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## Comparison of three survey methods applied to the recreational rock lobster fishery of Western Australia.

Tara Baharthah  
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# **Master of Science (Mathematics and Planning)**

## Comparison of three survey methods applied to the recreational rock lobster fishery of Western Australia.

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## ABSTRACT

A mail survey of recreational rock lobster licence holders has been conducted annually since 1986. The results from this survey have been used in the management of the recreational rock lobster fishery in Western Australia. Mail surveys are susceptible to non-response and recall bias. The key to determining useful estimates of fishing catch and effort is to minimise both biases.

Telephone recall surveys, with high response rates, effectively eliminate non-response bias. However, they still suffer from recall bias when the recall period is greater than two months. Telephone diary surveys are free of non-response bias and recall bias and provide the most accurate estimates of effort and catch.

In the 2001/02 season three independent surveys were conducted to estimate the recreational catch and fishing effort of the 37,000 fishers licensed to fish for rock lobsters. At the start of the season a random sample of rock lobster licence holders were encouraged to participate in a phone diary survey, with monthly calls, that spanned the length of the fishing season. A telephone recall survey was conducted at the completion of the rock lobster season using an independent random sample. The results of these surveys were compared to those of the annual mail survey, also conducted at the end of the season.

Two new methods of calculating catch and effort from licence holder surveys were developed for this study and compared to previously used calculations of catch and effort. The method using participation and catch rates to estimate catch and fishing effort provided all the information commonly reported for the management of the fishery.

The mail survey estimates of recreational fishing effort and catch were more than double the telephone diary survey estimates. The telephone recall survey estimates of recreational fishing effort and catch were also significantly greater than the diary survey estimates. Estimates of catch rates from all three survey methods were very similar. Results from this study have improved the data collection and analysis for other recreational fisheries throughout Western Australia.

## USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

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- iii) contain any defamatory material.

.....

Tara Baharthah

Friday 10<sup>th</sup> November 2006

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## 1.0 INTRODUCTION

The management of rock lobster stocks in Western Australia depends on accurate estimates of commercial and recreational catch and effort. Considerable research has been undertaken to better understand and manage the rock lobster stocks (Caputi *et al*, 1997; Caputi *et al*, 1990), with particular reference to the commercial sector.

Understanding the recreational component of the catch is essential to ensure the fishery is well managed and remains ecologically sustainable. Furthermore, the implementation of integrated fisheries management of Western Australian fisheries has meant that unbiased, precise estimates of catch are required if there is to be equitable resource allocation between the sectors. The methods employed in the collection of catch and effort data differs between commercial and recreational fisheries.

Commercial fishers are required to send in compulsory monthly returns detailing their fishing regions, catch, and fishing effort as a condition of their licence. Information on recreational catch and fishing effort is only obtained by surveying recreational fishers. A range of different survey methods is used for this purpose. The current estimation of the recreational catch relies on a mail survey known to suffer from non-response and recall bias (Tarrant *et al*, 1993). At present, there is no measure of the extent of the recall and non-response bias in the estimate.

The purpose of this study was to investigate various survey methods to estimate the recreational catch and fishing effort for western rock lobsters in Western Australia. The research undertook the design of two new surveys, conducted concurrently with an annual mail survey. A comparison of the catch and effort estimates from each survey for the same season, allowed the determination of the effect of non-response and recall bias on the results. Different calculations for estimating the recreational catch and fishing effort and their associated errors were investigated and the assumptions were tested by bootstrapping.

## 1.1 Recreational Rock Lobster Fishery

The western rock lobster fishery is Western Australia's largest and most valuable fishery (Department of the Fisheries, 2001) and forms an important part of Western Australia's economy. The fishery in 2001 generated some \$500 million of export income (Department of Fisheries, 2001). Considerable research has been conducted for the commercial rock lobster fishery (Philips *et al*, 2001; Hall and Brown, 2000; Caputi *et al*, 2001) and some research on recreational rock lobster fisheries in Australia (Forward and Lyle, 2002; Melville-Smith *et al*, 2001; McGlennon, 1999; Norton, 1981).

Of the eight species of rock lobsters caught in Western Australian waters, the most prolific is the western rock lobster (*Panulirus cygnus*). This marine crustacean spends much of its life on reef platforms on the west coast of Western Australia between Augusta and Carnarvon.

The southern rock lobster (*Jasus edwardsii*) is commonly caught in the southern part of the state, but can be found in warmer waters. Tropical lobsters are caught in the northern part of the state. These include the painted lobster (*Panulirus versicolor*), ornate lobster (*Panulirus ornatus*) and the two-spined lobster (*Panulirus penicillatus*), which are often difficult to identify. The catch of southern and tropical lobsters is small in comparison to that of western rock lobsters. This study focuses on the recreational catch and fishing effort of western rock lobsters.

Recreational fishing for rock lobsters in Western Australia is restricted to those holding a current recreational rock lobster fishing licence. Recreational fishing licences may be purchased separately for individual fisheries or as an overall "umbrella" licence. Fishers are restricted to the use of 2 pots and a maximum of 4 pots per fishing vessel. Divers catch lobsters by hand using a noose or crook and are permitted to use SCUBA or hookah. A bag limit of 8 lobsters per licence holder per day, or 16 per boat per day (2 or more licence holders) applies to all recreational rock lobster fishers. There are also size restrictions for the different species and the prevention of taking breeding or egg bearing females.

The minimum legal size for western rock lobsters is 77mm from 15 November to 31 January when they weigh approximately 0.5kg (Sumner and Williamson, 1999), then 76mm from February 1 to June 30. The minimum legal size limits were changed to allow increased numbers of rock lobsters to migrate to deep water where mating takes place.

## **2.0 REVIEW OF LITERATURE**

Publications from fisheries science, leisure sciences and social research were reviewed, covering survey methods and survey biases.

### **2.1 Survey Literature**

Mail surveys are known to suffer from non-response bias and recall bias. Knowledge about the extent of these biases is limited. Studies have shown that recall and non-response bias both contribute to non-sampling error (Assael and Keon, 1982). Both non-response and recall bias need to be minimised if an accurate estimate is to be determined.

Interviewing the non-respondents, often by telephone, is used to treat the problem of non-response bias in mail surveys. The corrected estimate should remove the effect of non-response bias (Brown, 1991). Unfortunately, the estimates are still affected by recall bias. A study of non-response bias and recall bias in angling participation found that non-response bias and recall bias are related. Respondents can be more susceptible to recall bias because they are more likely to fish than non-respondents (Tarrant *et al*, 1993). As levels of fishing participation affect both biases, non-response bias can not be estimated by conducting interviews with non-respondents.

The Fisheries Division of the Northern Territory and Laurie West of Kewagama Research jointly developed the telephone diary survey method. It was designed for large scale data collection of recreational fishing effort, catch and expenditure in the Northern Territory. An initial interview was followed by the diary survey and an attitudinal survey (Coleman, 1998).

A national survey of recreational and indigenous fishing used a telephone diary survey technique in conjunction with a number of on-site surveys. A screening survey was used to determine intending fishers. These people were asked to participate in a 12-month survey of their fishing activities. Non-respondents to the screening survey were called back and their fishing details recorded. The diary was employed as a “memory jogger” rather than a record that would be returned to the researchers. “Regular

telephone contact was maintained with diarists throughout the diary period in order to collect details of any fishing or fishing related expenditure” (Henry and Lyle, 2003).

In one fishing study by Connelly and Knuth (1999), diaries were used to examine children’s fishing patterns. Diaries were sent at the start of the study and telephone contacts were made each month for five months. At the completion of the study the diaries were returned to the researchers. The results were compared to data collected in a mail survey to the parents. “The children’s diaries showed that parents overestimated children’s fishing participation by up to two times. Thus, diaries provide a method free from this type of recall bias” (Connelly and Knuth, 1999). The study found that information from diaries may be more accurate than that obtained from mail or telephone surveys, particularly for records of frequent events. The diaries eliminated digit preference where responses are rounded to numbers ending in 0 or 5 and provided detailed information on each fishing trip. One of the concerns mentioned in the study was that telephone diary surveys could be prone to low participation and completion rates. This may be due to the burden placed on participants. High drop out rates can also be a problem.

Tarrant and Manfredo (1993) addressed the problems of recall and non-response bias in self-report angling participation surveys. A diary format was used for immediate recall, and telephone surveys were conducted at 3 month and 6 month intervals. They found that “bias traditionally attributable to recall and nonresponse may be a function of digit preference.”

Over the course of 6 years a state wide angler survey was conducted by telephone in Missouri (Weithman, 1991). A stratified random sample of licence holders were contacted by telephone and asked to participate in the 2-year survey. Then they were sent a letter of introduction, instructions and record cards. Survey participants were contacted by telephone between one and three months, depending on level of fishing. Weithman found that the survey’s estimates of catch and fishing effort were reliable when compared to known fisheries. “A telephone survey is superior to other methods of estimating angler effort and success, including on-site surveys and mail-out questionnaires, with respect to data quality, state wide consistency, and cost.” Recall problems were found to exist in other surveys which could lead to overestimation of fishing effort.

A survey of the recreational rock lobster fishery in Tasmania used a phone diary survey and a recall survey to determine the recreational catch and fishing effort. A comparison of survey methods was used to make recommendations for future assessment options. “This study demonstrated that application of a simple correction factor would not be appropriate and that the recall-based approach was less sensitive at identifying variations in effort and harvest levels than the alternative diary approach” (Forward and Lyle, 2002). The phone diary survey estimates of catch were up to 1.6 times lower than those produced by the recall survey.

Recall surveys have been used over many years. There seems to be two distinct groups of studies with very different research outcomes. Recall studies in crime, health and expenditure have been conducted where the recalled response could be compared to actual data (medical and police records) (Cohen *et al*, 1984; Chu *et al* 1992). These studies have all found that respondents were more likely to underestimate their incidences of arrest, ill-health, accidents and expenditure (Vaske *et al*, 2003). It is believed that the reason for under-reporting these incidences is due to their being undesirable or less socially acceptable.

Studies of fishing and hunting where there is the possibility of prestige bias are more likely to overestimate the occurrence of the activity. The literature supports the assumption that the longer the recall period the greater the number of activities that need to be reported and the greater the bias in recalling the events.

Findings from previous telephone survey studies (Chu *et al*, 1992; Tarrant and Manfredo, 1993; Vaske *et al*, 1996) indicate that recall bias increases when respondents are asked to recall events occurring over long time periods or seasons (Appendix A).

A study conducted in the U.S. around 1988 was used to assess levels of recall over different lengths of time (Chu *et al*, 1992). The estimates for number of days fished and catch increased with the length of the recall period. It is likely that “anglers may provide overestimates because their pleasant memories exaggerate the number of events, or it is more desirable or prestigious to have higher rather than lower estimates”. Also periods of higher activity can lead to respondents using estimation strategies or multiples rather than recalling actual episodes to provide an answer. They also found that results for two-week and monthly calls were similar which indicates that monthly calls are adequate to reduce recall error.

Another study in the use of multiples in estimating fishing harvest in 2003 found that when participation questions are closely followed by a quantity question, the quantity responses resulted in more multiples of days fished than would be expected by chance (Vaske *et al*, 2003). They found that “quantity responses obtained by multiplication can be expected to be systematically in error and that the use of multipliers can theoretically cause serious bias in quantity estimates”. They found that those that fished more often were more likely to use multipliers and “that the multipliers selected tend to result in a larger estimate”.

Miller and Anderson (2001) sent mail survey participants pre-season harvest cards to record their hunting activities during the season. They found that this resulted in more accurate harvest data than when no harvest card had been sent.

The Department of Fisheries has conducted a telephone recall survey of recreational licence holders to assess the catch and fishing effort for marron over a number of years. The response rate for these surveys is around 90% so non-response bias is considered to be small but the recall period may affect the results. The survey is conducted at the completion of the sixteen day recreational marron season. The results compare favourably with studies of log book holders and with expected catches based on rainfall.

## **2.2 Comparisons of Survey Methods**

There are a number of survey techniques that are used to determine recreational fishing catch and effort. These depend on the type of recreational fishery and whether or not there is a licence frame to identify participants.

The national recreational and indigenous fishing survey used a telephone diary survey technique in conjunction with a number of on-site surveys (Henry and Lyle, 2003). A state survey of recreational abalone fishing was conducted for the same season as the national recreational and indigenous fishing survey. There was disagreement between the catch estimates for abalone probably due to the different methodologies.

A state survey of recreational boat-based fishers was conducted during 1996/1997 (Sumner and Williamson, 1999). The boat catch estimates for an important finfish species, dhufish, were considerably different to those obtained from the national recreational and indigenous fishing survey. The catch rate estimates were higher from

the telephone survey and the bag limits were exceeded more often than expected. One possible reason for the discrepancy may be that respondents were reporting the total catch for the boat rather than their personal catch.

A telephone recall survey of recreational abalone fishing was conducted in 2003. For the same season an on-site survey was conducted independently. The results for the Perth metropolitan area were very similar, with the recall survey estimates slightly higher than the field survey estimates. The telephone recall survey was conducted within a short time of the completion of the recreational abalone season. The Perth metropolitan season lasts for 1.5 hours on six consecutive Sunday mornings. The recall period was kept to a minimum and the fishing days were distinctive as there could only be a maximum of six fishing trips to recall.

A comparison of data collected by telephone and a roving creel survey was conducted by Weithman and Haverland (1991). Estimates of angler effort from the telephone survey were double the estimates from the creel survey. They mentioned several possible explanations for this difference. They found that catch estimates for certain species from the creel survey exceeded the telephone survey estimates by about 20% on average. The on-site creel survey was conducted during daylight, from a boat and for 9 months of the year. The telephone survey is not limited by the same factors, as the on-site survey so would include night fishing, unseen fishing, and a full 12-month study.

Telephone surveys that require the respondent to recall events over a period greater than two months are subject to recall bias (Tarrant *et al*, 1993). The high response rates in telephone surveys will eliminate the problem of non-response bias.

A telephone diary survey should be free from non-response bias and recall bias. Non-response is minimised with high response rates. Recall bias is removed by very short recall periods and the use of a diary as a memory prompt.

A comparison of mail and telephone surveys for conducting a travel coupon study found that the telephone method was faster and probably more accurate (Hunt and Dalton, 1983). The researchers were concerned that the low response rates commonly found in mail conversion studies resulted in significant non-response bias. The authors recommended that response rates of less than 80% in a mail conversion study should be



regarded with suspicion. It was suggested that mail surveys should involve extra mailings, incentives or reminders to increase the return of questionnaires.

Angler diaries have been used to examine biases in a recall mail survey (Connelly and Brown, 1995). Participation in the study was solicited by the sending of personalised letters and follow-up telephone calls to non-respondents. Every three months respondents were telephoned and their fishing activity and consumption details were collected. Unfortunately, the comparison of diary assisted results and mail survey results were for two distinct years and the study would have been improved by running both surveys for the same year. However, there were some significant findings. Fishing effort was found to be overestimated by around 45% by the mail survey. Interestingly, the catch rates from both studies were quite similar. They also found that “avid participants are more prone to overestimation in recall surveys”.

A comparison of mail and telephone interviews by McHorney *et al* (1994) found that the cost of the telephone survey per interview far outweighed the cost of the mail interview. Both the telephone survey and the mail survey were found to suffer from bias. The response rates for their mail survey were 79.2%, significantly higher than the response rates for the telephone survey (68.9%). Health ratings were less favourable from the mail survey respondents and there were more reports of chronic illness. There was also a higher rate of missing responses from the mail survey.

Other studies of telephone and mail surveys suggest that mail surveys are superior to telephone surveys for sensitive issues. The survey methods differ primarily in the amount of interviewer respondent contact. Thus, mail surveys have the least amount of interaction between interviewer and respondent.

Armstrong (2000) suggests “telephone surveys suffer greatly from non-response”. Although this is substantially reduced by call-backs, the number of people not available may be high. He feels it is unusual to gain high response rates in telephone surveys. The author does not deny that mail surveys also have a serious problem with non-response. Follow-up has been shown to be an effective way to improve response rates. Small monetary incentives and interesting cover letters have also been effective ways of increasing the rate of questionnaire return. “Surprisingly, length of questionnaire has a negligible effect” on non-response (Armstrong, 2000). He recommended an eclectic approach to survey data collection. Mail surveys should be

used to collect the bulk of the information and telephone surveys can be used to interview non-respondents.

Response bias was consistently larger for telephone surveys, which may be attributed to having to provide an instant answer (Assael and Keon, 1982). Personal interviews did not suffer with larger response bias so perhaps the respondent concentrates more than if they are asked a quick question over the phone.

## **2.3 Sampling Error**

Sampling error is the difference between the estimate obtained by interviewing a sample and the value that would have been obtained if the whole population had been sampled. Sampling error is affected by the size of the sample and the similarity of units in the population.

The most basic sampling technique is simple random sampling. Simple random sampling without replacement means that each sampling unit has equal chance of being selected and once selected is not returned to the pool to be sampled again. There is also an equal chance that all possible combinations of sampling units could be selected for the chosen sample. A simple random sample of rock lobster licence holders from the licensing database were sent a questionnaire for the recreational mail survey of rock lobster fishing (Melville-Smith and Anderton, 2000).

Stratified random sampling without replacement divides the population into strata that are more homogeneous than the population as a whole. From each of these strata a simple random sample is taken. This method may reduce the variance of an estimate and therefore improve the overall precision. It may also provide more information about the strata themselves. Stratification can reduce the levels of heterogeneity in a population, which produces a gain in precision (Malvestuto, 1983).

In 2000, a telephone survey of 800 randomly selected licence holders was performed by the recreational fishing survey and statistics section of the Department of Fisheries (Molony and Bird, 2002). The sample was stratified by licence type and region (country or Perth metropolitan area), thus providing more detailed information about participation and catch rates.

Weithman and Haverland (1991) found that the level of detection of change in catch relates to sample size. Extremely low catch rates are likely to have higher variance and as a result a greater sample size will be required if significant differences are to be determined. “Meaningful data on species that account for 5% or less of the fishing will force more intensive sampling.”

The problems of sampling and non-sampling errors in surveys have been researched. “Random sampling error is encountered in survey research because the sample selected is not a perfect representation of the test population” (Assael and Keon, 1982). This is well understood and measures are in place to control the level of sampling error. A careful sampling of the population and increasing the size of the sample minimises sampling error. One study found that sampling error contributed only 5% toward the total survey error. Surveying large representative samples of the population does not ensure that the bias in the results is minimised. “Non-sampling error was clearly the dominant component of survey error” (Assael and Keon, 1982).

## **2.4 Non-sampling Error**

Non-sampling error refers to all the other errors in the estimate including those caused by non-response, poorly designed questionnaires, interviewer bias, respondent bias, and processing errors (Australian Bureau of Statistics, 2001). Non-response bias, response bias including digit preference and interviewer bias are discussed in more detail in the following subsections.

### **2.4.1 Non-Response Bias**

Non-response error (or bias) occurs when some sample members do not respond, causing responses to be an unreliable representation of the selected sample (Assael and Keon, 1982). Non-response bias is of particular concern with mail surveys because of the difficulty of getting high numbers of survey returns. Achieving a high response rate is the best way to reduce the effects of non-response bias (Fisher, 1996).

“Non-response to mail surveys is not a problem in itself; the problem is that non-response induces a non-response bias in the estimates” (Pollock *et al*, 1994). Non-response bias occurs when the fishing activities of those that participate in the survey are different to those that chose not to participate. In most cases, anglers who are active

or keen fishers are more likely to report their fishing activities. Anglers who have not participated in the fishery are more likely to ignore the questionnaire. Non-participants may assume that their information is not useful. The effect of non-response bias may be considerable in mail surveys. Even with a well-managed survey, “the response rate may only reach 50-75%” (Pollock *et al*, 1994).

“The mail survey has been criticised for non-response bias” (Armstrong and Overton, 1977). The most commonly suggested method to deal with this is minimising non-response itself by increasing the response rate. One approach is to sample and interview non-respondents themselves to determine what the population of non-respondents are like. Estimating the effect of non-response is a separate approach. Extrapolation techniques work under the assumption that those who respond less readily (after reminders) are more like non-respondents. Using successive waves in a mail survey, the researcher can assume that those who respond after stimulus are expected to be similar to non-respondents, though this technique has not been thoroughly tested using external validation checks.

One way to understand non-response is to consider a population divided into two strata. The response stratum may be described as having a population fraction  $W_1 = N_1 / N$  and mean  $\bar{y}_1$ , the non-response stratum with a population fraction  $W_2 = N_2 / N$  and mean  $\bar{y}_2$ . If the means are equal,  $\bar{y}_1 = \bar{y}_2$ , there is the assumption that the random sample is a simple random sample of the whole population and there is no non-response bias. If  $\bar{y}_1 \neq \bar{y}_2$  then the non-response bias is  $B = W_2(\bar{y}_1 - \bar{y}_2)$ . As the proportion of non-respondents increases and the difference between non-respondents and respondents increases the level of non-response bias increases (Pollock *et al*, 1994).

Non-response and recall errors were researched in a study of absence because of illness (Van Goor and Verhage, 1999). Their mail survey had a response rate of 77% and their results still exhibited non-response bias, as non respondents were more likely to have been on sick leave than respondents. Mail survey respondents consistently under reported absence due to illness. “Nonresponse and recall errors had a cumulative effect on the distribution of the absence variables.” This highlights the case where respondents underestimate their activity due to social desirability.

Armstrong suggests it is “possible to estimate the non-response bias in mail surveys” by interviewing non-respondents (Armstrong, 2000). This method is useful if

the survey is based on determining opinions but not if the survey is designed to estimate participation in an activity. It does not account for interactions between non-response bias and recall bias.

#### **2.4.2 Response Error**

“Response error deals with the differences between a respondents’ reported answers and actual values of a survey item” (Assael and Keon, 1982). Estimating response error is extremely difficult because access to external validation checks is limited. Response error is difficult to isolate from non-sampling error. “The response biases obtained in the study indicate that respondents tended to over report” all the information they were asked for (Assael and Keon, 1982). This study was able to estimate non-sampling error because external validation of the results was possible.

Armstrong (2000) suggests that the responses from telephone, mail and personal interviews for most issues are similar. However, if the issue is sensitive then there may be differences in results from the different survey methods. In studies of sensitive issues, mail surveys were found to have the advantage over other survey methods. Mail surveys are viewed as a superior survey method because they have little respondent-researcher interaction (Armstrong, 2000). Anything that may influence a respondent’s answer increases the effect of response error on the survey results.

Recreational fishing is not a sensitive topic but may suffer from prestige bias, where respondents exaggerate their fishing activity. In a study of walleye catches by Alberta anglers, Sullivan (2003) found that anglers reported 2.2 times more walleyes than were caught by test anglers. He uses angler exaggeration as a synonym for self-reporting bias, encompassing prestige bias and social desirability bias. His study compared reported catches from an onsite survey and reported catches from a mail survey to test anglers and their catches. He found that anglers exaggerated their catches more as fishing success declined. His data showed that exaggeration occurred between being out in the boat and catching a fish and coming to shore. Due to the nature of the study the onsite survey interviewers weren’t able to verify the catches. “Mail surveys are useful for gathering many types of data, but catch and harvest data (and any resulting trends) should be considered suspect, especially if recall periods are long or catch rates may be declining”.

Pollock *et al* (1994) states that annual recall surveys have been found to produce large overestimates of fishing effort and catch compared to on site surveys.

In many recreational surveys, recall periods of 6 to 12 months are common. A few studies have found that people can not accurately recall their leisure activities over this length of time. Recall bias has typically produced overestimates of recreational participation (Chase and Godbey, 1983). The accuracy of self reported recreational participation was questioned after two studies of leisure activities. “The two studies support the suggestion that self-reported surveys in the frequency of participation in recreation activities provide inaccurate information. This implies an inefficient use of public money spent on this type of research” (Chase and Godbey, 1983). If the biases in such studies are not measured or at least understood then participation estimates may give misleading information used for management decisions.

Tarrant and Manfredo (1993) found that digit preference, and recall and non-response bias were related. Digit preference occurs in long recall periods but not in short recall periods and contributes to response error.

Both telephone and mail surveys can be affected by recall bias. The length of time between the fishing activity and the survey can affect the accuracy of the information of the fisher. Memory recall of specific events fade soon after the event occurs. One of the types of memory recall error is called telescoping. Survey respondents can include fishing events that occur prior to the time frame in question. This causes the number of fishing trips to be over reported and increases the estimate for fishing effort. By overestimating the effort, survey participants are more likely to overstate their catch when multiples are used.

Of the few studies that have addressed the effects of recall bias most have used a diary survey to provide the most accurate results and a telephone or mail recall survey to gather information about recall bias. Most studies found that respondents over estimated the information they were asked to provide, whether it was number of telephones in a business or the number of fishing trips in the past year.

A study of response error in self-reported recreation participation by Chase and Harada (1984) found that the “percentage error of estimation increases directly with the size of the estimate. Thus, those who make the largest estimates of participation typically have the largest amount of error.”

Tarrant *et al* (1993) addressed the problems of recall and non-response bias in self-report angling participation surveys. A diary format was used for immediate recall, and telephone surveys were conducted at 3 month and 6 month intervals. They measured non-response bias by telephoning non-participants in the other surveys. Interactions were found between non-response and recall bias as recall bias seemed to be related to levels of fishing activity, which was different for respondents and non-respondents. Non-respondents were more likely to report lower levels of participation and respondents reported higher levels of fishing activity. Findings indicate that studies that use long recall periods, or do not control non-response bias, overestimate use. Future studies can control recall and non-response biases by combining frequent sampling with telephone interviews that request short recall periods (Tarrant *et al*, 1993).

Begovic and Picone (2000) found in a telephone recall study of weekly working hours that recall periods of one, two and three weeks had little effect on the results. This is most likely due to there being too small a time frame to examine recall bias in survey results. Though it is interesting to note that a recall period of three weeks is just as effective as one week.

A study of childhood illness found that respondents tended to underestimate socially undesirable or emotionally laden events (Mheen *et al*, 1998). So recall bias does not have to cause an overestimate in the measures of activity.

A comparison of response and non-response bias found that neither “is consistently the larger contributor to non-sampling error” (Assael and Keon, 1982). Therefore the survey researcher must be concerned with both of these components of non-sampling error.

### **2.4.3 Interviewer Bias**

Interviewer characteristics were found to have an effect on survey response rates under certain conditions (Brick *et al*, 1995). Not only can the interviewer affect the contact and cooperation rates but also influence responses. As expected, interviewers had the largest effect on open-ended questions, where reports had to be summarised or coded. Telephone surveys can be designed considering this. Open-ended questions can be reduced and the interviewers can participate in thorough training sessions.

#### **2.4.4 Digit Preference**

Digit preference is when respondents report the number of events with preference for certain numbers, often numbers ending in a zero or five. Digit preference is a response error that may lead reports to be rounded up to the nearest five or ten and can cause an overestimate in behaviour.

Some studies assert that digit preference is more obvious in respondents who report high levels of participation (Vaske *et al*, 1996; Beaman *et al*, 1997; Chu *et al*, 1992). Digit preference has been found to increase with respondents who do not keep records and thus rely on memory to recall events. Vaske's result indicate a change in the way angler surveys are conducted is required.

Vaske *et al* (2003) suggest "those who fish more are more prone to use multipliers and that the multipliers selected tend to results in a larger estimate". One recommendation is that quantity questions could be asked before the number of times questions.

Tarrant and Manfredo (1993) found that digit preference, recall and nonresponse biases are related, which explains why nonresponse and recall biases occur in recreation studies. They found that the "gap between respondents and nonrespondents is widened by subject tendency to exhibit digit preference." They found that digit preference was less of a problem for respondents and nonrespondents with shorter recall periods and that digit preference may explain errors previously attributed to non-response bias and recall bias. They concluded that the method least susceptible to these biases was "a telephone interview requesting subjects to recall participation over a short interval".

Miller and Anderson (2002) studied digit preference in waterfowl hunters and found that digit preference and recall bias effects not only reported participation but also harvest data. They found that those with a harvest record card did not exhibit individual digit preference.

### **2.5 Catch and Effort Calculations**

For comparisons with commercial catches an estimate of total catch is required in Australian fisheries. Like this study, other studies in Australia Forward and Lyle (2002) and McGlennon (1999) have also used the catch and effort calculations



developed by Pollock *et al* (1991). The mean effort of each stratum is calculated as the sum of the number of days fished by each respondent divided by the stratum sample size. The total effort is the sum of the mean effort for each stratum. The mean catch of each stratum is calculated as the sum of the total catch by each respondent divided by the stratum sample size. The total catch is the sum of the mean catch for each stratum.

### **2.5.1 Bootstrap & Winsorization**

The bootstrap is a non parametric method of resampling distributions to determine the mean and associated standard errors (Efron and Tibshirani, 1993). Bootstrapping has been widely used to determine 95% confidence intervals for estimates of catch and effort (Ye and Mohammed, 1999; Pollock, 1991; Smith, 1997). McGarvey *et al* (1997) used bootstrap estimates of standard error to assess the reliability of estimating lobster recruitment and exploitation rates from landings by weight and numbers.

The bootstrap can be used to check the robustness of standard parametric methods and provide the primary statistical analysis for moderately sized samples and highly skewed data (Barber and Thompson, 2000). The robust bootstrap, which limits the proportion of outliers that may be resampled when a normal bootstrap is applied to data, was investigated by Amado and Pires (2002).

Another study trialed different bootstrapping techniques for dealing with skewed data and small sample sizes in a trawl fishery (Smith, 1997). “The bootstrap offers a natural way of modelling survey estimates given that its basis is very similar to that of the randomization basis for finite population theory”. Smith compared three variations of the bootstrap technique to the stratified mean number of Haddock from groundfish trawl surveys. Smith found that the naïve bootstrap, resampling observations independently within each stratum, caused the bootstrap to underestimate the variance around the estimate. However, his study had generally low catch numbers and then an exceedingly high catch in one stratum which heavily influenced the results.

“Bootstrap analysis was used to determine the appropriate sample sizes for improved precision in exploitation rate estimates” (Frusher *et al*, 1997). This meant that sampling could be conducted more efficiently and that the cost of sampling could be balanced against the precision required for management decisions.

Winsorization is a “method of extreme value adjustment that replaces extreme values with the critical values used for defining low and high extreme values” (Chen *et al*, 2004). Winsorization has been used in a number of studies to assist with reducing the effect of extreme values in surveys (Chen *et al*, 2004; Smith and Jones, 2003).

Rivest and Hidioglou (2004) investigated winsorization use in outlier treatment for disaggregated estimates while keeping aggregated estimates unchanged. They suggest a method for “selecting the threshold that optimizes the estimators of the stratum means”.

Rivest (1994) found that “winsorized means are attractive alternatives to the sample mean for skewed populations”. He found that even with heavy skewness, once winsorized means were most efficient.

Kokic and Bell (1994) investigated optimal cut off values for winsorizing repeated stratified surveys. They found that winsorizing “in sample surveys is a practical and effective tool for improving the efficiency of estimation”.

## **3.0 METHODS**

### **3.1 Design of Surveys**

The purpose of the study is to determine the most suitable method to estimate the recreational catch and fishing effort for western rock lobsters in Western Australia. This required the development of two new survey methods that had not been applied to this recreational fishery previously. This is in addition to a mail survey currently used by the Department of Fisheries.

The three survey methods are a telephone diary survey, a telephone recall survey, and a mail recall survey. Each of these methods has advantages and disadvantages in terms of cost, time, and the accuracy of the estimate.

The three surveys were conducted for the same rock lobster season using the licences from the Department of Fisheries licensing database. Licences are valid for one year and one month prior to the expiration of the licence a renewal notice is sent encouraging licence holders to renew their licence for the following year.

The telephone diary survey started with the commencement of the rock lobster season in November 2001 and continued for the duration of the fishing season until June 2002. The telephone recall survey and the mail survey commenced at the close of the season. They were run at the start of July 2002. Both telephone surveys were conducted with the same five telephone interviewers. The surveys compared in this study will not attempt to estimate the illegal catch of rock lobsters by non-licence holders.

The total catch and fishing effort for recreational rock lobster fishers was estimated using three different calculations on the initial validated data from both telephone surveys. These estimates were compared to the same data before and after different winsorization techniques were applied.

The initial data was bootstrapped to check assumptions of normality in the catch and effort calculations. The level of bias in the survey results was investigated and the

cumulative density functions compared. An examination of the differences between telephone interviewers was undertaken using logistic regression.

## **3.2 Mail Survey**

The mail survey has been in operation for a number of years. The basic design and methods have remained unchanged.

### **3.2.1 Survey Design**

The rock lobster section of the Research Division of Department of Fisheries manages the data collection and analysis of the data. Questionnaires were sent out at the end of the rock lobster season. Licence holders were asked to fill out the 3 page questionnaire and return it to the Department of Fisheries by 14<sup>th</sup> August. A reminder postcard was sent to all randomly selected licence holders two weeks after the initial letter and questionnaire. Completed questionnaires were still accepted as late 31<sup>st</sup> of December 2002. Incentives have been used in previous years to improve response rates but no incentive was used for the 2001/2002 rock lobster survey.

### **3.2.2 Sampling Design**

The database of recreational fishing licence holders was used as the sampling frame. A simple random sample without replacement of 5,000 licence holders was selected.

### **3.2.3 Questionnaire Design**

The questionnaire has changed very little over the years. It collected information on licence type, rock lobster fishing participation, fishing method, total number of western rock lobsters kept by fishing method, total days fished by fishing method, and a range of other details.

### **3.2.4 Operation of Survey**

The mail survey is relatively simple to perform. The survey administrator has to organise the random selection of licence holders and ensure that the forms are mailed at the correct time. This method does not rely on field staff to conduct interviews.

The survey forms were sent to the random selection of licence holders, with reply paid envelopes. After two weeks a reminder postcard was sent.

The selected licence holder is expected to return the completed form. Once the forms were returned the data was entered, and the analysis performed.

### **3.2.5 Cost of Survey**

The cost of the mail survey was approximately \$10,000. This included the printing of the questionnaires, personalised letters, postage, reminder postcards, and the portion of the time for a statistical officer to analyse and report on the results.

### **3.2.6 Assumptions and Limitations**

One limitation of this survey is that the fishing activities of respondents holding a single species licence are treated no differently to those holding an all species or 'umbrella' licence as there is no stratification by licence type. This was examined by comparing participation, catch and fishing effort.

This survey assumed that the sampling error is minimal. That is, the sample of licence holders selected for the mail survey was representative of the population of recreational rock lobster fishers.

Non-response bias is a concern for mail surveys. The problem occurs when the fishing activity of respondents is different to those who chose not to respond. Low response or return rates may indicate that non-response bias is a limitation of this method.

One of the limitations of the mail survey is that respondents are expected to accurately recall their past fishing activity over a period of 7½ months. Respondents who fish more often may be inclined to overstate their fishing effort. This may be caused by having a large number of fishing events to remember accurately. It seems to be much easier to recall an event that happened one or two times than something that

happened 20 to 30 times. Also respondents tend to round their estimates to a value ending in zero or five.

### **3.3 Telephone Diary Survey**

The telephone diary survey was based on the telephone diary survey method used by Fishcount in the Northern Territory (Coleman, 1998; Lyle *et al*, 2002).

#### **3.3.1 Survey Design**

The telephone diary survey was designed to collect detailed catch and effort information from recreational fishers licensed to take rock lobsters on a trip by trip basis. The telephone diary survey asked similar questions to the mail survey but in a very different format.

The procedure for a diary survey is more complex than a mail or telephone recall survey and involves two stages. A screening survey was commenced on the 31<sup>st</sup> October 2001 after a random sample of licence holders was taken. The initial workload control sheets were returned to the office by 9<sup>th</sup> November so that the database could be updated with any change of address details. Letters and labels were personalised using a mail merge. Diaries were sent to all participants prior to the start of the rock lobster season. The first diary calls were made after the 15<sup>th</sup> of November and the survey was completed after a final interview in July 2002. The same interviewer contacted them once a month for the duration of the rock lobster season. After each rock lobster fishing trip a diarist was encouraged to record their catch and effort information in the diary provided. A final interview was conducted to finish the survey and thank the diarists for their participation.

#### **3.3.2 Sampling Design**

The Department of Fisheries licensing database provided the data frame for sampling rock lobster licence holders and umbrella licence holders. In addition to the mail survey of rock lobster licence holders, telephone surveys of recreational abalone, marron and southwest freshwater angling have been conducted on an annual basis since 2000.

During a telephone survey of recreational marron and abalone licence holders conducted by the research division of the Department of Fisheries in 2001, umbrella licence holders were asked whether they went rock lobster fishing in the previous 12 months. If they had participated in the recreational rock lobster fishery, they were then asked about the number of days they had been fishing. This particular survey was stratified by licence type and by region of residence. Of the 400 umbrella licence holders interviewed, 200 lived in the Perth metropolitan area and 200 resided in country areas. Around 58.0% of metropolitan umbrella licence holders had fished for rock lobsters and 58.6% of country umbrella licence holders had fished for rock lobsters in the previous 12-months. There was no significant difference ( $p > 0.05$ ) between the results from metropolitan and country umbrella licences in regards to their rock lobster fishing activities so there was no need to stratify by region in the telephone diary survey.

The same survey found differences in the fishing behaviour of those with a single species licence and those with an 'all species' or umbrella licence. The telephone diary survey employed a stratified random sample of licence holders, stratified by licence type. This reduces the variance of the population estimate, as there was reason to believe that the licence strata are more homogenous than the population as a whole.

To determine the sample size for the telephone diary survey the binomial distribution was used to estimate the maximum sampling error by assuming that the participation rate is 50%, which incurs the highest level of error. If the participation rate of rock lobster fishing is assumed to be 50% then it will give a maximum sampling error of less than 5%, based on 37,000 licence holders in total using the finite population correction factor (Figure 3.3.1). The actual participation rates may be different, either greater or less than 50% but this will only decrease the sampling error.

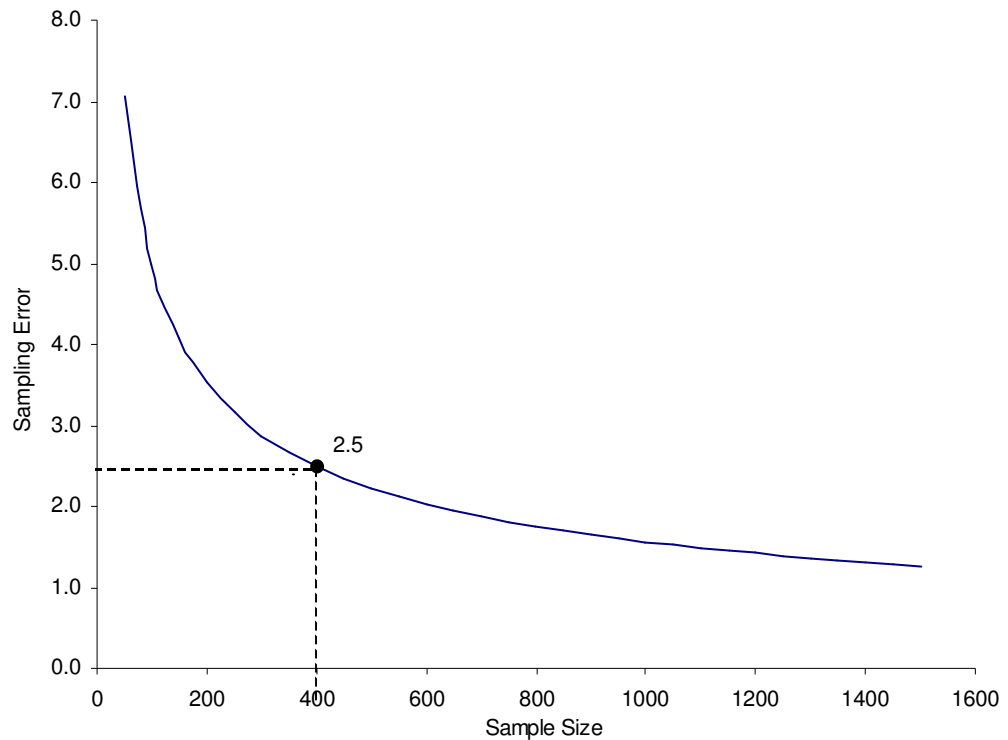
The sampling error of the estimated participation rate is calculated as:

$$e = \sqrt{1 - \frac{n}{N}} \sqrt{\frac{p(1-p)}{n}}$$

where  $p$  = estimated proportion participating

$n$  = sample size

$N$  = population size



**Figure 3.3.1: Effect of sample size on sampling errors for rock lobster and umbrella licence holders combined**

The minimum number of licence holders chosen to be in the diary survey was 400 to ensure that the sampling error of participation rate was less than 5%. To ensure that at least this number of respondents remained in the survey for the entire duration, 450 were selected in the initial interview.

