CSIRO Marine Laboratories Report

The Fish Resources of Tropical Northeastern Australian Waters

Final Report
FRDC Project 88/77

Principal Investigator: Dr SJM Blaber
CSIRO Division of Fisheries
Marine Laboratories
P.O. Box 120
Cleveland Qld 4163
Phone: (07) 286 8214
Fax: (07) 286 2582

Funded by the Fisheries Research and Development Corporation

CSIRO Division of Fisheries

CSIRO
AUSTRALIA

January 1993

TABLE OF CONTENTS

Summary

This project consisted of two one month research cruises by FRV "Southern Surveyor" in the Gulf of Carpentaria and the subsequent analyses and interpretation of the data collected. The primary objectives were to determine the size and availability of commercial fish resources and to determine the distribution of the fish fauna. Secondary objectives included measuring the level of fish predation on commercial prawns (extending the work of FRDC projects 85/85 and 89/13 to the entire Gulf) and investigating the composition and fate of bycatch discards.

During the first survey in November-December 1990, 108 stations arranged in a systematic grid were sampled. At each station fish were caught with a Frank and Bryce otter trawl, invertebrate epibenthos with a Church dredge, invertebrate infauna and sediment with a Smith MacIntyre grab and temperature, salinity and turbidity profiles measured. The second survey in November-December 1991 used the same sampling techniques across 65 stations in the northern Gulf, concentrating on the areas of greatest commercial fish abundance and subject to exploitation by fish trawlers.

The absolute mean biomass of fish was 124.8 kg ha^{-1} (SE = 44.1) for day trawls and 53.7 kg ha^{-1} (SE = 6.0) for night trawls. The overall mean catch rates were 421.3 kg h^{-1} (SE = 128.5) for day trawls and 198.6 kg h^{-1} (SE = 21.5) for night trawls. Twenty five species made up 75% of both total biomass and overall catch rate. The most abundant 25 species from night catches formed 70% of both total biomass and overall catch rate. The dominant family in the daytime was the Haemulidae (28.8% of biomass), followed by the Carangidae (13.1%), Leiognathidae (8.1%) and Nemipteridae (7.3%). At night the biomass was more evenly distributed among the dominant families: Nemipteridae (13.2% of biomass), Carangidae (9.7%), Synodidae (9.4%), Lutjanidae (8.9%) and Haemulidae (6.1%).

Pomadasys maculatus was the most abundant species caught during the day, but only in the eastern and western Gulf; it was not caught at central, southern and northern stations. Upeneus sulphureus, Pentaprion longimanus, Nemipterus hexodon, Saurida sp. 2, Leiognathus bindus, Secutor insidiator, Nemipterus nematopus, Carcharhinus dussumieri, Himantura toshi and Saurida micropectoralis were widely distributed throughout the Gulf. Caranx bucculentus had a coastal distribution around the entire Gulf. Three of the abundant commercial species, Lutjanus malabaricus, Lethrinus lentjan and Lethrinus laticaudis, were unevenly distributed, with the first species occurring mainly in the northern Gulf and the other two in the north and the south.

Distribution patterns were analysed using cluster analysis and principal coordinates analysis. The stations were separated into six site groups at a dissimilarity level of 0.87 : the largest, consisting of 62 stations, occupies the central Gulf; the second largest, of 19 stations, the shallower waters of the eastern Gulf; the third, of 11 stations, occupies areas in the north and north-east; and the fourth, of 8 shallow stations, is found in the south-east, south-west and north-east. The remaining two groups of 3 stations are widely distributed. Based on their occurrences at the sites and their biomasses, the fishes were separated into 15 groups at a dissimilarity level of 1.2. Below this level there were too many small, apparently biologically meaningless groups.

The principal coordinates analysis (PCOA) indicated at least six site groups similar to the UPGMA classification results. Correlation and partial correlation analyses were then performed on the results using the PCOA eigenvalues for the first three vectors and the abiotic parameters at each site. The first and second axes of the PCOA (PCOA1 and PCOA2) explained 12% and 8% respectively of the variation in association between sites. If the data were random each axis would explain only slightly less than 1% of variation. The complexity of the data is illustrated by the fact that 27 axes were necessary to explain 80% of the variance. Using correlation analysis PCOA1 was significantly correlated with depth ($r^2 = -0.53$, $P<0.0001$), bottom turbidity ($r^2 = -0.08$, $P<0.003$), %mud ($r^2 = -0.52$, $P<0.0001$), %sand ($r^2 = 0.52$, $P<0.0001$), %gravel ($r^2 = 0.07$, $P<0.005$), bottom temperature ($r^2 = 0.34$, $P<0.0001$) and bottom salinity ($r^2 = 0.04$, $P<0.04$). However, there were significant correlations between depth and bottom temperature, %mud and %sand, as well as between bottom turbidity, %mud and % sand. Hence partial correlation analyses were necessary and these revealed that only depth was significant ($r^2 = -0.53$, $P<0.0001$).

The biomasses of fish in the prawn grounds are about double those for the Gulf as a whole although the catch rates are similar. The species composition of the fish community in prawn ground areas may be the result of intensive prawn trawling. Fishing effort and discarding of bycatch in the prawn grounds of the Gulf may cause changes in the species composition of the fish community. The commonest species on the prawn grounds included some of the most abundant in the Gulf as a whole, these species providing the bulk of the discards from prawn trawling.

Penaeids were found in the diets of 27 predators *Carcharhinus dussumieri*, *Himantura toshi*, *Caranx bucculentus* and *Lutjanus vittus* consumed commercially important prawn species. However, most penaeid prey consisted of small, non-commercial species such as *Metapenaeopsis* and *Trachypenaeus*. Penaeidae were the most important prey item by weight for *Epinephalus sexfasciatus* and *Nemipterus furcosus*, and the second most important prey item for *Carcharhinus macloti*, *Carangoides caeruleopinnatus*, *H. toshi* and *C. bucculentus*. Penaeids accounted for 18% of the total Crustacea or 1.6% of the total prey weight.

The fish trawl bycatch consists of an array of some 200 smaller fish species. Nearly a third of the bycatch floats when discarded. The remainder, of which the majority are fish, sinks. Of the sinking material less than 1% of the fish survive.

It is concluded that species of commercial importance to the Australian market are patchily distributed across the northern Gulf in sufficient quantities to support a commercial trawl fishery. Estimates of standing stock of commercial species have been provided for the 1991 and 1992 Northern Trawl Fisheries Stock Assessment Workshops - these were vital both in terms of setting up the new management zones and in providing estimates to assist managers in setting TAC's. It is important that the yearly scientific surveys of these stocks continue if the stocks are to managed properly. Further work is required on the effects of trawling on the benthos and the relative merits of various 'environmentally friendly' trawls.

SECTION 3: BACKGROUND

No detailed surveys have been undertaken of the fish fauna of the entire Gulf of Carpentaria, although there was an exploratory study by CSIRO in 1980 (Okera and Gunn, 1986). Detailed information is available on the fishes of several small areas of this shallow tropical sea, such as Albatross Bay in the north-east (Blaber et al. 1990) and an area in the south-east corner (Rainer and Munro 1982, Harris and Poiner 1991). Trawl fisheries are well established on the north-west shelf of Australia and in the western Arafura Sea (Sainsbury 1987), but the Gulf of Carpentaria has been effectively closed to fish trawling since the declaration of the Australian Fishing Zone in 1979. The fish stocks of this area are one of the few near-unexploited fisheries resources left in Australia and certainly the only substantial unexploited shallow-water fish community anywhere in the tropics. A demersal trawl fishery has recently developed in the northern Gulf of Carpentaria, fishing mainly for lutjanids and lethrinids, and is likely to extend to most of the deeper waters of the Gulf in the near future. This development and the lack of knowledge of the fish fauna, particularly those aspects relevant to management for sustainable yield, necessitated the detailed surveys that formed the basis of this project.

Although approved in 1988 this project was deferred twice until 1990/91 due to difficulties in the scheduling of FRV 'Soela' and pending the commissioning of the FRV 'Southern Surveyor'. Various items of equipment were purchased in 1989/90.

SECTION 4 - OBJECTIVES

A. Primary

1. To determine the size and availability of commercial fish resources of the Gulf of Carpentaria (GOC), the portion of the AFZ north of the GOC, and the western portion of the Torres Strait Protected Zone.

2. To determine the distribution of the demersal fish fauna of the above areas, particularly in relation to:
   a) the distribution of the benthos
   b) the distribution of sediments
   c) depth

B. Secondary

1. To determine which species of fish feed on penaeid prawns in selected prawn-trawl areas of the GOC (Albatross Bay, Groote Eylandt and Southeast Gulf) - thus extending the work of FIRDC Projects 85/85 and 89/13.

2. To describe the bycatch and determine the fate of bycatch of commercial trawls.

3. To determine the differences in the fish communities of areas of high and low prawn trawl effort.

SECTION 5 - RESEARCH PROBLEM

Trawl fisheries are well established on the NW Shelf and in the Timor and western Arafura Seas. A demersal trawl fishery has recently developed in the northern GOC and is likely to extend to most of the deeper waters of the GOC in the near future. Whereas TAC's and management plans have been instituted for the established fisheries (See BRR Information Paper IP/6/90), insufficient was known of the GOC fish stocks for even interim management measures.

The lack of knowledge of species compositions and catch rates in the various regions of the GOC, particularly in relation to factors such as depth and benthos (ie. bottom structure), were addressed by the CSIRO/Raptis & Co. collaborative cruise of 1990 (supported also by AFS) and by the FIRDC Project 88/77 "Southern Surveyor" cruises of November-December 1990 and 1991. These two research cruises are providing a vast amount of basic data which will be analysed in the next two to three years. To provide adequate biological data and support for management, information on growth, mortality, spawning and specific relationships with benthos (i.e. structure and prey items) were required. The samples necessary for providing these data were collected and analysed under funding provided by FIRDC Grant 90/29. Hence the important data for calculating meaningful TAC's and making rational management decisions were dependent on the interrelated FIRDC projects 88/77 and 90/29.

The increasing pressure from industry for the opening of the central GOC to commercial fin-fish trawling made it imperative that the data from the two cruises were made available as soon as possible. Some biological data (e.g. growth, mortality, spawning seasons) were available from NW Shelf (CSIRO) and Arafura (NT) work for certain species. However, these are likely to vary and the GOC represents an essentially unfished stock in an area where the bottom structure is minimally disturbed. In view of these points, and the differences between the GOC and the NW Shelf/Timor/Arafura Seas with regard to both physical (e.g. GOC not deeper than about 80 m) and biological factors (e.g. GOC has relatively high productivity) independent data had to be obtained for the GOC. The sentiments expressed by Jernakoff and Sainsbury (BRR IP/6/90) that early scientific advice is vital for the future development of fisheries in the Arafura and Timor Seas was equally, if not more applicable, to the rapidly developing situation in the GOC.

CSIRO studies of the effects of fishing on yields and the composition of the demersal fish community of the Northwest Shelf had shown that changes have occurred since exploitation began in 1972. Although the total abundance of fish has not changed, there have been significant declines (From 65% down to 21% by weight) in the abundance of the commercially important lethrinids, lutjanids and serranids and significant increases (12% to 33% by weight) in the non-commercial nemipterids and saurids. These changes in fish composition were coupled with significant fishing- induced declines in the abundance of benthic habitats (sponges, soft corals, gorgonians etc.) of the lethrinid and lutjanid populations. The saurids and nemipterids are associated with habitats containing none or few of these benthic organisms. Thus the total biomass of the fish community has not changed but its composition has shifted. The changes in fish community have decreased the value of the catch to the trawl fishery. In the Gulf of Carpentaria this project (88/77) undertook to examine the relationship between fish and benthos and comprehensive results should be available within the next two years.

The aims of the prawn predation study were firstly to describe the diets of a range of predators, particularly those that eat penaeid prawns; thus extending the work in Albatross Bay (Brewer et al. 1991) to the entire GOC; and secondly to provide baseline information for studies of predator prey relationships in the GOC as they may relate to the distribution and structure of the benthos.

Information about the diets of many of the predatory fishes of the Gulf of Carpentaria is available only from studies in other parts of the Indo-Pacific. Broad diet categories have been summarised for the Lutjanids and Serranids of the Indo-Pacific (Parrish 1987), *Rachycentron canadum* (Shaffer & Nakamura 1989; Darracott 1977), *Arius thalassinus* from the Bay of Bengal (Mojumber 1969) and *Scomberomorus commerson* from the east coast of Australia (McPherson 1987). The feeding biology of three species of Nemipteridae from the South China Sea has been described by Eggleston (1972). Previously existing information for the Gulf of Carpentaria consisted only of that from Albatross Bay (Brewer et al. 1989, 1991) and adjacent estuarine areas (Salini et al. 1990, 1992) and data on the diets of sharks from across northern Australia (Stevens & McCloughlan 1991).

The wide diversity of animals in tropical waters results in target species in trawling making up only a minor part of the catch. This results in very large amounts of dead and living material being discarded from trawlers. Studies of Australian prawn fisheries have shown that discards separate into floating and sinking components both of which are scavenged by birds, dolphins, sharks, teleosts and crabs. Dolphins and some species of birds have learned to associate trawlers and food. In Moreton Bay, birds such as seagulls that commonly scavenge during the day, frequently follow trawlers at night and feed on discards. These observations suggest that at least some scavengers may learn to associate trawlers with food and respond positively to them. In the Gulf of Carpentaria, there is an intense prawn trawl fishery, but it is largely coastal and, except in the southwest is mostly within 100 km of the coast. Thus large areas are not trawled. Research cruises in November - December 1990 and 1991, offered the opportunity to examine surface scavenging by birds, dolphins and sharks and to decide whether there was a relationship between scavenging and the occurrence of trawling.

SECTION 6 - RESEARCH METHODS

Surveys

In November 1990, the FRV 'Southern Surveyor' systematically transected the Gulf of Carpentaria and over 4 weeks sampled 108 stations in the stock assessment part of the survey (Fig. 1). At each station, a Frank and Bryce demersal fish trawl was towed at a speed of 3.3 knots (max 5.5 knots, min 2.3 knots) for 30 minutes, day or night, but not 0.5 h either side of dawn and dusk or at depths less than 17 m. The Frank and Bryce trawl had a 26 m headrope and 50 mm cod end and was rigged with 50 m bridles to otterboards. Also at each station, a 4 m Church dredge was towed for 15 min for epibenthos, replicate sediment and infaunal samples taken with a 'Smith McIntyre' grab, and temperature, salinity, turbidity against depth profiles made with a 'Yeokal' data logger (Blaber et al. 1992).

