MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

ISSN 1175-1584

Feasibility of sampling the recreational fishery to monitor the kahawai stock

Elizabeth Bradford

New Zealand Fisheries Assessment Report 2000/11
April 2000

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Elizabeth Bradford

NIWA
PO Box 14 901
Wellington

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Published by Ministry of Fisheries
Wellington
2000

ISSN 1175-1584

Citation: Bradford, E. 2000:
Feasibility of sampling the recreational fishery to monitor the kahawai stock.
New Zealand Fisheries Assessment Report 2000/11. 34 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

Bradford, Elizabeth. 2000: Feasibility of sampling the recreational fishery to monitor the kahawai stock.
New Zealand Fisheries Assessment Report 2000/11. **34 p.**

This report addresses Objective 1 of Ministry of Fisheries project KAH9801: *To determine the feasibility of developing a time series of indices to indicate the status of the kahawai stock available to commercial and non-commercial fishers, and make recommendations on the development of an ongoing program to monitor the same.*

The tender for this project was based on using data from the recreational fishery. Several methods of developing a time series of indices to monitor the kahawai stock had already been rejected.

A lumped age-length key was applied to the length frequency distributions obtained in historic boat ramp surveys of recreational catch to give an idea of the age distributions expected from the recreational catch. This showed that ageing the recreational catch each year is a possible method of monitoring the kahawai stock. The relative strengths of 3, 4, and 5 year old kahawai from year to year and from area to area could be obtained. Changes in the proportions of older and larger kahawai in an area can be estimated.

Sampling of the recreational kahawai catch could be done during the peak fishing season (roughly Boxing Day to Anzac Day). The main annual rings in kahawai otoliths appear to be laid down during the winter months so difficulties in ageing arising from having otoliths collected before, during, and after this ring is laid down should be avoided.

Positional distributions of the kahawai catch by purseseine and recreational fishing (both diary and boat ramp) in KAH 1 were examined to see how well these fisheries might sample the kahawai stock. The recreational catch is taken all along the coastline of KAH 1 out to about 10 km from shore and is fairly evenly spread, with higher catches from the Bay of Plenty. The commercial kahawai catch is taken further offshore than the recreational catch but the fishing areas do overlap. Most of the commercial catch in KAH 1 comes from part of the Bay of Plenty.

Where recreational fishers live and holiday has a strong influence on where and when they fish. The fisher (and total) population densities are not uniform throughout the country. So, the numbers of recreational fishing trips that might catch kahawai will not be uniform along the coast, nor are they likely to have the same density as the kahawai stock. Kahawai movements should help overcome the sampling problems arising from these causes. However, the recreational fishery does appear to randomly sample the kahawai stock, including juvenile kahawai that live in the shallower waters, and the samples will be more representative of the kahawai stock than the commercial fishery, particularly the purseseine fishery.

Recreational harvest rates from boat ramp (target and bycatch kahawai fisheries) and diary surveys were examined in some depth. They appear of dubious value for monitoring the kahawai stock. Recreational harvest rates can be confounded by many unquantified factors, including changes in fisher behaviour or skill mix, and changes in local distribution of the fish from year to year.

It is recommended annual boat ramp surveys of the recreational kahawai catch take place during the main recreational fishing period between Boxing Day and Anzac Day in all parts of the country where kahawai are caught.

- All kahawai Fishstocks need to be monitored.
- As many as possible of the kahawai caught should be measured for length, and otoliths taken where possible.
- The kahawai should also be weighed, at least during one survey.
- Sexing the kahawai would be desirable but not essential.
- Collecting harvest rate data should be done at a lower priority, except for those trips where kahawai was a specific target fish.

Though the recreational fishery samples the kahawai population more randomly and representatively than the commercial purseseine fishery, any samples obtained may not be sufficiently random and/or representative, and kahawai movement may mean that the samples are not comparable from year to year.

The cost of a boat ramp survey depends on the amount of surveying undertaken. To monitor the kahawai stock, a sample size of 400–500 otoliths per stratum would be required. To reduce the size of the survey, the number of areas (strata) surveyed should be reduced, not the sample size in each stratum. There are costs associated with training interviewers, collecting data, reading otoliths, storing data in the appropriate database, analysing, and reporting on the data.

A costly annual survey covering all areas may not be realistic for kahawai alone. However, there is a possibility that annual boat ramp measurements will be required for snapper in SNA 1 and 8, and perhaps for rock lobster in CRA 1–5 and may be for other species. Boat ramp surveys could have a range of objectives with little additional cost. Surveys may need to be organised so that costs are shared among the projects for different species.

1. INTRODUCTION

As kahawai school by size, the kahawai population is heterogeneously distributed. The predominantly purseseine commercial fishery makes a few large landings and some small ones. Sampling that fishery inevitably involves taking large samples from the small number of landings. Bradford (1998a) showed that an unbiased age distribution of the kahawai population could not be obtained by sampling the kahawai purseseine landings because too few landings were made to take into account the heterogeneity of kahawai schools. Of course, the age distribution of the commercial catch could be obtained. Francis (1999) showed by simulation of the shed sampling in the eel fishery that, in such a heterogeneous fishery, for a given total sample size greater precision can be achieved by sampling a few eels from many landings rather than many eels from a few landings. Sampling schooling fish is, in many respects, similar.

The recreational fishers are widely dispersed and the numbers of kahawai counted, measured, or otolithed during any boat ramp session will be comparatively small. Thus sampling the recreational fishery is likely to give better estimates of variables describing the kahawai population than sampling the commercial fishery, provided that the recreational fishers access the whole kahawai population reasonably well.

Changes in recreational harvest rates were suggested as a way of monitoring changes in the kahawai population as well as being a measure of recreational success. The work of Bradford & Francis (1999) was extended to kahawai caught as a bycatch of the snapper target fishery and using boat ramp data. Recreational harvest rates from the regional and national diary surveys were examined qualitatively to ascertain their suitability as tools for monitoring the kahawai stock. The values of harvest rate were examined in the light of the simulations of Bradford & Francis (1999) and other simulations carried out for this report.

The report

- examines (approximately) the age distribution of the kahawai measured from past boat ramp surveys;
- discusses the number of otoliths that would be required to get an age distribution in an area at a given time;
- discusses where kahawai are caught by the recreational and commercial fisheries in KAH 1 (and by analogy in the rest of New Zealand);
- discusses the use of recreational harvest rates to monitor the stock;
- recommends annual boat ramp surveys to take otoliths from, and measure lengths, weights, and possibly harvest rates of, recreationally caught kahawai.

This report addresses Objective 1 of Ministry of Fisheries project KAH9801: *To determine the feasibility of developing a time series of indices to indicate the status of the kahawai stock available to commercial and non-commercial fishers, and make recommendations on the development of an ongoing program to monitor the same.*

2. KAHAWAI AGE DISTRIBUTION IN THE RECREATIONAL CATCH

2.1 Introduction

Length frequencies of the kahawai recreational catch are available for several years: Hartill *et al.* (1998) described the length sampling conducted in the 1996 national boat ramp survey and Bradford (1999) described and compared size distributions from the three recreational boat ramp surveys conducted in the North region in 1991, 1994, and 1996. Age length keys were obtained during the kahawai commercial catch sampling programme in 1990–93 (Bradford 1998a). The times of collection of otoliths rarely coincided with recreational boat ramp surveys.

2.2 Numbers at age

To get a rough idea of the numbers at age represented by the size distributions from the recreational fishery, the catch sampling age length keys were lumped into one key for the whole country, all years, and both sexes. Data from otoliths of young kahawai collected in 1996 off the west coast of the North Island by Jeremy McKenzie (NIWA) during voyage KAH9615 were added. Some outlying points in the age length key were removed or adjusted. All data were lumped in an attempt to smooth out anomalies and the effects of large year classes. Nevertheless, some anomalies remain, for example, the 2^+, 3^+, and 4^+ year classes may not be fully represented and a stronger 11^+ year class appears in all plots. Small kahawai are infrequent in the commercial catch, but common in the recreational catch and the age length keys derived from the commercial catch are inadequate for the recreational catch. Sex differences in the available age-length keys are small and rarely significant (Bradford 1998a).

Figures 1, 2, and 3 contain the length and age frequencies of kahawai from the three North region boat ramp surveys with data for the Bay of Plenty, Hauraki Gulf, and East Northland. These figures show that the numbers at age in the recreational catch for these areas are dominated by 3–6 year old kahawai with occasional 2 year olds and a declining tail of older fish. The size and age distributions of the kahawai vary with area.

Figures 4 and 5 contain similar data for KAH 9, KAH 3, and KAH 2. The proportions of older kahawai seem to change from year to year in KAH 9 and possibly in KAH 3, but the number of measured fish in the latter area was small in 1996.

The age distribution in the recreational kahawai catch could give useful information about the annual variation in the relative sizes of the younger age classes. Other useful monitoring indices, such as major changes in the older age classes and numbers of larger fish, would be available. Ideally, age length key data need to be collected at the same time and in the same area as the length distributions. Thus measuring the age distribution of the recreational catch could be a useful way of monitoring the kahawai stock. How feasible the method is will depend upon the cost of obtaining sufficient otoliths and how well the recreational fishers sample the kahawai population.

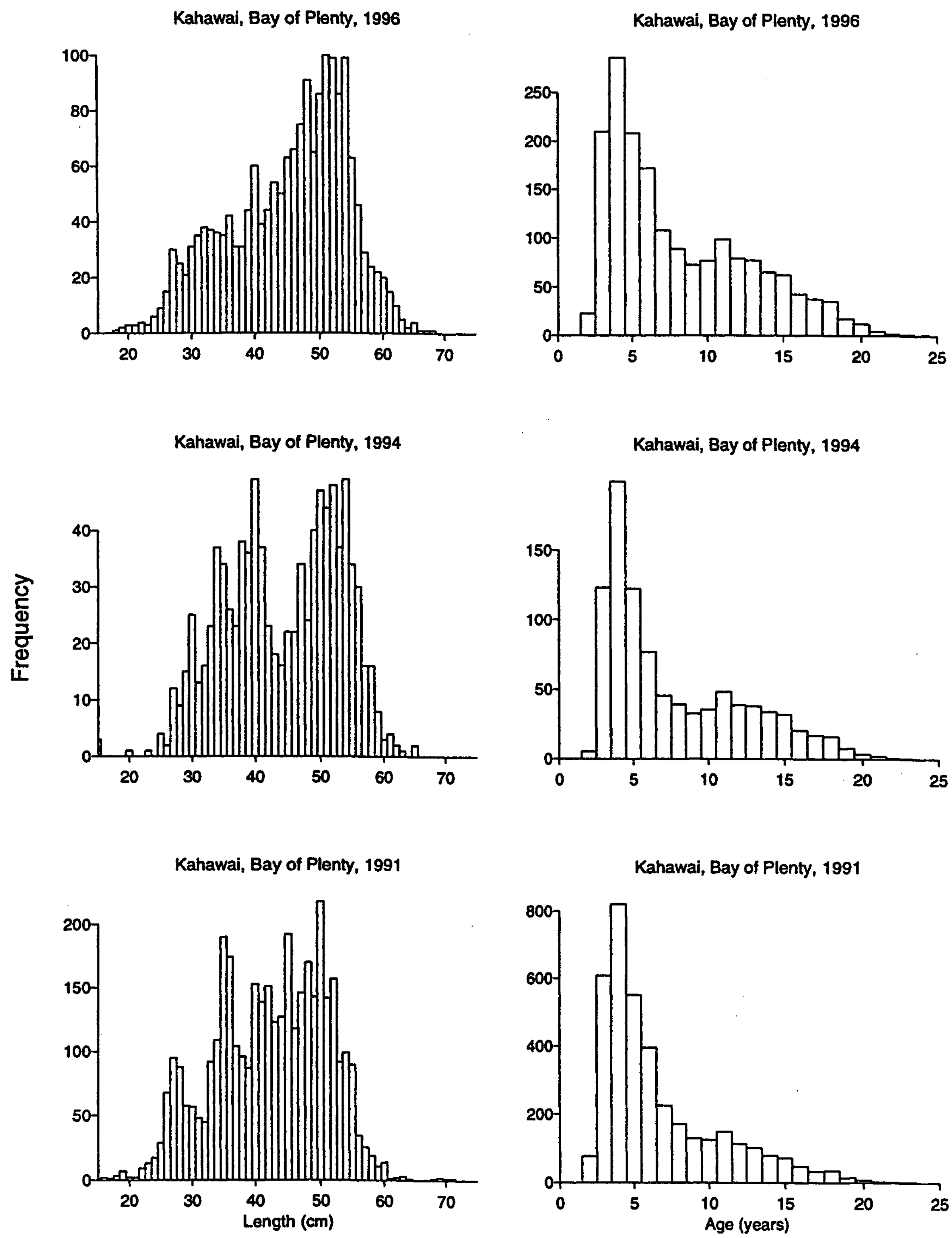

Figure 1: Kahawai length size distributions and approximate numbers at age from data measured in the North region boat ramp surveys in 1996, 1994, and 1991 in the Bay of Plenty.