The initial sample from the licensing database was 375 rock lobster licence holders and 375 umbrella licence holders. Each interviewer was given 150 licence holders from which they had to make contact with 45 rock lobster licence holders and 45 umbrella licence holders.

### 3.3.3 Questionnaire Design

#### Screening Survey

The screening survey interview (Appendix C) was designed to encourage the respondent to participate in the seven and a half month diary survey. Some instructions were written on the questionnaire itself, more detailed instructions were on a separate sheet. Only a few questions were asked of the respondent and the answers to these were recorded on a diary cover sheet printed on green card (Appendix D). This form was used to record the diarist's personal details and to keep track of the calls. Space was



available on the back for added notes and comments, which the interviewer could use to prompt their own memory about the diarist.

### Diary Survey

Each time an interviewer called a diary survey participant they asked questions about the diarist fishing trips since the last time they spoke. The same questionnaire was used for each trip and the answers were recorded on a fishing event sheet (Appendix F). The event sheet was designed to be easy for data recording, quick to check for missing values and simple to validate. The questions were simple and ordered in a logical manner starting from the date the fishing occurred through to what was kept and released. Only closed ended questions were asked which avoids interviewer bias in recording the information. An instruction sheet was also written for the diary event sheet (Appendix G).

### **3.3.4 Operation of Survey**

#### **Training**

All five interviewers were required to attend a two day training session. The first day was mostly spent training them for the screening survey and the second day spent preparing them for the regular calls during the season. Each interviewer was given a file containing sample forms and diaries, instructions, practice session information, workload control sheets, two expanding files, and query forms.

There were two sets of workload control sheets used in the diary survey. The first contained lists of randomly selected licence holders and their phone numbers. Response codes were recorded on the list to determine the types of responses (Appendix E). The second set of workload control sheets were the lists of diary participants and the months of attempted contact. Letters were sent if the interviewer could not make contact after two months.

Interviewers were given instruction on gaining cooperation, arranging appointment, and determining the best times to call. The interviewers were instructed to ring between two times a month for regular fishers and two months if the respondent says they are unlikely to go fishing.

Interviewers were well paid for completed screening interviews as an incentive for them to keep attempting contact. Diary interviewers were paid on a monthly basis regardless of how many times they had to make contact.

Where the interviewer had a query or a respondent required another diary sent out to them, a pink query form was filled in and returned to the office. In the cases where licence holders were children, the interviewer was instructed to speak to a parent or guardian first. If they gave permission for the interviewer to speak directly to the child then the interview was conducted as normal. Otherwise, the parent spoke on the child's behalf. In every case, the parent accompanied the child for the fishing activities.

## Contact Arrangements

The interviewers were instructed to start at the top of their list and try to contact each licence holder at least four times before moving on to the next person in the screening survey. They were told to attempt contact on varying days and times to give the licence holder every opportunity to be interviewed. If someone in the licence holder's household was contacted an appointment was made to speak to the licence holder and more than four calls could be made to catch this person.

In the screening survey interview the respondents were asked for the best times to contact them and for any other numbers they could be contacted on. They were also asked to provide the name and telephone number of someone who would know how to contact them. This was to improve the ease with which contact could be made and ensure that contact could be maintained even if their situation changed.

The interviewers attempted to contact all diary holders each month. This limits the recall error for non-diarised fishing events, as the recall period is no greater than one month.

## Data Validation and Storage

The event sheets were checked for missing values after each interview and when the sheets were returned to the office. The data were validated each month after data collection. Inconsistent data or discrepancies in the data were dealt with by recontacting the survey participant. A Microsoft Access database was created for the diary survey and its associated data entry screens were designed with built in error trapping. A skilled data entry operator entered the forms.

### **3.3.5 Cost of Survey**

The cost of the phone diary survey is relatively high. Telephone staff are paid to attend training, for completed interviews and some calls not resulting in an interview. Telephone calls can be costly when respondents live outside the metropolitan area or can only be contacted using a mobile. A good estimate of the cost of this survey would be \$20,000 - \$25,000.

### **3.3.6 Assumptions and Limitations**

The research is based on the assumption that the data to be collected from the phone diary survey over the length of the season is the most accurate data on the recreational rock lobster fishing activity. This can be assumed because the data is recorded each time the survey participant goes fishing. Anecdotal evidence showed that in general, the diarists took the research seriously and completed their diary at the time of the fishing activity. Depending on the frequency of the fishing activity, respondents were telephoned by experienced telephone interviewers a minimum of once every month. Some participants' fished almost every day during the season and these people were contacted more often.

If the survey participant does not record the fishing times, dates, fishing method, and catch in their diary it is noted as a non diarised event. As they are contacted regularly the possibility of recall error is minimised, as the recall period can not be more than a few weeks.

Another assumption is that the sampling error is minimal. That is, the sample of licence holders selected for the three surveys are representative of the population of recreational rock lobster fishers. Licence holders are selected at random to participate in the survey and the sample size is sufficient for a level of precision of less than 5%.

One of the limitations of the diary method in the way it is designed is that it does not account for new rock lobster fishers taking out a licence after the sample has been created. The numbers of licence holders, both of rock lobster and the all species licence, is fairly stable. This was monitored on a monthly basis throughout the season.

## **3.4 Telephone Recall Survey**

The telephone is an excellent tool for collecting state wide recreational fishing data (Weithman, 1991). The telephone recall survey commenced on 3<sup>rd</sup> of July 2002 and finished on 17<sup>th</sup> July.

### **3.4.1 Survey Design**

The telephone recall survey was designed to collect information from recreational rock lobster fishers at the end of the 2001/2002 rock lobster season. The survey asked similar questions to the mail and telephone diary survey so that the results could be compared.

### **3.4.2 Sampling Design**

The same sampling design was applied to both telephone surveys. The telephone recall survey used a stratified random sample of licence holders, stratified by licence type.

The initial sample from the licensing database was 400 rock lobster licence holders and 400 umbrella licence holders. Each interviewer was given 160 licence holders from which they had to make contact with 40 rock lobster licence holders and 40 umbrella licence holders. It was decided that the minimum number of licence holders to be in the recall survey was 400. This would give a sampling error of less than 5% in participation.

Careful measures were taken to ensure that the random samples of licence holders were independent. Participants in the phone diary survey were excluded from participating in the phone recall survey, which in turn were removed from the population prior to the sampling for the 5000 questionnaires sent out for the mail survey.

### **3.4.3 Questionnaire design**

The recall survey questionnaire was designed to collect the same information as the diary survey for ease of comparison between methods (Appendix H). More detailed

instructions were written on a separate instruction sheet (Appendix I). The respondents were asked for the number of days they went fishing and the total catch of the three species of lobsters by region and fishing method.

The questions were kept short and simple. The time period of the survey was repeated in each question. The questions emphasized that the information required was for the individual's catch and fishing effort and not for other accompanying licence holders. The interview time was kept to under 10 minutes if they had been fishing and less than 2 minutes for non-fishers.

#### **3.4.4 Operation of Survey**

##### Training

All five interviewers were required to attend a one day training session. Each interviewer was given a file containing sample forms and diaries, instructions, practice session information, workload control sheets and query forms.

Interviewers were given instruction on gaining cooperation, arranging appointment, and determining the best times to call. In the cases where licence holders were children, the interviewer was instructed to speak to a parent or guardian first. If they gave permission for the interviewer to speak directly to the child then the interview was conducted as normal. Otherwise, the parent spoke on the child's behalf. In every case, the parent accompanied the child for the fishing activities.

##### Contact Arrangements

The interviewers were instructed to start at the top of their list and try to contact each licence holder at least four times before moving on to the next person. They were told to attempt contact on varying days and times to give the licence holder every opportunity to be interviewed. If someone in the licence holder's household was contacted an appointment was made to speak to the licence holder and more than four calls may be made to catch this person. The interviewer was instructed to stop on reaching 40 umbrella and 40 rock lobster licence holders.

## Data Validation and Storage

The completed questionnaires were validated for missing values after each interview and when they were returned to the office. All data was entered into a Microsoft Access database designed for the recall survey results.

Inconsistent data or discrepancies in the data were dealt with by recontacting the survey participant. A Microsoft Access database was created for the survey and its associated data entry screens were designed with built in error trapping. A skilled data entry operator entered the forms.

### **3.4.5 Cost of Survey**

The telephone recall survey costs less to run than the telephone diary survey. The same initial costs apply; however, there are no ongoing costs. This survey was relatively inexpensive costing \$3,500 - \$4,500.

### **3.4.6 Assumptions and Limitations**

One assumption of the survey design was that the sampling error was minimal. That is, the sample of licence holders selected for the recall survey was representative of the population of recreational rock lobster fishers. Licence holders were selected at random to participate in the survey and the sample size was sufficient for a level of precision of less than 5% for participation rate.

A high uptake of licence holders into the telephone recall survey was achieved so non-response bias was minimised.

One of the limitations of the telephone recall survey is that respondents are expected to accurately recall their past fishing activity over a period of 7½ months. Respondents who fish more often may be inclined to overstate their fishing effort. Some studies have found (Tarrant and Manfredo, 1993) that more avid fishers are more likely to overstate the number of fishing events. Respondents may use the number of day's effort and some idea of estimated catch rate to calculate on the fly the total catch. So an overestimate of effort may cause an overestimated catch.

## **3.5 Estimation of Catch and Effort**

The estimates of catch and fishing effort were based on the calculations produced by Pollock *et al* (1994).

### **3.5.1 Exploratory Data Analysis**

Exploratory data analysis was performed on the data collected from the telephone surveys. Summary statistics were calculated and the data was viewed graphically. A group of plots for each stratum in each survey was created including histogram, density plot, boxplot, and qq-plot. The histogram and density plot give an overall picture of the shape of the data, while the boxplot and qq-plot help identify outliers. Post stratification estimates by licence type of the mail survey were calculated and compared to the results from the stratified telephone surveys.

The distributions for days fished, catch and catch rates were compared graphically and then tested using a two sample Kolmogorov-Smirnov test. The moments, kurtosis and skewness, were examined by bootstrapping the statistics, finding the confidence limits and determining whether the differences in the distributions are due to the shape or level of skewness of the distribution.

Frequency plots of the data helped identify digit bias, where respondents round their responses to numbers ending in zero or five, particularly for the mail and telephone recall surveys. Cumulative frequency distributions were used to show the differences between survey methods and the effect of bias on the results.

### **3.5.2 Comparison of Catch and Effort Calculations**

The catch and fishing effort for both telephone surveys was estimated by three calculation methods. Two new methods were developed by the author. They use participation rates and catch rates to increase the precision in the estimates and provide more information about the strata. These were compared to the formulae described by Pollock *et al* (1994), called Method 1 for ease of comparison (Appendix B).

Method 2, utilises participation rates, determines total number of fishes for each strata, utilises catch rates and provides the most information for each strata.



## Method 2

### Estimation of Participation

The mean fishing effort  $q_k$  for stratum  $k$  is estimated as follows:

$$q_k = \frac{P_k}{n_k} \quad (1)$$

where  $n_k$  is the sample size in the stratum and  $p_k$  is the total number of respondents who fished.

The estimated variance for participation within stratum  $k$  with finite population correction is:

$$Var(q_k) = \frac{q_k(1-q_k)}{n_k} \frac{(N_k - n_k)}{(N_k - 1)} \quad (2)$$

where  $n_k$  is the sample size and  $N_k$  is the population size for stratum  $k$ .

The total number of fishers in stratum  $k$  is estimated by

$$f_k = N_k q_k \quad (3)$$

The estimated variance for the total number of fishers within stratum  $k$  is:

$$Var(f_k) = N_k^2 Var(q_k) \quad (4)$$

### Estimation of Total Effort

The mean fishing effort  $\bar{e}_k$  for stratum  $k$  is estimated as follows:

$$\bar{e}_k = \frac{\sum_{i=1}^{p_k} e_i}{p_k} \quad (5)$$

where  $p_k$  is the participation in each stratum  $k$  and  $e_i$  is the total number of days fished by each respondent  $i$ .

The estimated variance within stratum  $k$  is:

$$Var(e_k) = \frac{p_k \sum_{i=1}^{p_k} e_i^2 - \left( \sum_{i=1}^{p_k} e_i \right)^2}{p_k(p_k - 1)} \quad (6)$$

where  $p_k$  is the participation for stratum  $k$  and  $e_i$  is the total number of days fished by each respondent  $i$ .

The variance associated with the estimate of the mean, with finite population correction (Neter *et al*, 1988) is:

$$\hat{V}ar(\bar{e}_k) = \left( \frac{N_k - p_k}{N_k - 1} \right) \frac{s_k^2}{p_k} \quad (7)$$

The total effort  $E_k$  for stratum  $k$  is estimated as:

$$E_k = f_k \bar{e}_k \quad (8)$$

where  $f_k$  is the total number of fishers in stratum  $k$ .

The variance associated with  $\hat{E}_k$  is estimated by

$$Var(\hat{E}_k) = E_k \left( \frac{\hat{V}ar(f_k)}{f_k^2} + \frac{\hat{V}ar(e_k)}{e_k^2} \right) \quad (9)$$

The total effort  $\hat{E}$  is calculated by summing the effort for the strata as follows

$$\hat{E} = \sum_{k=1}^n \hat{E}_k \quad (10)$$

where  $n$  is the number of strata.

The variance is estimated in the same way

$$Var(\hat{E}) = \sum_{k=1}^n Var(\hat{E}_k) \quad (11)$$

The standard error is calculated by the usual method

$$SE(\hat{E}) = \sqrt{Var(\hat{E})} \quad (12)$$

## Estimation of Total Catch

The catch rate  $r_k$  for stratum  $k$  is estimated as follows:

$$r_k = \frac{\sum_{i=1}^{p_k} c_i}{\sum_{i=1}^{p_k} e_i} \quad (13)$$

where  $e_i$  is the effort for stratum  $k$  and  $c_i$  is the total number of days fished by each respondent  $i$ .

The estimated variance within stratum  $k$  is:

$$Var(r_k) = \frac{\sum_{i=1}^{p_k} e_i (r_i - \bar{r}_k)^2}{\sum e_k} \quad (14)$$

where  $\bar{r}_k$  is the mean catch rate for stratum  $k$ .

The variance associated with the estimate of the mean, with finite population correction (Neter *et al*, 1988) is:

$$\hat{V}ar(\bar{r}_k) = \left( \frac{N_k - p_k}{N_k - 1} \right) \frac{Var(r_k)}{p_k} \quad (15)$$

The total catch for stratum  $k$  is estimated as:

$$C_k = E_k r_k \quad (16)$$

where  $E_k$  is the effort for stratum  $k$ .

The variance associated with  $\hat{C}_k$  is estimated by

$$Var(\hat{C}_k) = E_k^2 C_k^2 \left( \frac{\hat{V}ar(\hat{E}_k)}{E_k^2} + \frac{\hat{V}ar(\bar{r}_k)}{C_k^2} \right) \quad (17)$$

The total catch  $\hat{C}$  is calculated by summing the catch for the strata as follows

$$\hat{C} = \sum_{k=1}^n \hat{C}_k \quad (18)$$

where  $n$  is the number of strata.

The variance is estimated in the same way

$$Var(\hat{C}) = \sum_{k=1}^n Var(\hat{C}_k) \quad (19)$$

The standard error is calculated by the usual method

$$SE(\hat{C}) = \sqrt{Var(\hat{C})} \quad (20)$$

Method 3 also utilises participation rates and determines total number of fishers for each strata and then uses mean catch and effort to calculate total catch and effort for the population. The estimates of catch and effort for all three methods should be identical though the estimates of standard error may vary.

### Method 3

#### Estimation of Participation

The mean fishing effort  $q_k$  for stratum  $k$  is estimated as follows:

$$q_k = \frac{p_k}{n_k} \quad (21)$$

where  $n_k$  is the sample size in each stratum  $k$  and  $p_k$  is the total number of respondents who fished.

The estimated variance for participation within stratum  $k$  with finite population correction is:

$$Var(q_k) = \frac{q_k(1-q_k)}{n_k} \frac{(N_k - n_k)}{(N_k - 1)} \quad (22)$$

where  $n_k$  is the sample size and  $N_k$  is the population size for stratum  $k$ .

#### Estimation of Total Effort

The mean fishing effort  $\bar{e}_k$  for stratum  $k$  is estimated as follows:

$$\bar{e}_k = \frac{\sum_{i=1}^{p_k} e_i}{p_k} \quad (23)$$

where  $p_k$  is the participation in each stratum  $k$  and  $e_i$  is the total number of days fished by each respondent  $i$ .

The estimated variance within stratum  $k$  is:

$$Var(e_k) = \frac{p_k \sum_{i=1}^{p_k} e_i^2 - \left( \sum_{i=1}^{p_k} e_i \right)^2}{p_k(p_k - 1)} \quad (24)$$

where  $p_k$  is the participation for stratum  $k$  and  $e_i$  is the total number of days fished by each respondent  $i$ .

The variance associated with the estimate of the mean, with finite population correction (Neter *et al*, 1988) is:

$$V\hat{a}r(\bar{e}_k) = \left( \frac{N_k - p_k}{N_k - 1} \right) \frac{s_k^2}{p_k} \quad (25)$$

The total effort  $E_k$  for stratum  $k$  is estimated as:

$$E_k = N_k \bar{e}_k q_k \quad (26)$$

where  $N_k$  is the population size,  $\bar{e}_k$  is the mean effort and  $q_k$  is the participation rate for of stratum  $k$ .

The variance associated with  $\hat{E}_k$  is estimated by

$$Var(\hat{E}_1) = N_1^2 \bar{e}_1^2 q_1^2 \left( \frac{V\hat{a}r(\bar{e}_1)}{\bar{e}_1^2} + \frac{V\hat{a}r(q_1)}{q_1^2} \right) \quad (28)$$

The total effort is calculated by summing the effort for the strata as follows

$$\hat{E} = \sum_{k=1}^n \hat{E}_k \quad (29)$$

where  $n$  is the number of strata.

The variance is estimated in the same way

$$Var(\hat{E}) = \sum_{k=1}^n Var(\hat{E}_k) \quad (30)$$

The standard error is calculated by the usual method

$$SE(\hat{E}) = \sqrt{Var(\hat{E})} \quad (31)$$

## Estimation of Total Catch

The mean catch  $\bar{c}_k$  for each stratum  $k$  is estimated as follows:

$$\bar{c}_k = \frac{\sum_{i=1}^{p_k} c_i}{p_k} \quad (32)$$

where  $c_i$  is the catch by each respondent  $i$  in stratum  $k$ .

The estimated variance within stratum  $k$  is:

$$Var(c_k) = \frac{p_k \sum_{i=1}^{p_k} c_k^2 - (\sum c_k)^2}{p_k(p_k - 1)} \quad (33)$$

The variance associated with the estimate of the mean, with finite population correction (Neter *et al*, 1988) is:

$$\hat{Var}(\bar{c}_k) = \left( \frac{N_k - p_k}{N_k - 1} \right) \frac{Var(c_k)}{p_k} \quad (34)$$

The total catch  $\hat{C}_k$  for stratum  $k$  is estimated as:

$$\hat{C}_k = N_k \bar{c}_k q_k \quad (35)$$

The variance associated with  $\hat{C}_k$  is estimated by

$$Var(\hat{C}_k) = N_k^2 \bar{c}_k^2 q_k^2 \left( \frac{\hat{Var}(\bar{c}_k)}{\bar{c}_k^2} + \frac{\hat{Var}(q_k)}{q_k^2} \right) \quad (36)$$

The total catch is calculated by summing the catch for the strata as follows

$$\hat{C} = \sum_{k=1}^n \hat{C}_k \quad (37)$$

where  $n$  is the number of strata.

The variance is estimated in the same way

$$Var(\hat{C}) = \sum_{k=1}^n Var(\hat{C}_k) \quad (38)$$

The standard error is calculated by the usual method

$$SE(\hat{C}) = \sqrt{Var(\hat{C})} \quad (39)$$

A simple comparison between the total catch and effort as estimated by the three methods for the two telephone surveys involved finding the difference between the estimated totals and their respective standard errors. The differences were investigated to determine which calculation gives the most precise estimate and the reason why this is not consistent for all strata. The limitations and benefits of the three methods of calculating catch and effort were determined.

### 3.5.3 Bootstrapping

The catch and effort calculations and their standard errors rely on the central limit theorem. That is, they assume that the mean of the average days fished and mean of the average catch is normally distributed. For each of the survey estimates, S-Plus was used to generate independent bootstrap samples, drawn randomly with replacement (Efron and Tibshirani, 1993).

The sample means were calculated and the total mean determined (Appendix J). The confidence intervals surrounding the catch and effort estimates were calculated using the bootstrap estimates of the standard errors. The same catch and effort calculations were also performed using the methods described by Pollock *et al* (1994) that rely on the central limit theorem. Bootstrap statistics were also calculated for skewness and kurtosis (Appendix K).

### 3.5.4 Digit Preference

Digit preference occurs when respondents report activity in numbers ending in zeros or fives. The following definition of individual digit bias provides a biased estimate as it is expected that 20% of all numbers will end in a zero or five.

$$IDP_{0or5} = \frac{\sum (\text{Observed responses ending in 0 or 5})}{\text{Total Responses}}$$

Beaman *et al* (1997) developed a formula for aggregate digit preference that provides an unbiased estimate of the existence of digit preference.

$$ADP_{0or5} = \frac{\text{Estimated number exhibiting DP}}{\text{Total Responses}} = \frac{\sum (\text{Observed frequencies} - \text{Estimated number not exhibiting DP})}{\text{Total Responses}}$$

Where the sum equals all responses ending in 0 or 5 if the sum of residuals >0.

If the sum of residuals is < 0:

$$ADP_{0or5} = 0$$

When DP is present, the numerator for the equation will be greater than 0.

If DP is not present, the sum of the observed frequencies minus responses not exhibiting DP can be negative. Therefore, a high probability exists that the resulting average of the residuals will be negative. The observed frequencies are the sum of each reported value ending in 0 or 5. The estimated number not exhibiting DP are the means of the sum for reported two values preceding and following each digit ending in 0 or 5.

### 3.5.5 Winsorization

Two different winsorization techniques were trialled on the telephone recall survey data and the mail survey data. Winsorization was not applied to the diary survey data because most fishing events and catch information were diarised. The simplest use of winsorization is to truncate the series at 4 standard deviations from the mean, setting returns outside this range equal to the boundary value. This prevents the outliers from having undue influence on the findings (Connor, 2001).

The Australian Bureau of Statistics defines the technique for dealing with outliers as “sample values greater than a predetermined cut-off are replaced by the cut-off plus a small additional amount”. This amount is the difference between the sample value and the cut-off multiplied by the stratum sampling fraction. Effectively, this method results in the outlier only representing itself, with the remaining population units that would have been represented by the outlier being instead represented by the cut-off (Australian Bureau of Statistics, 2001).



The estimates of total catch and fishing effort were calculated after winsorization and compared to earlier estimates. The cumulative density functions of days fished and catch were also examined after winsorization to determine whether the estimates from the recall survey could be improved by reducing the recall bias.

### 3.5.6 Interviewer Bias

A final comparison between the five interviewers was done to see if the interviewers affected whether or not a respondent went fishing. The same five interviewers that carried out the data collection for the telephone diary survey also conducted the interviews for the telephone recall survey. Different telephone interviewers produce varying response rates and this may affect levels of participation in the survey.

Logistic regression was used to estimate the effect of interviewer bias on the whether or not respondents participated in recreational rock lobster fishing (Appendix L).

Logistic regression is a special case of a generalised linear model defined as follows (MathSoft, Inc, 1997),

$$g(E(Y | x)) = g(\mu) = \beta_0 + \sum_{i=1}^p \beta_i x_i = \eta(x)$$

Where  $g$  is the link function.

The logit link function is used for logistic regression and is defined by

$$g(p) = \text{logit}(p) = \log \frac{p}{1-p}$$

The variance defined by

$$\text{var}(Y) = \phi \frac{p}{1-p}$$

Where  $p$  is the probability of an event occurring and  $\phi$  is fixed to be one. In logistic regression the probability of some event occurring is modelled as a linear function of a set of predictors.

Logistic regression has been used in a number of studies to look at relationships in survey responses (Mheen *et al*, 1998).

### **3.5.7 Estimation of Recall and Non-response Bias**

With the following assumptions it was possible to determine the distribution of recall bias in the telephone recall survey.

1. The phone diary method produced an unbiased estimate of the catch and fishing effort for recreational rock lobster licence holders;
2. The telephone recall survey produced an estimate of the catch and fishing effort that contains a recall bias;
3. The mail survey produced an estimate of the catch and fishing effort that contains both a recall bias and a non-response bias.

The level of recall bias in the telephone recall survey was determined by comparing the results with the telephone diary survey. It was not expected that the estimate of recall bias would be a simple value that can be applied to the estimate produced in telephone recall surveys. It is more likely that the level of fishing participation affects the recall of particular fishing events. In this case, a cumulative frequency distribution of both the diary survey and the recall survey and their relative estimate of effort gave a picture of recall bias against levels of participation.

The estimations of non-response bias and recall bias in the mail survey are more complex and in this situation they can not be treated independently. For this reason an estimate of the combined biases was calculated for the mail survey. It was possible to compare recall bias in the telephone survey with the recall and non-response bias in the mail survey and determine which, if either, had a greater effect on estimates of catch and fishing effort.

## 4.0 RESULTS

### 4.1 Response Rates

The mail survey response rate is the number of returned completed questionnaires from the number mailed at the completion of the rock lobster season. The telephone survey response rates include refusals, non-contacts, and completed interviews. The diary screening survey response rate is the proportion of initial contacts that agreed to participate in the seven and a half month survey (Table 4.1.1). The diary ongoing survey response rate (98.6%) was the proportion of respondents who remained in the survey for the full duration.

**Table 4.1.1: Survey responses and response rates for all three surveys**

		Telephone Diary Screening Survey	Telephone Diary Ongoing Survey	Telephone Recall Survey	Mail Survey
Full response	1	450	444	401	1,813
Full refusal	2	28	0	1	
Part refusal	3	0	3	0	
Full non-contact	4	99	0	69	
Part non-contact	5	0	3	14	
Out of scope	9	5	0	14	
Overall Response Rate (%) *		77.9	98.6	85.1	51.0

\* In the calculation of response rates only response codes 1 to 5 are included. Disconnected numbers and other non-responses are considered out of scope of the survey.

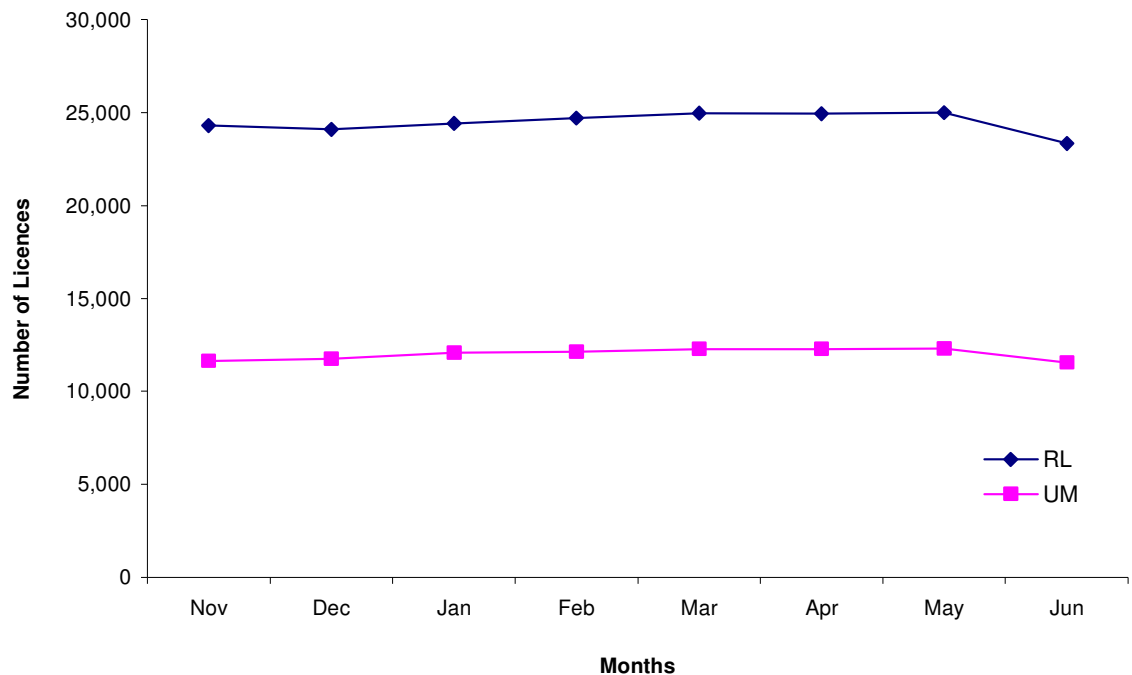
Only 4.9% of respondents refused to participate in the telephone diary survey. The remaining 17.2% were unable to be contacted. Less than one percent dropped out

during the course of the diary survey. Only 0.2% of respondents refused to participate in the telephone recall survey. The remaining 17.1% were unable to be contacted.

In the diary survey 95% of respondents diarised their fishing events. As all respondents were telephoned each month the 5% who did not diarise had a recall period of no more than one month.

## 4.2 Population and Sample Size

The total number of recreational fishing licences was measured each month for the duration of the rock lobster season for 2001/2002. There was very little change in the number of licences between November and June, however the number seemed to drop slightly toward the end of the season (Figure 4.2.1).



**Figure 4.2.1: Number of recreational fishing licences November 2001- June 2002 (RL – Rock Lobster licences, UM – Umbrella licences)**

The average of each licence type was used as the estimate of the population size in all telephone survey calculations (Table 4.2.1). The mail survey estimate was the total number of licences that were valid at any stage during the seven and half month season. This measure of the total number of licences is greater than the estimate used in the telephone survey analysis.

Of the mail survey questionnaires returned, around 100 respondents did not provide information on whether they owned a rock lobster or umbrella licence.

However, it was possible to match up their names and addresses (where they gave this information) to determine what type of licence they used. The remaining (19) were removed from the sample for analysis using a post stratification of the responses.

**Table 4.2.1: Population and sample sizes for each survey**

Total	Telephone Diary Survey	Telephone Recall Survey	Mail Survey
Number of Licences (N)	36,500	36,500	39,623
Sample Size (n)	444	401	1,813

A minimum sample size of 400 was chosen for both telephone surveys. It gives a sampling error of less than 5%. This is based on 36,500 licence holders in total. The sample sizes in each stratum were 200. This gives each stratum a sampling error less than 7%. Equal sized strata simplify the data collection and have no effect on the level of precision.

## **4.3 Participation**

### **4.3.1 Participation Estimates**

Around 55% of licence holders participated in recreational rock lobster fishing in the 2001/2002 season according to the telephone diary survey (Table 4.3.1). The telephone recall found that 62% of licence holders went fishing during this time. The mail survey showed a participation rate of 69%, which is 14% or 1.25 times greater than the diary estimate. The significant difference ( $p < 0.05$ ) between the mail survey and the diary survey could be attributed to both recall and non-response bias. This leads the mail survey to overestimate the total number of fishers by more than 7,000.

**Table 4.3.1: Survey estimates of participation and total number of fishers**

	Telephone Diary Survey	Telephone Recall Survey	Mail Survey Unstratified	Mail Survey Stratified
Number of Fishers (F)	19,942	22,734	27,275	26,878
SE(F)	898	901	431	412
Participation (P)	0.55	0.62	0.69	0.68
SE(P)	0.05	0.05	N/A	0.02

Around 38% of licence holders participated in recreational rock lobster fishing using pots in the 2001/2002 season according to the telephone diary survey (Table 4.3.2). The telephone recall found that 39% of licence holders used the same method. There is no significant difference between these participation rates. The mail survey showed a participation rate of 42%, which is 1.1 times greater than the diary estimate. This difference in levels of participation leads the mail survey to overestimate the total number of fishers using pots by more than 4,000.

**Table 4.3.2: Survey estimates of participation by potters**

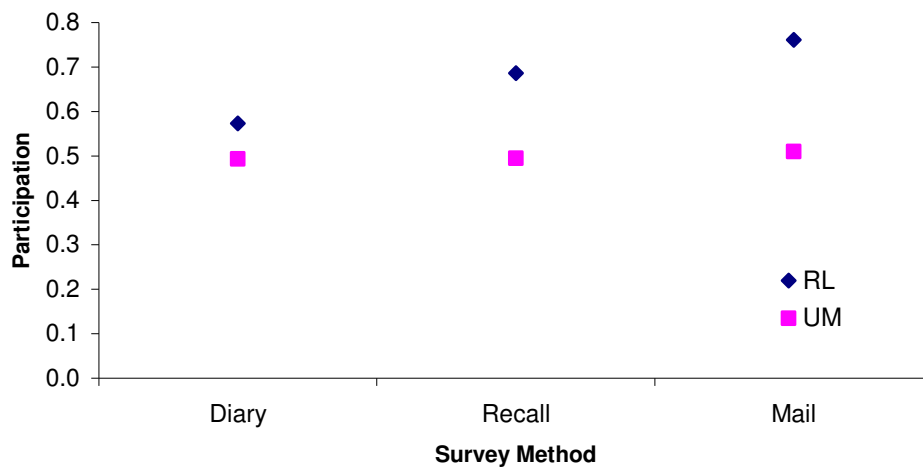
	Telephone Diary Survey	Telephone Recall Survey	Mail Survey Unstratified	Mail Survey Stratified
Number of Fishers	13,836	14,129	18,161	18,174
SE(F)	882	933	473	444
Participation Rate	0.38	0.39	0.46	0.42
SE(P)	0.05	0.05	N/A	0.02

Around 25% of licence holders dived for recreational rock lobsters during the 2001/2002 season according to the telephone diary survey (Table 4.3.3). The telephone recall found that 27% of licence holders fished using the same method. There is no significant difference between these participation rates. The mail survey showed a participation rate of 29%, which is 1.2 times greater than the diary estimate. This difference in levels of participation leads the mail survey to overestimate the total number of fishers by more than 2,500.

**Table 4.3.3: Survey estimates of participation by divers**

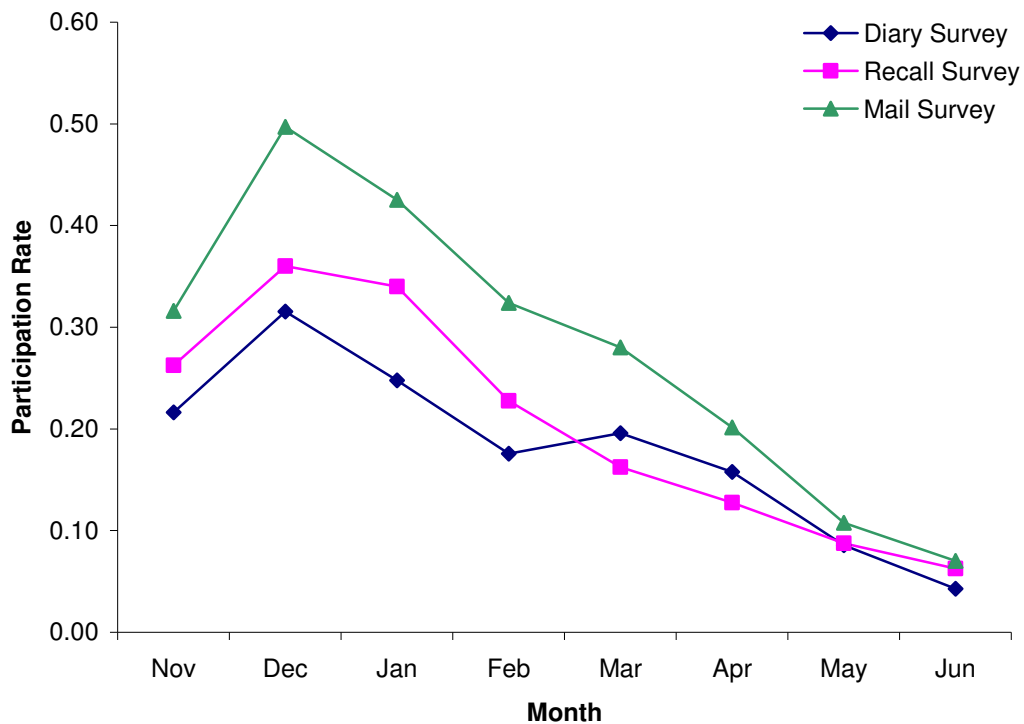
	Telephone Diary Survey	Telephone Recall Survey	Mail Survey Unstratified	Mail Survey Stratified
Number of Fishers	9,047	9,871	11,692	11,425
SE(F)	783	849	410	414
Participation Rate	0.25	0.27	0.30	0.29
SE(P)	0.04	0.04	N/A	0.02

Table 4.3.3 shows that the estimates of participation vary most by those with a rock lobster licence. Umbrella licence estimates of participation are consistent around 50% for each survey (Figure 4.3.1).



**Figure 4.3.1: Participation rate by licence type for the telephone diary, telephone recall and mail surveys**

Participation for each month of the season is overestimated by the telephone recall survey in the early months where the participation is greatest and underestimated in March and April (Figure 4.3.2). The second peak of participation, seen in the diary survey results is most probably due to an increase in abundance of legal size rock lobsters related to a moult in February. The mail survey overestimates participation for every month except for June where very little fishing occurs. There appears to be less recall bias in March to June than November to February as these were the months closest to when the survey was conducted.



**Figure 4.3.2:** Participation rates by month for the telephone diary, telephone recall and mail surveys

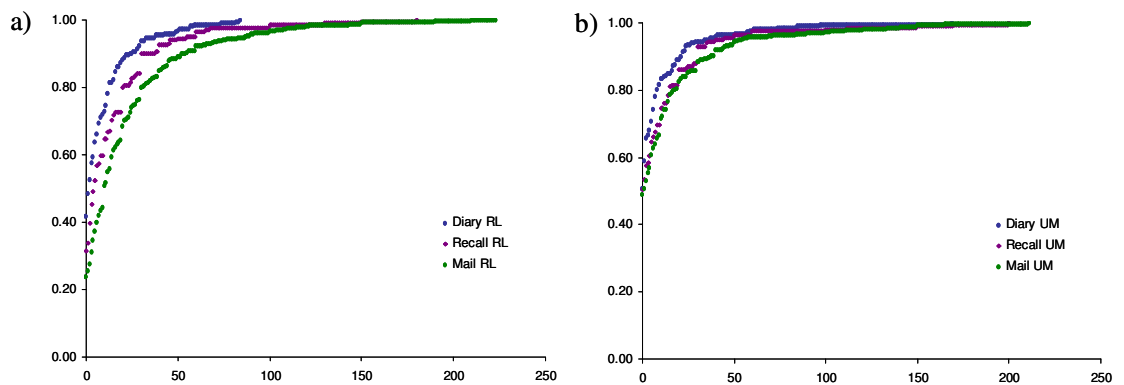
### 4.3.2 Distributions

The distributions of number of days fished were examined by plotting the cumulative density functions. This included the respondents who fished zero number of days.

The cumulative density function for the number of days fished by rock lobster licence holders shows considerable differences between the recall, diary, and mail surveys. The diary survey respondents' estimates of number of days fished was more



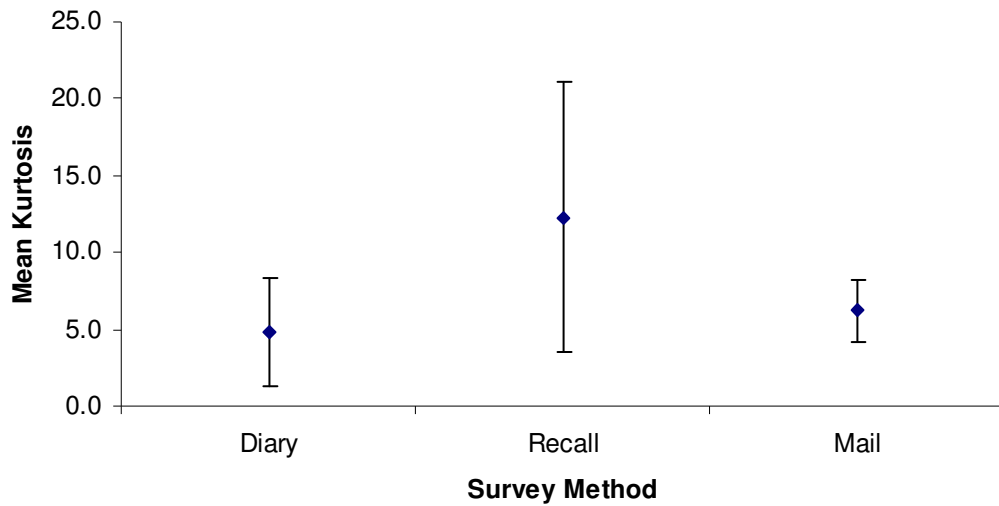
closely grouped than either the recall survey or the mail survey (Figure 4.3.3). The proportion of responses from the recall survey was closer to the diary than the mail survey responses. The differences were tested using a Kolmogorov-Smirnov test.



