COCKBURN SOUND STUDY

TECHNICAL REPORT ON FISH PRODUCTIVITY

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Department of Conservation & Environment

REPORT No. 4

JUNE 1979

TECHNICAL REPORT ON
FISH PRODUCTIVITY -

An assessment of the marine faunal
resources of Cockburn Sound.

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June 1979

A report to the
COCKBURN SOUND STUDY
1976-1979

Department of Conservation and Environment
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FOREWORD

Cockburn Sound began its development as the outer harbour for the Perth-Fremantle area in the 1950's. Since then a major industrial complex has been built up on the eastern shores. Waste water from several industries and from a major sewage treatment plant is discharged directly into the Sound's waters. A naval facility has been established on Garden Island, which is now linked with the mainland by a causeway, whose construction was completed in 1973.

The industrial area has continued to expand and the Sound's waters are used increasingly for recreation and fishing by both commercial and amateur fishermen.

Deterioration of the marine environment and the building of the causeway led to a series of baseline studies carried out between 1970 and 1975 on the ecology, hydrology and beach morphology of Cockburn Sound. Early in 1975 the Environmental Protection Authority let a contract to a consultant to make a comprehensive review of these studies, to identify problems, to propose approaches to solutions and to point out aspects requiring further research. After the report had been considered by the Environmental Protection Authority and the Conservation and Environment Council the Western Australian Government allocated $500 000 for a three-year (1976-1979) environmental study.

The objective, as approved by Cabinet, was to obtain the information necessary to manage the Sound for multipurpose use, accommodating recreational and fishing activities as well as use for port and industry.

In November 1976 a project leader was appointed and the Cockburn Sound Study Group, a core group of professional and technical personnel, was established. Expertise was also drawn from consultants, government departments and universities. The major aspects requiring investigation were identified and designated as segments of the overall study.

This report covers the work of one of these segments. The conclusions and recommendations presented here relate specifically to the work of this segment. They do not necessarily reflect the conclusions or management proposals detailed in the overview Cockburn Sound Study Report, which has drawn from all segment reports.

CONTENTS

SUMMARY

1. The quantitative assessment of the faunal resources of Cockburn Sound presented in this study support earlier qualitative observations that the Cockburn Sound ecosystem is important in contributing directly or indirectly to harvestable resources from the sea.

2. Cockburn Sound supports a substantial commercial fishery. Total professional production for the 1977/78 fiscal year was 760 910 kg (live weight). The total estimated value of this catch to the fishermen was $486 287. The five most important species taken by professional fishermen were (1) scaly mackerel (*Amblygaster postera*), (2) mussel (*Mytilus edulis*), (3) pilchard (*Sardinops neopilchardus*), (4) Perth herring (*Nematalosa vlaminghi*), and (5) blue manna crab (*Portunus pelagicus*).

3. The number of fish caught in Cockburn Sound by amateur boat fishermen during the year 1978 is estimated to be greater than 2.5 million fish. Ranked by numbers of individuals caught, the four most important species are (1) blue manna crab (*Portunus pelagicus*), (2) Australian herring (*Arripis georgianus*), (3) whiting species (*Sillago* spp.), and (4) skipjack (*Caranx georgianus*). The number of blue manna crabs taken by amateurs from Cockburn Sound is estimated to be about one and a half times the total commercial catch of this species for all Western Australia during the 1977/78 fiscal year.

4. Increased exploitation of species considered potentially more productive is uncertain. One of the resources considered most promising, the edible mussel (*Mytilus edulis*), is threatened by bacteriological and heavy metal contamination.

5. During the faunal survey, 73 fish species and 8 invertebrate species of commercial and recreational fishing interest were identified out of a total of 144 species collected. As both juvenile and breeding adult sized individuals of commercial and non commercial fish species were collected, Cockburn Sound is evidently a nursery and spawning area for a large number of species.

6. The resident species characteristic of the seagrass habitat are of limited direct commercial or recreational fishing interest. The degradation or loss of the seagrass habitat is likely to affect species of commercial or recreational interest indirectly through reduced input of seagrass detritus to the nutrient cycle.

RECOMMENDATIONS

1. The commercial fishery should continue to be monitored, so that any significant changes in catch rates of different species can be detected.

2. Evidence from this study has shown the amateur fishery in Cockburn Sound to be substantial and increasing rapidly with the increase in boat ownership. This resource, which services most of the metropolitan area, should be protected. To this end the fishery could be monitored at a three to five yearly interval.

3. The fishing industry, under the direction of the Department of Fisheries and Wildlife, should be given the opportunity to exploit presently under exploited fisheries of species such as mussels, octopus and western king prawns.

4. The management programme for Cockburn Sound should be directed towards eradication of contamination of mussels (*Mytilus edulis*) by bacteria and heavy metals so that this presently under utilised resource may be exploited.

5. In view of the considerable catch of the blue manna crab (*Portunus pelagicus*) by both commercial and amateur fishermen every effort should be made to reduce the present levels of heavy metals in this species.

6. Cockburn Sound contributes directly and indirectly to the harvestable resources of the sea, particularly by functioning as a proven nursery and breeding area for many important fish species. Thus it should be managed in such a way that, at the very least, will maintain the status quo. This would include ensuring the survival of the remaining seagrass meadows.

7. Further research should be directed at identifying the principle nutrient source for the food web of Cockburn Sound, i.e. seagrass detritus, phytoplankton, micro-algae or some other source.

1. GENERAL INTRODUCTION

The overall objective of the Cockburn Sound Study is orientated to understanding the environment of the Sound so that its various uses can continue. Comprehensive background information on Cockburn Sound as well as an overview of the results of the various segments of the Study is contained in the main report of the Cockburn Sound Study (1).

In the past Cockburn Sound was thought to be an important area of fish productivity near to metropolitan Perth not only in terms of the fish caught by commercial and recreational interests, but also as a protected embayment that many marine species depended upon at some time during their life cycles (2-5).

As the value of the Cockburn Sound ecosystem in contributing directly or indirectly to harvestable resources from the sea had previously not been well quantified, the research of the fish production segment of the Study was directed towards making an assessment of the present and potential productivity for professional and amateur fishermen. More specifically the objectives contained in the working brief for the fisheries segment were the following:-

- To document present production in terms of catches taken by both commercial fishermen and those fishing for recreation.
- To assess potential production, including resources not yet utilised.
- To investigate Cockburn Sound's role as a breeding and nursery area for species fished either in the Sound or taken in adjacent waters.
- To advise on the effects of changing habitats in the Sound.

With regard to the above objectives, the study described in this report provides an assessment of the marine faunal resources in the Sound, using a variety of methods:

- Commercial catch return statistics compiled by the Australian Bureau of Statistics provided the main source of information on the utilisation of the Sound's resources by professional fishermen.
- A creel survey of fishermen interviewed as they returned to boat ramps within the Sound allowed an estimate to be made of the total fish catch of amateur sportsmen.
- Projects conducted by the Fisheries Development Section of the Department of Fisheries and Wildlife were used to evaluate potential production in the Sound.
- Using a variety of trawls, seines and set nets, the Sound's waters were sampled and an inventory of the marine species in the various habitats in Cockburn Sound was compiled in close collaboration with the Department of Fisheries and Wildlife. The size of the fish caught by these conventional fishing methods was measured to evaluate the Sound's importance as a breeding and nursery area for each species.
- As an indirect means of appraising which species assemblages might occur as habitats change, multivariate methods of classification and ordination were used to group together habitats characterised by similar fauna listed in the inventory.

1. (Cont'd)
As these methods were quite different from each other, the various aspects of the marine faunal resource assessment are presented in separate chapters.

2. THE PROFESSIONAL FISHERY

2.1 Introduction

Historically, Cockburn Sound has been a major commercial fishing area from which much of the fresh fish for the metropolitan area has been caught (Penn (5)). As early as 1832, a certain John Thomas is recorded as making a precarious living fishing in the Sound from a crude raft of yoked logs (6). Since those early days the fishing has expanded considerably. During the last financial year 1977/78 the Bureau of Census and Statistics lists 28 full-time commercial fishermen as having operated in the Sound; 20 of these being principally concerned with catching bait fish (for angling and the rock lobster fishery), while catches of the remaining eight contributed to the fresh food fish market of the metropolitan area.

Techniques most commonly used at present include beach seine or haul net (species such as mullet, perth herring, sandy sprat), purse seine (pilchards, scaly mackerel), mesh net (crabs, shark, Australian herring, tailor, etc.) and land line (snapper, mulloway). Dredging is also permitted for the capture of scallops.

In the past some trawling was practiced. However, this has been banned since 1970 (5). Details of this regulation and others relating to professional fishermen operating in closed waters, such as Cockburn Sound, may be read in the Government Gazette (No. 81) of 28 August, 1970 and (No. 56) of 17 September 1976, pertaining to the Fisheries Act, 1905-1969 and 1905-1975 respectively. Unfortunately, as the professional fishery catch within the Sound had not been documented prior to this study comparisons could not be made with the present catch figures.

2.2 Methods

Pursuant to the provisions of the Fisheries Act, 1905-1975, licensed professional fishermen are required to submit monthly details of their catch on the form supplied by the Department of Fisheries and Wildlife. On this form the numbers of fish caught are recorded as well as the species, type of gear used, and location using a numbered block system which is based on a 1^{o} latitude/longitude area grid of the waters fished off Western Australia. These details are then collated for each fiscal year and the results computerised by the Australian Bureau of Statistics.

Until recently, the fish caught in Cockburn Sound were statistically included in the area adjacent to the coast south of the Fremantle Harbour (Block 3215). For a better assessment of the Sound's importance to professional fishermen, Cockburn Sound was designated as a separate area (Block 9600) at the beginning of the fiscal year 1977/78. The Cockburn Sound block is the area enclosed by a line drawn from the South Mole to the Fremantle Inner Harbour through Stragglers Rocks, to Mewstone, Carnac Island, and north end of Garden Island to John Point at Cape Peron on the mainland (see Figure 3.1).

The professional fish catch was further documented for the Cockburn Sound Study by ten fishermen who cooperated in keeping private log books showing the location of their fishing activity and catches within the Sound. These fishermen recorded their activities using the same map location areas designated for the amateur creel survey (see Chapter 3).

2.3 Results

The total commercial fish catch*from Cockburn Sound for the year July 1977 to June 1978 was 760 910 kg (live weight): This amounted to 2.8 per cent of the total Western Australian fish catch of 27 115 906 kg** (live weight) for the fiscal year 1977/78 (unpublished preliminary figures by courtesy of the Australian Bureau of Statistics).

A breakdown by species of the commercial fish catch is shown in Table 2.1. A total of 29 species was caught. Ranked by live weight, the five most important species caught by professional fishermen in Cockburn Sound were: 1 - scaly mackerel (*Amblygaster postera*), 2 - mussel (*Mytilus edulis*), 3 - pilchard (*Sardinops neopilchardus*), 4 - Perth herring (*Nematalosa vlaminghi*), and 5 - blue manna crab (*Portunus pelagicus*).

The total estimated value for the commercial fish catch of Cockburn Sound for the 1977/78 year was $486 778. Ranked by estimated monetary value, the same five species are again the most important but are ordered slightly differently: 1 - scaly mackerel, 2 - mussel, 3 - pilchard, 4 - blue manna crab, and 5 - Perth herring.

The three scale fish among the five top ranked species (by live weight or monetary value) are all used as bait fish, mainly to supply the rock lobster fishery in Western Australia (7). As can be seen from Table 2.1., Cockburn Sound provides a large percentage of the State's catch for these bait fish.

There are approximately 30 professional fishermen deriving their livelihood from Cockburn Sound (several of these are semi-retired and fish only occasionally). Most of these fishermen derive their income from bait fish which are netted using either a purse seine or a beach seine.

Private records of ten professional bait fishermen showed that a large proportion of these fish were caught in map area No. 1 (Fremantle-south), No. 2 (Owen Anchorage) and No. 5 (Success Bank) at the northern end of the Cockburn Sound block (see Figure 3.1). These areas were not highly fished by amateur sportsmen (see Section 3.3).

Mussels are collected for the domestic market and are either sold as fresh mussels to outlets such as restaurants or pickled and distributed as bottled meat. Crabs are usually marketed already cooked in local fish shops. Although of less weight and monetary value than the five key species, many of the other species caught in Cockburn Sound (Table 2.1) are important in providing much of the fresh fish for the Perth metropolitan area (5).

2.4 Discussion

Although 29 species were caught commercially in Cockburn Sound during the year 1977/78 (Table 2.1), the five ranked species, scaly mackerel, mussels, pilchards, Perth herring and blue manna crabs, accounted for 95 per cent of the total catch by live weight. These same five species also accounted for 91 per cent of the estimated income earnings to professional fishermen from Cockburn Sound during the year 1977/78.

* Commercial fish catch includes fish, crustacea and molluscs caught commercially.

** Catch includes fish, crustacea (lobster and prawns) and molluscs.

2.4 (Cont'd)

The other species which are caught in relatively small numbers, are still important because the professional fishery in Cockburn Sound is predominantly a multispecies and multimethod fishery. Exceptions are one man fishing almost exclusively for squid and another diving only for mussels. The reason for this is economic, for in order to make a reasonable living, the other fishermen have to use a variety of fishing methods directed at a variety of species. Thus, some of the species for example snapper, mullet, mulloway and sharks etc., are important in terms of the yearly operations of some fishermen, for they provide some income at times of the year when other species such as bait fish are unavailable.

The number of fishermen operating today is mainly due to the dependence of the rock lobster fishery on a supply of cheap bait. The value of the rock lobster fishery in Western Australia during 1977/78 was more than $50 000 000 and thus provided more than half of the total earnings from fish production in Western Australia (G. Morgan, pers. comm). Some of the pilchards (mulies) caught by professionals are also used as bait by amateur fishermen.

Many of these bait fish were recorded as being caught near the effluent outfalls of the noxious industries in Owen Anchorage and the Woodman Point sewage outfall. These discharges contain high levels of nutrients (8) which enter the planktonic food cycle (9). As these bait fish are mainly planktonic feeders, the bait fishermen probably reap one of the few benefits of this enrichment.

TABLE 2.1

COMMERCIAL FISH CATCH FROM COCKBURN SOUND 1977/78

Species given in kg live weight and value to fishermen.

Log book species code	Species	Live wt. kg	% of State	% of Cockburn Sound	Price per kg*	Value in $
151	Flounder	62	17.9	-	2.00	124
176	Sole	6	0.1	-	2.00	12
251	Pilchard	149,493	13.5	19.6	0.60	89,696
265	Scaly Mackerel	319,418	60.9	42.0	0.50	159,709
276	Sandy Sprat	480	0.8	-	2.00	960
285	Perth Herring	71,505	23.0	9.4	0.40	28,602
320	Bonito	2	-	-	1.00	2
351	Sea Mullet	2,069	0.4	0.3	1.10	2,276
370	Yellow-eye Mullet	6,305	1.4	0.8	0.80	5,044
402	Trevally	180	0.2	-	0.80	144
425	Yellowtail Kingfish	548	1.3	-	0.50	274
490	Australian Salmon	50	-	-	0.30	15
491	Australian Herring	2,510	0.3	0.3	0.80	2,001
495	Snapper	6,678	0.3	0.9	1.50	10,017
510	Mulloway	4,451	37.7	0.6	0.50	2,226
522	Western-Sand Whiting	257	0.2	-	1.40	360
525	King George Whiting	35	-	-	3.50	123
6151	Flathead, Sand & Dusty	9	-	-	0.40	4
651	Gummy Shark	1,542	1.7	0.2	1.00	1,542
660	Bronze Whaler Shark	2,957	2.2	0.4	1.10	3,253
668	Wobbegong	10	-	-	1.00	10
679	Shark, other	1,345	0.3	0.2	1.00	1,345
700	Skates & Rays, other	1,242	24.6	0.2	0.50	621
712	Sea Garfish	179	0.8	-	0.60	107
801	Blue Manna Crab	27,565	21.8	3.6	1.40	38,591
826	Octopus	172	32.4	-	1.00	172
827	Squid	5,629	10.5	0.7	2.50	14,073
828	Cuttle Fish	20	2.2	-	1.25	25
841	Mussel	156,200	68.9	20.5	0.80	124,960
	Total	760,910	2.8	100.0		486,287

* Price per kg is an average paid to fishermen during 1978 from information obtained from Cicerello's Fishmarkets and Kailis M.G. Pty. Ltd.

3. THE RECREATIONAL FISHERY

3.1 Introduction

Whereas the professional catch could be relatively easily obtained from fishermen's monthly returns, no such catch data was available for the amateur fishery. A preliminary survey of fish caught in Cockburn Sound was, therefore, incorporated into the recreational segment of the Cockburn Sound Study (10). This survey provided a very limited cover of the range of recreational fishing activities in Cockburn Sound. In summary it found that, whereas 66 per cent of the boat users interviewed (n = 6 128) listed fishing as their preferred main activity, only two per cent of the beach users interviewed (n = 4 261) did so. In addition this survey established that most of the boat fishermen used boat ramps at locations within Cockburn Sound rather than launch their boats from ramps along the Swan River.

3.2 Methods

Findings of the recreation survey suggested that the fish catch of the amateur sportsman was best estimated from interviews of boat users on their return to boat ramps after fishing on the Sound. From fishermen interviewed in this manner, the creel survey determined the following:-

- which species were being sought and caught in Cockburn Sound,
- where these species were caught,
- when during the year each species was caught, and
- the success rate or number of fish caught per man per hour of fishing.

Following recommendations on methods to minimise error in catch estimates of other creel surveys (11) boat ramp interviews were conducted at the Cockburn public boat ramp and Palm Beach boat ramp (see Figure 3.1) on four weekdays (Monday through Friday) and four weekend days (Saturday and Sunday) each month throughout 1978. The 96 days of these interviews were randomly selected at the beginning of the survey (Appendix 1).

A preliminary survey conducted at the Cockburn Power Boat Club ramp during December 1977, established that the peak period for returning fishermen was between 1130-1430 WST (n = 13 days). Thus interviews were conducted during these three hours. Road traffic counters across the boat ramps were used to determine the proportion of boats using the ramps during these three hours out of the overall ramp use throughout each 24 hour day.

To enable the data obtained during the Recreation Survey to be used for comparison, the same interview sheets and activity area maps (Table 3.1, Figure 3.1) were used in this survey. Those interviewed were requested to state the number of fish of each species they caught, in which map area these were caught, the number of people on their boat fishing for each species, and the hours they spent fishing for their catch.

The above information from interviews was summarised using a computer program to give monthly totals of both weekday and weekend fish catches for each boat ramp. Incomplete interviews were considered invalid and not used in the compilation of these totals.

3.2 (Cont'd)

The type of fishing undertaken was divided into four general categories, namely line, crab, rock lobster and other fishing. This was done to prevent misinterpretation of the fishing success rate (many fishermen stated they were fishing for one species but had caught other species as well). In deciding which of these categories the man-hours fished should be assigned to, the following criteria were considered:

- If the stated prey was any of the species numbering 1 to 8 in Table 3.2 (skipjack to garfish) or if no prey was stated but some fish species of numbers 1 to 8 were caught, then the man-hours were classed as line fishing.

- If the stated prey was crab or if no prey was stated but crabs were caught (and none of species numbers 1 to 8 were caught) then the man-hours were classed as crab fishing.

- If the stated prey was rock lobster or if no prey was stated but rock lobsters were caught (and none of species numbers 1 to 8 or crabs were caught) then the man-hours were classed rock lobster fishing.

- For records falling into none of the above categories, man-hours were classed as other fishing. An examination of the raw data indicates that those falling into the 'other' category were those whose stated prey was 'other' or those who stated no prey and caught nothing or caught 'other'.

3.3 Results

The fish catches of people interviewed during the 1978 creel survey in boats returning to boat ramps in Cockburn Sound (n = 2 035 valid interviews) are presented by weekday and weekend catches for each species in Table 3.2. The number of people fishing for each species is also presented as an indication of angling interest. For comparative purposes, this table also contains the total fish catch for each species by boat users during the 1977 Cockburn Sound Recreation Survey (10).

If the number of fish caught under the 'other' species heading in Table 3.2 are disregarded, the four most important species, ranked by individuals caught, are: 1 - *Portunus pelagicus*, commonly referred to as the blue manna crab, 2 - *Arripis georgianus* or Australian herring, 3 - *Sillago* spp. or whiting species, and 4 - *Caranx georgianus* or skipjack. The number of people who stated they were fishing for a certain species also listed these species as the most important, although in rank order more people fished for skipjack than whiting.

The fishing Success Rate for fish caught during these surveys is given in Table 3.3. The weekday fishermen in the 1978 creel survey are seen to have had the highest rate of success for each division.

During this creel survey, the weekday boat users were characterised by a high percentage of people giving their main activity as fishing (Table 3.4) and they visited the Sound more frequently than the weekend boat users (Table 3.5). The figures for the 1977 Recreation Survey included in Table 3.5 were based on boat users interviewed on six summer days. These included weekdays, weekend days and public holidays (10).

3.3 (Cont'd)
A summary of monthly totals of fish caught during the creel survey for boat ramps on weekend days and weekdays is on file in the Cockburn Sound Study Data Repository (12). As proportionally more weekend than weekdays were surveyed each month, total weekend and weekday fish catches for the three hours of the survey were calculated for a given month by simple proportion extrapolation. These estimates were then combined for both boat ramps. For the three hours of the survey, the estimated monthly catch figures for each species are given in Table 3.6. For many species the greatest number of individuals were caught in the month of April.

Ranked by abundance of individuals of all species caught during the month, the warmer months of January to April were most important. Less fish and noticeably fewer crabs were caught in the colder months of July to September.

Extrapolated in a similar manner to the preceeding months' catches, the weekend and weekday fish catches combined for both boat ramps are also shown classified by the area in Cockburn Sound in which they were caught (Table 3.7). (Note: As the computer program rounded the summary catch data to the nearest 10 units, the extrapolated total catch values for each species in Table 3.6 and 3.7 will not necessarily match). Ranked by percentage of the total catch for all species most fish are caught in map area No. 8 (Cockburn Sound Central), No. 3 (Jervoise Bay), and No. 13 (Southern Flats). In the 1977 Recreation Survey (10), these areas were also found to be among the most intensively fished by boat users.

Map areas No. 1 (Fremantle-south), No. 2 (Owen Anchorage) and No. 5 (Success Bank) rank among the lowest areas of fishing activities for amateur sportsmen in both the 1977 Recreation Survey (10) and the 1978 creel survey. This contrasts with their importance to commercial fishermen (see Section 2.3).

The total number of fish caught in Cockburn Sound by amateur fishermen in boats during the year 1978 is estimated to be 2 581 000 fish (Appendix 2). This estimate is based on a summation of the total numbers of fish caught on weekend days and weekdays (Table 3.2) during the 1978 creel survey. To derive a total catch figure for weekend day fishermen, the total number of fish caught (26 110) by interviewed fishermen was extrapolated upward to the figure of 1 826 000 fish, assuming the following:-

(1) that all interviews were valid,

(2) that all weekend days during the year were surveyed,

(3) that all boat owners using the boat ramps during the weekend days were interviewed,

(4) that all public ramps in Cockburn Sound were surveyed,

(5) that the boat ramps at the Cockburn Power Boat Club were included in the creel survey.

3.3 (Cont'd)
Using similar assumptions, the total weekday catch (16 110 fish) during the creel survey was extrapolated upward to the figure of 754 000 fish caught during the year by amateur fishermen in Cockburn Sound. This weekday catch is combined with the catch on the weekend days to give the overall figure of 2 581 000 fish. The details of the various substudies required to derive the proportional contributions of each of the above assumptions in this extrapolation are on file in the Cockburn Sound Study Data Repository (12).

These estimated fish catch figures show that more than twice as many fish are caught on the weekends as during the rest of the week. This mainly reflects the doubling in numbers of fishermen on the weekends rather than the success rate which is slightly lower on weekend days than on weekdays (Table 3.3).

Probably of more importance is an estimate of the total yearly catch of a given species by boat users that can be derived from the proportion of a species out of the total catch in the original creel survey results (Table 3.2). For example, blue manna crabs represented 8 070/26 110 or 31 per cent of the weekend day catch (1 826 000), giving a total of 564 400 crabs caught during the year on weekends. On weekdays, blue manna crabs represented 6 850/16 110 or 42 per cent of the catch (754 000), giving a total of 320 600 crabs caught during the year on weekdays. If the grand total of 885 000 crabs caught by amateur sportsmen during the year in Cockburn Sound is converted to a weight using a conversion factor (1 dozen - 2.7 kg) (13), the resulting weight of 119 125 kg is seen to be many times the commercial catch of 27 565 kg of these crabs in Cockburn Sound (Table 2.1) and is about one and a half times the total commercial catch of 126 169 kg for all of Western Australia during the 1977/78 fiscal year (unpublished preliminary figures by courtesy of the Australian Bureau of Statistics).

