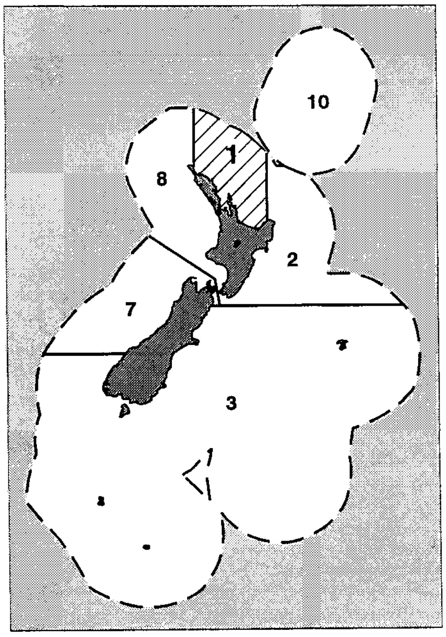
Modelling the recreational snapper harvest in SNA 1

Elizabeth Bradford



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Contents

Abstract

Bradford, E. 1997: Modelling the recreational snapper harvest in SNA 1.
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The data on the snapper harvests in SNA 1 from the 1994 North region and 1996 national diary surveys were examined for major differences which should be explained by any model of the data. The important differences are:

- fewer trips and lower catch were made in 1996, particularly in January, November, and December
- low trip numbers and catch in February 1994
- fewer trips and lower catch were made in the Hauraki Gulf in all months

The recreational snapper harvest is assumed to be determined largely by the recreational effort and then by harvest rate, though large changes in harvest rate on a time scale of decades must be considered. Estimates of the numbers of recreational fishers were made. Only the numbers from the two telephone surveys made in association with the recent diary surveys are known with some reliability, but there are indications that the numbers of recreational fishers in the North region may have declined in the recent past.

A regression analysis was used to predict the daily numbers of trips using the "lines from private boats" fishing method. The predictor variables included factors to differentiate holidays and some of the seasonal pattern and climate data from Leigh. The important climatic variables either had a seasonal cycle or were wind related variables. The results of this analysis should be treated as indicative because of technical problems with the data.

Todd Sylvester (Ministry of Fisheries, Auckland) proposed a model using the annual total number of onshore wind days at Leigh as a predictor of the three known recreational snapper harvests in SNA 1 (including the tagging estimate from 1985) which is sensitive to small changes in data. The slight increase in the 1996 harvest estimate since Sylvester performed his analysis and uncertainty in the number of onshore wind days in 1996 because of missing data reduced the correlation of the three pairs of data.

Not all the monthly differences in trip numbers seen in the two diary surveys could be reconciled with the numbers of onshore wind days in a month, or with the number of calm days in a month (another variable used by Sylvester). It seemed that rough days reduced fishing effort rather than calm days increasing it. A combined variable which includes wind speed and direction and sea state seemed to be required to account for most of the monthly differences. Weather related variables probably do not account for the all of the reduction in fishing effort in the Hauraki Gulf between the two surveys. More work will be required to define a fishing day index which would describe the probability of fishing taking place on a given day.

A definitive model of the recreational snapper harvest has not been derived. However, when the snapper recreational harvest has to be included in a model, it should have a highly variable component imposed on a variety of trends and so arranged that the model values agree with the known harvests. The possibility that more people went fishing in the past has to be considered. A predictive model should be stochastic with a highly variable component.

Introduction

In 1996 the Snapper Fisheries Assessment Working Group modelled the recreational snapper harvest with a linear increase as a result of the observed population increase in the North region (Annala & Sullivan 1997). The model was based on a tagging estimate of recreational harvest in SNA 1 of 1600 t in 1985 and an estimate of 2850 t in 1994. In early 1997, it became clear that the 1996 recreational snapper harvest in SNA 1 was going to be considerably less than that in 1994; the September 1997 estimate was 2320 t (Bradford, unpubl. data). The 1994 and 1996 estimates come from fishing diaries kept for a year by random samples of marine recreational fishers (Bradford 1996, Bradford *et al.* 1998). A reduction in bag limit and an increase in minimum legal size between the two diary surveys were considered unlikely to produce a change as large as this in recreational harvest. However, the regulatory changes between 1994 and 1996 mean that the 1996 estimate of recreational harvest is not strictly comparable with the earlier estimates. The SNA 1 Fishstock is defined in Figure 1.

Todd Sylvester (Ministry of Fisheries, Auckland, unpubl. results) presented a paper to the Snapper Working Group in 1997 which showed that the annual estimates of recreational snapper harvest in SNA 1 correlated well with both the annual number of days with onshore winds at Leigh (negative correlation) and the annual number of calm days (positive correlation). He argued that the recreational fishing effort might remain reasonably stable, even though the population was increasing.

The level of recreational fishing effort may be the dominant factor in determining the harvest. Changes in harvest rate will be of secondary importance at least over a few years. Obviously increased harvest rates with the same effort will lead to increased harvest, and rumours of good harvests may lead to increased effort, and vice versa. Currently we do not have enough data to determine what factors control recreational fishing effort.

This report will discuss the recreational catch and effort from the two diary surveys from SNA 1, what is known about the number of recreational fishers, environmental data from the area, and the work that has been done to date on modelling the recreational snapper harvest in SNA 1.

This work was funded by the Ministry of Fisheries under the modelling recreational fisheries project (RFFM01).

Programme objective

1. To build models of recreational fisheries for use in stock assessment and management

Objectives for 1996–97

1. To build a model which incorporates observed changes in the SNA 1 recreational fishery and which is consistent with the dynamics of this stock

2. To incorporate a predictive model of recreational catch and effort in SNA 1 assessments

Results from the North region and national diary surveys

Survey method

A telephone survey of a random sample of residential telephone subscribers was used to locate the households which contain recreational fishers. A randomly chosen fisher from the households with fishers was asked if he/she would keep a fishing diary for a year. This fisher was asked some questions relating to fishing activity and demography. Thus we have data on the number of trips made by diarists in the year before the diary survey as well as the number of trips they recorded during the survey.

As the diarists form a random sample, their catches can be scaled to give an estimate of recreational harvest for the whole population. The estimation of the scaling factor depends upon the sampling fraction in the survey design and has to take into account non-response and other factors (Bradford 1998).

The North region diary survey ran from 1 December 1993 to 30 November 1994, though it is loosely referred to as the 1994 survey, and the 1996 national diary survey ran from 1 January to 31 December 1996. The sampling fractions in these two surveys were different, which means that the unscaled survey results are not comparable without adjustment. The 1996 national survey data have been multiplied by the ratio of the 1996 scaling factor to the 1994 scaling factor (called the scaling factor ratio) to give comparable data.

The diary surveys have been designed to give harvest estimates in Fishstocks. There is no guarantee that the amount of fishing done on a particular day is an unbiased estimate of overall fishing activity on that day. In this report, daily numbers of trips in SNA 1 are used and these numbers should be treated as indicative.

Results

Results from two diary surveys relevant to the recreational snapper fishery in SNA 1 are discussed.

Figures 2 and 3 show the monthly snapper catch and trips, by area, where snapper were reported caught in the 1994 North region diary survey and the 1996 national survey. The 1996 data were multiplied by the scaling factor ratio. Figures 2 and 3 show that:

- the 1996 catch and effort values were often less than the 1994 values
- the greatest decline in catch and effort took place in the Hauraki Gulf, and in particular, in the inner Hauraki Gulf
- the catch rate, on trips where snapper were caught, has declined (that is, the catch tended to decline more than the number of trips made)
- catch was substantially down in January, March, April, and December 1996
- catch and effort in February 1994 were lower than might be expected from the January and March data
- there was a strong seasonal pattern in effort and hence catch.

The December 1993 and 1996 results are not directly comparable as December 1993 was at the beginning of the survey year and December 1996 was at the end of the survey year and the non-response rate increases during diary surveys. Even so, the December 1996 snapper catch and fishing effort are lower than might be expected. The summer fishing season starts after Christmas and there was very little fishing in the week after Christmas 1996 because of cyclonic weather.

These results suggest that we need to examine the factors which influence the potential fishers in Auckland to go fishing as these are the people who are most likely to fish in the inner Hauraki Gulf. Bradford (1996) showed that 97% of trips to the inner Hauraki Gulf in the 1994 North region survey were made by Auckland residents. A similar result holds for the national survey (Bradford, unpubl. data). I found no significant difference in the fishing activity between Auckland residents and other North region residents. There were demographic differences which are probably representative of the general population. Detailed results are given in Appendix 1.

In early 1997, I used the hypothesis (based on the 1994 data) that about three-quarters of the recreational snapper harvest in SNA 1 was taken in the first 6 months of the year in order to estimate the 1996 snapper harvest from 6 months of catch data. This ratio also applied to the 1984 tag return data (Kevin Sullivan, Ministry of Fisheries, Wellington, unpubl. data). The final results from the 1996 survey showed that the snapper harvest was less than predicted for the second half of the year, except in East Northland where the prediction held.

Figure 4 shows catch by method in SNA 1. Most of the snapper catch is taken using "lines from private boats". I shall assume that understanding the variations in the number of trips using that method will give an understanding of the variations in the recreational fishing effort directed towards snapper in recent years.

Figure 5 compares the number of trips on which a given catch was made, the number of respondents who made a given number of trips, and the number of respondents who made a given annual catch. Again, the 1996 national survey data are multiplied by the scaling factor ratio to make them comparable with the 1994 North region data. It is not appropriate to scale the daily trip numbers to population estimates as the trip data on a daily basis cannot be guaranteed to be unbiased random sample. The plots in Figure 5 show:

- the effect of the reduced bag limit (dropped from 20 to 9 snapper on 1 October 1995)
- a marked drop in the number of unsuccessful trips
- a reduction in the number of trips made
- a reduction in the number of diarists catching no snapper during the year

The implication of these results may be that the inexperienced, or fair weather, fishers were less likely to fish in 1996 than in 1994.

Given the importance of the "lines from private boats" method for catching snapper, Figure 6 shows the daily numbers of such trips from the two surveys. Again, the 1996 data were scaled to be comparable with the 1994 data. The upper axes in Figure 6 indicate the days which were weekends and holidays. Figure 6 shows:

- increased fishing effort at weekends and holidays
- a seasonal pattern in effort
- a marked drop in effort in January and late December 1996 compared to 1994
- somewhat more fishing effort at Easter 1996 than Easter 1994

When Waitangi Day and Anzac Day fall on a Tuesday or a Thursday (as both did in 1996), it appears that the preceding Monday or following Friday should be considered as a holiday.

Figures 7, 8, and 9 are similar to Figure 6, but are for the three sub-regions, East Northland, Hauraki Gulf, and the Bay of Plenty separately. These figures demonstrate regional differences in recreational fishing effort.

The numbers of trips using "lines from private boats" as recorded in the 1994 North region and the 1996 national diary surveys in SNA 1 are tabulated in Table 1 by month and sub-region. The national survey trip numbers were multiplied by the scaling factor ratio. The numbers in Table 1 are summations of the data plotted in Figures 6–9. Overall, the number of trips was down, and nearly all of the reduction occurred in East Northland and the Hauraki Gulf. January, November, and December had considerably fewer trips recorded in the 1996 survey. Part of the drop in December will have come from the increase in non-response rate as the survey progressed, but a cyclone in the week after Christmas severely limited fishing. The numbers of trips in February were comparable overall, but down in the Hauraki Gulf. February 1994 appeared to have less fishing than expected.

An average of 10.1 fishing trips was made by North region diary respondents in 1996. The same people when questioned about their fishing activity in the previous 12 months during the telephone survey (run in November 1995 to select the diarists for 1996) gave an estimated mean trip number of 13.3. However, the mean number of trips made by respondents in the 1994 North region diary survey was 10.6 suggesting that about 10 trips per year might be a reasonable average (for North region fishers who respond to diary surveys).

Numbers of recreational fishers

Two important components of the marine recreational fishing effort in a year are the number of fishers and the mean number of trips they make. Below, I outline the survey information that we have on the numbers of fishers.

The telephone surveys give estimates of the number of marine recreational fishers during the year before each diary survey.

From the 1994 North region telephone and diary survey: 15 015 households were surveyed; of these 3363 (22.4%) contained people who had been saltwater fishing in the 12 months before November 1993. Where the households contained fishers, the average number of fishers in the household was 2.05 persons (J. D. Bell & Associates 1994). Assuming 579 200 households in the North region at the time (taken from the average of the 1991 and 1996 census data for households in the Northland, Auckland, Waikato, and Bay of Plenty regional council areas) gives an estimate of 265 970 marine recreational fishers in the North region in 1993.

From the 1996 national telephone and diary survey: 13 893 households were surveyed in the North region; of these 2418 (17.4%) contained people who had been saltwater fishing in the 12 months before November 1995. Where households contained fishers, the average number of fishers in a household was 2.00 persons (J. D. Bell & Associates 1996). Assuming that there were 613 548 households in the North region (taken from the 1996 census results) gave an estimate of 213 520 fishers. Thus there was a 20% drop in the estimated number of fishers in the North region between 1993 and 1995.

The NRB report on the economic worth of recreational fishing in New Zealand (Anon. 1991) found that 38% of their sample (42% in the top half of the North Island) had done some form of recreational fishing in the 12 months before September 1991. This number included freshwater recreational fishing and the categories for which percentages are given are not mutually exclusive. The sample size was small and did not include children under 16. However, 28% of residents from the top half of the North Island had made at least one trip saltwater fishing from a boat, and 23% had made at least one trip saltwater fishing from land. Thus we can conclude that more than 28% and less than 42% (say 30–35%) of the North region population 16 years of age and over went marine recreational fishing in 1991. The total population of the area spanned by the Northland, Auckland, Waikato, and Bay of Plenty regional councils in the 1991 census was 1 632 722. Hence the number of fishers (allowing a lower fraction of fishers under 16 in the population) in the North region in 1991 may have been of the order of 400 000. This number is unreliable given the assumptions made in its derivation. However, 1991 may have been a year with high recreational fishing effort as it had the lowest number of onshore wind days at Leigh in recent times (*see* Tables 2, 3, and 4).

The 1987 National Marine Recreational Fishing Survey estimated that 270 000 fishers caught snapper in the North region (Sylvester *et al.* 1994, Kevin Sullivan, Ministry of Fisheries, Wellington, unpublished results).

The two recent telephone surveys give comparable numbers. I estimated the number of fishers catching snapper in QMAs 1 and 9 in the 1994 North region and 1996 national diary surveys as 144 600 and 120 500 respectively. These numbers should be comparable with the number given by the 1987 survey. The scaling factor used in the diary surveys assumes (almost certainly wrongly) that equal numbers enter and leave the fishery in any year, so there should have been the same number of fishers in 1994 as in 1993 and 1996 as in 1995. Thus roughly half the marine recreational fishers in the North region caught snapper in 1994 and 1996. Therefore, we might, with little reliability, conclude that 200 000 fishers caught snapper in the North region in 1991.

Some of these numbers are highly uncertain, but they suggest that the fishing population in the North region is highly variable from year to year and may have declined in the recent past despite the population increase (from 1 528 507 to 1 806 819 between 1986 and 1996).

Climatic variables

A major hypothesis of this work is that much of the variation in recreational effort is driven by climatic variations. In this section, I will examine the variation in some climatic variables.

I used the NIWA climate database to obtain data from several stations in the North region to investigate regional differences. A description of useful variables and stations is given in Appendix 2.

Figure 10 shows the monthly mean temperature for the eight stations: Whangarei, Leigh, Whitianga, Tauranga, Whakatane, Mokohinau, Takapuna, and Tiri Tiri lighthouse. These all showed the expected cyclical pattern. The temperature maximum in 1994 occurred in

January, and the February 1994 mean temperature may have been below normal (an indication of worse than average weather).

Figure 11 shows the monthly average wind speed at four sites (some sites were omitted for clarity). Winds were generally stronger in winter. As might be expected, Mokohinau had stronger winds than the other sites. The other three sites showed regionally dependent variation. Figures 12 and 13 show the fraction of the month with low daily mean wind speed (under 5 knots) and with low daily maximum gusts (under 25 knots). Figures 12 and 13 show same data as Figure 11 plotted in a different way. Winds at Mokohinau may have been lighter in early 1994 than at any time since.

Strong winds may prevent or strongly deter boat (and probably shore) fishing; onshore winds are likely to cause problems at a lower strength than offshore winds because of increased wave action. Hence wind direction is also likely to be important.

Figures 14–17 plot the daily maximum gust and its direction at Leigh, Mokohinau, Tauranga, and Whangarei for each month of the North region and national diary surveys. These plots are equi-scaled, though they appear flattened; the cross on each figure was drawn with the same algorithm. Figure 18 shows similar data for January and February in 1994, 1995, and 1996 for several sites (much of the recreational fishing effort occurs in January and February and differences in the effort recorded in the two diary surveys in these two months have been noted). These plots are difficult to interpret in terms of their effect on fishing effort without detailed knowledge of the extent of wind protection at any particular launching or fishing site.

