Characterisation of the inshore fish assemblages of the Pilbara and Kimberley coasts

Principal Investigator: Stephen J. Newman

Co-Investigators: Glen C. Young and Ian C. Potter

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Objectives:

1. To determine the overall catch of the key species of commercial and recreational fishing significance (that is, the recreational catch, commercial catch and other landed catch).
2. To determine the species composition and relative abundance of the inshore demersal finfish resource from the shoreline outward to a depth of 30 metres along the inner-continental shelf in north-western Australia.
3. To determine the nursery areas of fish species of commercial and recreational significance in the Pilbara and Kimberley regions.

Non-Technical Summary:

Outcomes Achieved

All of the objectives of this project have been met by documenting the following: the overall catch of the key commercial, recreational and charter boat fish species; the species composition and relative abundance of the inshore demersal finfish resource from the shoreline outward to a depth of 30 m along the inner continental shelf in north-western Australia; and the nursery areas of the major commercial and recreational fish species in the Pilbara and Kimberley regions.

The catches of the main fish species obtained by commercial, recreational and charter boat fishers along the Pilbara and Kimberley coasts have been determined by analysing the Department of Fisheries Western Australian Catch and Effort Database System (CAES), the results of a recreational creel survey and the statutory monthly reports of catch and effort by charter boat operators.

The weight of finfish caught by nearshore and inshore commercial fishers along this coast during 2002 was approximately 590 tonnes. The total annual recreational fishing effort along the coast between Onslow and Broome in 2002 was estimated as 190,000 fisher days, which yielded approximately 320 tonnes of fish. The 111 licensed charter boat operators in the Pilbara and Kimberley undertook 3628 tours in 2002, during which they caught 53 tonnes of fish. Thus, the total catch from all three sources approached 1000 tonnes.

Nearshore, shallow waters on beaches and in mangroves and intertidal pools in three regions along the Pilbara and Kimberley coasts were sampled during the wet and dry periods of two

consecutive years. Data derived from the resultant catches were used to determine the ways in which fish species use the different habitat types and how the characteristics of the fish faunas varied with latitude, habitat type and season.

The fish catches from all habitat types collectively yielded 170 species representing 66 families. Fifty three of these species are fished commercially and recreationally along the Pilbara and Kimberley coasts, and a further 17 fish species are caught solely by recreational fishers. The most abundant species included the blue and king threadfin salmons, salmon-tailed catfish, the blue-spot and large-scale mullets, queenfish, western school whiting, Quoy's garfish, Moses snapper and estuary rockcod.

Some species, such as the two threadfin salmons, spend the whole of their life cycle in nearshore, shallow waters, whereas others, such as Moses snapper and estuary rockcod, use those waters solely as a nursery area. Species such as the two threadfin salmons and also whiting species were caught predominantly over bare sand, whereas species such as the large-scale mullet and the nervous shark were obtained mainly from mangroves, and Moses snapper and estuary rockcod were collected almost exclusively from intertidal pools.

The species compositions of the fish assemblages were influenced not only by habitat type, but also by season and region and also apparently the extent of tidal action and thus turbidity. Differences between the compositions in the extreme wet and dry periods found in the region were attributable to emigrations and immigrations of large numbers of particular species at certain times. For example, mature catfish aggregate in nearshore, shallow waters during the wet period.

Sampling over reefs using fish traps and over soft substrates using an otter trawl net in both shallow (*ca* 15 m) and deeper inshore waters (*ca* 22 m) at seven regions along the Pilbara and Kimberley coasts yielded data on the species composition of the fish faunas and the relative abundances of the main commercial and recreational fish species in these waters. 132 fish species were caught over reefs and 279 species over soft substrates, of which 53 and 9% were of commercial and/or recreational importance, respectively.

Blue-spotted emperor, stripey snapper, grass emperor, golden trevally, Indonesian snapper, estuary rockcod and golden snapper were the most abundant commercial and/or recreational fish species over reefs and, during the day, collectively comprised *ca* 75% of the total catch. In contrast, the most abundant commercial and/or recreational fish species over soft substrates, namely threadfin emperor, blue-spotted trevally, sunrise goatfish, asymmetrical goatfish and threadfin bream, collectively contributed only *ca* 11% to the total catch. The most abundant fish species in the trawl catches were the splendid ponyfish (11.4%), smooth-tailed trevally (10.4%), Gulf damselfish (7.1%) and banded grunter (7.1%).

Species composition was strongly influenced by latitudinal position, with, for example, species such as golden snapper and Indonesian snapper being far more abundant over reefs in northern locations, whereas the reverse was the case for species such as blue-spotted emperor, yellow-tailed emperor and starry triggerfish. Species such as blue-spotted emperor and dark-tailed snapper were abundant in both shallow and deeper waters, whereas grass emperor and golden trevally were relatively more numerous in shallow water and black spinefooot and Indonesian snapper were more abundant in deeper water.

Species composition in the wet and dry seasons differed markedly, with, for example at Cape Voltaire, species such as Indonesian snapper being more common during the wet period, whereas the reverse was true for grass emperor and golden snapper. The numbers of species and numbers of individuals caught in traps over reefs were both greater during the day than night, reflecting greater feeding activity by particularly lethrinid species.

In the catches from over reefs, most blue-spotted emperor and red emperor were less than the minimum legal length (MLL), whereas most grass emperor and spangled emperor were greater than the MLL and considerable numbers of bar-cheeked coral trout were caught both above and below the MLL.

Only 0.6% of the number of individuals of fish in the by-catch of the Exmouth Gulf prawn fishery belonged to commercial and/or recreational species.

This project has synthesised the available data from commercial, recreational and charter boat fisheries with baseline survey data throughout the region. In order to build on the outcomes of this project a number of priority areas for research in this nearshore zone have been identified.

These priority areas of research include; estimation of biological parameters of key species for the purposes of fisheries management (a list of key species is provided in the Further Development Section of this Report); evaluation and assessment of recreational and aboriginal netting activities in the Pilbara and Kimberley region of north-western Australia; determination of the genetic stock structure of the key species of commercial and recreational fishing significance in the nearshore areas throughout north-western Australia to define the appropriate spatial scale for fisheries management; and refinement of commercial and recreational data collection programs in the Pilbara and Kimberley region of north-western Australia.

KEYWORDS: Tropical, commercial, recreational, nursery habitats, nearshore reefs, estuaries, beaches, intertidal, rockpools.

Acknowledgements

We gratefully acknowledge the financial support for this project from the Fisheries Research and Development Corporation and logistical support from the Fisheries Research Division, Department of Fisheries, Government of Western Australia and the Centre for Fish and Fisheries Research, Murdoch University, Perth, Western Australia. We thank the captain and crew of the RV *Flinders* and the RV *Naturaliste* for their assistance at sea during each of the survey periods that were undertaken over long time periods in some of the remotest areas of north-western Australia. The assistance of staff from the regional office of the Department of Fisheries in Broome is also greatly appreciated.

We would also like to thank the many volunteers for their assistance and help in the field, in particular, Steve Young, Chris Marsh, Mark Pember, Shawn Carman, Ian Mathers and Ava Young. In addition, we are indebted to the Cape Keraudren Ranger, Steve Bunce, for showing us around and generally being very helpful and the proprietors of Pardoo Road House, the proprietors of Port Smith Caravan Park and the proprietors of the Eighty Mile Beach Caravan Park for their assistance and allowing us to store some of our gear at their respective premises. Amazingly, several people went on more than one trip, which is a miracle really especially over the summer months.

We acknowledge, with gratitude, the commercial prawn trawl skippers from Exmouth Gulf for allowing us on board to get in the way of their usual operations and especially their crews for all their help and for pointing out virtually every stonefish and snake on the sorting tray. In particular we would like to thank Chris, Bluey, Darryl, Garth, Mick, Grayem, Mike, Nobby, Eric, Polly, Pinky, Boondie, Steve and Brendan. Thanks also to Errol Sporer, Prawn Section, Fisheries Research Division, Department of Fisheries, Government of Western Australia and Simon Boxshall from MG Kailis for their assistance with organising each sampling trip and also to all the other MG Kailis personnel who helped with the freezing and transportation of all by-catch samples. We would also like to thank the many friends and colleagues who helped collect by-catch samples throughout this project, namely Bernie Brix, Zoe Weldon, Steffen Linke, Collette Kneeling and Howard Christie.

Michael Travers and Mathew Pember completed much of the tough, uncompromising fieldwork undertaken for this project. This work will contribute in part to the requirements for a PhD degree to both these outstanding candidates from Murdoch University, Perth, Western Australia.

Finally, we would like to thank Drs. Penn and Lenanton for their helpful comments and suggestions in reviewing this report.

Background

To date, most of the finfish research effort in the Pilbara and Kimberley region of Western Australia has been in support of initiatives to manage the mid to outer shelf and deep slope finfish fishery resources, which have been variously exploited by both foreign and domestic fishing fleets since the early 1960s.

During the process of development, management and research into the mid to outer shelf fishery resources of the Pilbara and Kimberley region most of the key fishery resources are now under formal management arrangements. As part of this process, the trawl and trap fishers have been limited to waters deeper that 50 and 30 metres, respectively. The demersal finfish resources of the extensive nearshore area (< 30 m depth) that extends along approximately 3,000 km of coastline in north-western Australia (a length of coastline similar to that of Tasmania) is currently targeted by commercial line fishers (including charter operators), shoreline gill-net fishers, and recreational anglers. The inshore fish stocks of the Pilbara and Kimberley regions also sustain a low level of incidental mortality as prawn trawl by-catch. To date, this inshore zone has received little research attention. An intention to address these issues in a preliminary way in an earlier FRDC project (1991/028) was never realised.

A major creel survey of the recreational fishery of this region commenced in December 1999 in support of an important initiative to manage the recreational fishery for this extensive inshore resource. This creel survey will identify the key species and fishing locations of recreational fishers.

However, sound management of this inshore resource cannot proceed without a good understanding of the distribution and magnitude of the commercial catch on a comparable spatial scale to the recreational catch, thus providing estimates of the total catch of each of the key species. From this perspective, it is also important to understand the relationship between the commercial and recreational fisheries, and the distribution and abundance of the available resource.

This project will examine the catch and effort database for the inshore commercial fisheries off the north coast, resolving the data where necessary, to produce a description of the species composition in the various management zones and major fishing areas, and to identify the fishing methods in use. If possible, a validated time-series of catch and effort for the key inshore commercial species will be produced. This information will be used to describe the spatial distribution of the commercial catch and effort in the inshore region of north-western Australia.

There is also a need to identify additional sources of exploitation of the nearshore resource. Inshore prawn trawlers take as by-catch juveniles of many of the economically important finfish of the region. For example, Stephenson and Mant (1999) sampled juveniles of the key indicator species (*Lutjanus sebae, Epinephelus multinotatus, Lethrinus hutchinsi* and *Lutjanus vitta*) in the Pilbara Fish Trawl Fishery from the nearby Nickol Bay Prawn Fishery in order to complete age and growth studies. It should also be recognised that nearshore shallow waters (< 2 m depth) act as a nursery area for some fish species in tropical waters (see Blaber *et al.* 1995) and that Blaber *et al.* (1985) found that the fish community in the Damper region underwent a pronounced change at water depths of approx. 20 metres. It is important to identify those species of commercial and recreational fishing significance and hence of major economic importance that may be landed as by-catch from prawn trawl vessels.

In the process of undertaking this work, it is also important to understand the extent to which fish of commercial and recreational fishing significance are located within areas identified in the Marine Parks and Reserve Selection Working Group Report (CALM, 1994). Collecting baseline information on the fishery resources in areas nominated as future marine reserve sites is essential in order to assess the likely impacts on commercial and recreational fishers should access to these areas become restricted.

Thus, the documentation of the overall catches of the demersal finfish resources in the inshore region of north-western Australia from the shoreline outward to a depth of 30 metres is essential for the development of management plans for the sustainable exploitation of the demersal fish resource shared by recreational and commercial fishers of Australia's north-west. This study will also provide a basis for identifying tropical inshore species in need of future detailed stock status advice in support of fisheries management. Furthermore, this project should identify possible nursery areas of species of commercial and recreational fishing significance along the north-west coastline.

Need

Inshore demersal fish stocks in Australia's north-west face increased exploitation pressure by an ever increasing number of recreational fishers in direct competition with an adjacent commercial fishing industry. There is, therefore, an urgent need to determine the species distribution and the composition of demersal scalefish resources in the inshore region of north-western Australia in waters outward from the shoreline to depths of 30 metres, including the documentation of the abundance and diversity of any significant finfish by-catch of prawn trawlers operating within the region, as a basis for formulating rational management plans for the exploitation of the demersal scalefish resource among user-groups.

The sharing of the inshore demersal fish resource in this region will require careful future management to ensure sustainability and avoid conflict among these user groups. This project will provide baseline information on the species composition and relative abundance of the inshore fishes of Australia's north-west and identify possible nursery areas of species of commercial and recreational fishing significance which may need protection, possibly as nursery closures, in the future. Furthermore, in order to facilitate sagacious management plans and to safeguard the interests of commercial and recreational fishers, the baseline information on the nearshore fishery resources of the north-west provided by this study can be used to assess the impact of any possible access restrictions that may be imposed in areas nominated as future marine reserve sites in north-western Australia.

Objectives

1. To determine the overall catch of the key species of commercial and recreational fishing significance (that is, the recreational catch, commercial catch and other landed catch).
2. To determine the species composition and relative abundance of the inshore demersal finfish resource from the shoreline outward to a depth of 30 metres along the inner-continental shelf in north-western Australia.
3. To determine the nursery areas of fish species of commercial and recreational significance in the Pilbara and Kimberley regions.

1.0 Spatial distribution of commercial, recreational and charter vessel catch and effort data

Stephen J. Newman, Craig L. Skepper and Peta C. Williamson

1.1 Nearshore commercial finfish fisheries

The Department of Fisheries (Western Australia) catch and effort database system (CAES) was interrogated to determine major fishing areas and fishing methods in inner shelf waters, and to produce a time-series of catch and effort for the key inshore commercial species. Catches of the key inshore species by gear type and location were determined over time in association with the spatial distribution of fishing catch and effort in inner shelf waters.

The spatial distribution of catch and effort data from the commercial fishing sector in the nearshore waters of north-western Australia is examined on a fishery basis looking at specific gear types where possible (note that catch data represent reported landings). Analysis includes all finfish species taken in the period from 1990–2002 from those blocks that incorporate a major proportion of area inside the 30 m bathymetric contour. Each reporting block in the CAES database represents a 1° square that is approximately 60 × 56 nautical miles (60 × 60 minute grids). However, many of the nearshore blocks cover a much smaller area of seawater. The catch of each nearshore fishery and the finfish species of commercial importance are described below.

1.1.1 Exmouth Gulf Beach Seine Fishery

Netting first commenced in Exmouth Gulf during the early 1950's, when two vessels began fishing for mullet. However, these fishing operations were short-lived as a result of a cyclone destroying the local cannery in 1953 and the venture being abandoned. Net fishing resumed in 1967, and by 1969 five operators were fishing for bony (Perth) herring (*Nematalosa vlaminghi*, used as rock lobster bait) for 2 months (August and September) during the winter of each year. This continued for 20 years until demand dropped. The Exmouth Gulf Beach Seine Fishery (EGBSF) was formally created in 1989 as a restricted entry fishery when 12 fishing units were licensed. The licence endorsed commercial beach seine and gillnet operations south of the line drawn from Point Murat to the south shore of the south arm of the Ashburton River mouth. Each licence (unit) was able to use 4 dinghies. The number of licences has gradually decreased (via transfer or through the Fisheries Adjustment Scheme) to seven by 1992, six by 1996, three by 1998 and to two operators at the present time (which is considered sustainable).

The key species are sea mullet (*Mugil cephalus*), western sand whiting (*Sillago analis* and *S. schomburgkii*), Perth herring (*Nematalosa vlaminghi*) and yellowfin bream (*Acanthopagrus latus*). Whiting are mostly caught over the warmer months from September through to April when these species reportedly spawn in the region. Mullet are largely targeted on demand, with most sold frozen as bait. Bream are mostly caught between May and July when they school to spawn. Perth herring are mainly caught in the winter months from July through to September when they reportedly spawn in the southern waters of Exmouth Gulf. In recent years Perth herring has been absent from catches in the EGBSF.

Beach seines and gillnets are used in the fishery. Where possible, gill nets are hauled on the incoming high tide on to available sandy beaches. Alternatively in rough bottom areas where nets cannot be hauled, nets are circled around schools on a high to falling tide, allowing the receding tide to trap the fish in the net.

The catch and percentage composition of the total catch of the EGBSF is shown in Figures 1.1.1 and 1.1.2. The total catch in the EGBSF has declined since the peak catch in 1993. The reduced catch is associated with a decrease in fishing effort in recent years, reflecting a reduced number of licensees operating in the fishery. The catch and effort of the EGBSF is restricted to the area within Exmouth Gulf (Figs. 1.1.3-1.1.4).

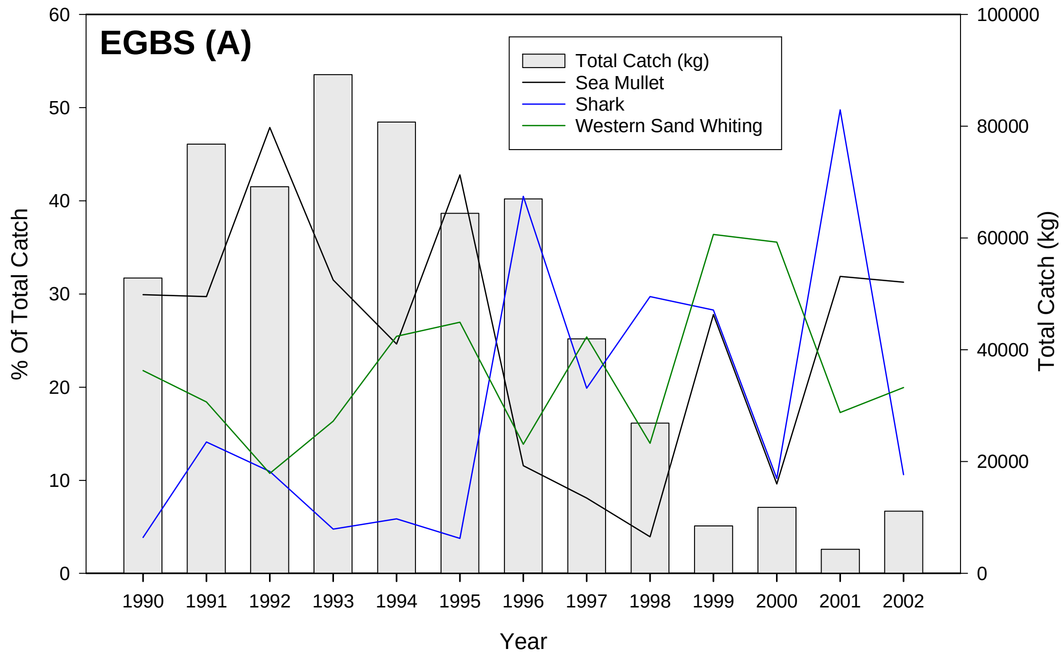

Figure 1.1.1 The total catch of the EGBSF from 1990 to 2002 and the percentage composition of key selected species.

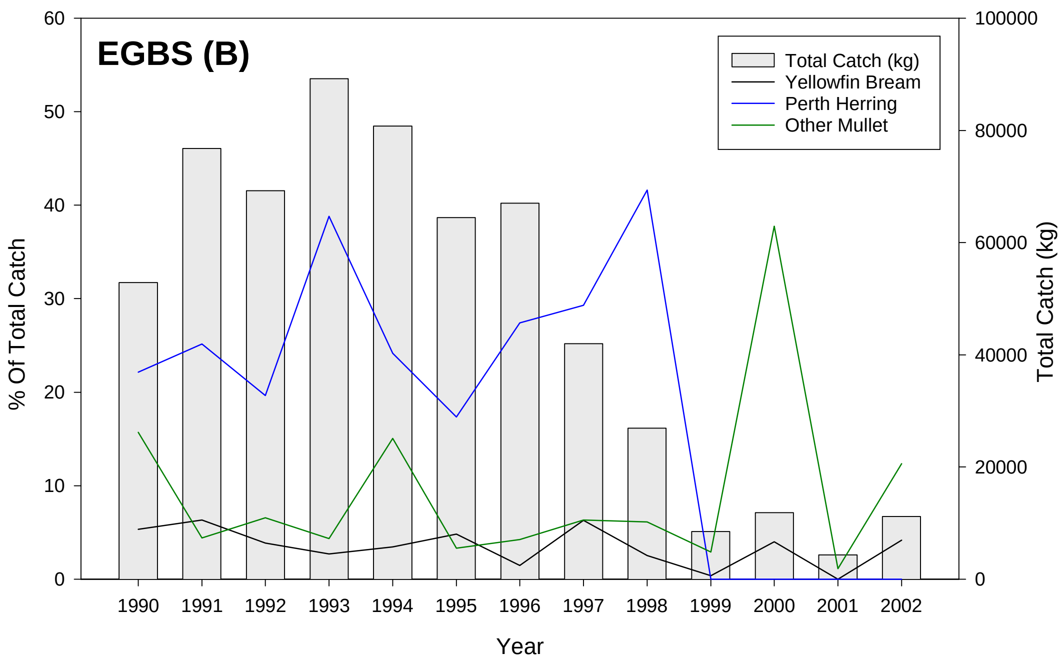

Figure 1.1.2 The total catch of the EGBSF from 1990 to 2002 and the percentage composition of key selected species.

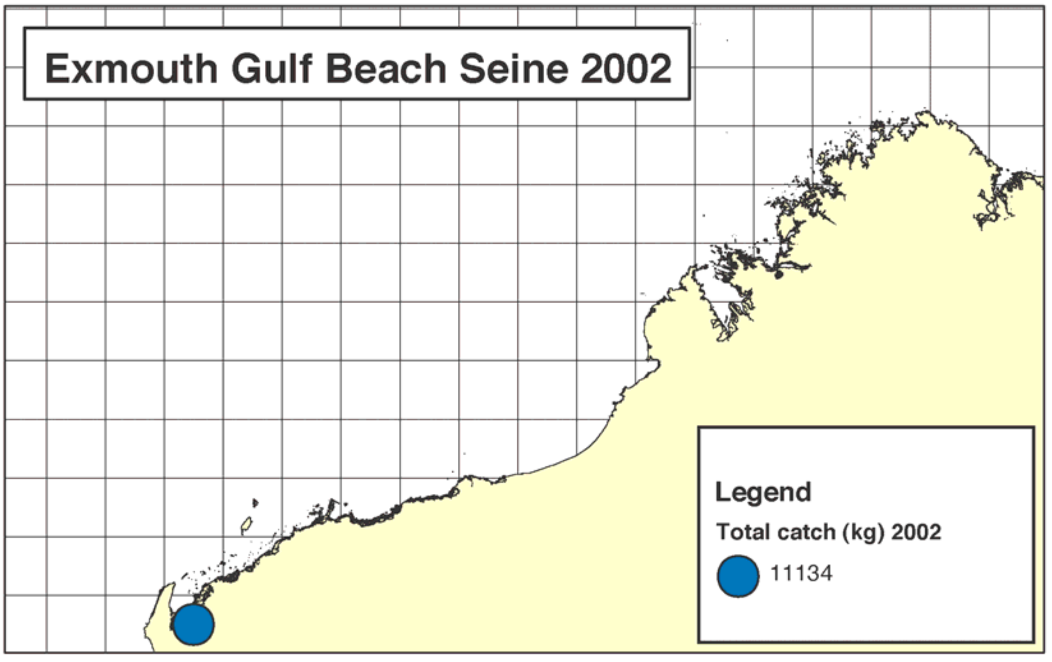

Figure 1.1.3 Spatial distribution of the total catch from the Exmouth Gulf Beach Seine Fishery off north-western Australia in 2002.

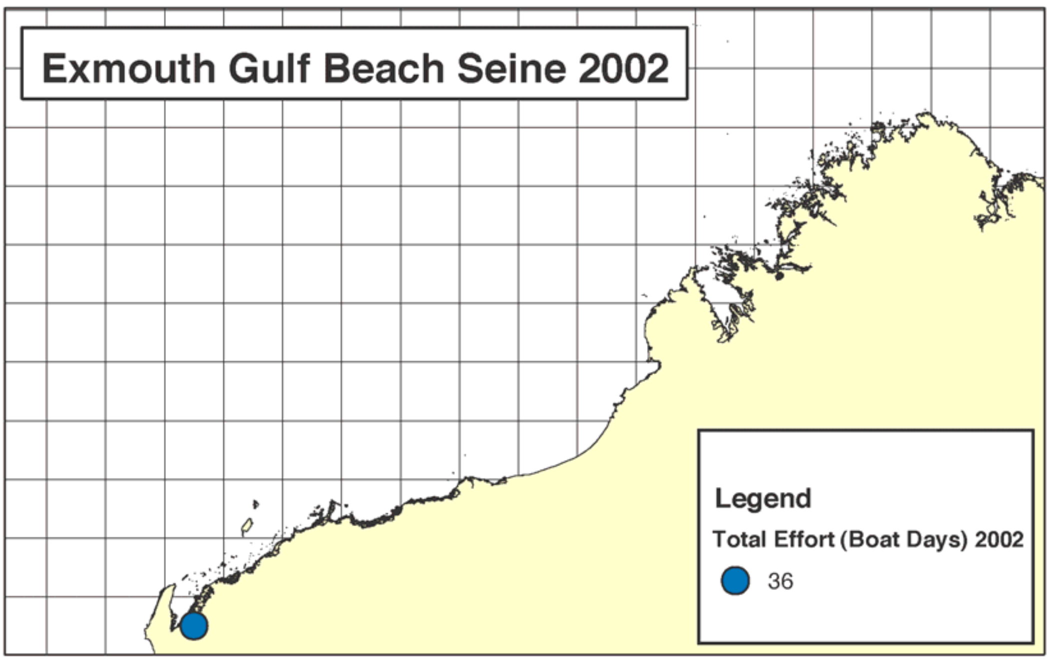

Figure 1.1.4 Spatial distribution of the effort from the Exmouth Gulf Beach Seine Fishery off north-western Australia in 2002.

1.1.2 Kimberley Gillnet and Barramundi Fishery

The Kimberley Gillnet and Barramundi Fishery (KGBF) first came under management in 1989 when 17 licences were initially issued. Prior to this time the fishery was open to all holders of a Western Australian Fishing Boat Licence. Licences endorse the taking of all finfish by gillnet (and barramundi by any method) from waters lying north of 19°S and west of 129°E within 3 nautical miles of the coastline at the low water mark, and within tidal areas of rivers. Areas within these boundaries that are closed to fishing are those in the vicinity of Crab, Jacks, Thangoo, and Yardogarra Creeks, Cape Bossut, the Fitzroy River mouth and the Derby Jetty. An Accord between commercial fishers, recreational anglers and charter fishers in regard to fishing zones and exclusion zones to prevent resource user conflict was negotiated in 2000 and is currently in practice. KGBF licences are presently non-transferrable (transferability is scheduled to be introduced to the fishery during 2003), and in the period between 1989 and 1998 the number of licences fell from 17 to 10. The Fisheries Adjustment Scheme (FAS) was offered in 1998 (for one year only) to reduce the number of licensees in the fishery and the FAS offer resulted in the number of licences being reduced to 7. In the most recent fishing year (2002) seven vessels fished in the fishery.

The main areas of the fishery are the river systems of the northern Kimberley, King Sound, Roebuck Bay and the top end of Eighty Mile Beach. The area of the fishery east of Cunningham Point (123°08.12'E) is closed from 1 November to 31 January, while the fishery west of Cunningham Point (123°08.12'E) is closed from 1 December to 31 January.

Gillnets used in the fishery must not exceed 500m in length, and have a mesh size between 165 mm and 177.8 mm east of Cunningham Point, and between 112 mm and 150 mm west of Cunningham Point. The breaking strain of the mesh must not be greater than 70 kg. One fishing unit is equivalent to a licensed fishing boat plus a netting dinghy.

The catch and percentage composition of the total catch of the KGBF is shown in Figure 1.1.5. The total catch in the KGBF has increased in recent years, with the catch of threadfin salmons increasing while the catch of barramundi is declining. The key species are barramundi (*Lates calcarifer*), giant threadfin salmon (*Polydactylus macrochir*) and blue threadfin salmon (*Eleutheronema tetradactylum*). The KGBF stock of barramundi is considered on average to be fully exploited, with breeding stock levels adequate in most areas. The spatial distribution of the catch and effort of the KGBF extends from Broome in the south throughout the Kimberley region to the Northern Territory border (Figs. 1.1.6-1.1.7).

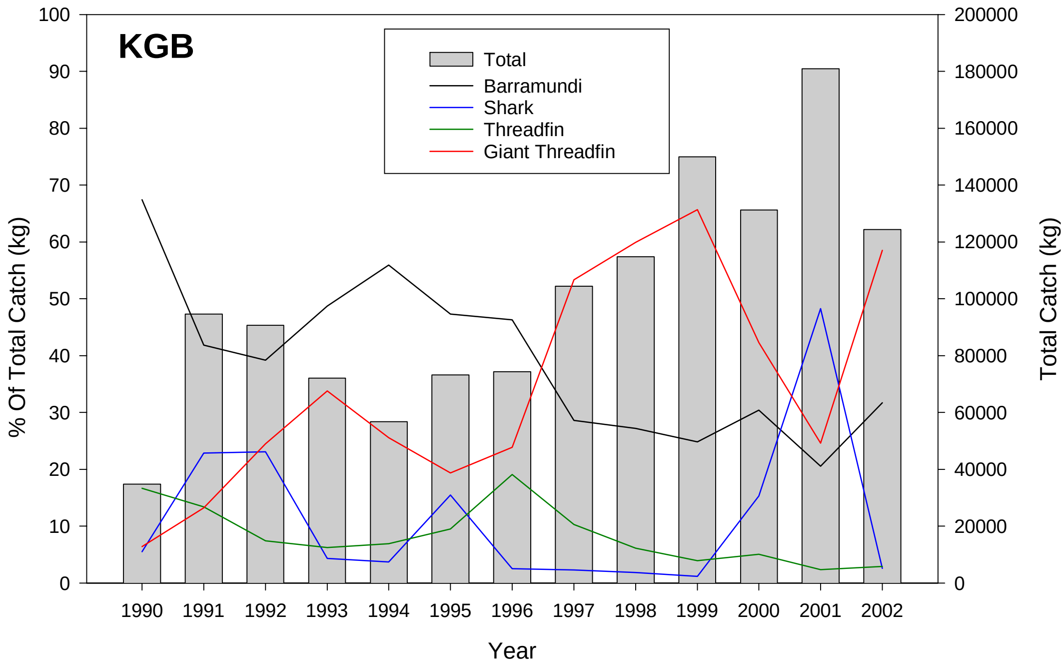

Figure 1.1.5 The total catch of the KGBF from 1990 to 2002 and the percentage composition of key selected species.

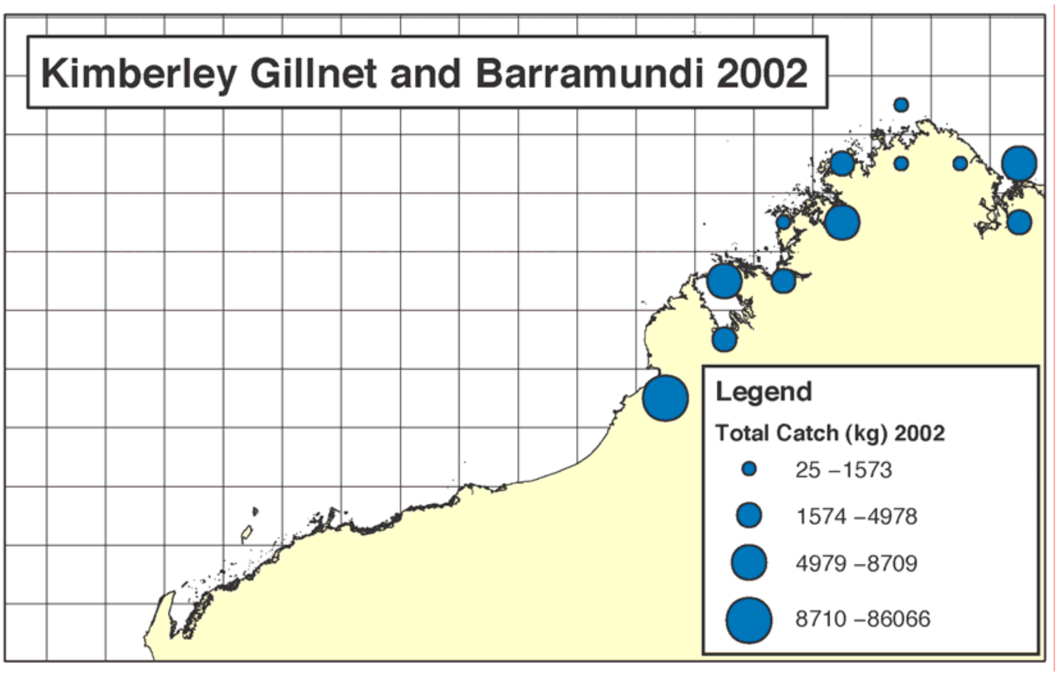

Figure 1.1.6 Spatial distribution of the catch from the Kimberley Gillnet and Barramundi Fishery off north-western Australia in 2002.

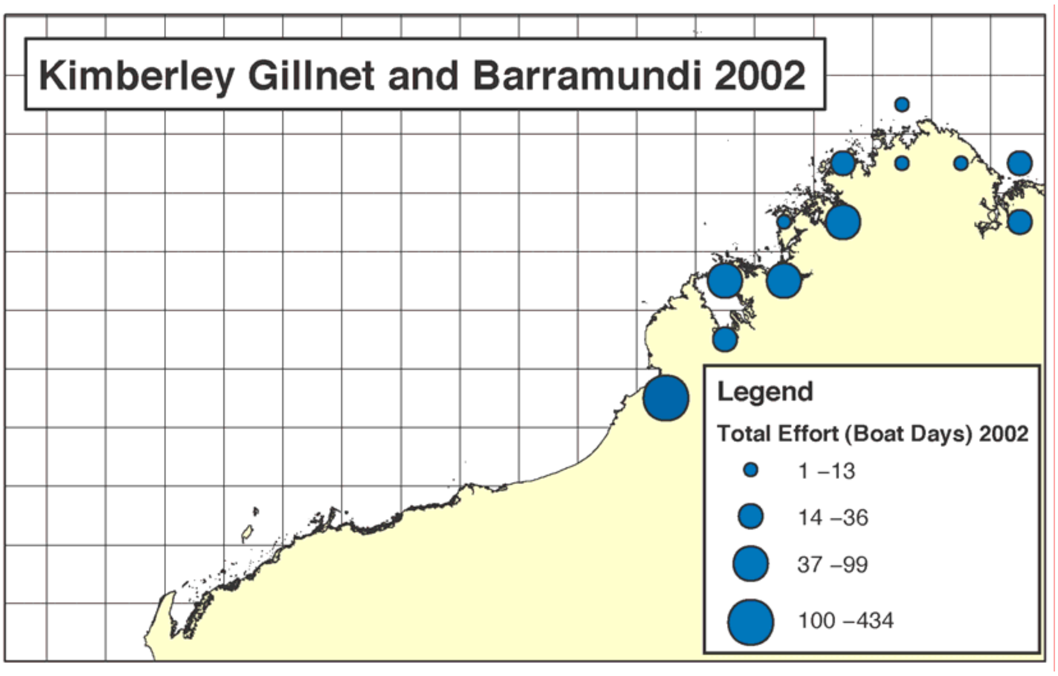

Figure 1.1.7 Spatial distribution of the effort from the Kimberley Gillnet and Barramundi Fishery off north-western Australia in 2002.

1.1.3 Northern Demersal Scalefish Fishery – Area 1

The Northern Demersal Scalefish Fishery is divided into two fishing zones, an inshore zone (Area 1) and an offshore zone (Area 2). The inshore zone (Area 1) extends from the shore to a line approximating the 30 m bathymetric contour. The inshore waters in the vicinity of Broome are closed to commercial fishing. The closed area extends from Cape Bossut to Cape Coulomb, inside a line that approximates as closely as possible the 30 m bathymetric contour.

Licensees within Area 1 of the NDSF are authorized to fish for demersal finfish using handlines only. Access to Area 1 of the NDSF is currently limited to 4 licences. Licensees are permitted to use up to 5 handlines at any one time, with no more than 6 hooks on each line. Catch and effort in Area 1 of the NDSF has been low and variable since the introduction of formal management in 1998. Catches in this area peaked in 1992 at 5.4 tonnes (Fig. 1.1.8-1.1.9), although since 1999 annual catches have been approximately 1 tonne per year. The key historical species landed in Area 1 (Fig. 1.1.8) include blue-lined emperor (*Lethrinus laticaudis*), cod (Serranidae), other non-specified fish species and assorted shark species. In recent years golden snapper or fingermark (*Lutjanus johnii*), northern mulloway or black jewfish (*Protonibea diacanthus*) and sea catfish (*Arius thalassinus*) have been prominent in the total catch figures (Fig. 1.1.9).

The spatial distribution of the catch within Area 1 of the NDSF is concentrated in the eastern sector of the Kimberley region (Fig. 1.1.10). In contrast, the effort is higher in the western sector of the Kimberley region (Figs. 1.1.11). Note that both the catch and effort in Area 1 of the NDSF are low.