**Figure 4.3.3: Cumulative density functions of days fished for rock lobster a) and umbrella licence holders b) including zero days fished**

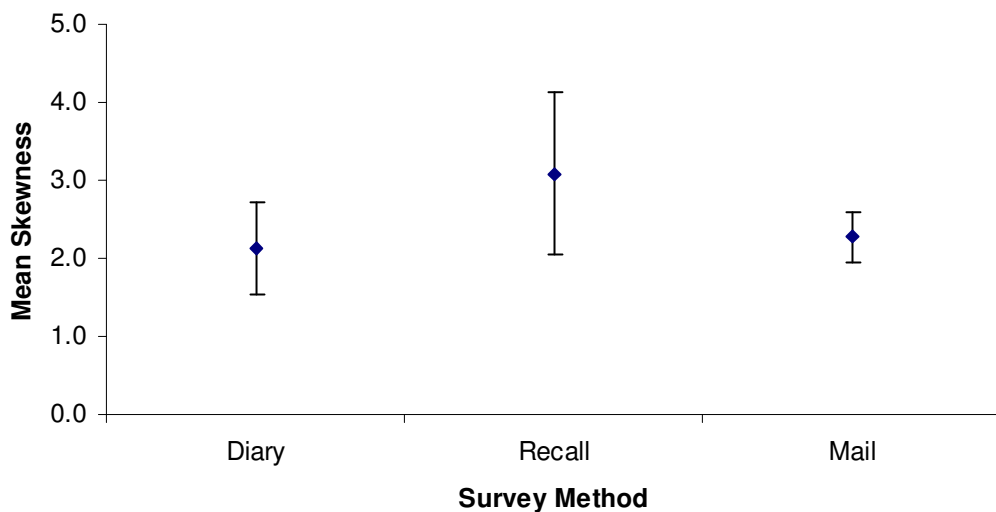
The Kolmogorov-Smirnov test showed significant differences between the distributions of days fished by rock lobster licence holders. A comparison of the distributions found the following: the telephone diary survey distribution was different to that of the telephone recall survey ( $p = 0.016$ ); the telephone diary survey distribution was different to that of the mail survey ( $p = 0.000$ ); and the telephone recall survey was different to that of the mail survey ( $p = 0.000$ ). In each case the null hypothesis was rejected at the 0.05 level of significance.

To test the reason for these differences the skewness and kurtosis was examined by bootstrapping the statistic and determining the confidence limits. The mean of the kurtosis from the diary survey was not significantly different from the recall and mail surveys (Figure 4.3.4).



**Figure 4.3.4: Mean kurtosis for days fished (including zero day) by rock lobster licence holders**

The mean of the skewness from the diary survey was not significantly different from the recall and mail surveys (Figure 4.3.5).

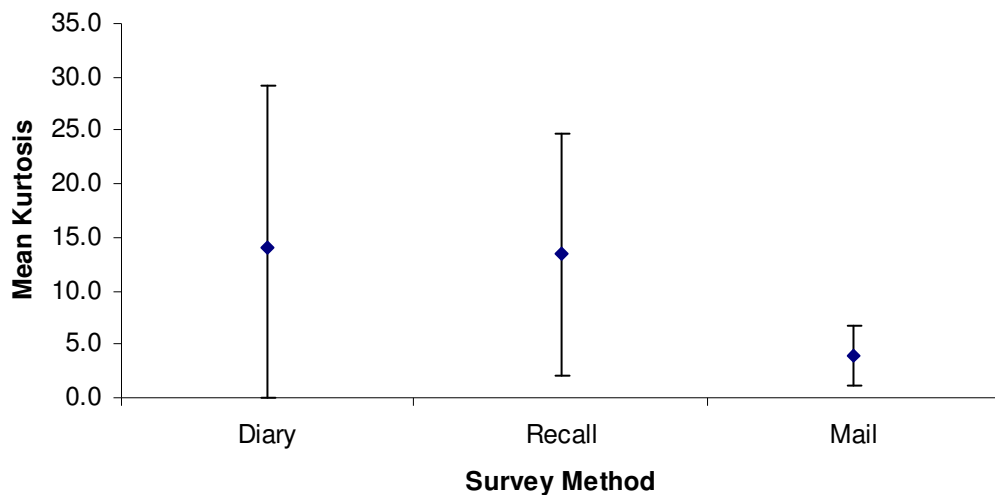


**Figure 4.3.5: Mean skewness for days fished (including zero days) by rock lobster licence holders**

The Kolmogorov-Smirnov test also showed significant differences between the distributions of days fished by umbrella licence holders. A comparison of the

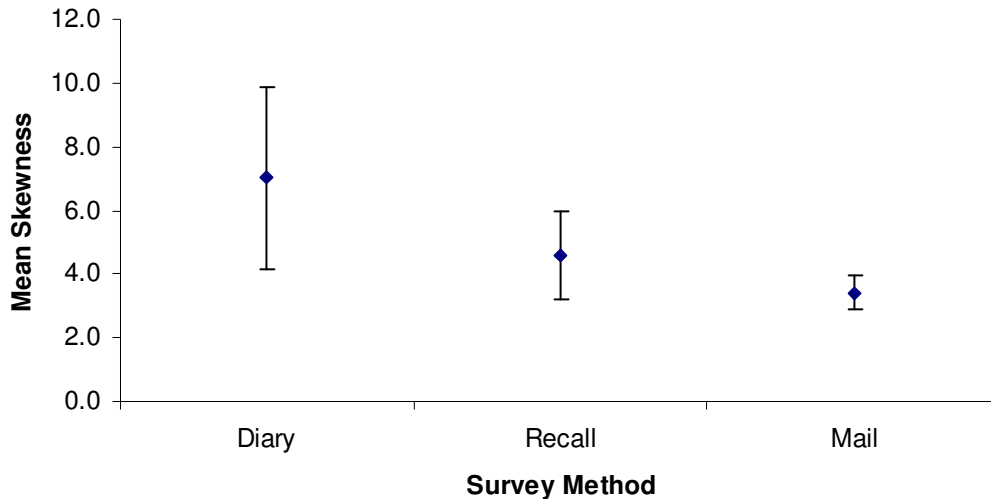
distributions found that the telephone diary survey distribution was different to that of the mail survey ( $p = 0.001$ ). In this case the null hypothesis was rejected at the 0.05 level of significance. There were no significant differences between the distributions of number kept from the telephone diary survey and the telephone recall survey ( $p = 0.074$ ) or the telephone recall survey and mail survey ( $p = 0.847$ ), so the null hypothesis of no difference was accepted in these cases.

To test the reason for these differences the skewness and kurtosis for umbrella licence holders was examined by bootstrapping the statistic and determining the confidence limits. Neither the kurtosis or skewness statistic could account for the difference in distributions. There was no significant difference between the mean kurtosis of the three surveys (Figure 4.3.6).



**Figure 4.3.6: Mean kurtosis for days fished (including zero days) by umbrella licence holders**

There was no significant difference between the mean skewness for the three surveys, however the skewness for the recall and mail surveys were the most similar (Figure 4.3.7).



**Figure 4.3.7: Mean skewness for days fished (including zero days) by umbrella licence holders**

### 4.3.3 Factors Affecting Participation

#### Diary Survey

Logistic regression was used to determine what factors most affected participation in recreational rock lobster fishing during the 2001/02 season. Factors included in the regression were interviewer, gender, age and licence type. Participation was recorded as zero for no fishing activity and one for at least one fishing event over the season. Ages were grouped into seven categories (Table 4.3.4).

**Table 4.3.4: Groupings for age (Diary Survey)**

Range	Group code
Less than 20	1
20 to 29	2
30 to 39	3
40 to 49	4
50 to 59	5
60 to 69	6
70 and over	7

The diary respondent's ages were compared to the population of rock lobster licence holders' ages using a chi-squared test. There was no significant difference at the

0.05 level of significance. The umbrella licence holders were also compared and there was no significant difference at the 0.05 level of significance. The samples were therefore considered representative of the population as a whole.

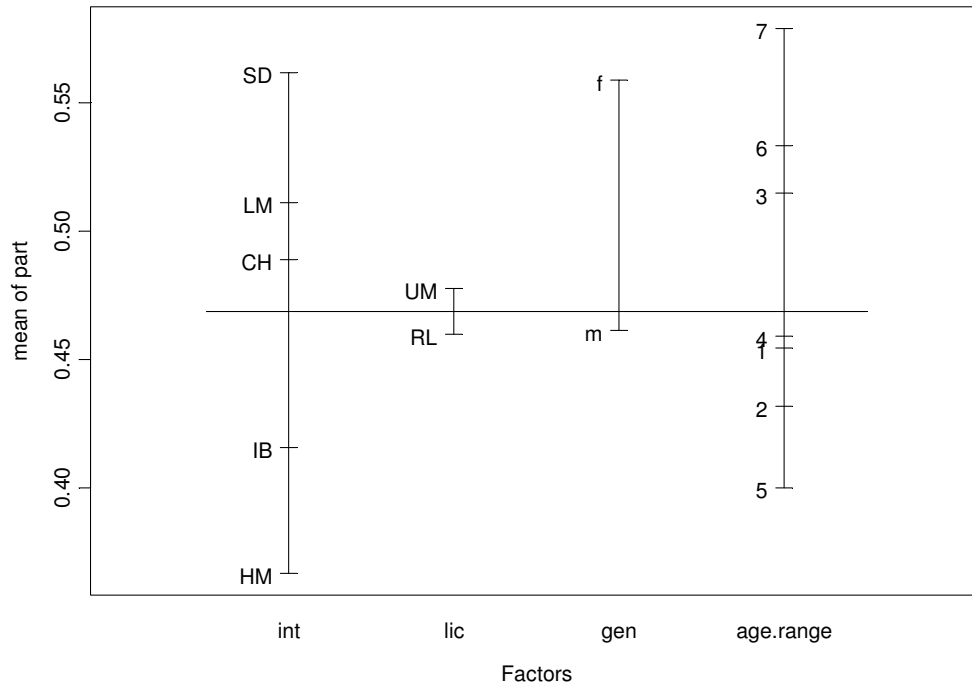
Most of the respondents were aged in their forties (Table 4.3.5). Very few respondents were female (7.6%).

**Table 4.3.5: Summary statistics for factors affecting participation (Diary Survey)**

Licence Type	Interviewer	Participation*	Gender**	Age.Range
RL: 224	CH: 90	0: 238	f:34	1:22
UM: 224	HM: 90	1: 210	m: 414	2:44
	IB: 90			3:101
	LM: 90			4:122
	SD: 89			5:95
				6:45
				7:19

Where \* 0 = zero participation, 1 = participation

Females more likely to utilise their licences (Figure 4.3.8). The oldest respondents were also more likely to go rock lobster fishing.



**Figure 4.3.8: Mean response for each level of each factor affecting participation (Diary Survey)**

A logistic regression on the diary survey data showed that interviewer had the most affect on the model ( $p=0.068$ ) but none of the factors was significant at the 5% level of significance.

## Recall Survey

The same logistic regression was used for the recall survey. The recall survey showed similar breakdowns by gender and age range (Table 4.3.6).

**Table 4.3.6: Summary statistics for factors affecting participation (Recall Survey)**

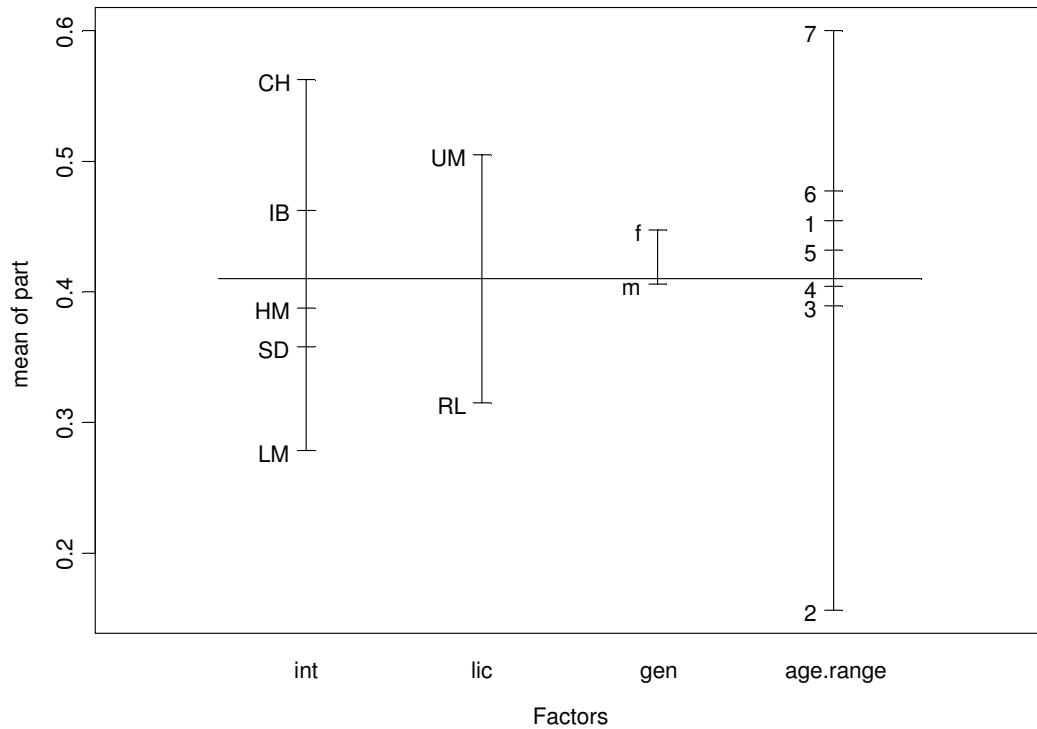
Licence Type	Interviewer	Participation*	Gender**	Age.Range
RL: 200	CH: 80	0: 236	f:38	1:22
UM: 200	HM: 80	1: 164	m: 362	2:32
	IB: 80			3:95
	LM: 79			4:94
	SD: 81			5:88
				6:44
				7:25

Where \* 0 = zero participation, 1 = participation

The plot of mean participation shows a very strong effect due to age range. For the oldest age range the participation was as high as 60%. Respondents aged between 20 and 29 were least likely to go rock lobster fishing.

The population of rock lobster licence holders' ages was compared to the recall survey respondents' ages using a chi-squared test. There was no significant difference at the 0.05 level of significance. The umbrella licence holders were also compared and there was no significant difference at the 0.05 level of significance. So the samples in terms of age were representative of the population.

Strong effects were also seen for licence type and interviewer (Figure 4.3.9). Mean participation ranged from 0.28 for interviewer LM to 0.56 for CH.



**Figure 4.3.9: Mean response for each level of each factor affecting participation (Recall Survey)**

A logistic regression on the recall survey data showed that interviewer, licence type and age range had a significant effect on participation. Gender had no effect on participation so was removed from the model. Licence type had the most effect on participation, followed by interviewer and age range. All were significant at the 0.05 level of significance.

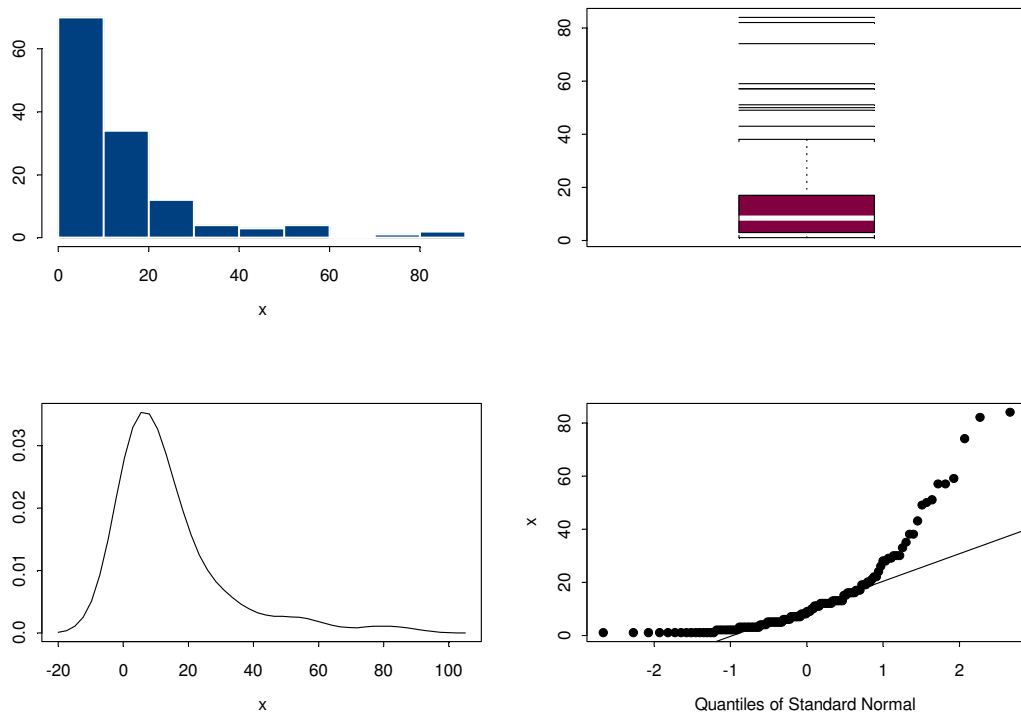


## 4.4 Fishing Effort

### 4.4.1 Exploratory Data Analysis

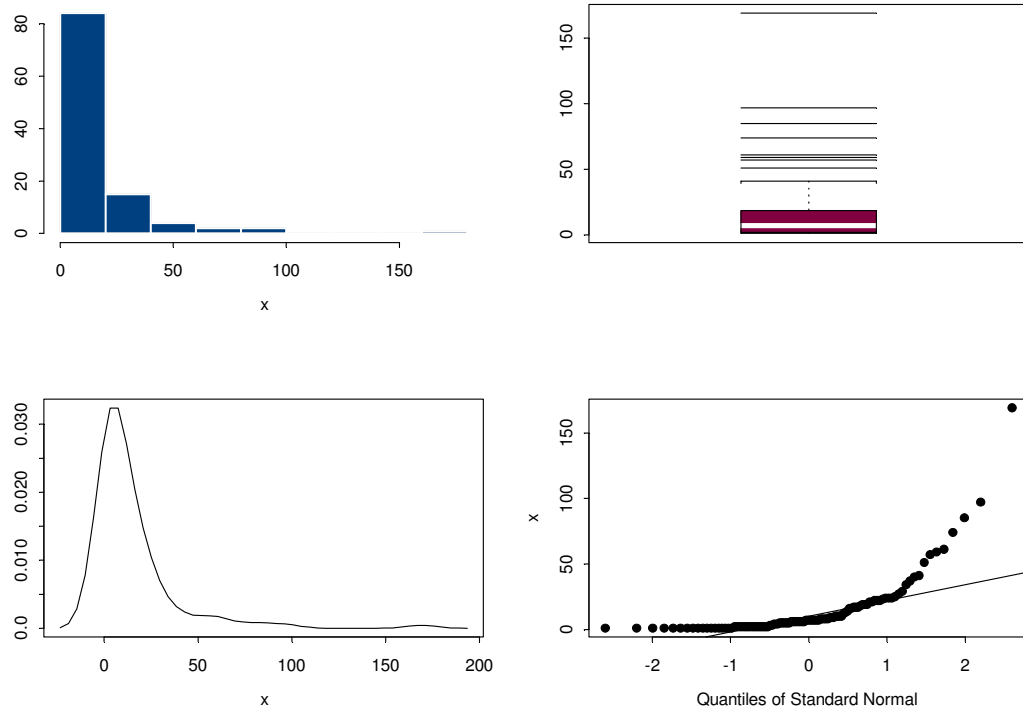
#### Diary Survey

The exploratory data analysis of fishing effort by rock lobster licence holders shows a highly skewed distribution (Figure 4.4.1). Most of the rock lobster licence holders (52.0%) fished between one and 10 days during the season. The mean number of days fished was 14.2 and the median was 8.5. The proportion of rock lobster licence holders that utilised their licence during the season was 58%.



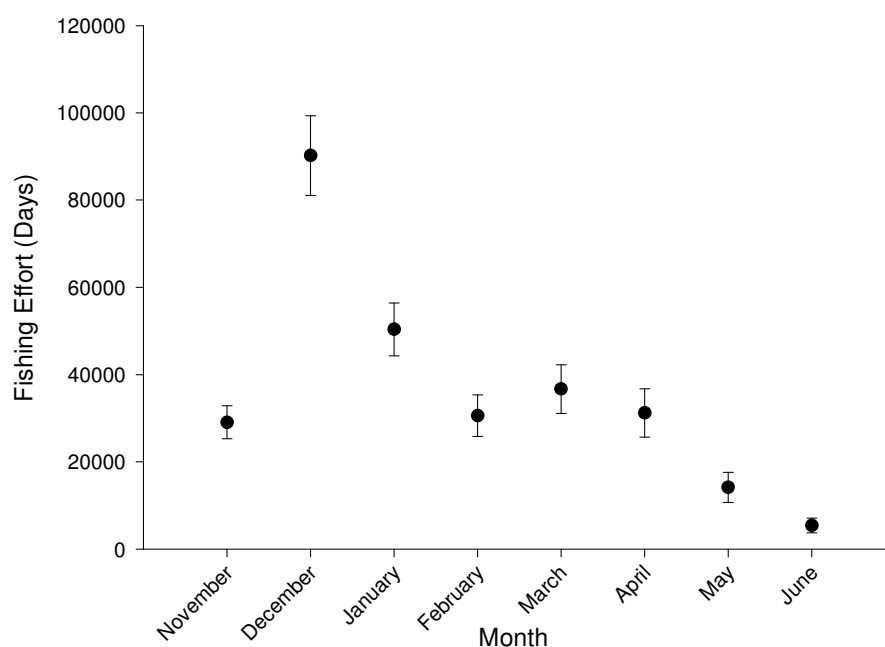
**Figure 4.4.1:** Exploratory data analysis of days fished by rock lobster licence holders (Diary Survey)

The exploratory data analysis of fishing effort by umbrella licence holders also shows a highly skewed distribution (Figure 4.4.2). Most of the umbrella licence holders (63.0%) fished between one and 10 days during the season. The mean number of days fished was 14.8 and the median was 7.0. The proportion of umbrella licence holders that utilised their licence during the season was 49%.



**Figure 4.4.2:** Exploratory data analysis of days fished by umbrella licence holders (Diary Survey)

December was by far the most popular month for recreational rock lobster fishing (Figure 4.4.3) with around 83% of rock lobster licence holders and 57% of umbrella licence holders utilising their licences during this month. November was also very popular, particularly as the season is only open for the last 15 days of the month.



**Figure 4.4.3: Fishing effort (days) by month for 2001-2002 season (Diary Survey)**

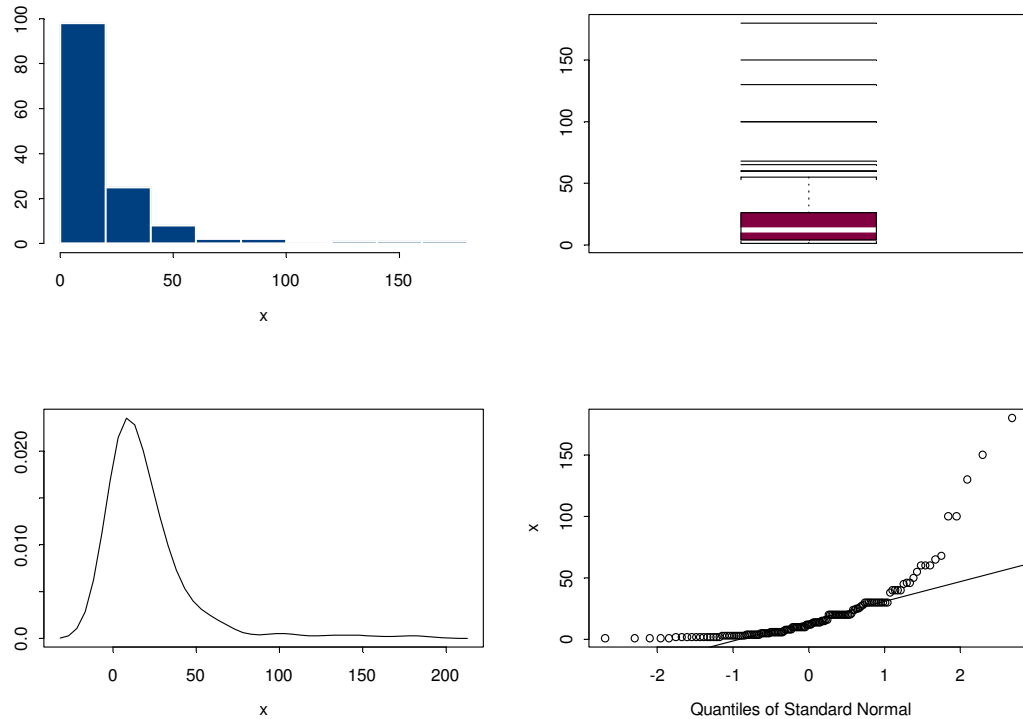
Estimates from the diary survey showed that in nearly 45% of fishing events more than one licence holder was fishing (Table 4.4.1). The catch was shared evenly between licence holders. This may not be discerned from the recall and mail surveys as it is not directly asked of the licence holder.

**Table 4.4.1: Number of licence holders on a single rock lobster fishing event (Diary Survey)**

Number of licence holders	RL	UM
1	860	1,048
2	976	538
3	8	6
4	2	0

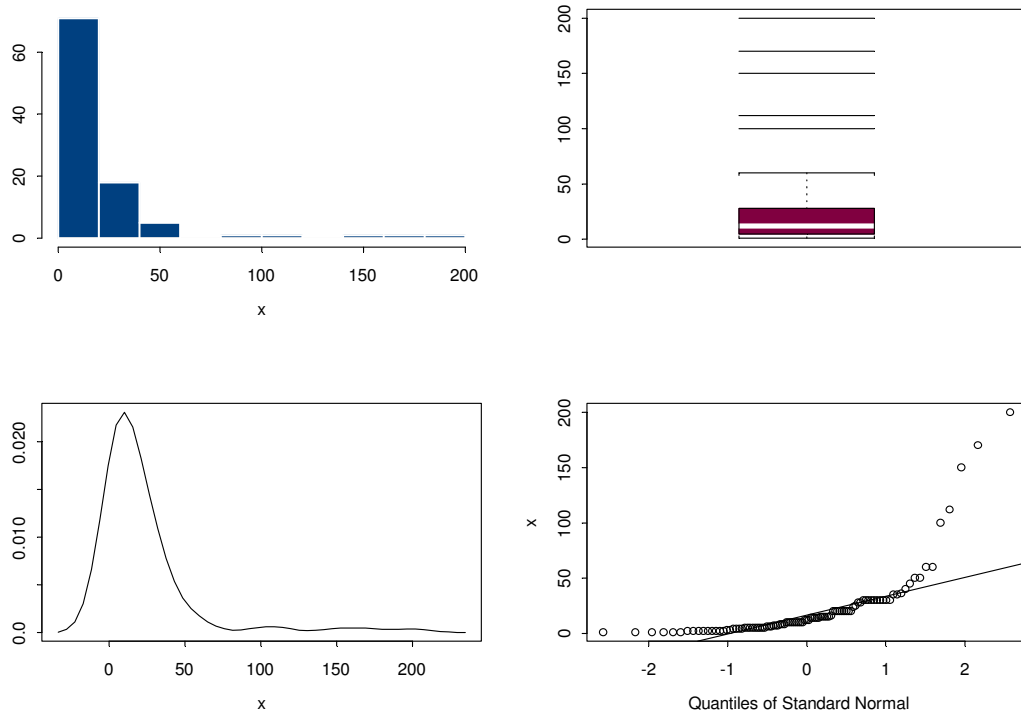
## Recall Survey

The exploratory data analysis of fishing effort by rock lobster licence holders shows a highly skewed distribution (Figure 4.4.4). Most of the rock lobster licence holders (53.6%) fished between one and 15 days during the season. The mean number of days fished was 20.4 and the median was 12.0. The proportion of rock lobster licence holders that utilised their licence during the season was 69%.



**Figure 4.4.4:** Exploratory data analysis of days fished by rock lobster licence holders (Recall Survey)

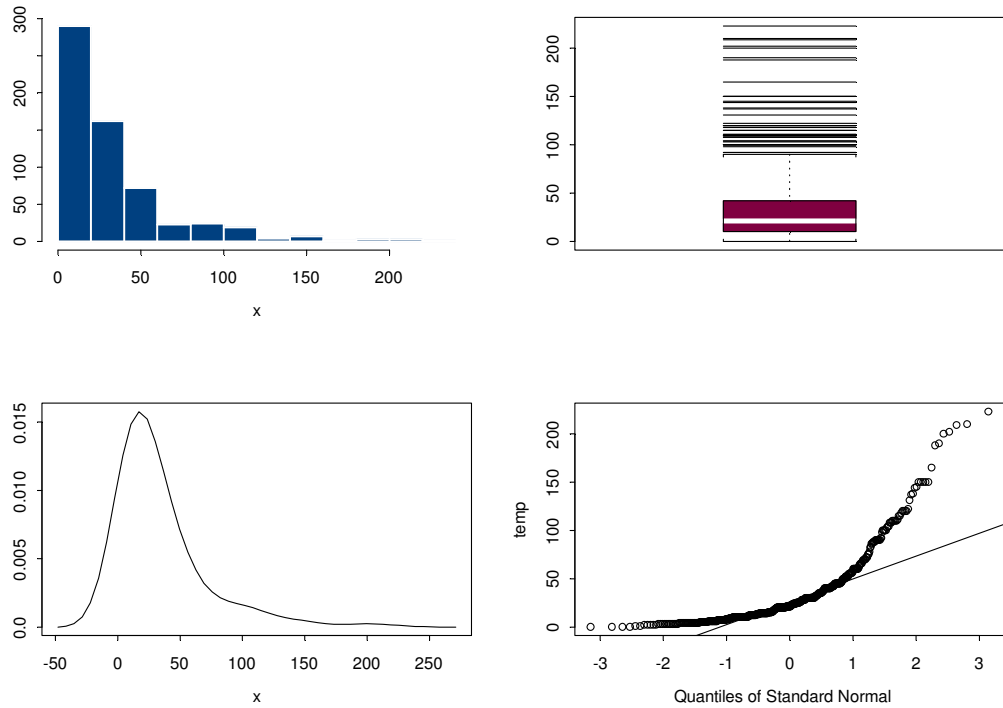
The exploratory data analysis of fishing effort by umbrella licence holders also shows a highly skewed distribution (Figure 4.4.5). Most of the umbrella licence holders (56.6%) fished between one and 15 days during the season. The mean number of days fished was 22.0 and the median was 12.0. The proportion of umbrella licence holders that utilised their licence during the season was 50%.



**Figure 4.4.5: Exploratory data analysis of days fished by umbrella licence holders (Recall Survey)**

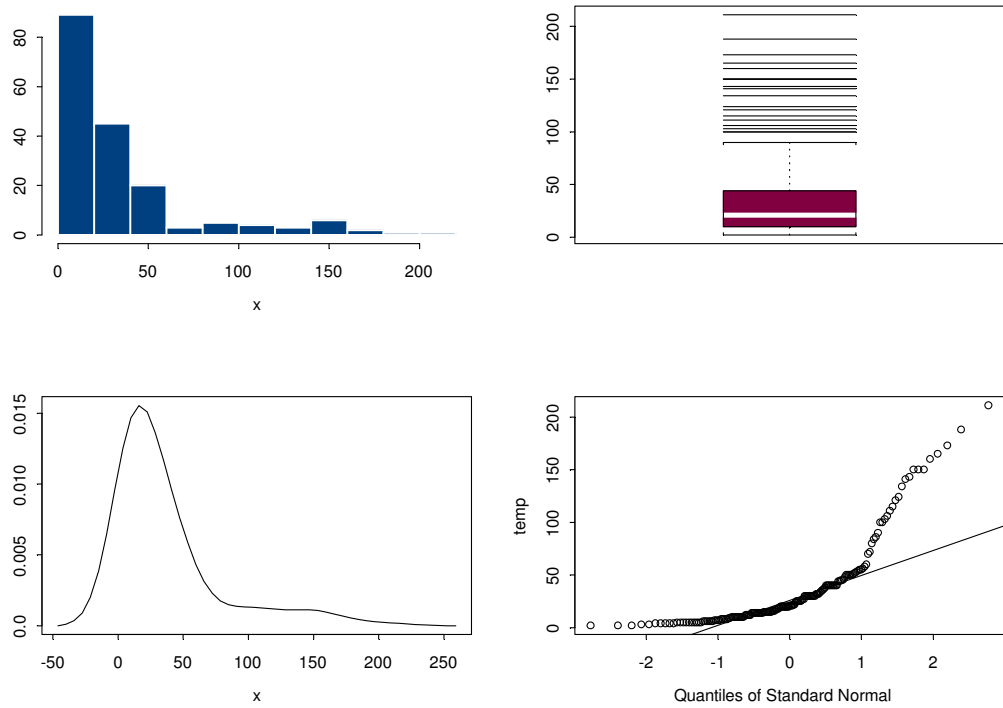
## Mail Survey

The exploratory data analysis of fishing effort by rock lobster licence holders shows a highly skewed distribution (Figure 4.4.6). The mean number of days fished was 33.7 and the median was 21.0. The proportion of rock lobster licence holders that utilised their licence during the season was 76%.



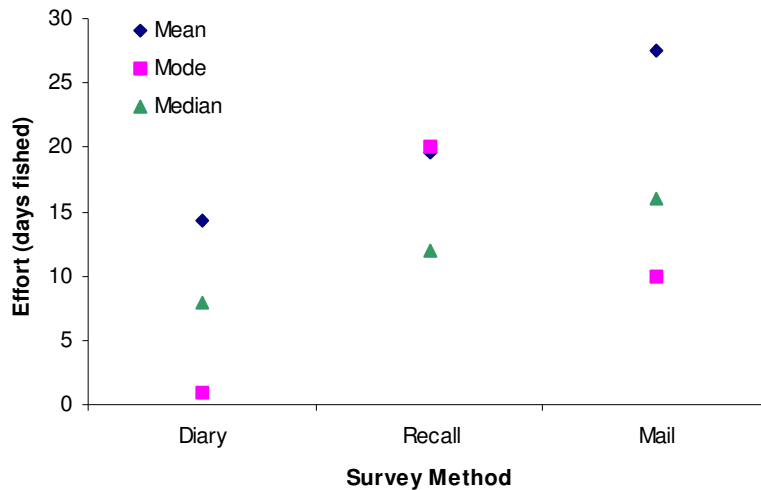
**Figure 4.4.6:** Exploratory data analysis of days fished by rock lobster licence holders (Mail Survey)

The exploratory data analysis of fishing effort by umbrella licence holders also shows a highly skewed distribution (Figure 4.4.7). The mean number of days fished was 36.3 and the median was 21.0. The proportion of umbrella licence holders that utilised their licence during the season was 51.0%.



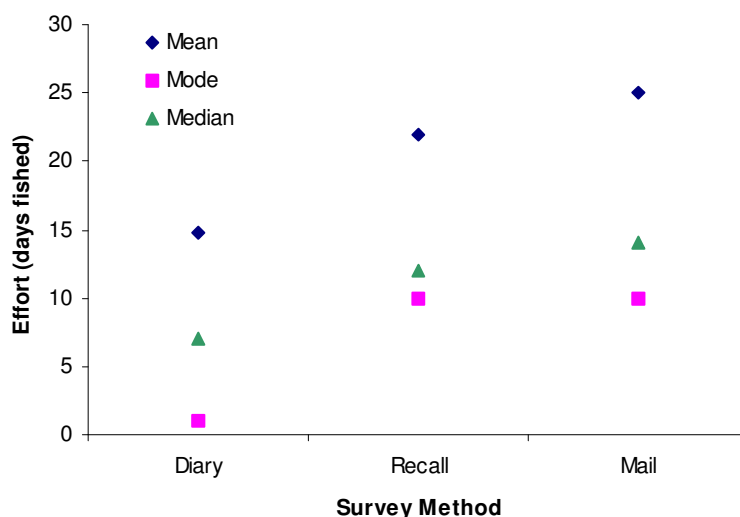
**Figure 4.4.7: Exploratory data analysis of days fished by umbrella licence holders (Mail Survey)**

Comparisons of the measures of central tendency show some interesting differences between the effort results for rock lobster licence holders. The mean, mode, and median are all lowest for the diary survey (Figure 4.4.8). For the recall survey the mode equals the mean which could be related to a rounding of most of the days fished to 20 days.



**Figure 4.4.8: Mean, mode and median number of days fished by rock lobster licence holders for the telephone diary, telephone recall and mail surveys**

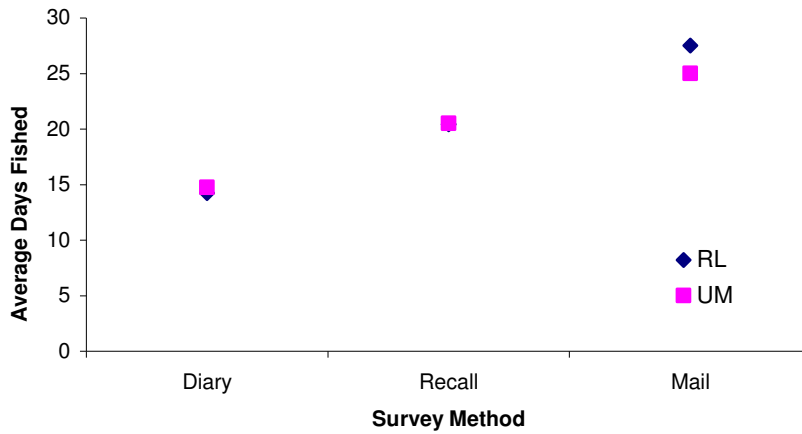
The mean, mode, and median for umbrella licence holders are all lowest for the diary survey and generally highest for the mail survey (Figure 4.4.9). The mode for both the recall and mail surveys is 10.



**Figure 4.4.9: Mean, mode and median number of days fished by umbrella licence holders for the telephone diary, telephone recall and mail surveys**



The average days fished for each survey method shows very little difference between rock lobster and umbrella licence holders (Figure 4.4.10). The mail survey estimates are greater than the recall, which in turn are greater than the diary.



**Figure 4.4.10: Average days fished by licence type and survey method**

#### 4.4.2 Effort Estimates

The telephone diary survey estimated the total number of days fished as 286,992 (Table 4.4.2). The telephone recall estimated the effort as 473,980. This was 1.7 times the diary survey estimate. The mail survey estimates were between 723,079 and 723,224. This was 2.5 times greater than the diary survey estimates.

**Table 4.4.2: Survey estimates of fishing effort for the telephone diary, telephone recall and mail surveys**

	Telephone Diary Survey	Telephone Recall Survey	Mail Survey Unstratified	Mail Survey Stratified
Effort	286,992	473,980	723,224	723,079
SE(E)	27,477	47,034	27,669	26,732

A comparison of monthly estimates of days fished between the diary and mail survey was attempted. Unfortunately around 28% of the monthly effort estimates from the mail survey did not add up to the total estimates. The ratio of diary to mail estimates varies between 1.69 and 2.78 but may not be completely accurate due to the mail survey reporting errors.

The percentage of total effort for rock lobster licence holders varies considerably by survey method (Figure 4.4.11). The effect of the higher days fished recorded by the recall and mail surveys is evident (16% of mail survey effort > 90 days compared to 3% diary survey effort). There is also a lower proportion of total effort recorded for 1 to 20 days fished from the recall and mail surveys.