Tabulation of some Leigh wind data

The wind data need to be transformed into a suitable form for use in a model. I start with the data from Leigh where annual summaries of several variables likely to influence fishing effort are already available from 1967 to 1991, 1994, and 1996. The Leigh climate data can be considered representative of conditions in the Hauraki Gulf.

The direction of the maximum gust on any day has been found to be a good indicator of the prevailing wind direction for that day (J. Evans, Leigh Marine Laboratory, pers. comm. to Todd Sylvester). Definitions of the terms used in describing climate variables are given in Table 2.

The historic data from 1968 to 1991 for the numbers of calm, rough, low wind, high wind, offshore, and onshore wind days at Leigh are given in Table 3 (from Sylvester unpubl. results). I have recalculated the number of onshore wind days in 1991 as the value of 69 given by Sylvester seemed too low. A revised value of 78 was used.

The monthly and annual totals of offshore and onshore wind days at Leigh are given in Table 4 for 1992 to July 1997. The gust records from Leigh are missing for a critical period from mid-December 1995 to early January 1996. There are some differences between the numbers given in Table 4 and those of Sylvester. Sylvester's 1994 data are for 1 December 1993 to 30 November 1994 (the period of the North region diary survey). The monthly mean daily wind runs at Leigh are given in Table 5.

To produce a variable which indicates both strength and direction of the wind, I categorised the strength of the maximum gust into three groups: low – less than 24 knots;

medium – greater than or equal to 24 knots and less than 33 knots; and high – greater than or equal to 33 knots. These breakpoints seem to be standard in climate data. A further break at greater than or equal to 51 knots is used in the climate database. Only a few gusts greater than or equal to 51 knots occur at the land based stations in the north of New Zealand, and these have not been separated out. Ideally, I would like to use the surface wind run and the direction of the maximum gust, but the different time periods of the measurements make this problematic. The number of days with (low, medium, strong) times (offshore, onshore, other) winds are given in Table 6 for Leigh in 1994 and 1996. The data plotted in Figure 14 are essentially those given in Table 6.

The numbers of calm, medium, and rough days at Leigh during December 1993, 1994, and 1996 are given in Table 7.

Tabulation of wind data from Tauranga and Whangarei airports

To get wind data which is possibly representative of conditions in the Bay of Plenty and East Northland, I have used data from the automatic weather stations (AWS) at Tauranga and Whangarei airports. Because the critical wind direction in these locations is not known to me, I have divided the direction of the maximum gust into four quadrants about north, south, east, and west. Otherwise Tables 8–10 for Tauranga and Tables 11–13 for Whangarei contain essentially the same information as Tables 4–6 for Leigh. One noticeable feature is the high number of days with westerly winds at Tauranga. The data plotted in Figures 16 and 17 are essentially those given in Tables 10 and 13.

The mean wind strength increases as one moves from Whangarei to Leigh to Tauranga.

Preliminary analysis using climatic variables from Leigh

To get an idea of which climatic variables are important in predicting fishing effort and hence snapper harvest, I tried using regression models with various climatic variables from Leigh (obtained from Sylvester) as predictors to explain the variation in the daily trip numbers. The obvious seasonal differences and the differences in fishing activity between holiday and work times have to be taken into account.

I included a factor which took account of the difference between weekdays and weekends and holidays. The number of weekend and holiday days varies slightly from year to year in New Zealand. The difference in the amount of fishing on weekend days and week days may have declined since the introduction of weekend shopping which has meant that a higher fraction of the population is working at weekends than previously.

The two main seasonal climatic variables which might explain the seasonal pattern are temperature and day length. I used sunshine hours as an approximation to day length. Maximum day length occurs about 22 December, and the maximum monthly temperature generally falls in February; neither of these correspond exactly to the seasonal cycle in fishing effort. I introduced a factor with three levels corresponding to: Christmas Day to Auckland Anniversary Day holiday (31 January 1994, 29 January 1996); Auckland Anniversary Day to Easter; and the rest of the year. This was reasonably effective but the models tended to need a slowly varying seasonal variable as well. The best of the available climate variables tended to be sea surface temperature (SST), I think because SST is smoother than air temperature (especially as I was using maximum air temperature which was the temperature variable in the Leigh data set).

Temperatures in the north are rarely low enough to prevent recreational fishing, but they probably do fall low enough to have a deterrent effect on all but the most avid fishers. As most recreational fishing takes place during daylight, the longer summer days give more opportunity for fishing, for example, after work. The seasonal factor is probably a combination of day length and temperature, but may be confounded by people being on holiday.

After these obvious patterns were accounted for, various variables related to wind strength and direction became important. Rain was not important, except in so far as strong winds are often associated with rain.

Sea swell is likely to be important in determining marine recreational fishing effort, but the reduced level of commercial shipping means that swell measurements at sea are becoming rare. As sea swell is caused by wind, a wind variable may have to be used as a proxy for sea swell.

A regression model using daily data is useful to determine the most important variables which might explain the number of fishing trips made. However, the variables to use did not seem to be consistent for the three sub-regions used in SNA 1, nor from year to year. As suggested earlier, the number of trips in a day is likely to be biased since there is no guarantee that the diary surveys still give a random sample of fishing on a particular day. Regression models which include autoregressive variables (that is, are partially dependent on past values) require the use of past as well as current values of the explanatory variables, and even then may not give clear cut results. I also suspected that, on a daily basis, I was getting a timing mismatch caused by the way the climate variables are stored. An international time system is used, but some variables are based on a 24 hour period ending at midnight, and some are based on a 24 hour period ending at 0900 hours and usually ascribed to the previous day. Although the above problems can be addressed, the subjective factors which influence whether fishing trips are made on a day to day basis cannot be included in a regression model. A model similar to that proposed by Sylvester (unpubl. results) but including more of the month to month and regional variation seems desirable.

Models of the recreational snapper harvest in SNA 1

Sylvester (unpubl. results) regressed the three known estimates of annual snapper harvests in SNA 1 against several variables, including the number of onshore wind days at Leigh. I have repeated this regression with slightly different data values: the snapper harvest values used are 1600 t in 1985, 2850 t in 1994, and 2500 t in 1996. The value of 2500 t has been increased from the actual value of 2320 t to allow for the increase in minimum legal size and the decrease in bag size before 1996. The values of 2850 t and 2500 t in 1994 and 1996 may be positively biased (by about 5%) because of a confusion between harvest and catch inadvertently introduced into the diary survey (Bradford 1998). Also, an alternative scaling factor would give a lower value for the snapper harvest in 1996. The two values arise depending upon whether or not the North region diarists are combined with the Central region diarists. The derivation of the scaling factors was described by Bradford (1998). The estimate for the 1996 snapper harvest in SNA 1 has increased since the preliminary estimate used by Sylvester. To allow for missing data (particularly in 1993), I have usually assumed that the proportion of onshore days is the same in the available and the missing data.

However, I have assumed most of the days with missing data in the first week of January 1996 had onshore winds (based on the direction of the maximum gust at Whangarei).

The regression relation obtained with the three known points is sensitive to the actual values used. The uncertainties caused by missing climate data over Christmas 1995 and the uncertainty in the snapper harvest are critical.

The number of onshore wind days in each year at Leigh is shown in the upper plot in Figure 18 and the relation

harvest = 5250 - 23 * (number of onshore days)

(which is a rounded version of one of the regression equations) in the lower plot in Figure 19. The known points are added (the 1994 harvest was not for the calendar year). The 1997 prediction is made from a scaled up number of onshore wind days for January to August to a full year and should be viewed with caution.

Figure 20 shows two other subjectively obtained versions of the estimated harvest. The upper plot shows a linear increase of 50 t per year plus a fluctuating term proportional to the number of onshore wind days in the year. The lower plot shows a linear decrease of 50 t per year plus a fluctuating term proportional to the number of onshore wind days in a year. The purpose of these plots is to show the fragility of a regression relation based upon three imprecisely know points.

One feature of all these plots is that the predicted snapper harvest has fallen during the 1990s. These results are dependent on the assumptions made to fill in missing data in the number of onshore wind days at Leigh series. The predicted harvests in 1987, 1991, 1994, and 1996 follow at least qualitatively the same pattern as the estimates of fishing population given above.

The data uncertainties mean that the relation given above cannot be considered to give a good estimate of the snapper harvest. There is no simple way of choosing between the three relations shown in Figures 19 and 20 (and any of the other possible relations not shown). The three estimates of predicted harvest shown lead to quite different cumulative withdrawals by the recreational fishery in the period 1973 to 1997. The cumulative withdrawals are:

with no trend	830 000 t
upward trend	660 000 t
downward trend	1 060 000 t

The two "models" with superimposed trends are given as examples of the range of relations that might have existed.

Month to month differences

I now investigate whether the month to month differences between the numbers of "lines from private boat" trips as recorded by diarists in the 1994 and 1996 diary surveys correlate with the month to month differences in the wind data. I shall use Leigh to indicate wind conditions in the Hauraki Gulf and to some extent East Northland, Whangarei airport for East Northland (and to some extent the Hauraki Gulf), and Tauranga airport for the Bay of Plenty.

The main differences in numbers of trips made are (*see* Table 1 and Figures 5–8):

- fewer trips overall were made in 1996
- fewer trips were made in all sub-regions in January, November, and December
- slightly more trips overall were made in 1996 in February, April, and October
- fewer trips were made in the Hauraki Gulf in all months

There were more onshore wind days at Leigh in 1996 than in 1994. In February 1994 there were many onshore wind days at Leigh (the highest monthly number in the years shown in Table 4) and the mean wind speed was high. There were 12–19 onshore wind days in January 1996 (the uncertainty is caused by missing data) compared to 13 in 1994. The wind was mainly from the easterly quarter at Whangarei in early January 1996, so the wind was probably onshore at Leigh on (most of) the days with missing data. The mean wind speed was about 50% higher in January 1996 than January 1994. March and April had more onshore wind days in 1996, but mean wind speeds were less.

I could not detect a consistent pattern between the monthly numbers of trips (in the Hauraki Gulf and East Northland) and the monthly numbers of onshore wind days throughout 1994 and 1995. I looked at the numbers of calm days (the other variable that Sylvester found gave a good relation with the snapper harvests). On a monthly basis, it seemed that what was important was the deleterious effects of the number of rough days, rather than the advantageous effects of the numbers of calm days. Probably of greatest importance in preventing fishing are long runs of strong onshore winds and rough seas. Near Leigh: January 1994 had many days with low to medium non-onshore winds and calm to medium seas; February 1994, January 1996, and February 1996 had many days with medium to high onshore winds and medium to rough seas. December 1996 had a week of medium to high mainly onshore winds with rough seas after Christmas. There seems no clear reason for the fewer trips in November 1996 compared to November 1994. Some of the other monthly differences in fishing effort between years can be explained.

The reduction in the number of trips made in the Hauraki Gulf in all months in 1996 is not consistent with wind (and related) factors alone. Most of the reduction in fishing effort occurred in the inner Hauraki Gulf which is an area fished predominantly by Auckland residents. As pointed out earlier, I was not able to detect any difference in the fishing activity of Auckland residents compared with other North region residents in the national survey diarists, but the mainly city dwellers in Auckland may have different motivations for how they spend their spare time from the other residents in the North.

Near Tauranga, the adverse winds are probably from the north and perhaps east, but also from the west on the eastern Bay of Plenty coast. The differences in direction of maximum gust vary from month to month and Bay of Plenty residents can easily travel to a suitable launching site. The mean wind speed was generally less in 1996 than in 1994, particularly in the first part of the year. There were slightly more days at Tauranga with a low maximum gust in 1996 than 1994. The higher number of days in January with easterly winds probably accounts for the drop in the number of trips made in the Bay of Plenty in January. Otherwise it is difficult to detect correlations between wind and fishing activity. The month to month differences in the winds were not extreme until the cyclone after Christmas 1996.

Comments on harvest rate

At least some of the wind data shown suggest that the weather became progressively less favourable for recreational fishing after 1991. Such a long period of adverse weather may have discouraged the occasional fishers so that by 1995 and 1996 the fishers available for selection by the telephone survey were the more able fishers. This may explain the apparent greater probability of catching a snapper on a trip in 1996 as compared to 1994 (*see* Figure 5). The decline in harvest rate on trips when snapper were caught between 1994 and 1996 could be a consequence of the introduction of a higher minimum legal size between the two surveys.

Conclusions from the modelling

It is highly likely that wind strength and direction and sea state strongly influence the level of recreational fishing effort. However, the relations derived by Sylvester (1997) were somewhat fortuitous, as not all the monthly differences in fishing activity can be explained just in terms of the variables used in them.

It should be possible to derive a "fishing day" index which would describe the probability of recreational fishing taking place on a given day. Such an index would have to include the higher likelihood of fishing at weekends and holidays, the seasonal effect, wind strength and direction, and maybe other weather variables, and probably some lagged values of the weather variables. Day length needs to be considered, (though it may be confounded with the seasonal factor) since most fishing trips take place during daylight, and there is about twice the time available for fishing at mid-summer as there is at mid-winter. Appendix 3 gives some data from the two diary surveys which show the change in fishing activity with day type and throughout the year. These figures give an indication of the pattern of fishing activity as it is at present, but this pattern may not be constant over decades.

It seems relatively easy to describe the very good (long periods of light off shore winds and calm seas over summer) and very bad (long periods of strong onshore winds and rough seas) days for recreational fishing. On the very good days, a high proportion of the fishing population will go, or consider going, fishing, on the very bad days only the foolhardy will go fishing. In between the index will become complex. The less keen fishers are likely to be more easily put off than the keen, skilled, well equipped fishers. When the weather conditions are not extreme, some fishers will have easy access to several fishing places and will be able to choose the most suitable for the conditions.

Only some of the drop in fishing effort in the inner Hauraki Gulf can be explained by weather variables. This area may be perceived as being "fished out", that is, harvest rates may be thought to have become too low. The motivations of Auckland fishers may be different from those of fishers elsewhere in the North.

An investigation into what motivates fishers to fish on a particular day would give valuable insights for modelling the recreational fishing effort.

A model for the recreational snapper harvest should include a highly variable component imposed on a variety of background trends and so arranged that the recreational harvest in the years where it is known are met within some acceptable bounds. The possibility of high recreational harvests in times past (over 20 years ago) due to possibly higher recreational harvest rates when the snapper biomass was higher, and the possibility that a higher fraction of the population went fishing in the past (Sylvester, unpubl. results), have to be considered. However, it seems likely that the number of people with access to reasonably powerful boats grew during the 1970s and 1980s as New Zealand became more prosperous, and there was probably a shift from shore based fishing to boat fishing.

A predictive model for the recreational harvest in the future should be stochastic, varying about a constant or a trend (or a series of functions if regulations are to be changed), or a function of the predicted biomass (to allow for harvest rate changes), or some other function considered desirable.

Discussion

In a stock assessment model for snapper, it seems that there is as yet no unique way to describe the recreational harvest over time. Almost certainly, the recreational effort in any year depends on the wind strength and direction and these can be highly variable from year to year. The harvest is likely to be strongly correlated with effort, but changes in harvest rate will influence the total harvest. Changes in harvest rate as well as changes in effort must be considered in a model for recreational harvest which extends back into the past. Recreational harvest rates are likely to have been higher in times past (1970s say) than they are in the 1990s, as the snapper biomass is thought to have been higher (Annala & Sullivan 1997). One might, for example, model the recreational harvest rate as being proportional to the biomass though even if we accept a direct relation between harvest rate and abundance, it will be the abundance in the areas accessible to the recreational fishery which is needed. It is likely that in earlier times, more of the recreational snapper harvest was taken from the shore or close to it. Currently most of the recreational snapper harvest in SNA 1 is taken by people using boats which can go considerable distances offshore. Any predictive model of recreational harvest will need to include the effect of change in harvest rate; if the snapper stock rebuilds, the recreational harvest rate is likely to increase. The effects of any changes in regulations need to be included in a model for the recreational snapper harvest.

Conclusions

1. A model for the recreational snapper harvest should include a highly variable component imposed on a variety of background trends and so arranged that the recreational harvest in the years where it is known are met within some acceptable bounds. The possibilities of high recreational harvests over 20 years ago due to higher recreational harvest rates (when the snapper biomass was higher), and that more people went fishing in the past (Sylvester 1997), have to be considered.

2. A predictive model for the recreational harvest in the future should be stochastic, varying about a constant or a trend (or a series of functions if regulations are to be changed), or a function of the predicted biomass (to allow for harvest rate changes), or some other function considered desirable.