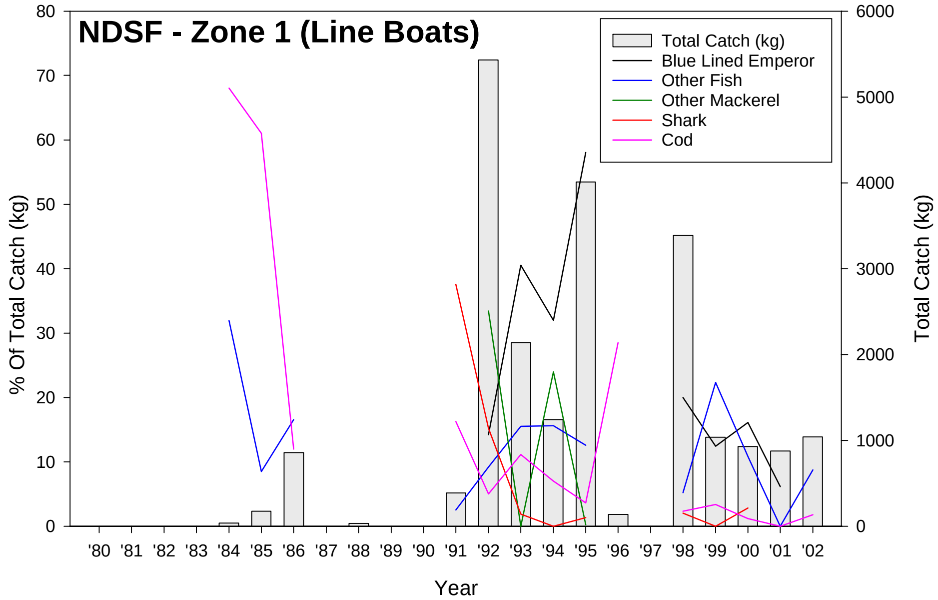

Figure 1.1.8 The total catch of the NDSF Zone 1 permit holders and the percentage composition of key selected species.

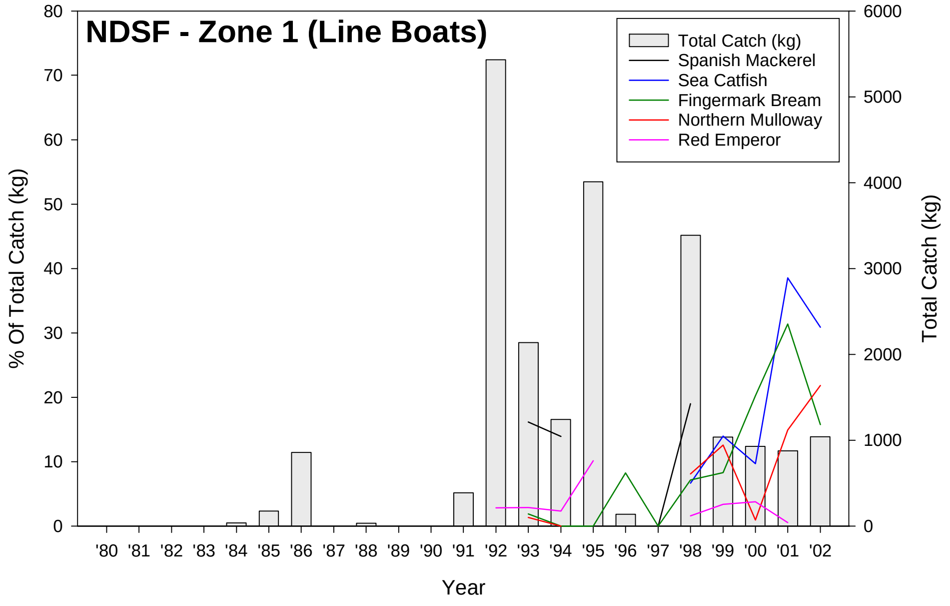

Figure 1.1.9 The total catch of the NDSF Zone 1 permit holders and the percentage composition of key selected species.

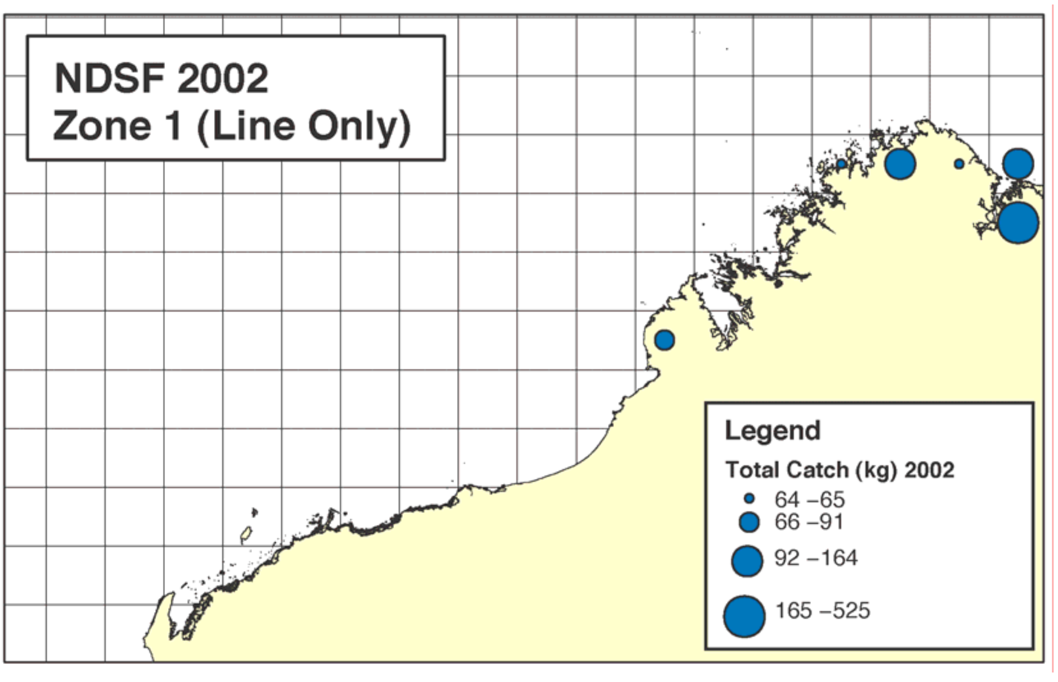

Figure 1.1.10 Spatial distribution of the catch from the inshore zone of the Northern Demersal Scalefish Fishery off north-western Australia in 2002.

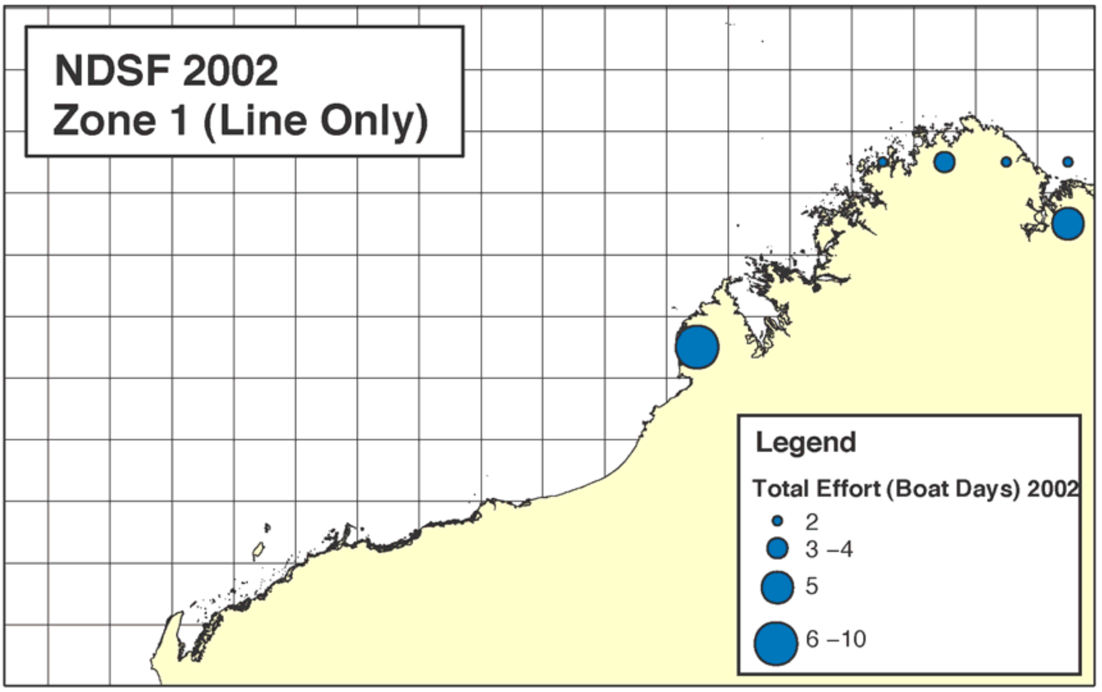

Figure 1.1.11 Spatial distribution of the effort from the inshore zone of the Northern Demersal Scalefish Fishery off north-western Australia in 2002.

1.1.4 Wetline Fishery

All vessels with a Western Australian Fishing Boat Licence (FBL) are able to catch finfish by gears other than those regulated in the managed fishery areas. These data include fishing activities for Spanish mackerel and other mackerels that will come under formal management arrangements from mid 2004. These data also include those vessels fishing gillnets under exemption south of the KGBF. The majority of fishers in this sector are utilising a variety of line methods such as trolling, hand line, drop line and long line. These data also incorporate the catch of charter vessels recorded on the CAES system. The charter vessel data are sparse and reflect catches recorded by operators prior to formal licensing. We have separated the wetline sector into two groups; those that fished with handlines and/or droplines and those that fished using nets; gillnets, haul nets or beach seines.

1.1.4.1 Pilbara Inshore – Hand line, dropline catch

Vessels using dropline and handline gear have historically landed demersal finfish species in the non-managed line sector of the Pilbara fishing area under an unrestricted Fishing Boat Licence. Catch and effort from this sector were examined using data from nearshore blocks in the CAES database that incorporate depths predominantly less than 30m. The number of vessels operating in this sector peaked at approximately 50 in 1984, although a gradual decline in participating vessels has been recorded since, with 20 vessels operating in 2002. The catch and percentage composition shown in Figure 1.1.12 reveals that total landings (excluding sharks and rays) peaked at around 171 tonnes in 1985, with a general steady decline in catch since 1990 (150 tonnes) to the current level of approximately 60 tonnes in 2002.

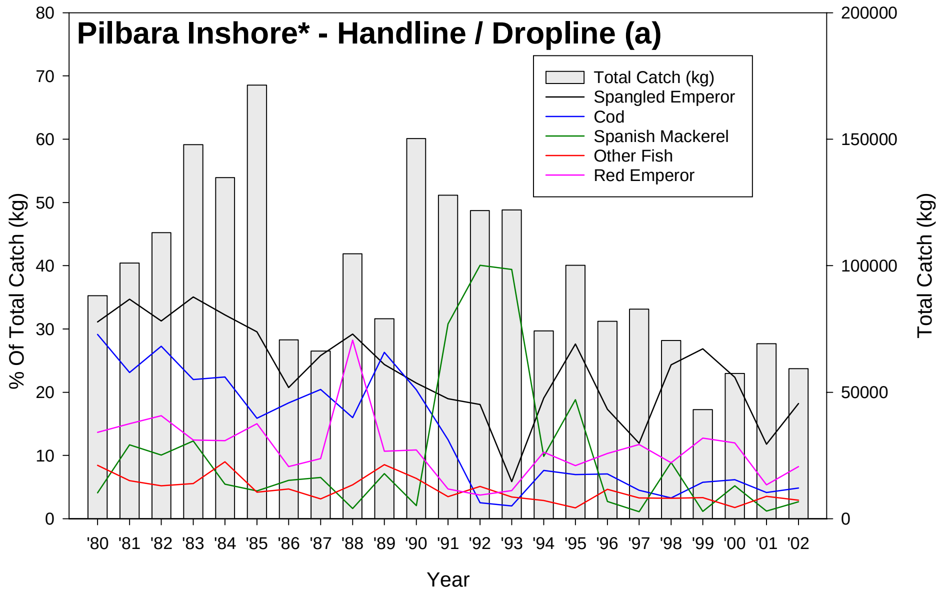

Figure 1.1.12 The total catch of the handline and dropline fishers in the inshore zone of the Pilbara coast and the percentage composition of key selected species.

Examination of the catch and effort returns for 2002 indicate that the effective line effort can vary considerably, for example, some vessels use up to 400 hooks while running droplines, and up to 24 hooks while using handlines. The key finfish species landed (Figure 1.1.12-1.1.13) since 1980 from the nearshore sector of this fishery include spangled emperor (*Lethrinus nebulosus*), red emperor (*Lutjanus sebae*), cod (Serranidae) and Spanish mackerel (*Scomberomorus commerson*). In recent years goldband snapper (*Pristipomoides multidens*) has formed a major component of the catch. The goldband snapper and the other key species reported in the catch are commonly found in depths greater than 30 m. This anomaly is a reflection of the way in which data is recorded by block within the CAES database. Unfortunately the catch and effort blocks are relatively large (approximately 60 × 56 nautical miles) and therefore by default contain fishing grounds which are greater than 30 m in depth where there are deep waters close to shore, and a significant proportion of the catch estimate for many of these blocks is derived from depths greater than 30 m even though they also encompass nearshore coastal waters.

The spatial distribution of the line catch and effort in the inshore zone of the Pilbara coast is concentrated in the west in close proximity to the ports of Exmouth and Onslow (Figs. 1.1.14-1.1.15).

1.1.4.2 Pilbara Inshore – Gill Net, Beach Seine and Haul Net Catch

Vessels using gillnets, haul nets and beach seines to land finfish in this sector have fished under unrestricted Fishing Boat Licences or exemption permits to land finfish from nearshore Pilbara waters south of the boundary for the Kimberley Gillnet and Barramundi fishery (19°S). The number of vessels operating in this sector peaked at 16 in 1982, although this figure has steadily decreased since, with only 3 vessels fishing this area in 2002. Total landings peaked during the early 1990's at around 60 tonnes (Fig. 1.1.16), with catches steadily declining to just under 3 tonnes in 2002. Catch and effort data for 2002 indicate that the length of gillnet used ranged from 60–120 m, while haul nets used were 120 m in length. Since 1980 gillnets have accounted for ~95% (584 tonnes) of the total catch, with beach seines and haul nets accounting for ~ 3% (19 tonnes) and ~2% (9.5 tonnes) respectively.

Historically the key species landed are bluenose salmon (*Eleutheronema tetradactylum*), barramundi (*Lates calcarifer*), sea mullet (*Mugil cephalus*), giant threadfin (*Polydactylus macrochir*) and various species of shark (Fig. 1.1.16). In recent years bluenose salmon (42% of landed weight in 2002) and sea mullet have constituted the bulk of the total catch. Catch and effort by net fishers is concentrated in close vicinity to Exmouth Gulf and the beaches north of Karratha (Figs. 1.1.17-1.1.18).

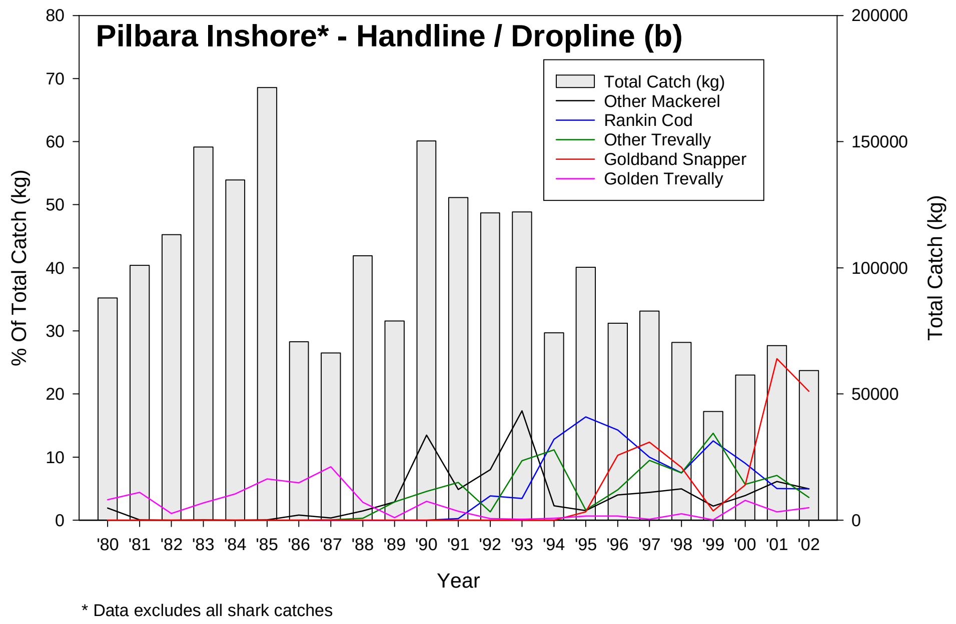

Figure 1.1.13 The total catch of the handline and dropline fishers in the inshore zone of the Pilbara coast and the percentage composition of key selected species.

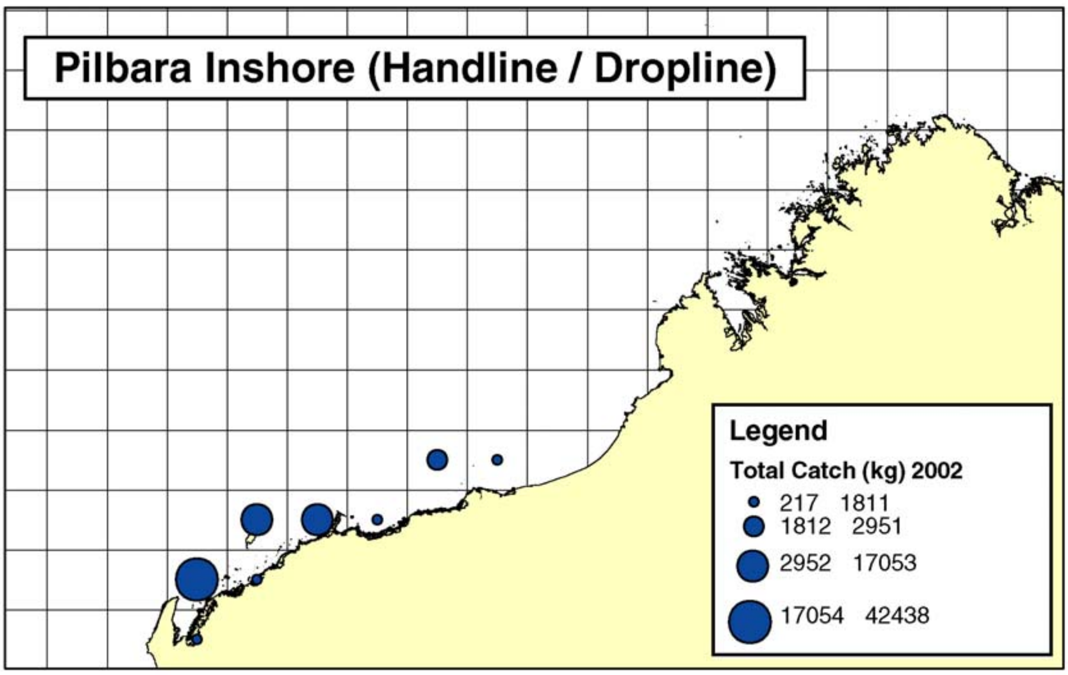

Figure 1.1.14 Spatial distribution of the catch from the inshore wetline fishing area along the Pilbara coast of north-western Australia in 2002.

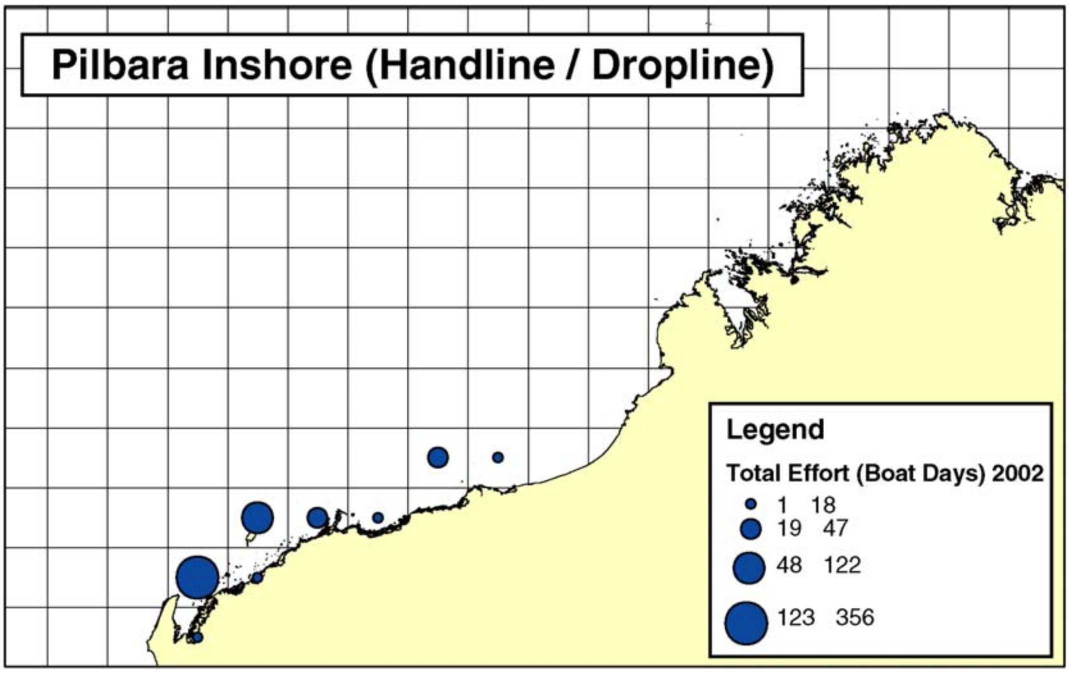

Figure 1.1.15 Spatial distribution of the effort from the inshore wetline fishing area along the Pilbara coast of north-western Australia in 2002.

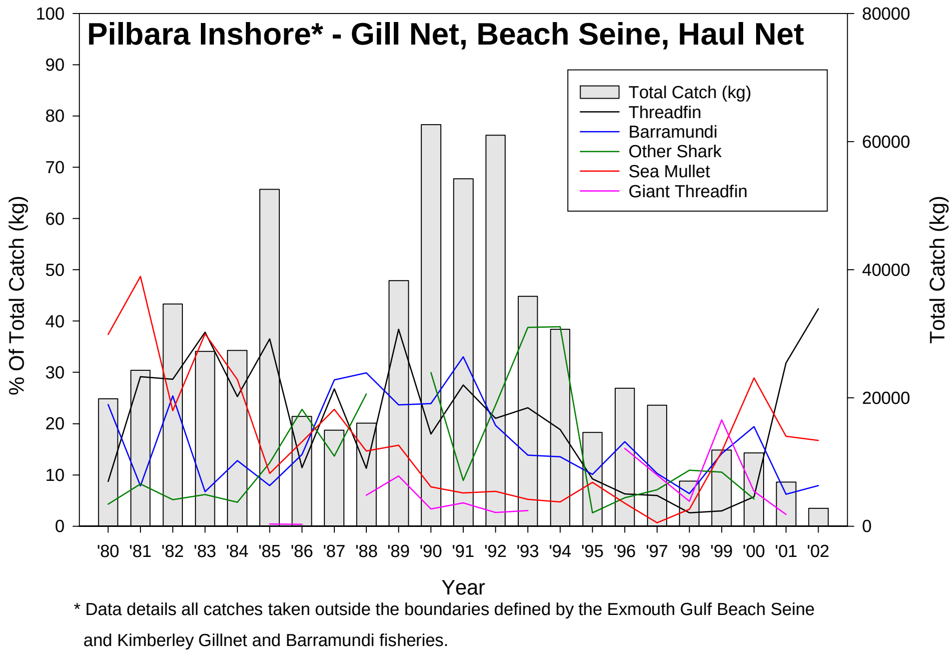

Figure 1.1.16 The total catch of the gillnet, haul net and beach seine fishers in the inshore zone of the Pilbara coast and the percentage composition of selected species.

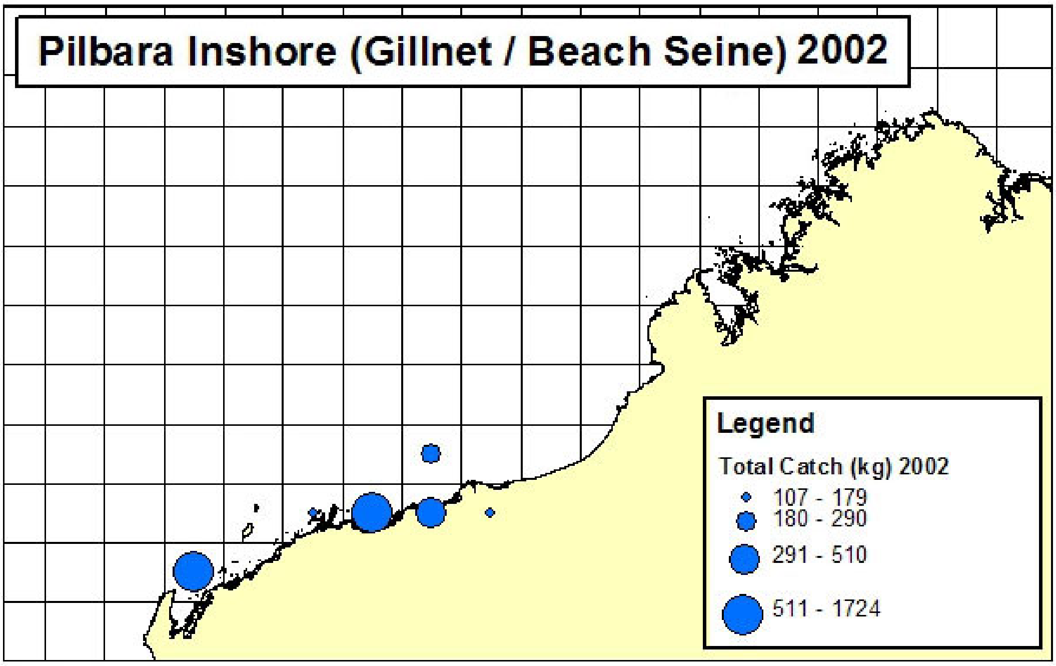

Figure 1.1.17 Spatial distribution of the catch from the inshore gillnet/beach seine fishing area along the Pilbara coast of north-western Australia in 2002.

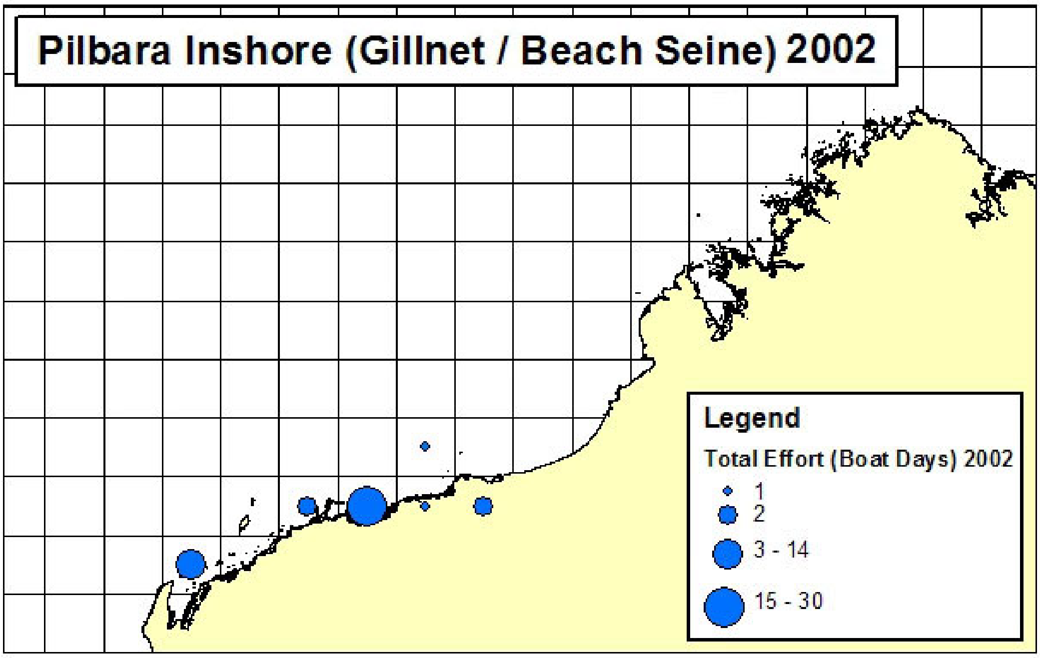

Figure 1.1.18 Spatial distribution of the effort from the inshore gillnet/beach seine fishing area along the Pilbara coast of north-western Australia in 2002.

1.2 Assessment of the finfish component of the landed catch from the prawn trawl fisheries along north-western Australia

The Department of Fisheries (WA) catch and effort database system (CAES) was examined to determine the magnitude of the reported catch of finfish by-product in each of the prawn fisheries in north-western Australia. These fisheries all operate in nearshore coastal waters.

1.2.1 Exmouth Gulf Prawn Fishery

There are 13 vessels licensed to fish for prawns in the Exmouth Gulf Prawn Managed Fishery (EGPMF; Kangas and Sporer 2003). The main fishing method is an otter trawl and all vessels tow quad gear (4 nets with 4.5-fathom headropes). The EGPMF targets western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*), endeavour prawns (*Metapenaeus endeavouri*) and coral prawns (*Metapenaeopsis* spp.). The EGPMF has seasonal opening and closing dates, as well as closure periods around the full moon. Trawling activities in the EGPMF are restricted with fishing permitted only between 1800 and 0800 hours each day. Management controls include limited entry, gear restrictions, and controls on vessel size and power.

The vessel monitoring system (VMS) was formally introduced to the fishery in the 2002 fishing season by way of an amendment to the Exmouth Gulf Prawn Management Plan 1989. The VMS is being used to monitor compliance with temporal and spatial closures within the EGPMF.

By-catch reduction devices (grids) were formally introduced to the fishery at the start of the 2002 season by way of a condition on the managed fishery license. Vessels are required to tow a grid in half the number of nets being used (that is, two grids when using quad gear). Full implementation of grids is expected to occur during 2003. Similarly, it is anticipated that secondary by-catch reduction devices (for example, square mesh panels) will be examined during the 2003 fishing season. Historically the fishery operated in shallow water areas (< 12 m) containing sponge habitats, but the refocusing of the fishery into deeper waters to take larger prawns since the early 1980s has reduced this interaction.

The catch of finfish by-product in the EGPMF has decreased in recent years and the fish component of the catch is low (Fig. 1.2.1). The dominant component of the landed by-product is shark. The total catch of finfish by-product in 2002 (excluding sharks) was less than 0.1 tonnes. A total of 2.1 tonnes of shark was also landed (Fig. 1.2.1).

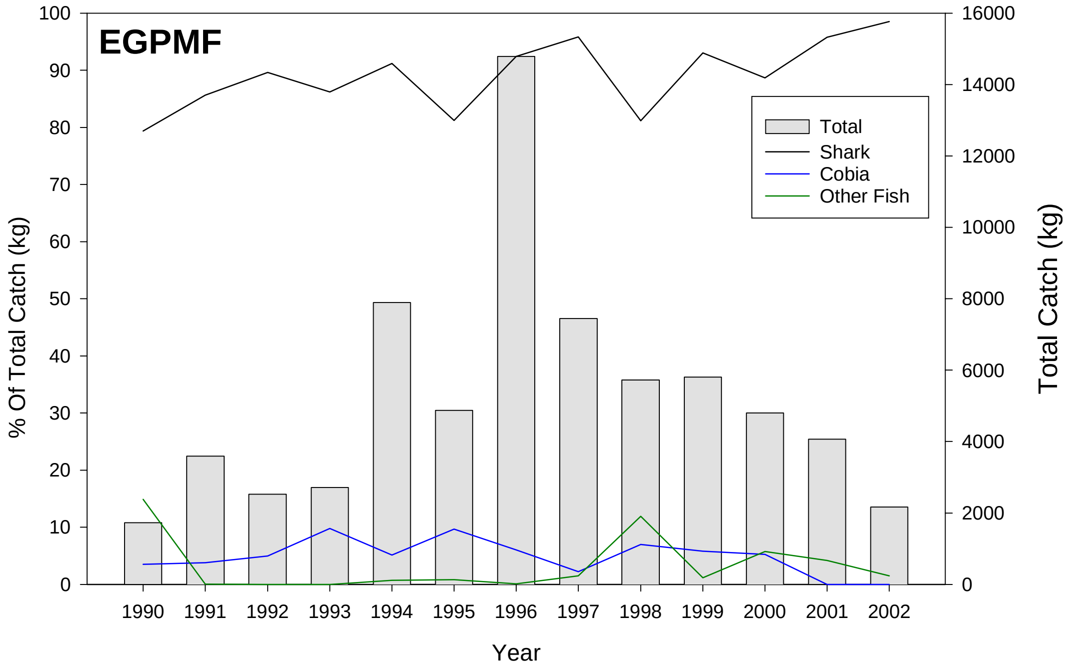

Figure 1.2.1 The total catch of fish by-product in the EGPMF and the percentage composition of the major species.

1.2.2 Onslow Prawn Fishery

There are 41 vessels licensed to fish for prawns in the Onslow Prawn Managed Fishery (OPMF), although different classifications of licence restrict access to 3 designated areas within the boundaries of the fishery (Area 1, 2 and 3). The main gear used is otter trawls with a 50 mm mesh size and a limit on the length of headrope. The OPMF targets western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*) and banana prawns (*Penaeus merguiensis*) and also lands a small amount of endeavour prawns (*Metapenaeus endeavouri*) and coral prawns (*Metapenaeopsis* spp.). The opening and closing dates for the fishery vary from year to year. The 2002-fishing season commenced on 1 March and ended on 15 November, which generally aligns with season dates for the adjacent EGPMF. However, different areas within the fishery have different season opening and closing dates that allows access to target species, usually tiger and banana prawns, at appropriate times.

Management controls for the OPMF are based on limited entry, seasonal and area closures, gear controls and restrictions on boat size. In 2002, by-catch reduction devices were introduced into the fishery with vessels required to have half their gear fitted with grids. The Vessel Monitoring System was also introduced into the fishery in 2002 to monitor compliance with temporal and spatial closures within the OPMF.

The amount of fish by-product landed in this fishery is negligible (Fig. 1.2.2). The dominant component of the landed by-product is shark. The total catch of finfish by-product in 2002 was 0.2 tonnes (Fig. 1.2.2).

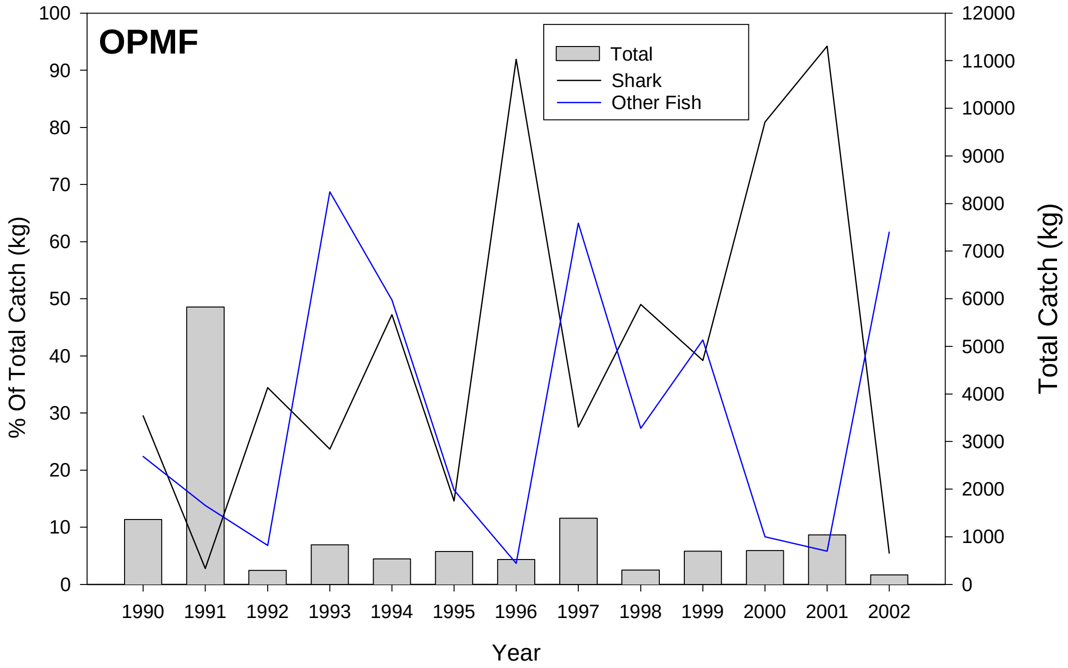

Figure 1.2.2 The total catch of fish by-product in the OPMF and the percentage composition of the major species.

1.2.3 Nickol Bay Prawn Fishery

There are 14 vessels licensed to fish for prawns in the Nickol Bay Prawn Managed Fishery (NBPMF), using otter trawls with a 50 mm mesh size. The NBPMF has 5 major fishing areas with varying temporal closures. The NBPMF targets banana prawns (*Penaeus merguiensis*) and western king prawns (*Penaeus latisulcatus*) and also lands brown tiger prawns (*Penaeus esculentus*), endeavour prawns (*Metapenaeus endeavouri*) and coral prawns (*Metapenaeopsis* spp.). Most prawn fishing occurs in inshore areas.