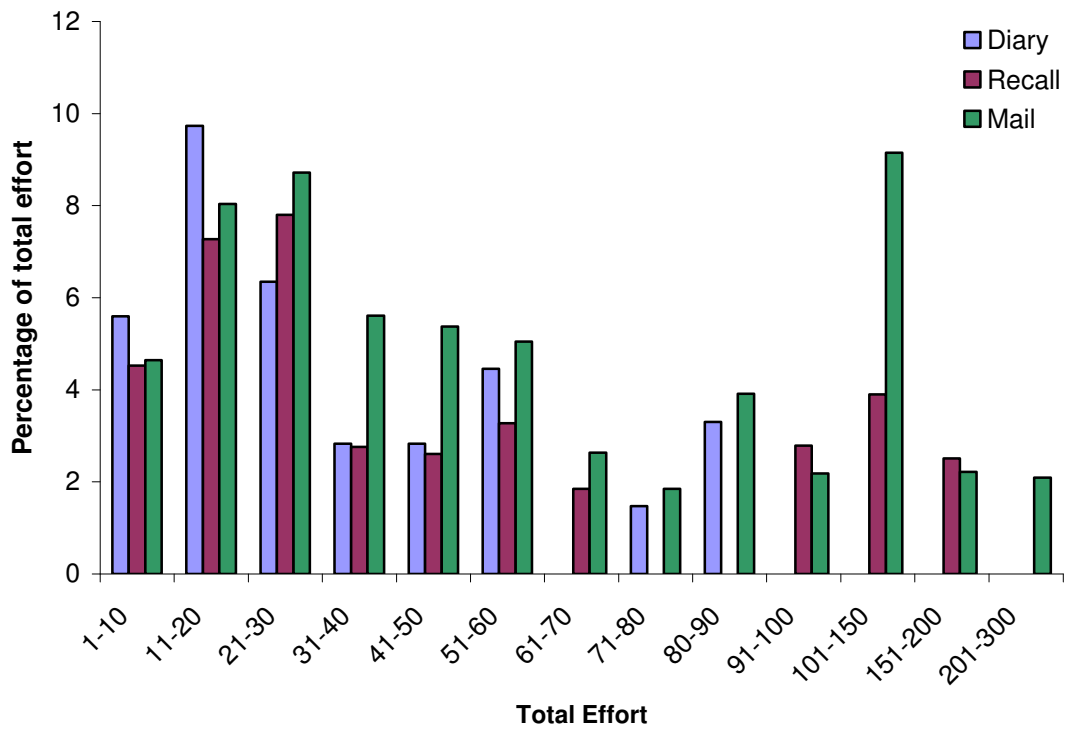
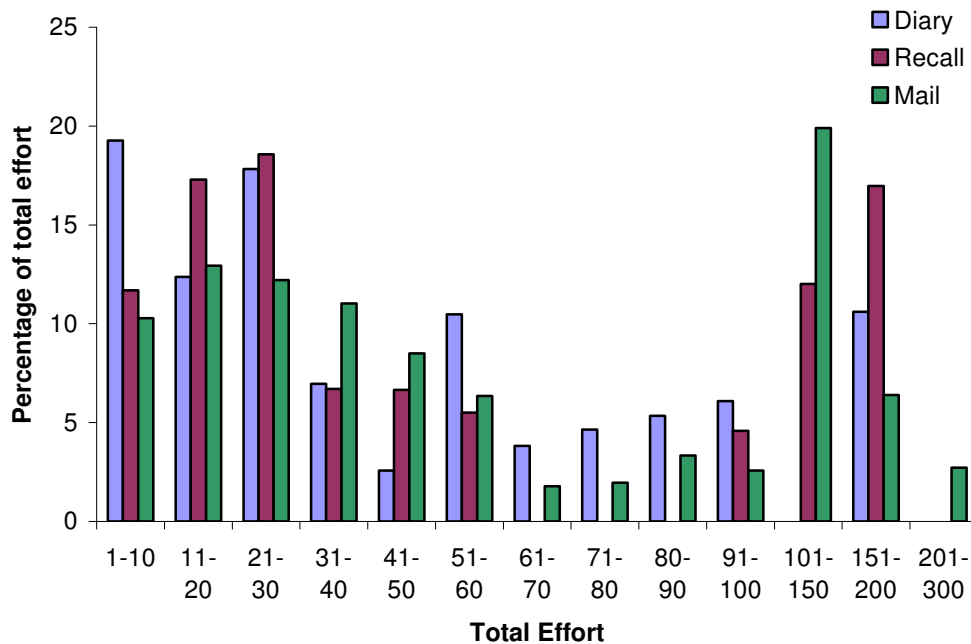


Figure 4.4.11: Comparison of total effort for rock lobster licence holders for the telephone diary, telephone recall and mail surveys

The percentage of total effort for umbrella licence varies considerably by survey method (Figure 4.4.12). The effect of the higher days fished recorded by the recall and mail surveys is evident. Around 32% of the mail survey effort is from fishing greater than 90 days, compared to 17% of the diary effort. There is also a much lower proportion of total effort recorded for 1 to 10 days fished by the recall and mail surveys.



**Figure 4.4.12: Comparison of total effort for umbrella licence holders for the telephone diary, telephone recall and mail surveys**

Around 80% of the effort is done by fishers using pots (83% diary, 81% recall and 83% mail survey).

The telephone diary survey estimated the total number of days fished by potters as 237,964 (Table 4.4.3). The telephone recall estimated the effort by potters as 383,088. This was 1.6 times the diary survey estimate. The mail survey estimates were between 599,809 and 600,380. This was 2.5 times greater than the diary survey estimates.

**Table 4.4.3: Survey estimates of fishing effort by potters for the telephone diary, telephone recall and mail surveys**

	Telephone Diary Survey	Telephone Recall Survey	Mail Survey Unstratified	Mail Survey Stratified
Effort	237,964	383,088	599,809	600,380
SE(E)	27,094	47,535	27,852	27,022

The telephone diary survey estimated the total number of days fished by divers as 50,007 (Table 4.4.4). The telephone recall estimated the effort as 94,748. This was 1.9 times the diary survey estimate. The mail survey estimates were between 122,133 and 122,699. This was 2.4 times greater than the diary survey estimates.

**Table 4.4.4: Survey estimates of fishing effort by divers for the telephone diary, telephone recall and mail surveys**

	Telephone Diary Survey	Telephone Recall Survey	Mail Survey Unstratified	Mail Survey Stratified
Effort	50,007	94,748	122,133	122,699
SE(E)	6,828	11,933	7,203	7,059

### 4.4.3 Comparison of Calculations

For participation rates less than 60%, Method 1 (Appendix B) has the smallest standard errors (Table 4.4.5) though there is very little difference between the standard errors from all three methods. However, in the calculation of Method 1, the participation rates and catch rates are not determined. Method 2, 3.5.2 (1-20), utilises the participation rate and the catch rate in the calculations, which are used to determine the overall participation rates and total number of fishers. Method 1 requires less information as it is based solely on summations. It is also simpler to calculate the standard errors of the estimate.

**Table 4.4.5: Comparison of analysis methods for telephone diary survey data**

<b>Totals</b>	<b>Method 1</b>	<b>Method 2</b>	<b>Method 3</b>
E	287,971	287,971	287,971
SE(E)	27,377	27,462	27,462

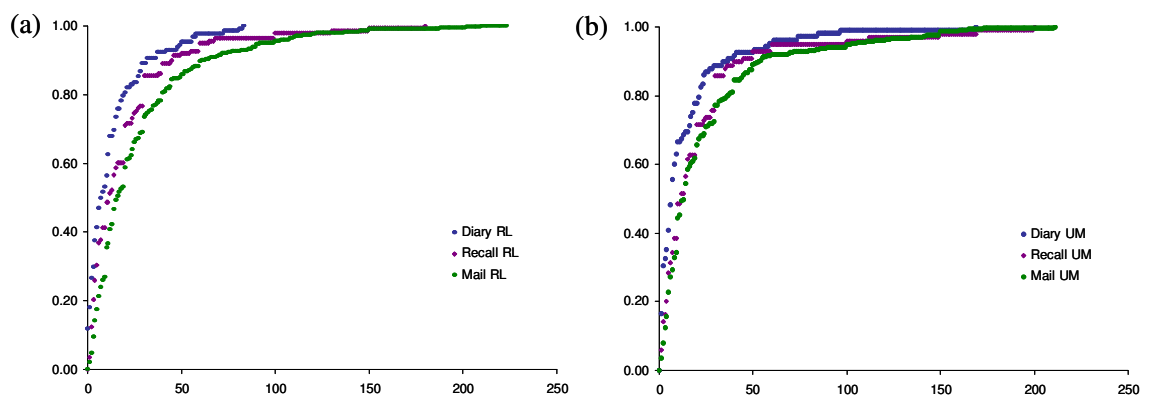
Method 2 is a more complex method of calculation because it requires more information about the participation rates. For participation rates greater than 60%, Method 2 gives a slightly more precise estimate for the catch (Table 4.4.6).

**Table 4.4.6: Comparison of analysis methods for telephone recall survey data**

<b>Totals</b>	<b>Method 1</b>	<b>Method 2</b>	<b>Method 3</b>
E	473,980	473,980	473,980
SE(E)	47,034	47,147	47,147

#### 4.4.4 Distributions

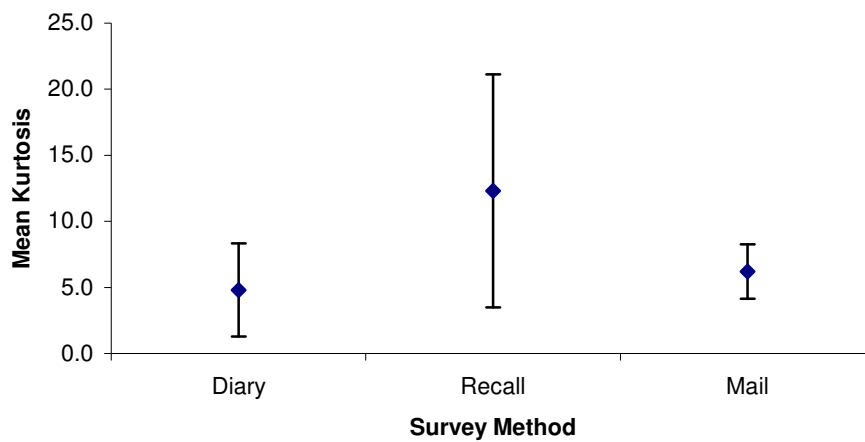
The cumulative density function for the number of days fished by rock lobster licence holders shows considerable differences between the number of days from the recall, diary and mail surveys (Figure 4.4.13). The diary survey respondents' estimates of number of days fished was more closely grouped than either the recall survey or the mail survey (a). The proportion of responses from the recall survey were closer to the diary than the mail survey responses. The differences were tested using a Kolmogorov-Smirnov test.



**Figure 4.4.13: Cumulative density functions: number of days fished by all respondents: rock lobster licence holders (a) and umbrella licence holders (b)**

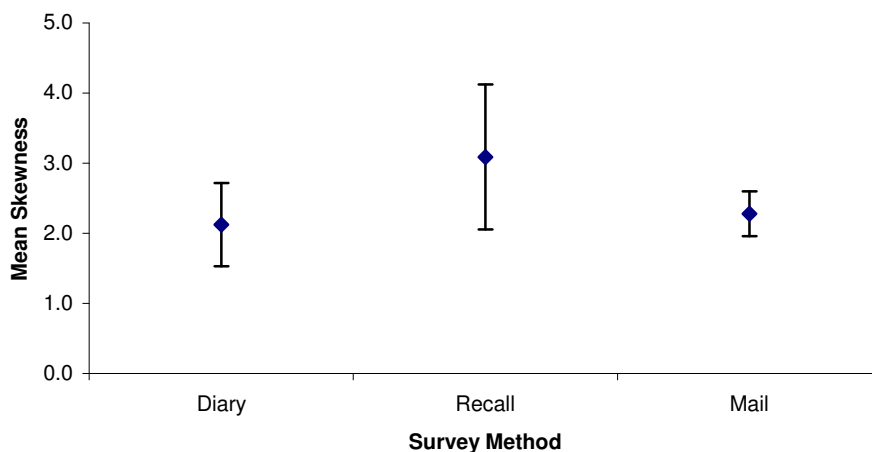
For rock lobster licence holders the Kolmogorov-Smirnov test showed that there were significant differences between the distribution of number of days fished from the telephone diary survey and the telephone recall survey ( $p = 0.005$ ), between the telephone diary survey and the mail survey ( $p = 0.000$ ) and between the telephone recall survey and the mail survey ( $p = 0.005$ ). In each case the null hypothesis was rejected at the 0.05 level of significance.

To test the reason for these differences the skewness and kurtosis was examined by bootstrapping the statistic and determining the confidence limits. The mean of the kurtosis from the diary survey was not significantly different from the recall survey (Figure 4.4.14). The measure of kurtosis is large, highly leptokurtic, for the distribution of days fished by rock lobster licence holders for the recall survey.



**Figure 4.4.14: Mean of kurtosis for rock lobster licence holders**

The mean of the skewness from the diary survey was not significantly different from the recall and mail surveys (Figure 4.4.15). Neither kurtosis nor skewness could account for the differences in cumulative density functions.



**Figure 4.4.15: Mean of skewness for rock lobster licence holders**

The cumulative density function for the number of days fished by umbrella licence holders shows considerable differences between the number of days from the recall, diary and mail surveys (b) (Figure 4.4.13). The results were not dissimilar to

those for rock lobster licence holders with the exception of an extreme value for one umbrella licence holder in the diary survey. This estimate of days fished was confirmed by the licence holder so it can not be considered an outlier in the true sense. The respondent's recording of the number of days fished was very different to any other estimate.

For umbrella licence holders the Kolmogorov-Smirnov test showed that there were significant differences between the distribution of number of days fished from the telephone diary survey and the telephone recall survey ( $p = 0.005$ ) and between the telephone diary survey and the mail survey ( $p = 0.000$ ). In both cases the null hypothesis was rejected at the 0.05 level of significance. There was no significant difference between the distributions of number of days fished from the telephone recall survey and the mail surveys ( $p = 0.510$ ), so the null hypothesis was accepted.

To test the reason for these differences the skewness and kurtosis was examined by bootstrapping the statistic and determining the confidence limits. Neither the kurtosis or skewness statistic could account for the difference in distributions. There was no significant difference between the diary and recall survey results (Figure 4.4.16). The measure of kurtosis is large, highly leptokurtic, for both telephone surveys.

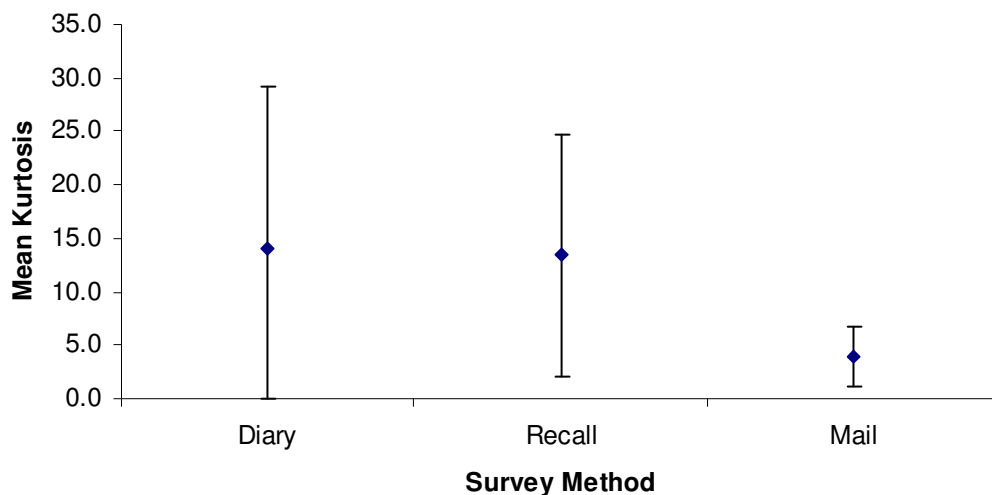
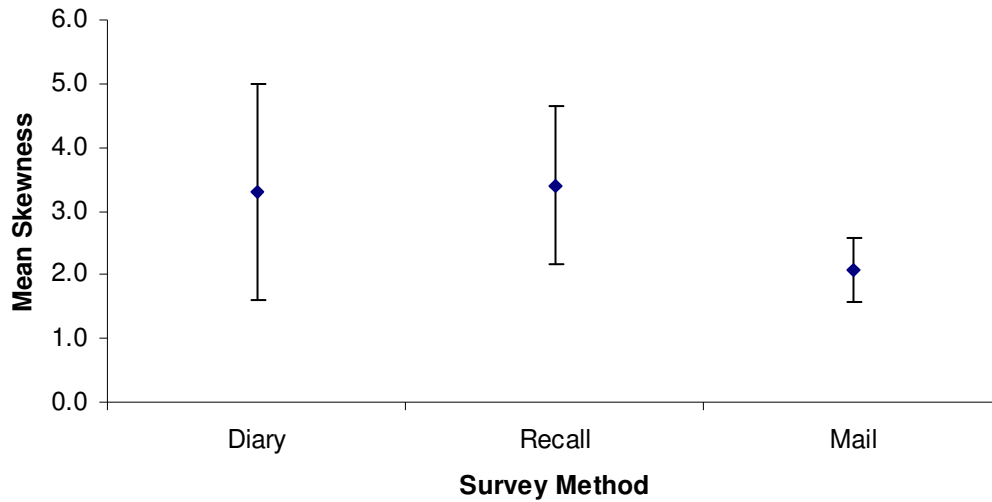


Figure 4.4.16: Mean kurtosis of umbrella licence holders



Interestingly, the mean kurtosis and skewness statistic from the diary and recall surveys were similar to each other but slightly different to those from the mail survey (Figure 4.4.16 and Figure 4.4.17). Less mail survey respondents reported zero days fished than either the recall or the diary survey.



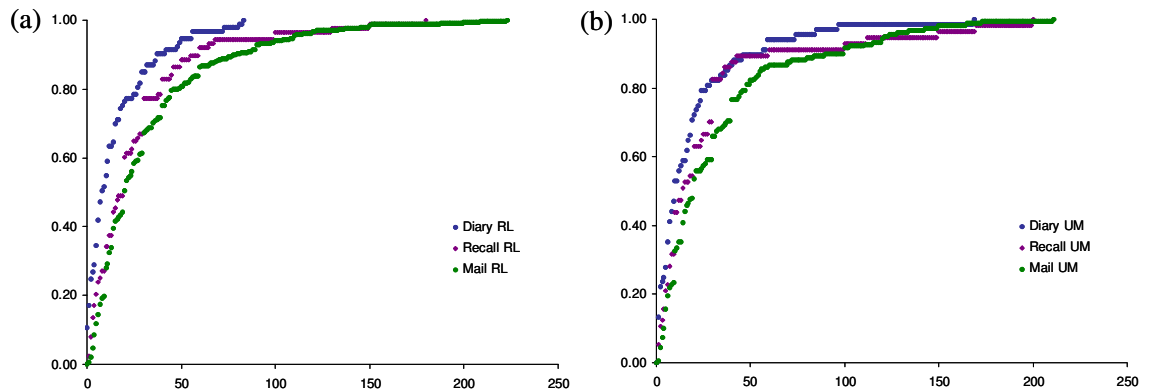
**Figure 4.4.17: Mean skewness of umbrella licence holders**

### ***Potters***

The cumulative density functions for potters and divers are examined separately.

The cumulative density function for the number of days fished by rock lobster licence holders using pots shows considerable differences between the number of days from the recall, diary and mail surveys (Figure 4.4.18). The diary survey respondents' estimates of number of days fished was more closely grouped than either the recall survey or the mail survey (a).

The proportion of responses from the recall survey were closer to the diary than the mail survey responses. For umbrella licence holders the diary survey responses were more spread out as were the recall and mail survey results (b). The differences were tested using a Kolmogorov-Smirnov test.



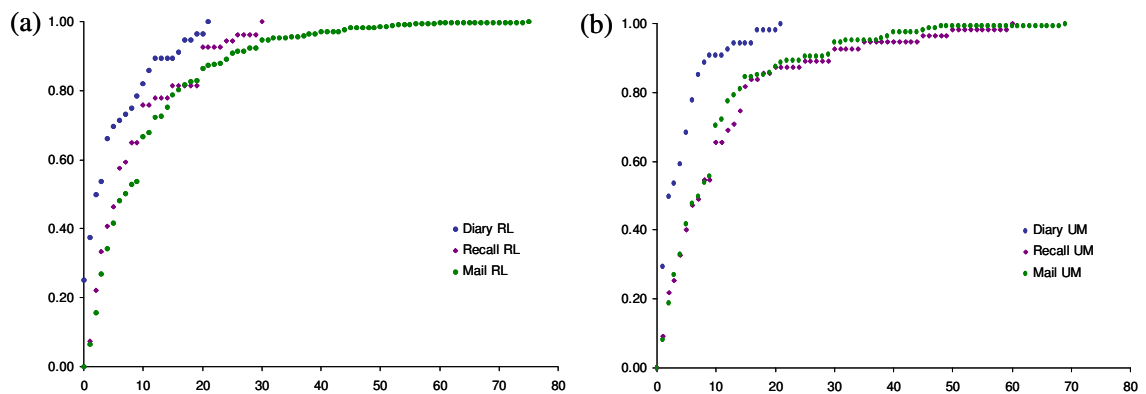
**Figure 4.4.18: Cumulative density functions: number of days fished by potters: rock lobster licence holders (a) and umbrella licence holders (b)**

For rock lobster licence holders the Kolmogorov-Smirnov test showed that there were significant differences between the distribution of days fished from the telephone diary survey and the mail survey ( $p = 0.003$ ) and the telephone diary survey and the telephone recall survey ( $p = 0.000$ ). In these cases the null hypothesis was rejected at the 0.05 level of significance. There was no significant difference between the distributions of days fished from the telephone recall survey and the mail surveys ( $p = 0.377$ ), so the null hypothesis was accepted.

For umbrella licence holders the Kolmogorov-Smirnov test showed that there were significant differences between the distribution of days fished from the telephone diary survey and the mail survey ( $p = 0.001$ ). In this case the null hypothesis was rejected at the 0.05 level of significance. There was no significant difference between the distributions of days fished between the telephone diary survey and the telephone recall survey ( $p = 0.312$ ) and the telephone recall survey and the mail survey ( $p = 0.093$ ) so the null hypothesis was accepted.

## Divers

The cumulative density function for the number of days fished by rock lobster licence holders diving shows considerable differences between the number of days fished from the recall, diary and mail surveys (Figure 4.4.19). The mail survey responses are very spread out and appear quite different to the recall and diary survey responses (a). The proportion of responses from the recall survey were closer to the diary than the mail survey responses. The mail survey responses were closer to the recall survey responses for umbrella licence holders diving for rock lobsters (b). This was tested using a Kolmogorov-Smirnov test.



**Figure 4.4.19: Cumulative density functions: number of days fished by divers: rock lobster licence holders (a) and umbrella licence holders (b)**

For rock lobster licence holders the Kolmogorov-Smirnov test showed that there were significant differences between the distribution of number of days fished from the telephone diary survey and the mail survey ( $p = 0.003$ ). In this case the null hypothesis was rejected at the 0.05 level of significance. There was no significant difference between the distributions of number of days fished from the telephone diary survey and the telephone recall survey ( $p = 0.175$ ) and the telephone recall survey and the mail surveys ( $p = 0.425$ ), so the null hypothesis was accepted.

For umbrella licence holders the Kolmogorov-Smirnov test showed that there were significant differences between the distribution of number of days fished from the telephone diary survey and the mail survey ( $p = 0.001$ ) and the telephone diary and telephone recall survey ( $p = 0.000$ ). In these cases the null hypothesis was rejected at the 0.05 level of significance. There was no significant difference between the distributions of number of days fished the telephone recall survey and the mail survey ( $p = 0.847$ ), so the null hypothesis was accepted.

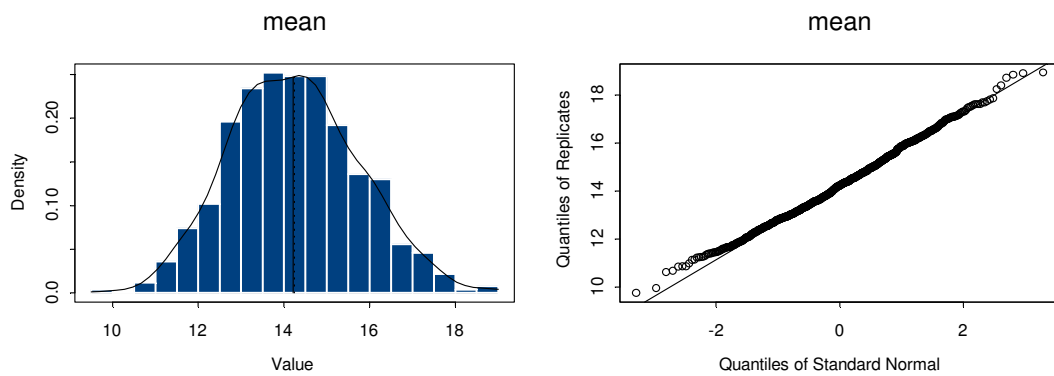
#### 4.4.5 Bootstrapped Results

A bootstrap estimate of effort was calculated for both the diary and recall survey. The mail survey is already calculated using this non-parametric method.

##### Diary Survey

The total effort for rock lobster and umbrella licence holders was calculated using bootstrap estimates of the mean number of days fished and bootstrap estimates of the variance. This was calculated separately for rock lobster licence holders and umbrella licence holders.

The distribution of bootstrapped estimates of the mean number of days fished by rock lobster licence holders shows a mean of 14.7 (Figure 4.4.20) and a symmetrical distribution about the mean.



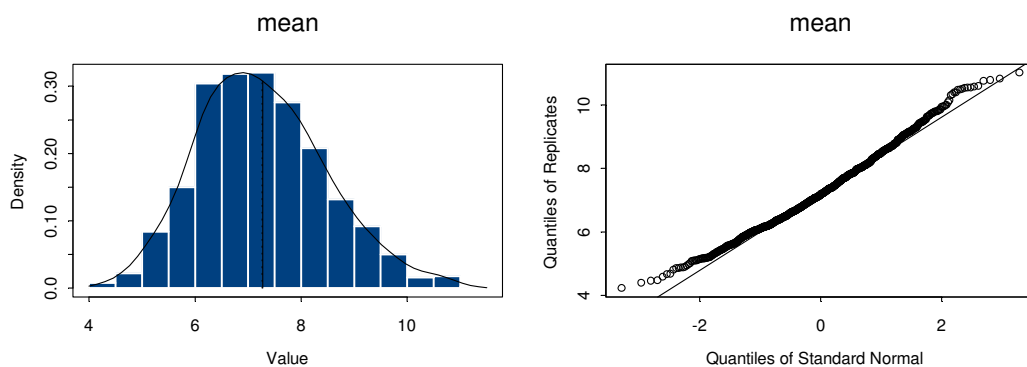
**Figure 4.4.20: Distribution of bootstrapped estimates for the mean number of days fished by rock lobster licence holders (Diary Survey)**

The bootstrap estimates for the mean number of days fished and the variance associated with that effort by umbrella licence holders was used to calculate the total effort. There was very little difference between the bootstrap estimates and the original estimates (Table 4.4.7).

**Table 4.4.7: Comparison between bootstrapped and initial estimates for Rock Lobster Licence Holders (Diary Survey)**

Totals	Initial Estimates	Bootstrapped Estimates
E	200,709	200,774
SE(E)	23,341	23,210

The distribution of bootstrapped estimates of the mean number of days fished by umbrella licence holders shows a mean of 7.3 (Figure 4.4.21) and a nearly symmetrical distribution about the mean.



**Figure 4.4.21: Distribution of bootstrapped estimates for the mean number of days fished by umbrella licence holders (Diary Survey)**

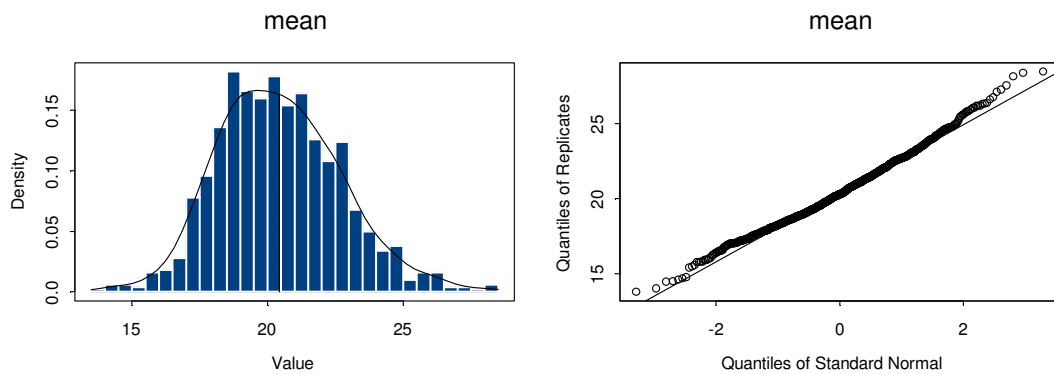
The bootstrap estimates for the mean number of days fished and the variance associated with that effort by umbrella licence holders was used to calculate the total effort. There was very little difference between the bootstrap estimates and the original estimates (Table 4.4.8).

**Table 4.4.8: Comparison between bootstrapped and initial estimates for umbrella licence holders (Diary Survey)**

Totals	Initial Estimates	Bootstrapped Estimates
E	87,261	87,775
SE(E)	14,468	14,186

#### Recall Survey

The distribution of bootstrapped estimates of the mean number of days fished by rock lobster licence holders shows a mean of 20.4 and a symmetrical distribution about the mean (Figure 4.4.22).



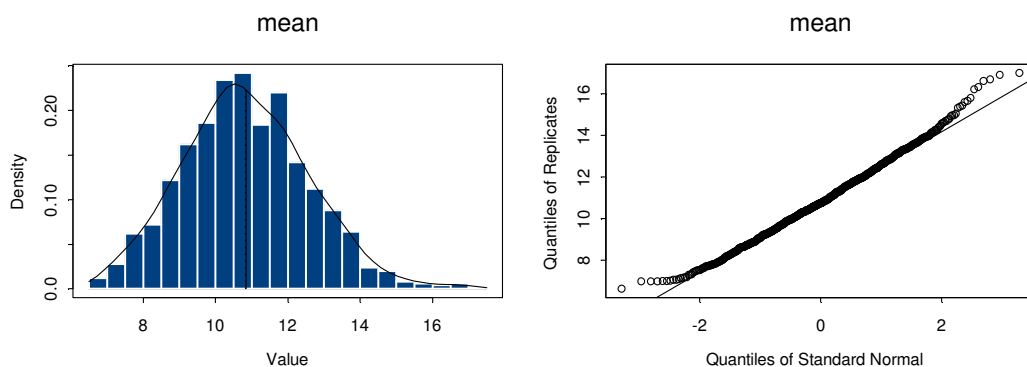
**Figure 4.4.22: Distribution of bootstrapped estimates for the mean number of days fished by rock lobster licence holders (Recall Survey)**

The bootstrap estimates for the mean number of days fished and the variance associated with that effort by rock lobster licence holders were used to calculate the total effort. This total effort was lower than the initial estimate. The standard error estimates are much smaller after bootstrapping (Table 4.4.9).

**Table 4.4.9: Comparison between bootstrapped and initial estimates for Rock Lobster Licence Holders (Recall Survey)**

Totals	Initial Estimates	Bootstrapped Estimates
E	343,219	343,797
SE(E)	41,913	41,744

The distribution of bootstrapped estimates of the mean number of days fished by umbrella licence holders shows a mean of 10.8 and a nearly symmetrical distribution about the mean (Figure 4.4.23).



**Figure 4.4.23: Distribution of bootstrapped estimates for the mean number of days fished by umbrella licence holders (Recall Survey)**

The bootstrap estimates for the mean number of days fished and the variance associated with that effort by umbrella licence holders were used to calculate the total effort. There was very little difference between the bootstrap estimates and the original estimates (Table 4.4.10).

**Table 4.4.10: Comparison between bootstrapped and initial estimates for umbrella licence holders (Recall Survey)**

<b>Totals</b>	<b>Initial Estimates</b>	<b>Bootstrapped Estimates</b>
E	130,760	129,958
SE(E)	19,445	21,376

#### **4.4.6 Digit Preference**

One could expect that the proportion of days fished ending in a zero or a five to be approximately 20%, which is two numbers out of a possible ten numbers. The proportion for mail survey respondents ending a zero or five while still significantly higher than for the diary survey is lower than for the recall survey (Table 4.4.11). This may be attributed to the mail survey allowing more time for the respondent to fill in the questionnaire while the recall survey requires an immediate response. Recall survey respondents are more likely to report days fished ending in a zero than either the diary or the mail survey.

**Table 4.4.11: Proportion of days fished ending in zeros or fives - Individual Digit Preference**

<b>Survey</b>	<b>Licence type</b>	<b>0</b>	<b>5</b>	<b>0 and 5</b>
Diary	RL (%)	6.20	9.30	15.50
	UM (%)	4.63	7.41	12.04
Recall	RL (%)	36.23	10.14	46.38
	UM (%)	38.38	17.17	55.56
Mail	RL (%)	26.97	12.99	39.96
	UM (%)	27.01	16.08	43.09



Aggregate digit preference (ADP) was determined for all three surveys by licence type (Table 4.4.12) using formulae from Beaman *et al* (1997) (see section 3.5.4). The diary survey measures of ADP were all negative indicating that ADP did not exist. Both the recall and mail surveys measures of ADP were largely positive indicating evidence of ADP.

**Table 4.4.12: Aggregate Digit Preference (ADP)**

<b>Survey</b>	<b>Licence type</b>	<b>Sum of Residuals</b>	<b>ADP</b>
Diary	RL	-101	-0.78
	UM	-111	-1.03
Recall	RL	1,927	13.97
	UM	1,604	16.20
Mail	RL	9,129	10.13
	UM	2,848	9.16

#### 4.4.7 Winsorization

Two methods of winsorization were used on the recall and mail survey datasets of days fished. The winsorization technique is used to reduce the effect of outliers on the overall result.

The simplest use of winsorization is to truncate the series at four standard deviations from the mean, setting returns outside this range equal to the boundary value. This prevents the outliers from having undue influence on the findings (Connor, 2001). Both the winsorized recall and mail survey estimates are significantly greater than the diary estimates of effort (Table 4.4.13). The estimates are 1.3 times and 1.9 times greater than the diary estimates for the recall and mail surveys respectively.

**Table 4.4.13: Truncation winsorization**

	Recall Survey	Mail Survey
E (Initial Estimate)	473,980	723,079
E (Winsorised Estimate)	386,803	540,271
SE(E)	32,337	24,107
Lower Limit (95%)	323,423	493,022
Upper Limit (95%)	450,183	587,520

The Australian Bureau of Statistics defines the technique for dealing with outliers as “sample values greater than a predetermined cut-off are replaced by the cut-off plus a small additional amount”. This amount is the difference between the sample value and the cut-off multiplied by the stratum sampling fraction. Effectively, this method results in the outlier only representing itself, with the remaining population units that would have been represented by the outlier being instead represented by the cut-off (Australian Bureau of Statistics, 2001). The predetermined cut off in this case was four standard deviations from the mean.

The effort estimates for the mail survey are still significantly greater than the diary survey (1.9 times). The recall survey estimates are not significantly different from the diary survey results at only 1.2 times the diary estimates of effort (Table 4.4.14).

**Table 4.4.14: Stratum sampling winsorization**

	Recall Survey	Mail Survey
E (Initial Estimate)	473,980	723,079
E (Winsorised Estimate)	330,647	390,890
SE(E)	36,497	22,030
Lower Limit (95%)	259,113	347,711
Upper Limit (95%)	402,180	434,069

Interestingly, the simple truncation winsorization produced slightly better estimates for the mail survey and the sampling stratum factor winsorization produced much better estimates for the recall survey.

Other levels of winsorization were trialled on both the recall and mail survey data. Simple truncations at three standard deviations and sampling stratum calculations at three standard deviations were determined. None of these produced estimates of effort lower than those already reported.

#### 4.4.8 Interviewer Effect

To compare the effort by interviewer for the diary survey, the total effort was calculated as though only one interviewer collected the data. Then the total effort with confidence intervals was examined. It was found that there were significant differences in estimated effort between interviewers (Figure 4.4.24). One interviewer, HM, had a much higher estimated effort than the other four interviewers.

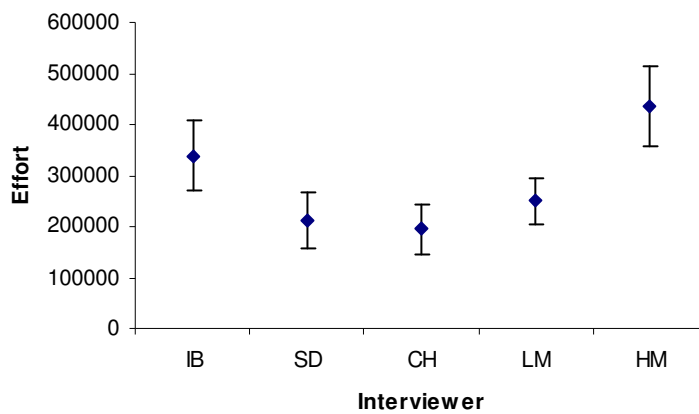


Figure 4.4.24: Comparison of effort by interviewer for the telephone diary survey

The same comparison was done for the recall survey. Once again there were significant differences in estimated effort between interviewers (Figure 4.4.25). In this survey, LM, had a significantly higher estimated effort than the total estimated effort.