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Table 1: Numbers of trips made using lines from private boats in SNA 1 from the 1994 North region and the 1996 national diary surveys. The national survey data are inflated by the ratio of the scaling factor. Tabulation is by month and the three subregions of SNA 1: ENLD, East Northland: HAGU, Hauraki Gulf; and BPLE, Bay of Plenty

				1994				1996
	ENLD	HAGU	BPLE	SNA 1	ENLD	HAGU	BPLE	SNA 1
December	333	467	352	1 152				
January	623	739	684	2 046	344	430	581	1 355
February	227	354	302	883	264	269	357	890
March	253	348	244	845	188	200	293	681
April	179	306	246	731	212	242	297	751
May	80	123	90	293	62	101	126	289
June	47	78	63	188	75	44	83	202
July	54	49	54	157	45	28	66	139
August	46	70	78	194	46	26	93	165
September	37	53	43	133	53	48	91	192
October	40	98	75	213	62	69	115	246
November	61	160	101	322	50	70	92	212
December					117	125	147	389
Year	1 980	2 845	2 332	7 157	1 424	1 549	2 196	5 169

Table 2: Definitions of terms used in following tables

Onshore	Onshore wind days at Leigh have direction of maximum gust 30°–110°
Offshore	Offshore wind days at Leigh have direction of maximum gust 210°–290°
Low gusts	Strength of maximum gust < 24 knots
Medium gusts	Strength of maximum gust ≥ 24 knots and < 33 knots
High gusts	Strength of maximum gust ≥ 33 knots
Wind run	Distance that would be travelled at the mean wind speed in the period (1 day)
North quadrant (N)	315°–45° (Maximum gust direction is given to the nearest 10°)
South quadrant (S)	45°–135°
East quadrant (E)	135°–225°
West quadrant (W)	225°–315°
LowOn	Low maximum gust in the onshore direction
MedOn	Medium maximum gust in the onshore direction
HigOn	High maximum gust in the onshore direction
LowOff, MedOff, HigOff	Similar definitions to the above
LowN	Low maximum gust from the northerly direction
MedN	Medium maximum gust from the northerly direction
HigN	High maximum gust from the northerly direction
	Similar definitions for the easterly, southerly, and westerly directions
Calm	Total number of calm days in a year (wave surge at 9 a.m. ≤ 0.6 m at Leigh)
Rough	Total number of rough days in a year (wave surge at 9 a.m. ≥ 2 m at Leigh)

Table 3: Historic data for the number of calm, rough, low wind, high wind, offshore, and onshore days at Leigh (Sylvester, unpubl. results)

Year	Calm	Rough	High wind	Low wind	Offshore	Onshore
1968	101	56	108	60		
1969	130	65	70	89		
1970	96	70	66	67		
1971	62	132	84	73		
1972	113	77	56	88		
1973	82	96	62	85	168	114
1974	73	97	88	82	142	144
1975	84	98	74	105	183	106
1976	78	104	108	62	196	111
1977	96	89	78	63	202	95
1978	78	132	88	74	157	154
1979	106	75	80	71	173	130
1980	131	82	88	73	215	82
1981	101	98	93	72	153	136
1982	107	77	64	87	180	106
1982	135	69	64	63	215	90
1984	88	68	82	92	155	129
1985	67	107	96	79	135	157
1986	101	47	62	94	163	115
1987	117	38	75	98	198	111
1988	103	48	90	78	202	112
1989	66	80	93	67	131	152
1990	99	55	60	90	198	83
1991	115	40	75	70	222	78

Table 4: Number of days per month and year when the maximum wind gust at Leigh was offshore (210°–290°), onshore (30°–110°), or other, and all the days with gust measurements in years 1992–97 (to 31 July 1997)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992													
Offshore	11	13	22	16	17	15	16	26	20	9	14	14	193
Onshore	16	8	4	8	9	10	7	1	4	11	10	9	97
Other	4	8	5	6	5	5	8	3	6	11	6	8	75
All	31	29	31	30	31	30	31	30	30	31	30	31	365
1993													
Offshore	20	0	5	15	11	16	13	20	16	18	19	20	173
Onshore	0	0	0	4	12	8	10	8	9	10	6	5	72
Other	3	0	3	6	8	6	8	3	5	3	5	4	54
All	23	0	8	25	31	30	31	31	30	31	30	29	299
1994													
Offshore	13	4	16	18	18	14	17	23	22	17	18	15	195
Onshore	13	20	10	11	4	3	8	4	5	10	11	12	111
Other	5	4	4	1	9	13	6	4	3	4	1	4	58
All	31	28	30	30	31	30	31	31	30	31	30	31	364
1995													
Offshore	2	12	13	9	9	22	17	22	13	19	14	5	157
Onshore	25	13	11	19	15	2	6	7	9	7	6	7	127
Other	4	3	7	2	7	6	8	2	8	5	10	2	64
All	31	28	31	30	31	30	31	31	30	31	30	14	348
1996													
Offshore	6	10	13	10	19	14	17	22	9	17	24	17	178
Onshore	12	15	13	13	7	9	9	3	15	11	3	10	120
Other	6	2	5	7	5	6	5	6	6	3	3	4	58
All	24	27	31	30	31	29	31	31	30	31	30	31	356
1997													
Offshore	13	10	16	20	9	15	20						103
Onshore	17	15	8	4	18	10	3						75
Other	1	3	7	5	4	5	8						33
All	31	28	31	29	31	30	31						211

Table 5: Monthly mean wind run (km) at Leigh from 1 January 1992 to 31 August 1997

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1992	283	287	322	249	298	317	413	392	309	305	366	318	322
1993	283	284	289	256	261	296	209	311	279	275	254	283	273
1994	216	352	319	311	362	333	394	271	377	353	310	291	323
1995	399	319	291	324	333	308	340	274	262	297	316	358	319
1996	316	316	307	271	325	394	289	382	322	340	336	290	324
1997	366	264	284	285	340	308	258	258					301
All years	310	304	302	283	319	326	317	326	310	314	317	308	311

Table 6: Numbers of days per month and year when the maximum gust at Leigh had the defined categories of strength and direction. Data are for 1994 and 1996

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1994													
LowOff	6	1	8	11	3	9	9	15	6	5	6	10	89
LowOn	13	11	6	7	1	1	2	0	2	4	8	11	66
LowOth	3	3	3	1	3	7	3	3	0	3	1	4	34
Low	22	15	17	19	7	17	14	18	8	12	15	25	189
MedOff	6	3	3	6	5	4	4	7	8	6	8	4	64
MedOn	0	5	3	3	3	0	1	2	1	2	2	1	23
MedOth	2	1	0	0	4	4	3	1	2	1	0	0	18
Medium	8	9	6	9	12	8	8	10	11	9	10	5	105
HigOff	1	0	5	1	10	1	4	1	8	6	4	1	42
HigOn	0	4	1	1	0	2	5	2	2	4	1	0	22
HigOth	0	0	1	0	2	2	0	0	1	0	0	0	6
High	1	4	7	2	12	5	9	3	11	10	5	1	70
All	31	28	30	30	31	30	31	31	30	31	30	31	364
1996													
LowOff	6	9	6	4	9	6	8	6	6	10	9	12	91
LowOn	9	9	7	11	3	5	5	1	4	3	3	5	65
LowOth	5	1	4	4	5	4	5	4	4	1	0	4	41
Low	20	19	17	19	17	15	18	11	14	14	12	21	197
MedOff	0	1	5	4	7	5	9	10	2	6	9	4	62
MedOn	1	4	4	2	1	1	1	0	7	7	0	3	31
MedOth	1	1	0	3	0	2	0	0	2	0	2	0	11
Medium	2	6	9	9	8	8	10	10	11	13	11	7	104
HigOff	0	0	2	2	3	3	0	6	1	1	6	1	25
HigOn	2	2	2	0	3	3	3	2	4	1	0	2	24
HigOth	0	0	1	0	0	0	0	2	0	2	1	0	6
High	2	2	5	2	6	6	3	10	5	4	7	3	55
All	24	27	31	30	31	29	31	31	30	31	30	31	356

Table 7: Monthly totals of calm, medium and rough days at Leigh in December 1993, 1994, and 1996

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Calm												12	
Medium												16	
Rough												3	
Total												31	
1994													
Calm	3	4	12	7	11	7	14	12	14	14	14	8	117
Medium	25	13	16	18	17	14	8	16	15	13	13	14	186
Rough	3	11	3	5	3	9	9	3	1	4	4	9	62
Total	31	28	31	30	31	30	31	31	30	31	30	31	365
1996													
Calm	2	4	6	5	10	12	8	15	1	1	13	7	94
Medium	23	22	21	24	19	12	20	13	24	24	12	18	226
Rough	6	3	4	1	2	6	3	3	5	5	6	6	46
Total	31	29	31	30	31	30	31	31	30	30	30	31	366

Table 8: Number of days per month and year when the maximum gust at Tauranga airport was from the north, south, east, or west quadrant for years 1992–97 (to 3 September 1997)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992													
N	14	8	7	7	2	3	3	5	4	13	8	12	86
S	3	0	3	6	8	6	4	2	6	5	4	2	49
E	5	6	1	3	6	7	6	1	4	6	6	6	57
W	7	14	19	14	15	13	17	23	16	5	11	11	165
All	29	28	30	30	31	29	30	31	30	29	29	31	357
1993													
N	4	3	9	7	9	6	3	2	6	10	10	8	77
S	1	5	6	2	3	2	12	5	6	2	2	4	50
E	1	12	6	8	3	2	5	9	5	1	2	4	58
W	25	8	10	13	15	19	10	15	13	15	16	15	174
All	31	28	31	30	30	29	30	31	30	28	30	31	359
1994													
N	16	12	8	6	3	3	7	8	5	4	10	10	92
S	3	0	7	6	4	10	2	3	2	2	1	3	43
E	6	13	4	7	4	3	6	2	1	8	1	5	60
W	6	3	11	11	20	14	14	17	22	14	18	13	163
All	31	28	30	30	31	30	29	30	30	28	30	31	358
1995													
N	17	10	11	13	6	2	4	3	13	8	12	8	107
S	0	3	1	3	6	4	8	5	5	4	3	2	44
E	12	9	8	11	8	7	3	7	2	4	4	9	84
W	2	6	11	3	11	16	16	15	10	15	11	12	128
All	31	28	31	30	31	29	31	31	30	31	30	31	364
1996													
N	15	10	12	15	4	1	3	2	11	8	3	5	89
S	5	4	6	4	8	8	5	6	4	5	2	5	62
E	10	9	4	1	4	5	10	7	8	5	3	6	72
W	1	6	9	10	14	16	13	14	7	12	21	15	138
All	31	29	31	30	30	30	31	31	30	31	30	31	365
1997													
N	8	9	5	4	8	4	0	4	0				42
S	2	1	8	3	6	8	12	5	0				45
E	11	9	9	2	8	7	5	7	1				59
W	10	9	8	20	9	10	13	14	2				95
All	31	28	31	30	31	30	31	31	3				246

Table 9: Monthly mean wind run (km) at Tauranga airport from 1 January 1992 to 3 September 1997

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992	312	359	393	263	332	295	419	446	332	307	374	355	350
1993	433	358	347	305	300	359	244	332	390	404	360	363	349
1994	329	301	322	290	425	289	375	284	402	432	451	393	358
1995	324	302	315	277	307	309	369	313	333	361	371	378	330
1996	312	304	312	256	333	382	270	387	333	387	464	369	342
1997	404	326	333	324	256	270	278	345	260				316
Total	353	325	337	286	326	317	326	351	355	378	404	372	342

Table 10: Number of days per month and year when the maximum gust at Tauranga airport had the given strength and direction categories. Data are given for 1994 and 1996

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1994													
LowN	16	12	7	6	3	1	6	5	2	4	7	10	79
LowS	1	0	6	6	4	9	2	3	2	2	1	3	39
LowE	6	12	4	7	4	3	5	2	0	4	1	5	53
LowW	3	2	7	6	7	11	7	13	9	2	5	5	77
Low	26	26	24	25	18	24	20	23	13	12	14	23	248
MedN	0	0	1	0	0	2	1	2	1	0	2	0	9
MedS	2	0	1	0	0	1	0	0	0	0	0	0	4
MedE	0	1	0	0	0	0	0	0	0	4	0	0	5
MedW	2	1	2	4	3	1	3	4	8	10	11	3	52
Medium	4	2	4	4	3	4	4	6	9	14	13	3	70
HigN	0	0	0	0	0	0	0	1	2	0	1	0	4
HigS	0	0	0	0	0	0	0	0	0	0	0	0	0
HigE	0	0	0	0	0	0	1	0	1	0	0	0	2
HigW	1	0	2	1	10	2	4	0	5	2	2	5	34
High	0	0	4	1	6	5	1	7	3	2	10	2	40
All	31	28	30	30	31	30	29	30	30	28	30	31	358
1996													
LowN	13	10	9	12	2	1	2	1	7	6	2	5	70
LowS	3	4	5	4	7	7	5	5	3	3	2	5	53
LowE	10	9	4	1	4	2	7	5	5	3	3	4	57
LowW	1	5	5	8	5	6	10	5	4	8	6	11	74
Low	27	28	23	25	18	16	24	17	19	20	13	25	255
MedN	2	0	1	2	0	0	1	0	4	2	1	0	13
MedS	2	0	0	0	0	1	0	0	1	2	0	0	6
MedE	0	0	0	0	0	0	3	2	1	2	0	1	9
MedW	0	1	3	2	6	8	2	4	2	2	6	3	39
Medium	4	1	4	4	6	9	6	7	8	9	7	4	69
HigN	0	0	2	1	2	0	0	1	0	0	0	0	6
HigS	0	0	1	0	1	0	0	1	0	0	0	0	3
HigE	0	0	0	0	0	3	0	0	2	0	0	1	6
HigW	0	0	1	0	3	2	1	5	1	2	9	1	25
High	0	0	4	1	6	5	1	7	3	2	10	2	41
All	31	29	31	30	30	30	31	31	30	31	30	31	365

Table 11: Number of days per month and year when the maximum gust at Whangarei airport was from the north, south, east, or west quadrant for years 1992 –97 (to 3 September 1997)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992													
N	9	6	3	7	4	3	11	2	5	10	7	10	77
S	11	9	5	13	5	5	5	3	4	4	6	8	78
E	7	7	5	5	7	12	4	2	4	6	7	5	71
W	2	6	14	3	15	10	10	17	17	9	9	8	120
All	29	28	27	28	31	30	30	24	30	29	29	31	346
1993													
N	3	0	5	2	12	7	3	3	3	7	4	2	51
S	14	4	8	12	6	8	9	11	7	5	9	10	103
E	2	13	5	7	6	1	10	7	9	6	3	7	76
W	12	7	5	9	7	14	7	10	11	11	13	12	118
All	31	24	23	30	31	30	29	31	30	29	29	31	348
1994													
N	10	4	5	4	3	8	3	7	6	6	8	1	65
S	9	2	9	12	2	10	4	7	6	4	7	13	85
E	6	18	8	6	4	1	8	0	0	5	6	8	70
W	6	4	8	8	22	11	16	16	18	14	8	8	139
All	31	28	30	30	31	30	31	30	30	29	29	30	359
1995													
N	9	3	7	11	4	2	5	6	11	4	6	8	76
S	5	5	3	7	6	3	3	8	7	8	6	7	68
E	16	11	8	9	9	1	1	4	4	4	9	7	83
W	1	8	12	3	11	24	21	13	8	15	9	7	132
All	31	28	31	30	31	30	31	31	30	31	30	29	363
1996													
N	4	6	8	12	3	3	9	5	10	7	2	6	75
S	6	8	6	5	10	8	4	4	4	5	7	11	78
E	15	9	8	4	5	6	6	3	9	6	2	6	79
W	3	4	9	7	13	11	11	19	7	12	18	7	121
All	28	27	31	30	31	29	31	31	30	31	30	31	360
1997													
N	3	0	0	3	7	4	3	6	0				26
S	12	6	9	12	3	9	10	5	1				67
E	13	11	10	3	14	6	3	5	0				65
W	2	8	8	10	6	8	13	15	2				72
All	30	25	31	30	31	27	31	31	3				239

Table 12: Monthly mean wind run (km) at Whangarei airport from 1 January 1992 to 3 September 1997

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992	257	310	318	252	299	253	339	378	284	297	336	306	302
1993	320	356	252	230	271	264	213	309	313	282	292	261	280
1994	237	299	260	234	298	243	272	208	338	361	325	302	281
1995	288	295	200	171	189	213	248	265	237	313	309	300	252
1996	304	294	286	244	287	289	287	331	270	334	338	314	298
1997	346	260	256	206	207	200	188	280	214				243
Total	292	302	262	222	260	244	259	293	287	317	320	296	278

