# A review and evaluation of the Set Pocket Net Prawn Fishery in New South Wales

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## Discussion and Summary

Catches in the Set Pocket Net fishery in the Clarence River were extremely variable. In the period 1991-1993 the top ten digs accounted for over 85% of total catch in the fishery. On average, 38.2% of the 138 digs available are not taken each lunar month. Only the top 18 digs produced a monthly income in excess of $1000/month (assuming $4.50/kg and based on landings over the period of the study).

Set pocket netting accounted for a relatively small proportion of the Clarence River school prawn fishery in the 1991-92 and 1992-93 seasons (12 and 26% respectively). This small contribution to the total river catch was largely because of the decline in fishing effort, particularly in 1991-92, after the opening of the trawling season in December each year.

Extreme variability in catch, the administration of the fishery by ballot and the potentially large number of applicants in the ballot each month make the fishery very unpredictable. For this reason, pocket netting is not popular with many fishers. Unlike most other fisheries in New South Wales, the expectation of catch is linked not only to the state of the resource, fishing skill and application, but in large measure to chance. There is no clear alternative to balloting digs each lunar month as this is the only means of allowing equitable access to the resource. Greater predictability could, however, be achieved by reducing the number of people in each ballot. It is important to stress that such a reduction may not reduce catch substantially because effort in the fishery is limited by the number of productive digs, not by the number of applicants in the ballot.

There were no clear trends in total catch (both river and ocean) of school prawns as landed through the Maclean Cooperative between 1966 and 1993. More complete examination of trends in catches, particularly catch rates, is required to interpret these patterns. Such an examination is beyond the scope of the present study. The significant correlation noted in previous studies between river discharge and catch in the ocean fishery was also reported in the present study.

It is not possible to comment on the potential impact of pocket netting on catches of school prawns in the ocean because of a lack of historical data that separates prawns caught by pocket netting and trawling in the river. The high correlation between river discharge and catch means that data from the present study are insufficient from which to generalize to other years. Anecdotal information suggests that effort has increased in all sectors of the school prawn fishery in and adjacent to the Clarence River since 1966.

During both 1991-92 and 1992-93, the by-catch of the set pocket fishery in the Clarence River was dominated by small fish of no monetary value. These fish accounted for more than 93% by number and 60% by weight of the total by-catch recorded during the study. Bream, followed by tailor, tarwhine and river and snub-nosed garfish accounted for the great majority of commercial species. More than 98% of the 67 231 bream estimated to have been caught in both years would be expected to die of natural causes before reaching the minimum legal size. These results suggest that set pocket netting has minimal impact on co-existing commercial and recreational fisheries for fin-fishes.

The total by-catch from the set pocket net fishery was small compared to the trawl fishery. Large by-catches were, however, recorded on several nights during the study. These large catches coincided with unusually high river discharge and suggest that the amount of by-catch taken by pocket netting in the river will be closely related to river discharge.

In this study we have demonstrated that set pocket netting, as practised in the Clarence River, has a relatively small by-catch. It is likely, however, that the timing and location of large catches of fish will differ among years with different river discharge and among estuaries, therefore few generalisations are possible. There was a great deal of variance in catches of both prawns and by-catch in the Clarence River that required intensive sampling to adequately describe. The size and composition of the by-catch is likely to differ enormously among locations. Of particular importance, will be the propensity of the river or estuary to flooding.

If set pocket netting were to be extended to other locations then it is likely that some form of balloting (as found in all other locations) will be required. Although no clear alternatives are apparent, administration of the fishery by this means would likely make the fishery unprofitable for most of the participants unless access was strictly limited.

In order to investigate the distribution of school prawns we have developed an improved beam trawl that provides reliable samples of the abundance of juveniles prawns. Sampling in the Clarence River using this electric beam trawl revealed that school prawns are patchy in their abundance and used a wide range of habitats in the river. Of particular interest was their great abundance in small creeks and tributaries, as well as the Broadwater and Lake Wooloweyah. These patterns indicate that juvenile school prawns utilise a far greater range of habitats and are more mobile within the river system than previously thought. This result reinforces the importance of preserving a wide range of habitat within the Clarence River. Of the sites sampled, several consistently yielded large catches of juvenile prawns, particularly the Coldstream River. The recent closure of the Broadwater to prawn trawling is, therefore, supported by the findings of this study. Further fishery independent sampling is required to confirm the importance of the Coldstream River.

The set pocket net fishery in Myall Lake is much smaller than that in the Clarence River and catches greasyback and small numbers of king prawns in addition to school prawns. The sizes of school prawns in this fishery were much larger than in the Clarence River. The by-catch in Myall lake over the period of sampling was very different and was dominated by eels, which were relatively rare in the Clarence River.

CHAPTER ONE: INTRODUCTION



CHAPTER TWO: DYNAMICS OF THE POCKET NET FISHERY IN THE CLARENCE RIVER



CHAPTER THREE: BY-CATCH OF THE CLARENCE RIVER FISHERY

APPENDICES

# CHAPTER ONE: INTRODUCTION

## 1.1 General

School prawns (*Metapenaeus macleayi*) are caught in many estuaries in New South Wales. The principal means of capturing prawns is otter trawling, which is permitted in the Hawkesbury, Hunter and Clarence rivers and in Botany Bay and Port Jackson. Estuarine trawl fisheries have been the subject of extensive research in New South Wales (e.g. Dannevig 1904, Racek 1959, Ruello 1971, 1973a, b, 1975a, b, 1977, Glaister 1976, 1977, 1978a, b, Henry 1984, Kennelly et al. 1993, Broadhurst and Kennelly in press). Ruello (1975b) describes the historical development of the New South Wales prawn fisheries and summarises much of the early research.

Few data exist on catch rates of prawns taken by other methods such as set pocket netting and hauling and there remains no account of the amount and kind of by-catch. It is generally considered that catches of non-target species by set pocket netting varies considerably among places and months, depending on the salinity of the river and other environmental variables such as current velocity and turbidity. In order to formulate a management plan for the estuarine prawn fisheries in New South Wales it is necessary to evaluate the dynamics of set pocket net fishing.

Set pocket netting was developed to catch prawns migrating to ocean waters to spawn (Dakin 1935, 1938, 1940, Racek 1959, Glaister 1978). At certain times, king prawns (*Penaeus plebejus*) and school prawns (*Metapenaeus macleayi*) travel against the tide in areas close to the shoreline or river bank where the tide is weak. At other times, they travel with the stronger midstream currents to the sea. A modified trawl net is set across a tidal channel using anchors, stakes and sometimes trees on nearby banks. As the prawns migrate they are trapped in the cod end of the net. The composition of the catch differs among fisheries, for example, the Clarence River fishery catch is comprised almost exclusively of school prawns whereas the fisheries in Myall and Wallis lakes are a mixture of school and king prawns. In some areas where king prawns are caught as well as school prawns, the net reaches from the bottom to the surface to catch school prawns travelling along the bottom and king prawns travelling on the surface (Ruello 1975).

### 1.2 Set Pocket Net Fishing in New South Wales

Pocket netting in New South Wales is believed to have begun in 1932 on Lake Illawarra (Ruello 1969) but is also now carried out on the Myall River, Wallis Lakes, Queens Lake entrance, Watson Taylor Lake, Tuggerah Lakes, Cathie Creek, Sussex Inlet, Limeburners Creek and the Clarence River. Of these, the Clarence River fishery is by far the largest and coexists in the river with a large otter trawl fishery.

Little published information is available on the beginnings of pocket netting in New South Wales. McNeill (1944), when referring to the benefits of prawn hauling, wrote

*"Unfortunately, however a new type of net can now be lawfully operated. This is known as the "set pocket net", and is used most effectively for capturing the prawns making their way out to sea through the narrow channels. A continuance of the practice might well spell disaster to our prawn fishing industry before many years have passed. Let us trust that this fine marine industry, second only to similar fisheries in the United States of America, will not be allowed to reach a stage of deterioration where recovery will be virtually impossible."*

Later, McNeill (1958) again expressed his concern about pocket netting

*"At present the custom of netting prawns in the river estuaries and the coastal lakes continues, even set purse nets are used across the outlet channels connecting lakes to the sea. It is obvious that the industry must eventually cease to be profitable if it is exploited from both ends".*

Racek (1959) mentions set pocket netting several times as a sampling method and used the method to establish lunar periodicity of king and school prawns in off-shore migrations from the central and southern N.S.W. coast. Glaister (1976) stated that set pocket netting commenced on the Clarence River in 1965. According to Ruello (1967) the important set pocket net grounds were at Wallis Lakes, Tuggerah Lakes, Lake Illawarra and Sussex Inlet and, while no information was available at the time on set pocket net catches, the total catch of prawns from all N.S.W. estuaries in 1965-66 by all methods was 1.4 million lbs.

The following information on set pocket netting as currently practised in Lake Illawarra, Cathie Creek, Lake Innes, Watson Taylor Lake and Queens Lake Entrance (Stingray Creek) was taken from anecdotal reports and from discussions with Fisheries Inspectors and experienced set pocket netters. The fisheries in the Clarence River and Myall Lakes are described in more detail below. Small pocket net fisheries also exist in Tuross Lake, Sussex Inlet, Limeburners Creek and Tuggerah Lakes. These fisheries will not be described here. The Wallis lake set pocket net fishery will be described separately (McDonell, Grey and Kennelly, in preparation).

**Lake Illawarra**

Lake Illawarra is believed to be the oldest set pocket net fishery in New South Wales. Today, pocket netting occurs at three places near the entrance to the ocean. The nets can be operated in a line towards the entrance or, as is often the case, staked with steel poles side by side across the river. Fishers are allocated positions in a random draw held on the full moon of every month. The number of crews participating in the draw is usually between 6 and 12 but up to 19 crews have nominated in the past.

When there are more fishermen than the three available sites can accommodate, the fourth crew from the draw start on the next night of the moon and so on until all the crews are allocated a night. For the remainder of nights left in the lunar month the order is repeated until all nights are taken. Pocket netting is permitted all year round, however, most interest is shown during late spring and summer with the best catches usually obtained in January and February.

**Cathie Creek and Lake Innes**

Fishers believe set pocket netting began in Cathie Creek (near Lake Macquarie) in the 1950's, taking over from running netting as the preferred method of catching prawns (running netting involves using a long strip of net, not staked to the bottom except in some areas of Tuggerah Lakes to guide the prawns into the end of the net). Early fishing attempts took place between the bridge at Cathie and the entrance to the sea, but soon progressed west to the narrow canal or 'drain' between Lake Innes and Cathie Creek then into Lake Innes itself.

Cathie Creek is a tidal creek that is prone to closure by big seas or tides depositing sand across the narrow entrance to the sea. On some occasions the creek has been closed to the ocean for up to 10 years. Despite these extended closures to the sea, prawns continue to be caught in the lake, suggesting that prawns may breed there. Because of the general lack of tide in Lake Innes and the periodic closure of the entrance, fishers developed a method of pocket netting called 'peddling' to catch school prawns.

When peddling, fishers use stakes to anchor a small boat in the curve of the net and the current created by the outboard motor pushes the prawns into the net. A net funnel with a steel hoop sewn to the widest end is used in the throat of the net to stop prawns swimming back out of the net.

This method of operating a pocket net in non-tidal areas has been used in Lake Innes virtually since pocket netting began there. Although pocket nets used in Cathie Creek and Lake Innes must have a headrope 10 m long, each year fishers obtain a concession to extend the length of the head rope to 70 m to fish in Lake Innes. A 30 m strip of net is added to the wings of the standard pocket net at an angle so the ends are not more than 50 m apart. The only similar method of pocket netting is the up-tide netting on the Clarence River which began in 1965 (see below).

Peddling is only permitted in non-tidal areas of Lake Innes and nets and boats must be staked more than 500 metres from the start of the canal or 'the drain' between Cathie Creek and Lake Innes. Pocket netting in Cathie Creek therefore is tidal only and relies on the entrance to the sea being open for prawns to be caught.

There are seven pocket net positions in Lake Innes and Cathie Creek. These positions are allocated by random draw at 3 pm on the day of the full moon each month. Each position is determined in turn at the draw. If the crew comes out first they will have position one, and so-on. After all the crews have been allocated a site for the first night of the moon, the sites are rotated for the rest of the moon so each crew has a turn at the best positions. If there are more crews than positions, the positions are allocated into the second night of the moon, and so on until all crews have a position.

The positions are numbered from the confluence of the drain and Lake Innes out into the Lake and down towards Cathie Creek. Peddling can only take place from sites 2-7.

Generally there are only 2 or 3 crews in the draw for each position and not all seven sites are taken. In this situation, the other positions may be used. If a crew moves up to a position above them, the crew at the position below is entitled to also move up. This makes a difference in Lake Innes where fishermen believe the prawns can be caught at the western end of the Lake early in the moon and the eastern end, where the lake narrows, as the moon progresses.

Although pocket netting is permitted throughout the year in Cathie Creek and Lake Innes, most effort is between August and May. As with most other set pocket net fisheries, the majority of the prawns are caught from 7 to 14 nights after the full moon. The main species caught are school prawns although king prawns and greasybacks also form part of the catch.

**Watson Taylor Lake and Queens Lake Entrance (Stingray Creek)**

Pocket netting in Stingray Creek (from Queens Lake) and Camden Haven River (Watson Taylor Lake is part of the river system) began in the 1950's at the same time as Cathie Creek and Lake Innes. The pocket netting in this area is slightly different, however, in that the Camden Haven River is open to the sea all the time and in both areas tidal netting only is permitted. Legal net size is 20 m and while pocket netting is permitted all year, the season generally runs from August to May. Fishers state that Stingray Creek is more productive than Queens Lake, but that the latter has a greater variety of prawns, including tiger, king, school, leader, greasyback, banana, and what are believed to be racek prawns.

There are 9 sites in Stingray Creek and 5 sites in Camden Haven River. The pocket net draw takes place at 3 pm on the day of the full moon of every month. Each crew that nominates to pocket net for the month gets to draw a position out of the barrel. After all the crews have drawn a position, the next nights are rotated continually for the rest of the moon.

The draw used for Stingray Creek also applies to Watson Taylor Lake. Watson Taylor Lake, however, has no sites numbered 6 to 9 so if a crew draws one of these numbers on Watson Taylor Lake, they can work the corresponding site at Stingray Creek on that particular night.

As with Lake Innes and Cathie Creek, the best catching nights throughout the moon fall approximately between the seventh and the tenth night.

### 1.3 The Clarence River School Prawn Fishery

Prawning began slowly in the Clarence river with the first attempts in 1887 finding the prawns difficult to catch. In 1889, good quantities of prawns were caught and the following year, Hunter River fishers tried establishing a fishery on the Clarence river. A small local market, however, meant the fishery remained small for some time although good catches of prawns were made (Ruello 1974, Glaister 1976). From 1906 school prawns were caught in near-shore waters in good quantities. Anecdotal evidence from local fishers suggests that this near-shore fishery preceded king prawning in the area.

Glaister (1976) states that "until 1946 annual catches fluctuated between 5 3/4 and 55 1/4 baskets but in 1947, local fishermen caught school prawns in commercial quantities in Lake Wooloweyah". By towing a modified haul net between two boats, good quantities of school prawns could be caught consistently. Otter board trawling was first used in the river in 1949 and co-incided with the beginnings of the ocean prawn fishery in this area.

The fishery in Lake Wooloweyah continued to be viable and as the river fishery grew, vessels were designed and built to fish in the different areas. A shallow draft allowed the vessels to trawl the lake, but they were large enough to trawl the river and near-shore oceanic areas for king and school prawns.

Trawling for school prawns continued in the river with steadily increasing numbers of fishers. In the late 1970's and early 1980's there was a rapid development in the river fishery. No more licences are being issued for this fishery. Trends in catches of the river and oceanic parts of the school prawn fishery based around the Clarence River are presented in Section 2.3.

Clarence River trawl endorsement holders are permitted to fish in the main channel as far inland as Ulmarra ferry wire and in South Arm, Coldstream River and North Arm. The river trawl season commences on 1 December and ends on 31 May, however, concessions to open the river to fishing earlier are sometimes granted. Fishing is not allowed on weekends after 0900 hrs on Saturdays.

### 1.4 Historical Development of Set Pocket Netting in the Clarence River

Pocket netting in the Clarence river was first tried in Palmer's channel in approximately 1962, without much success. It was not until 1965 that success with pocket netting was achieved when propeller wash from trawlers was used to assist the outgoing tide. Early pocket netting using a vessel was all "out tide" netting but as vessel size and horsepower increased, fishers were able to use the propeller wash to 'push' the flood tide and catch the prawns migrating to sea in the quieter water out of the tidal influence. In the mid - 1970's one fisher started consistently set pocket netting with the out tide, not using a trawler. This was done near Maclean and a range of nets were made to suit differing conditions. At this time, approximately 15 - 20 fishers were set pocket netting, though not all of the time, and all had their favoured sites. Positions near the Broadwater, Maclean rocks and the Lawrence Beacon were all found to be profitable.

In 1976, because of increasing conflict among fishers, pocket netting was restricted to 1 net per fisher and a distance of at least 400 m between sites was required to stop adjacent positions reducing catches from those immediately 'downstream' (later to be reduced to 300 m in 1984). The rocks at Maclean proved profitable and were soon much sought-after positions. Fishers claimed a position by anchoring a float with their name on it at the site they wanted by 8.00 am on the 1st of August each year. But this often led to arguments when two or more fishers wanted the same site.

In 1984, arguments over positions on the Maclean Rocks led to the running of the first draw for the 16 Rocks positions at the rocks. The draw was held in August and first out of the hat took a site until none were left.

Positions could be held until May 31st. If a fisher wanted to work an unattended site they could negotiate with the site holder to operate the site.

In 1985 the draw system was applied to the whole river and approximately 150 positions were created from Ulmarra ferry to Freeburn Island. While no figures are available on attendances at the first draw, in 1986 828 positions were taken by 166 fishers at all draws throughout the year (Table 1.1).

Table 1.1: Total number of positions taken in the monthly draw per year and the total numbers of fishers claiming those positions. Note this does not reflect fishing effort as many positions taken in the draw are not fished. Data for 1985 not available.

| Year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|
| Positions taken | 828 | 804 | 509 | 497 | 643 | 659 | 315 |
| Fishers | 166 | 158 | 149 | 151 | 141 | 138 | 111 |

In 1991, the positions on the river were changed and the total number reduced to 138 (Fig. 1.1). The draw system continues today, with minor modifications and the Clarence River fishery is now the largest set pocket net fishery in New South Wales.

### 1.5 Current Management of the Clarence River Pocket Net Fishery

Set pocket netting is permitted at 138 positions (or 'digs', Fig. 1.1) on the main channel of the river between the first full moon in August and 31 May the following year. The digs are spread from Freeburn Island, 5 km from the mouth of the river to Ulmarra, 50 km upstream (Fig. 1.1). Each lunar month fishers are allocated a dig by ballot. Anyone holding a NSW commercial fishing licence is permitted to enter the ballot. At the end of each lunar month the digs are randomly re-allocated. There is enormous variability in the economic value of the digs (approximately 80% of the catch is caught at 5% of the digs). The location of the most prized digs varies with the time of year, the amount of fresh water in the river and the flow rate (Racek 1959, Glaister 1978a, b).

At each draw fishers are allocated a number when they nominate for the draw and each number is represented by a marble and put into a barrel at the draw. When the first number comes out of the barrel, the corresponding fisher chooses a site on the river. This process continues until either all the sites are taken or there are no marbles left. The number of fishers attending the draw varies over the season, from more than 100 per draw to as few as 3 or 4.

Fishers are allowed to form a crew to operate a site if the crew are in the draw (and present) but have not already taken a site and they have the necessary licences for pocket nets and boats. Only one site is allowed per fisher. As of August 1992, fishers taking a site were required to use their own licensed boat when pocket netting.

Current regulations restrict fishers to nets with ten fathom headlines with no restriction on net depth. All nets are required to be set within 5 m of the bank at low water mark except in the area known as the South Arm Rocks (or Maclean Rocks).

Pocket netting is restricted to certain weekends over the period of the moon. Weekends that fall within 3 days of the full moon may not be fished. All other weekends of the month are open to pocket netting. In months when trawling does not take place in the river, pocket netting is restricted to the hours between sunset and sunrise, but when the river trawl season commences on 1 December, pocket netting is allowed in daylight hours as well.

Fishers are required to use a 20 m headrope length net with 32 mm mesh when pocket netting but different lengths and depths of nets are made to suit various situations in the river. When up-tide netting, for example, fishers tend to use nets that are shallower in the wings (200-250 meshes deep) and shorter in length to be able to push the tide. The nets are also cut to form a curve so the vessel can be placed well back in the net to make the most of the propeller wash.

Out-tide nets are made to get the most from the 20 m headrope rule and are cut straight across the mouth. The depth of the wing panels for out-tide nets is generally 300 meshes though some 400 mesh nets are used depending on individual preference and the depth of water at the site.

**How pocket nets are set**

The set pocket nets used in the Clarence River vary in both cut and how they are deployed (Figs. 1.2 - 1.5). Two basic methods are employed: (i) fishing in the centre of the river and (ii) fishing adjacent to the bank. Fishing in the centre of the river always occurs with the outgoing tide while fishing adjacent to the bank usually involves the use of a boat and may be done with or against the tide, these methods are discussed separately below.

**(i) Pocket nets staked in middle of river.**

When fishing in the centre of the river, pocket nets are usually staked open with two, sometimes three, stakes (Fig. 1.2). Floats are attached to the headrope and weights to the footrope. At sites other than Maclean Rocks (digs 73 to 80, Fig. 1.1), anchors and long bridles are used to hold the net. The net has to be 5 m from the low tide mark on the bank side so generally the inside wing has bridles that attach to trees and/or anchors, rocks, etc on the shore. At the Maclean Rocks, all bridles have to be attached to their respective points along a long length of cable. That cable is anchored in such a way that all the nets can be set off it and that each position does not interfere with any others. Unlike nets used against the incoming tide, these nets are cut to obtain maximum width, given the 20 m restriction, while still maintaining a good shape in the water.

(ii) Pocket netting adjacent to the bank

The method of pocket netting adjacent to the bank is similar to that used in the centre of the river except that the nets are generally larger and the mouth of the net is not spread so widely. The depth and length of the wings differ depending on the depth of river and slope of the bank. A boat is generally employed to provide propeller wash so that fishing can be carried out with or against the tide, these two methods are detailed below.

**(a) Fishing against the incoming tide**

At some digs on the banks of the river, particularly at digs 36 - 38, 41 - 50 and 81 - 89, fishers attempt to catch prawns going to sea against the incoming tide. Many sites are not 'in tide' sites because the prawns do not run on the bank on the in-tide (because it is too strong). In these instances the pocket net is set against the tide and propeller wash is used to push water into the net to keep the net open and the codend straight against the tide, thus stopping the prawns escaping (Fig. 1.3). When used in this way, although the headline remains the same length, the body is shorter and the wings longer so the boat can be put further back into the body of the net. The wings of the net curve around the boat with one wing right in on the bank to capture prawns travelling in the slower water along the bank.

The net is anchored by itself with the sweeps being attached to poles pushed into the mud. Another pole tied to the footrope is pushed down alongside the anchored poles to open the mouth of the net and to keep it open. Weights are also used in the middle of the net to keep the ground rope on the bottom. The boat is anchored separately. Poles are pushed into the mud around the back of the boat to stop the net being pushed into the propeller by a stronger than expected tide.

(b) Fishing with the out-going tide

Trawlers are also used to accelerate water through nets when fishing on the out-going tide. The net is set in a similar way to that when set for the incoming tide, however, it is deeper in the wings, (200-400+ meshes), larger in the body and longer (Fig. 1.4). The aim is to maximise headrope length and some nets are specifically cut virtually straight across. At some sites the fishers position the poles and boat out further in the stream than when working the incoming tide, and change the net to this larger type. This usually happens when the prawns stop running on the incoming tide and change to going with the out-going tide.

Most digs where trawlers are used are generally operated like this with only the out-tide being worked, the propeller wash enhances the speed of the tide, arguably increasing catches. Floats and weights are also used on the headrope and footropes, and poles pushed down to open the net wings, and therefore the mouth.

### 1.6 Objectives of this Study

To evaluate the potential for expansion of the set pocket net prawn fishery in New South Wales by the following steps:

1) To quantify the species composition and the biomass of prawns and by-catch taken by commercially operated set pocket nets in the Clarence River, Hastings River and Wallis Lake.

2) To test for differences between estuaries, sites within estuaries, seasons and other environmental data, in terms of prawn catch and by-catch of non-target species.

3) To compare this passive fishing method to the more active methods of prawn trawling and hauling.

Preliminary sampling in the early stages of this project indicated that there was a large amount of variability in catches in the largest set pocket net fishery, in the Clarence River. This observation was supported by previous studies of the trawl fishery in the Clarence River and in other estuarine prawn fisheries in New South Wales and subsequently confirmed by the sampling done in the present study. This variability meant that intensive sampling was required to obtain repeatable estimates of catches in the fishery. For this reason, the great majority of sampling was restricted to the Clarence River, at the exclusion of sampling in other estuaries during the peak set pocket season (August to February). The short-term sampling in the Myall Lake pocket net fishery strongly suggested that conclusions drawn from exploratory fishing for short periods in other rivers and estuaries would have little generality. The present study was therefore restricted to providing an adequate description of the Clarence River Set pocket fishery and a short-term quantification of the Myall Lake fishery. The set pocket net fishery in Wallis Lake has been the subject of a separate study that will be described elsewhere (McDonell et al., in preparation).

This Report is divided into descriptions of the dynamics of catches of prawns (Chapter 2), by-catch (Chapter 3), fishery independent surveys of juvenile prawns (Chapter 4), a comparison of trawling and set pocket netting in the Clarence River (Chapter 5), and a preliminary description of the Myall Lakes pocket net fishery (Chapter 6). Each chapter has been written relatively independently in preparation for publication in journals. Some material is therefore repeated, particularly in the Introductions.

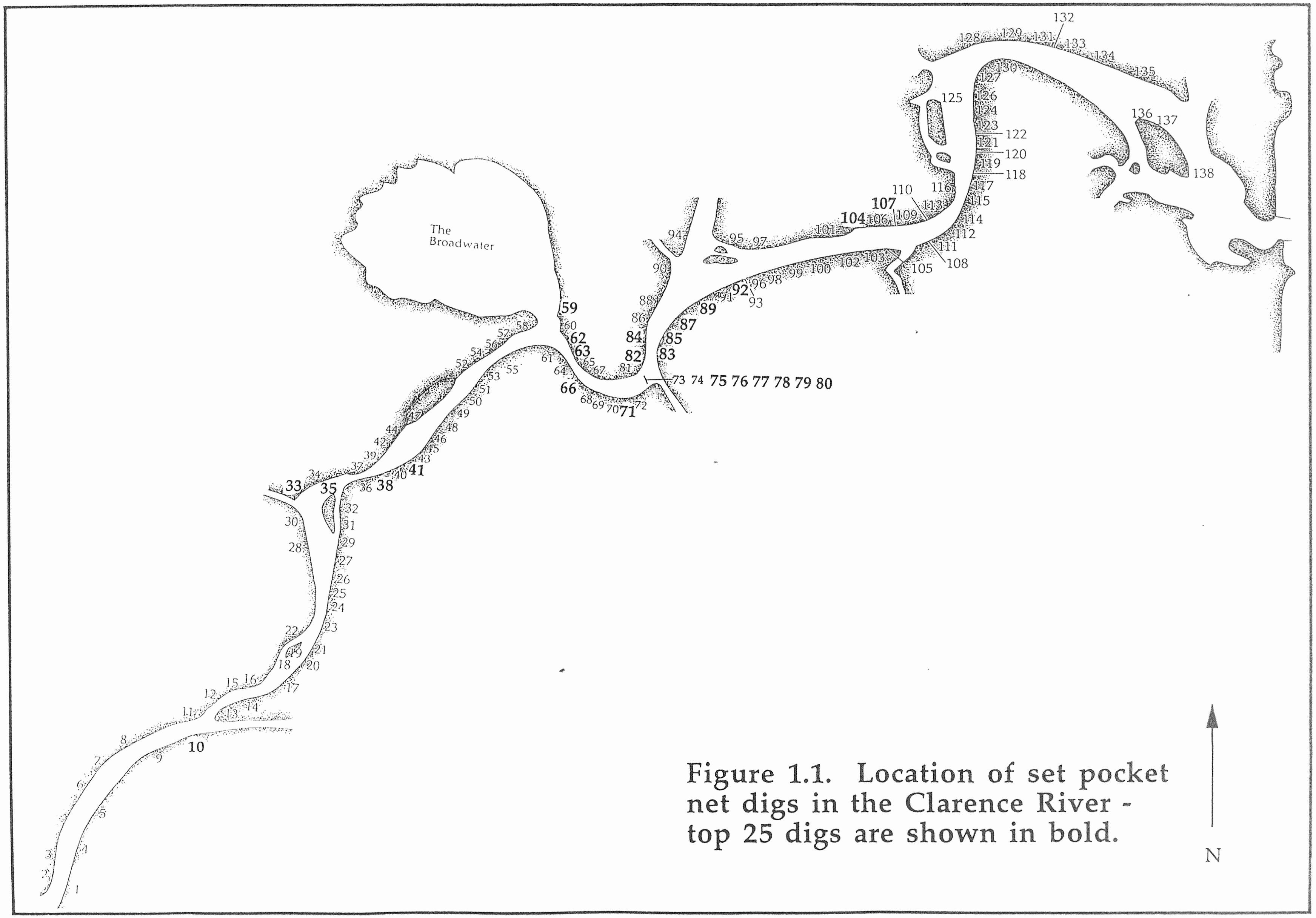



**Figure 1.1. Location of set pocket net digs in the Clarence River - top 25 digs are shown in bold.**

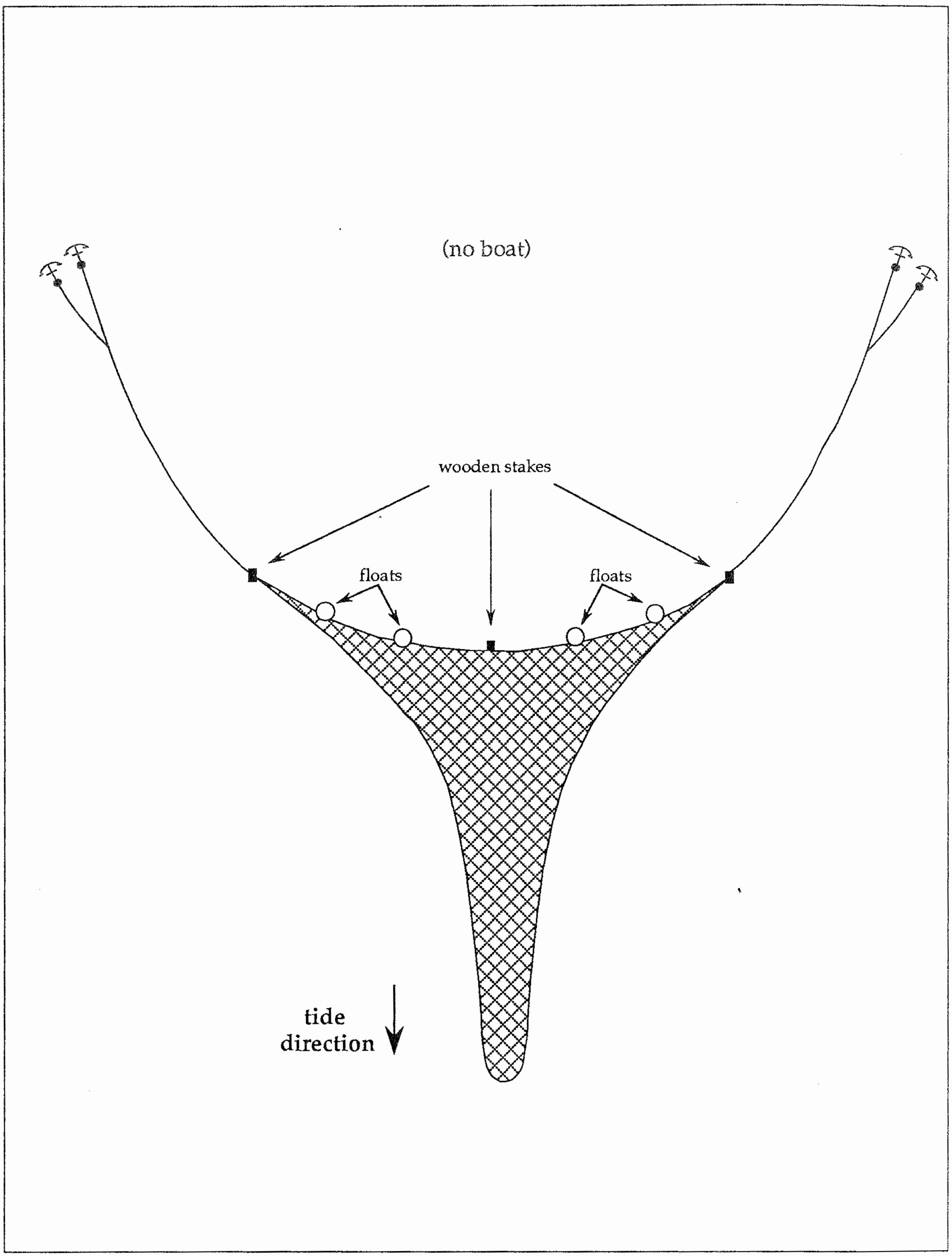



Figure 1.2. Configuration of the net for set pocket netting. Anchors hold the net in position and wooden stakes are used to keep the mouth of the net open for fishing with the tide.

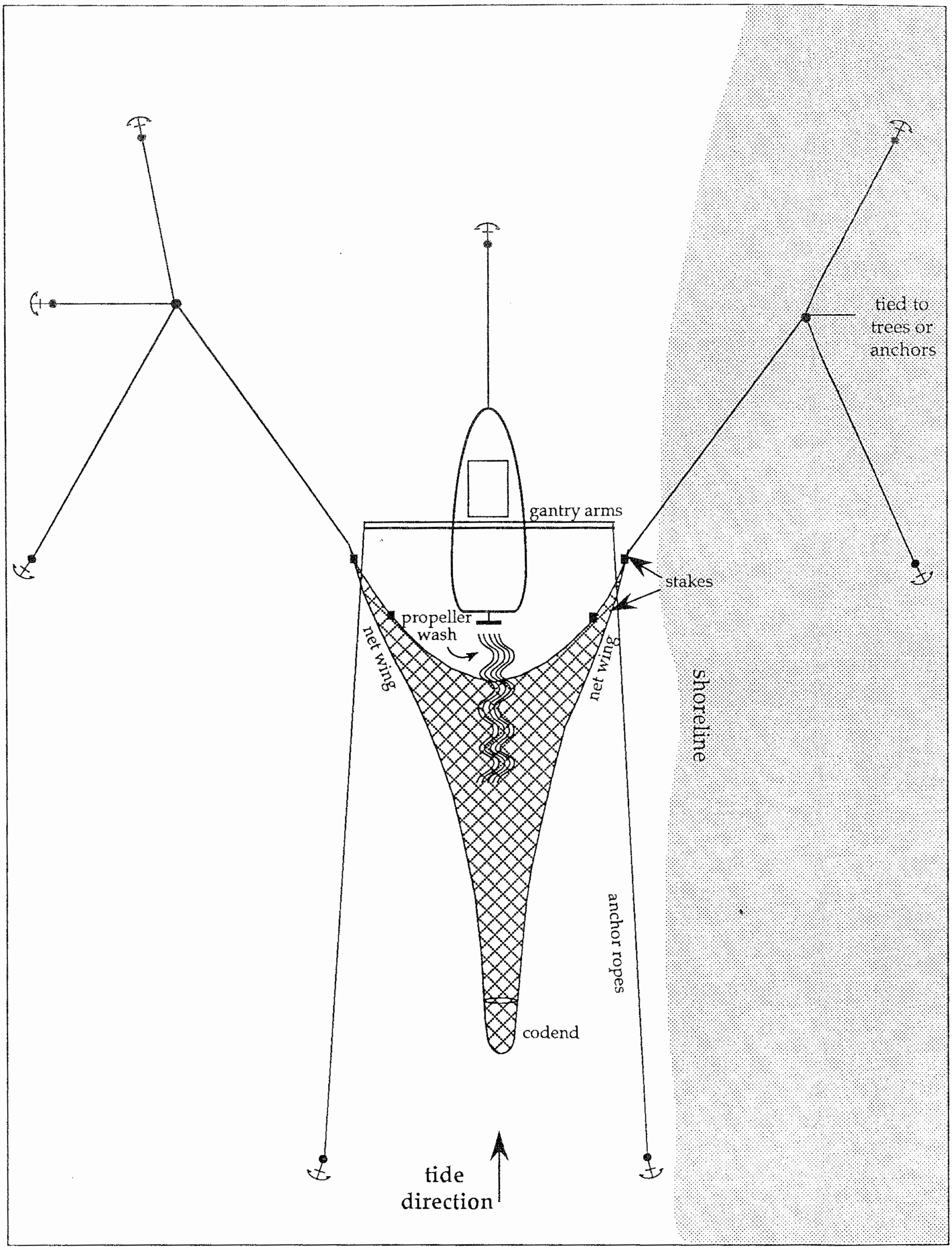



Figure 1.3. Diagrammatic configuration of the net for fishing against the direction of the tide with the assistance of a boat. Anchors are used in both directions and the boat's **propeller wash** serves to hold open the net.

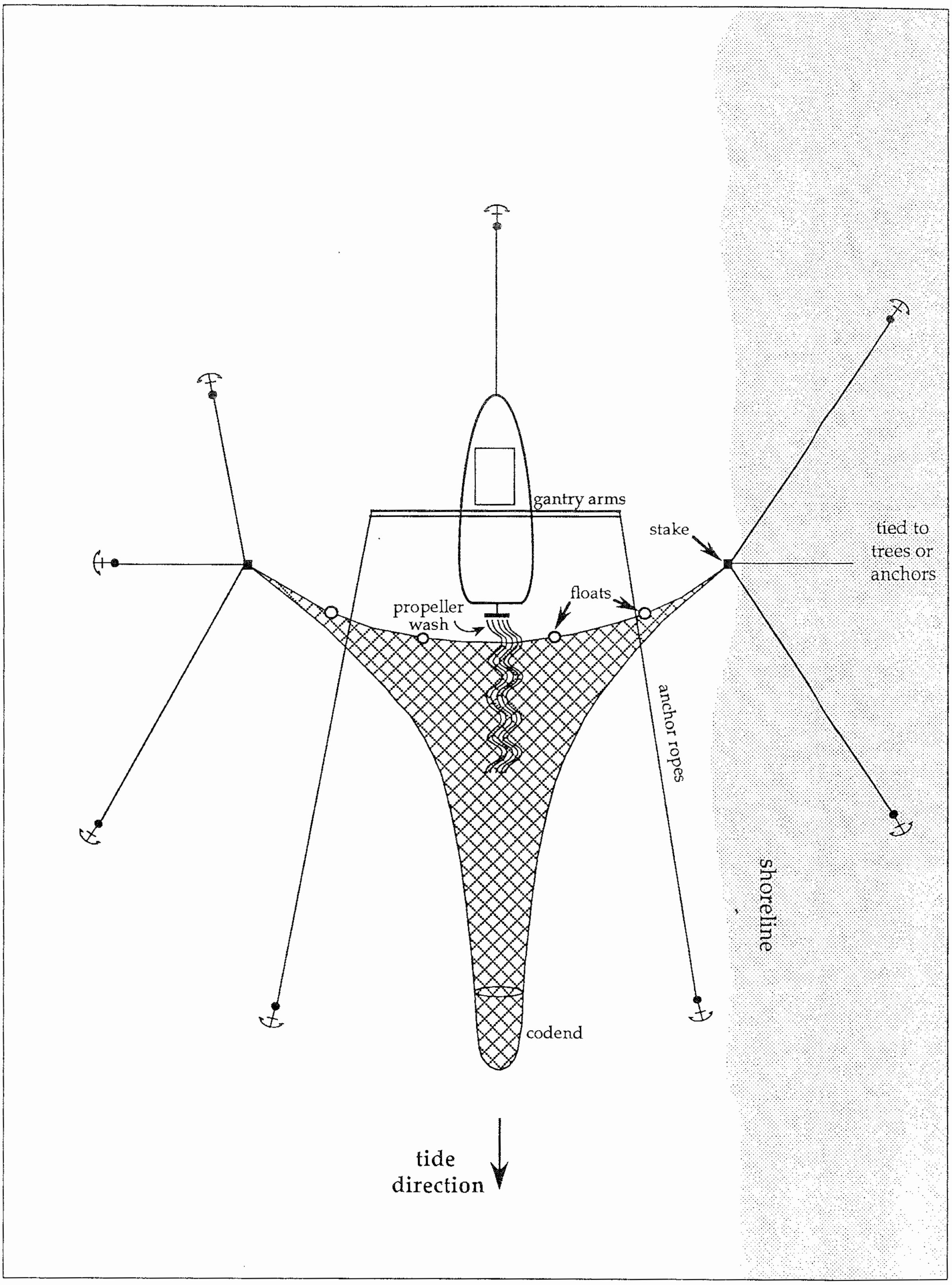



Figure 1.4. Fishing with the tide with the assistance of a boat. This configuration accelerates the flow of water through the net, maximising the catch of prawns.

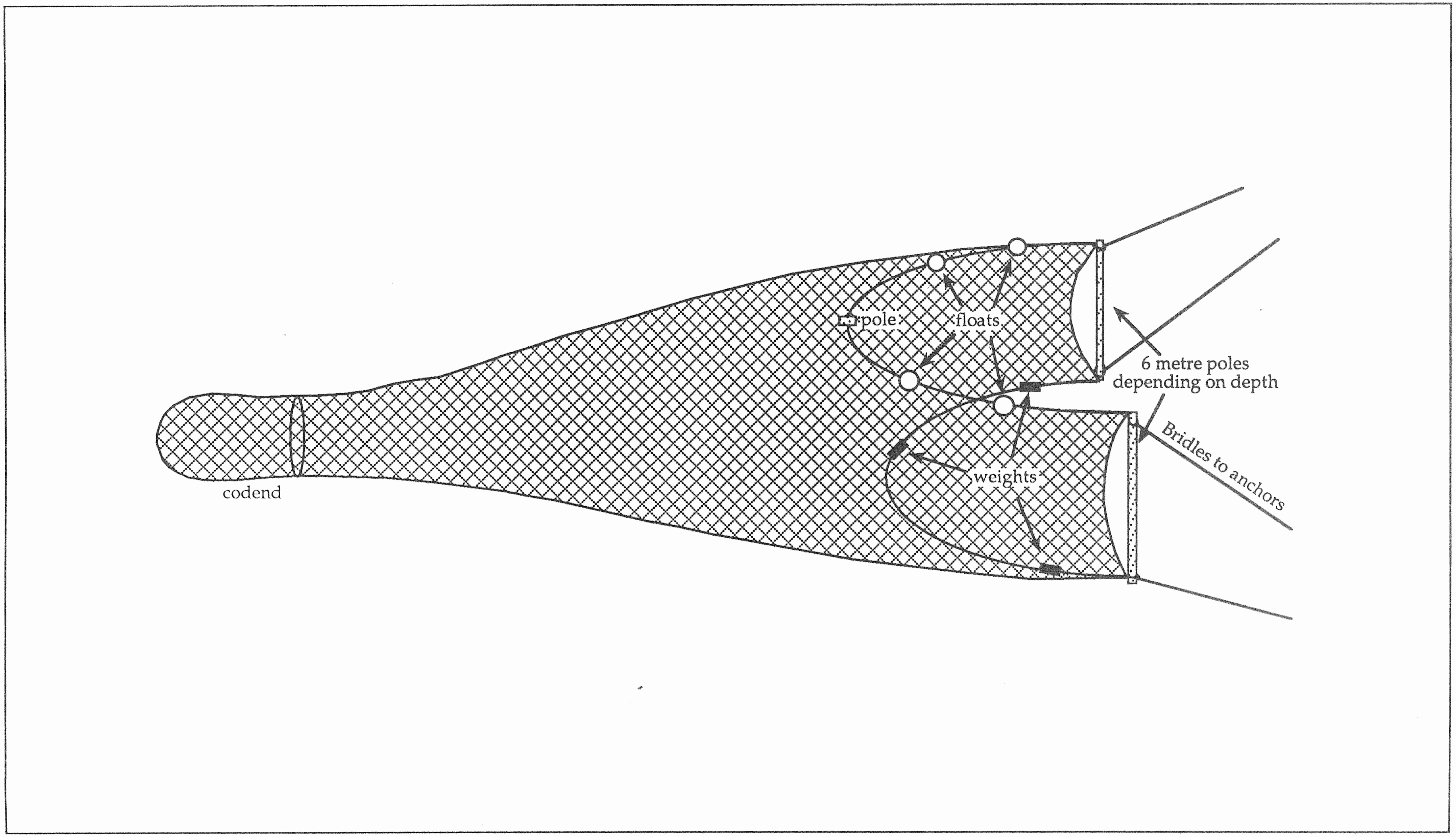



Figure 1.5. Side view of the Set pocket net configuration.

# CHAPTER TWO: DYNAMICS OF THE SET POCKET NET FISHERY FOR SCHOOL PRAWNS (*METAPENAEUS MACLEAYI*) IN THE CLARENCE RIVER

## 2.1 Catch and Effort

### 2.1.1 Introduction

The great majority of the worlds catch of prawns, including those in Australia, is from trawl fisheries (Wickens 1976, Gulland and Rothschild 1984). The dynamics of fisheries utilising other methods are poorly understood. Of these alternative methods, traps (e.g. Yamane and Flores 1989, Buckworth 1992) and stow or set nets are possibly the most described (e.g. Guthrie 1966, Glaister 1977, 1978a, Le Reste 1980, Changcheng 1992, Chavez 1992). The potential advantages of these methods include smaller by-catches, less habitat damage and reduced fuel costs for fishers (Buckworth 1992, Andrew et al. sub. ms.).

Because methods such as traps and stow nets are passive, catches are likely to be more variable and influenced by factors such as environmental variables and the migratory behaviour of the prawns to a much greater extent than trawling. In Australia, the best known stow net fishery is the set pocket net fishery in the Clarence River (Glaister 1978a). Glaister described the strong lunar periodicity in catches in the set pocket net fishery and suggested that this was related to the migratory behaviour of the prawns.

In this section we describe trends in catch and effort in the set pocket net fishery for school prawns (*Metapenaeus macleayi*) in the Clarence River over two seasons between 1991 and 1993. This fishery is unusual in many respects, particularly the random allocation of fishers to fishing positions on the river. The present study builds on the earlier work of Racek (1956, 1959), Ruello (1973a, b) and Glaister (1977, 1978a, b) who described many aspects of the biology of *M. macleayi* and fisheries for this species. The set pocket net fishery developed in the mid 1950's to target prawns migrating to sea during spring and summer each year. The historical development and current fishing practices in the fishery have been described in Sections 1.4 and 1.5. Glaister's (1978) analysis of the fishery for school prawns in the Clarence River was largely concerned with the total catch in the river, including trawling, and did not partition out set pocket net catches to any great extent. The Maclean Cooperative, which processes the great majority of the school prawn catch does not differentiate prawns caught by pocket netting and trawling. In order to understand this fishery, it was therefore necessary to isolate the catch of the pocket net fishery using observers and information from logbooks.

### 2.1.2 Materials and Methods

Information on catch and effort was gathered by a voluntary logbook program and by observers placed on vessels. The great majority of information came from logbooks. The voluntary logbook program began in September 1991 and ended in May 1993. At each draw, fishers were given a logbook and asked to provide information on catch and effort for the subsequent lunar month (Appendix 2). Each month fishers who returned a logbook were sent a graph showing how their catch contrasted to the average of the fleet and the phase of the moon through the month (Appendix 2). Logbooks were returned by fishers from an average of 53.0% (± 5.3, range 10.9 to 100.0%, Fig. 2.2) of the digs taken per month. We assume that catch rates estimated by the logbooks are representative of the fleet. Although information was collected on a finer temporal scale (each lift of the net through the night), the data here will be presented and analysed only per night or longer intervals.

Additional information on catch rate was gained from the observers placed on vessels to quantify by-catch (see Chapter 3 for details). Information on catches of school prawns from previous years was collected from (Glaister (1978; 1966-76), Montgomery and McDonall (1987; 1976-1985) and directly from records held at the Maclean Cooperative (1985-1993). It was not possible to partition pocket net catch from trawl-caught prawns for these historical data. Note, however, that set pocket netting is the only means by which school prawns may be caught in the river during August and September each year. For the period 1985-1993 information on the price paid by the Maclean Cooperative was also gathered.

In order to compare catch among places on the river, digs were grouped into six zones (Fig. 2.1). Digs within each zone were as follows: Zone 1, digs 1 - 11; Zone 2, digs 12 - 32; Zone 3, digs 33 - 55; Zone 4, digs 56 - 81; Zone 5, digs 82 - 110; Zone 6, digs 111 - 138. These zones divide the main river channel into units that are bounded, in as much as possible, by the entry or exit of major channels or tributaries in the river (e.g. Zone 2 is bounded by the head of South Arm and the entrance of Fisherman's Creek, Fig. 2.1). Subsequent analysis indicated that these zones were useful subdivisions. Because information was collected from relatively few dig-nights in zones 1, 2, and 6, further grouping of digs was required for statistical comparisons. Dig-nights in zones 2-3 were pooled and compared with zones 4 and 5. Because only 5 nights were sampled in zone 1 and 18 nights in zone 6 during the study, data from these zones were not analysed.

There were sufficient dig-nights sampled per month to statistically compare catches only in September, October and November of each year. Effort in the set pocket net fishery in both 1991-92 and 1992-93 sharply declined in December. Differences in mean catch of prawns among zones, years and months were compared by three factor analysis of variance (Winer, 1971). All factors, Zone (2-3, 4 and 5, considered a fixed factor), Year (1991-92 and 1992-93, random factor) and Month (September, October and November, fixed factor) were orthogonal. SNK tests were used to separate means after significant $F$ tests (Snedecor and Cochran 1982). Means presented in the text are accompanied by standard errors.

Total effort in the fishery per month was estimated by accounting for as many as possible of the dig-nights using data from logbooks, observers and from information collected at each draw. The maximum possible effort in the Clarence River pocket net fishery is limited to 3864 dig-nights per lunar month (28 nights x 138 digs). The number of nights fished was calculated by multiplying the number of digs taken by the mean number of nights worked per dig per month from logbooks. The effort accounted for by the observer data was subtracted from this estimate to avoid duplication wherever appropriate.

Estimates of the total catch per month for the fishery were made by extrapolating estimates of catch per night by estimates of effort in the fishery. Total catch per month was estimated by summing:

1) Known catch from observer-nights.

2) Known catch from logbooks.

3) Mean catch/dig-month (estimated from logbooks)x number of digs taken but not sampled.

The variances associated with estimates of 3) were calculated following the rules of Cochran (1963). Estimates of total catch for each year were obtained by summing these components of variation for each month.

The value of the fishery was calculated using the average weekly pool price of prawns landed at the Maclean Cooperative. The pool price is the average of weekly prices paid by the Sydney, Brisbane and local markets. The Cooperative grades school prawns based on size, cooked or green, and river or ocean-caught and the prices differ among grades. The weekly price used is the average of the price paid for these grades. No data on total prawn catch were collected for 1993.

In order to quantify trends in the sizes of prawns caught, prawns from each zone were sampled each lunar month. One kilogram of prawns was purchased from set pocket netters each month in all zones where fishing occurred. Because not all zones were fished in all months, there are some month-zone combinations for which we have no data. Sampled prawns were sexed and measured to the nearest mm carapace length. In addition, the maturity of the prawns were determined by macroscopic inspection.

### 2.1.3 Results

#### Effort

Within lunar months effort was greatest 5 to 12 nights after the full moon (Fig. 2.3a). In both the 1991-92 and 1992-93 fishing seasons, most effort was concentrated between August and November (Fig. 2.4). After December, when trawling was permitted in the river, there was little effort in the pocket net fishery, particularly in 1991-92 (Fig. 2.4).

Of the 138 digs available each lunar month, an average of 38.2% (± 5.6) were taken by fishers (Fig. 2.2). There was a large amount of variability in the number of nights worked at each dig (Fig. 2.5a). The 25 most productive digs were worked for an average of 6.5 ± 0.12 nights per month and the mean for all digs for which data were returned was 3.77 ± 0.02 (compare Fig. 2.5 a & b). During the present study, the great majority of effort was limited to zones 3-5 (digs 33-110), centred around Maclean (Figs. 1.1, 2.1).

#### Catch rates

There were significant differences among months, years and zones in the mean nightly catch of prawns as estimated from logbooks and observers (Table 2.1). These differences were not consistent across any combination of these factors (see three factor interaction term, Table 2.1). *A posteriori* means tests revealed that the significant interaction term was caused by changes in the magnitude of differences among zones rather than their order. In all months and years there were no significant differences in catch between zones 4 and 5 and catches in both were significantly larger than in zone 2-3, except in October

1992 (SNK tests, $p < 0.05$). Catches in September were significantly smaller than October -November in all zones except zone 2-3 in 1991-92 and zone 4 in 1992-93 (SNK tests).

The factor Zone accounted for 23.2% of the variance in the model, suggesting that differences amongst zones had a large influence on catch rates relative to years and months. The majority of variance (57.5%) resided in the error term in the analysis of variance model (Table 2.1), suggesting that there were large differences among dig-nights when compared to higher level factors such as Zone and Month. The Mo x Yr x Zo interaction accounted for 13.6% of the variance.

The mean catch per dig-night was greatest 7-10 nights after the full moon (Fig. 2.3b). An increase in catch rate was also evident in the last 2 days of the lunar month (Fig. 2.3b). This peak was caused by fishers with good digs fishing in order to decide whether to seek that dig for the following month. Because relatively few digs are fished in this way (Fig. 2.5), the second peak in catch rate was not evident in the summed catch from all digs for which there was logbook data (Fig. 2.3c).

There were large differences in the way the digs were fished within months. Some digs, such as No. 59 were fished, on average, 12.3 (± 1.9) nights per lunar month while others, such as 79 and 38, although they were fished less often (8.2 ± 2.1 and 9.5 ± 6.5 nights respectively), produced larger average catches per night (Fig. 2.5c). The largest total catches were produced from digs which had moderate to high catches per night and fished for a relatively large number of nights per lunar month (Fig. 2.5b).

When catches from all months were pooled, catch rates were greatest in zones 4 and 5 and least in zone 2 and 6 (Fig. 2.6). Although only five nights were fished in zone 1, large catches were recorded on those nights. Only small nightly catches were recorded in the zone nearest the mouth of the river, zone 6 (Figs. 2.6, 2.7).

There was a relatively poor relationship between the expectation of fishers (as indicated by rank at the ballot) and subsequent catch for all months studied. Although the rank of catch was broadly in line with expectation, particularly the first 5 digs selected, few ranked catches were predicted and smaller than expected catches were as common as larger than expected catches (Fig. 2.8a, b).

**Total catch**

The total catch of the set pocket net fishery during 1991-92 and 1992-93 was greatest prior to December and sharply declined thereafter (Fig. 2.9). In 1991-92 the total catch was less than 535 kg after November 1991. In contrast, total catch increased in the latter months of the season in 1993 (Fig. 2.9). The extrapolated estimates of total catch in the pocket net fishery broadly agreed with estimates of landed catch from the Maclean Cooperative (Fig. 2.9). There was no evidence of consistent bias in the difference between the two estimates. We infer from this that our extrapolations of total catch for the remainder of the season, when trawling is permitted, are good estimates of total catch. Using these estimates, set pocket netting accounted for 11.6% of the total river catch in 1991-92 and 25.6% in 1992-93. After trawling was permitted in the river, in December each year, pocket netting accounted for only 0.5% of total catch in 1991-92 and 14.0% in the following year.

**Sizes and maturity of prawns**

Very few prawns with ripe gonads (< 0.01 %) were sampled from the set pocket fishery during the present study.

Although similar sized prawns were caught in all zones and months (Fig. 2.10 a-d), there was a trend toward decreasing size with distance from the mouth of the river in some months. For example, in September-October 1991 mean size of females decreased from 17.9 ± 0.96 in zone 6 to 15.9 ± 1.70 in zone

2. Such trends were not evident in other months, for example, November-December 1991 (Fig. 2.10a). In all samples the average size of males was 1-2 mm smaller than females and all length - frequency distributions were unimodal (Appendix 1) (Fig. 2.10 a-d). The largest prawn measured during this sampling had a carapace length of 24 mm. Complete length frequency distributions from all samples are presented in Appendix 1.

**Value of the Set Pocket Net Fishery**

The value of the total river fishery (trawling and pocket netting) was estimated to be $1 913 091 in 1991-92 and $824 932 in 1992-93. Although catch and value of the trawl component in 1991-92 was more than twice that of 1992-93, set pocket net values for these two years were similar. Preliminary best estimates indicate that set pocket netting accounted for 15.5 and 27.4% of this total value in the two years studied ($295 911 in 1991-92 and $226 351 in 1992-93). Note that these estimates are based on extrapolated estimates of catch in the set pocket net fishery. Price per kg of prawns was relatively constant over the study period, although variation in 1991-92 was greater than 1992-93.

The value of the fishery was closely correlated with catch (Fig. 2.11). Most of the value of the fishery was in the first 4 months, after which time catches and therefore total value was relatively low. There was little effort, catch or value in the set pocket net fishery after November in 1991-92 (Fig. 2.11). In 1992-93, there was greater effort in the set pocket net fishery (Fig. 2.4) and this was reflected in the value of the total catch (Fig. 2.11). Prices per kilo were greatest at the beginning of each season (Table 2.2) and declined after the opening of the trawl season in December. Prices remained relatively stable in the latter half of both seasons (Table 2.2).

### 2.1.4 Conclusions

Set pocket netting accounted for a relatively small proportion of the Clarence River school prawn fishery in the 1991-92 and 1992-93 seasons (12 and 26% respectively). This small contribution to the total river catch was largely because of the dramatic decline in fishing effort, particularly in 1991-92, after the opening of the trawling season in December each year.

The prawns caught in the fishery over the period of the study were relatively small and none were gravid. There was no evidence that set pocket netting was catching prawns that would have spawned immediately upon leaving the river. Regrettably there are few data with which to compare the sizes of prawns currently caught and those caught in previous years. Although prawns have been measured in the Clarence River since at least 1970, we can find no data that are specifically identified as coming from the set pocket net fishery, and therefore comparable with the present study.

Effort in the fishery is less than is possible under the present management regime, as evidenced by the number of digs not taken in the draw each month and the number of digs taken but not worked. On average only 38.2% (± 5.6) of the 138 available digs are taken per month. This apparent under-utilisation reflects the complexity of the fishery and the large variability in the profitability of digs. The ten most productive digs accounted for more than 85% of the total catch in the pocket net fishery and only 18 digs produced more than $1000 worth of prawns per month (assuming $4.50/kg and using the mean monthly production figures presented in Fig. 2.5). Production in the set pocket net fishery in Clarence River is unlikely to significantly increase without allowing digs to be established outside the main channel.