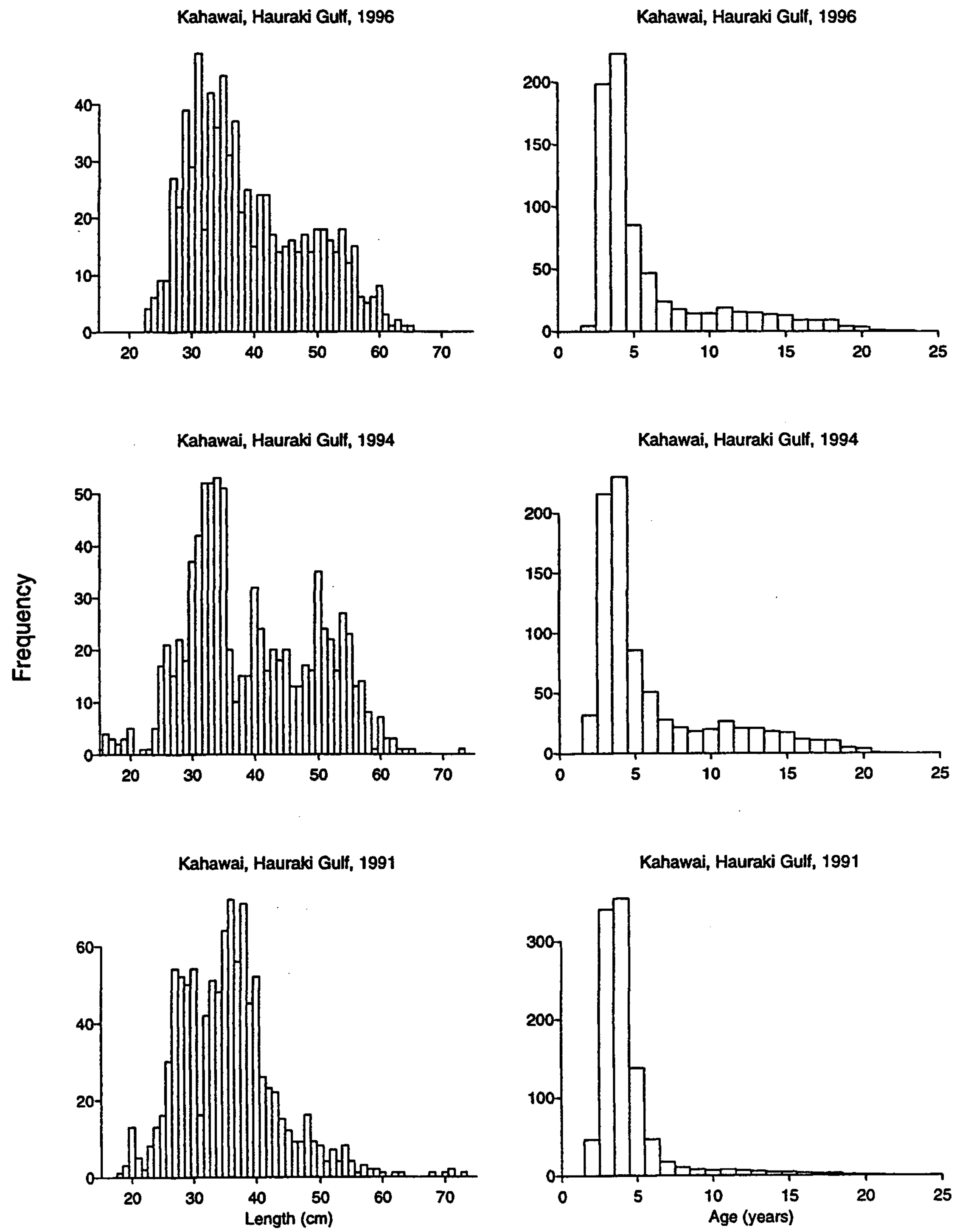

Figure 2: As for Figure 1, but with data from the Hauraki Gulf.

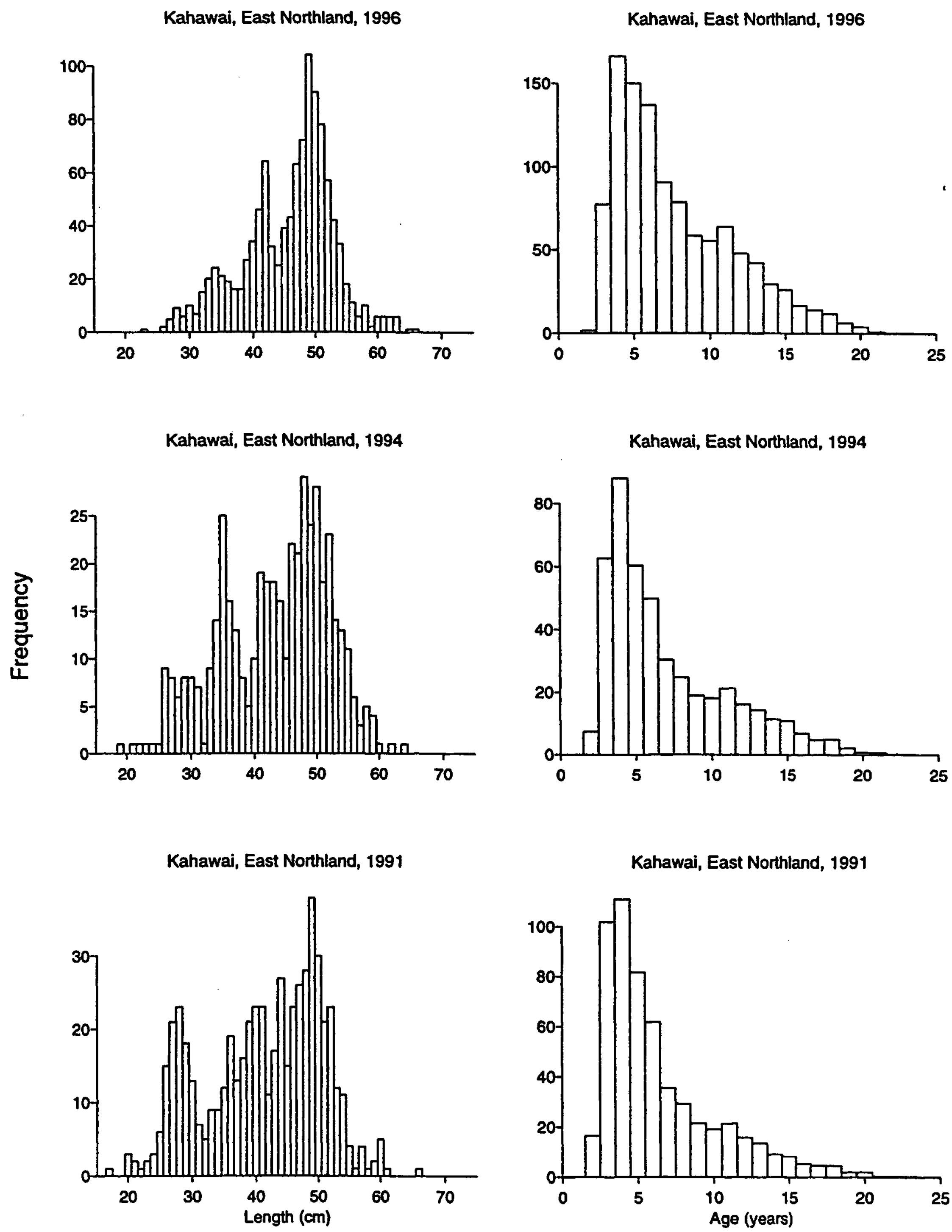

Figure 3: As for Figure 1, but with data from East Northland.

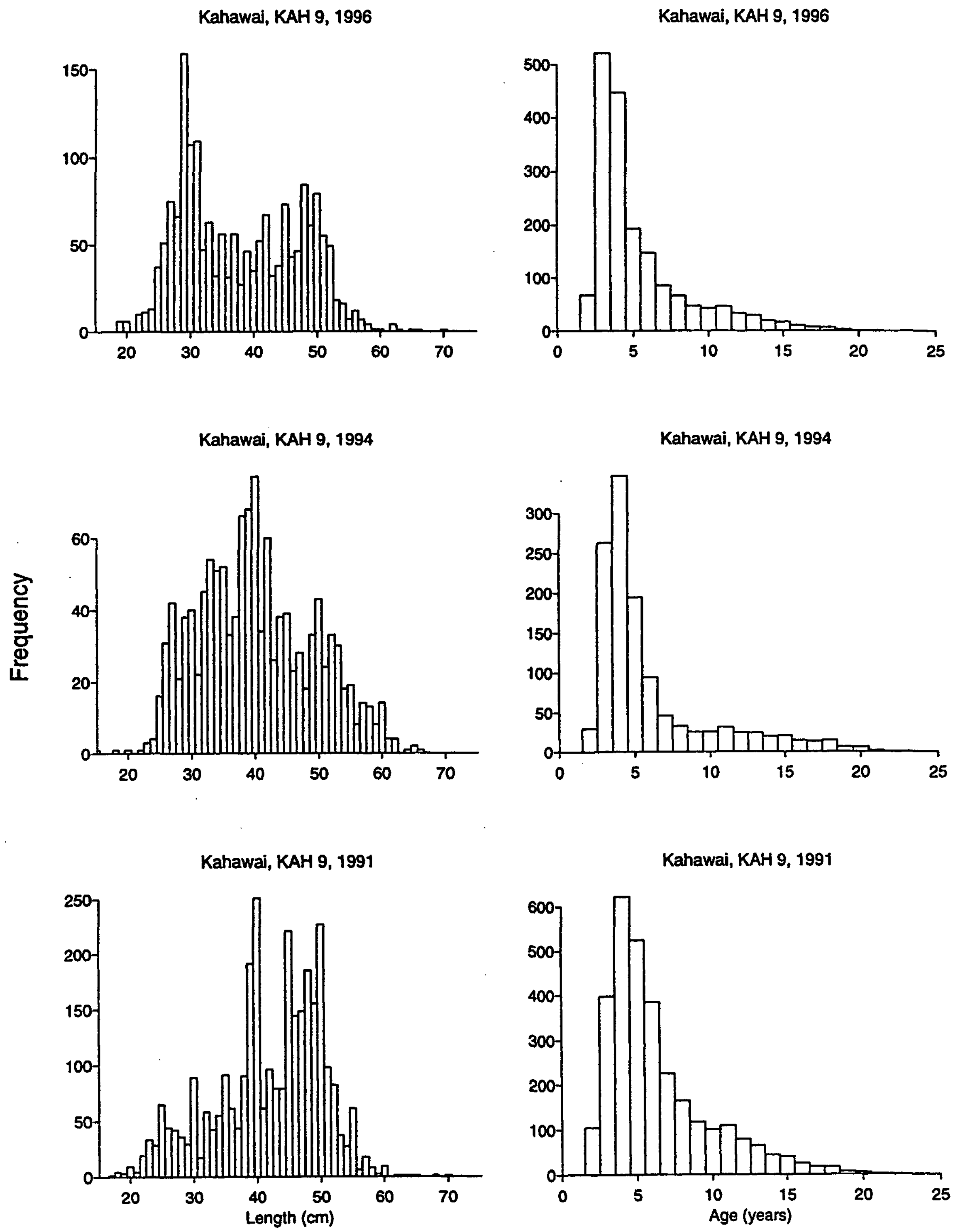

Figure 4: As for Figure 1, but with data from KAH 9 (west coast North Island).