Table 13: Number of days per month and year when the maximum gust at Whangarei airport had the given strength and direction categories. Data are given for 1994 and 1996

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1994													
LowN	9	4	5	3	3	5	3	4	3	4	3	1	47
LowS	8	2	6	11	2	8	3	5	3	3	5	12	68
LowE	6	11	7	6	2	1	4	0	0	4	5	6	52
LowW	6	4	4	4	9	8	10	12	7	6	8	4	82
Low	29	21	22	24	16	22	20	21	13	17	21	23	249
MedN	1	0	0	1	0	3	0	3	0	2	2	0	12
MedS	1	0	3	1	0	2	1	2	3	1	1	1	16
MedE	0	6	1	0	2	0	3	0	0	1	1	2	16
MedW	0	0	4	3	12	3	3	4	6	4	0	3	42
Medium	2	6	8	5	14	8	7	9	9	8	4	6	86
HigN	0	0	0	0	0	0	0	0	3	0	3	0	6
HigS	0	0	0	0	0	0	0	0	0	0	1	0	1
HigE	0	1	0	0	0	0	1	0	0	0	0	0	2
HigW	0	0	0	1	1	0	3	0	5	4	0	1	15
High	0	1	0	1	1	0	4	0	8	4	4	1	24
All	31	28	30	30	31	30	31	30	30	29	29	30	359
1996													
LowN	3	6	6	11	2	3	7	4	7	5	1	6	61
LowS	5	7	4	3	8	7	3	3	4	4	6	9	63
LowE	13	5	5	4	5	3	1	1	6	2	2	3	50
LowW	3	4	6	4	8	6	9	9	5	7	9	6	76
Low	24	22	21	24	23	19	21	17	22	18	18	24	253
MedN	1	0	1	1	0	0	1	1	3	2	1	0	11
MedS	1	1	2	1	1	1	1	1	0	1	1	1	12
MedE	1	3	3	0	0	1	4	1	2	4	0	1	20
MedW	0	0	3	3	4	4	2	7	1	1	8	1	34
Medium	3	4	9	5	5	7	8	10	6	9	11	4	81
HigN	0	0	1	0	1	0	1	0	0	0	0	0	3
HigS	0	0	0	1	1	0	0	0	0	0	0	1	3
HigE	1	1	0	0	0	2	1	1	1	0	0	2	9
HigW	0	0	0	0	1	1	0	3	1	4	1	0	11
High	1	1	1	1	3	3	2	4	2	4	1	3	26
All	28	27	31	30	31	29	31	31	30	31	30	31	360

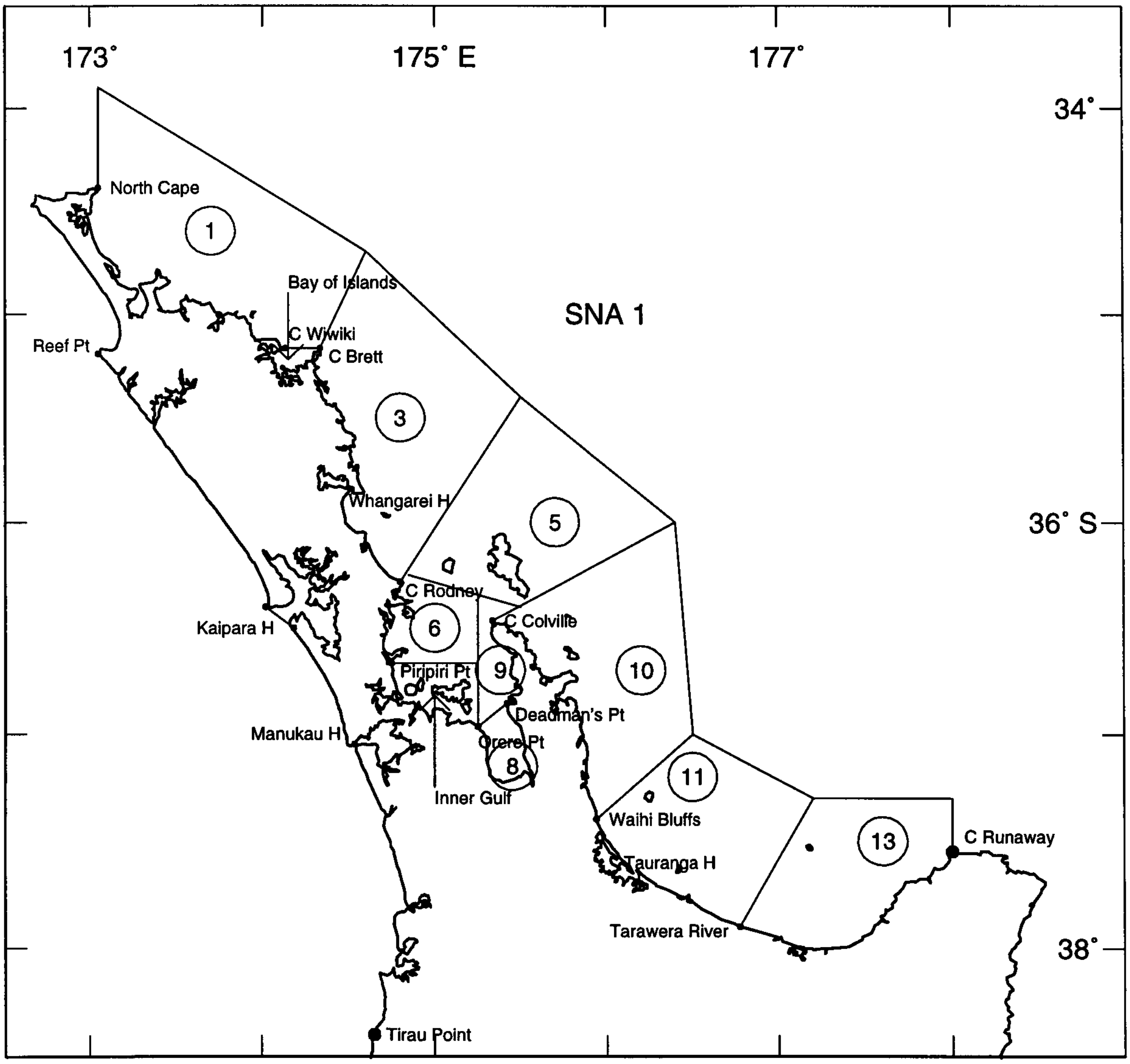

Figure 1: Map of the north of New Zealand showing the area of SNA 1, including the positions of the fishing zones used in the diary surveys.

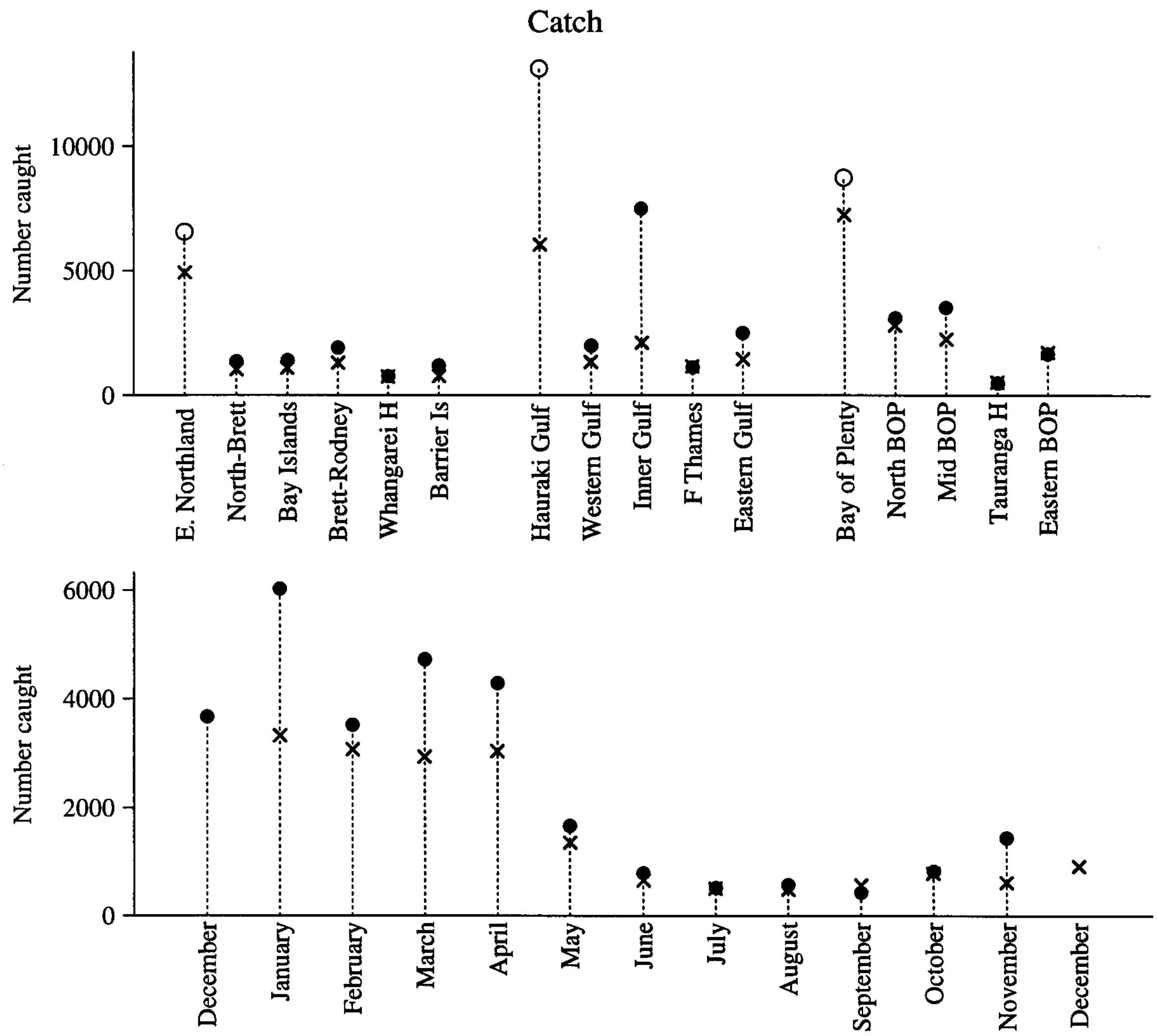

Figure 2: Upper: numbers of snapper caught by diary zone and main region. Regional totals (1994 North region survey) are shown with an open circle
Lower: numbers of snapper caught by month.
• 1994 North region survey; × 1996 national survey. The 1996 data were scaled to be compatible with the 1994 data (see text).

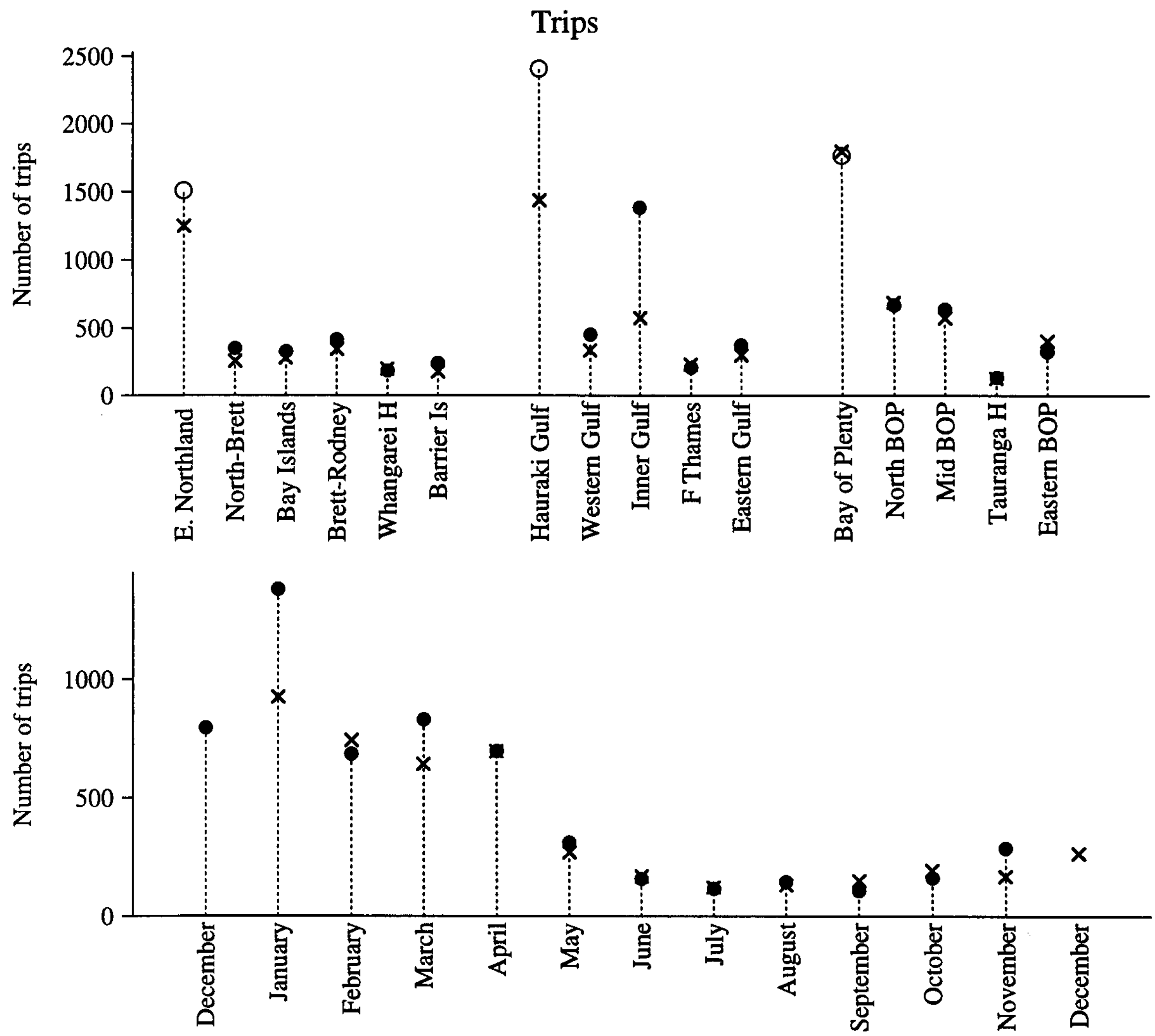

Figure 3: Upper: numbers of trips catching snapper by diary zone and main region. Regional totals (1994 North region survey) are shown with an open circle
Lower: numbers of trips catching snapper by month.
• 1994 North region survey; × 1996 national survey. The 1996 data were scaled to be compatible with the 1994 data (see text).

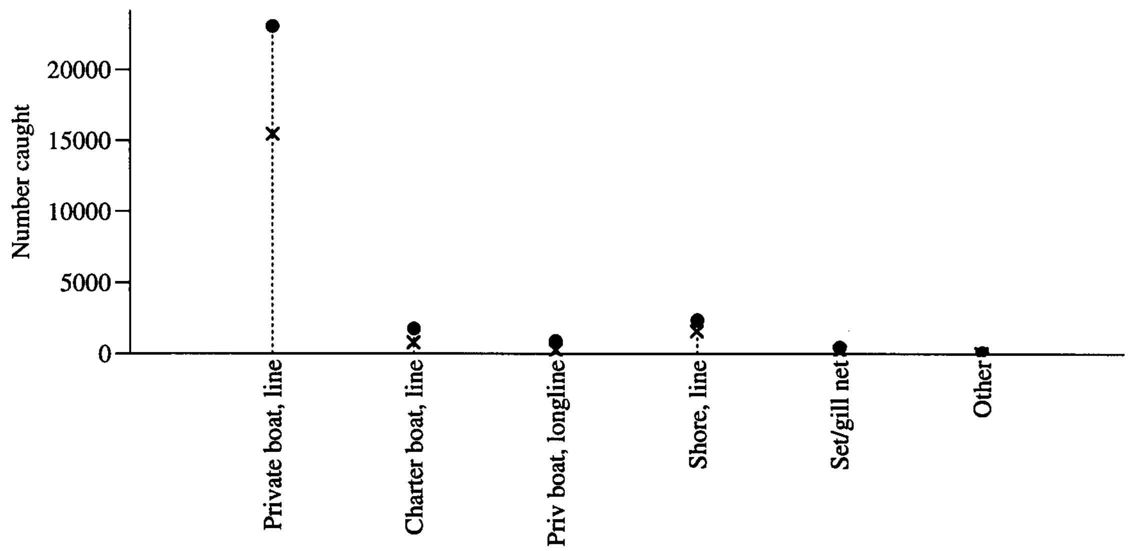

Figure 4: Numbers of snapper caught by the main fishing methods used in SNA 1.
• 1994 North region survey; × 1996 national survey. The 1996 data were scaled to be compatible with the 1994 data (see text).