During two weeks in November 1991, the FRV 'Southern Surveyor' randomly sampled 65 stations in the Northern Gulf of Carpentaria. The Frank and Bryce trawl was rigged and used as in the previous November survey except that a 'Photosea' camera was mounted on the headrope. This camera took flash photographs of the substrate in front of the groundrope every minute. Shallower areas (>8m) were also sampled.

The catch composition in all surveys was determined by sorting the whole or a sub-sample of the catch to species level. The weight and numbers of each species were recorded and the standard lengths of all commercial fishes measured. During the November 1990 cruise, all fish were weighed (± 1 g), sexed and both otoliths (sagittae) removed dried and stored for later analysis. Subsequently, in November 1991, otoliths were kept only from fish in size classes that were underrepresented in previous samples. Vertebrae and scales were also taken from these fish and frozen for later examination of banding patterns.

Fishes were obtained for stomach content analysis from two cruises; firstly from a CSIRO survey on the commercial trawler *Clipper Bird* in June 1990, and secondly from a systematic grid-pattern survey on *FRV Southern Surveyor* in November-December 1990. Most of the results were taken from the November-December cruise. Diet data from the

June 1990 cruise (winter) were used for seasonal comparison with the data from the November-December cruise (early summer). The sampling details and stations for both cruises are given in Brewer *et al.* (1992). In addition, 21 extra stations 6 x 3-hour trawls and 15 x 15-minute trawls were worked in November-December 1990 to collect samples. The Gulf of Carpentaria study area is described in Somers and Long (1992).

All fish taken for stomach content analysis were weighed (±1 g) and measured - standard length (SL) for teleosts, total length (TL) for sharks and disc width for rays. All predator species that were known to eat penaeids or that were considered likely to eat penaeids were collected.

Epibenthic beam trawl samples were sorted fresh on board into family taxa and frozen for transport to the laboratory. The large sedentary fauna, mainly sponges, were sorted into categories immediately after collection, counted and their fresh weight recorded to the nearest 100 g. A subsample was frozen for later identification. All taxa were identified to species taxa wherever possible, and otherwise were assigned to unique categories and given a reference name. Taxonomic samples have been lodged at the Queensland Museum, Brisbane. Species were counted, weighed to the nearest gram and placed into feeding guilds herbivores, deposit feeders, scavengers/carnivores and suspension feeders by consulting relevant texts. Species were also scored into size classes: large (> 1 kg), medium (0.1 kg < 1 kg) and small (< 100 g), and mobility classes: sessile and mobile.

For the benthic infauna the contents of each grab were emptied into a tray with two and one mm mesh sieves. A sediment sample (approx. 200 g) was taken from the first grab at each station, labelled, placed in a plastic bag and frozen for subsequent grain size, organic carbon and pigment analysis. The sediment was washed by deck hose and the animals and sediment retained on the two and one mm mesh put in separate calico bags and placed into 25 l drums of 8% neutral formalin stained with rose bengal. All benthos were identified to species taxa and counted. Nemerteans were identified to phyla only because of taxonomic difficulties. Individual colonies of bryozoans, hydroids and ascidians were also counted. Families were placed into feeding guilds - herbivores, deposit feeders, carnivores/scavengers and suspension feeders - by consulting Fauchald and Jumars (1979) for polychaetes, Short and Potter (1987) for Molluscs, and Barnes (1974) for the remaining phyla.

Sediment samples were collected with a 0.1 m Smith-MacIntyre grab. Grain size analysis was carried out in the laboratory by a modification of Folks (1968) method described in McLoughlin and Young (1985).
With regard to the bycatch commercially important species of fish and crustacea were sorted from the catch of the 3 h trawls as soon as possible after it came on board. A 50

kg sample of the discards was taken for experiments and the balance was sorted and weighed. The partitioning of discards was investigated as follows: Thirty minutes after the codend of the trawl net was lifted from the water, half of a 50 kg sample was put into a 120 X 60 X 75 cm tank containing 60 cm depth of sea water. This water was continuously aerated and exchanged from a running sea water system with a temperature of 28 to 29 C which was similar to that of the sea. After another 10 min the rest of the sample was put into a similar tank. After 1 h, all animals floating on the surface were removed, sorted into taxonomic categories and weighed. These were classified as dead. All dead animals on the bottom of the tank were also removed and weighed. Thereafter, the tanks were checked for dead animals every 12 h for a total of 4 days. During the day when the trawl net reached the stern ramp and the ship was travelling at about 2 knots, a bucket of fish was dumped overboard to determine the identity of surface scavengers. An observer on the trawl gallows 9 m above water level over the stern noted the number and species of birds and other scavengers that fed on the discards in the following 5 min. After the trawl was hauled on board, the ship was stopped. A further batch of discards was dumped over the side and observed for 5 min to establish whether there were sharks, fish or dolphins scavenging on discards. This observation could be carried out at night as well as during the day.

Analyses

Biomass and distribution patterns

Biomasses of the fishes were calculated from the wingspread of the net, the towing speed and catchability coefficients. The wingspread of the net remained constant at 15.6 m (60% of headrope length measured with SCANMAR). The net was towed at an average speed of 5.76 km h^{-1}, resulting in a swept area of 0.045 km^2 for a 30 min tow.

Catchability coefficients (q) used follow Blaber et al. (1990) and the species were divided into three groups: small (<225 mm) species q = 0.3; larger species (>225 mm) q = 0.47; and large (>1000 mm) slow moving species q = 1.0.

Mean catch rates expressed as kg h^{-1} were calculated from the following:

$$\text{Mean catch rate} \quad (W_i) = \frac{1}{n}\sum_{j=1}^{n}\frac{C_{ij}}{t_j}$$

Where C_{ij} = catch in weight of species i in jth trawl, n = number of trawl shots and t_j = duration of jth trawl as a proportion of 1 h.

Biomass expressed as kg ha^{-1} was estimated as follows:

$$\text{Biomass} = \frac{W_i}{Aq_i}$$

Where A = area (ha) swept in 1 h of trawling, and q_i = catchability of species i.

CSIRO had previously conducted research in the prawn grounds of Albatross Bay. To compare this work with our own survey, we carried out five 15 min shots in Albatross Bay during the day. In our survey we used the same trawl gear with the same wingspread (60%), the same 15 min trawl duration, but a different vessel (Blaber et al. 1990). Similarly, five 15 min trawls were shot in the prawn grounds of the south-east Gulf (night-time only) and off Groote Eylandt (daytime only) (Fig.1). Thus the species compositions in the prawn grounds could also be compared with one another and with those of the Gulf of Carpentaria as a whole.

Classification and principle coordinates analysis ordination techniques were used on species biomass data from each station using PATN software (Belbin 1991). A total of 286 species were analysed. Biomass values (kg ha^{-1}) were transformed ($\log_{10}$ x + 1) to decrease dominance of very large species, and of large catches of smaller species. Transformed biomass values for each station (i) at each taxon (j) were then 'range standardised' by $(x_{ij} - xmin_j)/(xmax_j - xmin_j)$ where $xmin_j$ and $xmax_j$ were the minimum and maximum abundances recorded for the j^{th} taxon in the data set. This has the effect of re-scaling all values to between zero and one and weights all attributes equally before using the Bray-Curtis association measure.

A q-mode cluster analysis (clustering stations on species composition) was performed with the Bray-Curtis dissimilarity measure to produce a dissimilarity matrix (Bray and Curtis 1957). This matrix was sorted by hierarchical agglomerative fusion (Flexible UPGMA, Belbin 1991) of un-weighted pair group mean averages (Beta = -0.1).

Community structure patterns in relation to abiotic parameters were investigated using principle coordinates analysis (PCOA) data. Three dimensions were chosen for the PCOA of the standardised association between the species composition at each site. The Gower correction option was used for the PCOA. Correlations and partial correlations were then performed between eigenvalues from each PCOA axis and the following abiotic parameters: depth; surface, mid- and bottom water turbidity; percentages of sand, mud and gravel in the sediment; surface and bottom temperature; and surface and bottom salinity from each station. Partial correlations were used to examine the relationships between the PCOA axes and each abiotic parameter while holding the effect of other abiotic parameters constant. These correlations were required to explain the representation of each PCOA eigenvector.

An r-mode cluster analysis (clustering species/taxa on their distribution and abundance in stations), as described above, was also performed on a transposed matrix of the transformed and standardised biomass data, and a dendrogram was produced. A two-way density table of species versus stations was used to help interpret the dendrogram groupings (Belbin 1991).

The fish species composition on the three prawn trawl grounds was compared by non-parametric statistics (Spearmans Rank correlation coefficient and Friedman two-way analysis of variance) as well as the Bray-Curtis dissimilarity measure.

Diets

All stomachs were analysed using the gravimetric (percentage dry weight) and frequency of occurrence methods (Hyslop 1980) and followed the procedures described in Brewer *et al.* (1991) and Salini *et al.* (1990). Whenever possible, prey items were identified to their lowest taxon. Diet values in the tables refer to numbers of fish with food in their stomachs unless otherwise stated. Teleosts were identified from morphological features and, when necessary, an otolith reference collection. Penaeids were identified from hard parts using the taxonomic keys of Racek and Dall (1965) and Grey *et al.* (1983). Numbers of prey items were recorded; in the case of penaeids, the sex and carapace length were also recorded. Percentage dry weight was used to describe the diets in terms of (a) the general diet using 9 categories, (b) the teleost diet using 16 categories and (c) the penaeid diet using 14 categories. Nine general diet categories - Annelida, Brachyura, Cephalopoda, Crustacea (crustacea other than Brachyura, Penaeidae and Stomatopoda), Mollusca, Penaeidae, Stomatopoda, Teleostei and 'other' - were chosen to accommodate the diets of all predators and for ease of comparison with published results.

The habitat of each diet category was described as benthic, bentho-pelagic or pelagic and the 16 categories within the teleost component indicate the feeding habit of each predator. Details of the penaeid prey are presented to distinguish the contribution of commercial and non-commercial penaeids.

Epibenthos

Presence/absence data was analysed using the PATN classification and ordination software (Belbin 1991). Presence/absence data was used instead of biomass or abundance because of the taxonomically and physiologically divergent types of epifauna, which covered both plant and animal kingdom and ranged from solitary corals, colonial corals, bryozoans, hydroids, seagrasses and algae to massive sponges and small molluscs. The use of presence/absence data permitted an analysis of the full data set and avoided the problematical decisions of what constitutes an individual or unit biomass. There is also evidence to suggest that binary data is suitable for classification and ordination. The Bray -Curtis association measure was used to calculate the dissimilarity between stations based on taxa presence/absence (Q-mode). The Gower metric was used for the R-mode analysis. Station by station dissimilarities were sorted using the un-weighted pair, group-mean-average (UPGMA) fusion algorithm with a slightly space dilating beta value of -0.1. Only species found at more than two stations were used for the classification and ordination analysis. This was done to reduce the number of chance co-occurrences between rare species. Field (1976) has shown that removing rare species has little effect on the outcome of the analysis. Station by station dissimilarities were ordinated using principal co-ordinate analysis (PCA) rather than multi-dimensional scaling because PCA tends to force group formation (Belbin 1991). The relationship between the biological and environmental data was measured by correlating the PCA scores with the abiotics.

Benthic infauna

Contour plots of abundance and species richness were produced using SPANS GIS software (SPANS 1991). The contouring algorithm was based on triangulated, irregular network interpolation techniques. The contour surface is forced through all data points and contours restricted to interpolation within the convex hull of points. Abundance data was square root transformed to normalise the data Sokal and Rholf 1981) for the Q-mode analysis. The Bray -Curtis association measure was used to calculate the dissimilarity between stations based on taxa abundances (Q-mode). Station dissimilarites were sorted using the un-weighted pair group mean average (UPGMA) fusion algorithm with slightly space dilating beta value of -0.1. Only species found at more than two stations were used in the classification and ordination analyses. Stephenson and Cook (1980) have shown that removing rare species had little effect on the results of the classification and ordination. Station dissimilarities were ordinated using principal co-ordinate analysis (PCO), which tends to separate station groups more than Multi-Dimensional Scaling (Belbin 1991). The relationship between the biological and physical data was measured by Pearson correlations of the numerically dominant taxa, functional groups and principal co-ordinate scores with depth, sediment grain size, surface minus bottom temperature, bottom turbidity. Salinity was relatively constant, both horizontally and vertically, throughout the study area and were not included in the analysis.

Abiotic data

Salinity and temperature: surface to bottom profiles were measured at each station with a Yeokal submersible data logger.

Turbidity: surface, mid-water and bottom water samples were collected at each station with Nisken bottles, and turbidities were measured with a Hach nephelometer.

Bottom sediment: sediment samples were collected at each station using a Smith-McIntyre grab. Grain size analyses were carried out in the laboratory using a graduated series of Endecott sieves.

SECTION 7 - RESULTS

At present, only results from the November-December 1990 cruise have been fully analysed. Those from the 1991 cruise will be completed within the next year.

Fish biomass and distribution

General

Approximately 412100 fish weighing 15900 kg and consisting of over 300 species from 85 families were collected from the 107 stations. The absolute mean biomass was 124.8 kg ha^{-1} (SE = 44.1) for day trawls and 53.7 kg ha^{-1} (SE = 6.0) for night trawls (Table 1). The overall mean catch rates were 421.3 kg h^{-1} (SE = 128.5) for day trawls and 198.6 kg h^{-1} (SE = 21.5) for night trawls (Table 2).

The absolute mean biomass and mean catch rates of each of the 25 most abundant species in the daytime are shown in Table 1. These 25 species made up 75% of both total biomass and overall catch rate. The most abundant 25 species from night catches (Table 2) formed 70% of both total biomass and overall catch rate. The dominant family in the daytime was the Haemulidae (28.8% of biomass), followed by the Carangidae (13.1%), Leiognathidae (8.1%) and Nemipteridae (7.3%). At night the biomass was more evenly distributed among the dominant families: Nemipteridae (13.2% of biomass), Carangidae (9.7%), Synodidae (9.4%), Lutjanidae (8.9%) and Haemulidae (6.1%).