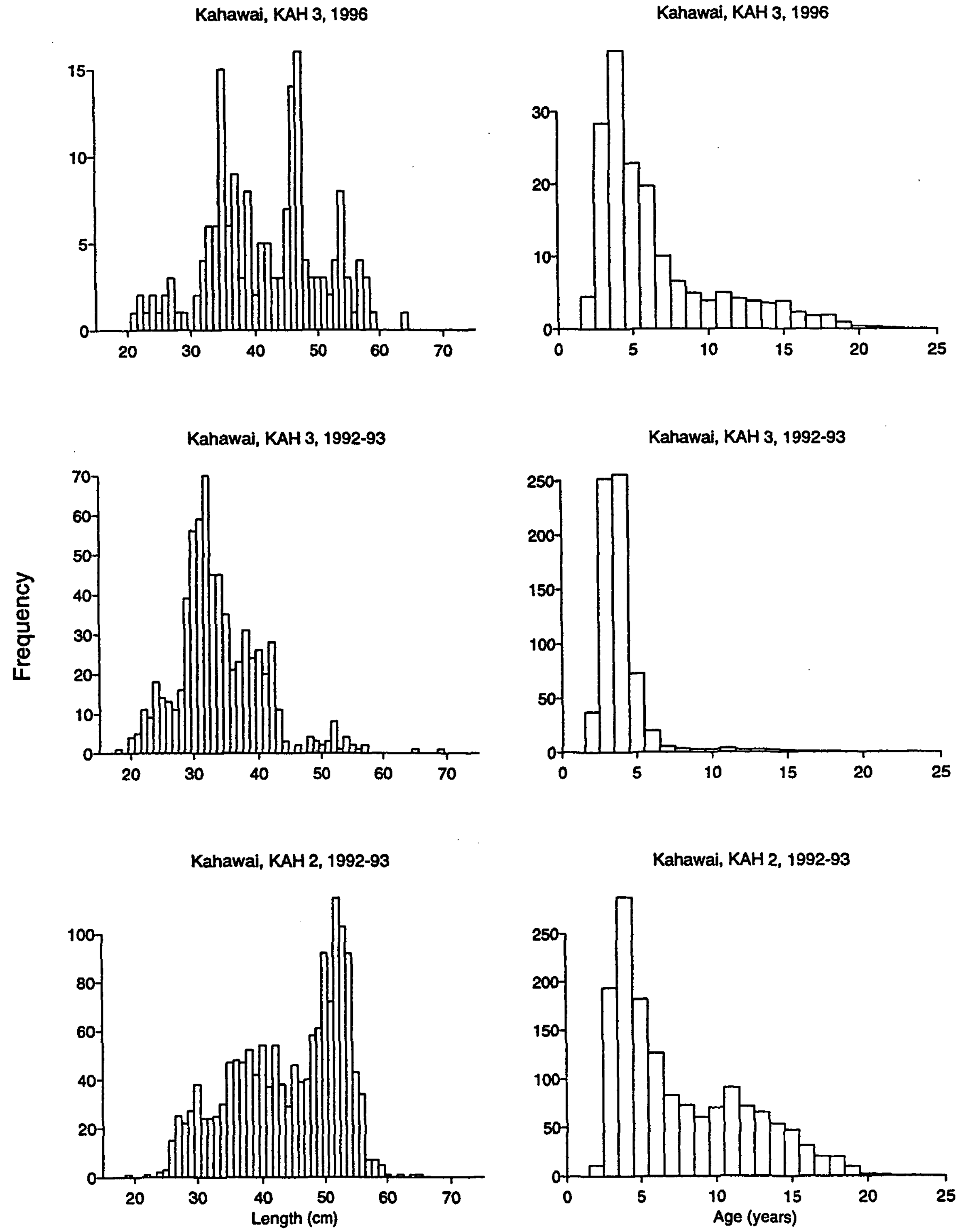

Figure 5: Kahawai length size distributions and approximate numbers at age from data measured in the national boat ramp survey in 1996 and the Central region boat ramp survey in 1992–93. Data are for KAH 2 and KAH 3.

2.3 Sample size of otoliths required (cost)

Thompson (1987) gave a method for determining the sample size required when estimating multinomial populations. Such a sample is involved when trying to estimate the numbers at age in an animal population. A sample size of 510 is required at significance level 0.05 and 403 at 0.1. Thus we need to take 400–500 otoliths in each stratum to be sampled. Random sampling is assumed.

The otolith sample is likely to be reasonably random if the otoliths are taken from the kahawai caught by all fishers intercepted in a boat ramp survey who were willing to have their fish dissected. Probably not all fishers would be willing. The boat ramp survey would have to be designed with some degree of randomness throughout the time period and area involved. Hartill *et al.* (1998) gave the numbers of kahawai caught and measured in the 1996 national diary survey (Table 1). Data from the Central region boat ramp survey in 1992–93 are from the recreational fishing database ***rec_data***. These data were first presented by M. P. Ryan & A. R. Kilner (unpubl. draft New Zealand Fisheries Assessment Research Document "Comparison of boat ramp and fishing diary surveys of marine recreational fishing in MAF Fisheries Central Region", 1994).

Table 1: Numbers of kahawai caught and measured during the 1996 national boat ramp survey in the three main subdivisions of QMA 1, KAH 9, and KAH 3 (Hartill *et al.* 1998). Data are also given for the 1992–93 Central region boat ramp survey in KAH 2 and KAH 3 (Ryan & Kilner, unpubl. data). The latter survey was conducted in the summer months

	Number caught		Number measured	
Area	Summer	All year	Summer	All year
Bay of Plenty	1 893	2 770	1 306	1 800
Hauraki Gulf	599	1 371	369	727
East Northland	1 481	2 090	876	1 129
KAH 9	1 722	3 026	1 084	1 797
KAH 3 (1996)	121	192	106	168
KAH 3 (1992–93)	1 190		672	
KAH 2 (1992–93)	3 416		1 504	

Limiting the sampling period is desirable to minimise complications due to fish growth. For practical purposes, this would mean sampling over the main summer holiday months. For various reasons not all fish caught are available for measuring (fish not available, fisher objected, sampling priority, and so on). Sampling priority could be modified depending upon the main aims of the survey. Assume that a third of the kahawai measured for length in the 1996 survey could have their otoliths removed. Then we can see that getting a sufficiently large sample size of otoliths is likely to be possible in the Bay of Plenty and KAH 9, marginal in East Northland and KAH 2, and unlikely in the Hauraki Gulf and KAH 3. This assumes a survey of the same size as the national survey. Obviously, the survey size could be increased to increase the sample size but the cost would increase.

3. KAHAWAI POPULATION SAMPLED BY THE RECREATIONAL FISHERY

3.1 Distribution of recreational kahawai catch out from the coast in KAH 1

KAH 1 data are examined in detail. The general results are assumed to extend to the rest of the stock. Diarists in the diary survey were asked to describe their fishing locality in words (as well as assign it to one of the diary zones shown in Figure 6).

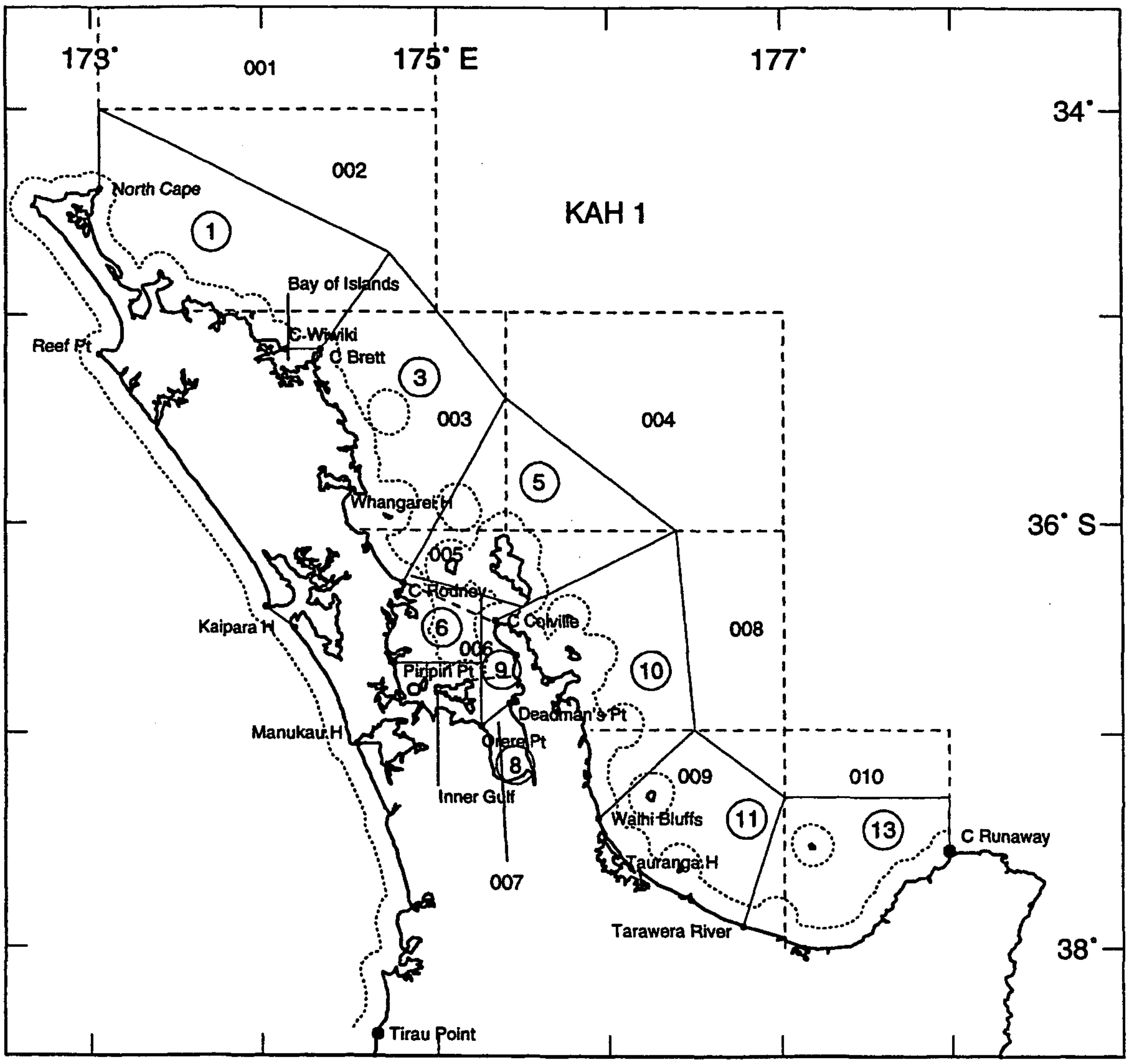

Figure 6: Map of the North region of New Zealand showing the diary zones in KAH 1 (circled numbers). The dashed lines mark the boundaries of the statistical areas (001 to 010) used by the commercial fishery. The dotted line is about 10 km from the coast.

The fishing locality was extracted from the 1996 national survey for all trips on which kahawai were caught and categorised as:

- *Coastal*: All trips from shore and or using boats within about 10 km of the shore (Figure 6).
- *Harbours*: All trips within one of the harbours.
- *Islands*: All trips to one or more of the offshore islands.
- *Outer*: All localities that appeared to be more than 10 km from land.
- *Unknown*: No information or locality unknown.

KAH 1 was divided into the Bay of Plenty (BPLE), Hauraki Gulf (HAGU), East Northland (ENLD), and unknown (NA).

The numbers of trips made and numbers of kahawai caught in a locality were counted (Table 2).

Table 2: Numbers of trips made and numbers of kahawai caught by fishing area

	Trips					Catch				
	BPLE	ENLD	HAGU	NA	All	BPLE	ENLD	HAGU	NA	All
Coastal	635	321	267	2	1 225	1 623	791	743	6	3 163
Harbours	104	62	17	0	183	250	141	36	0	427
Islands	224	81	103	0	408	626	165	231	0	1 022
Outer	16	0	11	0	27	36	0	17	0	53
Unknown	7	6	7	0	20	20	11	10	0	41
Total	986	470	405	2	1 863	2 555	1 108	1 037	6	4 706

The assignment of fishing localities was partly subjective, but it should be clear that most of the kahawai catches by recreational fishers were made within about 10 km of the shore. Though many of the offshore islands are further out than this, fishing is likely to be close to the island in question. The dotted line in Figure 6 is a smoothed line drawn 10 km from the coast of the mainland and the outlying islands.