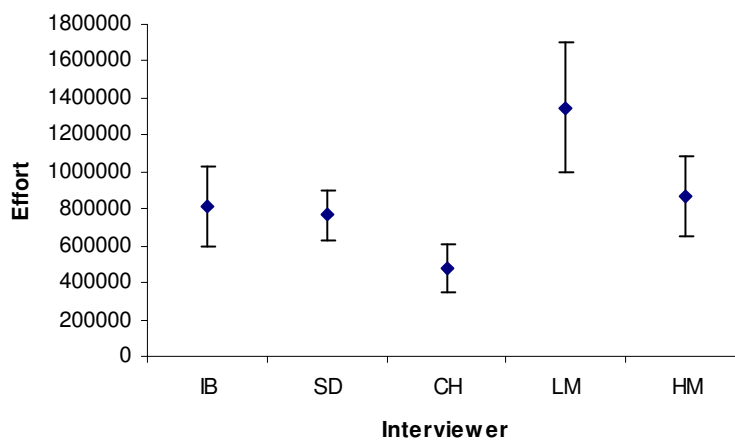


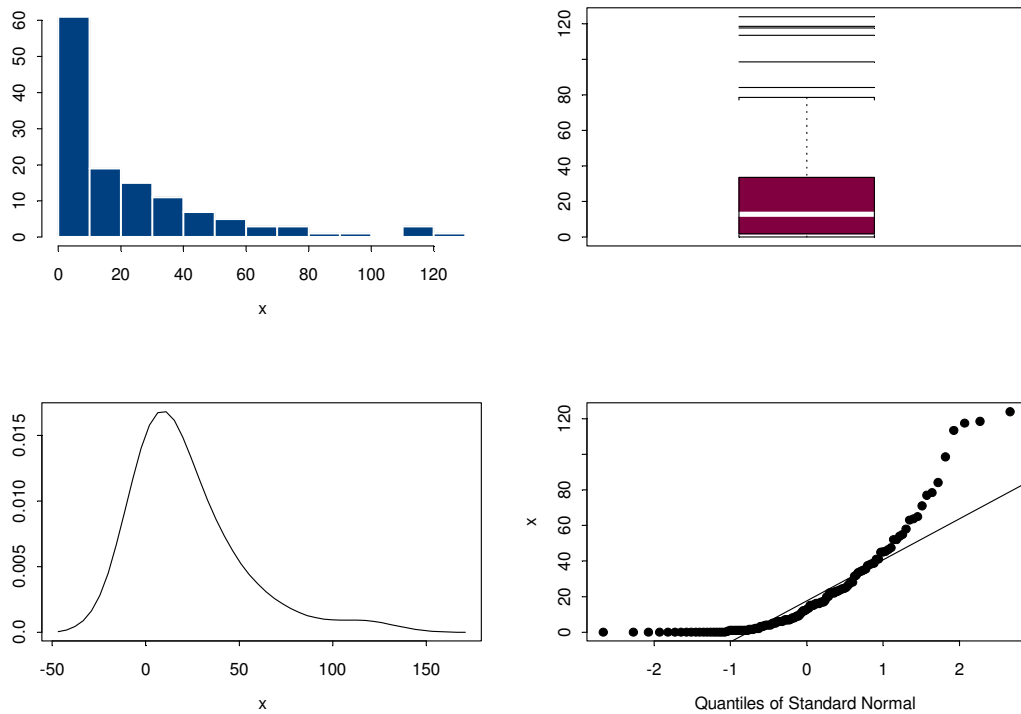
Figure 4.4.25: Comparison of effort by interviewer for the telephone recall survey

## 4.5 Catch

### 4.5.1 Exploratory Data Analysis

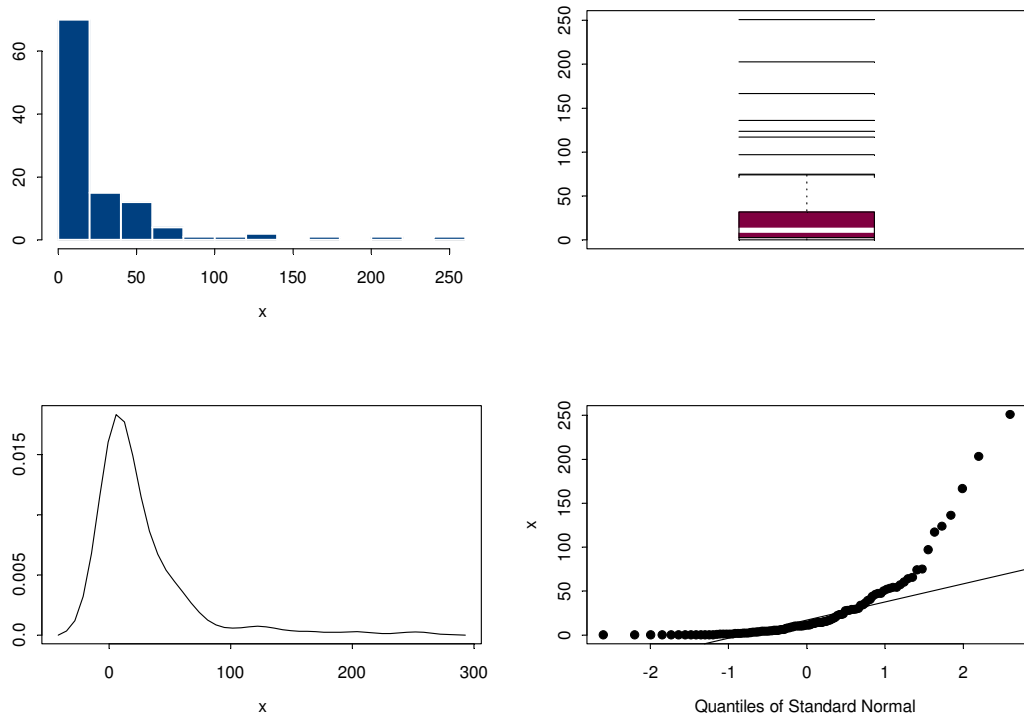
#### Diary Survey

The exploratory data analysis of catch of western rock lobsters by rock lobster licence holders shows a highly skewed distribution (Figure 4.5.1). Most of the rock lobster licence holders (51.5%) kept between 1 and 15 western rock lobsters during the season. The mean number of rock lobsters kept was 22.1 and the median was 12.8.



**Figure 4.5.1:** Exploratory data analysis of western rock lobsters kept by rock lobster licence holders (Diary Survey)

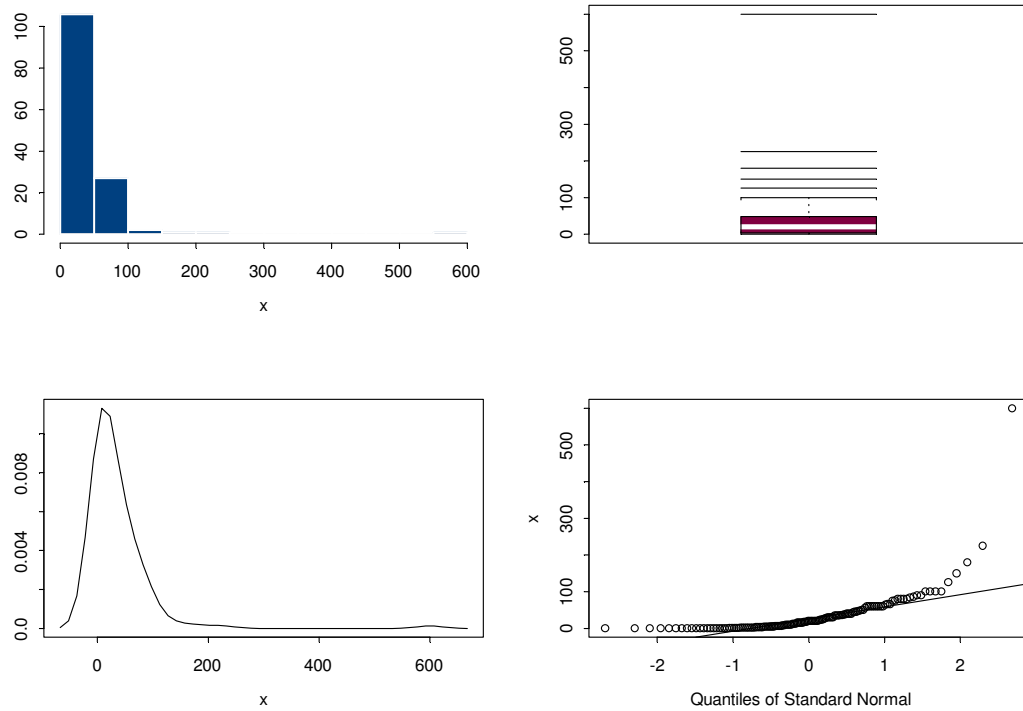
The exploratory data analysis of catch of western rock lobsters by umbrella licence holders also shows a highly skewed distribution (Figure 4.5.2). Most of the umbrella licence holders (58.0%) kept between one and 10 western rock lobsters during the season. The mean number of rock lobsters kept was 26.4 and the median was 11.0.



**Figure 4.5.2:** Exploratory data analysis of western rock lobsters kept by umbrella licence holders (Diary Survey)

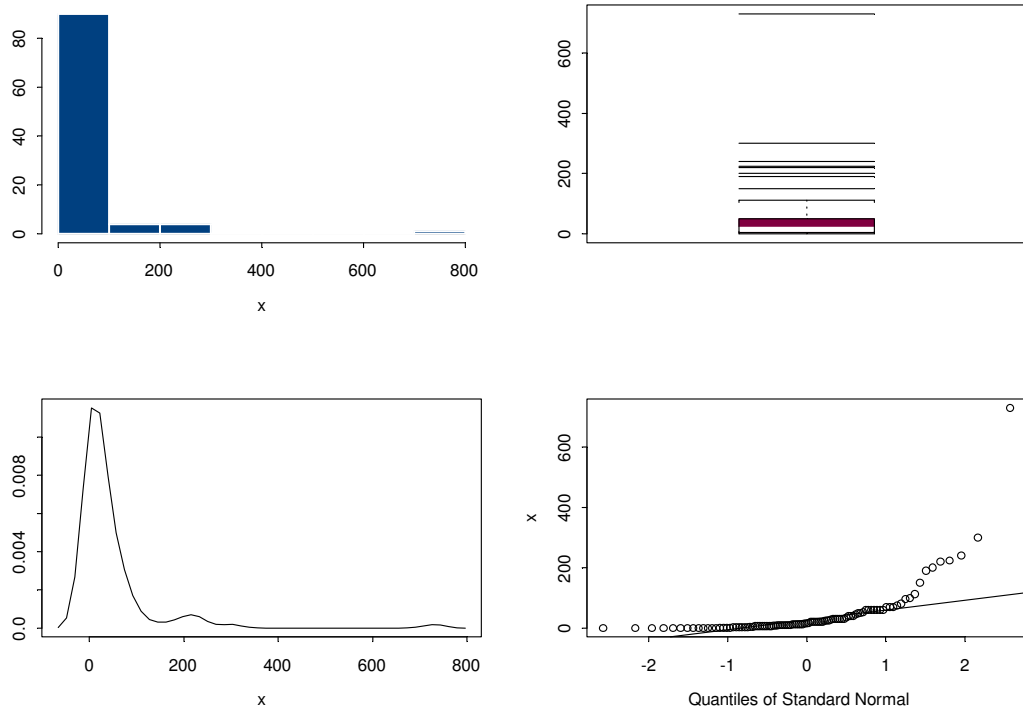
## Recall Survey

The exploratory data analysis of catch of western rock lobsters by rock lobster licence holders shows a highly skewed distribution (Figure 4.5.3). Most of the rock lobster licence holders (55.1%) kept between one and 30 western rock lobsters during the season. The mean number of rock lobsters kept was 35.2 and the median was 20.0.



**Figure 4.5.3: Exploratory data analysis of western rock lobsters kept by rock lobster licence holders (Recall Survey)**

The exploratory data analysis of catch of western rock lobsters by umbrella licence holders also shows a highly skewed distribution (Figure 4.5.4). Most of the umbrella licence holders (51.5%) kept between one and 20 western rock lobsters during the season. The mean number of rock lobsters kept was 44.4 and the median was 15.0. There was one significant outlier, an umbrella licence holder, in the recall survey who reported catching 730 western rock lobsters.

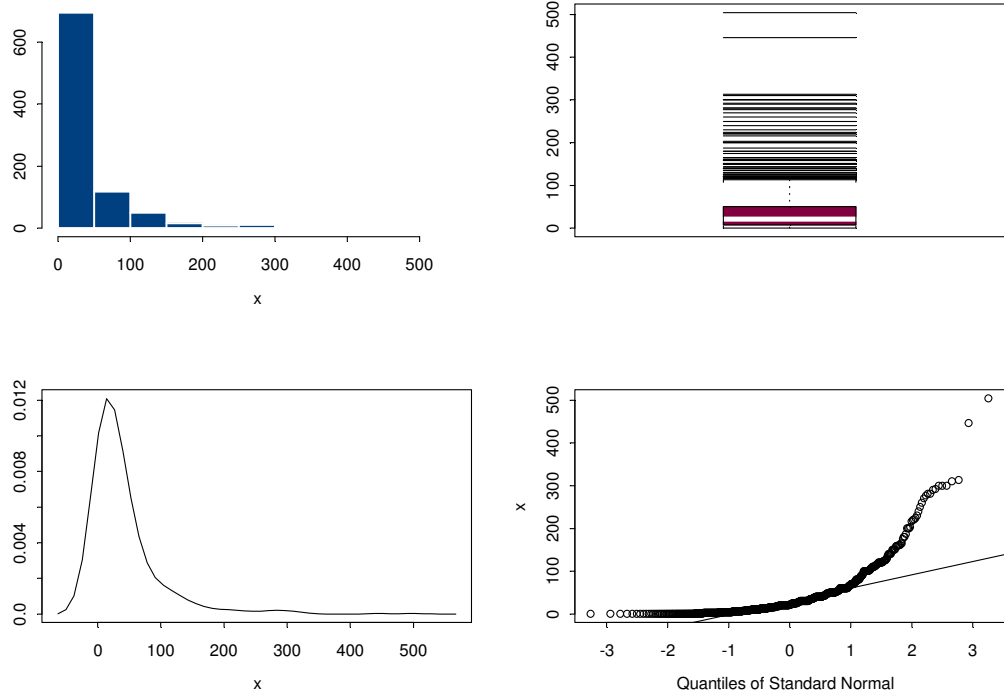


**Figure 4.5.4: Exploratory data analysis of western rock lobsters kept by umbrella licence holders (Recall Survey)**



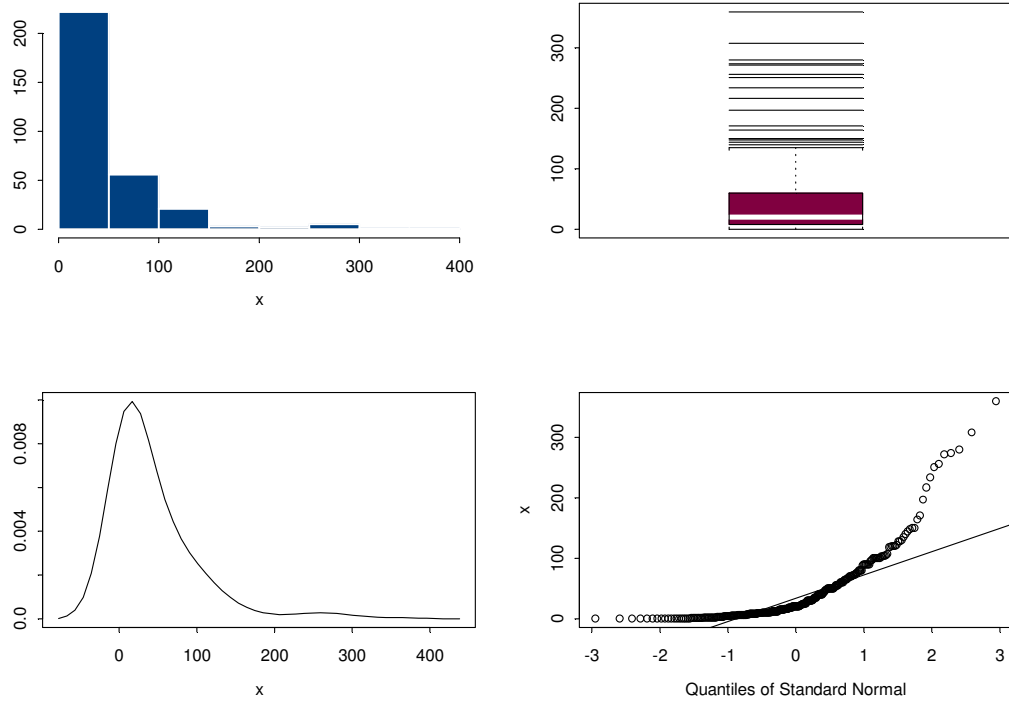
## Mail Survey

The exploratory data analysis of catch by rock lobster licence holders shows a highly skewed distribution (Figure 4.5.5). The mean number of rock lobsters kept was 39.9 and the median was 21.0.



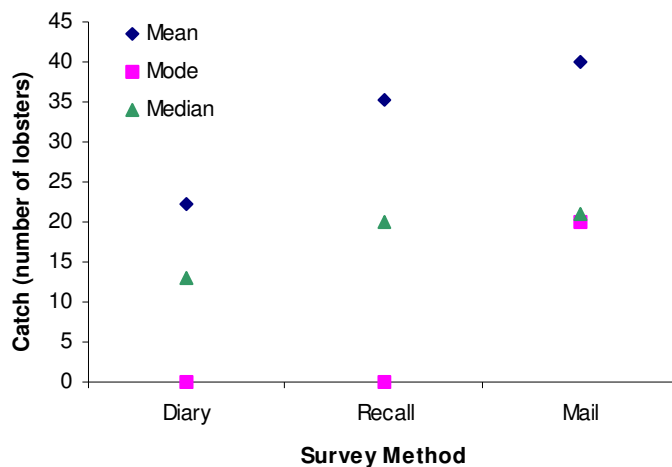
**Figure 4.5.5: Exploratory data analysis of days fished by rock lobster licence holders (Mail Survey)**

The exploratory data analysis of catch by umbrella licence holders shows a highly skewed distribution (Figure 4.5.6). The mean number of days fished was 42.9 and the median was 20.0.



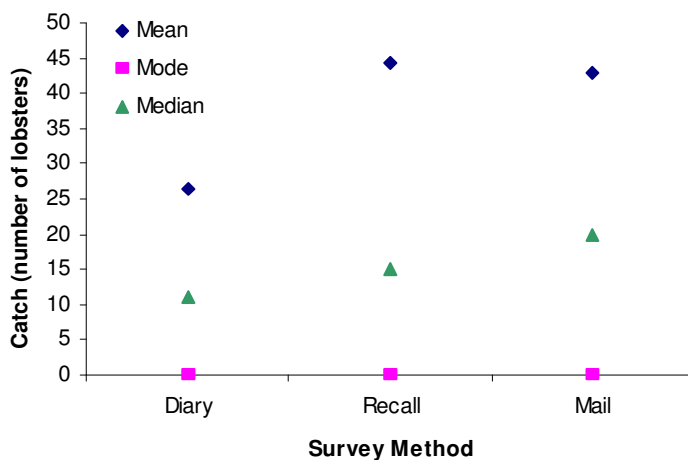
**Figure 4.5.6: Exploratory data analysis of days fished by umbrella licence holders (Mail Survey)**

Major differences are evident in the measures of central tendency for rock lobster licence holders' catch estimates. The mode is zero for both the diary and recall surveys and much higher at 20 for the mail survey (Figure 4.5.7). There were considerably less zeros recorded by mail survey respondents than for the other survey methods. The medians for the recall and mail surveys are very similar at around 20 lobsters. The mean catch of lobsters is much higher for the recall and mail surveys when compared to the diary survey.



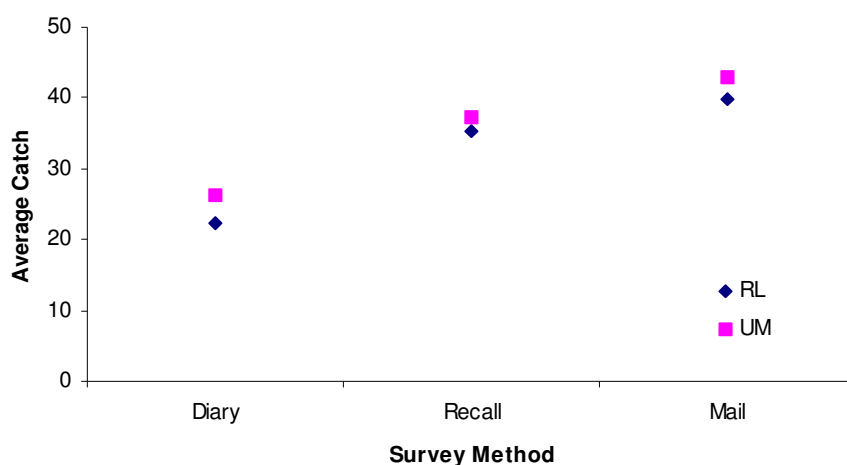
**Figure 4.5.7: Mean, mode and median rock lobsters kept by rock lobster licence holders**

Interestingly, the mode for all three surveys for umbrella licence holders is zero (Figure 4.5.8). A much higher proportion of zeros was recorded by umbrella licence holders in the mail survey compared to rock lobster licence holders.



**Figure 4.5.8: Mean, mode and median lobsters kept by umbrella licence holders**

The average catch for each survey method shows very little difference between rock lobster and umbrella licence holders (Figure 4.5.9). The mail survey estimates are slightly greater than the recall, which in turn are considerably greater than the diary.



**Figure 4.5.9: Average catch by licence type and survey method**

#### 4.5.2 Catch Estimates

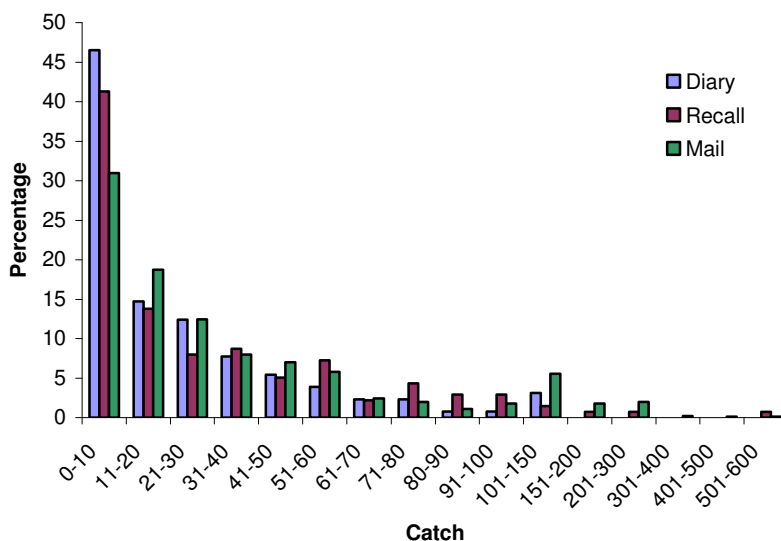
The telephone diary survey estimated the total catch of western rock lobsters as 469,032 (Table 4.5.1). The telephone recall estimated the catch as 854,882. This was 1.8 times the diary survey estimate. The mail survey estimates were between 1,090,365 and 1,092,953. This was 2.3 times greater than the diary survey estimates.

**Table 4.5.1: Survey estimates of catch for the telephone diary, telephone recall and mail surveys**

	Telephone Diary Survey	Telephone Recall Survey	Mail Survey Unstratified	Mail Survey Stratified
Catch	469,032	854,882	1,090,365	1,092,953
SE(C)	49,075	107,494	44,977	44,557
Catch (Tonnes)	235	427	545	546
SE(C) (Tonnes)	25	54	22	22

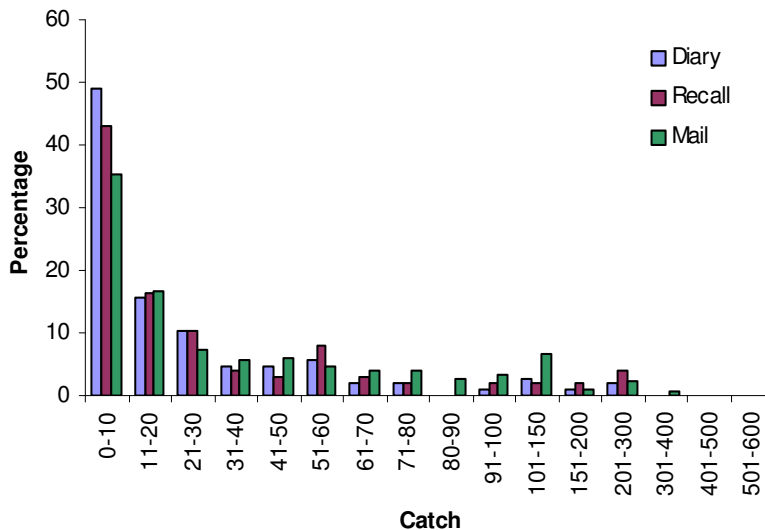
A comparison of monthly estimates of catch between the diary and mail survey had the ratio of diary to mail estimates vary between 1.49 and 2.00.

The frequency distribution of catch by rock lobster licence holders shows the differences in the reported levels of catch (Figure 4.5.10). The diary survey reports that the majority of respondents' catch is less than 10.



**Figure 4.5.10: Frequency of catches by rock lobster licence holders for the telephone diary, telephone recall and mail surveys**

The frequency distribution of catch by umbrella licence holders shows the differences between the surveys' reported catch (Figure 4.5.11).



**Figure 4.5.11: Frequency of catches by umbrella licence holders for the telephone diary, telephone recall and mail surveys**

To more closely examine the differences between the survey methods estimates of catch, a plot of catches from zero to 20 was examined (Figure 4.5.12). The largest difference lies in the percentage of respondents recording a zero catch. The recall and

diary surveys have a similar proportion of zeros. The mail survey has a much lower level of zeros reported. Figure 4.5.12 also shows the preference for 10, 12, 15 and 20 rock lobster caught from the recall and mail surveys.

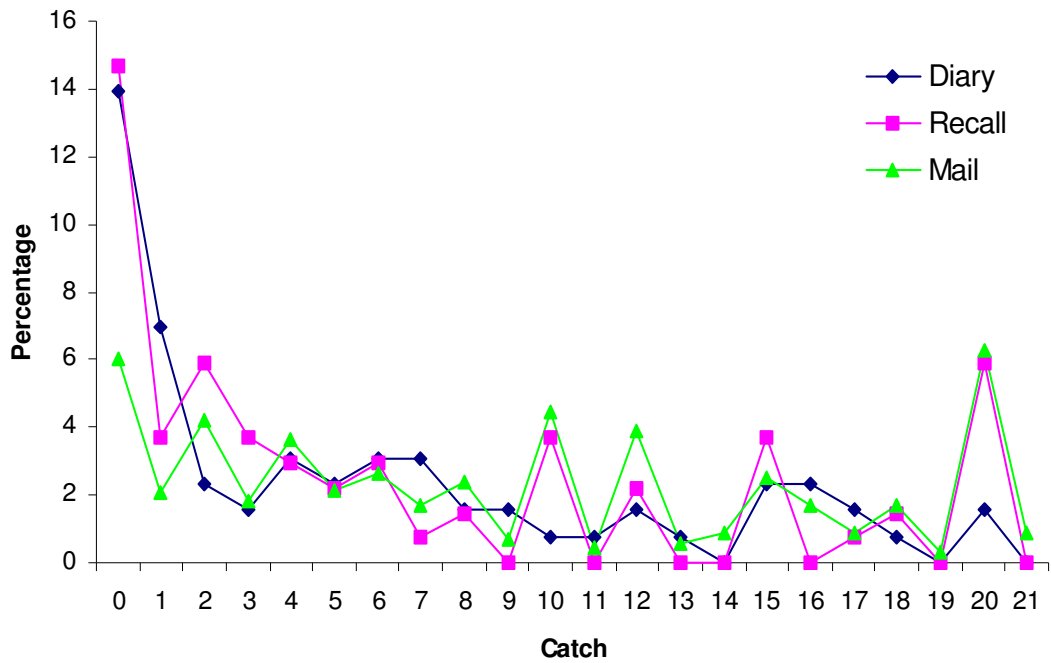
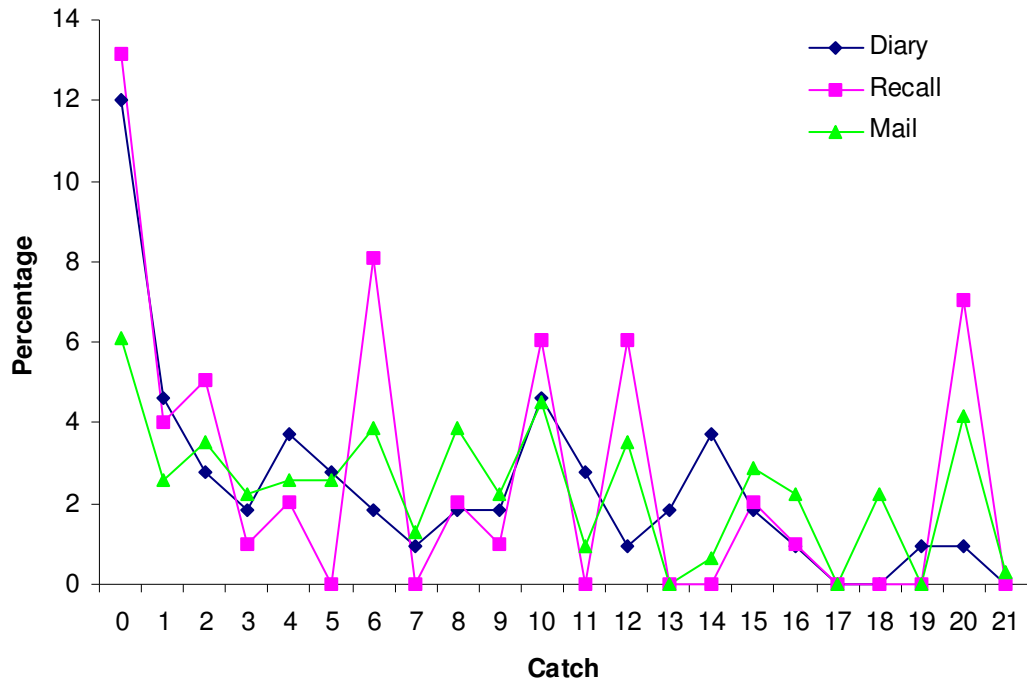


Figure 4.5.12: Comparison of catches from zero to 21 for rock lobster licence holders for the telephone diary, telephone recall and mail surveys

The same comparison was undertaken for umbrella licence holders (Figure 4.5.13). The same result was evident. Zero catches are underreported by the mail survey. It is also shows the preference for certain reported catches for the recall and mail surveys.



**Figure 4.5.13: Comparison of catches from zero to 21 for umbrella licence holders for the telephone diary, telephone recall and mail surveys**

Around 70% of the catch is taken by fishers using pots (72% diary, 73% recall and 70% mail survey). Catch estimates by divers and potters are now determined separately.

The telephone diary survey estimated the total catch of western rock lobsters by potters as 335,487 (Table 4.5.2). The telephone recall estimated the catch by potters as 623,938. This was 1.9 times the diary survey estimate. The mail survey estimates were 766,125 and 767,198 for the two methods. This was 2.3 times greater than the diary survey estimates.

**Table 4.5.2: Survey estimates of catch by potters for the telephone diary, telephone recall and mail surveys**

	Telephone Diary Survey	Telephone Recall Survey	Mail Survey Unstratified	Mail Survey Stratified
Catch	335,487	623,938	766,125	767,198
SE(C)	41,245	90,124	41,007	40,250
Catch (Tonnes)	168	312	383	384
SE(C) (Tonnes)	21	45	21	20

The telephone diary survey estimated the total catch of western rock lobsters by divers as 133,545 (Table 4.5.3). The telephone recall estimated the catch as 215,570. This was 1.6 times the diary survey estimate. The mail survey estimates were between 323,774 and 325,755. This was 2.4 times greater than the diary survey estimates.

**Table 4.5.3: Survey estimates of catch by divers for the telephone diary, telephone recall and mail surveys**

	Telephone Diary Survey	Telephone Recall Survey	Mail Survey Unstratified	Mail Survey Stratified
Catch	133,545	215,570	323,774	325,755
SE(C)	19,621	31,735	26,468	22,198
Catch (Tonnes)	67	108	162	163
SE(C) (Tonnes)	10	16	13	11



The highest catches from the diary survey were recorded in December (Figure 4.5.14).

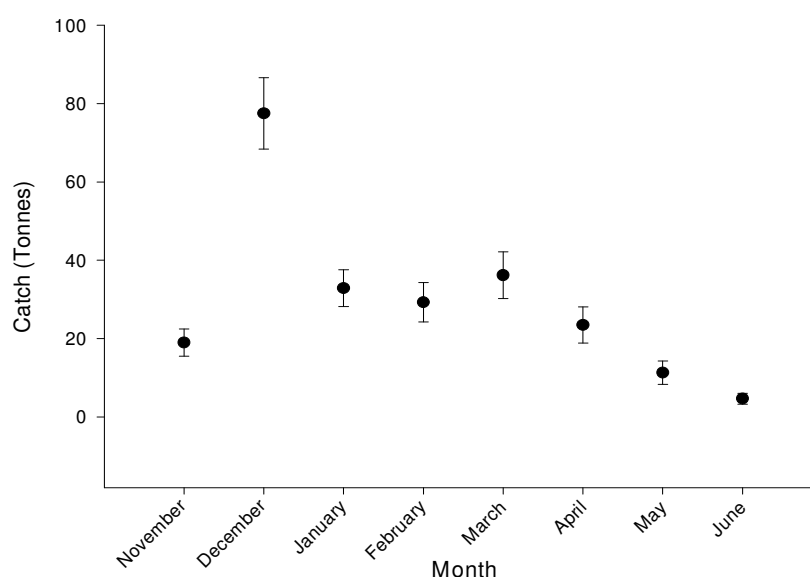


Figure 4.5.14: Western Rock Lobsters kept per month for 2001-2002 season (Diary Survey)

### 4.5.3 Tropical and Southern Rock Lobsters

The telephone recall survey estimate of catch of southern rock lobsters was 1.7 times greater than the diary estimate (Table 4.5.4). The mail survey estimate was 5 times greater than the recall survey estimate.

Table 4.5.4: Catch of Southern Rock Lobsters for the telephone diary, telephone recall and mail surveys

	Diary	Recall	Mail
Catch	2,132	3,675	18,707
Catch (C)	914	1,434	5,548
Catch (Tonnes)	1.1	1.8	9
SE(C Tonnes)	0.4	0.8	6

The telephone recall survey estimate of tropical lobsters was 1.9 times greater than the diary estimate (Table 4.5.5). The mail survey estimate was 2.4 times greater than the diary survey estimate.

**Table 4.5.5: Catch of Tropical Lobsters for the telephone diary, telephone recall and mail surveys**

	Diary	Recall	Mail
Catch	5,001	9,623	12,037
Catch (C)	2,667	4,794	4,282
Catch (Tonnes)	2.5	4.8	6
SE(C Tonnes)	2.2	4.2	2.0

#### **4.5.4 Comparison of Calculations**

Method 3 uses a combination of participation rates, mean number of days fished and mean catch. Method 1 has the smallest standard errors but does not calculate the total participation rate or the total number of fishers (Table 4.5.6).

**Table 4.5.6: Comparison of analysis methods for telephone diary survey data**

<b>Totals</b>	<b>Method 1</b>	<b>Method 2</b>	<b>Method 3</b>
C	469,032	469,032	469,032
SE(C)	45,722	48,949	45,873
C(Tonnes)	235	235	235

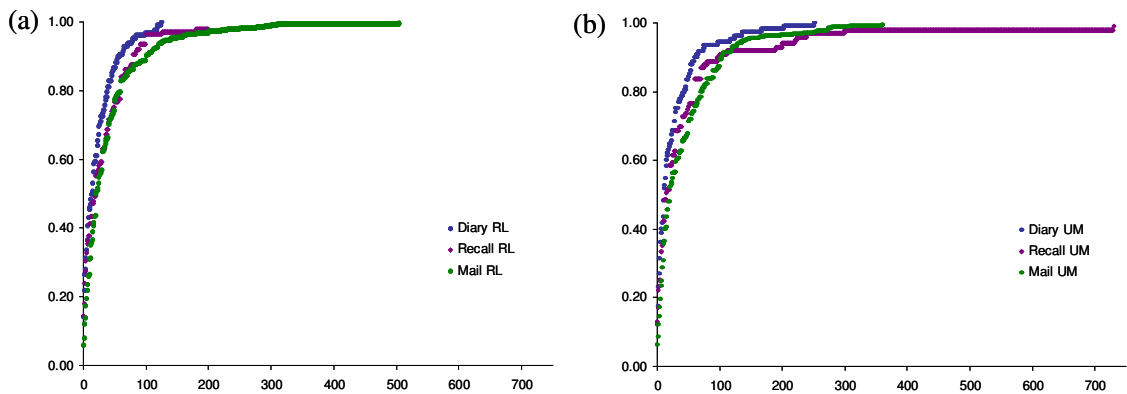
Method 2 is a more complex method of calculation because it requires more information about the participation rates. For participation rates greater than 60%, Method 2 gives a more precise estimate of the catch (Table 4.5.7).

**Table 4.5.7: Comparison of analysis methods for telephone recall survey data**

<b>Totals</b>	<b>Method 1</b>	<b>Method 2</b>	<b>Method 3</b>
C	854,882	854,882	854,882
SE(C)	107,494	96,379	107,821
C(Tonnes)	427	427	427

### 4.5.5 Distributions

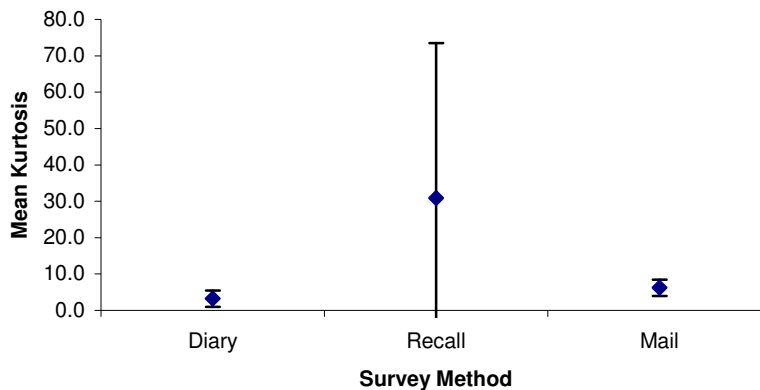
The cumulative density function for the catch of western rock lobsters by rock lobster licence holders shows considerable differences between the number of lobsters from the recall, diary and mail surveys (Figure 4.5.15). The diary survey respondents' estimates of number of lobsters kept was more closely grouped than either the recall survey or the mail survey (a) and (b). The proportion of responses from the recall survey were closer to the diary than the mail survey responses. The differences were tested using a Kolmogorov-Smirnov test.



**Figure 4.5.15: Cumulative density functions: number kept by all respondents: rock lobster licence holders (a) and umbrella licence holders (b)**

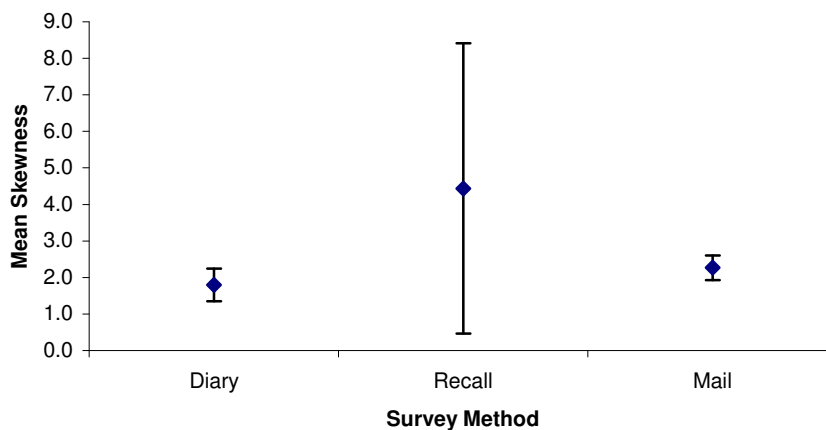
For rock lobster licence holders the Kolmogorov-Smirnov test showed that there were significant differences between the distribution of number kept from the telephone diary survey and the mail survey ( $p = 0.000$ ) and between the telephone recall survey and the mail survey ( $p = 0.019$ ). In both cases the null hypothesis was rejected at the 0.05 level of significance. There was no significant difference between the distributions of number kept from the telephone diary survey and the telephone recall surveys ( $p = 0.125$ ), so the null hypothesis was accepted.

To investigate the reason for these differences the skewness and kurtosis was examined by bootstrapping the statistic and determining the confidence limits. The mean of the kurtosis from the diary survey was not significantly different from both the recall and mail surveys (Figure 4.5.16). The recall survey distribution of catch by rock lobster licence holders is extremely leptokurtic.



**Figure 4.5.16: Mean of kurtosis for rock lobster licence holders**

The mean of the skewness from the diary survey was not significantly different from both the recall and mail surveys (Figure 4.5.17). Neither skewness of kurtosis could explain the differences in cumulative density functions.

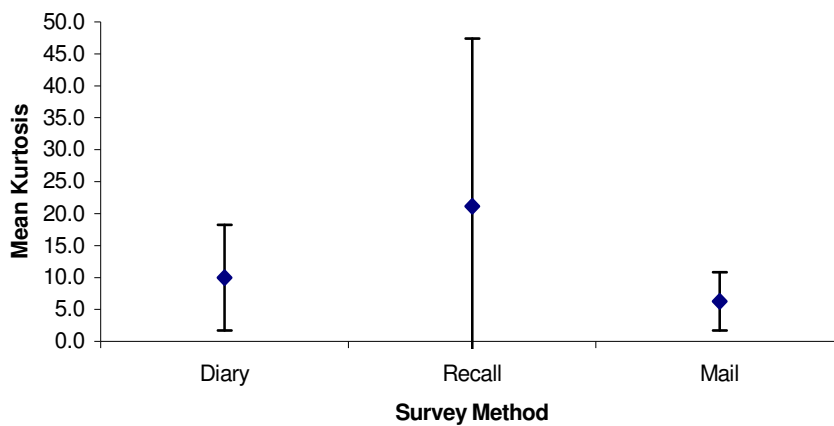


**Figure 4.5.17: Mean of skewness for rock lobster licence holders**

For umbrella licence holders the Kolmogorov-Smirnov test showed that there were significant differences between the distribution of number kept from the telephone diary survey and the mail survey ( $p = 0.010$ ). In this case the null hypothesis was rejected at the 0.05 level of significance. There was no significant difference between

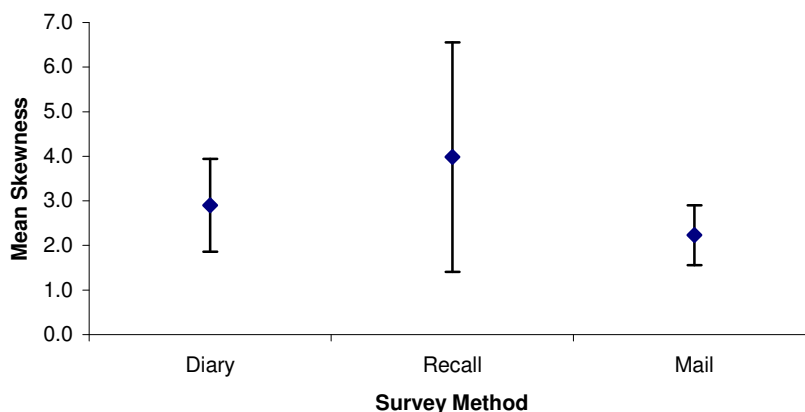
the distributions of number kept from the telephone diary survey and the telephone recall surveys ( $p = 0.343$ ), and between the telephone recall survey and the mail survey ( $p = 0.399$ ) so the null hypothesis was accepted.