The opening and closing of the major fishing areas within the NBPMF was initially associated with sampling to determine an appropriate size for the banana prawns to be targeted by the fishery. However, there is now a mandatory opening of the NBPMF in May. This delayed opening was facilitated in order to allow prawns to increase in size and also to allow vessels to fish in adjoining fisheries. The annual catch of banana prawns in the NBPMF is heavily influenced by environmental conditions.

Management controls for the NBPMF are based on limited entry, seasonal and area closures, gear controls and restrictions on boat size. In 2002, by-catch reduction devices were introduced into the fishery with vessels required to have half their gear fitted with grids. The Vessel Monitoring System was also introduced into the fishery in 2002 to monitor compliance with temporal and spatial closures within the NBPMF.

The seasonal total landing of fish by-product in this fishery is low (Fig. 1.2.3). The dominant component of the landed by-product is shark. The total recorded catch of finfish by-product in 2002 was less than 1.5 tonnes (Fig. 1.2.3).

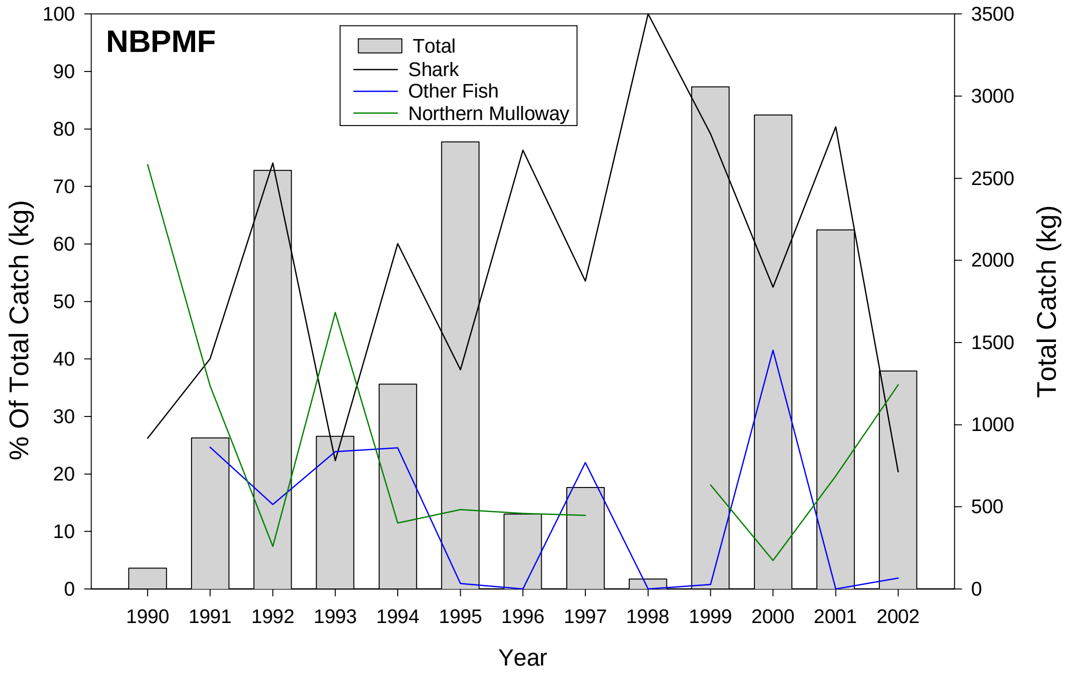

Figure 1.2.3 The total catch of fish by-product in the NBPMF and the percentage composition of the major species.

1.2.4 Kimberley Prawn Fishery

There are 133 vessels licensed to fish for prawns in the Kimberley Prawn Managed Fishery (KPMF), using otter trawls with a 50 mm mesh size. The KPMF targets banana prawns (*Penaeus merguiensis*) and operates off the northern Kimberley coast between Koolan Island and Cape Londonderry and abuts the western boundary of the Commonwealth Northern Prawn Fishery. A significant number of vessels hold authorisations to operate in both fisheries, and opening and closing dates are aligned to prevent large shifts of fishing effort into the Kimberley fishery.

The management controls for the KPMF are based on limited entry, seasonal closures, gear controls and restrictions on boat replacements. The VMS was introduced into the fishery in 2001. By-catch reduction devices were required to be installed by licensees in the KPMF in 2002.

The landing of fish by-product in this fishery is in general negligible, although a relatively large amount of fish was landed in 1993 (Fig. 1.2.4).

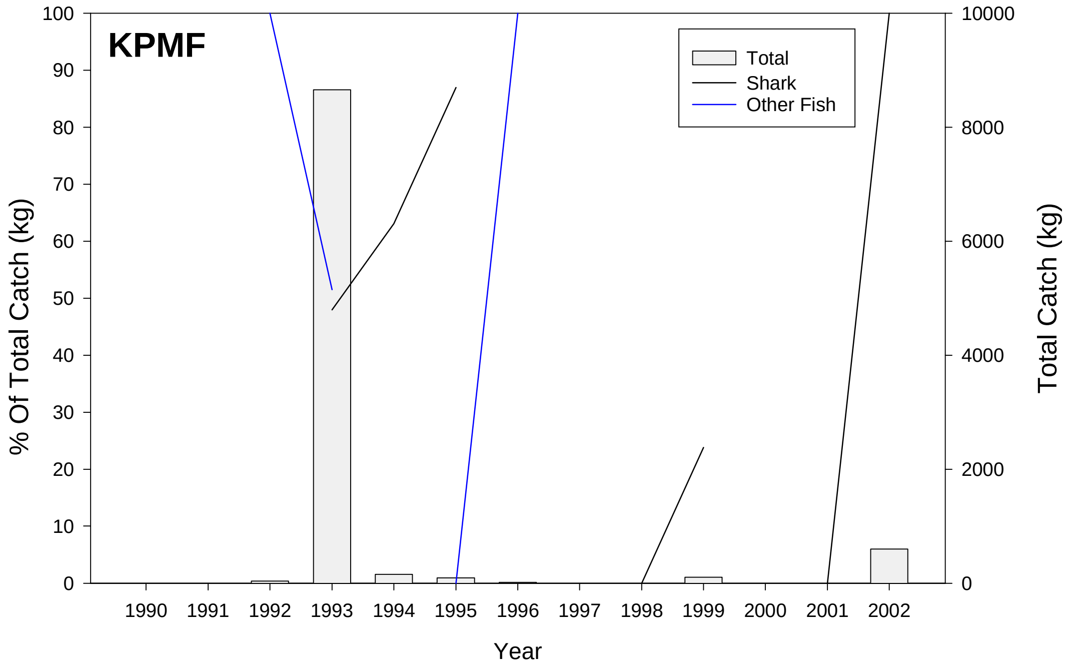

Figure 1.2.4 The total catch of fish by-product in the KPMF and the percentage composition of the major species.

1.3 Spatial distribution of the catch of key nearshore species

The spatial distribution of the commercial catch of significant nearshore species from both reef associated habitats and open beach/estuary habitats were examined. The blue-spot emperor (*Lethrinus hutchinsi*) is common in nearshore reef habitats in the Pilbara and is commonly caught and discarded by commercial line fishers. The spatial distribution of the commercial catch of this species is included here as surveys of nearshore reefs with fish traps revealed it is a dominant part of the fish assemblage. This species is a major component of the catch of the Pilbara Fish Trawl Fishery. The spatial distribution of the commercial catch of blue-spot emperor is concentrated across the continental shelf from 115°E to 120°E (Fig. 1.3.1). There is little commercial catch of blue-spot emperor in the Kimberley region.

The Chinaman fish (*Symphorus nematophorus*) is an important recreational and commercial species. The commercial catch of Chinaman fish is widespread in the Pilbara region close to nearshore islands and reefs but is much lower and more spatially limited in the Kimberley region (Fig. 1.3.2). Due to the difficulties of identifying a number of cod species (Serranidae) these species are often pooled by fishers on their catch returns. Consequently it is not possible to examine the spatial distribution of the catch of important nearshore cod species in isolation. Therefore, we have examined the distribution of the catch of all serranid species across north-western Australia (Fig. 1.3.3). The catch of cods is concentrated in the nearshore area of the Pilbara coast and in offshore areas in the northern Kimberley region. Cod are an important component of the trap, line and trawl fisheries across north-western Australia and their catch is widely distributed.

The bar-cheeked coral trout (*Plectropomus maculatus*) is an important component of the catch of commercial fishers due to its value and is considered a prized angling species by recreational fishers. The commercial catch is concentrated in the Pilbara region, but low levels of catch are widespread across north-western Australia (Fig. 1.3.4). Similarly, the commercial catch of mangrove jack (*Lutjanus argentimaculatus*) is concentrated in the

Pilbara region, but low levels of catch are widespread across north-western Australia (Fig. 1.3.5). Mangrove jack are one of the major target species of recreational anglers in nearshore estuaries and creeks in the region.

The commercial catch of barramundi (*Lates calcarifer*) is concentrated in the Kimberley region with low levels of catch reported in the Pilbara (Fig. 1.3.6). The spatial distribution of the commercial catch of barramundi is directly related to the size and number of rivers and creeks in the Kimberley region compared to the Pilbara. In contrast, the catch of bluenose threadfin salmon (*Eleutheronema tetradactylum*) is higher along the Pilbara coast than in the Kimberley region (Fig. 1.3.7). The catch of the giant threadfin salmon (*Polydactylus macrochir*) is widespread in both the eastern Pilbara and Kimberley region, with the highest catches reported along the Eighty Mile Beach area (Fig. 1.3.8). The commercial catch of northern mulloway or black jewfish (*Protonibea diacanthus*) is reported only from Roebuck Bay and King Sound (Fig. 1.3.9).

The commercial catch of mullet (Fig. 1.3.10) and whiting (Fig. 1.3.11) are generally restricted to the Pilbara coast, with catches highest in the region of Exmouth Gulf.

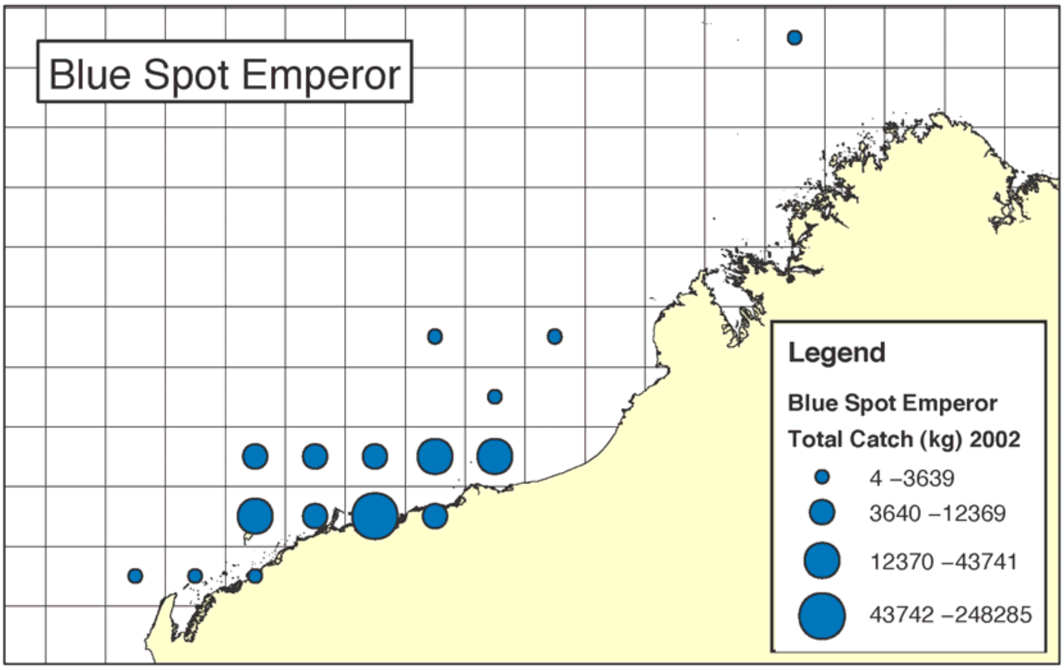

Figure 1.3.1 Spatial distribution of the commercial catches of blue-spot emperor (*Lethrinus hutchinsi*) across north-western Australia in 2002.

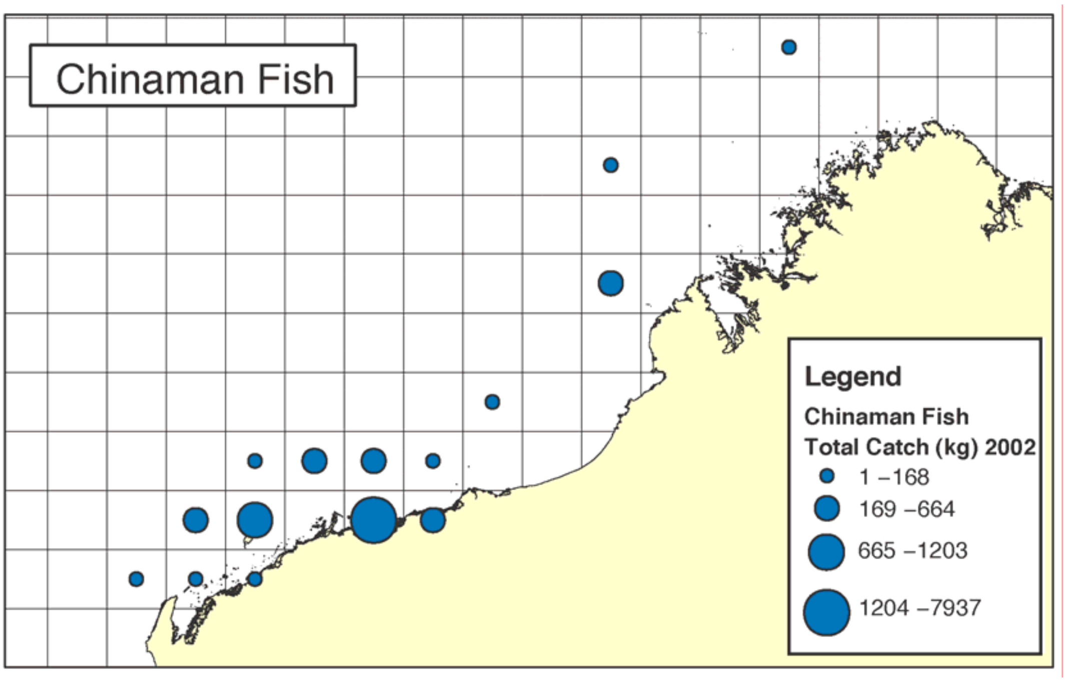

Figure 1.3.2 Spatial distribution of the commercial catches of Chinaman fish (*Symphorus nematophorus*) across north-western Australia in 2002.

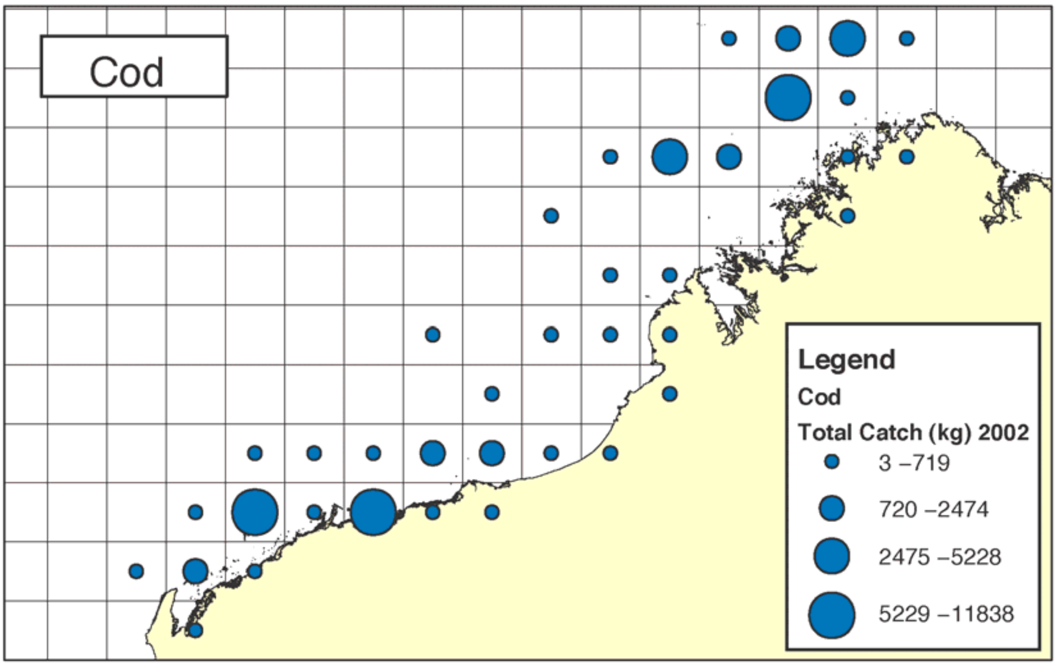

Figure 1.3.3 Spatial distribution of the commercial catches of cod (Serranidae) across north-western Australia in 2002.

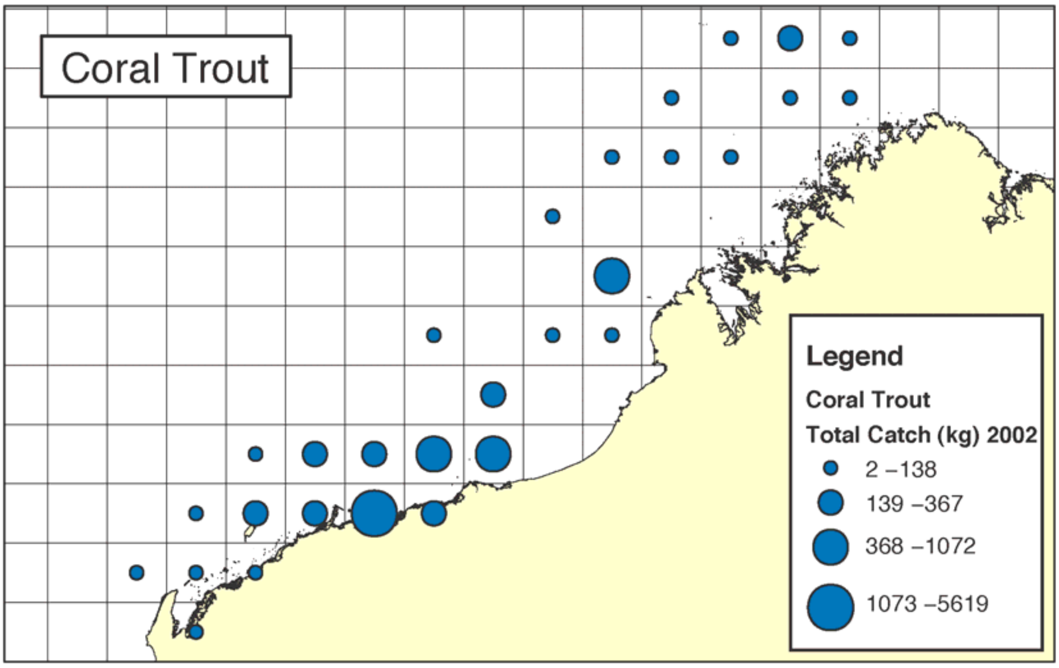

Figure 1.3.4 Spatial distribution of the commercial catches of bar cheeked coral trout (*Plectropomus maculatus*) across north-western Australia in 2002.

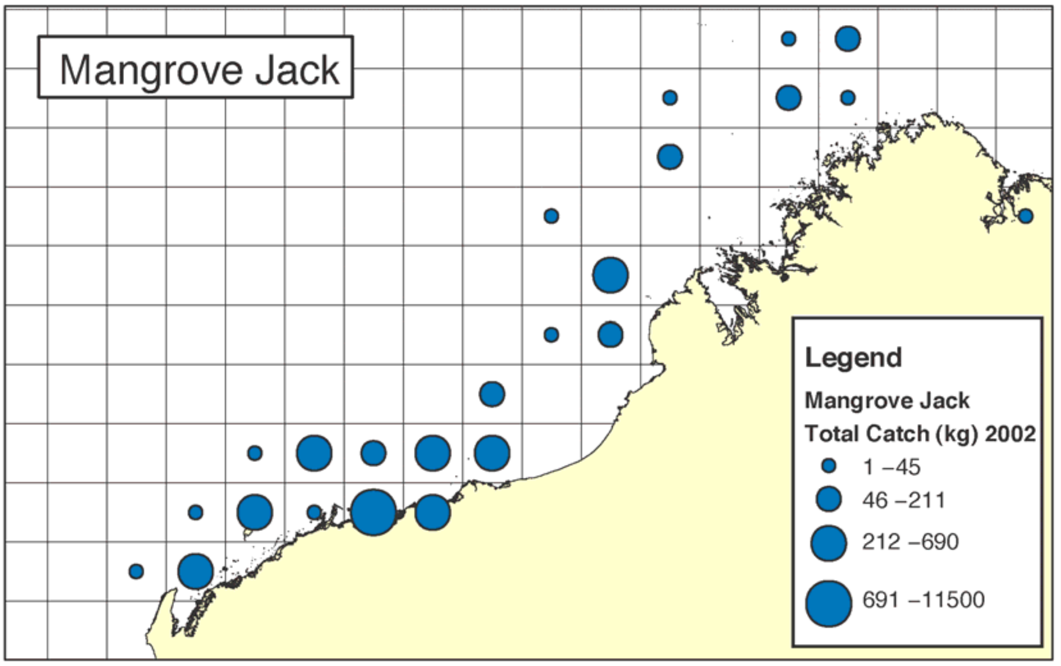

Figure 1.3.5 Spatial distribution of the commercial catches of mangrove jack (*Lutjanus argentimaculatus*) across north-western Australia in 2002.

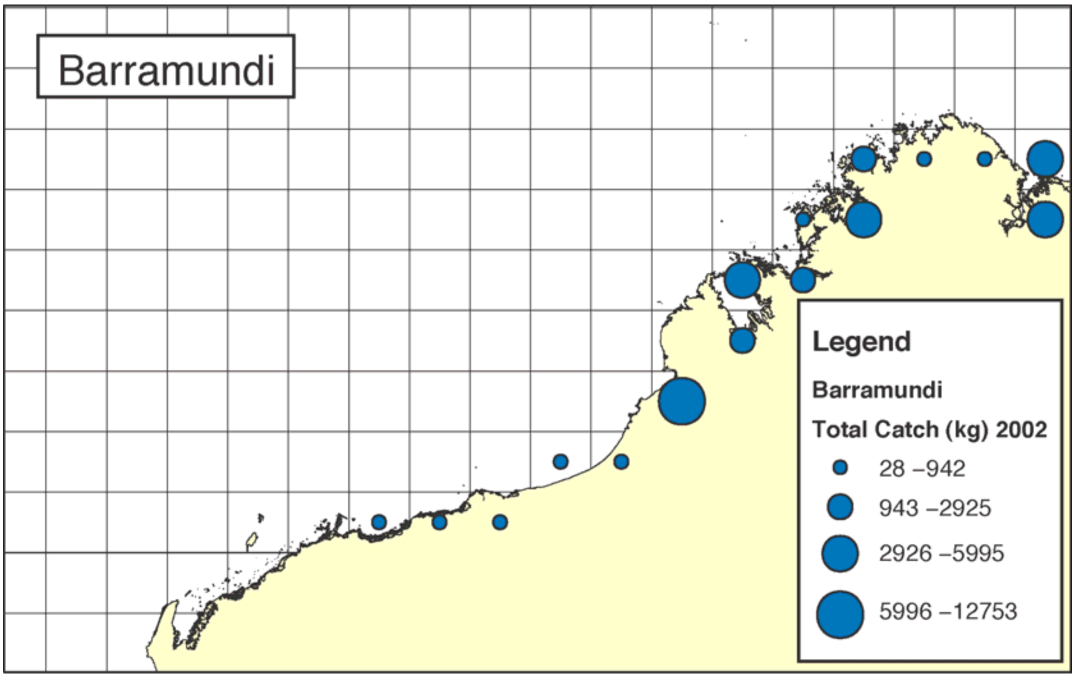

Figure 1.3.6 Spatial distribution of the commercial catches of barramundi (*Lates calcarifer*) across north-western Australia in 2002.

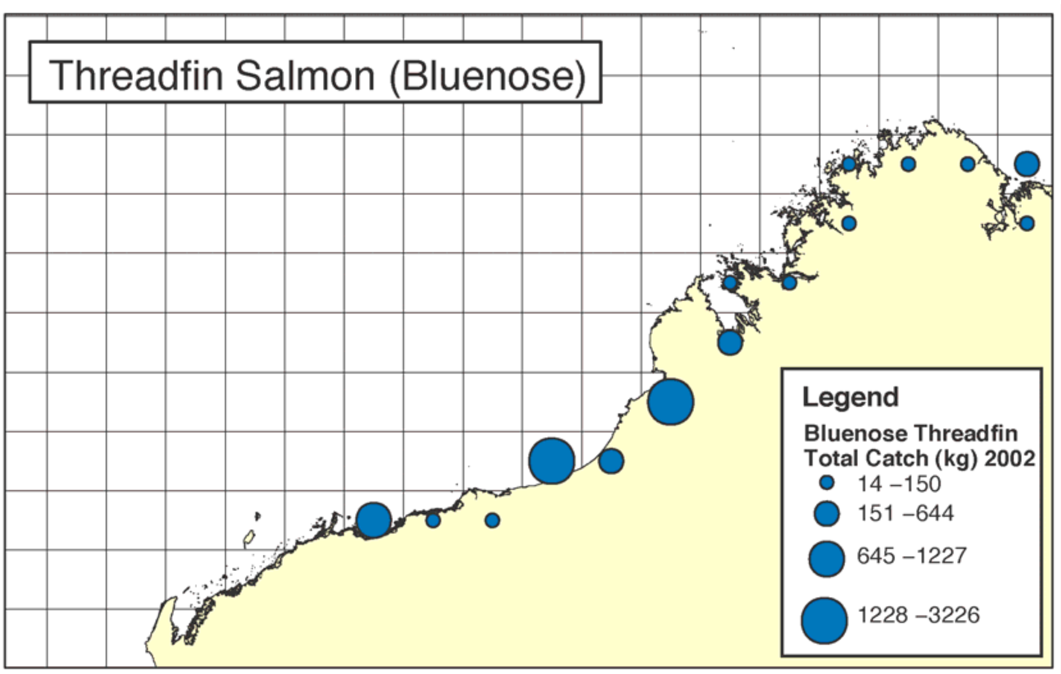

Figure 1.3.7 Spatial distribution of the commercial catches of bluenose threadfin salmon (*Eleutheronema tetradactylum*) across north-western Australia in 2002.

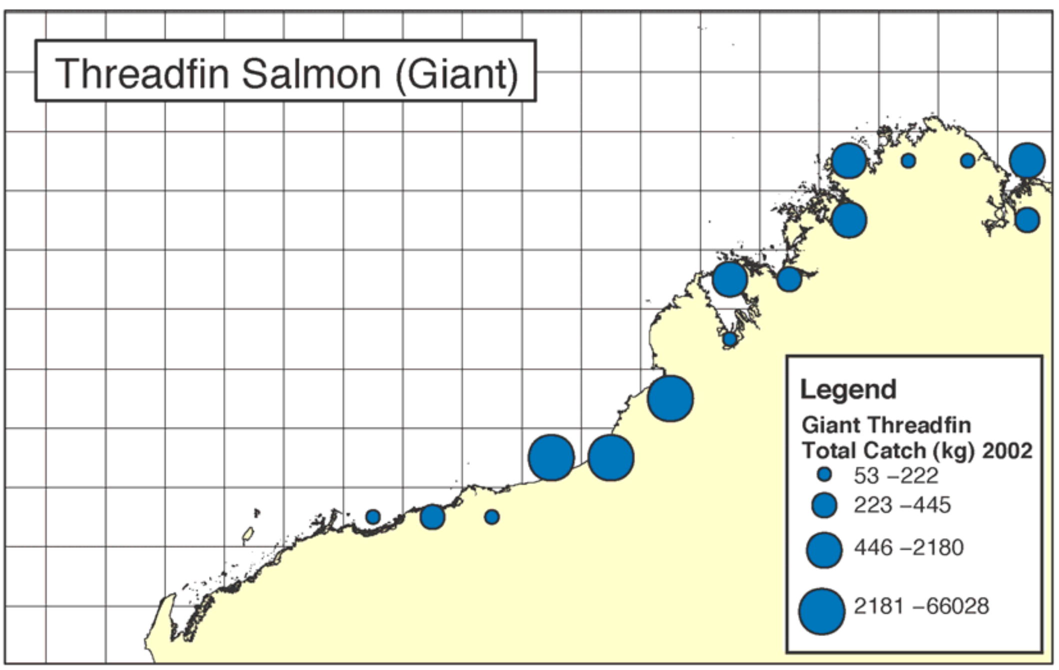

Figure 1.3.8 Spatial distribution of the commercial catches of giant threadfin salmon (*Polydactylus macrochir*) across north-western Australia in 2002.

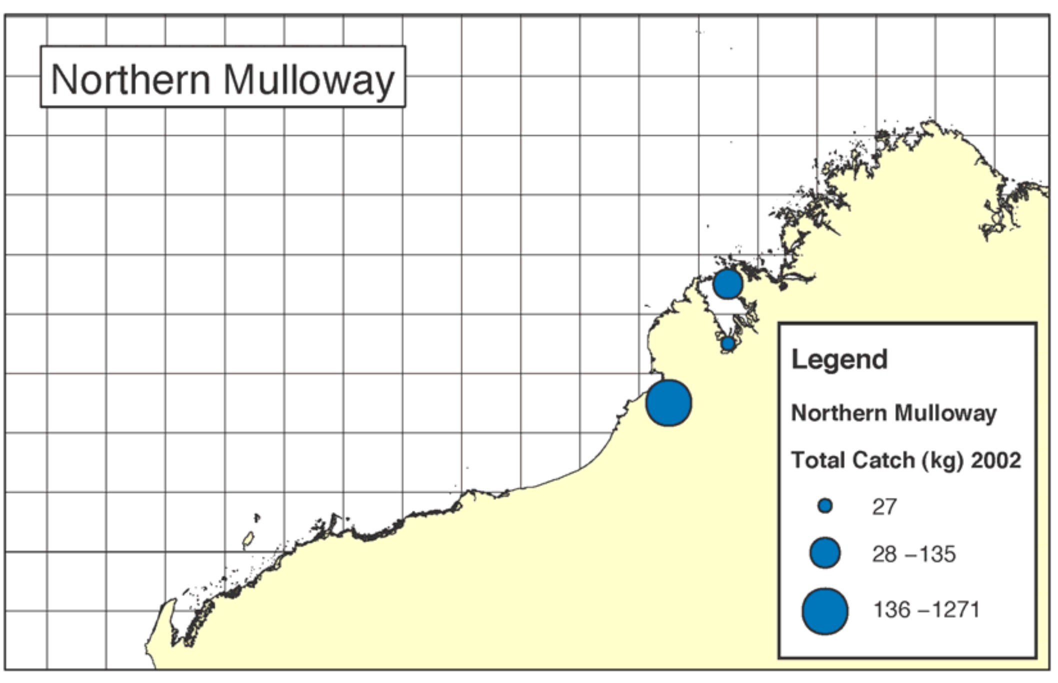

Figure 1.3.9 Spatial distribution of the commercial catches of northern mulloway or black jewfish (*Protonibea diacanthus*) across north-western Australia in 2002.

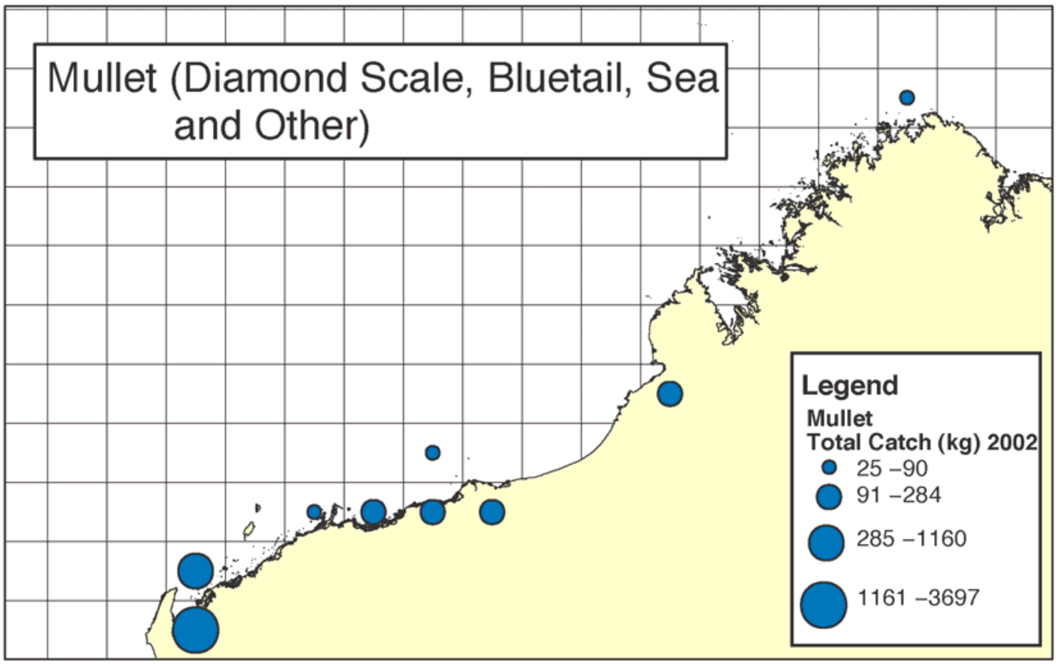

Figure 1.3.10 Spatial distribution of the commercial catches of mullets (Mugilidae) across north-western Australia in 2002.

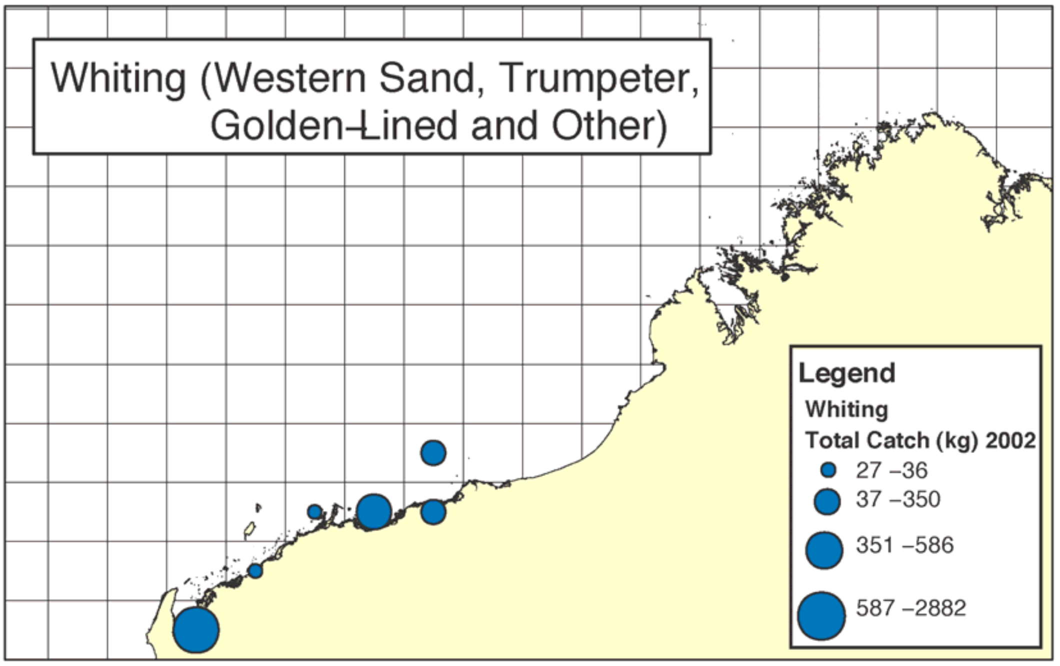

Figure 1.3.11 Spatial distribution of the commercial catches of whiting (Sillaginidae) across north-western Australia in 2002.

1.4 Recreational catch and effort in the Pilbara and West Kimberley region

1.4.1 Introduction

The Department of Fisheries (Western Australia) conducts creel surveys of recreational fishing activities in each of the states bioregions on a semi-rotational basis. The objectives of these creel surveys are to record and monitor changes in recreational catch and fishing effort. It is anticipated that each of the bioregions will be surveyed approximately every five to six years on an ongoing basis.

Information on the recreational catch and fishing effort for each bioregion of Western Australia is used to develop management strategies. These data assist in the assessment of the status of stocks, and provide fishing quality indicators such as catch rates, size composition, and the variety of species caught. This information will also be used in the development of a management plan for each bioregion and will form the basis for future management decisions to improve or maintain the quality and diversity of recreational fishing experiences, and to achieve equity between different users of this resource.