Trends in catch within each lunar month were similar to those described by Glaister (1978a). Catches were greatest 7-14 days after the full moon and many fishers fished only a few days either side of this time. There were, however, large differences among digs in the way they were fished. Some were fished relatively consistently through each lunar month while others were fished for only a few days.

The small income derived from even the most productive digs and the great economic uncertainty of each months catch supports the view that pocket netting can not alone be considered a viable source of income for fishers. The majority of fishers that participate in this sector of the Clarence River school prawn fishery also hold endorsements to trawl and the transfer of effort to trawling each December in both years of the present study clearly indicates that trawling is the preferred method of fishing.

The majority of the top 25 digs were centred around Maclean, particularly at the confluence of the main channel and South Arm. Despite this grouping, there was no simple relationship between location and catch and several productive digs were distant from Maclean (e.g. 10, 104, 107). The location of the most productive digs varied with time of year and discharge. Fishers reported very large catches in zones 1 and 6 in other years, depending on river discharge and other factors. Further evidence of the unpredictability of the fishery is provided by the fact that fishers were only moderately successful in predicting catch (as evidenced by their ranked expectation vs actual catch).

The net effect of the extreme variability in catch, the administration of the fishery by ballot and the large number of applicants in the ballot each month is to make the fishery very unpredictable. Unlike most other fisheries in New South Wales, the expectation of catch is linked not only to the state of the resource, fishing skill and application, but in large measure to chance. There is no clear alternative to balloting digs each lunar month as this is the only means of allowing equitable access to the resource. Greater predictability could, however, be achieved by reducing the number of people in each ballot. It is important to stress that such a reduction would not be a resource conservation measure. Effort in the fishery is limited by the number of productive digs, not by the number of applicants in the ballot.

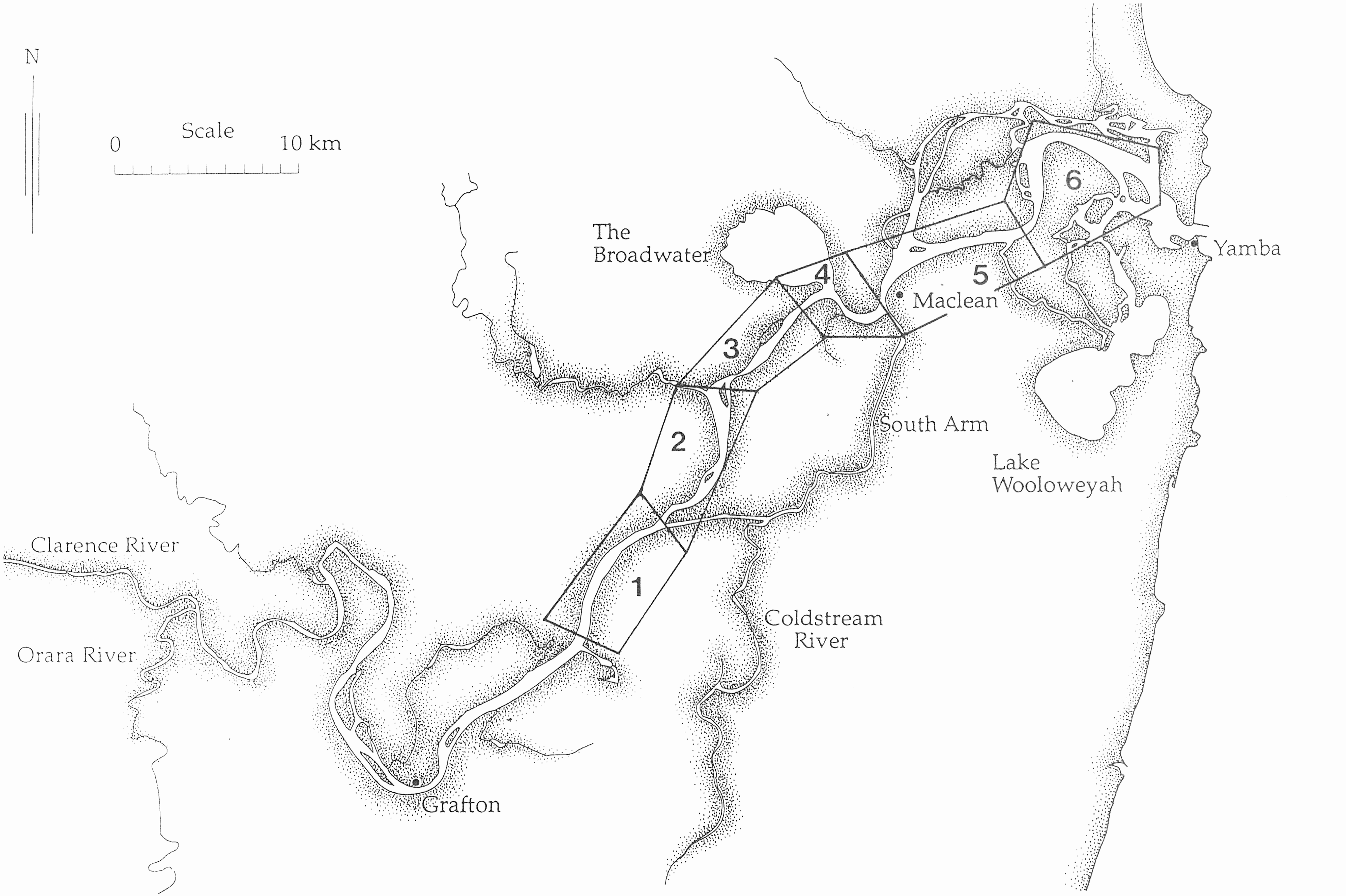



Figure 2.1. Location of zones used in the analysis of the set pocket net fishery.

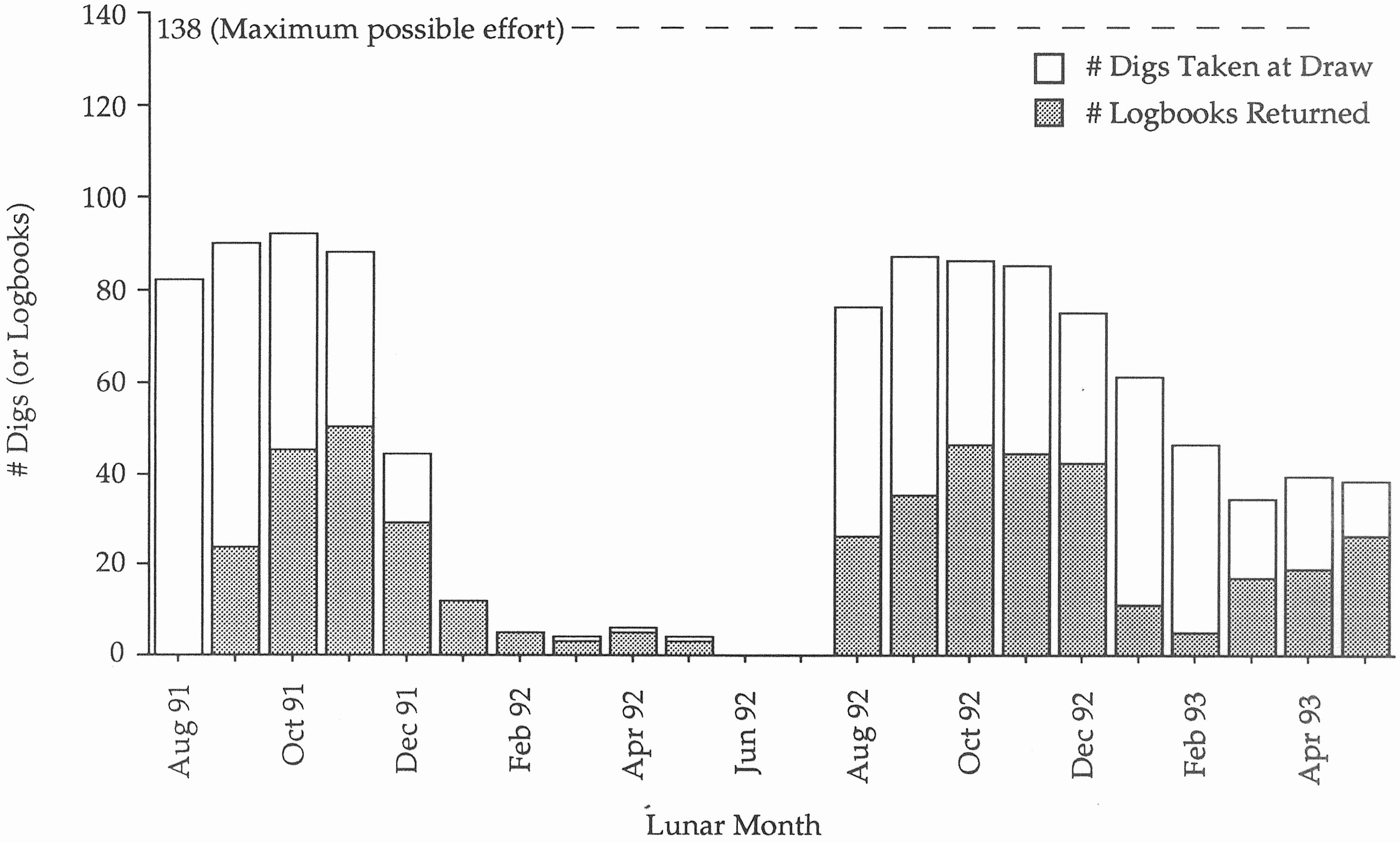



Figure 2.2. Number of digs worked per lunar month for the 1991-92 and 1992-93 set pocket net seasons. Shaded areas indicate those digs from which logbooks were returned. No logbooks were issued in August 1991.

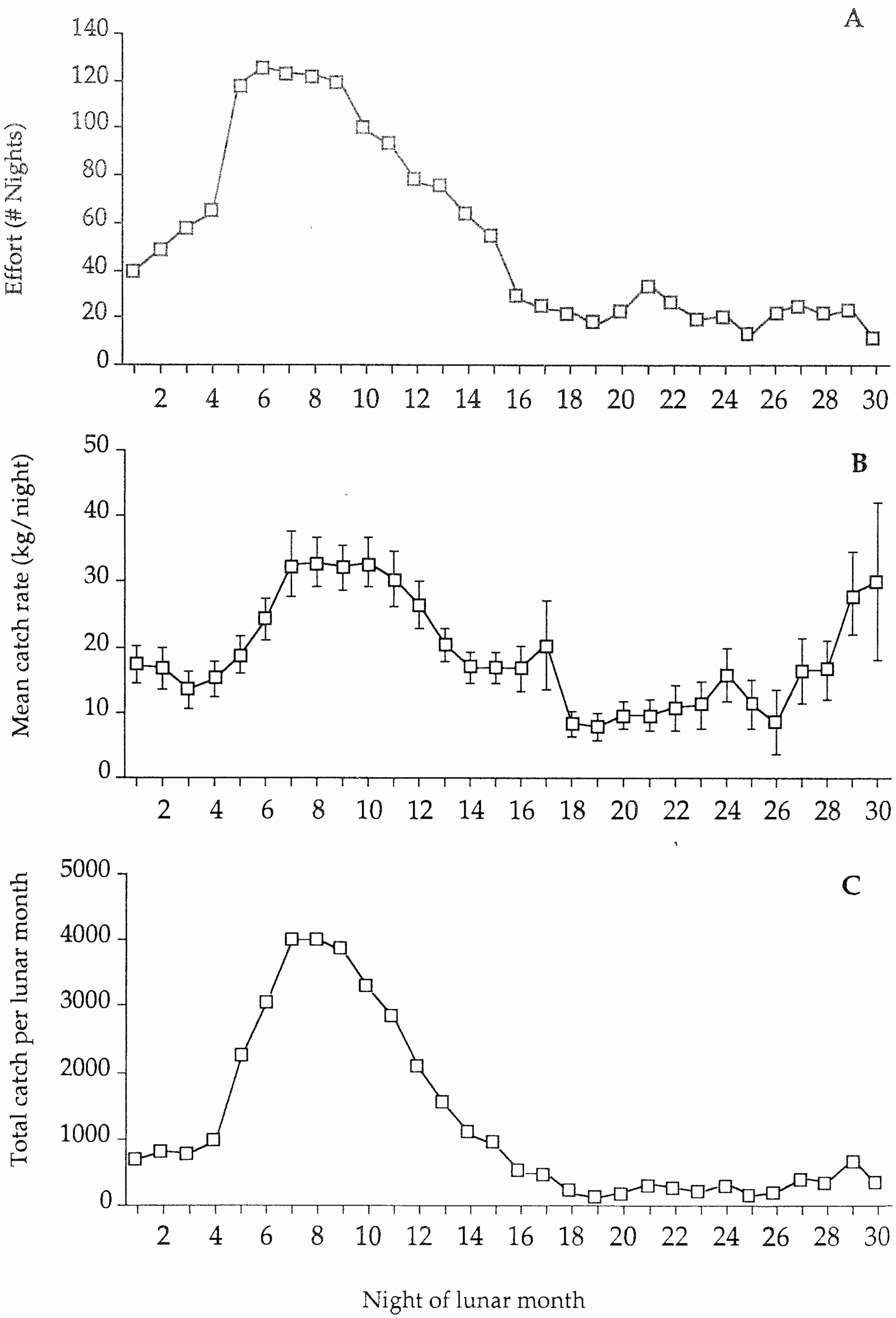



Figure 2.3. Relationship between catch and effort per lunar month (a) summed number of nights worked on each day of the lunar month for the study period. Night 1 was the full moon. (b) average catch per dig night (c) total catch per lunar night.

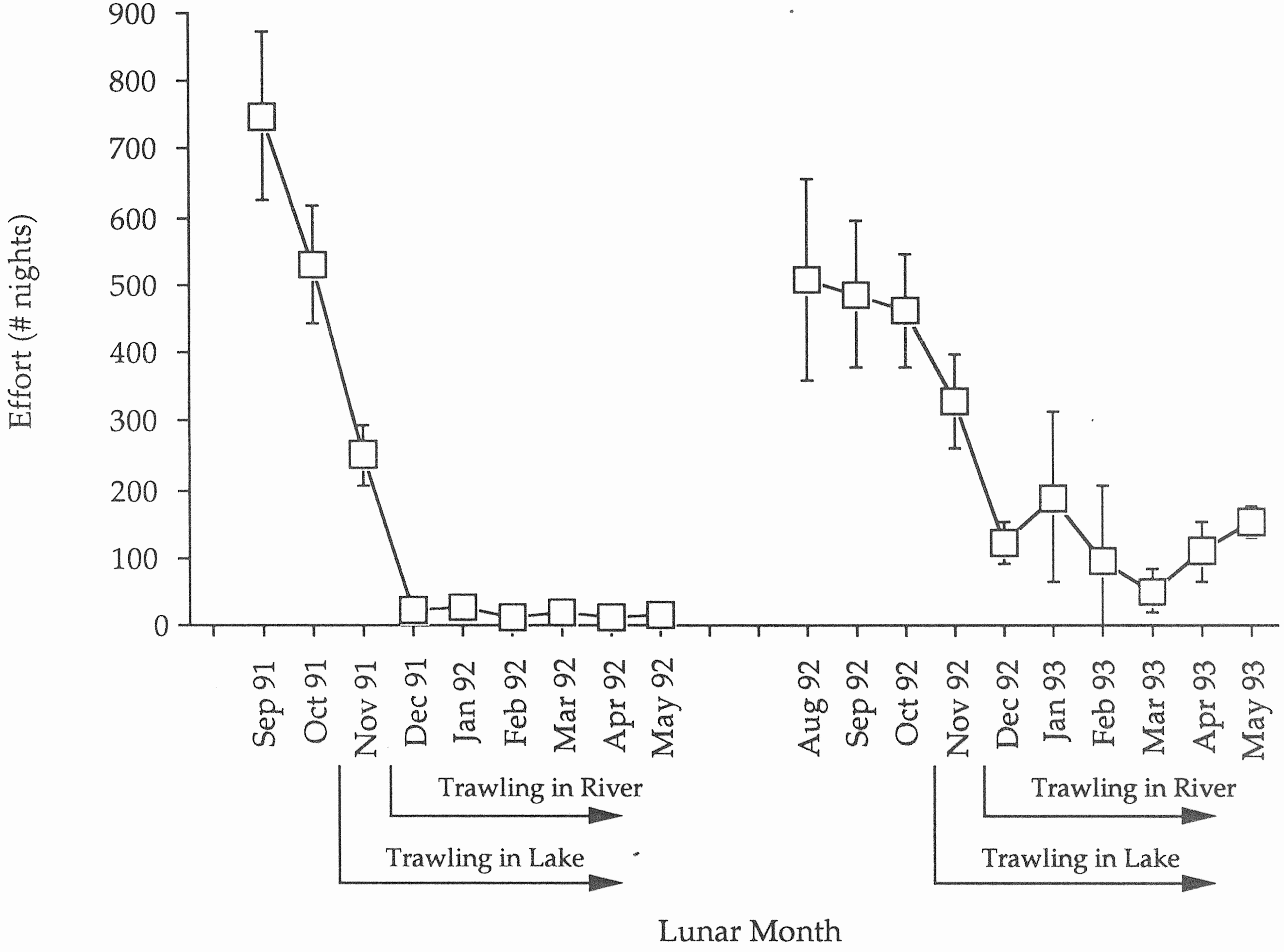



Figure 2.4. Estimated total effort (± 95% C.I.) for the 1991-92 and 1992-93 set pocket net seasons.

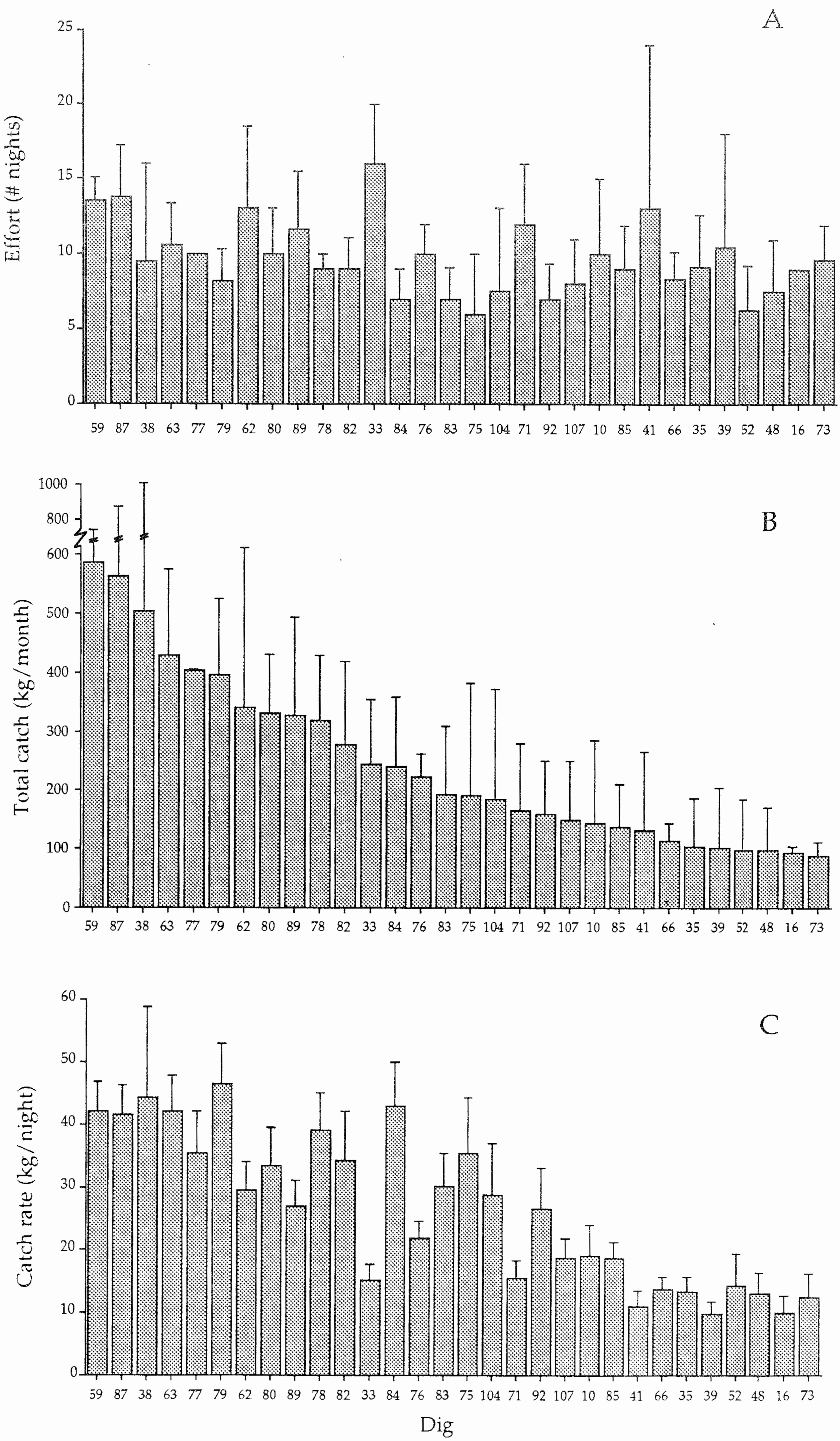



Figure 2.5. Patterns in mean (± S.E.) catch and effort per dig per lunar month. (a) Mean number of nights fished per lunar month, (b) Mean catch per lunar month and (c) Mean catch per night.

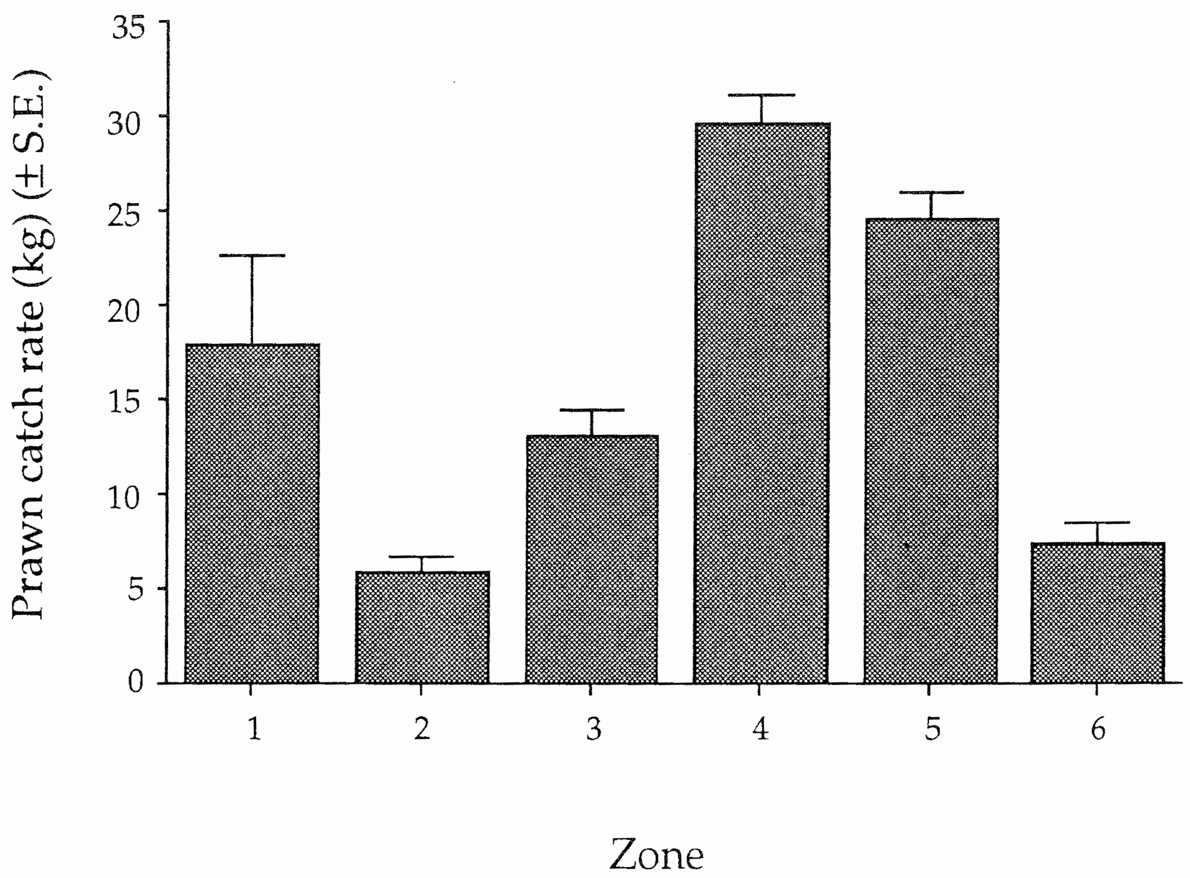
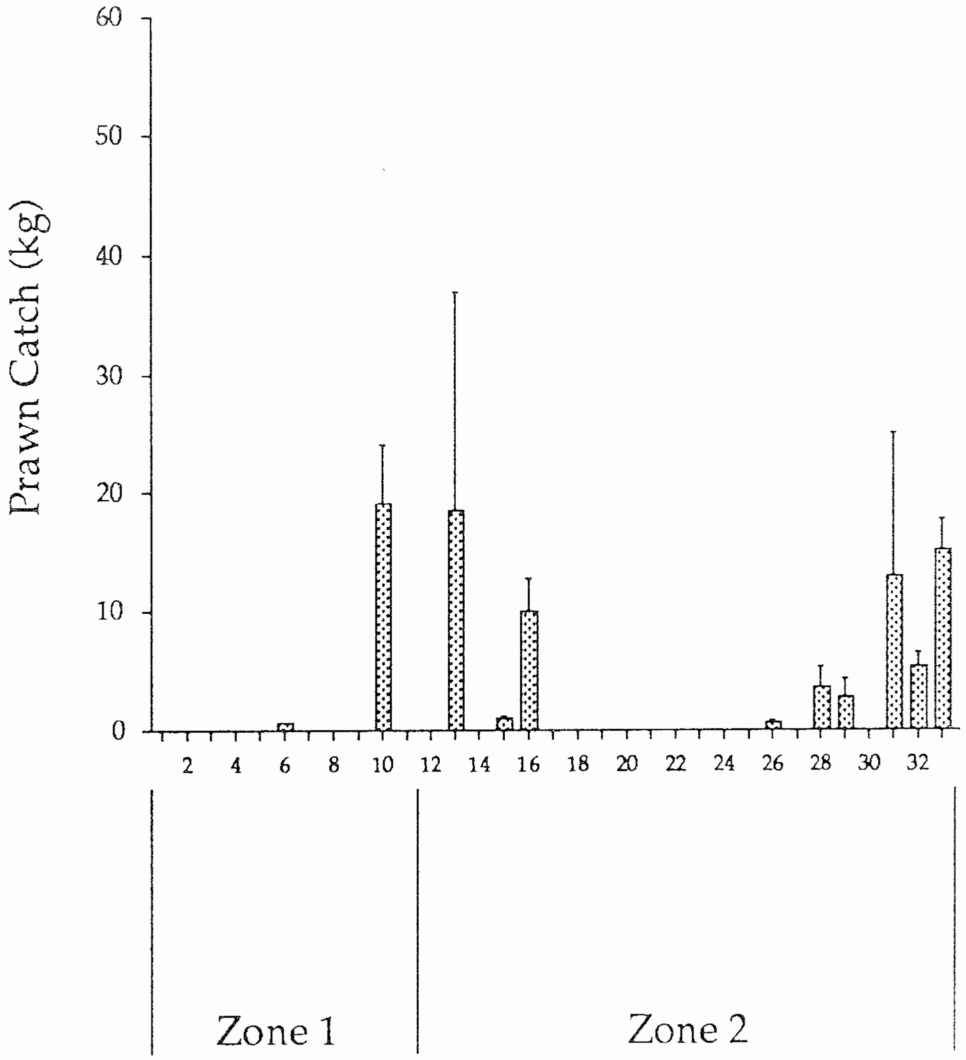



Figure 2.6. Mean number (± S.E.) of prawns caught per night per dig by zone in the Clarence River. Data pooled across all months


Prawn Catch (kg)
60
50
40
30
20
10
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Zone 1
Zone 2

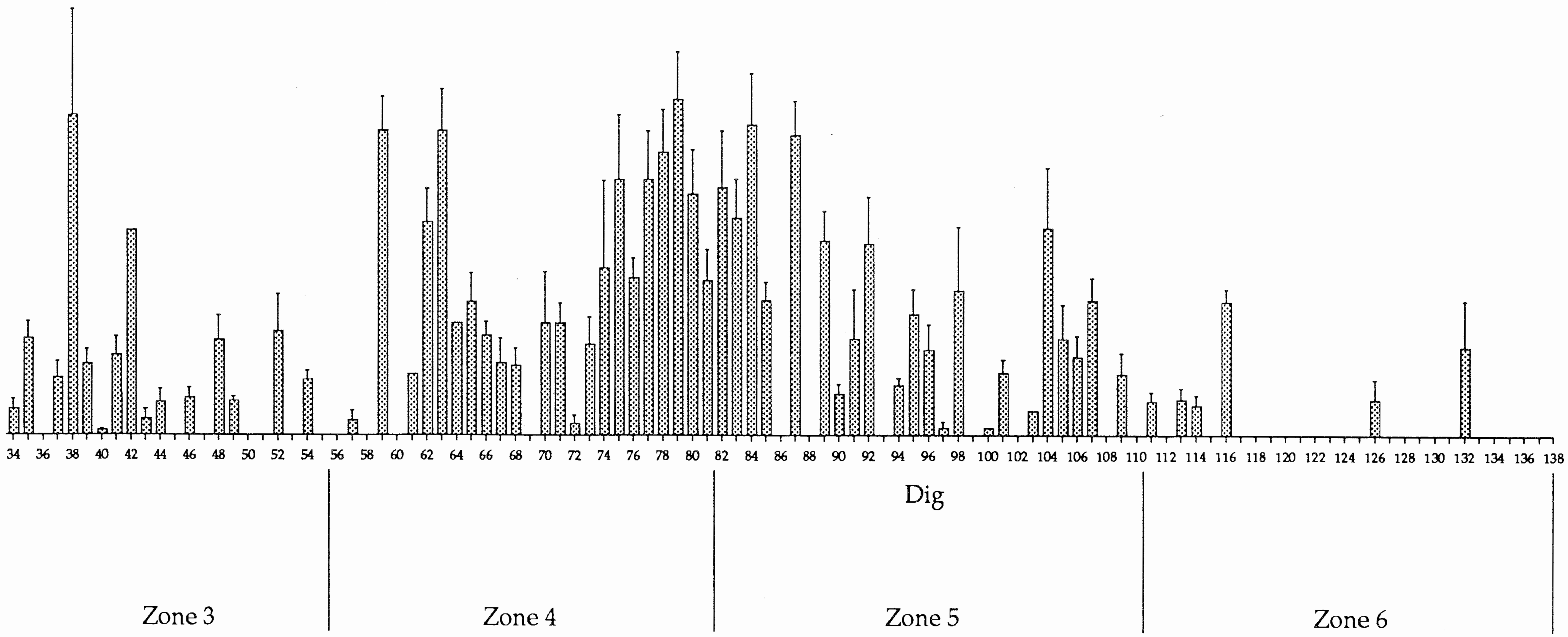



Figure 2.7. Mean (± S.E.) prawn catch per night for each dig. Data pooled across all months.

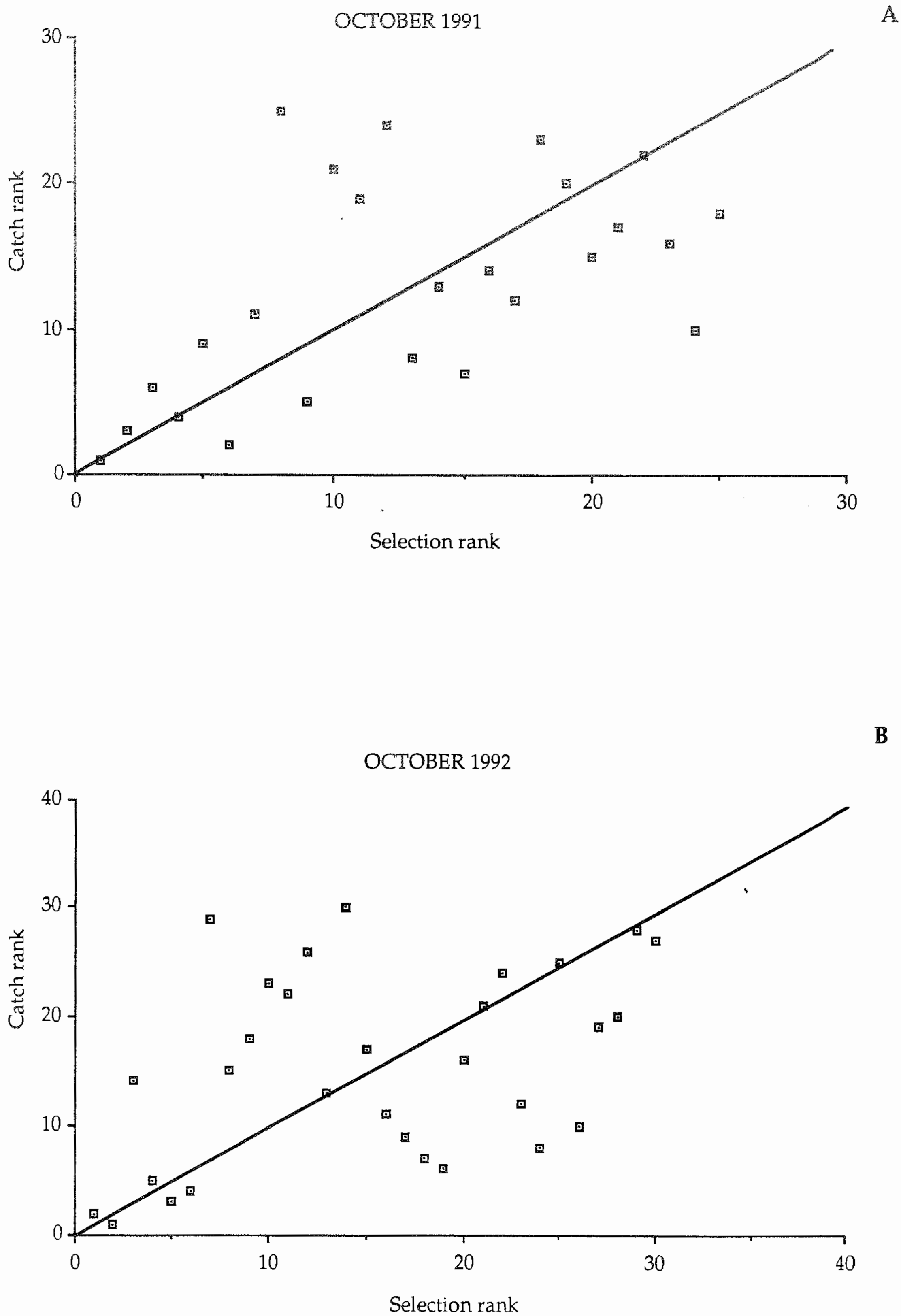



Figure 2.8. Relationship between the expectation of catch, as indicated by rank in the draw, and ranked catch for October 1991 and October 1992. The diagonal line indicates the line of correspondance between expectation and catch. Points below the line indicate better than expected ranked catches.

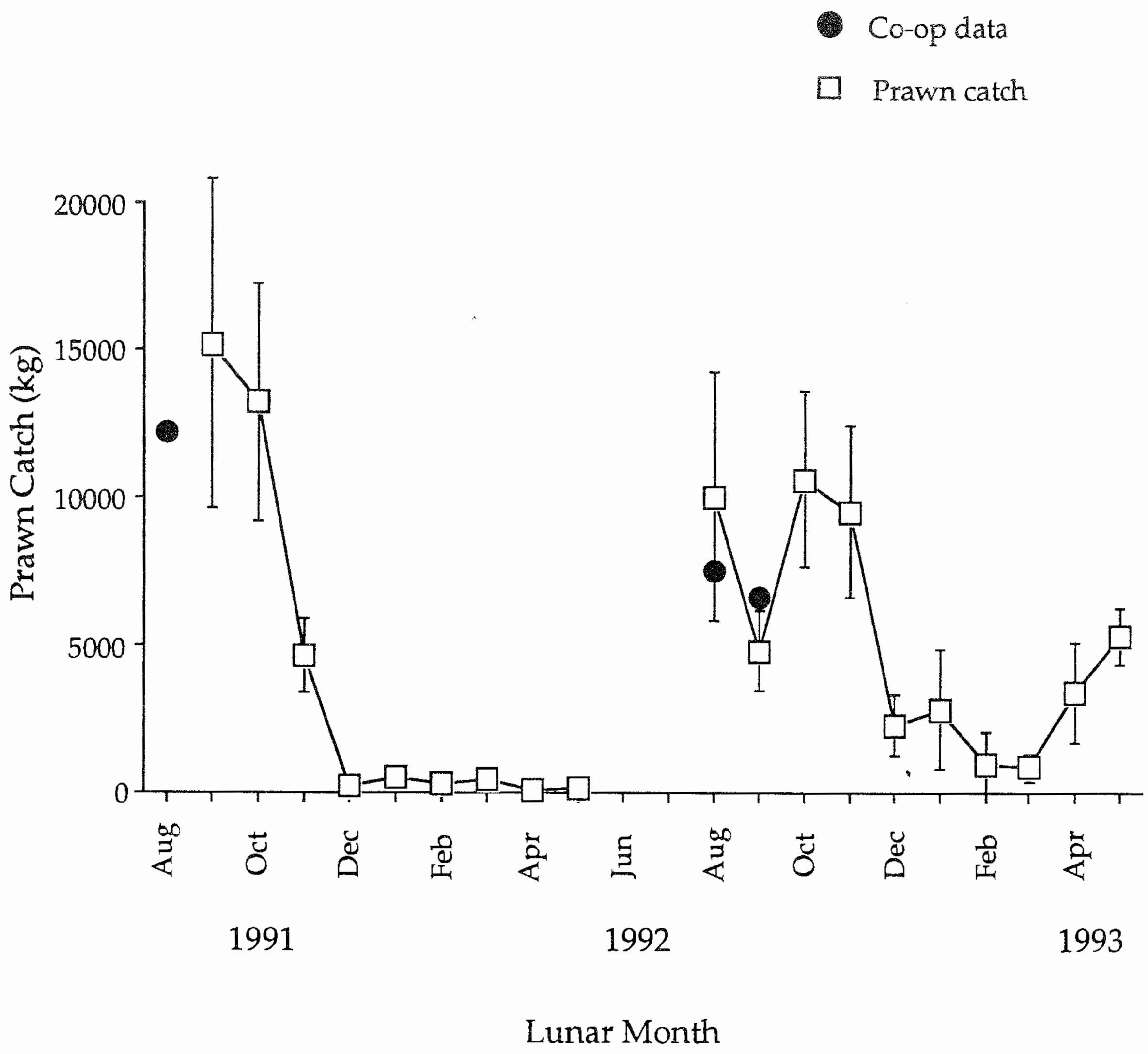



Figure 2.9. Comparison of extapolated pocket net catches (± 95% C.I.) and total school prawn catches from cooperative records. Total extrapolated catches for the August/September 1991 lunar month have been omitted because no logbooks were distributed in this month and therefore reliable samples of catch and effort were not possible. Total catch estimated from the Maclean Cooperative is indicated by the solid circles.

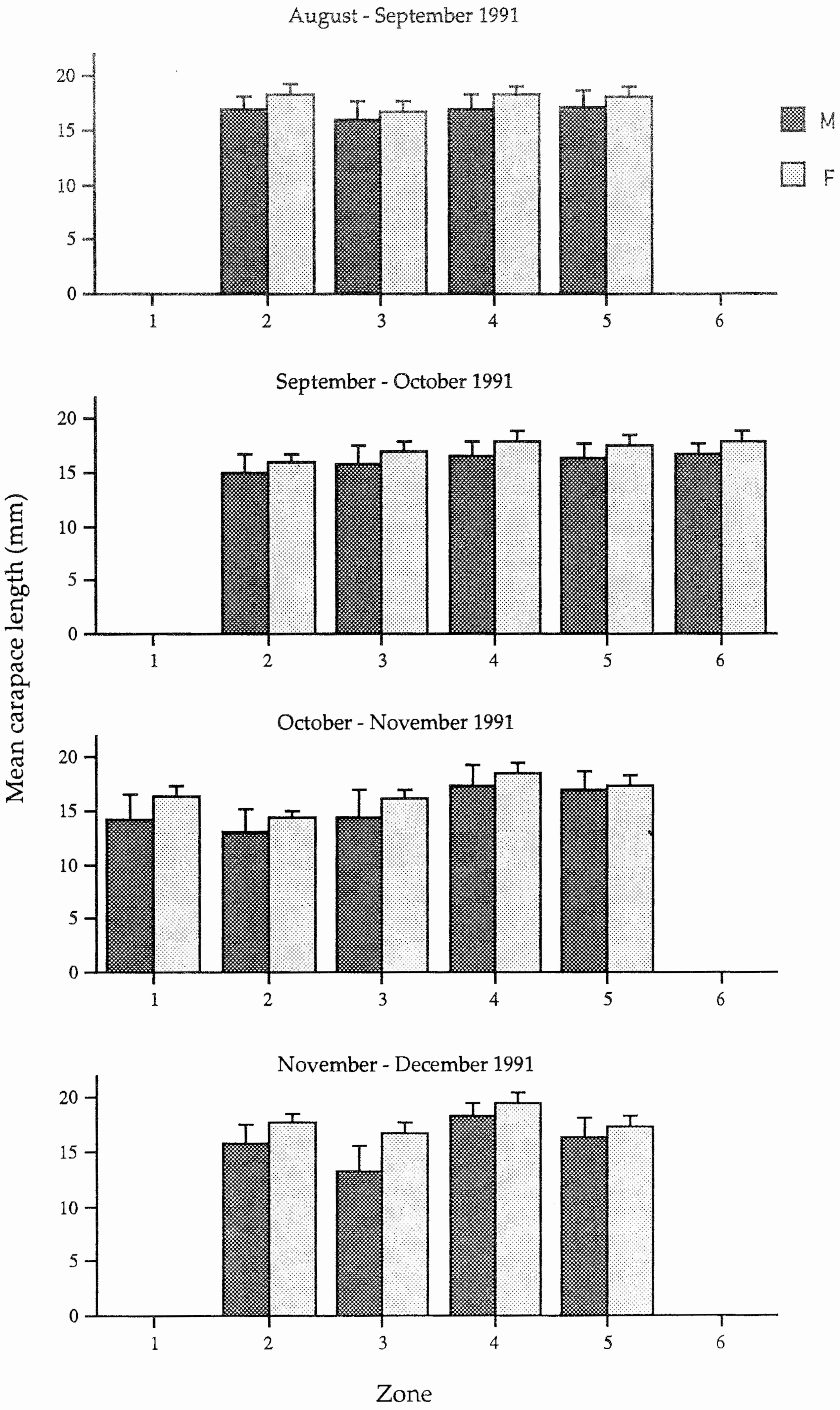



Figure 2.10a. Mean carapace lengths of school prawns in the Clarence River.

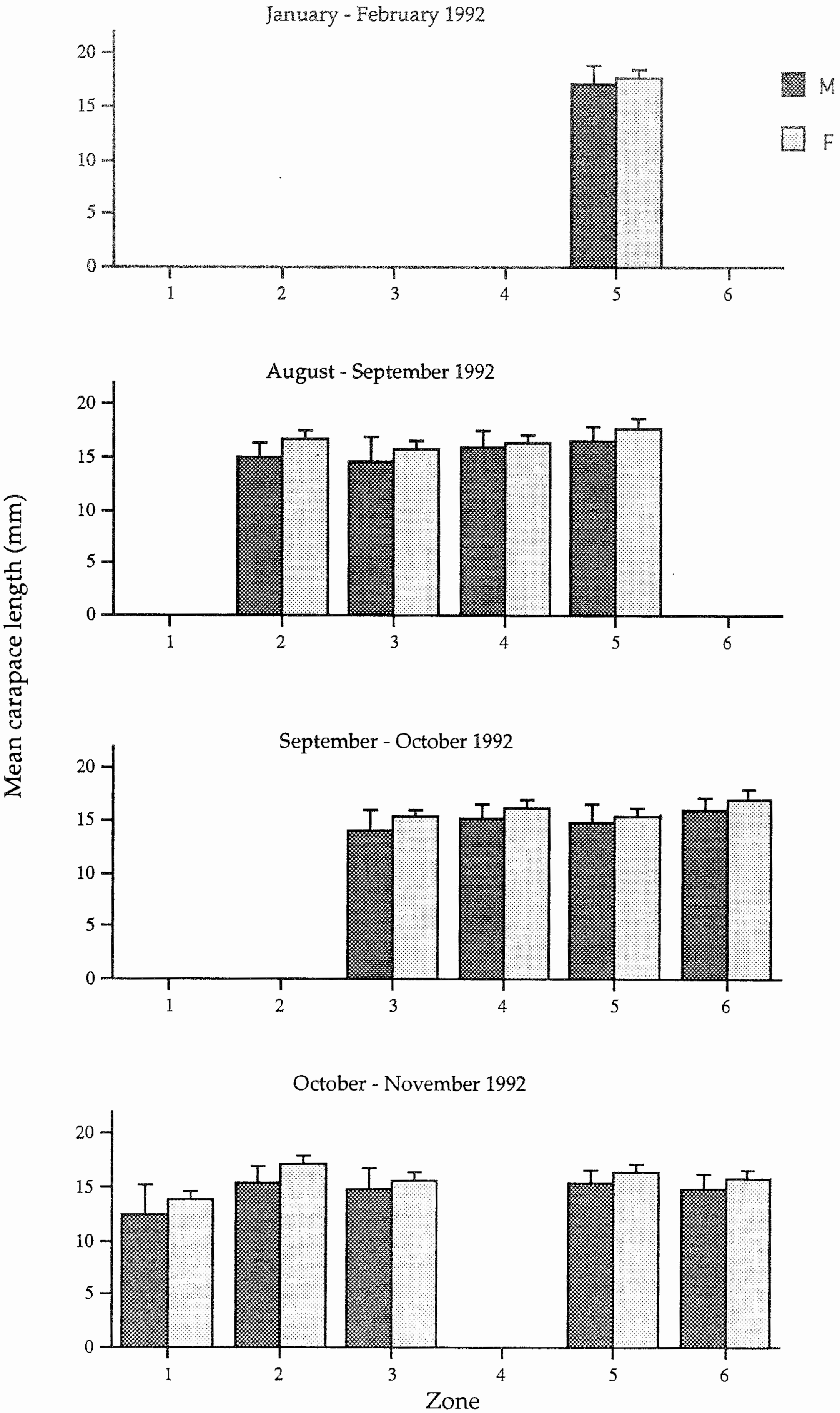



Figure 2.10b. Mean carapace lengths of school prawns in the Clarence River.

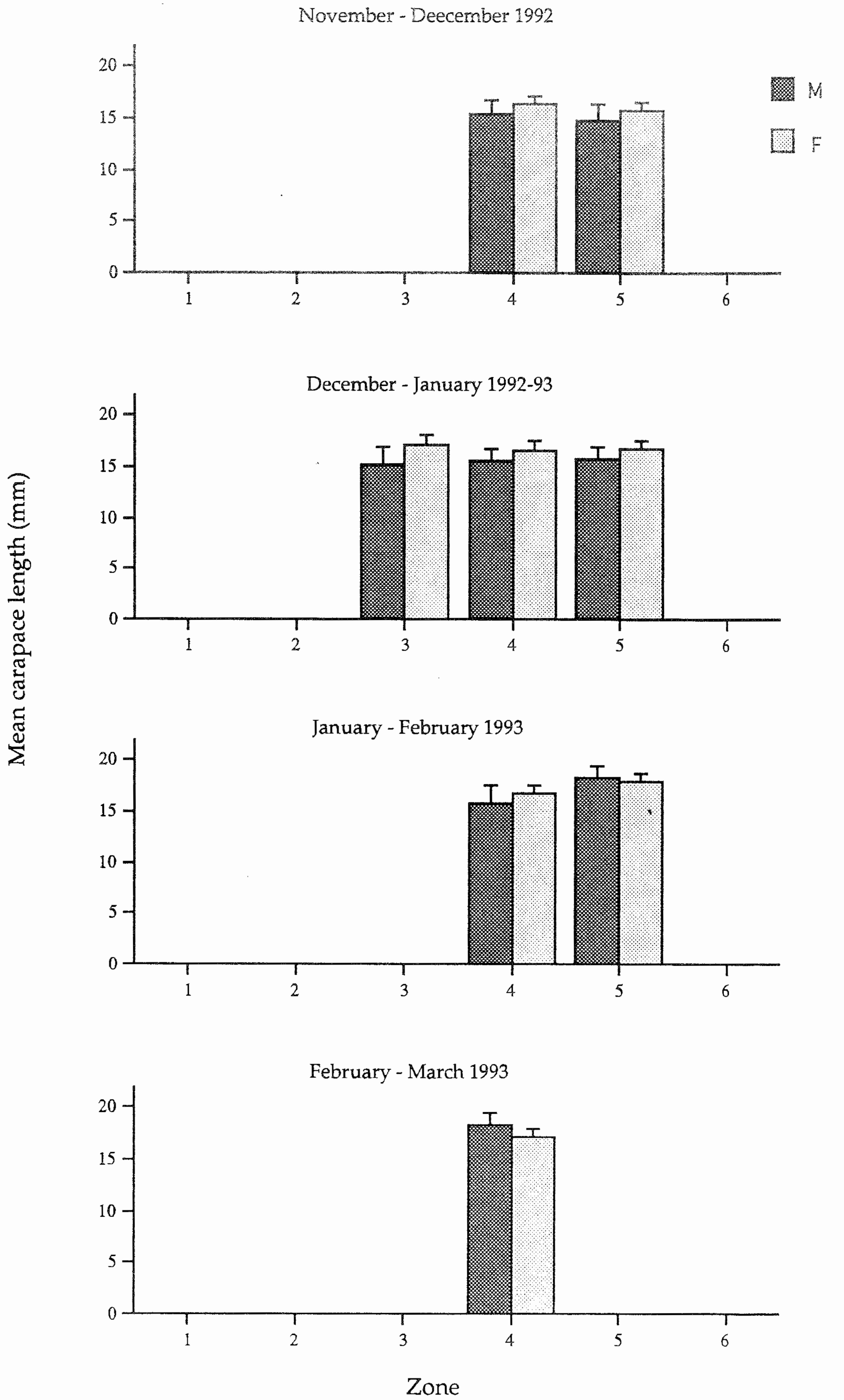



Figure 2.10c. Mean carapace lengths of school prawns in the Clarence River.

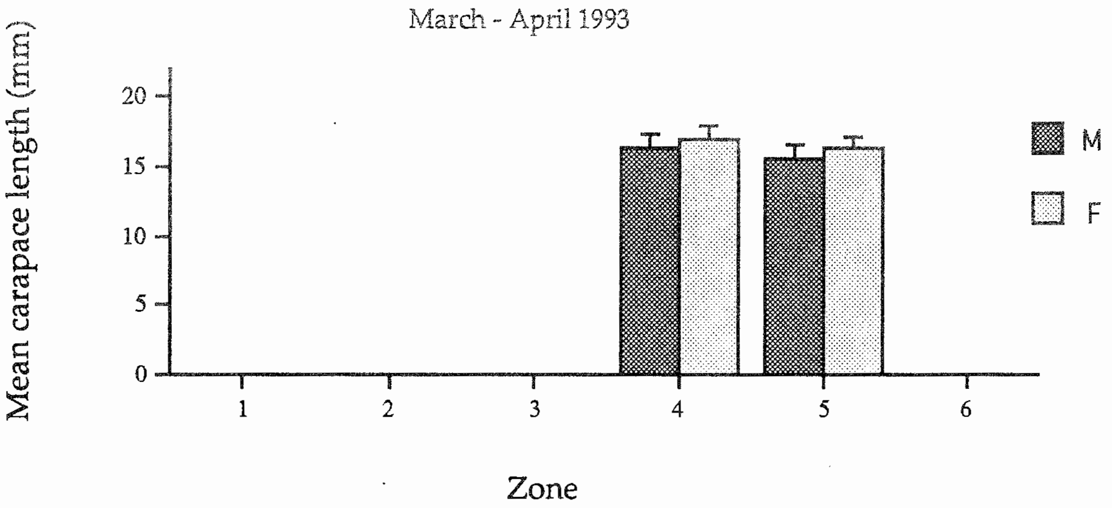



Figure 2.10d. Mean carapace lengths of school prawns in the Clarence River.

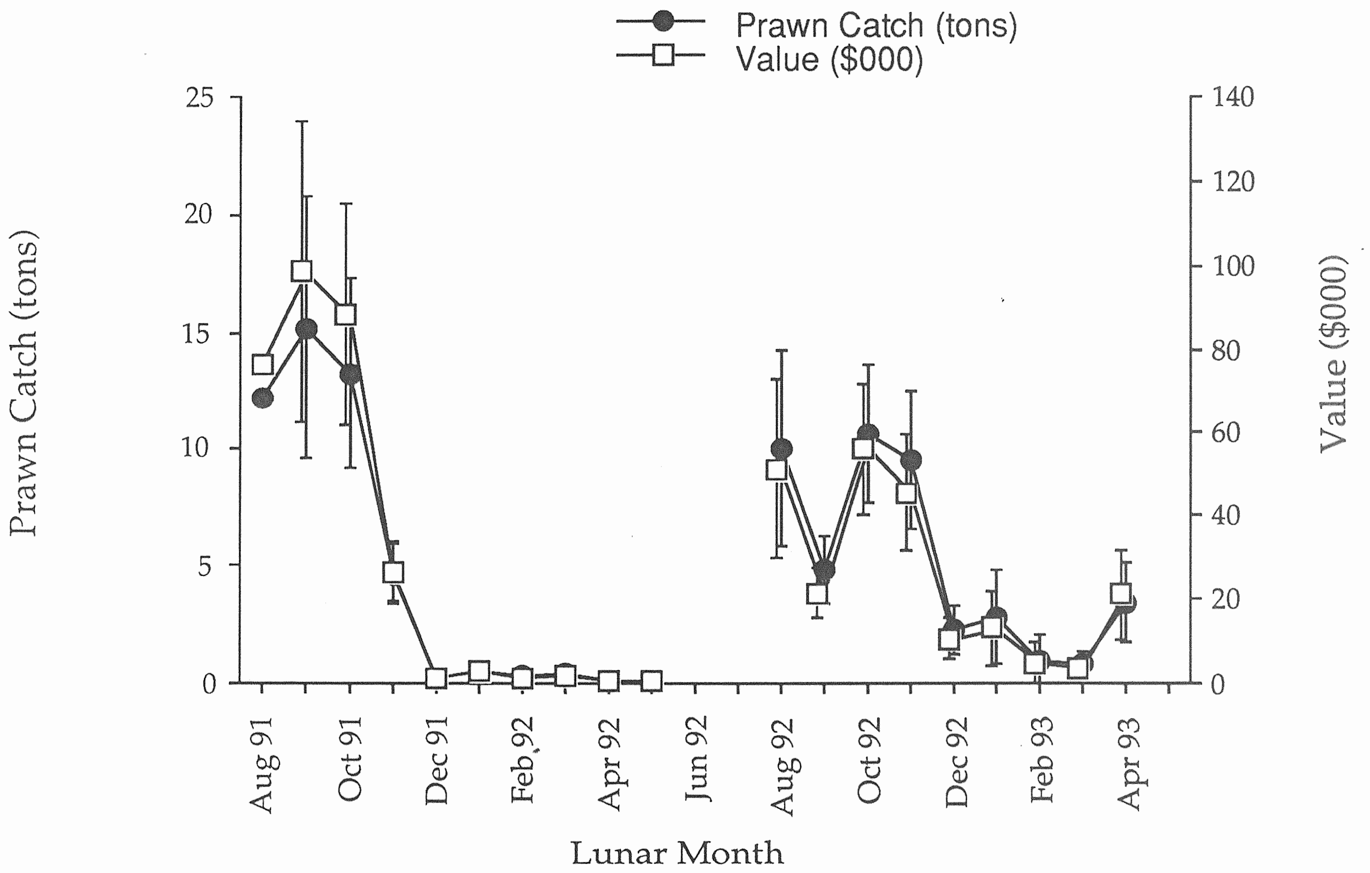



Figure 2.11. Trends in total catch and value in the Clarence River set pocket net fishery. Total catch is presented in tons and value presented in thousands of dollars.

Table 2.1. Analysis of variance of catch weight per night. Data square root transformed to reduce heterogeneity of variance, Cochran's test non-significant for data as analysed. (n = 45, cell means included in some cells to balance design and residual degrees of freedom reduced appropriately. Winer 1971)

| Source | df | S.S. | M.S. | F-ratio | Prob | % variance explained |
|---|---|---|---|---|---|---|
| Year | 1,702 | 0.38 | 0.38 | 0.86 | 0.35 | 0.0 |
| Month | 2,2 | 19.49 | 9.75 | 9.35 | 0.10 | 4.7 |
| Zone | 2,2 | 87.08 | 43.54 | 58.00 | 0.02 | 23.2 |
| Year x Month | 2,702 | 2.08 | 1.04 | 2.36 | 0.10 | 0.6 |
| Year x Zone | 2,702 | 1.50 | 0.75 | 1.70 | 0.18 | 0.3 |
| Month x Zone | 4,4 | 1.91 | 0.48 | 0.10 | 0.98 | 0.0 |
| Yr x Mo x Zn | 4,702 | 18.56 | 4.64 | 10.49 | 0.00 | 13.6 |
| Residual | 702 | 350.35 | 0.44 | | | 57.5 |

Table 2.2. Estimated total catch and value from the set pocket net fishery in the Clarence River. Estimates of total catch are derived from extrapolations of effort and nightly catch rate. Total landed catches for August and September as recorded by the Maclean Cooperative are also presented.

| Month | Catch (kg) ± 95% C.I. | Co-op Catch | Average Price ($/kg) | Value ($) ± 95% C.I. | Co-op Value |
|---|---|---|---|---|---|
| Aug 91 | - | 12196 | 6.24 | - | 76103 |
| Sep 91 | 15200 ± 5575 | | 6.44 | 97886 ± 35903 | |
| Oct 91 | 13261 ± 4015 | | 6.61 | 87658 ± 26541 | |
| Nov 91 | 4647 ± 1271 | | 5.74 | 26672 ± 7298 | |
| Dec 91 | 187 ± 86 | | 6.23 | 1165 ± 534 | |
| Jan 92 | 535 ± 0 | | 5.18 | 2769 ± 0 | |
| Feb 92 | 265 ± 0 | | 4.12 | 1092 ± 0 | |
| Mar 92 | 437 ± 218 | | 3.94 | 1720 ± 860 | |
| Apr 92 | 101 ± 32 | | 4.05 | 408 ± 131 | |
| May 92 | 111 ± 51 | | 4.68 | 518 ± 238 | |
| Jun 92 | 0 | | - | 0 | |
| Jul 92 | 0 | | - | 0 | |
| Aug 92 | 10035 ± 4238 | 7533 | 5.10 | 51176 ± 21612 | 38418 |
| Sep 92 | 4821 ± 1393 | 6609 | 4.46 | 21503 ± 6211 | 29476 |
| Oct 92 | 10645 ± 3011 | | 5.27 | 56098 ± 15866 | |
| Nov 92 | 9531 ± 2934 | | 4.78 | 45557 ± 14026 | |
| Dec 92 | 2268 ± 1030 | | 4.63 | 10500 ± 4768 | |
| Jan 93 | 2814 ± 2016 | | 4.41 | 12410 ± 8890 | |
| Feb 93 | 943 ± 1099 | | 4.75 | 4479 ± 5220 | |
| Mar 93 | 862 ± 476 | | 4.06 | 3501 ± 1934 | |
| Apr 93 | 3386 ± 1687 | | 4.57 | 21127 ± 10529 | |
| May 93 | 5288 ± 940 | | 4.76 | 25172 ± 4472 | |

## 2.2 Estuarine and oceanic catch of school prawns in the Clarence River

### 2.2.1 Introduction

As part of this evaluation of the set pocket net fishery, it is worthwhile to consider trends in catches of school prawns from all methods. School prawns are taken in the estuary both by set pocket netting and trawling and also in ocean waters by trawlers. Glaister (1978a), and McDonell and Montgomery (1988) have described trends in the catch of these sectors of the fishery. In both studies there was no clear trend through time in total catch.

