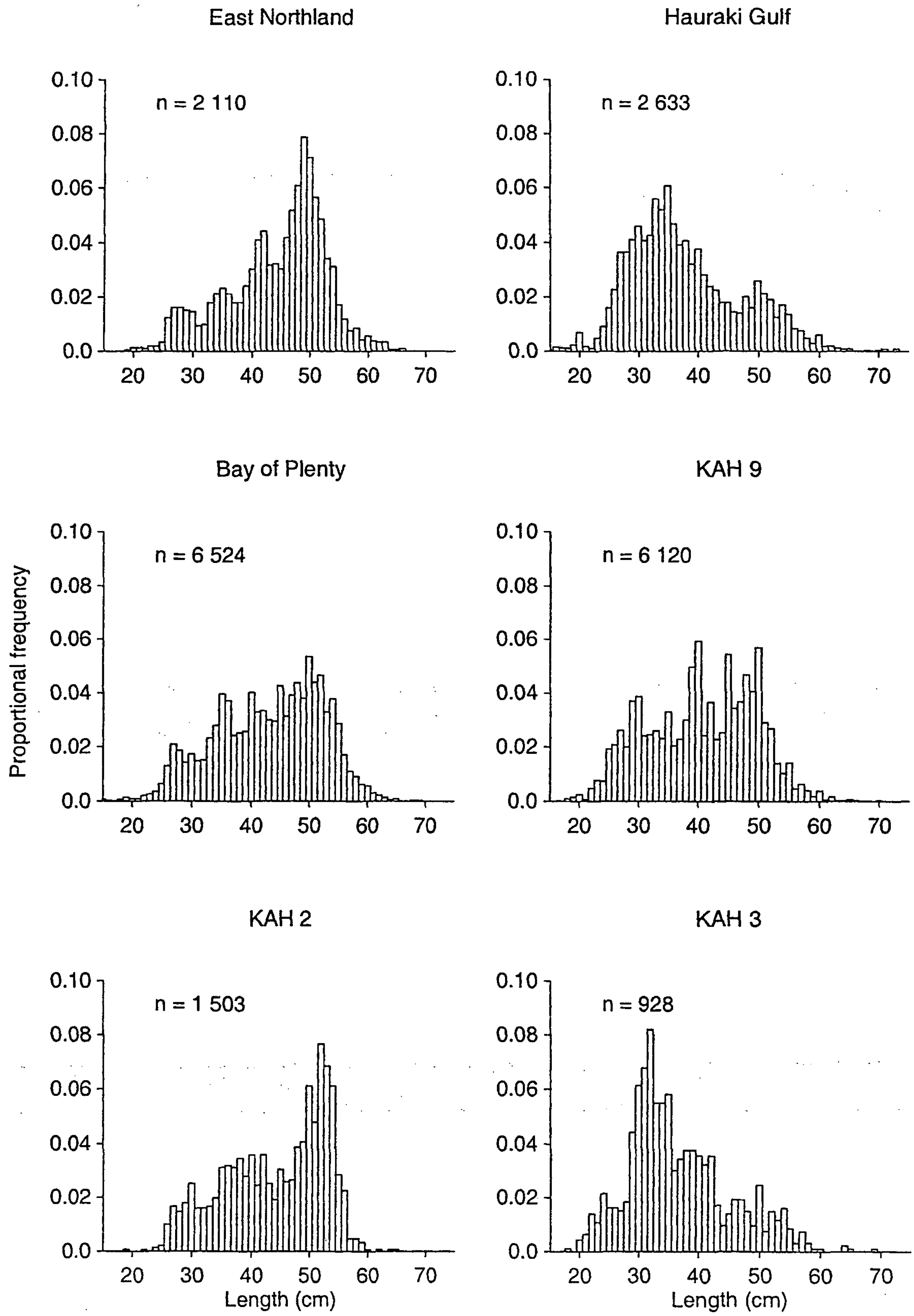

Figure 1: Amalgamated kahawai length frequencies used in the simulations. Length measurements are taken from the 1991 and 1994 North region survey, the 1992–93 Central region survey, and the 1996 national survey of marine recreational fishing.