The Pilbara/Kimberley bioregion encompasses the area from 114°50'E, a line west of the Ashburton River near Onslow to the WA/NT border at 129°E and includes approximately 2,000 kilometres of coastline. The bioregion includes many remote and isolated recreational fishing locations. Baharthah and Sumner (2002) estimated via a telephone survey that the recreational fishing participation rate for marine waters between Onslow and the WA/NT border was approximately 12% of Western Australia's recreational anglers or in excess of 70,000 anglers per year generating over 1 million fishing days. However, due to logistical constraints the creel survey of the Pilbara/Kimberley bioregion only extended from Onslow to Broome, representing the Pilbara and West Kimberley areas (Williamson *et al*. in prep.). The objective of this part of the project is to provide a summary of the recreational catch and fishing effort estimates for the Onslow to Broome section of the Pilbara/Kimberley bioregion of Western Australia that were derived by Williamson *et al*. (in prep.). The estimated catch for all species recorded is presented together with information on each of the individual species or species groups targeted.

1.4.2 Methods

The survey design and methodology including spatial and temporal stratification are described in detail in Williamson *et al.* (in prep.). Boats launched at public boat ramps were surveyed using the bus route method, whereas boats launched from beaches and shore-based fishing activities were assessed using a roving creel survey. The methods for estimating the total recreational catch and effort and their associated confidence intervals are also described in detail in Williamson *et al*. (in prep.).

1.4.3 Results

The total annual recreational fishing effort was estimated to be 190,000 fisher days in the Pilbara and West Kimberley region. The total annual recreational catch of finfish was estimated to be ~320 tonnes (range 270-370 tonnes). The estimated total recreational catch of finfish varied among the sampling districts and the fishing platforms surveyed (either boat or shore based). The total recreational catch estimates from boats among districts varied from 3-73 tonnes. The total recreational catch estimates of shore based fishers ranged from 4-53 tonnes and were concentrated in the area from Karratha to Broome (Table 1.4.1). The total recreational catch estimates from boats launched over beaches ranged from 8-22 tonnes and was also concentrated in the area from Karratha to Broome (Table 1.4.1). The region from Karratha to Broome has more access points along the coast that the region from Onslow to Karratha.

The total recreational fishing effort (in fisher days) also varied among the sampling districts and the fishing platforms surveyed (Figs. 1.4.1-1.4.4). Dampier and Broome were the key centres where recreational catch and effort was concentrated (Table 1.4.1, Fig. 1.4.1-1.4.4). The total recreational fishing effort expended in each of these locations was in excess of 30,000 fisher days over the 12-month survey period (Fig. 1.4.1 and 1.4.4). In addition, the level of recreational fishing effort was substantially higher in the dry season than in the wet season at all locations and across all fishing methods surveyed (Figs. 1.4.1-1.4.3).

The estimated total recreational catches by numbers for the major species of finfish caught by boats launched from public boat ramps in each district from the Pilbara and West Kimberley region are shown in Table 1.4.2. In addition, the total recreational catch by weight for the major species of finfish for each of these districts are shown in Table 1.4.3.

The estimated total recreational catches by numbers for the major species of finfish caught by shore based fishers in each of the patrol areas from Onslow to Broome are shown in Table 1.4.4. In addition, the total recreational catch by weight for the major species of finfish caught by shore based fishers in each of the patrol areas are shown in Table 1.4.5. The estimated total recreational catches for the major species of finfish caught from boats launched over beaches in each of the patrol areas from Onslow to Broome are shown by numbers in Table 1.4.6 and by weight in Table 1.4.7.

The finfish species landed by shore-based fishers tend to be associated with open beaches and mangrove-creek systems (Table 1.4.4-1.4.5). In contrast, the finfish species landed by boat-based fishers tend to be associated with reefs as well as mangrove-creek systems. Overall, the top 20 species landed by recreational fishers in the Pilbara and West Kimberley region were stripey seaperch (*Lutjanus carponotatus*), blue-lined emperor (*Lethrinus laticaudis*), spangled emperor (*Lethrinus nebulosus*), spotted mackerel (*Scomberomorus munroi*), golden trevally (*Gnathanodon speciosus*), mangrove jack (*Lutjanus argentimaculatus*), Spanish mackerel (*Scomberomorus commerson*), Moses perch (*Lutjanus russelli*), blackspot tuskfish (*Choerodon shoenleinii*), estuary cods (*Epinephelus coioides* and *E. malabaricus*), giant threadfin salmon (*Polydactylus macrochir*), western yellowfin bream (*Acanthopagrus latus*), school mackerel (*Scomberomorus queenslandicus*), spotted javelinfish (*Pomadasys kaakan*), big-eye trevally (*Caranx sexfasciatus*), coral trout (*Plectropomus maculatus*), giant trevally (*Caranx ignobilis*), Chinaman fish (*Symphorus nematophorus*), blue-spot emperor (*Lethrinus hutchinsi*) and northern mulloway or black jewfish (*Protonibea diacanthus*).

Table 1.4.1 Estimated total recreational catch (tonnes) of finfish in each district in the survey area from Onlsow to Broome.

Boats launched from public ramps	
District	Estimated Catch (tonnes)
Onslow	10
Dampier	73
Karratha	7
Point Samson	14
Port Hedland	23
Cape Keraudren	3
Broome	62
Shore Fishers	
District	Estimated Catch (tonnes)
Onslow to Karratha	4
Karratha to Broome	53
Boats launched over beaches	
District	Estimated Catch (tonnes)
Onslow to Karratha	8
Karratha to Broome	22

Table 1.4.2 Estimated total recreational catch by numbers for the major species of finfish caught by boats launched at public boat ramps in each district in the survey area from Onslow to Broome.

Onslow		
Rank	**Species**	**Number Kept**
1.	*Lutjanus carponotatus*	1,416
2.	*Lethrinus nebulosus*	894
3.	*Gnathanodon speciosus*	444
4.	*Lutjanus argentimaculatus*	335
5.	Carangidae (general)	320
6.	*Lethrinus laticaudis*	299
7.	*Epinephelus coioides/malabaricus*	299
8.	*Scomberomorus commerson*	197
9.	*Pristipomoides filamentosus*	184
10.	*Acanthopagrus latus*	151

Dampier		
Rank	**Species**	**Number Kept**
1.	*Scomberomorus munroi*	4,906
2.	*Lutjanus carponotatus*	3,308
3.	*Lethrinus laticaudis*	2,672
4.	*Plectropomus maculatus*	2,297
5.	*Lethrinus nebulosus*	2,147
6.	*Scomberomorus commerson*	2,024
7.	*Gnathanodon speciosus*	1,978
8.	*Choerodon schoenleinii*	1,864
9.	*Lutjanus argentimaculatus*	1,128
10.	*Epinephelus coioides/malabaricus*	997

Karratha		
Rank	**Species**	**Number Kept**
1.	Polynemidae (general)	1,073
2.	*Lethrinus laticaudis*	944
3.	*Lutjanus argentimaculatus*	826
4.	*Acanthopagrus palmaris*	447
5.	*Epinephelus coioides/malabaricus*	422
6.	*Lates calcarifer*	298
7.	*Platycephalus endrachtensis*	236
8.	*Lethrinus hutchinsi*	230
9.	*Symphorus nematophorus*	188
10.	*Acanthopagrus latus*	151

Table 1.4.2 continued.

Point Samson		
Rank	**Species**	**Number Kept**
1.	*Lethrinus laticaudis*	1,484
2.	*Lethrinus nebulosus*	1,180
3.	*Lutjanus carponotatus*	669
4.	*Scomberomorus munroi*	664
5.	*Lutjanus argentimaculatus*	546
6.	*Lutjanus sebae*	355
7.	*Symphorus nematophorus*	311
8.	*Lethrinus miniatus*	307
9.	*Epinephelus coioides/malabaricus*	304
10.	*Gnathanodon speciosus*	220

Port Hedland		
Rank	**Species**	**Number Kept**
1.	*Lethrinus laticaudis*	3,446
2.	*Lutjanus carponotatus*	1,497
3.	*Lethrinus nebulosus*	784
4.	*Scomberomorus queenslandicus*	755
5.	*Gnathanodon speciosus*	637
6.	*Acanthopagrus latus*	564
7.	*Scomberomorus munroi*	525
8.	*Lutjanus argentimaculatus*	478
9.	*Carangoides gymnostethus*	473
10.	Polynemidae (general)	462

Cape Keraudren		
Rank	**Species**	**Number Kept**
1.	*Lethrinus laticaudis*	547
2.	*Lutjanus argentimaculatus*	327
3.	*Lutjanus carponotatus*	326
4.	*Acanthopagrus palmaris*	107
5.	*Epinephelus coioides/malabaricus*	103
6.	*Lethrinus nebulosus*	98
7.	*Acanthopagrus latus*	89
8.	*Lutjanus russelli*	87
9.	*Symphorus nematophorus*	81
10.	*Pomadasys kaakan*	81

Table 1.4.2 continued.

Broome		
Rank	**Species**	**Number Kept**
1.	*Lutjanus carponotatus*	10,435
2.	*Lethrinus laticaudis*	5,423
3.	Polynemidae (general)	2,749
4.	*Lutjanus russelli*	2,561
5.	*Caranx sexfasciatus*	1,893
6.	*Lethrinus nebulosus*	1,780
7.	*Pomadasys kaakan*	1,654
8.	*Gnathanodon speciosus*	1,329
9.	*Arius thalassinus*	1,301
10.	Carangidae (general)	1,208

Table 1.4.3 Estimated total recreational catch by weight for the major species of finfish caught by boats launched at public boat ramps in each district in the survey area from Onslow to Broome.

Onslow		
Rank	**Species**	**Weight (kg)**
1.	*Lethrinus nebulosus*	1,629
2.	*Gnathanodon speciosus*	1,403
3.	*Scomberomorus commerson*	1,362
4.	Carangidae (general)	1,041
5.	*Lutjanus carponotatus*	722
6.	*Epinephelus coioides/malabaricus*	688
7.	*Lethrinus laticaudis*	362
8.	*Plectropomus maculatus*	322
9.	*Lutjanus argentimaculatus*	230
10.	*Caranx ignobilis*	179
11.	*Lethrinus miniatus*	159
12.	*Scomberomorus munroi*	156

Dampier		
Rank	**Species**	**Weight (kg)**
1.	*Scomberomorus commerson*	13,969
2.	*Gnathanodon speciosus*	6,243
3.	*Plectropomus maculatus*	5,980
4.	*Scomberomorus munroi*	5,956
5.	*Choerodon schoenleinii*	4,958
6.	*Lethrinus nebulosus*	3,913
7.	*Lethrinus laticaudis*	3,236
8.	*Lutjanus sebae*	2,956
9.	*Symphorus nematophorus*	2,395
10.	*Epinephelus coioides/malabaricus*	2,296
11.	*Lutjanus carponotatus*	1,687
12.	*Carangoides fulvoguttatus*	1,550
13.	*Caranx ignobilis*	1,406
14.	*Lethrinus miniatus*	1,289
15.	*Scomberomorus queenslandicus*	988
16.	*Lutjanus argentimaculatus*	774

Table 1.4.3 continued.

Karratha		
Rank	**Species**	**Weight (kg)**
1.	Polynemidae (general)	1,264
2.	*Lethrinus laticaudis*	1,144
3.	*Epinephelus coioides/malabaricus*	972
4.	*Symphorus nematophorus*	876
5.	*Lutjanus argentimaculatus*	566
6.	*Choerodon schoenleinii*	238
7.	*Caranx ignobilis*	222
8.	*Gnathanodon speciosus*	207
9.	*Acanthopagrus palmaris*	201
10.	*Lutjanus sebae*	190
11.	*Plectropomus maculatus*	180
12.	*Lethrinus nebulosus*	138
13.	*Scomberomorus munroi*	130

Point Samson		
Rank	**Species**	**Weight (kg)**
1.	*Lethrinus nebulosus*	2,151
2.	*Lethrinus laticaudis*	1,797
3.	*Symphorus nematophorus*	1,445
4.	*Lutjanus sebae*	1,309
5.	*Scomberomorus commerson*	998
6.	*Scomberomorus munroi*	806
7.	*Epinephelus coioides/malabaricus*	700
8.	*Gnathanodon speciosus*	695
9.	*Plectropomus maculatus*	516
10.	*Lethrinus miniatus*	450
11.	*Choerodon schoenleinii*	448
12.	*Lutjanus argentimaculatus*	375
13.	*Lutjanus carponotatus*	341

Port Hedland		
Rank	**Species**	**Weight (kg)**
1.	*Lethrinus laticaudis*	4,173
2.	*Scomberomorus commerson*	2,540
3.	*Gnathanodon speciosus*	2,011
4.	*Lethrinus nebulosus*	1,429
5.	*Symphorus nematophorus*	1,200
6.	*Lutjanus sebae*	937
7.	*Epinephelus coioides/malabaricus*	922
8.	*Lutjanus carponotatus*	763
9.	*Scomberomorus queenslandicus*	750
10.	*Scomberomorus munroi*	637
11.	*Arius thalassinus*	573
12.	*Caranx ignobilis*	564
13.	Polynemidae (general)	544
14.	*Choerodon schoenleinii*	348

Table 1.4.3 continued.

Cape Keraudren		
Rank	**Species**	**Weight (kg)**
1.	*Lethrinus laticaudis*	663
2.	*Symphorus nematophorus*	376
3.	*Lutjanus argentimaculatus*	224
4.	*Lethrinus nebulosus*	179
5.	*Gnathanodon speciosus*	179
6.	*Lutjanus carponotatus*	166
7.	*Pomadasys kaakan*	88
8.	*Lutjanus russelli*	83
9.	*Epinephelus coioides/malabaricus*	65
10.	*Scomberomorus commerson*	54
11.	*Acanthopagrus palmaris*	48
12.	*Plectropomus maculatus*	46
13.	*Acanthopagrus latus*	40

Broome		
Rank	**Species**	**Weight (kg)**
1.	*Lethrinus laticaudis*	6,567
2.	*Lutjanus carponotatus*	5,322
3.	*Caranx ignobilis*	4,493
4.	*Gnathanodon speciosus*	4,196
5.	*Arius thalassinus*	4,173
6.	*Scomberomorus commerson*	4,045
7.	*Lethrinus nebulosus*	3,244
8.	Polynemidae (general)	3,238
9.	Carangidae (general)	2,886
10.	*Choerodon schoenleinii*	2,542
11.	*Lutjanus russelli*	2,446
12.	*Pomadasys kaakan*	1,811
13.	*Caranx sexfasciatus*	1,653

Table 1.4.4 Estimated total recreational catch by numbers for the major species of finfish caught by shore based fishers in each of the patrol areas from Onslow to Broome.

Onslow – Karratha Patrol		
Rank	**Species**	**Number Kept**
1.	*Acanthopagrus latus*	2,537
2.	Sillaginidae (general)	1,854
3.	*Acanthopagrus palmaris*	780
4.	*Johnius amblycephalus*	550
5.	*Choerodon schoenleinii*	307
6.	Polynemidae (general)	275

Karratha – Broome Patrol		
Rank	**Species**	**Number Kept**
1.	Mugilidae (general)	21,098
2.	Polynemidae (general)	7,836
3.	*Amniataba caudovittatus*	7,014
4.	Sillaginidae (general)	5,177
5.	Carangidae (general)	4,047
6.	*Acanthopagrus latus*	3,861
7.	Hemiramphidae (general)	2,026
8.	*Lethrinus miniatus*	1,847
9.	*Arius graeffei*	1,539
10.	*Pomadasys kaakan*	1,501

Table 1.4.5 Estimated total recreational catch by weight for the major species of finfish caught by shore based fishers in each of the patrol areas from Onslow to Broome.

Onslow – Karratha Patrol		
Rank	**Species**	**Weight (kg)**
1.	*Acanthopagrus latus*	1,129
2.	*Choerodon schoenleinii*	816
3.	*Acanthopagrus palmaris*	351
4.	Polynemidae (general)	324
5.	*Gnathanodon speciosus*	290
6.	Sillaginidae (general)	189
7.	*Arius graeffei*	132

Karratha – Broome Patrol		
Rank	**Species**	**Weight (kg)**
1.	Carangidae (general)	12,776
2.	Mugilidae (general)	12,427
3.	Polynemidae (general)	9,231
4.	*Choerodon schoenleinii*	3,102
5.	*Lethrinus miniatus*	2,704
6.	*Arius graeffei*	1,767
7.	*Acanthopagrus latus*	1,718
8.	*Epinephelus coioides/malabaricus*	1,661
9.	*Pomadasys kaakan*	1,643
10.	*Amniataba caudovittatus*	1,403
11.	Sillaginidae (general)	528
12.	Hemiramphidae (general)	182

Table 1.4.6 Estimated total recreational catch by numbers for the major species of finfish caught from boats launched over beaches in each of the patrol areas from Onslow to Broome.

Onslow – Karratha Patrol		
Rank	**Species**	**Number Kept**
1.	*Lethrinus laticaudis*	913
2.	*Choerodon schoenleinii*	767
3.	*Lutjanus argentimaculatus*	730
4.	Polynemidae (general)	730
5.	*Lutjanus carponotatus*	694

Karratha – Broome Patrol		
Rank	**Species**	**Number Kept**
1.	*Lethrinus laticaudis*	2,676
2.	*Choerodon schoenleinii*	2,248
3.	*Lutjanus argentimaculatus*	2,141
4.	Polynemidae (general)	2,141
5.	*Lutjanus carponotatus*	2,034

Table 1.4.7 Estimated total recreational catch by weight for the major species of finfish caught from boats launched over beaches in each of the patrol areas from Onslow to Broome.

Onslow – Karratha Patrol		
Rank	**Species**	**Weight (kg)**
1.	*Choerodon schoenleinii*	2,039
2.	*Lethrinus laticaudis*	1,105
3.	Polynemidae (general)	860
4.	*Lutjanus argentimaculatus*	501
5.	*Lutjanus carponotatus*	354

Karratha – Broome Patrol		
Rank	**Species**	**Weight (kg)**
1.	*Choerodon schoenleinii*	5,980
2.	*Lethrinus laticaudis*	3,241
3.	Polynemidae (general)	2,522
4.	*Lutjanus argentimaculatus*	1,469
5.	*Lutjanus carponotatus*	1,037

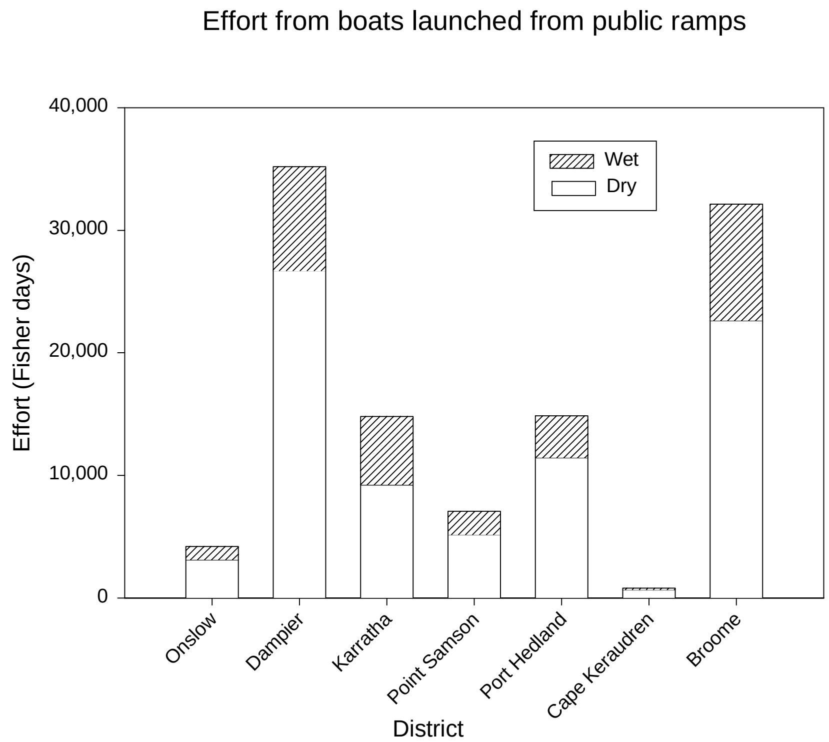

Figure 1.4.1 Estimated seasonal recreational fishing effort for boats launched from public boat ramps in each district in the survey area from Onslow to Broome (effort is in fisher days).

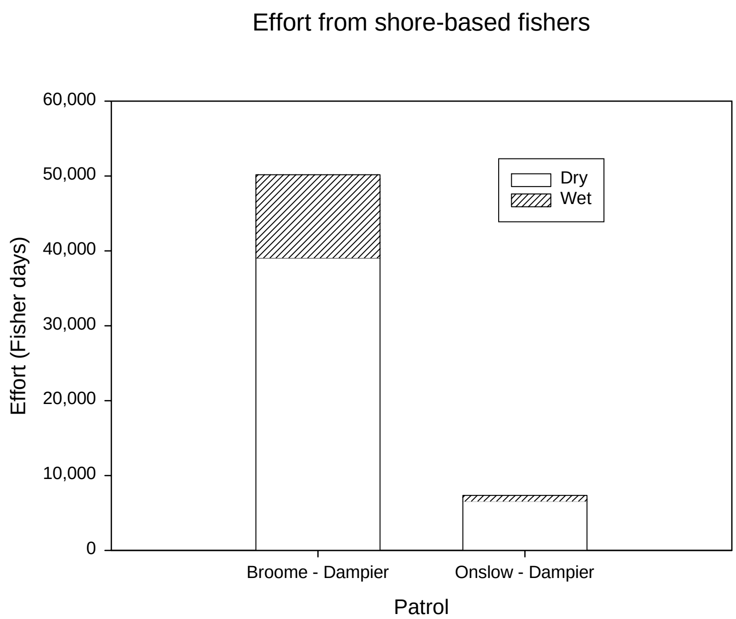

Figure 1.4.2 Estimated seasonal recreational fishing effort from shore based fishers in each of the patrol areas from Onslow to Broome (effort is in fisher days).

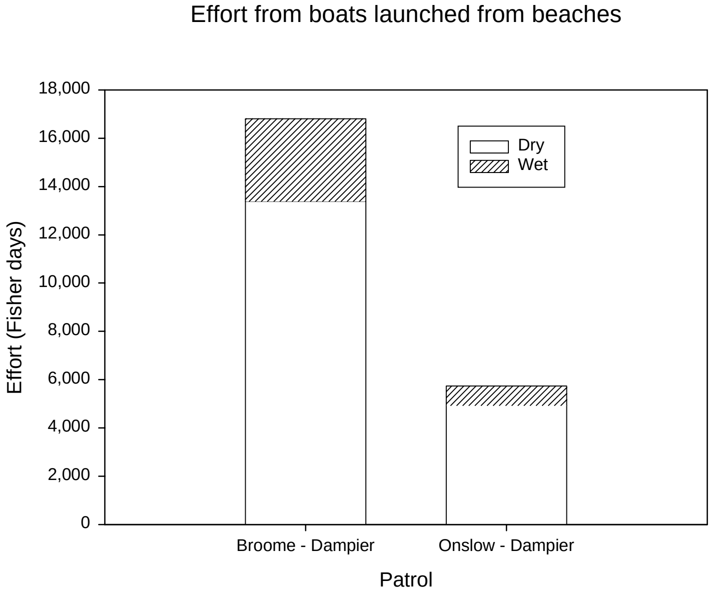

Figure 1.4.3 Estimated seasonal recreational fishing effort for boats launched over beaches in each of the patrol areas from Onslow to Broome (effort is in fisher days).

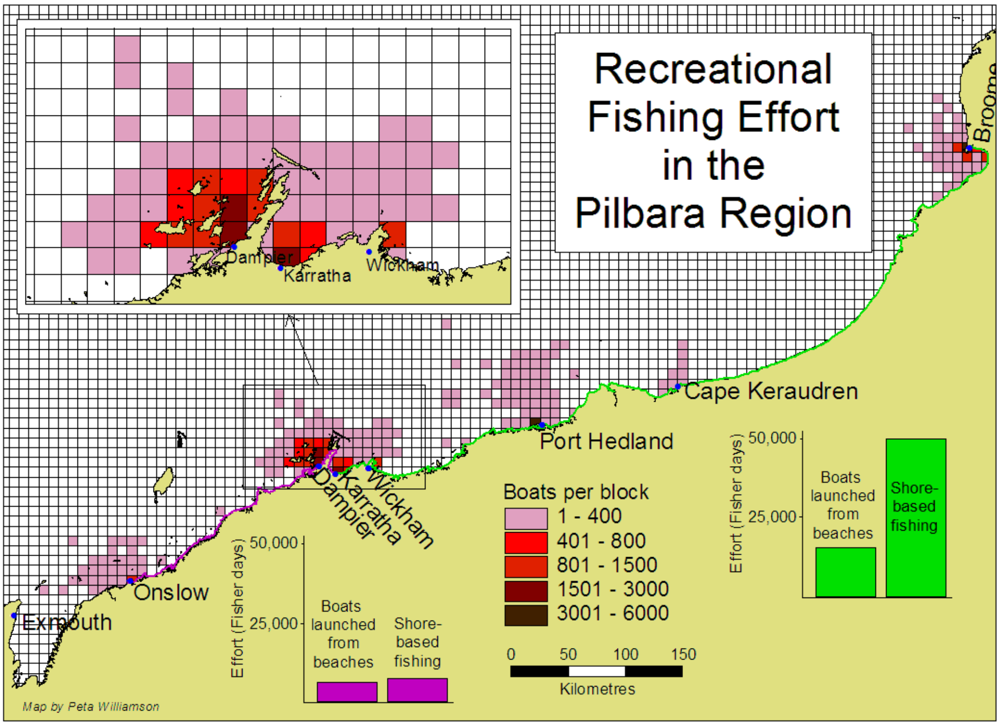

Figure 1.4.4 Spatial distribution of recreational fishing effort in the survey area from Onslow to Broome.

1.5 Charter vessel catch and effort in the Pilbara/Kimberley bioregion

In September 2001 the charter vessel industry in Western Australia was formally regulated. Since this time, statutory monthly reporting of the catch and effort by charter vessels has been required. The following data is a summary of the 2002 charter vessel catch from the Pilbara/Kimberley bioregion. This data is derived from the charter boat catch and effort database system.

There are a total of 111 licensed charter vessel operators for the Pilbara/Kimberley bioregion. In 2002 there were only 63 (57%) active operators in the Pilbara/Kimberley bioregion (an active licence is a licence that has been chartered in the last calendar year).

In 2002, a total of 3,628 tours were conducted in the Pilbara/Kimberley bioregion by charter vessels, of which, 2,954 (81%) were fishing tours. The average number of clients per tour in the Pilbara/Kimberley bioregion was 10.3 fishers per charter. The total amount of effort for extractive tours by operators in the Pilbara/Kimberley bioregion for 2002 was 18, 358 fisher days.

The species most commonly landed by charter vessel operators in the Pilbara/Kimberley bioregion are listed in Table 1.5.1. In terms of the numbers of fish kept, the most important species landed by charter vessels in the Pilbara/Kimberley bioregion are spangled emperor (*Lethrinus nebulosus*), stripey seaperch (*Lutjanus carponotatus*), golden snapper or fingermark (*Lutjanus johnii*), mangrove jack (*Lutjanus argentimaculatus*) and barramundi (*Lates calcarifer*).

Table 1.5.1. List of the top ten species landed by charter vessel operators in the Pilbara/Kimberley bioregion.

Species (Common Name)	Kept	Released	Estimated weight kept (tonnes) using average weight from Operators	Estimated weight kept (tonnes) using length /weight relationship
Lethrinus nebulosus (Spangled emperor)	2,510	451	7	6
Lutjanus carponotatus (Stripey seaperch)	1,773	4,613	1	1
Lutjanus johnii (Golden snapper or Fingermark)	1,632	2,722	4	#
Lutjanus argentimaculatus (Mangrove jack)	1,588	2,239	3	2
Lates calcarifer (Barramundi)	1,566	6,129	8	7
Lutjanus malabaricus (Scarlet seaperch)	1,485	589	4	3
Lethrinus laticaudis (Blue-lined emperor)	1,474	1,006	3	2
Scomberomorus commerson (Spanish mackerel)	1,281	570	14	13
Lutjanus sebae (Red emperor)	1,015	526	4	4
Symphorus nematophorus (Chinaman fish)	1,001	52	4	5

= no length/weight relationship available.

1.6 Discussion

The overall catch of the key species of commercial, recreational and charter fishing significance has been assessed. In the Kimberley region (from 120°E to the NT border) there are two commercial fisheries that overlap in area, but use different methods of capture. The inshore sector of the NDSF is a handline only fishery, while the KGBF utilises gillnets. Consequently, the habitats and areas fished within each fishery differ. The key species in the inshore sector of the NDSF are those associated with reef habitats and include blue-lined emperor, estuary cods and golden snapper. The catch from the inshore sector of the NDSF is very low. The key species in the KGBF are associated with rivers, creeks and open beaches and include the giant threadfin salmon, bluenose threadfin salmon and barramundi. The landed catch of the KGBF is significant for these species (a total of approximately 120 tonnes of finfish per year).

The estimated total commercial catch by weight from all fishing methods for the major species of finfish caught in the nearshore waters of the Pilbara and Kimberley bioregion in 2002 are listed in Table 1.6.1. The estimated total commercial catch from the nearshore waters of the Pilbara and Kimberley bioregion in 2002 was 589 tonnes. This is comparable to the recreational fishing catch that was estimated to be approximately 320 tonnes in the area from Onslow to Broome only.

The recreational catch from the West Kimberley region (including the districts of Cape Keraudren and Broome) encompasses species that are landed by both the handline and gillnet based commercial fisheries. In addition, the catch of charter vessels reflects similar target species to each of these commercial fisheries. Therefore, in the Kimberley region the key species of commercial, recreational and charter fisheries comprise both reef associated species and species that utilise mangrove creek and open beach systems. In terms of total fish landings from all sectors the dominant species are giant threadfin salmon, bluenose threadfin salmon, barramundi, blue-lined emperor, stripey seaperch, spangled emperor, golden snapper, mangrove jack, Moses perch, Chinaman fish and a number of trevally species.

It should be noted that at the time of the recreational survey there was a prohibition on recreational set netting and haul netting in the region that had been effective from September 1995 (Notice No. 691). However, in 2003 the regulations were changed and recreational fishers are now permitted to use haul nets. Thus the landed quantities of the giant threadfin salmon, bluenose threadfin salmon and barramundi by recreational fishers may increase in future years. The commercial catch of giant threadfin salmon has increased substantially since the prohibition on set netting by recreational fishers in 1995. The selectivity of gillnets and the proportion of the available stock harvested by commercial, recreational and indigenous fishers required further investigation. This information will be invaluable for future stock assessments of these species.

In the Pilbara region (from 114°E to 120°E) there are three commercial fisheries that essentially operate in distinct areas. The EGBSF is confined to Exmouth Gulf, while the gillnet operations are limited to the northern Pilbara, while the unregulated line fishery operates mostly in offshore waters. The target species of the EGBSF are not the key species landed by either recreational or charter boat fishers. In contrast, the key species in the catch of the commercial line and gillnet fishers are similar to those of the recreational and charter boat fishers. This was also the case in the Kimberley region, however, reef associated species dominate the landed catch from the Pilbara region. In terms of total fish landings from all sectors the dominant species in the Pilbara region are stripey seaperch, blue-lined emperor, spangled emperor, trevally, mangrove jack, Moses perch, blackspot tuskfish, cods, giant threadfin salmon and Chinaman fish.

Table 1.6.1 Estimated total commercial catch by weight from all methods for the major species of finfish caught in the nearshore waters of the Pilbara and Kimberley bioregion in 2002.

Common Name	Scientific Name	Catch (kg)	% Total Catch
Spanish mackerel	*Scomberomorus commerson*	312,257	52.99%
Giant threadfin salmon	*Polydactylus macrochir*	155,693	26.42%
Barramundi	*Lates calcarifer*	40,104	6.81%
Grey mackerel (broad barred)	*Scomberomorus semifasciatus*	12,086	2.05%
Blue threadfin salmon	*Eleutheronema tetradactylum*	8,929	1.52%
Mackerel (other)	*Scomberomorus sp.*	8,644	1.47%
Black jewfish (northern mulloway)	*Protonibea diacanthus*	7,129	1.21%
Emperor species	*Lethrinus sp.*	4,604	0.78%
Trevally (other)	Carangidae	4,109	0.70%
Sea mullet	*Mugil cephalus*	4,100	0.70%
Spangled emperor	*Lethrinus nebulosus*	3,988	0.68%
Cod	Serranidae	3,779	0.64%
Red emperor	*Lutjanus sebae*	2,746	0.47%
Rankin cod	*Epinephelus multinotatus*	2,318	0.39%
Western sand whiting	*Sillago analis* and *S. schomburgkii*	2,286	0.39%
Mullet (other)	Mugilidae	1,844	0.31%
Whiting (other)	*Sillago sp.*	1,795	0.30%
Sea catfish (golden cobbler)	*Arius thalassinus*	1,627	0.28%
Hardy head	Atherinidae	1,382	0.23%
Sea garfish	Hemiramphidae	1,216	0.21%
Other fish		845	0.14%
Cobia (black kingfish)	*Rachycentron canadus*	797	0.14%
Golden trevally	*Gnathanodon speciosus*	783	0.13%
Maroon sea perch	*Lutjanus lemniscatus*	954	0.13%
Queenfish	*Scomberoides sp.*	713	0.12%
Blue-spot emperor	*Lethrinus hutchinsi*	670	0.16%
Red snapper	*Lutjanus erythropterus*	562	0.10%
Tripletail	*Lobotes surinamensis*	532	0.09%
Western yellowfin bream	*Acanthopagrus latus*	464	0.08%
Wrasses (groper)	*Choerodon sp.*	449	0.08%
Mangrove jack	*Lutjanus argentimaculatus*	379	0.06%
Coral trout	*Plectropomus maculatus*	334	0.06%
Chinaman fish	*Symphorus nematophorus*	288	0.05%
Scarlet sea perch (Saddletail)	*Lutjanus malabaricus*	221	0.04%
Golden snapper (fingermark)	*Lutjanus johnii*	189	0.03%
Long nose emperor	*Lethrinus olivaceous*	185	0.03%
Wahoo	*Acanthocybium solandri*	182	0.03%
Moses perch	*Lutjanus russelli*	104	0.02%
Total (kg)		**589,287**	
Total Number Of Fishing Days		**3,676**	

2.0 Fish faunas of nearshore, shallow waters of the Pilbara and Kimberley coasts

Matthew B. Pember, Glen C. Young, Stephen J. Newman and Ian C. Potter

2.1 Introduction

Nearshore marine waters have long been recognised as important nursery habitats for various fish species in both temperate and tropical environments (*e.g.* Lasiak, 1981; Gibson *et al.*, 1993; Blaber, 2002). These waters provide an abundant source of food for juvenile fish and a less likelihood of predation by piscivorous fish than in waters further offshore. The juveniles of some species occupy mainly unvegetated areas, whereas those of others are found predominantly in either mangroves, seagrass or intertidal pools (*e.g.* Beckley, 1985; Robertson & Duke, 1990a,b; Laegdsgaard & Johnson, 1995; Travers & Potter, 2002; Griffiths, 2003).

The coastline of the Pilbara and Kimberley regions of north-western Australia is subjected to some of the largest tides in the world, *i.e.* >10m in tidal height in some areas during spring tides. The nearshore, shallow waters of this region receive very little fresh water input, apart from in some areas in the far eastern region of the Kimberley which contain large rivers. The extreme remoteness of the Pilbara and Kimberley coastline largely accounts for the fact that there has been only one study of the fish faunas of its nearshore waters. These were conducted in the Dampier region at 20°40' S, 116°40' E (Blaber *et al*., 1985; Blaber, 1986). The result of that study indicated that the juvenile fish in the nearshore, shallow waters of that region were subjected to heavy predation as a result of the waters being particularly clear, thus facilitating the detection of prey by predators. Since the juveniles of very few of the fish species found in water depths >20m on the North West Shelf were caught in nearshore waters, it was concluded that the latter waters did not constitute a significant nursery area for any of the commercially important deeper-water species of that region. The list of fish species provided by Blaber *et al*. (1985) for the Dampier region is complimented by those compiled by staff at the Western Australian Museum for the Kimberley region further to the north (Allen, 1992; Hutchins, 1995, 1996; Morrison & Hutchins, 1997).

The aim of this part of the project was to sample the fish faunas in nearshore waters of three locations, Cape Keraudren, Eighty Mile Beach and Port Smith, along the Pilbara and Kimberley coasts with the view to determining the following.

1. The fish species which (a) use bare sand, mangroves and/or intertidal pools as nursery areas and (b) spend the whole of their life-cycle in one or more of those habitats. This will focus on the species that are caught commercially and/or recreationally along the Pilbara and Kimberley coasts.
2. The ways in which the characteristics of the faunas in nearshore, shallow waters are influenced by latitudinal position, habitat type and season.

2.2 Materials and Methods

2.2.1 Sampling locations

The fish assemblages in nearshore, shallow waters at three locations along the Pilbara and Kimberley coasts of north-western Australia were sampled using seine and gill nets and the ichthyocide rotenone. This range of sampling methods enabled a number of different habitats to be sampled, including bare sand shorelines, mangroves and intertidal pools.