### 2.2.2 Methods

Information on catches of school prawns from previous years was collected from Glaister (1978, 1966-76), McDonnell and Montgomery (1987: 1976-1985) and directly from records held at the Maclean Cooperative (1985-1993). Only ocean caught prawns landed at Maclean cooperative were included. It was not possible to partition pocket net catch from trawl-caught prawns for these historical data, either from Cooperative records or from NSW Fisheries statistics. Separation of pocket net catch from other methods would greatly facilitate future studies of this fishery.

For the period 1985-1993 information on the price paid by the Maclean Cooperative was also gathered. Note, however, that set pocket netting is the only means by which school prawns may be caught in the river during August and September calendar months each year. Information on river discharge was obtained from the New South Wales Public Works Department.

### 2.2.3 Results

There have been large fluctuations in estuary and ocean prawn catches between consecutive years and over longer periods (Fig. 2.12, Table 2.3). Total catches from both methods declined over recent years (1988-89 to 1990-91). Estuary catch, however, increased in 1991-92 and ocean catch showed only a slight decline. Total annual catches do not appear to have declined or increased between 1986 and 1993.

Estuary and ocean annual catches show similar patterns over the period investigated (Fig. 2.12). The magnitude of these fluctuations was similar for both fisheries but average ocean catch was less than half that of estuary catch. In 1972-73 and 1975-76 there were very large catches of ocean prawns. These years also had the greatest amounts of river discharge (10.2 $\times 10^{12}$ and 9.2 $\times 10^{12}$ litres respectively, Fig. 2.13). There was, however, little fluctuation in estuary catch over this period. In 1977-8 estuary prawn catch was extremely low (65 644 kg). In this year, river discharge was also very low (1.2 $\times 10^{12}$ litres).

There was no relationship between estuary prawn catch and river discharge ($r^2 = 0.02$, Fig. 2.14) nor with discharge lagged one year ($r^2 = 0.002$) over the period 1966-67 to 1991-92. There was, however, a significant relationship between prawn catch in the ocean and river discharge ($r^2 = 0.63$, $p < 0.05$, Fig. 2.15). To further explore trends, we have plotted the residuals of the relationship between catch predicted by the linear regression and that observed each year (Fig. 2.16). This was done to remove any confounding influence of discharge on ocean prawn catch. Although residual catch fluctuated greatly through time, there were no clear trends in catch over the period investigated. Average catches in the estuary were greatest in summer (Fig. 2.17) and similar patterns were evident within many individual years (Table 2.4). Estuary catches in August and September were much lower than other months because only set pocket netting was allowed during these two months. No fishing was allowed in June and July.

Average monthly ocean catches were much less than estuary catches and were less variable than estuary catches (Fig. 2.17). Months of relatively large mean ocean catches (February, April and May) had large standard errors. These large errors were caused by large catches in these months in several years (February: 1990, April & May: 1988 & 1989, Table 2.4). Ocean catch was often low in January-February in individual years (Table 2.4), when estuary catches were large.

Although average price per kg per month fluctuated within and among years (Tables 2.3, 2.4), ocean-caught prawns usually fetched higher prices than estuary prawns (Table 2.4).

### 2.2.4 Conclusions

There were no clear trends in total catch of school prawns as landed through the Maclean Cooperative between 1966 and 1993. Total catches of school prawns both in the river and ocean were characterised by wide fluctuations both between consecutive years and over longer timeframes.

More complete examination of trends in catches, particularly catch rates, is required to interpret these patterns and to disentangle the effects of fishing from the influence of river discharge on catch rates and total catches. Such an examination is beyond the scope of the present study. Because catches of the set pocket net fishery were separated only in the last two years, it is not possible to discuss trends in either catch or catch rate in this sector of the fishery. We note, however, that anecdotal information suggests that effort has increased in all sectors of the school prawn fishery in and adjacent to the Clarence River over this period.

The significant correlation between river discharge and ocean catches reported in previous studies was also found in the present study. As with trends in the raw data, there was no clear trends when the residuals from the regression of catch on river discharge were plotted through time. It is not possible to comment on the potential impact of increases in pocket netting on catches of school prawns in the oceanic fishery because of a lack of historical data that separates prawns caught by pocket netting and trawling in the river.

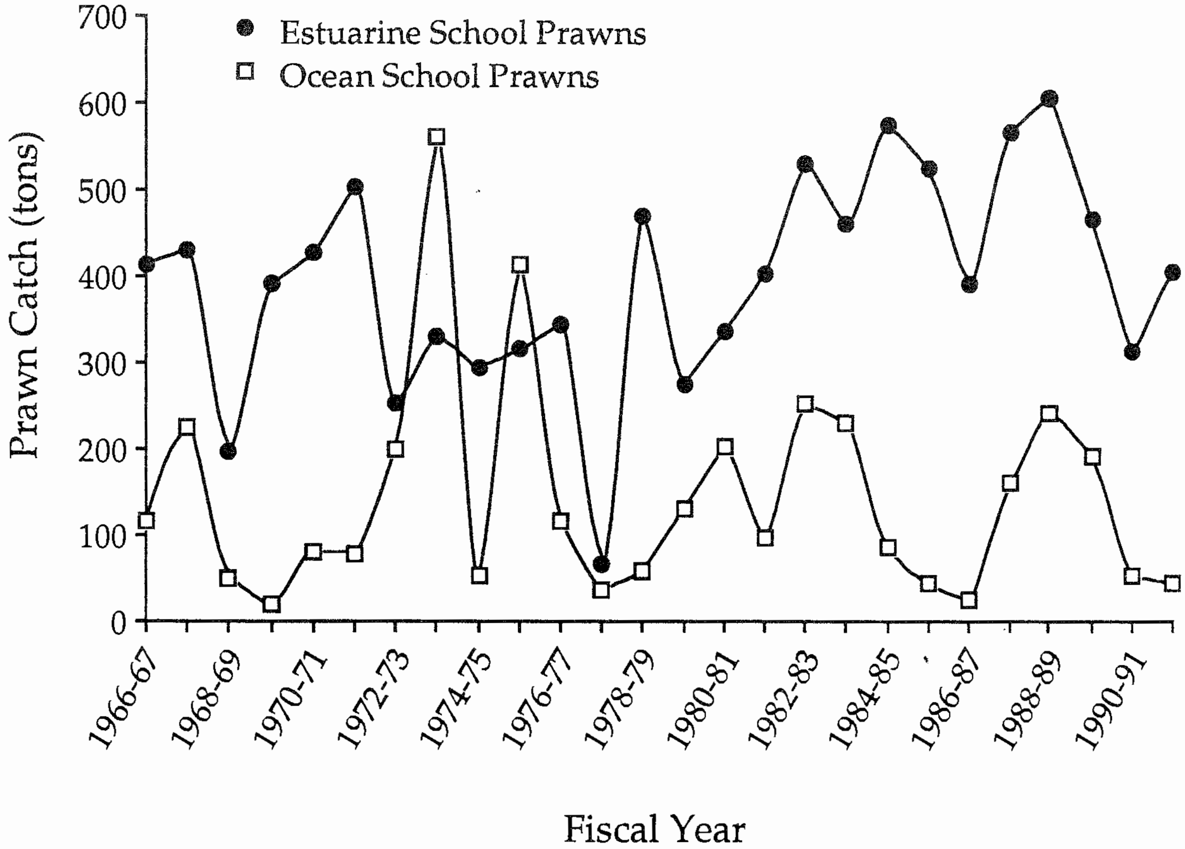



Figure 2.12. Estuary and Ocean school prawn production in the Clarence River for the period 1966 to 1993.

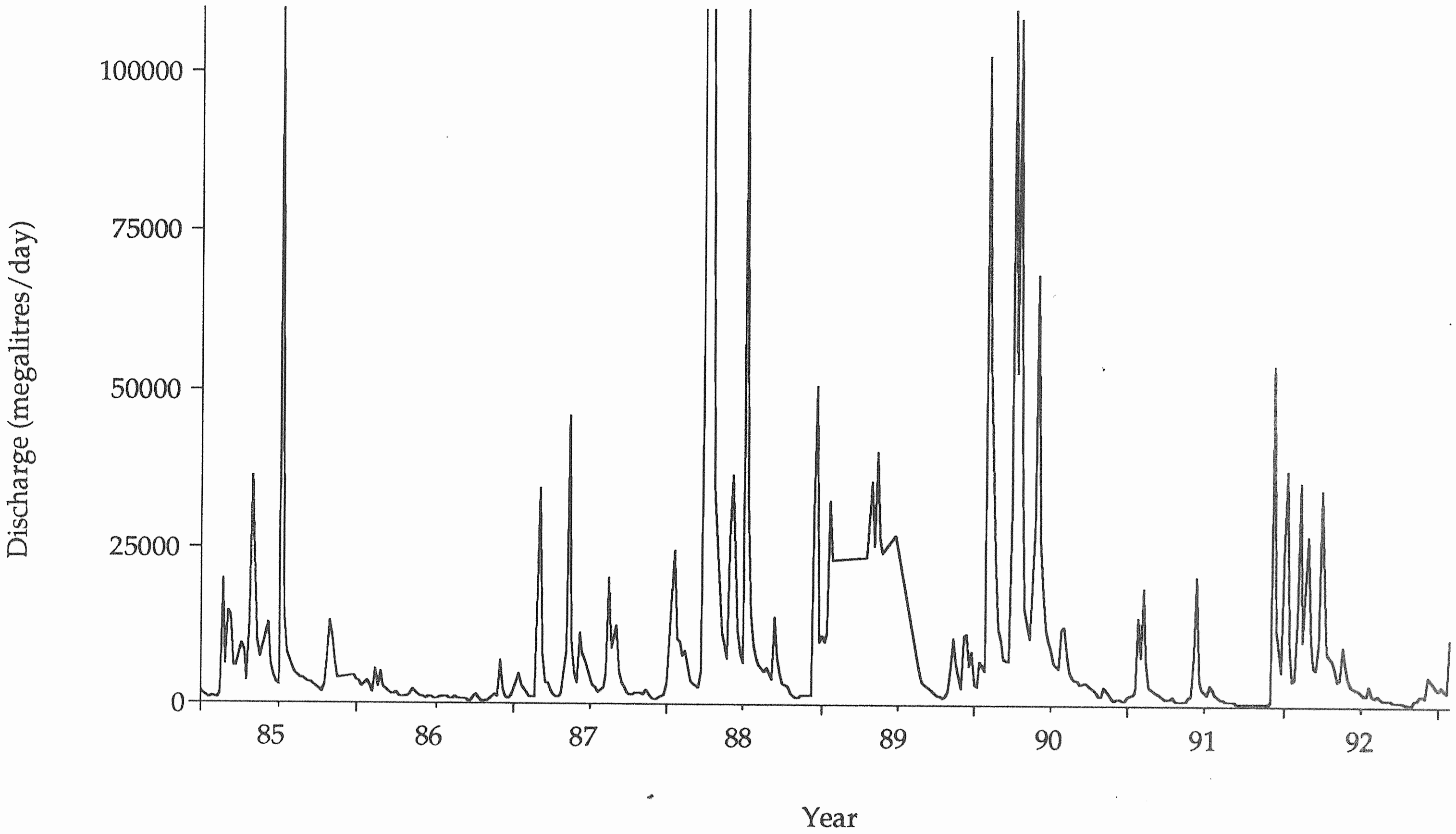



Figure 2.13. Combined mean weekly discharge from the Clarence and Orara Rivers. Data missing for some weeks.

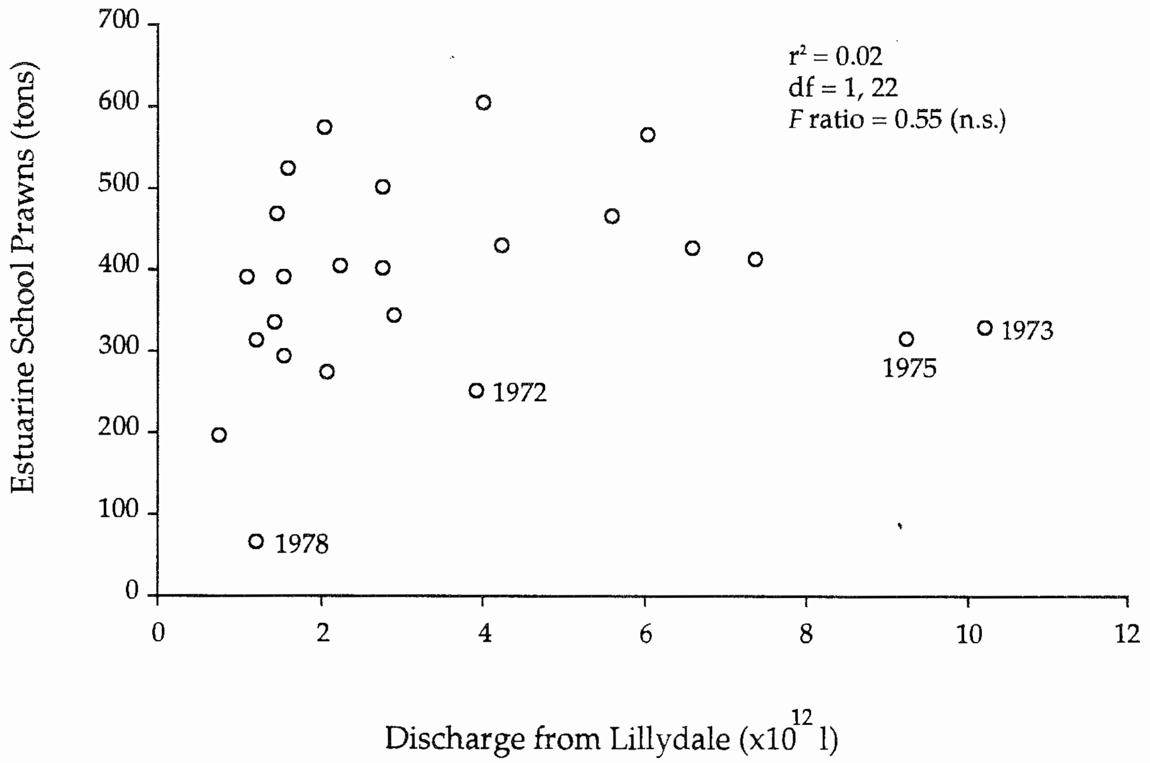



Figure 2.14. Estuarine school prawn production vs river discharge for 1966 to 1992.

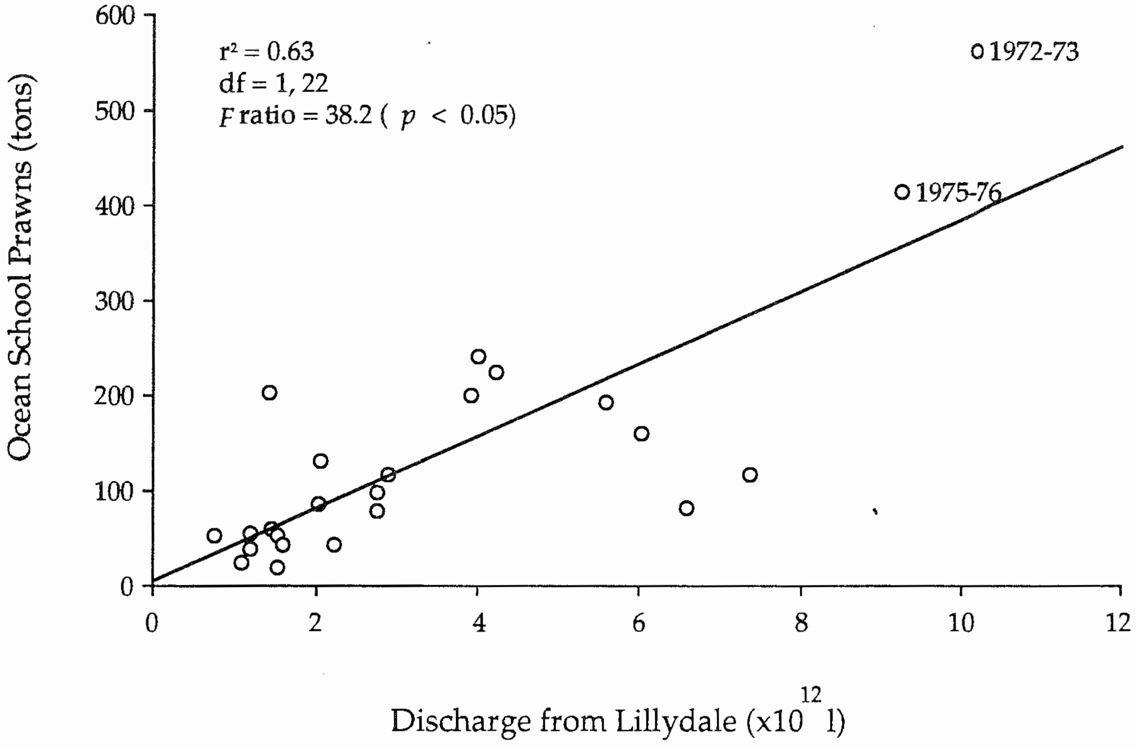



Figure 2.15. Relationship between oceanic prawn catch and river discharge, for the period 1966 to 1993 for the Clarence River. Data from Maclean Cooperative records.

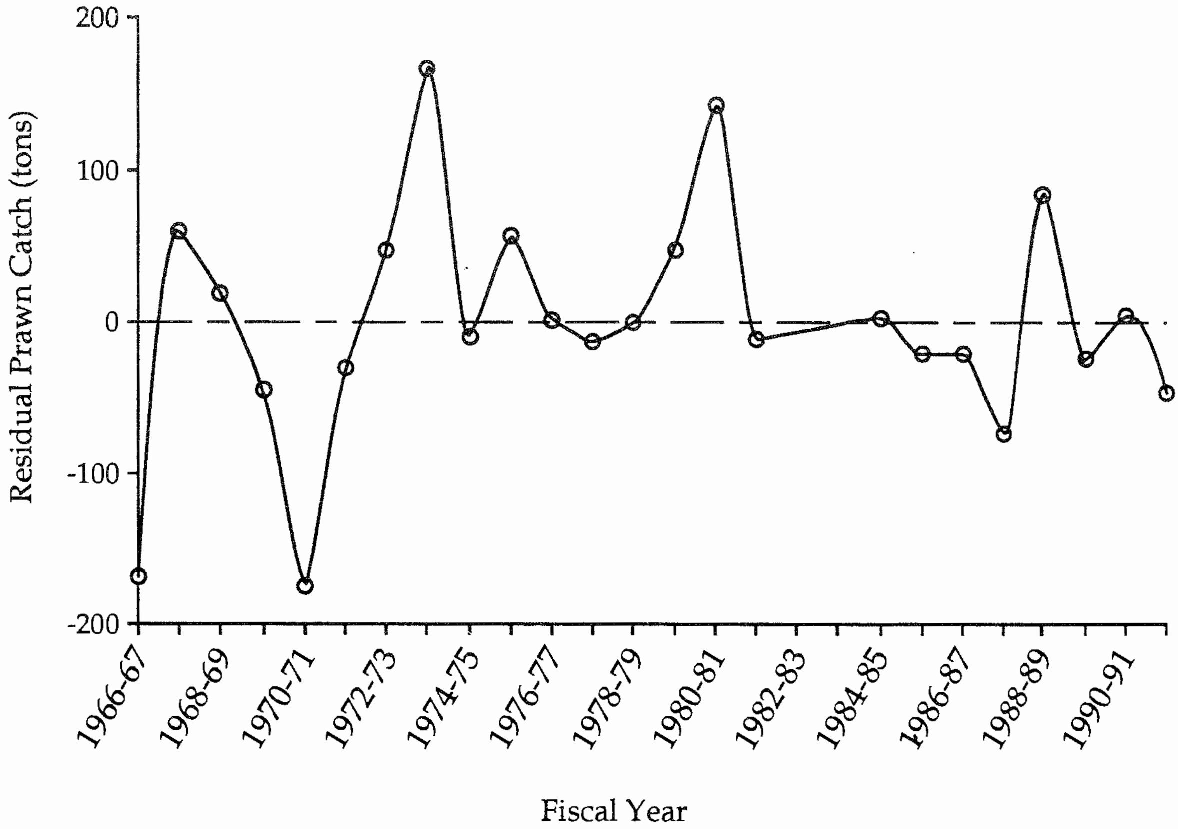



Figure 2.16. Residual oceanic prawn catch per fiscal year from oceanic production vs discharge.

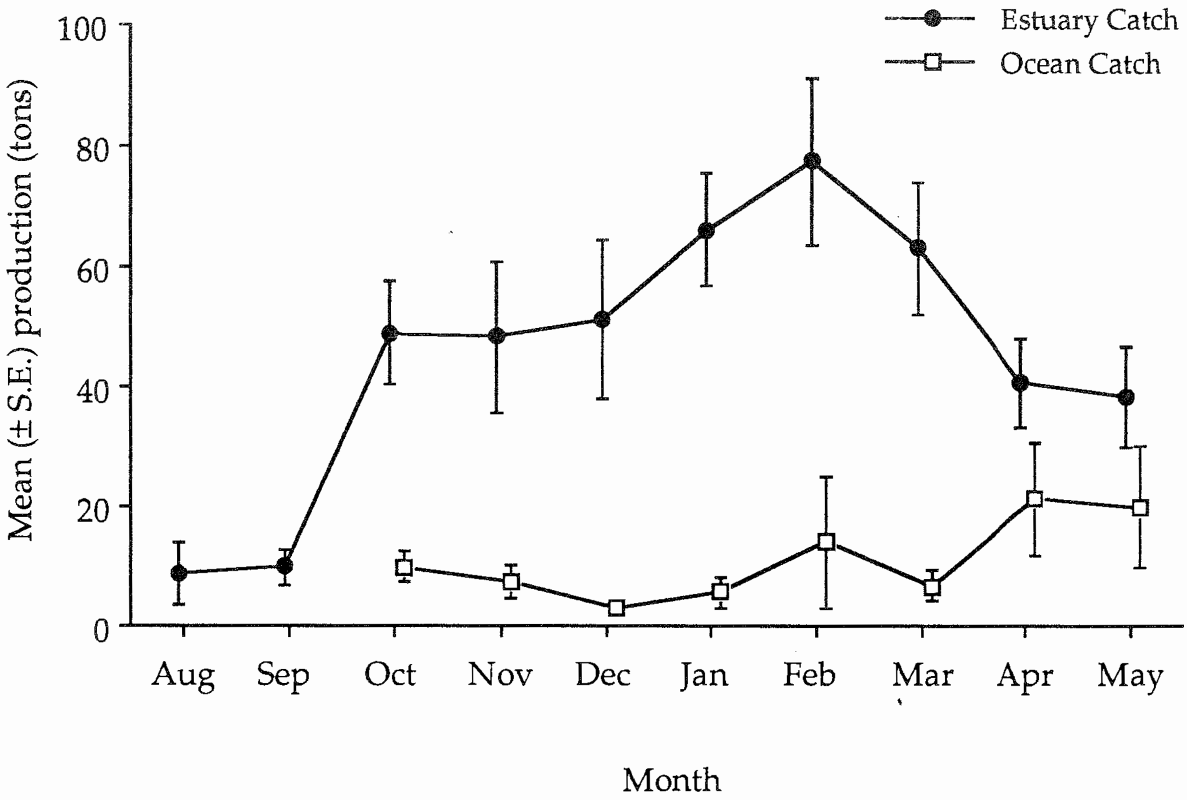



Figure 2.17. Mean (± S.E.) monthly estuarine and oceanic production of school prawns for 1985 to 1993.

Table 2.3. Historical catches of school prawns caught in the Clarence River and in ocean waters and landed at the Maclean Co-operative. Also provided are catch values by financial year (not CPI adjusted) and annual discharge at Lillydale. (May 1993 not included in total).

| | Catch (kg) | | | | Average $ per kg | | | Value of year's catch | | | | Discharge at Lillydale |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Estuary | Ocean | Total | Pocket net | Estuary | Ocean | Total | Estuary | Ocean | Total | Pocket net | (megalitres) |
| 1966-67 | 414668 | 117167 | 531835 | | - | - | - | | | | | 7381019 |
| 1967-68 | 429985 | 224617 | 654602 | | - | - | - | | | | | 4206644 |
| 1968-69 | 196905 | 51325 | 248230 | | - | - | - | | | | | 742414 |
| 1969-70 | 390300 | 18278 | 408578 | | - | - | - | | | | | 1533704 |
| 1970-71 | 427019 | 81167 | 508186 | | - | - | - | | | | | 6594082 |
| 1971-72 | 502083 | 79150 | 581233 | | - | - | - | | | | | 2774829 |
| 1972-73 | 252527 | 201143 | 453670 | | - | - | - | | | | | 3911866 |
| 1973-74 | 330188 | 560824 | 891012 | | - | - | 1.13 | 373112 | 633731 | 1006844 | | 10195430 |
| 1974-75 | 295460 | 53223 | 348683 | | - | - | 1.36 | 401826 | 72383 | 474209 | | 1525665 |
| 1975-76 | 315308 | 413905 | 729213 | | - | - | 1.81 | 570707 | 749168 | 1319876 | | 9235954 |
| 1976-77 | 344863 | 116854 | 461717 | | - | - | 2.03 | 700072 | 237214 | 937286 | | 2904942 |
| 1977-78 | 65644 | 37051 | 102695 | | - | - | 2.28 | 149668 | 84476 | 234145 | | 1202473 |
| 1978-79 | 470141 | 59128 | 529269 | | - | - | 3.06 | 1438631 | 180932 | 1619563 | | 1446332 |
| 1979-80 | 275234 | 131170 | 406404 | | - | - | 3.22 | 886253 | 422367 | 1308621 | | 2063811 |
| 1980-81 | 337115 | 202127 | 539242 | | - | - | 3.01 | 1014716 | 608402 | 1623118 | | 1434216 |
| 1981-82 | 403197 | 98321 | 501518 | | - | - | 2.60 | 1048312 | 255635 | 1303947 | | 2776286 |
| 1982-83 | 530665 | 252582 | 783247 | | - | - | - | - | - | - | | 2989268 |
| 1983-84 | 460293 | 231272 | 691565 | | - | - | 3.39 | 1560393 | 784012 | 2344405 | | 6644876 |
| 1984-85 | 573631 | 85514 | 659145 | | - | - | 4.10 | 2351887 | 350607 | 2702495 | | 2049769 |
| 1985-86 | 523892 | 43159 | 567051 | | 3.62 | 4.59 | 3.69 | 1894009 | 198237 | 2092246 | | 1578668 |
| 1986-87 | 390817 | 24715 | 415532 | | 4.31 | 5.33 | 4.37 | 1685185 | 131830 | 1817015 | | 1076613 |
| 1987-88 | 567671 | 160196 | 727868 | | 3.99 | 4.36 | 4.07 | 2263754 | 697949 | 2961703 | | 6014148 |
| 1988-89 | 604942 | 240965 | 845907 | | 3.64 | 4.02 | 3.75 | 2203671 | 967935 | 3171606 | | 3984272 |
| 1989-90 | 465408 | 192393 | 657801 | | 3.17 | 3.03 | 3.13 | 1473615 | 582086 | 2055701 | | 5576532 |
| 1990-91 | 312793 | 53666 | 366459 | | 4.32 | 4.73 | 4.38 | 1350350 | 253991 | 1604341 | | 1192087 |
| 1991-92 | 405360 | 43560 | 448920 | 46938 | 4.67 | 6.04 | 4.81 | 1894369 | 263206 | 2157575 | 295991 | 2226839 |
| 1992-93 | 203201 | 15351 | 218552 | 50593 | 4.02 | 5.21 | 4.10 | 816263 | 80037 | 896301 | 251523 | 4181408 |

Table 2.4. Catch, average price and value of school prawns per month from the Maclean Co-operative for the period 1985-1993.

| Year | Month | Catch (kg) | | Average Price ($/kg) | | Total Value | |
|---|---|---|---|---|---|---|---|
| | | Estuary | Ocean | Estuary | Ocean | Estuary | Ocean |
| 1985 | January | 86576 | 22512 | 2.84 | 3.94 | 245594 | 88768 |
| | February | 94501 | 5825 | 2.86 | 4.20 | 269800 | 24480 |
| | March | 106453 | 16517 | 2.56 | 4.02 | 272826 | 66323 |
| | April | 71277 | 7604 | 2.83 | 4.72 | 201788 | 35900 |
| | May | 60070 | 5456 | 2.93 | 4.82 | 176243 | 26318 |
| | June | - | - | - | - | - | - |
| | July | - | - | - | - | - | - |
| | August | 10445 | 1890 | 3.25 | 5.15 | 33983 | 9736 |
| | September | 26965 | 38 | 4.10 | 6.60 | 110624 | 251 |
| | October | 66702 | 18014 | 3.65 | 4.69 | 243547 | 84423 |
| | November | 98265 | 11288 | 3.42 | 4.80 | 336341 | 54126 |
| | December | 135397 | 6411 | 3.76 | 5.93 | 509039 | 37994 |
| 1986 | January | 71752 | 2570 | 4.11 | 6.81 | 294964 | 17508 |
| | February | 34360 | 2226 | 3.69 | 6.02 | 126724 | 13399 |
| | March | 24856 | 647 | 3.47 | 6.29 | 86250 | 4068 |
| | April | 18435 | 62 | 3.73 | 6.58 | 68674 | 408 |
| | May | 36716 | 13 | 3.75 | 6.60 | 137784 | 86 |
| | June | - | - | - | - | - | - |
| | July | - | - | - | - | - | - |
| | August | 786 | 2 | 5.00 | 6.29 | 3933 | 13 |
| | September | 3767 | 1541 | 5.63 | 6.15 | 21208 | 9469 |
| | October | 26134 | 5505 | 5.28 | 6.56 | 137968 | 36106 |
| | November | 30684 | 3034 | 5.16 | 6.53 | 158231 | 19797 |
| | December | 37845 | 767 | 5.12 | 6.69 | 193804 | 5130 |
| 1987 | January | 34418 | 317 | 4.66 | 5.90 | 160237 | 1870 |
| | February | 25339 | 1643 | 4.75 | 5.71 | 120405 | 9379 |
| | March | 87019 | 1582 | 4.08 | 6.67 | 355052 | 10548 |
| | April | 64796 | 412 | 4.31 | 5.71 | 278963 | 2353 |
| | May | 80029 | 9913 | 3.73 | 4.75 | 298798 | 47103 |
| | June | - | - | - | - | - | - |
| | July | - | - | - | - | - | - |

continued ...

Table 2.4 continued.

| Year | Month | Catch | | Average | | Total Value | |
|---|---|---|---|---|---|---|---|
| | | Estuary | Ocean | Estuary | Ocean | Estuary | Ocean |
| 1987 | August | 43971 | 5860 | 4.94 | 6.41 | 217034 | 37553 |
| | September | 15517 | 857 | 4.04 | 6.67 | 62663 | 5716 |
| | October | 69272 | 17769 | 4.45 | 6.54 | 308131 | 116165 |
| | November | 91548 | 13328 | 4.31 | 5.97 | 394425 | 79590 |
| | December | 30509 | 1675 | 4.53 | 5.71 | 138179 | 9564 |
| 1988 | January | 66804 | 986 | 4.36 | 6.92 | 291332 | 6823 |
| | February | 93058 | 831 | 3.83 | 4.90 | 356780 | 4070 |
| | March | 62430 | 617 | 4.11 | 5.63 | 256743 | 3473 |
| | April | 41963 | 52023 | 3.07 | 3.86 | 128722 | 200765 |
| | May | 52599 | 66251 | 3.13 | 3.52 | 164720 | 233424 |
| | June | - | - | - | - | - | - |
| | July | - | - | - | - | - | - |
| | August | 8322 | 3189 | 4.51 | 6.80 | 37507 | 21679 |
| | September | - | - | - | - | - | - |
| | October | 57363 | 15761 | 4.26 | 5.45 | 244605 | 85838 |
| | November | 79159 | 25826 | 4.28 | 5.71 | 339180 | 147492 |
| | December | 70081 | 9701 | 4.40 | 5.55 | 308400 | 53837 |
| 1989 | January | 106724 | 2177 | 3.84 | 6.00 | 409649 | 13053 |
| | February | 138015 | 517 | 2.55 | 4.50 | 352398 | 2325 |
| | March | 91671 | 22297 | 3.73 | 5.19 | 341780 | 115814 |
| | April | 35841 | 82628 | 3.85 | 3.61 | 137853 | 298287 |
| | May | 17767 | 78871 | 2.52 | 3.75 | 44755 | 295595 |
| | June | - | - | - | - | - | - |
| | July | - | - | - | - | - | - |
| | August | - | - | - | - | - | - |
| | September | 10048 | 4919 | 6.35 | 8.29 | 63782 | 40772 |
| | October | 84074 | 22192 | 3.70 | 4.02 | 310709 | 89123 |
| | November | 24013 | 11003 | 3.67 | 2.95 | 88028 | 32431 |
| | December | 53897 | 351 | 3.86 | 4.73 | 208042 | 1658 |
| 1990 | January | 51508 | 2034 | 3.62 | 5.04 | 186691 | 10241 |
| | February | 114464 | 101867 | 2.57 | 2.64 | 294459 | 269184 |
| | March | 94291 | 11101 | 2.80 | 2.79 | 264034 | 30972 |
| | April | 19851 | 26812 | 2.36 | 4.52 | 46832 | 121252 |
| | May | 13262 | 12114 | 3.52 | 4.59 | 46733 | 55597 |

continued ...

Table 2.4 continued.

| Year | Month | Catch | | Average | | Total Value | |
|---|---|---|---|---|---|---|---|
| | | Estuary | Ocean | Estuary | Ocean | Estuary | Ocean |
| | June | - | - | - | - | - | - |
| | July | - | - | - | - | - | - |
| | August | 1046 | 1033 | 3.88 | 4.71 | 4057 | 4860 |
| | September | 3448 | 172 | 5.61 | 6.36 | 19355 | 1094 |
| | October | 41107 | 3221 | 4.99 | 4.67 | 205014 | 15050 |
| | November | 28246 | 1699 | 4.54 | 5.03 | 128243 | 8547 |
| | December | 30034 | 5801 | 4.26 | 3.95 | 127986 | 22904 |
| 1991 | January | 48463 | 14656 | 4.47 | 5.24 | 216465 | 76802 |
| | February | 77231 | 7015 | 4.03 | 5.16 | 311106 | 36218 |
| | March | 26229 | 2572 | 4.04 | 6.23 | 106074 | 16020 |
| | April | 33542 | 15501 | 3.94 | 5.74 | 132272 | 88976 |
| | May | 23446 | 1997 | 4.45 | 6.14 | 104219 | 12254 |
| | June | - | - | - | - | - | - |
| | July | - | - | - | - | - | - |
| | August | 230 | - | 2.71 | - | 624 | - |
| | September | 12215 | 2300 | 6.44 | 7.48 | 78715 | 17201 |
| | October | 16596 | 6294 | 6.61 | 8.17 | 109641 | 51406 |
| | November | 10003 | 981 | 5.74 | 7.74 | 57380 | 7588 |
| | December | 23905 | 1317 | 6.23 | 8.95 | 148936 | 11792 |
| 1992 | January | 102799 | 4441 | 5.18 | 7.46 | 532262 | 33139 |
| | February | 99792 | 8510 | 4.12 | 5.76 | 410784 | 49052 |
| | March | 49742 | 5253 | 3.94 | 5.36 | 195876 | 28178 |
| | April | 67615 | 8179 | 4.05 | 5.77 | 273706 | 47220 |
| | May | 22462 | 6722 | 4.68 | 4.94 | 105167 | 33212 |
| | June | - | - | - | - | - | - |
| | July | - | - | - | - | - | - |
| | August | 5552 | 332 | 3.81 | 7.07 | 21130 | 2348 |
| | September | 6903 | 825 | 4.46 | 6.45 | 30773 | 5318 |
| | October | 30260 | 2915 | 5.27 | 6.87 | 159502 | 20019 |
| | November | 23959 | 1593 | 4.78 | 5.48 | 114584 | 8726 |
| | December | 26903 | 2399 | 4.63 | 6.25 | 124596 | 14988 |
| 1993 | January | 26377 | 2712 | 4.41 | 6.48 | 116423 | 17570 |
| | February | 19961 | 420 | 4.75 | 6.69 | 94910 | 2811 |
| | March | 25503 | 2283 | 4.06 | 6.47 | 103658 | 14760 |
| | April | 13002 | - | 4.57 | - | 59357 | - |

# CHAPTER THREE: BY-CATCH OF THE CLARENCE RIVER SET POCKET NET FISHERY

## 3.1 Text of a manuscript submitted to Fisheries Research

Below is a manuscript that summarises the major results of our study of the by-catch of the Set Pocket Net fishery in the Clarence River. The references cited in the text have been removed to Chapter 7 of the report.

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**By-catch of an Australian stow net fishery for school prawns (*Metapenaeus macleayi*)**

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**ABSTRACT**

The by-catch of the Clarence River stow net fishery during the 1991-92 and 1992-93 fishing seasons was comparatively small and dominated by small fish of no monetary value. 1 011 ± 297 fish are caught per dig-night (the basic unit of fishing effort) by the fleet. Of this number, 59.5 ± 20.0 were individuals of species of commercial or recreational importance. Estimates of the total by-catch for the fleet were dominated by exceptionally large catches during months with high effort, particularly the lunar month beginning in November 1991.

This combination of large catches and high effort for some days produced imprecise estimates of total by-catch for the 1991/92 fishing season. The impact of set pocket netting on coexisting fisheries was small. An estimated 1 144 of the 67 231 bream caught by set pocket netting during the study, would have survived to the minimum legal size for this species. We conclude that, although set pocket netting had comparatively little impact on other fisheries for finfish during our study, there exists the potential for very large catches and greater impacts. These large catches appear associated with increases in river discharge.

## INTRODUCTION

In trawl fisheries, such as those for prawns and demersal fishes, by-catch may be a large proportion of the total catch (e.g. IDRC, 1982; Wassenberg and Hill, 1989; Berghahn, 1990; Harris and Poiner, 1991; Ramm et al., 1990; Andrew and Pepperell, 1992; Klima, 1992). This by-catch is of concern to fisheries scientists and managers because it poses problems in the estimation and allocation of total allowable catches and promotes conflict among different sectors of the fishing industry. Although the ecological and fisheries impact of catching undersized individuals of non-target species is poorly understood (Sheridan et al., 1981), the quantities caught are often large and, for this reason alone, cause concern (see Andrew and Pepperell 1992 for review).

Relatively little is known of the magnitude and diversity of by-catch in fisheries for penaeid prawns that use alternative methods such as traps, push nets, trammel nets and stow nets (e.g. King, 1981; Moffit and Polovina, 1987; Vanderville, 1990; Buckworth, 1992; Changcheng, 1992; Chavez, 1992). These more passive methods rely on the feeding or migratory behaviour of prawns to a much greater extent than trawling. Although the quantity of by-catch is generally thought to be less than that caught by trawlers, there remain few quantitative descriptions of the by-catch of alternative methods of catching prawns. Chavez (1992) reported that the by-catch of a modified cast net used in the inshore shrimp fisheries of Mexico was approximately 10% of the prawn catch. In contrast, trawl fisheries usually catch far more by-catch than shrimps per unit of effort (Andrew and Pepperell, 1992).

In the present study we describe the by-catch of a stow net (known locally as a set pocket net) fishery for school prawns, *Metapenaeus macleayi*, on the Clarence river in northern New South Wales, Australia. This work was part of a larger study that evaluated the set pocket net fishery in reference to co-existing estuarine fisheries, particularly the trawl fishery for school prawns and a large recreational fishery that targets many of the fish caught as by-catch in the commercial fisheries. A description of the dynamics of the set pocket net fishery and patterns in catches of prawns will be published separately (Andrew et al., unpubl. data).

**The fishery**

The set pocket net fishery on the Clarence River is open between the first full moon in August and 31 May the following year. From December to May otter trawling is also permitted in the river and many fishers use both methods. Set pocket netting is mainly done at night and trawling is restricted to daylight hours. The nets used in the fishery are modified prawn trawl nets of 20 m head rope and with a mesh size of 32 mm (Fig. 3.1). The cut and arrangement of the nets differ depending on where they are set. For example, in most places the nets are set 5 m from the bank of the river and have extended wings. The depth and length of these wings differ, depending on the depth of the river and the slope of the river bank. When fishing against the current, smaller nets are used and trawlers' engines are used to force water into the net. Nets set in the middle of the river are smaller than those used on the banks of the river, and similar to those used for trawling.

Each lunar month fishers are randomly assigned (by lottery) one of 138 positions or 'digs' (Fig. 1.1). The digs are spread 5 km from the mouth of the river to 50 km upstream (Fig. 1.1). At the end of each lunar month the digs are randomly re-allocated. There is enormous variability in the economic value of the digs; approximately 80% of the prawn catch is taken from 5% of the digs (Andrew et al., unpubl. data). The location of the most prized digs varies with the time of year, the amount of fresh water in the river and the flow rate (Racek, 1959; Glaister, 1978a, b; Andrew et al., unpubl. data).

## MATERIALS AND METHODS

From August 1991 to March 1993 catches were quantified in the Clarence River set pocket net fishery. Each lunar month, observers recorded the catches from randomly selected digs on the river. On any predetermined night, digs were randomly chosen from the list available and permission to accompany the fisher was sought. If the dig was not being worked on that night, or permission refused (<1% of requests), then another dig was randomly selected.

Twenty such dig-nights were sampled per month to provide reliable estimates of catches in the fishery. This replication proved inadequate for November 1991 and January 1992 when exceptionally large catches were recorded on several nights. These catches were not predicted and, in any event, a sampling scheme that could have accommodated the variance introduced by these nights would have been logistically impossible. In some months there was very little effort in the fishery and fewer than 20 nights were sampled. A total of 211 dig-nights were sampled during the 13 lunar months of the study. Observer effort was proportional to the location and timing of fishing effort on the river. Over the course of the study, 66.8% of the fishing effort (as indicated by allocated digs) and 62.4% of the observer effort was in zones 4 and 5 (Andrew et al., unpubl. data, Fig. 3.2). Most fishing was between the 7th and 14th lunar night and observer effort was greatest between the 5th and 10th lunar night.

For each dig-night sampled, the date and site were recorded and the catch from each lift of the codend was quantified. The following variables were recorded:

-total weight of commercial and non-commercial species
-number of each non-commercial species
-number and sizes of individuals of commercial species
-weight of prawn catch

The codend of the net is lifted irregularly through the night based on the fisher's expectation of catch. Data from individual lifts were pooled for presentation and analysis. All fish caught were identified to species with the exception of *Ambassis* spp., which were identified only to genus. Three species of *Ambassis* dominated the catch: *A. agassizi*, *A. jacksoniensis* and *A. marianus*. Fork lengths of fish were measured.

In order to compare by-catch among places on the river, digs were grouped into six zones (Fig. 3.2): Zone 1, digs 1 - 11; Zone 2, digs 12 - 32; Zone 3, digs 33 - 55; Zone 4, digs 56 - 81; Zone 5, digs 82 - 110; Zone 6, digs 111 - 138. These zones coincide with those used in analyses of catches of prawns (Andrew et al., unpubl. data). Because relatively few dig-nights were sampled per zone, further grouping of digs was required for statistical comparisons. Dig-nights in zones 2-3 and 4-5 were pooled for each month. Because only 4 nights were sampled in zones 1 and 6 during the study, data from these zones are not presented. There were sufficient dig-nights sampled per month to statistically compare catches only in August, September and October of each year. Effort in the set pocket net fishery in both 1991 and 1992 sharply declined in December. Differences in mean by-catch among zones, years and months were compared by three factor analysis of variance (Winer, 1971). All factors, Zone (2-3 and 4-5, considered a fixed factor), Year (1991-92 and 1992-93, random factor) and Month (August, September and October, fixed factor) were orthogonal. Means presented in the text are accompanied by standard errors.

Estimates of the total by-catch per month for the fishery were made by extrapolating estimates of catch per night by estimates of effort in the fishery. Derivation of appropriate variances for these estimates was complicated because information came from several sources, some with associated error and some without. Unlike many fisheries, we knew the maximum number of nights that could be fished per lunar month. On average, 53 of the 138 digs offered each month were taken. Voluntary logbooks were returned by fishers from an average of 53.0% (± 5.3) of the digs taken per month. Effort for the remaining digs was calculated by multiplying the number of digs by the mean number of nights worked per dig per month from logbooks. The effort accounted for by the observer data was subtracted from this estimate to avoid duplicating data in the calculations. Total extrapolated by-catch per month was estimated by summing:

1) Known by-catch from observer-nights.

2) Known number of nights worked from logbooks multiplied by mean by-catch per night.

3) Estimated number of nights worked for remaining digs multiplied by the mean by-catch per night.

The variances associated with 2) and 3) were calculated following the rules of Cochran (1963). Estimates of total by-catch for each year were obtained by summing these components of variation for each month. We assumed that estimates of catch rate from the observer nights and effort from the logbooks were representative of the whole fishery. Because of the many sources of bias in these extrapolations we present a range of values considered to encompass the possible range of values as well as our best estimate. The minimum extrapolated catch was estimated as that if the only nights and digs worked were those sampled by logbooks or observers. The maximum extrapolated catch was estimated to be that if all digs taken were worked all nights.

RESULTS

A total of 52 species of fish and invertebrates was caught during the study. Of these, 18 species were considered commercially or recreationally important. In general, the numbers of species caught per month were small (mean = 11.3 ± 0.9, range 7.7 to 17.0). Fewer commercial species were caught than non-commercial species. A mean of 3.4 (± 0.4, range 1.6 - 5.5) commercial species and 7.9 (± 0.5, range 5.4 to 11.5) non-commercial species were caught per month. Non-commercial species accounted for 60.0% of the weight of total by-catch and 93.0% of all the individuals caught. Catches were dominated by finfish and five fish taxa accounted for 84.3% of the individuals caught (Table 3.1). Two taxa, perchlets (*Ambassis* spp.) and southern herring (*Herklotsichthys castelnaui*) accounted for 75.3% of the number of fish recorded by the observers. Invertebrates were rarely caught. Rock prawns (*Macrobrachium* spp.) were the most abundant invertebrates in catches (5.6% of the total number).

Commercial species accounted for only 7.0% of all fish caught during the observer program. The five most commonly caught commercial species were yellowfin bream (*Acanthopagrus australis*, 2.6% of total catch numbers), tailor (*Pomatomus saltator*, 1.0%), tarwhine (*Rhabdosargus sarba*, 0.7%), river gar (*Hyporhamphus regularis*, 0.6%) and snub-nosed gar (*Arrhamphus sclerolepis*, 0.4%) (Table 3.1). Tarwhine were only caught on 14 of the 211 nights sampled and 4 nights in November 1991 and January 1992 accounted for 98.3% of those caught. Few snapper (*Pagrus auratus*, N = 206) or mulloway (*Argyrosomus hololepidotus*, N = 3) were recorded in this study. These species are important components of the by-catch in other fisheries in New South Wales.

On average, more than 2 kg of prawns were caught for every 1 kg of by-catch (Table 3.2). There was no significant correlation between catches of prawns and by-catch per night ($r_{(209)} = 0.13$, n.s., Fig. 3.3). Less than 35 kg of by-catch was caught per observer-night for all but 5 nights and catches of prawns varied between 0 and 117 kg for all but the 3 largest catches (up to 200 kg). On average, prawns accounted for 71.0% (± 1.8%, n = 208) of the total nightly catch.

Although fewer than 3 000 individuals of by-catch species were usually caught per dig-night, extremely large catches were recorded in November 1991 and January 1992 (Fig. 3.4). There was no significant difference in the number of by-catch individuals caught among months between the two years studied (using August, September and October), nor was there any difference among these months between years (Table 3.3).

Patterns in the weight and numbers of commercial by-catch were not consistent with those for total by-catch (Fig. 3.4). The greatest difference between these two variables was the increased proportion of commercial species when expressed as weight (Fig. 3.4b). Commercial species made up a significantly larger proportion of the by-catch in November 1991 (27.9%, Fig. 3.4b) than in other months. These fishes were on average larger than in other months; the mean weight per fish in November 1991 was 26.4 g per fish, compared to 9.6 g per fish for all other months. The differences were caused by large catches of commercial fishes in November 1991. Months with large catches are examined in more detail below.

Catches of bream, the most numerous species of commercial by-catch, were dominated by three digs on 16 December 1991(in the November/December 1991 lunar month) and another two digs on four dig-nights on 22-25 January 1992 . 96.21% of the 5588 bream observed to be caught during the study were caught on these seven dig-nights. Excluding these nights, an average of 1.0 ± 0.2 bream were caught per dig-night (c.f. 26.5 ± 14.3 including these nights). Pooled estimates of catch rates of tailor, tarwhine and garfish were similarly small and strongly influenced by catches in the November 1991 and January 1992 lunar months (Table 3.1). Of all the tailor and tarwhine caught during the study, 24.83% and 98.25% respectively were caught over the seven dig-nights mentioned above. Fewer river gar and snub-nosed gar were caught over all months (Table 3.1). The increase in the numbers of commercial by-catch in November 1992 (Fig. 4b) was caused by an increase in the catches of these two species of garfish.

As noted above, against a background of relatively small catches (<35 kg per night, Fig. 3.3), by-catches exceeding 125 kg were recorded in November 1991 and January 1992. In particular, catches from digs 79 and 80 on the night of 16 December 1991 had a disproportionate influence on extrapolations of total by-catch. These large catches coincided with a sharp increase in river discharge (Fig. 3.5). Peak discharge was recorded on the 13th and catches were greatest on the first day fishing was permitted, the 16th. Although smaller, large catches were also recorded on the 17th and by the 18th catches had returned to normal levels. Bream accounted for 34.2% of the weight of by-catch on the night of the 16th.

Of the 211 observer-nights in the study, 89 and 52 were done in zones 4 and 5 respectively. Rates of capture of commercial and non-commercial by-catch were greatest by weight in zones 4 and 5 (Fig. 3.6). Fishes of commercial species were most numerous in zone 4 and fishes of no commercial value were most common in zone 5 (Fig. 3.6). There was significantly greater by-catch (both in numbers and weight) in the portion of the river closest to the mouth (zones 4 and 5) than further up river (zones 2 and 3). These differences were consistent among months and years (note non-significant interaction terms, Table 3.2). The lack of significant difference among zones in the total weight of by-catch (Table 3.3) was largely caused by the lack of power for this F test (1,1 degrees of freedom). The denominator for this test, the Year x Zone interaction term could not be combined into the interaction term using Winer's (1971) $p < 0.25$ pooling rule.

Almost all of the commercial fish caught in the study were smaller than the minimum legal size. The current New South Wales minimum legal sizes of the five most numerous commercial species caught are; bream, 250 mm;

tailor, 300 mm and tarwhine, 200 mm. Garfish do not have a minimum legal size. Commercial species were generally heavier (mean = 54.4 g per fish) than the non-commercial species (6.2 g per individual). Sufficient numbers of fish of commercial species were caught to produce length-frequency distributions only for bream, tailor, tarwhine and river and snub-nosed garfish (Fig. 3.7). Two size-classes of bream were apparent, the smaller with a modal size of 70 mm and the larger size-class with a peak at 160 mm (Fig. 3.7a). These apparent cohorts were artefacts of the fact that almost all the bream measured were caught in November 1991 and larger animals were caught throughout the study. The length distribution of river gar was also bimodal, with modes of 120 and 200 mm (Fig. 3.7d). The length-frequency distributions of the remaining species were unimodal (Fig. 3.7b, c, e).

**Extrapolated Catches**

Estimates of the by-catch of the fleet were the product of both fishing effort and catch rate. In both 1991-92 and 1992-93, fishing effort was greatest between August and November. In 1991-92 very few digs were taken after November (Fig. 3.8a). The reduction in effort in the following year was not so dramatic but nevertheless relatively few digs were fished each month after trawling began in the river (Fig. 3.8a).

The large differences in total effort in the fishery were reflected in estimates of by-catch for the fleet (Fig. 3.8b). The close correlation between numbers and weight of by-catch in 1992-93 was not evident in 1991-92 (Fig. 3.4a). In 1991/92 numbers of by-catch were greatest in October and least in November and the weight was greatest in November (Fig. 3.8b). The discrepancies between these two variables was largely due to the unusually high proportions of commercial species caught (see above; Fig. 3.9a). In November, the usual pattern of a greater proportion of non-commercial species was reversed and individuals of commercial species, particularly bream, dominated estimates of total by-catch (Fig. 3.9a). There was a similar reversal in November 1992 when catches of garfish were large (Fig. 3.9b). Although no observer data were collected between February and April 1992, the by-catch from these months is unlikely to contribute a large amount to the total catch because of the very small fishing effort in these months.

The summed estimates of total by-catch for the top five commercial species indicate that relatively small numbers of these species are caught in the set pocket net fishery each year (Table 3.4). Extrapolated catches for most species were greater in 1991/92 than in 1992/93. Very large catches recorded in November 1991 and January 1992 produced large confidence intervals on catches when extrapolated to total catches for 1991/92 (Table 3.3). Garfish were caught in greater abundance in 1992/93 (particularly in November) and there were relatively small catches throughout 1991/92.

## DISCUSSION

During both 1991-92 and 1992-93, the by-catch of the set pocket fishery in the Clarence River was dominated by small fish of no monetary value. These fish accounted for more than 93% by number and 60% by weight of the total by-catch recorded during the study. Furthermore, the nightly catch rates were usually small (59.5 ± 20.0 individuals and 4.7 ± 2.2 kg per dig-night for the fleet). An estimate of the likely impact of stow netting during the present study requires estimates of the proportion of those animals caught that would have reached minimum legal sizes and therefore contribute to other fisheries.

Estimates of size-at-age and instantaneous natural mortality rates do not exist for any of the top five commercial species recorded except bream, the most numerous of the commercial by-catch species. The best available estimate of instantaneous natural mortality (M) for bream is 0.09, (R. West, Fisheries

Research Institute, pers. comm.). The two modal sizes of bream captured by stow nets were 70 and 160 mm. More than 96% of these fish were caught in November and the 70 mm fish were an estimated 6 months old and the 160 mm fish 30 months old (R. West, pers. comm.). Bream are estimated to be 72 months old when they reach minimum legal size (R. West, pers. comm.). To estimate the number caught by the stow net fleet during the two year study period that would otherwise have reached this minimum legal size we used the relationship $N_{t+\Delta t} = N_{to}e^{-M\Delta t}$, where t is time in months. Using this relationship, 1 144 of the 67 231 bream estimated to have been caught in both years would have survived to minimum legal size. Whether it is worth foregoing the stow net catch of prawns for these fish, and the smaller numbers of tarwhine, tailor and garfish, remains unresolved. The ecological impact of removing these fish by stow netting can not be predicted.

In making these calculations we assume that all the bream caught by stow nets die. This may not be the case as anecdotal evidence suggests that most of the bream caught were in good condition and survived if returned to the water immediately. Other species, such as tailor, appeared to be more fragile and most did not survive the catching process. The sorting practises of the fishers meant, however, that the fish usually remained out of the water for extended periods before being discarded. No attempt was made to estimate the mortality of discarded by-catch in this study. We note, however, that the fish caught are less likely to be damaged by the stow net than by trawl nets. The mortality of discards in trawl fisheries for prawns has been shown to be high, but species specific (e.g. Wassenberg and Hill, 1989; Berghahn, 1990; Hill and Wassenberg, 1990).

The large catches of bream recorded on several nights during the study suggests that stow netting may have a large by-catch under certain conditions. Although the underlying causes of the large catches remains unclear, they coincided with unusually high amounts of river discharge. Possible causes of these large catches include: (i) the fish caught were attempting to move into more saline water, (ii) the increased turbidity associated with greater discharge meant that they did not see the net and/or (iii) the greater current velocity at those sites meant that the fish were not as capable of avoiding the net. Of these three, we believe that (i) was the most likely cause for several reasons. Most fishing was done at night so fish were unlikely to be able to see the net even in clear water. Also, current flow on the nights of large catches were not significantly different from other nights (Andrew et al., unpubl. data).

The relationship between salinity and the abundance of euryhaline fishes appears to be species-specific. For some species in some estuaries there are clear patterns in the abundance of species along gradients of salinity, while in others there is no clear relationship (e.g. Chrystal et al., 1985; Petersen and Ross, 1991). Less clear is the effect of rapid fluctuations in salinity on the abundance of euryhaline species, such as bream and tarwhine. Perez (1969) demonstrated in laboratory experiments that croaker and spot, species common in many North American estuaries, move at faster rates when salinity changes rapidly than under constant salinity regimes. We do not have sufficient data to discriminate among the alternative causes of the high catches of bream recorded in November 1991. Glaister (1978a, b) found a significant relationship between discharge and catches of prawns in the Clarence river. This relationship will be further explored in a separate publication.

The great variability in the relationship between by-catch and prawn catch reported in the present study indicates that prawn catch is not a useful predictor of by-catch. It is clear that direct estimation by observers is the only means of gaining reliable estimates of by-catch in this fishery. In contrast to most trawl fisheries for penaeid prawns (Andrew and Pepperell, 1992), stow nets generally catch more prawns than by-catch (by weight) per unit of effort. This pattern of catch produces by-catch: prawn ratios of less than one in the great majority of instances. This contrasts to ratios in excess of 20: 1 commonly reported for trawl fisheries (Andrew and Pepperell, 1992). The only other report we could find of by-catch: prawn ratios for a non-trawl penaeid fishery was that of Chavez (1992). In the cast-net fishery studied by Chavez, the by-catch: shrimp ratios varied between 0.5: 1 and 1.22: 1 depending on the type of net used.