Similarly the numbers of the five most important fish species to amateur fishermen (Table 3.2) were projected and converted to a weight using the following conversion factors:-

Australian herring	-	200 g each (11)	
Whiting spp.	-	172.5 g each)	Based on figures supplied by the Department of Fisheries and Wildlife.
Skipjack	-	137.5 g each)	
Garfish	-	120 g each)	
Yellowtail scad	-	100 g each)	

Thus the projected weight of these fish caught in one year by amateur fishermen amounts to 208 827 kg. The professional fishermen's catch of these species totals only 3 161 kg (Table 2.1) or 1.5 per cent of the amateur fishermen's catch. This clearly illustrates that the species caught by amateurs differ considerably from those sought by professional fishermen.

3.4 Discussion
The results of the 1978 creel survey agree closely with the findings of the 1977 Recreation Survey (10), both in terms of the species caught by amateur fishermen in Cockburn Sound (Table 3.2) and the areas of the Sound which were most intensively fished (Table 3.7 and p.179 (10)).

3.4 (Cont'd)

Many estimates of total fish catches derived from creel surveys suffer from the numbers of assumptions required to perform an extrapolation from the survey data (see Lenanton and Hall, 1976 (11)). For the surveys conducted in Cockburn Sound, however, the assumptions required are relatively minor as most fish appear to be caught by people fishing from boats which are mainly launched from only four locations (10).

The choice of hours to interview returning boat users was influenced by the prevailing summer wind pattern across Cockburn Sound (see Steedman and Craig, 1979 (14)). Many boat users returned to the ramps during these hours as the seas became choppy during the afternoon sea breeze. These hours, however, probably underestimated the 24 hour catch returns for species such as snapper in winter and tailor in summer which are often caught at night by fishermen who would have returned to the ramp before the interviews began.

The main species fished for in Cockburn Sound by amateur fishermen appear to be blue manna crabs, Australian herring, whiting and skipjack (Table 3.2). Thus with the exception of blue manna crabs, the main species caught by amateur fishermen are different from those sought by professional fishermen. The large numbers of amateur fishermen fishing for blue manna crabs (Table 3.2) indicates why the recreational catch of this species in Cockburn Sound is considerably greater than the professional catch. Moreover, as far as is known none of the professional fishermen in Cockburn Sound derive more than a small proportion of their income from their catch of crabs. Thus serious conflict of interest (see Lenanton, 1978 (13)) over the catch of the same species by amateur sportsmen and professional fishermen in Cockburn Sound is largely avoided.

Public pressure to restrict commercial fishing activities on the grounds that they are interfering in various ways with recreational fishing, should be viewed in the light of the above findings.

If the taking of crabs from Cockburn Sound is to continue some action should be taken to ensure that contamination by heavy metals is not perpetuated. Chegwidden (15) has found levels of lead in crab flesh and levels of cadmium in crab hepatopancreas which exceed the recommended National Health and Medical Research Council's standards. The maximum cadmium concentration (68 $\mu g\ g^{-1}$) in hepatopancreas was found in crabs collected near the CSBP jetty, although elevated levels were found from most sampling sites in Cockburn Sound.

The number of amateur fishermen using Cockburn Sound appears to be increasing much more rapidly than the number of professional fishermen. Although quantitative data is lacking for Cockburn Sound specifically, an indication of this increase may be seen in statewide registration of boats. While the total number of boats registered to professional fishermen in Western Australia has increased from 1 456 in 1963 to only 1 789 boats in 1978 (source: Department of Fisheries and Wildlife), the total number of registered power boats during the same period has increased from approximately 5 200 in 1963 to 52 161 in 1978 (Source: Harbour and Light Department). Many of these power boat owners would also be amateur fishermen; the number of amateur fishermen licenced in metropolitan Perth and Fremantle combined has increased from 5 624 in 1972 to 14 529 in 1977

3.4 (Cont'd)
Source: Department of Fisheries and Wildlife). In addition with increased fuel costs more people will be turning to areas closer to the metropolitan area for their fishing activities rather than drive some distance to reach other suitable fishing grounds.

During the creel survey, amateur sportsmen, who have had a long association with fishing in Cockburn Sound, were recorded as complaining that a decrease in their individual catch rates was an indication that fish stocks in the Sound were being overfished or degraded by industrial effluents. While no quantitative data on the abundance of fish stocks in previous years exists to substantiate these claims, one consequence of the increase in the number of amateur fishermen is that more fishermen are competing for a share of the available fish stock. Assuming that the fish numbers have remained fairly constant in the past, and that the stocks have always been fished to capacity, each fisherman's share of the total catch would tend to decrease inversely each year as the number of fishermen increased (13).

However, if the decline in the fish stocks of Cockburn Sound is real, the authorities condoning disturbances of Cockburn Sound must be prepared to weigh their actions with due regard for consequent changes to the environment. Although fish are poor indicators of subtle changes in water quality (16) their numbers tend to be regarded by the general public as an index of the success or otherwise of the activities of authorities in protecting the environment.

TABLE 3.1

SURVEY SHEET USED FOR INTERVIEWING BOAT USERS AT BOAT RAMPS IN COCKBURN SOUND DURING 1977 RECREATION SURVEY AND 1978 CREEL SURVEY

COCKBURN SOUND RECREATION SURVEY

DATE ______ ☐ ______________ LAUNCH RAMP DATA SHEET INTERVIEWER ______________ SHEET No ______

TIME	BOAT TYPE	REGISTRATION NUMBER	No. of PEOPLE ABOARD	FAMILY	POSTCODE of RESIDENCE of OWNER	ACTIVITY						MAIN AREA (Map No.)	TIME OUT (Hours)	FISH CATCH (numbers)											TIME FISHING (hours)	No of PERSONS FISHING	FISHING FOR ?	VISIT FREQ				COMMENTS	CODE
						PI BOAT	W/SKI	RACING	DIVING	FISHING	OTHER			1 SKIPPY	2 SNAPPER	3 TAILOR	4 WHITING	5 HERRING	6 YELLOW TAIL	7 BLOWFISH	8 GARFISH	9 ROCK LOBSTER	10 CRABS	11 OTHER				Daily	Weekly	Sometimes	1st Time		

TABLE 3.2

NUMBER OF INDIVIDUALS OF EACH SPECIES (TO THE NEAREST 10 UNITS) CAUGHT IN COCKBURN SOUND.

Indicated by interviewed boat users on their return to boat ramps within the Sound.

No.	Species	1977 RECREATIONAL SURVEY Total all ramps		1978 CREEL SURVEY Weekend total		1978 CREEL SURVEY Weekday total	
		No. fish caught	People fishing for	No. fish caught	People fishing for	No. fish caught	People fishing for
1	*Caranx georgianus* (Skipjack)	2,250	301	2,370	194	1,120	68
2	*Chrysophrys unicolor* (Snapper)	130	95	50	85	30	46
3	*Pomatomus saltatrix* (Tailor)	350	43	420	21	420	18
4	*Sillago* spp. (Whiting)	2,290	185	2,820	132	1,810	65
5	*Arripis georgianus* (Herring)	2,640	271	4,790	254	2,450	100
6	*Trachurus mccullochi* (Yellowtail scad)	1,380	5	1,850	2	850	0
7	*Torguigener pleurogramma* (Blowfish)	340	4	30	0	0	0
8	*Hyporhamphus melanochir* (Garfish)	740	6	2,200	24	870	10
9	*Panulirus cygnus* (Rock lobster)	70	170	80	9	20	2
10	*Portunus pelagicus* (Crab)	6,880	809	8,070	677	6,850	450
11	Various other species (Other)	2,470	140	3,430	1,108	1,700	493
	Total	19,530	1,876	26,110	2,506	16,110	1,252

TABLE 3.2

TABLE 3.3

THE SUCCESS RATE OF AMATEUR FISHERMEN INTERVIEWED DURING THE COCKBURN SOUND STUDY

Division	1977 RECREATIONAL SURVEY TOTAL ALL RAMPS			1978 CREEL SURVEY WEEKEND TOTAL			1978 CREEL SURVEY WEEKDAY TOTAL		
	No. fish caught	Man-hours fished	Fish caught man-hour	No. fish caught	Man-hours fished	Fish caught man-hour	No. fish caught	Man-hours fished	Fish caught man-hour
Line Fishing (Species Nos. 1-8)	10,120	3294.0	3.07	14,530	2531.3	5.74	7,550	1158.5	6.52
Rock Lobster Fishing (Species No. 9)	70	37.0	1.89	80	15.5	5.16	20	2.0	10.0
Crab Fishing (Species No. 10)	6,880	2536.0	2.71	8,070	2308.5	3.50	6,850	1527.7	4.48
Other Fishing (Species other than above)	2,470	4640.0	0.53	3,430	6441.0	0.53	1,700	2480.6	0.68

TABLE 3.4

THE PROPORTION OF PEOPLE FISHING OUT OF THE TOTAL NUMBER OF BOAT USERS INTERVIEWED DURING THE COCKBURN SOUND STUDY.

The number of hours these fishermen spent fishing during each boat trip is also given.

	1977 RECREATIONAL SURVEY TOTAL ALL RAMPS	1978 CREEL SURVEY WEEKEND TOTAL	1978 CREEL SURVEY WEEKDAY TOTAL
Total number of boat users interviewed	6,128	4,015	1,782
Number persuing activities other than fishing	2,649 (43.2%)	627 (15.6%)	250 (14.0%)
Number fishing	3,479 (56.8%)	3,388 (84.4%)	1,532 (86.0%)
Time spent fishing by fishermen (hours)			
Mode	3.0	4.0	3.0
Mean	3.0	3.3	3.3
Standard Deviation	1.8	1.4	1.5

TABLE 3.5

FREQUENCY OF VISIT TO COCKBURN SOUND BY BOAT OWNERS INTERVIEWED DURING THE COCKBURN SOUND STUDY

Frequency of Visit	1977 RECREATIONAL SURVEY TOTAL ALL RAMPS	1978 CREEL SURVEY WEEKEND TOTAL	1978 CREEL SURVEY WEEKDAY TOTAL
Daily basis	84 (4.9%)	11 (0.8%)	26 (3.7%)
Weekly basis	667 (39.3%)	312 (23.3%)	219 (31.5%)
Sometimes	775 (45.7%)	957 (71.5%)	408 (58.7%)
First time	171 (10.1%)	59 (4.4%)	42 (6.0%)
Total number of boat owners interviewed	1,697	1,339	695

TABLE 3.6

ESTIMATED MONTHLY NUMBER OF INDIVIDUALS (DIVIDED BY 10) OF SPECIES CAUGHT BETWEEN 1130-1430 WST IN COCKBURN SOUND BY BOAT USERS DURING THE 1978 CREEL SURVEY.

	MONTH												
Species	January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
Skipjack	80	15	61	438	224	66	32	44	26	20	36	69	1,111
Snapper	0	0	4	5	6	0	0	0	0	0	3	0	18
Tailor	206	14	21	35	12	2	3	4	7	12	7	5	327
Whiting	115	46	61	212	35	76	18	132	196	268	187	257	1,603
Herring	148	147	344	505	173	368	140	118	144	86	68	146	2,387
Yellow-Tail	137	69	120	198	86	58	18	49	18	42	10	68	873
Blowfish	0	0	2	5	0	0	0	0	0	0	0	0	7
Garfish	16	31	31	222	137	204	72	88	20	90	14	34	959
Lobster	2	4	2	8	0	0	0	0	0	0	0	5	21
Crabs	823	975	1,013	938	366	32	5	2	20	412	473	387	5,446
Other	192	129	147	310	36	123	25	115	97	152	178	180	1,684
Catch during month	1,718	1,430	1,806	2,876	1,075	929	313	552	528	1,082	976	1,151	14,436
% of total catch	11.9	9.9	12.5	19.9	7.4	6.4	2.2	3.8	3.6	7.5	6.8	8.0	100.00
Rank by catch	3	4	2	1	7	9	12	10	11	6	8	5	

TABLE 3.7

ESTIMATED NUMBER OF INDIVIDUALS (DIVIDED BY 10) OF EACH SPECIES CAUGHT BETWEEN 1130-1430 WST WITHIN THE MAP AREAS USED IN THE COCKBURN SOUND CREEL SURVEY

Species	MAP AREA																Species total catch
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Skipjack	9.8	33.2	69.8	6.7	18.5	20.1	25.7	258.3	37.7	24.8	50.0	2.2	491.2	66.1	15.9	12.0	1123.7
Snapper	0	0	0	0	0	0	0	5.3	4.5	2.2	0	0	7.5	2.2	0	7.5	27.1
Tailor	0	0	0	0	6.7	28.5	24.6	189.9	5.3	12.8	18.1	0	18.7	7.5	0	0	316.7
Whiting	0	0	64.2	24.6	0	188.8	17.3	143.0	217.3	22.3	16.5	30.1	250.8	281.8	266.4	74.9	1590.4
Herring	14.2	109.7	113.1	4.5	6.7	428.1	8.9	180.1	101.9	368.1	112.8	35.4	602.6	248.5	15.9	31.3	2370.0
Yellow-Tail	10.6	31.5	43.5	2.2	13.4	90.0	17.9	298.5	56.9	27.1	87.8	2.2	151.9	36.0	0	0	864.3
Blowfish	0	0	2.2	0	0	0	2.2	0	0	0	0	2.2	0	0	0	0	6.7
Garfish	0	29.9	66.0	0	10.6	136.6	10.6	145.0	12.8	24.8	53.0	16.5	263.1	178.7	0	2.2	953.1
Lobster	0	0	0	0	0	2.2	0	2.2	2.2	4.5	4.5	0	0	2.2	0	5.3	28.5
Crabs	0	99.4	2329.3	84.4	0	33.8	170.1	1337.1	321.2	72.6	84.6	121.3	756.2	28.5	0	0	5437.4
Other	6.7	48.8	80.1	18.1	2.2	197.7	32.4	310.2	170.7	126.8	89.3	12.0	186.3	234.5	62.5	86.6	1668.3
Map area total catch	39.1	344.4	2765.2	140.5	60.8	1119.3	304.4	2864.3	925.2	689.2	510.2	235.1	2726.1	1081.9	357.7	217.5	14381.0
Area per cent of total catch	0.3	2.4	19.2	1.0	0.4	7.8	2.1	19.9	6.4	4.8	3.5	1.6	19.0	7.5	2.5	1.5	100.00
Rank by catch	16	10	2	14	15	4	11	1	6	7	8	12	3	5	9	13	

TABLE 3.7

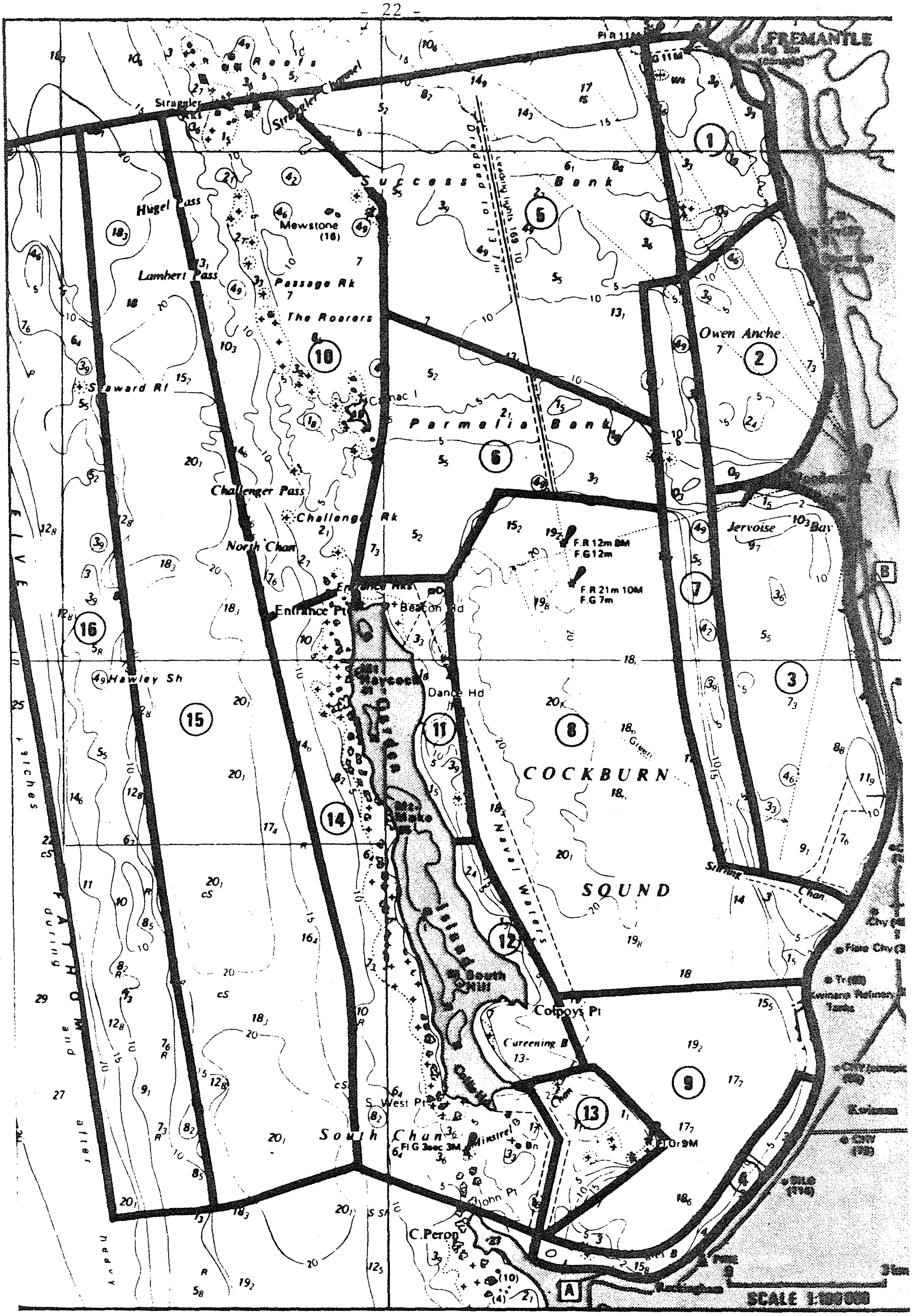

FIGURE 3.1

Map used to determine main areas (1-16) of fishing activity by boat users interviewed upon their return to either the Palm Beach boat ramp (A) or the Cockburn public boat ramp (B).

4. POTENTIAL PRODUCTION

4.1 Introduction

At the present time when many of Australia's fisheries are being exploited at near optimum sustainable yields, and as the human population continues to expand, methods of increasing fish production need to be developed (17). Increases in production have traditionally come from areas or species that previously have been under exploited. Historically, Cockburn Sound has been fished since the start of the colony (6), leaving no unexploited areas. Thus the best approach today may be directed toward species presently under utilised.

4.2 Methods

The assessment of potential production in Cockburn Sound was attempted only on a qualitative basis by talking with experienced fishermen and officers of the Department of Fisheries and Wildlife. The Development Research Section of this Department is currently investigating the future potential of several species in Cockburn Sound which are not yet being fished or are being lightly exploited at present.

4.3 Results

Of the various species that have been considered for increased production within Cockburn Sound by the Department of Fisheries and Wildlife, the edible mussel (*Mytilus edulis*) is one of the most promising. The species is present naturally in the *Posidonia* seagrass community in Cockburn Sound and as many as six spawnings per year have been recorded (18). Transplanted spat were found to grow extremely well on ropes suspended for experimental rafts in a project initiated by Dr. R.J. MacIntrye of the University of New South Wales (55). Mussels cultivated in this manner have a faster growth rate and are comparably clean and easier to harvest than mussels colonising the dead root-mesh of seagrass. Feasibility studies conducted by interested commercial fishermen on privately owned rafts suggest that the potential is limited only by the market capacity (R.K. Steedman, pers. comm.).

Another mollusc, the scallop *Pecten modestus*, is characteristic of the central basin of Cockburn Sound (19). During the peak of the fishery for this species between August and November 1970, catch rates of 200-400 kg per hour from the southern end of Cockburn Sound were resulting in an annual total catch of some 2 153 tonnes (D.I. Heald, unpublished) recorded. This fishery ceased in early 1974 after the catch rate declined to only 25 kg per hour (20). The latest scallop survey of Cockburn Sound in 1977 failed to catch this species in commercial quantities (D.I. Heald, pers. comm.). At present the Cockburn Sound stock is being monitored by the Department of Fisheries and Wildlife as scallops are renowned for their ability, following successful spatfall, to undergo large scale population changes from a low density to levels which would be considered highly economic.

Prawn catches in the study's survey (Table 5.1) show the species, *Penaeus latisulcatus*, to rank fourth in abundance. This and population estimates made by Penn (5) provide evidence of considerable numbers of prawns in Cockburn Sound which are not presently being exploited.

4.3 (Cont'd)
The Development Research Section of the Department of Fisheries and Wildlife, in conjunction with a Japanese research team, also surveyed the relative abundance of octopus (*Octopus tetricus*) in the Fremantle area between 18 March and 19 April, 1978. Using a pot longlining method, several thousand pots in Cockburn Sound resulted in the catpure of only several hundred octopus (J.P. Robins, pers. comm.). Subsequent studies in 1979 have shown that the catch rate in Cockburn Sound (10.3 octopus per 100 holes) using the pot method of capture was in fact better than in the Japanese octopus fishery for example where 8.8 octopus are caught per 100 holes.

4.4 Discussion
Given the 1979 catch rates of octopus this fishery could be viable. The potential for a market being mostly in export to Japan with a limited local market in Western Australia.

The potential of the mussel (*Mytilus edulis*) would appear much more promising. The ability of this species to accumulate high body tissue levels of contaminants, exceeding health standards, however, threatens the present production and possibility of future aquaculture. Mussels cultured in Owen Anchorage have been found to be contaminated to the extent that they exceed public health specifications in both the heavy metal, cadmium and *Salmonella* bacteria (15). Depuration processes by maintaining the mussels in uncontaminated water prior to marketing can eliminate the hazard of bacteria, although this requirement adds to the cost of production. One additional factor likely to threaten the expansion of any mussel culturing industry is the conflict of demands required of the Cockburn Sound area. Presently designated as the outer harbour of Fremantle, mussel rafts are considered to be a hazard to shipping manoevering in the harbour.

As the ability of the scallop to concentrate cadmium may be about 20 times that of the mussel (15), any future scallop fishery would require careful monitoring before marketing.

While the effects of heavy metal effluents in fish are discussed in greater detail by Chegwidden (15), a simple example affecting present potential productivity is the tainting of fish (generally said to have a "kereosene" flavour) in the vicinity of the oil refinery. One professional fisherman in Cockburn Sound reported a catch of 1 364 kg of tainted fish (21). Tainting of sea mullet (*Mugil cephalus*) in the Kwinana area, forced at least three professional fishermen during 1978 to sell their catch as rock lobster bait rather than for human consumption.

5. INVENTORY OF MARINE FAUNAL RESOURCES

5.1 Introduction

Detailed studies on the marine faunal resources of Cockburn Sound are limited. In an appendix of a study published in 1970 by the Australian Conservation Foundation (2), R.J. McKay, then of the Fish Department of the Western Australian Museum, listed 66 species regarded as food fishes that had been recorded from Cockburn Sound. Twenty two of these species were thought to use Cockburn Sound as a nursery area.

Since 1971 the deep waters of the northern portion of the Cockburn Sound basin have been used by the Fisheries Research Branch of the Department of Fisheries and Wildlife for king prawn research. Significant catches of crabs, prawns and fish taken from this research area by R.V. "Flinders" during night trawling operations has indicated that this area is a more important fish and crab habitat than was previously thought (5). Penn listed 46 species of fish, crustaceans and molluscs taken during these trawls (Table 2 (5)) of which 21 species were regarded as being of commercial importance.

5.2 Methods

Preliminary sampling trials with various conventional fishing methods were carried out at the beginning of the year 1977. These were used to establish the best locations for sampling sites and the effort required to make a faunal survey that could be repeated, usually on a bi-monthly basis, for a minimum of at least one year. The sampling effort was orientated towards those species which are of commercial or recreational value to fishermen. The fishing gear and sampling locations in this survey are summarised below. More detailed descriptions of nets used, methods employed and sampling site characteristics are held on File (#67/76/191) in the Cockburn Sound Study Data Repository (12).

- The large trawl, designated as net type No. 1, was an 18 m headrope flat trawl with 51 mm mesh wings and 45 mm mesh cod end. This net was trawled by the Department of Fisheries and Wildlife trawler, R.V. "Flinders", at nine sites chosen to give as wide a coverage as possible for the deep basin of Cockburn Sound. The bi-monthly programme (between June 1977 and September 1978) consisted of nine 15 minute trawl shots carried out after sunset and three 15 minute trawl shots between sunrise and sunset at the same positions as three of the night trawls (Figure 5.1).