The percentage frequency of each of the 22 species that occurred in over 50% of day trawls are shown in Table 3. They formed 33.6% of the overall daytime biomass but 10 of the species were not represented in the top 25 species in terms of biomass (cf. Tables 1 and 3). The most frequently caught species in the day trawls were Priacanthus tayenus and Saurida sp.2 (both 94% of trawls), followed by Leiognathus bindus and

Pentaprion longimanus (both 92% of trawls). The 25 species that were caught in more than 50% of night trawls are shown in Table 4. They formed 43.8% of the overall night-time biomass but 13 of the species were not among the top 25 species in terms of biomass (cf. Tables 2 and 4). The most frequently caught species in night trawls were Saurida sp.2 (98% of trawls) followed by Priacanthus tayenus (97%), Nemipterus hexodon and Pentaprion longimanus (both 85%).

There was a significant positive correlation between day and night catches in terms of frequency of occurrence of species (Spearmans r = 0.92, $P<0.001$).

Distribution of most abundant species

Pomadasys maculatus was the most abundant species caught during the day, but only in the eastern and western Gulf; it was not caught at central, southern and northern stations (Fig. 2). Upeneus sulphureus, Pentaprion longimanus, Nemipterus hexodon, Saurida sp. 2, Leiognathus bindus, Secutor insidiator, Nemipterus nematopus, Carcharhinus dussumieri, Himantura toshi and Saurida micropectoralis were widely distributed throughout the Gulf (Figs 2 and 3). Caranx bucculentus had a coastal distribution around the entire Gulf (see also Brewer et al. 1992 - this volume). Three of the abundant commercial species, Lutjanus malabaricus, Lethrinus lentjan and Lethrinus laticaudis, were unevenly distributed, with the first species occurring mainly in the northern Gulf and the other two in the north and the south (Fig. 4).

Abiotic factors

A summary is given in Table 5 of the mean, minimum and maximum values of the following physical parameters: depth, surface, mid-water and bottom turbidity; surface and bottom temperature; surface and bottom salinity; and percentages of mud, sand and gravel. Depth was positively correlated with % mud (r = 0.33, $P<0.0005$) but negatively correlated with % sand (rho = -0.36, $P<0.0001$). In addition depth was negatively correlated with bottom temperature (rho = -0.64, $P<0.0001$). Bottom turbidity was positively correlated with % mud (rho = 0.38, $P<0.0001$) and negatively correlated with % sand (rho = -0.41, $P<0.0001$).

Community structure and distribution patterns

Site groups

The similarities between stations characterised by fish species occurrences and biomasses are shown in Figure 5. The stations were separated into six groups at a dissimilarity level of 0.87 : the largest, consisting of 62 stations, occupies the central Gulf; the second largest, of 19 stations, the shallower waters of the eastern Gulf; the third, of 11 stations, occupies areas in the north and north-east; and the fourth, of 8 shallow stations, is found in the south-east, south-west and north-east. The remaining two groups of 3 stations are widely distributed.

Species groups

Based on their occurrences at the sites and their biomasses, the fishes were separated into 15 groups at a dissimilarity level of 1.2 (Fig. 6). Below this level there were too many small, apparently biologically meaningless groups.

Community structure patterns in relation to abiotic parameters

The principal coordinates analysis (PCOA) indicated at least six site groups similar to the UPGMA classification results (Fig.7). Correlation and partial correlation analyses were then performed on the results using the PCOA eigenvalues for the first three vectors and the abiotic parameters at each site. The first and second axes of the PCOA (PCOA1 and PCOA2) explained 12% and 8% respectively of the variation in association between sites. If the data were random each axis would explain only slightly less than 1% of variation. The complexity of the data is illustrated by the fact that 27 axes were necessary to explain 80% of the variance. Using correlation analysis PCOA1 was significantly correlated with depth (r^2 = -0.53, $P<0.0001$), bottom turbidity (r^2 =-0.08, $P<0.003$), %mud (r^2 = -0.52, $P<0.0001$), %sand (r^2 = 0.52, $P<0.0001$), %gravel (r^2 = 0.07, $P<0.005$), bottom temperature (r^2 = 0.34, $P<0.0001$) and bottom salinity (r^2 = 0.04, $P<0.04$). However, there were significant correlations between depth and bottom temperature, %mud and %sand, as well as between bottom turbidity, %mud and % sand. Hence partial correlation analyses were necessary and these revealed that only depth was significant (r^2 = -0.53, $P<0.0001$).

Prawn trawling areas

The overall mean biomasses and catch rates for the five trawls in each of the three prawn grounds (Albatross Bay, Groote Eylandt and south-east Gulf) are shown in Table 7. The biomasses are about double those for the Gulf as a whole although the catch rates are similar. There was a significant rank correlation between the daytime species composition (based on biomass of top 25 species) of the Gulf as a whole and Albatross Bay (Spearmans r = 0.46, $P<0.05$), but not between the Gulf and Groote Eylandt. There was no significant rank correlation between the night-time species composition (based on biomass of top 25 species) of the Gulf as a whole and the south-east Gulf prawn grounds.

The daytime species composition of the Groote Eylandt and Albatross Bay prawn grounds and that of the Gulf as a whole were compared by cluster analysis (based on biomass of top 25 species). Bray-Curtis dissimilarity and UPGMA (Group-Average) sorting showed that the Gulf and Albatross Bay were more similar to each other (dissimilarity level = 0.52) than either was to Groote Eylandt (dissimilarity levels 0.60). Pomadasys maculatus and several species of leiognathids were abundant in Albatross Bay, the south-east Gulf and the Gulf as a whole, but were absent from the top 25 at Groote Eylandt. A Friedman ANOVA using biomasses showed a significant difference between the species compositions of the Gulf, Groote Eylandt and Albatross Bay (Friedman $Chi_r = 38.9$, $P<0.05$). Also Bray-Curtis dissimilarity and UPGMA sorting indicated a 75% difference at night between the Gulf as a whole and the south-east Gulf prawn grounds.

The five daylight trawls in Albatross Bay during this study yielded similar results to those of the 97 daylight trawls of Blaber et al. (1990). The overall mean biomasses and catch rates were comparable: 248 kg ha^{-1} (SE=96) and 297 kg ha^{-1} (SE=38), and 1180 kg h^{-1} (SE=457) and 922 kg h^{-1} (SE=103). There was a significant rank correlation between the biomasses of species common to the two studies (Spearmans $r = 0.50$, $P<0.01$) and the top four species were present in the same order of biomass: *Leiognathus bindus, L. equulus, L.splendens* and *Pomadasys maculatus.*

Relationships with benthic structure and benthos

All samples of infauna and epibenthos collected during November 1990 and 1991 have been examined and all species identified to the lowest taxonomic level possible. The community structure, species density, spatial patterns of distribution of numerically dominant species of infauna has been completed (see Appendix 1: Long and Poiner 1993) and the abstract is attached (Appendix 2). A similar analysis of the community structure of the epibenthic fauna is currently being prepared for the special issue of Australian Journal of Marine and Freshwater Research **44** (3) next year (Long and Poiner in prep.).

The analysis of the degree of coupling between the fish and benthos will proceed after the epibenthic community structure has been determined. This will allow the fish-site groupings (Appendix 1: Blaber et al 1993) to be correlated with the benthos site-groupings.

The other aspect of the coupling between fish and benthos to be examined was the identification of key benthic prey and the degree of prey selectivity and its effect on fish distributions. The diets of abundant predatory fishes in the GOC has been examined. Analysis of prey selectivity and the identification of key benthic prey is in progress.

A total of 4143 stomachs of 79 fish species (teleost and elasmobranch) were analysed. Of these, 1831 or 44% were empty; the remainder contained a total of 3493 g dry weight of prey comprising 85.6% teleosts, 8.7% crustaceans, 2.5% molluscs (includes cephalopods), 2.1% annelids and 1.1% assorted other categories. Data are presented for all species where the number of stomachs containing food (NF in various tables) was ≥5 (40 species). Species with an NF <5 were excluded.

General diets

Twenty-three predators were major piscivores (cf. Salini et al. 1990); Teleostei formed >50% of their diet. The remaining 17 species were minor piscivores that had consumed <50% Teleostei (Tables 8 and 9 respectively). After teleosts, total Crustacea (Brachyura, Crustacea, Penaeidae and Stomatopoda combined) were the most important diet source for 10 of the major piscivore species (Table 8). For 5 predator species, Cephalopoda provided the next most important food source after Teleostei; Other Crustacea and Brachyura were next in importance for three species each; Annelida, Penaeidae and 'other' were next in importance for two species each. Mollusca (excluding Cephalopoda) was the next most important category after Teleostei for one major piscivore, *Saurida micropectoralis*.

The diets of minor piscivores (Table 9) had a different set of major prey categories. As a combined group, total Crustacea were the dominant prey for 14 of the 17 minor piscivore species.

Within the nine general prey categories, other Crustacea was the most important category for *Himantura toshi* (48.8%), *Epinephelus areolatus* (37.4%), *Priancanthus tayenus* (47.9%), *Scolopsis monogramma* (78.2%) and *Diagramma pictum* (35.5%). Brachyura were dominant in the diets of *Arius thalassinus* (34.5%), *Caranx bucculentus* (38.5%), *Nemipterus nematopus* (37.0%) and *N. peronii* (29.1%). Cephalopoda, Penaeidae or Teleostei dominated the diets of six minor piscivores, *Epinephelus sexfasciatus* (46.7%), *Nemipterus furcosus* (27.5%), *Carangoides malabaricus* (60.9%), *Lethrinus lentjan* (40.9%), *Carangoides humerosus* (42.3%) and *Nemipterus hexodon* (30.4%). Stomatopoda and 'other' were major diet sources for *Carcharhinus amblyrhynchos* (39.9%) and *Gnathanodon speciosus* (89.4%) respectively. Stones and pebbles represented 60.0% of the total diet of *G. speciosus*; presumably the stones were ingested while these fish fed on the bottom. Mollusca and Annelida were found in the diets of most species, but were never the major prey. Two species that were considered likely teleost predators, the serranid *Epinephelus sexfasciatus* and the nemipterid *Scolopsis monogramma*, ate no teleosts, but the number of stomachs of these species that contained food was low, at NF = 7 and 6 respectively.

Penaeid diet

Penaeids were found in the diets of 27 predators (Table 10). *Carcharhinus dussumieri*, *Himantura toshi*, *Caranx bucculentus* and *Lutjanus vittus* consumed commercially important prawn species. However, most penaeid prey consisted of small, non-commercial species such as *Metapenaeopsis* and *Trachypenaeus*. Penaeidae were the most important prey item by weight for *Epinephalus sexfasciatus* and *Nemipterus furcosus*, and the second most important prey item for *Carcharhinus macloti*, *Carangoides caeruleopinnatus*, *H. toshi* and *C. bucculentus*. Penaeids accounted for 18% of the total Crustacea or 1.6% of the total prey weight.

Bycatch

Composition of discards

The discards from the 3 h duration trawl hauls have been identified but as yet the data have not been compared with the standard 30 min hauls. The mean weight for the six 3 h duration trawl hauls was 677.5 kg (SD = 490.9 kg).

Partitioning of the discards

Nearly a third of the catch from 3h duration trawls floats and the rest sinks. The majority of this represents fish, with less than 2% comprising the cephalopods. Of the sinking material, only crustaceans (bugs and crabs) and < 1% of fish survived.

Identity of surface scavengers

On both cruises, sharks and sea birds were the major scavengers. Scavengers were observed on 36% of all stations in the first cruise and on 29% of all stations in the Gulf of Carpentaria on the second cruise. Preliminary analysis showed that scavenging was mostly on stations near the coast suggesting that there is an association with trawling grounds. In the case of birds, this is probably related to the distance from land. Sharks were only seen scavenging on one station further than 35 n.m. from land, whereas between 1 and 8 sharks were seen on nearly every occasion after trawls closer to shore. This could be the result of an association between sharks and inshore trawling.

SECTION 8 - DISCUSSION

The daytime mean biomasses and catch rates for the Gulf as a whole are similar to those of other tropical shallow-water demersal fish communities (Blaber et al. 1990; Longhurst and Pauly 1987; Lowe-McConnell 1987), catch rates ranging from about 100 kg h^{-1} to as much as 500 kg h^{-1}. It is evident however, that many of the abundant demersal species are unevenly distributed in the Gulf (Figs 2 to 4). Also, since this survey took place at a single time of year and previous work in Albatross Bay has demonstrated a complex of diel, seasonal and cruise- related patterns of abundance for the most common species (Blaber et al. 1990), any comparisons with other tropical areas should be made cautiously. Nevertheless, the broad-scale distribution patterns and abundances show many interesting features.

The values obtained in the three major prawn grounds during the present survey were similar to those recorded by Blaber et al. (1990) in the Albatross Bay prawn ground over two and a half years. Since the gear used in the present survey was the same, although the vessel was different, the results are probably directly comparable. Such a species composition may be the result of intensive prawn trawling. Harris and Poiner (1991) suggested that fishing effort and discarding of bycatch in the prawn grounds of the south-east Gulf caused changes in the species composition of the fish community over a 20 year period. Furthermore, they noted profound changes in the diel behaviour of some species after intensive trawling. The commonest species on the prawn grounds included some of the most abundant in the Gulf as a whole, such as *Pomadasys maculatus, Upeneus sulphureus, Pentaprion longimanus, Saurida* spp. and various leiognathids - these species providing the bulk of the discards from prawn trawling (Ramm et al. 1990; Harris and Poiner 1990,1991).

However, the prawn grounds did not fall out as discrete site groups in the classification analyses, but rather formed a part of larger groupings (Fig. 5). However, sampling in this survey did not cover all prawn ground areas because it could not include waters shallower than 17 m.