The southernmost location sampled, Cape Keraudren (19°57′ S, 119°46′ E), is situated *ca* 2000 km north of Perth and *ca* 150 km north east of Port Hedland (Fig. 2.2.1). The rocky headland at Cape Keraudren marks the southern boundary of Eighty Mile Beach. An area of

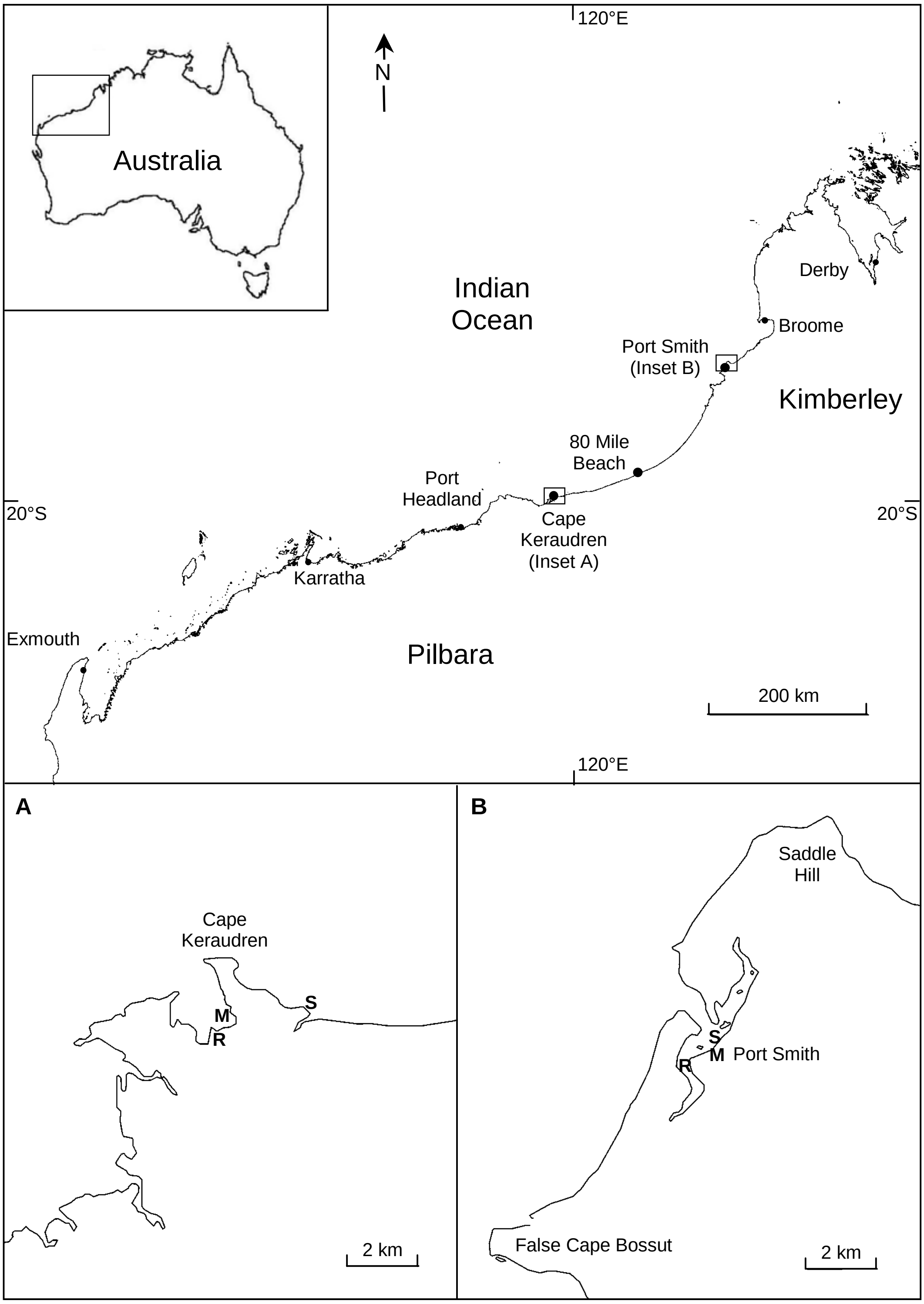

Figure 2.2.1 Map of north-western Australia showing the coastal locations (●) where the nearshore, shallow water fish communities were sampled. In insets A and B, M and S refer to sampling sites in mangroves and over bare sand and R to intertidal pools where rotenone was used.

ca 760 ha of relatively extensive mixed mangal environment with moderate creek development is located immediately to the south west of the cape (Fig. 2.2.1a). Although *Rhizophora stylosa* is the dominant species of mangrove in this area, other mangrove species are present, such as *Osbornia octodonata*, *Bruguiera exaristata*, *Aegiceras corniculatum*, *Ceriops tagal*, *Excoecaria agallocha*, *Avicennia marina* and *Aegialitis annulata* (Paling, 1996). On low tides, the water recedes from the mangroves leaving small to medium-sized tidal pools and exposing extensive intertidal platforms consisting of silt and rock. Similar examples of this type of headland and bay complex exist to the south west. To the north east of Cape Keraudren, the predominantly open beach coastline of Eighty Mile Beach stretches for approximately 220 km, broken occasionally by the presence of small tidal creeks or rock outcrops.

The second sampling location was located near the middle of Eighty Mile Beach (19°45′ S, 120°40′ E), close to Wallal Station, which is situated approximately 100 km to the north east of Cape Keraudren (Fig. 2.2.1). The section of Eighty Mile Beach sampled during this study had a north-west orientation, very slight gradient and contained no creeks or headlands. The slight gradient of the beach at the Eighty Mile Beach location, in combination with the large tidal range (>10m), results in very large areas of sand, silt and mud becoming exposed during low spring tide, with the distance between the high and low water marks often exceeding 2000 m. These extensive tidal flats contain a high diversity of invertebrates (Piersma *et al*., 1999) and sustain large numbers of migratory shorebirds, which has resulted in the area being recognized as a “Wetland of International Importance” following the guidelines of the 1974 Ramsar convention on wetlands

(http://www.ramsar.org/profiles_australia.htm).

The most northerly of the locations sampled was Port Smith (18°30′ S, 121°47′ E), which is located approximately 100 km south of Broome and *ca* 300 km north east of Cape Keraudren (Fig. 2.2.1). The area sampled at Port Smith consists of a large tidal lagoon formed by a breached dune ridge and is an example of the dominant type of bay found in this area. The lagoon, which runs along the landward side of the dune ridge, is fringed by an extensive (*ca* 670 ha) mangal development that is dominated by *Rhizophora stylosa* and *Avicennia marina*. On high spring tides, the fringing mangroves are inundated, however, as the tide recedes, the lagoon almost totally empties through a deep entrance channel connecting the lagoon to the ocean. On low spring tides, vast areas of sand and broken shell become exposed, with the only water remaining within the lagoon being found near the entrance channel and in intertidal pools of varying size.

2.2.2 Sampling regime and equipment

Cape Keraudren, Eighty Mile Beach and Port Smith were each sampled four times annually between December 2000 and November 2002 (Table 2.2.1). Thus, each location was sampled twice in each of the following “seasons”: early wet (November to January), late wet (February to April), early dry (May to July) and late dry (August to October) (Table 2.2.1).

The bare sand habitats at Cape Keraudren, Eighty Mile Beach and Port Smith, and the mangroves at the first and last of these locations, were sampled using a 60 m composite gill net. This gill net was 2 m high and consisted of six 10 m long monofilament panels, each with a different stretched mesh width of either 51, 76, 102, 127, 152 or 178 mm. For sampling bare sand substrates, the gill net was set parallel to the shoreline at low to mid tide and fixed in place using fencing pickets. The net was located in a position that would ensure that it would be covered by the incoming tide to a maximum depth of approximately 1.5-2.0 m for a period of approximately 3h (Plates 2.2.1, 2.2.2). When sampling mangroves, the gill net was extended parallel to the shoreline and attached to mangrove trunks in an area where it would likewise be covered to a maximum depth of 1.5-2.0 m for 3h at high tide (Plate 2.2.3).

Table 2.2.1 Regime for sampling at Cape Keraudren, 80 Mile Beach and Port Smith between December 2000 and November 2002. Samples were collected on each occasion using a 60 m composite monofilament gill net, a 60.5 m seine net and rotenone (*), except when either extreme cyclonic weather conditions existed (c) or, in the case of rotenone, sampling had not yet been initiated. Mean monthly values for rainfall and maximum air temperature in the study region are shown.

			Early Wet			Late Wet			Early Dry			Late Dry		
Method	Region	Habitat	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Gill net	Cape Keraudren	a) bare sand	*	c		c	*		*	*		*		*
		b) mangroves	*	c		c	*		*	*		*		*
	80 Mile Beach	a) bare sand	*	*		*	*		*	*		*		*
	Port Smith	a) bare sand	*	*		*	*		*	*		*		*
		b) mangroves	*	*		*	*		*	*		*		*
Seine Net	Cape Keraudren	a) bare sand	*	c		c	*		*	*		*		*
	80 Mile Beach	a) bare sand (north)	*	*		c	*		*	*		*		*
		b) bare sand (south)	*	*		*	*		*	*		*		*
	Port Smith	a) bare sand	*	*		*	*		*	*		*		*
		b) near mangroves	*	*		*	*		*	*		*		*
Rotenone	Cape Keraudren	intertidal pools	*	ns		*	ns		*	*		*		*
	Port Smith	intertidal pools	*	ns		*	ns		*	*		*		*

Mean maximum temperature (°C)

Mean rainfall (mm)

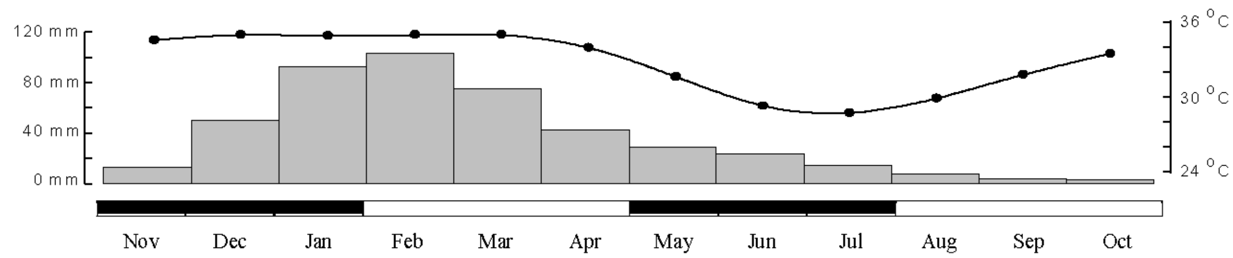

Plate 2.2.1 Bare sand habitat at Eighty Mile Beach during mid tide which was sampled with the staked composite gill net (pictured) and the 60 m seine net.

Plate 2.2.2 The bare sand habitat at Eighty Mile Beach close to high tide (during daylight) with the composite gill net partly submerged.

Plate 2.2.3 Photograph illustrating the composite gill net sampling method used in mangroves at both Port Smith and Cape Keraudren.

Gill netting was always conducted on spring tides and during darkness. On each sampling occasion, the gill nets were set four times in each habitat and on different nights.

The fish faunas over bare sand at Cape Keraudren, Eighty Mile Beach and Port Smith were also sampled using a 60.5 m seine net. Three seine net samples were collected during the day from a site just to the east of Cape Keraudren and from two sites (subsequently referred to as the northern and southern sites) at Eighty Mile Beach that were separated by approximately 2.5 km. Three replicate seine net samples were also obtained during the day from two sites over bare sand at Port Smith, one of which was located close to mangroves.

The 60.5 m seine net consisted of two 29 m long wings, each made of 25 mm mesh, and a 2.5 m bunt consisting of 9 mm mesh. This net fished to a depth of 2.5 m and swept an area of 583 m^2. The seine net was either laid in a semi-circle from the bow of a boat until fully extended or walked out from the beach and extended parallel to the shore and then rapidly dragged towards and on to the shore (Plate 2.2.4). Each site was sampled during the neap tidal phase, when the height of the tide was at or close to its maximum and water movement was least. Sampling was not undertaken at night because of the potential for shark and crocodile attacks.

The ichthyocide rotenone was used on six occasions to collect fish from three randomly-selected intertidal pools at both Cape Keraudren and Port Smith (Table 2.2.1). Powdered rotenone was first mixed with water to form a paste before being added to the pool in a concentration of *ca* 200 g of dry rotenone powder 10 m^{-2} of pool area. Every effort was made to ensure that neighbouring pools did not become contaminated with rotenone, which included constructing barriers to stop water moving out of the treated pool until it was diluted by the incoming tide. The pools sampled ranged from 10 to 20 m^2 in area and were up to 0.4 to 0.6 m in depth (Plates 2.2.5, 2.2.6). Ten minutes after rotenone treatment, the fish in the pools were sampled with a long-handled scoop net constructed of 5.0 mm mesh.

Plate 2.2.4 Photograph illustrating the method of deploying the 60.5 m seine net over sand in close proximity to a dense mangrove stand.

Plate 2.2.5 Typical intertidal pool sampled for fish using rotenone at Cape Keraudren.

Plate 2.2.6 Typical intertidal pool sampled for fish using rotenone at Port Smith.

Salinity and water temperature were recorded at each sampling site after that site had been sampled using the gill net, seine net or rotenone. Records were also kept of the time of sampling, the state of the tide, lunar period, weather conditions, substrate type and the dominant species of any mangroves present. When sampling the pools at Cape Keraudren and Port Smith with rotenone, records were also kept of the area, maximum and average depth, mangrove canopy cover and the percentage cover of any sand/silt, oysters, algae, mangrove pneumatophores or submerged snags.

The fish in each replicate sample obtained from each location were placed in an ice slurry and transported to a mobile laboratory where they were identified to species and measured to the nearest 1 mm (total length), except when the number of fish was large, in which case the lengths of fish in a randomly-selected subsample of 100 fish were measured. The individuals of each species in each replicate sample were counted and the total wet weight of all individuals of each species in each replicate sample was weighed to the nearest 0.1 g.

2.2.3 Statistical analysis

2.2.3.1 Gill net samples

The number and biomass of fish in each replicate gill net catch were converted to a catch rate, *i.e.* number of individuals caught $3h^{-1}$ and kg caught $3h^{-1}$, respectively. An examination of the relationship between the mean and standard deviation for the number of fish species, the number of fish caught $3h^{-1}$ and the biomass caught $3h^{-1}$ showed that, prior to subjection to analysis of variance (ANOVA), the first of these variables should be root transformed, while the last two should be $\log_{10}$ (n+1) transformed (see Clarke & Gorley (2001) for rationale for this approach).

The transformed values for the number of species and catch rates for the replicate gill net samples collected over bare sand habitats at each of the three locations on each sampling occasion were subjected to two-way ANOVA to determine whether these variables differed among sites and seasons. Three-way ANOVA was employed to determine whether these three variables differed among sites and seasons and between sand and mangrove habitats at Port Smith and Cape Keraurdren.

When ANOVA showed that the values for one or more of the main effects were significantly different and that there were no significant interactions between those effects, Scheffé's *a posteriori* test was used to determine which values where significantly different. Where there was a significant interaction between the main effects, the back-transformed mean values for these effects were plotted to elucidate the basis for the interaction.

The mean catch rates of each species in each gill net sample from over bare sand at Cape Keraudren, Eighty Mile Beach and Port Smith and in the mangroves at the first and third of these locations were ordinated using multi-dimensional scaling as described in the PRIMER v5 package (Clarke & Gorley, 2001). Prior to ordination, the densities were square root transformed and the Bray Curtis similarity measure used to produce the association matrix. One way, pair-wise and two-way crossed analysis of similarities (ANOSIM) were employed to test whether the species compositions in the different locations, seasons and habitats were significantly different (Clarke 1993). The R – statistic values in the ANOSIM tests were used to determine which variables were most important in contributing to any significant differences.

Since the above analyses showed that the compositions of the fish faunas at the three locations and in the two habitat types at Cape Keraudren and Port Smith were significantly different (see results), MDS ordination and ANOSIM tests were next employed to examine whether the compositions of the faunas in different habitat types and locations were significantly different. However, since there were only two points for each "season", the replicates for each habitat type and location on each sampling occasion were used for these ordinations and the associated ANOSIM tests. Where appropriate, ANOSIM was also employed to determine the degree to which the community composition was influenced by period. Separate 'wet' and 'dry' periods refer to a combination of early and late wet seasons and early and late dry seasons, respectively. Similarity percentages (SIMPER) were employed to determine, for each location, which species were most responsible for any dissimilarities in the species compositions of the different samples (Clarke 1993).

2.2.3.2 Seine net samples

The number and biomass of fish in each replicate seine net catch were converted to a density, *i.e.* number of individuals 500 m^{-2} and weight (kg) 500 m^{-2}, respectively. Following an examination of the relationship between the mean and standard deviation for the number of fish species and the density and biomass per unit area for each replicate sample, the values for the first variable were square root transformed, while the densities and biomass of fish per unit area were $\log_{10}$ (n+1) transformed.

The transformed values for the number of species, density and biomass of fish per unit area, derived from each replicate seine from each sampling site in each location on each sampling occasion, were subjected to two-way ANOVA to determine whether these variables differed among sites and seasons. The data were analysed and plotted following the same procedures as described earlier for the gill net data.

The mean densities of the fish species in the seine net samples obtained from each site on each sampling occasion were analysed using MDS ordination and associated tests in the same manner as described earlier for the gill net data. Note however that since, due mainly to severe weather, there was only one sample for both the early and late wet seasons at Cape Keraudren, it was necessary to use the replicates to investigate the influence of season in this location.

2.2.3.3 Rotenone sampling

The number and biomass of fish collected in samples using rotenone were converted to a density *i.e.* number of individuals 10 m^{-2} and weight per unit area, *i.e.* g 10 m^{-2}, respectively. The number of species collected in each pool satisfied the assumptions of ANOVA in an untransformed state. However, the density and biomass per unit area data were unable to be transformed in a manner that satisfied the assumptions of ANOVA and were therefore not subjected to univariate analysis.

The mean densities of the various fish species in the samples collected from intertidal pools using rotenone at Cape Keraudren and Port Smith were subjected to MDS ordination and associated tests in the same manner as described for the gill net data.

2.3 Results

2.3.1 Environmental variables

Mean monthly water temperatures in each location reached a maximum of between 31.8 ºC and 32.4 ºC in October, November or December and fell to a minimum of between 17.8ºC and 21.1ºC in June to August (Fig. 2.3.1). Mean monthly salinities at the sites in each of the three locations were always close to that of full strength seawater, *i.e.* 35 ‰.

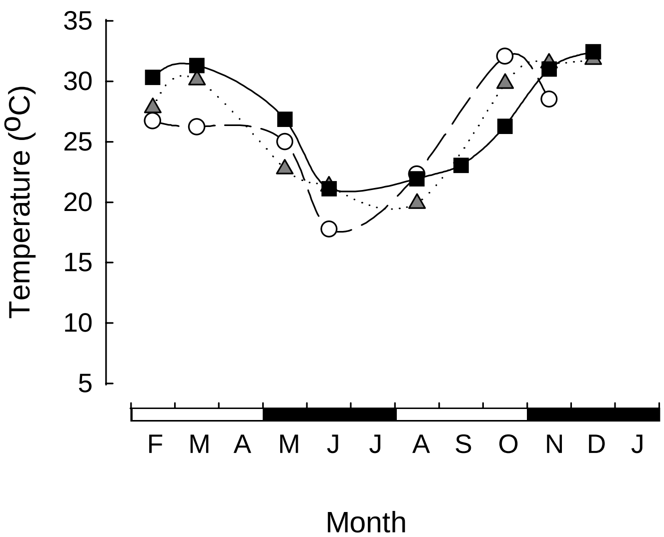

Figure 2.3.1 Mean water temperatures recorded when sampling Cape Keraudren (○), Eighty Mile Beach (▲) and Port Smith (■) between December 2000 and November 2002. On the x axis, open rectangles refer to the late dry and late wet seasons and black rectangles refer to the early wet and early dry seasons.

2.3.2 Gill net samples

2.3.2.1 Species composition

A total of 3209 fish, representing 75 species and 36 families and weighing 2680 kg, was collected using the 60 m long gill net over bare sand at Cape Keraudren, Eighty Mile Beach and Port Smith and from mangroves at Cape Keraudren and Port Smith (Table 2.3.1). Forty three of the 75 species were of commercial and recreational importance and contributed 90% to the total catch of fish. A further nine species were important only from a recreational perspective. The most abundant species (and their percentage contributions to the total catch) were all commercially and recreationally important and included the catfish *Arius proximus* (30.8%), followed by the two threadfin salmons, *Eleutheronema tetradactylum* (13.3%) and *Polydactylus macrochir* (12.5%) and two species of mullet, *Valamugil seheli* (9.2%) and *Liza macrolepis* (4.9%). Sixty three species contributed less than 1% and 35 of these contributed less than 0.1%.

The green sawfish *Pristis zijsron,* which attained lengths up to 400 cm and exceeded 33 kg in average weight, made the greatest contribution (21.4%) to the total biomass of fish (Table 2.3.1). The next ranked species in terms of biomass were *A. proximus* (13.2%), *E. tetradactylum* (12.5%) and *P. macrochir* (8.9%), while another sawfish, *Pristis clavata* (8.6%), ranked fifth. Species that are fished both commercially and recreationally accounted for 95% of the total biomass. Eighteen elasmobranch species, including the two *Pristis* species, collectively contributed 50.5% to the total weight of fish collected by gill netting. Although five of these species were amongst the top ten species in terms of biomass, they collectively contributed only 5.4% to the total number of fish and none ranked among the ten most abundant species (Table 2.3.1).

The number of species recorded over both bare sand and in mangroves at both Cape Keraudren and Port Smith ranged only from 34 to 39. However, the number of species was far less (24) over sand at Eighty Mile Beach where no vegetation was present in the vicinity (Table 2.3.1). Only 34 of the 69 species recorded at Cape Keraudren and Port Smith were found in both the bare sand and mangrove habitats of those locations. The species that were more common over bare sand than in mangroves included *E. tetradactylum, Sillago analis* and *Nematalosa come,* whereas *Plectorhinchus gibbosus, Lutjanus argentimaculatus, Selenotoca multifasciata* and *Monodactylus argenteus* were recorded in mangroves at both Cape Keraudren and Port Smith, but never over sand in those locations (Table 2.3.1). Although the samples from Eighty Mile Beach yielded the lowest number of species (24), they produced the greatest number of fish (1021), due, in particular, to a combination of large catches of the catfish *A. proximus* and *A. mastersi* and the threadfin salmons *E. tetradactylum* and *P. macrochir* (Table 2.3.1). The contribution of commercially and recreationally important species to the total number of fish caught at each location ranged from 79.9% in the mangroves at Port Smith to 95.6% in the mangroves at Cape Keraudren.

The weight of fish collected in samples from over bare sand at Cape Keraudren (1211.5 kg) was more than twice that recorded over bare sand at Eighty Mile Beach and Port Smith and in mangroves at Cape Keraudren and Port Smith (Table 2.3.1). The large biomass of fish caught over bare sand at Cape Keraudren, which contributed more than 45% to the total biomass recorded at all gill net sites, was due to the large number of elasmobranchs collected at this site, and in particular of sawfish (*P. zijsron* and *P. clavata*), which collectively weighed 772.6 kg (data not shown).

Table 2.3.1 Commercial (C) or recreational (R) importance, rank by abundance (R), number (N), percentage contribution (%) and length range of each fish species caught between December 2000 and November 2002 using the 60 m composite monofilament gill net over bare sand at Cape Keraudren, 80 Mile Beach, and Port Smith and in the mangroves at Cape Keraudren and Port Smith. The ranking by weight, total biomass (kg) and percentage contribution by biomass of each species caught in the study region is also given.

		Number			Numbers in each region					Biomass			
		Total			Cape Keraurdren		80 Mile Beach	Port Smith		Total			Length Range
Species	Fisheries	R	N	%	Sand	Mangroves	Sand	Sand	Mangroves	R	kg	%	(cm)
Arius proximus	C,R	1	989	30.8	23	342	356	180	88	2	354.44	13.2	15 - 46
Eleutheronema tetradactylum	C,R	2	426	13.3	262	26	118	16	4	3	333.98	12.5	18 - 69
Polydactylus macrochir	C,R	3	402	12.5	49	7	341	3	2	4	239.82	8.9	19 - 117
Valamugil seheli	C,R	4	295	9.2	41	58		131	65	9	71.70	2.7	19 - 65
Liza macrolepis	C,R	5	157	4.9	23	75		19	40	16	22.17	0.8	18 - 50
Scomberoides commersonnianus	C,R	6	133	4.1	8	117		8		11	51.64	1.9	21 - 52
Liza subviridis	C,R	7	104	3.2	25	19		39	21	22	13.72	0.5	13 - 33
Arius mastersi	C,R	8	80	2.5	11	9	60			10	55.55	2.1	20 - 55
Thryssa hamiltonii		9	72	2.2	15		54		3	33	5.27	0.2	19 - 23
Megalops cyprinoides	R	10	42	1.3		6		9	27	12	36.67	1.4	25 - 60
Carcharhinus cautus	C,R	11	35	1.1	8	19		5	3	6	202.53	7.6	49 - 124
Sillago analis	C,R	12	31	1.0	12	6		11	2	37	3.95	0.1	21 - 34
Nematalosa come		13	29	0.9	12	1	3	11	2	39	3.74	0.1	18 - 26
Rhizoprionodon taylori		14	28	0.9			28			15	24.74	0.9	36 - 69
Negaprion acutidens	C,R	15"	26	0.8	1	3	2	4	16	7	96.40	3.6	50 - 150
Drepane punctata		15"	26	0.8		11		9	6	27	7.50	0.3	16 - 30
Polydactylus multiradiatus		15"	26	0.8	12		14			46	2.37	<0.1	18 - 22
Chanos chanos	R	18"	24	0.7				21	3	21	14.32	0.5	32 - 56
Nibea microgenys	C,R	18"	24	0.7	5		19			42	2.60	<0.1	18 - 37
Rhinobatos typus	C,R	20	23	0.7	7	4	1	5	6	14	24.78	0.9	45 - 96
Pristis zijsron	C,R	21"	17	0.5	14		1	1	1	1	573.65	21.4	40 - 400
Liza vaigiensis	C,R	21"	17	0.5	2	7		2	6	23	13.55	0.5	29 - 51
Caranx sexfasciatus	C,R	23	16	0.5		10		5	1	30	5.76	0.2	17 - 36
Carcharhinus limbatus	C,R	24	15	0.5	9	1		5		8	82.09	3.1	50 - 143
Plectorhinchus gibbosus	C,R	25"	11	0.3		9			2	24	10.60	0.4	26 - 56
Arius agripterleroun	C,R	25"	11	0.3			9	1	1	28	7.02	0.3	21 - 51

Table 2.3.1 continued.

		Number			Numbers in each region					Biomass			
		Total			Cape Keraurdren		80 Mile Beach	Port Smith		Total			Length Range
Species	Fisheries	R	N	%	Sand	Mangroves	Sand	Sand	Mangroves	R	kg	%	(cm)
Lutjanus argentimaculatus	C,R	27"	10	0.3		4			6	29	5.78	0.2	25 - 41
Mugil cephalus	C,R	27"	10	0.3	1	7	1	1		36	4.20	0.2	21 - 43
Caranx bucculentus	C,R	27"	10	0.3				8	2	43	2.41	<0.1	20 - 30
Carcharhinus obscurus	C,R	30"	9	0.3	9					13	32.81	1.2	49 - 92
Pomadasys kaakan	R	30"	9	0.3		7		2		41	2.70	0.1	25 - 36
Amniataba caudavittatus		32	8	0.2				1	7	58	0.99	<0.1	14 - 25
Trachinotus blochii	R	33	7	0.2				3	4	20	14.82	0.6	42 - 67
Acanthopagrus latus	C,R	34"	6	0.2	1	2		1	2	45	2.40	<0.1	21 - 32
Selenotoca multifasciata		34"	6	0.2		2			4	53	1.59	<0.1	20 - 25
Herklotsichthys koningsbergeri		34"	6	0.2	4	2				66	0.32	<0.1	16 - 18
Elops hawaiensis	R	37	5	0.2	1	1		2	1	47	2.21	<0.1	34 - 55
Carcharhinus tilstoni	C,R	38"	4	0.1	1		2	1		19	15.72	0.6	54 - 100
Sphyraena qenie	R	38"	4	0.1					4	34	4.80	0.2	31 - 106
Valamugil cunnesius	C,R	38"	4	0.1			2	2		57	1.08	<0.1	21 - 36
Himantura undulata		41"	3	<0.1	2		1			32	5.50	0.2	36 - 40
Arius sp5	C,R	41"	3	<0.1		2	1			48	2.20	<0.1	33 - 53
Strongylura strongylura		41"	3	<0.1			1		2	62	0.50	<0.1	41 - 49
Monodactylus argenteus		41"	3	<0.1		2			1	64	0.35	<0.1	13 - 20
Pristis clavata	C,R	45"	2	<0.1	2					5	230.00	8.6	200 - 350
Carcharhinus amblyrhynchoides	C,R	45"	2	<0.1			2			18	16.02	0.6	77 - 129
Carcharhinus amboinensis	C,R	45"	2	<0.1			2			26	7.51	0.3	74 - 90
Lates calcarifer	C,R	45"	2	<0.1				1	1	49	2.19	<0.1	45 - 47
Caranx ignobilis	C,R	45"	2	<0.1		2				51	1.81	<0.1	22 - 51
Chirocentrus dorab	R	45"	2	<0.1	2					55	1.34	<0.1	59 - 62
Strongylura incisa		45"	2	<0.1				1	1	59	0.76	<0.1	59 - 59
Tylosurus gavioloides		45"	2	<0.1				1	1	60	0.70	<0.1	61 - 63

Table 2.3.1 continued.

		Number			Numbers in each region					Biomass			
		Total			Cape Keraurdren		80 Mile Beach	Port Smith		Total			Length Range
Species	Fisheries	R	N	%	Sand	Mangroves	Sand	Sand	Mangroves	R	kg	%	(cm)
Leiognathus equulus		45"	2	<0.1		1		1		67	0.27	<0.1	16 - 21
Rhynchobatus australiae	C,R	54"	1	<0.1			1			17	20.00	0.7	200
Eusphyra blochii	C,R	54"	1	<0.1	1					25	10.30	0.4	130
Sphyrna lewini	C,R	54"	1	<0.1				1		31	5.54	0.2	110
Protonibea diacanthus	C,R	54"	1	<0.1			1			35	4.36	0.2	76
Pastinachhus sephen		54"	1	<0.1	1					38	3.90	0.1	49
Lobotes surinamensis	C,R	54"	1	<0.1	1					40	2.73	0.1	51
Acanthopagrus palmaris	R	54"	1	<0.1					1	44	2.40	<0.1	30
Aetobatus narinari		54"	1	<0.1				1		50	2.16	<0.1	55
Epinephelus malabaricus	C,R	54"	1	<0.1		1				52	1.77	<0.1	52
Scomberomorus queenslandicus	C,R	54"	1	<0.1				1		54	1.50	<0.1	50
Taeniura lymma		54"	1	<0.1	1					56	1.10	<0.1	30
Arius sp4	C,R	54"	1	<0.1		1				61	0.61	<0.1	38
Psammoperca waigiensis		54"	1	<0.1		1				63	0.45	<0.1	32
Epinephelus coioides	C,R	54"	1	<0.1		1				65	0.33	<0.1	30
Rachycentron canadus	C,R	54"	1	<0.1				1		68	0.26	<0.1	37
Pantolobus radiatus		54"	1	<0.1				1		69	0.22	<0.1	26
Lutjanus russelli	C,R	54"	1	<0.1					1	70	0.20	<0.1	22
Scatophagus argus		54"	1	<0.1					1	71	0.18	<0.1	22
Rhinomugil nasutus		54"	1	<0.1			1			72	0.12	<0.1	24
Platycephalus endrachtensis	R	54"	1	<0.1				1		73	0.05	<0.1	20
Thryssa setrostris		54"	1	<0.1	1					74	0.03	<0.1	16
Remora remora		54"	1	<0.1	1					75	0.01	<0.1	15
Number of fish			3209		568	766	1021	516	338				
Number of species			75		34	34	24	39	36				
Biomass (kg)			2679.7		1211.5	447.9	508.0	287.9	224.5		2679.7		

2.3.2.2 Number of species, catch rate and biomass of fish

ANOVA showed that the number of species, number of fish caught $3h^{-1}$ and biomass of fish caught $3h^{-1}$ over bare sand habitats at Cape Keraudren, Eighty Mile Beach and Port Smith on each sampling occasion differed significantly ($p<0.001$ or <0.01) among seasons and also among locations in the case of the last two variables (Table 2.3.2). There was also a significant interaction between location and season in the case of both number of species and number of fish caught $3h^{-1}$.

Table 2.3.2 Mean squares and significance levels for ANOVAs of the number of species, number of fish caught $3h^{-1}$ and biomass of fish caught $3h^{-1}$ in gill nets set over bare sand in nearshore, shallow waters at Cape Keraudren, Eighty Mile Beach and Port Smith in each season between December 2000 and November 2002. *** $p<0.001$, ** $p<0.01$

	Main effects		**Interactions**	
Source	Location (L)	Season (S)	L x S	Residual
Degrees of freedom	2	3	6	63
Number of species	0.65	1.72 ***	1.29 ***	0.27
Number of fish $3h^{-1}$	0.67 **	0.38 **	0.70 ***	0.11
Biomass of fish $3h^{-1}$	4.24 ***	2.09 ***	0.03	0.34

The highest and lowest mean seasonal number of species of 15 and 3 were recorded at Cape Keraudren during the late wet and early wet seasons, respectively (Fig. 2.3.2a). In contrast, the mean seasonal number of species caught over sand at Eighty Mile Beach remained relatively constant at *ca* 4 during the late wet, early dry and late dry seasons and then rose to 6.2 during the early wet season, while those at Port Smith declined from 6.9 during the late wet season to 4 during the early and late dry season, before rising again to 7.1 during the early wet season (Fig. 2.3.2a). The markedly different trends exhibited by the mean numbers of species at the three locations over the four seasons accounts for the strong interaction between location and season. The trends exhibited by the catch rates of fish at the three locations over the four seasons were similar to those described for number of species. Thus, for example, the highest and lowest mean catch rates of 71.4 and 3.3 fish $3h^{-1}$ were recorded at Cape Keraudren during the late wet and early wet seasons, respectively (Fig. 2.3.2b).

The mean biomass of fish caught $3h^{-1}$ was significantly greater at Cape Keraudren ($p<0.05$) than at Eighty Mile Beach, which, in turn, was significantly greater ($p<0.05$) than at Port Smith (Fig. 2.3.2c). The mean biomass of fish $3h^{-1}$ recorded over bare sand declined from 18.7 kg $3h^{-1}$ during the late wet season to a minimum of 9.6 kg $3h^{-1}$ during the early dry season, before increasing to reach its maximum of 37.9 kg $3h^{-1}$ during the early wet season (Fig. 2.3.2d). The mean biomass was significantly greater during the early wet season than during both the early dry ($p<0.01$) and late dry seasons ($p<0.05$).

When the data for the mangrove as well as bare sand habitats at Cape Keraudren and Port Smith was analysed, ANOVA demonstrated that the number of species was significantly influenced by season and there was a significant interaction between location and season. The biomass of fish caught $3h^{-1}$ was significantly influenced by both location and season (Table 2.3.3). The fact that these results parallel those produced when only the data for bare sand were analysed, accounts for the trends exhibited by the number of fish species and the biomass of fish caught $3h^{-1}$, using data for both habitat types at Cape Keraudren and Port

Smith (Figs 2.3.3a,d,e), being very similar to those exhibited when using the data for over bare sand at the three locations (Figs 2.3.2a,c,d). However, when the number of fish caught $3h^{-1}$ in both habitat types at Cape Keraudren and Port Smith were subjected to ANOVA, location was the only main effect found to be significant and there was a significant interaction not only between location and season but also between habitat and season (Table 2.3.3). The mean square was greater for the main effect than for either of the interactions. The catch rates at Cape Keraudren declined markedly and progressively from very high levels in the late wet season, *i.e.* 59.1 fish $3h^{-1}$, to 10.9 fish $3h^{-1}$ in the early wet season, whereas, those in the late wet, early dry and late dry seasons at Port Smith were similar, 10.2 to 8.6 fish $3h^{-1}$, and then rose to 28.0 in the early wet season (Fig. 2.3.3b). The mean catch rates were greater over bare sand than in mangroves in each season except the early wet season (Fig. 2.3.3c). Furthermore, the mean catch rates over bare sand were greatest in the late wet season and least in the early wet season, whereas those in mangroves were least in the late dry season and greatest in the early wet season (Fig. 2.3.3c).