- The small trawl, designated as net type No. 2, was a 3.6 headrope otter trawl with 5.1 cm mesh body and 2.5 cm mesh cod end. This trawl was operated from the Cockburn Sound Study Group's boat, a 5.5 m fibreglass boat powered by an 85 h.p. outboard engine. At the start of the bi-monthly programme (between May 1977 and June 1978), all shots were 15 minutes in duration but owing to the difficulty in handling the size of the samples taken, the trawls were reduced to 7½ minutes in January 1979. Eight positions were sampled around the shallow periphery of the Sound (Figure 5.2).

- The beach seine, designated as net type No. 3, was 210 m long and 100 meshes deep with a mesh size of 2.45 cm. The central pocket is constructed from mesh grading from 1.58 to 0.9 cm. The area swept by the net during a shot was approximately

5.2 (Cont'd)

7 000 m^2. The net was set from a three m dingly at 11 locations around the periphery of the Sound (Figure 5.3). In April 1977, these sites were sampled during daylight hours; during the remainder of the bi-monthly programme (between May 1977 and June 1978) seining was carried out at night.

- Four 50 m long set nets, designated as net types No. 4, 5, 6 and 7, were of 35, 50, 75 and 100 mm mesh stretch mesh size respectively. Basic bi-monthly sampling (between July 1977 and July 1978) with this gear consisted of setting all four nets at each of four different stations (Figure 5.4); this sampling required four nights' work as the nets were set at nightfall and picked up at first light in the morning.

- A professional fishermen was employed to set a larger set net, designated as net type No. 8 with 150 mm stretch mesh size. All nets were 3.2 m deep but varied in length from 119 m to 586 m. Using two such nets, six locations (Figure 5.5) were each sampled for 24 hours during a three day period. The nets were set, retrieved the next day, and then reset at two more locations. Unlike the other methods above, sampling with this net was done only every three months (between April 1977 and April 1978).

The fish obtained from the sampling operations outlined above were sorted, identified to species and measured immediately after capture. If there were less than 50 individuals of a given species, all individuals were measured. With larger catches, a subset of only 50 individuals was measured and the remainder counted to obtain the total number of individuals caught.

All measurements were recorded to the nearest centimetre. Most 'fish' species were measured for 'total length' from the tip of the snout to the tip of the tail. Rays and skates, however, were measured for maximum width, not length. Crabs were measured for maximum carapace width. Measurement of several other species, e.g. cephalopod molluscs and prawns, was not attempted although the number of individuals caught was recorded.

For each species in a given collection sample, the date, net type, position, and the map area used in the creel survey (see Figure 3.1) was recorded for computer compilation and summary purposes. The species code number, the number of individuals caught and the number of individuals in a given size class were also recorded. The entire faunal inventory is stored on computer by the Department of Fisheries and Wildlife (enquiries should be directed to Mr. N. Hall).

5.3 Results

A total of 202 363 individuals representing 144 different species were counted and identified during the survey for the faunal inventory of Cockburn Sound using eight net types (Table 5.1). A check list of these species, their common names and whether the species is of commercial or recreational importance is given in Appendix 3.

Considerable variation in abundance existed among the species collected (Table 5.1). Many species were very rare (or at least not captured by sample. On the other hand the first 15 species ranked by abundance made up over 90 per cent of the total individuals captured.

5.3 (Cont'd)

Considerable variation was also evident in the number of individuals and species captured by the various fishing methods (Table 5.2). Although the small trawl and the set nets (net types # 2, 4, 5, 6, 7 and 8) together only accounted for 7.2 per cent of the total number of individuals captured in the survey, these methods were an important means of sampling shallow water benthic fauna or nectonic species that were not well represented in the catch of the large trawl or the beach seine. The species captured by the small trawl and these set nets are presented in Tables 5.3-5.8.

The large trawl (net type #1) and the beach seine (net type #3) together accounted for 92.2 per cent of all the individuals captured during the whole survey (Table 5.2). A large percentage of the total number of species collected in this faunal inventory is also represented in the catch of both these methods. The species caught in the large trawl ranked by abundance, are presented in Table 5.9. In a similar presentation, the species collected by the beach seine are shown in Table 5.10.

In all the tables showing the species collected by a given net type, the size range of the measured individuals for given species is presented as an indication of whether that species uses Cockburn Sound as a nursery and some information on the presence of adults capable of spawning. Although there was naturally some selective difference in the sizes of individuals of a species by a given fishing method, 65 per cent of the species captured during the whole faunal inventory were represented by both juvenile and adult sized specimens. Many of these species, including those considered to be of importance to professional and amateur fishermen, were represented by all size classes. This indicates that many of these fish species may spend their entire life cycle within Cockburn Sound, i.e. as a permanent breeding and nursery habitat.

5.4 Discussion

In using the trawl and seine methods the assumption was made that all fish species in the area sampled were caught by the nets. In effect some species have a greater ability to avoid capture than others. In addition with all net types inevitably some individuals escape capture. The 'catchability' of certain fish species is discussed by Lenanton (22) and the results should be viewed with these reservations in mind.

The 144 fish species listed as a result of the faunal survey of Cockburn Sound (Appendix 3) should certainly be regarded as incomplete. Sampling with additional fishing methods would have increased the number of species in this inventory. At least 20 additional fish species were observed while diving around reef structures or captured in seagrass meadows while sampling with a small beam trawl with a much finer mesh than any net used in the above inventory (23). Hutchins (24) lists some 350 fish species recorded in the waters off Rottnest Island which is less than 20 km to the north of Cockburn Sound. Using a variety of fishing gear including set lines, set nets, trawls, ring nets, beach seines, hand lines, trolling lines, traps and light attraction at night, Walker (25) recorded 247 fish species in the Geographe Bay and Bunbury marine area to the south of Cockburn Sound. Even in the estuarine environment of the nearby Swan River, 110 fish species have been recorded as a result of intensive sampling over the past three years (26).

5.4 (Cont'd)

Of the 144 species identified during this faunal inventory, 73 fish species and eight invertebrate species of commercial and recreational fishing interest were collected.

Cockburn Sound appears rich in terms of these important fish species compared to studies of other areas in the Southern hemisphere. Wallace and van der Elst (27) found only 30 species which are "valuable as human food" in the course of their South African estuarine fish study.

In Australia, Bass Becking *et. al.* (28) found 34 "species of commerce" in Lake Macquarie, NSW. The group currently studying fish habitat utilisation in Botany Bay have collected 55 fish species and 11 invertebrate species that are important to professional and amateur fishermen (Johann Bell, pers. comm.). The Port Phillip Bay Study (29) revealed 35 species.

In Western Australia, Lenanton (22) found 28 commercially and recreationally important species in the Blackwood River estuary and approximately 31 species of importance to fishermen in the Swan and Canning Estuary (13). Using more extensive fishing methods than were attempted in the Cockburn Sound Study, Walker (25) listed 98 fish species he considered to be of interest to the amateur angler and 87 species to the professional fishermen in the Bunbury and Geographe Bay area of Western Australia.

A given species may utilise the Sound in one of the following ways (13):

- as a permanent breeding and nursery habitat,
- as a nursery habitat for juveniles,
- as an occasional feeding area for maturing and mature adults.

Penn (5) has summarised present knowledge of the manner in which Cockburn Sound is utilised during the life cycle of the following species of commercial and recreational fishing interest. Snapper (*Chrysophrys unicolor*), trumpeter whiting (*Sillago maculata*) samson fish (*Seriola hippos*), mulloway (*Argyrosomus hololepidotus*) blue manna crab (*Portunus pelagicus*), and western king prawn (*Penaeus latisulcatus*). Penn concludes that:

> "There appears to be two major reasons why Cockburn Sound provides an ideal and essential environment for many species of marine life. Firstly, the Sound is the only significantly protected embayment between Cape Naturaliste and Shark Bay, a distance of 1 000 km. Secondly, the area with its associated shallow banks has many of the advantages of the productive coastal estuaries, without being subject to the radical salinity and temperature fluctuations which occur in estuaries during each year."

Cockburn Sound is also an important nursery and breeding area to species which are fished for outside the Sound. In documenting the fish and exploited crustaceans of the Swan-Canning estuary, Lenanton (13) stressed that the bulk of the catch of both commercial and amateur fishermen was composed of juvenile members of species derived from adult oceanic stocks.

5.4 (Cont'd)
The nearest oceanic population for many species is Cockburn Sound; and Penn (5) has suggested that Cockburn Sound would provide the spawning stock and hence recruitment to the Swan River fishery for such species as blue manna crabs and western king prawns.

TABLE 5.1

RANKING BY ABUNDANCE OF ALL SPECIES CAUGHT DURING COCKBURN SOUND FAUNAL SURVEY USING EIGHT NET TYPES.

Per cent of total fauna and cumulative per cent are indicated for each species.

Rank by No.	Species	No. of Individuals	Cumulative % by No.	% of fauna by No.
1	*Portunus rugosus*	33 029	16.32	16.32
2	*Callionymus goodladi*	25 425	28.88	12.56
3	*Apogon rueppellii*	23 048	40.28	11.39
4	*Penaeus latisulcatus*	19 610	49.96	9.69
5	*Portunus pelagicus*	18 810	59.26	9.30
6	*Atherinosoma presbyteroides*	14 751	66.55	7.29
7	*Pentapodus vitta*	11 878	72.42	5.87
8	*Caranx georgianus*	9 014	76.87	4.45
9	*Sillago maculata*	6 665	80.17	3.29
10	*Trachurus mccullochi*	4 910	82.59	2.43
11	*Thalamita sima*	4 344	84.74	2.15
12	*Aldrichetta forsteri*	3 819	86.63	1.89
13	*Pranesus ogilbyi*	2 582	87.90	1.28
14	*Platycephalus castelnaui*	2 496	89.14	1.23
15	*Monacanthus chinensis*	2 191	90.22	1.08
16	*Paraquula melbournensis*	1 949	91.18	0.96
17	*Pelates sexlineatus*	1 772	92.06	0.88
18	*Torquigener pleurogramma*	1 051	92.58	0.52
19	*Amblygaster postera*	1 042	93.09	0.51
20	*Heterodontus portusjacksoni*	948	93.56	0.47
21	*Squilla laevis*	922	94.02	0.46
22	*Sillago sp. a.*	891	94.46	0.44
23	*Upeneus tragula*	743	94.82	0.37
24	*Hyporhamphus melanochir*	699	95.17	0.34
25	*Sillago vittata*	583	95.46	0.29
26	*Parapegasus natans*	568	95.74	0.28
27	*Strophiurichthys robustus*	564	96.02	0.28
28	*Paratrigla papilio*	521	96.28	0.26
29	*Gymnapistes marmoratus*	480	96.51	0.24
30	*Sillago bassensis*	472	96.75	0.23
31	*Gerres subfasciatus*	415	96.95	0.20
32	*Platycephalus longispinis*	375	97.14	0.18
33	*Arripis georgianus*	355	97.31	0.18
34	*Contusus richei*	315	97.47	0.16
35	*Pseudorhombus jenynsii*	273	97.60	0.13
36	*Scobinichthys granulatus*	254	97.73	0.12
37	*Penicipelta vittiger*	252	97.85	0.12
38	*Sphyraena obtusata*	219	97.96	0.11
39	*Parapercis haackei*	213	98.07	0.10
40	*Atopomycterus nichthemerus*	207	98.17	0.10

TABLE 5.1 (Cont'd)

Rank by No.	Species	No. of Individuals	Cumulative % by No.	% of fauna by No.
41	*Nectocarcinus integrifrons*	199	98.27	0.10
42	*Ammotretis elongatus*	194	98.36	0.10
43	*Cnidoglanis macrocephalus*	185	98.45	0.09
44	*Favonogobius lateralis*	194	98.54	0.09
45	*Namatalosa vlaminghi*	181	98.63	0.09
46	*Sardinops neopilchardus*	179	98.72	0.09
47	*Pomatomus saltatrix*	169	98.81	0.08
48	*Sepioteuthis sp.*	167	98.89	0.08
49	*Cynoglossus broadhursti*	110	98.94	0.05
50	*Sillago schomburgkii*	105	98.99	0.05
51	*Upeneichthys lineatus*	103	99.04	0.05
52	*Sepia sp.*	103	99.10	0.05
53	*Myliobatis australis*	88	99.13	0.04
54	*Trygonorhina fasciata*	85	99.17	0.04
55	*Mugil cephalus*	79	99.21	0.04
56	*Enoplosus armatus*	73	99.24	0.04
57	*Platycephalus spinosus*	72	99.29	0.04
58	*Bigener brownii*	67	99.32	0.03
59	*Naxia aries*	67	99.36	0.03
60	*Piciiblennius tasmanianus*	65	99.39	0.03
61	*Sillaginodes punctatus*	65	99.42	0.03
62	*Eubalichthus mosaicus*	64	99.45	0.03
63	*Strophiurichthys robustus*	64	99.49	0.03
64	*Neoodax semifasciatus*	64	99.52	0.03
65	*Mustelus antarcticus*	61	99.54	0.03
66	*Aptychotremata vincentiana*	59	99.57	0.03
67	*Pelsartia humeralis*	55	99.60	0.03
68	*Cheilidonichthys kuma*	48	99.63	0.02
69	*Gonorhunchus greyi*	46	99.65	0.02
70	*Platycephalus haackei*	33	99.67	0.02
71	*Crapatalus arenarius*	32	99.68	0.02
72	*Neosebastes scarbriceps*	30	99.70	0.01
73	*Aspasminae sp. 1*	29	99.71	0.01
74	*Sarda orientalis*	29	99.73	0.01
75	*Carcharhinus brachyurus*	26	99.74	0.01
76	*Spratelloides robustus*	26	99.75	0.01
77	*Rhabdosargus sarba*	25	99.76	0.01
78	*Ovalipes australiensis*	25	99.78	0.01
79	*Brachaluteres jacksonianus*	25	99.79	0.01
80	*Urolophus testaceus*	23	99.80	0.01
81	*Cristiceps australis*	22	99.81	0.01
82	*Plotosus lineatus*	21	99.82	0.01
83	*Dasyatis thetidis*	20	99.83	0.01
84	*Meuschenia freycineti*	19	99.84	0.01
85	*Octopus tetricus*	17	99.85	0.01
86	*Stigmatopora argus*	17	99.86	0.01
87	*Pempheris klunzingeri*	17	99.87	0.01
88	*Chrysophrys unicolor*	16	99.87	0.01
89	*Amoya bifrenatus*	16	99.88	0.01
90	*Neoodax radiatus*	15	99.89	0.01
91	*Sphyrna zygaena*	14	99.90	0.01
92	*Metavelifer multiradiatus*	13	99.90	0.01
93	*Arripis trutta esper*	12	99.91	0.01
94	*Dactylopus dactylopus*	12	99.91	0.01
95	*Heteroclinus sp. a.*	11	99.92	0.01

TABLE 5.1 (Cont'd)

Rank by No.	Species	No. of Individuals	Cumulative % by No.	% of fauna by No.
96	*Portunus sanguinolentus*	10		
97	*Hyperlophus vittatus*	10	99.93	
98	*Neosebastes pandus*	10		
99	*Argyrosomus hololepidotus*	8	99.94	
100	*Trioris reipublicae*	7		
101	*Plotosus lineatus*	7		
102	*Scomber australiansicus*	7	99.95	
103	*Hippocampus breviceps*	7		
104	*Sutorectus tentaculates*	7	99.96	
105	*Orectolobus ornatus*	6		
106	*Arothron armilla*	5		
107	*Aracana auritta*	5		
108	*Microcanthus strigatus*	5	99.97	
109	*Apogon victoriae*	5		
110	*Ophichthid* eel sp.	4		
111	*Siphonognathus argyrophanes*	4		
112	*Neoodax balteatus*	4		
113	*Etrumeus jacksoniensis*	4	99.98	
114	*Heteroscarus arcroptilus*	3		
115	*Pseudolabrus parilus*	3		
116	*Aploactisoma milesii*	3		
117	*Aseraggodes haackeanus*	2		
118	*Engraulis australis*	2		
119	*Strophiurichthys robustus*	2		
120	*Carcharhinus brevipinna*	2		
121	*Lotella callarias*	2	99.99	
122	*Heteroclinus adelaidae*	2		
123	*Parapriacantus elongatus*	2		
124	*Scorpis georgianus*	2		
125	*Chaetoderma penicilligera*	2		
126	*Acanthaluterus spilomeanurus*	1		
127	*Torquigener sp.*	1		
128	*Nelusetta ayraudi*	1		
129	*Helicolenus papillosus*	1		
130	*Portunus pubescens*	1		
131	*Dasyatis thetidis*	1		
132	*Saurida undosquamis*	1		
133	*Paraplotosus alibilabris*	1		
134	*Hupnos monopterygium*	1		
135	*Odontaspis taurus*	1		
136	*Belone ciconia*	1		
137	*Dasyatis brevicaudata*	1		
138	*Rachycentron canadus*	1		
139	*Platycephalus laevigatus*	1		
140	*Seriola hippos*	1		
141	*Panulirus cygnus*	1		
142	*Dactylophora nigricans*	1		
143	*Squatina tergocellata*	1		
144	*Strabozebrias cancellatus*	1	100.00	
	Total	202 363		

TABLE 5.2

THE NUMBER OF INDIVIDUALS CAPTURED AND SPECIES REPRESENTED IN THE CATCH OF EACH NET TYPE DURING COCKBURN SOUND FAUNAL SURVEY.

For each net type, the per cent of total individuals and species captured during this survey is also indicated. The last column exceeds 100 per cent as a given species may have been represented in the catch of more than one net type.

Net type	Individuals captured	% of Total	Species represented	% of Total
Net type #1 (large trawl)	153,366	75.8	82	56.9
Net type #2 (small trawl)	9,480	4.7	62	43.0
Net type #3 (beach seine)	33,210	16.4	94	65.3
Net type #4 (set net, 35 mm mesh)	3,106	1.5	42	29.2
Net type #5 (set net, 50 mm mesh)	1,994	1.0	31	21.5
Net type #6 (set net, 75 mm mesh)	178	0.1	15	10.4
Net type #7 (set net, 100 mm mesh)	451	0.2	16	11.1
Net type #8 (set net, 150 mm mesh)	581	0.3	21	14.6
Total all net types	202,363	100	144	

TABLE 5.3

RANKING BY ABUNDANCE OF SPECIES CAUGHT IN SMALL TRAWL (NET TYPE #2) IN BI-MONTHLY SAMPLING PROGRAMME BETWEEN MAY 1977 AND JUNE 1978.

Per cent of total fauna and cumulative per cent are indicated for each species, as well as a summary of biological information based on measured individuals of each species.

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
1	*Portunus pelagicus*	4,979	52.52	52.52	2,364	9.4*	0.07	1.0-19.0	J A
2	*Thalamites sima*	3,389	88.27	35.75	1,272	4.9*	0.03	2.0-10.0	J A
3	*Portunus rugosus*	304	91.48	3.21	231	3.4*	0.04	1.0-5.0	J A
4	*Nectocarcinus integrifrons*	158	93.15	1.67	158	5.0*	0.11	2.0-9.0	J A
5	*Apogon rueppellii*	129	94.51	1.36	129	7.0	0.08	4.0-8.0	J A
6	*Gymnapistes marmoratus*	61	95.15	0.64	61	8.3	0.11	7.0-10.0	J A
7	*Scobinichthys granulatus*	59	95.77	0.62	59	8.6	0.34	2.0-14.0	J A?
8	*Penaeus latisulcatis*	48	96.28	0.51		not	measured		
9	*Bigener brownii*	30	96.59	0.32	30	8.6	0.34	6.0-15.0	J A?
10	*Penicipelta vittiger*	29	96.90	0.32	29	9.0	0.69	7.0-11.0	J
11	*Pseudorhombus jenynsii*	24	97.15	0.25	22	27.3	1.52	13.0-38.0	J A
12	*Neosebastes scabriceps*	22	97.38	0.23	22	7.6	0.27	6.0-11.0	J A
13	*Plotosus lineatus*	21	97.61	0.22	21	9.2	0.11	8.0-10.0	J
14	*Monacanthus chinensis*	18	97.80	0.19	18	9.3	0.47	7.0-15.0	J A?
15	*Naxia aries*	16	97.96	0.17	12	3.3*	0.58	2.0-9.0	J A
16	*Platycephalus spinosus*	15	98.12	0.16	15	11.5	0.30	10.0-15.0	J
17	*Neoodax semifasciatus*	12	98.25	0.13	12	22.2	1.54	13.0-28.0	J A
18	*Upeneichthys lineatus*	11	98.36	0.11	11	13.8	1.20	10.0-26.0	J A
19	*Cynoglossus broadhursti*	11	98.48	0.11	11	15.9	1.58	7.0-27.0	J A
20	*Brachaluteres jacksonianus*	10	98.59	0.11	10	5.5	0.51	4.0-8.0	J
21	*Callionymus goodladi*	10	98.69	0.11	10	11.1	0.58	8.0-14.0	J A
22	*Cnidoglanis macrocephalus*	10	98.80	0.11	10	26.2	3.20	12.0-55.0	J A
23	*Octopus tetricus*	10	98.90	0.11		not	measured		
24	*Atopomycterus nichthemerus*	8	98.99	0.08	8	7.5	0.79	3.0-11.0	J A?
25	*Platycephalus haackei*	7	99.06	0.07	7	30.5	1.41	25.0-36.0	A

TABLE 5.3 (Cont'd)

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
26	*Sepia sp.*	7	99.14	0.07		not	measured		
27	*Meuschenia freycineti*	6	99.20	0.06	5	14.1	4.87	9.0-20.0	J A
28	*Sillago maculata*	6	99.26	0.06	5	19.9	2.27	13.0-25.0	J A
29	*Pelates sexlineatus*	5	99.31	0.05	5	18.5	1.84	12.0-22.0	J A
30	*Platycephalus castelnaui*	5	99.37	0.05	5	17.1	3.82	12.0-33.0	J A
31	*Cheilodactylus gibbosus*	4	99.41	0.04	4	7.0	0.70	5.0-8.0	J
32	*Neosebastes pandus*	4	99.45	0.04	4	9.4	0.61	8.0-11.0	J
33	*Dasyatis thetidis*	3	99.48	0.03	3	16.9†	2.96	13.0-22.0	J
34	*Enoplosus armatus*	3	99.51	0.03	3	15.4	2.59	13.0-21.0	A
35	*Parapercis haackei*	3	99.55	0.03	3	11.0	0.58	10.0-12.0	A
36	*Pseudolabris parilus*	3	99.58	0.03	3	18.6	2.00	10.0-21.0	J A
37	*Heteroscarus acroptilus*	3	99.61	0.03	3	14.7	3.53	8.0-20.0	J A
38	*Urolophus testaccus*	3	99.64	0.03	2	14.0†	0	14.0-14.0	J
39	*Ammotretis elongatus*	2	99.66	0.02	2	14.0	0	14.0-14.0	J
40	*Trygonorhina fasciata*	2	99.68	0.02	1	51.5	0	51.5-51.5	A
41	*Cristiceps australis*	2	99.70	0.02	2	11.2	0.97	10.0-12.0	J
42	*Neoodax balteatus*	2	99.73	0.02	2	19.0	0	12.0-26.0	A
43	*Parequula melbournensis*	2	99.75	0.02	2	7.5	0	7.0-8.0	J
44	*Aracana aurita*	2	99.77	0.02	2	12.7	0	11.0-15.0	J A
45	*Torquigener pleurogramma*	2	99.79	0.02	2	18.0	0	18.0-18.0	A
46	*Aploactisoma milesii milesii*	2	99.81	0.02	2	13.0	0	12.0-14.0	J
47	*Strophiurichthys robustus*	2	99.83	0.02	2	12.7	8.01	7.0-24.0	J A
48	*Chaetoderma penicilligera*	1	99.84	0.01	1	17.0	0	17.0-17.0	A?
49	*Contusus richei*	1	99.85	0.01	1	20.0	0	20.0-20.0	A
50	*Portunus sanguinolentus*	1	99.86	0.01	1	5.0*	0	5.0-5.0	A
51	*Amoya bifrenatus*	1	99.87	0.01	1	12.0	0	12.0-12.0	A
52	*Paraploactis trachyderma*	1	99.88	0.01	1	12.0	0	12.0-12.0	A
53	*Panulirus cygnus*	1	99.89	0.01	1	3.0∇	0	3.0-3.0	J
54	*Paratrigla papilio*	1	99.90	0.01	1	11.0	0	11.0-11.0	A
55	*Sillago bassensis*	1	99.91	0.01	1	24.9	0	24.9-24.9	A

TABLE 5.3 (Cont'd)

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
56	*Pelsartia humeralis*	1	99.92	0.01	1	15.0	0	15.0-15.0	A
57	*Apogon victoriae*	1	99.93	0.01	1	8.0	0	8.0-8.0	A
58	*Orectolobus ornatus*	1	99.94	0.01	1	41.0	0	41.0-41.0	A
59	*Aseraggodes haackeanus haackeanus*	1	99.96	0.01	1	13.9	0	13.9-13.9	A
60	*Sutorectus tentaculatus*	1	99.97	0.01	1	55.0	0	55.0-55.0	A
61	*Portunus pubescens*	1	99.98	0.01	1	5.0	0	5.0-5.0	A
62	*Nelusetta ayraudi*	1	100.00	0.01	1	16.0	0	16.0-16.0	A?
	Total	9,480							

* Species measured for maximum carapace width rather than total length

∇ Species measured for maximum carapace length rather than total length

† Species measured for maximum width rather than total length

TABLE 5.3

TABLE 5.4

RANKING BY ABUNDANCE OF SPECIES CAUGHT IN SET NET OF 35 mm STRETCH MESH SIZE (NET TYPE #4) IN BI-MONTHLY SAMPLING PROGRAMME BETWEEN JULY 1977 AND JULY 1978.