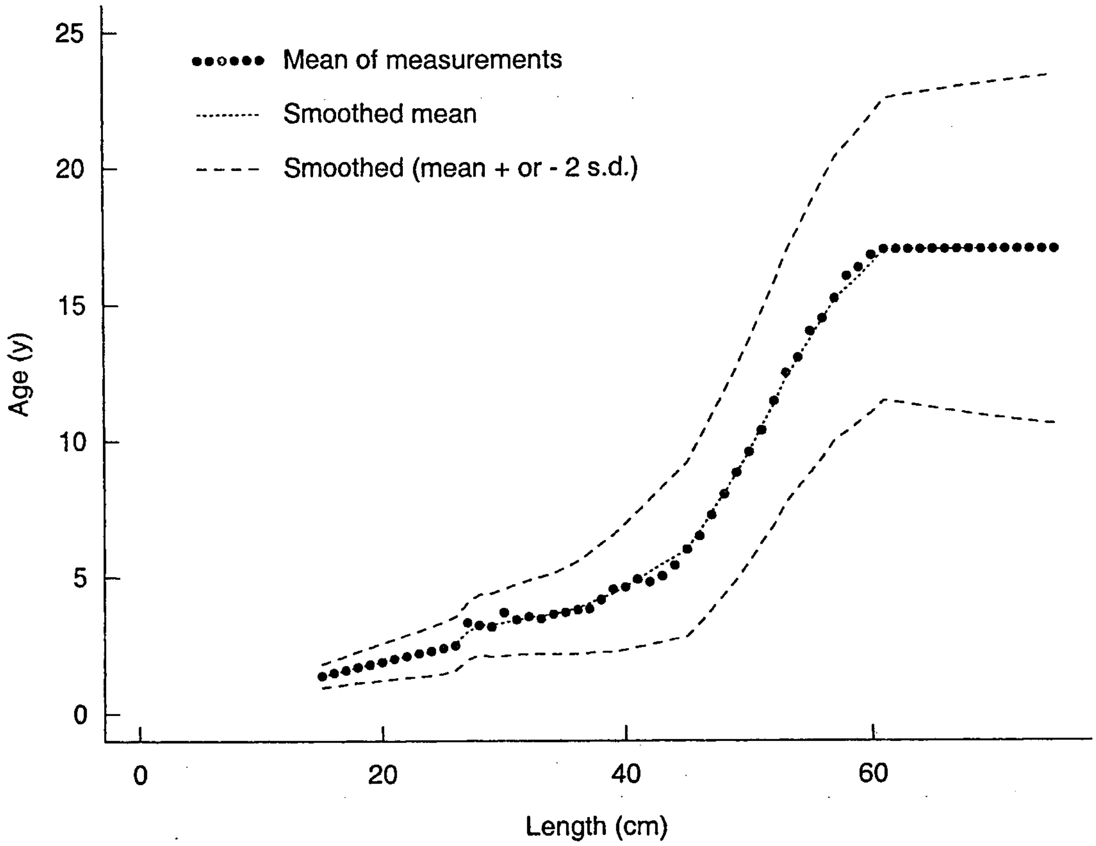

Figure 2: Kahawai mean measured age at length (including extrapolated values), and smoothed values of mean and its confidence interval used in the simulations to define the kahawai ages. Little is known about the ages of kahawai with lengths greater than 60 cm and the extrapolation chosen is probably inaccurate but will make little material change to the simulation results quoted in this report.

APPENDIX A: SURVEY DESIGN

Bradford (2000) outlined the design of the boat ramp surveys required to obtain about 500 kahawai otoliths in each region in a year. The assumption was made that recreational fishers would allow otoliths to be removed from about a third of the kahawai landed whole. (It seems more practical to ask to remove the kahawai heads and then remove the otoliths later.) Something like 60% of the kahawai recorded as caught during previous surveys were measured (see table 1 in Bradford 2000). Time constraints may have led to some kahawai not being measured, but kahawai are often filleted at sea or used for bait and thus not landed whole. Thus the fishers who caught about 2500 kahawai need to be intercepted at boat ramps in each region. Recreational fishing activity is highest on summer weekends and holidays, and sampling on such days was suggested. Kahawai normally lay down each annual ring in their otoliths during the winter, so summer sampling is also preferable for this reason. Summer was taken to be December to April inclusive; there are about 50 weekend and holiday days during this period.

The number of interview sessions on summer weekends and holidays and mean number of kahawai recorded on these interview sessions in each of the 1991 and 1994 North region, 1992–93 Central region, and 1996 national boat ramp surveys were extracted from the ***rec_data*** database (Table A1). It should be clear from Table A1 that in general, few kahawai were recorded during an interview session. Interview sessions were normally 2 hours long starting randomly throughout the day in the North region, 4 hours starting randomly throughout the day in the Central region during the 1996 national survey, and 8 or 9 hours including the late evening in the 1992–93 Central region survey.