3.2 Distribution of recreational kahawai catch along the coast in KAH 1

Figure 7 shows the numbers of kahawai caught in the 1996 diary survey by location. Todd Sylvester (Ministry of Fisheries, Auckland, unpubl. data) first defined the locations that divide the coast and offshore islands into small contiguous areas. Definitions of the locations are in the ***rec_data*** database. The fishing locality given by the diarists was used to place their catches within one of these locations. The centre of the plotted circle is representative of the fishing area, and does not mean all the recreational catch was taken at that point. The recreational effort in an area partly determines kahawai catch size and catch size is not a good indicator of kahawai abundance.

Figure 8 plots the numbers of kahawai counted in the boat ramp survey by location. In the boat ramp survey, the numbers of kahawai counted depended partly on the amount and position of the sampling effort. Table 3 was constructed to see if kahawai catches counted in the 1996 boat ramp survey were distributed geographically in the same way as the kahawai catches in the 1996 national diary survey.

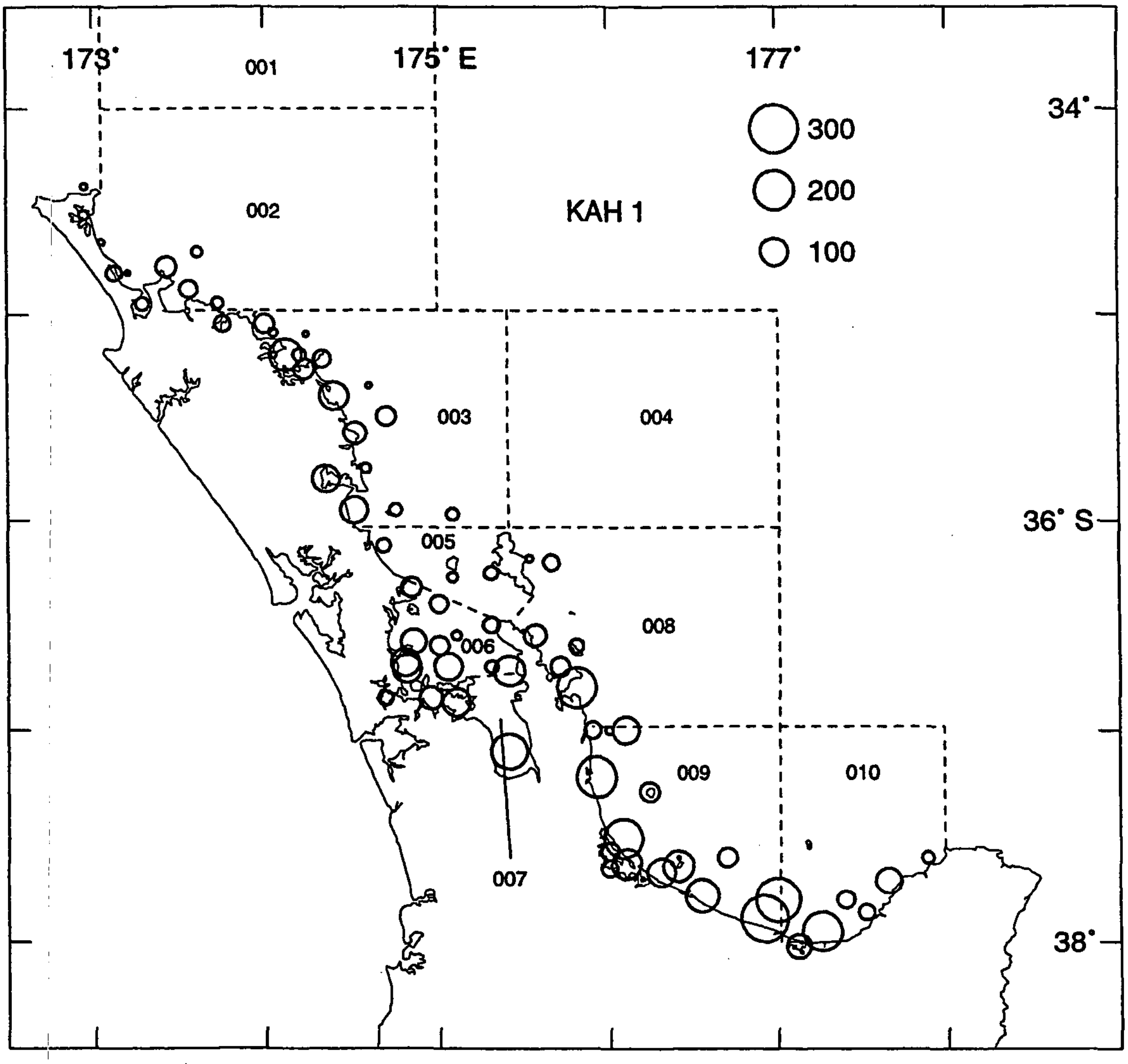

Figure 7: The numbers of kahawai caught in the 1996 diary survey in the "locations" defined by Sylvester are indicated. Some offshore points indicate catches that could be allocated only to a diary zone. The statistical areas are added for comparison with commercial catches.

Table 3 and Figures 7 and 8 suggest some discrepancies between recreational effort and sampling effort. Given the practicalities of running boat ramp surveys, the main change suggested is an increase in sampling effort in the eastern Coromandel (diary zone 10).

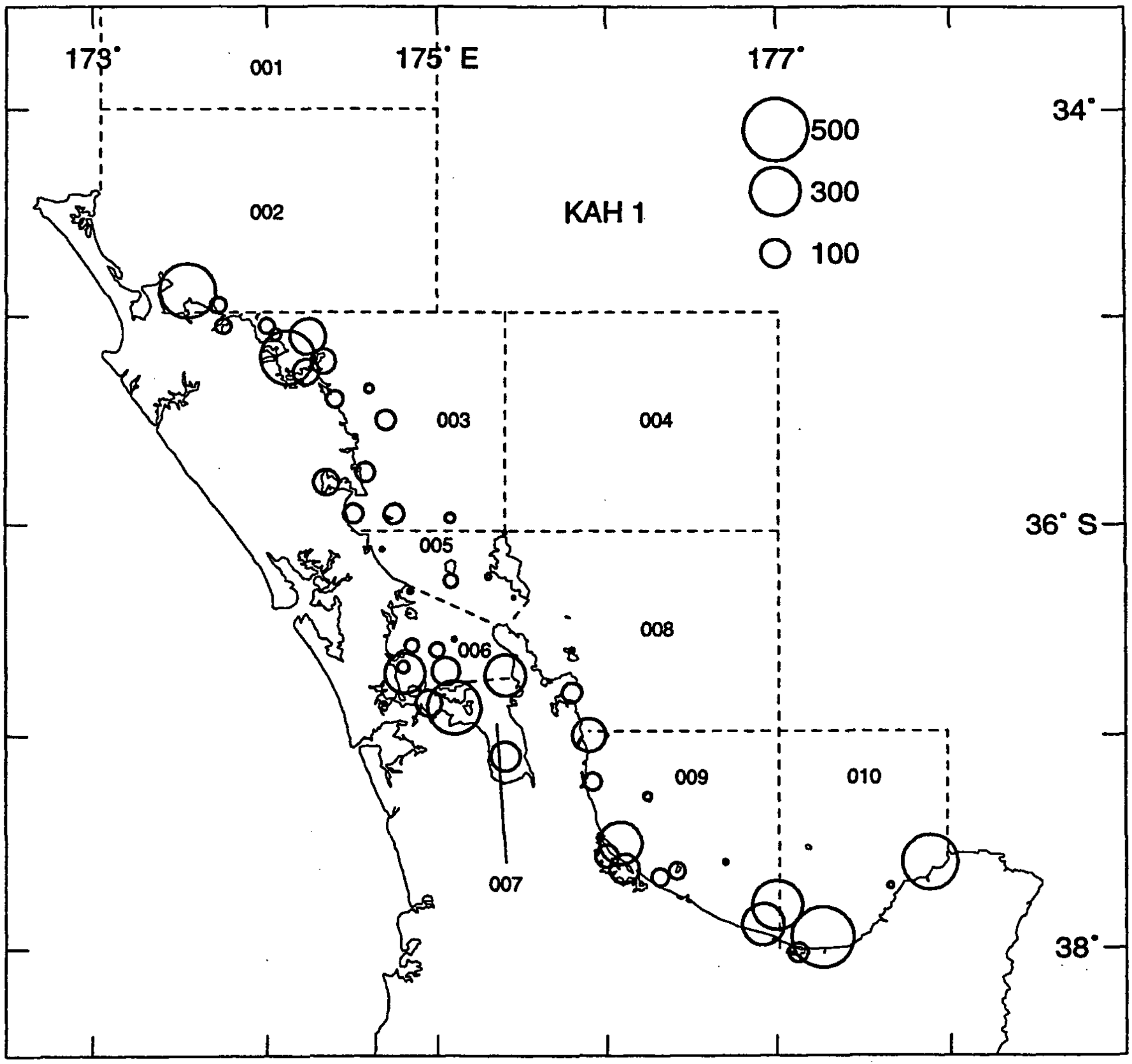

Figure 8: As for Figure 7, but for kahawai counted in the 1996 boat ramp survey.

The abundance of kahawai and the number of recreational trips made will determine the size of recreational kahawai catch in the rest of the country. The number of trips depends on the fisher population within travelling distance of the area, environmental factors, including the weather, and the suitability of the area for fishing.

Table 3: Numbers of kahawai caught in each diary zone in the 1996 boat ramp and diary surveys. These numbers are expressed as a percentage of the KAH 1 total

Zone		Boat ramp		Diary	
		Number	Percentage	Number	Percentage
1	North Cape to Cape Brett	485	10.0	297	6.3
2	Bay of Islands	747	15.4	236	5.0
3	Cape Brett to Cape Rodney	200	4.1	393	8.4
4	Whangarei Harbour	85	1.7	83	1.8
5	Barrier Islands	43	0.9	99	2.1
6	Western Hauraki Gulf	46	0.9	276	5.9
7	Inner Hauraki Gulf	784	16.1	441	9.4
8	Firth of Thames	111	2.3	160	3.4
9	Eastern Hauraki Gulf	213	4.4	160	3.4
10	Eastern Coromandel	236	4.9	709	15.1
11	Middle Bay of Plenty	311	6.4	739	15.7
12	Tauranga Harbour	177	3.6	203	4.3
13	Eastern Bay of Plenty	1 427	29.3	904	19.2

3.3 Distribution of commercial catch in KAH 1

Most of the commercial catch is taken by purseseine (Annala *et al.* 1998). Figure 9 is a map (drawn to the same scale as Figures 6, 7, and 8) of the positions of purseseine catches of kahawai (over 1 t) between 1983 and 1993. Most of this catch came from statistical area 9 in the Bay of Plenty.

Old data were used in Figure 9 but the positions of purseseine sets catching kahawai is unlikely to have changed substantially in recent years. Table 4 contains the estimated catches of kahawai by statistical area from the catch effort database for all methods. These data were extracted on 16 February 1999 and the 1997–98 catch data may not be complete. Most of the kahawai commercial catch is still taken from statistical area 9. The Firth of Thames (statistical area 7) is the next most important area where kahawai are taken mainly by netting methods and bottom longline.