The poor precision of the extrapolated catch for the 1991-92 year was caused by the multiplication of imprecise estimates of catch rate in the November 1991 lunar month by the effort for that month. Because small catches were recorded for all but three nights in November 1991, this estimate of total catch almost certainly is an overestimate. In order to get reasonable estimates of total by-catch for the pocket net fishery, observer sampling would have to be stratified by periods of high discharge and, further, large numbers of dig-nights would be need to be sampled. Compulsory logbooks would also contribute to increases in precision because a better estimate of the number of digs worked per night per month could be obtained, thereby allowing exceptionally large catches to be weighted by effort. Such weighting would minimise the disproportionate influence of these large catches on estimates of mean monthly by-catch and total by-catch. The maximum estimates of total by-catch reported in Table 3 are gross overestimates. They assume that all of the digs for which we have no information (on average, about half of them per month) were fished on every available day. Our best estimate is much closer to the minimum estimate (if none of the 'unknown' digs were fished at all) and assumes that the fishers returning logbooks are representative of the fleet. Even given the poor confidence we have in the totals for 1991/92, our estimates of commercial finfish by-catch are small.

In this study we have presented one of the first quantitative descriptions of the by-catch of a prawn fishery that uses a method other than trawling. Despite the imprecise estimate of total by-catch for the 1991-92 year, it is clear that by-catch is relatively small compared to prawn catch and small in absolute terms in comparison to many prawn trawl fisheries (Andrew and Pepperell 1992). Their exists, however, the potential for the by-catch to be very large. These large by-catches appear related to increases in the amount of fresh water flowing down the river. Catches of school prawns have previously been related to discharge (Ruello, 1973; Glaister, 1978a). The two years we studied the by-catch of the Clarence River set pocket fishery were relatively dry years. It is likely that the timing and location of large catches of fish will differ among years with different river discharge and therefore few generalisations among years are possible.

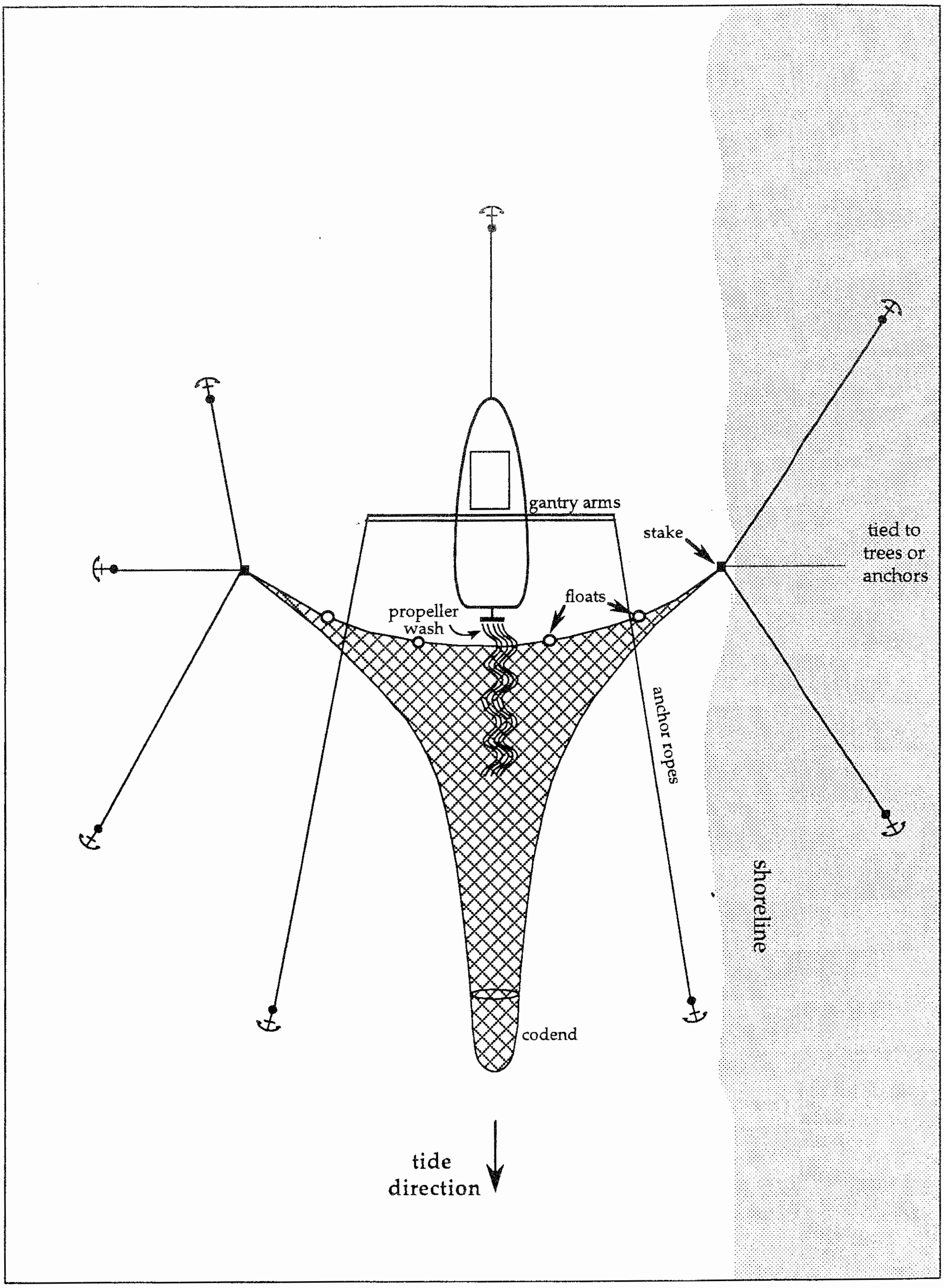


Figure 3.1. Stylized set pocket net.

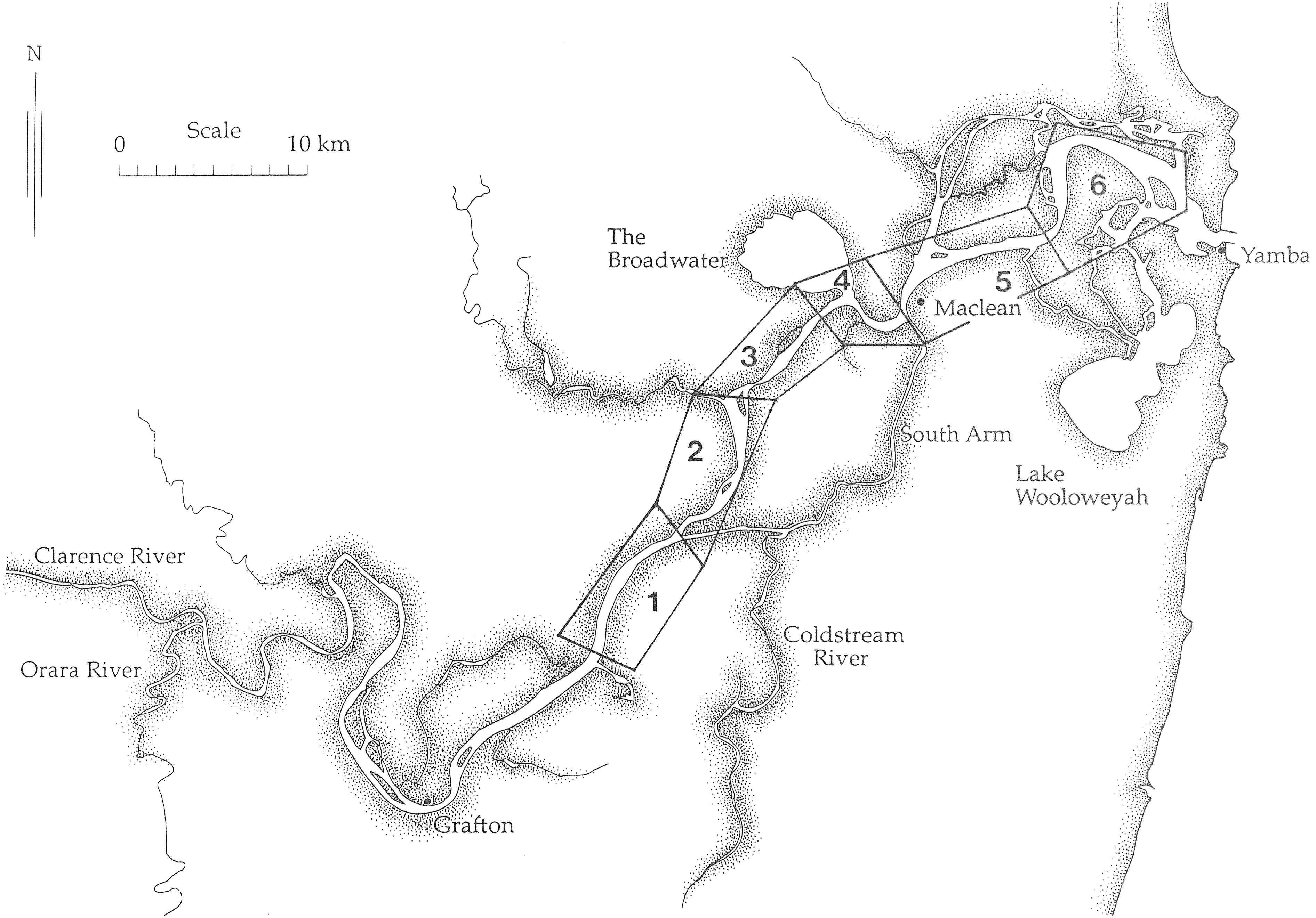


Figure 3.2. Map showing the zones used in the analysis of catches of school prawns.

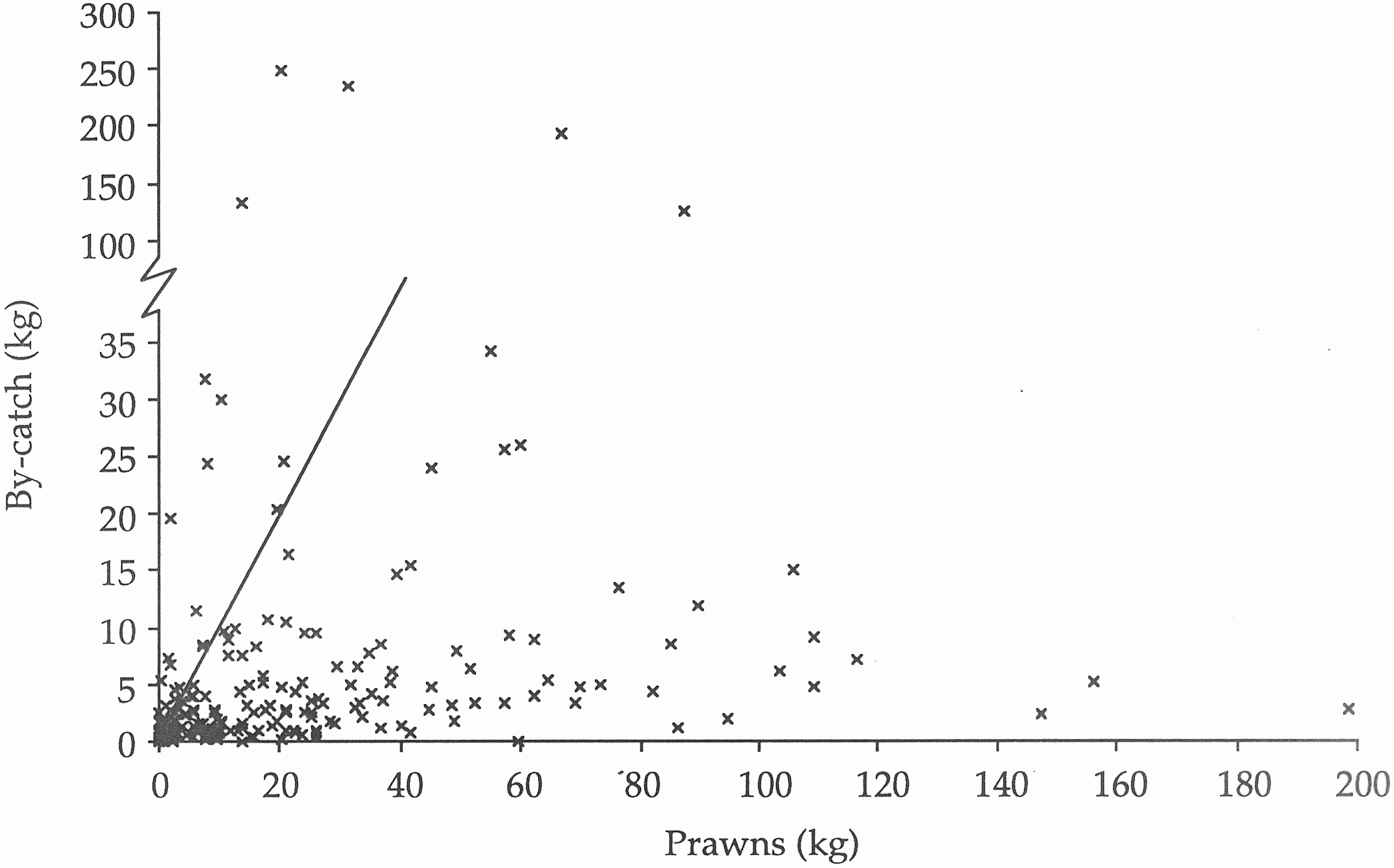


Figure 3.3. Relationship between prawn catch and by-catch with 1:1 line.

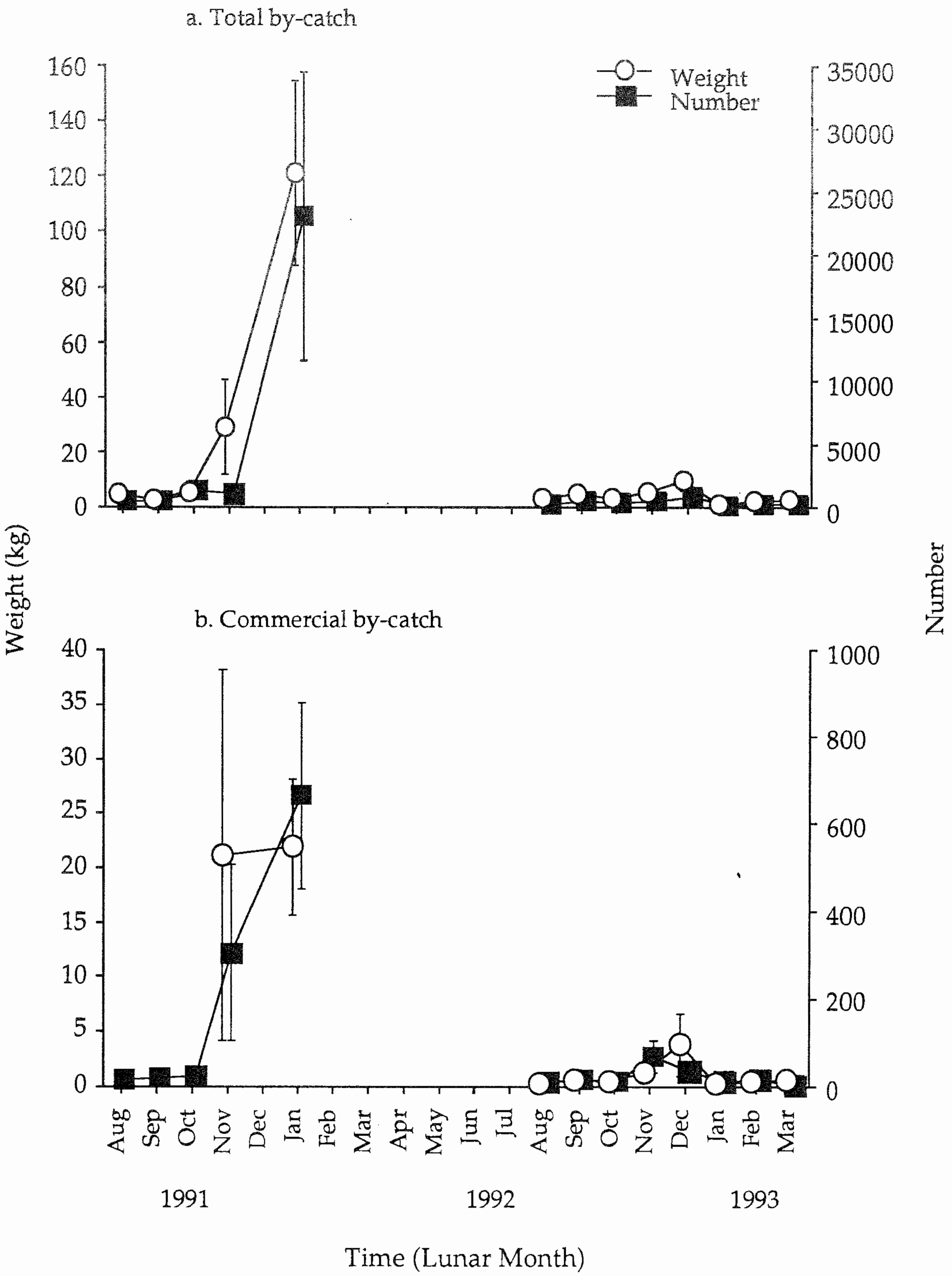


Figure 3.4. Mean (± S.E.) nightly number and weight of by-catch through time for (a) total by-catch and (b) commercial species only. In this and subsequent figures, the calendar month shown is the month in which the lunar month starts.

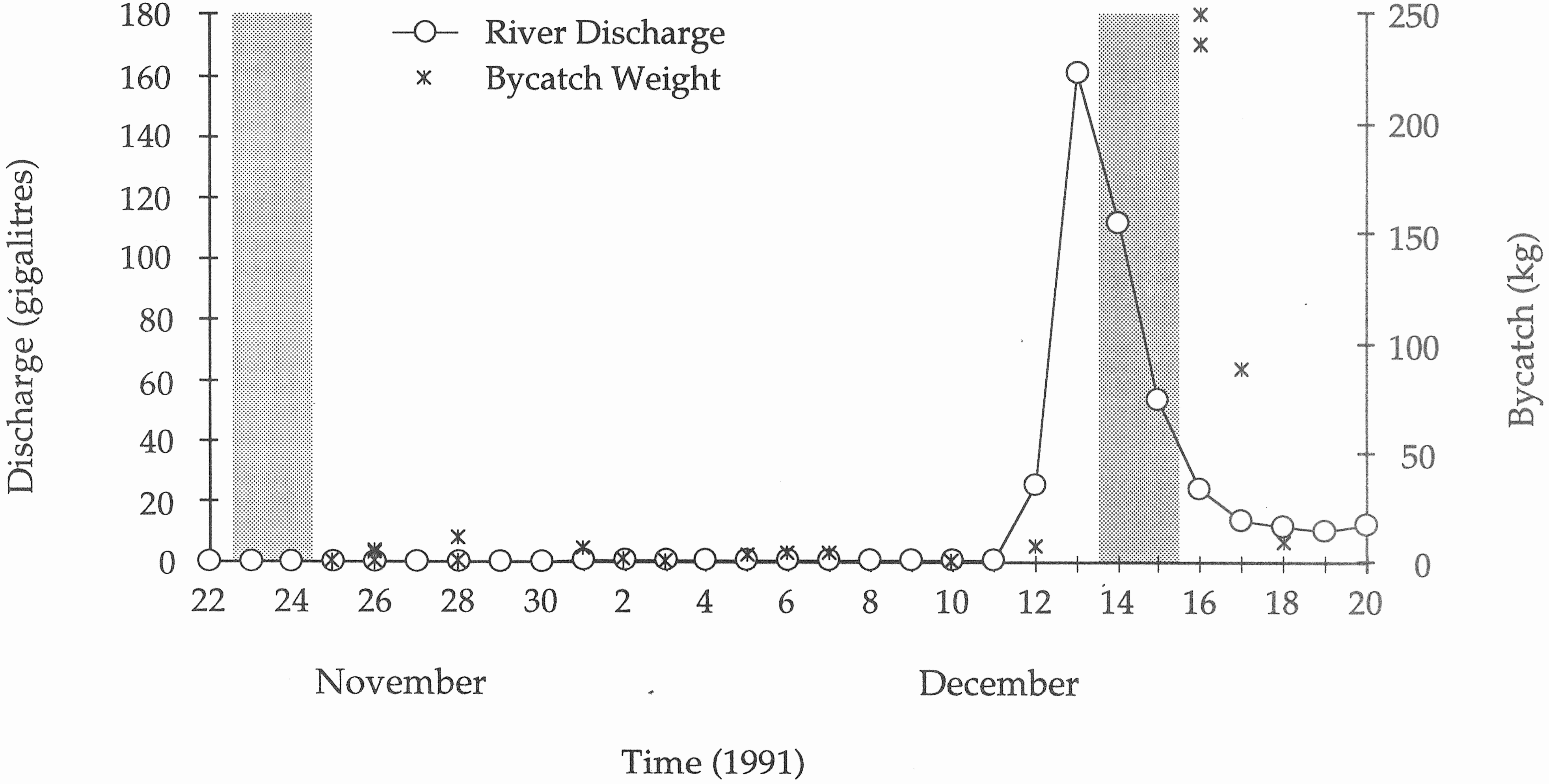


Figure 3.5. Total by-catch and river discharge for the lunar month beginning 22 November 1991. The shaded areas (▨) indicate weekends when fishing was not allowed.

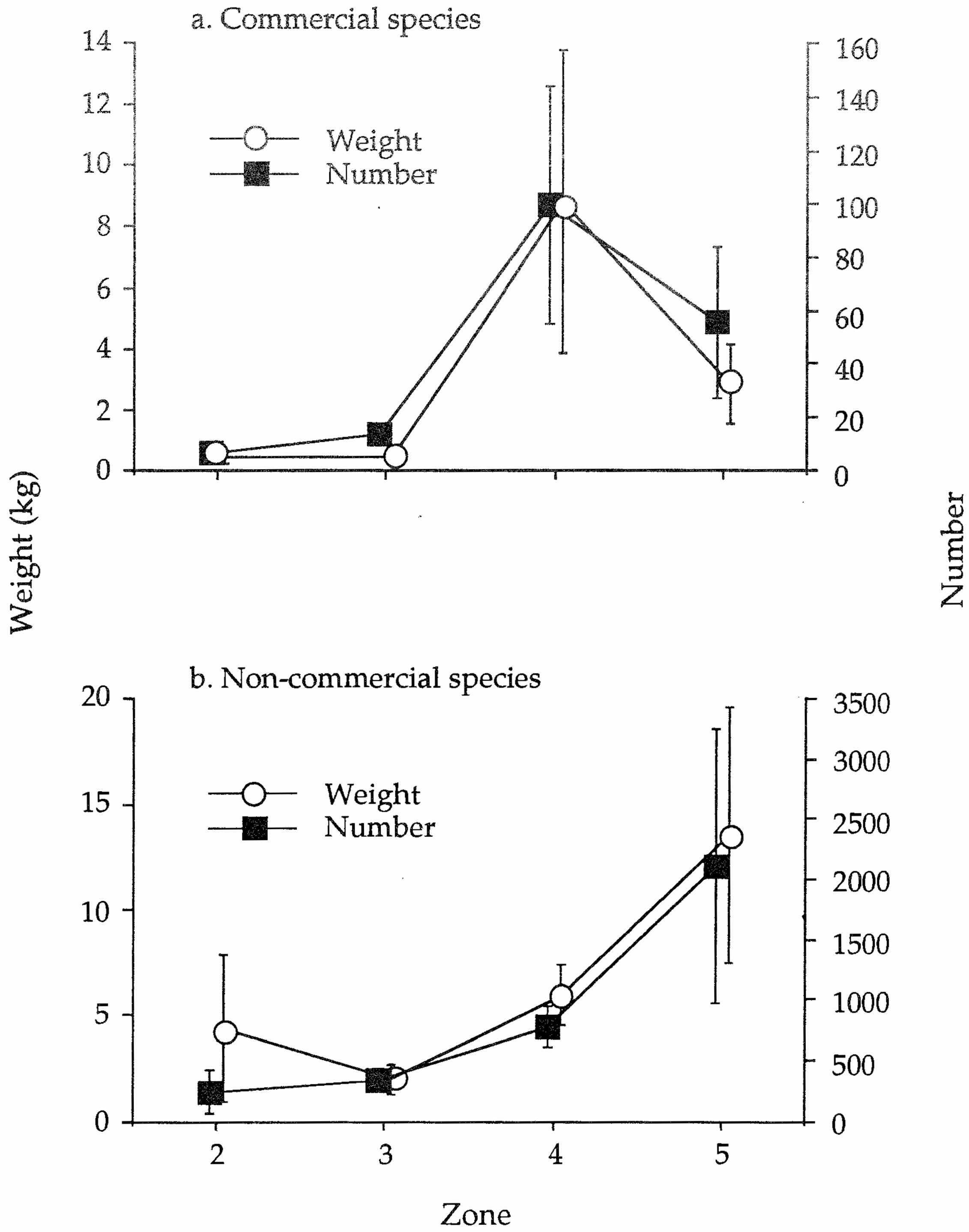


Figure 3.6. Mean (± S.E.) by-catch weight and number per zone for (a) commercial and (b) non-commercial species. Data pooled accross months and seasons.

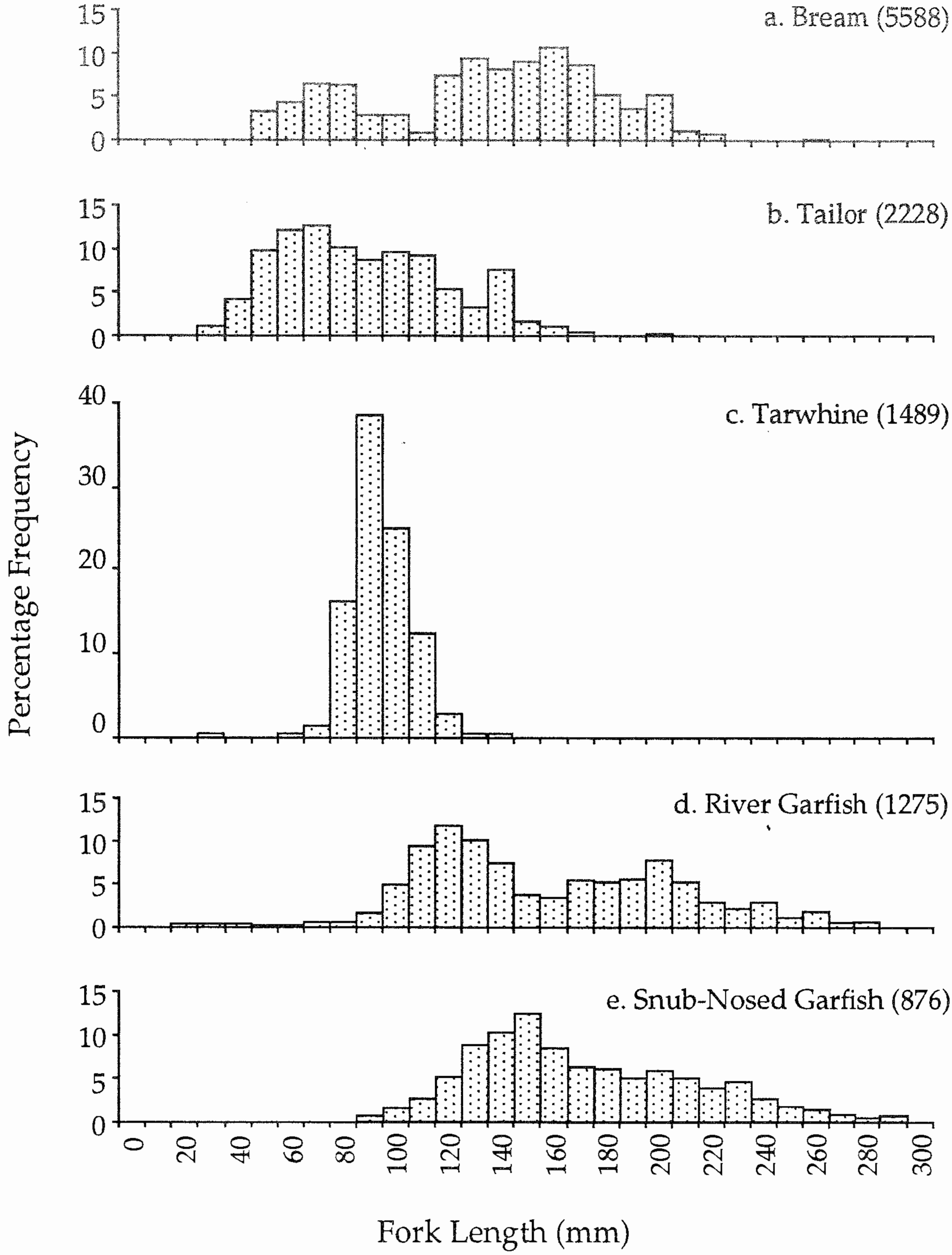


Figure 3.7. Length-frequency distributions of (a) bream, (b) tailor, (c) tarwhine, (d) river garfish and (e) snub-nosed garfish. Sample sizes are given in parentheses.

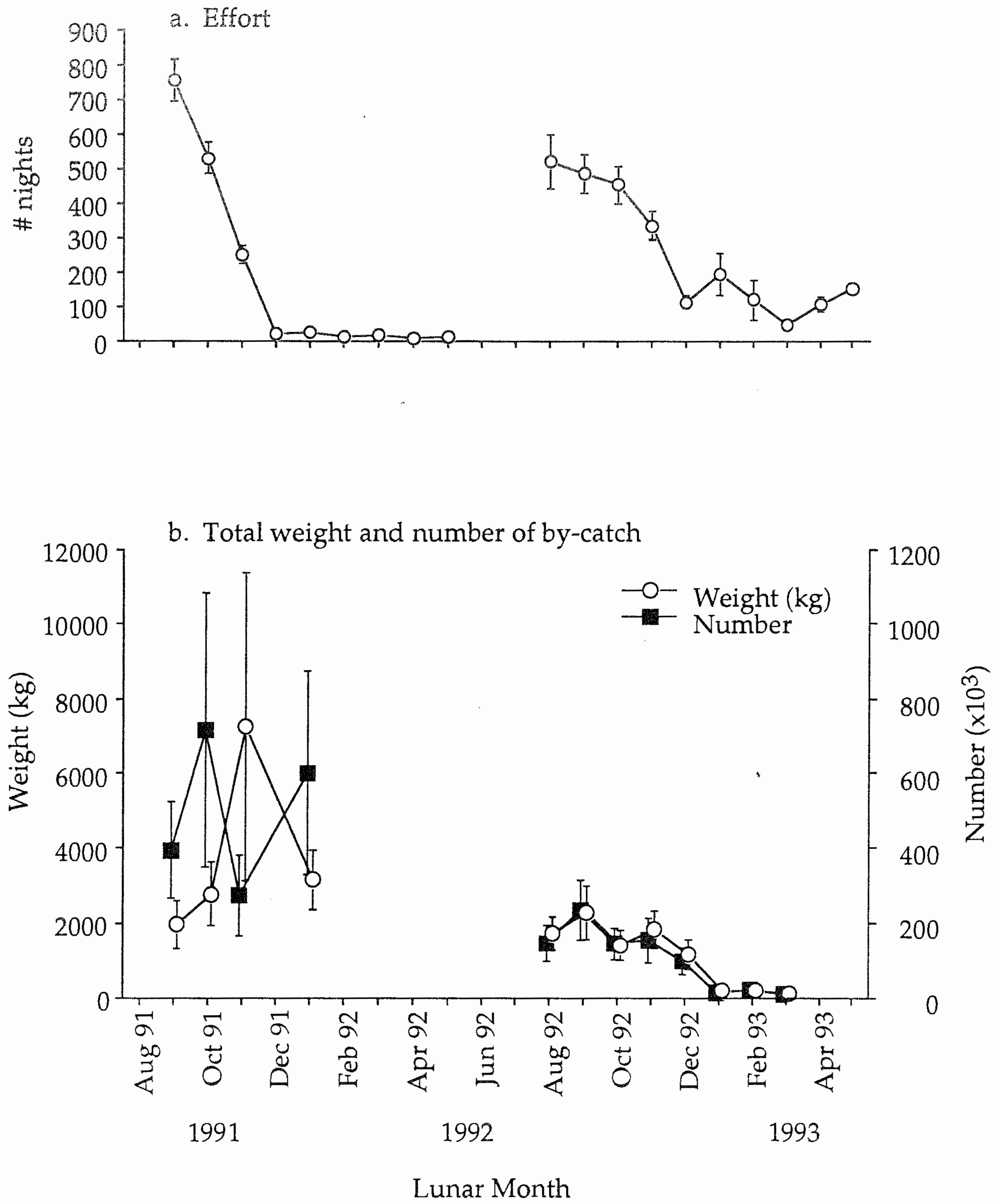


Figure 3.8. Estimates of (a) total effort and (b) total weight and number of by-catch for the whole fleet catch.

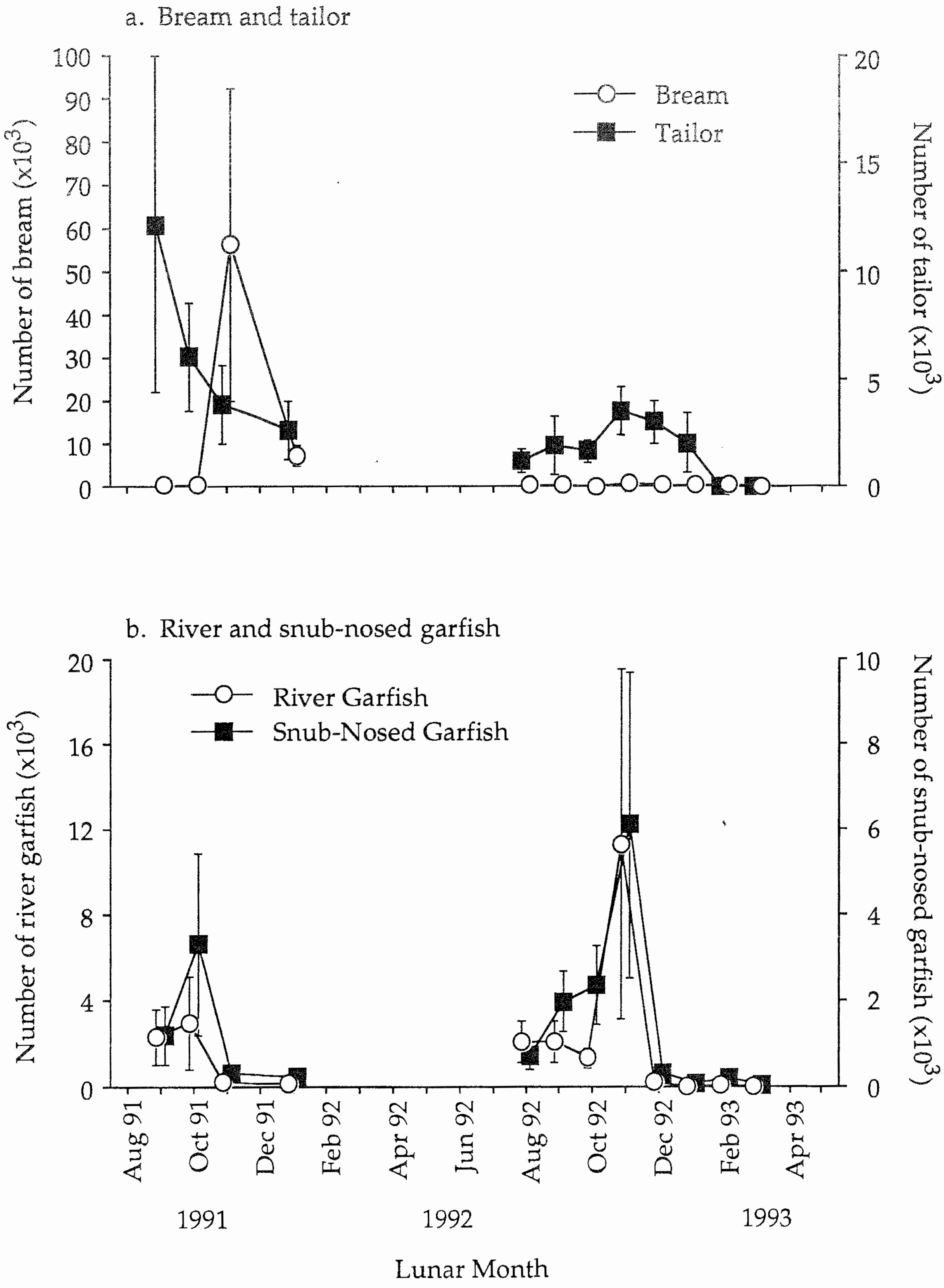


Figure 3.9. Estimates of total catch of (a) bream and tailor and (b) river and snub-nosed garfish for the whole fleet.

Table 3.1. Mean (± S.E., n = 211) catches per dig night in the set pocket net fishery. Means are calculated by pooling data accross all sampled months. The weights of individual species were not estimated, nor were the numbers of prawns counted.

| Variable | mean number per dig-night | mean number per dig-night without 7 large catches | mean wt (kg) per dig-night | mean wt (kg) per dig-night without 7 large catches |
|---|---|---|---|---|
| Bream | 26.5 ± 14.2 | 1.0 ± 0.2 | | |
| Tailor | 10.6 ± 2.3 | 8.2 ± 1.9 | | |
| Tarwhine | 7.1 ± 3.7 | 0.1 ± 0.1 | | |
| River Gar | 6.0 ± 2.1 | 6.1 ± 2.2 | | |
| Snub-nosed Gar | 4.2 ± 1.0 | 4.1 ± 1.1 | | |
| Perchlet | 360.8 ± 73.5 | 318.3 ± 70.9 | | |
| Herring | 399.9 ± 211.6 | 123.2 ± 22.6 | | |
| Total By-catch | 1010.8 ± 297.0 | 529.7 ± 81.4 | 8.7 ± 2.0 | 4.2± 0.4 |
| Non-comm. | 951.3 ± 290.9 | 508.5 ± 79.6 | 7.0 ± 1.8 | 3.3 ± 0.4 |
| Comm. | 59.5 ± 20.1 | 21.2 ± 3.8 | 4.7 ± 2.2 | 1.0 ± 0.3 |
| Prawns | N/A | N/A | 22.7 ± 0.8 | 22.87 ± 2.16 |

Table 3.2. Analyses of variance of mean numbers of total, commercial and non-commercial by-catch and total by-catch weight Data transformed as indicated to reduce heterogeneity of variances, Cochran's test non-significant for all data as analysed). - indicates the factor has been pooled. Degrees of freedom indicated are those for the original test and the mean squares are those for the pooled *F*-test.

| | | Total by-catch number | | Total by-catch weight | | Commercial number | | Non-commercial number | |
|---|---|---|---|---|---|---|---|---|---|
| Source | df for *F* | MS | *P* | MS | *P* | MS | *P* | MS | *P* |
| Year | 1,96 | 81.8 | n.s. | 158.9 | n.s. | 1.3 | n.s. | 90.8 | n.s. |
| Month | 2,2 | 30.0 | n.s. | 1922.3 | n.s. | 5.2 | n.s. | 28.45 | n.s. |
| Zone | 1,1 | 1173.5 | $p<0.01$ | 10502.1 | n.s. | 33.3 | $p<0.05$ | 1102.08 | $p<0.05$ |
| Year x Month | 2,96 | 237.5 | n.s. | 3107.8 | n.s. | - | n.s. | 229.19 | n.s. |
| Year x Zone | 1,96 | - | n.s. | 1817.1 | n.s. | - | n.s. | - | n.s. |
| Month x Zone | 2,2 | 225.6 | n.s. | 1539.4 | n.s. | - | n.s. | 218.58 | n.s. |
| Yr x Mo x Zn | 2,96 | - | n.s. | - | n.s. | - | n.s. | - | n.s. |
| Residual | | 130.7 | | 1044.33 | | 5.7 | | 128.45 | |
| Transformation | | none | | square root | | square root | | none | |

Table 3.3. Total (± 95% confidence intervals) estimated number of bream, tailor, river gar and snub nosed gar and non-commercials with total, commercial and non-commercial weight. 1991/92 estimated totals are for September - November 1991 and January 1992 (4 months); 1992/93 are for August 1992 - March 1993 (8 months).

| Variable | 1991/92 total estimate | | | 1992/93 total estimate | | |
|---|---|---|---|---|---|---|
| | minimum | best | maximum | minimum | best | maximum |
| Bream | 40060± 41027 | 64079± 72678 | 249753± 320121 | 1186± 425 | 3152± 979 | 16860± 4923 |
| Tailor | 11430± 5996 | 24777± 17084 | 66611± 44465 | 5681± 2014 | 13307± 5162 | 66444± 28585 |
| Tarwhine | 10196± 8883 | 13085± 13825 | 35622± 56761 | 74± 35 | 298± 88 | 2263± 560 |
| River Gar | 2419± 2257 | 5625± 5074 | 15346± 14524 | 7912± 7936 | 17199± 16697 | 63037± 65333 |
| Snub-nosed Gar | 2416± 2120 | 5070± 4454 | 14325± 13135 | 5334± 3573 | 11775± 7582 | 43869± 29360 |
| Perchlet | 487844± 352993 | 1013501± 735599 | 2856442± 2170216 | 173353± 61797 | 402741± 143202 | 1458079± 493155 |
| Herring | 437136± 464258 | 500271± 468221 | 731452± 507113 | 137904± 50922 | 316754± 113049 | 1424487± 696807 |
| Total By-catch | 1231603± 668626 | 1987963± 974940 | 4848661± 2528573 | 357367± 106038 | 833970± 246446 | 3394350± 1002870 |
| Non-comm. | 1158536± 660097 | 1864331± 950311 | 4424180± 2377101 | 335653± 99251 | 784182± 232641 | 3184836± 952419 |
| Comm. | 73070± 55639 | 123633± 99010 | 424465± 429696 | 21714± 11729 | 49789± 24964 | 209515± 99665 |

## 3.2 Additional information on the by-catch of the set pocket net fishery

The information presented in Section 3.1 represents only the most important information from our quantification of the by-catch. Because the manuscript has been submitted to an international journal, a lot of information of only local interest was excluded. In this section we present the information excluded from the manuscript. Although not essential, we feel the information collected may be of use to future researchers and therefore should be presented.

The average number of species caught per night for each month steadily increased from September 1991 to January 1992, but there was little change in 1992-93 (Fig. 3.10). Trends in the number of commercial and non-commercial by-catch species caught were similar in both 1991 - 92 and 1992 - 93 (Fig. 3.10) Species of commercial value accounted for approximately one third of the total number of species caught (Fig. 3.10.).

Trends in catches of bream were similar to those for the combined catches of all by-catch (Fig. 3.4, 3.11a). In the 1992-93 season, the greatest catches of bream were also recorded in November - January, but were of a much lesser magnitude (1/100). Similar patterns were evident for tailor (Fig. 3.11b) and tarwhine (Fig. 3.11c), although tarwhine were almost absent except for in November 1991 and January 1992. Catches of garfish (Fig. 3.11 d, e) in November 1991 and January 1992 were not very large. Largest catches for both garfish species were made in November 1992, but these were caused by few very large catches.

A complete species list of fish caught during the observer program is given in Appendix 3.

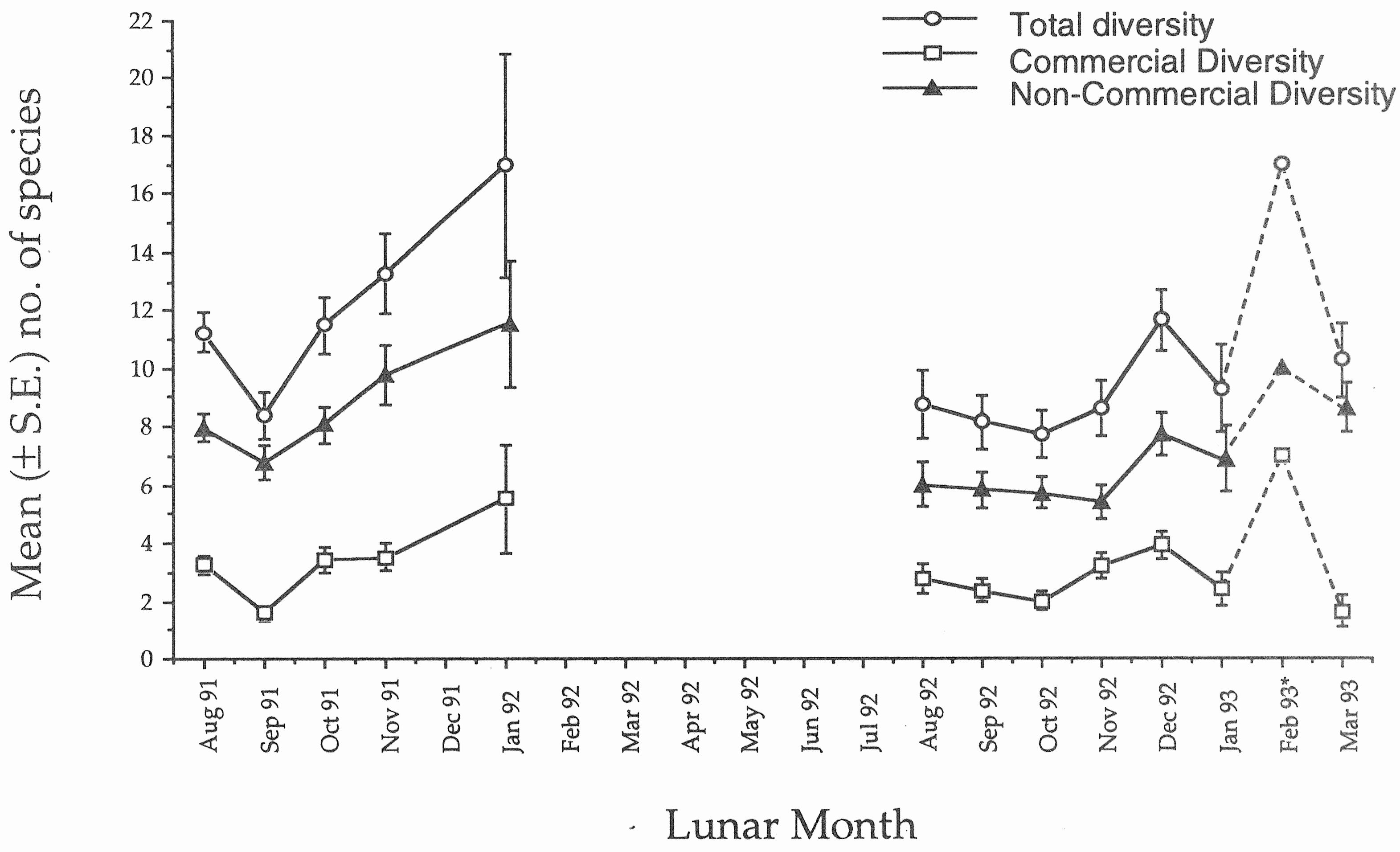


Figure 3.10. Mean number of species caught per night of by-catch partitioned into commercial and non-commercial species. Note, only fin-fishes are included in this estimate. There was only one sample taken in February 1993*.

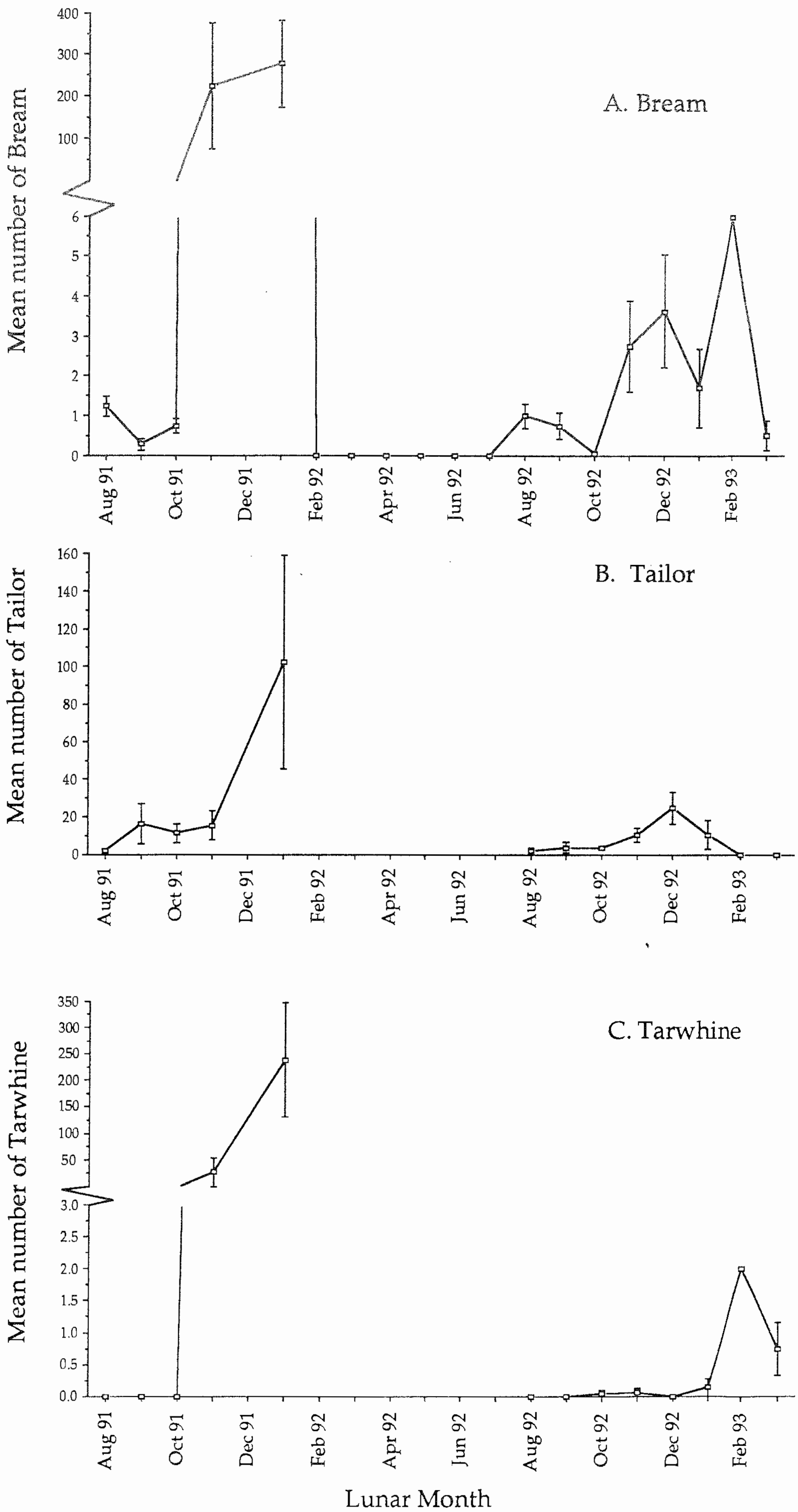


Figure 3.11. Mean (± S.E.) catches per night of the main by-catch species in the Clarence River set pocket net fishery.

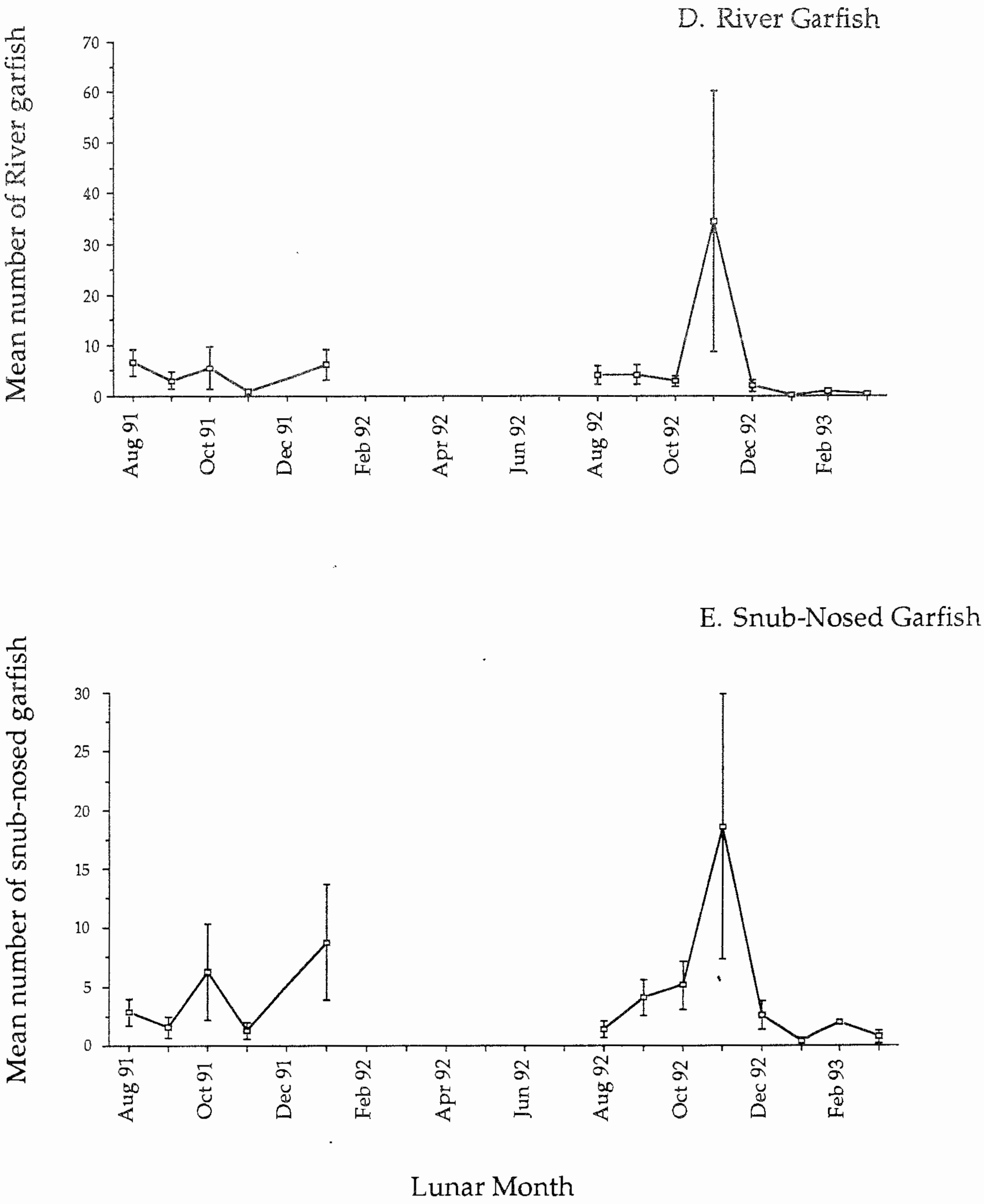


Figure 3.11. Continued mean (± S.E.) catches per night of the main by-catch species in the Clarence River set pocket net fishery.

# CHAPTER FOUR: PATTERNS OF ABUNDANCE OF JUVENILE SCHOOL PRAWNS IN THE CLARENCE RIVER

## 4.1 Introduction

To manage penaeid prawn fisheries effectively it is important to know the types of habitat and the locations used by prawns at the various stages of their life-cycle. This is particularly so for species inhabiting estuaries that have been modified by human activity. Monitoring commercial catches can provide some information but, because this sampling is 'directed' and limited to a relatively small proportion of the estuary, it can not provide an unbiased description of habitat usage. A further limitation of relying on catch statistics is that no information can be collected on individuals that have not yet recruited to the fishery. These limitations of catch statistics make the possibility of detecting long-term changes in usage patterns and changes in abundance difficult (e.g. Ruello 1973, Glaister 1978, Lucas et al. 1979).

In the previous chapters we have described catches from the pocket net fishery. Here we broaden our evaluation of the pocket net fishery to independent sampling of the abundance of school prawns, particularly juveniles. There is currently no information on the abundance of juvenile school prawns in the Clarence River. The sampling described in this chapter is designed to provide estimates of the relative abundance of prawns, and the sizes of those prawns, throughout the river system. The fishery-independent sampling further allows the abundance of juvenile prawns to be related to environmental variables such as salinity and discharge. This analysis will allow an independent test of the relationships described in Section 2.2 and extends the analysis to smaller prawns, not caught in the pocket net fishery.

A final result from the work presented in this chapter is that it provides the foundation for developing indices of abundance of prawns in the Clarence River. Such pre-recruit indices have been successfully used to predict catch in several prawn fisheries (e.g. the Northern Prawn Fishery, Staples and Vance 1986).

## 4.2 An electrified beam trawl for sampling juvenile prawns in estuaries

### 4.2.1 Introduction

The development of effective sampling devices is critical for reliable estimation of abundance. Although some animals are large and/or easily counted by direct observation, most are not and considerable effort has been expended in developing sampling methods that provide accurate and precise estimates of abundance. Estimating numbers of juvenile penaeid prawns in estuaries and rivers is a case where direct observation is not possible and precise estimates are difficult to obtain. Effective management of the fisheries that these prawns support often requires knowledge of patterns of abundance that are independent of the fishery.

Prawns are difficult to sample reliably, they often live in turbid water, and their behaviour is influenced by a range of environmental variables such as the state of the tide, depth, and time of day/night (Young 1973, Staples 1980, Staples and Vance 1986, Quinn and Kojis 1987, Stoner 1991, Vance and Staples 1992). In the face of these changes in catchability, there are two broad alternatives available for gaining reliable estimates of abundance (Vance and Staples 1992). In the first alternative, knowledge of the influence of environmental variables such as tide, day/night, lunar periodicity etc. may be used to restrict sampling to only those times/places where catchability is thought to be similar. This avenue has been used effectively in studies of juvenile prawns in the Gulf of Carpenteria (e.g. Vance and Staples 1992). There are however, many disadvantages to this form of sampling. First, it requires considerable knowledge of patterns of behaviour and catchability of prawns (Vance and Staples 1992). Much of this knowledge is likely to be species-specific and is available for relatively few species. This lack of generality means that the conclusions drawn from these studies of catchability may not be transferable among species. A second problem with this sampling method is that it does not allow broad comparisons among habitats and times. This is particularly the case in large estuaries/rivers in which it is difficult to determine the timing of tide states, in various parts of the river and to ensure similarity of other environmental variables such as salinity and turbidity.

Traditionally trawls, particularly beam trawls, and traps have been used to sample prawn populations (e.g. Racek 1959, Young 1973, Glaister 1977, Staples and Vance 1979, Vance and Staples 1992, Turnbull and Watson 1990). These methods have been shown to be vulnerable to differences in catchability. Sampling using these methods is therefore restricted to those times and places that have similar catchabilities.

The second broad approach to sampling prawns is to develop sample techniques that minimise differences in catchability. Examples of such methods include more effective beam trawls, incorporating water jets (Penn and Stalker 1975) and electric currents (Watson, 1976; Turnbull and Watson, 1990). Such sampling methods allow sampling over a wider range of habitats and environmental conditions. We have adopted this second alternative in the present study because we wished to sample a broad range of habitats over a large spatial scale. It was not, therefore, possible to standardise our sampling to a defined set of environmental conditions.

In the present study we introduce an electrified beam trawl to sample *M. macleayi* to investigate distribution and abundance of *M. macleayi* within the Clarence River. The affects of location, tide state, depth and direction on the number of prawns caught are examined. The results are discussed in relation to developing an effective sampling program for *M. macleayi* in the Clarence estuary, aimed at providing important information for the management of the fishery.

*Metapenaeus macleayi* in the Clarence River in northern New South Wales supports an important commercial fishery (Racek 1959, Glaister 1977). *M. macleayi* spawn at sea and enter the estuary as post-larvae (Racek 1959). They remain in the estuary until they reach maturity or the river floods (Racek 1959, Glaister 1977). Generally, the adults migrate from the estuary to the ocean from September to May (Glaister 1977). Although considerable work has been done on the biology of *M. macleayi* (Racek 1959, Glaister 1977, Ruello 1973 a, b, 1977) little information has been collected on the biology of the juveniles less than 10 mm carapace length since Racek's (1959) pioneering work.