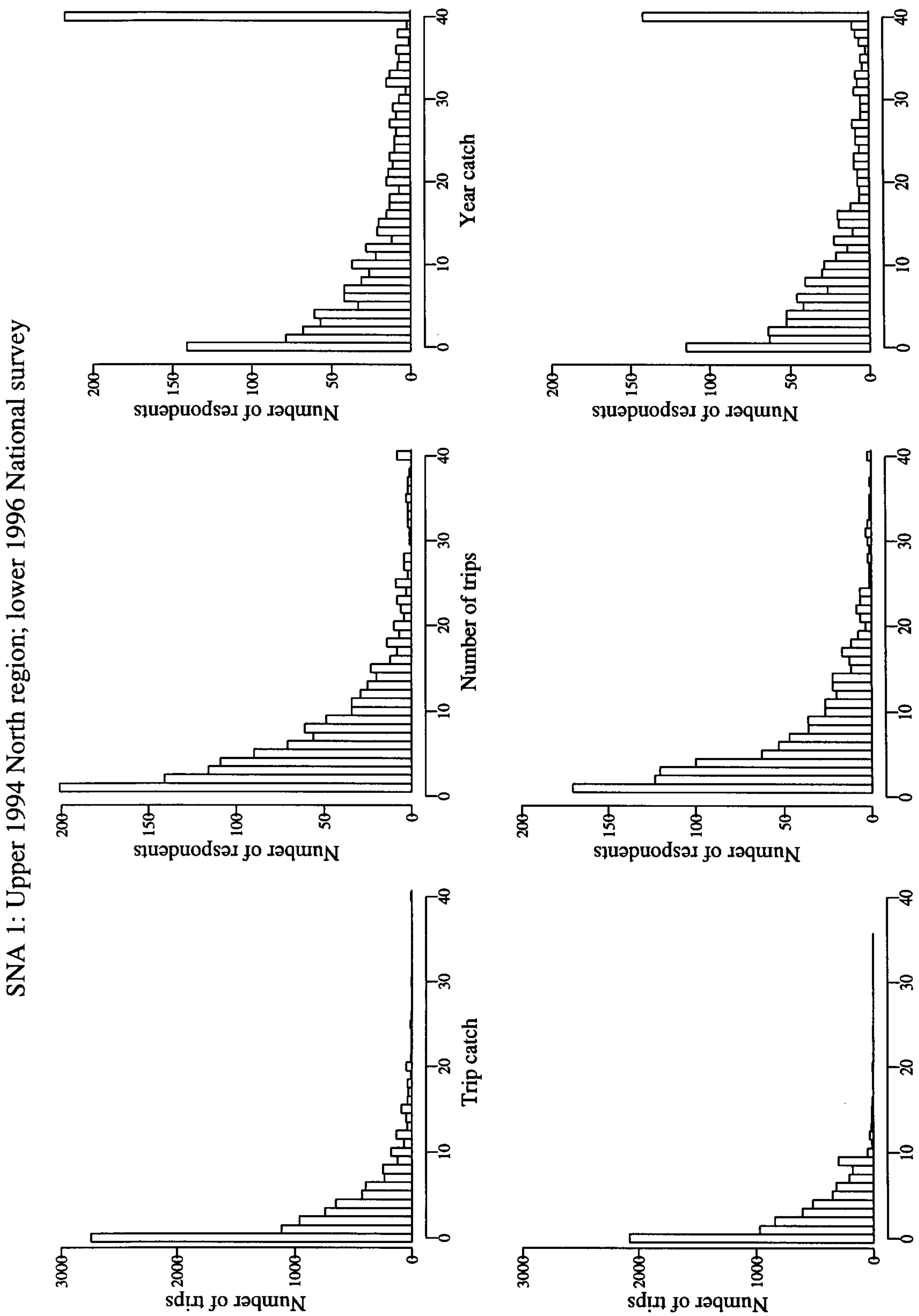

Figure 5: Number of trips on which a given number of snapper were caught; number of trips made by a given number of respondents; the number of respondents with a given annual total catch. The data set included all trips where snapper were targeted or caught; all x-values greater than 40 are plotted at 40. The 1996 data were scaled to be compatible with the 1994 data (see text).

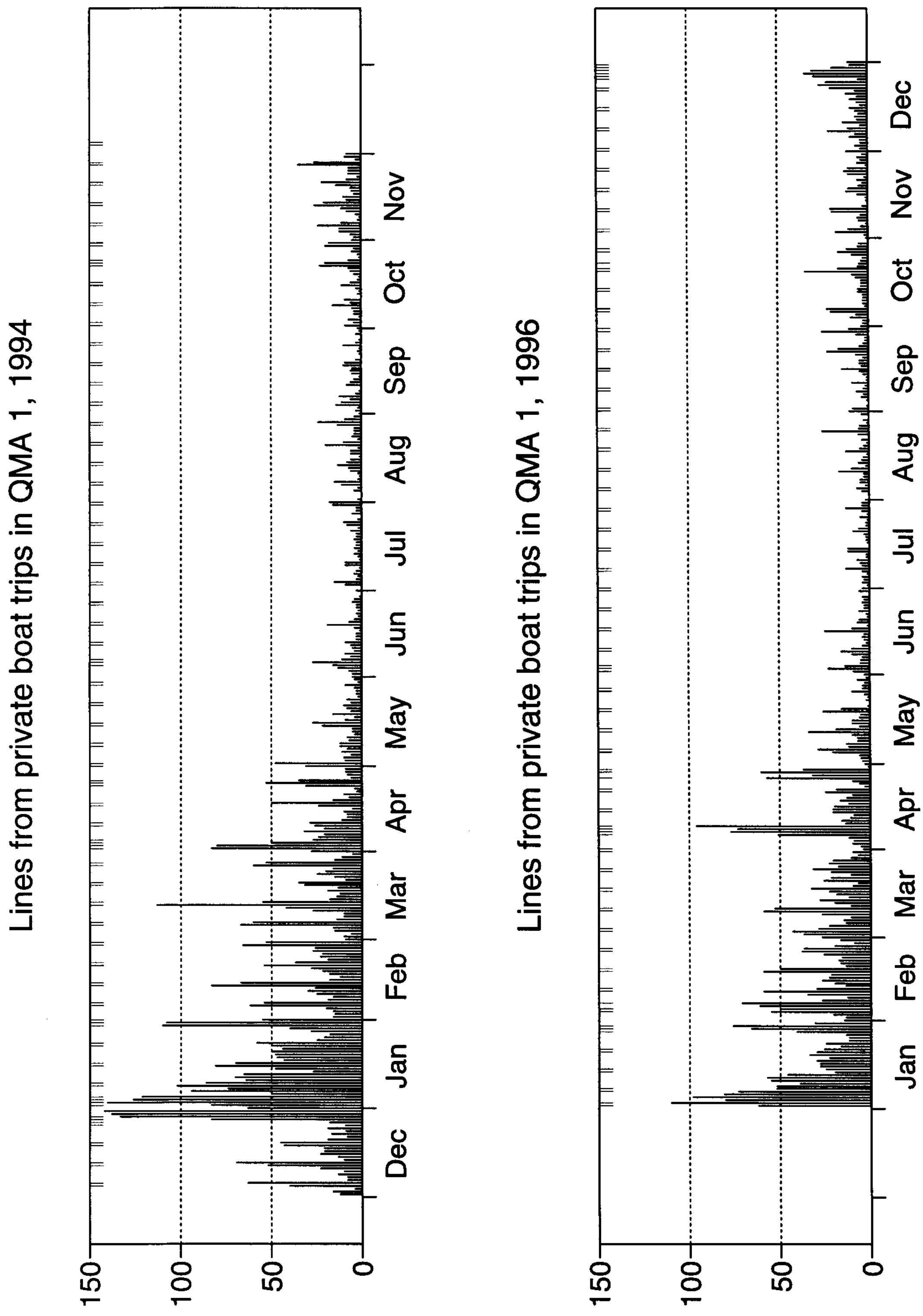

Figure 6: Daily totals of numbers of "Lines from private boats" trips made in QMA 1 in the North region diary survey and the national survey. Tick marks on the upper axis represent weekends and holidays. The 1996 data were scaled to be compatible with the 1994 data (see text).

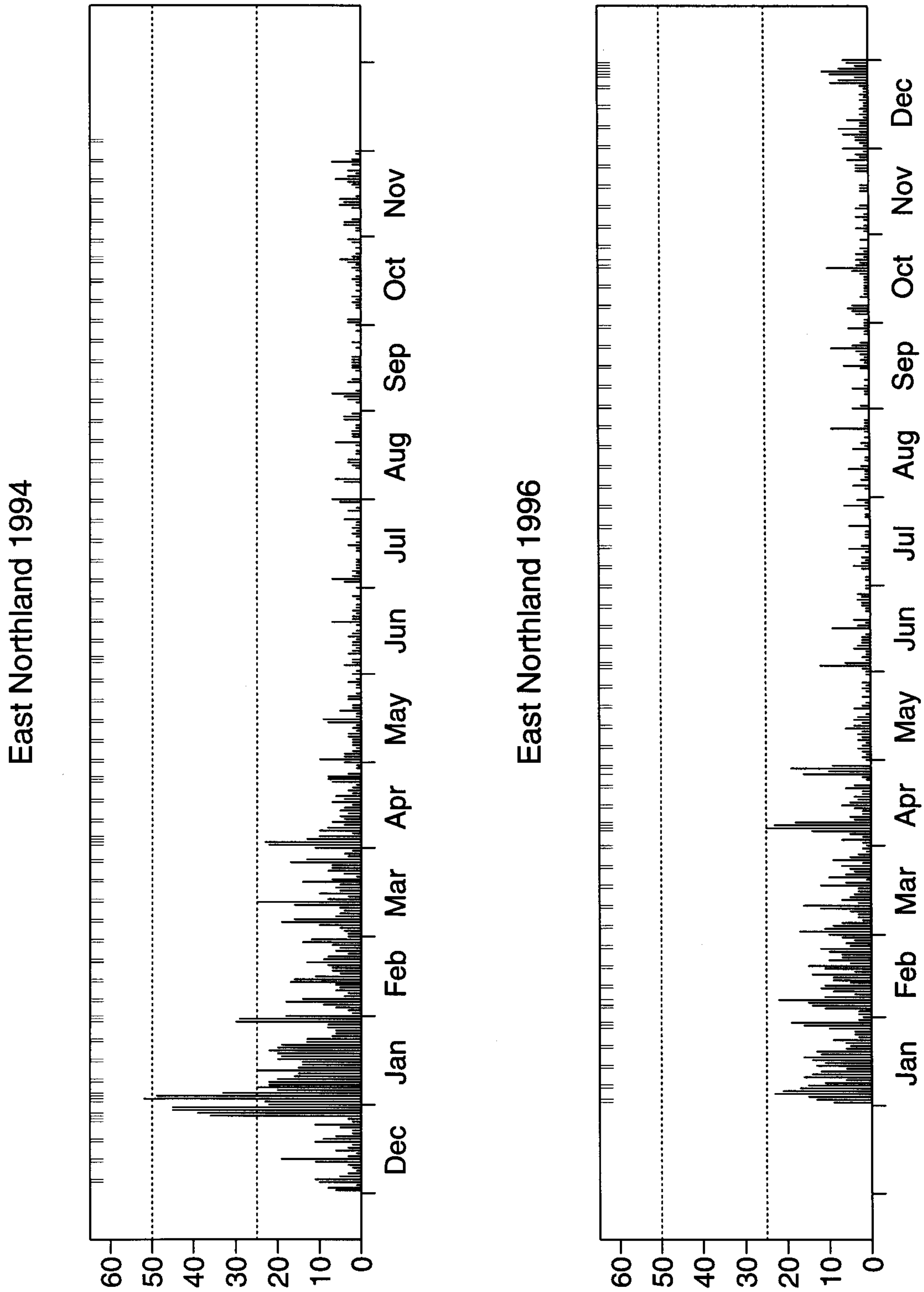

Figure 7: Daily totals of numbers of "Lines from private boats" trips made in East Northland in the North region diary survey and the national survey. Tick marks on the upper axis represent weekends and holidays. The 1996 data were scaled to be compatible with the 1994 data (see text).

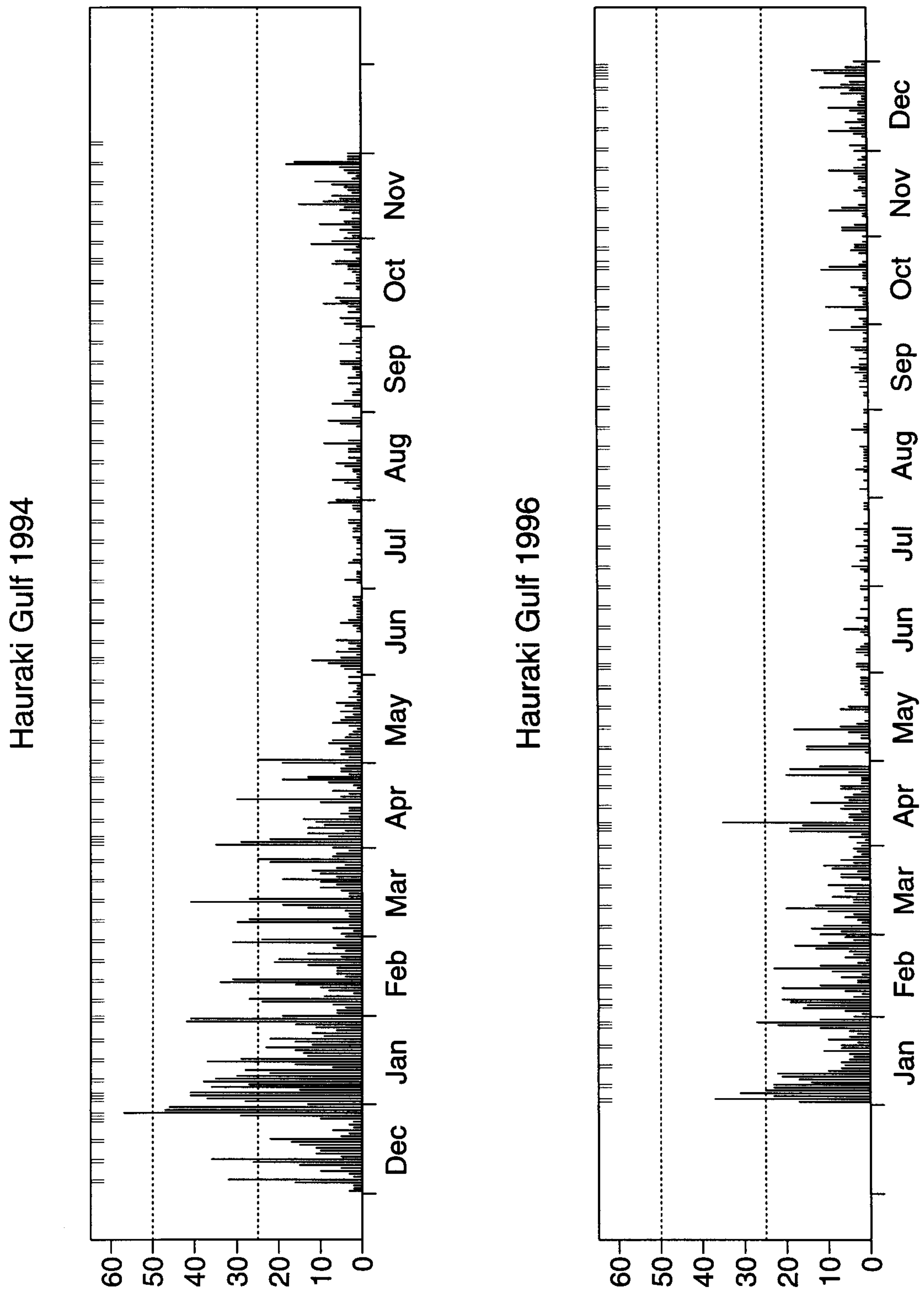

Figure 8: Daily totals of numbers of "Lines from private boats" trips made in the Hauraki Gulf in the North region diary survey and the national survey. Tick marks on the upper axis represent weekends and holidays. The 1996 data were scaled to be compatible with the 1994 data (see text).