The numbers given in Table A1 suggest the following values for the number of interview sessions required to collect sufficient otoliths. For most regions, the expectation is that two or three kahawai heads will be collected each interview session. The willingness of fishers to sacrifice kahawai heads is a major unknown.

	Sessions			
Region	Number	Length (h)	Number per day	Ramps
Bay of Plenty	200	2	4	9
Hauraki Gulf	200	4	4	9
East Northland	200	3	4	5
KAH 9	200	2	4	11
KAH 3	200	8	4	5
KAH 2	100	8	2	8

It has been assumed that the ramps where kahawai were recorded in larger numbers in previous surveys (marked with an asterisk in Table A1) would be used and that the surveying would be done at times of high ramp usage (survey times need not be randomly assigned during the day). Days on which a ramp was used could be allocated semi-randomly so that each ramp was used throughout the period of the survey, and should be allocated more or less interactively depending on the fishing activity in the year of the survey. A back-up day should be provided in case the weather is so bad that little or no fishing will take place. The number of times each ramp was used would vary depending upon how many ramps in the vicinity were involved in the survey and the likely number of kahawai that will be landed there (to attempt to get a representative coverage of the fishery). The survey sessions need to be spread throughout the region in an attempt to sample the recreational kahawai catch in a representative way. Some of these assumptions and requirements may conflict with the requirements of any other recreational fishing survey work being done at the same time.

Table A1: Number of boat ramp sessions, N_S, and mean number of kahawai recorded as caught per session, $\overline{N}_k$, at ramps used in the 1991 and 1994 North region surveys, the 1992–93 Central region survey, and the 1996 national survey and where some kahawai were recorded. * likely to be a suitable ramp; – no data.

		North 1991		North 1994		National 1996	
		N_S	$\overline{N}_k$	N_S	$\overline{N}_k$	N_S	$\overline{N}_k$
Bay of Plenty							
Bowentown	*	14	21.0	14	6.9	17	7.1
Katikati		–	–	19	3.3	5	0.4
Kuaotuna		–	–	–	–	1	5.0
Matata Beach		7	2.4	–	–	–	–
Ohope	*	19	12.4	–	–	10	11.9
Opotiki Beach	*	9	6.4	–	–	12	8.1
Pilots Bay		15	7.2	2	3.0	–	–
Pauanui	*	14	7.4	7	10.4	–	–
Sulphur Point	*	32	14.2	15	6.9	16	5.6
Te Kaka		1	21.0	–	–	1	1.0
Toll Bridge (Tauranga)		18	5.3	–	–	–	–
Tairau		–	–	18	2.6	19	3.9
Waihau Bay	*	–	–	–	–	17	12.9
Whakatane	*	25	43.4	10	39.5	16	27.1
Whangamata	*	17	9.8	34	5.6	4	4.3
Whitianga	*	21	11.7	25	1.9	11	4.2
Hauraki Gulf							
Algies Bay		6	0.3	15	0.7	–	–
Army Bay		–	–	7	1.3	1	0.0
Browns Bay		3	4.7	–	–	–	–
Coromandel Long Bay	*	6	17.5	–	–	–	–
Dawson's Landing		–	–	1	1.0	–	–
Furuno Contest Kawau		–	–	2	43.5	–	–
Gulf Harbour Marina		–	–	31	2.4	–	–
Gulf Harbour Ramp		5	3.6	27	2.5	1	0
Half Moon Bay Ramp	*	27	5.5	46	7.1	14	11.1
Hobson Bay	*	6	7.7	5	3.4	–	–
Hatfields Beach		–	–	3	0.7	–	–
Half Moon Bay Marina		–	–	7	0.9	–	–
Inner Gulf		–	–	2	6.0	–	–
Kawakawa Bay	*	14	6.5	21	1.6	17	11.4
Kaiaua		–	–	–	–	1	1.0
Kereta		–	–	–	–	3	1.7
Maraetai	*	10	2.4	34	7.7	8	4.4
Martins Bay		7	0.1	–	–	9	1.1
Okahu Bay		14	3.4	9	2.2	–	–
Omaha		–	–	–	–	1	3.0
Orere Point		–	–	1	1.0	–	–
Sandspit		11	1.6	21	0.9	–	–
Stanmore Bay		4	0.3	3	1.3	–	–
Takapuna	*	30	6.2	36	7.7	2	0.5
Te Kouma		–	–	–	–	18	2.1
Westhaven Ramp		35	4.0	40	2.0	2	1.0
Wenderholm		9	0.7	–	–	–	–
West Park Marina	*	–	–	5	3.6	–	–
Westhaven Marina		–	–	13	2.2	–	–