Per cent of total fauna and cumulative per cent are indicated for each species, as well as a summary of biological information based on measured individuals of each species.

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult	
1	*Pelates sexlineatus*	989	31.84	31.84	296	16.4	0.05	14.0-21.0	J	A
2	*Amblygaster postera*	820	58.24	26.40	243	18.2	0.06	16.0-25.0		A
3	*Pentapodus vitta*	234	65.78	7.53	224	15.0	0.06	13.0-17.0		A
4	*Trachurus mccullochi*	198	72.15	6.37	186	17.1	0.11	12.0-21.0	J	A
5	*Sillago maculata*	157	77.21	5.05	109	18.1	0.09	16.0-23.0	J	A
6	*Sardinops neopilchardus*	147	81.94	4.73	111	19.6	0.09	15.0-22.0		A
7	*Caranx georgianus*	147	86.67	4.73	146	13.1	0.10	9.0-18.0	J	A
8	*Sphyraena obtusata*	147	91.40	4.73	142	30.1	0.80	15.0-70.0	J	A
9	*Portunus pelagicus*	59	93.30	1.90	57	9.2*	0.52	4.0-15.0	J	A
10	*Pomatomus saltatrix*	28	94.20	0.90	28	18.3	0.36	16.0-24.0		A
11	*Gonorhynchus greyi*	25	95.01	0.80	5	28.2	0.49	27.0-30.0		A
12	*Cnidoglanis macrocephalus*	21	95.69	0.68	21	25.6	0.80	21.0-36.0	J	
13	*Platycephalus longispinis*	21	96.36	0.68	20	22.2	0.48	18.0-28.0		A
14	*Penicipelta vittiger*	19	96.97	0.61	19	12.2	0.12	11.0-13.0	J	
15	*Ovalipes australiensis*	14	97.42	0.45	14	not	measured			
16	*Parequula melbournensis*	14	97.88	0.45	14	11.4	0.29	10.0-14.0	J	
17	*Neoodax semifasciatus*	8	98.13	0.26	8	20.5	0.46	18.0-22.0		A?
18	*Pempheris klunzingeri*	8	98.39	0.26	8	11.5	0.42	10.0-14.0		A
19	*Neosebastes scabriceps*	7	98.62	0.23	7	10.3	0.18	10.0-11.0		A
20	*Sillago sp. a.*	5	98.78	0.16	5	19.8	0.58	18.0-21.0	J	

TABLE 5.4 (Cont'd)

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
21	*Apogon victoriae*	4	98.91	0.13	4	11.2	0.50	11.0-12.0	A
22	*Upeneus tragula*	4	99.03	0.13	4	14.2	1.03	12.0-16.0	J? A
23	*Neosebastes pandus*	3	99.13	0.10	3	18.3	5.46	11.0-29.0	J A
24	*Sillago vittata*	3	99.23	0.10	3	18.0	0.58	17.0-19.0	J A?
25	*Meuschenia freycineti*	2	99.29	0.06	2	12.0	0	12.0-12.0	J
26	*Platycephalus castelnaui*	2	99.36	0.06	2	26.5	5.50	21.0-32.0	J? A
27	*Platycephalus haackei*	2	99.42	0.06	2	18.0	4.00	14.0-22.0	J A
28	*Sillago schomburgkii*	2	99.48	0.06	2	20.5	0.50	20.0-21.0	J
29	*Sarda orientalis*	2	99.55	0.06	2	49.5	7.50	42.0-57.0	A
30	*Sphyrna zygaena*	2	99.61	0.06	2	97.0	48.00	59.0-145.0	J A
31	*Arripis georgianus*	1	99.65	0.03	1	21.0	0	21.0-21.0	A
32	*Monacanthus chinensis*	1	99.68	0.03	1	7.0	0	7.0-7.0	J
33	*Pseudorhombus jenynsii*	1	99.71	0.03	1	11.0	0	11.0-11.0	J
34	*Portunus rugosus*	1	99.74	0.03	1	3.0*	0	3.0-3.0	J
35	*Upeneichthys lineatus*	1	99.77	0.03	1	14.0	0	14.0-14.0	J
36	*Sillago bassensis*	1	99.81	0.03	1	18.0	0	18.0-18.0	J
37	*Scobinichthys granulatus*	1	99.84	0.03	1	10.0	0	10.0-10.0	A
38	*Gerres subfasciatus*	1	99.87	0.03	1	13.0	0	13.0-13.0	J
39	*Thalamites sima*	1	99.90	0.03	1	4.0	0	4.0-4.0	J
40	*Carcharhinus brevipinna*	1	99.94	0.03	1	106.0	0	106.0-106.0	A
41	*Rachycentron canadus*	1	99.97	0.03	1	31.0	0	31.0-31.0	J
42	*Hetroscarus acroptilus*	1	100.00	0.03	1	12.0	0	12.0-12.0	J
	Total	3,106							

* Species measured for maximum carapace width rather than total length

TABLE 5.4

TABLE 5.5

RANKING BY ABUNDANCE OF SPECIES CAUGHT IN SET NET OF 50 mm STRETCH MESH SIZE (NET TYPE #5) IN BI-MONTHLY SAMPLING PROGRAMME BETWEEN JULY 1977 AND JULY 1978.

Per cent of total fauna and cumulative per cent are indicated for each species, as well as a summary of biological information based on measured individuals of each species.

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile	Adult
1	*Caranx georgianus*	633	31.75	31.75	405	17.6	0.07	13.0-24.0	J	A
2	*Pelates sexlineatus*	440	53.81	22.07	267	19.7	0.07	14.0-23.0	J	A
3	*Pentapodus vitta*	244	66.05	12.24	236	18.4	0.07	16.0-23.0		A
4	*Amblygaster postera*	174	74.77	8.73	158	23.5	0.68	20.0-26.0		A
5	*Sillago maculata*	124	80.99	6.22	112	22.6	0.13	20.0-29.0	J?	A
6	*Gerres subfasciatus*	76	84.80	3.81	76	15.9	0.11	14.0-18.0	J	A?
7	*Trachurus mccullochi*	64	88.01	3.21	63	20.9	0.25	10.0-24.0	J	A
8	*Portunus pelagicus*	61	91.07	3.06	61	12.8*	0.23	9.0-16.0	J?	A
9	*Pomatomus saltatrix*	39	93.03	1.96	39	24.5	0.50	16.0-32.0	J	A
10	*Arripis georgianus*	38	94.93	1.91	38	22.4	0.19	19.0-25.0		A
11	*Sphyraena obtusata*	28	96.34	1.40	28	36.4	1.76	30.0-66.0	J	A
12	*Cnidoglanis macrocephalus*	11	96.89	0.55	11	29.4	0.51	26.0-32.0	J	
13	*Nematalosa vlaminghi*	8	97.29	0.40	8	18.7	0.25	18.0-20.0		A
14	*Pelsartia humeralis*	7	97.64	0.35	7	19.3	0.52	17.0-21.0		A
15	*Scomber australasicus*	7	97.99	0.35	7	21.8	0.77	20.0-26.0	J	A?
16	*Sarda orientalis*	7	98.35	0.35	7	52.0	2.29	46.0-63.0		A
17	*Sillago bassensis*	5	98.60	0.25	5	23.6	1.17	22.0-28.0		A
18	*Platycephalus castelnaui*	4	98.80	0.20	4	39.2	0.85	37.0-41.0		A
19	*Upeneichthys lineatus*	4	99.00	0.20	4	17.5	0.50	16.0-18.0	J	A?
20	*Parequula melbournensis*	3	99.15	0.15	3	12.7	0.33	12.0-13.0		A?

TABLE 5.5

TABLE 5.5 (Cont'd)

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
21	*Monacanthus chinensis*	2	99.25	0.10	2	14.0	1.00	13.0-15.0	A
22	*Neoodax semifasciatus*	2	99.35	0.10	2	23.5	0.50	23.0-24.0	A
23	*Platycephalus longispinis*	2	99.45	0.10	2	24.5	0.50	24.0-25.0	A
24	*Sphyrna zygaena*	2	99.55	0.10	2	141.0	11.00	130.0-152.0	A
25	*Aldrichetta forsteri*	2	99.65	0.10	2	25.5	3.5	22.0-29.0	J A
26	*Strophiurichthys robustus*	2	99.75	0.10	2	49.5	6.5	43.0-56.0	A
27	*Heterodontus portusjacksoni*	1	99.80	0.05	1	35.0	0	35.0-35.0	A
28	*Neosebastes pandus*	1	99.85	0.05	1	38.0	0	38.0-38.0	A
29	*Pempheris klunzingeri*	1	99.90	0.05	1	14.0	0	14.0-14.0	A
30	*Argyrosomus hololepidotus*	1	99.95	0.05	1	112.0	0	112.0-112.0	A
31	*Sardinops neopilchardus*	1	100.00	0.05	1	18.0	0	18.0-18.0	A
	Total	1,994							

* Species measured for maximum carapace width rather than total length

TABLE 5.6

RANKING BY ABUNDANCE OF SPECIES CAUGHT IN SET NET OF 75 mm STRETCH MESH SIZE (NET TYPE #6) IN BI-MONTHLY SAMPLING PROGRAMME BETWEEN JULY 1977 AND JULY 1978.

Per cent of total fauna and cumulative per cent are indicated for each species, as well as a summary of biological information based on measured individuals of each species.

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
1	*Portunus pelagicus*	80	44.94	44.94	70	13.6*	0.22	8.0-17.0	A
2	*Heterodontus portusjacksoni*	57	76.97	32.02	52	34.8	1.02	24.0-63.0	J A
3	*Sarda orientalis*	9	82.02	5.06	9	51.0	1.01	47.0-55.0	A
4	*Sphyrna zygaena*	6	85.39	3.37	6	154.4	11.89	126.0-203.0	A
5	*Penaeus latisulcatus*	6	88.76	3.37		not	measured		
6	*Caranx georgianus*	5	91.57	2.81	5	18.5	1.09	15.0-21.0	J A
7	*Amblygaster postera*	4	93.82	2.25	4	18.5	0.28	18.0-19.0	A
8	*Trachurus mccullochi*	3	95.51	1.69	3	19.0	0.48	18.0-20.0	A
9	*Strophiurichthys robustus*	2	96.63	1.12	2	58.0	4.00	54.0-62.0	A
10	*Monacanthus chinensis*	1	97.19	0.56	1	33.0	0	33.0-33.0	A
11	*Myliobatis australis*	1	97.75	0.56	1	77.0†	0	77.0-77.0	A
12	*Sardinops neopilchardus*	1	98.31	0 56	1	19.0	0	19.0-19.0	A
13	*Sillago maculata*	1	98.88	0.56	1	22.0	0	22.0-22.0	A
14	*Arripis georgianus*	1	99.44	0.56	1	33.0	0	33.0-33.0	A
15	*Carcharhinus brevipinna*	1	100.00	0.56	1	128.0	0	128.0-128.0	A
	Total	178							

* Species measured for maximum carapace width rather than total length
† Species measured for maximum width rather than total length

TABLE 5.7

RANKING BY ABUNDANCE OF SPECIES CAUGHT IN SET NET OF 100 mm STRETCH SIZE (NET TYPE #7) IN BI-MONTHLY SAMPLING PROGRAMME BETWEEN JULY 1977 AND JULY 1978.

Per cent of total fauna and cumulative per cent are indicated for each species, as well as a summary of biological information based on measured individuals of each species.

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult	
1	*Heterodontus portusjacksoni*	306	67.85	67.85	251	43.8	0.54	32.5-65.5	J	A
2	*Portunus pelagicus*	88	87.36	19.51	67	14.1*	0.31	9.0-18.0		A
3	*Caranx georgianus*	13	90.24	2.88	13	18.0	0.49	16.0-21.0	J?	A
4	*Amblygaster postera*	11	92.68	2.44	8	23.0	0.56	19.0-25.0		A
5	*Sarda orientalis*	11	95.12	2.44	11	53.3	1.04	45.0-57.0		A
6	*Myliobatis australis*	7	96.67	1.55	7	72.9†	2.65	53.0-84.0		A
7	*Pomatomus saltatrix*	4	97.56	0.89	2	23.5	2.50	21.0-26.0	J	A?
8	*Sphyrna zygaena*	3	98.23	0.67	3	115.0	9.00	92.0-125.0		A
9	*Aptychotremata vincentiana*	1	98.45	0.22	1	40.0	0	40.0-40.0		A
10	*Neosebastes pandus*	1	98.67	0.22	1	33.0	0	33.0-33.0		A
11	*Pentapodus vitta*	1	98.89	0.22	1	18.0	0	18.0-18.0		A?
12	*Platycephalus longispinis*	1	99.11	0.22	1	20.0	0	20.0-20.0		A
13	*Pseudorhombus jenynsii*	1	99.33	0.22	1	30.0	0	30.0-30.0		A
14	*Sardinops neopilchardus*	1	99.56	0.22	1	19.0	0	19.0-19.0		A
15	*Sillago sp. a*	1	99.78	0.22	1	18.0	0	18.0-18.0	J	
16	*Strophiurichthys robustus*	1	100.00	0.22	1	52.0	0	52.0-52.0		A
	Total	451								

* Species measured for maximum carapace width rather than total length
† Species measured for maximum width rather than total length

TABLE 5.8

RANKING BY ABUNDANCE OF SPECIES CAUGHT IN SET NET OF 150 mm STRETCH MESH SIZE (NET TYPE #8) IN BI-MONTHLY SAMPLING PROGRAMME BETWEEN APRIL 1977 AND JUNE 1978.

Per cent of total fauna and cumulative per cent are indicated for each species, as well as a summary of biological information based on measured individuals of each species.

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult	
1	*Heterdontus portusjacksoni*	268	46.13	46.13	261	47.9	0.88	24.0-73.0	J	A
2	*Portunus pelagicus*	117	66.27	20.14	116	15.2*	0.15	9.0-19.0		A
3	*Mustelus antarcticus*	57	76.08	9.81	57	115.0	1.23	99.0-147.0		A
4	*Myliobatis australis*	44	83.65	7.57	44	61.8†	2.23	27.0-130.0	J	A
5	*Aptychotremata vincentiana*	36	89.85	6.20	35	73.0	1.28	60.0-87.0		A
6	*Carcharhinus brachyurus*	26	94.32	4.48	26	114.5	2.36	97.0-142.0		A
7	*Pseudorhombus jenynsii*	7	95.52	1.20	5	32.6	0.98	30.0-36.0		A
8	*Strophiurichthys robustus*	6	96.56	1.03	6	26.9	2.60	22.0-44.0		A
9	*Chrysophrys unicolor*	3	97.07	0.52	3	83.7	2.73	80.0-89.0		A
10	*Trygonorhina fasciata*	3	97.59	0.52	3	62.0	6.03	50.0-69.0		A
11	*Argyrosomus hololepidotus*	2	97.93	0.34	2	111.0	2.00	109.0-113.0		A
12	*Orectolobus ornatus*	2	98.28	0.34	2	78.5	0.50	78.0-79.0		A
13	*Urolophus testaceus*	2	98.62	0.34	2	29.0†	8.00	21.0-37.0		A
14	*Dactylophora nigricans*	1	98.80	0.17	1	108.0	0	108.0-108.0		A
15	*Neosebastes pandus*	1	98.97	0.17	1	37.0	0	37.0-37.0		A
16	*Amblygaster postera*	1	99.14	0.17	1	23.0	0	23.0-23.0		A
17	*Sphyrna zygaena*	1	99.31	0.17	1	87.0	0	87.0-87.0		A
18	*Squatina tergocellata*	1	99.48	0.17	1	24.0	0	24.0-24.0		A
19	*Odontaspis taurus*	1	99.66	0.17	1	130.0	0	130.0-130.0		A
20	*Helicolenus papillosus*	1	99.83	0.17	1	37.0	0	37.0-37.0		A
21	*Dasyatis thetidis*	1	100.00	0.17	1	27.0†	0	27.0-27.0		A
	Total	581								

* Species measured for maximum capapace width rather than total length
† Species measured for maximum width rather than total length

TABLE 5.9

RANKING BY ABUNDANCE OF SPECIES CAUGHT IN LARGE TRAWL (NET TYPE #1) IN BI-MONTHLY SAMPLING PROGRAMME BETWEEN JUNE 1977 AND SEPTEMBER 1978.

Per cent of total fauna and cumulative per cent are indicated for each species, as well as a summary of biological information based on measured individuals of each species.

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
1	*Portunus rugosus*	32,720	21.33	21.33	3,039	4.1*	0.01	2.0-7.0	J A
2	*Callionymus goodladi*	25,407	37.90	16.57	4,027	11.3	0.02	6.0-16.0	J A
3	*Apogon rueppellii*	21,832	52.14	14.27	4,201	6.6	0.02	4.0-9.0	J A
4	*Penaeus latisulcatus*	19,499	64.85	12.71		not	measured		
5	*Portunus pelagicus*	11,855	72.58	7.73	3,775	10.0*	0.05	2.0-19.0	J A
6	*Pentapodus vitta*	11,396	80.01	7.43	3,283	14.1	0.05	5.0-27.0	J A
7	*Caranx georgianus*	8,028	85.25	5.23	2,500	15.7	0.06	4.0-21.0	J A
8	*Sillago maculata*	5,873	89.07	3.83	2,508	18.5	0.04	9.0-25.0	J A
9	*Trachurus mccullochi*	3,408	91.30	2.22	1,334	13.7	0.06	6.0-22.0	J A
10	*Platycephalus castelnaui*	2,402	92.86	1.57	2,174	15.9	0.07	7.0-51.0	J A
11	*Monocanthus chinensis*	2,165	94.27	1.41	1,747	8.5	0.04	4.0-18.0	J A?
12	*Parequula melbournensis*	1,930	95.53	1.26	1,697	11.7	0.05	6.0-29.0	J A
13	*Squilla laevis*	922	96.13	0.60		not	measured		
14	*Upeneus tragula*	733	96.61	0.48	578	13.9	0.09	7.0-18.0	J A
15	*Parapegasus natans*	568	96.98	0.37	464	10.4	0.05	7.0-13.0	J A
16	*Strophiurichthys robustus*	553	97.34	0.36		not	measured		
17	*Paratrigla papilio*	520	97.68	0.34	520	9.4	0.04	7.0-15.0	J A
18	*Platycephalus longispinis*	341	97.90	0.22	335	22.4	0.18	10.0-34.0	J A
19	*Sillago vittata*	330	98.12	0.22	260	15.9	0.07	12.0-19.0	J
20	*Heterodontus portusjacksoni*	314	98.32	0.20	313	46.9	0.50	22.0-74.0	J A
21	*Thalamita sima*	289	98.51	0.19	270	4.2*	0.05	2.0-8.0	J A
22	*Gymnapistes marmoratus*	255	98.68	0.17	112	8.2	0.10	6.0-12.0	J
23	*Penicipelta vittiger*	201	98.81	0.13	201	10.8	0.09	8.0-14.0	J
24	*Parapercis haackei*	196	98.94	0.13	196	8.6	0.10	4.0-12.0	J A
25	*Pseudorhombus jenynsii*	188	99.06	0.12	186	22.8	0.59	9.0-38.0	J A

TABLE 5.9 (Cont'd)

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
26	*Scobinichthys granulatus*	138	99.15	0.09	138	7.5	0.09	5.0-10.0	J
27	*Pelates sexlineatus*	129	99.23	0.08	129	12.4	0.26	8.0-21.0	J A
28	*Sepioteuthis sp.*	119	99.31	0.08		not	measured		
29	*Upeneichthys lineatus*	84	99.37	0.05	84	13.3	0.28	9.0-20.0	J A
30	*Sepia sp.*	78	99.42	0.05		not	measured		
31	*Trygonorhina fasciata*	69	99.46	0.04	69	67.9	1.83	27.0-102.0	J A
32	*Sillago bassensis*	65	99.51	0.04	31	17.9	0.50	8.0-24.0	J A
33	*Atopomycterus nichthemerus*	64	99.55	0.04	64	20.2	0.40	13.0-28.0	J A
34	*Eubalichthus mosaicus*	64	99.59	0.04	64	8.2	0.20	5.0-14.0	J
35	*Strophiurichthys inermis*	64	99.63	0.04	64	26.7	0.52	18.0-46.0	J A
36	*Platycephalus spinosus*	55	99.67	0.04	55	9.2	0.15	7.0-14.0	J
37	*Naxia aries*	50	99.70	0.03		not	measured		
38	*Cheilidonichthys kuma*	48	99.73	0.03	48	13.8	0.75	7.0-27.0	J A
39	*Myliobatis australis*	36	99.75	0.02	35	56.4†	1.85	26.0-201.0	J A
40	*Pomatomus saltatrix*	35	99.78	0.02	34	14.9	0.41	11.0-19.0	J
41	*Cynoglossus broadhursti*	34	99.80	0.02	34	13.2	0.21	11.0-16.0	J
42	*Amblygaster postera*	32	99.82	0.02	31	17.9	0.48	8.0-24.0	J A
43	*Sardinops neopilchardus*	29	99.84	0.02	29	18.6	0.15	17.0-20.0	A
44	*Gerres subfasciatus*	26	99.86	0.02	26	14.7	0.29	9.0-17.0	J A?
45	*Sillago sp. a*	20	99.87	0.01	4	13.1	0.61	9.0-14.0	J
46	*Aptychotremata vincentiana*	19	99.88	0.01	19	70.6	3.70	45.0-104.0	J A
47	*Urolophus testaceus*	16	99.89	0.01	16	22.2†	1.42	21.0-46.0	J A
48	*Sphyraena obtusata*	15	99.90	0.01	15	19.5	0.89	16.0-28.0	J A
49	*Dasyatis thetidis*	13	99.91	0.01	4	27.5†	4.57	21.0-41.0	J A
50	*Chrysophrys unicolor*	13	99.92	0.01	13	17.4	5.81	7.0-87.0	J A
51	*Metavelifer multiradiatus*	13	99.93	0.01	13	12.8	0.83	8.0-17.0	J
52	*Ammotretis elongatus*	12	99.93	0.01	12	10.2	0.42	8.0-14.0	J
53	*Dactylopus dactylopus*	10	99.94	0.01	10	11.8	0.70	10.0-16.0	J A
54	*Trioris reipublicae*	7	99.95		7	9.7	1.66	3.0-13.0	J
55	*Brachaluteres jacksonianus*	7	99.95		7	6.0	0.57	4.0-8.0	J A

TABLE 5.9 (Cont'd)

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult	
56	*Hyporhamphus melanochir*	7	99.96		7	17.1	1.25	14.0-23.0	J	
57	*Meuschenia freycineti*	6	99.96		6	8.8	0.48	7.0-10.0	J	
58	*Platycephalus haackei*	6	99.96		6	9.2	0.17	9.0-10.0	J	
59	*Sutorectus tentaculatus*	6	99.97		6	44.2	2.73	35.0-52.0	J?	A
60	*Spratelloides robustus*	5			5	15.0	1.67	9.0-19.0?		A
61	*Arothron armilla*	5			5	17.8	1.36	15.0-22.0	J	A
62	*Argyrosomus hololepidotus*	5	99.98		5	118.6	2.52	111.0-126.0		A
63	*Mustelus antarcticus*	4			4	112.6	3.64	102.0-117.0		A
64	*Etrumeus jacksoniensis*	4			4	18.8	0.48	18.0-20.0		A
65	*Stigmatopora argus*	3			3	25.6	2.03	22.0-29.0		A
66	*Aracana aurita*	3			3	16.0	0.58	15.0-17.0		A
67	*Orectolobus ornatus*	3	99.99		3	38.8	3.58	34.0-46.0	J	
68	*Lotella callarias*	2			2	11.5	1.50	10.0-13.0	J	
69	*Hippocampus breviceps*	2				not	measured			
70	*Contusus richei*	2			2	6.5	0.50	6.0-7.0	J	
71	*Cheilodactylus gibbosus*	2			2	14.5	2.50	12.0-17.0	J	
72	*Chaetoderma penicilligera*	1			1	17.0	0.00	17.0-17.0	J	
73	*Portunus sanguinolentus*	1			1	6.0*	0.00	6.0-6.0		A
74	*Cristiceps australis*	1			1	17.0	0.00	17.0-17.0		A
75	*Neosebastes pandus*	1			1	10.0	0.00	10.0-10.0	J	
76	*Pempheris klunzingeri*	1			1	14.0	0.00	14.0-14.0		A
77	*Seriola hippos*	1			1	11.0	0.00	11.0-11.0	J	
78	*Dasyatis brevicaudata*	1			1	63.0†	0.00	63.0-63.0		A
79	*Engraulis australis*	1			1	11.0	0.00	11.0-11.0		A
80	*Saurida undosquamis*	1			1	31.0	0.00	31.0-31.0		A
81	*Torquigener sp.*	1				not	measured			
82	*Acanthaluteres spilomelanurus*	1	100.00		1	11.0	0.00	11.0-11.0		A

Total 153,366

* Species measured for maximum carapace width rather than total length

† Species measured for maximum width rather than total length

TABLE 5.10

RANKING BY ABUNDANCE OF SPECIES CAUGHT IN BEACH SEINE (NET TYPE #3) IN BI-MONTHLY SAMPLING PROGRAMME BETWEEN APRIL 1977 AND JUNE 1978.
Per cent of total fauna and cumulative per cent are indicated for each species, as well as a summary of biological information based on measured individuals of each species.