To investigate the reason for the difference the skewness and kurtosis was examined by bootstrapping the statistic and determining the confidence limits. The mean of the kurtosis from the diary survey was not significantly different from both the recall and mail surveys (Figure 4.5.18). The recall survey distribution of catch by umbrella licence holders is extremely leptokurtic.



**Figure 4.5.18: Mean of kurtosis for umbrella licence holders**

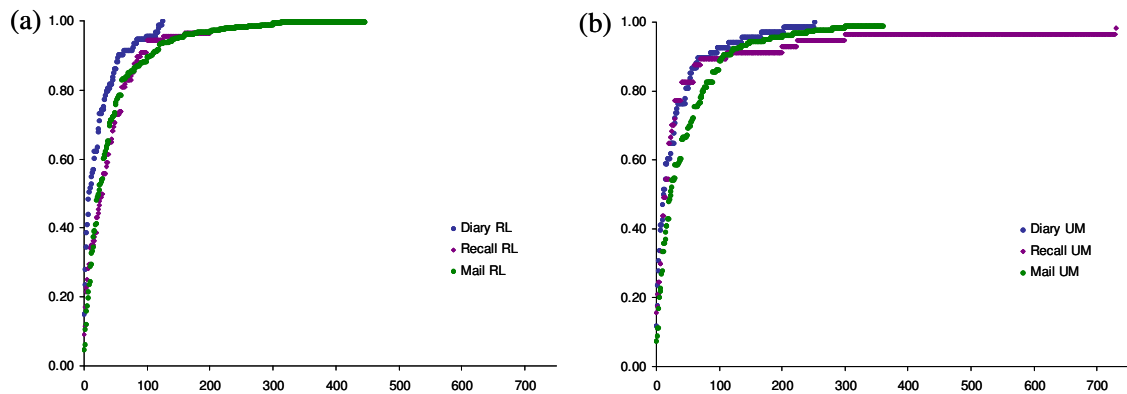
The mean of the skewness from the diary survey was not significantly different from both the recall and mail surveys (Figure 4.5.19).



**Figure 4.5.19: Mean of skewness for umbrella licence holders**

## Potters

The cumulative density function for the catch of western rock lobsters by rock lobster licence holders using pots shows considerable differences between the number of days from the recall, diary and mail surveys (Figure 4.5.20). The diary survey respondents' estimates of number of days fished was more closely grouped than either the recall survey or the mail survey (a). Once again there appears to be an outlier in the recall survey from an umbrella licence holder. The differences were tested using a Kolmogorov-Smirnov test.



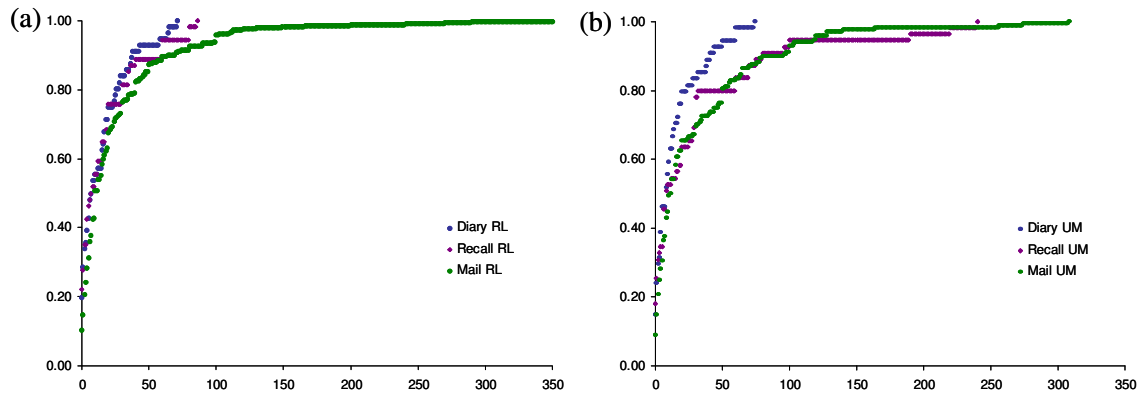
**Figure 4.5.20: Cumulative density functions: number kept by potters: rock lobster licence holders (a) and umbrella licence holders (b)**

For rock lobster licence holders the Kolmogorov-Smirnov test showed that there were significant differences between the distribution of number kept from the telephone diary survey and the mail survey ( $p = 0.000$ ) and the telephone diary survey and the telephone recall survey ( $p = 0.004$ ). In these cases the null hypothesis was rejected at the 0.05 level of significance. There was no significant difference between the distributions of number kept from the telephone recall survey and the mail surveys ( $p = 0.473$ ), so the null hypothesis was accepted.

For umbrella licence holders the Kolmogorov-Smirnov test showed that there were significant differences between the distribution of number kept from the telephone diary survey and the mail survey ( $p = 0.012$ ) and the telephone recall survey and the mail survey ( $p = 0.045$ ). In these cases the null hypothesis was rejected at the 0.05 level of significance. There was no significant difference between the distributions of number kept between the telephone diary survey and the telephone recall survey ( $p = 0.723$ ) so the null hypothesis was accepted.

## Divers

The cumulative density function for the catch of western rock lobsters by rock lobster licence holders diving shows some differences between the number of days from the recall, diary and mail surveys (Figure 4.5.21). The proportion of responses from the recall survey were closer to the diary than the mail survey responses. The differences were tested using a Kolmogorov-Smirnov test.



**Figure 4.5.21: Cumulative density functions: number kept by divers: rock lobster licence holders (a) and umbrella licence holders (b)**

For rock lobster licence holders the Kolmogorov-Smirnov test showed that there was no significant difference between the distributions of number kept from the telephone diary survey and the telephone recall surveys ( $p = 0.972$ ), the telephone diary and the mail survey ( $p = 0.242$ ) or between the telephone recall survey and the mail survey ( $p = 0.174$ ), so the null hypothesis was accepted in each case.

For umbrella licence holders the Kolmogorov-Smirnov test showed that there was no significant difference between the distributions of number kept from the telephone diary survey and the telephone recall surveys ( $p = 0.271$ ), the telephone diary and the mail survey ( $p = 0.071$ ) or between the telephone recall survey and the mail survey ( $p = 0.585$ ), so the null hypothesis was accepted in each case.

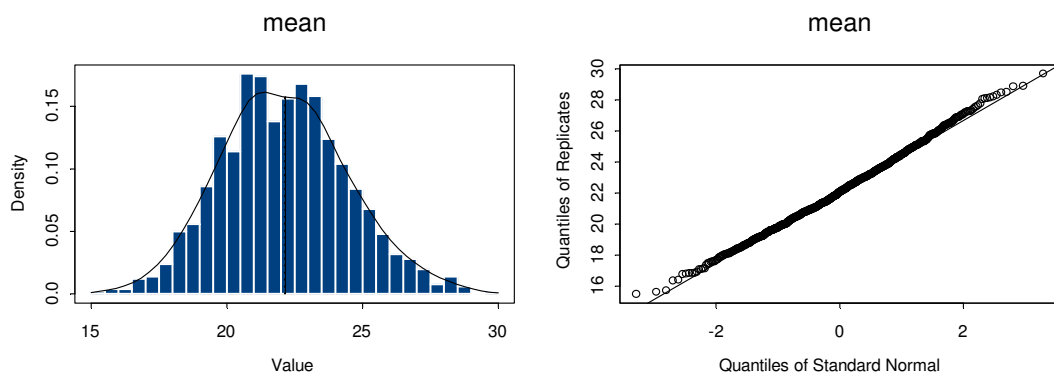
#### 4.5.6 Bootstrapped Results

A bootstrap estimate of catch was calculated for both the diary and recall survey. It was not required for the mail survey as it is already calculated using this bootstrapping.

##### Diary Survey

The total catch of western rock lobsters for rock lobster and umbrella licence holders was calculated using bootstrap estimates of the mean catch and bootstrap estimates of the variance. This was calculated separately for rock lobster licence holders and umbrella licence holders.

The symmetrical distribution of bootstrapped estimates of the mean catch by rock lobster licence holders shows a mean of 22.2 (Figure 4.5.22).



**Figure 4.5.22: Distribution of bootstrapped estimates for the mean number of rock lobsters kept by rock lobster licence holders (Diary Survey)**

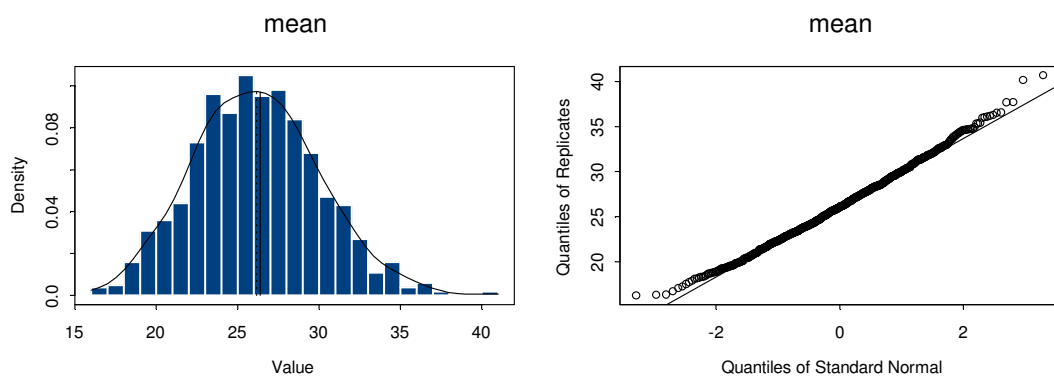


The bootstrap estimates for the mean catch and the variance associated with that catch by umbrella licence holders were used to calculate the total catch. There is very little difference between the bootstrap estimates and the original estimates (Table 4.5.8).

**Table 4.5.8: Comparison between bootstrapped and initial estimates for Rock Lobster Licence Holders (Diary Survey)**

Totals	Initial Estimates	Bootstrapped Estimates
C	312,979	312,057
SE(C)	40,443	37,726

The distribution of bootstrapped estimates of the mean number of days fished by umbrella licence holders shows a mean of 26.4 and a symmetrical distribution about the mean (Figure 4.5.23).



**Figure 4.5.23: Distribution of bootstrapped estimates for the mean number of rock lobsters kept by umbrella licence holders (Diary Survey)**

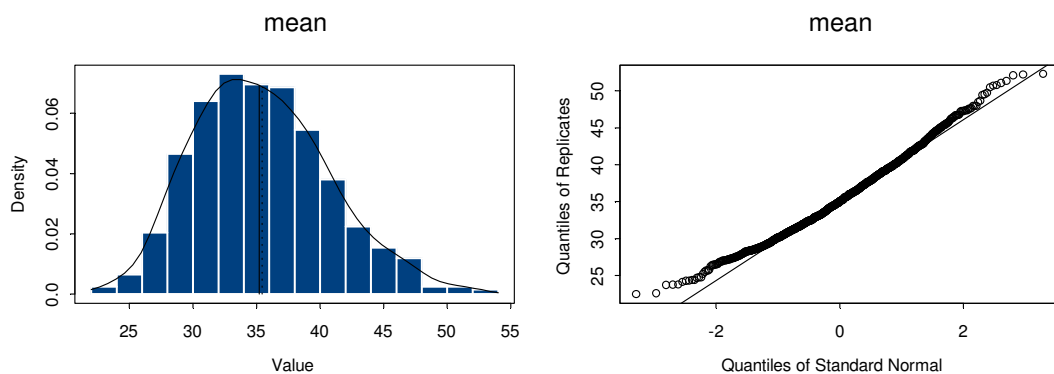
The bootstrap estimates for the mean catch and the variance associated with that catch by umbrella licence holders were used to calculate the total catch. There is very little difference between the bootstrap estimates and the original estimates (Table 4.5.9).

**Table 4.5.9: Comparison between bootstrapped and initial estimates for umbrella licence holders (Diary Survey)**

Totals	Initial Estimates	Bootstrapped Estimates
C	156,053	156,176
SE(C)	27,574	25,139

### Recall Survey

The distribution of bootstrapped estimates of the mean catch by rock lobster licence holders shows a mean of 35.2 and a nearly symmetrical distribution about the mean (Figure 4.5.24).



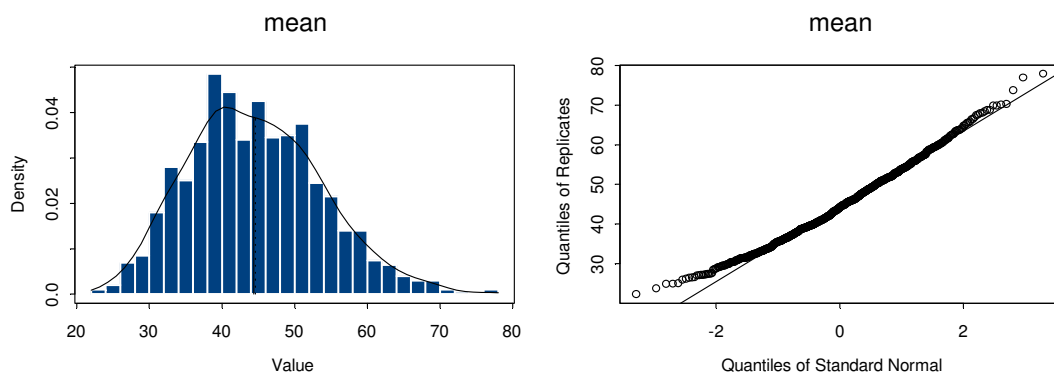
**Figure 4.5.24: Distribution of bootstrapped estimates for the mean number of rock lobsters kept by rock lobster licence holders (Recall Survey)**

The bootstrap estimates for the mean catch of western rock lobsters and the variance associated with that catch by rock lobster licence holders were used to calculate the total catch. There is very little difference between the bootstrap estimates and the original estimates (Table 4.5.10).

**Table 4.5.10: Comparison between bootstrapped and initial estimates for Rock Lobster Licence Holders (Recall Survey)**

Totals	Initial Estimates	Bootstrapped Estimates
C	591,262	593,248
SE(C)	82,542	91,782

The distribution of bootstrapped estimates of the mean catch by umbrella licence holders shows a mean of 44.4 and a nearly symmetrical distribution about the mean (Figure 4.5.25).



**Figure 4.5.25: Distribution of bootstrapped estimates for the mean number of rock lobsters kept by umbrella licence holders (Recall Survey)**

The bootstrap estimates for the mean catch of western rock lobsters and the variance associated with that catch by umbrella licence holders were used to calculate the total catch. There is very little difference between the bootstrap estimates and the original estimates (Table 4.5.11).

**Table 4.5.11: Comparison between bootstrapped and initial estimates for umbrella licence holders (Recall Survey)**

<b>Totals</b>	<b>Initial Estimates</b>	<b>Bootstrapped Estimates</b>
C	263,620	263,310
SE(C)	49,756	56,268

#### **4.5.7 Digit Preference**

Digit preference occurs if a respondent rounds their estimate to the nearest 5 or 10. The expected catches ending in a zero or five should be around 20%. Table 4.5.12 shows that the recall survey (61% and 63%) and mail survey (50% and 47%) far exceed the 20% level.

**Table 4.5.12: Proportion of catch ending in zeros or fives**

		<b>0</b>	<b>5</b>	<b>0 and 5</b>
Diary	RL (%)	16.28	11.63	27.91
	UM (%)	20.37	7.41	27.78
Recall	RL (%)	47.83	13.04	60.87
	UM (%)	55.56	7.07	62.63
Mail	RL (%)	39.84	9.99	49.83
	UM (%)	35.37	11.90	47.27

Around 50% of mail survey respondents record their catch ending in a zero or a five. Most recall respondents' catches end in a zero. The proportion of diary catches may be higher than the 20% due to the high proportion of licence holders who fish together and share their catch.

Aggregate digit preference was determined for all three surveys by licence type (Table 4.5.13). The diary survey measures of ADP for umbrella licence holders were negative indicating that ADP did not exist. The ADP for the rock lobster licence holders was positive but very close to zero. Both the recall and mail surveys measures of ADP were largely positive indicating evidence of ADP. The ADP for the diary survey was estimated using the calculated sums of rock lobster catches. To check whether this had an affect on the results ADP was estimated using individual days catches (ADP = -0.07).

**Table 4.5.13: Aggregate Digit Preference (ADP)**

		<b>Sum of Residuals</b>	<b>ADP</b>
Diary	RL	7	0.05
	UM	-94	-1.45
Recall	RL	2,591	24.75
	UM	2,222	27.33
Mail	RL	14,794	18.74
	UM	46,90	15.85

#### 4.5.8 Winsorization

Two methods of winsorization were used on the recall and mail survey catch datasets. The simplest use of winsorization is to truncate the series at four standard deviations from the mean. Both the winsorized recall and mail survey estimates are significantly greater than the diary estimates of catch (Table 4.5.14). The estimates are 1.6 times and 1.7 times greater than the diary estimates for the recall and mail surveys respectively.

**Table 4.5.14: Truncation winsorization for the telephone recall and mail surveys**

	Recall Survey	Mail Survey
C (Initial Estimate)	854,882	1,092,953
C (Initial Estimate Tonnes)	427	546
C (Winsorization Estimate)	551,827	775,295
SE(E)	65,442	38,461
Lower Limit (95%)	276	388
Upper Limit (95%)	212	350
C (Winsorization Estimate)	340	425

The second winsorization technique using the stratum factor and four standard deviations from the mean also produced results for the mail survey far in excess of the diary survey estimates (1.7 times).

The recall survey estimates are not significantly different from the diary survey results at only 1.2 times the diary estimates of catch (Table 4.5.15).

**Table 4.5.15: Stratum sampling winsorization for the telephone recall and mail surveys**

	Recall Survey	Mail Survey
C (Initial Estimate)	854,882	1,092,953
C (Initial Estimate Tonnes)	427	546
C (Winsorization Estimate)	551,727	776,840
SE(E)	65,442	38,711
Lower Limit (95%)	276	388
Upper Limit (95%)	212	350
C (Winsorization Estimate)	340	426

Interestingly, the simple truncation produced slightly better estimates for the mail survey and the sampling stratum factor winsorization produced much better estimates for the recall survey.

Other levels of winsorization were trialled on both the recall and mail survey data. Simple truncations at three standard deviations and sampling stratum calculations at three standard deviations were determined. None of these produced estimates of catch lower than those already reported.

#### 4.5.9 Interviewer Effect

The total catch from the diary survey was calculated as though each interviewer had interviewed the total sample. Figure 4.5.26 shows that if HM had been the only interviewer conducting the survey then the estimated catch would be considerably higher than the current estimate.

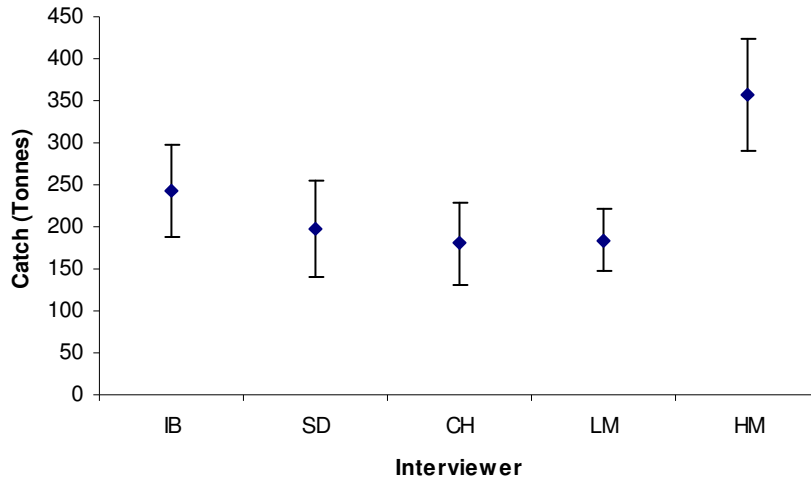


Figure 4.5.26: Comparison of catch by interviewer for the telephone diary survey

All the same interviewers conducted the telephone diary survey and the telephone recall survey. In the telephone recall a different interviewer, LM, had a higher estimated catch than the other interviewers (Figure 4.5.27).

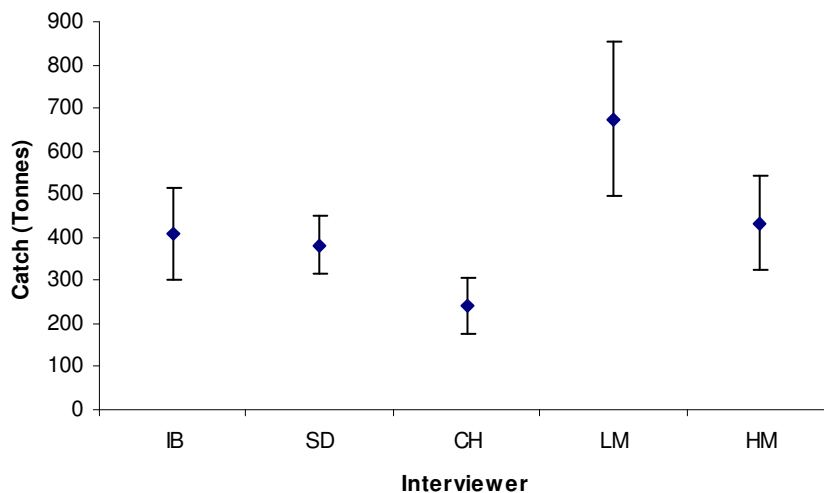


Figure 4.5.27: Comparison of catch by interviewer for the telephone recall survey



## 4.6 Catch Rate

### 4.6.1 Exploratory Data Analysis

#### Diary Survey

The exploratory data analysis of catch rates by rock lobster licence holders shows a skewed distribution (Figure 4.6.1). The average catch rate of rock lobsters was 1.56 and the median was 1.36.

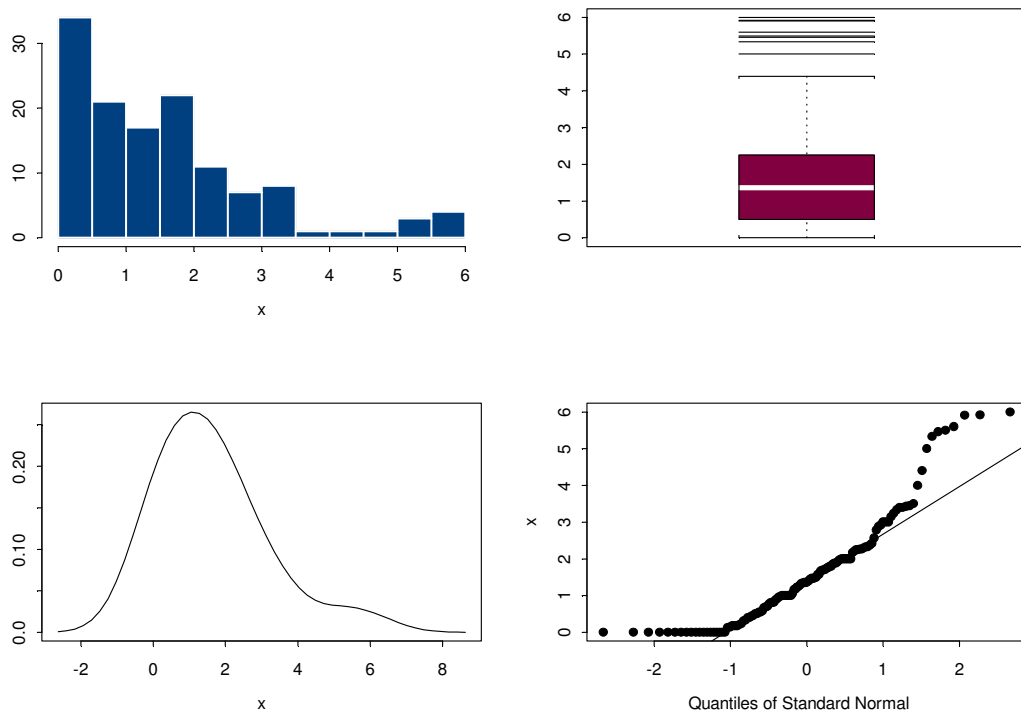
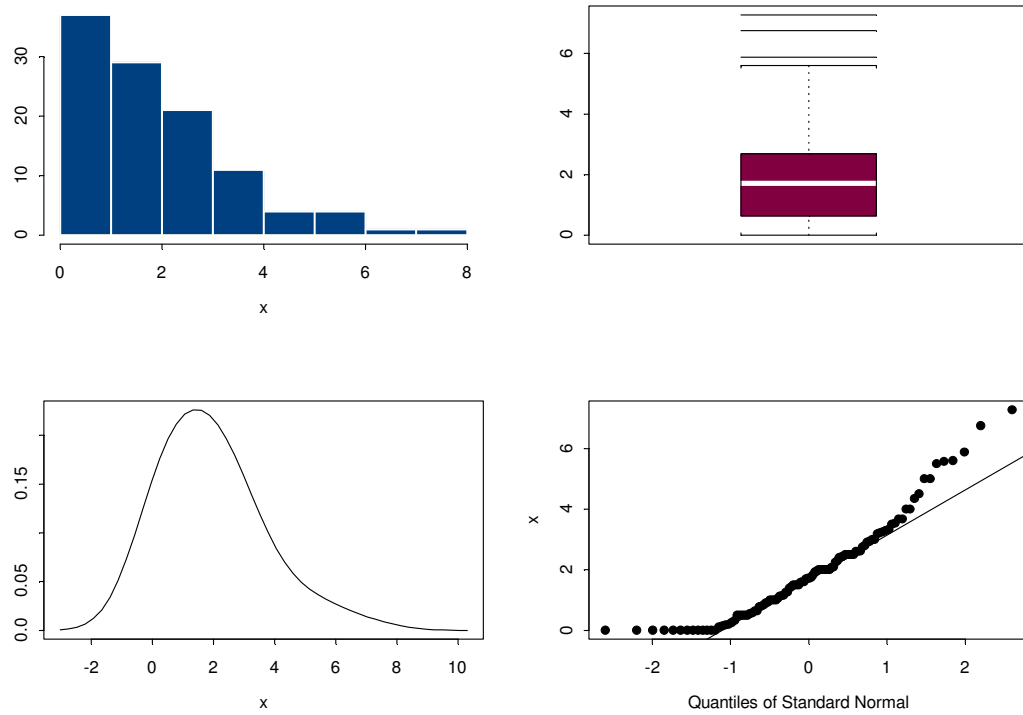


Figure 4.6.1: Exploratory data analysis of catch rates of western rock lobsters of rock lobster licence holders (Diary Survey)

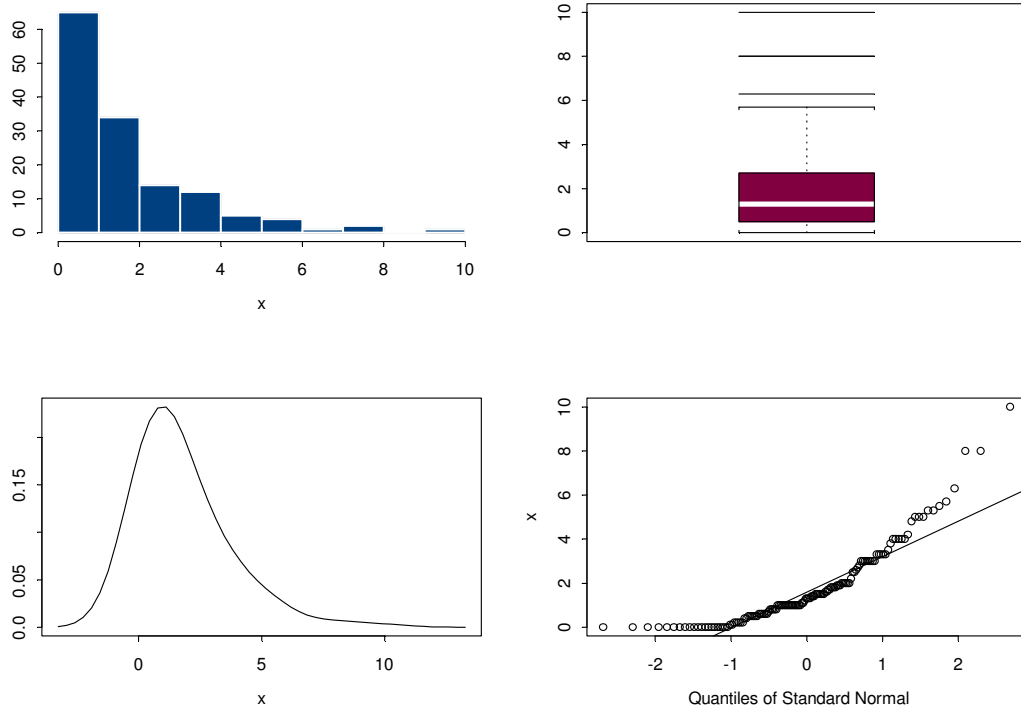
The exploratory data analysis of catch rates by umbrella licence holders shows a skewed distribution (Figure 4.6.2). The average catch rate of rock lobsters was 1.79 and the median was 1.72.



**Figure 4.6.2: Exploratory data analysis of catch rates of western rock lobsters of umbrella licence holders (Diary Survey)**

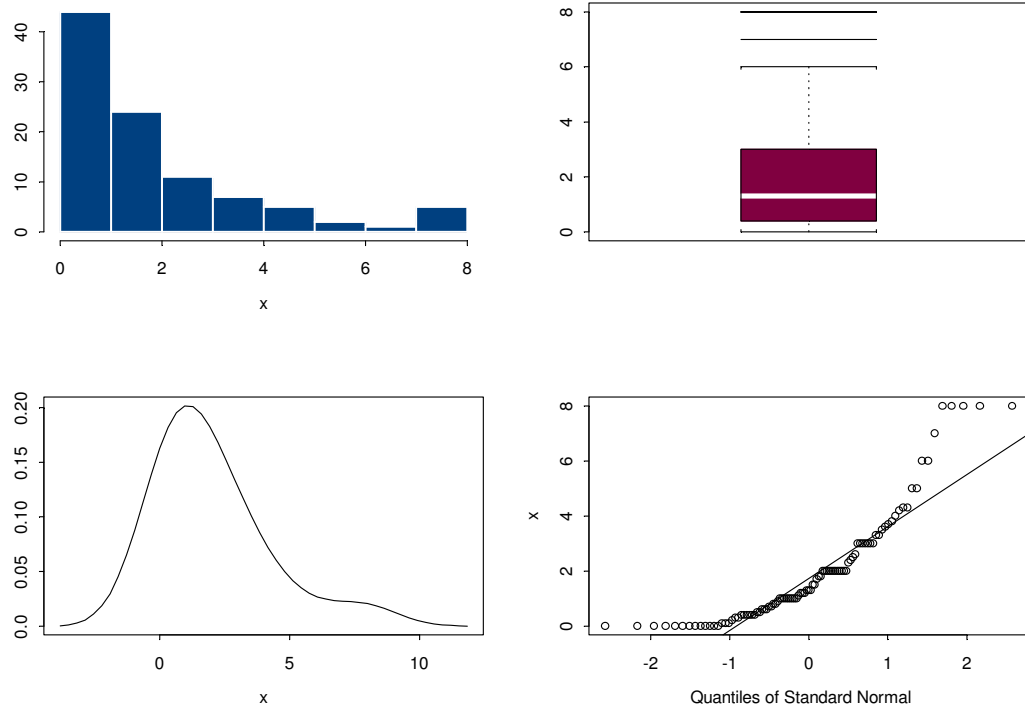
## Recall Survey

The exploratory data analysis of catch rates by rock lobster licence holders shows a skewed distribution (Figure 4.6.3). The average catch rate of rock lobsters was 1.72 and the median was 1.33.



**Figure 4.6.3:** Exploratory data analysis of catch rates of western rock lobsters of rock lobster licence holders (Recall Survey)

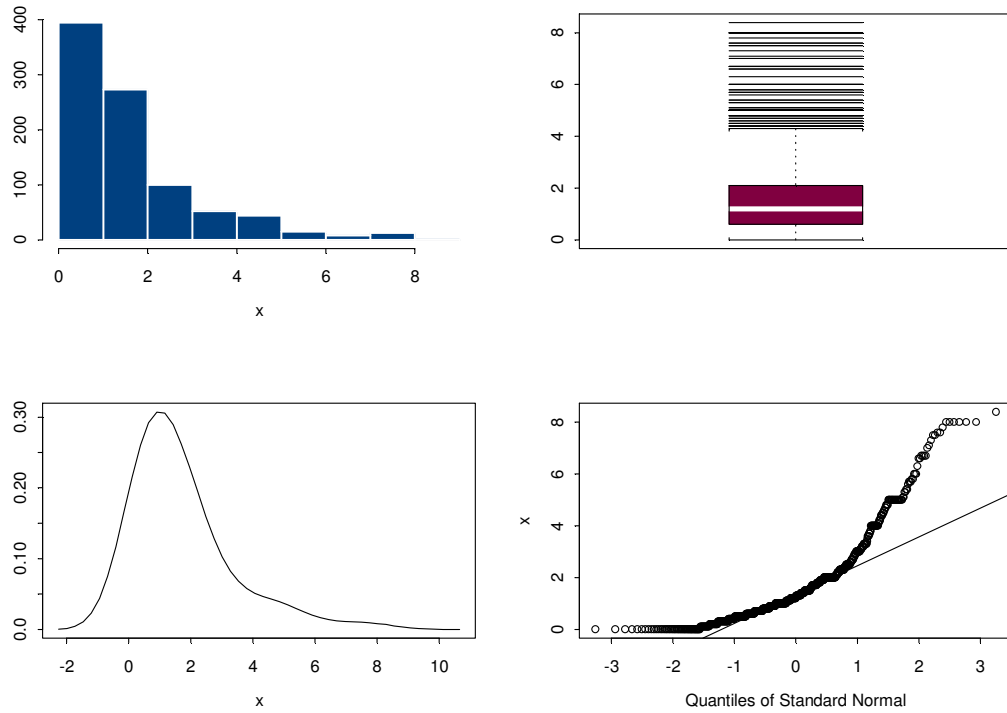
The exploratory data analysis of catch rates by umbrella licence holders shows a skewed distribution (Figure 4.6.4). The average catch rate of rock lobsters was 2.02 and the median was 1.33.



**Figure 4.6.4: Exploratory data analysis of catch rates of western rock lobsters of umbrella licence holders (Recall Survey)**

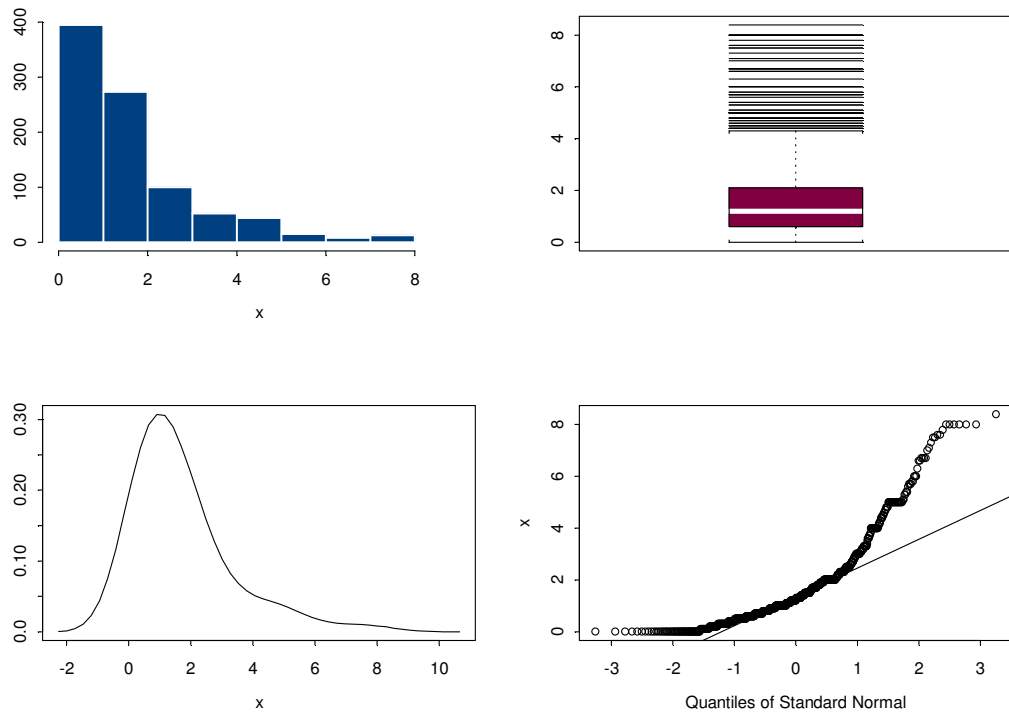
## Mail Survey

The exploratory data analysis of catch rates by rock lobster licence holders shows a skewed distribution (Figure 4.6.5). The average catch rate of rock lobsters was 1.71 and the median was 1.20.



**Figure 4.6.5:** Exploratory data analysis of catch rates of western rock lobsters of rock lobster licence holders (Mail Survey)

The exploratory data analysis of catch rates by umbrella holders shows a skewed distribution (Figure 4.6.6). The average catch rate of rock lobsters was 2.20 and the median was 1.50.



**Figure 4.6.6: Exploratory data analysis of catch rates of western rock lobsters of umbrella licence holders (Mail Survey)**

The catch rates for both types of licence holder and all three survey methods were very similar (Figure 4.6.7).

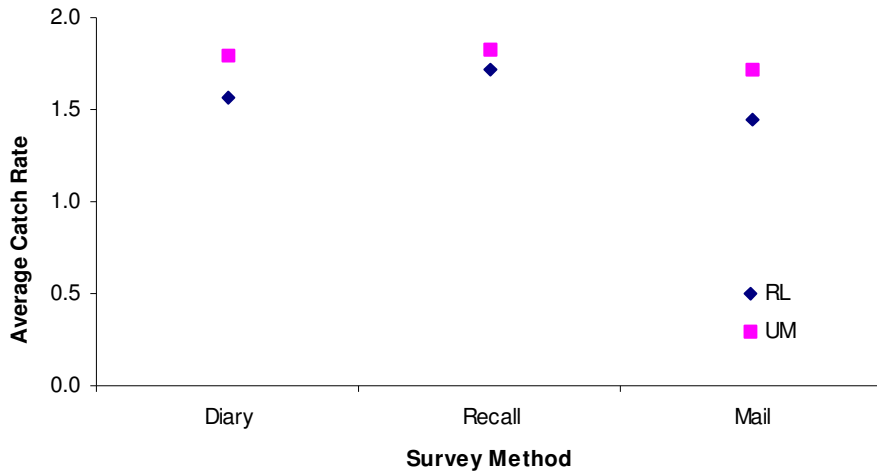


Figure 4.6.7: Average catch rate by licence type and survey method

#### 4.6.2 Catch Rate Estimates

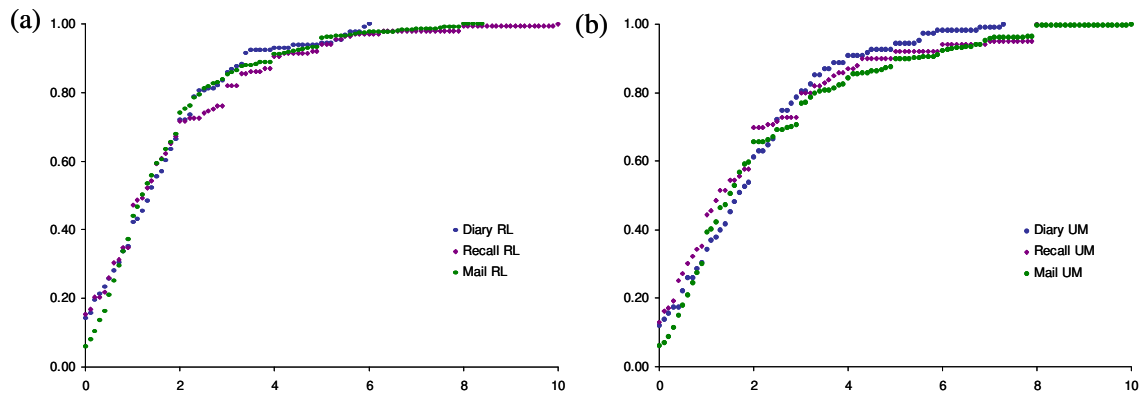
Estimated catch rates from the telephone recall survey were the highest at 1.8 western rock lobsters caught per fisher day. The mail survey had the lowest catch rate estimated at 1.5 (Table 4.6.1).