Table A1 — continued

		North 1991		North 1994		National 1996	
		N_S	$\bar{N}_k$	N_S	$\bar{N}_k$	N_S	$\bar{N}_k$
East Northland							
Bay of Islands		8	2.8	–	–	–	–
Houhora	*	4	3.0	–	–	2	4.5
Kerikeri		13	2.2	35	2.3	–	–
Mangonui	*	12	10.0	8	7.9	28	10.5
Parua Bay	*	24	2.5	17	3.8	22	5.9
Totara North		13	2.7	–	–	15	2.5
Tutukata	*	24	2.8	18	4.1	26	3.8
Tryphena		–	–	–	–	1	1.0
Waitangi	*	14	4.1	39	7.1	27	13.1
Whangaroa		4	2.0	–	–	3	0.3
KAH 9							
Bethells Beach		3	3.3	–	–	–	–
Cornwallis	*	9	29.0	34	10.4	10	20.8
Dargaville Beach		2	2.0	–	–	–	–
Hamiltons Gap		3	12.0	–	–	–	–
Kapiapia Rocks		1	16.0	–	–	–	–
Kawhai	*	13	17.2	–	–	10	2.1
Little Huia	*	7	23.0	–	–	1	26.0
Mangere Bridge	*	6	11.2	14	4.4	11	19.4
Manu Bay	*	5	91.4	6	30.3	–	–
Manukau Head South		1	10.0	–	–	–	–
Muriwai (boats)		–	–	3	29.0	–	–
Muriwai	*	7	9.4	3	3.3	–	–
Ninety Mile Beach		4	7.5	17	0.4	–	–
Opononi	*	3	18.0	21	9.2	13	4.7
Omapere		–	–	2	8.0	–	–
Piha		6	3.8	–	–	–	–
Raglan	*	7	8.7	9	2.7	22	11.9
Shelly Beach	*	14	24.7	10	15.7	10	11.6
Te Toro		3	5.7	1	0.0	–	–
Waiau Pa	*	17	7.6	30	2.1	11	5.5
Whatipu		7	5.4	–	–	–	–
Weymouth	*	16	7.4	25	3.6	23	5.0

		North 1991		Central 1992–93		National 1996	
		N_S	$\bar{N}_k$	N_S	$\bar{N}_k$	N_S	$\bar{N}_k$
KAH 3							
Havelock		–	–	–	–	8	0.9
Kaikoura	?	–	–	–	–	5	0.6
Motanau	?	–	–	–	–	17	1.0
Nelson	*	–	–	34	14.1	8	12.1
New Plymoth	*	3	20.3	–	–	10	3.7
Okiwi Bay	?	–	–	32	8.0	11	0.8
Queen Charlotte Sound		–	–	–	–	1	1.0
Waikawa		–	–	24	1.6	7	1.0
Wanganui	*	3	15.3	–	–	–	–
Paraparaumu	?						

Table A1 — continued

		North 1991		Central 1992–93		National 1996	
		N_S	$\overline{N}_k$	N_S	$\overline{N}_k$	N_S	$\overline{N}_k$
KAH 2							
Clifton	*	–	–	26	45.6	–	–
Napier Game Fishing Club	*	–	–	24	52.5	–	–
Napier Sailing Club	*	–	–	30	30.0	–	–
Gisborne 1	?						
Gisborne 2	?						
Castlepoint	?						
Wellington Harbour	?						
Wellington South Coast	?						

A.1 Regional issues

A.1.1 Northern regions

There is now considerable information on the recreational usage of ramps and fishing patterns in the North region and a survey can be designed that will have a good chance of succeeding. However, annual changes in kahawai behaviour, fisher behaviour, and environmental factors cannot be totally covered by any design.

The length of interview sessions in the North region was increased to reduce their number. Hence, 200 four hour sessions in the Hauraki Gulf (few kahawai are caught in the Hauraki Gulf despite high levels of recreational fishing) and 200 three hour sessions in East Northland assumed.

Results from the survey currently running in the Maketu Taiapure (project REC1999/02) suggest that the Groyne at the mouth of the Kaituna River is another site where kahawai are landed in reasonable numbers and this could be considered as a survey location in the Bay of Plenty.

A.1.2 KAH 3

Major problems exist in surveying the recreational kahawai catch in KAH 3 because of the large coastline, the lower numbers of recreational fishers in the south, and kahawai numbers appear to have declined in some areas such as the east coast of the South Island. No kahawai were recorded from any of the survey sites south of Motanau in the 1996 national boat ramp survey and few were recorded in the 1996 national diary survey.