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult	
1	*Atherinosoma presbyteroides*	14,751	44.42	44.42	1,343	5.3	0.02	2.0-8.0	J	A
2	*Aldrichetta forsteri*	3,817	55.91	11.49	2,266	19.2	0.15	3.0-35.0	J	A
3	*Pranesus ogilbyi*	2,582	63.69	7.77	1,305	9.3	0.10	4.0-18.0	J	A
4	*Portunus pelagicus*	1,562	68.39	4.70	1,419	9.1*	0.08	2.0-18.0	J	A
5	*Trachurus mccullochi*	1,237	72.11	3.72	572	19.3	0.06	7.0-27.0	J	A
6	*Apogon rueppellii*	1,087	75.39	3.27	787	5.7	0.06	3.0-8.0	J	A
7	*Torquigener pleurogramma*	1,049	78.55	3.16	381	12.0	0.15	3.0-21.0	J	A
8	*Sillago sp. a.*	865	81.15	2.60	370	7.6	0.14	3.0-24.0	J	A
9	*Hyporhamphus melanochir*	692	83.23	2.08	657	23.8	0.33	3.0-39.0	J	A
10	*Thalamita sima*	665	85.24	2.00	264	4.4*	0.07	2.0-7.0	J	A
11	*Sillago maculata*	504	86.75	1.52	464	18.7	0.24	5.0-28.0	J	A
12	*Sillago bassensis*	400	87.96	1.20	400	10.3	0.15	4.0-24.0	J	A
13	*Arripis georgianus*	316	88.91	0.95	316	18.9	0.30	3.0-29.0	J	A
14	*Gerres subfasciatus*	312	89.89	0.94	143	16.7	0.19	5.0-27.0	J	A
15	*Contusus richei*	312	90.79	0.94	312	11.2	0.30	2.0-29.0	J	A
16	*Sillago vittata*	250	91.54	0.75	249	12.2	0.28	5.0-23.0	J	A
17	*Pelates sexlineatus*	209	92.17	0.63	209	19.4	0.27	3.0-23.0	J	A
18	*Caranx georgianus*	188	92.74	0.57	187	18.4	0.33	5.0-30.0	J	A
19	*Favonogobius lateralis*	184	93.29	0.55	184	4.1	0.08	2.0-7.0	J	A
20	*Ammotretis elongatus*	180	93.83	0.54	180	8.8	0.21	2.0-23.0	J	A
21	*Nematalosa vlaminghi*	173	94.35	0.52	172	20.6	0.22	7.0-27.0	J	A
22	*Gymnapistes marmoratus*	164	94.85	0.49	164	8.7	0.11	4.0-13.0	J	A
23	*Cnidoglanis macrocephalus*	143	95.28	0.43	143	21.1	1.05	8.0-60.0	J	A
24	*Atopomycterus nichthemerus*	135	95.69	0.41	135	6.0	0.12	3.0-17.0	J	A
25	*Sillago schomburgkii*	103	96.00	0.31	101	22.7	0.53	4.0-33.0	J	A

TABLE 5.10

TABLE 5.10 (Cont'd)

Rank by No.	Species	No of. individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
26	*Platycephalus castelnaui*	83	96.25	0.25	83	15.1	1.06	4.0-46.0	J A
27	*Mugil cephalus*	79	96.48	0.24	79	25.1	0.68	10.0-44.0	J A
28	*Enoplosus armatus*	70	96.69	0.21	70	9.7	0.50	2.0-17.0	J A
29	*Cynoglossus broadhursti*	66	96.89	0.20	66	14.8	0.60	3.0-26.0	J A
30	*Pictiblennius tasmanianus*	65	97.09	0.20	65	4.6	0.07	4.0-6.0	J A
31	*Sillaginodes punctatus*	65	97.28	0.20	65	17.7	0.80	5.0-35.0	J A
32	*Pomatomus saltatrix*	62	97.47	0.19	62	15.7	0.84	11.0-41.0	J A
33	*Penaeus latisulcatus*	57	97.64	0.17		not	measured		
34	*Scobinichthys granulatus*	56	97.81	0.17	56	7.8	0.42	2.0-17.0	J A?
35	*Pseudorhombus jenynsii*	52	97.97	0.16	52	19.8	1.39	5.0-37.0	J A
36	*Sepioteuthis sp.*	48	98.11	0.14		not	measured		
37	*Pelsartia humeralis*	47	98.25	0.14	47	10.4	0.75	4.0-24.0	J A
38	*Neoodax semifasciatus*	42	98.38	0.13	42	15.6	0.56	9.0-27.0	J A
39	*Nectocarcinus integrifrons*	41	98.50	0.12	41	5.4*	0.29	2.0-9.0	J A
40	*Bigener brownii*	37	98.61	0.11	37	3.7	0.34	4.0-10.0	J A?
41	*Crapatalus arenarius*	32	98.71	0.10	32	7.2	0.22	5.0-10.0	J A
42	*Aspasminae sp. 1*	29	98.80	0.09	29	5.1	0.10	4.0-6.0	J A
43	*Sphyraena obtusata*	29	98.89	0.09	29	18.6	1.33	8.0-36.0	J A
44	*Rhabdosargus sarba*	25	98.96	0.08	25	16.6	0.80	7.0-20.0	J
45	*Spratelloides robustus*	21	99.02	0.06	21	6.0	0.28	4.0-8.0	J A
46	*Gonorhynchus greyi*	21	99.09	0.06	21	23.4	1.35	8.0-33.0	J A
47	*Cristiceps australis*	19	99.14	0.06	19	8.9	0.64	6.0-18.0	J A
48	*Platycephalus haackei*	18	99.20	0.05	16	24.9	2.64	10.0-44.0	J A
49	*Sepia sp.*	18	99.25	0.05		not	measured		
50	*Amoya bifrenatus*	15	99.30	0.05	15	5.3	0.32	3.0-8.0	J A
51	*Neoodax radiatus*	15	99.34	0.05	15	14.6	0.60	9.0-18.0	J A
52	*Parapercis haackei*	14	99.39	0.04	14	6.5	0.72	5.0-15.0	J A
53	*Stigmatopora argus*	14	99.43	0.04	14	18.0	1.22	7.0-23.0	J A
54	*Arripis trutta esper*	12	99.46	0.04	12	23.7	1.28	18.0-34.0	J
55	*Heteroclinus sp. A*	11	99.50	0.03	11	9.7	0.45	7.0-12.0	J A

TABLE 5.10 (Cont'd)

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
56	*Trygonorhina fasciata*	11	99.53	0.03	11	34.8	1.35	29.0-43.0	J
57	*Ovalipes australiensis*	11	99.56	0.03	11	8.0*	0.64	4.0-10.0	J A
58	*Hyperlophus vittatus*	10	99.59	0.03	2	5.9	2.70	5.0-14.0	J A
59	*Platycephalus longispinis*	10	99.62	0.03	10	17.7	2.72	8.0-35.0	J A
60	*Brachaluteres jacksonianus*	8	99.65	0.02	7	4.6	0.20	4.0-5.0	J A
61	*Callionymus goodladi*	8	99.67	0.02	8	10.0	0.78	6.0-13.0	J A
62	*Portunus sanguinolentus*	8	99.70	0.02	8	6.0*	1.11	3.0-13.0	J A
63	*Octopus tetricus*	7	99.72	0.02		not	measured		
64	*Pempheris klunzingeri*	7	99.74	0.02	7	9.6	1.21	3.0-12.0	J A
65	*Schuettea woodwardi*	7	99.76	0.02	7	10.6	1.09	8.0-15.0	J A
66	*Upeneus tragula*	6	99.78	0.02	5	5.6	0.24	5.0-6.0	J
67	*Meuschenia freycineti*	5	99.79	0.02	5	18.3	2.12	14.0-25.0	J A
68	*Hippocampus breviceps*	5	99.81	0.02		not	measured		
69	*Microcanthus strigatus*	5	99.82	0.02	5	5.0	0.32	4.0-6.0	J A
70	*Monacanthus chinensis*	4	99.83	0.01	4	8.8	1.42	7.0-13.0	J
71	*Siphonognathus argyrophanes*	4	99.85	0.01	3	35.0	2.31	31.0-39.00	A
72	*Ophichthid sp.*	4	99.86	0.01	4	41.0	5.08	33.0-55.0	A
73	*Dasyatis thetidis*	4	99.87	0.01	4	27.5†	4.57	21.0-41.0	J A
74	*Portunus rugosus*	4	99.88	0.01	4	3.5*	0.29	3.0-4.0	A
75	*Pentapodus vitta*	3	99.89	0.01	3	10.1	3.48	5.0-17.0	J A
76	*Penticipelta vittiger*	3	99.90	0.01	3	9.7	0.33	9.0-10.0	J
77	*Upeneichthys lineatus*	3	99.91	0.01	3	15.2	3.10	11.0-12.0	J
78	*Aptychotremata vincentiana*	3	99.92	0.01	3	52.7	7.80	39.0-66.0	A?
79	*Scorpis georgianus*	2	99.92	0.01	2	4.5	0.50	4.0-5.0	J
80	*Dactylopus dactylopus*	2	99.93	0.01	2	10.5	1.50	9.0-12.0	J A?
81	*Neoodax balteatus*	2	99.94	0.01	2	11.0	0.00	11.0-11.0	A
82	*Parapriacanthus elongatus*	2	99.94	0.01	2	7.5	0.50	7.0-8.0	A?
83	*Platycephalus spinosus*	2	99.95	0.01	2	11.0	0.00	11.0-11.0	J
84	*Heterodontus portusjacksoni*	2	99.95	0.01	2	36.5	0.50	36.0-37.0	A?
85	*Urolophus testaceus*	2	99.96	0.01	1	21.0†	0.00	21.0-21.0	J?

TABLE 5.10 (Cont'd)

Rank by No.	Species	No. of individuals caught	Cumulative % by No.	% of fauna by No.	Number measured	Mean size TL cm	Standard error	Size Range TL cm	Juvenile-Adult
86	*Heteroclinus adelaidae*	2	99.97	0.01		not	measured		
87	*Pseudolabrus parilus*	2	99.97	0.01		not	measured		
88	*Naxia aries*	1	99.98		1	4.0*	0.00	4.0-4.0	A
89	*Aploactisoma milesii milesii*	1	99.98		1	10.0	0.00	10.0-10.0	J
90	*Platycephalus laevigatus*	1	99.98			not	measured		
91	*Belone ciconia*	1	99.99		1	63.0	0.00	63.0-63.0	A
92	*Engraulis australis*	1	99.99		1	4.0	0.00	4.0-4.0	J
93	*Hypnos monopterygium*	1	99.99		1	19.0	0.00	19.0-19.0	J
94	*Paraplotosus albilabris*	1	100.00		1	27.0	0.00	27.0-27.0	A
	Total	33,210							

* Species measured for maximum carapace width rather than total length

† Species measured for maximum width rather than total length

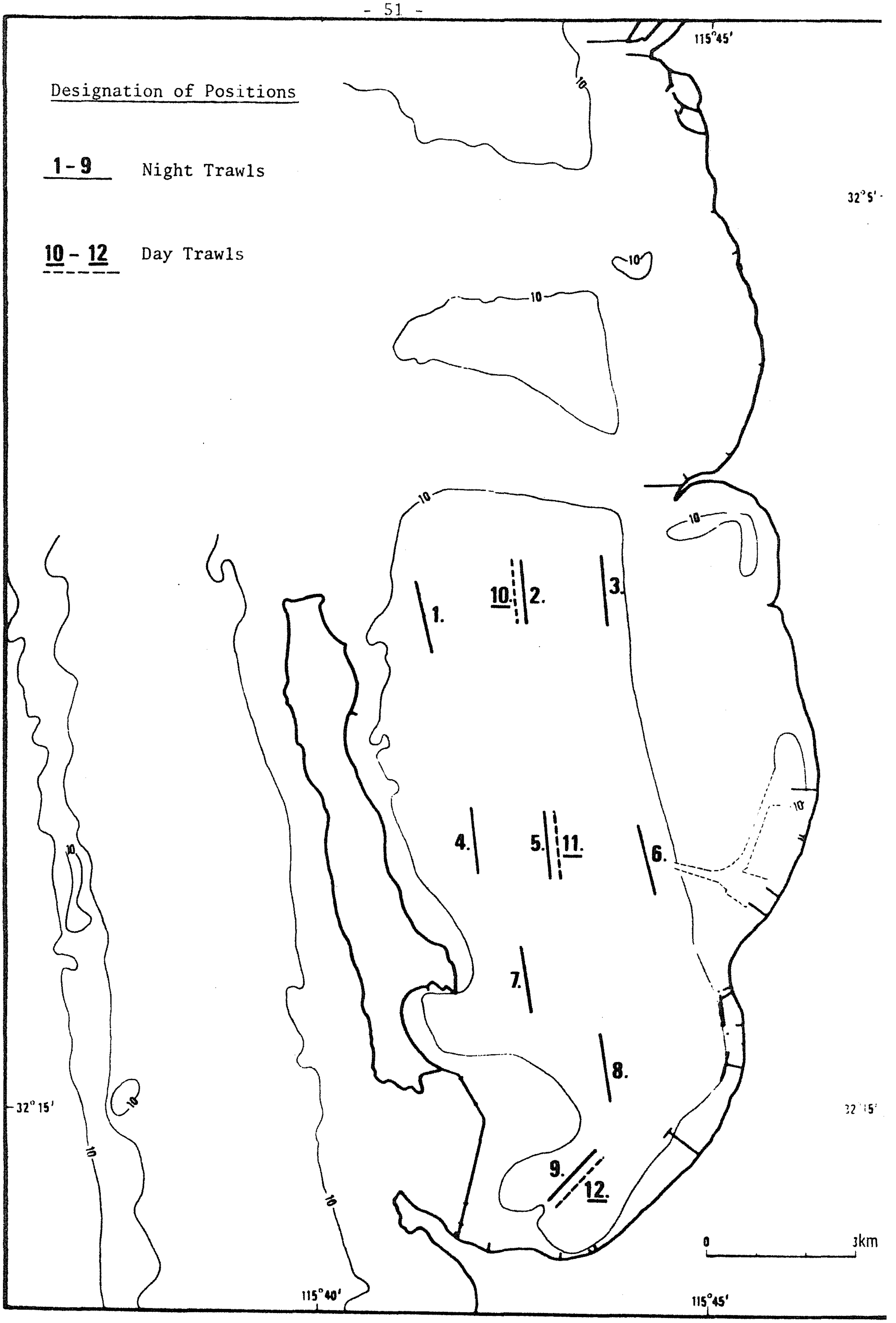

FIGURE 5.1

Positions sampled using large trawl (net type #1) during faunal survey of Cockburn Sound.

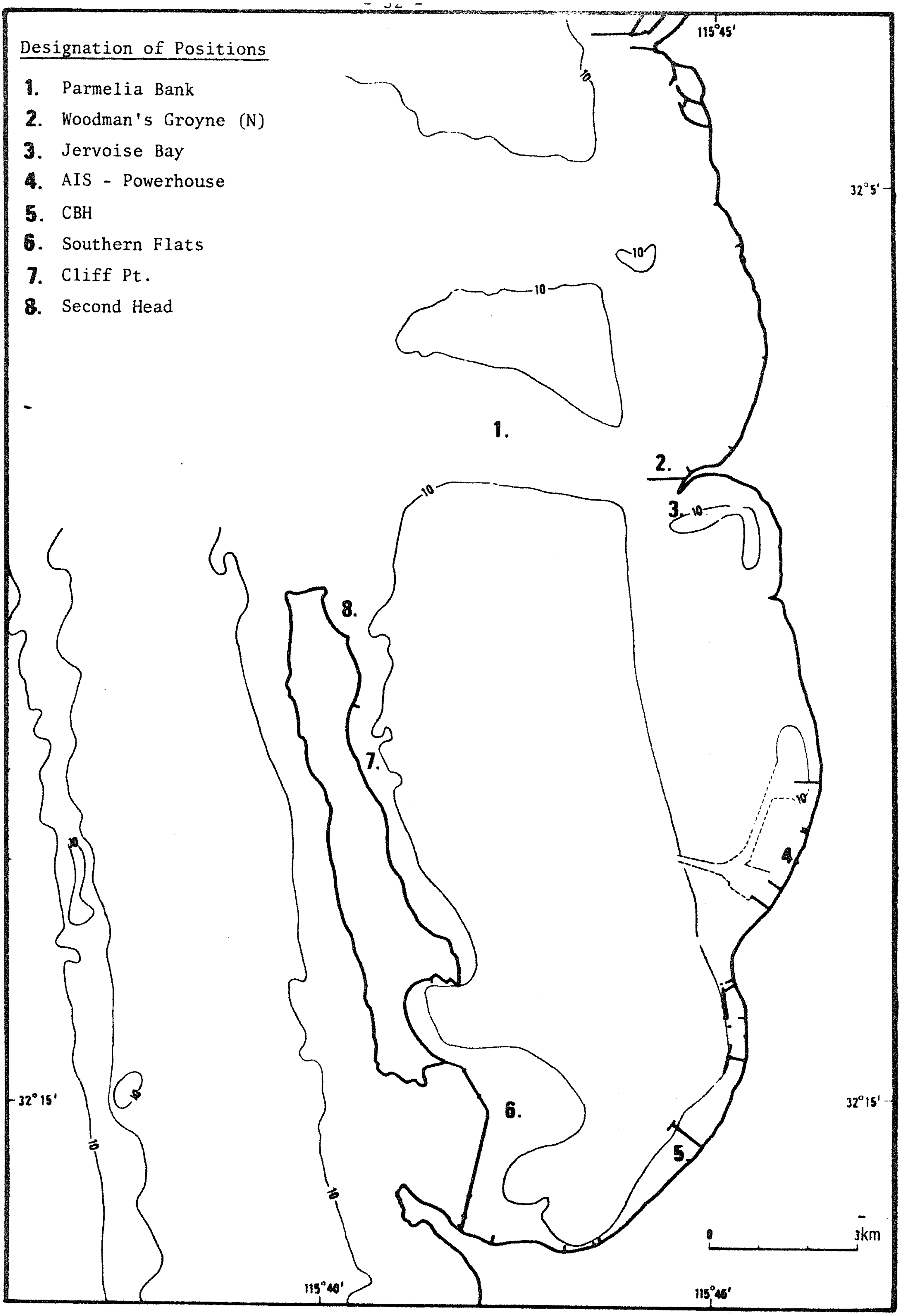

FIGURE 5.2

Positions sampled using small trawl (net type #2) during faunal survey of Cockburn Sound.

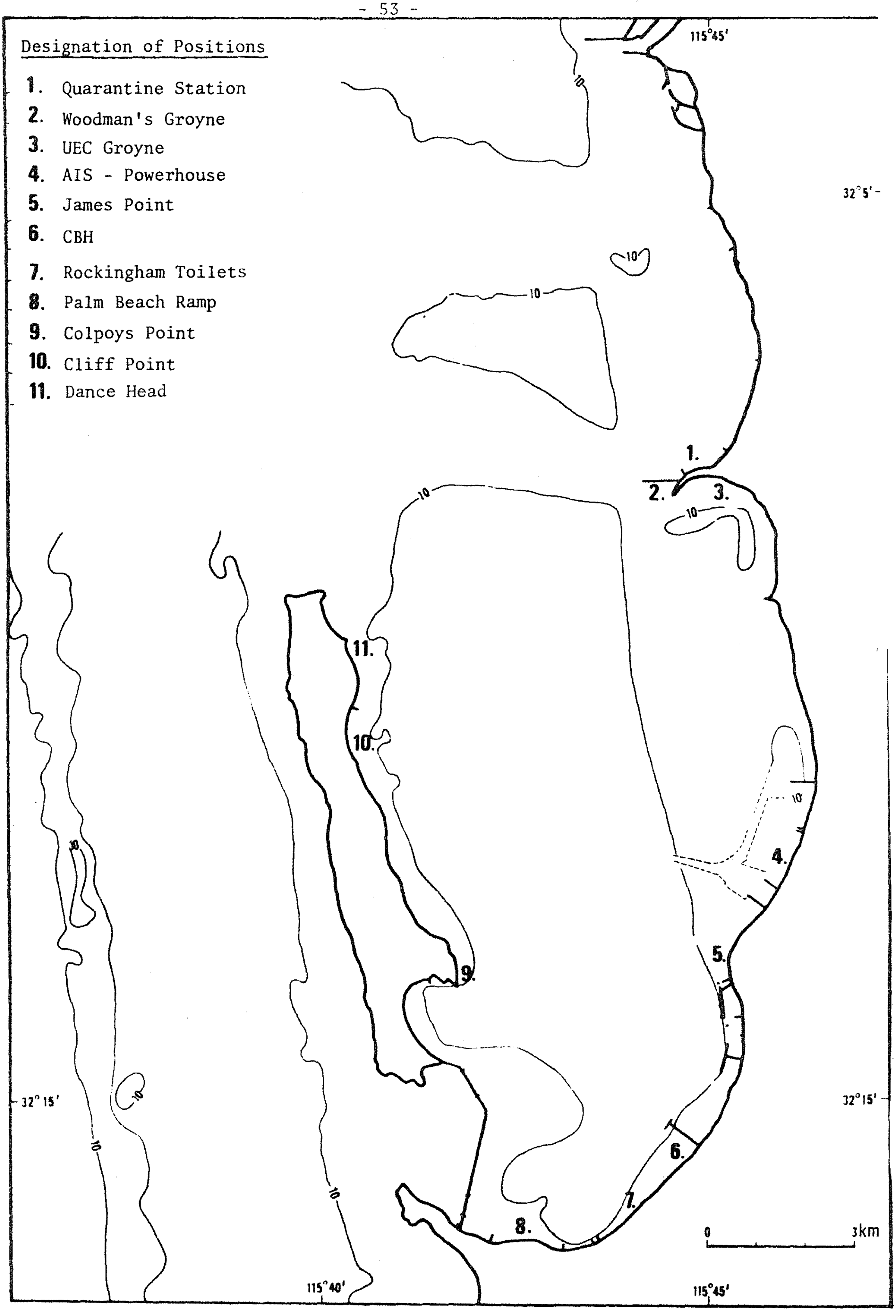

FIGURE 5.3

Positions sampled using beach seine (net type #3) during faunal survey of Cockburn Sound.