Table 2.3.3 Mean squares and significance levels for ANOVAs of the number of species, number of fish caught $3h^{-1}$ and biomass of fish caught $3h^{-1}$ in gill nets set over bare sand and in mangroves in nearshore, shallow waters at Cape Keraudren and Port Smith in each season between December 2000 and November 2002. *** p<0.001, ** p<0.01

	Main effects			Interactions				
Source	Location (L)	Season (S)	Habitat (H)	L x S	L x H	H x S	L x S x H	Residual
Degrees of freedom	1	3	1	3	1	3	3	15
Number of species	1.35	3.14 ***	0.11	3.25 ***	0.05	0.93	0.41	0.43
Number of fish $3h^{-1}$	1.58 **	0.30	0.01	0.94 ***	0.31	0.59 **	0.10	0.15
Biomass of fish $3h^{-1}$	10.27 ***	2.53 **	0.57	0.53	0.76	0.13	0.48	0.50

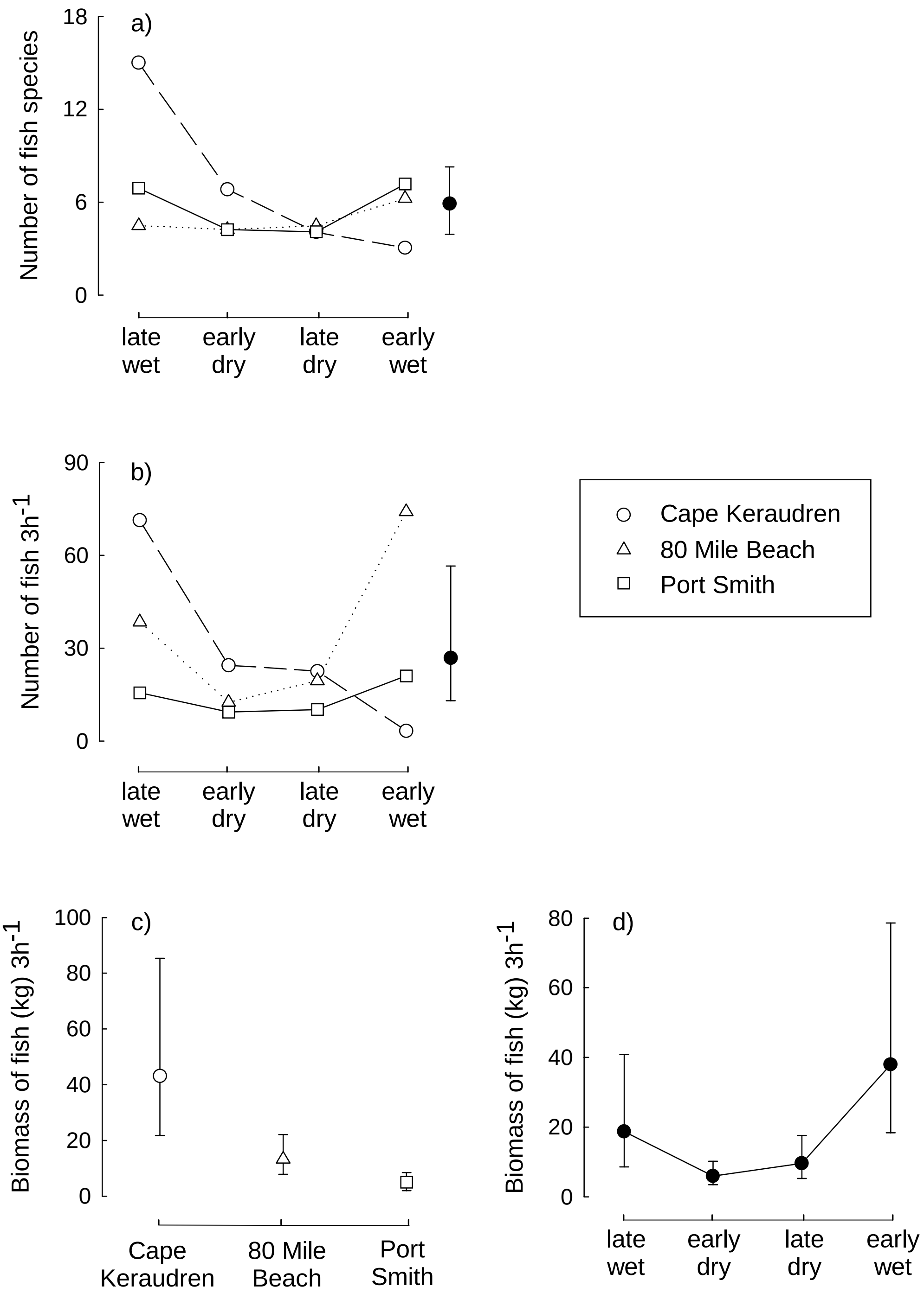

Figure 2.3.2 a) Mean number of fish species ± 95% CL, b) catch rates ± 95% CL and c,d) biomass of fish ± 95% CL collected by gill netting over bare sand at Cape Keraudren, Eighty Mile Beach and Port Smith in each season between December 2000 and November 2002. In this Fig. and Figs 4, 8 and 11, a common mean and 95% CL is shown when there are significant interactions between the main effects.

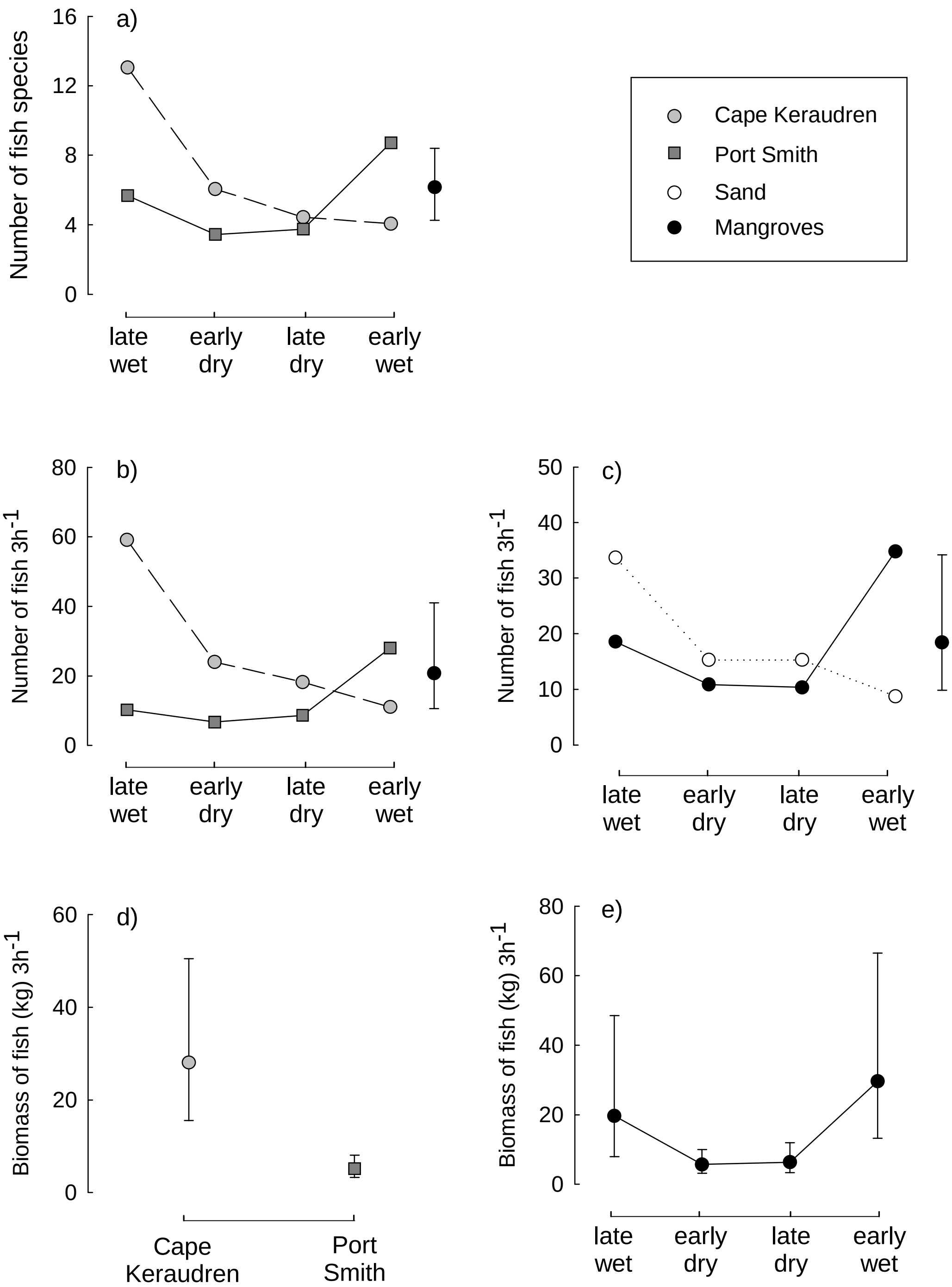

Figure 2.3.3 a) Mean number of fish species ± 95% CL, b,c) catch rates ± 95% CL and d,e) biomass of fish ± 95% CL collected with the gill net over bare sand and from mangroves at Cape Keraudren and Port Smith in each season between December 2000 and November 2002.

2.3.2.3 Ichthyofaunal compositions of gill net samples

When the mean catch rates of the various species in the different habitat types and locations on each gill net sampling occasion were subjected to MDS ordination, the samples from over bare sand at Eighty Mile Beach formed a tight cluster in the extreme left of the ordination plot, whereas those from over bare sand and in mangroves at Port Smith formed a widely dispersed group in the right half of the plot (Fig. 2.3.4). The samples from Cape Keraudren largely lay between those for Eighty Mile Beach and Port Smith. In the case of Cape Keraudren, the samples from over bare sand lay predominantly above those for mangroves, while at Port Smith those from the former habitat type lay largely to the left of those from mangroves (Fig. 2.3.4).

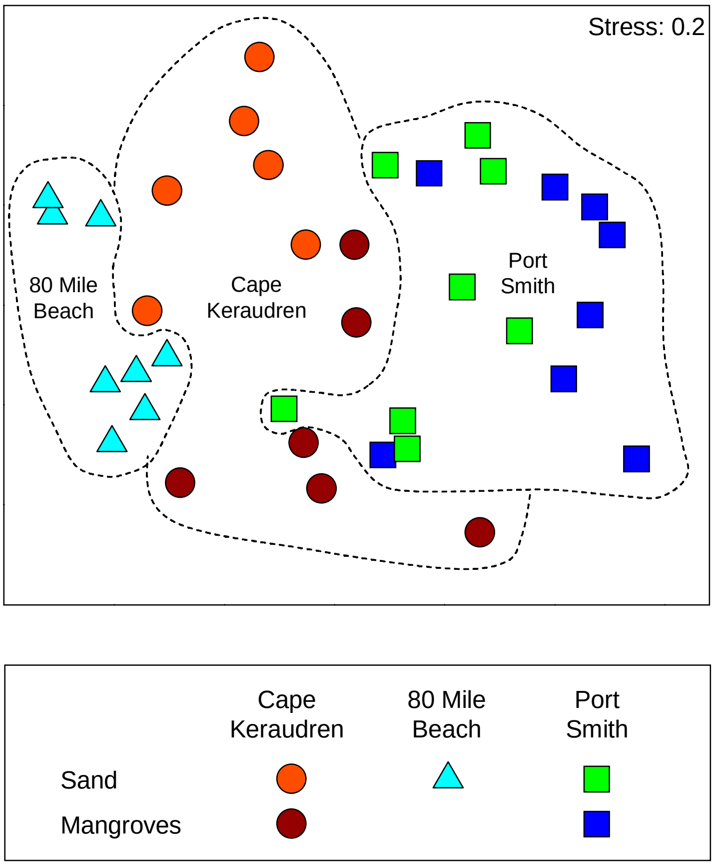

Figure 2.3.4 Nonmetric multidimensional scaling ordination of the mean catch rates of the various species in samples collected with the gill net over bare sand at Cape Keraudren, Eighty Mile Beach and Port Smith and in mangroves at Cape Keraudren and Port Smith on each of the eight sampling occasions between December 2000 and November 2002.

A one-way ANOSIM, using just the data for over bare sand, confirmed that the compositions of the fish faunas in the three locations were highly significantly different ($p<0.001$, Global R-statistic = 0.661) and that the difference was greatest between those at Eighty Mile Beach and Port Smith ($p<0.01$, R-statistic = 0.838) (Table 2.3.4). SIMPER demonstrated that the gill net samples collected from over bare sand at Cape Keraudren were typified by relatively high numbers of *E. tetradactylum* and *P. zijsron*, whereas those from Eighty Mile Beach had high numbers of *P. macrochir* and *A. proximus* and Port Smith was typified by *V. seheli* (Table 2.3.5).

Table 2.3.4 R-statistic values and significance levels for pair-wise ANOSIM tests comparing the community composition over bare sand at with gill nets at Cape Keraudren, Eighty Mile Beach and Port Smith between December 2000 and November 2002. *** $p<0.001$, ** $p<0.01$

	Cape Keraudren	80 Mile Beach
80 Mile Beach	0.430 **	
Port Smith	0.592 **	0.838 **

Table 2.3.5 Species identified by SIMPER as typifying fish samples collected with the monofilament gill net over bare sand at Cape Keraudren, Eighty Mile Beach and Port Smith between December 2000 and November 2002. When a species typified more than one location, the numbers after those species names refer to the order of abundance of that species in all locations.

Cape Keraudren	80 Mile Beach	Port Smith
Eleutheronema tetradactylum 1	*Polydactylus macrochir* 1	*Valamugil seheli*
Pristis zijsron	*Arius proximus* 1	*Arius proximus* 2
Polydactylus macrochir 2	*Eleutheronema tetradactylum* 2	*Eleutheronema tetradactylum* 3
Arius proximus 3	*Arius mastersi* 1	
Arius mastersi 2	*Nibea microgenys*	

Two-way crossed ANOSIM, using the data for both habitat types at Cape Keraudren and Port Smith, demonstrated that the compositions of the samples in these two locations were significantly different ($p<0.001$, R-statistic = 0.469), as were those between sand and mangrove habitats ($p<0.001$, R-statistic = 0.222). Separate one-way ANOSIM tests demonstrated that this habitat difference was greater at Cape Keraudren ($p<0.05$, R-statistic = 0.281) than at Port Smith ($p<0.05$, R-statistic = 0.192). At Cape Keraudren, samples of fish collected with the gill net over bare sand were typified by relatively high numbers of *E. tetradactylum, P. macrochir* and *P. zijsron*, whereas mangrove samples were typified by *A. proximus, Liza macrolepis* and *Carcharhinus cautus* (Table 2.3.6). At Port Smith, species typifying samples from over bare sand included *A. Proximus, Chanos chanos* and *V. seheli,* whereas *L. macrolepis, Megalops cyprinoides* and *Negaprion acutidens* typified the mangrove fish fauna at this location (Table 2.3.6).

When the catch rates of the various species in each sample collected over bare sand at Cape Keraudren were subjected to ordination, the points tended to group according to season, with the samples from the early and late dry seasons typically lying above and/or to the left of those representing both the early and late wet seasons (Fig. 2.3.5a). ANOSIM confirmed that the community composition over bare sand at Cape Keraudren was significantly influenced by season ($p<0.01$, Global R-statistic = 0.306) (Table 2.3.7). The difference in the composition of the fish fauna was greatest between the late wet and late dry seasons ($p<0.05$, R-statistic = 0.635) (Table 2.3.8). SIMPER demonstrated that gill net samples during the late dry season were typified by *E. tetradactylum*, whereas samples from the late wet season were typified by greater numbers of *P. macrochir* (Table 2.3.9). ANOSIM also demonstrated that the composition of the fish fauna over bare sand at Cape Keraudren in the wet and dry periods was significantly different ($p<0.05$, R-statistic = 0.219) (Table 2.3.7). Greater numbers of *A. proximus* and *P. macrochir* during the wet and of *E. tetradactylum* during the dry were identified by SIMPER as being most responsible for the change in community composition.

Table 2.3.6 Species that were identified by SIMPER as typifying fish samples collected with the monofilament gill net from either bare sand or from mangroves at Cape Keraudren and Port Smith.

	Bare Sand	Mangroves
Cape Keraudren	*Eleutheronema tetradactylum* *Polydactylus macrochir* *Pristis zijsron*	*Arius proximus* *Liza macrolepis* *Carcharhinus cautus*
Port Smith	*A. proximus* *Chanos chanos* *Valamugil seheli* *E. tetradactylum* *Scomberoides commersonnianus* *Sillago analis* *Caranx bucculentus*	*L. macrolepis* *Megalops cyprinoides* *Negaprion acutidens*

Table 2.3.7 R-statistic values and significance levels for one-way ANOSIM tests for the effect of season or period (*i.e.* wet *vs* dry) on the fish fauna collected between December 2000 and November 2002 in gill nets over bare sand at Cape Keraudren, Eighty Mile Beach and Port Smith and from mangroves at Cape Keraudren and Port Smith. *** $p<0.001$, ** $p<0.01$, * $p<0.05$

	Cape Keraudren		80 Mile Beach	Port Smith	
	Sand	Mangroves	Sand	Sand	Mangroves
Season	0.306 **	0.078	0.427 ***	0.069	0.172 *
Period	0.219 *	0.003	0.555 ***	0.009	0.062

Table 2.3.8 R-statistic values and significance levels for pair-wise ANOSIM tests comparing the community composition during each of the four seasons sampled with gill nets over bare sand at Cape Keraudren between December 2000 and November 2002. * $p<0.05$

	Early dry	Late dry	Early wet
Late Dry	0.168		
Early wet	0.388 *	0.429 *	
Late wet	-0.052	0.635 *	0.429

Table 2.3.9 Species identified by SIMPER as typifying fish samples from each season collected with the monofilament gill net over bare sand at Cape Keraudren between December 2000 and November 2002. When a species typified more than one season, the numbers after those species names refer to the order of abundance of that species in all seasons.

Early dry	Late dry	Early wet	Late wet
Eleutheronema tetradactylum 2	*Eleutheronema tetradactylum* 1	*Pristis zijsron* 3	*Polydactylus macrochir* 1
Liza subviridis	*Pristis zijsron* 2	*Arius proximus*	*Nematalosa come*
Polydactylus macrochir 2	*Sillago analis* 1	*Polydactylus macrochir* 3	*Arius proximus* 2
Liza macrolepis		*Sillago analis* 2	*Carcharhinus limbatus*
Pristis zijsron 1			

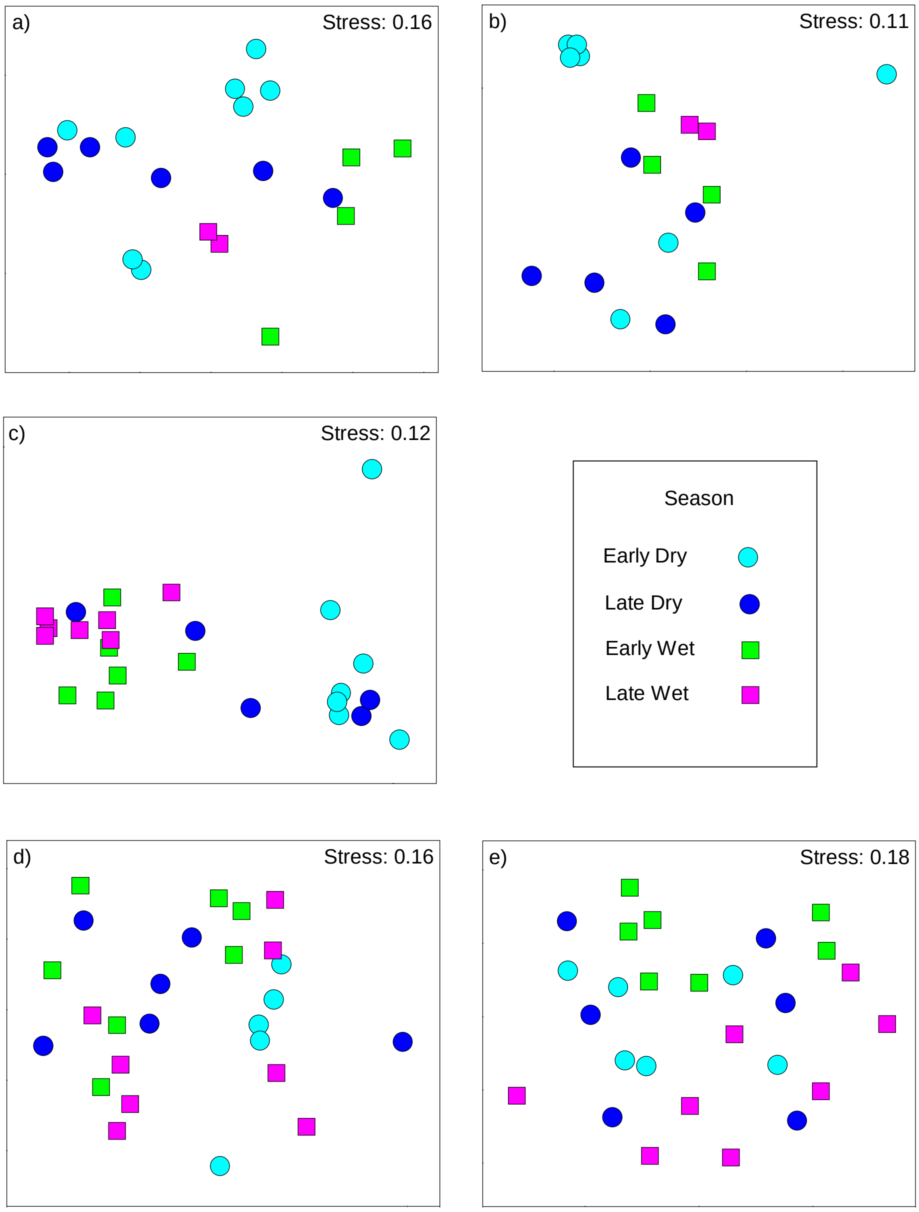

Figure 2.3.5 Nonmetric multidimensional scaling ordination of the catch rates of the various species in replicate samples collected with the gill net a) over bare sand at Cape Keraudren, b) in mangroves at Cape Keraudren, c) over bare sand at Eighty Mile Beach, d) over bare sand at Port Smith and e) in mangroves at Port Smith on each sampling occasion between December 2000 and November 2002.

The points representing samples collected with the gill net in mangroves at Cape Keraudren tended to be less tightly grouped according to season, with the samples from the early dry season being widely spread throughout the plot (Fig. 2.3.5b). However, the samples from the late dry season all lay in the bottom left hand quadrant of the plot and to the left of the majority of samples from the early and late wet. ANOSIM demonstrated that neither season nor period had a significant influence on the community composition in the mangroves at Cape Keraudren (Table 2.3.7).

Following subjection to MDS ordination of the catch rates in the replicate gill net samples collected over bare sand on each sampling occasion at Eighty Mile Beach, all but one of the samples from the early and late dry seasons lay to the right of all of those from the early and late wet seasons (Fig. 2.3.5c). Furthermore, the samples from the early wet season tended to lie below those from the late wet season. ANOSIM demonstrated that the composition of the fish fauna differed significantly among seasons ($p<0.001$, Global R-statistic = 0.427) (Table 2.3.7). The greatest difference in faunal composition was between the samples from the late wet season and the early dry season ($p<0.001$, R-statistic = 0.732) (Table 2.3.10). SIMPER demonstrated that the samples from the early dry were separated from those from the late wet season by relatively higher numbers of *Nibea microgenys* and lower numbers of *A. proximus, P. macrochir* and *A. mastersi* (Table 2.3.11).

Table 2.3.10 R-statistic values and significance levels for pair-wise ANOSIM tests comparing the community composition during each of the four seasons sampled with gill nets over bare sand at Eighty Mile Beach between December 2000 and November 2002. *** $p<0.001$, ** $p<0.01$, * $p<0.05$

	Early dry	Late dry	Early wet
Late Dry	0.078		
Early wet	0.609 **	0.348 *	
Late wet	0.732 ***	0.480 **	0.234 **

Table 2.3.11 Species identified by SIMPER as typifying fish samples from each season collected with the monofilament gill net over bare sand at Eighty Mile Beach between December 2000 and November 2002. When a species typified more than one season, the numbers after those species names refer to the order of abundance of that species in all seasons.

Early dry	Late dry	Early wet	Late wet
Polydactylus macrochir 4	*Polydactylus macrochir* 3	*Arius proximus* 1	*Arius proximus* 2
Eleutheronema tetradactylum 3	*Eleutheronema tetradactylum* 2	*Polydactylus macrochir* 1	*Polydactylus macrochir* 2
Nibea microgenys	*Arius proximus* 3	*Arius mastersi* 1	*Arius mastersi* 2
Polydactylus multradiatus		*Eleutheronema tetradactylum* 1	

The tendency for the differences in community composition to be greater between certain wet and dry periods is reflected in the greater R-statisic value (0.555) for the influence of period rather than season at this location (Table 2.3.7). The species identified by SIMPER as most responsible for the considerable shift in community composition between the wet and dry periods included relatively greater numbers of *A. proximus* and *A. mastersi* during the wet period and higher numbers of *N. microgenys* during the dry period.

When the replicate catch rates of the various species in the samples collected with gill nets over bare sand and in mangroves at Port Smith were subjected to MDS ordination separately, the samples did not tend to group tightly together according to season (Fig. 2.3.5d,e). However, four of the five samples collected over sand during the early dry formed a group that lay to the right and/or below those for the late wet. ANOSIM illustrated that the composition of the fish fauna over bare sand at Port Smith was not influenced by season or period (Table 2.3.7). Although the community composition of mangrove samples at Port Smith was influenced by season ($p<0.05$, R-statistic = 0.172) only the early wet and late wet seasons were significantly different from one another (Table 2.3.12). SIMPER identified the relatively greater numbers of *A. proximus* and *L. macrolepis* during the early wet and of *L. subviridis* during the late wet season as accounting for the difference in the community composition between these seasons (Table 2.3.13).

Table 2.3.12 R-statistic values and significance levels for pair-wise ANOSIM tests comparing the community composition during each of the four seasons sampled with gill nets in mangroves at Port Smith between December 2000 and November 2002. * $p<0.05$

	Early dry	Late dry	Early wet
Late Dry	0.129		
Early wet	0.163	0.075	
Late wet	0.214	0.180	0.251*

Table 2.3.13 Species identified by SIMPER as typifying fish samples from each season collected with the monofilament gill net in mangroves at Port Smith between December 2000 and November 2002. When a species typified more than one season, the numbers after those species names refer to the order of abundance of that species in all seasons.

Early dry	Late dry	Early wet	Late wet
Liza macrolepis 2	*Arius proximus* 2	*Arius proximus* 1	*Valamugil seheli* 3
Megalops cyprinoids	*Valamugil seheli* 2	*Valamugil seheli* 1	*Liza subviridis* 1
Negaprion acutidens 3	*Liza macrolepis* 3	*Liza macrolepis* 1	*Negaprion acutidens* 2
		Negaprion acutidens 1	

When the catch rates of the various species in the samples collected with gill nets over bare sand and in mangroves at Port Smith were coded for year, most of the samples collected in the first four sampling trips (seasons) in each of those habitats lay to the left of the samples collected during the second year of sampling (Fig. 2.3.6a,c). ANOSIM demonstrated that the ichthyofaunal compositions over bare sand and in mangroves at Port Smith were significantly influenced by year, with the *p* values and R-statistic values being $p<0.05$ and 0.157 and $p<0.01$ and 0.326, respectively.

When the mean catch rates of the various species in the samples collected with gill nets over bare sand and in mangroves at Port Smith in 2001 and 2002 were ordinated, the samples from 2001 lay to the left of those from 2002 in the case of both habitat types (Figs 2.3.6a,c). In the ordination plot for the bare sand samples, the samples for both years progressed in an approximately cyclical manner (Fig. 2.3.6b). The samples from the mangroves at Port Smith did not follow as clear a cyclical patter in the two years (Fig. 2.3.6b). The mangrove samples from Port Smith were also well separated by year and, in both years, the seasonal points follow a progression from the early dry season near the top of the plot to the late wet season toward the bottom of the plot (Fig. 2.3.6d). SIMPER demonstrated that, in both habitats, the significant change in community composition between years was due to relatively higher numbers of *A. proximus* during the first years and relatively higher numbers of *V. seheli* during the second year.

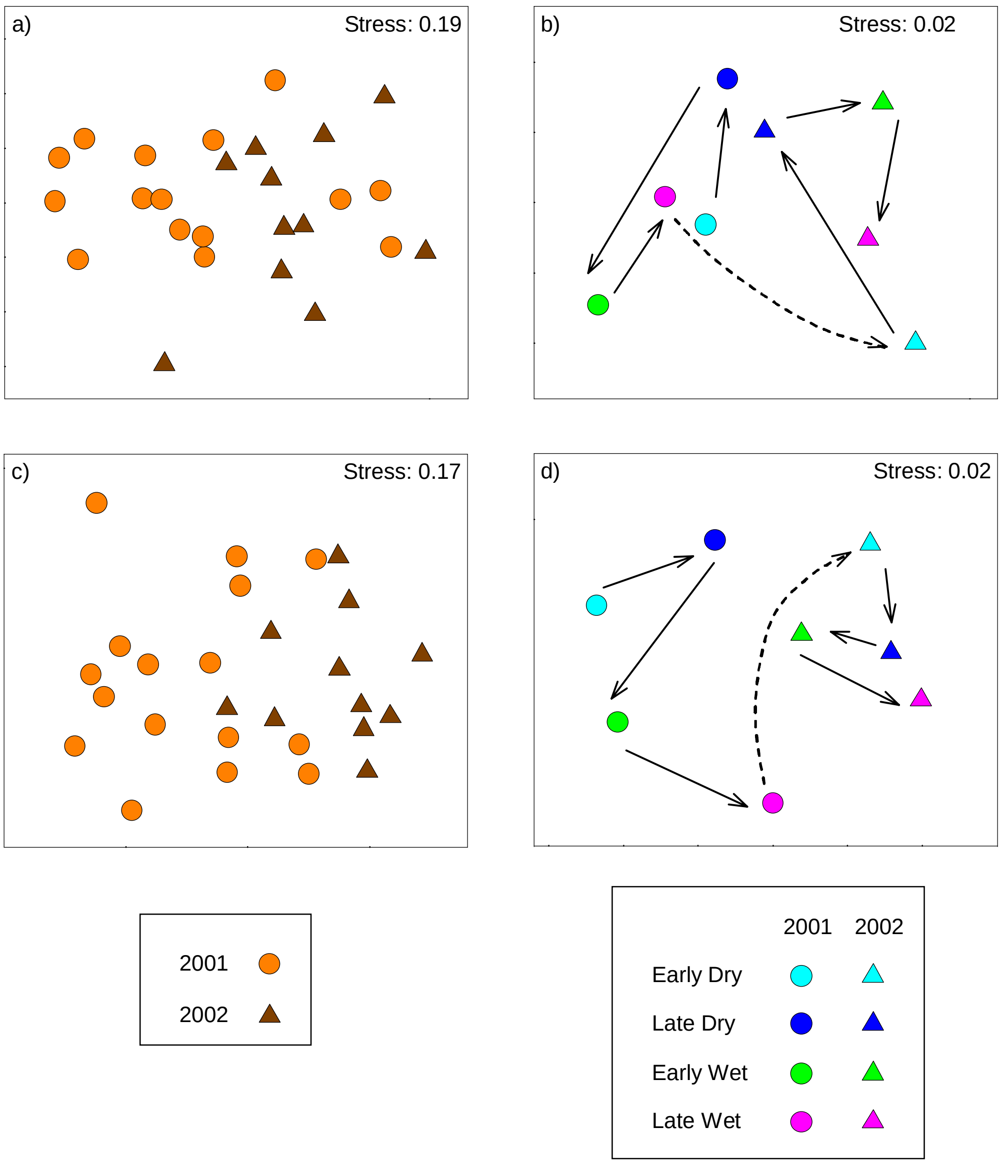

Figure 2.3.6 Nonmetric multidimensional scaling ordinations of a) replicate and b) mean catch rates of the various species in samples collected with the gill net over bare sand and c) replicate and d) mean catch rates of the various species in samples collected with the gill net in mangroves at Port Smith on each of the sampling occasions during 2001 and 2002.

2.3.3 Seine net samples

2.3.3.1 Species composition

A total of 36059 fish, representing 91 species and 39 families and weighing 319 kg, was caught using the 60.5 m seine net over bare sand at the Cape Keraudren site, the two Eighty Mile Beach sites and the two Port Smith sites, one of which was near mangroves

(Table 2.3.14). Twenty five of the 91 species were of commercial and recreational importance and these constituted 5.6% of the total catch of fish. A further 12 species were important only to the recreational sector and contributed a further 3.4% to the total catch. The most abundant species (and their percentage contributions to the total catch) were the engraulid *Stolephorus carpentariae* (19.1%), the clupeid *Sardinella brachysoma* (14.7%), two species of atherinid, *i.e. Atherinomorus lacunosus* (11.8%) and *Craterocephalus pauciradiatus* (8.7%), and another clupeid, *Spratelloides delicatulus* (7.8%). The only other species that contributed more than 5% to the total number of fish caught by the 60.5 m seine was the atherinid *Craterocephalus mugiloides* (7.7%) and another clupeid, *Sardinella fijiense* (5.4%). None of the above seven species are targeted by commercial or recreational fishers (Table 2.3.14).

Although these seven abundant species collectively contributed more than 75% to the total number of fish caught by the 60.5 m seine over bare sand, only 25 individuals of these species collectively were recorded at the Eighty Mile Beach sites. The low contribution of these seven species to the total number of fish obtained from the Eighty Mile Beach sites (0.5%) helps account for the much lower total number of fish at both of these sites (1190 and 3452) than at Cape Keraudren (10233) or either of the Port Smith sites (9274 and 11909). In contrast, the total number of species recorded over bare sand was greater at each of the two Eighty Mile Beach sites (47 and 53) than that at Cape Keraudren (44) and even more particularly at the sites at Port Smith (30 and 34) (Table 2.3.14). The contribution of commercially and/or recreationally important species to the total catch of fish in each location ranged from 2.9% at the Port Smith site near mangroves to 40.8% at the southern Eighty Mile Beach site (Table 2.3.14).

The spotted whipray *Himantura undulata* made the greatest contribution (16.8%) to the total biomass of fish collected by seine netting, followed by the cowtail stingray *Pastinachus sephen* (16.8%) and the green sawfish *P. zijsron* (10.0%) (Table 2.3.14). Although these three elasmobranch species collectively contributed 39.5% to the total biomass, none of these species ranked higher than 37th or contributed more than 0.1% in terms of the total number of fish caught with this net. The next ranked species in terms of biomass were the threadfin salmons *P. macrochir* (9.4%) and *E. tetradactylum* (5.1%). In contrast to their low contribution to the total number of individuals, the species of commercial and recreational significance constituted 140.9 kg (44.2%) of the total weight of the seine net catch, with those species important only to recreational fishers contributing a further 24.6 kg (7.7%) (Table 2.3.14).

Table 2.3.14 Commercial (C) or recreational (R) importance, rank by abundance (R), number (N), percentage contribution (%) and length range of each fish species caught between December 2000 and November 2002 using the 60.5 m seine net over bare sand five sites at Cape Keraudren, 80 Mile Beach and Port Smith. The ranking by weight, total biomass (g) and percentage contribution by weight of each species caught in the study region is also given.

		Number			Numbers in each region					Biomass			
		Total			Cape Keraudren	80 Mile Beach		Port Smith		Total			Length Range
	Fisheries	R	N	%	Sand	North	South	Sand	Mangroves	R	g	%	(mm)
Stolephorus carpentariae		1	6895	19.1	5820	2	4	1003	66	6	13467.5	4.2	19 - 61
Sardinella brachysoma		2	5313	14.7	836	6	12	2981	1478	27	1871.4	0.6	23 - 132
Atherinomorus lacunosus		3	4241	11.8				483	3758	24	2447.8	0.8	20 - 75
Craterocephalus pauciradiatus		4	3138	8.7	15			826	2297	28	1825.1	0.6	23 - 74
Spratelloides delicatulus		5	2808	7.8				1175	1633	30	1526.2	0.5	25 - 57
Craterocephalus mugiloides		6	2774	7.7	2703	1		3	67	18	3185.8	1.0	18 - 73
Sardinella fijiense		7	1956	5.4	21			817	1118	38	463.2	0.1	24 - 72
Thryssa hamiltonii		8	1402	3.9	5	227	1170			10	10263.5	3.2	23 - 273
Leiognathus equulus		9	1203	3.3		7	3	791	402	48	178.4	<0.1	12 - 69
Hyporhamphus quoyi	R	10	977	2.7	50	67	719	60	81	14	5467.2	1.7	43 - 335
Sillago vittata	C,R	11	812	2.3	68		2	538	204	34	991.1	0.3	17 - 223
Escualosa thoracata		12	706	2.0	8	462	236			35	984.5	0.3	22 - 78
Gerres oyena		13	485	1.3	16		1	357	111	49	160.3	<0.1	18 - 83
Gerres subfasciatus		14	472	1.3	18			117	337	43	271.5	<0.1	14 - 93
Valamugil cunnesius	C,R	15	404	1.1	32	25	347			7	13259.8	4.2	14 - 362
Stolephorus andhraensis		16	342	0.9	10	25	307			40	352.7	0.1	32 - 95
Eleutheronema tetradactylum	C,R	17	277	0.8	2	76	199			5	16379.9	5.1	42 - 471
Ambassis vachelli		18	266	0.7					266	54	105.1	<0.1	15 - 60
Sillago lutea		19	245	0.7	30	98	107		10	33	997.3	0.3	21 - 400
Arrhamphus sclerolepis	R	20	207	0.6	172	5	21		9	13	7299.8	2.3	35 - 240
Strongylura strongylura		21	189	0.5	96	18	55	20		11	10079.8	3.2	132 - 490
Liza macrolepis	C,R	22	143	0.4	130	1	1	1	10	8	11933.0	3.7	17 - 280
Thryssa setrostris		23	104	0.3		53	51			50	145.8	<0.1	25 - 102
Sillago analis	C,R	24	87	0.2	73	3	9	2		19	3041.0	1.0	24 - 295
Polydactylus macrochir	C,R	25	71	0.2	1	16	54			4	29975.6	9.4	147 - 576
Sillago burrus	C,R	26	36	<0.1	14			17	5	55	90.2	<0.1	31 - 112
Liza subviridis	C,R	27	33	<0.1	31	1	1			17	3870.2	1.2	127 - 317
Secutor insidiator		28	32	<0.1		9	6	13	4	60	62.7	<0.1	12 - 69
Nibea microgenys	C,R	29"	29	<0.1		3	26			15	4419.2	1.4	189 - 382
Plagiopsetta glossa		29"	29	<0.1				22	7	67	14.6	<0.1	17 - 73
Leptobrama mulleri		31"	25	<0.1	16	3	6			29	1636.8	0.5	130 - 255

Table 2.3.14 continued.