### 4.2.2 Materials and Methods

#### The beam trawl

A small mesh net was towed behind a "D" shaped beam trawl frame for both experiments. The net had 12 mm mesh in the main body and 4 mm mesh in the codend and had a 1 m X 0.5 m opening at the mouth. Electricity was set at 80 volts R.M.S. (1 khz) with 1 ampere power and was delivered by braided copper wire laced along the foot rope of the net.

#### Trawl experiments

Three experiments using the electrified beam trawl were done on the Clarence River in northern New South Wales. *M. macleayi* is generally caught in larger numbers during the day than at night (Racek 1959, Coles 1979), consequently all the sampling for this study has been done during the day. The trawl locations extended from 7.2 to 42 kilometres from the river mouth and included known *M. macleayi* fishing grounds.

In all experiments the trawl was towed for 250 m at 2.0 knots. Towing speed was determined by timing the vessel along the 250 m course and was regulated using the vessel's engine tachometer. The distance trawled was determined using a length of light rope and marker buoys.

Trawl Experiment 1: Electricity

This experiment examined the effect of site, tide, depth and electricity on the number of prawns caught in the beam trawl. Four sites were sampled at two depths (1 m and 3 m) on each of four stages of the tide (run-in, high, run-out, low), with and without electricity. For each site, depth, tide and electricity combination, three replicate trawls were done. Trawling was carried out for a two hour period across the mid point of each tide state. Levels of Depth and Electricity were sampled in random order for each tide state at each site. It was not possible to sample all sites in the one day, therefore sites were sampled on different days. Any effect of days is therefore combined with site.

The data were square root transformed to homogenise the variances (Cochrans test, Winer 1971). The results were analysed using analysis of variance with 4 factors: Site (4 levels); Tide (4 levels); Depth (2 levels); Electricity (2 levels). Site was considered random and all other factors were considered fixed.

**Trawl Experiment 2: Direction**

The second experiment investigated the influence of the direction of the trawl relative to current direction on catch rates. Again, four sites were sampled at two depths. In this experiment, however, water flow was required so only two stages of tide were sampled (run-in, run-out). The net was towed with and against the current and was electrified for all samples. For each site, depth, tide and direction combination five replicate trawls were done. The other experimental conditions were the same as for experiment 1.

The data were square root transformed to homogenise the variances, (Cochran's test Winer 1971). The results were analysed using analysis of variance with 4 factors: Site (4 levels); Tide (2 levels); Depth (2 levels);

Direction (2 levels). Site was considered random and all other factors were considered fixed.

Trawl Experiment 3: "TED" (Trash Eradication Device)

This experiment was done to test the effect of adding a "TED" (known locally as a "blubber chute") to the front of the beam trawl to exclude cnidarian medusae (*Catostylus* spp). The TED was constructed of 50 mm mesh supported by a frame and was located in front of the net 100 mm above the base of the trawl. It sloped up and back to the headrope of the net to deflect large medusae over the net. This TED was necessary at certain times when there were large numbers of medusae which filled the net when trawling. Trawls were done at one site, with and without the TED and also with and without electricity. For each combination of TED and electricity there were 7 replicates. Treatments were allocated in a random order. The results were analysed using analysis of variance with 2 factors: TED (2 levels); Electricity (2 levels). Both factors were considered fixed.

### 4.2.3 Results

**Trawl Experiment 1. Electricity**

Patterns in catches of juvenile *M. macleayi* were a complex result of site interacting with position and electricity (Table 4.1) and site interacting with depth and tide (Table 4.1). 83% of the observed variance in the model was accounted for by treatment effects and only 17% by error associated with replicates. Site accounted for 56% of total variation and the site x depth interaction for 14%. Tide and electricity both had significant effects but accounted for little of the observed variance compared to site and depth. Using electricity increased the catch at three of the four sites. The only site at which there was no significant effect of electricity was site 1. Very few prawns were caught making it difficult to detect any effect of electricity (Fig. 4.2a).

The magnitude of the effect of electricity on the catch varied between depths at different sites, with no clear pattern other than a general increase in the catch with electricity. A complex pattern in catches was also associated with tide, no two sites showed the same pattern of catches in relation to the state of the tide (Fig. 4.2b).

**Trawl Experiment 2. Direction**

Patterns in catches of juvenile *M. macleayi* differed depending on the location of sampling and on depth and tide (Table 4.2). Direction of tow did not have a significant affect on the catches (Table 4.2). As with experiment 1, there was relatively little variation (16% of observed variance in the model) associated with replicate trawls (Table 4.2). The factor site contributed the great majority of variance, contributing 77% of the observed variation in the model (Table 4.2, Fig. 4.3a). Tide, in conjunction with site, had a small (1% of observed variance in the model) but significant effect on the numbers of prawns caught. More prawns were caught at sites 2 and 4 on the incoming tide than the falling tide. At sites 1 and 3 there was no difference in catch between tide states (Fig. 4.3a). At site 2, 3 and 4 there were more prawns caught in shallow sites than deep sites (Fig. 4.3b), at site 1, however, there was no difference between the depths. The site x depth interaction explained a large percentage of the observed variance (Table 4.2). Depth combined with tide, had a small (<1% of observed variance in the model) but significant effect on the number of prawns caught (Table 4.2, Fig. 4.3c).

**Trawl Experiment 3: Effect of Trash Eradication Device (TED)**

The number of juvenile *M. macleayi* caught in the trawl was not influenced by the presence of the TED (Table 4.3, Fig. 4.4). Electrifying the leadline of the beam trawl significantly increased the catch of prawns (Table 4.3, Fig 4.4). This result supports the result of experiment 1, the use of electricity increased the catch of prawns at all sites where more than five prawns were caught per trawl.

### 4.2.4 Discussion

The beam trawl used in this study provided precise estimates of the number of prawns in a location at a particular time. The variability of within cell replication was relatively small (20% or less of the observed variation associated with the models in experiment 1 and 2). The relatively low variability among replicate samples found in this study indicates that the electrified beam trawl compares favourably to other methods used for sampling juvenile penaeid prawns (e.g. Stoner 1991, Turnbull and Watson 1990, Vance and Staples 1992).

Complex patterns in the catches of prawns were evident in this study, the number of prawns caught varied according to depth, site, and state of the tide. Previous work has demonstrated an influence of tide state and distance from the edge of the bank on the catchability of a number of penaeid species (e.g. Staples and Vance 1979, Stoner 1991, and Vance and Staples 1992). In the present study, however, no consistent patterns were found in relation to tide state or depth and their effect was small relative to location. This suggests that these factors do not influence the catchability of *M. macleayi* in the Clarence estuary when sampled by electrified beam trawl to the same extent as found in previous studies of different species.

Electrifying the lead line of the beam trawl significantly increased the catch at most locations, while direction of tow and the presence of the TED had no significant effect. At no location was the catch smaller with electricity than without. When comparing methods of sampling populations the greatest estimate of abundance is often the most accurate as under-estimation is unlikely. The use of electricity in the leadline appears, therefore, to increase the accuracy of the beam trawl, although there was an interaction between site and electricity, examination of the data (Fig. 4.2a) shows it is due to extremely low numbers at site 1, at all other sites electricity increased the catch of *M. macleayi*. Day and night has also been shown to influence the catch of prawns (Stoner 1991, Turnbull and Watson 1992, Vance and Staples 1992). *M. macleayi*, however, has previously been shown to be caught in larger numbers during the day (Racek 1959, Coles 1979), so diel cycle was not re-examined here. The multiple interaction of factors in both experiments 1 and 2 indicate the complex nature of the abundance and distribution of *M. macleayi* in the Clarence estuary. Location, both site and depth, contributed far more to the variance than any of the other factors. This has important implications for the design of a sampling program aimed at describing the distribution and abundance of *M. macleayi* in this estuary. Because location is contributing a large proportion of the variance, the sampling program needs to target many locations to provide useful information. While the state of the tide had a significant effect, it contributed very little to the observed variance, consequently the sampling effort expended on quantifying the effect of tide should be small relative to location.

Previous workers have had mixed results using electricity in trawling for penaeid prawns. Studies by Pease and Seidel (Pease and Seidel 1967, Seidel 1969) found that electricity increased the daytime catch of prawns. Watson and Turnbull (1992), in contrast, found the use of electricity ineffective for sampling prawns. The difference between Watson and Turnbull's work and the present study may be due to the species involved and the amount of electricity delivered to the net 20 volts was delivered to the trawl in Watson and Turnbull's work compared to 80 volts in the current study.

This pilot study provides the basis for designing a survey to sample the distribution and abundance of *M. macleayi* in the Clarence estuary. The study has shown that the electrified beam trawl is a useful sampling tool which provides consistent results among replicates. The pilot study has also provided important information on the main sources of variation within the system being studied. In particular, it has shown that sampling effort should be concentrated on describing differences among locations.

Estimating the abundance and distribution of pre-recruit prawns in a commercial fishery allows estimates of the population to be made that are not influenced by changes in the fishing effort. Consequently this survey method will facilitate the detection of long-term changes in the population which may otherwise be masked by changes in effort of the commercial fishery. In the present study we have introduced a sampling tool that significantly improves the catchability of pre-recruit prawns. The electric beam trawl will allow fishery independent sampling of the status of the school prawn resource over a wide range of habitats and locations in the Clarence River.

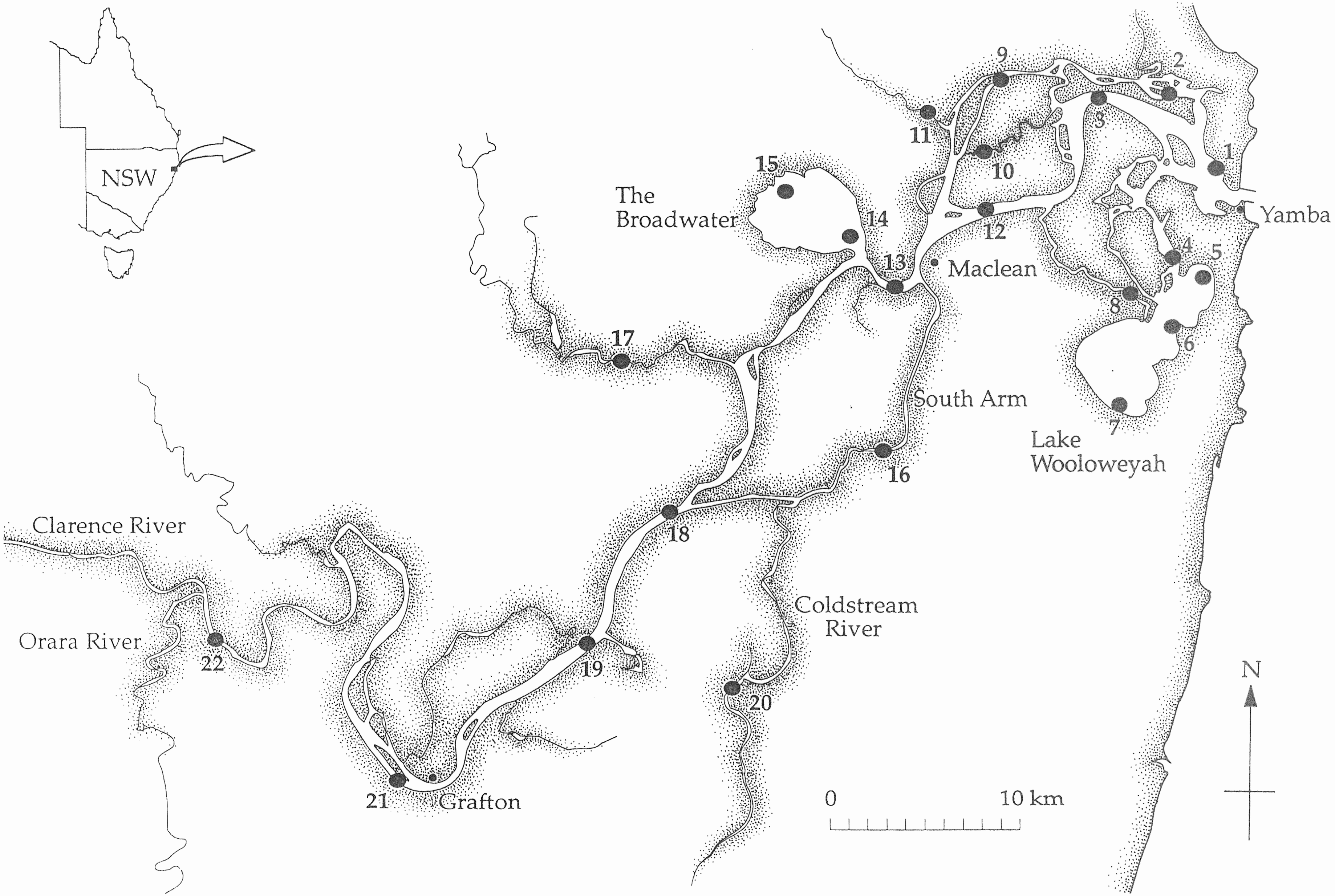


Figure 4.1. Map of the Clarence River estuary, New South Wales, Australia showing sites sampled. Sites are not necessarily numbered in order of distance from river mouth.

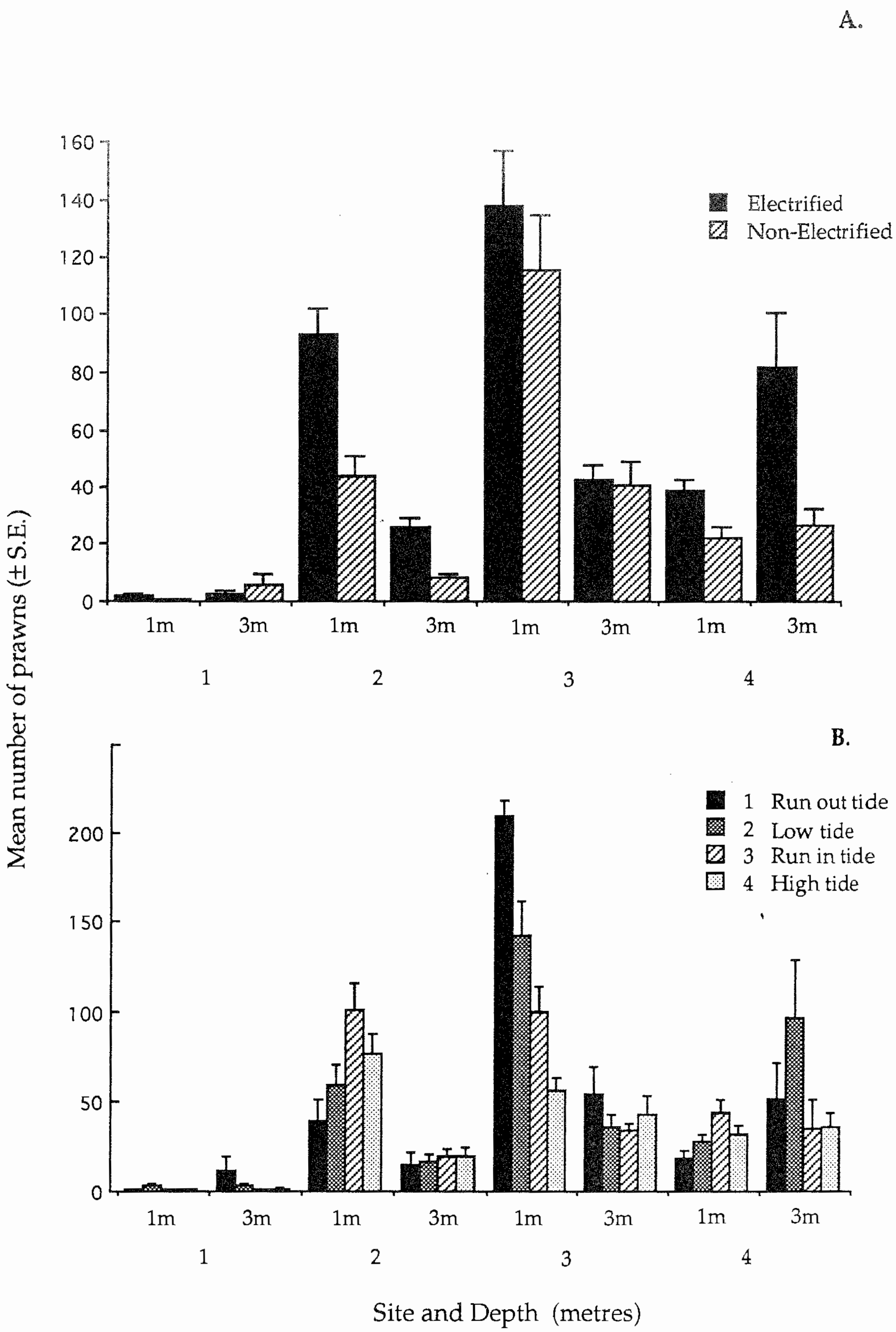


Figure 4.2. a. Comparison of catches of *M. macleayi* with and without electricity by site and depth in experiment 1. b. Comparison of catches of *M. macleayi* by site, depth and tide in experiment 1.

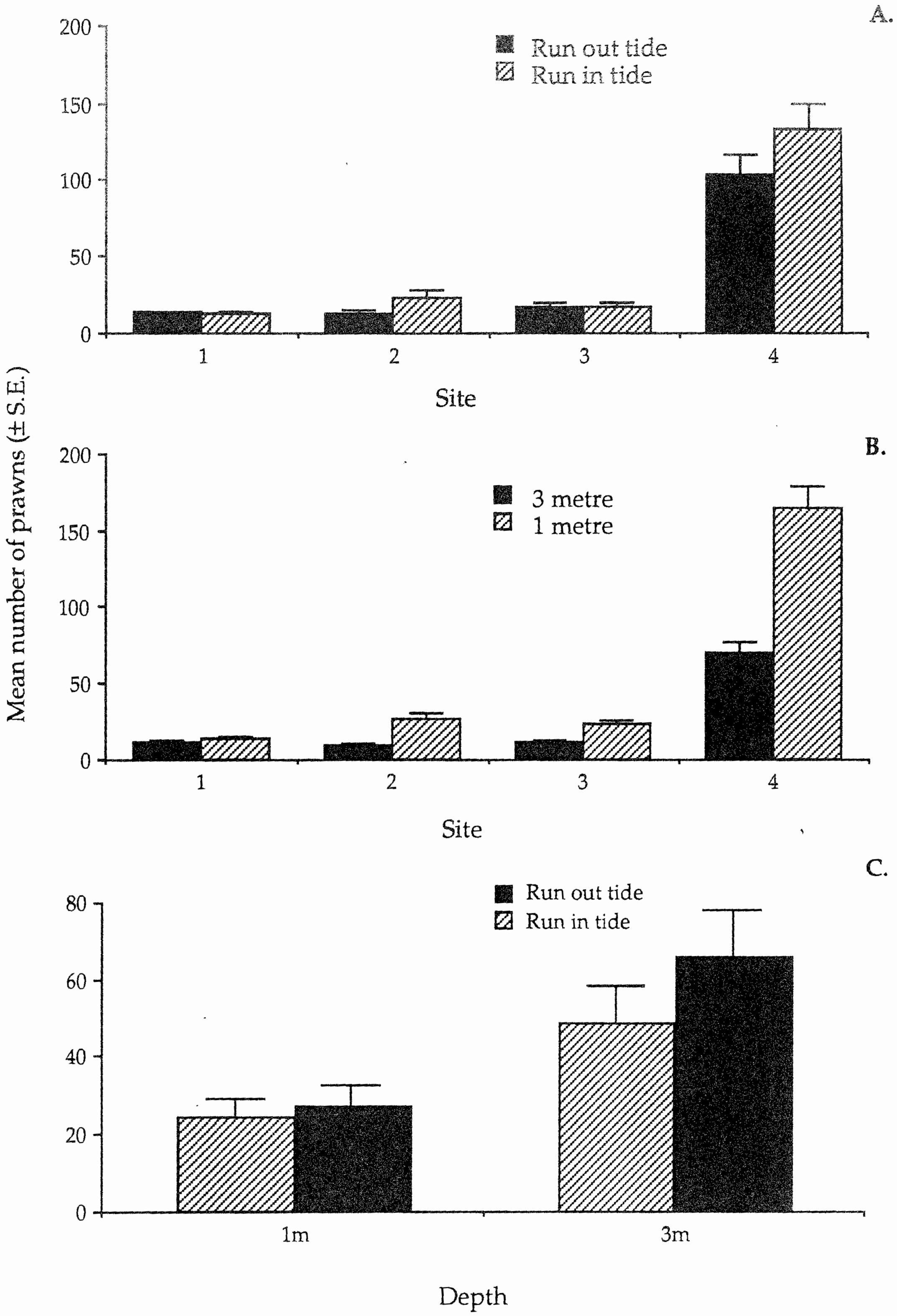


Figure 4.3. Comparison of the catch of *M. macleayi* in experiment 2 by a) site and tide b) site and depth and c) tide and depth.

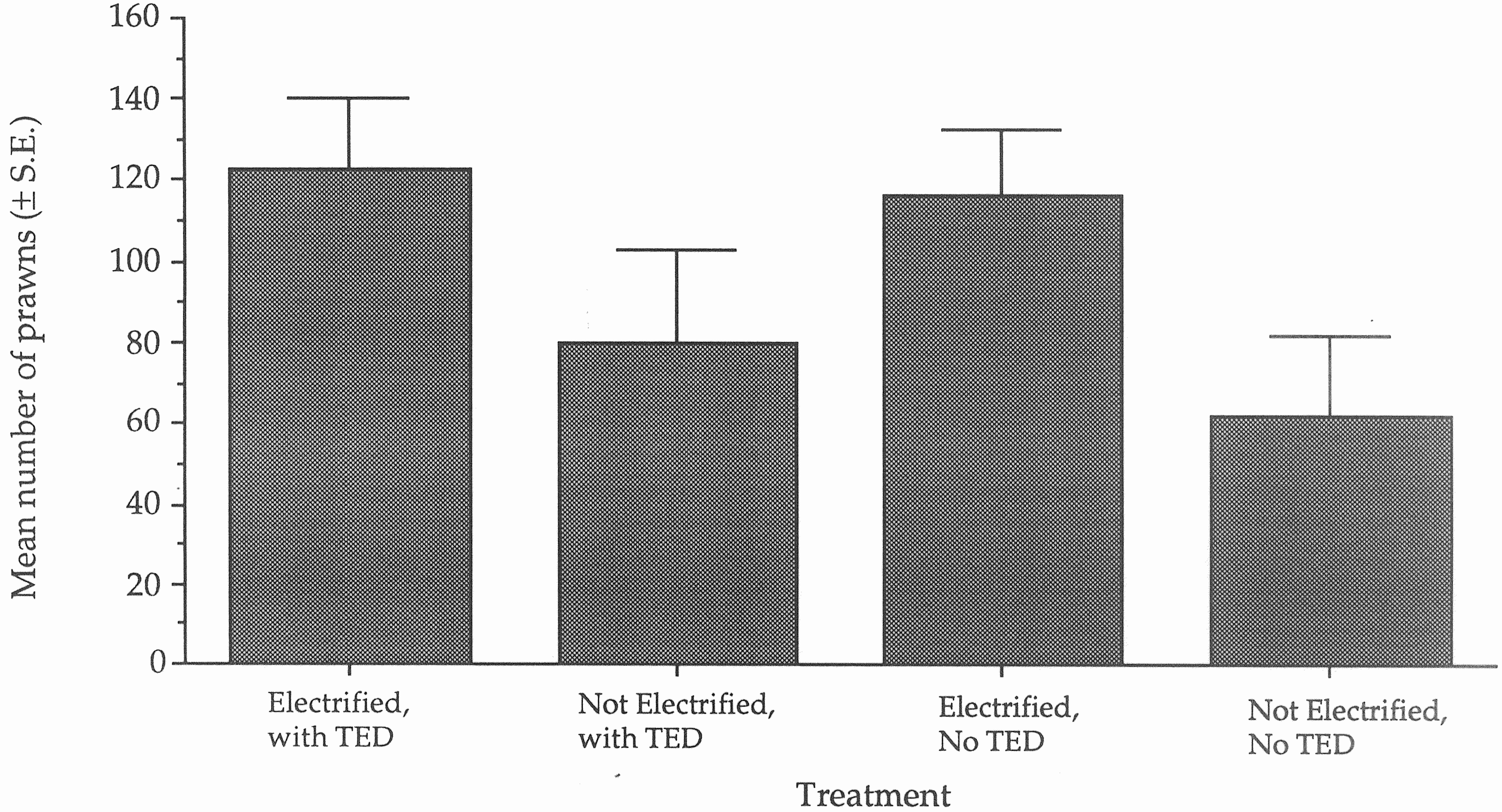


Figure 4.4. Comparison of the catches of *M. macleayi* with and without electricity and with and without the TED in experiment 3.

Table 4.1. Analysis of variance for beam trawl Experimant 1 examining the effect of site, tide, depth and electrifying the net. Data square root transformed.

| Source | df | Sum of Squares | Mean Square | F-ratio | Prob | Magnitude of effect (%) |
|---|---|---|---|---|---|---|
| Site | 3 | 1382.87 | 460.96 | 205.76 | *** | 55.85 |
| Tide | 3 | 20.84 | 6.95 | 0.40 | NS | 0.00 |
| Depth | 1 | 144.68 | 144.68 | 1.26 | NS | 0.02 |
| Electricity | 1 | 121.72 | 121.72 | 6.27 | NS | 0.48 |
| pDexE | 1 | 0.11 | 0.11 | 0.02 | NS | 0.00 |
| SxDe | 3 | 345.56 | 115.19 | 51.42 | *** | 13.75 |
| SxE | 3 | 58.20 | 19.40 | 8.66 | *** | 2.09 |
| SxT | 9 | 158.25 | 17.58 | 7.85 | *** | 5.61 |
| pTxDe | 3 | 18.56 | 6.19 | 0.45 | NS | 0.00 |
| pTxE | 3 | 3.91 | 1.30 | 0.63 | NS | 0.00 |
| SxDexE | 3 | 18.33 | 6.11 | 2.73 | * | 0.47 |
| SxTxDe | 9 | 122.81 | 13.65 | 6.09 | *** | 4.17 |
| pSxTxE | 9 | 21.97 | 2.44 | 1.12 | NS | 0.10 |
| pTxDexE | 3 | 2.78 | 0.93 | 0.42 | NS | 0.00 |
| pSxTxDexE | 9 | 17.69 | 1.97 | 0.88 | NS | 0.00 |
| Error | 128 | 284.47 | 2.22 | | | 17.46 |
| Total | 191 | 2722.73 | | | | 100.00 |

p : pooled * p<0.05, **p<0.01, ***p<0.001

Table 4.2. Analysis of variance for beam trawl Experiment 2 examining the effect of site, tide, depth and direction of tow. Data square root transformed.

| Source | df | Sum of Squares | Mean Square | F-ratio | Prob | Magnitude of effect (%) |
|---|---|---|---|---|---|---|
| Site | 3 | 1310.47 | 436.82 | 261.84 | *** | 77.03 |
| Tide | 1 | 14.09 | 14.09 | 1.96 | NS | 0.09 |
| Depth | 1 | 161.17 | 161.17 | 5.79 | NS | 0.47 |
| Direction | 1 | 2.38 | 2.38 | 1.43 | NS | 0.04 |
| pDexDi | 1 | 1.87 | 1.87 | 1.12 | NS | 0.01 |
| SxDe | 3 | 83.54 | 27.85 | 16.69 | *** | 4.63 |
| pSxDi | 3 | 1.87 | 0.62 | 0.37 | NS | 0.00 |
| SxT | 3 | 21.54 | 7.18 | 4.30 | ** | 0.97 |
| TxDe | 1 | 9.53 | 9.53 | 5.71 | * | 0.46 |
| pTxDi | 1 | 4.85 | 4.85 | 1.21 | NS | 0.02 |
| pSxDexDi | 3 | 1.02 | 0.34 | 0.20 | NS | 0.00 |
| pSxTxDe | 3 | 6.43 | 2.14 | 1.29 | NS | 0.09 |
| SxTxDi | 3 | 12.04 | 4.01 | 2.41 | NS | 0.42 |
| pTxDexDi | 1 | 0.00 | 0.00 | 0.00 | NS | 0.00 |
| pSxTxDexDi | 3 | 1.28 | 0.43 | 0.25 | NS | 0.00 |
| Error | 128 | 221.25 | 1.73 | | | 15.75 |
| Total | 159 | 1853.32 | | | | 100.00 |

p : pooled * p<0.05, **p<0.01, ***p<0.001

Table 4.3. Analysis of variance examining the effect of using the Trash Eradication Device.

| Source | df | Sum of Squares | Mean Square | F-ratio | Prob |
|---|---|---|---|---|---|
| Electricity | 1 | 16709 | 16709 | 7.9769 | ** |
| Shute | 1 | 1056.6 | 1056.6 | 0.5044 | NS |
| PExS | 1 | 252 | 252 | 0.1161 | NS |
| Error | 24 | 52115 | 2171.5 | | |
| Total | 27 | 70133 | | | |

p : pooled * p<0.05, **p<0.01, ***p<0.001

## 4.3 Patterns in the distribution and abundance of juvenile *Metapenaeus macleayi* in the Clarence River estuary.

### 4.3.1 Introduction

Many of the world's fisheries for penaeid prawns are based in or near estuaries. Prawns utilise a range of estuarine habitats at different stages of their life cycles and considerable effort has been expended in describing the distribution of prawns in estuaries (e.g. Ruello 1973a, b, 1977, Penn 1975, Coles and Greenwood 1983, de Freitas 1986, Potter *et al.* 1991,). Knowledge of how prawns utilise estuarine habitats will become increasingly important to the management of fisheries because estuaries are increasingly threatened by human activity. Understanding the relationship between habitat and abundance of prawns is important if we are to separate the effects of habitat loss from the effects of fishing.

Monitoring commercial catches provides only limited information on trends in catch that may be related to the utilisation of habitat. Difficulties in partitioning effort in space and time, the 'directed' sampling of the fleet and the lack of information on under-size prawns means that catch statistics alone are insufficient to understand the dynamics of populations of prawns in estuaries. These limitations together with any seasonal or yearly variations make detecting long-term changes in the population very difficult (e.g. Ruello 1973a, Glaister 1978, Lucas *et al.* 1979). Independent sampling of pre-recruits and in areas not fished by the fleet can provide important information on which management decisions can be based (e.g. Staples & Vance 1979, 1980, 1986).

The school prawn *Metapenaeus macleayi* supports an important commercial fishery in the Clarence River (N.S.W.) (Racek 1959, Glaister 1977) (Fig. 1.1). The life cycle of *M. macleayi* is similar to that of most species of *Penaeus* and *Metapenaeus*. Adults mate and spawn during summer and autumn (Ruello 1973b, Glaister 1978a) in coastal waters of approximately 60 meters or less in depth. (Kirkgaard and Walker 1970). The larvae migrate to estuarine nursery areas, probably using active vertical migration to take advantage of water currents (Dall et al. 1990). Post-larvae enter estuaries soon after, probably in the water column on flood tides (Dall et al. 1990). They move upriver and inhabit areas of salinity less than 20 ppt (Ruello 1973b). Juveniles overwinter in the estuary, growing only slightly. In spring, growth rate increases and the larger, maturing individuals move downstream, emigrating to the sea (Ruello 1973b, Glaister 1978a). Although work has been done on the life-cycle of *M. macleayi* in estuaries (Racek 1959), there is little information on the distribution and abundance of small (< 10 mm carapace length) individuals.

The wetland areas in the Clarence flood plain have been subject to widespread alteration in attempts to mitigate the effects of floods and to irrigate for agriculture. It is estimated that 98% of wetlands in the catchment of the river have been altered in some way, either for drainage or grazing (Pressey 1987). The effect of this massive reduction in the area of wetlands on populations of *M. macleayi* is poorly understood, largely because we do not understand patterns of utilisation by prawns in the river. *M. macleayi* may also have been affected indirectly by a reduction in food supply, as organic detritus has been shown to be important part of their diet (Ruello 1973b).

In this section we provide information on the distribution and abundance of *M. macleayi* in the Clarence River estuary. We identify areas occupied by *M. macleayi* and provide the basis for a long-term sampling program in the river. Sampling that was independent of the fishery was done over a wide range of habitats, both in areas that were subject to trawling and set pocket netting and in areas where there was no commercial fishing.

### 4.3.2 Materials and Methods

#### Sampling

School prawns were sampled in the Clarence River (Fig. 4.1) using an electrified beam trawl. This beam trawl is a modified version of that described in McNeill and Bell (1992), and is described in Section 4.2.2. The catches of school prawns using this beam trawl have been demonstrated to be 1.6 times larger than those using the same beam trawl without electricity. Use of this electrified beam trawl allowed us to sample at different times of the day and tidal cycle thereby allowing many more sites to be sampled than would otherwise have been possible. We assume constant catchability of prawns. Without the electric beam trawl it would have been impractical to sample the many locations under the same environmental conditions over the broad range of habitats and over the large distances involved.

All sampling was done during the day between 0830 and 1630 hours. At each site, four replicate tows were done per sample. The trawl was towed at 2 knots over a 250 m course laid out by light string strung between two buoys. No tows were done over the same ground.

Sampling was done quarterly and monthly. The quarterly sampling was designed to provide descriptions of large scale spatial and seasonal patterns in the distribution and abundance. The monthly sampling, provided a more detailed picture of variations in abundance through time at fewer sites.

The quarterly sampling was done at 22 sites on the river. These sites ranged from near the mouth of the river to nearly 100 km upstream (Fig 4.1) Within this range, sites in the main channel of the river, in large embayments and in small tributaries were sampled. The broad habitat types represented in the study were: shallow lake areas (sites 5, 6, 7, 14, 15), tributaries and branches (2, 4, 8, 9, 16, 20), small creeks (10, 11, 17) and the main river channel (1, 3, 12, 13, 18, 19, 21, 22). Two of the sites on the main river channel (13 and 18) were in deep holes (15 m).

Monthly samples were taken at 6 of the 22 sites sampled quarterly (3, 7, 13, 14, 18, 19). At each site four replicates were done in two positions, one in the centre of the channel and the other at the edge (hereafter edge and centre positions respectively). At the sites in the shallow lake habitats (sites 7 and 14), one site was sampled near the shore and the other approximately 200 m towards the centre of the lake. Due to the small size of the channels sampled and difficulties in finding clear areas to trawl, it was not possible to sample two positions at each of the sites in the quarterly program.

On all sampling occasions (monthly and quarterly) the salinity, temperature, and secchi depth of the water were recorded. The carapace length of a random sample of prawns from all four shots pooled were measured to the nearest millimetre using vernier callipers. 100 individuals were measured from each sample, or the whole catch was measured if less than 100 prawns were caught.

**Statistical Analyses**

Differences in mean catches were compared using analysis of variance. The monthly sampling program was analysed using an orthogonal three factor model in which site and month were considered random factors and position as fixed. The quarterly samples were analysed using an orthogonal two factor model in which site and month were random factors. At those sites used for the monthly samples, four of the total of eight replicates were randomly chosen for analysis.

Sites 7 and 17 were excluded in the analysis of the quarterly data because in April 1993 it was not possible to sample because large amounts of algae fouled the beam trawl. For the same reason, site 7 could not be sampled in August 1992 and April 1993, and was therefore not included in the monthly analysis. On 5 other occasions not all replicates could be sampled. In such instances the cell mean was inserted and equivalent degrees of freedom subtracted from the residual degrees of freedom (Winer 1971).

In both analyses of the quarterly and monthly samples, heterogeneity of variance could not be removed, even after a range of transformations. The analyses were therefore done using the best available transformation (quarterly: ln (x + 1), Cochran's C = 0.11, $p < 0.05$ and monthly: ln (x + 1), C = 0.11, $p < 0.01$). In both analyses the highest order interaction term was significant at $p < 0.0001$ and the results were interpreted with caution.

Multiple regression analyses were used to explore the relationship between catches of school prawns and environmental variables. Catches of *M. macleayi* were regressed against nine environmental variables to determine which were of greatest influence (Table 4.4). The independent variable MRCL was included to determine if there was an increased effect of river discharge at main river channel locations. For each of the dependent variables (Table 4.4) a multiple regression model including only a subset of the independent variables was chosen through backward elimination (Hocking 1976, Kleinbaum et al. 1988). Although this selection procedure does not guarantee the choice of the best model, the "all-possible" regression procedure was not feasible given the large number of independent variables. The dominance of a few variables in the maximum model also suggested that this procedure would select the best model. Cases where data for any variable was missing were deleted to ensure all models had the same sample size. All variables were checked for normality using normal probability plots and transformations made where necessary. Collinearity was checked using condition indices and variance proportions (Kleinbaum *et al.* 1988). Residual plots were examined to check for heterogeneity of variances. Outliers were not removed except where stated.

### 4.3.3 Results

#### Monthly Sampling

There were no consistent patterns in the catches of *M. macleayi* among sites, months and positions (see significant 3 way interaction term, Table 4.5). A large percentage of the observed variation was explained by the interaction between Site and Month (Table 4.5). Large site-specific fluctuations in catches at sites 7, 18 and 19 appear to be responsible for the majority of this variation (Fig. 4.5). Mean catches at site 3 never exceeded 3.0 *M. macleayi* per shot and over all months the mean was 0.37 per shot. Due to these low values, data for this site will not be presented further. Mean catches at edge and centre positions were similar at most sites (Fig. 4.6).

Although erratic, the catches at a particular site appear to be related to changes in population structure and, possibly, movement of prawns (Fig. 4.7 a-d). At site 13 there is a reduction in mean length between July and August 1992 associated with a dramatic decline in catch. A similar phenomenon was observed at sites 18 and 19 between the same months (Fig. 4.7) and at site 7 between June and July 1992. At all these sites the smaller size classes remaining appear to have existed prior to this decline. In the following four months relatively small catches were made and there was no consistent trend in the length-frequency distributions at sites 13, 18 and 19 (Fig. 4.7). However, at site 7 there was an increase in modal length during this period (Fig. 4.7). At all sites there was an increase in the proportion of smaller individuals in December 1992 or January 1993 (Fig. 4.7) associated with an increase in catches (Fig. 4.5). This also occurred in April 1993 at site 14. The shift in the length-frequency distribution at site 7 resulted from decreased catches of large individuals ($\geq$ 8.5 mm CL) concomitant with increased catches of small individuals ($<$ 5.5 mm CL). This was not the case at any of the other sites.

Changes in the distribution of *M. macleayi* between positions varied according to site. A greater proportion of large individuals were caught in the centre position at site 13 (Fig. 4.7). At site 7 there was an increase in the proportion of individuals found at the edge position between July and December 1992. This was associated with a shift in the length-frequency distribution towards larger size classes (Fig. 4.7). At the other sites there was no consistent pattern in the distribution of *M. macleayi* between positions (Fig. 4.7).

Fluctuations in catches and changes in length-frequency distributions have been pooled over all sites to summarise the data (Fig. 4.8). Marked reductions in mean size were associated with declines in catches in June and August 1992 and increases in December 1992 and January 1993. Note also the increase in mean size between August and December.

**Quarterly Program**

The catches of *M. macleayi* at sites sampled quarterly were highly variable and never consistent at any one site and no trend with distance upstream was evident for any one quarter (Fig. 4.9). Sites downstream from site 13 generally had low catches (Fig. 4.9), although sites 6 and 7 in Lake Wooloweyah were exceptions. Large catches at site 8 in January 1993 and April 1993 were concurrent with decreases in catches at Wooloweyah sites 6 and 7. Furthermore, the mean carapace length of these prawns was the largest recorded in the quarterly sampling program (Fig. 4.10).

There were no clear trends in the sizes of prawns and distance from the river mouth (Fig. 4.10). In June 1992 there was a decline in mean carapace length further upriver (Fig. 4.10). Sites on tributaries and in large enclosed areas had smaller individuals than those in the main channel. This pattern no longer existed in October 1992, with most sites showing a reduction in mean size. A reduction in mean size in Lake Wooloweyah (sites 6 and 7) did not occur until January 1993. Both these observations were consistent with changes in length-frequency distributions observed in the monthly program.

Multiple Regression Analyses

Significant regression models were generated for the number of *M. macleayi* caught in each of the three size classes and in total (Table 4.7). In all cases there was an inverse relationship between water turbidity (secchi depth) and the number of prawns. There were, however, differences in the significance of other variables among size classes (Table 4.7). Partial regression plots for each model indicate some outliers and possibly non-linear relationships. These plots show the relationship between an independent variable and the dependent variable after the linear effects of the other independent variables have been removed from it. Sites 21 and 22 had smaller total catches of prawns than expected from a linear relationship (Fig. 4.11a). Site 22 also had fewer prawns than expected from the relationship with secchi depth (Fig. 4.11b). When site 22 was removed from the model the $r^2$ value increased to 55%. A similar pattern is observed in partial regression plots involving numbers in size class two. The other size classes have no obvious sites which are outliers although note the Lake Wooloweyah locations in some months for size class one (Fig. 4.12).

### 4.3.4 Discussion

The patterns of distribution and abundance of *M. macleayi* in the Clarence River as sampled in 1992-93 were complex. The quarterly sampling program showed that the prawns were distributed over a large proportion of the estuary, extending from the mouth of the river to almost 100 km upstream and over a range of salinities from oceanic water to essentially fresh water. The distribution was extremely patchy, large numbers were caught in some sites while nearby sites were depauperate. The sites at which large numbers of prawns were caught were different for each sampling period. The results were similar for the monthly sampling program except that particular sites dominated the catch for several months. These patterns suggest that prawns are moving from site to site within the estuary over a period of a couple of months.

The dramatic decline in the number and size of prawns caught in August 1992 suggests that prawns were emigrating from the estuary at this time. This suggestion is supported by the large catch of prawns in the set pocket net fishery at this time (Section 2.1) as the set pocket nets predominantly catch prawns that are migrating down stream. Catches in the pocket net fishery were small at other times of the year and significant only during spring.

The survey shows that *M. macleayi* occur in all sections of the Clarence estuary that were regularly sampled. They were most abundant in the fresh water section of the estuary and were common in the smallest streams that could be sampled with the electric beam trawl. Large numbers of *M. macleayi* were caught at a few sites over each period of the survey, for example, catches in the Coldstream River were consistently large. However there was no consistent pattern in the abundance through time. At other sampling sites large numbers were caught at different times (e.g. Broadwater and Lake Wooloweyah). This suggests that *M. macleayi* occurs in schools which move around the estuary as seasons and conditions change. This pattern of catches throughout the river system, and in areas with very low salinity suggests that the distribution of *M. macleayi* is probably limited only by physical barriers such as flood mitigation gates. Given that an estimated 98% of the river catchment has been lost or altered (Pressey 1987), there is a high probability that there has been a large reduction in the productivity of the river.

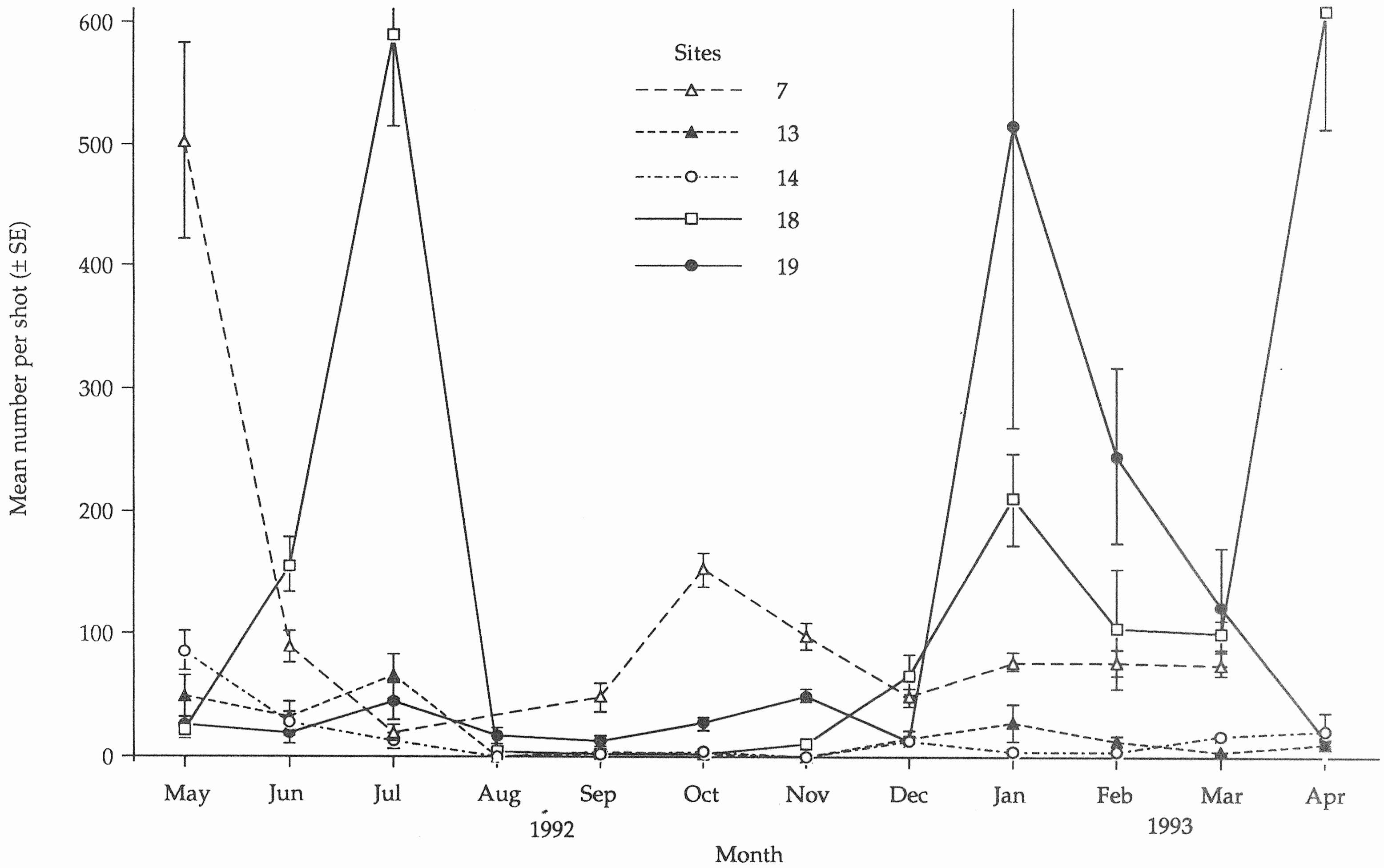


Figure 4.5. Fluctuations in the number of *M. macleayi* caught at each of the sites sampled monthly. Due to consistently low numbers data for site 3 not shown. Note that data was pooled across position.

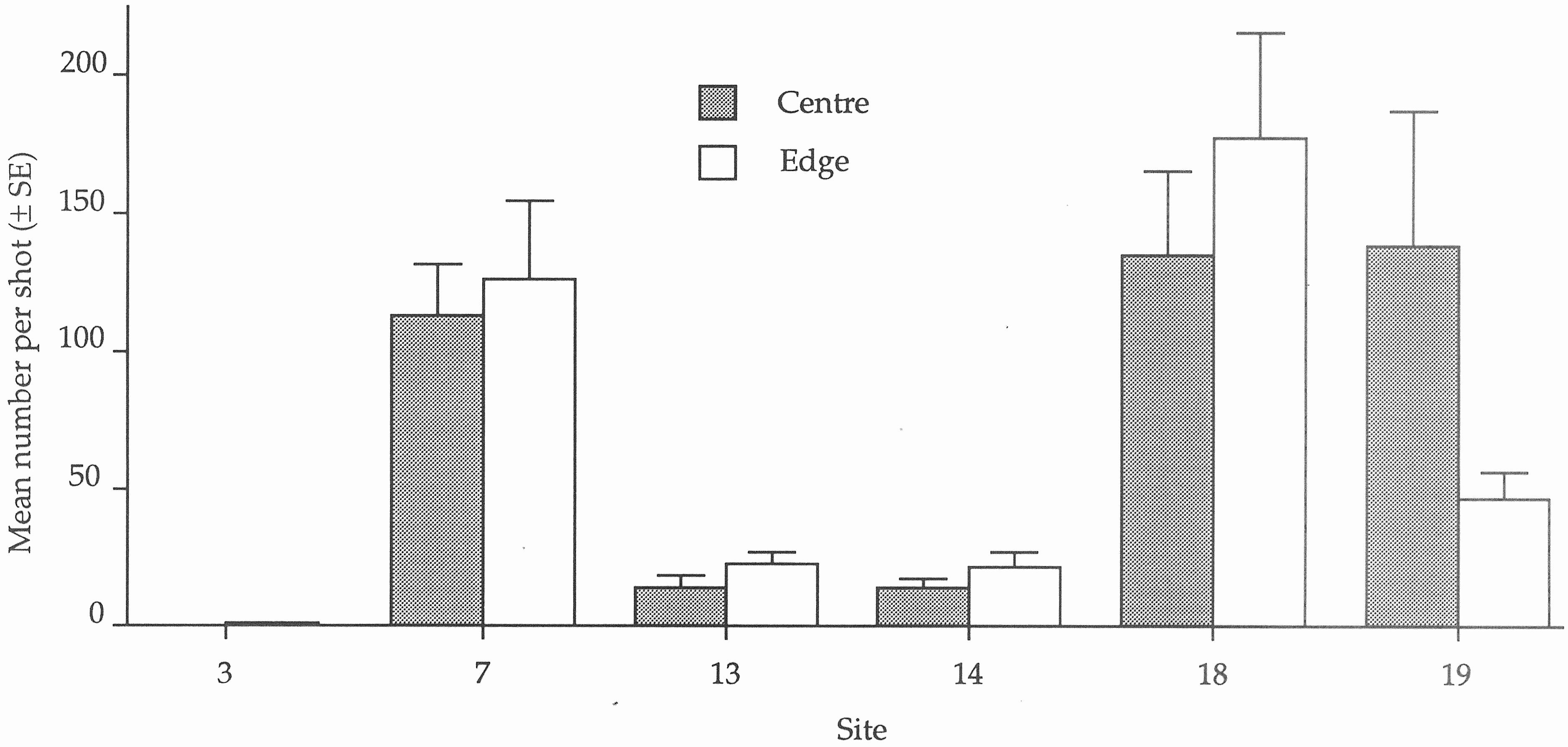


Figure 4.6. Mean catches of school prawns at centre and edge positions at each monthly site, pooled over all months. See Fig. 4.1 for location of sites.

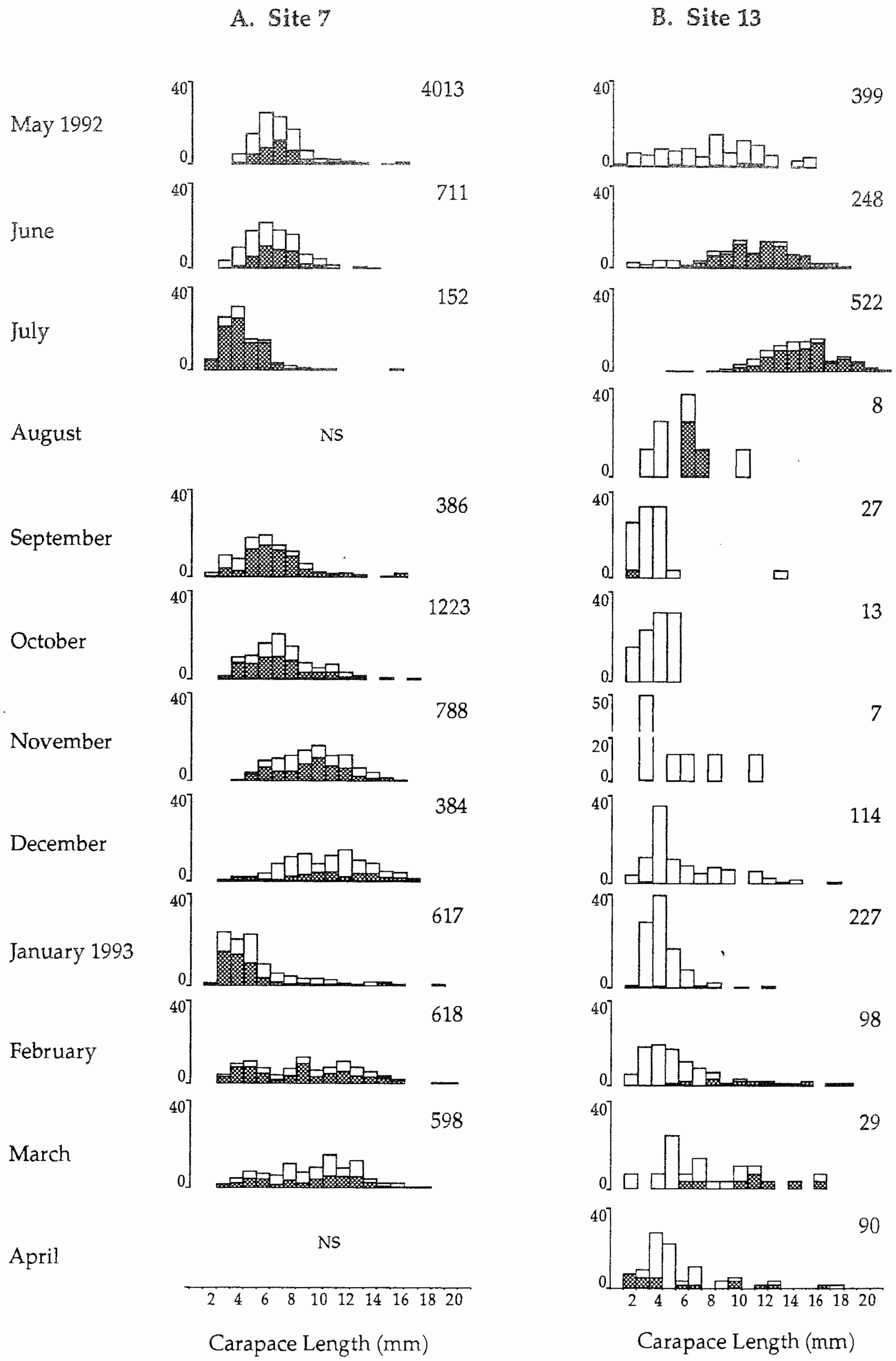


Figure 4.7. Carapace length frequency distributions for *M. macleayi* caught at each of the sites sampled monthly. Shaded parts of bars represent individuals caught in centre position. Values indicate the total number caught in each month. Sample size for length frequency distributions is 200 or the total number caught where fewer animals were caught. Distributions weighted for the number caught in centre and edge positions. Sites 3 and 14 not shown due to low sample sizes in most months. NS = not sampled.

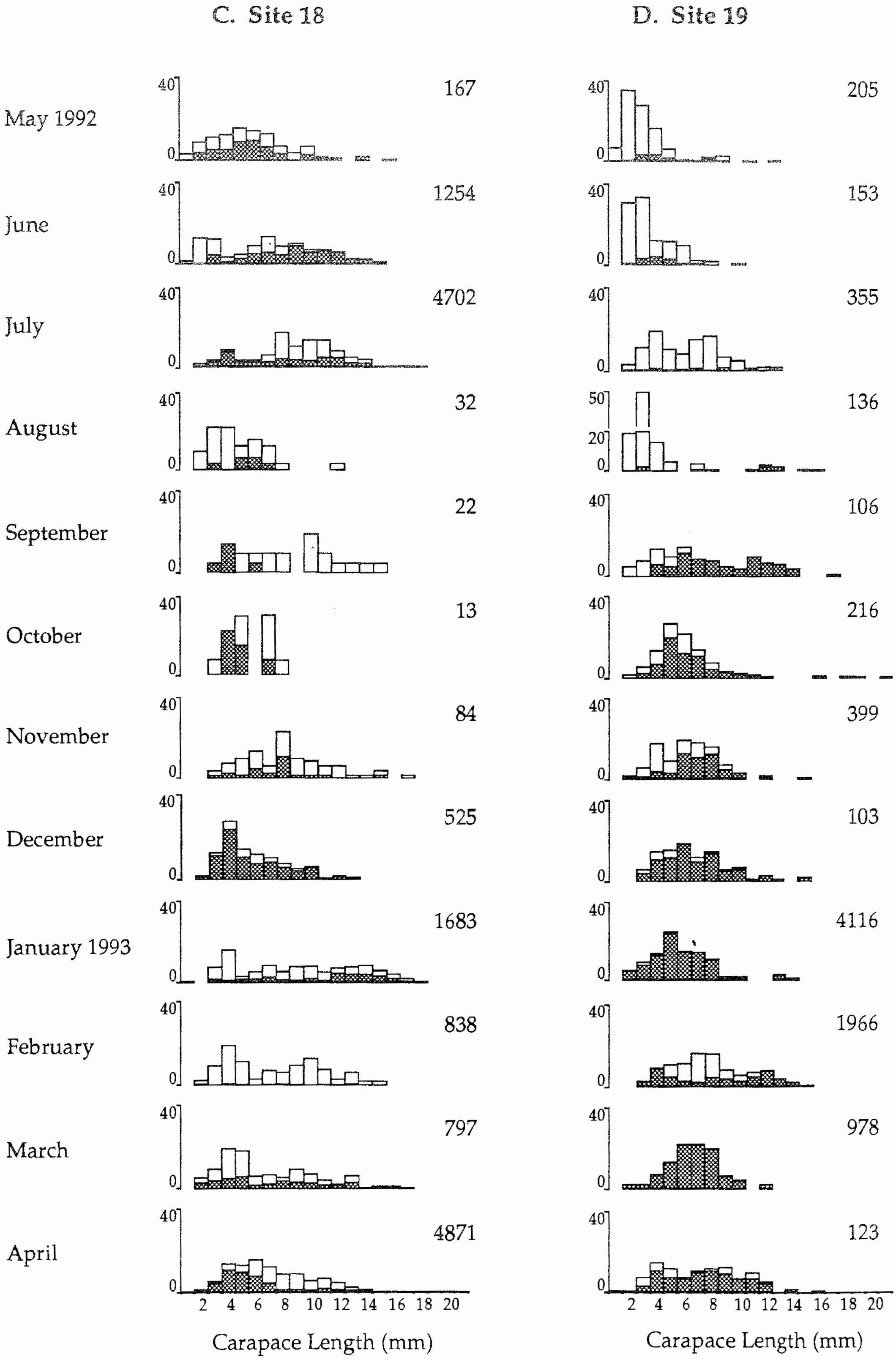


Figure 4.7. Carapace length frequency distributions for *M. macleayi* continued.