The community analysis suggested that the fish fauna of the Gulf could be split into three major groups plus a fourth group of 'misfits' (Table 6). The widespread and abundant species - again those characteristic of prawn trawl grounds and discards - form the most ubiquitous group. Most of these species are also characteristic of shallow (<80 m), soft-bottom trawl grounds throughout south-east Asia (Mohsin et al. 1988; Pauly 1988) and the wider Indo-West Pacific region (Longhurst and Pauly 1987).

A number of regional groups have cohesive distributions (Fig. 5 and Table 6), but the statistical analyses did not reveal any strong correlations between these patterns and abiotic parameters, except for depth. This depth relationship accords with results from studies of limited areas of the Gulf, such as the south-east corner and Albatross Bay, where depth strongly influenced the catch rates of many species (Rainer and Munro 1982; Blaber et al. 1990). Ramm et al. (1990) showed that 115 prawn trawl bycatch taxa across northern Australia were distributed along geographic (west of 131°E and east of 133°E) or bathymetric gradients, but samples from the Gulf were only from the western side. Unfortunately, major differences in prawn trawl gear (which catches only a subset of the fish community, in terms of both fish size and species composition) and fish trawl gear preclude useful comparisons between our results and those of Ramm et al. (1990). McManus (1986) considered depth the primary gradient affecting shallow-water demersal fish distribution. The present results (which exclude inshore waters of less than 17 m) suggest that this may also be the case in the Gulf of Carpentaria, where depths do not exceed 80 m and depth gradients are slight.

Although depth may be the major determinant of fish distribution in the Gulf of Carpentaria, the results of the correlation analyses suggest that sediment type, turbidity and temperature may be worth further investigation. Turbidity is a primary factor affecting the distribution of estuarine and inshore fishes of the subtropics and tropics (Blaber and Blaber 1980; Cyrus and Blaber 1987) but has not previously been considered in relation to the distribution of tropical marine shelf communities. The third group of apparently unrelated fish communities (Table 6), consisting mainly of reef-associated species in restricted areas or at single sampling stations, suggest relationships with sediment type, benthos or benthic structure. Reef areas are also usually areas of low turbidity water.

The distribution of many of the larger, commercially important, species of lutjanids and lethrinids is centred on a series of stations across the northern Gulf. On the north-west Shelf of Australia, commercially high value lutjanids and lethrinids have been replaced by smaller, low value saurids and nemipterids. Sainsbury (1987) has suggested that much of this change was the result of trawls removing benthic structure. The further analyses of relationships between benthic structure, benthos and fish distribution that are in progress will be required before this possibility can be confirmed for the Gulf of Carpentaria. Key epibenthic and infaunal prey can then be related to their contribution to the diets of the commercial species (Salini et al 1993).

SECTION 9 - IMPLICATIONS AND RECOMMENDATIONS

1. The fish fauna of the Gulf of Carpentaria is similar to that of other large shallow water tropical areas. Catch rates are similar to those of, for example, the Gulf of Thailand prior to heavy exploitation.

2. Species of commercial importance to the Australian market are patchily distributed across the northern Gulf in sufficient quantities to support a commercial trawl fishery.

3. Estimates of standing stock of commercial species have been provided for the 1991 and 1992 Northern Trawl Fisheries Stock Assessment Workshops - these were vital both in terms of setting up the new management zones and in providing estimates to assist managers in setting TAC's. It is important that the yearly scientific surveys of these stocks continue if the stocks are to managed properly.

4. Further work is required on the effects of trawling on the benthos and the relative merits of various 'environmentally friendly' trawls.

SECTION 10 - INTELLECTUAL PROPERTY

There was no commercially significant development that arose as a result of this study and no patents have been applied for.

SECTION 11 - TECHNICAL SUMMARY

1. The daytime mean biomasses and catch rates for the Gulf as a whole are similar to those of other tropical shallow-water demersal fish communities, catch rates ranging from about 100 kg h^{-1} to as much as 500 kg h^{-1}.

2. The species composition of the fish community in prawn ground areas may be the result of intensive prawn trawling. Fishing effort and discarding of bycatch in the prawn grounds of the Gulf may cause changes in the species composition of the fish community. The commonest species on the prawn grounds included some of the most abundant in the Gulf as a whole, these species providing the bulk of the discards from prawn trawling.

3. Depth is the primary determinant of fish distribution in the Gulf although the roles of sediment type, turbidity and temperature may be worth further investigation.

4. The distribution of many of the larger, commercially important, species of lutjanids and lethrinids is centred on a series of stations across the northern Gulf.

5. The distribution of the invertebrate infauna and epibenthos is correlated with sediment type. Relationships between fish and benthos are still being analysed.

6. For the Gulf of Carpentaria as a whole, Penaeidae were found in the diets of 27 predatory fish species but most of the prawns were of small non-commercial species. The situation in prawn grounds is more complex and has benn previously reported (see also FIRDC 85/85 and 89/13).

7. The fish trawl bycatch consists of an array of some 200 smaller fish species. Nearly a third of the bycatch floats when discarded. The remainder, of which the majority are fish, sinks. Of the sinking material less than 1% of the fish survive.

Literature Cited

Barnes, R. D. (1974). Invertebrate Zoology. (W.B. Saunders: Philadelphia.).

Belbin, L. (1991). 'PATN Technical Reference'. (CSIRO Division of Wildlife and Ecology: Canberra).

Blaber, S.J.M., and Blaber, T.G. (1980). Factors affecting the distribution of juvenile inshore and estuarine fish. Journal of Fish Biology **17,** 143-162.

Blaber, S.J.M., Brewer, D.T., Salini, J.P., and Kerr, J. (1990). Biomasses, catch rates and abundances of demersal fishes, particularly predators of prawns, in a tropical bay in the Gulf of Carpentaria, Australia. Marine Biology **107,** 397-408.

Blaber, S.J.M., Brewer, D.T. and Harris, A.N. (1993). The distribution, biomasses and community structure of fishes of the Gulf of Carpentaria. Aust. J. Mar. Freshw. Res. **44,**in press.

Bray, J.R., and Curtis, J.T. (1957). An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs **27,** 325-349.

Brewer, D. T., Blaber, S. J. M., & Salini, J. P. (1989). The feeding biology of Caranx bucculentus Alleyne and Macleay (Teleostei:Carangidae) in Albatross Bay, Gulf of Carpentaria; with special reference to predation on penaeid prawns. Australian Journal of Marine and Freshwater Research **40,** 657-668.

Brewer, D.T., Blaber, S.J.M., and Salini, J.P. (1991). Predation on penaeid prawns by fishes in Albatross Bay, Gulf of Carpentaria. Marine Biology **109,** 231-240.

Brewer, D.T., Blaber, S.J.M., Salini, J.P., and Milton, D.A. (1992). Aspects of the biology of Caranx bucculentus (Teleostei : Carangidae) from the Gulf of Carpentaria. Australian Journal of Marine and Freshwater Research **44,** in press.

Cyrus, D.P., and Blaber, S.J.M. (1987). The influence of turbidity on juvenile marine fishes in estuaries. Part 1. Journal of Experimental Marine Biology and Ecology **109,** 53-70.

Darracott, A. (1977). Availability, morphometrics, feeding and breeding activity in a multi-species, demersal fish stock of the Western Indian Ocean. Journal of Fish Biology **10,** 1-16.

Eggleston, D. (1972). Patterns of biology in the Nemipteridae. Journal of the Marine Biological Association of India **14,** 357-364.

Fauchauld, K., and Jumars, P. A. (1979). The diet of worms: a study of polychaete feeding guilds. Oceanography and Marine Biology an Annual Review **17**, 193-284.

Folk, R. L. (1965). Petrology of Sedimentary Rocks. (Austin University Press: Texas.).

Grey, D. L., Dall, W., & Baker, A. (1983). A Guide to the Australian Penaeid Prawns. Northern Territory Department of Primary Production, Darwin.

Harris, A.N., and Poiner, I.R. (1990). By-catch of the prawn fishery of Torres Strait; competition and partitioning of the discards into components that float or sink. Australian Journal of Marine and Freshwater Research **41,** 37-52.

Harris, A.N., and Poiner, I.R. (1991). Changes in species composition of demersal fish fauna of southeast Gulf of Carpentaria, Australia after 20 years of fishing. Marine Biology **111,** 503-519.

Hyslop, E. J. (1980). Stomach contents analysis-a review of methods and their application. Journal of Fish Biology **17,** 411-429.

Longhurst, A.R., and Pauly, D. (1987). 'Ecology of tropical oceans'. (Academic Press, London).

Lowe-McConnell, R. H. (1987). Ecological Studies in Tropical Fish Communities. Cambridge University Press: Cambridge.

McLoughlin, R.J. and Young, P.C. (1985). Sedimentary provinces of the fishing grounds of the North West Shelf of Australia: grain size frequency analysis of surficial sediments. Aust. J. Mar. Freshw. Res. **36**, 671-682.

McManus, J.W. (1986). Depth zonation in a demersal fishery in the Samar Sea, Philippines. In 'The first Asian fisheries forum'. (Eds. Maclean, J.L., Dizon, L.B., Hosiilos, L.V.). pp. 483-486.(Asian Fisheries Society, Manila, Philippines).

Mohsin, A.K.M., Said, M.Z.B.M., Ambak, M.A.B., Salam, M.N.B.A.,Hayase, M.N., and Sekioka, M. (1988). Marine catch by experimental trawlings in the south-western portion of the South China Sea. In 'Ekspedisi Matahari' (Eds. Mohsin, A.K.M., Rahman, R.A., Ambak, M.A.) pp. 113-120. (Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia).

McPherson, G. R. (1987). Food of narrow barred Spanish mackerel in north Queensland waters, and their relevance to the commercial troll fishery. Queensland Journal of Agricultural and Animal Sciences **44**, 69-73.

Mojumber, P. (1969). Food of the cat-fish, *Tachysurus thalassinus* (Ruppell). Indian Journal of Fisheries **16,** 161-169.

Parrish, J. D. (1987). The trophic biology of snappers and groupers. In 'Tropical snappers and groupers: biology and fisheries management'. (eds. Polovina, J. J., Ralston, S.) pp.405-463. (Westview Press: Colorado).

Okera, W., and Gunn, J.S. (1986). Exploratory trawl surveys by F.R.V. Soela in the Australian Fishing Zone sector of the Timor-Arafura Seas and in the Gulf of Carpentaria, 1980-81. CSIRO Marine Laboratories Report **150,** 1-104.

Pauly, D. (1988). Fisheries research and the demersal fisheries of south-east Asia. In 'Fish population dynamics' (Ed. Gulland, J.A.). pp. 329-348. (John Wiley: London).

Racek, A. A., & Dall, W. (1965). Littoral Penaeidae (Crustacea:Decapoda) from northern Australia, New Guinea, and adjacent waters. Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen, AFD. Natuurkunde; tweede reeks) **56**, 1-116.

Rainer, S.F., and Munro, I.S.R. (1982). Demersal fish and cephalopod communities of an unexploited coastal environment in northern Australia. Australian Journal of Marine and Freshwater Research **33,** 1039-1055.

Ramm, D.C., Pender, P.J., Willing, R.S., and Buckworth, R.C. (1990). Large-scale spatial patterns of abundance within the assemblage of fish caught by prawn trawlers in northern Australian waters. Australian Journal of Marine and Freshwater Research **41,** 97-110.

Sainsbury, K.J. (1987). Assessment and management of the demersal fishery on the continental shelf of northwestern Australia. In 'Tropical snappers and groupers: biology and fisheries management'. (eds. Polovina, J.J., Ralston, S.) pp. 465-503. (Westview Press: Colorado).

Salini, J. P., Blaber, S. J. M., & Brewer, D. T. (1990). Diets of piscivorous fishes in a tropical Australian estuary, with special reference to predation on penaeid prawns. Marine Biology **105,** 363-374.

Salini, J. P., Blaber, S. J. M., & Brewer, D. T. (1992). Diets of sharks from estuaries and adjacent waters of the northeastern Gulf of Carpentaria, Australia. Australian Journal of Marine and Freshwater Research **43,** 87-96.

Shaffer, R. V., & Nakamura, E. N. (1989). Synopsis of biological data on the cobia *Rachycentron canadum* (Pisces: Rachycentridae). NOAA Technichal Report NMFS 82 FAO Fisheries Synopsis 153.

Short, J. W., and Potter, D. G. (1987). 'Shells of Queensland and The Great Barrier Reef Marine Gastropods.' (Golden Press: New South Wales).

Somers, I. F., & Long, B. (1992). The physical environment of the Gulf of Carpentaria, Australia. Australian Journal of Marine and Freshwater Research **44,** in press.

Sokal, R.R. and F.J. Rohlf (1981). Biometry. W.H. Freeman and Co. New York. 2nd Edition. 859pp.

Somers, I.F. and B.G. Long (1992) A note on the sediments and hydrology of the Gulf of Carpentaria. Aust. J. Mar. Freshw. Res. (in press).

SPANS (1991). Spatial Analysis System, Intera Tydac Technologies Inc. Nepean, Ontario.

Stephenson, W., and Cook, S. D. (1980). Elimination of species prior to cluster analysis. Australian Journal of Ecology **5,** 263-273.

Stevens, J. D., & McLoughlin, K. J. (1991). Distribution, size and sex composition, reproductive biology and diet of sharks from northern Australia. Australian Journal of Marine and Freshwater Research **42,** 151-99.

Legends for Tables

Table 1. Absolute mean biomasses and mean catch rates of 25 most abundant species of fish caught in day trawls in the Gulf of Carpentaria

Table 2. Absolute mean biomasses and mean catch rates of 25 most abundant species of fish caught in night trawls in the Gulf of Carpentaria

Table 3. Percentage frequency of occurrence of the 22 species caught in >50% of day trawls (%d) in the Gulf of Carpentaria. Also shown are percentages of biomass (%b) represented by each species.

Table 4. Percentage frequency of occurrence of the 25 species caught in >50% of night trawls (%n) in the Gulf of Carpentaria. Also shown are percentages of biomass (%b) represented by each species.