		Number			Numbers in each region					Biomass			
		Total			Cape Keraurdren	80 Mile Beach		Port Smith		Total			Length Range
	Fisheries	R	N	%	Sand	North	South	Sand	Mangroves	R	g	%	(mm)
Thryssa aestuaria		31"	25	<0.1		7	18			46	209.8	<0.1	46 - 138
Paraplagusia bilineata		33	24	<0.1		20	4			62	45.0	<0.1	27 - 140
Scomberoides commersonnianus	C,R	34	23	<0.1	7	1	5	4	6	25	2346.6	0.7	23 - 207
juvenile teleost F		35	20	<0.1		16	4			75	4.5	<0.1	18 - 29
Liza vaigiensis	C,R	36	19	<0.1	4				15	21	2993.6	0.9	15 - 450
Arothron manilensis		37"	15	<0.1	2	1	1	9	2	26	1937.1	0.6	117 - 183
Himantura undulata		37"	15	<0.1	2	3	10			1	53500.0	16.8	200 - 700
Caranx ignobilis	C,R	39	14	<0.1	12	2				51	137.6	<0.1	62 - 167
Pastinachhus sephen		40	13	<0.1	3	1	9			2	39500.0	12.4	350 - 650
Craterocephalus capreoli		41"	11	<0.1		1	10			73	6.1	<0.1	30 - 56
Platycephalus endrachtensis	R	41"	11	<0.1				6	5	59	65.5	<0.1	38 - 152
Valamugil seheli	C,R	43	10	<0.1	4			2	4	32	1130.7	0.4	95 - 318
Scomberoides tol	R	44"	9	<0.1	4			4	1	58	68.2	<0.1	28 - 141
Stolephorus nelsoni		44"	9	<0.1	2	2	5			74	5.9	<0.1	45 - 56
Caranx sexfasciatus	C,R	46"	8	<0.1	1	2	5			42	294.6	<0.1	72 - 220
Hyporhamphus neglectisimus		46"	8	<0.1	3	4	1			71	10.4	<0.1	41 - 122
Lutjanus russelli	C,R	46"	8	<0.1		5	1		2	77	3.2	<0.1	28 - 34
Pseudorhombus arsius	R	46"	8	<0.1				8		76	3.4	<0.1	21 - 42
Trachinotus blochii	R	46"	8	<0.1				8		9	11200.0	3.5	460 - 460
Favonigobius lateralis		51"	7	<0.1		4	3			78	1.3	<0.1	27 - 31
Rhinobatos typus	C,R	51"	7	<0.1	2	2	2	1		12	9800.0	3.1	400 - 700
Sillago sihama	C,R	53	6	<0.1	3		3			63	29.0	<0.1	86 - 98
Liza planiceps	C,R	54"	5	<0.1	5					52	116.4	<0.1	144 - 164
Nematalosa come		54"	5	<0.1		2	3			61	58.8	<0.1	38 - 133
Polydactylus multiradiatus		54"	5	<0.1		1	4			39	362.0	0.1	180 - 203
Arius proximus	C,R	54"	5	<0.1			5			23	2503.0	0.8	252 - 436
Terapon jarbua		58"	4	<0.1	4					64	27.6	<0.1	64 - 98
Arius mastersi	C,R	58"	4	<0.1		1	3			22	2873.5	0.9	116 - 507
juvenile teleost D		58"	4	<0.1		1	3			84"	0.3	<0.1	16 - 17
Gerres filamentosus		61"	3	<0.1					3	68	14.0	<0.1	67 - 73
Hyporhamphus affinis	R	61"	3	<0.1		1		1	1	66	14.7	<0.1	38 - 157
Pristis zijsron	C,R	61"	3	<0.1	3					3	32000.0	10.0	1000 - 1500
Sphyraena qenie	R	61"	3	<0.1		1	2			80"	0.6	<0.1	31 - 37

Table 2.3.14 continued.

		Number			Numbers in each region					Biomass			
		Total			Cape Keraurdren	80 Mile Beach		Port Smith		Total			Length Range
	Fisheries	R	N	%	Sand	North	South	Sand	Mangroves	R	g	%	(mm)
Amniataba caudavittatus		65"	2	<0.1					2	65	18.6	<0.1	86 - 88
Drepane punctata		65"	2	<0.1			1		1	41	351.3	0.1	123 - 250
Mugil cephalus	C,R	65"	2	<0.1	1		1			36	688.5	0.2	134 - 402
Rhinomugil nasutus		65"	2	<0.1			2			45	220.9	<0.1	210 - 236
Selenotoca multifasciata		65"	2	<0.1			1	1		53	114.6	<0.1	45 - 181
Strongylura incisa		65"	2	<0.1				2		72	8.0	<0.1	150 - 155
Arius agripterleroun	C,R	65"	2	<0.1			2			31	1342.5	0.4	354 - 453
Arius sp4	C,R	65"	2	<0.1			2			37	628.7	0.2	246 - 376
juvenile teleost G		65"	2	<0.1			2			91	0.0	<0.1	9 - 10
Chanos chanos	R	74"	1	<0.1					1	47	196.9	<0.1	290
Elops hawaiensis	R	74"	1	<0.1	1					44	237.5	<0.1	356
Himantura far		74"	1	<0.1	1					16	4000.0	1.3	600
Pomadasys kaakan	R	74"	1	<0.1	1					80"	0.6	<0.1	37
Remora remora		74"	1	<0.1			1			69	13.7	<0.1	172
Rendahlia jaubertensis		74"	1	<0.1		1				84"	0.3	<0.1	32
Scobinichthys granulatus	R	74"	1	<0.1		1				82	0.6	<0.1	31
*Scomberomorus sp_*		74"	1	<0.1			1			84"	0.3	<0.1	35
Tripodichthys angustifrons		74"	1	<0.1				1		56	84.4	<0.1	211
Tylosurus crocodiles		74"	1	<0.1					1	70	11.8	<0.1	213
juvenile teleost A		74"	1	<0.1		1				87"	0.1	<0.1	16
juvenile teleost B		74"	1	<0.1		1				87"	0.1	<0.1	18
juvenile teleost C		74"	1	<0.1		1				87"	0.1	<0.1	24
tetraodontid sp1		74"	1	<0.1					1	90	0.1	<0.1	12
Upeneus tragula		74"	1	<0.1				1		83	0.5	<0.1	37
Urogymnus asperrimus		74"	1	<0.1			1			20	3000.0	0.9	500
Valamugil perusii	C,R	74"	1	<0.1	1					57	68.9	<0.1	183
Zenarchopterus buffonis		74"	1	<0.1					1	79	1.0	<0.1	81
Total fish			36059		10233	1190	3452	9274	11909				
Number of species			91		44	47	53	30	34				
Total biomass (kg)			319.0		118.1	24.8	142.4	18.8	15.0				

2.3.3.2 Number of species, densities and biomass of fish

ANOVA of the number of species caught by seine net over bare sand at the Cape Keraudren site and at the two sites at both Eighty Mile Beach and Port Smith on each sampling occasion in the different seasons showed that the number of species differed significantly ($p<0.001$) among those sites but not among seasons (Table 2.3.15). The density and biomass of fish were both significantly influenced by site and season ($p<0.05$ or $p<0.001$) and there was a significant interaction between those two variables in the case of biomass.

Table 2.3.15 Mean squares and significance levels for ANOVAs of the number of species, density and biomass per unit area of fish in seine net samples collected from over bare sand in nearshore shallow waters at one site at Cape Keraudren and two sites at both Eighty Mile Beach and Port Smith in each season between December 2000 and November 2002. *** $p<0.001$, * $p<0.05$

	Main effects		Interactions	
Source	Site (St)	Season (Sn)	St x Sn	Residual
Degrees of freedom	4	3	12	79
Number of species	3.07 ***	0.39	0.42	0.34
Density (500 m^{-1})	1.58 *	1.57 *	0.25	0.48
Biomass (500 m^{-1})	3.99 ***	1.62 *	0.97 *	0.51

The mean number of species at the northern Eighty Mile Beach site (8.1) and southern Eighty Mile Beach site (9.2) were both significantly greater ($p<0.01$) than over bare sand or sand close to mangroves at Port Smith (4.4 and 5.5 species, respectively). Similarly, the mean number of species at the Cape Keraudren site (8.2) was also significantly greater ($p<0.05$) than at the bare sand site at Port Smith (Fig. 2.3.7a). The mean densities of fish at the five sites sampled with the seine net ranged from 54.7 fish 500 m^{-2} at the northern Eighty Mile Beach site to 259.7 fish 500 m^{-2} at the Port Smith site, which was located close to mangroves (Fig. 2.3.7b). The mean density of fish during the early dry season (212.1 fish 500 m^{-2}) was significantly greater than during the late dry season (52.5 fish 500 m^{-2}) (Fig. 2.3.7c). The biomass of fish at Cape Keraudren declined from a high of 8.2 kg 500 m^{-2} during the late wet season to a low of 0.6 kg 500 m^{-2} during the late dry season, before increasing to 3.4 kg 500 m^{-2} during the early wet season (Fig. 2.3.7d). In contrast, the biomass at both the northern and southern Eighty Mile Beach sites increased between the late wet and early dry seasons, reaching 6.7 and 1.9 kg 500 m^{-2}, respectively, before declining progressively to a minimum of approximately 0.3 kg 500 m^{-2} during the early wet. The biomass of fish at both Port Smith sites remained relatively constant, never exceeding 1.3 kg 500 m^{-2} during any season (Fig. 2.3.7d).

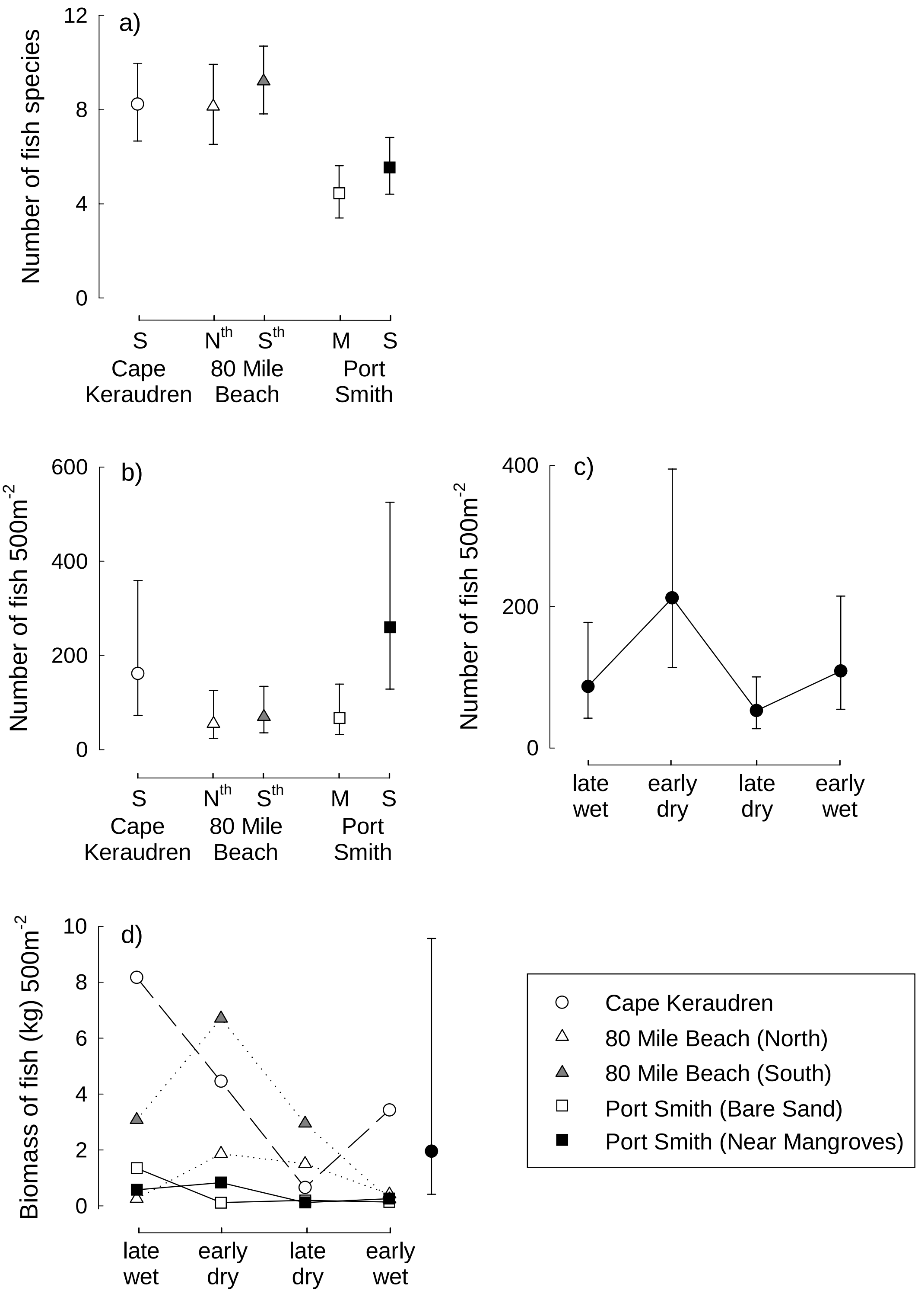

Figure 2.3.7 a) Mean number of fish species ± 95% CL, b,c) mean number of fish 500 m^{-2} ± 95% CL and d) mean biomass of fish 500 m^{-2} ± 95% CL collected with the seine net over bare sand at sites at Cape Keraudren, Eighty Mile Beach and Port Smith in each season between December 2000 and November 2002.

2.3.3.3 Ichthyofaunal composition of seine net catches

When the mean densities of the various species over bare sand at the five sites on the different sampling occasions were subjected to MDS ordination, the samples from the Eighty Mile Beach (north and south) formed a discrete group in the top right hand corner of the plot (Fig. 2.3.8). All but one of the samples from the sites over bare sand and close to mangroves at Port Smith formed a tight and discrete group in the top left hand corner of the ordination plot. The samples from Cape Keraudren formed a separate group that lay largely between and below those from Eighty Mile Beach and Port Smith (Fig. 2.3.8).

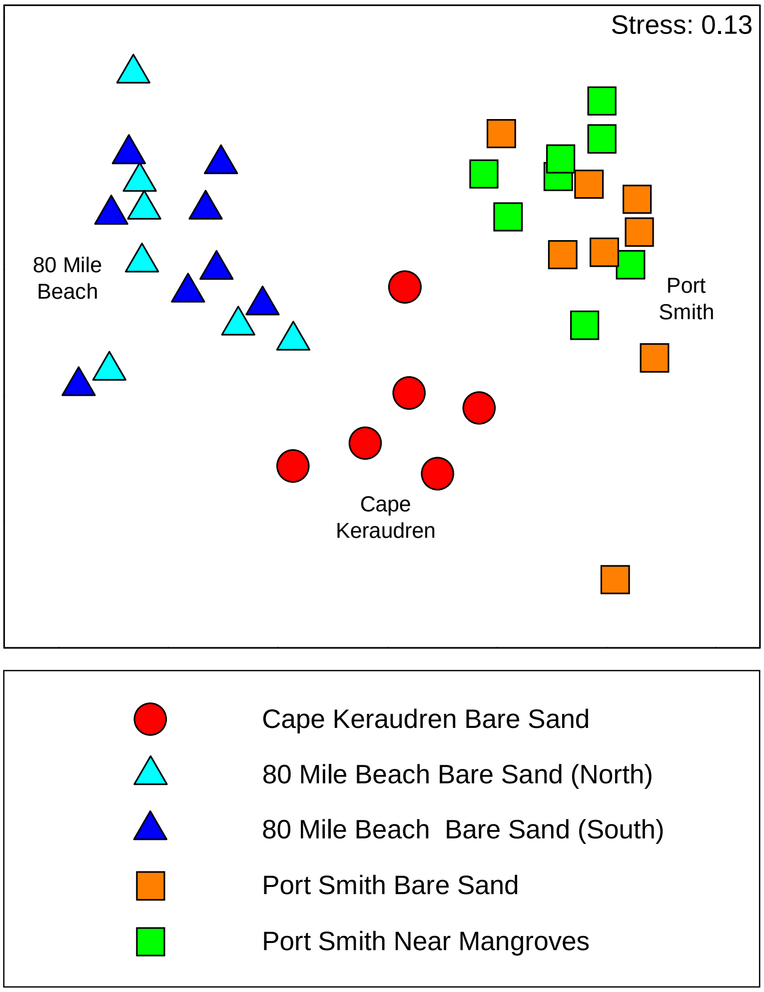

Figure 2.3.8 Nonmetric multidimensional scaling ordination of the mean catch rates of the various species in samples collected with the seine net on each sampling occasion between December 2000 and November 2002 over bare sand at one site at Cape Keraudren and two sites at both Eighty Mile Beach and Port Smith.

A one-way ANOSIM confirmed that the compositions of the fish fauna at the five sites were significantly different (p<0.001, Global R-statistic = 0.715). Pairwise ANOSIM tests revealed that the composition of the fish fauna at the bare sand site at Port Smith did not differ significantly from that at the other Port Smith site, which was close to mangroves, and neither were there significant differences between the compositions of the fish faunas at the two sites at Eighty Mile Beach. However, the faunal composition did differ significantly between sites in the different locations, with p<0.01 or p<0.001 in each case, and the R-statistic of 0.993 being greatest for the comparison between the southern Eighty Mile Beach site and the Port

Smith site that was close to mangroves (Table 2.3.16). SIMPER demonstrated that the community composition at Cape Keraudren was typified by *Craterocephalus mugiloides* and *Arrhamphus sclerolepis.* Samples collected from Eighty Mile Beach were typified by *Escualosa thoracata, Thryssa hamiltonii* and *E. tetradactylum,* whereas *Craterocephalus pauciradiatus* and *Sillago vittata* were more common in seine net samples from Port Smith (Table 2.3.17).

Table 2.3.16 R-statistic values and significance levels for pair-wise ANOSIM tests comparing the fish community composition at each of the five sites sampled with the 60.5 m seine net at Cape Keraudren, Eighty Mile Beach and Port Smith between December 2000 and November 2002. *** $p<0.001$, ** $p<0.01$

	Cape Keraudren	80 Mile Beach North	80 Mile Beach South	Port Smith Bare Sand
80 Mile Beach - North	0.905 ***			
80 Mile Beach - South	0.953 **	0.030		
Port Smith - Bare Sand	0.725 ***	0.949 ***	0.961 **	
Port Smith - Mangroves	0.868 **	0.974 **	0.993 **	0.003

Table 2.3.17 Species identified by SIMPER as typifying fish samples collected with the 60.5 m seine net over bare sand at Cape Keraudren, Eighty Mile Beach and Port Smith between December 2000 and November 2002. When a species typified more than one location, the numbers after those species names refer to the order of abundance of that species in all locations.

Cape Keraudren	80 Mile Beach	Port Smith
Craterocephalus mugiloides	*Escualosa thoracata*	*Craterocephalus pauciradiatus*
Arrhamphus sclerolepis	*Thryssa hamiltonii*	*Atherinomorus lacunosus*
Sillago analis	*Eleutheronema tetradactylum*	*Sillago vittata*
Strongylura strongylura	*Valamugil cunnesius*	*Gerres subfasciatus*
	Polydactylus macrochir	

When the densities of the various species, derived from replicate samples at Cape Keraudren were subjected to MDS ordination, the samples from the late dry season lay towards the bottom left hand corner of the plot and were separated from the early wet samples in the top right hand corner by those for the samples for the early dry season and late wet season (Fig. 2.3.9a). A one-way ANOSIM performed on replicate data revealed that the community composition at Cape Keraudren was significantly influenced by season ($p<0.01$, Global R-statistic = 0.410) (Table 2.3.18). Pairwise ANOSIM tests further revealed that the community composition differed significantly between each season ($p<0.05$ or $p<0.01$), except in the case of late wet *vs* late dry and late wet *vs* early wet (Table 2.3.19). Seine net samples typically contained relatively greater numbers of *Stolephorus carpentariae* in the early dry, *Hyporhamphus quoyi* in the late dry and *C. mugiloides* in the early and late wet (Table 2.3.20).

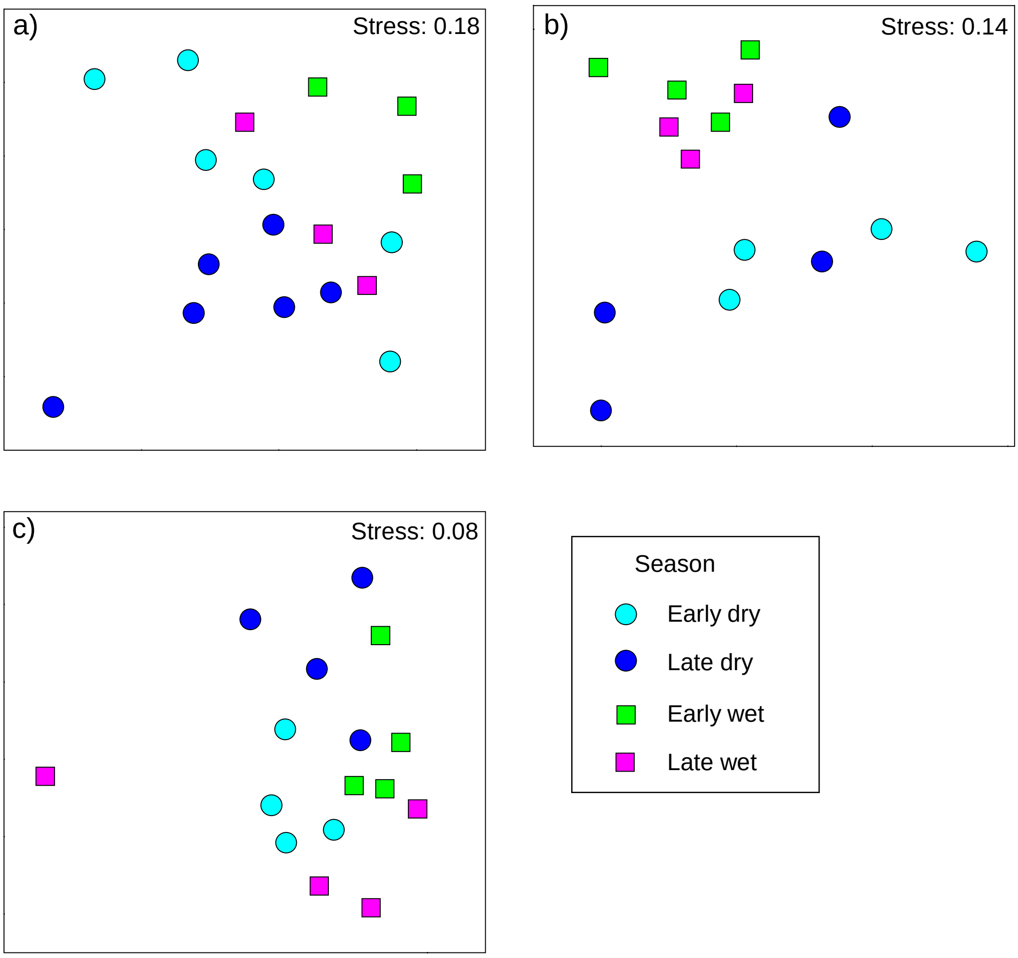

Figure 2.3.9 Nonmetric multidimensional scaling ordination of a) the replicate catch rates of the various species in samples collected with the seine net at Cape Keraudren and the mean catch rates of the various species in samples collected with the seine net at b) Eighty Mile Beach and c) Port Smith over bare sand on each sampling occasion between December 2000 and November 2002.

Table 2.3.18 R-statistic values and significance levels for one-way ANOSIM tests for the effect of season and period (*i.e.* wet *vs* dry) on the fish fauna collected between December 2000 and November 2002 in seine nets over bare sand at Cape Keraudren, Eighty Mile Beach and Port Smith. *** $p<0.001$, ** $p<0.01$

	Cape Keraudren	80 Mile Beach	Port Smith
Season	0.410 **	0.327 **	0.418 ***
Period	0.156	0.468 ***	0.131

Table 2.3.19 R-statistic values and significance levels for pair-wise ANOSIM tests comparing the community composition during each of the four seasons sampled with the 60.5 m seine net at Cape Keraudren between December 2000 and November 2002. ** $p<0.01$, * $p<0.05$

	Early dry	Late dry	Early wet
Late Dry	0.387 **		
Early wet	0.438 *	0.654 *	
Late wet	0.352 *	0.148	0.778

Table 2.3.20 Species identified by SIMPER as typifying fish samples from each season collected with the 60.5 m seine net over bare sand at Cape Keraudren between December 2000 and November 2002. When a species typified more than one season, the numbers after those species names refer to the order of abundance of that species in all seasons.

Early dry	Late dry	Early wet	Late wet
Stolephorus carpentariae	*Craterocephalus mugiloides* [4]	*Craterocephalus mugiloides* [1]	*Craterocephalus mugiloides* [2]
Craterocephalus mugiloides [3]	*Hyporhamphus quoyi*	*Sardinella brachysoma*	
Arrhamphus sclerolepis	*Sillago vittata*	*Gerres oyena*	

When the densities for the various species in samples from Eighty Mile Beach were subjected to MDS ordination, the samples from both the early and late wet seasons formed a relatively tight group in the top left-hand corner of the ordination plot, whereas all but one of those from both the early and late dry seasons were located in the bottom half of the plot (Fig. 2.3.9b). ANOSIM confirmed that the faunal composition at Eighty Mile Beach was significantly influenced by season ($p<0.01$, Global R-statistic = 0.327) and that the composition in the early wet season differed significantly from that in both the early and late dry seasons (Table 2.3.21). SIMPER revealed that this difference in community composition could be attributed to relatively greater numbers of *T. hamiltonii* and *T. setrostris* during the early wet season, whereas large numbers of *H. quoyi* and *E. thoracata* typified the fauna during early dry season and *E. thoracata and Strongylura strongylura* typified the late dry season (Table 2.3.22). ANOSIM also demonstrated that the fish fauna at Eighty Mile Beach was strongly influenced by period, *i.e.* wet *vs* dry ($p<0.001$, R-statistic = 0.468) (Table 2.3.18). SIMPER showed that the difference in community composition between the wet and dry periods was due to the presence of relatively greater numbers of *T. hamiltonii* and *T. setrostris* during the former period and greater numbers of *E. thoracata* and *V. cunnesius* during the latter period.

Table 2.3.21 R-statistic values and significance levels for pair-wise ANOSIM tests comparing the community composition during each of the four seasons sampled with the 60.5 m seine net at Eighty Mile Beach between December 2000 and November 2002. * $p<0.05$

	Early dry	Late dry	Early wet
Late Dry	0.042		
Early wet	0.677 *	0.427 *	
Late wet	0.537	0.130	-0.111

Table 2.3.22 Species identified by SIMPER as typifying fish samples from each season collected with the 60.5 m seine net over bare sand at Eighty Mile Beach between December 2000 and November 2002. When a species typified more than one season, the numbers after those species names refer to the order of abundance of that species in all seasons.

Early dry	Late dry	Early wet	Late wet
Hyporhamphus quoyi	*Escualosa thoracata* 2	*Thryssa hamiltonii* 2	*Thryssa hamiltonii* 1
Escualosa thoracata 1	*Strongylura strongylura*	*Escualosa thoracata* 4	*Escualosa thoracata* 3
Valamugil cunnesius 1	*Valamugil cunnesius* 2	*Thryssa setrostris*	*Eleutheronema tetradactylum* 3
Thryssa hamiltonii 3	*Eleutheronema tetradactylum* 1	*Valamugil cunnesius* 3	*Valamugil cunnesius* 4
Polydactylus macrochir 2	*Paraplagusia bilineata*	*Eleutheronema tetradactylum* 2	*Polydactylus macrochir* 1
Eleutheronema tetradactylum 4	*Polydactylus macrochir* 3		

When the mean densities of the various fish species at Port Smith were subjected to ordination, the samples from each of the four seasons formed groups that progressed cyclically in a clockwise direction (Fig. 2.3.9c). Thus, samples from the early dry season are located toward the lower centre part of the plot, directly below those for the late dry season and to the left of those from the early wet season, which are located above three of the four samples from the late wet season in the bottom right of the plot (Fig. 2.3.9c). ANOSIM revealed that the faunal composition at Port Smith was significantly influenced by season ($p<0.01$, Global R-statistic = 0.418) (Table 2.3.18). The greatest seasonal difference ($p<0.05$, R-statistic = 0.688) was that recorded between the early dry and early wet seasons (Table 2.3.23). SIMPER showed that the early dry season was typified by *Atherinomorus lacunosus* and *Spratelloides delicatulus* whereas the early wet season was typified by *C. pauciradiatus* and *Sardinella brachysoma* (Table 2.3.24).

Table 2.3.23 R-statistic values and significance levels for pair-wise ANOSIM tests comparing the community composition during each of the four seasons sampled using mean density data of fish collected with the 60.5 m seine net at Port Smith between December 2000 and November 2002. * $p<0.05$

	Early dry	Late dry	Early wet
Late Dry	0.458 *		
Early wet	0.688 *	0.313	
Late wet	0.302	0.365	0.500 *

Table 2.3.24 Species identified by SIMPER as typifying fish samples from each season collected with the 60.5 m seine net over bare sand at Port Smith between December 2000 and November 2002. When a species typified more than one season, the numbers after those species names refer to the order of abundance of that species in all seasons.

Early dry	Late dry	Early wet	Late wet
Craterocephalus pauciradiatus 2	*Craterocephalus pauciradiatus* 4	*Craterocephalus pauciradiatus* 1	*Hyporhamphus quoyi* 1
Atherinomorus lacunosus 1	*Sardinella fijiense*	*Sillago vittata* 3	*Atherinomorus lacunosus* 2
Spratelloides delicatulus	*Sillago vittata* 2	*Sardinella brachysoma*	*Craterocephalus pauciradiatus* 3
Hyporhamphus quoyi 2		*Gerres subfasciatus*	*Leiognathus equulus*
Sillago vittata 1		*Atherinomorus lacunosus* 3	*Stolephorus carpentariae*

2.3.4 Rotenone samples

2.3.4.1 Species composition

A total of 3281 fish, representing 82 species and 38 families and weighing 15.58 kg, was collected using the ichthyocide rotenone in intertidal pools at Cape Keraudren and Port Smith (Table 2.3.25). Nineteen of the 82 species were of commercial and recreational importance and contributed 23.1% to the total catch of fish. A further five species were important only from a recreational perspective. The most abundant species (and their percentage contributions to the total catch) were the glassfish *Ambassis vachelli* (32.5%), two species of atherinid, *C. pauciradiatus* (14.4%) and *Atherinomorus lacunosus* (7.5%), and the Moses snapper *Lutjanus russelli* (5.2%), of which only the last is fished commercially or recreationally. The top ranked species in terms of biomass was the estuary rockcod *Epinephelus coioides* (19.3%), the individuals of which ranged from 22 to 302 mm in total length, followed by *Liza macrolepis* (13.3%) and *L. russelli* (8.3%). Species of commercial and recreational significance contributed 68.7% to the total weight of fish collected using rotenone (Table 2.3.25).

Although the total number and total biomass of fish caught at Cape Keraudren (1710 fish and 7.72 kg) was similar to that collected at Port Smith (1571 fish and 7.86 kg), the total number of species recorded at Cape Keraudren (39) was far less than at Port Smith (65) (Table 2.3.25). Furthermore, only 22 of the species, *i.e.* 27%, were common to both locations. Although most of the species unique to one location were rare at that location, others, such as *A. lacunosus* and *S. vittata,* which ranked third and eighth in terms of their contribution to the total number of fish, were recorded only at Port Smith (Table 2.3.25).

2.3.4.2 Number of species, densities and biomass of fish

ANOVA of the number of fish species caught in intertidal pools using rotenone at Cape Keraudren and Port Smith on each sampling occasion showed a significant difference in this variable between locations ($p<0.01$) but not among seasons (Table 2.3.26). The mean number of species at Port Smith, 16.7, was greater than at Cape Keraudren, 11.4 (Fig. 2.3.10a).

Table 2.3.26 Mean squares and significance levels for ANOVAs of the number of species, density and biomass per unit area of fish in rotenone samples collected from intertidal pools at Cape Keraudren and Port Smith in each season between June 2001 and November 2002. ** $p<0.01$

	Main effects		**Interactions**	
Source	Location (L)	Season (S)	L x S	Residual
Degrees of freedom	1	3	3	21
Number of species	179.15 **	28.44	32.15	21.85

The mean number of fish caught using rotenone in intertidal pools at Cape Keraudren rose from a minimum of 39.7 fish $10m^{-2}$ during the late wet season to a maximum of 198.5 fish $10m^{-2}$ during the late dry season, before declining to 153.0 fish $10m^{-2}$ during the early wet season (Fig. 2.3.10b). In contrast, the mean number of fish at Port Smith was highest in the early dry season (139.2 fish $10m^{-2}$) and lowest during the late dry season (64.6 fish $10m^{-2}$). The mean biomass of fish at Cape Keraudren followed a similar trend to the number of fish, rising from 98.3 g $10m^{-2}$ in the late wet season to 728.9 g $10m^{-2}$ during the late dry season before declining to 494.5 g $10m^{-2}$ during the early wet season (Fig. 2.3.10c). The mean biomass at Port Smith remained relatively constant at *ca* 450 g $10m^{-2}$ between the late wet and late dry seasons before increasing markedly to 1073.9 g $10m^{-2}$ in the early dry season (Fig. 2.3.12c).

Table 2.3.25 Commercial (C) or recreational (R) importance, rank by abundance (R), number (N), percentage contribution (%) and length range of each fish species caught between June 2001 and November 2002 using rotenone in intertidal rock pools at Cape Keraudren and Port Smith. The ranking by weight, total biomass (g) and percentage contribution by weight of each species caught in the study region is also given.

		Numbers									Biomass			Length
		Total			Cape Keraurdren			Port Smith			Total			Range
Species	Fisheries	R	N	%	R	N	%	R	N	%	R	g	%	(mm)
Ambassis vachelli		1	1066	32.5	1	895	52.3	3	171	10.9	6	1003.2	6.4	21 - 76
Craterocephalus pauciradiatus		2	474	14.4	2	147	8.6	1	327	20.8	14	249.6	1.6	14 - 60
Atherinomorus lacunosus		3	247	7.5				2	247	15.7	13	251.5	1.6	29 - 84
Lutjanus russelli	C,R	4	171	5.2	7	54	3.2	4	117	7.4	3	1300.9	8.3	26 - 159
Amniataba caudavittatus		5	143	4.4	3	142	8.3	45	1	0.1	8	815.3	5.2	19 - 126
Liza macrolepis	C,R	6	125	3.8	4	115	6.7	20	10	0.6	2	2078.1	13.3	16 - 223
Gerres subfasciatus		7	117	3.6	8	42	2.5	6	75	4.8	11	427.0	2.7	23 - 110
Sillago vittata	C,R	8	100	3.0				5	100	6.4	17	165.2	1.1	21 - 106
Acanthopagrus latus	C,R	9	80	2.4	5	73	4.3	25	7	0.4	7	885.5	5.7	23 - 124
Epinephelus coioides	C,R	10	73	2.2	10	17	1.0	8	56	3.6	1	3007.9	19.3	22 - 302
Favonigobius lateralis		11	72	2.2				7	72	4.6	44	7.7	>0.1	14 - 33
Gerres oyena		12	71	2.2	9	26	1.5	9	45	2.9	21	115.9	0.7	14 - 84
Liza subviridis	C,R	13	64	2.0	6	64	3.7				5	1044.5	6.7	41 - 198
Abudefduf septemfasciatus		14	44	1.3	20	5	0.3	10	39	2.5	15	197.2	1.3	14 - 116
Platycephalus endrachtensis	R	15	36	1.1	33	1	0.1	11	35	2.2	18	164.5	1.1	12 - 153
Omobranchus germaini		16	27	0.8	25	2	0.1	13	25	1.6	40	13.5	0.1	18 - 69
Sillago burrus	C,R	17	26	0.8				12	26	1.7	35	19.4	0.1	25 - 74
Goby sp7		18	25	0.8	16	7	0.4	16	18	1.1	41	13.3	0.1	13 - 55
Glossogobius sp1		19	24	0.7	33	1	0.1	14	23	1.5	27	42.2	0.3	31 - 75
Goby sp6		20	21	0.6	14	12	0.7	22	9	0.6	33	28.7	0.2	12 - 83
Bathygobius fuscus		21	20	0.6				15	20	1.3	29	33.2	0.2	14 - 83
Epinephelus malabaricus	C,R	22"	17	0.5	11	14	0.8	32	3	0.2	9	737.9	4.7	23 - 286
Epinephelus quoyanus	C,R	22"	17	0.5	16	7	0.4	20	10	0.6	10	442.2	2.8	37 - 172
Youngeichthys nebulosus		24	16	0.5	11	14	0.8	37	2	0.1	26	49.9	0.3	25 - 74
Arothron manilensis		25"	15	0.5				17	15	1.0	4	1060.9	6.8	96 - 163
Leviprora inops	R	25"	15	0.5	25	2	0.1	18	13	0.8	24	55.3	0.4	24 - 154
Valamugil seheli	C,R	27	13	0.4	13	13	0.8				19	161.0	1.0	53 - 156
Valamugil perusii	C,R	28	11	0.3				19	11	0.7	20	121.3	0.8	76 - 132
Acanthurus grammoptilus		29"	10	0.3	23	3	0.2	25	7	0.4	23	84.3	0.5	31 - 93
Terapon jarbua		29"	10	0.3	15	10	0.6				34	21.6	0.1	40 - 72

Table 2.3.25 continued.