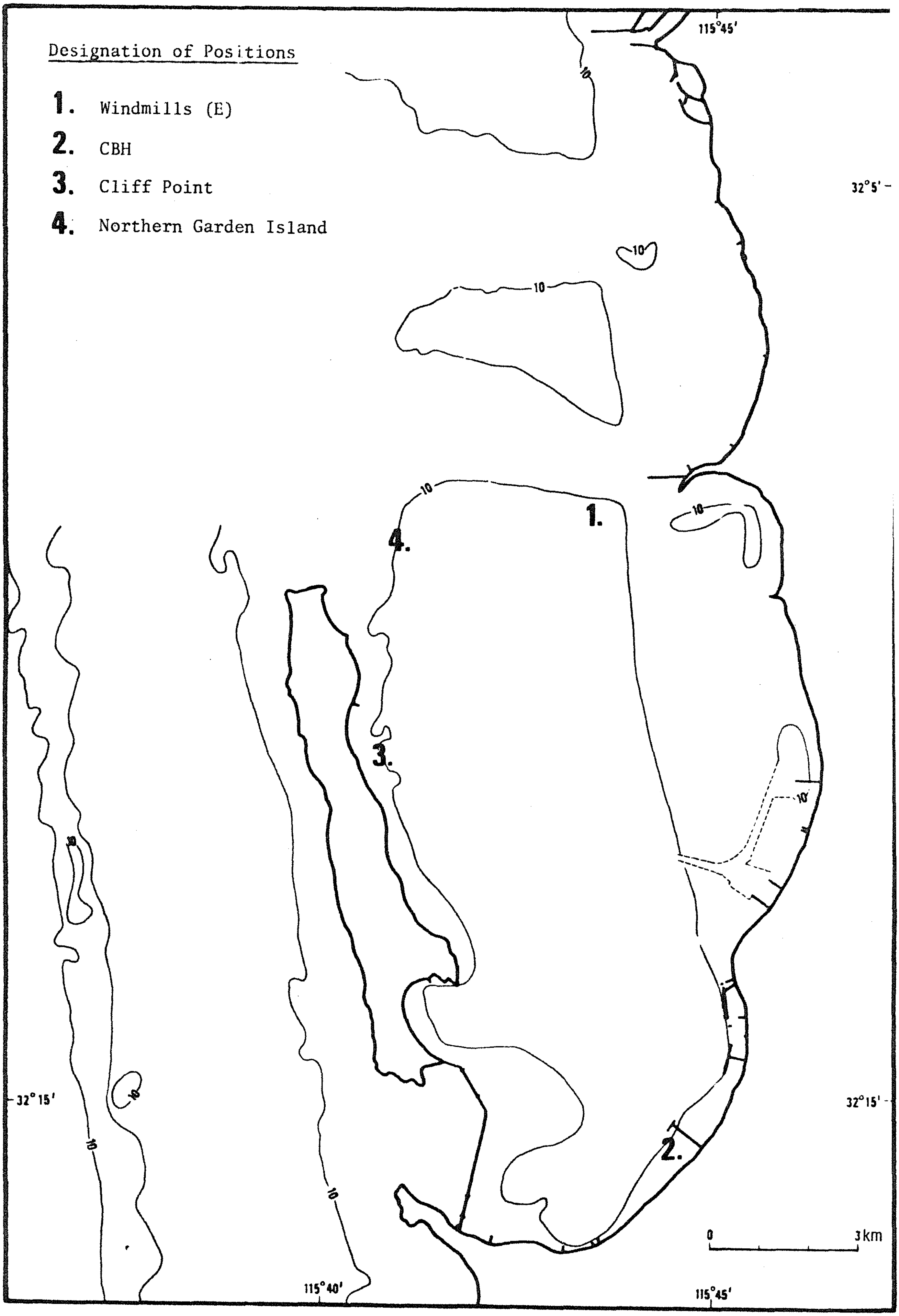

FIGURE 5.4

Positions sampled using set nets (net types #4, #5, #6, and #7) during faunal survey of Cockburn Sound.

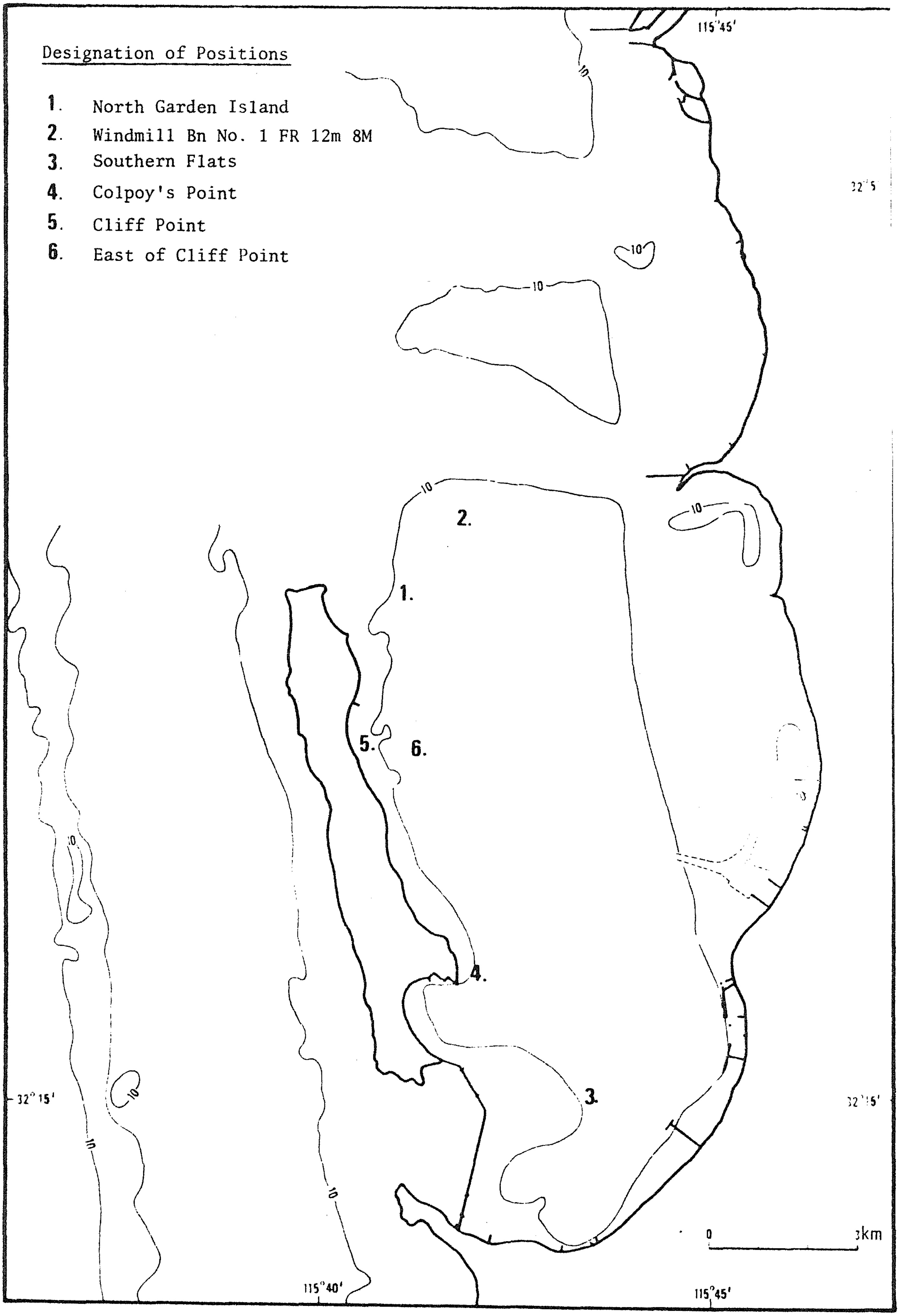

FIGURE 5.5

Positions sampled using large set net (net type #8) during faunal survey of Cockburn sound.

6. EFFECTS OF CHANGING HABITATS

6.1 Introduction

Of the many human activities which are likely to change habitats and affect fish and shellfish populations in Cockburn Sound (30), (31), the most important ones include:

- dredging and filling,
- the process of building structures such as jetties, shipping berths and the causeway,
- the use of the Sound as a receptacle for municipal and industrial wastes, which can lead to eutrophication of the waterbody (9) and contamination of fish (15).

The dependence upon specific habitats of the different life cycle stages of many species means that disturbances to any of these habitats will probably affect the population parameters of the species. Some habitat changes, such as the decline of the seagrass meadows (32), are known to have taken place in Cockburn Sound during the past 20 years. As far as is known, however, no detailed study in the past has documented fish species characteristic of specific habitats within Cockburn Sound, thereby making it impossible to compare them with the present species composition and to draw conclusions concerning the effects of habitat changes during the intervening period.

In the present study, sites sampled using the beach seine and large trawl in the faunal survey were each compared in terms of their species composition to determine which species were characteristic of sampling sites in different habitats. Changes to these habitats would presumably result in changes to their component faunal assemblages.

The most straight forward measure of faunal similarity between sampling sites is the number of species in common (33). The concept of species shared is biologically meaningful and can be readily visualised in terms of species distribution. To group together sampling sites characterised by a similar fauna, the composition of species sampled at sites was compared for a given net type using multivariate methods of classification and ordination (34).

Although classification and ordination are conceptually quite different, their results can be complementary and both methods have the following advantages (35):

(a) they effectively reduce and order large matrixes of data; (b) they are repeatable and the results from different surveys can be compared; (c) they often readily summarise trends in the data that are not immediately obvious from visual inspection or from less powerful types of analysis; and (d) the results are usually in a form that can be easily interpreted and communicated to others.

6.2 Methods

For each net type, the number of species collected at each sampling site for each sampling period, during the faunal survey was examined initially to determine the source of variation in the number of different species between collections.

6.2 (Cont'd)
For the beach seine (net type #3) the number of species collected at each sampling site during the eight nocturnal collections of the bi-monthly sampling programme (between May 1977 and June 1978) were tested during a two way analysis of variance. This analysis determined whether or not the number of species collected differed significantly between sampling site positions and between sampling periods.

The mean number of species collected at each sampling site over seagrass (positions 1, 2, 8, 10, and 11) were then compared to the mean number of species collected at each sampling site over a sandy substrate (positions 3, 4, 5, 6, 7, and 9) by means of a one tail t-test with unequal variance to determine whether or not more species were collected at the seagrass sampling site positions than at the sandy sampling site positions.

For the large trawl (net type #1), the number of species collected at each sampling programme (between June 1977 and September 1978) were tested using a three way analysis of variance. This analysis determined whether or not the number of species collected differered significantly between sampling periods, between sampling positions and between the diurnal and nocturnal catches at the same site.

Using only the nocturnal sampling sites (positions 1-9) of the large trawl, the number of species collected at each sampling site during the eight collections of the bi-monthly sampling programme were tested using a two way analysis of variance. This analysis determined whether or not the number of species collected still differed significantly between sampling periods and between positions without the effects of differences in the diurnal and nocturnal catches at the same site.

A minimum of two annual cycles is required to adequately demonstrate seasonality (36). As the faunal survey was of shorter duration, differences between sampling periods (seasonal effects) in the above analysis were illustrated using the number of the blue manna crabs (*Portunus pelagicus*) caught during each sampling for each net type. The blue manna crab was chosen as the life cycle stages and spatial movements of this species have been studied in considerable detail using Cockburn Sound as one of the major study areas (5), (37), (38). To further illustrate sampling period differences the weighted frequency of the crabs in different size classes are presented. To make samples in different months comparable, as not all crabs were measured in the larger catches, the frequency at each length has been multiplied by the total number of crabs caught in a sample divided by the total number measured in that sample.

Having established the source of variation in qualitative changes of species composition in space and time, the changes in the relative frequencies of occurrence of species with location were then examined by multivariate classification methods based on information analysis in order to group together sites characterised by similar fauna.

Polythetic agglomerative methods were used in this classification which proceeds by uniting, at each stage, that pair of sites for which the information gain (ΔI), or dissimilarity, is a minimum (34). Thus the sites united are the two resembling each other most closely in the number of species common to both.

6.2 (Cont'd)
For the large trawl, distribution of the species collected bi-monthly from 12 stations between June, 1977 and September, 1978 were investigated. Similarly the species in bi-monthly night collections using the beach seine from 11 stations during the period April 1977 and July 1978, were compared. To minimise comparisons between sites for rare species, only species occurring in at least 9 (i.e. >10 per cent) of the samples for each net type were used. For the large trawl, sampling sites were compared for the remaining 44 more abundant species. For the beach seine, sampling sites were compared using the remaining 42 more abundant species.

For each net type, the presence or absence of these species were summed separately at each sampling site for all eight sampling periods, producing the frequency with which each species occurred in the eight samples from each station. A dissimilarity matrix between sampling sites was then obtained using the information statistic. This matrix was then classified for each net type using the information gain (ΔI) as given by Dale *et. al.* (39). Adopting the usual classificatory hypothesis that there are no differences between sampling sites, program CENPERC proceeds by uniting sampling sites for which the information gain in the matrix of dissimilarities is minimum, i.e. sampling sites which are the least dissimilar are the first to be united or fused. This process is then repeated until all the sampling sites are combined.

The program used in this classification, as well as the two programs specified below, are held on a permanent library file named TAXON on the Cyber 7600, and were run from the CSIRONET terminal at the CSIRO Division of Computing Research in Perth (40), (34).

As intergroup relationships cannot be profitably elucidated further from the dendrogram produced by the above classification, the sampling sites for each net type were further examined by ordination techniques as another means of comparing sites by their species compositions to look for gradients which describe dissimilarity between the collection sites (41). The difference between any two sites is the number of species in one or the other not in common, and the corresponding distance (ΔI) is ordinated by principle coordinate analysis (42). In general the majority of usefully interpretable information can be obtained from a consideration of the first three eigenvectors extracted and ordinations are, therefore, presented in relation to these three axes (Program GOWER) (34).

To help interpret the configuration of sampling sites on these eigenvectors, the eigenvector scores for the sites for each of the three axes were correlated with the frequency occurrence for each species at each sampling site. The correlations were then sorted into descending order of absolute magnitude (high negative coefficients are as informative as high positive ones) to discover for each eigenvector, which of the original species it most strongly reflects (Program GOWECOR) (34). The ten species with the highest correlations for each eigenvector were listed as diagnostic species to be used in the interpretation of sampling site differences. For example, a given species with a positive correlation for the first eigenvector implies that the species is more likely to be caught at sampling sites with higher eigenvector scores than at sampling sites with lower eigenvector scores. The reverse interpretation would be given to species with a negative correlation for the first eigenvector.

6.3 Results

6.3.1 Variation in species numbers between collections

The numbers of species collected during the faunal survey at the different sampling sites by the beach seine are shown in Table 6.1.

When the numbers of species collected at each of the eleven sampling sites, for each of the eight sampling periods, are tested by a two way analysis of variance, the differences in species numbers between various sampling periods (seasonal effects) are significant ($F_{7, 69} = 2.622$, $p < 0.05$) (Table 6.2).

The sampling periods with the highest mean number of species collected over all sites were in February and April 1978 while the sampling periods with lowest mean number of species collected were seen to be in June of both years (Table 6.1).

The analysis of variance (Table 6.2) failed to show significant differences in species numbers between various sampling sites ($F_{10, 69} = 1.523$, $p > 0.05$). However, when the number of species collected per sample from samples from seagrass sites are compared using a one tail t-test with unequal variance to the number of species collected from samples from sampling sites over sand, there is a highly significant difference ($t = 3.098$, 36df, $p < 0.01$). Thus, despite the large variation in the number of species collected within sampling sites at different sampling periods, more species were usually collected over seagrass sites (positions 1, 2, 8, 10 and 11) than at other sites over a sandy substrate (positions 3, 4, 5, 6, 7 and 9).

The number of species collected at the different sampling sites during the faunal survey by the large trawl are shown in Table 6.3. The mean number of species per sampling site is seen to be always higher during the nocturnal collection than during the diurnal collection at the same location (positions 2 versus 10, 5 versus 11 and 9 versus 12, see Figure 5.1).

When the numbers of species collected at each of the above three nocturnal sampling sites were compared to the number of species collected at these sites during daylight over each of the eight sampling periods, using a three way analysis of variance, the differences in the numbers of species were significant between sampling periods ($F_{7, 36} = 3.010$, $p < 0.05$), between positions ($F_{2, 36} = 8.645$, $p < 0.001$) and between the diurnal and nocturnal catches ($F_{1, 36} = 18.637$, $p < 0.001$ (Table 6.4).

When the number of species collected at each of the nine nocturnal sampling sites were compared over each of the eight sampling periods using a two way analysis of variance, the differences in the numbers of species were still highly significant between sampling periods ($F_{7, 56} = 4.357$, $p < 0.001$) as well as between sampling sites ($F_{8, 56} = 7.337$, $p < 0.001$) (Table 6.5).

From Table 6.3 the sampling period with the highest mean number of species collected over all sites was in June 1977 while the sampling period with the lowest mean number collection is seen to be in February 1978.

The nocturnal sampling site with the highest mean number of species collected over all sampling periods is position 1 at the north end of Cockburn Sound while the sampling site with the lowest number of species collected is position 9 at the southern end of the Sound (Table 6.3).

6.3.1 (Cont'd)
The seasonal fluctuation in number of species caught in the beach seine and the large trawl is probably correlated with seasonal movements of some species i.e. species inhabiting the shallow banks during the warmer months then moving to the central basin during the cooler months (see Lenanton, 1978 (13)). The numbers of blue manna crabs caught in the beach seine during different sampling periods (Table 6.6) is presented as a comparison to the numbers caught in the large trawl during the sample program (Table 6.7). The greatest numbers of crabs were caught by the beach seine during May 1977 and April 1978 while the lowest numbers were caught in June of both years. The greatest numbers of crabs were caught by the large trawl, however, in June 1977, and May 1978 while the lowest numbers were caught in December 1977 and February 1978.

The annual recruitment of small juvenile crabs to the shallow banks in February (see Meagher, 1971 (38)) is reflected in the size frequency of small juveniles (2-4 cm C.W.) collected in the beach seine during that sampling period (Table 6.6).

6.3.2 Changes in the relative frequencies of occurrence of species with location
The successive hierarchal fusions of the 11 sampling sites of the beach seine (net type #3) based on information gain (Program CENPERC) are set out in Table 6.8 and the hierarchy is plotted as a dendrogram in Figure 6.1.

In this classification, the sampling sites with a seagrass substrate (positions 1, 2, 8, 10 and 11) are very distinct from the sampling sites with a bare sandy substrate (positions 3, 4, 5, 6, 7 and 9). Within these two major groupings, the sites along the industrial foreshore (positions 4, 5 and 6) are more similar to each other than sandy sites further away (positions 3, 7 and 9); within the seagrass substrate group of sampling sites, similar sampling sites are seen at Garden Island (positions 10 and 11) and Woodman Point (positions 1 and 2) whereas the Palm Beach site (position 8) is relatively isolated.

The above sites were then examined by ordination using principle coordinate analysis (program GOWER) to look for gradients of dissimilarity common to all sampling sites. Eigenvectors and eigenvalues were obtained from the dissimilarity matrix between sites. The first three eigenvalues account for over 59.7 per cent of the information in the distance matrix (Table 6.9) indicating a high tendancy of species to occur in discrete assocations (43).

The sampling sites are plotted in terms of their eigenvector scores for each pair of the first three eigenvectors in Figure 6.2). The first dimension shows that the seagrass sampling sites (positions 1, 2, 8, 10 and 11) occur closer together to each other than to the sampling sites on a sandy substrate (positions 3, 4, 5, 6, 7 and 9) Dimensions two and three exhibit differences within each of these two major groups of sampling sites. More variation is exhibited by the plotted positions of the seagrass sampling sites than by the sandy substrate sampling sites which tend to occur together regardless of the dimension examined.

6.3.2 (Cont'd)
The ten most important species, ranked by the absolute value of their correlation coefficient, (Program GOWECOR) for each of the first three eigenvectors from the above ordination of beach seine sampling sites are given in Table 6.10.

For the first eigenvector, for example, the species with negative correlation coefficient values and non-commercial species (Table 6.10) were much more likely to have been collected at seagrass sampling sites than at sites over a sandy substrate. The reverse interpretation would be made for the two species, tailor and whiting, with positive correlation coefficient values.

When the preceding three multivariate analyses are applied to the number of species collected at the twelve sampling positions of the large trawl (net type #1), the similarity of the various sites based on shared species can again be demonstrated by classification and ordination techniques. The successive hierarchal fusions of these 12 positions based on information gain (Program CENPERC) are set out in Table 6.11 and this hierarchy is plotted as a dendrogram in Figure 6.3.

In this classification, the daytime trawls' collections (positions 10, 11 and 12) are very distinct from the nocturnal trawls (positions 1-9). In other words, the species caught at given sampling sites in a daytime trawl, were more similar to other daytime trawls at other sampling sites, than to the species in the nocturnal trawl at the same location (positions 2 versus 10, 5 versus 11 and 9 versus 12). The daytime collections at the northern end of the Sound (positions 10 and 11) were more similar to each other than to the daytime collection at the southern end of the Sound (position 12).

Within the nocturnal collections, the sampling sites at the northern end of the Sound (positions 1, 2 and 3) are quite distinct from the other sampling sites which form two separate subgroups (positions 4, 5 and 9; and 6, 7 and 8).

When the above sampling sites were examined by ordination (Program GOWER) the first three eigenvalues account for over 68 per cent of the information in the distance matrix (Table 6.12) indicating a high tendancy for certain species to be collected at given sampling positions (43).

The sampling sites are plotted in terms of their eigenvector scores for each pair of the first three eigenvectors in Figure 6.4. The first dimension shows that the diurnal sampling sites (positions 10-12) occur closer together to each other than to the nocturnal sampling sites (positions 1-9). Dimensions two and three exhibit differences within each of these major groups. Within the nocturnal sampling sites, for each pair of the first three eigenvectors, the subgroup at the northern end of Cockburn Sound (positions 1-3) tend to occur together and at some distance from the other nocturnal sampling sites that formed two separate subgroups when classified above (positions 4, 5 and 9; and 6, 7 and 8).

The ten most important species, ranked by the absolute value of their correlation coefficient (Program GOWECOR), for each of the first three eigenvectors from the above ordination of the large trawl sampling sites are given in Table 6.13.

6.3.2 (Cont'd)

For the first eigenvector, for example, the species with positive correlation coefficients were much more likely to have been collected at nocturnal sampling sites than at diurnal sampling sites. The reverse interpretation would be made for the two species with negative correlation coefficient values.

6.4 Discussion

There are many abiotic environmental factors which collectively influence the manner and extent to which species use the marine environment; the most important of these includes salinity, temperature, dissolved oxygen, bottom sediments, turbidity, shelter, nutrients and pollution (44). The species response to these factors may well be historic or there may be some new response to changes induced into the environment by human activities. Unfortunately, the autecology of very few species found in Cockburn Sound is known well enough to elucidate which of the above factors influence the observed variation in number of species collected at the different sampling sites and at the same site at different sampling periods during the faunal survey.

The seasonal component of the observed variation was illustrated by using the numbers of blue manna crabs (*Portunus pelagicus*) caught at different sampling periods. This species was selected as its autecology has been studied in some detail (5), (37), (38). Temperature appears to be the critical factor controlling such activities as mating and spawning and the associated movements to the shallow banks and deeper basin of Cockburn Sound. During mid May to mid June there is a migration of this species from the shallow banks to the deeper basin (where the water temperature may be 1^{o}C warmer than on the shallow banks (9). The large difference in the number caught with the beach seine in April and May compared with the numbers caught in June (Table 6.6) probably reflects this migration as the largest catches of blue manna crab were taken in the basin with the large trawl during winter months (Table 6.7).

The blue manna crab is also known to move back onto the shallow banks as the water temperature is elevated by local heating above that of the deeper basin during the spring months. After moulting in December the large crabs again move into deeper water. Juveniles are recruited to the shallow banks in February (38) which is reflected in the size frequency of the measured catch during this sampling period (Table 6.6).

While knowledge of the life cycle stages and spatial movements of the blue manna crab helps explain the seasonal fluctuations in the observed catches in the shallow bank and deep basin habitats, *Portunus pelagicus* also appears to be a diagnostic species in terms of the beach seine sampling sites (Table 6.10). *Portunus pelagicus* has the highest correlation coefficient value for eigenvector 3 from the ordination of beach seine sampling sites. Of the total of 1 562 crabs caught using the beach seine during the faunal inventory (Table 5.10) only a total of 12 or less than 0.8 per cent were collected at sampling site positions 10 and 11 (Figure 5.4) which sampled the seagrass (*Posidonia* spp.) meadows on Garden Island. Cambridge (32) describes the condition of the seagrass at these sites as healthy with a high biomass. As the blue manna crab was ubiquitous at all other sampling sites, this species apparently prefers sites without dense seagrass probably because of the difficulty it must experience trying to feed or bury itself in the dense root-mesh of healthy seagrass. Approximately ten per cent of the total crab catch was

6.4 (Cont'd)
collected at each of the other seagrass sampling sites (positions 1, 2 and 8). Cambridge (32) describes the condition of the seagrass at these sites as much less healthy than when previously observed and points out that much of seagrass biomass has disappeared leaving bare sandy substrate. During field observations most of the crabs seen at these sites were on the sandy areas rather than in the remaining patches of seagrass.

In the Western Australian estuaries that have been studied, the shallow banks, in particular the seagrass (*Halophila ovalis* and *Ruppia maritima*) areas are the most important nursery habitats for the bulk of the most important commercial and amateur species (13), (29), mainly because of the abundant supply of small crustaceans such as shrimps and amphipods which are the principal source of food for these juvenile fish (45), (46).

Scott *et. al*. (47) found that the 11 most abundant fish species (Table 6.14) from the seagrass beds (*Posidonia* spp.) of Cockburn Sound are also largely dependent upon crustacea despite the large number of categories ingested by each species.