Table 4: Kahawai catch by statistical area in KAH 1 since the 1989–90 fishing year. Statistical areas 105 and 106 are in the outer parts of the EEZ. Data extracted on 16 February 1999

	Statistical area											
Fishing year	1	2	3	4	5	6	7	8	9	10	105	106
1989–90	6	58	38	1	26	26	170	4	1 478	154		
1990–91	14	40	36	46	6	38	153	80	1 039	46		
1991–92	23	58	41	0	18	17	129	43	1 391	31	0	
1992–93	9	116	78	2	25	30	279	102	1 804	157		15
1993–94	5	148	113	0	124	24	180	25	983	158		
1994–95	6	81	55	1	69	24	151	29	839	55	0	20
1995–96	4	73	33	1	37	9	116	22	1 151	57		0
1996–97	7	135	24	7	10	10	84	35	1 178	22		21
1997–98	3	149	31	2	24	6	87	13	613	10		

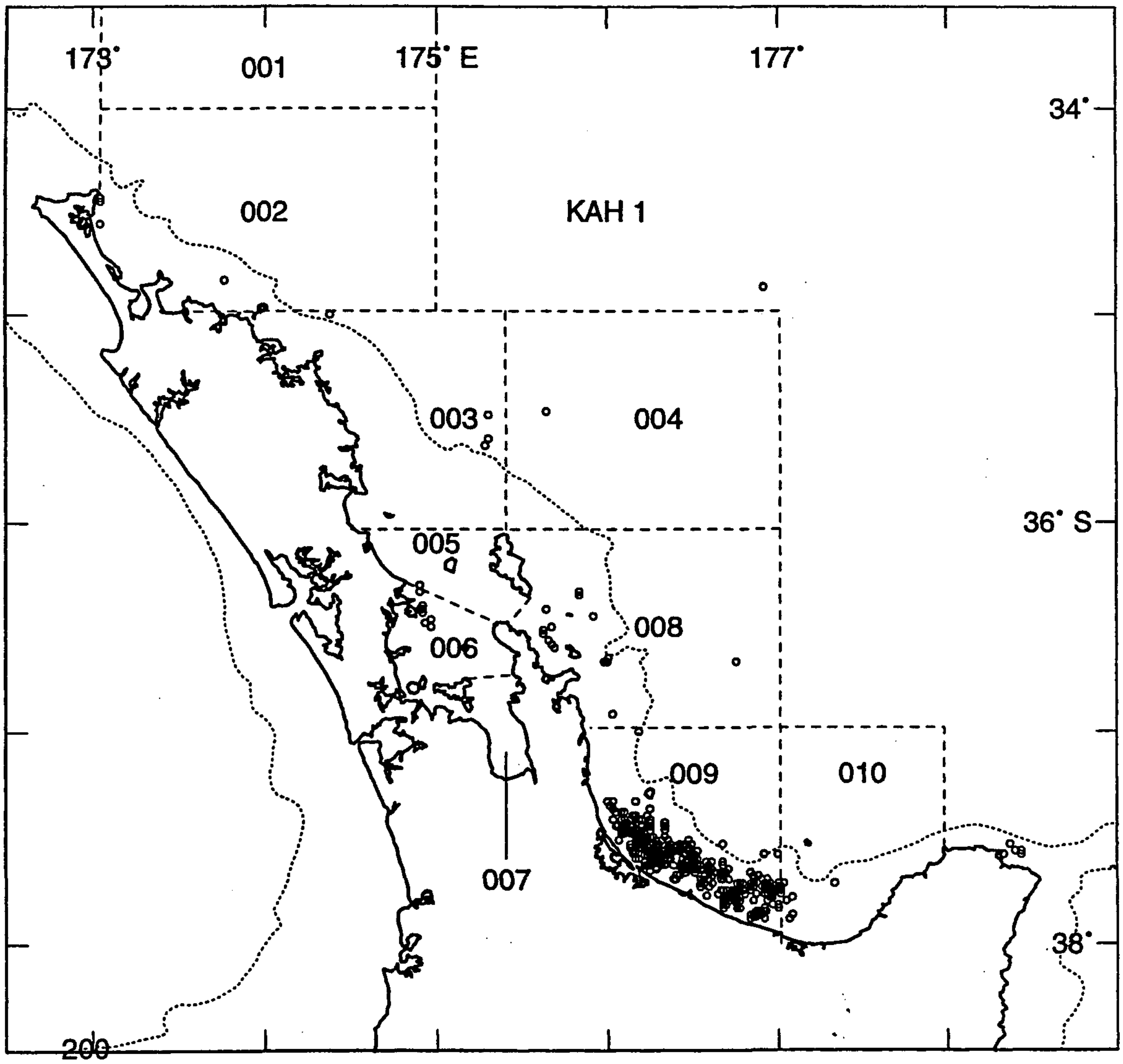

Figure 9: The same coastal region of New Zealand as in Figures 6, 7, and 8 with the positions of purseseine catches of kahawai (> 1 t) between 1983 and 1993. The dotted line is the 200 m depth contour. The main statistical areas are marked. Areas 105 and 106 are outside these.

In other parts of the country, the commercial catch tends to be concentrated in particular areas, though the puseseine catch sites are more variable from year to year in KAH 2 and KAH 3 than in KAH 1. Large catches were taken off Kaikoura in past years. Voluntary agreements in some places prevent purseseining close to the coast (within 12 n. mile).

4. RECREATIONAL HARVEST RATES TO MONITOR THE KAHAWAI FISHERY

4.1 Power to detect changes in mean harvest rate

Bradford & Francis (1999) investigated the power of the mean-of-ratios estimator to detect changes in harvest rate in the snapper and kahawai recreational target fisheries in QMA 1 using data sets from the 1996 national boat ramp and diary surveys. Their results suggest that the sample size required to detect a 20% decrease (25% increase) in the mean harvest rate in the kahawai target fishery will be prohibitively large.

The kahawai target fishery is small and many kahawai are caught as bycatch of the snapper target fishery. The procedures of Bradford & Francis (1999) were used below to investigate the mean-of-ratios estimator of harvest rate of kahawai caught as bycatch of the snapper target fishery. This fishery was called the kahawai bycatch fishery. Only boat ramp data were used and trips selected that belonged to the snapper and kahawai target fisheries.

The **snapper target fishery** was defined as those trips on which snapper or general fish was the specified target and the method used was a baited line or jigging with or without bait. Only one target species was recorded in the boat ramp surveys. Since almost all the boats using boat ramps are "trailer boats", the data were restricted to trips using such boats. These trips also define the kahawai bycatch fishery.

The **kahawai target fishery** was defined as all trips in KAH 1 on which kahawai was the target species, any line method was used, and a trailer boat was used. Most kahawai target trips used trolling.

4.1.1 Simulation methods

The general question we are considering here is how large a sample is required in a boat ramp survey to be confident that we will detect a change in mean harvest rate. To address this we must first ask (a) how large (or small) a change do we want to be able to detect? and (b) how confident do we want to be that we will detect it? In response to the first of these two questions we have chosen to consider reductions of 20%, 35%, and 50%. Reductions of 10% were considered but not presented. The basis for this choice is that it is unusual in fisheries science to be able to detect changes in catch rates (or abundance) of less than 10%, and that surveys that cannot detect a drop of 50% must be considered as of limited value as management tools. As to confidence levels, in the absence of any other guidelines we adopted the level of 80% as commonly used in statistical power analyses. Thus we address the more specific question: how large a sample is required so that we can be 80% confident of detecting a drop in mean harvest rate of 20%, 35%, or 50%? Because of the symmetry of the test that is used, detecting a drop of x% is logically equivalent to detecting an increase in $100x/(100-x)$ %. Thus, the results will apply equally to harvest-rate increases of 25%, 54%, and 100%.

Two obvious ways in which the survey data sets differ from each other is in the fraction of unsuccessful trips, p_0, and the skewness of the distribution of the non-zero harvest rates (Table 5, Figure 10).

All sufficiently large sets of data from the kahawai bycatch and target fisheries were used in the simulations (Table 5, Figure 10). Sufficiently large was defined as at least 400 trips. Data from the adjacent zones 8 and 9 were similar and were combined. The fraction of unsuccessful trips is large in the kahawai bycatch fishery and the skewness of the distribution of non-zero harvest rates is moderately large.

Table 5: Data from the 1996 recreational boat ramp survey for the kahawai bycatch and target line fisheries in QMA 1 used to select examples for simulation. *, data used in simulations (data from zones 8 and 9 were combined); *Z*, 1996 national diary survey zone number; *n*, the number of trips; p_0, the fraction of unsuccessful trips; Skew is the skewness of the non-zero part of the catch rate distribution. Skew is plotted against p_0 in Figure 10

No.	Area	Z	n	P_0	Skew
1	North Cape to Cape Brett	1 *	744	0.749	3.565
2	Bay of Islands	2 *	902	0.702	2.957
3	Cape Brett to Cape Rodney	3 *	599	0.855	2.648
4	Whangarei Harbour	4	307	0.863	2.030
5	Barrier Islands	5	69	0.870	0.340
6	Western Hauraki Gulf	6 *	415	0.949	2.088
7	Inner Hauraki Gulf	7 *	2 339	0.841	4.916
8	Firth of Thames	8| *	346	0.853	2.543
9	Eastern Hauraki Gulf	9| *	732	0.854	3.060
10	Eastern Coromandel	10 *	819	0.886	2.546
11	Middle Bay of Plenty	11 *	704	0.807	2.421
12	Tauranga Harbour	12 *	587	0.872	3.280
13	Eastern Bay of Plenty	13 *	1 399	0.630	2.368
T	KAH 1, boat, target	1–13 *	408	0.525	3.786

The statistical test used in the simulation study was the t-test, the conventional test for detecting a difference in the means of two populations. It is known to be quite robust to departures from the usual assumption that the sampled distributions are normally distributed. The following procedure was used with each data set in turn to check that the harvest-rate distributions were not too extreme for satisfactory test performance. Two samples of size 100 were drawn randomly with replacement from the data set and the usual t-test (assuming equal variances) was applied, using a 5% significance level. This was repeated 10 000 times and the percentage of significant results was recorded. For the 10 data sets from the kahawai bycatch fishery, the percentage of significant results varied between 3.5% and 5.3% with a mean value of 4.3% which was considered adequate for a 5% test.

The following simulation procedure was followed for each of the nine data sets.

1. Create a modified version of the data set in which the mean harvest rate was 10% less than that in the unmodified data (see below for details).
2. Generate 1000 pairs of samples of size 50, where each pair contains a sample from both the modified and unmodified data sets and all samples are drawn at random with replacement.
3. Carry out a t-test (assuming equal variances) for each pair of samples and record the proportion, $\hat{\pi}$, of results that is significant ($\hat{\pi}$ is an estimate of power).
4. Repeat steps 2 and 3 with sample sizes of 100, 150, ... 1000.
5. Find the smallest sample size (if any) for which $\hat{\pi} \geq 0.8$.
6. Repeat steps 1–5 with mean harvest rate differences of 20% and 50%.

Two different methods of generating the modified data set in step 1 were used:

(a) each individual harvest rate was multiplied by 0.9 (or 0.8, or 0.5); and
(b) the number of fish caught in each trip was reduced by a factor of 0.9 (or 0.8, or 0.5) on average (specifically, the number of fish, m_i, caught in the *i*th trip was replaced by rnd($pm_i + u_i$), where p was 0.9 (or 0.8, or 0.5), u_i was a random number between -0.5 and 0.5, and rnd is the usual rounding function).