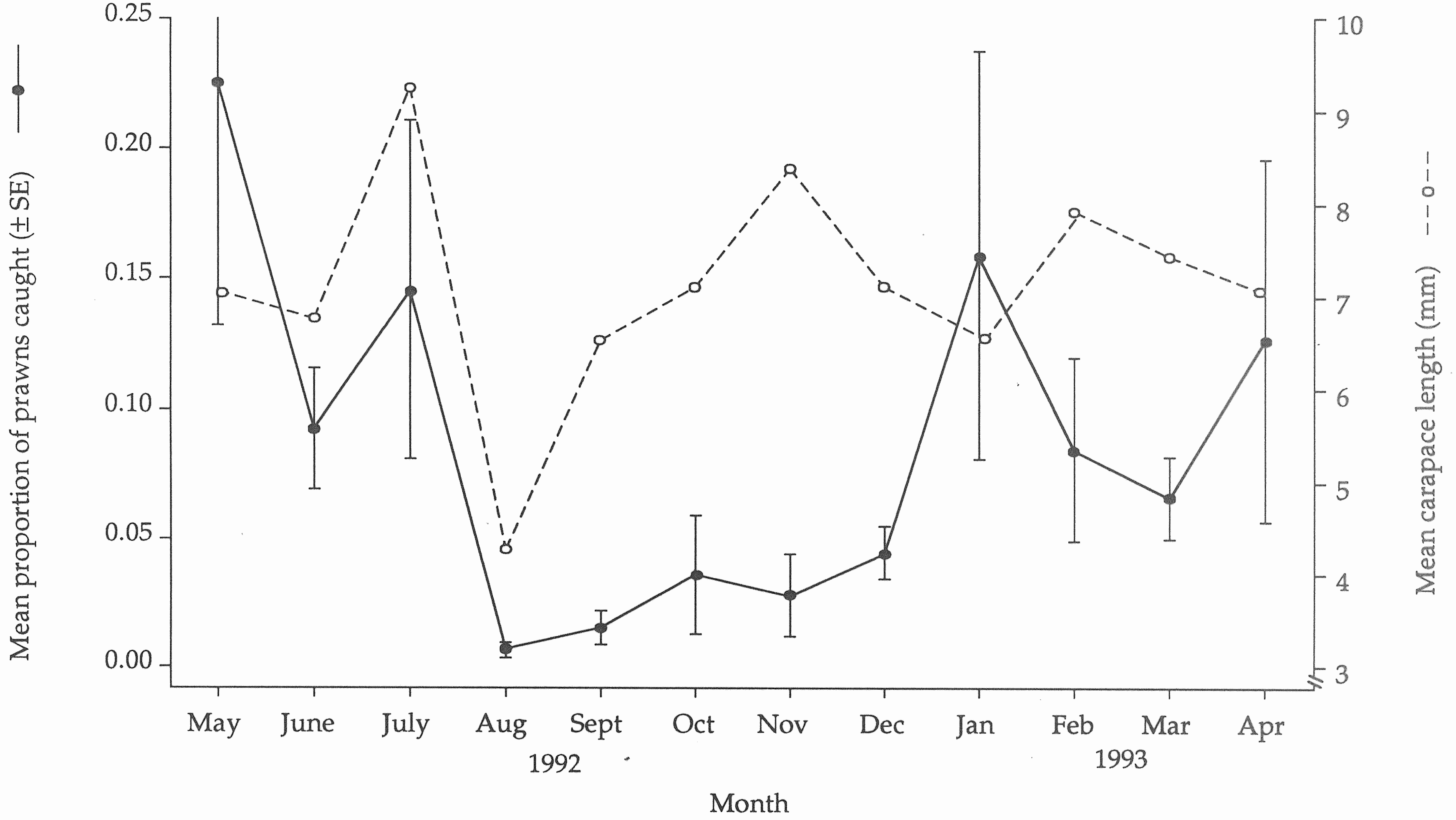


Figure 4.8. Fluctuation in the relative abundance (number caught each month as a proportion of the total number caught at that site) and mean size (weighted for the number caught at each site) of *M.macleayi* caught at the sites sampled monthly. Data for site 3 not included. Standard error on mean size too small to be visible (n > 180 ) in all months.

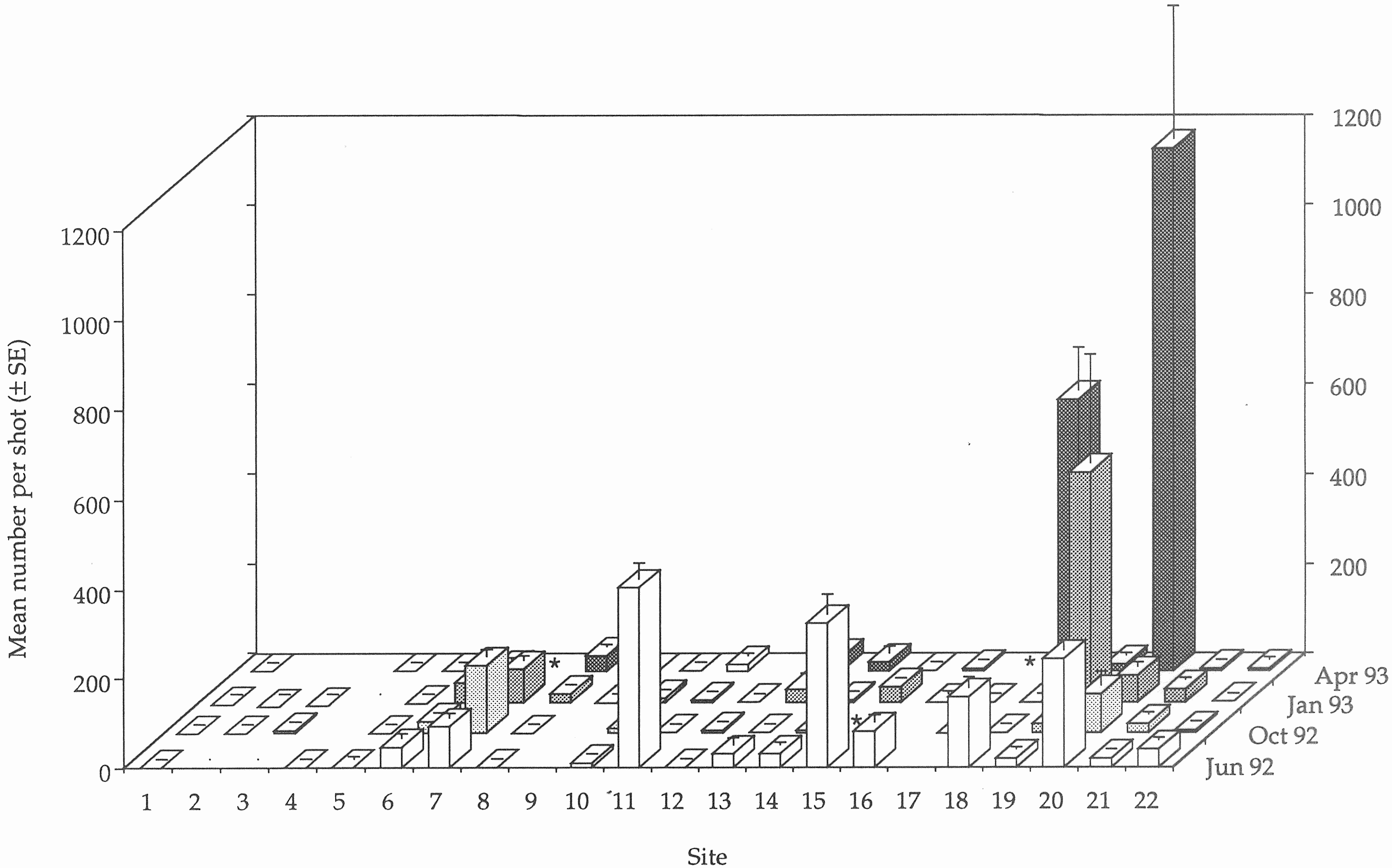


Figure 4.9. Catches of *M. macleayi* at all sites during the quarterly sampling program. No non-zero catches are obscured. * indicates site not sampled. Where sites were sampled at mid channel and edge positions the data were pooled.

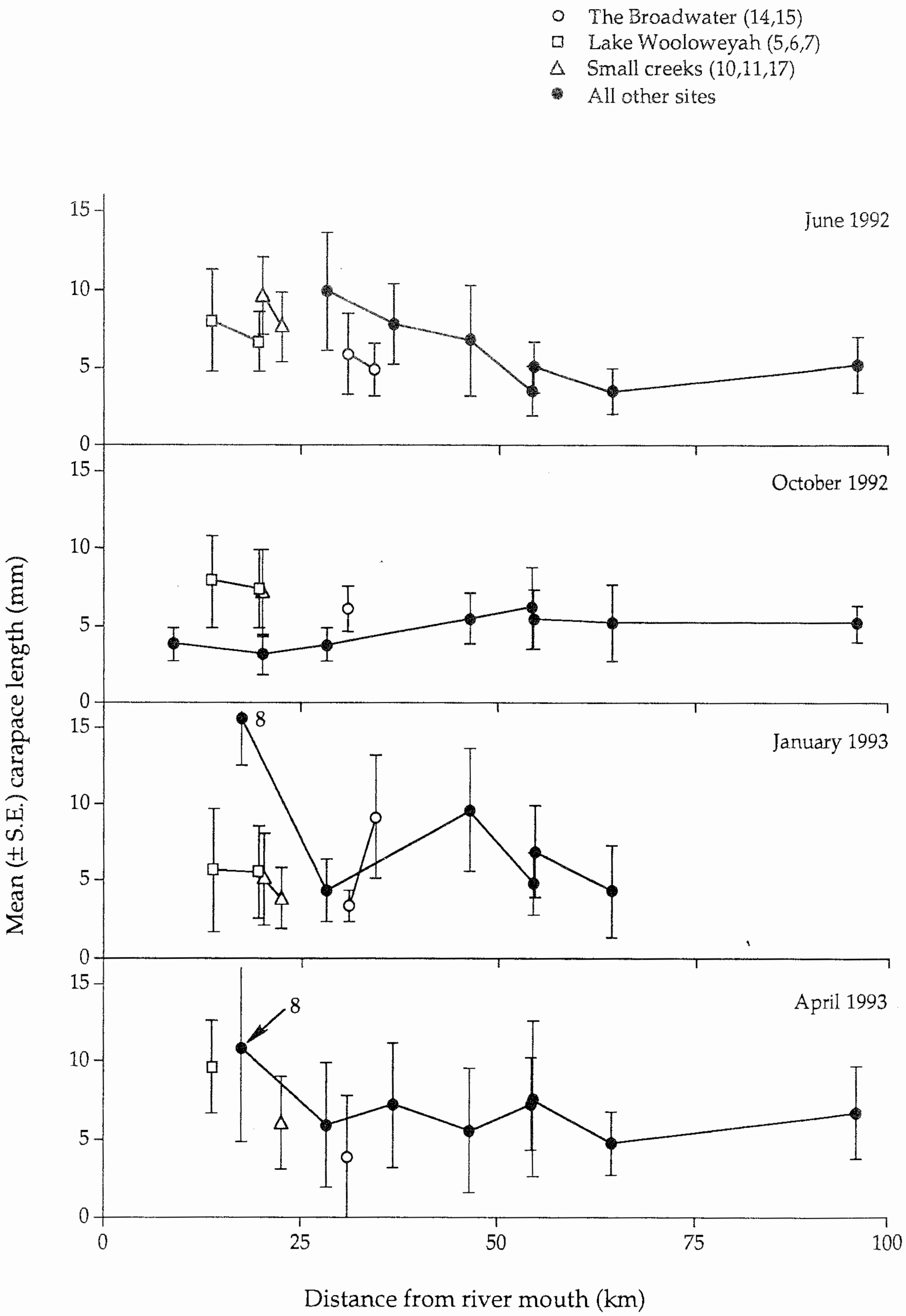


Figure 4.10. Plots of mean carapace length of *M.macleayi* caught against distance from river mouth for each quarterly site where n ≥ 10. Where sites were sampled at mid channel and edge positions the data were pooled. All carapace length-frequency distributions unimodal.

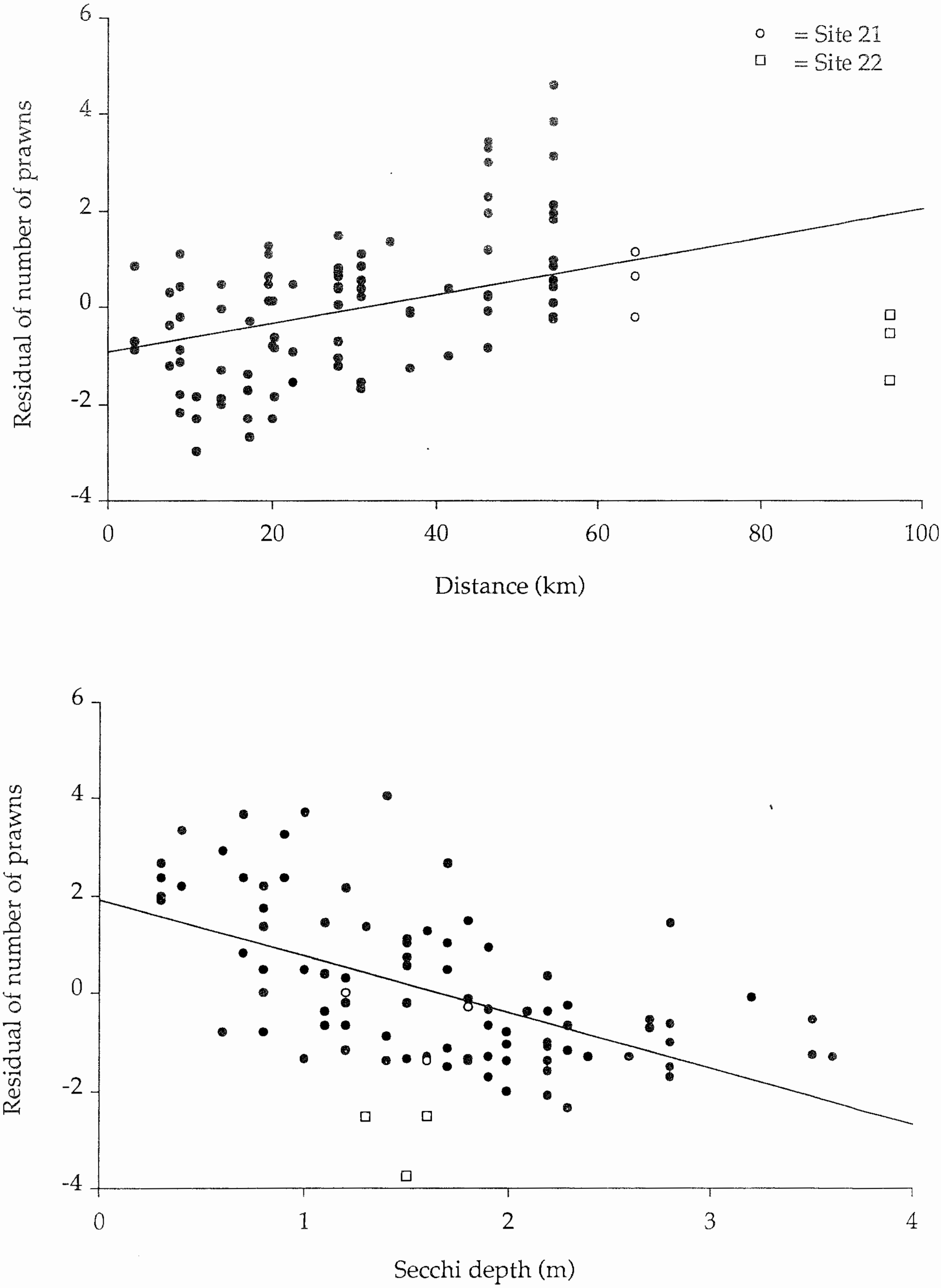


Figure 4.11. Partial regression plots for (A) Distance, and (B) Secchi depth from the final multiple regression model of total numbers of *M. macleayi*.

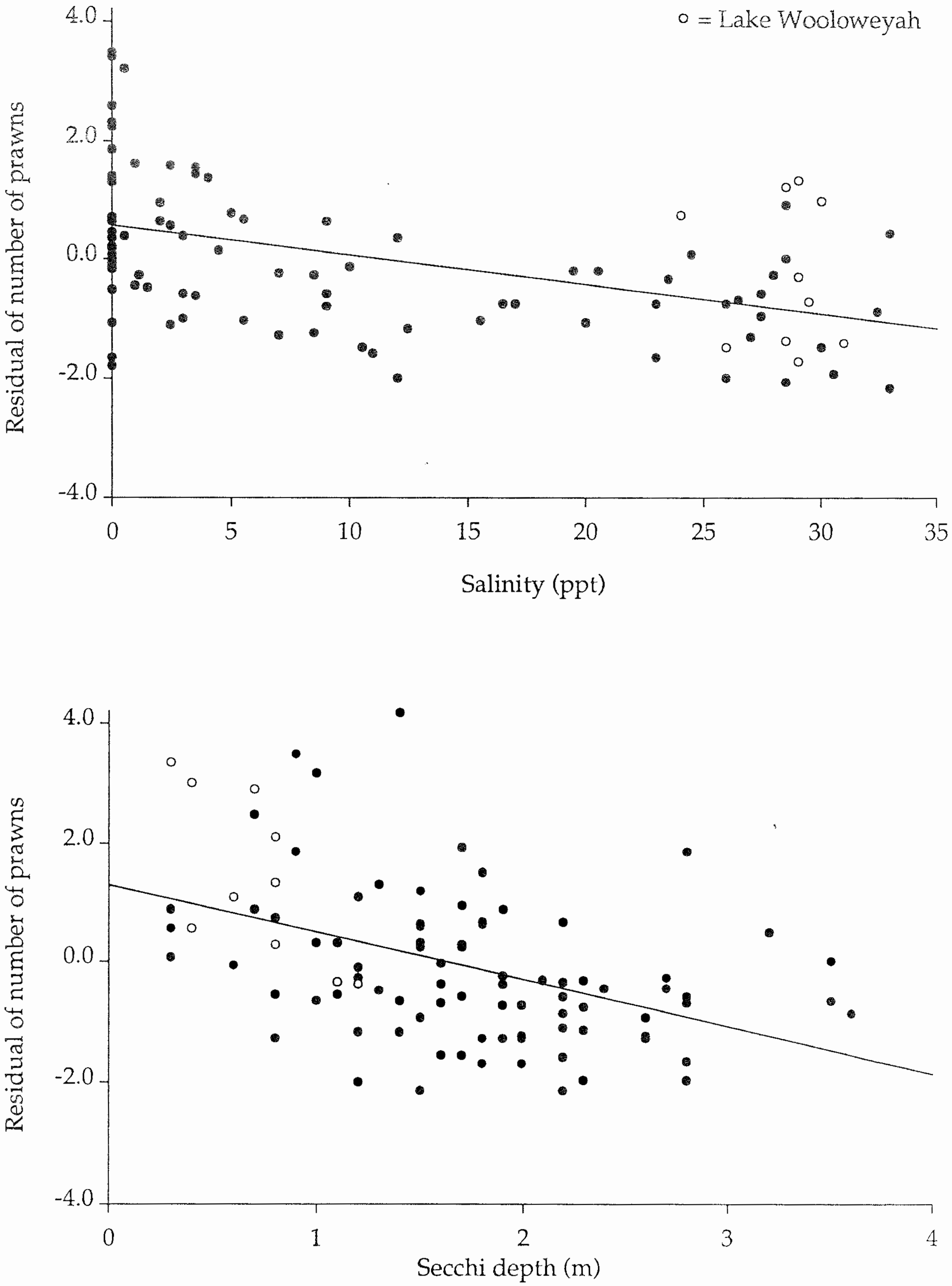


Figure 4.12. Partial regression plots for (A) Salinity and (B) Secchi depth, from the final multiple regression model of numbers of *M. macleayi* in the < 5.5 mm size class (size class 1).

Table 4.4 Variables used in the multiple regression analyses. MRCS : dummy variable for main river channel locations (1, 3, 12, 13, 18, 19, 21, 22). Weekly mean discharges from the Clarence and Orara Rivers (Figure 1) was combined. Data obtained from NSW Department of Water Resources.

| Dependent Variables | Independent variables |
|---|---|
| Total number of prawns caught | Temperature (°C) |
| Number of prawns caught in the < 5.5 mm size class (SC1) | Secchi depth (m) |
| Number of prawns caught in the 5.5 to 8.49 mm size class (SC2) | Salinity (ppt) |
| Number of prawns caught in the >8.5 mm size class (SC3) | Salinty x Temperature |
| | Distance from river mouth (km) |
| | Discharge (megalitres) |
| | Discharge lagged 1 weeks (megalitres) |
| | Discharge lagged 2 weeks (megalitres) |
| | MRCSx Discharge |

Table 4.5. Analysis of variance table for number of *M. macleayi* per shot in the monthly data set.

| Source of variation | df | MS | F | p | % Var |
|---|---|---|---|---|---|
| Position (P) | 1 | 21.37 | - | - | 0 |
| Site (S) | 4 | 180.58 | 18.67 | ** | 10 |
| S x P | 4 | 6.16 | 1.57 | NS | 1 |
| Month (M) | 11 | 23.66 | 2.44 | * | 1 |
| M x P | 11 | 2.73 | 0.69 | NS | 0 |
| S x M | 44 | 9.67 | 28.54 | ** | 40 |
| S x M x P | 44 | 3.93 | 11.60 | ** | 23 |
| Residual | 351 | 0.34 | | | 25 |

NS = not significant, * $0.01 < p < 0.05$, ** $p < 0.0001$, data ln (x+1) transformed prior to analysis

Table 4.6. Analysis of variance table for number of *M. macleayi* per shot in the quarterly data set.

| Source of variation | df | MS | *F* | *p* | % Var |
|---|---|---|---|---|---|
| Month (M) | 3 | 17.44 | 3.07 | * | 1 |
| Site (S) | 19 | 36.46 | 6.43 | ** | 16 |
| S x M | 57 | 5.67 | 16.76 | ** | 62 |
| Residual | 234 | 0.34 | | | 21 |

* $0.01 < p < 0.05$, ** $p < 0.0001$, data ln (x+1) transformed prior to analysis

Table 4.7. Final multiple regression models for each dependent variable. $R_p^2$ = squared partial correlation coefficient; $R^2$ = percentage of variation explained by model. All regressions significant, $p < 0.001$.

| Dependent Variables | Independent Variables | Sign of coefficient | $R_p^2$ | $R^2$ | $F_{df}$ |
|---|---|---|---|---|---|
| Total | SEC | - | 31 | 44 | $36.0_{2,93}$ |
| | DIST | + | 18 | | |
| SC 1 | SEC | - | 20 | 35 | $24.5_{2,93}$ |
| | SAL | - | 20 | | |
| SC 2 | SEC | - | 20 | 32 | $21.5_{2,93}$ |
| | DIST | + | 12 | | |
| SC 3 | SEC | - | 29 | 29 | $39.1_{1,94}$ |

# CHAPTER FIVE: COMPARISON OF TRAWLING AND SET POCKET NETTING IN THE CLARENCE RIVER

## 5.1 Introduction

As noted in Chapter One, school prawns are caught in the Clarence River by two methods, trawling and set pocket netting. These methods co-occur in the river between December and May each year. The by-catch of the trawl fishery in the river was quantified between December 1990 and May 1992 as part of the recently completed FRDC funded prawn trawl by-catch project (Kennelly 1993).

The sampling on the trawl by-catch project overlapped with the present study only during the summer of 1991-92. Direct comparison of by-catch between these methods of catching prawns is therefore possible only for this time. Catches before and after this period, however, allow inferences to be made about the representativeness of those months. We are grateful to Steve Kennelly and Geoff Liggins for providing their unpublished data on the trawl fishery.

## 5.2 Materials and Methods

The catch of prawns and by-catch in the set pocket net fishery were estimated as described in Section 3.2. The prawn catch and by-catch of the trawl fishery was quantified by observers on 3-4 boat-days per calender month. In the trawl by-catch study, catches were sampled both in the River and in Lake Wooloweyah. For the present comparison, only data from the River were used. Estimates of total effort in the trawl fishery were obtained from the NSW Fisheries form 19 database. Further details of the methods used to quantify catch rates in the trawl fishery may be found in Kennelly (1993) but were similar to those used in the present study.

An important difference between the two studies was that data from the set pocket net fishery were collected per lunar month and those for the trawl fishery on a calender month basis. We have not attempted to recalculate catch rates and estimates of total catch for comparison because we believe biases introduced in doing so would invalidate the re-calculated estimates. For example, the peaks in catch rate and effort in the set pocket net fishery are in response to lunar phase and the upcoming draw. Because lunar and calender months are out of phase, changing from one to another may artificially inflate or reduce estimates of total catch. Similarly the timing of the days sampled in the trawl by-catch study (n = 3-4 days/month) may be disproportionately allocated to lunar months. For November/December 1991 and December/January 1991-92 only, the pocket net data have been converted to calender month to allow a direct comparison, however, as noted above this should be interpreted with caution.

Pocket netting was done at night and trawling was restricted to daylight hours. For the purposes of this comparison a 'day' should be read as a 'day or night'.

## 5.3 Results

### Effort

There was an inverse relationship between effort in the trawl and set pocket net fisheries in December-February 1991-92 (Fig. 5.1). Effort in the trawl fishery peaked in January-March each year whereas the set pocket nets were most fished in August-September and declined thereafter (Fig. 5.1). Trawling on the river began 10 days prior to the end of the November lunar month. There was little effort in the pocket net fishery during the latter half of this lunar month. Trawling in Lake Wooloweyah was allowed from the beginning of October which may have diverted some of the effort from the set pocket net fishery.

Catch Rates for the period 1989 to 1993

Trawling generally caught more prawns (by weight) per boat-day than set pocket netting (Fig. 5.2). Trawl catch rates were characterised by a single peak, with smaller catch rates thereafter. This peak occurred in December in 1989-90 and February in 1990-91 and 1991-92. There was no consistent trend among months for set pocket net catch rates. The smaller standard errors associated with set pocket net estimates reflect both smaller variances and larger sample sizes.

There were large differences in the rate of by-catch caught per day among months within a method and between methods over the period of study, both in weight (Fig. 5.3) and numbers (Fig. 5.4). Rates of by-catch for both methods were greatest in summer 1991-92 but otherwise there were few consistent patterns among years in catches per fisher per day (Figs. 5.2, 5.3). Although the largest mean by-catch per day was recorded by pocket netting, in January/February 1992, by-catch from pocket netting was otherwise less than that for trawling.

Mean catch rate, in numbers, of commercial by-catch species was slightly lower for set pocket netting (Fig. 5.5). Catch rates of both methods were greatest, and most variable, in the 1991-92 season. Three species, bream, tailor and tarwhine were caught in sufficient numbers by both methods to allow a meaningful comparison to be made (Figs. 5.6-5.8). Catch rates of bream by trawling were larger than those for pocket netting for all but two months (Fig. 5.6, see below for more detailed comparison). Catches of all three species, particularly bream and tarwhine, were greatest in the summer of 1991-92 (Figs 5.6-5.8). The large mean catches reported in summer 1991-92 were accompanied by large standard errors (Fig. 5.6-5.8).

In both methods of fishing, bream was by far the most common species caught (26.5 ± 14.3 and 111.5 ± 18.7 individuals per day for set pocket net and trawling). Tailor were the second most caught species in both methods. Of the other species commonly caught by set pocket netting, tarwhine and garfish were the most common. Garfish are surface-dwelling fish and therefore unlikely to be caught by demersal trawling. The other species caught in large numbers by trawling (e.g. large toothed flounder and dusky flathead) were demersal. These two species generally spend long periods of time lying on the substratum and are therefore more prone to capture by trawling than by set pocket netting.

There were differences in the species of commercial fish caught between trawling and set pocket netting (Table 5.1). Some species commonly caught by trawling were rare in set pocket net catches, for example, sand whiting (34.5 ± 7.3 vs 0.24 ± 0.10 individuals per day in trawl and set pocket nets respectively). Others were common in set pocket net but rare in trawl catches, e.g. river garfish (6.04 ± 2.09 and 0.04 ± 0.02 individuals respectively) and snub-nosed garfish (4.25 ± 1.02 and 0.21 ± 0.16 individuals in set pocket net and trawl catches respectively). All commercial species caught by set pocket netting were caught by trawling, but not the other way around.

Table 5.1. Rank order of catch of five most caught commercial species of finfish in the trawl and set pocket net fishery. Ranks based on summed catches for the period of each study (set pocket net, August 1991 - May 1993 and trawling, December 1990 - May 1992).

| Set Pocket Netting | Trawling |
|---|---|
| Bream | Bream |
| Tailor | Tailor |
| Tarwhine | Sand Whiting |
| River Garfish | Large-toothed Flounder |
| Snub-nosed Garfish | Dusky Flathead |

### Catch rates for November-December 1991

The catch rate of prawns in December 1991 by both methods was less than half that for January 92 (Fig. 5.9). Catch rates of prawns by trawling and set pocket netting were similar in both months (Fig. 5.9). Pocket netting caught more by-catch per day than trawling in January but not in December, as expressed both in number and weight (Fig. 5.9). Commercial species made up a larger proportion of the total catch in the trawl samples than those from pocket netting in both months, particularly in January (Fig. 5.9).

### Sizes of Fish Caught

Length-frequency data are presented only for Bream because sample sizes were large enough only for this species (Fig. 5.10). Length measurements were obtained from 1989 to 1993 from the trawl and set pocket net fisheries, however, data for the two fisheries overlaps for one year only, the 1991-92 year. Measurements of trawl-caught fish were obtained from 1989 to 1992 and these show several size classes. Two size classes of trawl caught fish were evident in all three years of trawl data, these were of fish of 8-9 cm and 13-14 cm. Bream from the set pocket net fishery were of a similar size range to those from the trawl fishery but had less distinct size classes. The trawl fishery also caught a greater percentage of under-size fish than the set pocket net fishery, (98% of fish caught were smaller than the minimum legal size compared to 88% from the set pocket net fishery). Note that, in order to obtain adequate sample sizes, data were pooled over several months. The "cohorts" apparent in these graphs may therefore, be an artefact.

Estimates of total catch and by-catch

There was a close correlation between effort and catch rates in the set pocket net fishery (Fig. 5.1). Most trawling occurred after December and peaked in the middle of the season. Effort in this fishery varied less than that in the set pocket net fishery and estimates of total catch and by-catch reflect this pattern. Estimates of the total catch of prawns were much larger in the trawl fishery than in the pocket net fishery during summer-autumn of 1992 (Fig. 5.11). Evidence from previous years also indicates that total catches were larger in the trawl fishery, however, the standard errors around these means were large.

The extrapolated estimates of the weight and number of individuals of by-catch caught by trawling were larger than that for the set pocket net fleet (Figs. 5.12, 5.13). In months during which there was overlap, the estimate of total by-catch in the trawl fishery was 2-3 times as large as the set pocket net fishery. The larger total catch of prawns and by-catch from trawling was due mainly to the much greater effort in this fishery than in the set pocket net fishery (Fig. 5.1). Only 7.0% of by-catch from the set pocket net fishery (by number) was of commercial value in contrast to 12.8% of the trawl by-catch. In the 1991-92 season the numbers of fish of commercial species in the trawl by-catch declined steadily from December-May (Fig. 5.14).

Bream dominated the commercial by-catch from both methods. Patterns of total estimated catches of bream were therefore very similar to total commercial by-catch (Figs. 5.14, 5.15). Estimated by-catch of tailor and tarwhine from the set pocket net fishery was of similar magnitude to trawling (Figs. 5.16, 5.17). Trawl catches of tailor were smallest in the middle of each season (Fig. 5.16). In the 1991-92 season, total catch of tailor from the set pocket net fishery declined from September -January but in 1992-93 it peaked around November then declined. The catch rate, however, peaked in the middle of each season

(Fig. 5.7), so this trend was mostly due to changes in effort. Catches of tarwhine were sporadic in both the set pocket net and trawl fisheries. Larger than usual catches were recorded in February 1990, January 1991, and December-January 1992 in the trawl fishery and in November-January 1992 in the set pocket net fishery.

**5.4 Discussion**

The rate at which by-catch was caught in the set pocket net fishery was greater than that of the trawl fishery during only 1 month between December 1989 and May 1993 - in December 1991. This was also the only month in which both fisheries were sampled concurrently. The large by-catch in the pocket net fishery in this month coincided with a large river discharge (see Chapter 3 for more details). For all other months, estimated by-catch was small compared to that from the trawl fishery. The greater effort in the trawl fishery means that differences in catch rate between the two methods are exaggerated in estimates of total by-catch, making total catches of prawns and by-catch much larger in the trawl fishery.

Although trawling caught more bream than the pocket netting during the present study, several factors limit generalisations both about the relative magnitudes of the by-catch and its effect on populations of the fishes caught. Firstly, it is apparent from this study and from anecdotal evidence from fishers that by-catch in both fisheries is related to river discharge. If this is the case then there is likely to be large differences among years with different rainfall patterns. We do not have sufficient information at the appropriate temporal scale to determine whether trawling or pocket netting is more susceptible to increases in by-catch during these periods. Further, patterns are likely to differ in different parts of the river where salinity and flow rate differ.

It is clear from this study that the response of species such as bream to rapid changes in salinity increases their catch rates enormously, but that the effect is relatively short-lived. The rates at which fishes are caught by trawling appear to be more consistent than in the pocket net fishery. Methods by which this trawl by-catch may be reduced is currently the subject of an FRDC funded project (S.J. Kennelly, research in progress).

Trawling and pocket netting caught similar species and bream was the most caught species of commercial importance in both methods. Similarly, lesser weights and numbers of tailor and tarwhine were caught in both fisheries. There were differences in the species composition of catches of other commercial species. Trawling caught more demersal species such as flathead and flounder and pocket netting caught more surface dwelling fish such as garfish. The sizes of bream caught by both methods was similar.

In discussing the relative impacts of trawling and pocket netting it is important to note that the method by which these fish are caught is likely to have an impact on subsequent survivorship. Because pocket netting is a more passive form of fishing, fish are less likely to be damaged during capture than when trawled. No attempt was made to estimate the mortality of discarded by-catch in this study. The mortality of discards in trawl fisheries for prawns has been shown to be high, but species-specific (e.g. Wassenberg and Hill 1989, Berghahn 1990, Hill and Wassenberg, 1990).

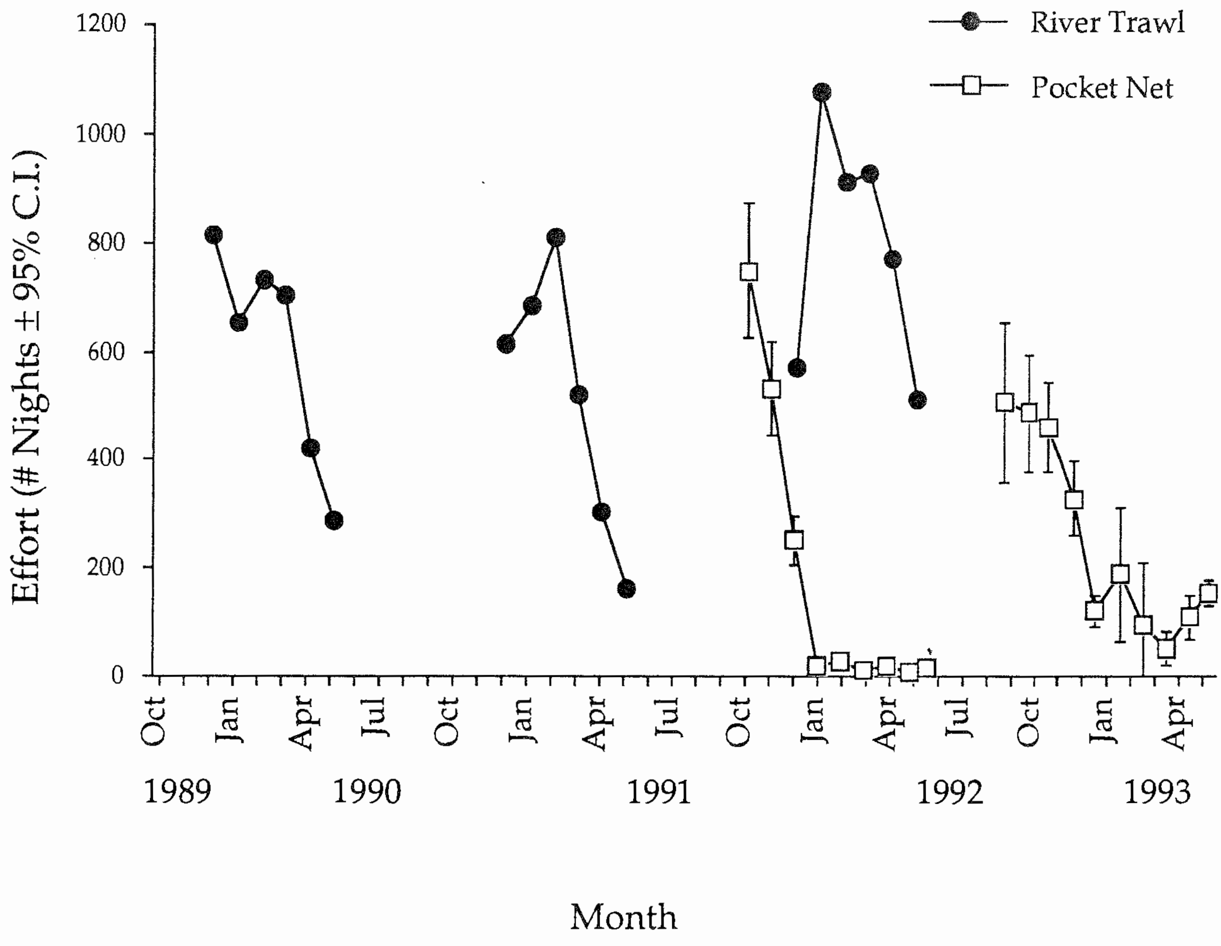


Figure 5.1. Total effort (nights/month) in the Clarence River trawl and set pocket net fisheries.

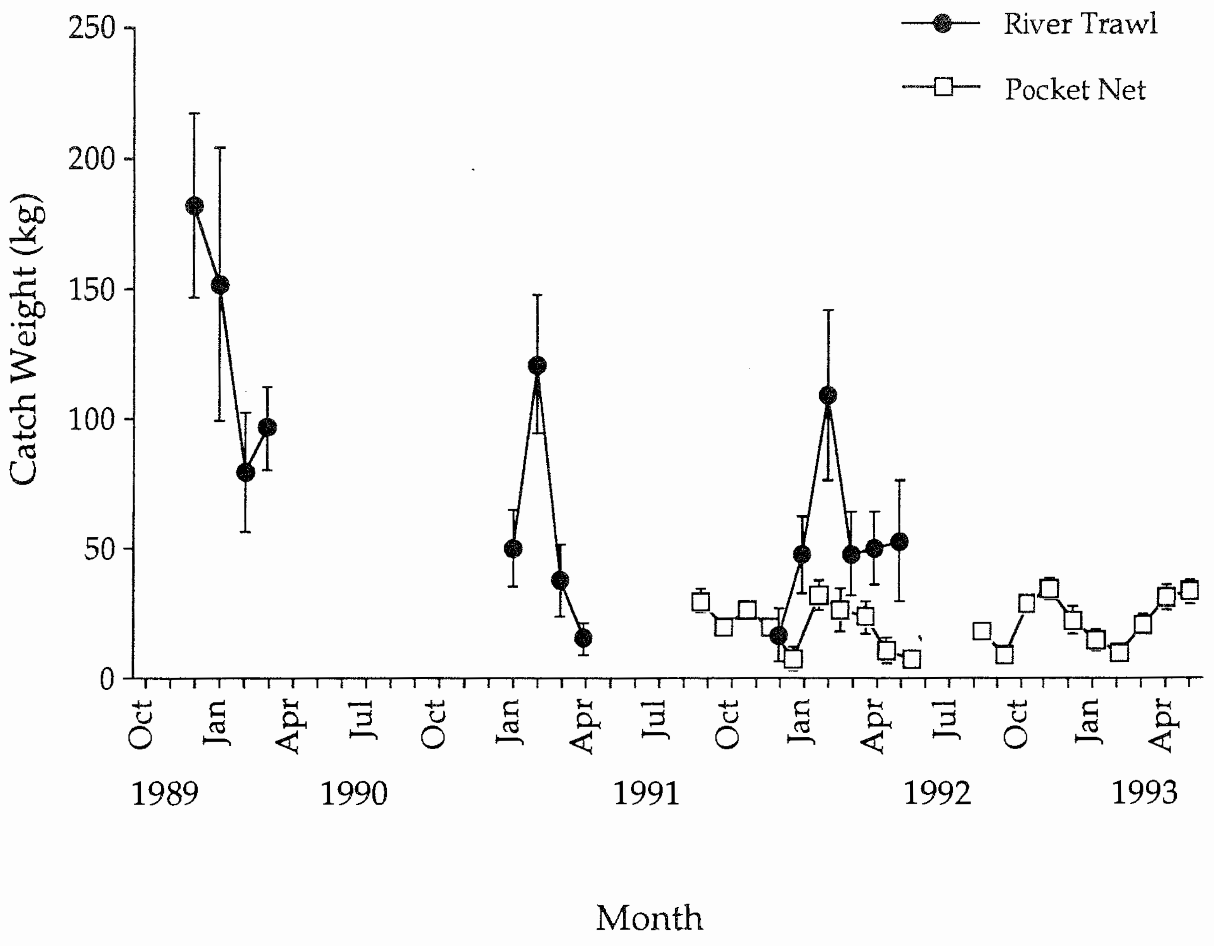


Figure 5.2. Catch rate of prawns in the Clarence River trawl and set pocket net fisheries. Data presented as mean (± S.E.). For trawling n = 3-4, set pocket netting n = 15 - 20.

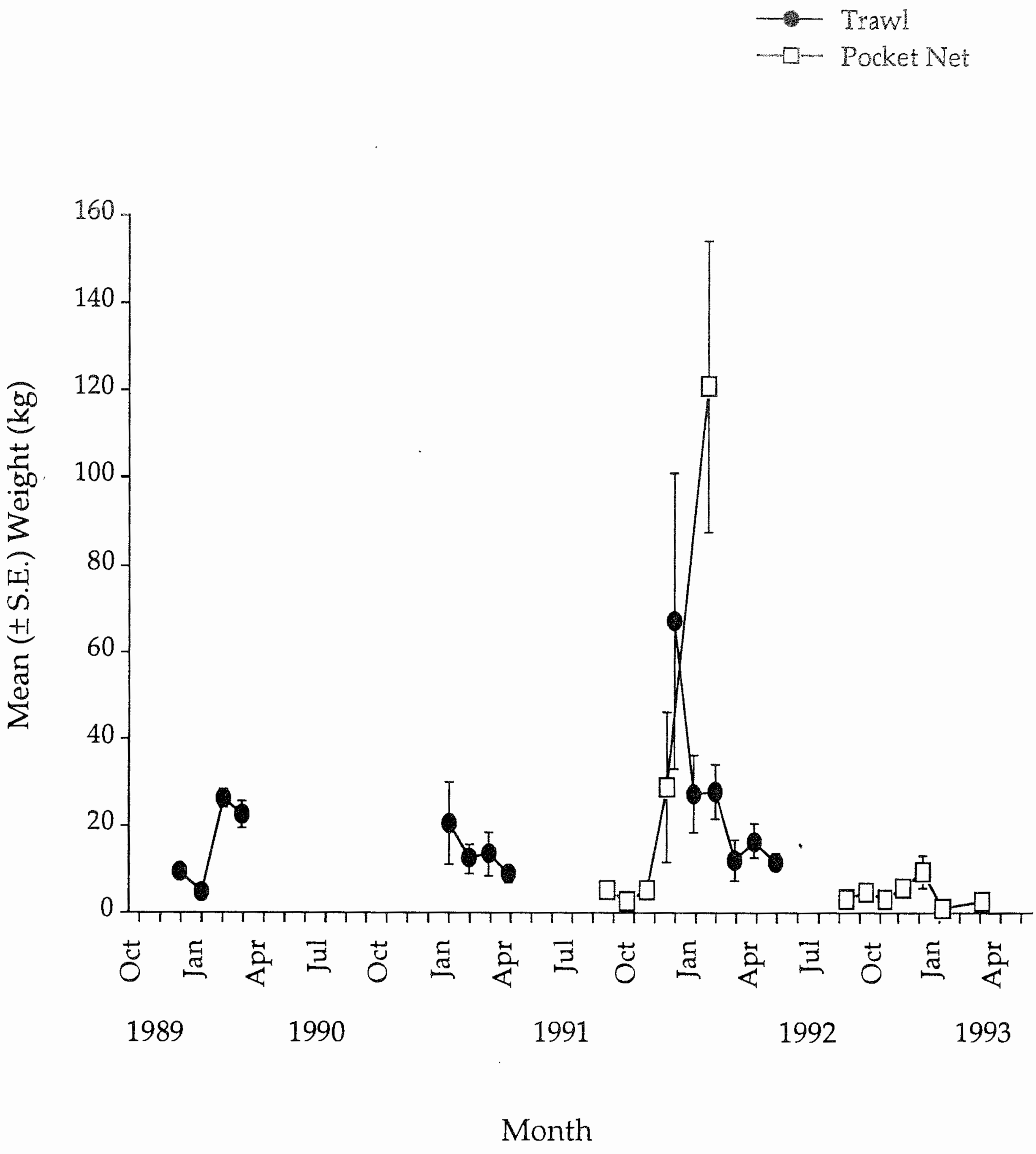


Figure 5.3. Catch rate (mean ± S.E. / day) of total by-catch, in the Clarence River trawl and set pocket net fisheries.

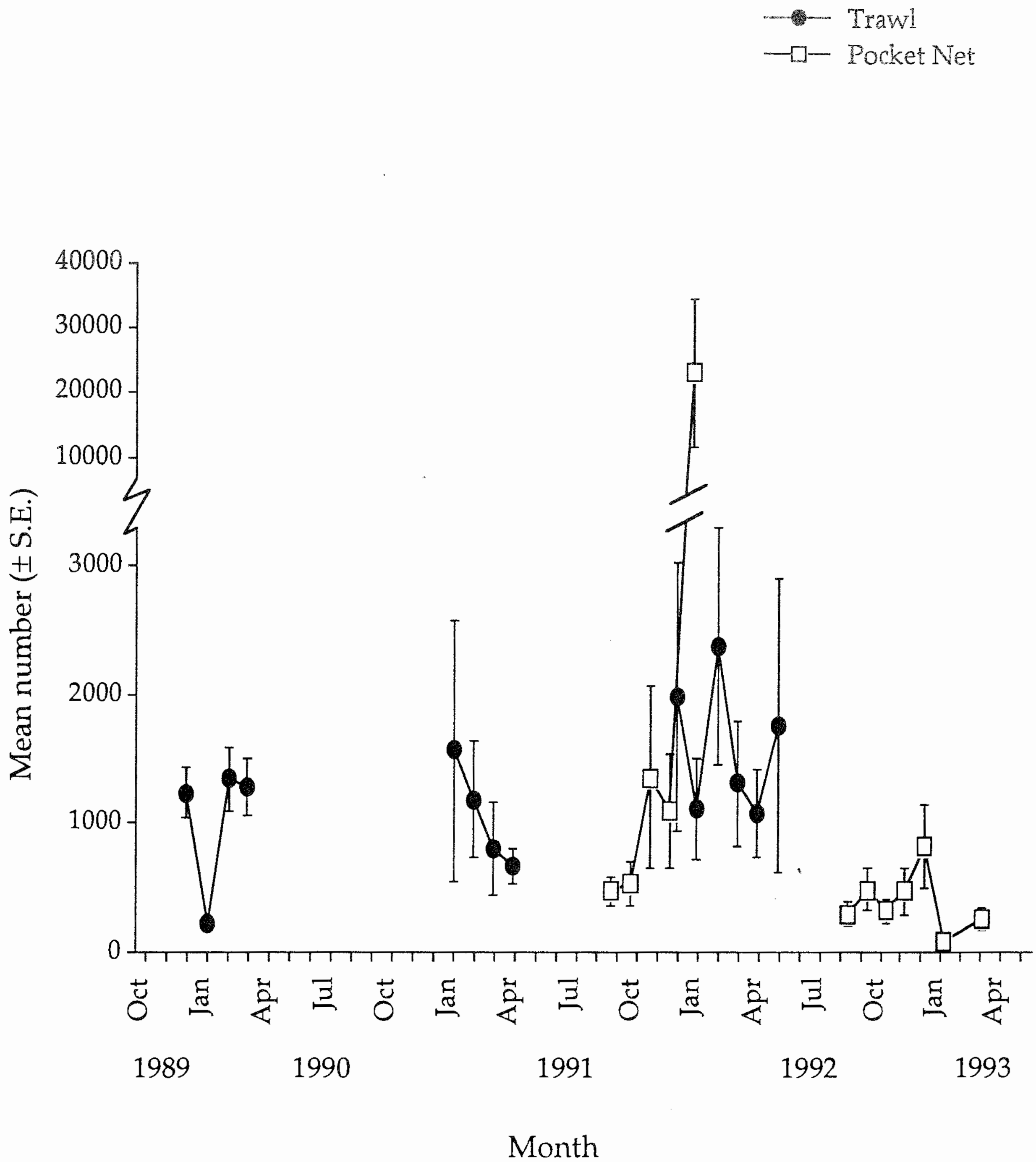


Figure 5.4. Catch rate (± S.E.) of total by-catch in the Clarence River trawl and set pocket net fisheries.

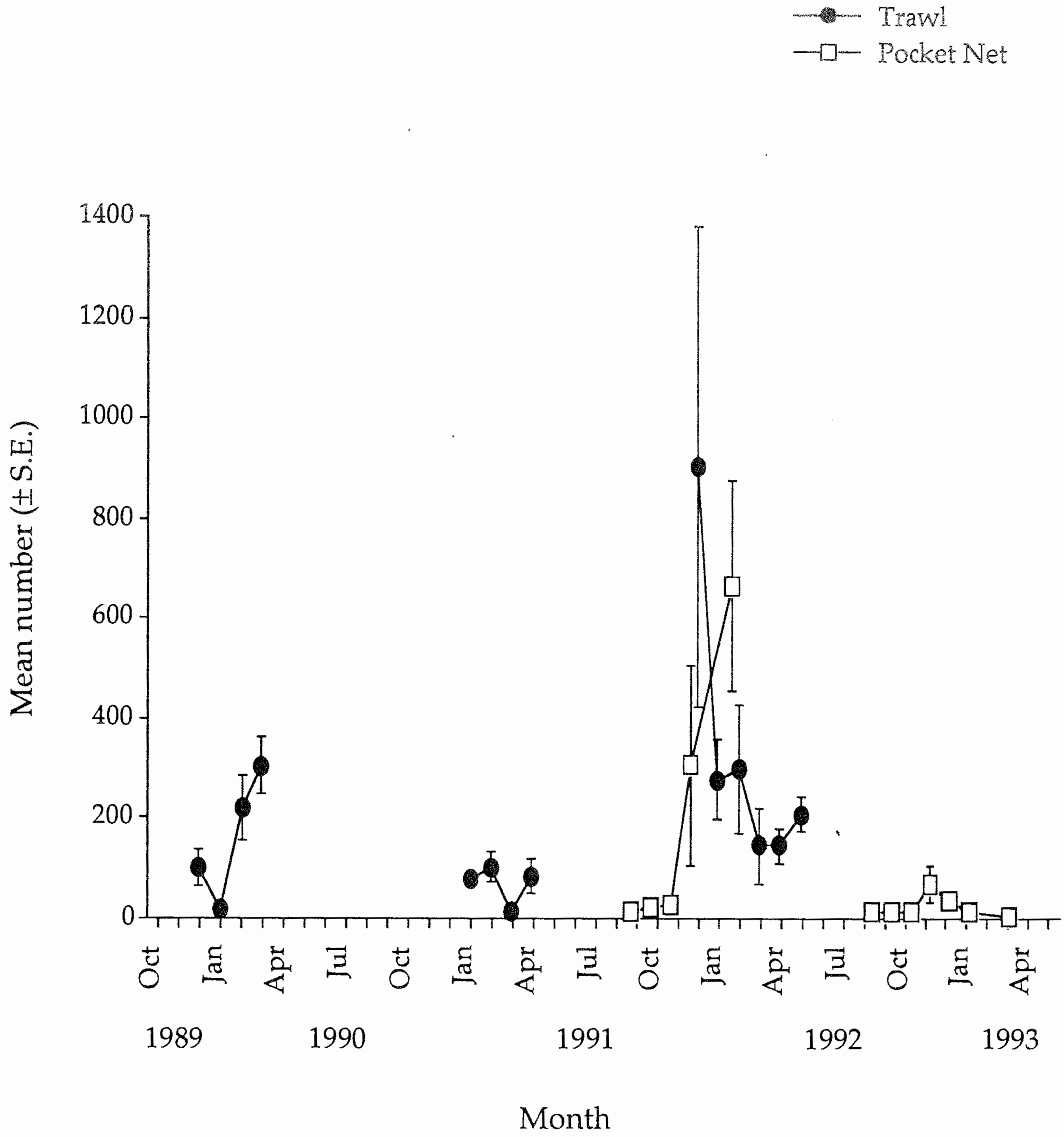


Figure 5.5. Mean catch rate of numbers of individuals of commercial species in the Clarence River trawl and set pocket net fisheries.

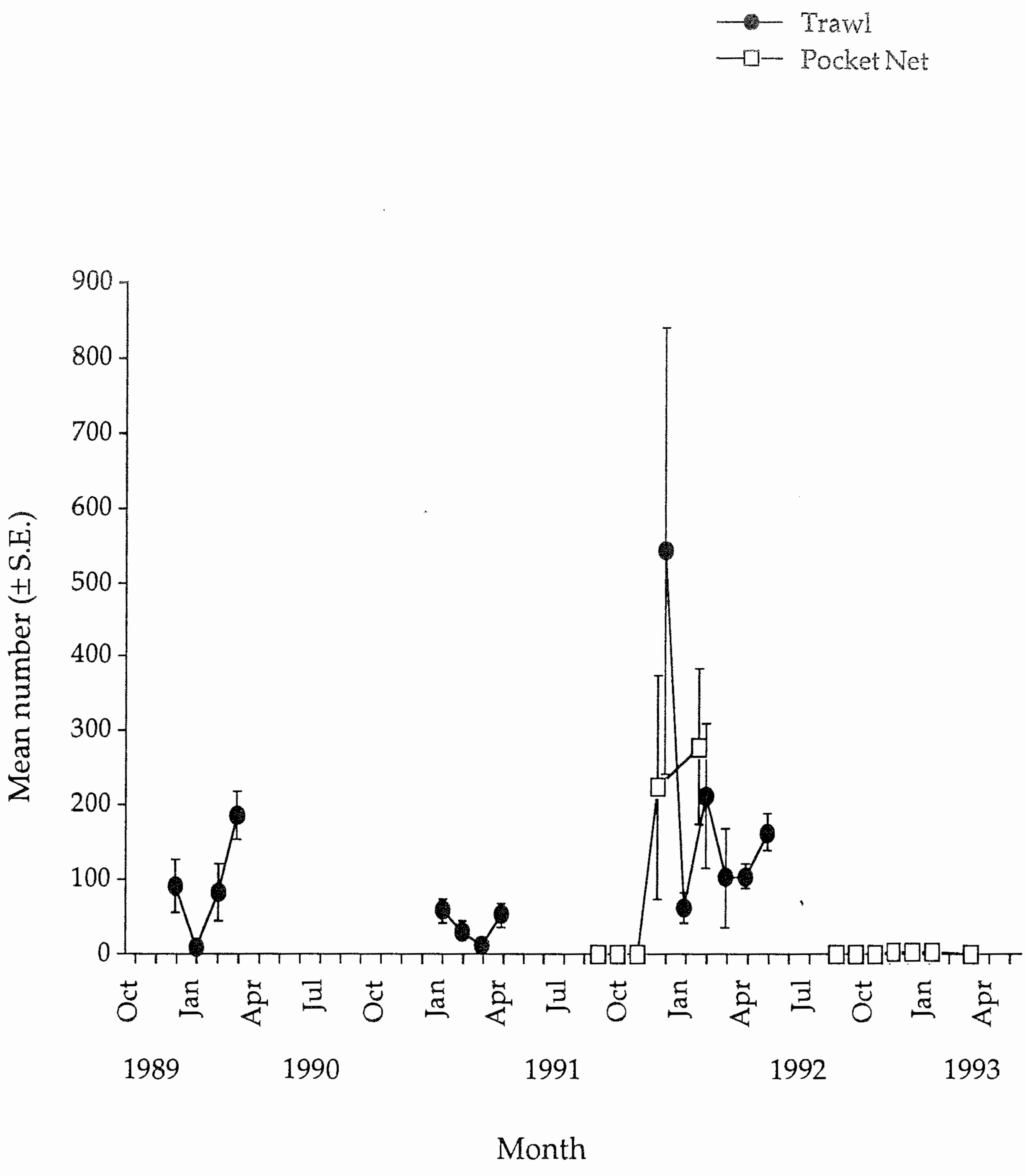


Figure 5.6. Mean catch rate of Bream in the Clarence river trawl and set pocket net fisheries.

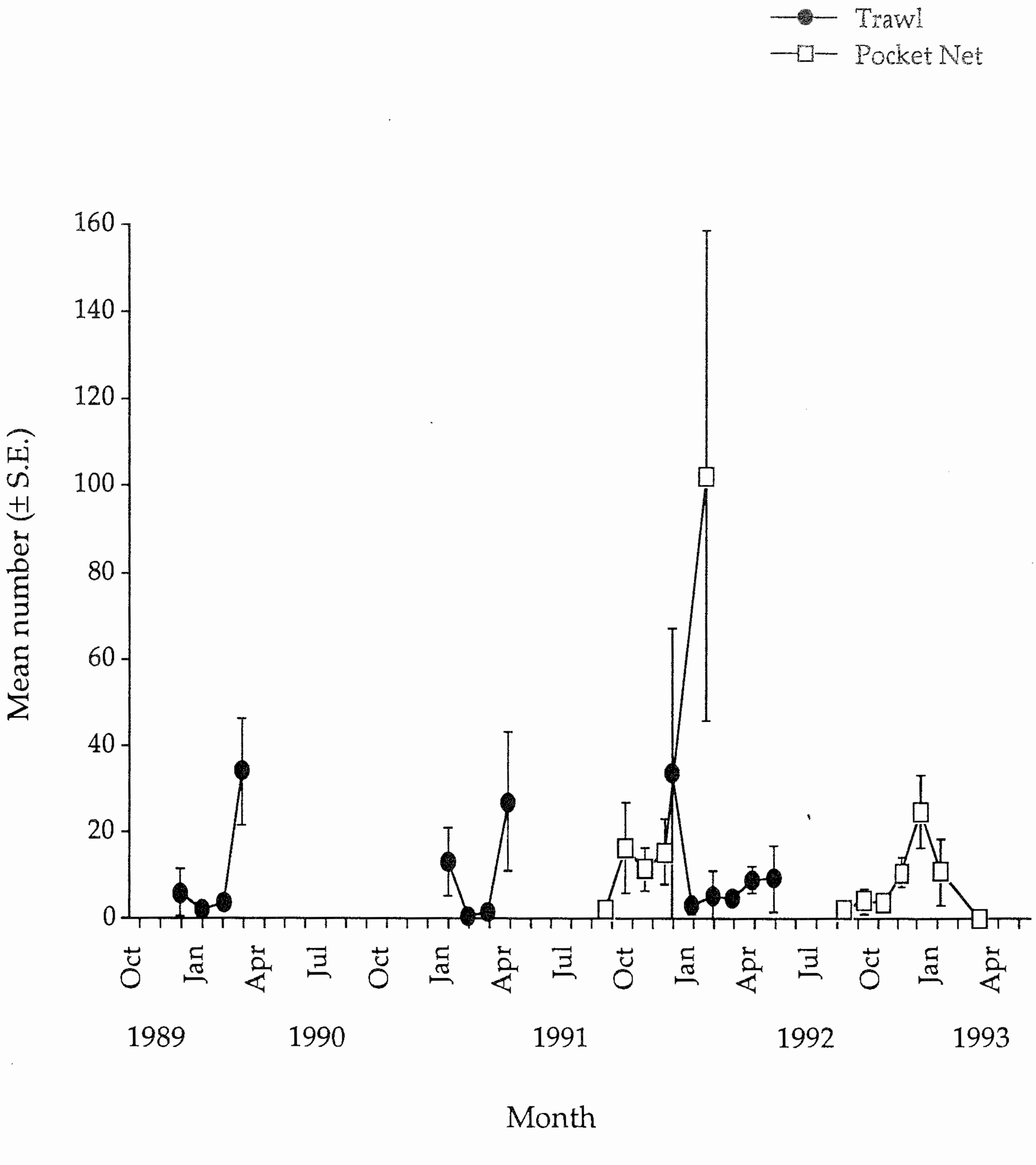


Figure 5.7. Mean catch rate of Tailor for the Clarence River trawl and set pocket net fisheries.