Table 5. Summary of abiotic parameters for the 107 stations used in the PATN analysis

Table 6. Summary into 4 categories of the 15 species groups based on their distribution and abundance (biomass) and using site groups shown in Figure 5

Table 7. Overall mean biomass and catch rate of fish caught in the three prawn trawl grounds

Table 8. Percentage dry weight (g) contribution of nine prey categories to the diets of major piscivores in the Gulf of Carpentaria during November 1990

Table 9 Percentage dry weight contribution of nine prey categories to the diets of minor piscivores in the Gulf of Carpentaria during November 1990

Table 10. Percentage contribution by dry weight of penaeids to prawn-eating fish in November 1990

Table 1. Absolute mean biomasses and mean catch rates of 25 most abundant species of fish caught in day trawls in the Gulf of Carpentaria

Species	Biomass kg ha^{-1}		Catch rate kg h^{-1}	
	x	SE	x	SE
Pomadasys maculatus	34.4	34.2	95.5	94.8
Upeneus sulphureus	4.2	1.2	11.8	3.4
Pentaprion longimanus	4.0	0.8	11.3	2.3
Nemipterus hexodon	3.9	1.0	10.8	2.8
Saurida sp.2	3.5	0.4	9.9	1.2
Leiognathus bindus	3.5	1.8	10.0	5.1
Secutor insidiator	2.9	2.5	8.2	7.1
Nemipterus nematopus	2.8	0.6	7.9	1.6
Priacanthus tayenus	2.7	0.8	7.6	2.3
Caranx bucculentus	2.6	2.4	11.3	10.2
Carcharhinus dussumieri	2.5	0.4	11.2	1.8
Lethrinus laticaudis	2.5	1.5	2.0	1.4
Lutjanus malabaricus	2.4	0.9	11.8	4.6
Himantura toshi	2.4	1.0	21.6	9.1
Leiognathus splendens	2.3	2.1	6.3	5.9
Lethrinus lentjan	2.2	1.0	6.6	2.9
Selaroides leptolepis	2.1	0.6	5.9	1.8
Alepes sp.	1.9	1.5	5.4	4.0
Saurida micropectoralis	1.9	0.3	5.4	0.8
Carangoides malabaricus	1.7	0.4	4.8	1.2
Selar crumenophthalmus	1.6	0.9	4.6	2.5
Paramonacanthus filicauda 1.6	0.8	4.7	2.3	
Terapon theraps	1.5	1.4	4.3	3.8
Carangoides talamporoides 1.5	0.4	4.1	1.0	
Abalistes stellaris	1.4	0.3	3.9	0.9
Totals (these 25 species)	93.6		286.9	
Overall x all species	124.8	44.0	421.3	128.5

Table 2. Absolute mean biomasses and mean catch rates of 25 most abundant species of fish caught in night trawls in the Gulf of Carpentaria

Species	Biomass kg ha^{-1}		Catch rate kg h^{-1}	
	x	SE	x	SE
Lutjanus malabaricus	3.7	1.4	16.3	6.0
Saurida sp.2		3.6	0.4	10.6
1.3				
Priacanthus tayenus	2.2	0.4	6.5	1.2
Nemipterus hexodon	2.2	0.4	6.4	1.0
Pomadasys maculatus	2.1	1.3	6.0	3.6
Pentaprion longimanus	2.1	0.8	5.9	2.2
Upeneus sulphureus	2.0	0.5	5.9	1.3
Arius thalassinus	1.9	0.8	5.4	2.2
Nemipterus nematopus	1.8	0.5	5.2	1.3
Nemipterus furcosus	1.6	0.5	4.6	1.6
Lethrinus lentjan	1.6	0.8	4.4	2.3
Saurida micropectoralis	1.4	0.3	4.1	0.8
Carcharhinus dussumieri	1.3	0.3	5.7	1.3
Paramonacanthus filicauda1.1	0.4	3.3	1.2	
Selaroides leptolepis	1.0	0.3	3.0	0.9
Diagramma pictum	1.0	0.4	4.7	1.7
Himantura toshi	1.0	0.3	9.6	2.6
Carangoides malabaricus	0.9	0.2	2.6	0.7
Decapterus russelli	0.9	0.4	2.6	1.1
Leiognathus bindus	0.9	0.4	2.4	1.1
Trixiphichthys weberi	0.8	0.5	2.4	1.5
Abalistes stellaris	0.8	0.6	2.3	1.8
Leiognathus leuciscus	0.6	0.5	1.6	1.4
Nemipterus peronii	0.6	0.2	1.6	0.6
Leiognathus splendens	0.5	0.5	1.6	1.6
Totals (these 25 species)	37.6		124.7	
Overall x all species	53.7	6.0	198.6	21.5

Table 3. Percentage frequency of occurrence of the 22 species caught in > 50% of day trawls (%d) in the Gulf of Carpentaria. Also shown are percentages of biomass (%b) represented by each species. Those species not represented in the top 25 species in terms of biomass are indicated with an (*).

Species	%d	%b
Priacanthus tayenus	93.6	2.2
Saurida sp.2	93.6	2.8
Leiognathus bindus	91.5	2.8
Pentaprion longimanus	91.5	3.2
Nemipterus hexodon	85.1	3.1
Saurida micropectoralis	83.1	1.5
Nemipterus nematopus	80.9	2.3
Fistularia petimba	78.7	0.3*
Carangoides malabaricus	70.2	1.4
Carcharhinus dussumieri	70.2	2.0
Upeneus sulphureus	70.2	3.3
Carangoides talamporoides	68.1	1.2*
Trixiphichthys weberi	66.0	0.6*
Carangoides caeruleopinnatus	61.7	0.6*
Decapterus russelli	59.6	0.5*
Abalistes stellaris	59.6	1.1*
Paramonacanthus filicauda	59.6	1.3
Selaroides leptolepis	59.6	1.7
Apogon fasciatus	57.4	1.1*
Upeneus sp. 1	55.3	0.3*
Leiognathus moretoniensis	53.2	0.1*
Seriolina nigrofasciata	53.2	0.2*

Table 4. Percentage frequency of occurrence of the 25 species caught in >50% of night trawls (%n) in the Gulf of Carpentaria. Also shown are percentages of biomass (%b) represented by each species. Those species not represented in the top 25 species in terms of biomass are indicated with an (*).

Species	%n	%b
Saurida sp.2	98.3	6.8
Priacanthus tayenus	96.7	4.2
Nemipterus hexodon	85.0	4.2
Pentaprion longimanus	85.0	3.9
Saurida micropectoralis	85.0	2.7
Nemipterus nematopus	83.3	3.4
Leiognathus bindus	83.3	1.6
Upeneus sulphureus	80.0	3.8
Fistularia petimba	80.0	0.3*
Paramonacanthus filicauda	76.7	2.1
Carangoides malabaricus	73.3	1.7
Apogon fasciatus	73.3	0.2*
Suggrundus macracanthus	71.7	0.3*
Pseudorhombus elevatus	66.7	0.2*
Elates ransonetti	66.7	<0.1*
Arius thalassinus	65.0	3.5
Upeneus sp.1	63.3	0.5*
Leiognathus moretoniensis	61.7	0.3*
Apogon poecilopterus	60.0	0.2*
Grammatobothus polyophthalmus	58.3	<0.1*
Lepidotrigla sp.2	56.7	0.4*
Carangoides talamporoides	55.0	0.8*
Apogon elliotti	55.0	<0.1*
Carangoides caeruleopinnatus	53.3	0.7*
Selaroides leptolepis	50.0	1.9

Table 5. Summary of abiotic parameters for the 107 stations used in the PATN analysis

Physical parameter	mean	SD	minimum	maximum
Depth (m)	47.2	10.9	17.0	63.0
Surface Turbidity (NTU)	0.9	0.4	0.1	2.8
Mid-water Turbidity	1.0	0.5	0.1	2.6
Bottom Turbidity	1.6	0.7	0.4	3.8
Surface Temperature (°C)	29.5	0.9	27.1	30.9
Bottom Temperature	26.7	1.6	24.0	30.8
Surface Salinity (ppt)	35.1	1.6	22.1	37.3
Bottom Salinity	34.9	2.6	20.0	36.6
% mud	47.3	24.9	3.6	97.4
% sand	46.1	22.4	2.6	89.2
% gravel	6.6	6.2	0	42.0

Table 6. Summary into 4 categories of the 15 species groups based on their distribution and abundance (biomass) and using site groups shown in Figure 5
(n = number of species)

Category	Species group	n	Site group	Characteristics
Widespread	12	44	all	Abundant species
	2	69	all	Centred mainly in north and central Gulf
Regional	3	22	5	Mixed species and trophic levels
	6	24	3	Larger species, mainly commercial
	9	35	4	Mixed species
	13	21	4 + southern stations	Mixed species
Reef-associated	1	12	NE Gulf	Stns 51,59 & 60
	4	4	NW Gulf	Mainly stn 4
	7	15	6	Mainly large spp
	8	4	S. Gulf	Station 73 only
	15	9	S. Gulf	Station 39 only
Others	5	3	E. Gulf	Station 69 only
	10	4	W. Gulf	Station 9 only, pelagics
	11	8	S. Gulf	Mainly station 95, elasmobranchs
	14	12	4	Mainly pelagic

Table 7. Overall mean biomass and catch rate of fish caught in the three prawn trawl grounds (n = number of trawls, n/d = night or day trawls).

Prawn ground	n	kg ha^{-1}	SE	kg h^{-1}	SE	n/d
Groote Eylandt	5	250.0	91.2	1148.6	409.5	d
Albatross Bay	5	247.6	95.7	1179.9	456.9	d
South-east Gulf	5	127.4	47.1	607.6	224.7	n

Table 8. Percentage dry weight (g) contribution of nine prey categories to the diets of major piscivores in the Gulf of Carpentaria during November 1990. LR(mm): length range - standard length for teleosts, total length for sharks and disc width for rays. N: number of stomachs examined. NF: number of stomachs containing food; Total Wt - total weight of food in grams. Ann: Annelida. Br: Brachyura. Cep: Cephalopoda. Cr: other Crustacea. Mo: Mollusca excluding cephalopods. Pen: Penaeidae. St: Stomatopoda. Tel: Teleostei. Oth: Other. B: Benthic. V: Variable.

Predator species	LR(mm)	N	NF	Total Wt	Ann (B)	Br (B)	Cep (V)	Cr (B)	Mo (B)	Pen (B)	St (B)	Tel (V)	Oth (V)	HABITAT % B:NonB
Rhizoprionodon acutus	290-850	22	14	99.7	-	-	1.9	9.2	-	2.5	-	85.9	0.5	13.2:76.0
Carcharhinus dussumieri	475-821	150	128	301.8	4.9	4.0	13.9	4.2	0.7	5.3	0.9	62.2	3.9	36.6: 7.6
C. macloti	560-825	37	33	61.9	-	1.0	7.0	2.1	-	21.2	1.9	66.4	0.6	26.6:35.3
Saurida micropectoralis	112-350	172	69	154.1	19.0	-	8.4	<0.1	-	-	-	71.1	1.5	23.9:29.6
S. filamentosa	161-222	32	10	8.6	-	-	-	3.2	-	-	0.1	96.8	-	4.8:73.1
Saurida sp.2	120-266	236	105	169.9	0.1	<0.1	11.8	0.6	-	3.4	-	80.1	4.0	9.2:27.6
Rachycentron canadum	252-790	25	24	208.9	-	14.6	1.4	2.2	0.1	0.9	1.2	74.8	4.9	35.3:22.9
Carangoides chrysophrys	145-635	65	42	41.2	4.6	1.2	-	1.4	-	0.4	-	92.1	0.3	9.1:56.8
C. caeruleopinnatus	117-320	85	51	54.3	-	-	1.6	0.7	-	6.4	0.1	91.3	-	15.7:14.0
C. fulvoguttatus	245-281	12	5	5.4	-	-	-	-	<0.1	-	-	99.9	<0.1	- :34.1
C. talamparoides	110-196	58	44	6.1	-	4.9	16.2	4.1	-	0.5	1.2	73.2	-	10.7:21.2
Caranx sexfasciatus	206-400	14	13	60.7	-	<0.1	-	0.2	-	-	-	99.8	-	0.2: -
Lutjanus vittus	140-223	47	40	33.2	0.8	5.8	2.2	23.4	<0.1	9.2	2.3	55.8	0.5	42.6:29.0
L. sebae	110-387	113	82	142.9	5.3	9.8	3.5	4.3	0.6	0.2	1.1	73.0	2.3	25.2:60.4
L. erythropterus	144-415	63	23	21.2	-	-	14.1	<0.1	-	-	-	71.7	14.3	- :63.0
L. malabaricus	96-490	403	207	1034.0	2.0	1.0	0.4	0.2	<0.1	0.1	0.2	96.0	0.1	3.8:8.9
L. russelli	105-395	99	20	33.3	-	2.3	<0.1	13.0	<0.1	4.0	0.2	80.1	0.2	20.2:48.0
L. johni	265-490	35	10	36.5	-	24.5	-	0.1	1.6	-	13.5	60.2	-	39.7: -
Lethrinus nebulosus	180-370	101	44	36.4	2.0	2.3	5.2	3.3	1.2	-	0.4	82.9	2.7	12.7:76.8
L. laticaudis	218-332	39	12	12.1	0.2	-	-	2.3	1.7	-	-	92.5	3.3	7.8:81.9
Argyrops spinifer	156-292	13	8	37.5	<0.1	0.3	0.9	<0.1	3.2	-	-	94.6	1.0	3.6:86.7
Sphyraena forsteri	117-282	79	50	23.1	1.6	-	20.4	0.5	-	-	-	77.3	0.2	13.0: -
Scomberomorus queenslandicus	184-632	27	16	29.0	-	-	1.8	-	-	0.4	-	97.8	-	0.4:61.2

Table 9. Percentage dry weight contribution of nine prey categories to the diets of minor piscivores in the Gulf of Carpentaria during November 1990. LR(mm): length range - standard length for teleosts, total length for sharks and disc width for rays. N: number of stomachs examined. NF: number of stomachs containing food. Total Wt: total weight in grams. Ann: Annelida. Br: Brachyura. Cep: Cephalopoda. Cr: other Crustacea. Mo: Mollusca excluding cephalopods. Pen: Penaeidae. St: Stomatopoda. Tel: Teleostei. Oth: Other. B: Benthic. V: Variable.