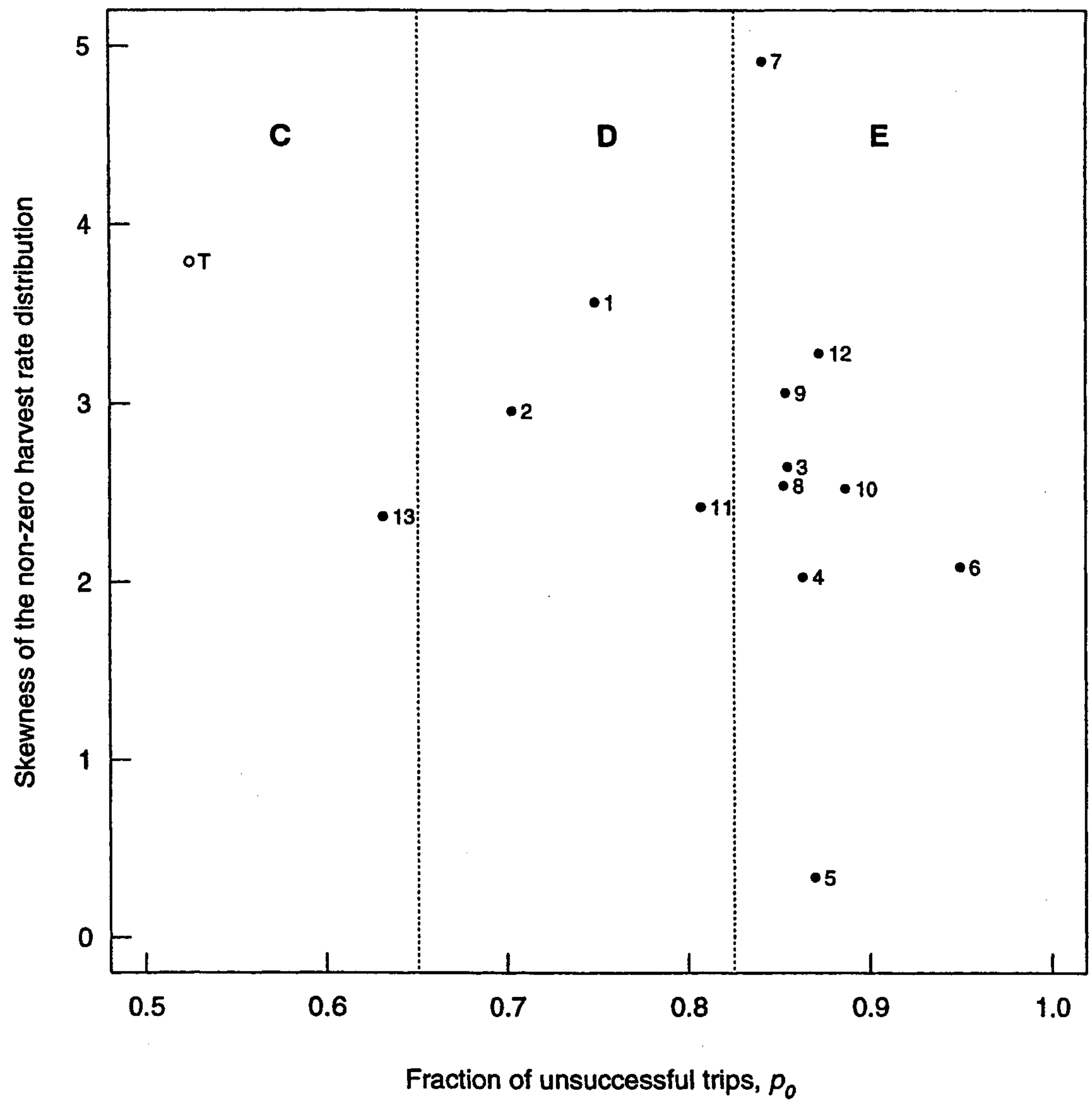

Figure 10: Skewness of the non-zero harvest rate distribution plotted against the fraction of unsuccessful trips for the kahawai target fishery in KAH 1 and the kahawai bycatch fishery by diary zone (*see* Table 5 to identify data sets). The dotted lines indicate groups of data, labelled as C, D, and E, used in Table 7.

The former method simulates the drop in mean harvest rate that would arise when there is an increase in fishing time but no change in the number of fish caught per trip. The latter simulates the opposite situation where fishing times do not change but there is a drop in the number of fish caught per trip.

4.1.2 Simulation results

The results in Table 6 show that a reduction of 50% in mean harvest rate would be reliably detected with sample sizes from 150 to about 1000 for the bycatch fishery and 200 for the target fishery. A reduction of 20% (and under) could not be detected with sample sizes of 1000 or less. A drop of 35% could be detected in the target fishery and the bycatch fishery in some areas. The two methods used to simulate a reduction in harvest rate [methods (a) and (b)] produced similar results but tend to differ more when the required sample size is greater than 500.

Table 6: Number of points to reliably detect a reduction in mean harvest rate of the stated size for each of the data sets used in the simulation and the two methods of modifying the data

	20%		35%		50%	
Data	Meth a	Meth b	Meth a	Meth b	Meth a	Meth b
Target kahawai	> 1 000	> 1 000	400	350	200	200
Snapper bycatch						
Zone 13	> 1 000	> 1 000	400	400	150	150
Zone 11	> 1 000	> 1 000	700	650	300	300
Zone 1	> 1 000	> 1 000	600	800	250	300
Zone 2	> 1 000	> 1 000	550	500	250	300
Zone 7	> 1 000	> 1 000	950	900	400	400
Zone 8 & 9	> 1 000	> 1 000	> 1 000	> 1 000	500	700
Zone 3	> 1 000	> 1 000	> 1 000	> 1 000	550	550
Zone 10	> 1 000	> 1 000	> 1 000	> 1 000	600	450
Zone 12	> 1 000	> 1 000	> 1 000	> 1 000	700	500
Zone 6	> 1 000	> 1 000	> 1 000	> 1 000	> 1 000	800

Bradford & Francis (1999) divided the data sets they used into four groups to simplify the presentation of results:

Group	p_0	Skewness
A	< 0.35	< 2.75
B	> 0.35 and < 0.65	> 2.75
C	> 0.35 and < 0.65	> 2.75
D	> 0.65	< 2.75

The skewness for the zone 13 data is less than 2.75 and for the target kahawai fishery is greater than 2.75 which means the above classification puts these data sets into different groups. The differences in the power curves for the target kahawai fishery and the bycatch fishery in zone 13 (eastern Bay of Plenty) are too small to separate them. Hence the above grouping was modified and the results were divided into three groups (Table 7, Figure 10) depending on the value of p_0 (the main discriminating variable). All of the data sets used in the simulations had skewness between 2 and 7 and p_0 greater than 0.5.

Changes of 20% could not be detected with power of 0.8 or above in any of the data sets used. A change of 35% will be difficult to detect in region E (highest p_0) with power of 0.8 or above and requires a sample greater than 500 region in D (moderately high p_0). A change of 50% in mean harvest rate can be detected with increasing sample size as p_0 increases with sample size of 150 or more.

The differences in detectability between regions are clearly shown by the associated power curves (Figure 11). A drop of 35% in region D can be detected with almost the same sampling effort as a drop of 50% in region E (the dotted line labelled D is almost the same as the dashed line labelled E). Also, it is about equally difficult to detect a drop of 20% for a data set in region C as to detect a drop of 35% in region E (the solid line labelled C is almost coincident with the dotted line labelled E).

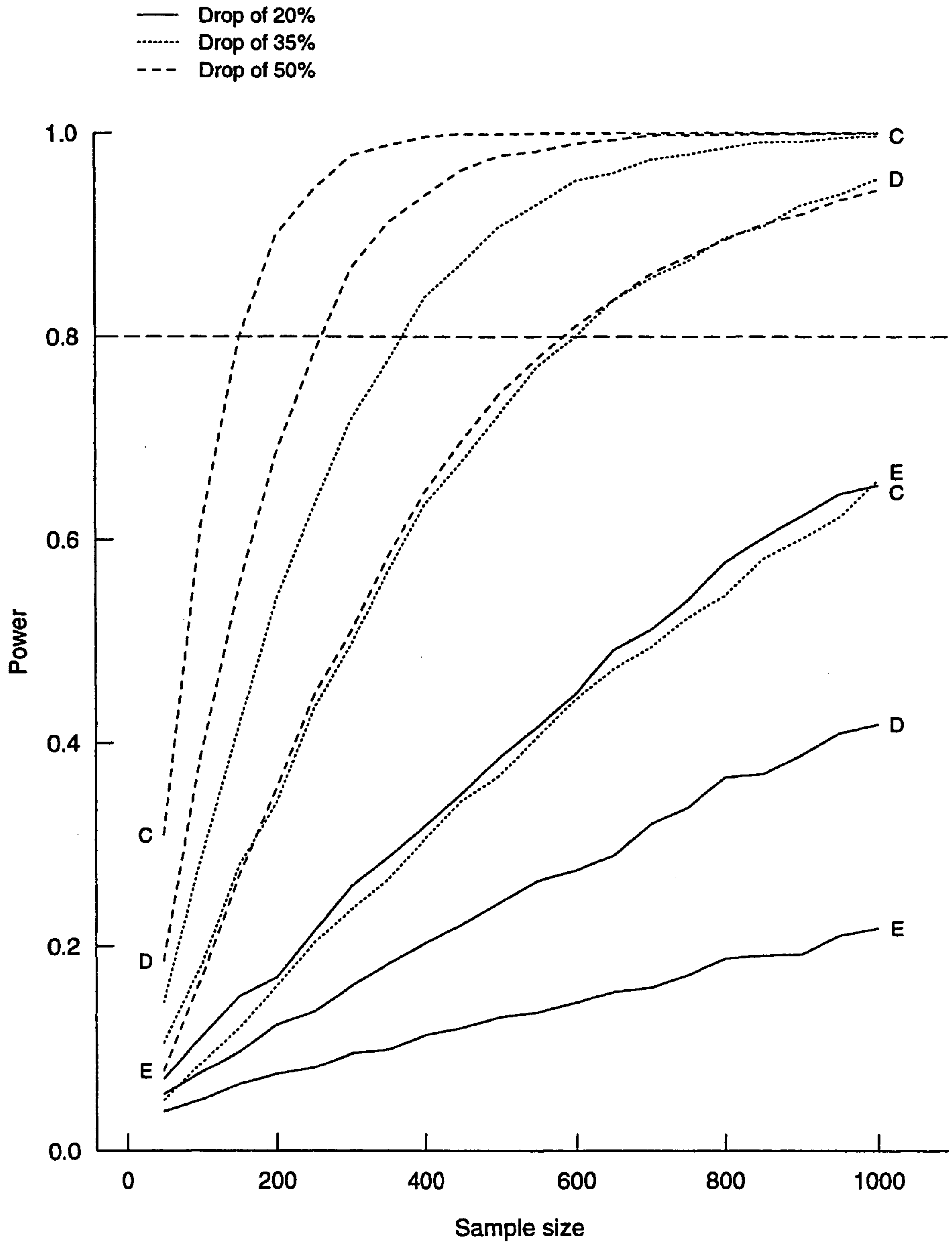

Figure 11: Power curves for the data sets in the three regions (C, D, E) of Figure 7 and the three levels of change in mean harvest rate (a drop of 20%, 35%, or 50%). Each curve averages simulation results from all data sets within the region and for methods (a) and (b) of simulating a reduction in harvest rate.

Table 7: Sample size required to reliably detect a reduction in mean catch rate of the stated size. p_0, the fraction of unsuccessful trips; the groupings are shown in Figure 10

Group	p_0	Reduction 20%	35%	50%
C	> 0.35 and < 0.65	>1 000	350–400	150–200
D	> 0.65 and < 0.825	>1 000	400–800	250–300
E	> 0.825	>1 000	≥ 800	> 400

4.1.3 Changes in fraction of zeros

There are obviously many other ways that the catch rate distribution could change. As p_0 becomes large, it is probably the most useful indicator of harvest rate and harvest rate change. The detection of change in the harvest rate as p_0 is changed was investigated. New data sets were created by adding (subtracting) a number of zeroes and subtracting (adding) a sample of equal size from the non-zero harvest rates to a given data set. The original and modified data sets were compared as above. The data from the kahawai bycatch fishery in zone 13 were used (Table 8).

Table 8: Sample size to detect the modification to the data. Δ # zeroes is the change in the number of zeroes. A change of the same size but opposite sign is made to the non-zero harvest rates. The vales of p_0 and skewness for the modified data are given.

Δ # zeroes	p_0	Skewness	Sample size
-400	0.916	2.309	100
-200	0.773	2.214	350
-150	0.738	2.639	600
-120	0.716	2.465	> 1 000
+120	0.545	2.355	> 1 000
+150	0.523	2.355	1000
+200	0.487	2.294	550
+400	0.345	2.264	150
0 (original data)	0.630	2.368	

This modification mainly changed p_0 and the results suggest that if p_0 is moderately large, we might expect to be able to detect a change of about plus or minus 0.15 in it with an acceptable sample size.

4.2 Use of harvest rates from the diary survey data

4.2.1 Interpretation of harvest rates from the diary surveys

The marine recreational fishing diary surveys in New Zealand were designed to measure catch and effort in the recreational fishery. The fishing time for a trip was recorded but could be difficult to remember correctly. However, where comparison is possible, average fishing trip times by method appear to be about the same as those recorded in the boat ramp surveys. Comparison of the diary survey results with the boat ramp survey results suggested some non-recording of unsuccessful and less successful trips

(Bradford 1996, Ryan & Kilner, Ministry of Fisheries, unpubl. data). Bradford & Francis (1999) compared the values of p_0 (fraction of unsuccessful trips) and skewness of the non-zero harvest rate distribution for the data sets they considered. The values of p_0 from the diary survey were consistently below those from the boat ramp survey in the same areas. The comparison of the skewness of the non-zero parts of the harvest rate distributions showed a small range of skewness for the diary survey data and a much wider range of skewness for the boat ramp survey data.