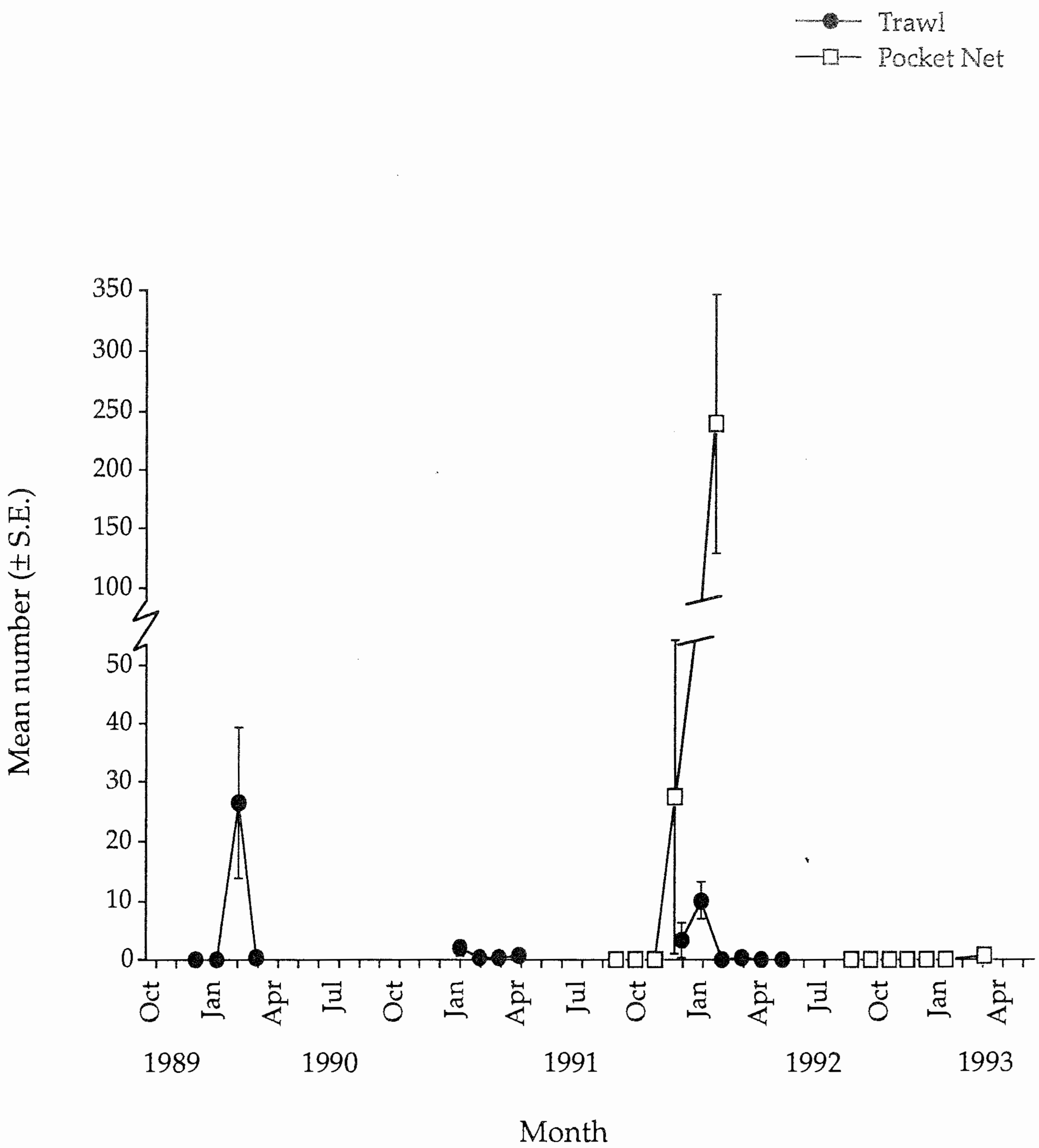


Figure 5.8. Mean catch rate of Tarwhine for the Clarence River trawl and set pocket net fisheries.

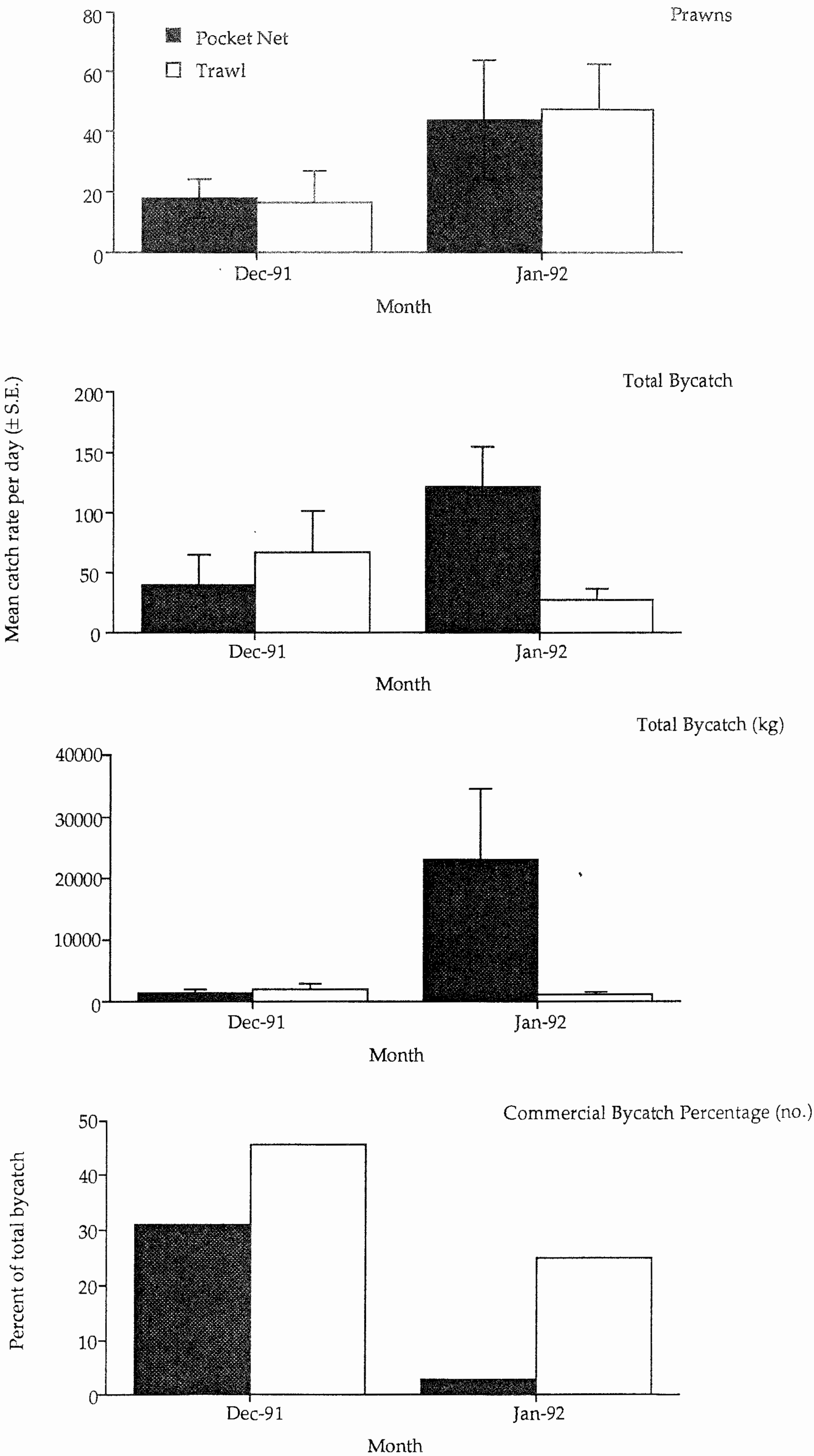


Figure 5.9. Comparison of rates of catch and by-catch for the trawl and set pocket net fisheries in the Clarence River

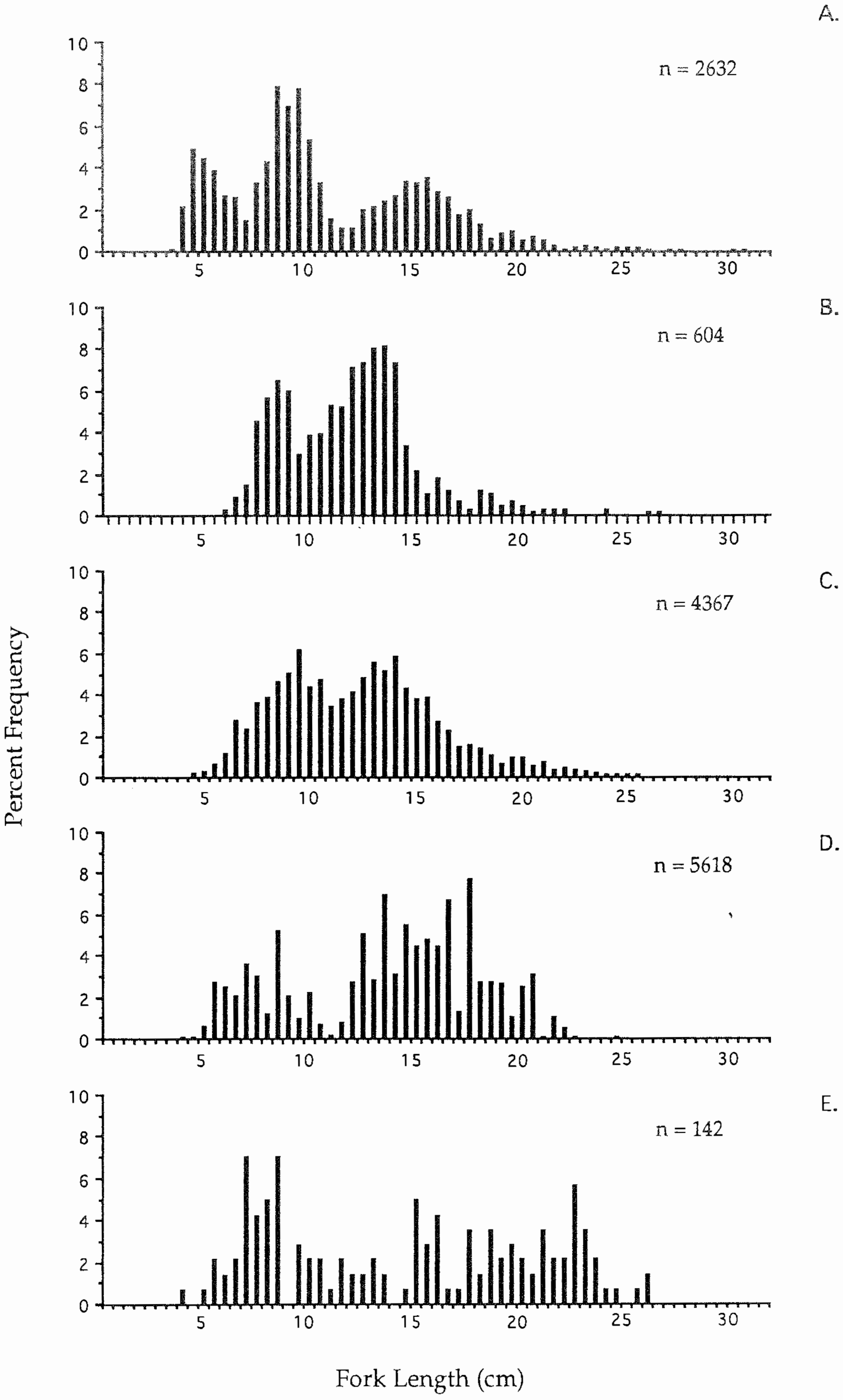


Figure 5.10. Length frequencies of bream caught between 1989 and 1993 in trawl and pocket nets. a. trawl catch from 1989-90. b. trawl catch from 1990-91. c. trawl catch from 1991-92. d. pocket net catch from 1991-92. and e. pocket net catch from 1992-93.

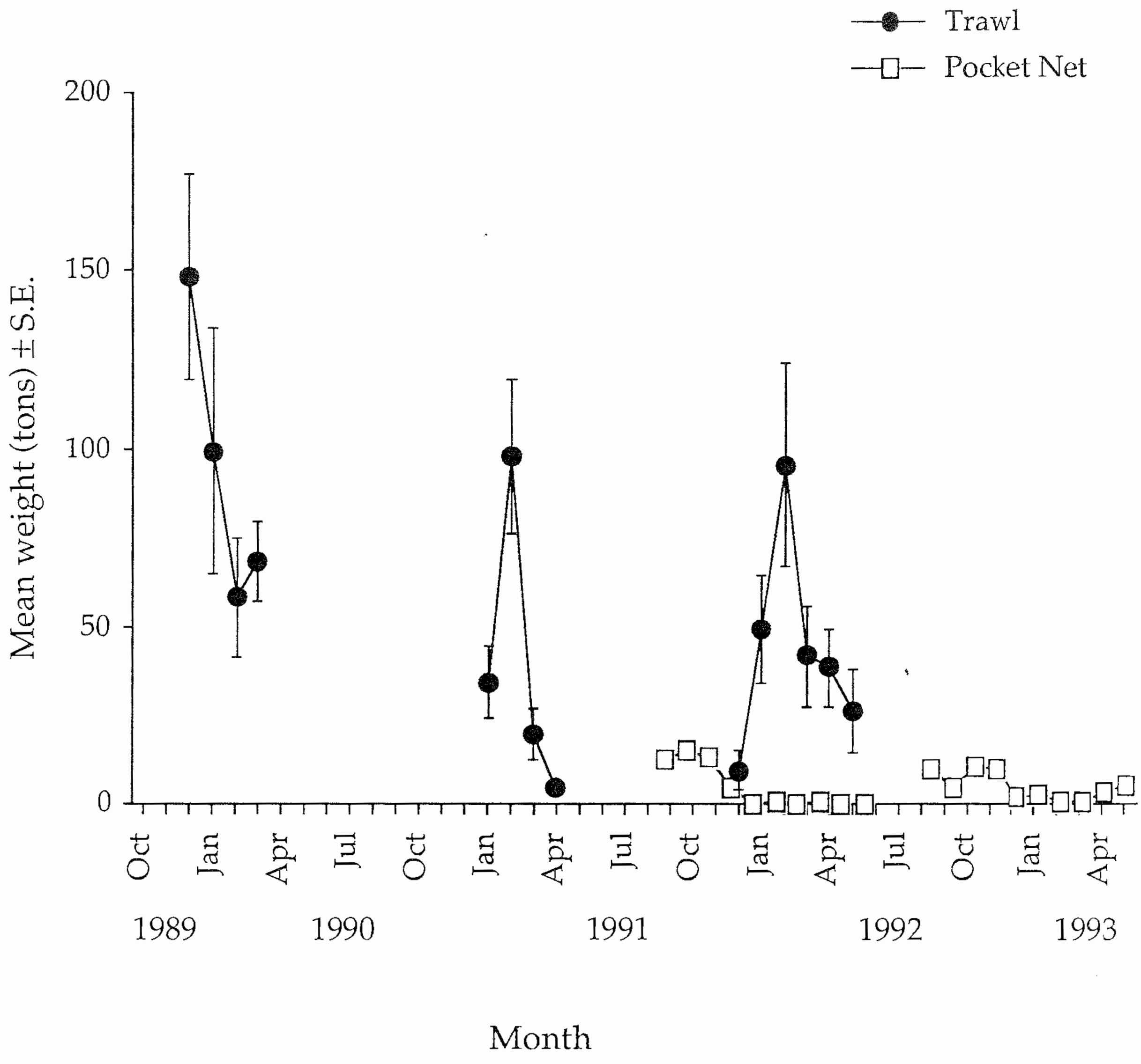


Figure 5.11. Estimate of total catch (± S.E.) of prawns for the Clarence River trawl and set pocket net fisheries.

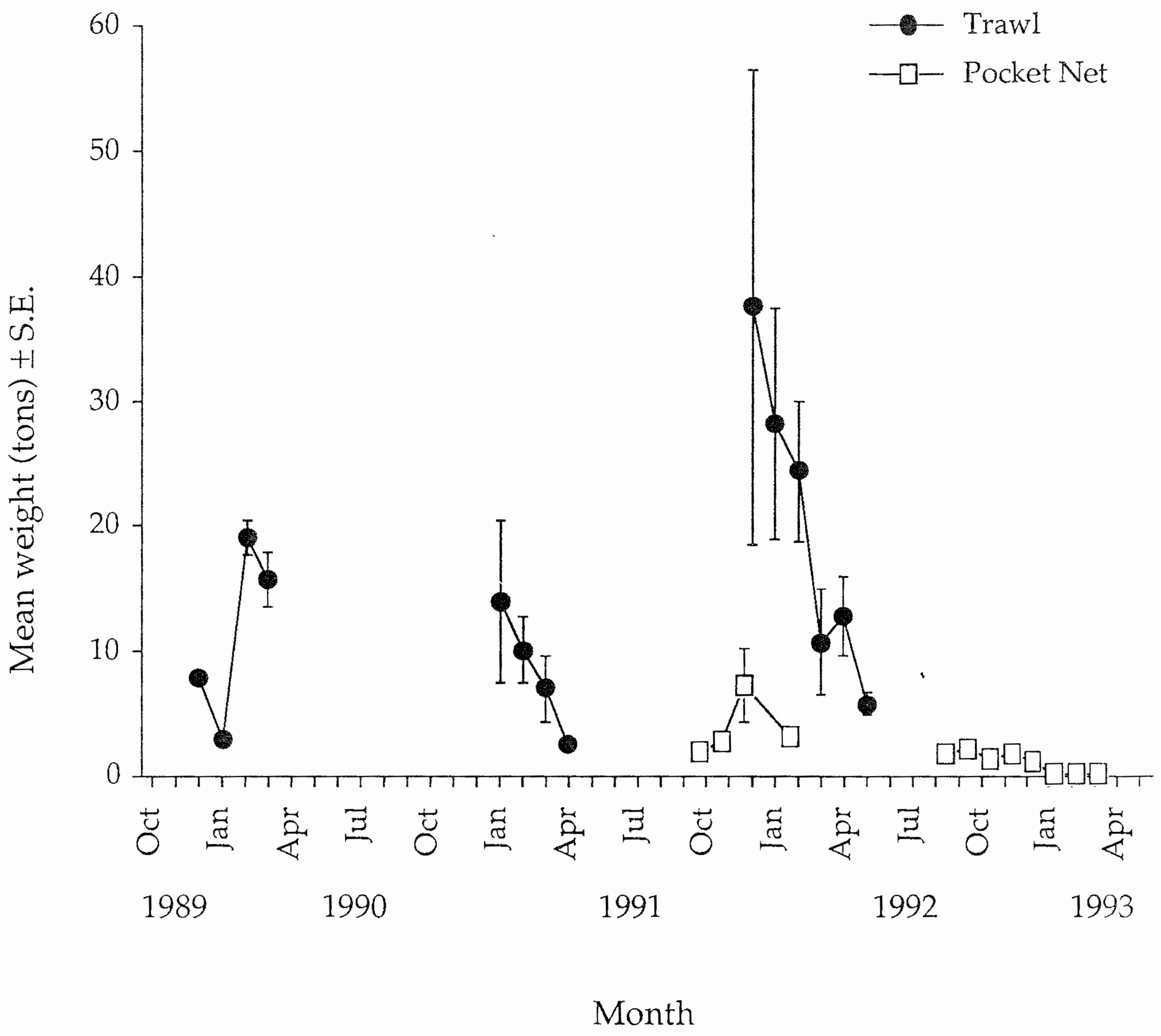


Figure 5.12. Estimate of total by-catch weight (± S.E.) for the Clarence River trawl and set pocket net fisheries.

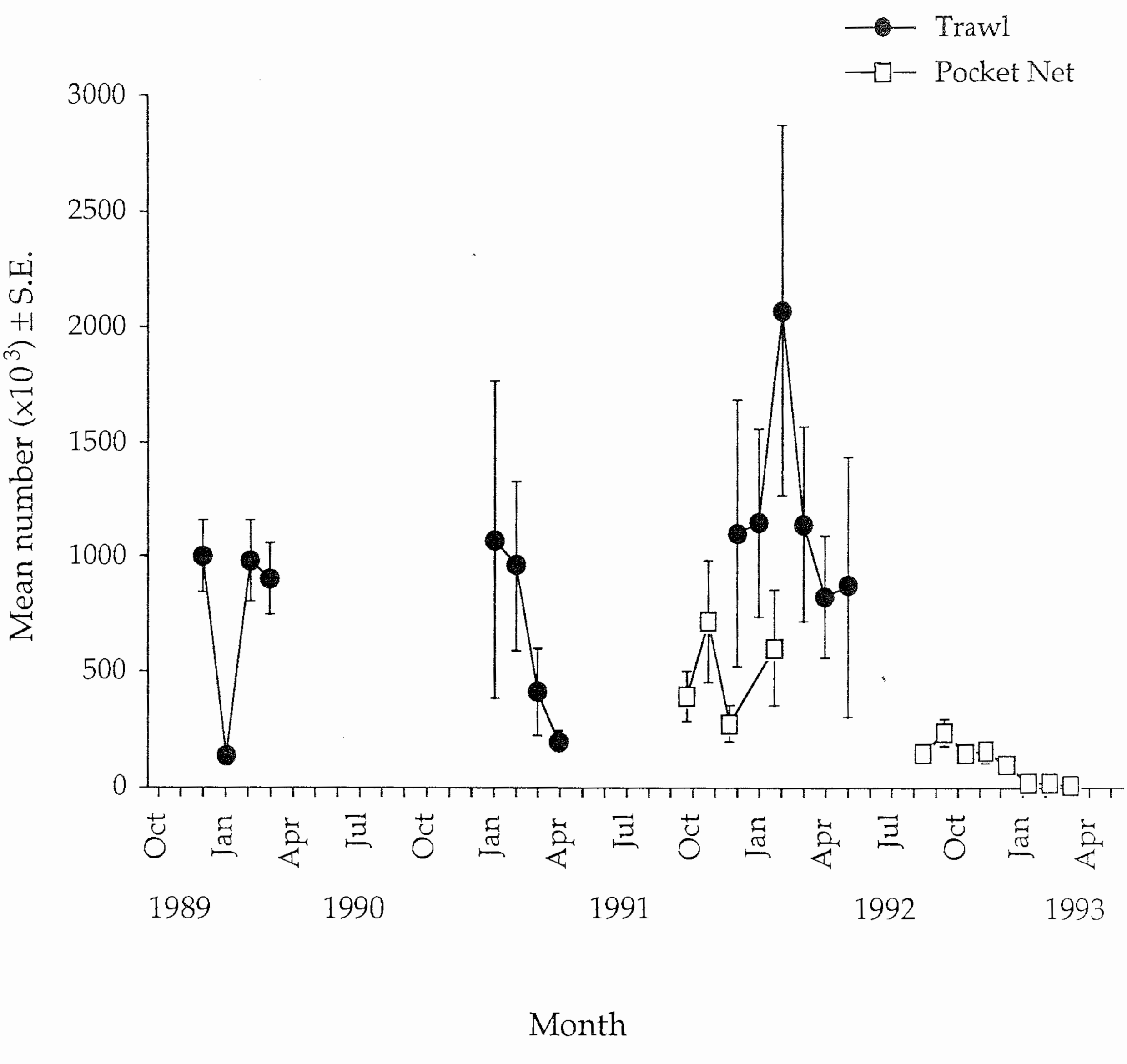


Figure 5.13. Estimate of total by-catch number (± S.E.) for the Clarence River trawl and set pocket net fisheries.

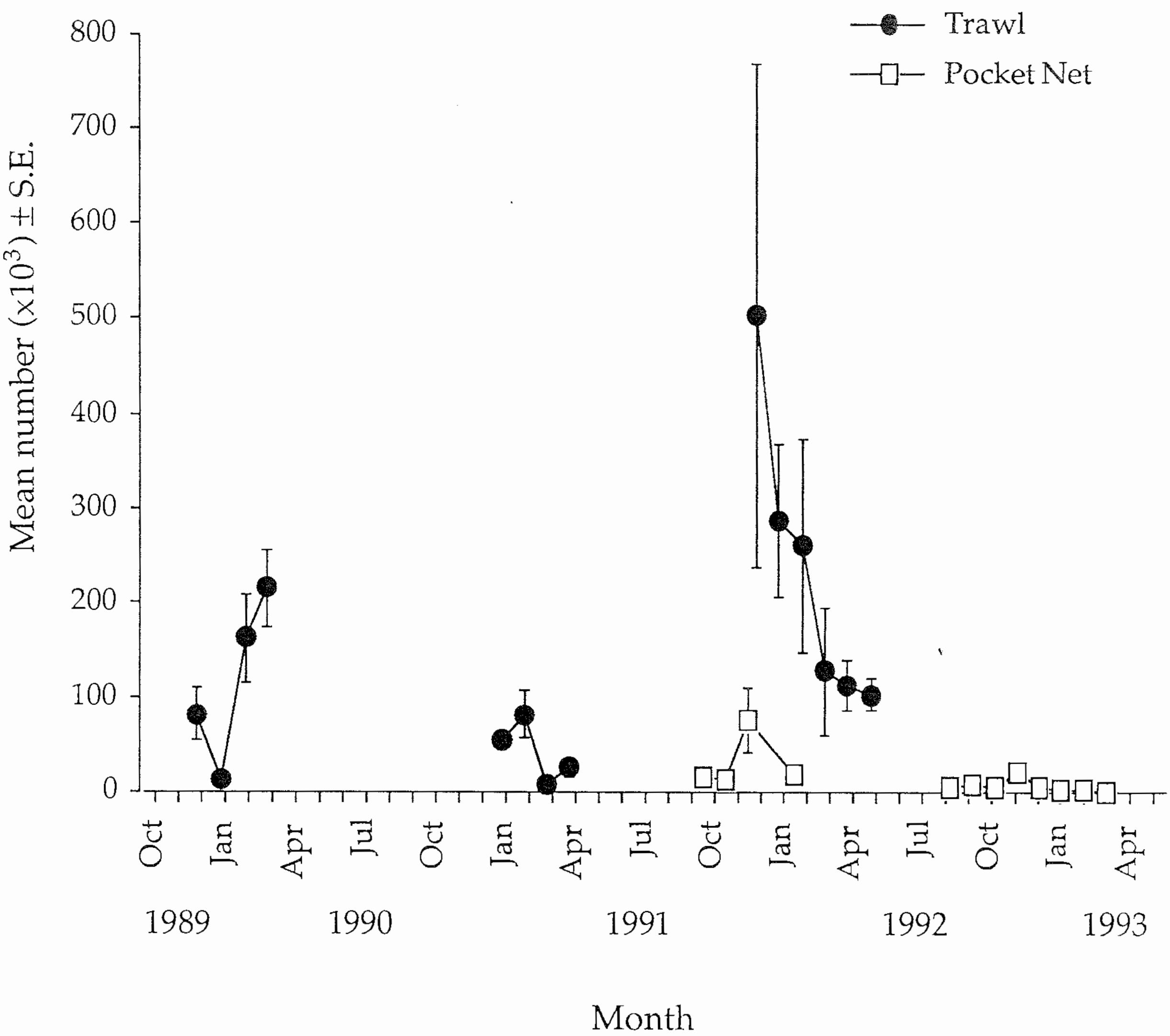


Figure 5.14. Estimates of mean number (± S.E.) of individuals of commercial species for the Clarence River trawl and set pocket net fisheries.

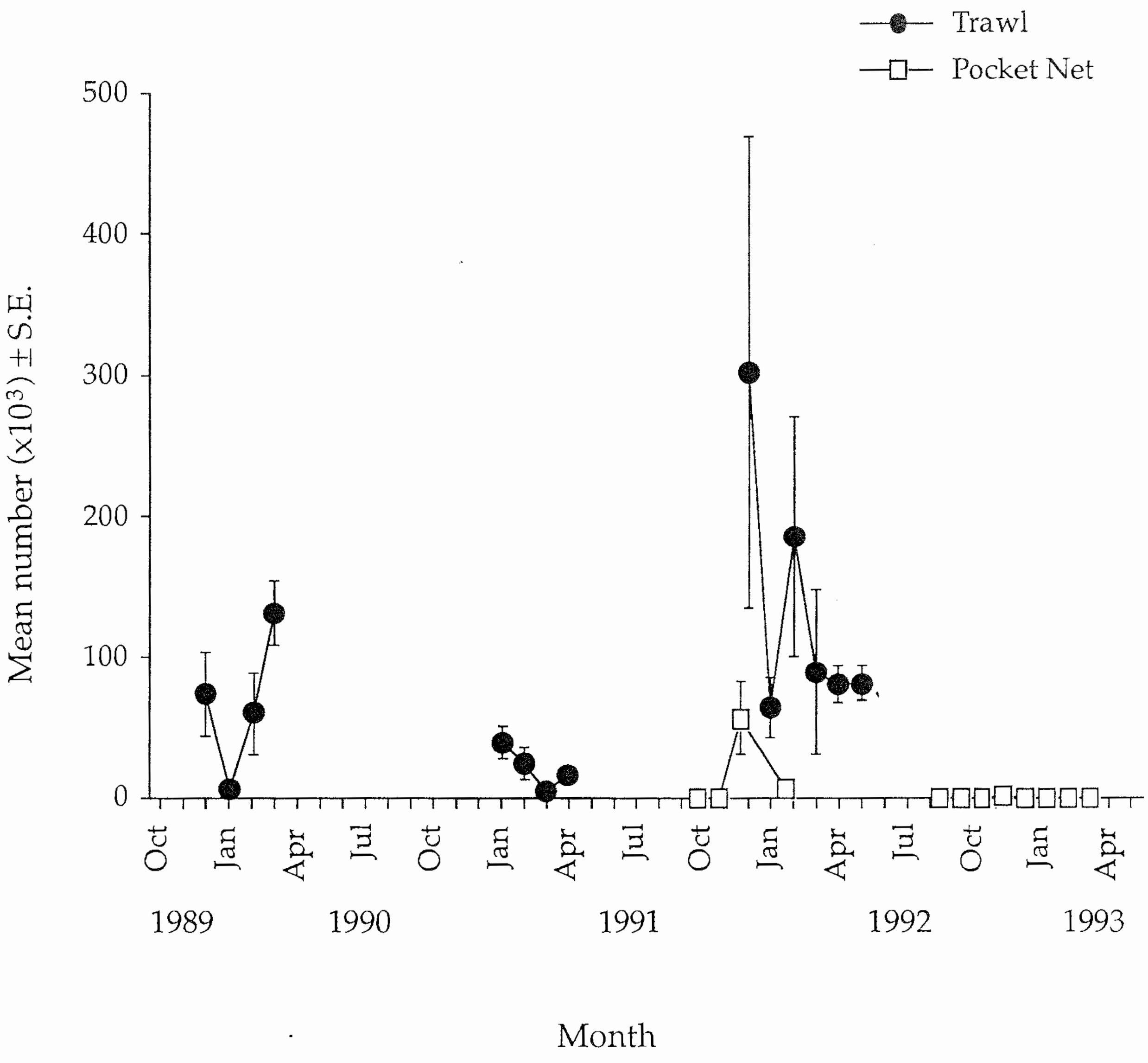


Figure 5.15 Estimate of total number (± S.E.) of bream for the Clarence River trawl and set pocket net fisheries.

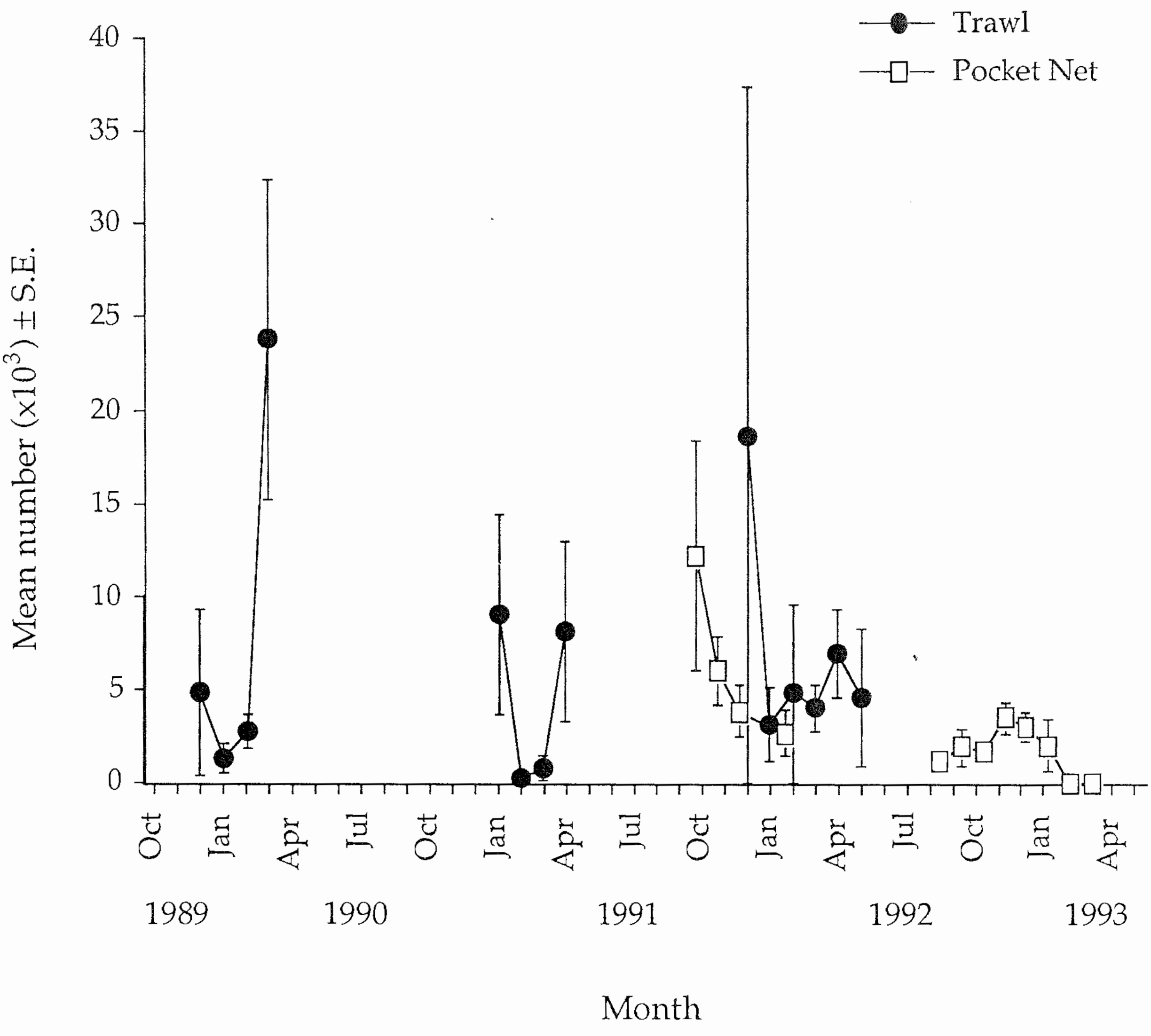


Figure 5.16 Estimate of total number (± S.E.) of tailor for the Clarence River trawl and set pocket net fisheries.

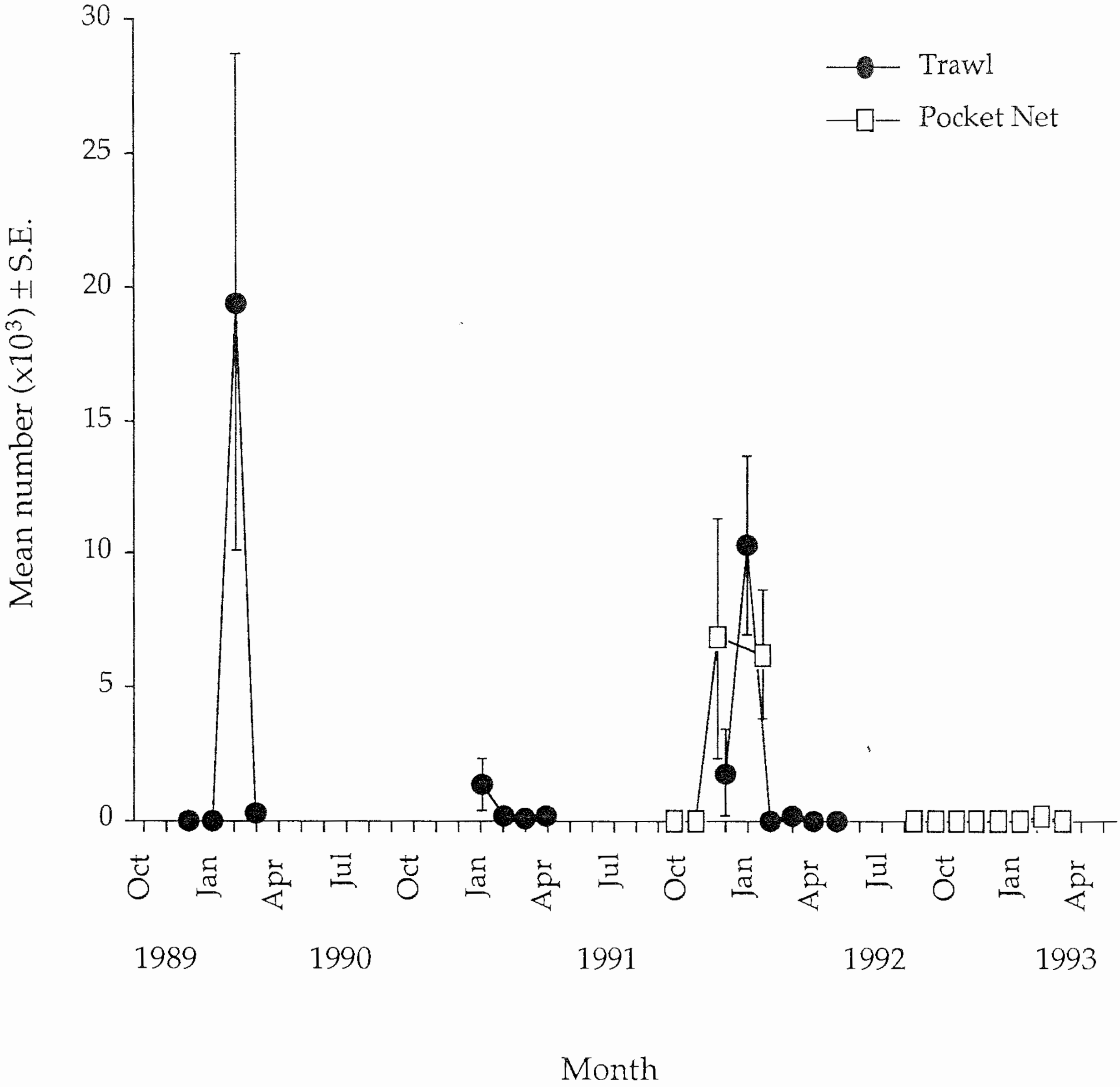


Figure 5.17 Estimate of total number (± S.E.) of tarwhine for the Clarence River trawl and set pocket net fisheries.

# CHAPTER SIX: MYALL RIVER SET POCKET FISHERY

## 6.1 Introduction

The Myall River is a 23 kilometre long tidal river that connects Myall Lake to the Port Stephens estuary on the N.S.W. central coast. The narrow ocean entrance to Port Stephens is approximately 3.5 kilometres to the south of the town of Hawks Nest. Myall Lake supports fish, eel, crab and prawn fisheries. The Upper Myall flows into the south-west corner of Myall Lake carrying run-off from the hills to the north-west of Bulahdelah. Prawn trawling is prohibited in Port Stephens, the Myall River and Myall Lake but according to local fishers set pocket netting has occurred in the area since 1935. The Myall River is narrow, (50-100 m wide) for most of its length but has two wider sections called the Brasswater and Little Brasswater. Pocket nets must have a headrope length of 20 m and, because the river is narrow, fishers usually set the net with the bridles running to fixed points on the river bank such as trees or rocks. Legal net size is 20 m corkline length and wooden poles are used to spread the net while weights are tied to the ground rope to keep it on the bottom. The following account of the fishery is taken from discussions with experienced fishers and fisheries officers.

In the past, pocket netting was a very local fishery with the main participants coming from Tea Gardens, Hawks Nest and Nelsons Bay on the southern side of Port Stephens. Fishers now also come from Forster/Tuncurry, Karuah and Newcastle to take pocket net sites. There are 17 pocket net sites along the river and while pocket netting can occur throughout the year, the prawns generally run from August to May. At most sites the pocket nets are set across a significant portion of the river, greatly reducing the catch of the site behind. The most sought after sites therefore are the "Top Shot" at Tamboy and the Back-up Shot 100 m further down river.

Sites are allocated to fishers at a pocket net draw held at Tea Gardens each month on the day of the full moon. Fishers nominate the site they want to work for the month. The nominations for a site are drawn at random for each night of the month until all those who have nominated for the site have been allocated a night, then the next site is settled. Only one site can be nominated by a fisher or crew and only pairs can work the Top Shot and Back-up Shot. For example, if there were 45 nominations in the draw for the Top Shot the first 28 fishers drawn would have one night at the Top Shot and the next 17 drawn would take the first 17 nights at the Back-up Shot. When the 45 nominations have been drawn the remainder of the nights at the Back-up Shot would be allocated in the order that the first names were drawn. The fishers who came out of the draw in the first 11 would therefore get to work the Top Shot one night and the Back-up Shot one night, while the rest would only get one night's fishing.

### 6.2 Sampling Methods

Data were collected over 4-6 nights per month on the Myall fishery over a period of 4 months between March and June 1992, usually between the 4th and 12th night after the full moon. Because of the greater priority given to sampling in the Clarence River, sampling dates for the Myall Lakes were not chosen randomly but selected to minimise impact on the Clarence sampling program. There was heavy rain in the region during the sampling period and from March the river became fresh, with little or no in-tide occurring at the Top Shot for March, April and May.

Sites were sampled from Tea Gardens to Tamboy because the fresh water in the river and a lack of prawns caused most fishing effort was concentrated in these first 4-5 sites. Each site was sampled using the same method employed for the Clarence River and 3 x 1 kg prawn samples were collected over each period to determine species composition, and to gather length frequency data.

## 6.3 Results

Average nightly prawn catches in the Myall River set pocket net fishery were larger and more variable than those on the Clarence River (53.2 ± 19.1 vs 22.7 ± 0.8 kg respectively). Over the three months of study the largest average catch rate was in February 1992 (Fig. 6.1). School prawns, eastern king prawns and greasyback prawns were all caught by pocket netting in the Myall Lakes. It was not logistically possible to estimate the proportion of each species in nightly catches, however, composition varied from largely single species catches to mixed catches containing large proportions of all species. Over the course of the sampling period school and greasyback prawns dominated catches although large catches of king prawns have been reported by fishers. Total catch for the fishery could not be estimated because there was no available information on effort in all digs. There was no relationship between catches of prawns and by-catch (Fig. 6.2.).

The school prawns caught in the Myall lake pocket net fishery were much larger than those taken in the Clarence River (Fig. 6.3, see also Fig. 2.10). The average size of school prawns caught was 23.6 mm CL (± 0.1, N = 296, sexes combined). Greasyback prawns (*Metapenaeus bennettae*) were also caught in large numbers (Fig. 6.3; mean size 23.9 ± 0.2 mm CL, N = 386, sexes combined).

The amount of by-catch per kilogram of prawns caught per night was much greater than that of the Clarence River. Prawns averaged 45.3% ± 6.5 of the total catch weight on the Myall River (Table 6.1), and less than 30% of total catches in the Clarence River. This varied with time, however, the greatest average amount of by-catch per kg of prawns was recorded in March. In April, both prawn catch and by-catch were relatively low. The average total by-catch from the Myall River set pocket net fishery was 48.3 ± 12.6 kg per night.

Commercial by-catch made up a large proportion of the total by-catch (30.7 ± 12.6 %, Fig. 6.1, Table 6.1). The majority of this by-catch was eels, particularly shortfinned (*Anguilla australis*) and longfinned eels (*Anguilla reinhardti*). An average of 13.9 ± 6.5 kg of eels were caught per night and except for one large catch of 101 kg, catches of eels did not exceed 26 kg. Excluding eels, the commercial by-catch was 4.1 ± 0.9 % of the total by-catch.

The average commercial by-catch weight in Myall Lakes was 15.1 ± 6.5 kg or 1.4 ± 0.3 kg excluding eels. An average of 33.1 ± 6.4 commercial individuals were caught per night, of which the five most abundant species are recorded in table 6.2. Two eel species; shortfinned (*Anguilla australis*, 12.8 ± 3.7 individuals) and longfinned (*Anguilla reinhardti*, 7.1 ± 3.0 individuals) accounted for 53.4 ± 9.6 % of the number and 64.3 ± 9.7 % of the weight of commercial by-catch in the Myall River study. The three next most caught species were river gar (*Hyporamphus ardelio*, 3.5 ± 2.1 individuals), tarwhine (*Rabdosargus sarba*, 2.4 ± 1.0) and bream (*Acanthopagrus australis*, 1.5 ± 1.1 ). Unlike by-catch from the Clarence River, tailor (0.2 ± 0.1) and snub-nosed garfish (0.1 ± 0.1) were relatively rare.

Non-commercial species accounted for an average of 15.3 ± 6.5 kg per night which was 69.3 ± 6.0 % of total by-catch. The most common non-commercial species were; herring (*Herklotsichthys castelnaui*, 1303 ± 716 individuals per night), mud gudgeons (*Bunaka herwerdenii*, 304 ± 202), silver biddies (*Gerres subfasciatus*, 48.5 ± 37.1), fortescues (*Centropogon australis*, 43.5 ± 21.7) and perchlets (*Ambassis spp.* 34.7 ± 17.6) (Table 6.3). Rock prawns (*Macrobrachium spp.*) were not caught during this study.

By-catch composition of the Myall River was unlike that from the Clarence River except for the domination of herring which accounted for on average 54.4 ± 9.1 % of total non commercial by-catch by number. Perchlets, however, only made up 4.7 ± 2.2 % of the total non-commercial by-catch. Mud gudgeons were much more common in Myall catches than Clarence catches. The weight of eels caught in the Myall Lakes was far in excess of that caught in the Clarence River.

## 6.4 Discussion

Information collected in the Clarence River (Chapter 2) suggests that catches of school prawns are greatest 7-12 days after the full moon. The data presented here for the Myall Lake pocket net fishery were all collected during this time of the lunar month and are therefore probably over-estimates of the average catch rate for the entire month. Estimates of average catch are likely to be further inflated by the fact that the river was running fresh throughout the period sampled. We have demonstrated (Chapter 3) that rates of by-catch on the Clarence River were affected by rainfall.

The great influence of variables such as lunar periodicity and river discharge on catchability of both prawns and by-catch demonstrate the problems associated with limited sampling of these extremely variable fisheries. It is likely that the timing and location of large catches of fish will differ among years with different river discharge and among estuaries, therefore few generalisations are possible.

This preliminary study of the Myall Lake set pocket net fishery has indicated several major differences from the fishery in the Clarence River. The most important of these are: (i) the mixed species composition of the prawn catch (ii) the greater catch of eels and the other commercial species of the by-catch (iii) the much larger size of school prawns. The underlying causes of these differences are unknown. Sampling in the Myall Lakes pocket net fishery was restricted to a relatively short period of time due to the need to sample the Clarence River fishery adequately.

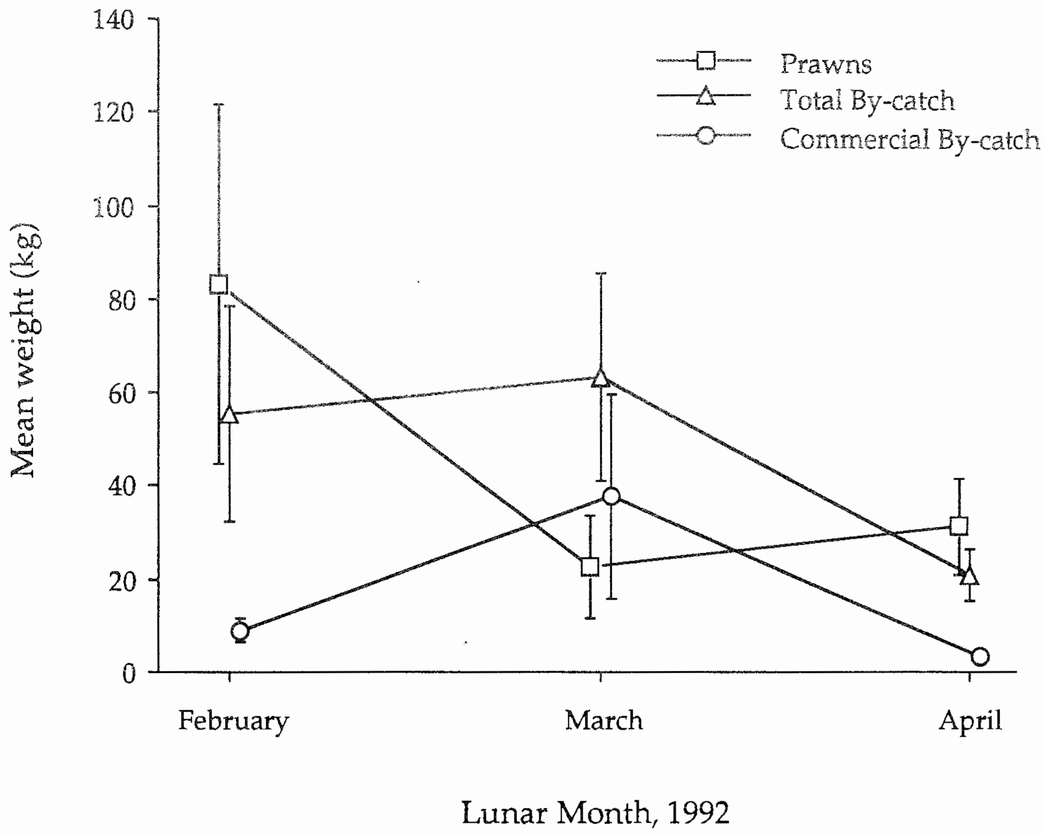


Figure 6.1. Mean (± S.E.) prawn catch and by-catch (kg) from the Myall Lake set pocket net fishery.

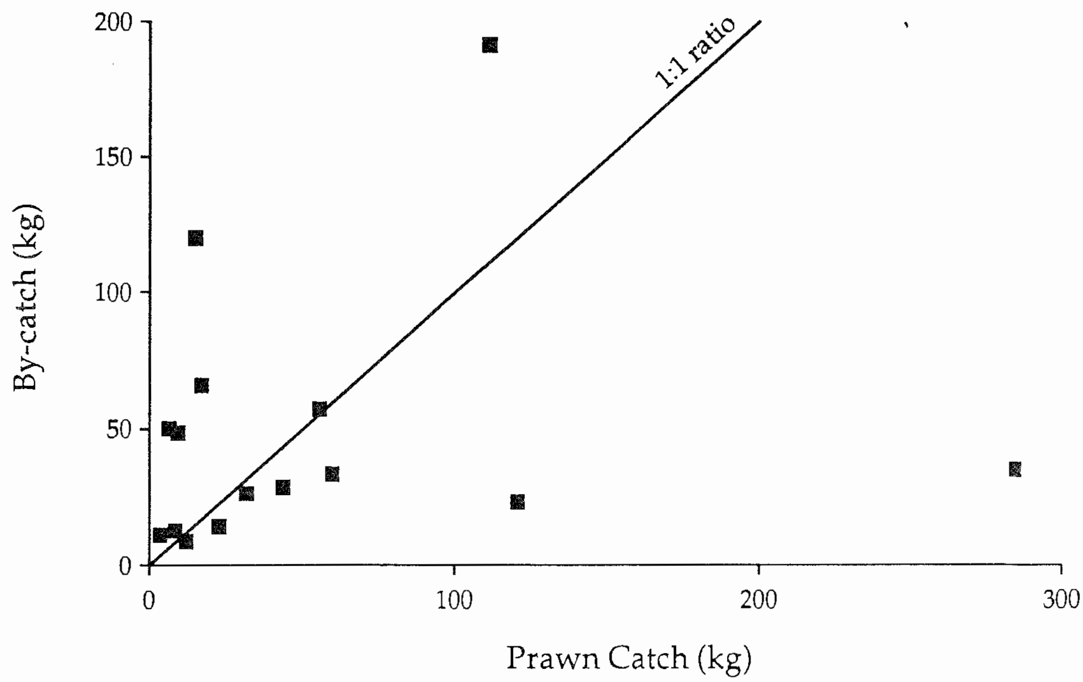


Figure 6.2. Relationship between catch and by-catch in the Myall Lake set pocket net fishery.

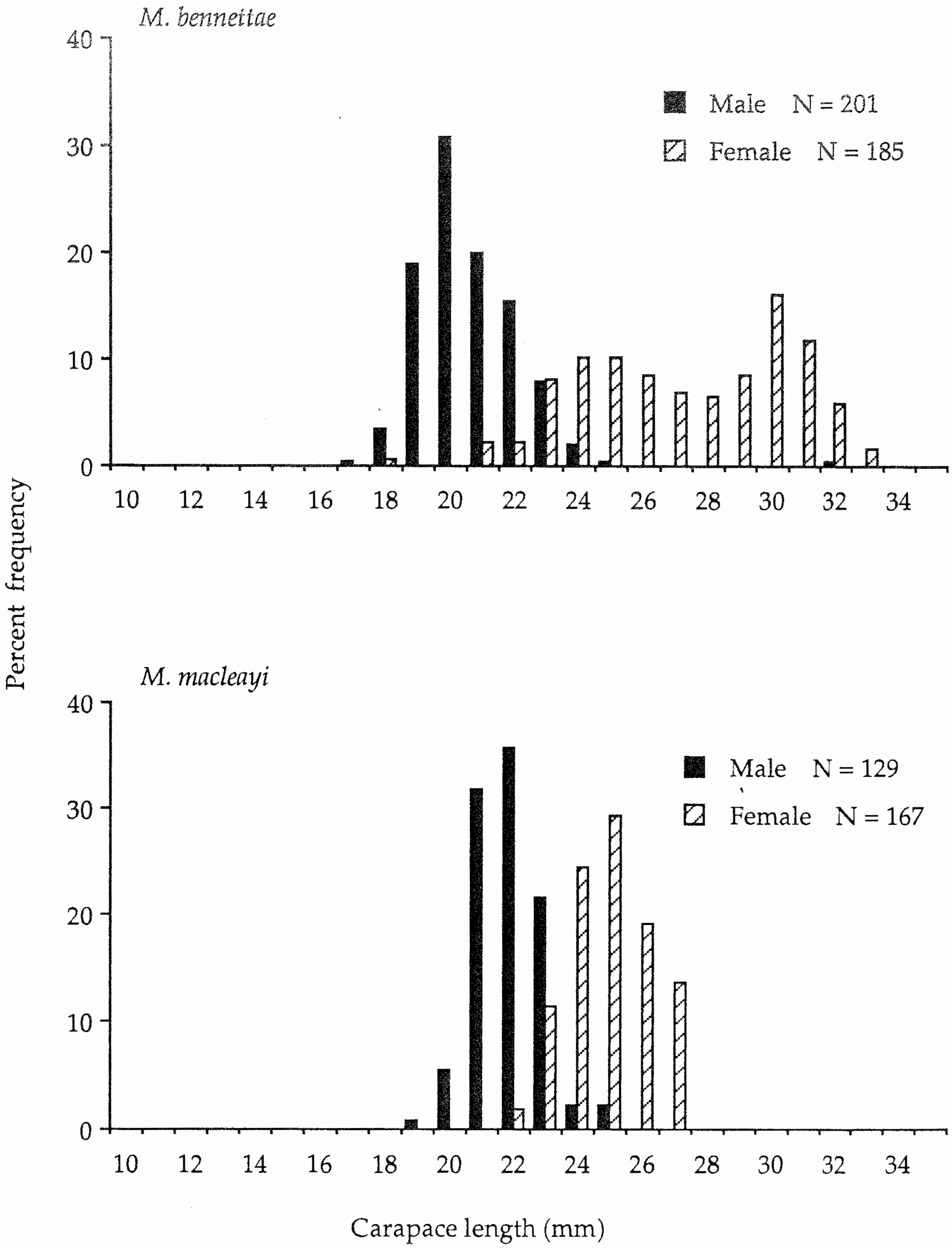


Figure 6.3. Length-frequency distributions of school prawns (*Metapenaeus macleayi*) and greasybacks (*Metapenaeus bennettae*) from the Myall Lakes set pocket net fishery. Samples pooled for the period 25/2/92 to 25/4/92.