This is essentially similar to the most detailed studies known on seagrass fish communities by Kikuchi (48), (49) on Japanese eelgrass (*Zostera marina* L.) where again most fish also feed mainly on crustaceans. The dependence upon food from the seagrass beds is one of the main reasons cited to explain the disappearance of resident species when the eelgrass beds declined in several areas in Japan.

In studies by Kikuchi (49) the abundance and composition of the fish fauna were compared at three stations that were formally all covered by dense eelgrass beds. At the time of collection at the first station the condition of the seagrass bed was dense, i.e. well preserved; at the second, the seagrass had declined until it was sparse, i.e. less well preserved; and at the third station the seagrass had completely disappeared. In the first station, resident seagrass species were abundant along with some juveniles of some commercially valuable species; at the second station they were rare and none were found in the third station. On the other hand, species normally found on bare muddy-bottom substrates showed the reverse trend. As there were earlier records of the fish fauna in the eelgrass beds in the same region, a comparison of records suggested a positive correlation between the decline of the seagrass fish community species and the decline of the seagrass.

As similar detailed faunal records do not exist for Cockburn Sound the comparison of the fish species characteristic of certain sampling sites can only provide an indication of what the fish community is likely to be as the habitat changes. With the beach seine sampling sites, the most obvious differences between sites are species characteristic of the seagrass beds compared to species characteristically found over sandy substrates that rarely enter seagrass (Table 6.10). If the seagrass were to gradually disappear the species characteristic of the seagrass would undoubtably decline while the other species would have the opportunity to occupy substrate over a greater area.

6.4 (Cont'd)

It must be pointed out, however, that species that are most abundant in the *Posidonia* spp. beds of Cockburn Sound are generally small in size and of little direct commercial or recreation fishing interest. Of the 16 most abundant species collected in the seagrass during a separate survey (22) the only fish thought to be of interest to fishermen were three species of leatherjackets, *Bigener brownii*, *Acanthaluteres spilomelanurus* and *Scobinichthys granulatus*. As these three species were present as juveniles the meadows in Cockburn Sound of *Posidonia sinuosa* are evidently important as a nursery habitat for this family. Other authors (49), (50), (51) have cited seagrass meadows of different species as having a role as nursery habitats for juvenile fish.

As few fish feed directly on live *Posidonia* in Cockburn Sound (47) probably the main value of the seagrass to fish species of commercial and recreational fishing interest is their provision of large quantities of detrital material which, along with its resident microbes, provide a major food source for the Sound's ecosystem. In *Thalassia* seagrass beds that have been studied at least 90 per cent of the energy makes its way to the high trophic levels via the detrital food chain (52). Detrital food cycles are discussed in more detail by Cambridge (35).

As seagrass detrital material takes many years to decompose completely (53), the effects of the loss of seagrass on the fish species composition in the Sound are not likely to be seen immediately. If the seagrass disappears entirely, the present detritus-based food web would gradually diminish as the reservoir of slowly decomposing material was utilised. The loss of seagrass would then almost certainly diminish the relative abundance of species that are part of this food web. If the seagrass did not repopulate the Sound the detritus based system would probably be replaced by one or more dependent upon phytoplankton. The success of the bait fishermen in Cockburn Sound (see Section 2.3) is evidence of the many planktivorous fish already a part of this food web.

The indirect importance to juvenile fish of decaying seagrass shed periodically from healthy meadows and carried into protected shallows and onto beaches at the tidal level has been recorded in Geographe Bay (Lenanton, pers. comm.). He found that banks of decomposing seagrass provided an ideal habitat for small invertebrate fauna. These were the main food source for juvenile fish which fed in the shallows. A similar food chain linking seagrass with fish species could well have operated in the past along the eastern shores of Cockburn Sound, and could still be important in those areas where seagrass meadows remain.

The effects of changing habitats on the species found in the central basin are much more difficult to examine as not only are previous studies on the fish fauna lacking, but the central basin appears to be comparatively uniform in terms of abiotic environmental factors such as salinity, temperature, depth, currents and bottom sediments, that have been measured (9), (15), (14).

6.4 (Cont'd)
The difference between the diurnal and nocturnal species changes at the same sampling position can, however, be explained. Such species differences have also been seen in other trawling surveys (51), (54). The difference is probably behavioural as most diagnostic species (Table 6.13) with a positive correlation coefficient for the first eigenvector such as the smooth mantis shrimp (*Squilla laevis*) are strongly nocturnal. Mantis shrimps construct a tubular burrow in which they retreat well below the level disturbed by the trawl which enables them to completely escape capture during daylight. The two species with negative correlation coefficient values for the first eigenvector, the tailor (*Pomatomus saltatrix*) and the striped sea pike (*Sphyraena obtusata*) are piscivores that feed on the shallow banks at night and are probably caught while resting in the central basin during the day.

The species characteristic of certain sampling sites within the central basin undoubtably reflect some combination of environmental conditions that have yet to be elucidated. To attempt further explanation concerning the effects of changes in habitat with the central basin would invite speculation. In this the results of this investigation are not conclusive. However, the faunal survey of this study provides much of the basic information necessary for future ecologists who may wish to study the distribution of the species of the higher trophic levels of the Cockburn Sound ecosystem, or who may be interested in the autecology of one of the predominant species within this marine embayment.

TABLE 6.1

THE NUMBER OF SPECIES COLLECTED BY THE BEACH SEINE (NET TYPE #3) AT EACH SAMPLING SITE DURING THE BI-MONTHLY FAUNAL SURVEY (MAY 1977 TO JUNE 1978).

The mean and standard error of the number of species caught at each site over all sampling periods and during each sampling period over all sites is also given.

Sampling Sites	Sampling Period (Month and Year) 5/77	6/77	9/77	11/77	12/77	2/78	4/78	6/78	Sampling site $\bar{X}$	S.E.
1 SG	17	18	22	13	8	24	18	11	16.5	1.94
2 SG	22	7	15	14	16	23	29	16	17.8	2.36
3 S	10	11	8	12	10	12	16	9	11.0	0.85
4 S	14	9	9	5	14	14	10	12	10.9	1.13
5 S	10	13	-	10	9	10	16	12	11.4	0.91
6 S	15	12	10	15	14	21	20	8	14.4	1.59
7 S	1	10	15	21	13	16	20	8	13.0	2.33
8 SG	21	14	22	4	19	30	38	8	19.5	3.92
9 S	13	13	7	13	19	18	20	17	15.0	1.50
10 SG	23	14	13	17	17	18	17	8	15.9	1.56
11 SG	7	19	19	22	23	21	20	10	17.6	2.08
Sampling period $\bar{X}$	13.9	12.8	14.0	13.3	14.7	18.8	20.4	10.8		
S.E.	2.03	1.13	1.77	1.71	1.40	1.75	2.23	0.97		

SG = Seagrass
S = Sand

TABLE 6.2

TWO WAY ANALYSIS OF VARIANCE FOR THE NUMBER OF SPECIES COLLECTED BY THE BEACH SEINE (NET TYPE #3).

Data from 11 different sampling sites, and eight different collecting periods during the bi-monthly sampling programme, May 1977 to June 1978.

Source	df	SS	MS	F
Main Effects	17	6.821	4.001	1.971 *
Sampling periods	7	3.737	0.534	2.622 *
Sampling sites	10	3.101	0.310	1.523 NS
Residual	69	14.047	0.204	
Total	86	20.868		

N.B. on this and subsequent analyses of variance, data was transformed using natural logarithms. Significance denoted as follows:-

*** analysis significant at $p<0.001$

** analysis significant at $p<0.01$

* analysis significant at $p<0.05$

NS analysis not significant $p>0.05$

TABLE 6.3

THE NUMBER OF SPECIES COLLECTED BY THE LARGE TRAWL (NET TYPE #1) AT EACH SAMPLING SITE DURING THE BI-MONTHLY FAUNAL SURVEY BETWEEN JUNE 1977 AND SEPTEMBER 1978.

The mean standard error of the number of species caught at each site over all sampling periods and during each sampling period over all sites is given.

Sampling Sites	Sampling Period (Month and Year) 6/77	8/77	10/77	11/77	2/78	5/78	7/78	9/78	Sampling Site $\bar{X}$	S.E.
1	35	34	33	24	25	35	29	21	29.5	1.96
2	34	33	33	28	27	28	29	22	29.2	1.41
3	29	29	28	26	20	23	23	23	25.1	1.19
4	20	24	23	16	20	26	26	21	22.0	1.21
5	22	22	25	20	24	21	30	23	23.4	1.10
6	27	29	28	20	30	25	29	28	27.0	1.13
7	30	26	28	22	27	30	28	22	26.6	1.12
8	29	27	23	23	21	28	26	23	25.0	1.02
9	20	21	17	22	12	25	24	21	20.2	1.46
10	30	24	19	17	16	23	20	14	20.4	1.82
11	26	23	20	18	16	22	19	20	20.5	1.10
12	-	17	15	17	14	22	21	18	17.7	1.11
Sampling period $\bar{X}$	27.4	24.1	26.0	21.1	21.0	25.7	25.3	21.3		
S.E.	1.54	1.96	1.50	1.09	1.65	1.27	1.12	0.96		

TABLE 6.4

THREE WAY ANALYSIS OF VARIANCE FOR THE NUMBER OF SPECIES COLLECTED BY THE LARGE TRAWL (NET TYPE #1).

Data compares three sites, diurnal and nocturnal trawls, and eight different collection periods during the bi-monthly sampling programme between June 1977 and September 1978.

Source	df	SS	MS	F
Main Effects	10	1.594	0.159	5.883 ***
Sampling periods	7	0.571	0.082	3.010 *
Sampling sites	2	0.468	0.234	8.645 ***
Diurnal-nocturnal	1	0.505	0.505	18.637 ***
Residual	36	0.975	0.027	
Total	46	2.569		

TABLE 6.5

TWO WAY ANALYSIS OF VARIANCE FOR THE NUMBER OF SPECIES COLLECTED BY THE LARGE TRAWL (NET TYPE #1).

Data collected at nine different nocturnal sampling sites and eight different collecting periods during the bi-monthly sampling programme between June 1977 and September 1978.

Source	df	SS	MS	F
Main Effects	15	1.594	0.106	5.946 ***
Sampling periods	7	0.545	0.078	4.357 ***
Sampling sites	8	1.049	0.131	7.337 ***
Residual	56	1.001	0.108	
Total	72	2.595		

TABLE 6.6

WEIGHTED SIZE FREQUENCY OF CARAPACE WIDTH OF MEASURED BLUE MANNA CRABS (*PORTUNUS PELAGICUS*) - BEACH SEINE (NET TYPE #3).

Data collected during bi-monthly faunal survey between May 1977 and June 1978. The total number of crabs caught during sampling period is also given.

Carapace width (cm)	Sampling Period (Month and Year) 5/77	6/77	9/77	11/77	12/77	2/78	4/78	6/78
18								
17	2							
16	12	1		1	2		1	
15	37			2	5	6	4	1
14	51	1		2	1	2	12	
13	72		1	2	2	16	12	
12	39	1	2	1	14	11	5	2
11	10	2	1	6	20	13	12	3
10	2	1	3	14	40	3	49	9
9	5	5	4	29	55	3	69	11
8	11	6	9	26	49	3	68	7
7	23	6	12	36	22		77	6
6	8	3	13	28	3	3	79	5
5	13	4	8	11	1		50	1
4	5	2	7	3	1	4	12	
3	3		7			5	4	1
2	4		1			2		
1								
Number caught during sampling period	329	35	68	178	238	76	504	49

TABLE 6.7

WEIGHTED SIZE FREQUENCY OF CARAPACE WIDTH OF MEASURED BLUE MANNA CRABS (*PORTUNUS PELAGICUS*) - LARGE TRAWL (NET TYPE #1).

Data collected during bi-monthly faunal survey between June 1977 and September 1978. The total number of crabs caught during sampling period is also given.

Carapace width (cm)	Sampling Period (Month and Year) 6/77	8/77	10/77	11/77	2/78	5/78	7/78	9/78
18		1			2			
17	1	13	7	1	4	6	3	6
16	29	24	14	10	6	27	7	9
15	45	35	23	4	16	58	26	28
14	48	29	13	16	25	53	51	23
13	11	13	9	27	31	73	44	37
12	2	3	2	35	31	38	47	30
11	10	6	6	56	19	113	95	45
10	25	21	10	81	7	143	128	61
9	54	32	17	121	2	192	114	39
8	75	33	15	115	1	140	59	19
7	140	30	8	43		42	29	12
6	127	18	13	29		9	10	3
5	217	18	5	1				
4	62	2	2					
3								
2								
1								
Number caught during sampling period	2483	881	357	1732	464	2880	1959	999

TABLE 6.8

HIERARCHAL FUSIONS OF DISSIMILARITY MATRIXS FOR SPECIES COLLECTED IN THE 11 SAMPLING SITES FOR THE BEACH SEINE.

On fusion, each composite group allotted next free serial number.

Fusion	Information gain (ΔI)	Information Content (I)
4+ 5= 12	28.4807	225.6361
3+ 7= 13	28.7658	274.5477
1+ 2= 14	31.4604	323.5999
12+ 6= 15	33.8222	388.1889
10+ 11= 16	40.5359	321.7778
13+ 9= 17	43.1890	425.7468
16+ 8= 18	57.8815	549.0149
17+ 15= 19	61.8380	875.7737
18+ 14= 20	61.9656	934.5805
20+ 19= 21	154.9374	1965.2916

TABLE 6.9

FIRST THREE EIGENVALUES OF DISTANCE MATRIX BETWEEN ELEVEN SAMPLING SITES FOR 42 SPECIES - BEACH SEINE (NET TYPE #3).

Eigenvalues		% of total information in distance matrix	Cumulative %
1	.106	31.98	31.98
2	.049	14.78	46.76
3	.043	12.97	59.73

TABLE 6.10

THE TEN MOST IMPORTANT SPECIES (ranked by absolute value of correlation coefficient) FOR EACH OF THE FIRST THREE EIGENVECTORS FROM ORDINATION OF BEACH SEINE SAMPLING SITES.

	Rank	Species	Value
Eigenvector 1	1	*Apogon rueppelli*	-.9517
	2	*Gymnapistes marmoratus*	-.9313
	3	*Atopomycterus nichthemerus*	-.8729
	4	*Scobinichthys granulatus*	-.8553
	5	*Enoplosus armatus*	-.8411
	6	*Nectocarcinus integrifrons*	-.8105
	7	*Siphonognathus argyrophanes*	-.7939
	8	*Sillago maculata*	.7675
	9	*Pomatomus saltatrix*	.7574
	10	*Stigmatopora argus*	-.7423
Eigenvector 2	1	*Sillago punctatus*	-.8204
	2	*Cnidoglanis macrocephalus*	-.7706
	3	*Trygonorhina fasciata*	-.7381
	4	*Atherinosoma presbyteroides*	-.7020
	5	*Pelates sexlineatus*	-.6904
	6	*Ammotretis elongatus*	-.6853
	7	*Hyporhamphus melanochir*	.6835
	8	*Cynoglossus broardhursti*	-.6395
	9	*Contusus richei*	-.6181
	10	*Aldrichetta forsteri*	-.6035
Eigenvector 3	1	*Portunus pelagicus*	.8504
	2	*Parapriacantus elongatus*	-.7398
	3	*Thalamites sima*	.7040
	4	*Crapatulus arenarius*	-.6515
	5	*Brachaluteres jacksonianus*	.6474
	6	*Platycephalus haackei*	.6247
	7	*Callionymus goodladi*	.6134
	8	*Stigmatopora argus*	.6133
	9	*Hippocampus breviceps*	.6016
	10	*Neoodax radiatus*	-.5742

TABLE 6.11

HIERARCHAL FUSIONS OF DISSIMILARITY MATRIXS FROM SPECIES COLLECTED IN THE 12 SAMPLING SITES FOR THE LARGE TRAWL.

On fusion, each composite group allotted next free serial number.

Fusion	Information gain (ΔI)	Information Content (I)
4+ 5= 13	15.1246	249.7810
1+ 2= 14	17.1717	275.8077
7+ 8= 15	18.2532	273.8041
10+ 11= 16	20.2127	260.1631
15+ 6= 17	23.0683	435.3929
14+ 3= 18	28.2373	413.7237
13+ 9= 19	32.5529	397.5463
16+ 12= 20	39.2539	388.7566
19+ 17= 21	62.9945	895.9337
21+ 18= 22	80.2635	1389.9209
22+ 20= 23	178.4417	1957.1192

TABLE 6.12

FIRST THREE EIGENVALUES OF DISTANCE MATRIX OF 12 SAMPLING SITES FOR 44 SPECIES - LARGE TRAWL (NET TYPE #1).

Eigenvalues		% of total information in distance matrix	Cumulative %
1	.123	39.37	39.37
2	.057	18.24	57.61
3	.034	10.88	68.49

TABLE 6.13

THE TEN MOST IMPORTANT SPECIES (ranked by absolute value of correlation coefficient) FOR EACH OF THE FIRST THREE EIGENVECTORS FROM ORDINATION OF LARGE TRAWL SAMPLING SITES.

	Rank	Species	Value
Eigenvector 1	1	*Platycephalus castelnaui*	.9320
	2	*Squilla laevis*	.9314
	3	*Parapegasus natans*	.8968
	4	*Callionymus goodladi*	.8746
	5	*Pomatomus saltatrix*	-.8625
	6	*Parapercis haackei*	.8599
	7	*Monacanthus chinesis*	.8456
	8	*Cheilodonichthys kuma*	.8144
	9	*Portunus rugosus*	.8016
	10	*Sphyraena obtusata*	-.8005
Eigenvector 2	1	*Heterodontus portusjacksoni*	-.8634
	2	*Sillago vittata*	.8074
	3	*Upeneichthys lineatus*	-.7532
	4	*Pencipelta vittiger*	-.7215
	5	*Sillago bassensis*	.6705
	6	*Thalamites sima*	.6670
	7	*Sepia* spp.	-.6468
	8	*Upeneus tragula*	-.6465
	9	*Penaeus latisulcatus*	-.5984
	10	*Orectolobus ornatus*	-.5760
Eigenvector 3	1	*Atopomycterus nichthemerus*	-.7983
	2	*Gerres subfasciatus*	-.7947
	3	*Platycephalus haackei*	-.6233
	4	*Penaeus latisulcatus*	.5764
	5	*Platycephalus spinosus*	-.5457
	6	*Trygonorhina fasciata*	-.5296
	7	*Platycephalus lonispinis*	.5130
	8	*Stophiurichthys robustus*	-.4961
	9	*Dactylopus dactylopus*	-.4933
	10	*Metavelifer multiradiatus*	-.4851

TABLE 6.14

THE ELEVEN MOST ABUNDANT FISH SPECIES FROM SEAGRASS BEDS (*POSIDONIA* SPP.) IN COCKBURN SOUND.

After Scott, J.K. and Dybdahl, R.E., 1979 (22).

FAMILY	SPECIES	RANK BY SPECIES ABUNDANCE
APOGONIDAE	*Apogon rueppellii* Günther	1
SCORPAENIDAE	*Gymnapistes marmoratus* (Cuvier)	2
SYNGNATHIDAE	*Stigmatophora argus* (Richardson)	3
SYNGNATHIDAE	*Syngnathus poecilolaemus* Peters	4
ODACIDAE	*Neoodax semifasciatus* (Valenciennes)	5
ODACIDAE	*Neoodax radiatus* (Quoy & Gaimard)	6
MONACANTHIDAE	*Bigener brownii* (Richardson)	7
ODACIDAE	*Neoodax balteatus* (Valenciennes)	8
MONACANTHIDAE	*Acanthaluteres spilomelanurus* (Quoy & Gaimard)	9
MONACANTHIDAE	*Scobinichthys granulatus* (Shaw)	10
LABRIDAE	*Halichoeres brownfieldi* (Whitley)	11

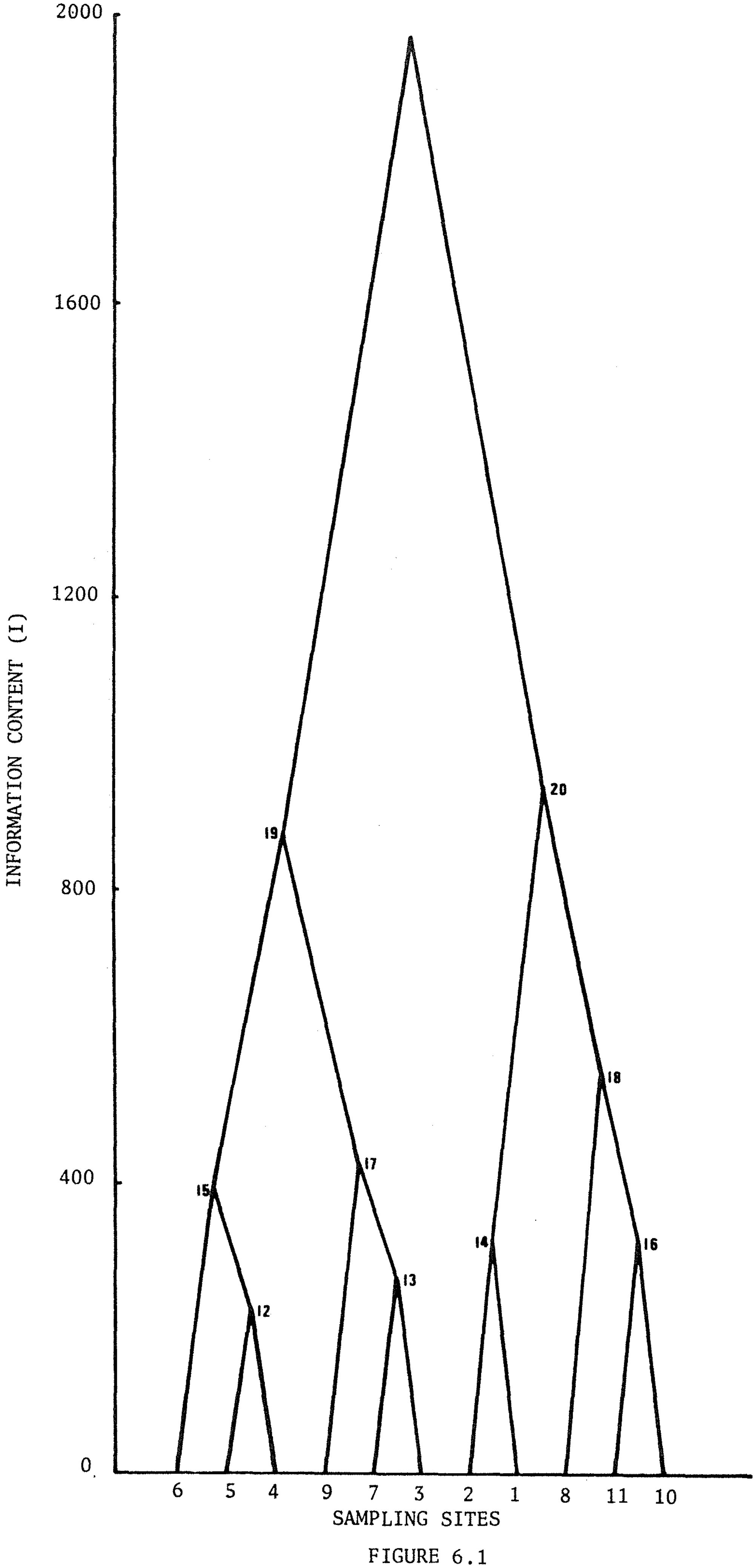

FIGURE 6.1

Dendrogram showing hierarchical classification of eleven beach seine (net type #3) sampling sites (Program CENPERC)

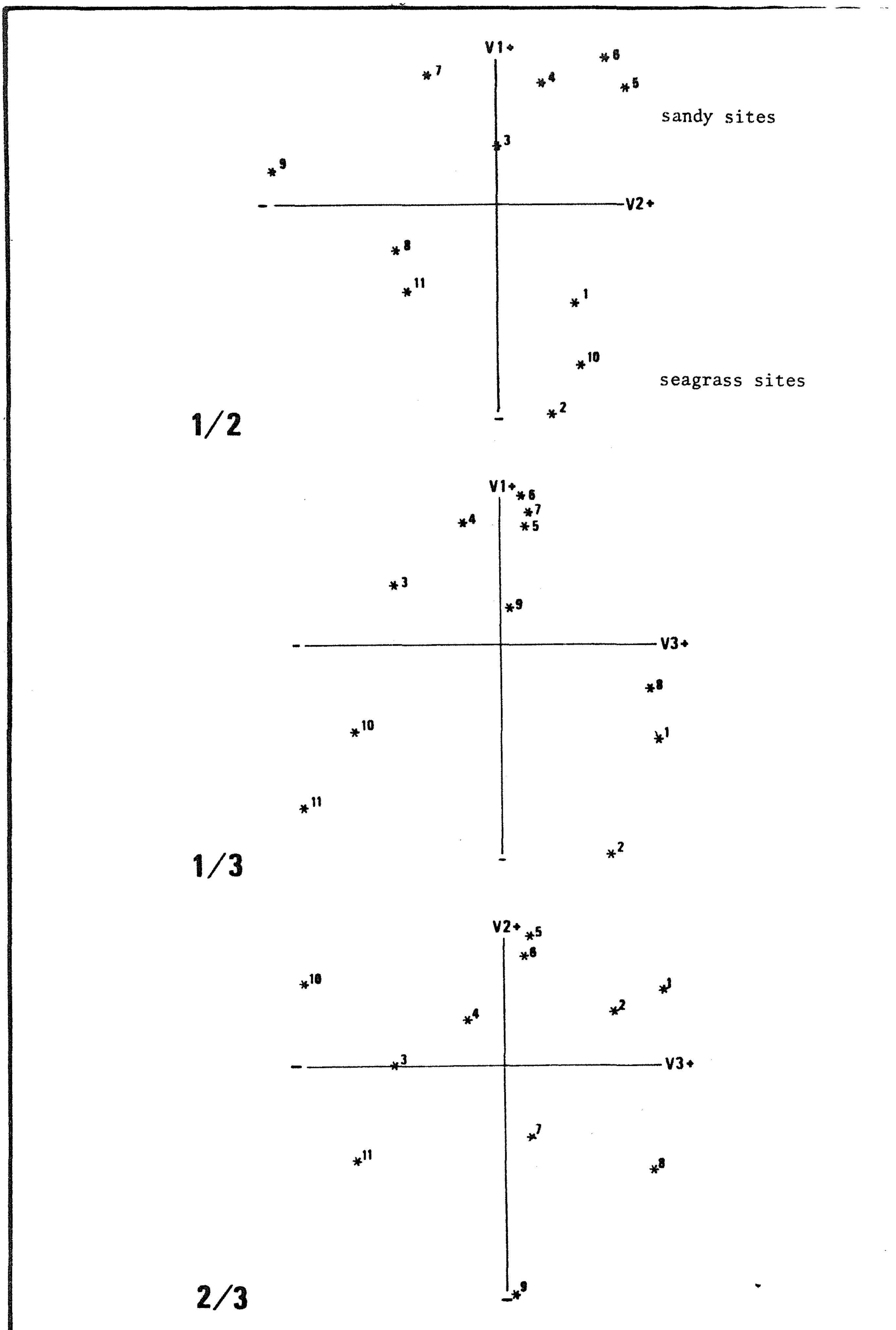

FIGURE 6.2

GOWER ordination of eleven sampling sites for beach seine (net type #3) with each pair of the first three eigenvectors shown.