Predator species	LR(mm)	N	NF	Total Wt	Ann (B)	Br (B)	Cep (V)	Cr (B)	Mo (B)	Pen (B)	St (B)	Tel (V)	Oth (V)	HABITAT % B:NonB
Carcharhinus amblyrhynchos	500-803	13	8	73.5	-	0.2	36.8	-	-	0.2	39.9	23.0	-	41.4:18.6
Himantura toshi	230-890	58	56	237.9	0.3	14.1	<0.1	48.8	<0.1	20.3	7.3	6.1	2.9	95.6: -
Arius thalassinus	210-635	55	37	46.9	<0.1	34.5	7.6	4.2	0.3	0.6	16.0	29.0	7.8	55.9:15.6
Epinephelus areolatus	140-520	24	10	0.5	1.7	36.6	-	37.4	-	6.5	-	7.6	9.4	82.2: -
E. sexfasciatus	110-195	29	7	2.4	-	6.5	0.4	3.8	0.8	46.7	42.0	-	-	99.8: -
Priacanthus tayenus	93-200	244	222	38.6	1.3	0.4	0.9	47.9	<0.1	2.3	0.1	15.9	31.2	53.2: 1.9
Carangoides malabaricus	117-167	18	10	2.5	-	2.6	60.9	9.7	0.7	1.4	-	24.9	-	14.4: -
C. humerosus	114-262	140	76	9.1	-	17.2	11.7	26.6	0.3	1.8	0.3	42.3	-	53.3: -
Gnathanodon speciosus	352-510	8	8	18.9	1.0	0.7	-	0.3	0.8	-	<0.1	7.7	89.4	2.8: -
Caranx bucculentus	100-474	329	217	109.7	<0.1	38.5	3.5	6.6	12.5	19.1	3.6	14.7	1.6	83.9: 0.1
Nemipterus nematopus	100-174	21	11	2.3	-	37.0	-	33.7	-	-	18.2	8.4	2.6	88.9: -
N. peronii	93-220	123	70	8.0	6.1	29.1	5.0	26.3	0.1	15.4	4.0	8.0	5.9	85.6: 0.1
N. furcosus	108-230	321	202	60.2	2.8	17.6	4.9	25.3	0.4	27.5	1.1	10.9	9.5	76.3: 1.2
N. hexodon	101-194	125	102	20.1	3.7	15.7	0.4	17.5	2.4	10.4	16.5	30.4	3.0	73.5: 0.2
Scolopsis monagramma	172-218	6	6	1.3	3.0	1.7	-	78.2	-	-	-	-	16.7	82.9: -
Diagramma pictum	85-790	280	109	25.9	11.7	8.1	1.4	35.5	1.2	3.0	1.2	15.0	23.1	64.5: 4.9
Lethrinus lentjan	130-562	297	70	20.5	3.5	9.2	40.9	6.8	6.9	-	<0.1	26.1	6.6	26.4:12.4

Table 10. Percentage contribution by dry weight of penaeids to prawn-eating fish in November 1990. Atyp: *Atypopenaeus*. Aste: *Atypopenaeus stenodactylus*. Meta: *Metapenaeus*. Mend: *M. endeavouri*. Mops: *Metapenaeopsis*. Mmog: *M. mogiensis*. Mpal: *M. palmensis*. Mros: *M. rosae*. Pena: *Penaeidae*. Ps/e: *Penaeus semisulcatus/esculentus*. Trac: *Trachypenaeus*. Tanc: *T. anchoralis*. Tcur: *T. curvirostris*. Tgra: *T. granulosus*. * = commercial prawn species.

Predator species	NF	Atyp	Aste	Meta	Mend	Mops	Mmog	Mpal	Mros	Pena	Ps/e*	Trac	Tanc	Tcur	Tgra
Rhizoprionodon acutus	2	-	-	-	-	-	-	88.6	-	11.3	-	-	-	-	-
Carcharhinus dussumieri	30	-	-	-	8.1	25.1	-	34.5	-	16.2	-	9.8	6.2	-	-
C. macloti	2	-	-	-	-	-	-	15.9	-	-	-	-	-	-	84.1
C. amblyrhynchos	1	-	-	-	-	100.0	-	-	-	-	-	-	-	-	-
Himantura toshi	25		-	-	7.7	15.2	-	60.5	-	7.0	-	-	5.2	-	4.4
H. uarnak	1	-	-	-	-	51.6	-	-	-	47.6	-	-	-	-	-
Saurida sp.2	9	-	3.3	-	-	33.4	-	61.1	-	2.4	-	-	-	-	-
Arius thalassinus	1	-	-	-	-	-	-	100.0	-	-	-	-	-	-	-
Epinephelus areolatus	1	-	-	-	-	100.0	-	-	-	-	-	-	-	-	-
E. sexfasciatus	1	-	-	-	-	-	-	100.0	-	-	-	-	-	-	-
Priacanthus tayenus	5	-	-	-	-	31.3	-	10.9	-	17.5	-	-	40.5	-	-
Rachycentron canadum	1-	-	-	-	-	-	-	100.0	-	-	-	-	-	-	-
Carangoides malabaricus	1	-	-	-	-	-	-	100.0	-	-	-	-	-	-	-
C. chrysophrys	2	-	-	-	-	-	-	-	-	26.8	-	-	73.7	-	-
C. caeruleopinnatus	3	-	-	-	-	59.8	-	30.3	-	9.7	-	-	-	-	-
C. humerosus	4	-	-	-	-	100.0	-	-	-	-	-	-	-	-	-
C. talamparoides	1	-	-	-	-	-	-	-	-	100.0	-	-	-	-	-
Caranx bucculentus	48	-	-	-	-	46.9	-	18.9	-	12.3	7.5	-	-	-	14.3
Lutjanus vittus	14	-	-	-	-	65.8	4.1	-	-	9.7	20.4	-	-	-	-
L. sebae	3	-	-	-	-	95.5	-	-	-	4.5	-	-	-	-	-
L. malabaricus	16	2.6	1.0	5.2	-	25.4	-	16.3	2.0	1.8	-	-	24.3	-	21.4
L. russelli	2	-	-	-	-	100.0	-	-	-	-	-	-	-	-	-
Nemipterus peronii	5	-	-	-	-	93.9	-	-	-	-	-	-	6.0	-	-
N. furcosus	31	-	-	0.1	-	14.9	-	5.8	3.1	0.7	-	0.4	6.4	60.6	8.2
N. hexodon	7	-	-	-	-	54.4	-	-	-	25.6	-	-	19.8	-	-
Diagramma pictum	8	-	-	-	-	94.8	-	-	-	5.2	-	-	-	-	-
Scomberomorus queenslandicus	1	-	-	-	-	100.0	-	-	-	-	-	-	-	-	-

Legends for Figures

Fig. 1. Gulf of Carpentaria showing FRV *Southern Surveyor* sampling stations. Cruise track follows numerical order from 1 to 107

Fig. 2. Distribution (biomass - kg ha^{-1}) of (a) *Pomadasys maculatus*, (b) *Upeneus sulphureus*, (c) *Pentaprion longimanus*, (d) *Nemipterus hexodon*, (e) *Saurida* sp.2 and (f) *Leiognathus bindus*

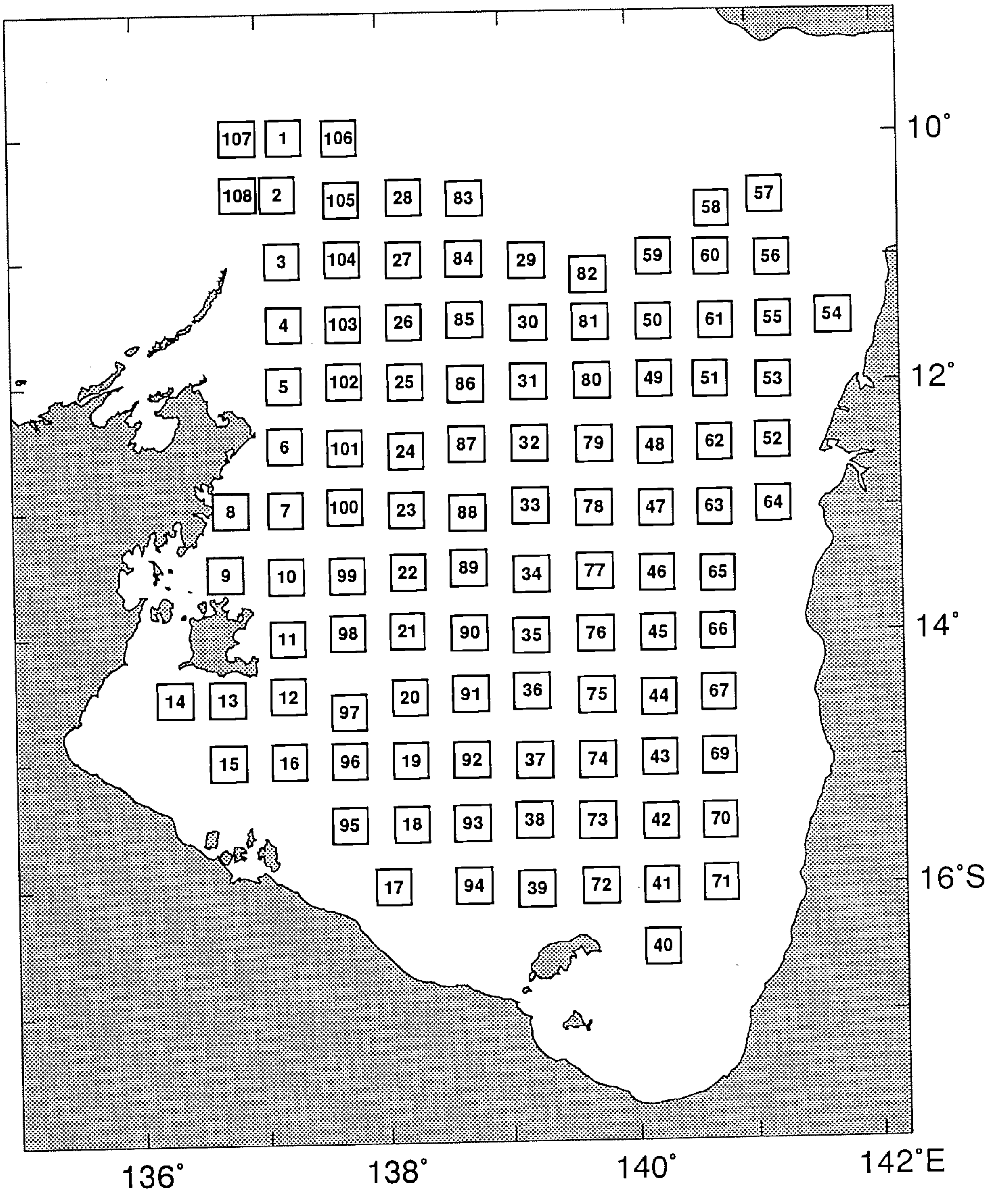
Fig. 3. Distribution (biomass - kg ha^{-1}) of (a) *Secutor insidiator*, (b) *Nemipterus nematopus*, (c) *Carcharhinus dussumieri* and (d) *Saurida micropectoralis*

Fig. 4. Distribution (biomass - kg ha^{-1}) of (a) *Lutjanus malabaricus* (b) *Lethrinus lentjan*, (c) *Lethrinus laticaudis* and (d) *Himantura toshi*

Fig. 5. Site similarity based on Bray-Curtis dissimilarity measures and flexible UPGMA sorting strategy of species occurrences and biomasses (Sites are numbered according to the degree of similarity between groups)

Fig. 6. The relationships between 286 species from the Gulf of Carpentaria based on their distribution and abundance (biomass). Fifteen species groups are indicated.

Fig. 7. Plot of axes 1 and 2 of the principal coordinates analysis of 107 sites based on species composition, indicating grouping of sites 1 to 6. (1 = ○, 2 = ▲, 3 = ▩, 4 = □, 5 = ●, 6 = △).



107
1
106
108
2
105
28
83
58
57
3
104
27
84
29
82
59
60
56
4
103
26
85
30
81
50
61
55
54
5
102
25
86
31
80
49
51
53
6
101
24
87
32
79
48
62
52
8
7
100
23
88
33
78
47
63
64
9
10
99
22
89
34
77
46
65
11
98
21
90
35
76
45
66
14
13
12
97
20
91
36
75
44
67
15
16
96
19
92
37
74
43
69
95
18
93
38
73
42
70
17
94
39
72
41
71
40
10°
12°
14°
16°S
136°
138°
140°
142°E