Estimates of mean harvest rate from the diary surveys can be used provided we interpret the values in context. If comparing mean harvest rates from year to year, we have to assume no changes in underreporting of unsuccessful trips and in the reporting of catches and times in general. Any problems encountered with interpreting harvest rates from the diary survey are a consequence of using the data for purposes for which they were not designed.

4.2.2 Calculation of harvest rates from the diary surveys

We consider the mean-of-ratios and the ratio-of-means estimators, H_1 and H_2, from the 1996 national diary survey by Fishstock and method (Table 9). A method was included when there were more than 10 trips using it in the Fishstock. When there were less than 10 longline trips, they were included with the line fishing trips. A nominal coefficient of variation (*c.v.*) was estimated as the square root of the variances of catch and effort divided by the harvest rate estimate. This should be conservative. All trips on which kahawai were targeted or caught were included. Table 9 also gives the fraction of unsuccessful trips, p_0, the total harvest and effort, and mean effort. The average length of a fishing trip is about half a day, except for gill and set netting when it is longer.

Although Bradford & Francis (1999) investigated only the power of H_1 (the mean-of-ratios estimator of harvest rate) to detect changes in harvest rate, their results are expected to be applicable H_2 as well, at least approximately. Their results suggest that 50% (100%) decrease (increase) in harvest rate will be detectable with sample sizes of 150–200. Recent results suggest that slightly smaller sample sizes may be required to reliably detect changes in H_2 than in H_1, but the required sample sizes are still large (Bradford unpubl. data).

The data selection used here included the non-target trips on which kahawai were caught. This increased the number of trips involved (as trips catching kahawai but not targeting it were included). We may conclude from the sample sizes given in Table 9, that *only the methods using lines from either private boats or from shore will have enough trips to be useful.* Further discussion is limited to these methods.

Table 10 repeats the values of mean harvest rates in Table 9 for the national diary survey for the line fishing methods (no longline trips are included) and includes similar data from the three regional diary surveys. Table 10 also contains values for target trips only (as used by Bradford & Francis (1999) in KAH 1). Of course, the sample size decreases and p_0 increases when only target trips are included. None of the values in Table 10 decrease by 50% or increase by 100% between the appropriate regional diary survey and the national survey, though some sample sizes are large and smaller changes may be significant.

KAH 3 spans QMAs 2, 3, 5, 7, and 8 and is fished by South, Central, and a few North region fishers. South region diarists who fished in QMA 7 were included in the South survey KAH 3 totals; a substantial number of South region residents fish outside the South region.

Table 9: Number of trips (*N*), total harvest and effort (*H, E*), and harvest rate estimators p_0, H_1, and H_2 of kahawai harvests by diarists in the 1996 national diary survey by Fishstock and fishing method

	Fishstock	*N*	*H*	*E*(h)	$\bar{E}$(h)	p_0	H_1	H_2
Private boat; lines	KAH 1	1 533	3 269	6 115.0	3.989	0.192	0.710	0.535
Charter boat; lines		60	96	305.5	5.092	0.233	0.394	0.314
Pvt boat; longlines		32	31	70.5	2.203	0.438	0.576	0.440
Shore; line fishing		747	1 092	2 501.2	3.348	0.373	0.546	0.437
Shore; longline		45	72	158.0	3.511	0.267	0.509	0.456
Set/gill netting		59	103	598.7	10.147	0.254	0.564	0.172
Private boat; lines	KAH 2	196	484	781.8	3.989	0.153	0.732	0.619
Charter boat; lines		11	20	35.5	3.227	0.091	1.029	0.563
Shore; line fishing		361	348	1 110.7	3.077	0.562	0.332	0.313
Set/gill netting		40	134	277.0	6.925	0.100	0.846	0.484
Private boat; lines	KAH 3	340	747	1 288.9	3.791	0.185	0.704	0.580
Charter boat; lines		15	22	77.0	5.133	0.200	0.323	0.286
Pvt boat; longlines		28	59	99.0	3.536	0.286	0.709	0.596
Shore; line fishing		709	628	2 427.1	3.423	0.568	0.317	0.259
Shore; longline		31	29	94.4	3.045	0.452	0.450	0.307
Set/gill netting		71	173	473.5	6.669	0.282	0.586	0.365
Private boat; lines	KAH 9	200	563	838.7	4.194	0.240	0.712	0.671
Charter boat; lines		20	57	113.3	5.665	0.300	0.832	0.503
Shore; line fishing		338	682	1 306.3	3.865	0.352	0.549	0.522
Shore; longline		13	11	55.0	4.231	0.385	0.217	0.200
Set/gill netting		30	87	342.6	11.420	0.267	0.423	0.254

Table 10: Number of trips (N), and harvest rate estimators p_0, H_1, and H_2 of kahawai harvests by diarists in the 1996 national diary survey by Fishstock and main fishing method for trips that targeted or caught kahawai and trips that targeted kahawai. Data from the regional diary surveys as well as the 1996 national survey are included

		Targeting or catching kahawai				Targeting kahawai			
	Fishstock	*N*	p_0	H_1	H_2	*N*	p_0	H_1	H_2
National 1996									
Private boat; lines	KAH 1	1 533	0.192	0.710	0.535	677	0.436	0.696	0.484
Shore; line fishing		747	0.373	0.546	0.437	540	0.517	0.495	0.391
Private boat; lines	KAH 2	195	0.154	0.725	0.617	85	0.353	0.731	0.584
Shore; line fishing		355	0.569	0.324	0.301	305	0.662	0.261	0.266
Private boat; lines	KAH 3	340	0.185	0.704	0.580	149	0.423	0.687	0.576
Shore; line fishing		709	0.568	0.317	0.259	574	0.702	0.244	0.197
Private boat; lines	KAH 9	199	0.241	0.709	0.669	113	0.425	0.523	0.430
Shore; line fishing		338	0.352	0.549	0.522	262	0.454	0.505	0.502
North 1993–94									
Private boat; lines	KAH 1	1 604	0.257	0.867	0.612	782	0.527	0.986	0.608
Shore; line fishing		717	0.490	0.373	0.355	530	0.662	0.281	0.285
Private boat; lines	KAH 9	252	0.155	1.010	0.809	101	0.386	0.983	0.747
Shore; line fishing		395	0.332	0.538	0.522	284	0.461	0.479	0.469
Central 1992–93									
Private boat; lines	KAH 2	231	0.117	0.837	0.708	81	0.333	1.257	1.143
Shore; line fishing		339	0.628	0.449	0.362	297	0.717	0.411	0.321
Private boat; lines	KAH 3	230	0.148	0.864	0.693	99	0.343	1.094	0.824
Shore; line fishing		292	0.623	0.371	0.352	247	0.737	0.303	0.317
South 1991–92									
Private boat; lines	KAH 3	87	0.402	0.655	0.614	49	0.714	0.524	0.612
Shore; line fishing		294	0.558	0.379	0.333	227	0.722	0.305	0.265

4.2.3 Significance level of changes in harvest rate over time

The change in H_1 and H_2 between the regional and national surveys was tested to see if any were significant. Data from trips that targeted or caught kahawai and trips that targeted kahawai were tested. A two-sided randomisation test (Manly 1991) was used to accommodate H_2 that has a complicated variance and is not defined in the usual manner of variables entering a t-test. In the randomisation test, the magnitude of the observed change in mean harvest rate was compared with the magnitude of the changes in mean harvest rate found after assigning 4999 random re-orderings of the individual harvest rates into two groups (representing the two surveys). The number of times the magnitude of the observed change was exceeded gave the *p*-value. This is a two-sided test. The *p*-value would be roughly half the tabulated values for a one-sided test.

Table 11 contains the test results and includes the mean harvest rates from the regional and national surveys that were tested and the sample sizes. Table 11 also presents the ratios of the mean harvest rates, H_1 and H_2, in the national survey to those in the regional surveys.

Table 11: Significance levels of differences between mean harvest rates from the 1996 national diary survey and the designated regional survey. B – lines from private boats; S – lines from shore; TC – targeting or catching kahawai; T – targeting kahawai; superscript N – national survey; superscript R – regional survey; N_T – number of trips; H_1 – mean-of-ratios harvest rate; H_2 – ratio-of-means harvest rate. R_1 and R_2 are the ratios H_1 and H_2 respectively in the national survey to regional survey

Survey	Fishstock	B/S	TC/T	N_T^N	H_1^N	H_2^N	N_T^R	H_1^R	H_2^R	R_1	$p(H_1)$	R_2	$p(H_2)$
North	KAH 1	B	TC	1 533	0.710	0.535	1 604	0.867	0.612	0.82	0.006	0.87	0.017
			T	677	0.696	0.484	782	0.986	0.608	0.71	0.005	0.80	0.031
		S	TC	747	0.546	0.437	717	0.373	0.355	1.46	0.000	1.23	0.013
			T	540	0.495	0.391	530	0.281	0.285	1.76	0.000	1.37	0.005
	KAH 9	B	TC	199	0.709	0.669	252	1.010	0.809	0.70	0.010	0.83	0.121
			T	113	0.523	0.430	101	0.983	0.747	0.53	0.008	0.58	0.005
		S	TC	338	0.549	0.522	395	0.538	0.522	1.02	0.842	1.00	0.997
			T	262	0.505	0.502	284	0.479	0.469	1.05	0.669	1.07	0.578
Central	KAH 2	B	TC	195	0.725	0.617	231	0.837	0.708	0.87	0.340	0.87	0.276
			T	85	0.731	0.548	81	1.257	1.143	0.58	0.039	0.51	0.006
		S	TC	355	0.324	0.301	339	0.449	0.362	0.72	0.096	0.83	0.265
			T	305	0.261	0.266	297	0.411	0.321	0.64	0.076	0.83	0.377
	KAH 3	B	TC	340	0.704	0.580	230	0.864	0.693	0.81	0.117	0.84	0.078
			T	149	0.687	0.576	99	1.094	0.824	0.63	0.026	0.70	0.041
		S	TC	709	0.317	0.259	292	0.371	0.352	0.85	0.328	0.74	0.059
			T	574	0.244	0.197	247	0.303	0.317	0.81	0.318	0.62	0.035
South	KAH 3	B	TC	340	0.704	0.580	87	0.655	0.614	1.07	0.694	0.94	0.675
			T	149	0.687	0.576	49	0.524	0.612	1.31	0.379	0.94	0.813
		S	TC	709	0.317	0.259	294	0.379	0.333	0.84	0.197	0.78	0.043
			T	574	0.244	0.197	227	0.305	0.265	0.80	0.252	0.74	0.092
Central & South	KAH 3	B	TC	340	0.704	0.580	317	0.807	0.676	0.87	0.262	0.86	0.111
			T	149	0.687	0.576	149	0.906	0.770	0.76	0.199	0.75	0.103
		S	TC	709	0.317	0.259	586	0.375	0.342	0.85	0.192	0.76	0.034
			T	574	0.244	0.197	474	0.304	0.291	0.80	0.210	0.68	0.032

The results in Table 11 suggest that in KAH 1 there was a significant decline in kahawai harvest rate when fishing with lines from a private boat, but a significant increase when fishing with lines from the shore. This suggests a difference in either kahawai or fisher behaviour between 1994 and 1996. There was probably a significant decrease in harvest rate using lines from private boats in KAH 9, though the result from the change in H_2 suggests significance at the 10% level.

The results from KAH 2 and KAH 3 are less clear cut partly because the sample sizes are smaller. As KAH 3 is in both the South and Central management regions, it has major contributions from both the South and Central regional surveys and the results for this area are confounded. Table 13 includes KAH 3 results from both the South and Central surveys combined. This meant combining data from different years, but the sample size of the regional survey data increased and a better comparison with the national survey probably resulted. Comparing the Central region survey results with the national survey results suggests that there was a significant decline in the target kahawai boat fishery but the sample sizes are quite small. When the South and Central results are combined, the decline in H_2 appears significant for line fishing from shore, but not the decline in H_1. The other results are probably not significant.