Table 4.6.1: Survey estimates of catch for the telephone diary, telephone recall and mail surveys

	Telephone Diary Survey	Telephone Recall Survey	Mail Survey
Catch Rate	1.63	1.80	1.51

### 4.6.3 Distributions

The cumulative density function for the catch rates of rock lobster licence holders shows very little difference between the catch rates from the recall, diary and mail surveys (a) (Figure 4.6.8). The catch rate distributions from umbrella licence holders were also quite similar (b).



**Figure 4.6.8: Cumulative density functions: catch rates by all respondents: rock lobster licence holders (a) and umbrella licence holders (b)**

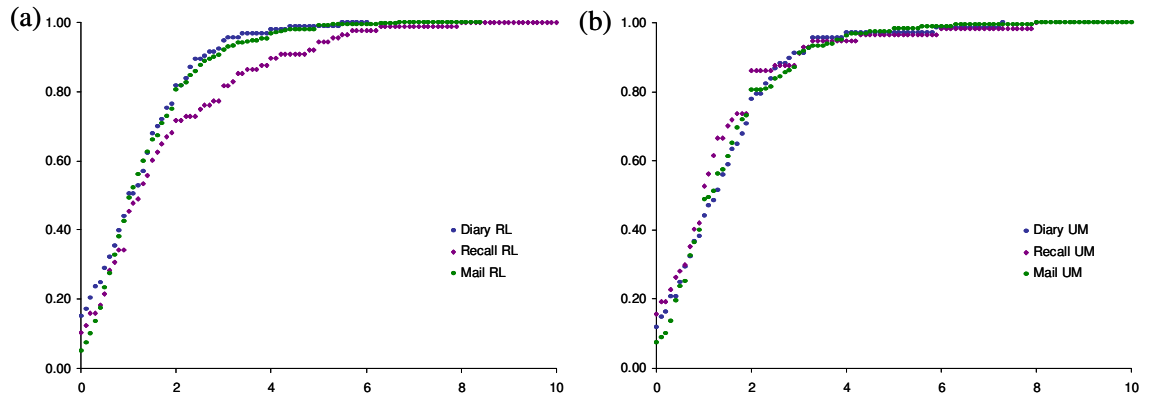
For rock lobster licence holders the Kolmogorov-Smirnov test showed that there were no significant differences between the distribution of catch rates from the telephone diary survey and the mail survey ( $p = 0.154$ ), telephone diary survey and the telephone recall surveys ( $p = 0.674$ ), or between the telephone recall survey and the mail survey ( $p = 0.163$ ). In each case the null hypothesis was accepted at the 0.05 level of significance.

For umbrella licence holders the Kolmogorov-Smirnov test showed that there were no significant differences between the distribution of catch rates from the telephone diary survey and the telephone recall surveys ( $p = 0.408$ ), the telephone diary survey and the mail survey ( $p = 0.537$ ), or between the telephone recall survey and the mail survey ( $p = 0.383$ ). In each case the null hypothesis was accepted at the 0.05 level of significance.



## Potters

The cumulative density function for the catch rate by rock lobster licence holders (a) and umbrella licence holders (b) using pots shows very little difference between the catch rate from the recall, diary and mail surveys (Figure 4.6.9).



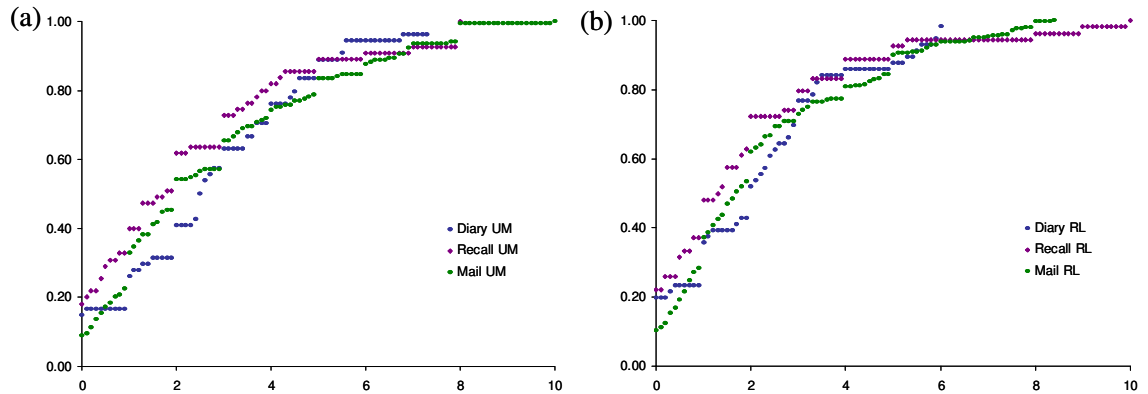
**Figure 4.6.9: Cumulative density functions: catch rates by potters: rock lobster licence holders (a) and umbrella licence holders (b)**

For rock lobster licence holders the Kolmogorov-Smirnov test showed that there was no significant difference between the distributions of catch rates from the telephone diary survey and the telephone recall surveys ( $p = 0.134$ ), the telephone diary and the mail survey ( $p = 0.312$ ) or between the telephone recall survey and the mail survey ( $p = 0.114$ ), so the null hypothesis was accepted in each case.

For umbrella licence holders the Kolmogorov-Smirnov test showed that there was no significant difference between the distributions of catch rates from the telephone diary survey and the telephone recall surveys ( $p = 0.383$ ), the telephone diary and the mail survey ( $p = 0.847$ ) or between the telephone recall survey and the mail survey ( $p = 0.512$ ), so the null hypothesis was accepted in each case.

## Divers

The cumulative density function for the catch rate by rock lobster licence holders (a) and umbrella licence holders (b) diving for rock lobsters shows very little difference between the catch rate from the recall, diary and mail surveys (Figure 4.6.10).



**Figure 4.6.10: Cumulative density functions: catch rates by divers: rock lobster licence holders (a) and umbrella licence holders (b)**

For rock lobster licence holders the Kolmogorov-Smirnov test showed that there was no significant difference between the distributions of catch rates from the telephone diary survey and the telephone recall surveys ( $p = 0.150$ ), the telephone diary and the mail survey ( $p = 0.591$ ) or between the telephone recall survey and the mail survey ( $p = 0.288$ ), so the null hypothesis was accepted in each case.

For umbrella licence holders the Kolmogorov-Smirnov test showed that there was no significant difference between the distributions of catch rates from the telephone diary survey and the telephone recall surveys ( $p = 0.083$ ), the telephone diary and the mail survey ( $p = 0.265$ ) or between the telephone recall survey and the mail survey ( $p = 0.368$ ), so the null hypothesis was accepted in each case.

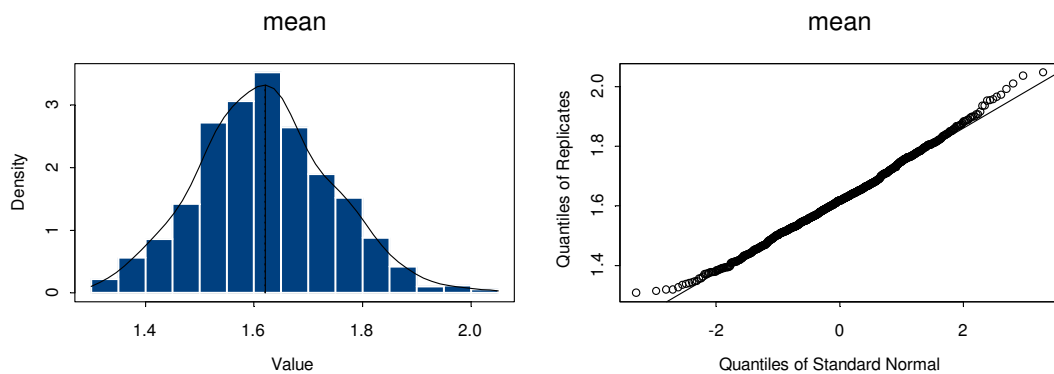
#### 4.6.4 Bootstrapped Results

A bootstrap estimate of catch rate was calculated for both the diary and recall survey. It was not required for the mail survey as it is already calculated using bootstrapping.

##### Diary Survey

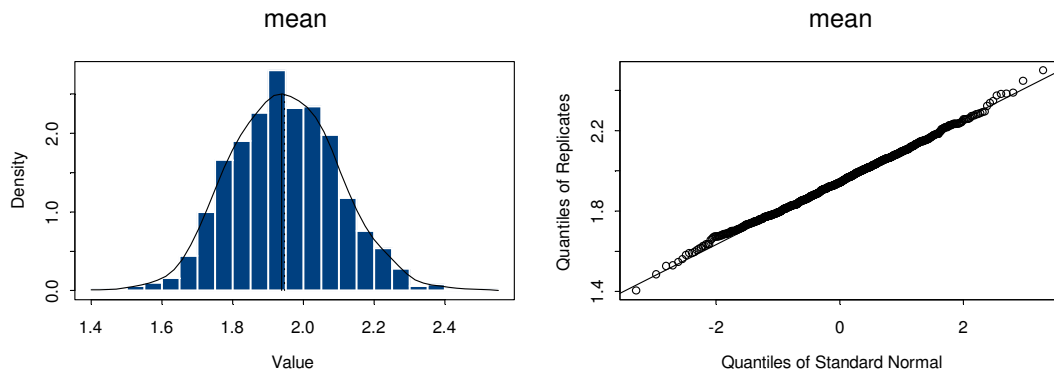
The catch rate of western rock lobsters for rock lobster and umbrella licence holders from the diary survey was calculated using bootstrap estimates of the average catch rate and bootstrap estimates of the variance. This was calculated separately for rock lobster licence holders and umbrella licence holders.

The distribution of bootstrapped estimates of the mean catch by rock lobster licence holders shows a mean of 1.62 and a symmetrical distribution about the mean (Figure 4.6.11).



**Figure 4.6.11: Distribution of bootstrapped estimates for catch rates by rock lobster licence holders (Diary Survey)**

The distribution of bootstrapped estimates of the mean catch by umbrella licence holders shows a mean of 1.94 and a symmetrical distribution about the mean (Figure 4.6.12).

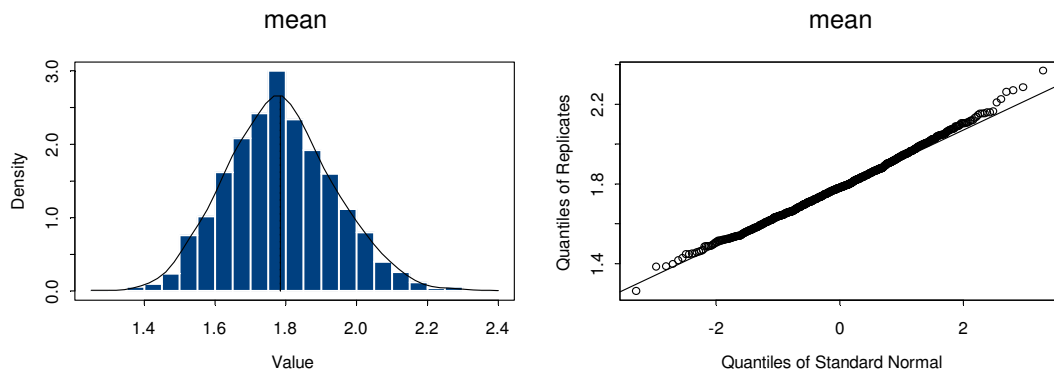


**Figure 4.6.12: Distribution of bootstrapped estimates for catch rates by umbrella licence holders (Diary Survey)**

#### Recall Survey

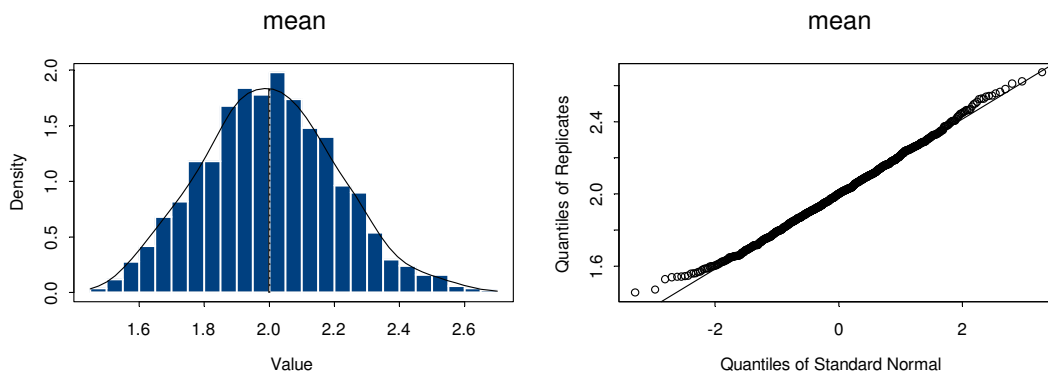
The catch rate of western rock lobsters for rock lobster and umbrella licence holders from the recall survey was calculated using bootstrap estimates of the average catch rate and bootstrap estimates of the variance. This was calculated separately for rock lobster licence holders and umbrella licence holders.

The distribution of bootstrapped estimates of the mean catch by rock lobster licence holders shows a mean of 1.78 and a symmetrical distribution about the mean (Figure 4.6.13).



**Figure 4.6.13: Distribution of bootstrapped estimates for catch rates by rock lobster licence holders (Recall Survey)**

The distribution of bootstrapped estimates of the mean catch by umbrella licence holders shows a mean of 2.00 and a symmetrical distribution about the mean (Figure 4.6.14).



**Figure 4.6.14: Distribution of bootstrapped estimates for catch rates by umbrella licence holders (Recall Survey)**

The bootstrap estimates for the recall and diary surveys were very similar to the initial catch rate estimates (Table 4.6.2).

**Table 4.6.2: Estimates of catch rate for the telephone diary and telephone recall surveys**

		Diary	Recall
RL	Initial Estimate	1.57	1.72
	Bootstrap Estimate	1.62	1.78
UM	Initial Estimate	1.79	2.02
	Bootstrap Estimate	1.84	1.99

#### 4.6.5 Interviewer Effect

There was no significant difference in estimated catch rates between interviewers for telephone diary survey (Figure 4.6.15).

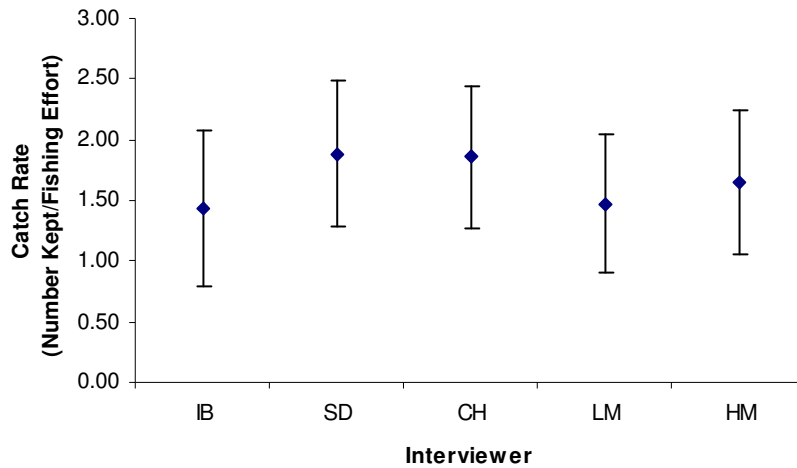


Figure 4.6.15: Comparison of catch rates by interviewer for the telephone diary survey

There were some differences in estimated catch rates by interviewer for the telephone recall survey (Figure 4.6.16). Interviewer LM had a slightly higher estimated catch rate and HM was slightly lower than the other interviewers.

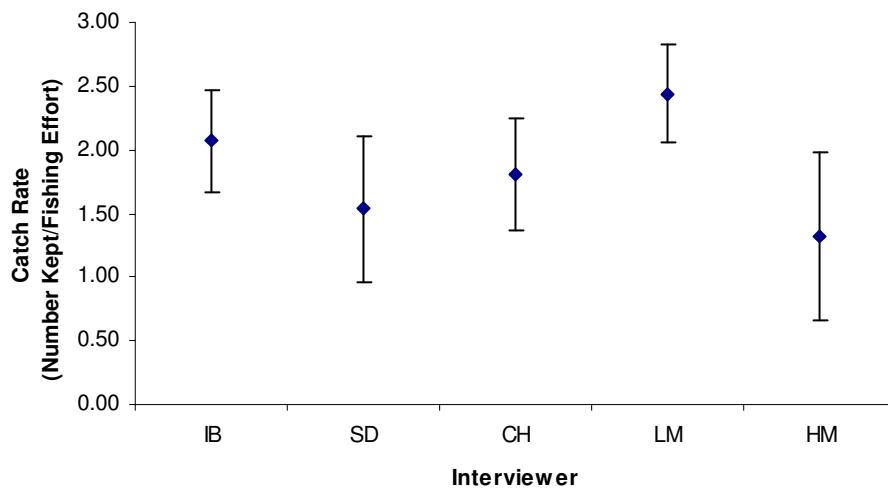


Figure 4.6.16: Comparison of catch rates by interviewer for the telephone recall survey

## **5.0 DISCUSSION**

### **5.1 Overview of Survey Methods**

An evaluation of the mail, telephone recall and telephone diary surveys has revealed advantages and disadvantages for each method. The cost, expertise required and duration of the surveys were weighed against the accuracy, reliability and susceptibility to bias in order to determine the most effective survey method. The mail survey was a low cost method for a large sample size but was highly affected by non-response and recall bias. The telephone recall survey was the least expensive method but recall bias still caused an overestimation of catch and effort. The telephone diary survey was the most expensive method but was free of non-response and recall bias and provided the most accurate estimates of recreational catch and fishing effort of western rock lobsters in Western Australia.

#### **Mail Survey**

The mail survey has a number of advantages over telephone surveys. It is not particularly expensive to run given the large sample size. There are no staff costs to conduct the research other than overseeing the sampling, mail out and data analysis. A larger sample may be selected with only the cost of the postage and printing to consider.

Respondents are able to respond to the questionnaire in their own time and at their convenience, which allows them to read the entire questionnaire before they answer any questions. Respondents to a mail survey may also feel more confident that their answers are confidential, particularly if they have the option of whether or not to include their name. Unlike a telephone survey, a mail survey does not have to be concerned with interviewer bias.

Mail surveys can take considerable time to finalise. Respondents may not return their questionnaire in a timely fashion and there is no guarantee that the person sent the questionnaire in the household is the one that fills in the answers. Some respondents in

the 2001/02 rock lobster mail survey were not actually in the selected sample. It appeared that another member of the household answered in their place.

Respondents are not able to seek clarification of a question and may skip questions accidentally or deliberately. Sometimes it is a disadvantage to the study for respondents to know the next question before an earlier one is entered, as they may not work through the questionnaire in the correct order. There is also no opportunity to verify questions that appear to be answered incorrectly.

The key disadvantages of the mail survey are the low response rates and length of recall. As there is a relationship between the people that respond and their fishing activity this leads to non-response bias. Recall bias exists in surveys that require a long recall period (Pollock *et al*, 1994; Tarrant *et al*, 1993).

### **Telephone Recall Surveys**

Telephone surveys have increased in popularity as telephone ownership has increased. However, the technology for avoiding telemarketers has also increased because people value their privacy and their time. Silent numbers, caller ID and answering machines all assist with avoiding calls. It is therefore important to limit the length of a telephone interview to ensure high response rates.

There are a number of advantages of telephone surveys over other data collection methods. A telephone survey asks for the respondent by name, allows clarification of questions and can confirm unusual answers at the time of the interview. Questions can also be skipped where appropriate and the recall period for the study is known. Most telephone surveys allow the data to be collected quickly and there is no delay in receiving responses or the need for reminders to be sent (Pollock *et al*, 1994). The telephone recall survey was the least expensive of the rock lobster surveys.

The design of the questionnaire is an important part of the survey process. Questionnaires that are long, cumbersome, or unclear increase the chance of missed questions or giving the wrong information to the respondent. A number of questionnaire conventions were introduced for all the telephone surveys to simplify the questionnaire and give the interviewer clear instructions.

Telephone recall surveys have some disadvantages. Many people screen their calls so actually making contact with respondents can be a time consuming process.



Some people can not be contacted due to wrong or disconnected numbers. These non-respondents are not of concern, as their fishing activity is not related to their being a non-respondent. Telephone interviewers need to be trained and may introduce a bias in the results.

Another disadvantage of telephone recall surveys is that respondents do not have long to think about their responses. This may be the cause of the increased digit preference found in the telephone recall survey compared to the mail survey. The questionnaire for the telephone recall survey asked respondents to recall total catch and total effort for the season. This may be more accurate than respondents' attempting to estimate an average catch and effort.

Telephone recall surveys have the advantages of a telephone survey in the reduction of non-response bias but still have a problem with the length of recall. A national telephone survey of recreational fishing in the United States of America found that four month recall period to be the optimum in terms of length of recall and cost (Essig and Holliday, 1991). So the telephone recall survey in this study, with a recall period of eight months, was going to have a problem with recall bias.

### **Diary Survey**

The telephone diary survey utilised the benefits of a telephone survey combined with the benefits of a diary (Coleman, 1998). Respondents were able to record their fishing activity after each event and then read them out to the interviewer over the telephone each month. There was a high level of respondent commitment, particularly for respondents with high levels of activity. To reduce the length of the telephone interviews, the interviewers collected the information that remained unchanged for all events (location, fishing platform) and then recorded dates, times and catches one after another. The interviewer then filled in these details after the call, minimising the call length for the respondent and ensuring that respondents were content to remain in the study.

The interviewer's questionnaire was designed to have clear sections, using white on black writing and black borders, to reduce missing answers and improve the ease of recording the answers. Each questionnaire had minimal written instructions on the actual sheet. Questionnaires cluttered with excess information can lead to confusion for the interview and may slow down the interview. This in turn makes it more difficult for

the respondent to answer accurately. However, if the interviewer comes across a situation that cannot be answered simply, a separate instruction sheet was written for each questionnaire. If the interviewer still can not find the solution they were instructed to telephone the author. By using clear questionnaires the interviewers gain confidence and this in turn improves the data collection for long term surveys.

Some previous diary surveys have had problems with drop out of diarists (Connelly and Knuth, 1999). The drop out rate for the telephone diary survey in this study was less than 1% and the non-contact rate was also less than 1%. Other surveys using diaries do not telephone the participants each month. Rather they wait until the end of the survey period and request the respondents to return their diaries. While this has been found to have better results than relying on recall, diary holders do not get the monthly reminder to continue completing their diary which leads to a greater recall period than the monthly calls. Monthly calls also ensure that the survey is operating according to plan. There are no surprises at the end of the study and each month the interviewers can encourage the respondents to fill in their diaries and continue in the survey.

Studies have found that respondents' ability to recall deteriorates after two months (Tarrant and Manfredo, 1993; Fisher *et al*, 1991). The telephone diary survey is designed to minimise recall time. If a diary holder does not record their fishing activity in their diary then the greatest recall period should be the one month since the last call. Even in cases where a respondent is hard to contact the recall period does not exceed two months. At the start of the survey, the respondent is asked to provide a name and phone number of someone who will know their new details if they move unexpectedly. While this is a difficult question for most people to answer it has saved a lot of time tracking down the respondents whereabouts. Where contact has been lost due to a move or household change and there is no other contact person, the new contact details are looked up on the whitepages online or letters are sent.

The telephone interviewers used a green card to note each contact made with each respondent. On this card they could record anything of interest about the respondent to make it easier for them to recall the person to mind before they were telephoned. These notes are very important when building rapport with the respondent. Each diary holder is made to feel that they are important and this encourages them to record their fishing activity in their diary and continue participating in the study. At the

completion of the diary survey many respondents are saddened that this is their final call and often express the wish to participate in other studies. This reflects very well on the telephone interviewers.

The training and support of the telephone interviewers is extremely important. Ensuring that they fully understand the project guidelines and how to record the answers is imperative for the overall success of the study. Each of the interviewers had extensive training for the telephone diary survey and regular contact with their supervisor. They were able to contact their supervisor after hours to ask questions when they were working rather than having to wait until office hours. Problems were resolved at the time and the interviewer could resume work confidently. Within the training sessions practice interviews were conducted to help clarify the flow of questions and illuminate any problems or misunderstandings.

All questions in the telephone surveys were closed questions; most had the answer written on the questionnaire that just had to be circled. There was space for comments but these were kept to a minimum and only used to help explain unusual activity. This meant that the validation was simpler, data entry was fast, the data analysis was effortless and there was no misinterpretation.

The diary survey allowed the respondent who fished with another person to report a shared catch. A large number of potters fished in a boat with a friend or family member and shared the catch. The other survey methods request the catch for the licence holder only which can lead to a bias in results. This is evident where two people go fishing together using pots and their combined catch is three rock lobsters. The respondent then has to decide to overestimate or underestimate, as there is no provision to equally share the catch. The respondents also have to recall that the catch was shared.

A problem with the diary survey is the high cost and level of expertise required. The cost of the telephone diary survey is more than double the cost of the mail survey. The planning for a telephone diary survey is extremely important and usually requires two to three months' preparation before the start of the study. If the standard errors around the estimates of catch and effort need to be reduced then the cost of increasing the sample size is quite substantial.

## 5.2 Participation

The differences in levels of participation between the surveys were caused by a combination of recall and non-response bias in the mail survey and recall bias in the telephone recall survey. The high estimate of participation together with higher effort estimates indicated that the non-respondents in the mail survey were more likely to be non-fishers or fishers who only fished a small number of times. Conversely, keen fishers were more likely to respond resulting in over representation in the sample.

This response of fishers was evident in the diary screening survey, where people who did not fish regularly, or did not intend to fish, were reluctant to be involved in the survey or even suggested other people they knew who fished more. This effect of non-response bias was further emphasized in the mail survey by the low response rates resulting in a sample of fishers not representative of the population of rock lobster fishers.

The high response rates in the telephone recall and telephone diary survey minimised the influence of non-response bias in the telephone surveys. The persistence of the telephone interviewers contributed to the high response rates.

Recall bias resulted in overestimated participation estimates for the telephone recall survey and mail survey. Respondents may report what they normally do rather than remembering actual episodes. People minimise poor behaviour or unhappy events and tend to exaggerate socially desirable behaviour or events (Chu *et al*, 1992). Consequently, fishers may recall fishing events from previous seasons or report the amount they usually fish. As the season covered months in two calendar years people may have had more difficulty accurately recalling fishing events and may have recalled a time period greater than the one requested. This type of recall error, known as telescoping error, has been documented in other recall studies (Pollock *et al*, 1993). Telescoping error is most likely responsible for the overestimation of participation in the telephone recall survey.

Differences in participation by month were evident between the recall and diary surveys and indicate that recall bias varied across the season. The impact of recall bias appeared to be compounded for fishing events at the start of the season, when the recall period was greatest and participation was highest. Interestingly, recall survey

participants underestimated participation for the months of March and April. This may relate to respondents not recalling their participation around Easter when there is usually a second peak in levels of participation. The participation by month was greatly overestimated by the mail survey for all the months of the season except for the low participation months, May and June, when the recall period was shortest.

Interestingly, there were no differences in levels of participation between surveys for umbrella licence holders. The participation of umbrella licence holders did not appear to be strongly influenced by non-response or recall bias. Umbrella licence holders who did not fish were more likely to respond accurately to the mail survey than rock lobster licence holders who did not fish. The reduced influence of recall bias on the mail and telephone recall survey for umbrella licence holders could be explained by differences in the attitudes of these fishers, since umbrella licence holders may not expect to fish every season or may purchase an umbrella licence with no intention of utilising the rock lobster component.

### 5.3 Calculation Methods

Three different calculations were applied to the telephone surveys to estimate effort, catch and their associated standard errors. These estimates were supported by the bootstrapped estimates. The central limit theory assumption was shown to be correct for all three calculation methods as the distributions of the bootstrap estimates were symmetrical about the mean and close to normally distributed.

The calculation methods that use the participation rate were particularly relevant to the fishery (Methods 2 and 3) since levels of participation in a fishery and the total number of fishers that went fishing in a particular season are both important in the management of the fishery.

The calculations developed by the author, Methods 2 and 3, yield additional information in a single method. Method 2 provides the most additional information about each strata including participation, total number of fishers and catch rates making it the most useful of the three methods investigated. The additional statistics estimated by Method 2 would improve comparisons between seasons.

In this case it also made comparison between surveys easier, as an array of information can be quickly compared. Similar estimated catch rates between survey methods hid significant differences in levels of participation. Method 2 has since been used for all telephone surveys of recreational fishing in Western Australia.

## 5.4 Fishing Effort

### Exploratory data analysis

The number of days fished estimated by the three survey methods differed considerably. The diary estimate was lowest, followed by the telephone recall and then the mail survey. This supported the hypothesis that the diary results were least biased, that the recall survey was affected by recall bias and that the mail survey was affected by both recall and non-response bias, with all biases resulting in overestimation of fishing effort.

The mail survey estimates of recreational fishing effort were 2.5 times greater than the telephone diary survey estimates. The telephone recall survey estimates were 1.7 times greater than the diary survey estimates. Both the recall survey and the mail survey had a high proportion of respondents reporting high numbers of days fished in the season, whereas the diary survey had a small number of respondents reporting high numbers of days fished for the season. Another study of recreational rock lobster fishing using a telephone recall survey (six month recall period) and telephone diary survey had a comparable result (Lyle, 1999) with estimates of effort being overestimated by around a factor of two. These results indicate that respondents were not able to accurately recall the number of days fished in a season, and tended to overestimate considerably. Since fishers who report high fishing effort are more likely to respond to the mail survey, the impact of recall bias is compounded in the mail survey estimates of effort.

The exploratory data analysis of all three surveys highlighted the differences between methods. All the survey methods demonstrated a skewed distribution but the average days fished and the length of the tail varied between methods. The number of respondents recalling a high number of days fished was greatest in the mail survey. There was a much lower proportion of total effort recorded for low numbers of days fished in both the recall and the mail survey. The long tails of the distributions were evidence of recall and non-response bias on the results.

The average days fished by licence type is similar for all three surveys, the difference in fishing effort between licence types seem to be due to the different levels of participation not the average number of days fished. The cumulative density

functions of all three methods by licence type showed significant differences between surveys. In general there was no significant difference between the telephone recall and mail surveys, but there were differences between the telephone diary and mail surveys. None of the differences were related to skewness or kurtosis. It appeared to be related to different proportions of low values and the length of tail of the distribution. The estimates of fishing effort by potters and divers were also examined and the same proportions existed between potters and divers for all three surveys. So there appears to be no relationship between fishing method and overestimation of effort.

One benefit of the mail survey was that the sample size was large and the resulting standard errors were relatively small. This produces estimates that are fairly precise if not accurate.

A limitation of the mail survey was that the number of days fished in each month did not necessarily add up to the total for the season. A comparison trialled in this study between the mail and telephone diary surveys to determine whether recall bias varied by month indicated that the bias varied over the season. Unfortunately, 28% of the monthly estimates did not add up to the total fishing days in the mail survey so the comparison was unable to be completed. Interestingly, the sum of the days fished for each month in the mail survey were lower than the total days fished, which is used to calculate effort. The days fished each month may provide a better estimate of effort because the respondents have to spend more time recalling actual events. In contrast, the telephone diary survey records each fishing event separately and did not require the respondent to report totals. The telephone recall survey provided the interviewer with an opportunity to confirm unusual fishing activity.

#### Digit preference

The measures of central tendency from all three surveys revealed strong digit preference in the telephone recall and mail surveys for both rock lobster and umbrella licence holders. The mean days fished are highest from the mail survey, lower for the telephone diary survey and lowest for the telephone diary survey. This indicates the bias in both the telephone recall and mail surveys. The mode days fished from the diary survey was one and considerably lower than the mode for the telephone recall and mail surveys. This indicated that both the telephone recall survey and the mail survey did not accurately capture fishers that fished a small number of days in the season, which resulted in overestimation of the days fished.



Digit preference appeared to have considerable affect on the fishing effort and could be one of the main components of recall bias. There was no evidence of digit preference in the telephone diary results because 95% of respondents diarised their fishing activity and the recall period for the other 5% was no longer than four weeks, with few fishing events to recall. Digit preference was evident for both the recall and the mail surveys. It appears to be greater for the recall survey (higher estimates of aggregate digit preference) than the mail survey, possibly due to mail survey respondents having more time to recall their fishing activity. However, the mail survey was still strongly affected by digit preference and hence overestimation of fishing effort.

#### Recall and non-response bias

Recall bias, including digit preference, explains the disparity between the telephone recall survey and the telephone diary survey. Other studies have also determined that recall bias leads to an overestimation of activity, some by a factor of three (Weithman, 1991). The extent of this overestimation is influenced by the level of participation and by the length of recall (Brown, 1991; Chu *et al*, 1992). Respondents that went fishing more often appear to have overestimated their participation to a greater degree than those who went less frequently.

Recall bias was also evident in the mail survey though it was not possible to separate the influence of recall bias from non-response bias in the estimation of fishing effort. However, the combination of non-response and recall bias in the mail survey lead to a far greater overestimation of fishing effort than that of recall bias alone in the telephone recall survey. Recall bias leads the recall survey to overestimate the level of fishing effort by 1.7 times for this rock lobster season. Recall bias and non-response bias leads the mail survey to overestimate the level of fishing effort by 2.5 times.

## 5.5 Catch

### Exploratory data analysis

The catch estimates by the three survey methods were significantly different. The diary survey estimate was lowest, followed by the telephone recall survey and then the mail survey. These estimates supported the hypothesis that the diary results were least biased, that the recall survey was affected by recall bias and that the mail survey was affected by both recall and non-response bias.

The mail survey estimates of recreational catch of western rock lobsters were 2.3 times greater than the telephone diary survey estimates, indicating the combined impact of non-response and recall bias. The telephone recall survey estimates were 1.8 times greater than the diary survey estimates due to recall bias.

The exploratory data analysis of all three surveys highlights the differences between methods. All the survey methods demonstrated a skewed distribution but the number caught and the length of the distribution's tail varied between methods. The number of respondents recalling a high catch was greatest in the mail survey and lowest in the telephone diary survey. There was a much smaller proportion of low catches recorded in both the recall and the mail surveys.

The cumulative density functions of all three methods by licence type were examined and significant differences were identified between the diary survey and the mail survey. None of the differences were related to skewness or kurtosis. There were no significant differences found between the distributions of catch from the recall and diary surveys. Recall bias alone did not affect the distribution of catch significantly, but the combination of recall bias and non-response bias in the mail survey lead to the differences between the mail and diary surveys.

The estimates of catch by potters and divers were also examined and the same proportions were found to exist between potters and divers for all three surveys. So there appeared to be no relationship between fishing method and overestimation of catch.

The reporting of shared catches was a problem with the mail survey, since it was assumed that respondents that fished with other licence holders reported only their

individual catch, not that of the group. Even when the individual reported their share of the catch accurately, rounding up to a whole number of lobsters may have resulted in overestimation of catch.

The catches of the other species of lobsters were also examined for each survey method. These species are much less common and a smaller number are caught each season (Tarrant and Manfredo, 1993). The difference between telephone recall survey and the telephone diary survey estimates of tropical and southern lobsters were consistent with the differences between western rock lobsters, indicating that recall bias was consistent across all species. The difference between the mail survey catch estimates for southern rock lobsters and the diary survey estimates was great, possibly exaggerated by species identification issues. The differences between the mail survey estimates and the diary survey for the catch of tropical lobsters was consistent with that of western rock lobsters, indicating that the biases in the mail survey were consistent across both species.

#### Digit preference

The measures of central tendency from all three surveys revealed that there was considerable non-response bias in the mail survey and that digit preference was greatest in the telephone recall survey and evident in the mail survey. The mode for the catch from rock lobster licence holders was zero for both the diary and the recall surveys and was zero for all three survey methods of umbrella licence holders. The much higher mode (20) of catches for the rock lobster licence holders in the mail survey was evidence that few fishers with small or zero catches responded to the mail survey.

The telephone diary results exhibited a small amount of digit preference, which was probably related to the high number of zero catches recorded. Digit preference was far greater in both the recall and the mail surveys, and appeared to be more prominent in the recall survey. This was probably because the mail survey respondents had more time to consider their answer than the recall survey respondents.

The peaks of catches at 6, 10, 12, 15 and 20 from the recall and mail surveys were evidence of rounding to a dozen and half a dozen, which will not be reflected in the determination of digit preference. This supported the hypothesis that the recall survey suffered from digit preference or rounding to a greater extent than the mail survey.

Digit preference has been shown to occur on “numbers that a person has a disposition to use instead of “true” values” (Vaske *et al*, 1996) not just zeros and fives. It is evident in this study that digit preference in reported catches includes dozen, half a dozen and could potentially include bag limits.

#### Recall and non-response bias

Other studies have determined that recall bias leads to an overestimation of activity (Fisher *et al*, 1991; Miller and Anderson, 2002; Tarrant and Manfredo, 2002; Connelly and Brown, 1995). The extent of this overestimation is influenced by the level of participation and by the length of recall (Chu *et al*, 1992; Chase and Godbey, 1983). Respondents that fished more often appear to have overestimated their catches to a higher level than those who went less frequently.

The recall and diary surveys had a similar number of zero catches, for both rock lobster and umbrella licence holders, while there were a much lower number of zero catches in the mail survey results for rock lobster licence holders. The lower number of zeros in the mail survey were evidence of non-response bias, probably caused by fewer responses from fishers who fished a low number of times or those who caught very little. This was eliminated in the telephone recall survey method by the high response rates in this study.

As there may be a correlation between recall and non-response bias (Tarrant and Manfredo, 1993) it was not possible to determine the levels of recall and non-response bias separately in the mail survey. The effect of recall bias leads the recall survey to overestimate the catch by 1.6 times. The combination of recall bias and non-response bias acting on the mail survey leads it to overestimate the catch by 2.3 times.

## **5.6 Catch Rates**

The catch rates estimated by the three survey methods were remarkably similar despite the significant differences in participation, fishing effort and catch. The estimated catch rates appeared not to be influenced by biases to the same extent as the catch or effort estimates, or catch and effort were overestimated equally.

The cumulative density functions of all three methods were examined and no significant differences between surveys were identified by licence type or by fishing method.

## 5.7 Interviewer Effect

There were different levels of participation, catch and effort between interviewers for both telephone surveys. The cause of these differences was unclear. All the interviewers on both telephone surveys had the same training and similar levels of telephone interviewing experience. The same interviewers conducted both the telephone diary and the telephone recall survey and all had equal number of respondents in both surveys. They also had equal numbers of umbrella and rock lobster licence holders.

Previous studies have shown that interviewers have more effect on open answered questions (Brick *et al*, 1995) than the closed questions in the telephone surveys in this study, particularly where opinions and responses need to be summarised before being recorded on the questionnaires. In this study the telephone interviewers had limited scope for influence.

The interviewer HM had significantly higher estimated effort and catch in the telephone diary survey. However, the catch rates were consistent between interviewers. This suggests that the sample HM received could have consisted of more prolific rock lobster fishers than that of the other interviewers. HM did not have a significantly different response rate in the screening survey to any of the other interviewers, so the difference in effort and catch were not due to biasing the people in the sample by being either more or less persuasive. The logistic regression of participation showed that less of HM's respondents actually went rock lobster fishing, so those that did fish were more avid.

In the telephone recall survey, LM had significantly higher estimates of effort and catch, and had a higher catch rate. LM's response rate for the telephone recall survey was not significantly different from the other interviews. LM may have had a sample with more avid fishers or may have influenced the respondents in some way. The logistic regression of participation also found that LM's respondents were less

likely to go fishing, so those that did participate were more avid fishers than the other interviewers' respondents.