Fig.1

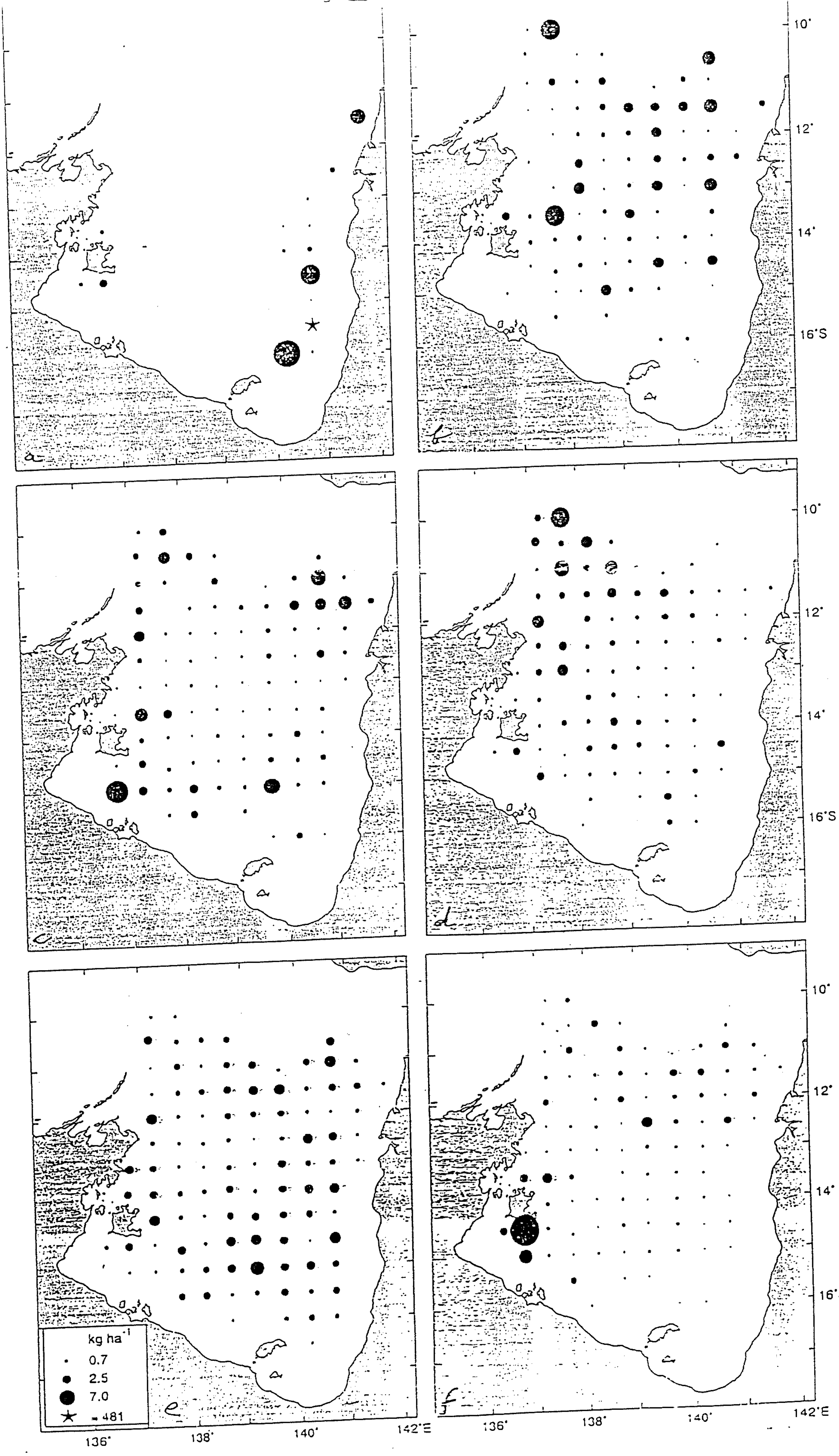


Fig.2

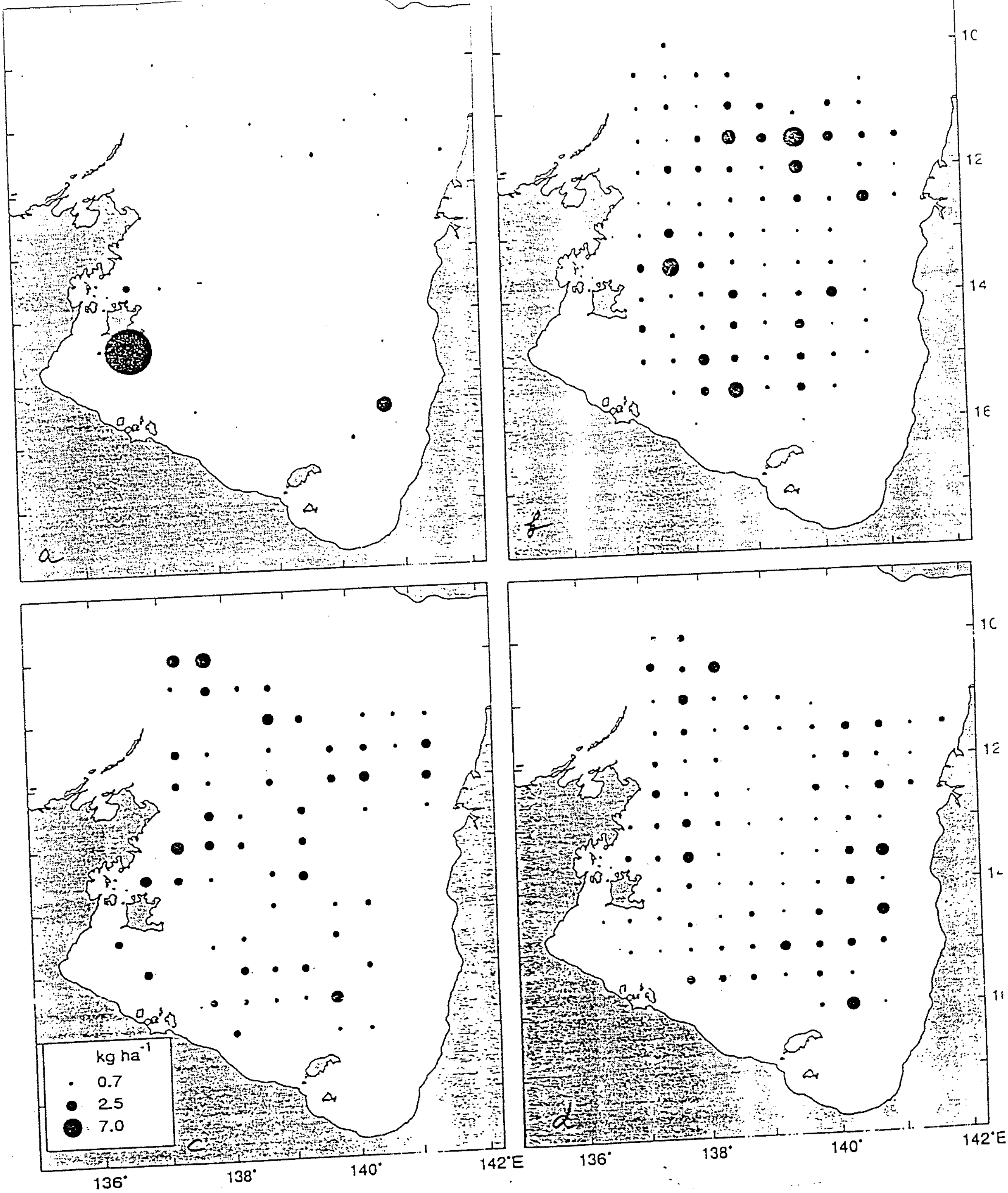


Fig.3

Fig.4

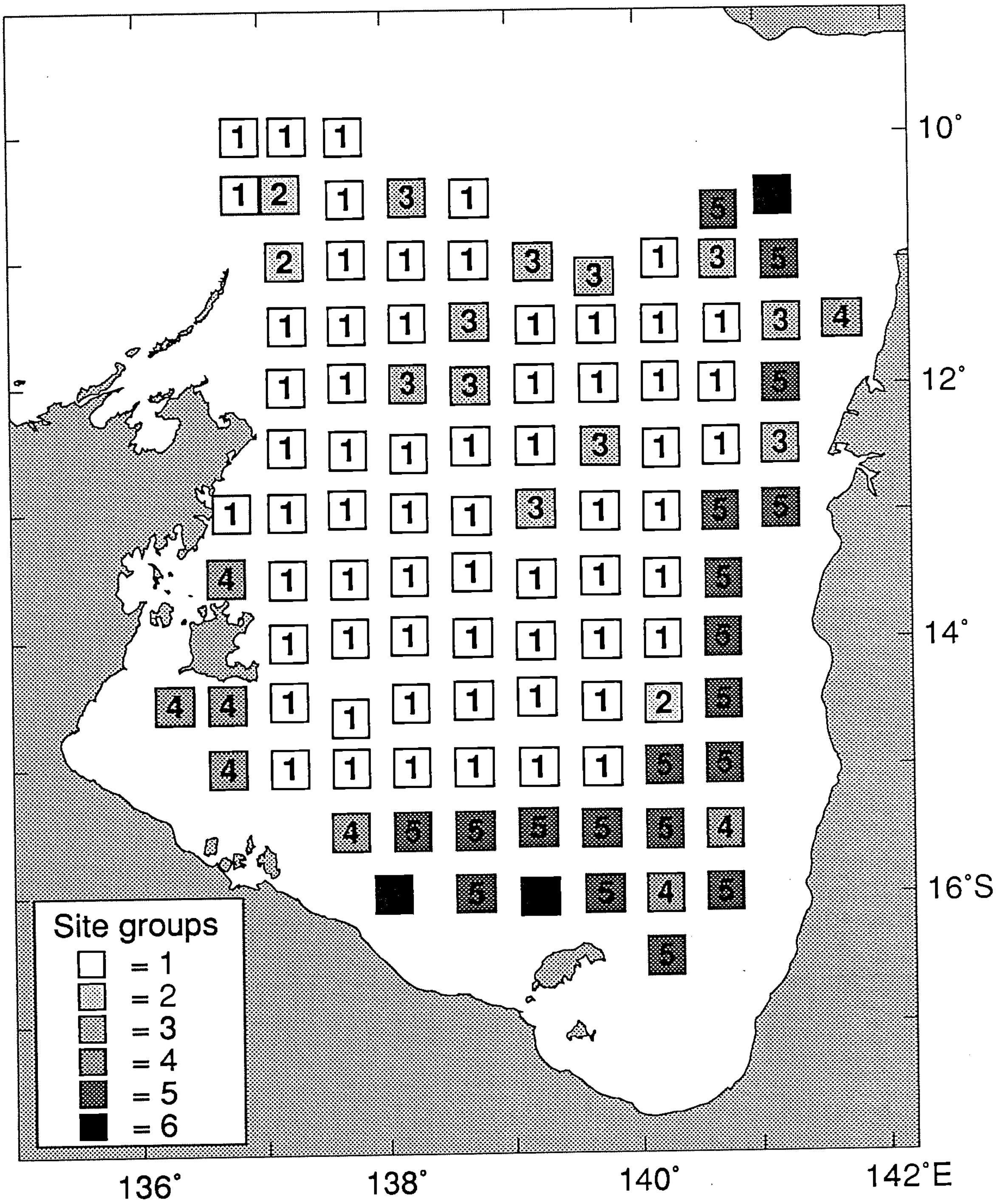
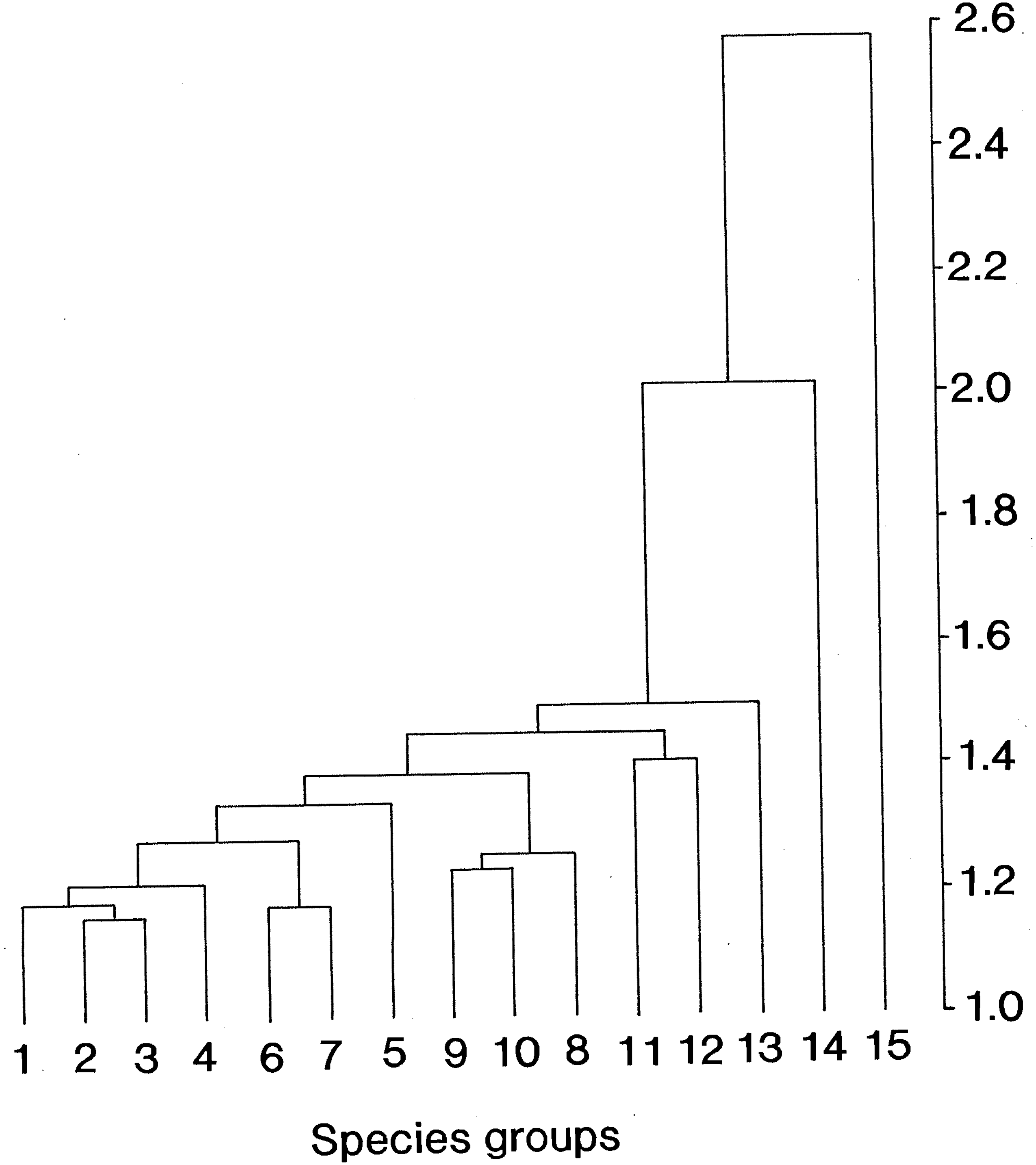

10°
12°
14°
16°S
136°
138°
140°
142°E
Site groups
= 1
= 2
= 3
= 4
= 5
= 6
1 1 1
1 2 1 3 1 5
2 1 1 1 3 3 1 3 5
1 1 1 3 1 1 1 1 3 4
1 1 3 3 1 1 1 1 5
1 1 1 1 1 3 1 1 3
1 1 1 1 1 3 1 1 5 5
4 1 1 1 1 1 1 1 5
1 1 1 1 1 1 1 5
4 4 1 1 1 1 1 1 2 5
4 1 1 1 1 1 1 5 5
4 5 5 5 5 5 4
5 5 4 5
5