It appears that there was a significant decline in harvest rate for the lines from boat target fishery in KAH 2.

4.3 Definition of mean harvest rate

Two definitions of mean harvest rate were used above: others are possible. The most appropriate definition depends on the purpose for which the harvest rate is required. So, we might say that the mean-of-ratios estimate is most appropriate if we are interested in an average of individual fishers and the ratio-or-means estimator when we are interested in wide area harvest rates for the whole fisher community. Both these estimators are potentially biased and have different meanings. As they both presumably capture somewhat different properties of the harvest rate distribution, we could use a rule of thumb which said that changes in both had to be significant before a significant change in harvest rate was claimed.

The mean-of-ratios estimator, H_1, can be biased by incorrect values, particularly large values caused by mis-recording or mis-estimation of times or catches. High catches in short times are possible in the kahawai recreational fishery if fishing starts after a school is located. One might, for example, ignore all trips with a fishing time less than about half an hour (Hoenig *et al.* 1997). This would remove biases due to the difficulties in measuring fishing times accurately, but would also remove the (real) high harvest rates that come from making large catches in a short time. How fishing time is defined is critical in such cases. Equivalent problems are encountered when deciding on the fishing effort to use in CPUE estimations in commercial fisheries on schooling pelagics (Fréon & Misund 1999). The mean-of-ratios estimator, H_2, should be less susceptible to such errors in the estimation of fishing times, if these are assumed random and symmetrically distributed.

5. DISCUSSION

5.1 Kahawai age distribution in the recreational catch

Ageing the recreational catch each year gives a possible method of monitoring the kahawai stock. The relative strengths of 3, 4, and 5 year old kahawai from year to year and from area to area could be obtained. Changes in the proportions of older and larger kahawai in an area could be monitored. Proportions of larger kahawai caught in the North region recreational kahawai fishery were examined previously (Bradford 1999).

Sampling the recreational kahawai catch could be done during the peak fishing season (roughly Boxing Day to Anzac Day). The main annual rings in kahawai otoliths appear to be laid down during the winter (Stevens & Kalish 1998), so difficulties in ageing arising from having otoliths collected before, during, and after this ring is laid down should be avoided.

A sample size of 400–500 otoliths per stratum would be required. To reduce the size of the survey, the number of areas (strata) surveyed should be reduced, not the sample size in each stratum.

5.2 Distribution of commercial and recreational catches

A good tool for monitoring kahawai should be able to sample the whole kahawai population. The kahawai population is unlikely to have uniform density. Any sampling programme is likely to use different sampling rates within predetermined strata. Sampling within a stratum should at least be representative of the kahawai population in the stratum. Kahawai movements (Wood *et al.* 1990, Griggs *et al.* 1998) will help improve the randomness of sampling.

Little is known of kahawai behaviour. They are mobile and form schools, so their abundance is neither constant nor of uniform density in either space or time. Environmental factors, such as water temperature and salinity, that change over time may help determine their abundance in an area. The commercial fishery uses aerial spotting of surface schools to direct the purseseiners to suitable sites. The pilot estimates of kahawai abundance in surface schools show that only some of the kahawai can be in surface schools at any one time (*see*, for example, the sizes of the indices calculated by Bradford & Taylor (1995)). Also, most recreational kahawai are taken by using a line on or near the bottom (compare the numbers of kahawai caught as bycatch of the snapper target fishery and in the kahawai target fishery (Bradford 1999)).

5.2.1 Sampling the commercial catch

Sampling the commercial purseseine catch gives a poor tool for monitoring the kahawai population. The purseseine landings are large, few in number, come from surface schools, and are taken over a limited part of the kahawai range. Although landings can be sampled randomly, the kahawai stock is not sampled randomly.

The kahawai bycatch from the west coast North Island pair trawl fishery is probably the only other commercial kahawai fishery suitable for catch sampling. Here the kahawai landings are small and frequent. This fishery was sampled in the past (McKenzie *et al.* 1992, Bradford 1998a).

5.2.2 Sampling the recreational catch

Kahawai are caught in large numbers by recreational fishers, but trips are widely spread and the number of kahawai landed per trip is usually small. On most trips targeting or catching kahawai in the 1996 national diary survey, the mean catch per trip varied from 1.4 in KAH 3 to 2.3 in KAH 9 (from data in the Ministry of Fisheries database ***rec_data***). Bradford (unpubl. data, Final Research Report for Ministry of Fisheries Research Project9701, October 1998, appendix 2) plotted catch size distributions by Fishstock for several species. The catch size distributions for kahawai fall more rapidly as the catch size increases than for many of the other Fishstocks considered. This probably reflects how many kahawai fishers kept rather than how many they could catch. Catch samples from the recreational fishery are likely to be random samples from the kahawai stock.

Detailed examination of the places where kahawai were caught by recreational fishers in KAH 1 shows that the catch is taken along the whole coastline and is fairly evenly spread with higher catches from the Bay of Plenty. The recreational catch is mainly taken within about 10 km of the coast and does not sample kahawai from deeper waters very well. The recreational fishery will sample juvenile kahawai well as these fish mainly live in the inshore regions. A similar recreational fishing pattern will occur throughout the country.

Where recreational fishers live and holiday has a strong influence on where they fish and the fisher population is not uniformly distributed throughout the country. Recreational effort is strongly seasonal, concentrated in holiday periods, and probably weather dependent (Bradford 1998b). Access to good fishing spots has become easier for those able to afford the boats and transport required. Even so, the numbers of recreational fishing trips suitable for catching kahawai will not be uniformly distributed along the coast nor are they likely to have the same density as the kahawai population.

However, despite the provisos discussed above, the recreational fishery provides a better sampling tool for monitoring the kahawai stock than the commercial fishery.

5.3 Harvest rates in the recreational kahawai fishery

The use of recreational harvest rates to monitor the kahawai stock appears of dubious value. The problems encountered will not be unique to the kahawai recreational fishery.

5.3.1 Boat ramp measured harvest rates

The results using boat ramp survey data suggest that recreational harvest rate would not be a very useful monitoring or management tool for kahawai. Detection of even a moderately large change in harvest rate (35%) would require a large sample size. Ideally the target fishery would be sampled. Just over 400 trips targeting kahawai were recorded in KAH 1 in the 1996 boat ramp survey and this sample size is adequate to detect a 35% (54%) decrease (increase) with 80% power in this fishery.

If the kahawai bycatch of the snapper target fishery is used, the fraction of trips that did not catch kahawai, p_0, becomes large. When the value of p_0 is large, very large sample sizes are required to detect a decrease (increase) of 50% (100%) in harvest rate with 80% power.

5.3.2 Diary survey measured harvest rates

In diary surveys of the size of the 1996 national survey, the sample sizes for kahawai trips (targeting or targeting/catching kahawai) in the kahawai Fishstocks seem adequate to give a reliable catch rate for both major line methods. However, conflicting results arose in some kahawai Fishstocks when the results from the three regional surveys and the national survey were compared. Thus

- changes in shore fishing and boat fishing catch rates could be in the opposite direction and significance levels could be different;
- changes in catch rates could be different depending upon whether trips targeting kahawai or trips targeting or catching kahawai were considered;
- changes using both estimators of catch rate were usually but not always in the same direction but significance levels of the change could be different.

5.3.3 Other concerns

There are technical problems associated with the large sample size likely to be required to detect changes, how to select the trips sampled, and how to determine an optimum estimator of mean catch rate. The effort (time spent fishing) used can be difficult to define (how much of the fishing operation is included in the fishing time) and measure. Care would be needed if the harvest rates over time or space were standardised using a regression model. The fraction of zeroes is large and has to be treated correctly and very high catch rates are possible and should not be excluded. Some important standardising variables may not be available.

Many factors can influence the recreational harvest rate so that even if the technical problems are overcome, we are still left with answering the question: "What is being measured?" For example, the probability of catching a kahawai will depend on the density of the fish at a location and the skill mix of the fishers (Cryer & McLean 1991). Sufficient trips need to be made to an area to get a reliable estimate of the average harvest rate. Areas/times of high kahawai abundance are not necessarily areas/times of high recreational fisher abundance.

6. RECOMMENDATIONS

The schooling behaviour and short and long term movements of kahawai mean that the stock is difficult to sample randomly and/or representively. We believe that samples obtained from the recreational fishery will be better for statistical purposes than samples obtained from the commercial purseseine fishery. Such samples may still be inadequate.

We recommend annual boat ramp surveys of the recreational kahawai catch take place during the main recreational fishing period between Boxing Day and Anzac Day in all parts of the country where kahawai are caught.

- All kahawai Fishstocks should to be monitored. Currently the information on kahawai movements around New Zealand is scanty, though some kahawai do move the length of the country (Wood *et al.* 1990, Griggs *et al.* 1998). We cannot assume that changes in one area will be reflected in all areas, nor that kahawai will be distributed in the same way from year to year.

- As many as possible of the kahawai caught should be measured for length, and otoliths taken where possible. A sample size of more than 400 is required in each stratum (smaller sample sizes would be useless). This will give a reasonable approximation of the proportional numbers at age in the population and age-length relations.

- The kahawai should also be weighed, at least during one survey. The weight-length relations available come from the commercial catch and do not necessarily represent the smaller fish very well.

- Sexing the kahawai would be desirable but not essential. The kahawai growth equations have so far showed little significant sex difference (Bradford 1998a). The suggested survey period partly coincides with the kahawai spawning period and this could aid external determination of sex.

- Collecting harvest rate data should be done at a lower priority, except for those trips where kahawai was a specific target. The shape of the distribution of recreational catch rates and perhaps other factors mean that changes in average catch rates are difficult to measure. It is not known how such a catch rate relates to population size.

As boat ramps in all parts of the country would be surveyed, it will be desirable to use interviewers who live close to the ramps in the survey. These people would have to be trained to remove kahawai otoliths quickly and cleanly.

Some resistance to dissecting their kahawai for the extraction of otoliths is expected from recreational fishers. However, little of the edible parts of the kahawai would be damaged (kahawai are not generally considered a trophy fish) and most recreational fishers appear willing to help in research projects.

More sampling would be required in some areas than was done in the past. Particular difficulties may occur in KAH 3. The results from the current Wellington south coast survey should suggest whether surveying ramps in the Wellington region would result in adequate numbers of kahawai being caught to be cost effective. Kahawai from both KAH 2 and KAH 3 would be sampled. Kahawai catches along the South Island east coast were low in recent years, and conducting boat ramp surveys solely to measure the recreational catch of kahawai in this area would not be cost effective.

Surveying during the large competitions is not recommended as too many kahawai are likely to be sampled from a small area in a short time period. This could bias the data.

6.1 Cost

Mounting a nationwide series of boat ramp surveys to monitor the kahawai population will be costly, even if sampling is done from ramps where a large kahawai catch is likely to be landed by recreational fishers. There would be further costs from the time taken to prepare and read the otoliths and for processing and analysing the data.

The Pelagic Working Group suggested that the recreational kahawai catch be aged every third year. This has the disadvantage that any information on the progression of large year classes in an area will be lost. Figures 1–5 all show an apparently large 11^+ year class in all years and all areas that has been introduced through a bias in the combined all-length key used to generate the age distributions.

If recreational boat ramp surveys are being conducted for other reasons, the marginal cost for the extra work collecting kahawai otoliths could be small (providing the surveys are being done in suitable areas).

For example, annual boat ramp measurements may be required for snapper in SNA 1 and 8, and perhaps for rock lobster in CRA 1–5 and for other species. Boat ramp surveys could cover a range of objectives with little additional cost. Surveys may need to be organised so that costs are shared among the projects for different species.

7. ACKNOWLEDGMENTS

The Ministry of Fisheries funded this work under contract KAH9801. I thank Bruce Hartill (NIWA, Auckland) and Darren Stevens (NIWA, Wellington) for comments on the practicalities of running recreational surveys that would collect otoliths and Brent Wood (NIWA, Wellington) for providing the coordinates of the line 10 km from the North region coast. I thank Alistair Dunn and Mike Beardsell (NIWA, Wellington) for their comments on an earlier drafts of this document

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