Different interviewers caused the discrepancies between interviewers in each survey, indicating that there was not a problem with one interviewer in particular, and that the differences were possibly due to the samples rather than the interviewer.

## **5.8 Winsorization**

Winsorization is a useful technique for dealing with outliers and extreme values. One of the problems with surveys that rely on the recall of activities is that people overestimate the level of their activity, resulting in generally higher estimates and more extreme values. One of the disadvantages of the winsorization technique is that it uses the outliers in the calculation of the standard deviation and therefore they still have an effect on the result.

The methods of winsorization that were used in this study produced varied results. In the mail survey, for both effort and catch, the simple truncation at four standard deviations from the mean reduced the effect of the outliers better than the other methods. Unfortunately, winsorization could not make the mail survey estimates comparable with the diary survey estimates of catch and effort. It may help reduce the effect of recall bias but did not appear to help reduce the effect of non-response bias because it has no effect on the high estimates of participation and can not compensate for the low number of zero catches.

The stratum sampling method of winsorization was very useful when applied to the telephone recall survey results. The telephone recall estimates were still higher than the diary estimates after winsorization but were not significantly different. Winsorization does not solve the problem of digit preference found in the telephone recall survey but did lower the estimates of catch and effort by removing the extreme values.

It may be possible to reduce the effect of recall bias by applying winsorization to telephone recall survey results. This would need further research to adequately test this hypothesis.

## **5.9 Limitations and Further Research**

The mail survey, telephone recall survey and telephone diary survey are only able to estimate catch and effort by licence holders. Illegal fishing by non-licence holders can not be estimated using a telephone or mail survey.

In this study the numbers of licence holders remained fairly constant with only minor increases over the course of the season. The telephone diary method would need to be adjusted if a large number of people took out a licence during the season. A second wave of diary holders would need to be sampled to interview a selection of the new licence holders.

Studies into reducing non-response bias in mail surveys have telephoned non-respondents to find out if there are differences between respondents and non-respondents (Connelly and Brown, 1995; Jackson Fowler *et al*, 2002). Further research in this area could validate whether interactions between non-response and recall bias exist in mail surveys.

One possible extension or improvement to the telephone survey methods could be to use Computer Aided Telephone Interviewing (CATI). CATI helps avoid missing questions and handles the flow of the interview for the interviewers. This would be an improvement for the telephone recall survey as it is a short one-off interview, but less useful for the telephone diary survey. Some rock lobster fishers using pots set, pull and re-set their pots at the same time and location over consecutive days, sometimes weeks in a row. In these cases the interviewer records only the information that changes so that the interview is concise, and later fills in the remainder of the form. In these situations CATI would be restrictive and counter productive.

## **5.10 Conclusions and Recommendations**

The mail survey has been in operation for many years. It may provide information about trends in recreational fishing but does not give an accurate estimate of the recreational effort and catch each season. The mail survey has two strong biases affecting the results. Both recall and non-response biases cause an overestimation in catch and fishing effort and neither could be adjusted using winsorization. Furthermore, there may be an interaction between non-response and recall bias making it more

difficult to account for either bias individually. The catch rates were fairly close to the diary survey catch rates, which indicate that for the season studied both the effort and catch were equally overestimated.

The effects of non-response bias may fluctuate between seasons depending on the level of participation in the fishery and whether the season was good or poor. Therefore a simple conversion factor to compensate for bias in the mail survey may not be appropriate. However, research is being conducted to compare the mail and phone diary surveys for a number of years to assess the variation in the level of bias and see if a correction factor can be developed.

Recall and non-response bias led the mail survey to overestimate the catches and fishing effort of recreational rock lobster fishers. “Although mail surveys can be conducted at a lower cost, the reliability of data collected from anglers by telephone justifies the extra expense” (Weithman, 1991).

The telephone recall survey may be more useful than the mail survey for monitoring trends over time, particularly after applying winsorization, but is still affected by recall bias. Winsorization could reduce the outliers in the recall survey results but could not correct the overestimation of participation. The recall survey estimates of effort and catch were around 1.7 times the diary estimates. Recall bias may be influenced by the success of the season and the level of fishing effort of the respondent.

It might be useful to ask respondents for the catch first to avoid the use of multipliers in determining the catch. Vaske *et al* (2003) suggests, “those who fish more are more prone to use multipliers and that the multipliers selected tend to result in a larger estimate”. One recommendation is that quantity questions could be asked before the number of times fished questions.

There are a few ways to ensure that interviewer effect is minimised in a survey. The same training should be given to all interviewers and practice sessions are important to correct any misunderstandings in the training. At least four different interviewers should be used to minimise the effect of one interviewer over the results. This also allows for interviewer effect to be measured and checked.

Surveys of rock lobster fishing should stratify by type of licence. Umbrella licence holders were much more likely to return their mail survey results with nil



participation in the fishery. They were also more likely to report zero catches if they went fishing. This seems to indicate that non-response and recall bias in the mail survey are less of a problem for umbrella licence holders than for rock lobster licence holders.

The telephone diary survey was the best value for money, even accounting for the cost and expertise of staff required for this type of survey. Biases in the results are minimal or non-existent if there is a high response rate to the screening survey and experienced interviewers retain respondents in the diary survey.

The recreational rock lobster mail survey has been in operation for a number of years. If the survey method used to estimate recreational rock lobster catch and effort was changed it would need to be phased in over a number of seasons. “The relationships between estimates based on the old methodology and the new one can then be determined to allow old trend information to be converted to the base established by the new survey methodology” (Vaske *et al*, 2003).

Mail surveys seeking to determine levels of activity should be used with caution. Non-response bias and recall bias both affect the results significantly. Telephone recall surveys should only be used where the recall period is short to minimise the effect of recall bias. The telephone diary survey is the most accurate and reliable method and should be the method of choice whenever the study period is greater than four months in length.

Since the results from this research became available to the Department of Fisheries in Western Australia, the telephone diary survey method in the format outlined in this study has been used successfully to collect recreational fishing information. Telephone diary surveys have been conducted on recreational abalone and rock lobster fishing, recreational boat based fishing and recreational netting.

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## 7.0 APPENDICES

### Appendix A: Definition of Terms

*Recreational fishing* is non-commercial fishing, that is, to catch fish for oneself and family, not for sale or financial gain.

A recreational rock lobster licence may be purchased from the Department of Fisheries. It allows the licence holder to fish for rock lobsters during the rock lobster season from 15<sup>th</sup> November to 30<sup>th</sup> June. A licence holder is entitled to fish using diving gear and a snare or the use of two pots (with certain specifications).

A recreational all species licence known as an ‘umbrella’ licence may be purchased from the Department of Fisheries. It allows the licence holder to fish for rock lobsters, abalone, marron and to participate in netting and southwest freshwater angling.

*Non-response error*: occurs when some sample members do not respond, causing responses to be an unreliable representation of the selected sample (Assael and Keon, 1982).

*Response error*: occurs when sample members respond inaccurately. It can occur because subjects purposely misreport their answers, have faulty recall, are fatigued, are affected by interviewers or are influenced by a host of other environmental factors (Assael and Keon, 1982).

*Sampling error*: is the difference between the estimate obtained by interviewing a sample and the value that would have been obtained if the whole population had been sampled.

*Survey error*: is the term used to describe the total of sampling error non-response error, and response error.

## **Types of response errors**

*Error of omission:* a survey respondent may neglect to mention an event that occurred in the time period specified, which results in an underestimation of the catch (Chase and Harada, 1984).

*Intentional deception:* a survey respondent may lie to the interviewer if they believe that they took more than was legally allowed, if fishery rules may be influenced or they are not happy with the fisheries agency conducting the survey (Pollock *et al*, 1994).

*Rounding or digit bias:* Anglers may round their catch to numbers ending in zero or five (Pollock *et al*, 1994).

*Recall Bias:* Anglers may have difficulty recalling past events. Events may be forgotten or placed in the wrong time interval. There are two main types of recall bias, telescoping error and recall decay (see below).

*Recall decay:* occurs if a survey respondent neglects to mention a fishing event that occurred in the requested time frame. “Recall decay is especially prevalent for local fishing trips of short duration which tend not to be noteworthy”, (Pollock *et al*, 1994).

*Species misrepresentation:* in self-reported surveys a respondent may confuse one species with another. This is possible where there are species of similar appearance (Pollock *et al*, 1994).

*Telescoping errors* are the result of respondents’ reporting the occurrence of activities or events in a time period nearer the present than when the events actually occurred (Chase and Godfrey, 1983).

*Response rate:* the percentage of respondents that fully respond to the interview or questionnaire from the total number of people contacted (Pollock *et al*, 1994).

*Non-contact:* the selected participants that can not be contacted after a number of attempts.

*Part-refusal:* the survey respondents that quit part way through the questionnaire or telephone interview.



## Appendix B: Catch and Effort Calculations (Method 1)

### Estimation of Total Effort

The mean fishing effort for each stratum  $k$  is estimated by the method of Pollock *et al* (1994) as follows:

$$\bar{e}_k = \frac{\sum_{i=1}^{n_k} e_i}{n_k} \quad (1)$$

where  $n_k$  is the sample size in each stratum  $k$  and  $e_i$  is the total number of days fished by each respondent  $i$ .

The estimated variance within stratum  $k$  is:

$$s_k^2 = \frac{n_k \sum_{i=1}^{n_k} e_i^2 - (\sum_{i=1}^{n_k} e_i)^2}{n_k(n_k - 1)} \quad (2)$$

where  $n_k$  is the sample size for stratum  $k$  and  $e_i$  is the total number of days fished by each respondent  $i$ .

The variance associated with the estimate of the mean, with finite population correction (Neter *et al*, 1988) is:

$$\hat{V}ar(\bar{e}_k) = \left( \frac{N_k - n_k}{N_k - 1} \right) \frac{s_k^2}{n_k} \quad (3)$$

The total effort for stratum  $k$  is estimated as:

$$\hat{E}_k = N_k \bar{e}_k \quad (4)$$

where  $N_k$  is the population size of stratum  $k$ .

The variance associated with  $\hat{E}_k$  is estimated by

$$Var(\hat{E}_k) = N_k^2 \hat{V}ar(\bar{e}_k) \quad (5)$$

The total effort is calculated by summing the effort for the strata as follows

$$\hat{E} = \sum_{k=1}^n \hat{E}_k \quad (6)$$

where  $n$  is the number of strata.

The variance is estimated in the same way

$$Var(\hat{E}) = \sum_{k=1}^n Var(\hat{E}_k) \quad (7)$$

The standard error is calculated by the usual method

$$SE(\hat{E}) = \sqrt{Var(\hat{E})} \quad (8)$$

### Estimation of Total Catch

The mean catch for each stratum  $k$  is estimated by the method of Pollock *et al* (1994) as follows:

$$\bar{c}_k = \frac{\sum_{i=1}^{n_k} c_i}{n_k} \quad (9)$$

where  $n_k$  is the sample size in each stratum  $k$  and  $c_i$  is the total catch by each respondent  $i$ .

The estimated variance within stratum  $k$  is:

$$s_k^2 = \frac{n_k \sum_{i=1}^{n_k} c_i^2 - (\sum_{i=1}^{n_k} c_i)^2}{n_k(n_k - 1)} \quad (10)$$

where  $n_k$  is the sample size for stratum  $k$  and  $c_i$  is the total catch by each respondent  $i$ .

The variance associated with the estimate of the mean, with finite population correction (Neter *et al*, 1988) is:

$$\hat{Var}(\bar{c}_k) = \left( \frac{N_k - n_k}{N_k - 1} \right) \frac{s_k^2}{n_k} \quad (11)$$

The total catch for stratum  $k$  is estimated as:

$$\hat{C}_k = N_k \bar{c}_k \quad (12)$$

where  $N_k$  is the population size of stratum  $k$ .

The variance associated with  $\hat{C}_k$  is estimated by

$$Var(\hat{C}_k) = N_k^2 Var(\bar{c}_k) \quad (13)$$

The total catch is calculated by summing the catch for the strata as follows

$$\hat{C} = \sum_{k=1}^n \hat{C}_k \quad (14)$$

where  $n$  is the number of strata.

The variance is estimated in the same way

$$Var(\hat{C}) = \sum_{k=1}^n Var(\hat{C}_k) \quad (15)$$

The standard error is calculated by the usual method

$$SE(\hat{C}) = \sqrt{Var(\hat{C})} \quad (16)$$

## Appendix C: Diary Survey Screening Questionnaire

### SURVEY OF RECREATIONAL ROCK LOBSTER FISHING IN WESTERN AUSTRALIA - 2001/02 INITIAL INTERVIEW

Good morning/afternoon, my name is . . . . . from Fisheries Research.

May I please speak to . . . (NAME OF LICENCE HOLDER)?

Fisheries Research is conducting a survey of recreational rock lobster fishing during this coming rock lobster season.

We will provide you with a diary and we would like you to record brief details in your diary each time you go recreational rock lobster fishing during the next 7½ months.

It's quite simple and it only takes a minute.

I'll call you every now and then to get the information from you (over the phone).

It is important that you record each time you go rock lobster fishing whether you catch anything or not.

THEN EXPLAIN: The diary is to help you remember and we don't see it or get it back from you. Also, you may prefer to use your own codes and abbreviations ... really it's whatever works best for you. But please ensure that you record times and daily catch details for each time you go recreational rock lobster fishing whether or not you catch anything.

Just a couple of questions:

- 1) How many years have you been fishing for rock lobsters? (RECORD DETAILS ON FRONT PAGE OF DIARY SURVEY COVER SHEET IN APPROPRIATE SECTION)
- 2) NON-UMBRELLA LICENCE HOLDERS: Do you have any other recreational fishery licences? (IF YES) Have you participated in that fishery in the last 12 months? (RECORD ON FRONT PAGE OF DIARY SURVEY COVER SHEET IN APPROPRIATE SECTION).
- 3) UMBRELLA LICENCE HOLDERS: Which of the five recreational fisheries have you participated in the last 12 months? (RECORD ON FRONT PAGE OF DIARY SURVEY COVER SHEET IN APPROPRIATE SECTION).
- 4) How likely are you to participate in these fishery(ies) in the next twelve months?

Very Likely	<input type="checkbox"/>
Quite Likely	<input type="checkbox"/>
Not Very Likely	<input type="checkbox"/>
Not At All Likely	<input type="checkbox"/>
UNSURE	<input type="checkbox"/>

The survey starts on the 15<sup>th</sup> November 2001 ... do you have any fishing trips planned for next month? (MAKE APPOINTMENT FOR ASAP AFTER TRIP; OTHERWISE '2-3 WEEK RULE' INITIALLY; MONTHLY CALLS LATER IF APPROPRIATE). By the way, the aim of the survey is to measure what people normally do ... so, we don't want you to go fishing any more or any less often than you normally would have done during this time.

(CLOSE INTERVIEW NOW – OR IF APPROPRIATE, ASK) (And) if I couldn't contact you on this number, is there another number I could get you on? (WORK PHONE NOT USED UNLESS REQUESTED). (And) If for some reason I couldn't contact you (on either of these numbers), could you give me the name and phone number of someone who would know how to contact you? (RECORD ON FRONT PAGE; EXPLAIN AS APPROPRIATE, - DOESN'T HAPPEN OFTEN, BUT IN SURVEYS COVERING A PERIOD OF TIME, SOMETIMES PEOPLE MOVE UNEXPECTEDLY).

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- 1) How many years have you been fishing for rock lobsters? (RECORD DETAILS ON FRONT PAGE OF DIARY SURVEY COVER SHEET IN APPROPRIATE SECTION)
- 2) NON-UMBRELLA LICENCE HOLDERS: Do you have any other recreational fishery licences? (IF YES) Have you participated in that fishery in the last 12 months? (RECORD ON FRONT PAGE OF DIARY SURVEY COVER SHEET IN APPROPRIATE SECTION).
- 3) UMBRELLA LICENCE HOLDERS: Which of the five recreational fisheries have you participated in the last 12 months? (RECORD ON FRONT PAGE OF DIARY SURVEY COVER SHEET IN APPROPRIATE SECTION).
- 4) How likely are you to participate in these fishery(ies) in the next twelve months?

Very Likely	<input type="checkbox"/>
Quite Likely	<input type="checkbox"/>
Not Very Likely	<input type="checkbox"/>
Not At All Likely	<input type="checkbox"/>
UNSURE	<input type="checkbox"/>

The survey starts on the 15<sup>th</sup> November 2001 ... do you have any fishing trips planned for next month? (MAKE APPOINTMENT FOR ASAP AFTER TRIP; OTHERWISE '2-3 WEEK RULE' INITIALLY; MONTHLY CALLS LATER IF APPROPRIATE). By the way, the aim of the survey is to measure what people normally do ... so, we don't want you to go fishing any more or any less often than you normally would have done during this time.

(CLOSE INTERVIEW NOW – OR IF APPROPRIATE, ASK) (And) if I couldn't contact you on this number, is there another number I could get you on? (WORK PHONE NOT USED UNLESS REQUESTED). (And) If for some reason I couldn't contact you (on either of these numbers), could you give me the name and phone number of someone who would know how to contact you? (RECORD ON FRONT PAGE; EXPLAIN AS APPROPRIATE, - DOESN'T HAPPEN OFTEN, BUT IN SURVEYS COVERING A PERIOD OF TIME, SOMETIMES PEOPLE MOVE UNEXPECTEDLY).

## Appendix G: Telephone Diary Survey Event Sheet Instructions

### Diary Interviews Instructions

#### PART 1 IDENTIFICATION OF DAYS / DATES

Your survey period started... (Last time we spoke was ...)

Since then, have you done any recreational rock lobster fishing, including any days when you didn't catch anything? (STORE NUMBER OF SEPARATE DAYS)

IF ONE FISHING DAY ONLY: GO TO PART 2. IF MORE THAN ONE FISHING DAY:

So where did you go rock lobster fishing on these days? (STORE REGION INFO)

Did you fish for rock lobsters anywhere else during this time?

IF NO EVENT: GO TO PART 3.

#### PART 2 FOR EACH DATE / EVENT

(CHRONOLOGICAL ORDER USUALLY: What did you do first/next?)

- Q1. START DATE:** So (that/the first/the next) day was ...? (RECORD START DATE OF EACH EVENT; IF END DATE DIFFERENT, INSERT NUMBER OF ADDITIONAL DAYS [SET/PULL POTS USUALLY] – LEAVE BLANK IF SAME: *SPLIT EVENT* FOR EACH SEPARATE DAY UNLESS PASSIVE GEAR OR OTHER CONTINUOUS FISHING THROUGH MIDNIGHT)
- Q2. PERSONAL / PROXY:** ARE YOU SPEAKING TO THE LICENCE HOLDER PERSONALLY OR ANOTHER HOUSE MEMBER (PROXY)? PROXY INTERVIEWS TO BE CONFINED TO CHILDREN OR DEFINITE CASES OF NIL/JOINT ACTIVITY.
- Q3. DIARISED DATA:** (And) did you fill out your diary card for this day? Have you got it there?
- Q4. FISHING REGION:** Where did you go fishing that day? Did you fish anywhere else that day? (CLASSIFY REGION NO. FROM MAP. NEAREST 'LANDMARK' FOR OBSCURE LOCALITIES. SPLIT EVENT IF DIFFERENT REGIONS)
- Q5. (IF USED MORE THAN ONE METHOD THEN SPLIT EVENTS)**
- a) **NO. OF POTS:** (And) did you use pots? (IF YES) How many pots did you use?
  - b) **DIVING:** What other fishing method did you use to catch the rock lobsters – diving (scuba, hookah – surface air, snorkel) or reef walking?
  - c) **NO. OF SNARES:** Did you use snares? (IF YES) How many snares did you use (that day)?
  - d) **NO. OF PERSONS:** How many people were fishing with you? (RECORD NUMBER ACTUALLY INVOLVED)
  - e) **NO. OF LICENCES:** How many of those people had recreational rock lobster licences? (FOR THE CORRECT ALLOCATION OF THE CATCH)
- Q6. FISHING DEPTH (M):** At what depth does your rock lobster fishing occur? (FIVE METRE INCREMENTS – EXACT DEPTHS ARE NOT REQUIRED)
- a) **PLATFORM – BOAT/ShORE:** (And) did you fish from a boat or the shore (... or both?)
  - b) **PLATFORM – BOAT TYPE:** (IF BOAT) (And) whose boat was it? (CHARTER = SKIPPED, HIRE = NOT)
- Q8. TIMES:** (And) when did you actually start fishing ... (that day?) (FIRST POT SET/PULL OR SCUBA DIVER IN). (And) when did you finish? (LAST POT SET/PULL OR SCUBA DIVER OUT)
- (IF CONTINUOUS PASSIVE GEAR USED, E.G. POTS AND LAST CONTACT INCOMPLETE, FLAG 'OPEN EVENT' IN COMMENTS)
- Q9. CATCH:** (And) did you catch anything (that day)? (NUMBER LOBSTERS CAUGHT AND KEPT)
- (THEN ASK) Did you catch anything else (that day) that you released? (NUMBER CAUGHT AND RELEASED: IF ASKED, INCLUDE DEAD/DAMAGED RETURNS)
- (SHARED CATCHES: Catch per licence holder. If the number of persons fishing is greater than one and there is only the one licence holder, then record the total catch. However, if the total catch for two or more licence holders is given, record the number of licences for which the catch applies.)
- #### PART 3 AFTER LAST EVENT RECORDED
- Q10. COMMENTS:** (And) do you have any fishing trips planned for the next two-three weeks? (MAKE APPOINTMENT AS APPROPRIATE: IF NOT USE 'TWO-THREE WEEK' RULE INITIALLY, BUT MONTHLY (OR MORE) IF REQUIRED LATER IN DIARY PERIOD).

# Appendix H: Telephone Recall Questionnaire

Department of Fisheries

Rock Lobster Recall Survey

Season 2001/2002

Interviewer Name \_\_\_\_\_ Sample No

Sex  M  F Postcode

Day/Mth	Time	Result	Appointments/Other
/			
/			
/			
/			
/			
/			
/			
/			
/			
/			

Response Report	
Fully Responded	1
Full Refusal	2
Part Refusal	3
Full non-contact	4
Part non-contact	5
Number disconnected	6
Business number	7
Wrong Number	8
OTHER	

**Q1** Did you go **recreational rock lobster** fishing during the last season from November 2001 to June 2002?

1  2 The following questions apply to the days fished and catch for your licence only.

---

**Q2** Did you fish from the shore, from a boat or both?

Shore  1  
 Boat  2  
 Both  3

**Q3** How many **days** did you fish for rock lobster during the last season?

**Q4** How many **days** did you go fishing in the following regions? Were you diving, using pots or both?

Bioregions	Diving	Pots	Both
South Coast			
Perth Metro & Rottnest			
Other West Coast			
Gascoyne			
Pilbara / Kimberley			

**Q5** How many **Western** rock lobsters did you keep in total during the last season?

**Q6** How many **Western** rock lobsters did you keep from the following regions? Were they caught diving or using pots?

Bioregions	Diving	Pots
South Coast		
Perth Metro & Rottnest		
Other West Coast		
Gascoyne		

**Q7** How many **Southern** rock lobsters did you keep in total during the last season?

**Q8** How many **Southern** rock lobsters did you keep from the following regions? Were they caught diving or using pots?

Bioregions	Diving	Pots
South Coast		
Perth Metro & Rottnest		
Other West Coast		

**Q9** How many **Tropical** lobsters did you keep in total during the last season?

**Q10** How many **Tropical** lobsters did you keep from the following regions? Were they caught diving or using other methods?

Bioregions	Diving	Other
Perth Metro & Rottnest		
Other West Coast		
Gascoyne		
Pilbara / Kimberley		

**Q11** What months did you go fishing for rock lobsters?

Nov  Dec  Jan  Feb  
 Mar  Apr  May  Jun

## Appendix I: Telephone Recall Questionnaire Instructions

Rock Lobster Licence Holders

July 2002

### Instructions for Recreational Rock Lobster Licence Recall Survey

The recall survey is designed to determine how many people with rock lobster licences fished for rock lobsters during the last season. The information required includes how many days they spent fishing, where they fished, how they fished and the number of each species caught.

You will need to do 40 complete interviews of rock lobster licence holders and 40 complete interviews umbrella licence holders.

#### **Background**

The Rules: There are very strict rules governing the fishing for rock lobsters. See attached booklet on rules and regulations for recreational rock lobster fishing in Western Australia.

Remind the respondent (if necessary) that this survey is purely research and that their responses will remain confidential.

#### **Call Details**

Record the code and postcode (from your workload control sheet) and the sex of the licence holder in the top right hand corner. Stamp your name in the left hand corner of the questionnaire.

Record the day and month of the call, the time you called, the result (from the response report) and an appointment time if you need to call back.

#### **Questionnaire conventions**

Some reminders of questionnaire conventions follow:

Fill in your questionnaires in blue pen only.

Remember not to use liquid paper. Put a cross through an incorrect response and circle and then tick the correct response. If your page is too hard to read, copy the information on to another questionnaire.

A joined box indicates that only one answer is allowed.

#### **Questionnaire**

##### **Question 1**

*Did you go recreational rock lobster fishing during the last season from November 2001 to June 2002?*

If the respondent has not been rock lobster fishing in the last season then end the interview, *Thank you very much for your time.*

##### **Question 2**

*Did you fish from the shore, from a boat or both?*

Record only one response.

##### **Question 3**

*How many days did you fish for rock lobster during the last season?*

Ask them to estimate how many days in total they went fishing.

##### **Question 4**

*How many days did you go fishing in the following regions? Were you diving, using pots or both?:*

Read out the five locations. If they have trouble with the regions refer to attached map. The West Coast region excludes the Perth metropolitan region. The Perth Metropolitan area extends from Wedge Island (just north of Lancelin) to Mandurah (Cape Bouvard) and includes Rottnest. Make sure that the respondent understands the regions as defined in the map.

Make sure that the days fished are broken down by region and by the fishing method. Be aware that some fishers may have used different methods in different regions.

Please note for the following questions that the regions differ depending on the type of lobster found in those areas. The shaded areas show where the catch of that species of lobster is unlikely. If in doubt about the catch of a particular species check that the licence holder can tell the difference between species.

#### Question 5

*How many **Western** rock lobsters did you keep in total during the last season?*

Record the number kept (this does not include those released) in total.

#### Question 6

*How many **Western** rock lobsters did you keep from the following regions? Were they caught diving or using both?*

Record the number kept (this does not include those released) from each region. Only one method can be used to catch the rock lobsters. For those fishers that use both fishing methods ask them to estimate how many they would have caught using each method.

#### Question 7

*How many **Southern** rock lobsters did you keep in total during the last season?*

Record the number kept (this does not include those released) in total.

#### Question 8

*How many **Southern** rock lobsters did you keep from the following regions? Were they caught diving or using both?*

Record the number kept (this does not include those released) from each region. Only one method can be used to catch the rock lobsters. For those fishers that use both fishing methods ask them to estimate how many they would have caught using each method.

#### Question 9

*How many **Tropical** lobsters did you keep in total during the last season?*

Record the number kept (this does not include those released) in total.

#### Question 10

*How many **Tropical** lobsters did you keep from the following regions? Were they caught diving or using both?*

Record the number kept (this does not include those released) from each region. Only one method can be used to catch the lobsters. For those fishers that use both fishing methods ask them to estimate how many they would have caught using each method.

#### Question 11

*What months of the year did you go fishing for rock lobsters?*

Circle the months when the respondent fished for rock lobsters.

End the interview with "Thank you for your time".

## Appendix J: SPlus Program for Bootstrapping Catch and Effort

The same program is applied to each strata for the telephone surveys. Before the script is run, the relevant data frame is attached, and the number of licence holders and sample size is entered.

```
# -----
# This script file (analysis.ssc) performs the following:
# exploratory data analysis of the stratified survey results,
# bootstrapping of estimates of the mean,
# graphs of bootstrapped estimates, calculates total effort &
# calculates total weight of lobsters kept.
# For each set of results: attach the correct data frame,
# adjust the number of licences and the sample size.
# Adds effort and catch from stratified results to determine
# total catch and effort.
# -----
# Attach relevant data frame
attach(dfRUM)
#
# Assign number of licences
rlicences <- 11996
#
# Assign sample size
sample <- 200
#
# -----
# Participation calculations
#
participation <- count(days)
#
# Effort calculations
#
# Summary statistics of days
summary(days)
#
# Exploratory data analysis graphs of days
eda.shape(days)
#
# Bootstrap mean of days fished
temp <- bootstrap(days, mean)
#
summary(temp)
# Summary statistics, emp and BCa confidence limits
#
# Density and qq-norm plots of bootstrapped data
eda.b(temp)
#
# Calculate participation rate
prate <- count.rows(days)/sample
#
# Calculate finite population correction factor
cfactor <- (rlicences - sample)/(rlicences - 1)
#
# Calculate participation rate variance
pratevar <- (prate * (1 - prate)/ sample)* cfactor
#
# Calculate effort
reffort <- summary(temp)[4]$estimate[2]*rlicences*participation
#
# Calculate variance of the mean
varmeane <- cfactor * summary(temp)[4]$estimate[3]/count.rows(days)
#
# Calculate standard error of effort
effortse <-
  sqrt((rlicences^2)*(summary(temp)[4]$estimate[2]^2)*(prate^2)*((varmeane/
    (summary(temp)[4]$estimate[2]^2))+(pratevar/(prate^2))))
#
```

```

# Display effort
reffort
#
# Display standard error of effort
effortse
#
# -----
# Catch calculations
#
# Summary statistics of kept
summary(kept)
#
# Exploratory data analysis graphs of kept
eda.shape(kept)
#
# Bootstrap mean of number kept
temp <- bootstrap(kept, mean)
#
# Summary statistics, emp and BCa confidence limits
summary(temp)
#
# Density and qq-norm plots of bootstrapped data
eda.b(temp)
#
# Calculate participation rate
participation <- count.rows(kept)/sample
#
# Calculate total weight of rock lobster kept
rcatch <- summary(temp)[4]$estimate[2]*rlicences*participation
#
# Calculate variance of the mean
varmeanc <- cfactor * summary(temp)[4]$estimate[3]/count.rows(days)
#
# Calculate standard error of catch
catchse <-
  sqrt((rlicences^2)*(summary(temp)[4]$estimate[2]^2)*(prate^2)*((varmeanc/
    (summary(temp)[4]$estimate[2]^2))+pratevar/(prate^2))))
#
# Display total catch of western rock lobster kept
rcatch
#
# Display standard error of catch
catchse
#
# Assign weight 0.5kg
weight <- 0.5/1000
#
# Calculate total weight of rock lobster kept
rweight <- rcatch*weight
#
# Display total weight (tonnes) of western rock lobster kept
rweight
#
# Calculate standard error of catch weight estimate
rweightse <- sqrt((catchse^2)*(weight^2))
#
# Display weight standard error
rweightse
#
# Catch rate calculations
#
# Summary statistics of rate
summary(rate)
#
# Exploratory data analysis graphs of rate
eda.shape(rate)
#
# Bootstrap mean of catch rate
temp <- bootstrap(rate, mean)
#
# Summary statistics, emp and BCa confidence limits
summary(temp)
#
# Density and qq-norm plots of bootstrapped data
eda.b(temp)

```



## Appendix K: SPlus Program for Bootstrapping Kurtosis and Skewness

```
# Procedure will create bootstrap estimates of kurtosis

# attach required data frame
attach (dfdays)

#-----

kurtosis(drl, na.rm=TRUE, method="moment")

# Bootstrap measure of kurtosis; demonstrate summary(), plot(), qqnorm()
bootdrl.obj <- bootstrap(drl, kurtosis(drl, na.rm=TRUE, method="moment"),
assign.frame1=T, trace=F)
summary(bootdrl.obj)

kurt.drl <- bootdrl.obj$replicates

meandrl <-summary(bootdrl.obj)[4]$estimate[2]
meandrl
sedrl <-summary(bootdrl.obj)[4]$estimate[3]
sedrl

frame()
par(mfrow=c(2,2))
plot(bootdrl.obj, main="")
qqnorm(bootdrl.obj, main="")
par(mfrow=c(1,1))

# Jackknife after bootstrap
jabdrl.obj <- jack.after.bootstrap(bootdrl.obj)
jabdrl.obj
summary(jabdrl.obj)
plot(jabdrl.obj)

#-----

kurtosis(rrl, na.rm=TRUE, method="moment")

# Bootstrap measure of kurtosis; demonstrate summary(), plot(), qqnorm()
bootrrl.obj <- bootstrap(rrl, kurtosis(rrl, na.rm=TRUE, method="moment"),
assign.frame1=T, trace=F)
summary(bootrrl.obj)

kurt.rrl <- bootrrl.obj$replicates

meanrrl <-summary(bootrrl.obj)[4]$estimate[2]
meanrrl
serrl <-summary(bootrrl.obj)[4]$estimate[3]
serrl

frame()
par(mfrow=c(2,2))
plot(bootrrl.obj, main="")
qqnorm(bootrrl.obj, main="")
par(mfrow=c(1,1))

# Jackknife after bootstrap
jabrrl.obj <- jack.after.bootstrap(bootrrl.obj)
jabrrl.obj
summary(jabrrl.obj)
plot(jabrrl.obj)

#-----

kurtosis(mrl, na.rm=TRUE, method="moment")

# Bootstrap measure of kurtosis; demonstrate summary(), plot(), qqnorm()
bootmrl.obj <- bootstrap(mrl, kurtosis(mrl, na.rm=TRUE, method="moment"),
assign.frame1=T, trace=F)
```

```

summary(bootmrl.obj)

kurt.mrl <- bootmrl.obj$replicates

meanmrl <-summary(bootmrl.obj)[4]$estimate[2]
meanmrl
semr1 <-summary(bootmrl.obj)[4]$estimate[3]
semr1

frame()
par(mfrow=c(2,2))
plot(bootmrl.obj)
qqnorm(bootmrl.obj)
par(mfrow=c(1,1))

# Jackknife after bootstrap
jabmrl.obj <- jack.after.bootstrap(bootmrl.obj)
jabmrl.obj
summary(jabmrl.obj)
plot(jabmrl.obj)

#-----

# mean of kurtosis (days fished from Diary survey (RL))
meandr1
# standard error of kurtosis (days fished from Diary survey (RL))
sedr1

#-----

# mean of kurtosis (days fished from Recall survey (RL))
meanr1
# standard error of kurtosis (days fished from Recall survey (RL))
serr1

#-----

# mean of kurtosis (days fished from Mail survey (RL))
meanm1
# standard error of kurtosis (days fished from Mail survey (RL))
sem1

#-----

t.test(kurt.drl, kurt.r1, alternative="two.sided", mu=0, paired=F,
var.equal=F, conf.level=.95)

t.test(kurt.drl, kurt.m1, alternative="two.sided", mu=0, paired=F,
var.equal=F, conf.level=.95)

t.test(kurt.r1, kurt.m1, alternative="two.sided", mu=0, paired=F,
var.equal=F, conf.level=.95)

#-----

kurtosis(dum, na.rm=TRUE, method="moment")

# Bootstrap measure of kurtosis; demonstrate summary(), plot(), qqnorm()
bootdum.obj <- bootstrap(dum, kurtosis(dum, na.rm=TRUE, method="moment"),
assign.frame1=T, trace=F)
summary(bootdum.obj)

kurt.dum <- bootdum.obj$replicates

meandum <-summary(bootdum.obj)[4]$estimate[2]
meandum
sedum <-summary(bootdum.obj)[4]$estimate[3]
sedum

frame()
par(mfrow=c(2,2))
plot(bootdum.obj, main="")
qqnorm(bootdum.obj, main="")
par(mfrow=c(1,1))

```

```

# Jackknife after bootstrap
jabdum.obj <- jack.after.bootstrap(bootdum.obj)
jabdum.obj
summary(jabdum.obj)
plot(jabdum.obj)

#-----

kurtosis(rum, na.rm=TRUE, method="moment")

# Bootstrap measure of kurtosis; demonstrate summary(), plot(), qqnorm()
bootrum.obj <- bootstrap(rum, kurtosis(rum, na.rm=TRUE, method="moment"),
assign.frame1=T, trace=F)
summary(bootrum.obj)

kurt.rum <- bootrum.obj$replicates

meanrum <-summary(bootrum.obj)[4]$estimate[2]
meanrum
serum <-summary(bootrum.obj)[4]$estimate[3]
serum

frame()
par(mfrow=c(2,2))
plot(bootrum.obj, main="")
qqnorm(bootrum.obj, main="")
par(mfrow=c(1,1))

# Jackknife after bootstrap
jabrum.obj <- jack.after.bootstrap(bootrum.obj)
jabrum.obj
summary(jabrum.obj)
plot(jabrum.obj)

#-----

kurtosis(mum, na.rm=TRUE, method="moment")

# Bootstrap measure of kurtosis; demonstrate summary(), plot(), qqnorm()
bootmum.obj <- bootstrap(mum, kurtosis(mum, na.rm=TRUE, method="moment"),
assign.frame1=T, trace=F)
summary(bootmum.obj)

kurt.mum <- bootmum.obj$replicates

meanmum <-summary(bootmum.obj)[4]$estimate[2]
meanmum
semum <-summary(bootmum.obj)[4]$estimate[3]
semum

frame()
par(mfrow=c(2,2))
plot(bootmum.obj)
qqnorm(bootmum.obj)
par(mfrow=c(1,1))

# Jackknife after bootstrap
jabmum.obj <- jack.after.bootstrap(bootmum.obj)
jabmum.obj
summary(jabmum.obj)
plot(jabmum.obj)

#-----

# mean of kurtosis (days fished from Diary survey (RL))
meandum
# standard error of kurtosis (days fished from Diary survey (RL))
sedum

#-----

# mean of kurtosis (days fished from Recall survey (RL))
meanrum

```

```

# standard error of kurtosis (days fished from Recall survey (RL))
serum

#-----

# mean of kurtosis (days fished from Mail survey (RL))
meanmum
# standard error of kurtosis (days fished from Mail survey (RL))
semum

#-----

t.test(kurt.dum, kurt.rum, alternative="two.sided", mu=0, paired=F,
       var.equal=F, conf.level=.95)

t.test(kurt.dum, kurt.mum, alternative="two.sided", mu=0, paired=F,
       var.equal=F, conf.level=.95)

t.test(kurt.rum, kurt.mum, alternative="two.sided", mu=0, paired=F,
       var.equal=F, conf.level=.95)

t.test(kurt.dum, kurt.rum, alternative="two.sided", mu=0, paired=F,
       var.equal=T, conf.level=.95)

```

## Appendix L: SPlus Program for Logistic Regression

### Diary Model

```
attach(dmodel)

summary(dmodel)

' shows the effect of factors on participation
plot.design(part~int+lic+gen+age.range,data=dmodel)

'-----Fitting a linear logistic regression model-----

dmodel.glm.all<-glm(part~int+lic+gen+age.range,family=binomial, data=dmodel,
  na.action=na.exclude)

summary(dmodel.glm.all)
anova(dmodel.glm.all, test="Chi")

' gender is removed as it has least effect on the model
dmodel.glm.all<-glm(part~int+lic+age.range,family=binomial, data=dmodel,
  na.action=na.exclude)

' a null model is created and factors are added one at a time
dmodel.glm.null<-glm(part~1,family=binomial, data=dmodel,
  na.action=na.exclude)

summary(dmodel.glm.null)

add1(dmodel.glm.null, ~. +int+lic+gen)

par(mfrow=c(2,2))
plot(dmodel.glm.all)
```

### Recall Model

```
attach(rmodel)

summary(rmodel)

' shows the effect of factors on participation
plot.design(part~int+lic+gen+age.range,data=rmodel)

'-----Fitting a linear logistic regression model-----

rmodel.glm.all<-glm(part~int+lic+gen+age.range,family=binomial, data=rmodel,
  na.action=na.exclude)

summary(rmodel.glm.all)
anova(rmodel.glm.all, test="Chi")

' gender is removed as it has least effect on the model
rmodel.glm.all<-glm(part~int+lic+age.range,family=binomial, data=rmodel,
  na.action=na.exclude)

' a null model is created and factors are added one at a time
rmodel.glm.null<-glm(part~1,family=binomial, data=rmodel,
  na.action=na.exclude)

summary(rmodel.glm.null)

add1(rmodel.glm.null, ~. +int+lic+gen)

par(mfrow=c(2,2))
plot(rmodel.glm.all)
```