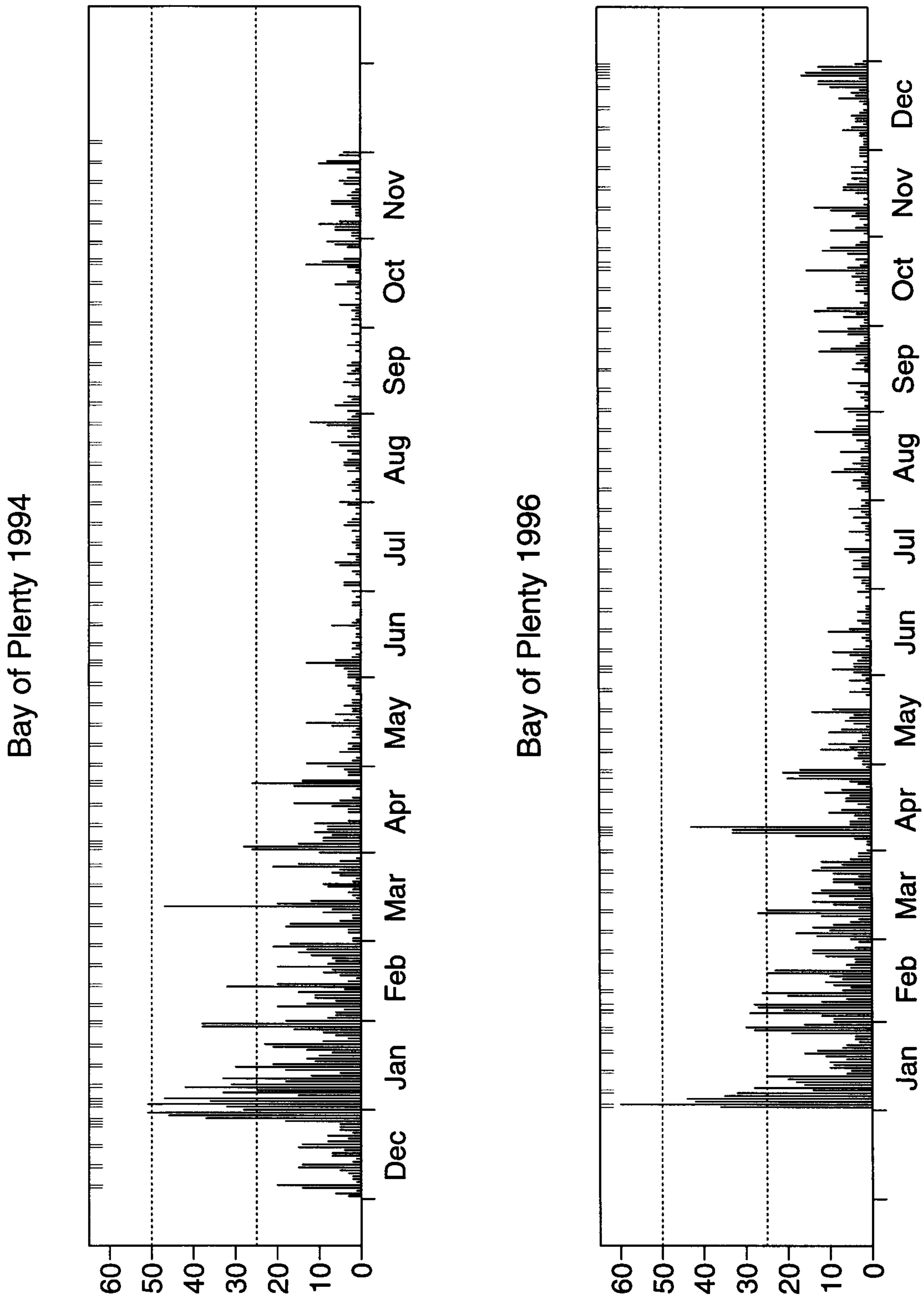

Figure 9: Daily totals of numbers of "Lines from private boats" trips made in the Bay of Plenty in the North region diary survey and the national survey. Tick marks on the upper axis represent weekends and holidays. The 1996 data were scaled to be compatible with the 1994 data (see text).

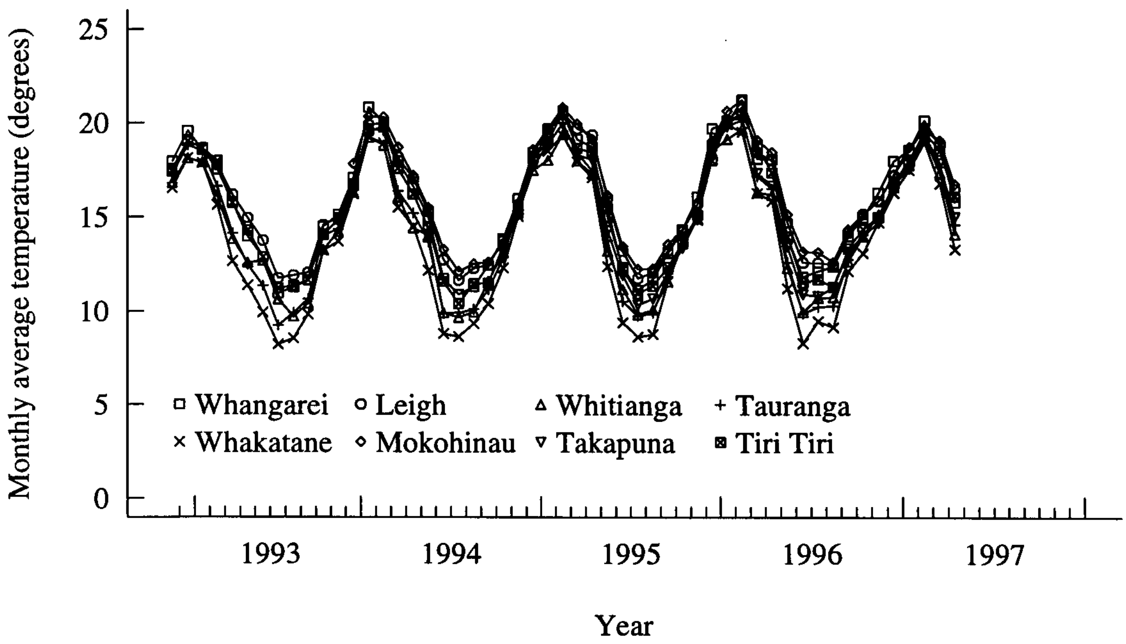

Figure 10: Monthly average temperature at eight places on or near the coast in SNA 1.

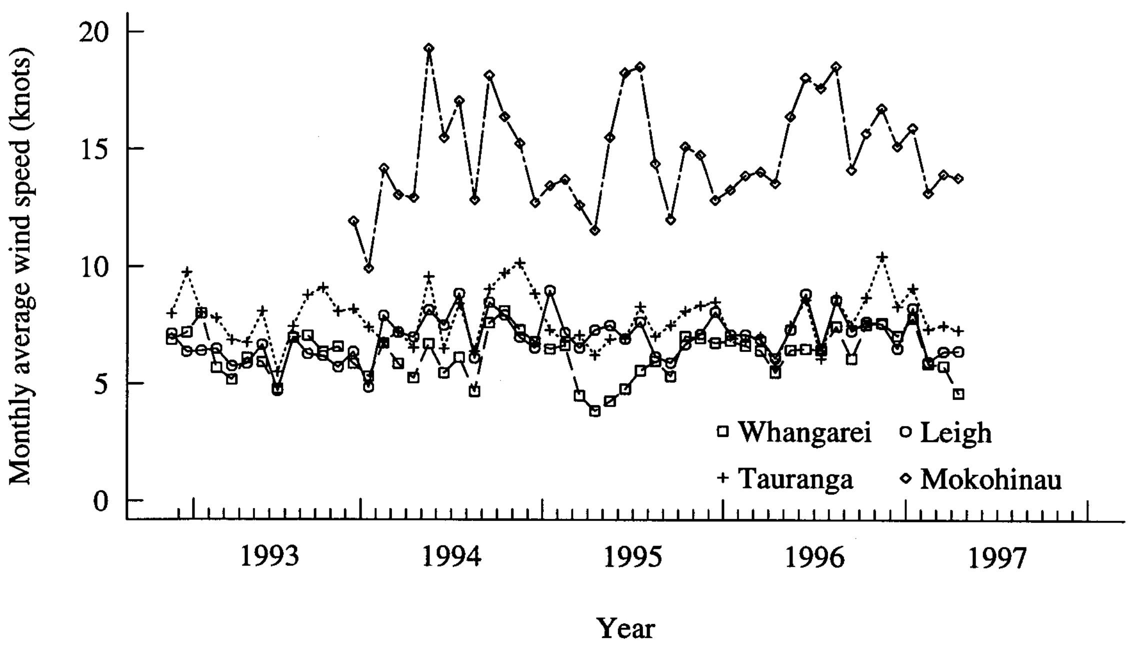

Figure 11: Monthly average wind speed at four places on or near the coast in SNA 1.

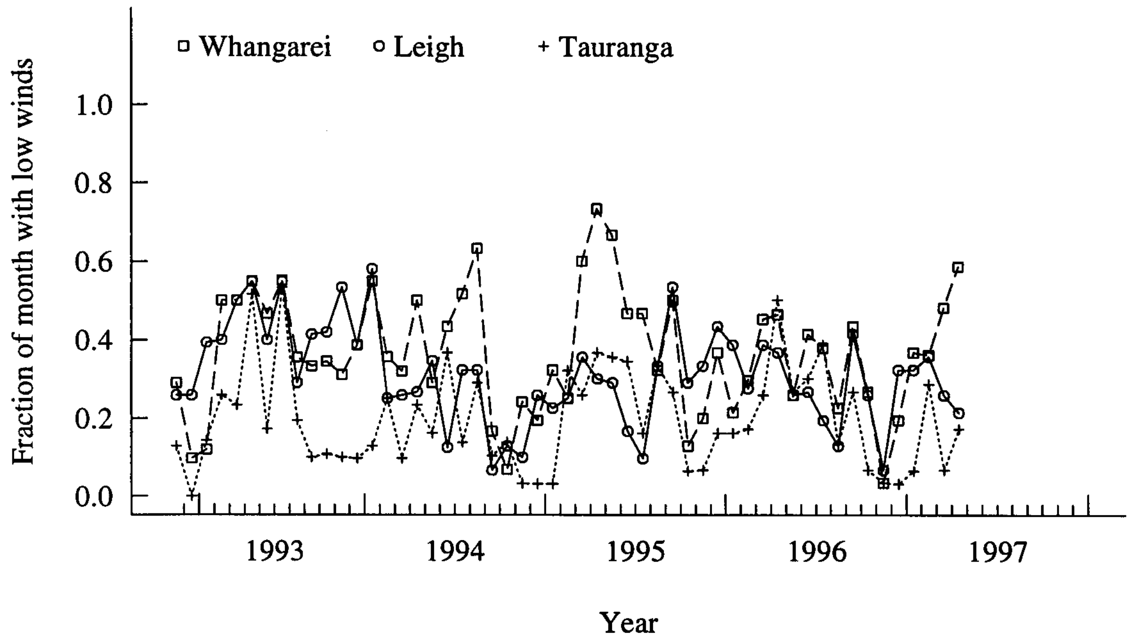

Figure 12: Fraction of the month with the daily average wind speed less than 5 knots in SNA 1. .

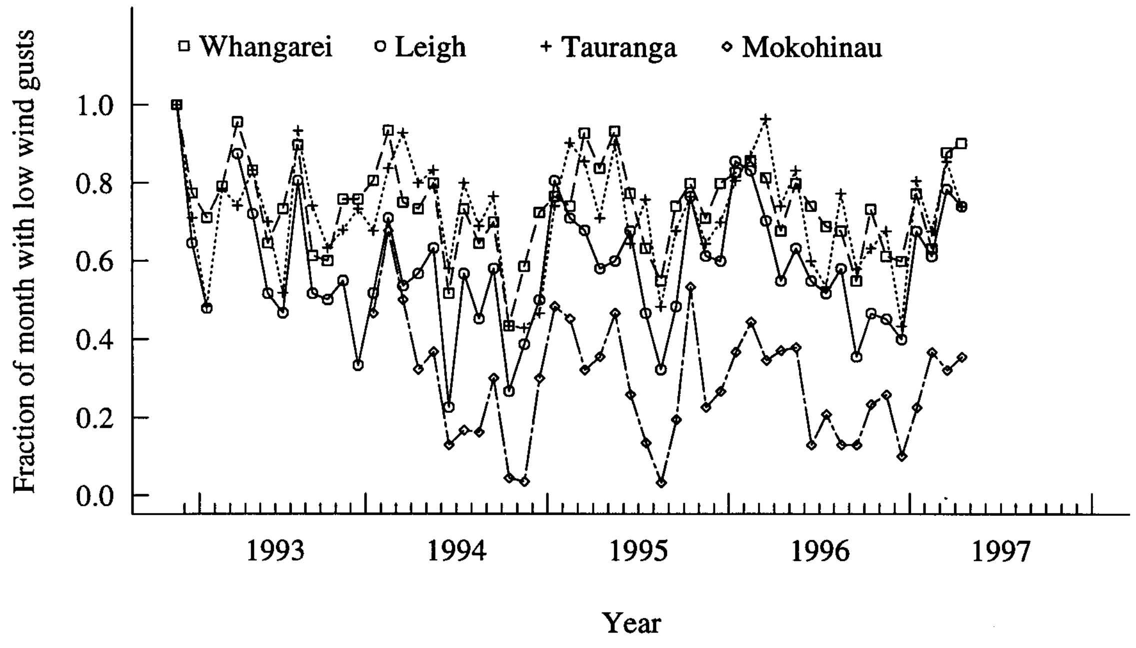

Figure 13: Fraction of the month with the maximum daily gusts less than 25 knots in SNA 1.

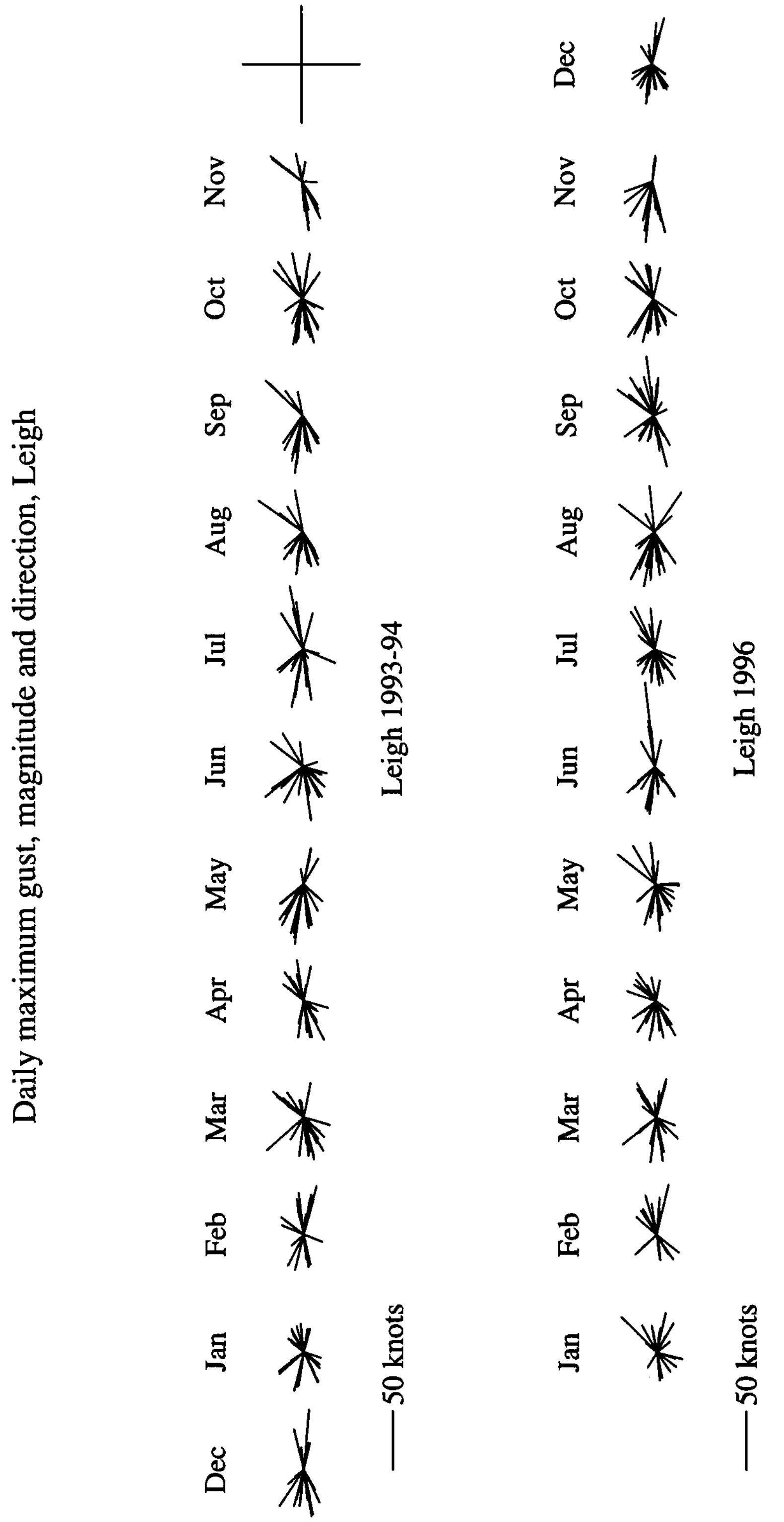

Figure 14: Maximum daily wind gust and its direction by month during the North region and national surveys at Leigh.