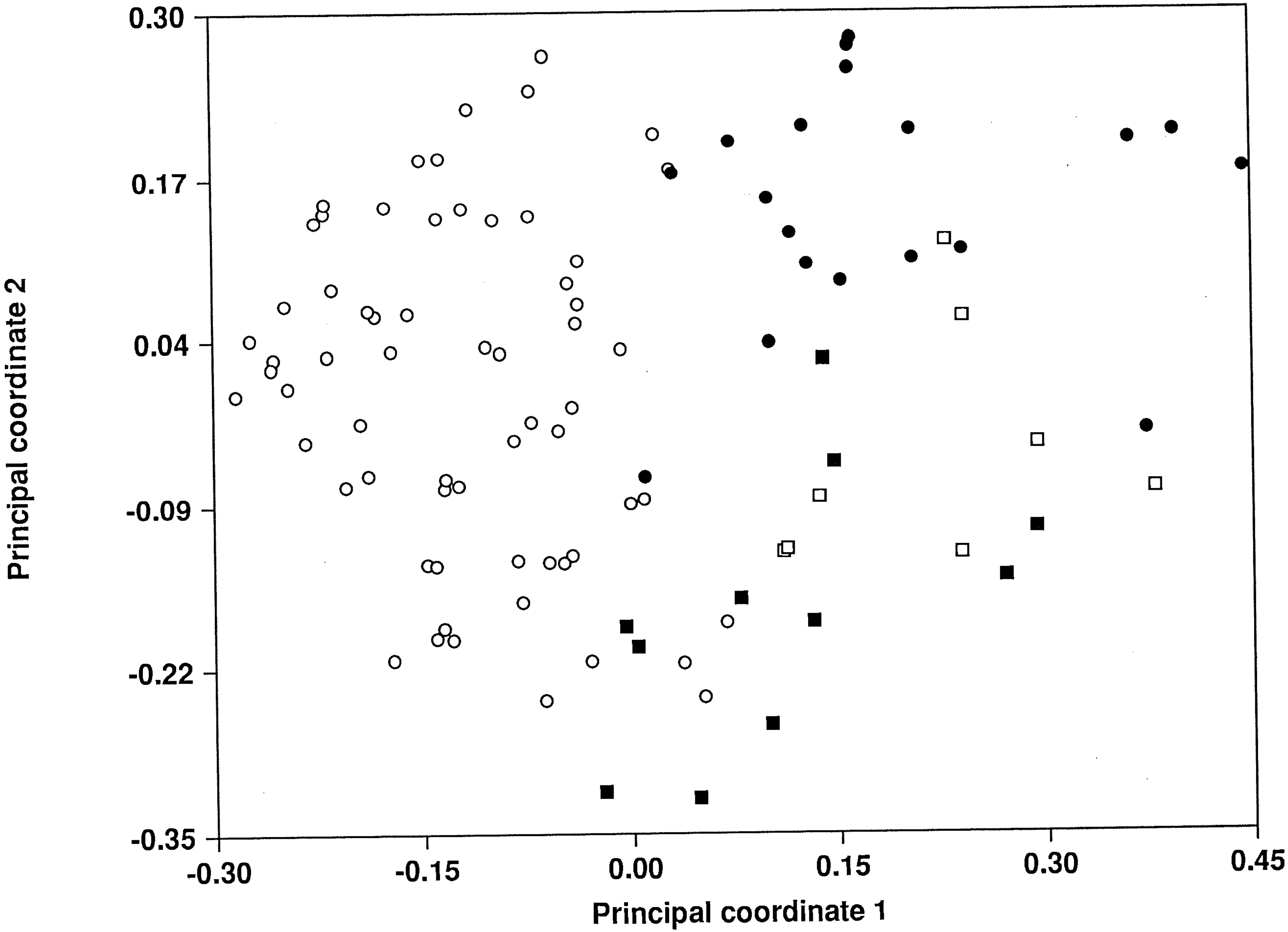
Fig.5



2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
Dissimilarity
1 2 3 4 6 7 5 9 10 8 11 12 13 14 15
Species groups

Fig.6

Fig.7



Principal coordinate 2
0.30
0.17
0.04
-0.09
-0.22
-0.35
-0.30
-0.15
0.00
0.15
0.30
0.45
Principal coordinate 1

APPENDIX 1

Scientific publications arising wholly or partially from FIRDC Grant 88/77

Special Issue of Australian Journal of Marine and Freshwater Research on Gulf of Carpentaria - Volume 44, 1993

Blaber, S.J.M. and Milton, D.A. (1993). The distribution of seabirds in the Gulf of Carpentaria. *Aust. J. Mar. Freshw. Res.*

Blaber, S.J.M., Brewer, D.T. and Harris, A.N. (1993). The distribution, biomasses and community structure of fishes of the Gulf of Carpentaria. *Aust. J. Mar. Freshw. Res.*

Brewer, D.T., Blaber, S.J.M., Milton, D.A. and Salini, J.P. (1993). Aspects of the biology of *Caranx bucculentus* (Teleostei: Carangidae) from the Gulf of Carpentaria. *Aust. J. Mar. Freshw. Res.*

Burford, M.A., Long, B.G. and Rothlisberg, P.C. (1993). Pigments and organic carbon in sediments as indicators of microalgal and benthic infaunal abundance in the Gulf of Carpentaria. *Aust. J. Mar. Freshw. Res.*

Dunning, M.D., McKinnon, S., Lu,C.C., Yeatman, J. and Cameron, D. (1993). Cephalopods of the Gulf of Carpentaria. *Aust. J. Mar. Freshw. Res.*

Harris, A.N., Blaber, S.J.M., Brewer, D.T. and Milton, D.A. (1993). Aspects of the biology and factors affecting the distribution of commercial fishes in the Gulf of Carpentaria. *Aust. J. Mar. Freshw. Res.*

Jackson, C.J. and Rothlisberg, P.C. (1993). Larval ecology of penaeids of the Gulf of Carpentaria, Australia. III. Assessing the reproductive activity of *Metapenaeus ensis* and *M. endeavouri* from the distribution and abundance of the protozoeal stages. *Aust. J. Mar. Freshw. Res.*

Long, B.G. and I.R. Poiner (1993). Infaunal benthic community structure and function in the Gulf of Carpentaria. *Aust. J. Mar. Freshw. Res.*

Long, B.G. and I.R. Poiner (1993) Community structure of the epibenthic fauna of the Gulf of Carpentaria. *Aust. J. Mar. Freshw. Res.*

Othman, B.H.R., Greenwood, J.G. and Rothlisberg, P.C. (1993). Patterns in copepod diversity, abundance, spatial and temporal distribution in the Gulf of Carpentaria. I. Species richness and abundance patterns. *Aust. J. Mar. Freshw. Res.*

Rothlisberg, P.C., Jackson, C.J., Phillips, B.F. and McWilliam, P.S. (1993). Distribution and abundance of Scyllarid and Palinurid lobster larvae in the Gulf of Carpentaria, Australia. *Aust. J. Mar. Freshw. Res.*

Rothlisberg, P.C., Pollard, P.C., Moriarty, D.J.W., Nichols, P.D., Forbes, A.M.G., Vaudrey, D. and Jackson C. (1993). Summer phytoplankton community structure and productivity in relation to the hydrological regime of the Gulf of Carpentaria. *Aust. J. Mar. Freshw. Res.*

Salini, J.P., Blaber, S.J.M. and Brewer, D.T. (1993). Diets of trawled predatory fish of the Gulf of Carpentaria with particular reference to prawn predation. *Aust. J. Mar. Freshw. Res.*

Somers, I.F. (1993). The species composition and distribution of commercial penaeid prawn catches of the Gulf of Carpentaria, Australia, in relation to depth and sediment-type. *Aust. J. Mar. Freshw. Res.*

Somers, I.F. and Long, B. (1993). A note on the hydrology and sediments of the Gulf of Carpentaria. *Aust. J. Mar. Freshw. Res.*

Wassenberg, T.J., Salini, J.P., Heatwold, H. and Kerr, J.D. (1993). The incidental capture of seasnakes (Hydrophiidae) by otter trawlers in the Gulf of Carpentaria, Australia. *Aust. J. Mar. Freshw. Res.*

APPENDIX 2

Infaunal Benthic Community Structure and Function

in the Gulf of Carpentaria,

Northern Australia

B. G. Long and I.R. Poiner

CSIRO Marine Laboratories, P.O Box 120, Cleveland
Queensland 4163, Australia

ABSTRACT

The infaunal benthos (> 20 m) of the Gulf of Carpentaria was surveyed during November and December 1990. Over 680 taxa were collected with three replicate 0.1m^2 Smith-McIntyre grab from 105 stations. The Gulf benthos was highly structured with trends in abundance and species richness which were related to Gulf wide trends in sediment texture. Highest abundance (200 - 1 530 m^{-2}), wet weight biomass (x = 76 g.m^{-2}) and species density (x = 25.8 0.1 m^{-2}) occurred in the sands and muddy sands along the eastern and south-eastern margins of the Gulf. Abundance (33 - 200 m^{-2}), biomass (x = 30 g.m^{-2}) and species density (9.5 m^{-2}) was lowest in the muds and sandy muds in the central, west and north-west Gulf. Within-station species density was generally low (3.0 - 53.5 0.1m^{-2}) but the species richness of the Gulf was high. This was due to a large number (486) of rare (< 4 individuals) species. The Gulf infaunal abundance and biomass was similar to other tropical shelves but was lower than some temperate region continental shelves and upwelling areas. Species richness was also lower than in temperate areas of upwelling or high production.

Scavengers/carnivores and deposit feeders numerically dominated throughout the Gulf with these two feeding modes found in 85% of the infauna (43 and 42% respectively). Suspension feeding was less prevalent (13%) and very few herbivores were found (< 1%). There was a trend in the proportion of deposit and suspension feeders which was related to sediment texture. Suspension feeding was highest in the muddy sands of the east and south-east Gulf and lowest in the muds of the north-west. The proportion of deposit feeders was highest in muddy sediments and lowest in sandy sediments. Small (< 5 mm) surface deposit feeders numerically dominated within this feeding mode.

The 15 numerically dominant taxa accounting for over 37% of the infauna collected were comprised mainly of opportunistic, or second stage colonizing taxa. Most had Gulf wide distribution patterns but levels of abundance were correlated with sediment.

Ten station groups, identified from classification and ordination of the abundance data, were also related to sediment texture. The spatial overlap of most station groups, and overlap of principal co-ordinate scores from the ordination analysis indicated that the species assemblages in the Gulf did not form discrete communities, either spatially or in terms of species composition but that species were responding individually to factors associated with, or correlated with, sediment grain size.

The communities in the Gulf of Carpentaria appear to be regulated by physical factors of the environment which correlate with sediment grain size. These results are consistent with other workers on tropical benthos that these are resilient communities, dominanted by small, predominantly surface feeding, stress tolerant or opportunistic species, and are regulated and structured by environmental factors.

APPENDIX 3

Form B

RURAL INDUSTRY RESEARCH FUND GRANT
Statement of Receipts and Expenditure
(For the year ending 30 June 1992)

QR

RESEARCH TRUST FUND

		Grant	$
Trust Fund:	FIRDC	Salaries	89,101.50
Project Number:	88/77	Travel	13,936.00
Grantee:	CSIRO Division of Fisheries	Operating	13,200.00
Title of Project:	Fish resources of Tropical NE Australia	Capital	–
		Total Grant	116,237.50

	Expenditure									
	Salaries		Travel		Operating		Capital		Total	
	$	¢	$	¢	$	¢	$	¢	$	¢
A) Uncommitted (c/f 1 July)	(216	00)	–	–	(1,735	27)	–	–	(1,951	27)
B) Outstanding commitments (c/f 1 July)	216	00	–	–	–	–	–	–	216	00
C) Refunds of Grant	–	–	–	–	–	–	–	–	–	–
D) Cash Received from Trust Fund	89,101	50	13,936	00	13,200	00	–	–	116,237	50
E) Approved transfers (from Form C)	(40,594	63)	(1,330	39)	41,925	02	–	–	–	–
F) Cash available (A+B–C+D±E)	48,506	87	12,605	61	53,389	75	–	–	114,502	23
G) Expenditure	28,706	87	12,605	61	23,377	49	–	–	64,689	97
H) Outstanding commitments (30 June)	19,800	00	–	–	32,102	40	–	–	51,902	40
I) Total funds committed (G+H)	48,506	87	12,605	61	55,479	89			116,592	37
J) Uncommitted (30 June) (F–I)	–	–	–	–	(2,090	14)	–	–	(2,090	14)
K) Other income (Paid to Trust Fund)	–	–	–	–	–	–	–	–	–	–

Note: Row B should be the same as Row H from the previous year and Row A the same as Row J from the previous year.

Certificate of Accounting Officer

I hereby certify that this statement is correct.

(Signature)	C Williamson (Printed Name)	A/g Finance Manager (Position)	(002) 206 233 (Phone No.)

Form C

RURAL INDUSTRY RESEARCH FUND GRANT
List of Transfers

(Attachment to the Statement of Receipts and Payments as at 30 June 1992)

Trust Fund: Fishing Industry RESEARCH TRUST FUND Project Number: 88/77

Grantee: CSIRO Division of Fisheries

Project: Fish resources of Tropical NE Australia

Transfers within Project QR

Project Number	Head of Expenditure			
	Transferred from	$	Transferred to	$
88/77 * (previously approved)	Salaries	24,000.00	Operating	24,000.00*
88/77	Salaries	16,594.63	Operating	16,594.63
88/77	Travel	1,330.39	Operating	1,330.39
		41,925.02		41,925.02

Transfers between Projects

Project Number	Transferred from Head of Expenditure	$	Project Number	Transferred to Head of Expenditure	$

Transfers from contingency reserves in accordance with Clause 26

Reserve (For Office Use Only)	Head of Expenditure	
	Transferred to	$

Net effect on project allocation of all transfers

Salaries $	Travel $	Operating $	Capital $	Total $
(40,594.63)	(1,330.39)	41,925.02	–	–

Certificate of Accounting Officer

I hereby certify that this statement is correct.

(Signature)	C Williamson (Printed Name)	A/g Finance Manager (Position)	(002) 206 233 (Phone No.)