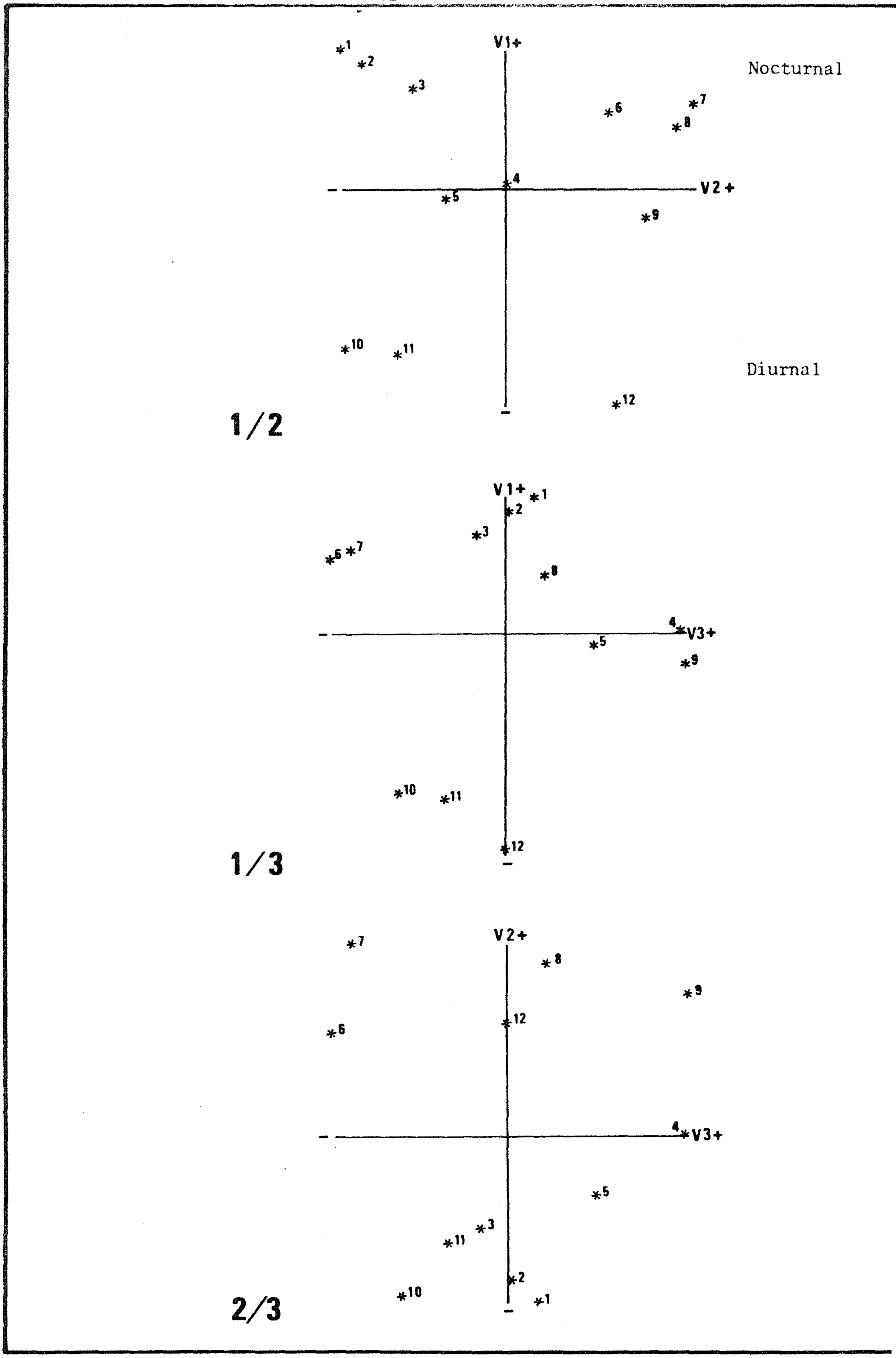

FIGURE 6.4

GOWER ordination of twelve sampling sites for large trawl (net type #1) with each pair of the first three eigenvectors shown.

ACKNOWLEDGEMENTS

I am grateful to all members of the Cockburn Sound Study Group for their assistance during this project. My predecessor, Dr. John Bass, is acknowledged for initiating the sampling programme.

I am indebted to the assistance given me by the personnel of the Department of Fisheries and Wildlife, especially R. Lenanton, N. Caputi, N. Hall and the Captain and crew of the R.V. "Flinders". I wish to thank the following for their assistance with taxonomy: R. George, B. Hutchins, N. Saiti and S. Slack-Smith (Western Australian Museum), and J. Scott (University of Western Australia).

The Town of Cockburn and the Shire of Rockingham are acknowledged for the provision of traffic counter data on the boat ramps.

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APPENDIX 1.

DATES ON WHICH THE FISH CREEL SURVEY WAS CONDUCTED DURING 1978

JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
Wednesday 4	Sunday 5	Wednesday 1	Saturday 1	Wednesday 10	Friday 2
Friday 6	Saturday 11	Saturday 4	Tuesday 4	Sunday 14	Wednesday 7
Saturday 7	Monday 13	Sunday 12	Sunday 9	Monday 15	Friday 9
Sunday 8	Saturday 18	Wednesday 15	Tuesday 11	Wednesday 17	Sunday 11
Monday 9	Wednesday 22	Friday 17	Friday 14	Saturday 20	Wednesday 14
Sunday 15	Friday 24	Saturday 18	Sunday 16	Sunday 21	Saturday 17
Wednesday 18	Saturday 25	Sunday 19	Wednesday 19	Wednesday 24	Sunday 18
Sunday 29	Tuesday 28	Monday 20	Sunday 23	Sunday 28	Sunday 25
JULY	**AUGUST**	**SEPTEMBER**	**OCTOBER**	**NOVEMBER***	**DECEMBER**
Sunday 9	Sunday 6	Sunday 10	Sunday 1	Saturday 4	Saturday 2
Monday 10	Friday 11	Thursday 14	Friday 6	Sunday 5	Sunday 3
Thursday 20	Thursday 17	Saturday 16	Saturday 7	Thursday 9	Monday 4
Sunday 23	Friday 18	Sunday 17	Monday 16	Friday 17	Saturday 9
Monday 24	Sunday 20	Monday 18	Saturday 21	Thursday 23	Friday 15
Thursday 27	Saturday 26	Saturday 23	Sunday 22	Friday 24	Sunday 17
Saturday 29	Sunday 27	Thursday 28	Monday 23	Saturday 25	Thursday 21
Sunday 30	Monday 28	Friday 29	Tuesday 24	Tuesday 28	Friday 29

* Due to oversight, interviews were conducted on three weekend days and five week days during November.

APPENDIX 2.

ESTIMATE OF TOTAL NUMBER OF FISH CAUGHT IN COCKBURN SOUND BY EXTRAPOLATION OF DATA FROM 1978 CREEL SURVEY AT COCKBURN SOUND PUBLIC BOAT RAMP AND PALM BEACH BOAT RAMPS.

Extrapolation Assumptions

(1) all interviews were valid:

2,237 total interviews/2,035 valid interviews = 1.099

the
(2a) that all weekend days during/year were surveyed:

105 weekend days in 1978/47 weekend days interviewed = 2.234

the
(2b) that all week days during/year were surveyed:

260 weekdays during 1978/49 weekdays interviewed = 5.306

(3a) that all boat owners using the boat ramps during the weekend days were interviewed:

(n = 8 days) 70 interviews/1,315 boat owners =0.053

(3b) that all boat owners using the boat ramp during the weekdays were interviewed:

(n = 18 days) 178 interviews/948 boat owners =0.188

(4) that all public ramps in Cockburn Sound were surveyed: from 1977 Recreational Survey

BOAT RAMP	TOTAL FISH CATCH	PROPORTION OF TOTAL
Riverside	320	0.016
Kwinana	2,050	0.102
Cockburn	9,450	0.472
Palm Beach	8,220	0.410
Total	20,040	1.000

(5a) that the boat ramp at Cockburn Power Boat Club was included in the survey:

(n = 12 days) 540 boats using CPBC ramp/768 boats using Cockburn ramp = 0.703

APPENDIX 2. (Cont'd)

(5b) Weekend day catch at Cockburn Power Boat Club (CPBC)

	1371347	weekend catch (see total in Extrapolation (4) below)
x	0.472	Cockburn Public Ramp proportion
	647276	Cockburn Public Ramp catch
x	0.703	CPBC proportion of Cockburn Public Ramp catch
	455035	CPBC catch

(5c) Weekday catch at Cockburn Power Boat Club

	566550	weekday catch (see total in extrapolation (4) below)
x	0.472	Cockburn Public Ramp proportion
	267411	Cockburn Public Ramp catch
x	0.703	CPBC proportion of Cockburn Public Ramp catch
	187990	CPBC catch

EXTRAPOLATION

Weekend day catch (Table 2)

	26110
(1)	x 1.099
	28695
(2a)	x 2.234
	64105
(3b)	÷ 0.053
	1209528
(4)	÷ 0.882
	1371347
(5)	+ 455035

Total Weekday Catch = 1826382

Total weekday catch (Table 2)

	16110
(1)	x 1.099
	17705
(2b)	x 5.306
	93943
(3b)	÷ 0.188
	499697
(4)	÷ 0.882
	566550
(5)	+ 187990

Total Weekday Catch = 754540

Combined weekend and weekday catch = 1826382 + 754540 = 2580922

APPENDIX 3.

SPECIES LIST FOR FISH, CRUSTACEANS AND MOLLUSCS TAKEN BY ALL NET TYPES DURING COCKBURN SOUND FAUNAL SURVEY.

Data collected over the period April 1977 to September 1978. An asterisk prefacing scientific name was used to designate species deemed to be of commercial or recreational fishing interest.

Family	Scientific Name	Common Name
ELASMOBRANCHII		
HETERODONTIDAE	*Heterodontus portusjacksoni* (Meyer)	Port Jackson Shark
ODONTASPIDIDAE	**Odontaspis taurus* (Rafinesque)	Grey Nurse Shark
ORECTOLOBIDAE	**Orectolobus ornatus* (De Vis)	Banded Wobbegong
	**Sutorectus tentaculatus* (Peters)	Cobbler Carpet Shark
TRIAKIDAE	**Mustelus antarticus* Gunther	Gummy Shark
CARCHARHINIDAE	**Carcharhinus brachyurus* (Gunther)	Bronze Whaler
	**Carcharhinus brevipinna* (Müller & Henle)	Longnosed Grey Shark
SPHYRNIDAE	**Sphyrna zygaena* (Linnaeus)	Smooth Hammerhead Shark
SQUATINIDAE	**Squatina tergocellata* McCulloch	Angel Shark
RHINOBATIDAE	*Aptychotremata vincentiana* (Haacke)	Southern Shovelnose Ray
	**Trygonorhina fasciata* Muller & Henle	Southern Fiddler
TORPEDINIDAE	*Hypnos monopterygium* (Shaw & Nodder)	Electric Ray
DASYATIDAE	*Dasyatis brevicaudata* (Hutton)	Smooth Stingray
	Dasyatis thetidis Waite	Black Stingray
UROLOPHIDAE	*Urolophus testaceus* Müller & Henle	Common Stingaree
MYLIOBATIDAE	**Myliobatus australis* Macleay	Eagle Ray
TELEOSTOMI		
OPHICHTHYIDAE	*Ophichthid sp.*	Sand Eel

APPENDIX 3. (Cont'd)

Family	Scientific Name	Common Name
CLUPEIDAE	**Amblygaster postera* Whitley	Scaly Mackerel
	**Etrumeus jacksoniensis* Macleay	Maray
	**Hyperlophus vittatus* (Castelnau)	Sandy Sprat
	**Nematalosa vlaminghi* (Munro)	Perth Herring
	**Sardinops neopilchardus* (Steindachner)	Australian Pilchard
	**Spratelloides robustus* Ogilby	Blue Sprat
ENGRAULIDAE	**Engraulis australis* (Shaw)	Anchovy
SYNODONTIDAE	*Saurida undosquamis* (Richardson)	Large-scaled Grinner
GONORHYNCHIDAE	*Gonorhynchus greyi* (Richardson)	Beaked Salmon
PLOTOSIDAE	**Cnidoglanis macrocephalus* (Valenciennes)	Cobbler
	**Paraplotosus albilabris* (Valenciennes)	White-lipped Catfish
	Plotosus lineatus (Thunberg)	Striped Catfish
GOBIESOCIDAE	*Aspasminae sp. 1*	Clingfish
MORIDAE	**Lotella callarias* Gunther	Beardie
BELONIDAE	*Belone ciconia* Richardson	Slender Longtom
HEMIRAMPHIDAE	**Hyporhamphus melanochir* (Valenciennes)	Sea Garfish
ATHERINIDAE	*Atherinosoma presbyteroides* (Richardson)	Swan River Hardyhead
	Pranesus ogilbyi Whitley	Ogilby's Hardyhead
VELIFERIDAE	*Metavelifer multiradiatus* (Regan)	Veilfin
SYNGNATHIDAE	*Hippocampus breviceps* Peters	Short-headed Seahorse
	Stigmatopora argus (Richardson)	Spotted Pipefish
SCORPAENIDAE	*Gymnapistes marmoratus* (Cuvier)	Fortesque
	**Helicolenus papillosus* (Bloch & Schneider)	Red Gurnard Perch
	**Neosebastes pandus* (Richardson)	Gurnard Perch

APPENDIX 3. (Cont'd)

Family	Scientific Name	Common Name
SCORPAENIDAE (Cont'd)	*Neosebastes scabriceps* (Whitley)	Little Scorpion Fish
	Paraploactis trachyderma Bleeker	Lichen Fish
	Aploactisoma milesii milesii (Macleay)	Velvet Fish
TRIGLIDAE	**Chelidonichthys kuma* (Lesson)	Red Butterfly Gurnard
	**Paratrigla papilio* (Cuvier)	Spiny Butterfly Gurnard
PLATYCEPHALIDAE	**Platycephalus castelnaui* Cuvier	Blue-spotted Flathead
	**Platycephalus laevigatus* Cuvier	Rock Flathead
	**Platycephalus longispinis* Macleay	Sand Flathead
	**Platycephalus spinosus* Bleeker	Tassel-snouted Flathead
	**Platycephalus haackei* Steindackner	Long-headed Flathead
PEGASIDAE	*Parapegasus natans* (Linnaeus)	Sea Moth
TERAPONIDAE	* *Pelates sexlineatus* (Quoy & Gaimard)	Striped Trumpeter
	* *Pelsartia humeralis* (Ogilby)	Sea Trumpeter
APOGONIDAE	*Apogon rueppellii* Günther	Gobbleguts
	Apogon victoriae Günther	Red-striped Cardinalfish
SILLAGINIDAE	**Sillaginodes punctatus* (Cuvier)	King George Whiting
	**Sillago maculata*	Trumpeter Whiting
	**Sillago bassensis* Cuvier	School Whiting
	**Sillago schomburgkii* Peters	Yellow-finned Whiting
	**Sillago spp. A.*	Juvenile Whiting spp.
	**Sillago vittata*	Lined Whiting
POMATOMIDAE	* *Pomatomus saltatrix* (Linnaeus)	Tailor
RACHYCENTRIDAE	**Rachycentron canadus* (Linneaus)	Cobia

APPENDIX 3. (Cont'd)

Family	Scientific Name	Common Name
CARANGIDAE	**Caranx georgianus* Cuvier	Skipjack Trevally
	**Seriola hippos* Günther	Samson Fish
	**Trachurus mccullochi* Nichols	Yellowtail Scad
ARRIPIDAE	**Arripis georgianus* (Valenciennes)	Tommy Rough
	**Arripis trutta esper* Whitley	Australian Salmon
NEMIPTERIDAE	**Pentapodus vitta* (Quoy & Gaimard)	Butterfish
GERRIDAE	*Parequula melbournensis* (Castelnau)	Silverbelly
	**Gerres subfasciatus* Cuvier	Roach
SPARIDAE	**Chrysophrys unicolor* (Quoy & Gaimard)	Pink Snapper
	**Rhabdosargus sarba* (Forsskol)	Tarwhine
SCIAENIDAE	**Argyrosomus hololepidotus* (Lacepede)	Mulloway
MULLIDAE	**Upeneichthys lineatus* (Bloch & Schneider)	Blue-spotted Goatfish
	Upeneus tragula Richardson	Long Goatfish
MONODACTYLIDAE	*Schuettea woodwardi* (Waite)	Woodward's Pomfret
PEMPHERIDAE	*Parapriacanthus elongatus* (McCulloch)	Slender Bullseye
	Pempheris klunzingeri McCulloch	Rough Bullseye
SCORPIDIDAE	*Microcanthus strigatus* (Cuvier)	Stripey
	**Scorpis georgianus* Valenciennes	Banded Sweep
ENOPLOSIDAE	**Enoplosus armatus* (Shaw)	Old Wife
CHEILODACTYLIDAE	**Cheilodactylus gibbosus* Richardson	Crested Morwong
	**Dactylophora nigricans* Richardson	Dusky Morwong
MUGILIDAE	**Aldrichetta forsteri* Valenciennes	Yelloweye Mullet
	**Mugil cephalus* Linnaeus	Sea Mullet
SPHYRAENIDAE	**Sphyraena obtusata* Cuvier	Striped Sea Pike

APPENDIX 3. (Cont'd)

Family	Scientific Name	Common Name
LABRIDAE	**Pseudolabrus parilus* (Richardson)	Brown-spotted Wrasse
ODACIDAE	*Neoodax balteatus* Valenciennes	Weedy Whiting
	Neoodax radiatus (Quoy & Gaimard)	Long-rayed Weed Whiting
	Siphonognathus argyrophanes Richardson	Tubemouth
	**Neoodax semifasciatus* (Valenciennes)	Blue Rock Whiting
SCARIDAE	*Heteroscarus acroptilus* (Richardson)	Rainbow Fish
MUGILOIDIDAE	*Parapercis haackei* (Steindachner)	Wavy Grubfish
LEPTOSCOPIDAE	*Crapatalus arenarius* McCulloch	Sand Fish
BLENNIIDAE	*Pictiblennius tasmanianus* (Richardson)	Tasmanian Blenny
CLINIDAE	*Cristiceps australis* Valenciennes	Crested Weedfish
	Heteroclinus adelaidae Castelnau	Adelaide's Weedfish
	Heteroclinus sp. A	
CALLIONYMIDAE	*Callionymus goodladi* (Whitley)	Goodlad's Stinkfish
	Dactylopus dactylopus (Valenciennes)	Pointed Stinkfish
GOBIIDAE	*Favonigobius lateralis* (Macleay	Long-finned Goby
	Amoya bifrenatus (Kner)	Bridled Goby
SCOMBRIDAE	**Sarda orientalis* (Temminck & Schlegel)	Oriental Bonito
	**Scomber australasicus* Cuvier	Blue Mackerel
BOTHIDAE	**Pseudorhombus jenynsii* (Bleeker)	Small-toothed Flounder
PLEURONECTIDAE	**Ammotretis elongatus* McCulloch	Elongate Flounder
SOLEIDAE	*Aseraggodes haackeanus haackeanus* (Steindachner)	Southern Sole
	Strabozebrias cancellatus McCulloch	Banded Sole
CYNOGLOSSIDAE	*Cynoglossus broadhursti* Waite	Broadhurst's Tongue Sole

APPENDIX 3. (Cont'd)

Family	Scientific Name	Common Name
MONACANTHIDAE	**Acanthaluteres spilomelanurus* (Quoy & Gaimard)	Bridled Leatherjacket
	**Bigener brownii* (Richardson)	Spiny-tailed Leatherjacket
	Brachaluteres jacksonianus (Quoy & Gaimard)	Pygmy Leatherjacket
	**Chaetoderma penicilligera* (Cuvier)	Prickly Leatherjacket
	**Eubalichthys mosaicus* (Ramsay & Ogilby	Mosaic Leatherjacket
	**Meuschenia freycineti* (Qyoy & Gaimard)	Six-spined Leatherjacket
	**Monacanthus chinensis* (Osbeck)	Fan-bellied Leatherjacket
	**Nelusetta ayraudi* (Quoy & Gaimard)	Chinaman Leatherjacket
	**Penicipelta vettiger* (Castelnau)	Toothbrush Leatherjacket
	**Scobinichthys granulatus* (Shaw)	Rough Leatherjacket
OSTRACIONTIDAE	*Aracana aurita* (Shaw)	Shan's Cowfish
	Strophiurichthys inermis Fraser-Brunner	Blue Boxfish
	Strophiurichthys robustus Fraser-Brunner	Robust Boxfish
	Trioris reipublicae (Ogilby)	Turret Fish
TETRAODONTIDAE	*Arothron armilla* (McCulloch & Waite)	Ringed Pufferfish
	Contusus richei (Freminville)	Prickly Pufferfish
	Torquigener pleurogramma (Regan)	Common Blowfish
	Torquigener sp.	Orange-barred Pufferfish
DIODONTIDAE	*Atopomycterus nicthemerus* (Cuvier)	Globe Fish
CRUSTACEA		
SQUILLIDAE	*Squilla laevis* (Hess)	Smooth Mantis Shrimp
PENAEIDAE	**Penaeus latisulcatus* Kishinouye	Western King Prawn
PALINURIDAE	**Panulirus cygnus* George	Western Rock Lobster

APPENDIX 3. (Cont'd)

Family	Scientific Name	Common Name
INACHIDAE	*Naxia aries* Guerin	Ram's Horn Crab
PORTUNIDAE	**Ovalipes australiensis* Stephenson	Sand Crab
	**Portunus sanguinolentus* (Herbst)	Red Spotted Swimming Crab
	**Portunus pelagicus* (Linnaeus)	Blue Manna Crab
	Portunus rugosus H. Milne-Edwards	Rough Crab
	Portunus pubescens (Dana)	Hairy Crab
	Thalamita sima H. Milne-Edwards	Four Lobed Crab
	Nectocarcinus integrifrons (Latreille)	Rocky crab
<u>CEPHALOPODA</u>		
LOLIGINIDAE	**Sepioteuthis spp.*	Squid
SEPIIDAE	**Sepia spp.*	Cuttlefish
OSTOPODIDAE	**Octopus tetricus* Gould	Octopus