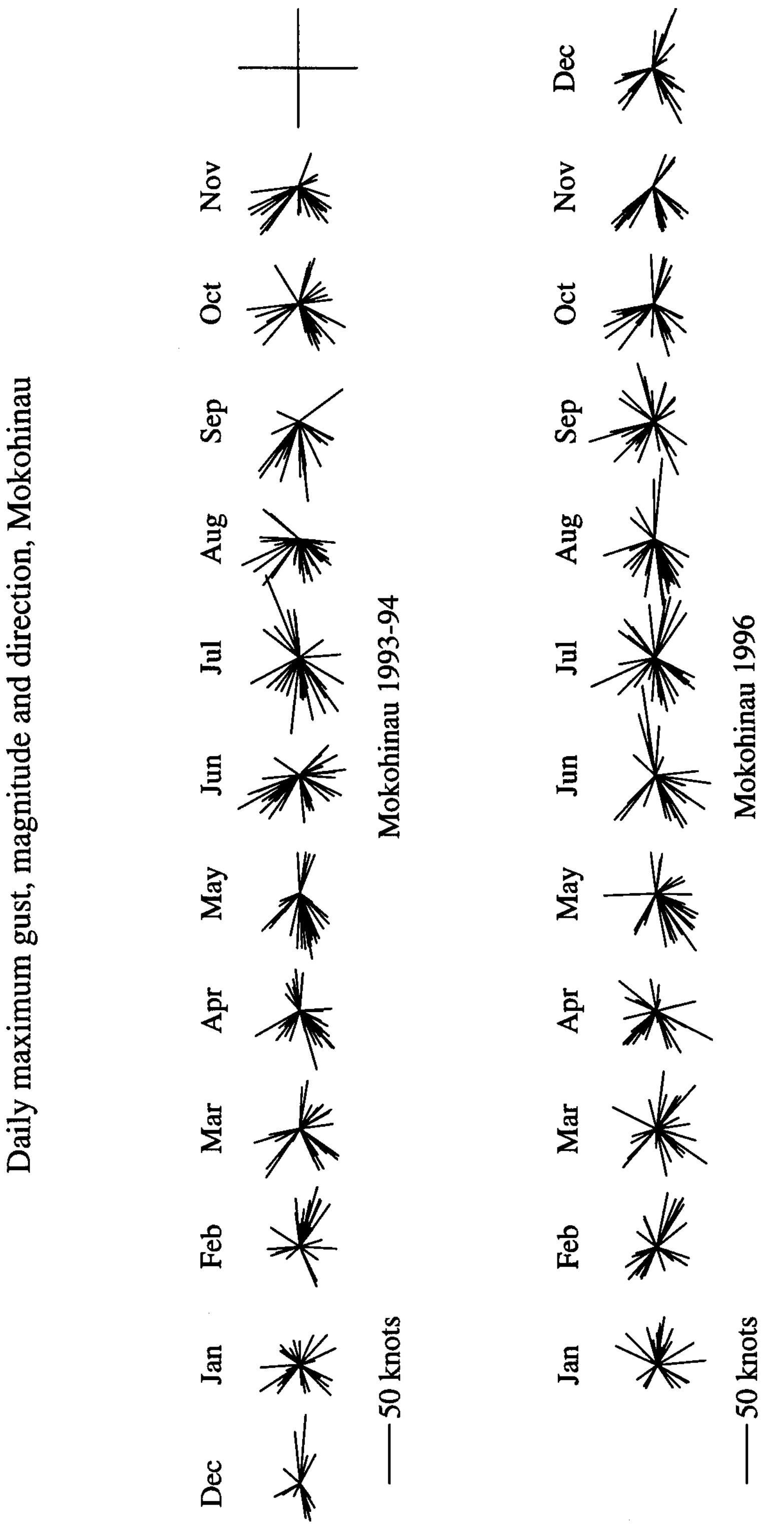

Figure 15: Maximum daily wind gust and its direction by month during the North region and national surveys at Mokohinau.

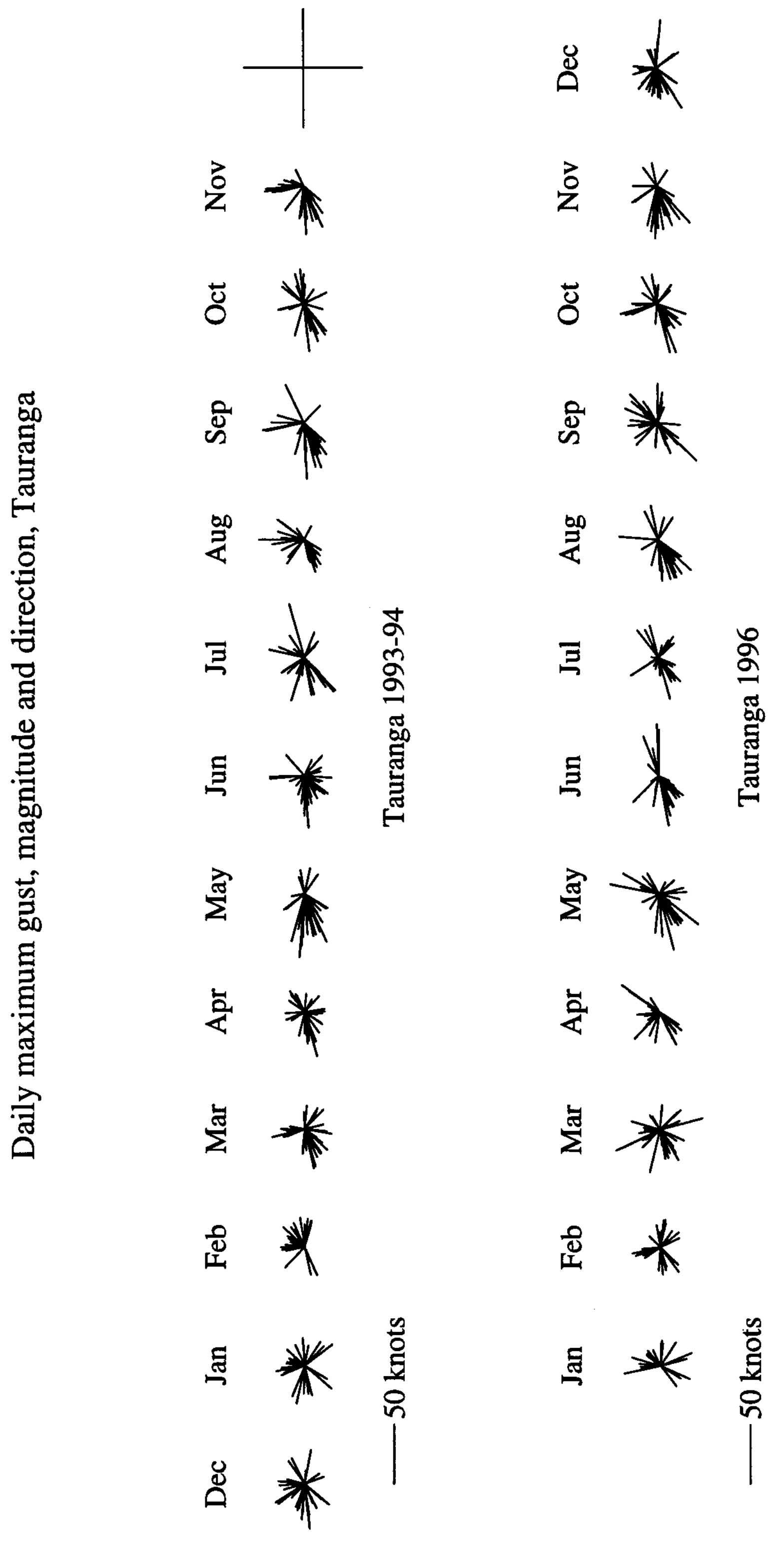

Figure 16: Maximum daily wind gust and its direction by month during the North region and national surveys at Tauranga.

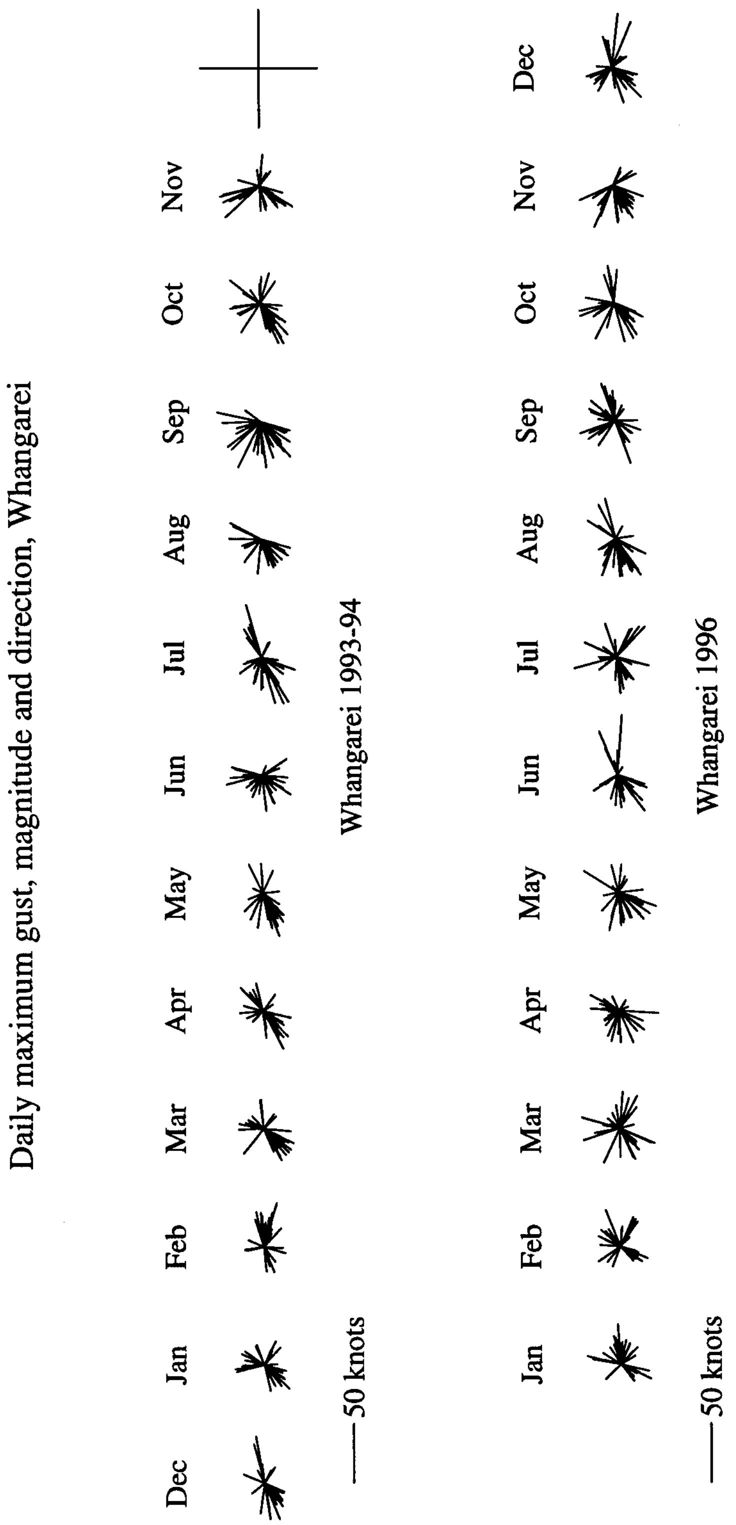

Figure 17: Maximum daily wind gust and its direction by month during the North region and national surveys at Whangarei.

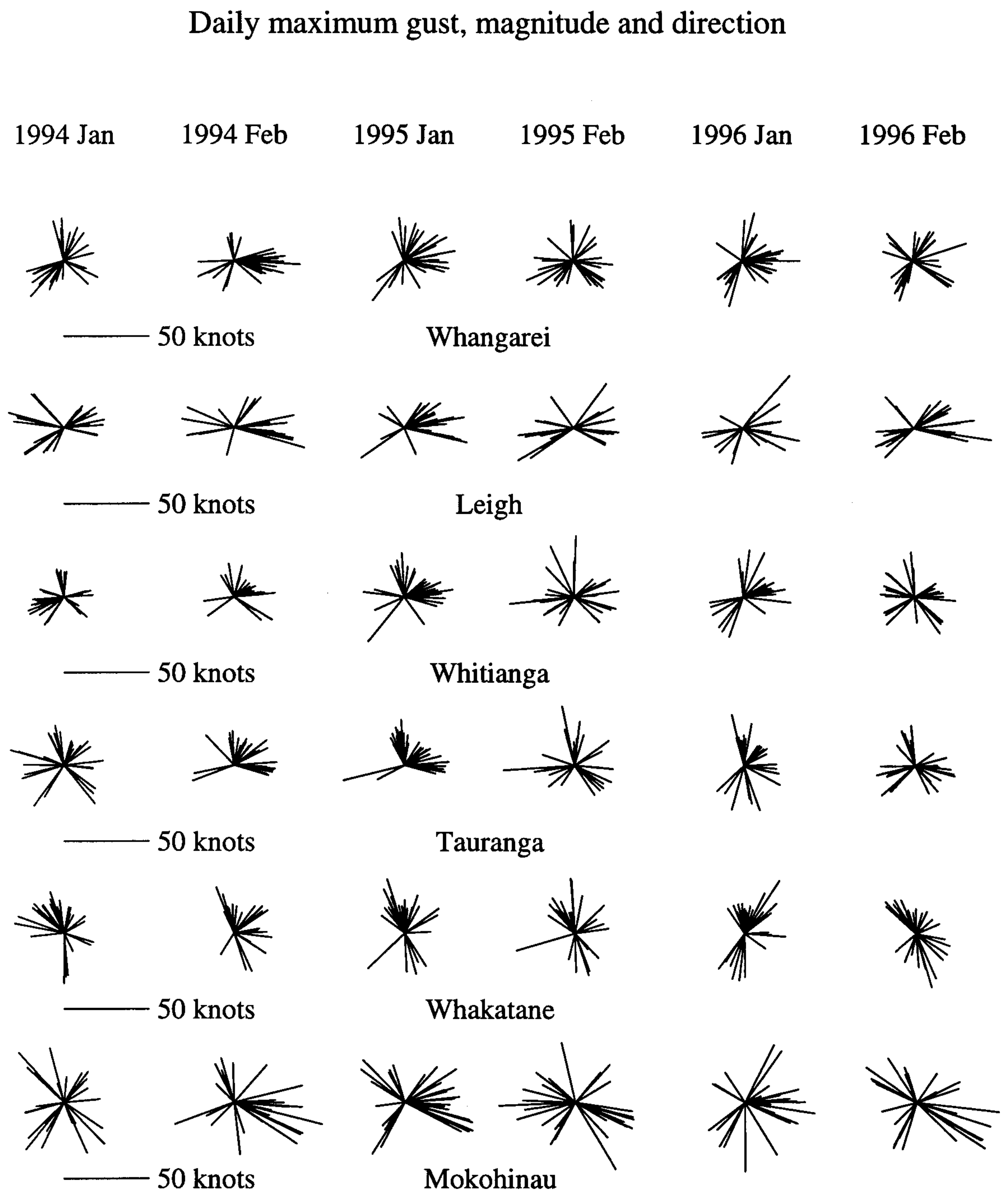

Figure 18: Maximum daily wind gust and its direction in January and February, 1994, 1995, and 1996 at 6 sites in SNA 1.