Table 6.1 The average (± S.E.) weight of total catches of prawns and by-catch per lunar month from the Myall lake study from February to May 1992.

| | Feb/Mar | Mar/Apr | Apr/May | Total |
|---|---|---|---|---|
| Total prawn catch | 83.2 ± 38.3 | 22.6 ± 11.3 | 31.3 ± 10.3 | 53.2 ± 19.1 |
| Total by-catch | 55.5 ± 23.2 | 64.1 ± 22.4 | 20.6 ± 5.5 | 48.5 ± 12.6 |
| Commercial by-catch | 8.8 ± 2.5 | 38.7 ± 21.7 | 3.2 ± 1.1 | 15.3 ± 6.6 |
| By-catch w/o eels | 48.1 ± 24.3 | 26.6 ± 10.3 | 19.2 ± 5.1 | 34.7 ± 11.7 |
| Eel catch (weight) | 7.5 ± 2.5 | 37.5 ± 21.5 | 1.5 ± 0.9 | 13.9 ± 6.5 |

Table 6.2 Average (± S.E.) catches per lunar month of the five most commonly caught commercial species in the Myall Lake set pocket net fishery in 1992.

| Species | Feb/Mar | Mar/Apr | Apr/May | Total |
|---|---|---|---|---|
| *A. australis* | 15.6 ± 5.8 | 19 ± 8.0 | 1.8 ± 1.2 | 12.8 ± 3.7 |
| *A. reinhardti* | 2.4 ± 1.7 | 20 ± 8.4 | 2.5 ± 1.9 | 7.1 ± 3.0 |
| *H. ardelio* | 5.0 ± 4.0 | 0 | 4.3 ± 3.6 | 3.5 ± 2.1 |
| *R. sarba* | 0.9 ± 0.5 | 3.3 ± 2.0 | 4.3 ± 3.3 | 2.4 ± 1.0 |
| *A. australis* | 0.3 ± 0.3 | 4.8 ± 3.8 | 0.5 ± 0.3 | 1.5 ± 1.1 |

Table 6.3 Average (± S.E.) catches per lunar month of the five most commonly caught non-commercial species in the Myall Lake set pocket net fishery in 1992.

| | Feb/Mar | Mar/Apr | Apr/Mar | Total |
|---|---|---|---|---|
| Total by-catch non-comm | 46.7 ± 24.2 | 25.5 ± 9.8 | 17.4 ± 4.5 | 33.2 ± 11.6 |
| *H. castelnaui* | 2621 ± 1421 | 127 ± 29.3 | 177 ± 91.8 | 1304 ± 716 |
| *B. herwerdenii* | 0.3 ± 0.2 | 1142 ± 629 | 1 ± 1 | 305 ± 202 |
| *G. subfasciatus* | 12.3 ± 11.6 | 155 ± 136 | 6 ± 3.5 | 48.5 ± 37.1 |
| *C. australis* | 13.6 ± 7.3 | 129 ± 68.6 | 10. ± 7.4 | 43.5 ± 21.7 |
| *Ambassis* spp. | 61.6 ± 35.6 | 14.5 ± 11.1 | 7.8 ± 6.5 | 34.7 ± 17.6 |

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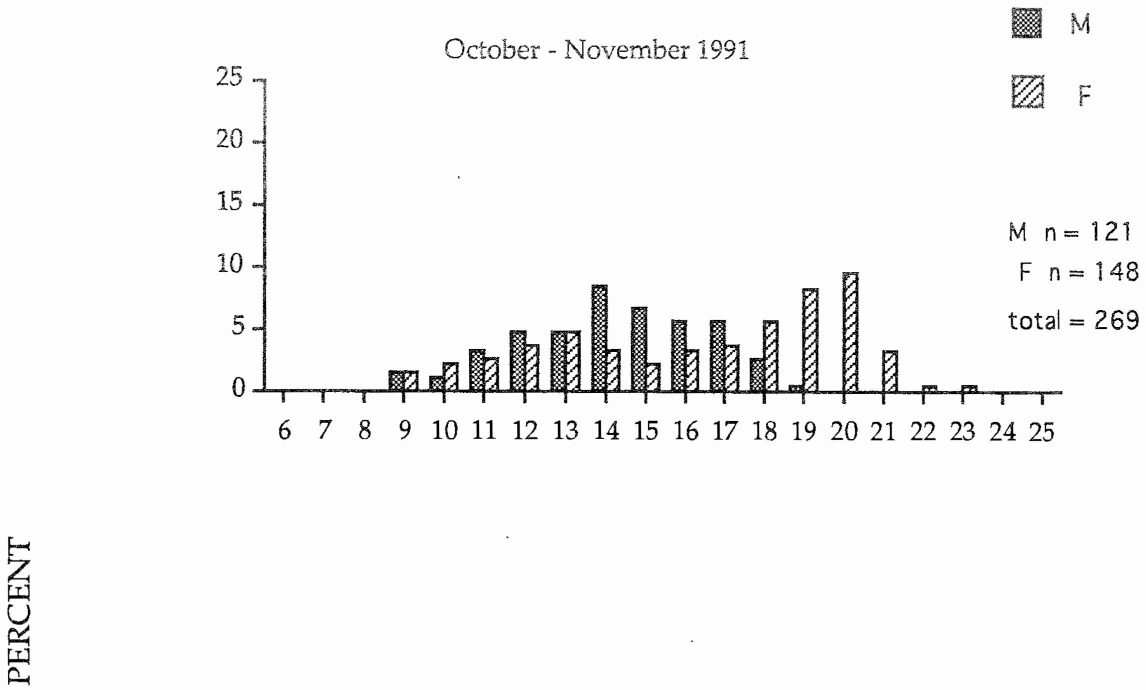
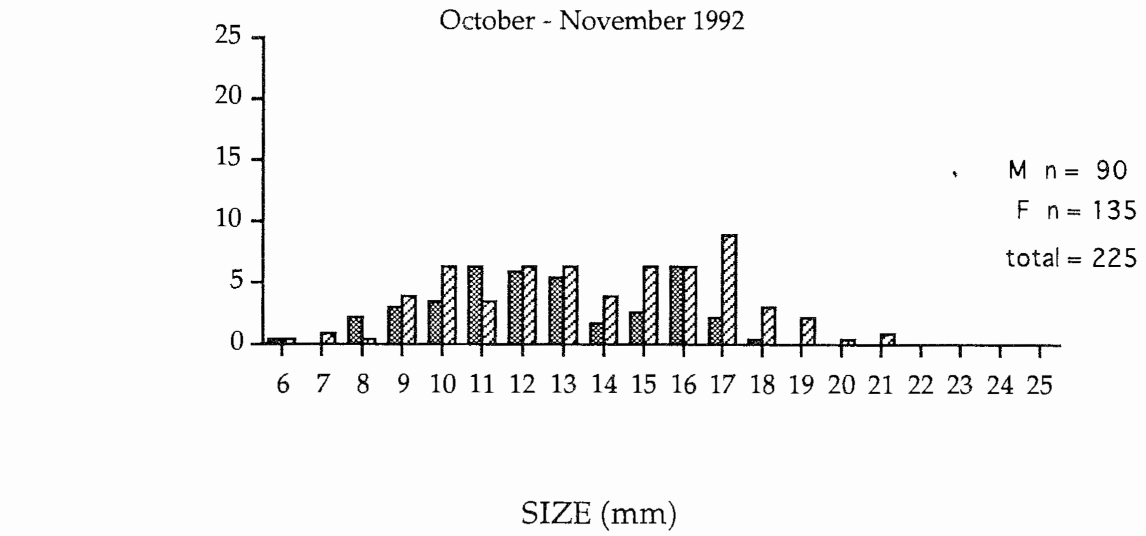
## Appendix One: Length-frequency of prawns caught by the Clarence River set pocket net fishery.

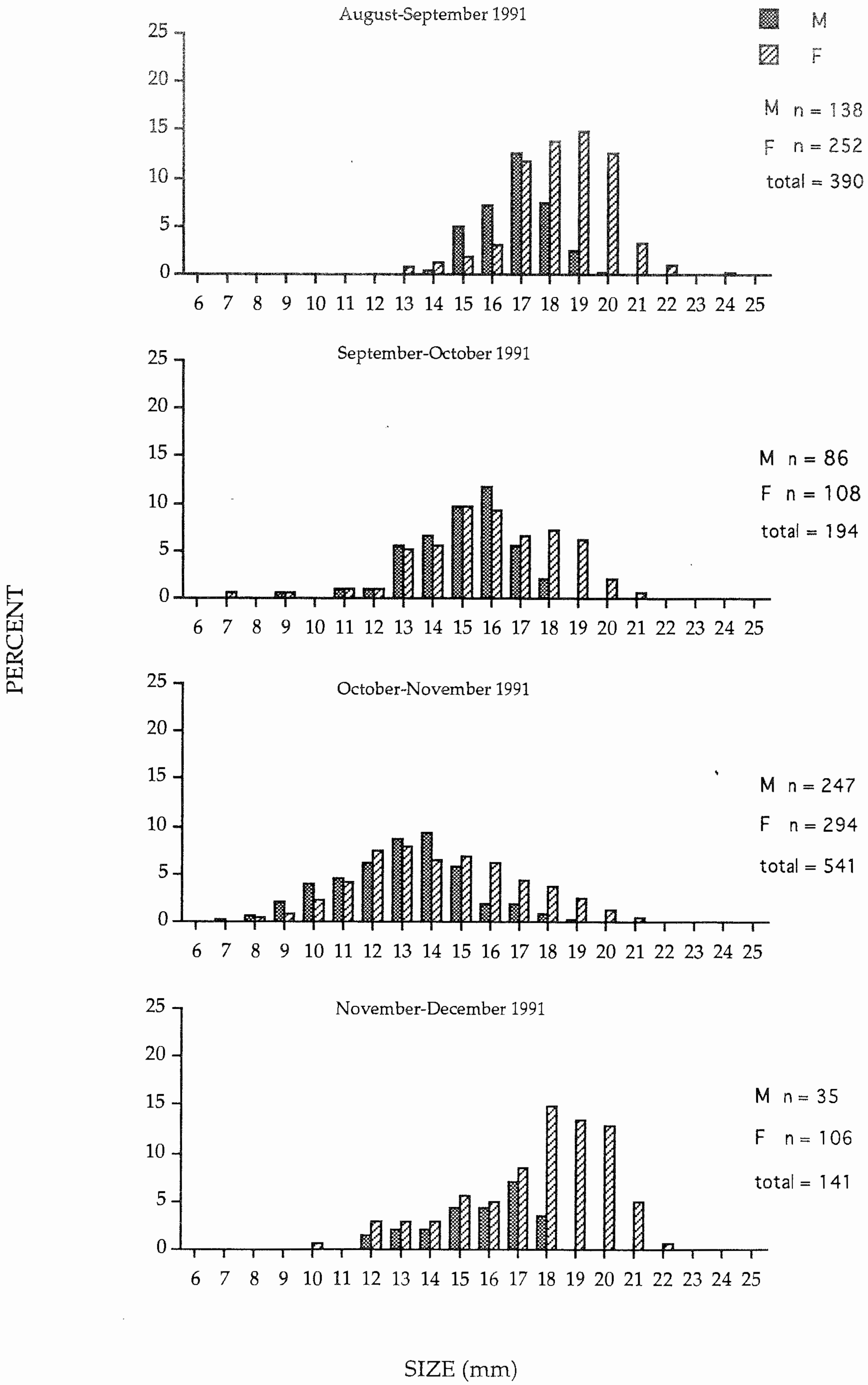
Length-frequencies are provided for each month and zone sampled. Each sample is separated by sex and sample sizes are indicated on the graph.

ZONE 1

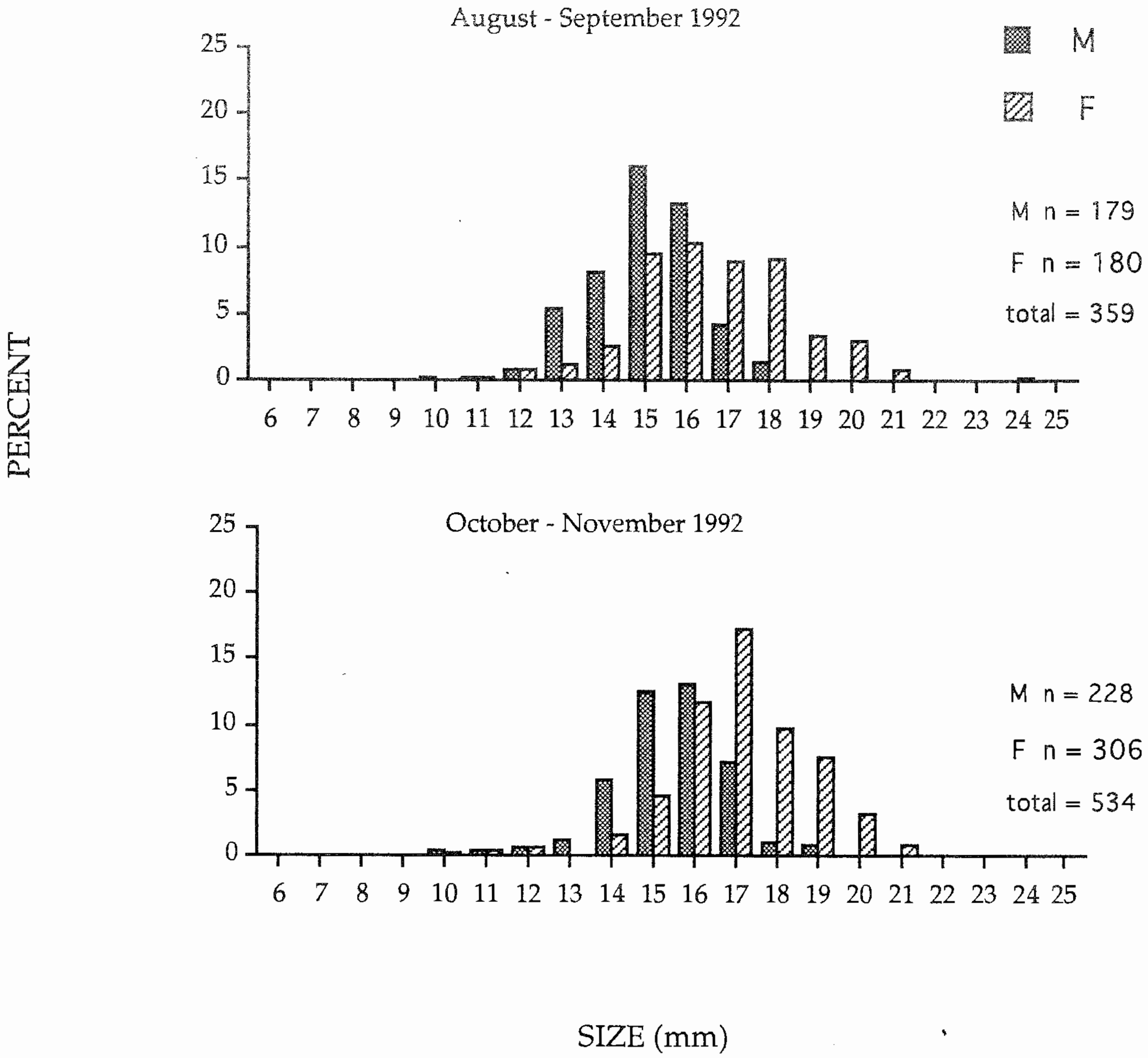

October - November 1991
M
F
25
20
15
10
5
0
M n = 121
F n = 148
total = 269
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
PERCENT


October - November 1992
25
20
15
10
5
0
M n = 90
F n = 135
total = 225
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
SIZE (mm)

ZONE 2

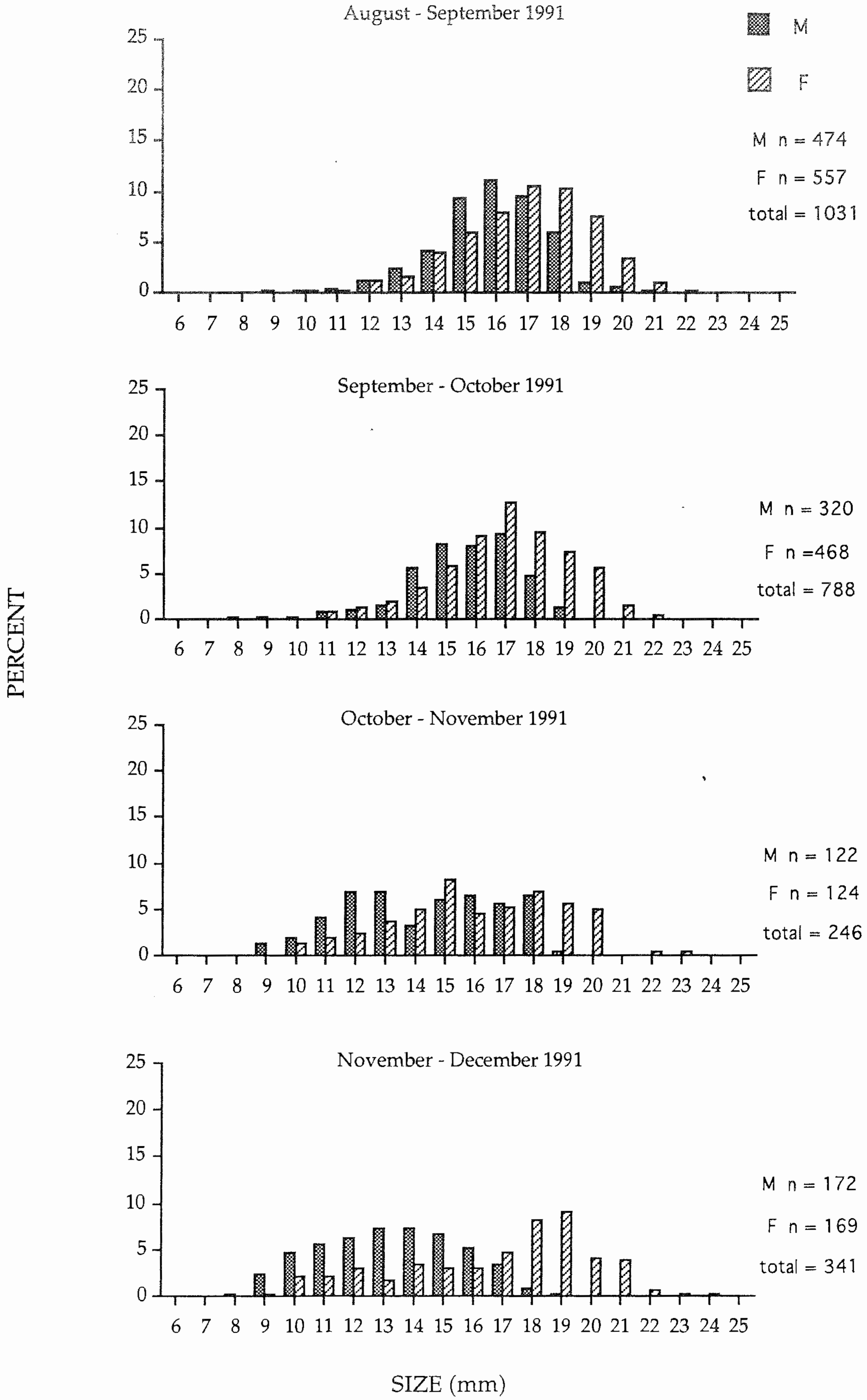

August-September 1991
M
F
M n = 138
F n = 252
total = 390
September-October 1991
M n = 86
F n = 108
total = 194
October-November 1991
M n = 247
F n = 294
total = 541
November-December 1991
M n = 35
F n = 106
total = 141
PERCENT
SIZE (mm)

ZONE 2



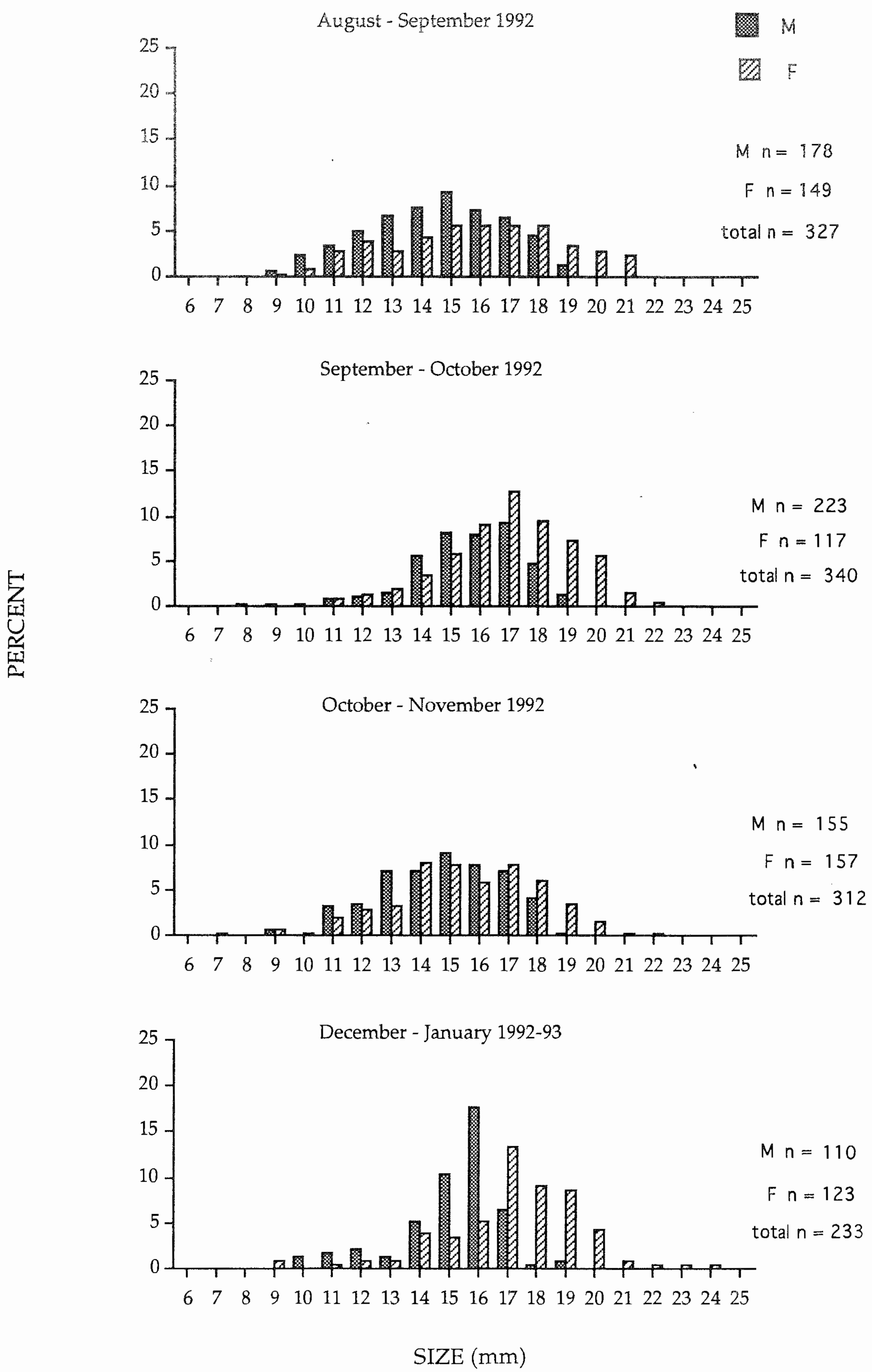
August - September 1992
M
F
M n = 179
F n = 180
total = 359
October - November 1992
M n = 228
F n = 306
total = 534
0
5
10
15
20
25
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
PERCENT
SIZE (mm)

# ZONE 3



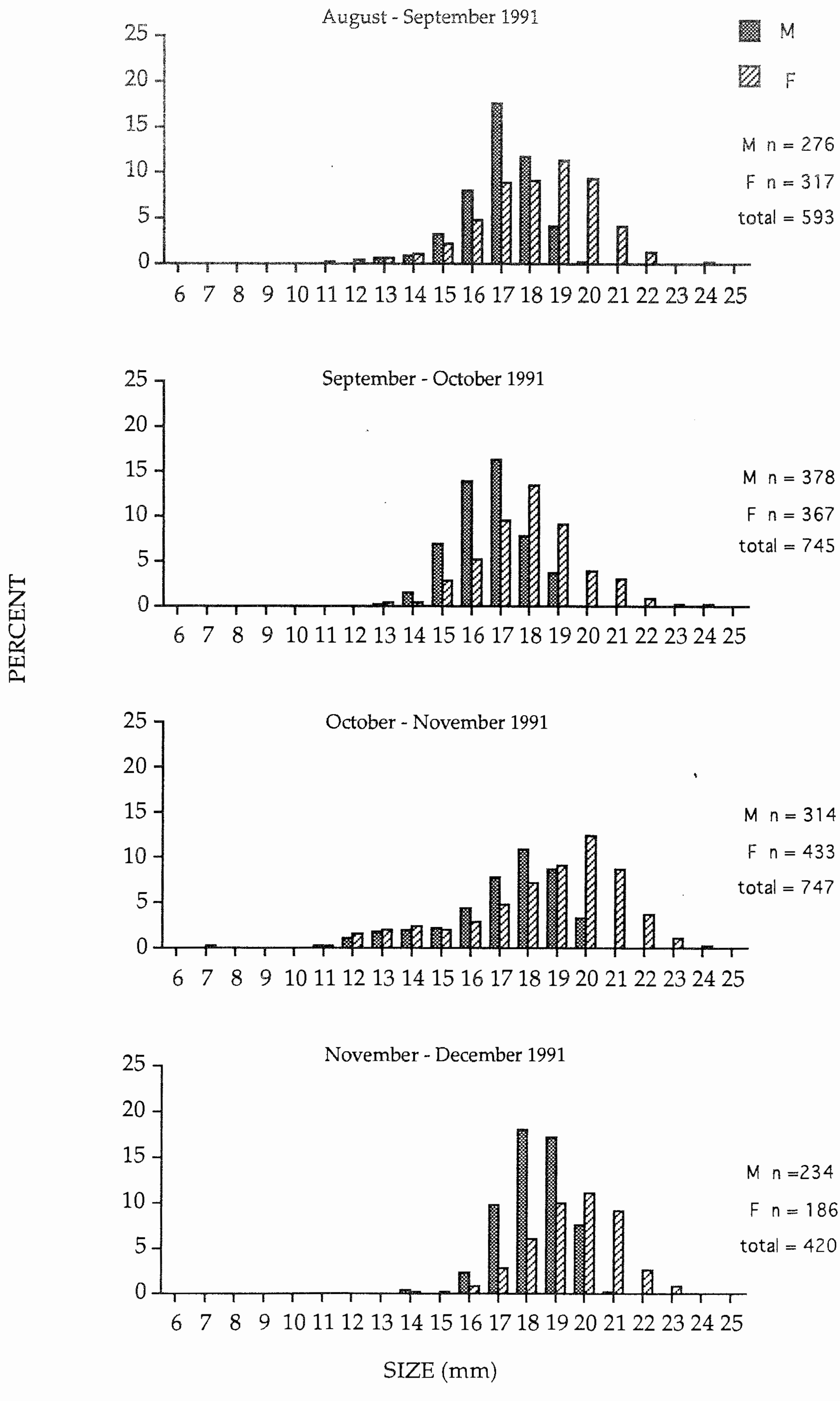
August - September 1991
M
F
M n = 474
F n = 557
total = 1031
September - October 1991
M n = 320
F n =468
total = 788
October - November 1991
M n = 122
F n = 124
total = 246
November - December 1991
M n = 172
F n = 169
total = 341
PERCENT
SIZE (mm)

ZONE 3



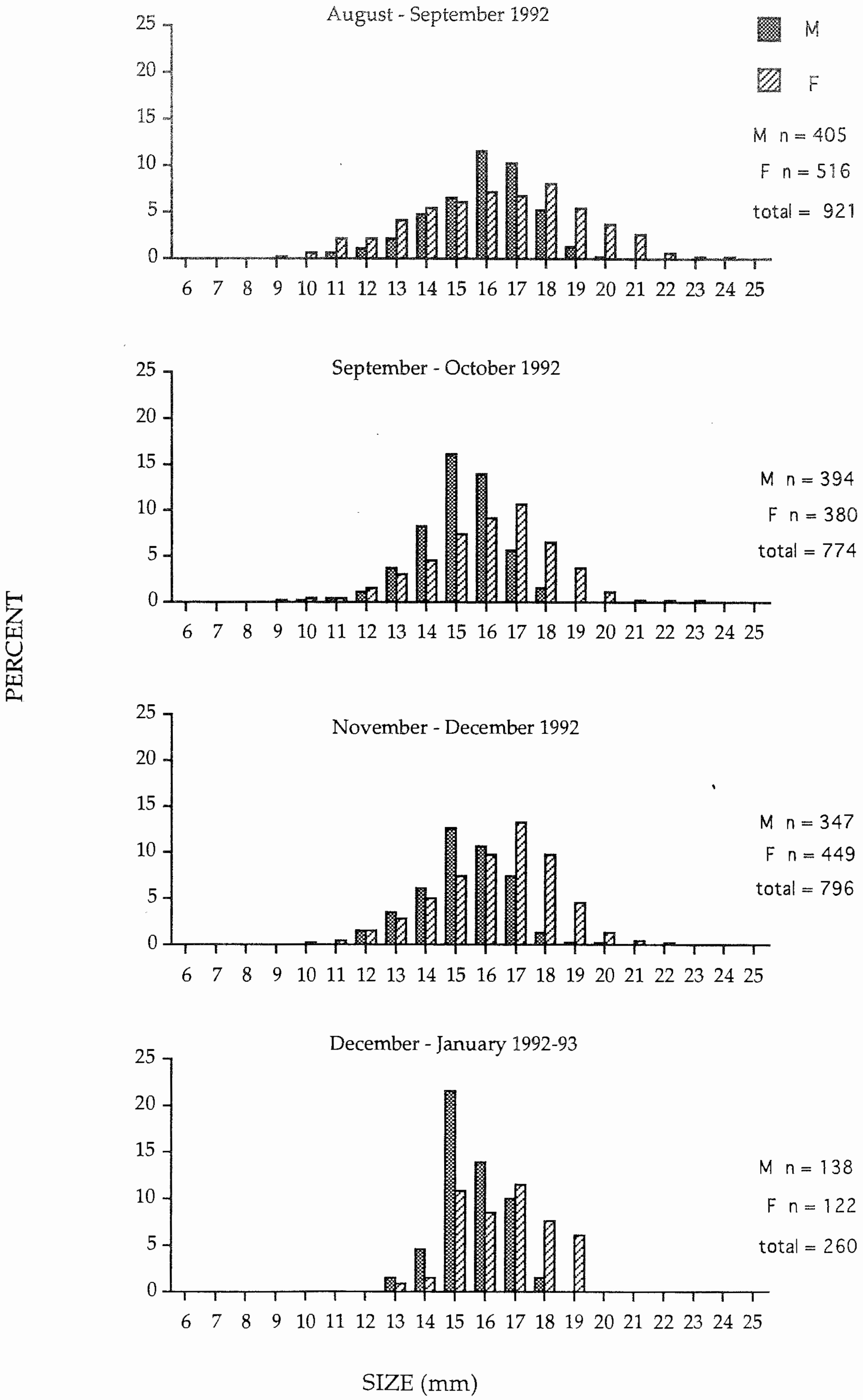
August - September 1992
M
F
M n = 178
F n = 149
total n = 327
September - October 1992
M n = 223
F n = 117
total n = 340
October - November 1992
M n = 155
F n = 157
total n = 312
December - January 1992-93
M n = 110
F n = 123
total n = 233
PERCENT
SIZE (mm)

ZONE 4

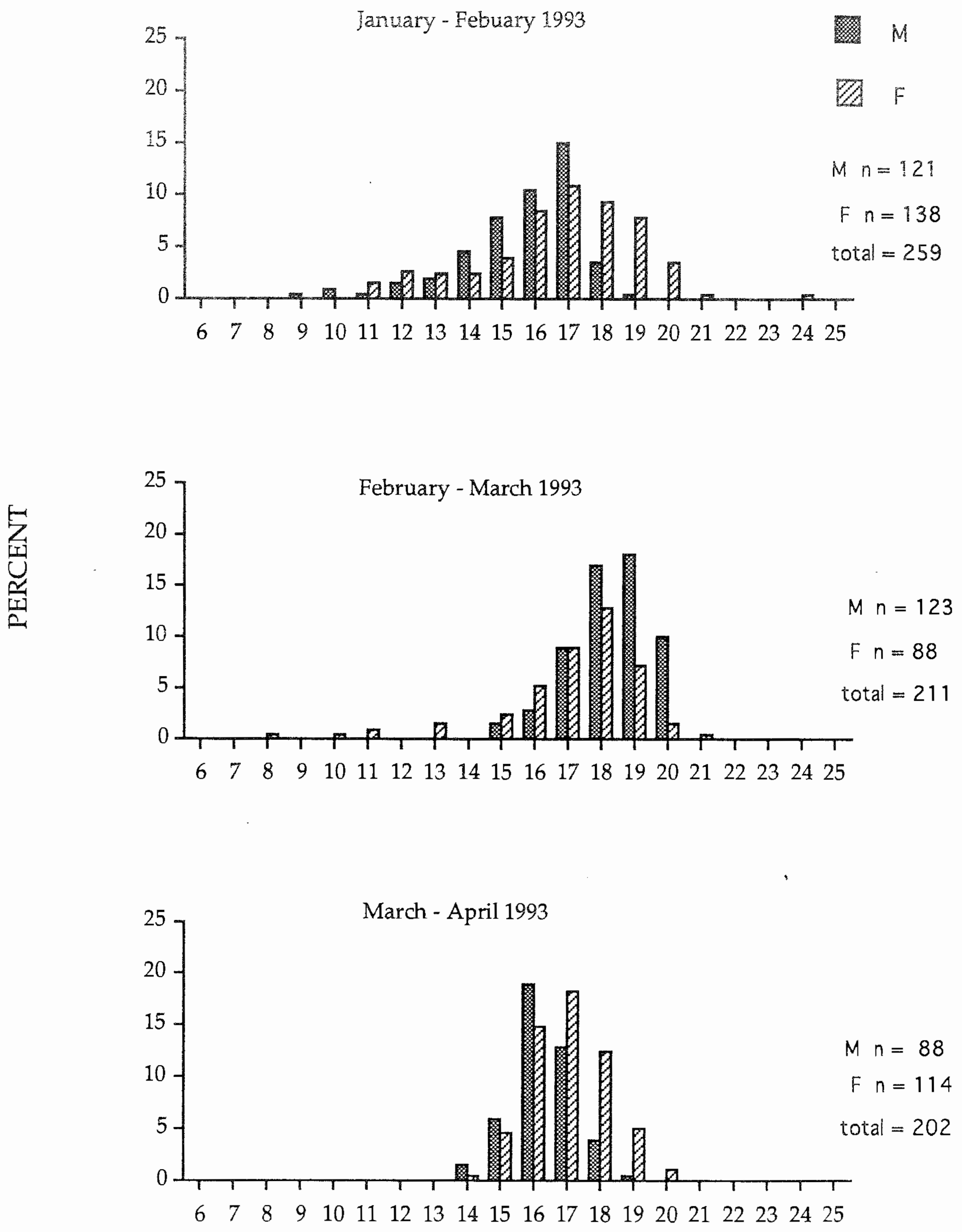


August - September 1991
M
F
M n = 276
F n = 317
total = 593
September - October 1991
M n = 378
F n = 367
total = 745
October - November 1991
M n = 314
F n = 433
total = 747
November - December 1991
M n =234
F n = 186
total = 420
PERCENT
0
5
10
15
20
25
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
SIZE (mm)

# ZONE 4

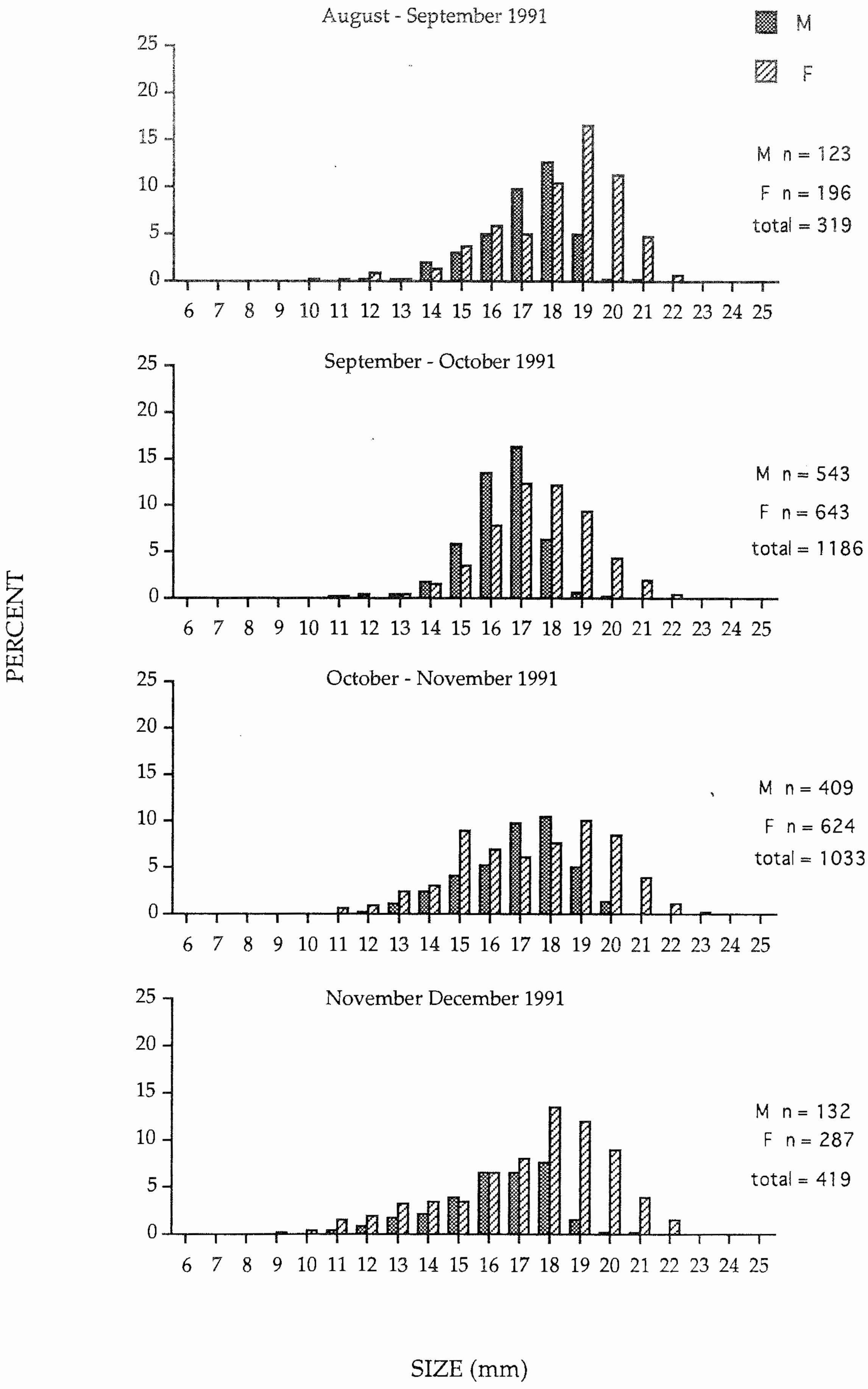

August - September 1992
M
F
M n = 405
F n = 516
total = 921
September - October 1992
M n = 394
F n = 380
total = 774
November - December 1992
M n = 347
F n = 449
total = 796
December - January 1992-93
M n = 138
F n = 122
total = 260
PERCENT
SIZE (mm)

ZONE 4

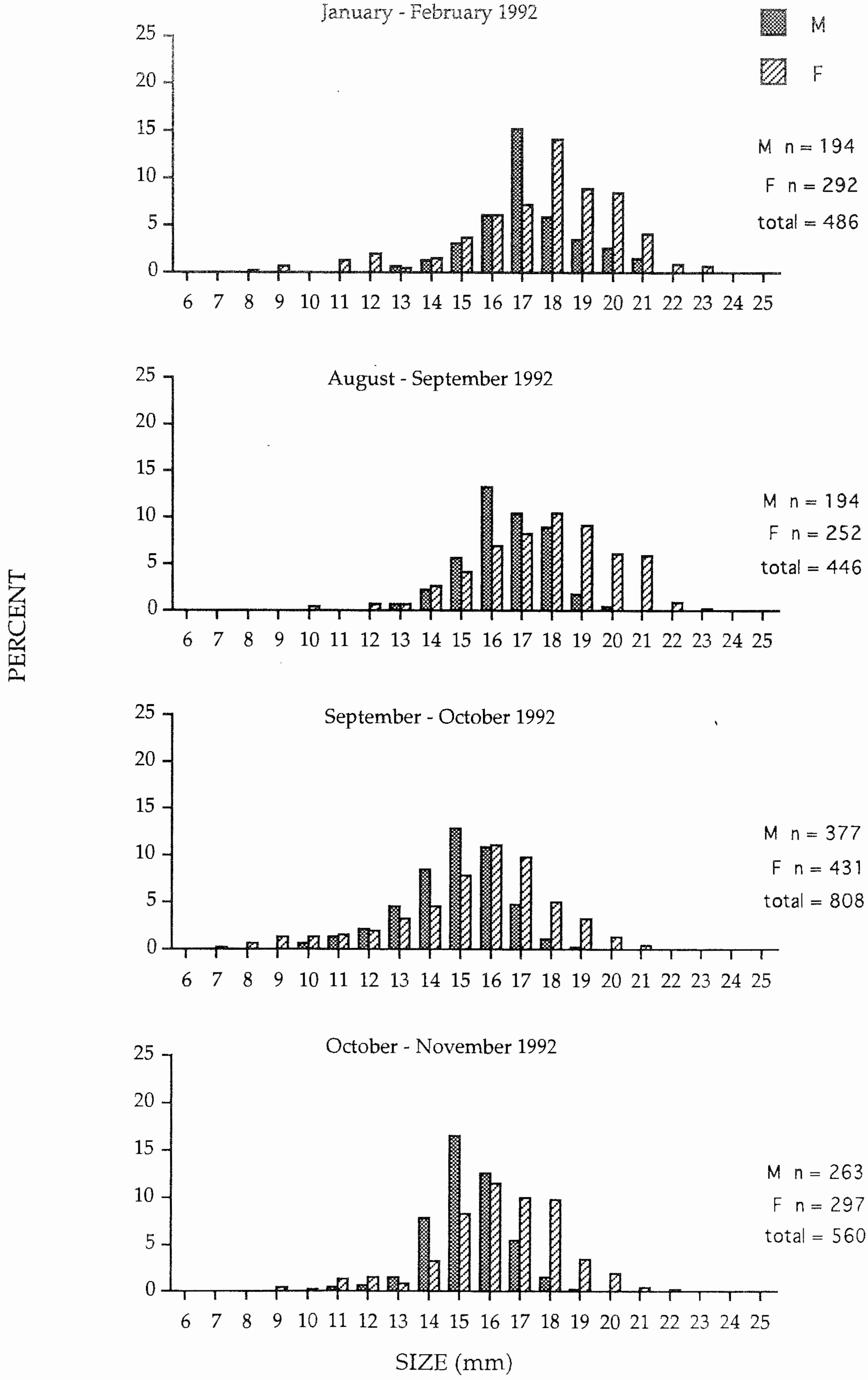



SIZE (mm)

ZONE 5

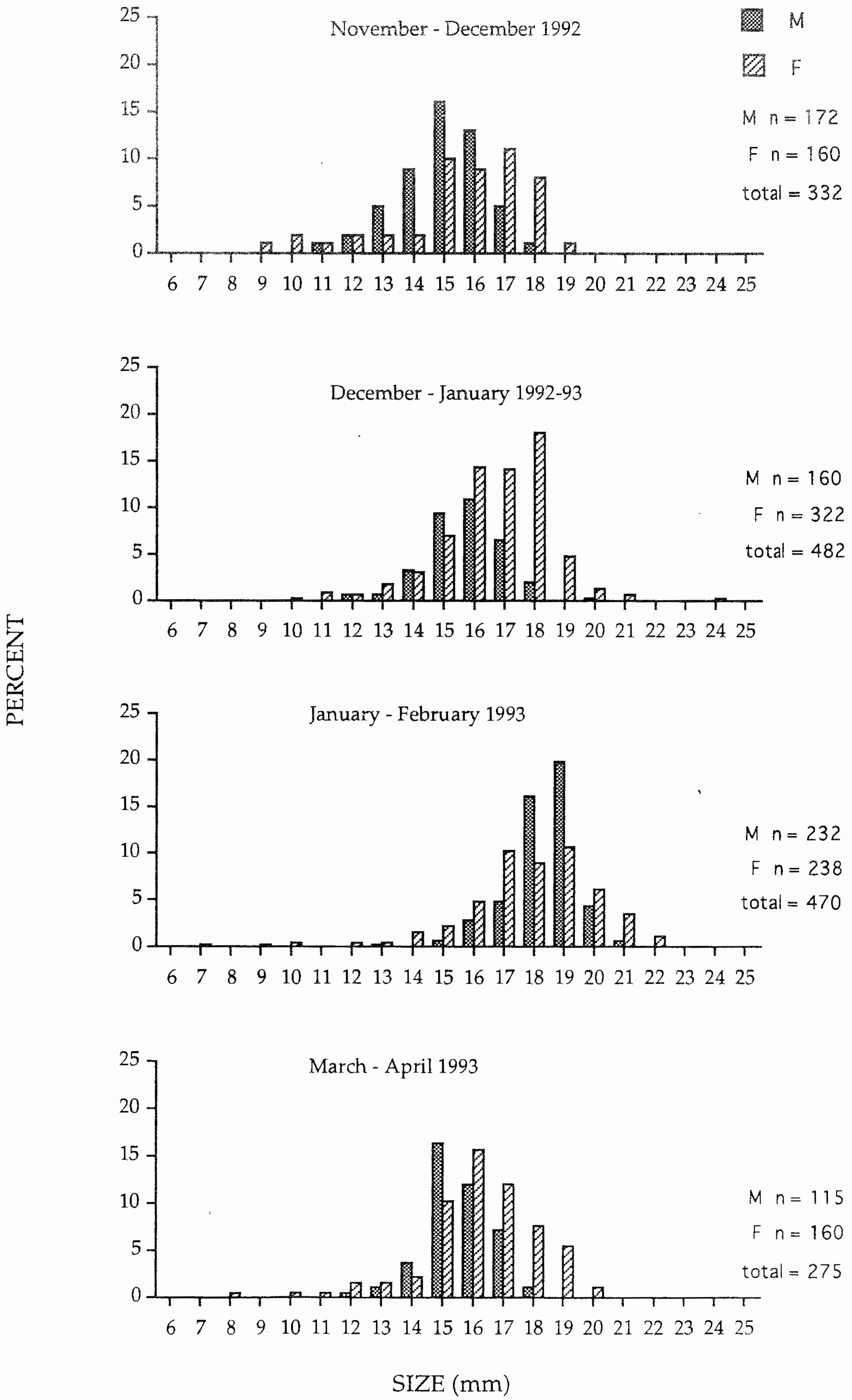

August - September 1991
M
F
M n = 123
F n = 196
total = 319
September - October 1991
M n = 543
F n = 643
total = 1186
October - November 1991
M n = 409
F n = 624
total = 1033
November December 1991
M n = 132
F n = 287
total = 419
PERCENT
0 5 10 15 20 25
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
SIZE (mm)

ZONE 5

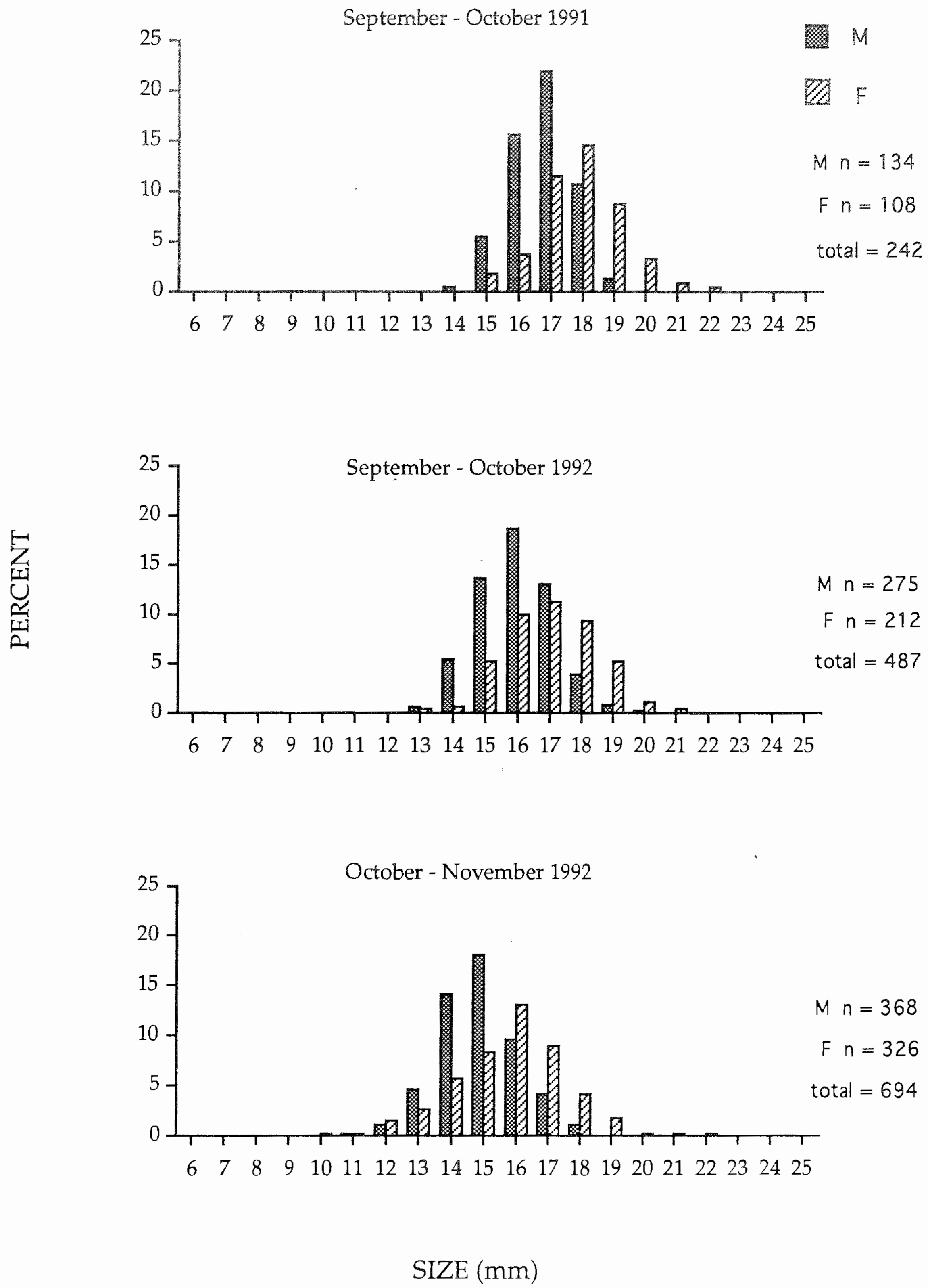


January - February 1992
M
F
M n = 194
F n = 292
total = 486
August - September 1992
M n = 194
F n = 252
total = 446
September - October 1992
M n = 377
F n = 431
total = 808
October - November 1992
M n = 263
F n = 297
total = 560
PERCENT
SIZE (mm)
0 5 10 15 20 25
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

ZONE 5

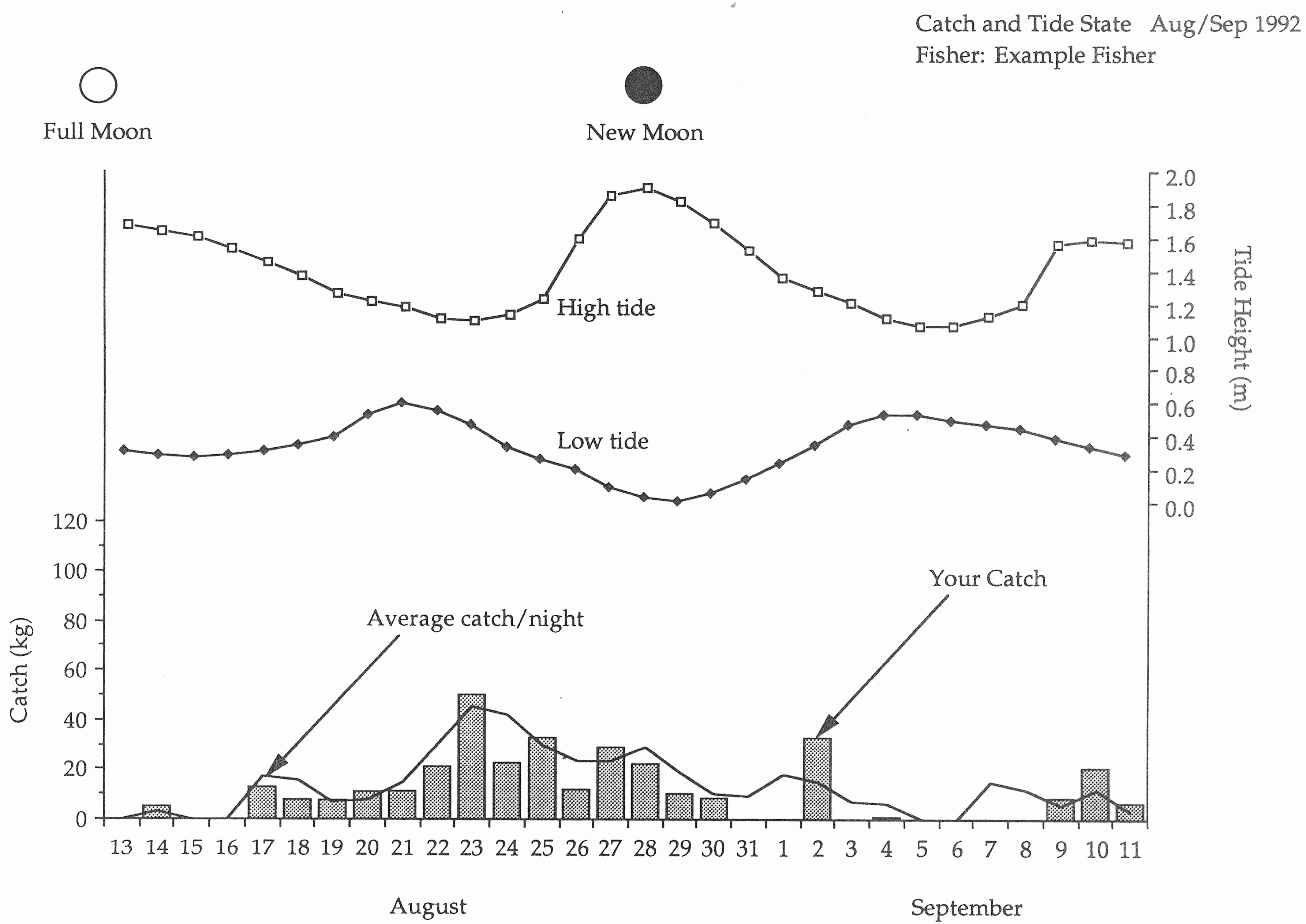

November - December 1992
M
F
M n = 172
F n = 160
total = 332
December - January 1992-93
M n = 160
F n = 322
total = 482
January - February 1993
M n = 232
F n = 238
total = 470
March - April 1993
M n = 115
F n = 160
total = 275
PERCENT
0
5
10
15
20
25
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
SIZE (mm)

ZONE 6


September - October 1991
M
F
M n = 134
F n = 108
total = 242
September - October 1992
M n = 275
F n = 212
total = 487
October - November 1992
M n = 368
F n = 326
total = 694
PERCENT
SIZE (mm)
0
5
10
15
20
25
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

# Appendix Two: Information returned to fishers who participated in the logbook programme and example of logsheet.

In order to promote cooperation with the research, all set pocket netters who participated in the voluntary log book programme received a monthly summary of their catch (see below). In these brief summaries, the catch of each fisher was compared to the monthly average of the fleet and related to lunar phase and state of tide. The response of fishers to this logbook programme was good and ≈ 53% of fishers returned logbooks. An example sheet from the logbook is included.



Catch and Tide State Aug/Sep 1992
Fisher: Example Fisher
Full Moon
New Moon
High tide
Low tide
Tide Height (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Catch (kg)
120
100
80
60
40
20
0
Average catch/night
Your Catch
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11
August
September

Date: ...................................

Dig No ............. LFB ................ Time(s) of slack water................................

Net Type ................................................ Head Rope Length (m).............

Depth of Wing (Meshes)................. Body Width (Meshes).................

| Lift | Start time | Time of lift | wght of prawns (kg) | Engine assist Y/N | Tide (In/Out) |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |
| 17 | | | | | |
| 18 | | | | | |
| 19 | | | | | |
| 20 | | | | | |
| 21 | | | | | |
| 22 | | | | | |
| 23 | | | | | |
| 24 | | | | | |
| 25 | | | | | |
| | | Total prawn catch | | | |

Appendix Three: List of By-catch species caught by pocket netting during this study.

## Species of Commercial value

| Common Name | Species Name |
|---|---|
| Yellowfin Bream | *Acanthopagrus australis* |
| Shortfinned Eel | *Anguilla australis* |
| Mulloway | *Argyrosomus hololepidotus* |
| Longfinned Eel | *Anguilla reinhardti* |
| Snub-Nosed Gar | *Arrhamphus sclerolepis* |
| Nannygai | *Centroberyx affinis* |
| Luderick | *Girella tricuspidata* |
| River Gar | *Hyporhamphus ardelio* |
| Sea Mullet | *Mugil cephalus* |
| Yellow-Finned Leather Jacket | *Meuschenia trachylepis* |
| Snapper | *Pagrus auratus* |
| Largetooth Flounder | *Pseudorhombus arsius* |
| Silver Trevally | *Pseudocaranx dentex* |
| Dusky Flathead | *Platycephalus fuscus* |
| Smalltooth Flounder | *Pseudorhombus jenynsii* |
| Tailor | *Pomatomus saltator* |
| Tarwhine | *Rhabdosargus sarba* |
| Sand Whiting | *Sillago ciliata* |
| Trumpeter Whiting | *Sillago maculata* |

## Species of no commercial value

| Common Name | Species Name |
|---|---|
| Glass Perchlet | *Ambassis spp.* |
| Bridled Goby | *Arenigobius bifrenatus* |
| Black Angler Fish | *Antennarius chironemus* |
| Eagle Ray | *Aetobatus narinari* |
| Narrow banded Sole | *Aseraggodes macleayanus* |
| Black Sole | *Synaptura nigra* |
| Hardyhead | *Pranesus ogilbi* |
| Striped Anglerfish | *Antennarius striatus* |
| Common Goby | *Bathygobius cocosensis* |

| | |
|---|---|
| Mudgudgeon | *Bunaka herwerdenii* |
| Krefft's Goby | *Bathygobius krefftii* |
| Fortesque | *Centropogon australis* |
| Estuary Catfish | *Cnidoglanis macrocephalus* |
| Porcupine Fish | *Dicotylichthys punctulatis* |
| Australian Anchovy | *Engraulis australis* |
| Eel Tail Catfish | *Euristhmus lepturus* |
| Silver Biddy | *Gerres subfasciatus* |
| Southern Herring | *Herklotsichthys castelnaui* |
| Sprat | *Hyperlophus translucidus* |
| Sandy Sprat | *Hyperlophus vittatus* |
| Spotted Stargazer | *Ichthyscopus lebeck* |
| Tiger Mullet | *Liza argentea* |
| Flattail Mullet | *Liza dussumieri* |
| Rock Prawn | *Macrobrachium spp.* |
| Pike Eel | *Muraenesox cinereus* |
| Silver Batfish | *Monodactylus argenteus* |
| Stripey | *Microcanthus strigatus* |
| Bullrout | *Notesthes robusta* |
| Striped Catfish | *Plotosis anguillaris* |
| Trumpeter | *Pelates quadrilineatus* |
| Spikey Flathead | *Ratabulus diversidens* |
| Large-Mouth Goby | *Redigobius macrostoma* |
| Southern Butterfish | *Selenotoca multifasciata* |
| Pink Breasted Siphon Fish | *Siphamia rosiegaster* |
| Toadfish | *Tetractenos hamiltoni* |
| Yellow Tail | *Trachurus novaezelandiae* |