The surveying at Motanau was intensive during the 1996 national survey, but still few kahawai were recorded. More kahawai were indicated as being caught off Kaikoura in the recent boat ramp part of the Kaikoura survey (Glen Carbines, Final Research Report on project REC9808) than in the 1996 national survey. This is probably mainly due to the boat ramp interviewing in the Kaikoura survey being restricted to the peak fishing time around Christmas. Some surveying at Kaikoura should be considered, but restricted to the Christmas period.

Surveying in the Marlborough Sounds is difficult because of the multiple access points and the recreational kahawai catch appears to be small. This area can probably be ignored unless there was another objective in the survey, say, to collect information on the recreational blue cod catch.

Kahawai are likely to be caught in Tasman and Golden Bays. The ramps at Nelson and Okiwi Bay should intercept adequate numbers of kahawai fishers.

Little recent surveying of recreational fishing has been undertaken along the coast from Titahi Bay northwards. This is an area where kahawai appear to be fairly abundant and recreational fishing activity is moderate. The Paraparaumu ramp seems to be the most frequented in the south of this area. Some boat ramp surveying was done in Wanganui and New Plymouth during the earlier North region surveys.

Long survey sessions extending into the evening are required in this area to intercept sufficient fishers. A criticism of the 1996 boat ramp survey in the Central region was that the 4 hour sessions were too short and at the wrong time of day to intercept the all-day fishers who tend to go further from the shore, so the results were not representative of the whole recreational fishery.

A.1.3 KAH 2

The 1992–93 Central region survey was the only survey available with information from KAH 2 (Ryan & Kilner, unpubl. report). All the ramps surveyed were close to Napier. These ramps were considered to be amongst those most representative of recreational fishing activity in the area (after consultation with interested parties) and suitably qualified local interviewers were available. Many of the survey days appear to have coincided with fishing contest days, but this was by accident rather than design (Allan Kilner, Ministry of Fisheries, Dunedin, pers. comm.).

There are two suitable boat ramps close to Gisborne that should be considered.

The Wellington south coast and the Wairarapa and some of the major ramps servicing these areas should be considered: Seaview Marina, and other marinas with public access ramps in Wellington Harbour, Island Bay, and other coastal access points, and Castlepoint are possible survey locations.

Long survey sessions seem desirable in this area. Some allowance has been made for a likely lower catch per session of kahawai in the southern part of the area than was observed around Napier in 1992–93.

APPENDIX B: SURVEY COST

The costs were determined based on indicative NIWA charge out rates and experience in running recreational surveys, but will differ for other providers. Final costs for a NIWA run survey could also differ. The interviewers were assumed to be employed on contract and paid for hours worked. Interview costs could be higher under other circumstances.

The estimated costs per region are as indicated. The lower estimate is unlikely to be attainable in all regions.

Tasks	Lower estimate ($)	Upper estimate ($)
Supervision	20 000	35 000
Interviewing	30 000	80 000
Ageing and analysis	40 000	65 000
Total	90 000	180 000

The activities and costs included under the tasks in the table follow:

Supervision

The activities involved are survey organisation and supervision and training of the interviewers.

The costs include salaries and travel expenses for the trainer and wages and expenses for the interviewers being trained. There will be ongoing costs checking that interviews are performed in the prescribed manner, and that monies owing to the interviewers are paid. An interviewer for each ramp was assumed.

Interviewing

The activities include interviewing, removal of otoliths, and data checking and entry to the database.

The length of an interview session was assumed to include travelling time, time for removal of otoliths after the session, as well as the time spent interviewing. Interviewers are assumed to live within a reasonable distance of the ramp to which they are assigned. The collection of session information similar to that from past North region surveys is assumed.

Form checking is required and will include a cross check between the forms and the otolith bag contents. An electronic version of data will be made to prescribed standards. Data will entered into a database to prescribed standards. Note: much of this work is required irrespective of the nature of the data to be collected.

Interview kits will be provided for each interviewer (that is, for each ramp) and include such items as measuring board; clipboard, pens/pencils/marker pens; plastic bags; scales; chilly bin for heads; scalpels; otolith packets; forms (special features are required); materials (ice, for example); courier or postage costs for return of forms and otoliths.

Ageing and analysis

Otoliths have to be prepared for reading, read, and the information stored on a database to prescribed standards. The age, length, and any other data collected have to be analysed and then reported upon.