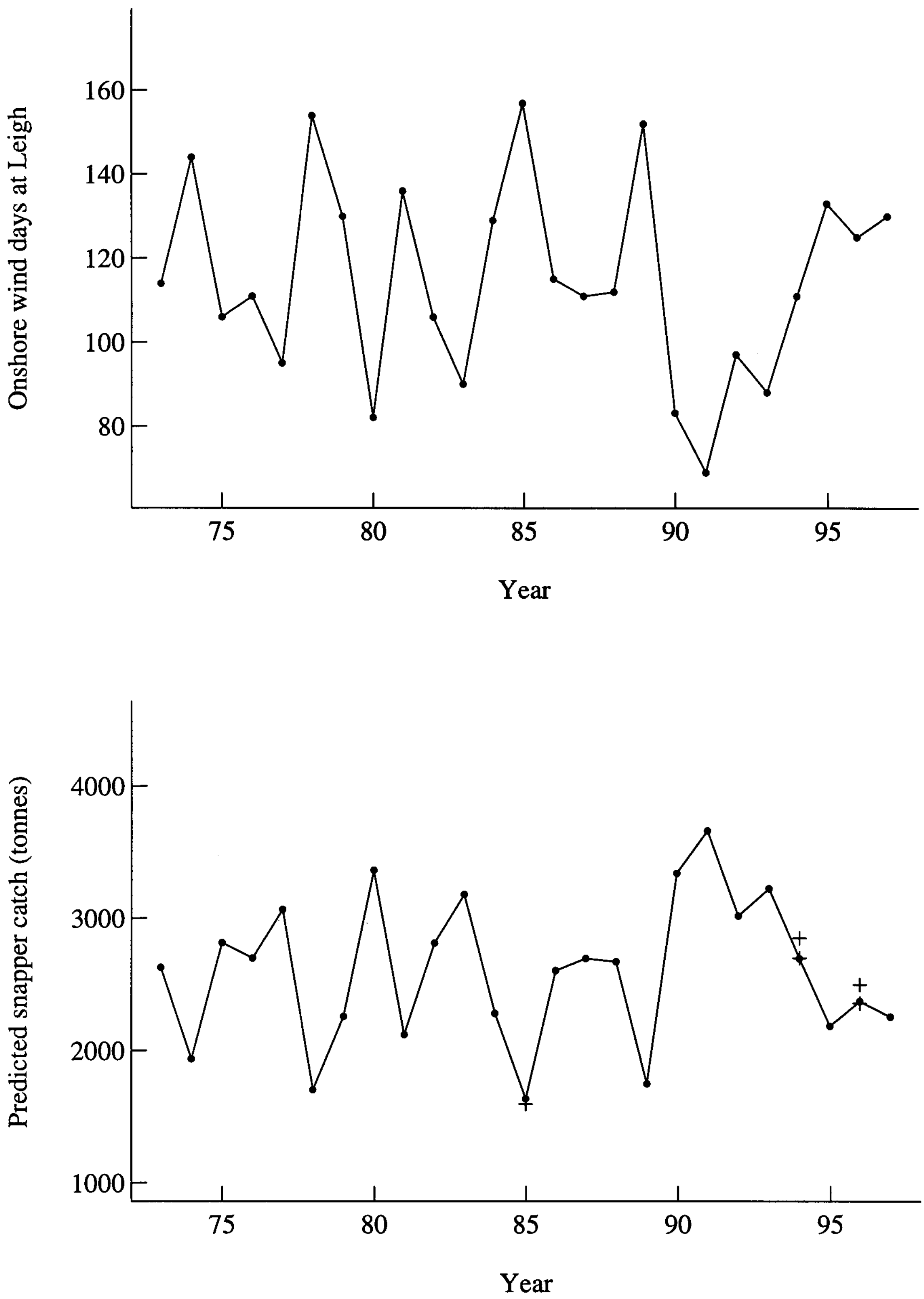

Figure 19: Upper: number of onshore wind days in each year at Leigh.
Lower: predicted snapper harvest in SNA 1 using the number of onshore wind days as predictor. + known harvest estimates (bias corrected and uncorrected values in 1994 and 1996). Note the 1994 estimate was not for the 1994 calendar year

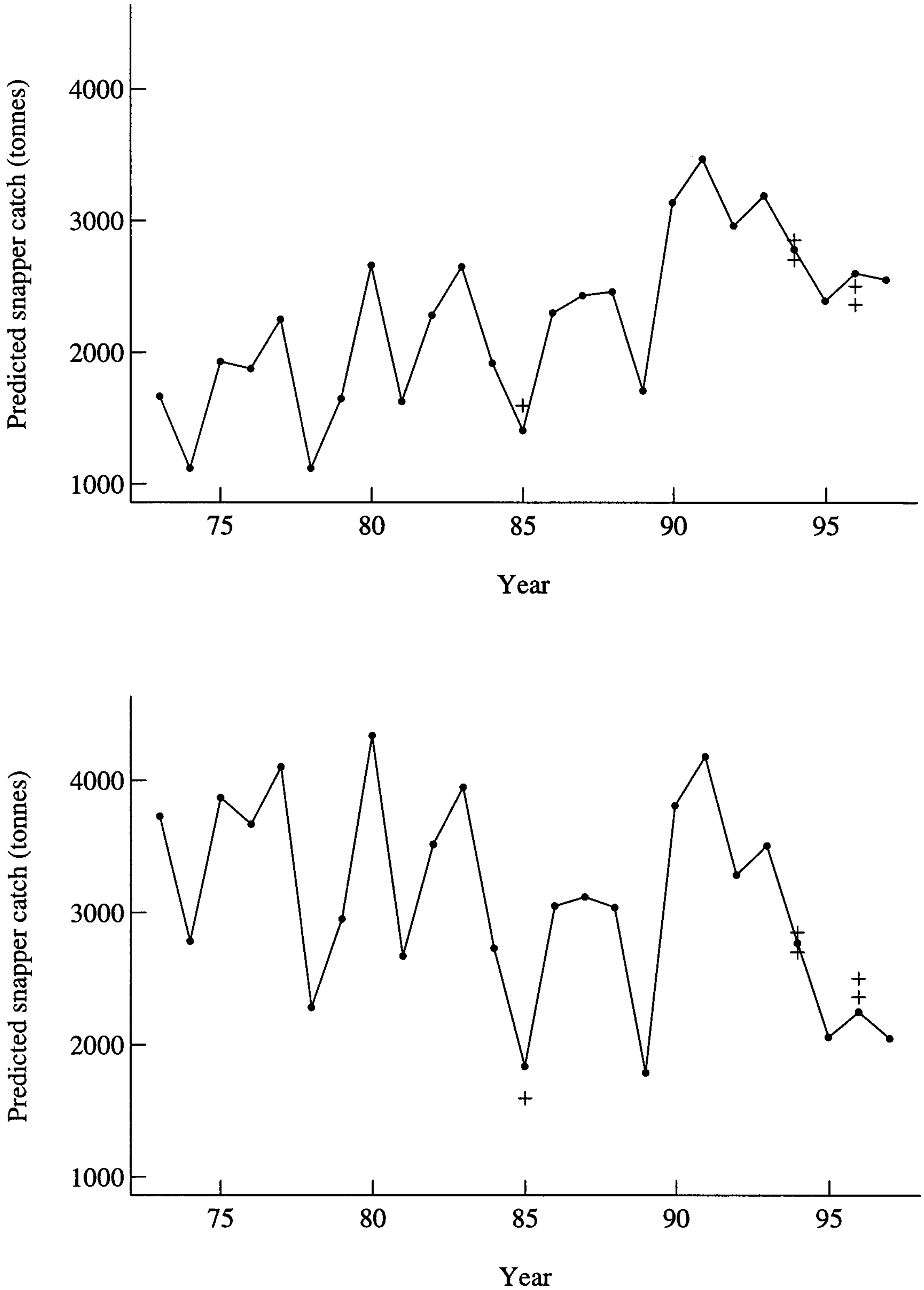

Figure 20: Upper: predicted snapper harvest using a linear upward trend and variability induced by the number of onshore wind days at Leigh.
Lower: predicted snapper harvest using a linear downward trend and variability induced by the number of onshore wind days at Leigh.
+ known harvest estimates (bias corrected and uncorrected values in 1994 and 1996)

Appendix 1

Comparison between eligible fishers from Auckland and from the rest of the North region

One of the obvious differences in the snapper harvest in SNA 1 in 1994 and 1996 is the large reduction in catch in the inner and western parts of the Hauraki Gulf. These areas are predominantly fished by Auckland residents. Hence, I looked for differences between the fishers interviewed in the 1995 telephone survey who lived in Auckland and those North region residents who lived outside the Auckland region. The results, which do not seem to give any useful differences, are given below. The estimated number of trips made by these fishers is given in Table A1.

Table A1: The estimated number of trips made by Auckland residents and North region residents who live in the North region but outside the Auckland area

	Number of trips					
	< 6	6–15	16–30	>30	Unknown	Not avail
Auckland	424	338	184	96	6	2
Not Auckland	555	446	220	144	3	0
Total	979	784	404	240	9	2

A chi-squared test using the data in the first four columns for Auckland and Not Auckland residents showed a non-significant difference ($\chi^2 = 1.90$, 3 degrees of freedom and $p = 0.59$).

There are demographic differences. First, the numbers by sex (Table A2).

Table A2: Numbers of male and female fishers who are Auckland residents and North region residents who live in the North region but outside the Auckland area

	Males	Females	Not given
Auckland	870	179	1
Not Auckland	1 077	287	4
Total	1 947	466	5

A chi-squared test showed there were more women fishers outside Auckland ($\chi^2 = 5.77$ with 1 degree of freedom and $p = 0.016$).

The numbers by age class are given in Table A3.

Table A3: Numbers fishers in the stated age classes who are Auckland residents and North region residents who live in the North region but outside the Auckland area. 5 people whose age was not given were omitted

	Age group						
	<15	15–20	21–30	31–40	41–50	51–60	>60
Auckland	3	38	194	328	254	132	99
Not Auckland	4	69	216	403	331	196	146
Total	7	107	410	731	585	328	245

A chi-squared test using age classes above 15 showed there were no significant age differences ($\chi^2 = 8.13$ with 5 degrees of freedom and $p = 0.15$).

The numbers by ethnic groups are given in Table A4:

Table A4: Numbers of fishers, by ethnic group, who are Auckland residents and North region residents who live in the North region but outside the Auckland area

					Ethnic group
	European	Maori	Pacific Is	Other	Not given
Auckland	951	58	7	29	5
Not Auckland	1 182	157	11	15	3
Total	2 133	215	18	44	8

A chi-squared test using the ethnic groups was significant (χ^2 = 34.06 with 3 degrees of freedom, and p = 0.000). This test shows more Europeans, less Maori and others in Auckland than outside Auckland. This difference may be representative of the whole population.

The mean number of trips reported by North region respondents in the 1996 national diary survey is given in Table A5:

Table A5: Response rate by diarists in the 1996 national diary survey

	Auckland	Not Auckland	Total
Made trips	378	604	982
Made no trips	143	176	319
Total respondents	521	780	1 301
Total diarists	794	1 085	1 879

The response rates were not significantly different.

The mean numbers of trips made by diarists reporting trips are: 9.7 for Auckland residents and 10.3 for Not Auckland residents. These numbers were not significantly different. The mean number of trips made by North region respondents was 10.3, compared with their estimated mean number for 1995 of 13.3 (from the telephone survey results). Fishers interviewed in the North region boat ramp survey in 1996 gave an estimated mean number of days fishing in the past year of 25.6 which is about twice the estimated mean umber of 13.3 given by diarists in the telephone survey.

Appendix 2

Data from the climate database

The climate data are stored in numerous tables in an Oracle database. The most useful tables, for these purposes, seem to be: Surface_wind, Max_gust, and Max_min_temp. Times are stored in the database as UTC times (Greenwich Mean Time for the old fashioned). Stations recording wind are uncommon. Wind is difficult to summarise quantitatively as it varies in both strength and direction. The climate database provides monthly averages (or totals) of more or less all variables, but it takes very few missing values for the whole month to be missing.

Weather stations have various degrees of reliability, and also vary in the recordings available. The automatic weather stations (AWS) introduced in the early 1990s seem to be the most useful. These record data at regular intervals (originally 3 hourly, currently hourly) and these data can, in principle, be averaged or extracted for any time or time period required. Not all AWS stations, for example Auckland Mangere, give recordings of maximum wind gust and direction.

The potentially useful stations I have found are:

1. AWS stations at Whangarei, Tauranga, and Whakatane airports and on Mokohinau Island. The AWS station at Whitianga airport had problems with its wind recordings during 1994 and until routine maintenance on 31 July 1995 and thus does not cover both of the diary surveys reliably. The Mokohinau station is on an island out to sea from the Hauraki Gulf and one might think that it would give a good representation of wind conditions at sea. However, wind shadowing problems are rife on islands and at least three different sites on Mokohinau have been tried (roughly, sea level, top, and on a flat headland). Wind data from these sites were not well correlated (Steve Reid, NIWA, pers. comm.)

2. The station run by the Auckland Regional Council in the Takapuna area. Data from this station do not include the direction of the maximum gust.

3. The stations at Leigh and Tiri Tiri Matangi lighthouse – the latter has no wind measurements.

The Hauraki Gulf has had no reliable wind measuring station (Steve Reid, NIWA pers. comm.) though NIWA has recently placed a metbouy in the Hauraki Gulf to provide America's Cup syndicates with quality data and forecast systems (Anon. 1998).

Wind speed and direction

Two tables in the climate database relating to wind are max_gust and surface_wind. Max_gust gives the speed (and usually) direction of the strongest wind gust in a period. I think the surface wind run comes originally from the number of times the anemometer cups have gone round in a day. The surface wind and maximum gust are measured on different instruments. The maximum gust data collection period runs from midnight to one minute before midnight. For automatic weather stations, the speed and direction of the wind is available every 10 minutes (usually). The daily value of surface wind run given from the climate database uses the day from 9 a.m. to 9 a.m.. The date associated with a value is the measurement date. Thus the period of maximum gust measurement and the period over which the daily wind run is found are not the same. For the automatic weather stations, it would be possible to extract the original data and perform one's own averages (this has not been attempted).

Appendix 3

Holiday and seasonal effect

I looked at the numbers of trips made on holidays and work days at different times of the year. I have defined holidays to be weekends, statutory holidays, all days between Christmas Day and the second weekend in January, and single days between Waitangi Day or Anzac Day and a weekend. I have introduced an "all holiday" period and I have changed from using Auckland Anniversary Day to Waitangi Day as the end of the main summer holiday period. I have defined the seasonal periods to be:

- S1 Christmas Day to second weekend in January
- S2 after second weekend in January to Waitangi Day (6 February) or the following weekend
- S3 after Waitangi Day (or the following weekend) to end of April
- S4 May to Christmas Eve

I wanted estimates of how the number of marine recreational fishing trips varies by day type and throughout the year. This information should be included in a detailed model of fishing activity. The seasonal period "S1" is defined in terms of current behaviour patterns. In the not too distant past, when many businesses were closed until about the third weekend in January, this period of "all holidays" would need to be longer.

Table A6 gives the mean number of "lines from private boat" trips per day in the above defined categories of holidays and work days and seasons from data collected in the two diary surveys in the North region.

Table A6: Mean number of "lines from private boat" trips per day for holidays, workdays by season for the two diary surveys in the North region

	S1	S2	S3	S4	Year
1994					
Holidays	91.38	72.00	52.08	16.91	38.59
Work days		37.11	16.18	5.32	10.31
All days	91.38	48.32	27.42	8.68	19.61
1996					
Holidays	46.71	43.10	38.81	12.43	24.82
Work days		28.75	15.28	4.23	8.80
All days	46.71	33.53	22.85	6.64	14.10

The numbers in Table A6 are as recorded by the surveyed diarists, and are thus not strictly comparable because of the different numbers of diarists involved in the two surveys. Table A7 expresses the numbers of trips in terms of the overall mean number of trips in each survey. There are still some incompatibilities in the results from the two surveys caused by the slightly different time periods they ran for. Thus S1 from the 1996 survey has two components, one at the beginning and one at the end of the survey (the same applies to S4 in the 1994 survey). Another complicating feature, which is not taken into account, is the increasing rate of non-response throughout the surveys. The data from the three sub-regions vary somewhat from region to region.

Table A7: As for Table A6 but with the numbers given in terms of the overall mean number of trips recorded in each survey

	S1	S2	S3	S4	Year
1994					
Holidays	4.660	3.672	2.656	0.863	1.968
Work days		1.892	0.825	0.271	0.526
All days	4.660	2.464	1.398	0.443	1.000
1996					
Holidays	3.314	3.058	2.754	0.882	1.761
Work days		2.040	1.084	0.300	0.624
All days	3.314	2.379	1.621	0.471	1.000

From numbers like those in Table A7 and acquired in future surveys we can gradually build up a pattern of expected fishing activity on a given day type, provided nothing has changed between the surveys. The figures given in Tables A6 and A7 already have some weather dependent effects in them. For example, the cyclone after Christmas 1996 meant that the fishing activity was much lower in S1 for 1996.

The probability of fishing activity in "normal" circumstances may be roughly constant in the period S1, but it will have a declining trend during S2 and S3 (with a peak of activity at Easter), and S4 will have a trend which declines to perhaps the end of July and then rises. As mentioned above in relation to S1, the patterns of recreational fishing activity could have been different in the past and could be different in the future. For example, in the past, the contrast between weekends and work days might have been stronger (with almost total weekend closure of workplaces), and this contrast might become less in the future (if more of the population works part-time or over days which include weekends).