Species	Fisheries	Abundance									Biomass			Length
		Total			Cape Keraurdren			Port Smith			Total			Range
		R	*n*	%	R	*n*	%	R	*n*	%	R	g	%	(mm)
Cephalopholis boenak	C,R	31"	9	0.3				22	9	0.6	12	377.5	2.4	34 - 235
Plagiopsetta glossa		31"	9	0.3				22	9	0.6	28	34.4	0.2	18 - 94
Butis sp1		33"	7	0.2	16	7	0.4				31	30.9	0.2	48 - 109
Lutjanus argentimaculatus	C,R	33"	7	0.2	16	7	0.4				22	94.9	0.6	48 - 114
Siganus fuscescens		35	6	0.2				27	6	0.4	30	31.4	0.2	60 - 77
Goby sp14		36"	5	0.2				28	5	0.3	82	0.1	>0.1	9 - 11
Mugil cephalus	C,R	36"	5	0.2	20	5	0.3				16	170.0	1.1	138 - 156
Pelates sexlineatus		36"	5	0.2	20	5	0.3				49	5.0	>0.1	34 - 52
Paracentropogon vespa		39"	4	0.1				29	4	0.3	54	2.9	>0.1	18 - 43
Priolepis semidoliatus		39"	4	0.1				29	4	0.3	64	0.9	>0.1	25 - 26
Scobinichthys granulatus	R	39"	4	0.1				29	4	0.3	50	4.8	>0.1	33 - 52
Engyprosopon grandisquama		42"	3	0.1				32	3	0.2	61	1.6	>0.1	26 - 43
Festucalex scalaris		42"	3	0.1	23	3	0.2				66	0.8	>0.1	70 - 83
Omobranchus ferox		42"	3	0.1				32	3	0.2	67	0.6	>0.1	21 - 40
Sillago analis	C,R	42"	3	0.1				32	3	0.2	32	29.3	0.2	83 - 136
Upeneus tragula		42"	3	0.1				32	3	0.2	47	6.0	>0.1	53 - 59
Chelmon marginalis		47"	2	0.1				37	2	0.1	48	6.0	>0.1	42 - 57
Craterocephalus mugiloides		47"	2	0.1				37	2	0.1	72	0.3	>0.1	28 - 33
Enneapterygius sp.		47"	2	0.1				37	2	0.1	68	0.5	>0.1	27 - 28
Goby sp12b		47"	2	0.1				37	2	0.1	75	0.2	>0.1	17 - 22
Goby sp15		47"	2	0.1	33	1	0.1	45	1	0.1	75	0.2	>0.1	12 - 16
Goby sp16		47"	2	0.1	25	2	0.1				75	0.2	>0.1	18 - 23
Periophthalmus argentilineatus		47"	2	0.1	25	2	0.1				52	3.3	>0.1	44 - 63
Plectorhinchus polytaenia		47"	2	0.1	33	1	0.1	45	1	0.1	38	15.6	0.1	65 - 88
Pseudorhombus arsius	R	47"	2	0.1				37	2	0.1	37	16.5	0.1	26 - 120
Repomucenus russelli		47"	2	0.1				37	2	0.1	71	0.4	>0.1	20 - 35
Scatophagus argus		47"	2	0.1	25	2	0.1				45	7.5	>0.1	43 - 47
Selenotoca multifasciata		47"	2	0.1	25	2	0.1				39	15.4	0.1	65 - 76
Sphyraena fostersi	R	47"	2	0.1	25	2	0.1				43	10.3	0.1	97 - 100
Stolephorus carpentariae		47"	2	0.1				37	2	0.1	70	0.4	>0.1	31 - 32

Table 2.3.25 continued.

		Abundance									Biomass			Length
		Total			Cape Keraurdren			Port Smith			Total			Range
Species	Fisheries	R	*n*	%	R	*n*	%	R	*n*	%	R	g	%	(mm)
Valamugil cunnesius	C,R	47"	2	0.1	25	2	0.1				25	51.5	0.3	91 - 163
Apogon sp.		62"	1	<0.1				45	1	0.1	74	0.2	>0.1	25
Bostrychus sinensis		62"	1	<0.1	33	1	0.1				51	3.6	>0.1	74
Calliurichthys afilum		62"	1	<0.1				45	1	0.1	75	0.2	>0.1	32
Choerodon cauteroma	C,R	62"	1	<0.1				45	1	0.1	58	2.1	>0.1	48
Cynoglossus puncticeps		62"	1	<0.1				45	1	0.1	72	0.3	>0.1	31
Eurypegasus draconis		62"	1	<0.1				45	1	0.1	79	0.1	>0.1	8
Goby sp10		62"	1	<0.1				45	1	0.1	69	0.5	>0.1	35
Goby sp13		62"	1	<0.1	33	1	0.1				56	2.8	>0.1	71
Goby sp9		62"	1	<0.1				45	1	0.1	55	2.8	>0.1	55
Heniochus acuminatus		62"	1	<0.1				45	1	0.1	42	11.5	0.1	73
Istiblennius meleagris		62"	1	<0.1				45	1	0.1	57	2.7	>0.1	71
Istigobius nigroocellatus		62"	1	<0.1				45	1	0.1	58	2.1	>0.1	61
Lutjanus carponotatus	C,R	62"	1	<0.1				45	1	0.1	53	3.0	>0.1	60
Omobranchus lineolatus		62"	1	<0.1				45	1	0.1	63	1.0	>0.1	43
Pelates quadrilineatus		62"	1	<0.1				45	1	0.1	46	6.6	>0.1	78
Plectropomus maculatus	C,R	62"	1	<0.1				45	1	0.1	36	18.7	0.1	109
Pseudomugil cyanodorsalis		62"	1	<0.1	33	1	0.1				79	0.1	>0.1	25
Pterois antennata		62"	1	<0.1				45	1	0.1	65	0.9	>0.1	41
Sardinella fijiense		62"	1	<0.1				45	1	0.1	60	1.9	>0.1	61
Scaevius milii		62"	1	<0.1				45	1	0.1	62	1.4	>0.1	43
juvenile teleost E		62"	1	<0.1				45	1	0.1	79	0.1	>0.1	23
Total fish			3281			1710			1571					
Number of species			82			39			65					
Total biomass (kg)			15.58			7.72			7.86					

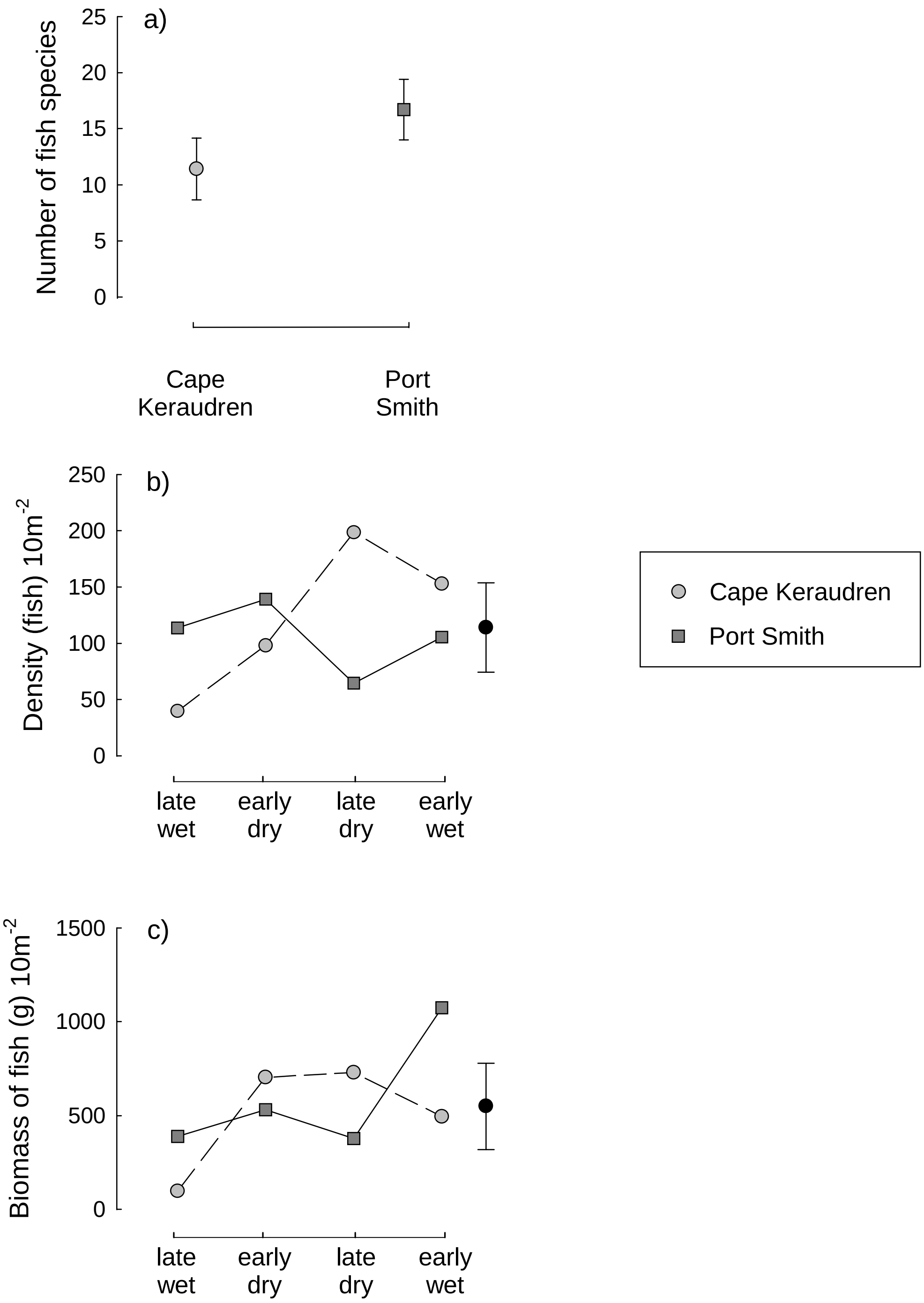

Figure 2.3.10 a) Mean number of fish species ± 95% CL, b) density of fish 500 m^{-2} ± 95% CL and c) biomass of fish 500 m^{-2} ± 95% CL collected with rotenone from intertidal pools at Cape Keraudren and Port Smith in each season between June 2001 and November 2002.

2.3.4.3 Ichthyofaunal composition of rotenone samples

When the mean densities of the various fish species in samples collected on the different sampling occasions from intertidal pools using rotenone were subjected to MDS ordination, the samples from Cape Keraudren formed a group on the left of the plot that showed no overlap with the samples from Port Smith on the right of the plot (Fig. 2.3.11a). One-way ANOSIM confirmed that the compositions of the fish faunas in intertidal pools was strongly influenced by location (p<0.01, R-statistic = 0.876). Relatively greater numbers of *Amniataba* *caudavittatus* and *L. macrolepis* at Cape Keraudren and *S. vittata* and *A. lacunosus* at Port Smith were identified by SIMPER as contributing, in particular, to the difference in community composition between these two locations (Table 2.3.27).

Table 2.3.27 Species identified by SIMPER as typifying fish samples collected with rotenone from intertidal pools at Cape Keraudren, Eighty Mile Beach and Port Smith between December 2000 and November 2002.

Cape Keraudren	Port Smith
Amniataba caudavittatus	*Sillago vittata*
Liza macrolepis	*Atherinomorus lacunosus*
Ambassis vachelli	*Platycephalus endrachtensis*
Acanthopagrus latus	*Arothron manilensis*
	Craterocephalus pauciradiatus

In Figs 2.3.11b,c the arrows join the points for the samples obtained from intertidal pools for sequential seasons at both Cape Keraudren and Port Smith, irrespective of the year. Thus, there are two points for the samples in the early dry and late dry seasons, but only a single point for both the early wet and late wet seasons at both locations. The points for the samples for the sequential seasons followed a clearly cyclical pattern at Port Smith but not at Cape Keraudren.

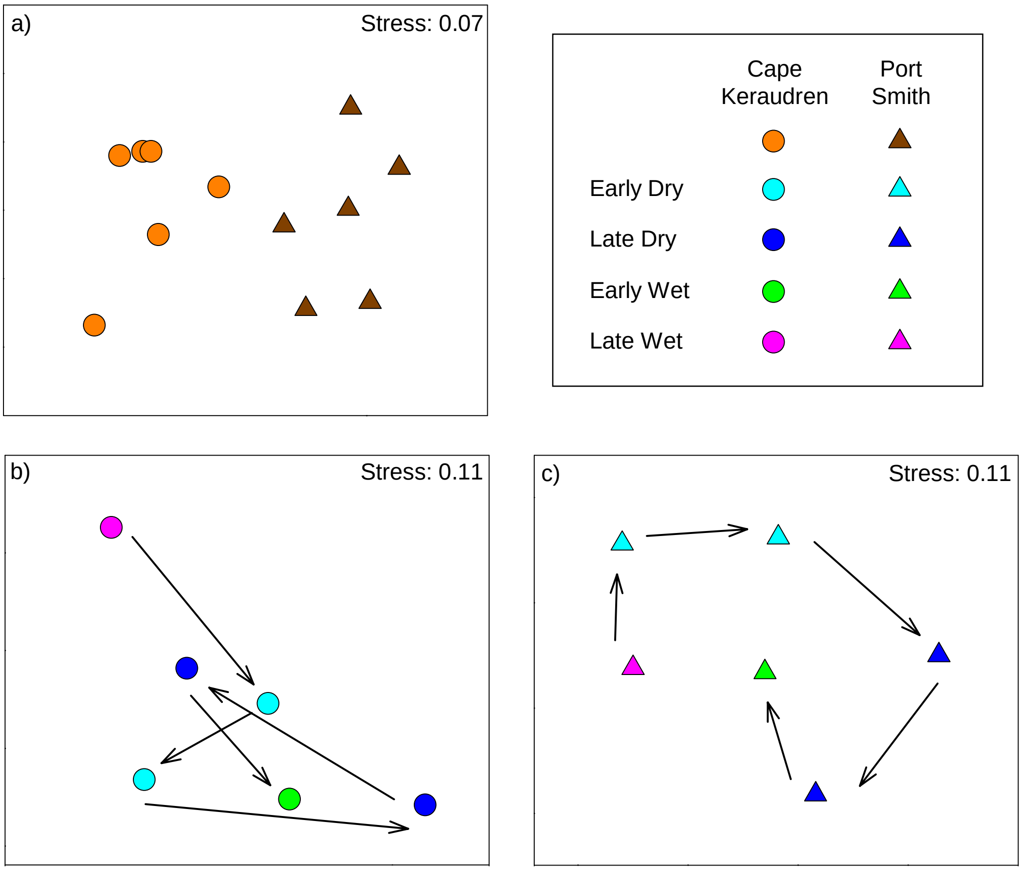

Figure 2.3.11 Nonmetric multidimensional scaling ordination of the mean densities of the various species in samples collected using rotenone in intertidal pools at (a) Cape Keraudren and Port Smith and (b) Cape Keraudren and (c) Port Smith on each sampling occasion between June 2001 and November 2002.

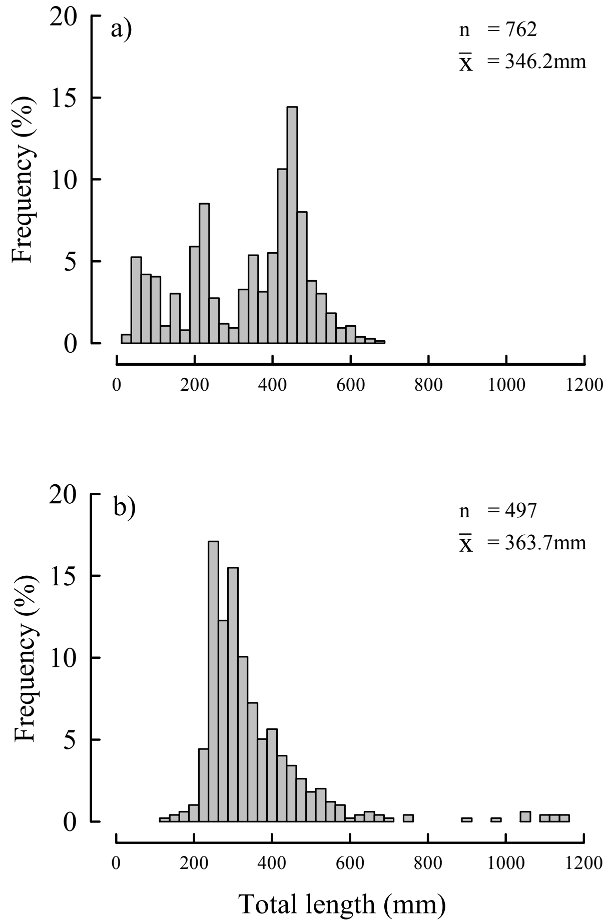

Figure 2.3.12 Length-frequency histograms for a) *Eleutheronema tetradactylum* and b) *Polydactylus macrochir* caught by gill and seine netting in nearshore, shallow waters.

2.3.5 Length-frequency distributions

A combination of the size of catches, length-frequency distributions and size at maturity of the more important commercial and/or recreational fish species can be used to elucidate the ways in which nearshore waters are used by those species and to provide an idea of the relative importance of those waters to those species. Thus, for example, the question of whether a species is resident in those waters throughout its life cycle or uses those waters mainly as a nursery area can be ascertained from the catches of its juveniles and adults. However, the limited published data on the size at maturity of the species in nearshore waters (*e.g.* Kaiola *et al*., 1993, www.fishbase.org), makes it difficult to determine whether a "medium sized" individual of a species is a juvenile or an adult. For this reason, we have had to supplement those data with preliminary data on maturity that we have collected during this study and in a current FRDC on the biology of some of these species in north western Australia FRDC (2002/003), the results of which, in some cases, conflict with those recorded in the above two references.

Both of the threadfin salmons, *E. tetradactylum* and *P. macrochir*, which are protandrous hermaphrodites, reach maturity at about 250mm. Thus, the very substantial numbers of the juveniles and adults of *E. tetradactylum* in catches obtained from nearshore, shallow waters along the Pilbara and Kimberley coasts demonstrate that this species is resident in this type of habitat (Fig. 2.3.12a). Although large numbers of the adults of *P. macrochir* were caught in the same habitats, the numbers of smaller juveniles obtained from those same waters was relatively small (Fig. 2.3.12b). This obviously implies that the smaller juveniles tend to occupy a type of habitat not sampled during the present study.

In contrast to the situation with the two species of threadfin salmon, the estuary rockcod *Epinephelus coioides* and malabar grouper *Epinephelus malabaricus*, which are protogynous hermaphrodites, were represented entirely by juveniles in our samples from nearshore, shallow waters and these came almost exclusively from intertidal pools. The conclusion that these individuals are juveniles is based on the fact that only one individual of either species exceeded 500mm, the approximate length at which both of these species reach maturity (Fig. 2.3.13a,b). It is also consistent with the capture of substantial numbers of the adults of these species further offshore in waters of 15 to 30m depth (Chapter 3). Thus, the above two species emigrate offshore from their nursery areas in nearshore, shallow waters before they reach maturity. The far smaller catch of *E. malabaricus* than *E. coioides* in nearshore, shallow waters parallels the situation found offshore (Chapter 3).

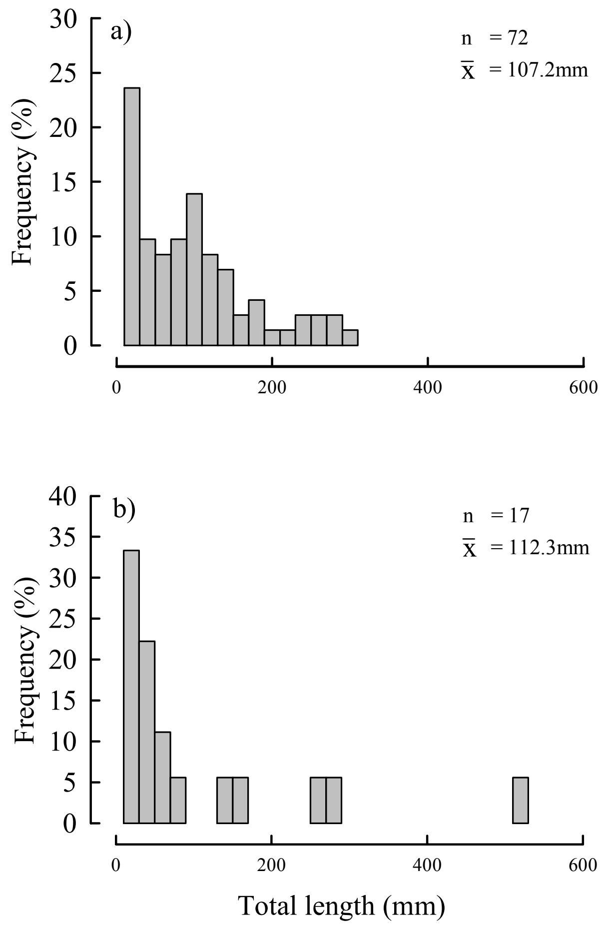

Figure 2.3.13 Length-frequency histograms for a) *Epinephelus coioides* and b) *Epinephelus malarbaricus* caught by gill and seine netting and the use of rotenone in nearshore, shallow waters.

Virtually all of the individuals of *Lutjanus russelli* were caught in intertidal pools and very few of these exceeded 125 mm, a length well below that at which this species reaches maturity (Fig. 2.3.14a). All of the relatively small number of *Lutjanus argentimaculatus* that were caught were also juveniles (Fig. 2.3.14b). This suggests that these two congeneric lutjanids use nearshore, shallow waters as nursery areas before migrating offshore, where they become susceptible to capture by commercial fishers (Chapter 1).

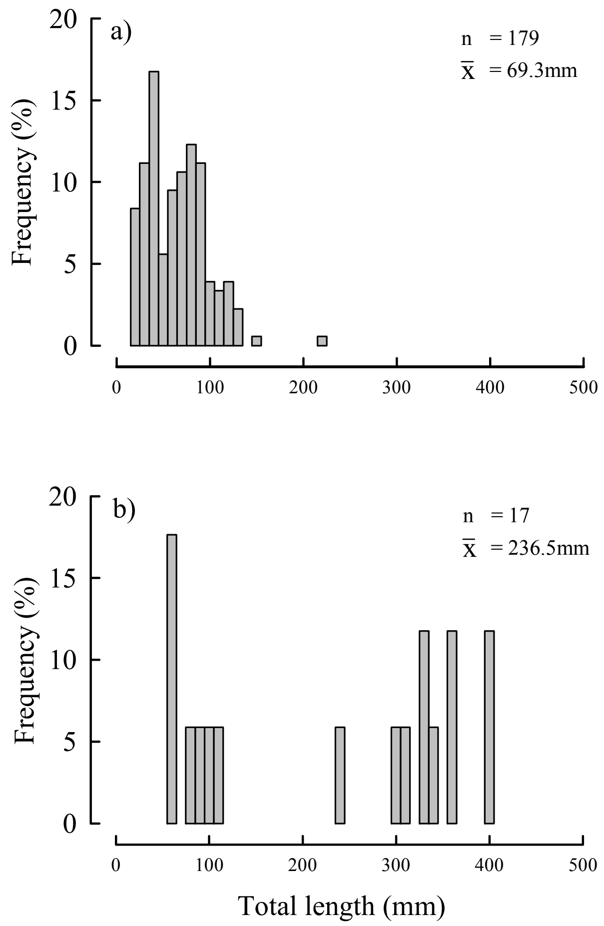

Figure 2.3.14 Length-frequency histograms for a) *Lutjanus russelli* and b) *Lutjanus argentimaculatus* caught by gill and seine netting and the use of rotenone in nearshore, shallow waters.

Since the lengths of the sharks *Rhizoprionodon taylori* and *Carcharhinus cautus* ranged upwards to close to their maximum, these two species can complete their life cycles within nearshore, shallow waters and are thus residents in these waters (Fig. 2.3.15a,b). In contrast, the maximum lengths of *Negaprion acutidens* and *Pristis zijsron* were far less than the maxima recorded for these chondrichthyans and thus these species use nearshore, shallow waters as nuresery areas (Fig. 2.3.16a,b).

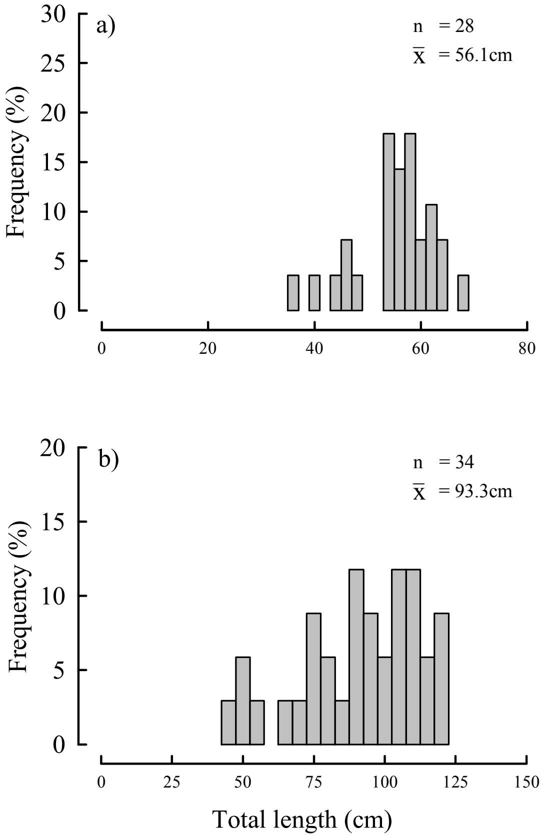

Figure 2.3.15 Length-frequency histograms for a) *Rhizoprionodon taylori* and b) *Carcharhinus cautus* caught by gill and seine netting in nearshore, shallow waters.

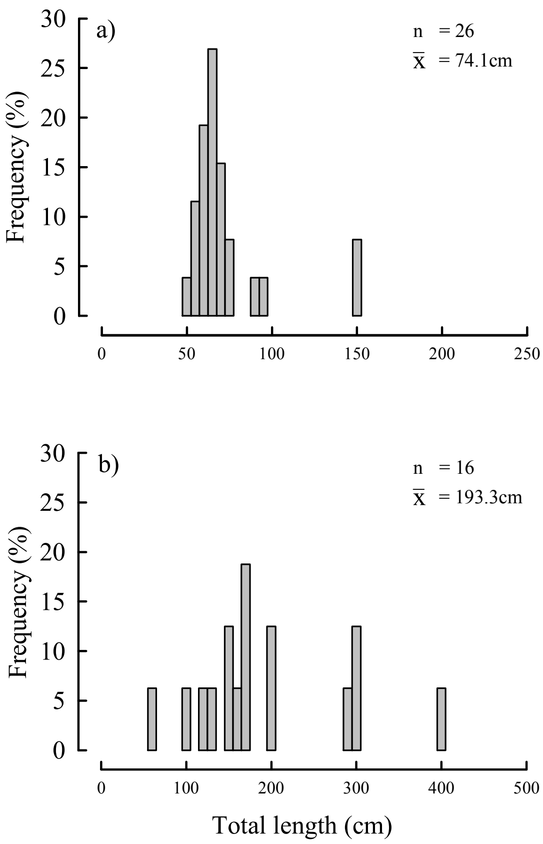

Figure 2.3.16 Length-frequency histograms for a) *Negaprion acutidens* and b) *Pristis zijsron* caught by gill and seine netting in nearshore, shallow waters.

2.4 Discussion

2.4.1 Use of nearshore waters by commercial and recreational fish species

The fish caught in nearshore waters of the Pilbara and Kimberley coasts, using three different sampling methods, comprised 170 identifiable species representing 66 families. Fifty three of these species are fished commercially and recreationally in this location and a further 17 are fished exclusively by recreational fishers. The number of commercially and/or recreationally important species caught by gill nets (52) was greater than by seine net (37) and by using rotenone (24). This difference is mainly due to the fact that gill nets catch the larger species that are sought after as food fish, such as the barramundi *Lates calcarifer* and several species of carcharhinid shark. These larger species are less abundant in the shallower waters sampled by the seine net and by rotenone. Larger more mobile fish species would also tend to avoid the seine net.

Juveniles represented sixty of the 70 species, that were caught in nearshore, shallow waters and which contributed to the commercial and/or recreational fishery. However, less than half of these species (24) were also caught as adults. Thus, as they approach adulthood, the individuals of these latter species presumably emigrate from nearshore, shallow waters into deeper, offshore waters where they spawn. For example, the juveniles of the Moses snapper *Lutjanus russelli* were largely confined to intertidal pools, in which they were very abundant, while the adults of this lutjanid were caught neither in these pools nor by seine and gill netting in waters near to the shore. The adults of *L. russelli,* which contribute *ca* 27 t per year to the offshore trawl fishery along the Pilbara and Kimberley coasts (Department of Fisheries Western Australia, CAES), are caught further offshore (Chapters 1,3). The estuary cod *Epinephelus coioides* was likewise largely found as juveniles in intertidal pools and as adults in offshore waters. Thus, although none of the individuals of *E. coioides* caught in intertidal pools exceeded 350 mm, the adults of this serranid grow to more than 1200 mm and 30 kg (G. Young, unpublished data) and make a significant contribution to the offshore trawl and trap fishery in Western Australia (Department of Fisheries Western Australia, CAES). Yet, it should be recognized that the pools were sampled at low tide and that the mangroves that surround these pools only become covered by water at high tide. This point is important because studies conducted elsewhere (Sheaves, 1992, 1996) indicate that the juveniles of these species may have a preference for mangrove habitats and may thus move into these areas as the tide begins to rise.

Our catch data demonstrate that certain species of elasmobranch also use the nearshore waters along the Pilbara and Kimberley coasts only as nursery areas. This applied, for example, to the lemon shark *Negaprion acutidens,* which was caught solely as juveniles and predominantly in mangroves, and the green sawfish *Pristis zijsron,* which was also caught only as juveniles, but, in the case of this species, came from exclusively over bare sand. The identification of the nursery habitat of *P. zijsron* is very important because this species has been placed on the IUCN red list of endangered species.

In contrast to the situation with species such as *L. russelli, E. coioides*, *N. acutidens* and *P. zijsron,* the juveniles and adults of both the king and blue threadfin salmons, *Polydactylus macrochir* and *Eleutheronema tetradactylum,* were caught in large numbers over sand in nearshore, shallow waters. Although no small juveniles of *P. macrochir* were collected in this study, it is assumed that these small individuals occupy an unsampled habitat in this region. These two species, which are thus considered permanent residents in these waters, were the most abundant of the commercial fish species caught during the present study. The combined landings of these two polynemid species in the Kimberley Gill Net and Barramundi Fishery over recent years have ranged from 47 to 95 t (Department of Fisheries Western Australia, CAES, Chapter 1). Although the juveniles and adults of the nervous shark *Carcharhinus cautus* were also relatively abundant in our gill net samples, they were caught mainly in mangroves rather than over bare sand. This nearshore resident carcharinid species also occupies mangrove habitats in Shark Bay, approximately 1000 km to the south of our study area (White & Potter, in press).

When all of the 170 fish species that were caught during the present study are taken into account, including the smaller species that are not fished commercially and/or recreationally, it was found that the juveniles of 152 of these species (89.9%) were caught in nearshore, shallow waters. This high percentage contribution parallels the values of 80 – 97% recorded in comparable nearshore habitats in Selangor, Malaysia (Sasekumar *et al.,* 1992) and exceeds that of the *ca* 70% estimated for nearshore waters at Dampier (Blaber *et al.,* 1985), which is located *ca* 300 km to the south west of our study area.

In terms of numbers, the fish faunas in nearshore, shallow waters along the Pilbara and Kimberley coasts were dominated by small species and particularly those of engraulids, atherinids and clupeids. Thus, although emphasis has previously been placed on commercially and/or recreationally important species, the importance of these small species in maintaining the commercial and/or recreational fish stocks in these waters cannot be underestimated. This conclusion is based on the fact that the members of the above three families typically constitute the prey of large predatory fish (see for *e.g.* Blaber *et al.* 1990; Robertson and Duke, 1990a,b), and preliminary work conducted during this study and a current FRDC (2002/003), has shown this to be particularly the case for the threadfin salmons, estuary rockcod, malabar grouper and mangrove jack along the Pilbara and Kimberley coasts.

2.4.2 Habitat and location differences in the fish faunas.

The use of three sampling methods enabled the fish faunas in different habitat types to be sampled and increased the chances of catching species that are not susceptible to capture by a particular sampling technique. Thus, rotenone is especially effective in sampling small and isolated water bodies, while seine netting is useful for catching fish that occupy shallow water near the water's edge and gill nets are effective in sampling waters slightly further from the shoreline. The differences in the fish faunas obtained from intertidal pools using rotenone and from nearshore, unvegetated shallow waters by seine netting are demonstrated by the fact that only 28 of a collective total of 145 species were recorded in both of these habitat types. The major difference between the fish faunas of intertidal pools and nearshore bare sand areas resides in the fact that *Ambassis vachelli, L. russelli* and *Amniataba caudavittatus* were relatively far more abundant in the former habitat type, whereas the small pelagic species *Stolephorus carpentariae, Sardinella brachysoma, Spratelloides delicatulus* and *Sardinella fijiense* were relatively far more numerous in the latter habitat type.

Gill netting was the only sampling technique that was used in more than one habitat type, *i.e.* bare sand and mangroves. The compositions of the fish faunas caught by gill netting over bare sand and in mangroves at Cape Keraudren and Port Smith were significantly different, and this was particularly the case in the former location where the sites representing the two habitat types were further apart. Thus, *E. tetradactylum*, *P. macrochir, Sillago analis* and *Chanos chanos* were relatively more abundant over bare sand than in mangroves, whereas the reverse was true for *Liza macrolepis, C. cautus* and *L. argentimaculatus*. In both locations, *E. tetradactylum* was an important typifying species for the bare sand habitat and *L. macrolepis* was an important diagnostic species for the mangrove habitat. However, the suites of species that typified the faunas in the two habitat types at the above locations otherwise had little in common.

Since Port Smith, the most northerly location, and Eighty Mile Beach are separated by a distance of *ca* 200 km, and a further 100 km separates the latter location from Cape Keraudren, the most southerly location, it is not surprising that the compositions of the fish faunas in the nearshore waters of these three locations were significantly different. However, although Eighty Mile Beach is located between Port Smith and Cape Keraudren, the points on the ordination plots for the samples obtained by gill netting and seine netting at this location lay to the left of those for the other locations. In other words, the composition of the fish fauna in nearshore waters at Eighty Mile Beach was not intermediate between those at Port Smith and Cape Keraudren, as might have been expected from their relative geographical locations. It is thus relevant that the progressive change that occurred in the fauna from Port Smith to Cape Keraudren to Eighty Mile Beach paralleled the progressive shift that occurred in the degree of exposure to tidal action and thus the turbidity of the water, with the conditions being least extreme at Port Smith and most extreme at Eighty Mile Beach.

The conclusion that, at least in part, the above types of environmental variation could have been responsible for the differences in the fish faunas of the three locations is consistent with the differences found between the types of habitat *vis a vis* the sediment type of the habitats occupied by *Valamugil cunnesius* and *Liza macrolepis* (Blaber, 1976). Thus, paralleling the results of Blaber (1976), *V. cunnesius* was the most common mullet species in the fine silty sediment that characterised Eighty Mile Beach, while *L. macrolepis* was very abundant over the coarse sediment at Port Smith. If the above conclusions are correct, the influence of tidal action and other associated environmental effects exert a greater influence on ichthyofaunal composition than those that are associated with latitude.

One of the most important typifying species of the gill net samples over bare sand at Cape Keraudren was a chondricthyan, namely the green sawfish *Pritis zijsron*. This contrasts markedly with the samples collected using this method over bare sand at Eighty Mile Beach and Port Smith. Indeed, the gill net samples at Cape Keraudren contained a greater number of chondricthyans, which are generally very much larger than the common fish species found at these locations, than those obtained from the other two locations. This accounts for the fact that the biomass in gill net samples from the former location was significantly greater than those obtained using the same method in the other two locations. A larger number of chondricthyan species also accounts for the number of fish species being far higher in the late wet period at Cape Keraudren than at the other two locations and even at Cape Keraudren at other times of the year. This is paralleled by the situation in the seine net catches. Since the elasmobranchs in both the gill and seine net catches were mainly young juveniles, the nearshore, shallow waters at Cape Keraudren clearly play an important nursery role for chondricthyans during the late wet period.

MDS ordination and the results of ANOSIM tests demonstrated very clearly that the compositions of the fish faunas in the intertidal pools at Port Smith and Cape Keraudren differed markedly. Indeed, no species contributed to the suite of main typifying species of the fish faunas in the pools of both locations. However, these differences are hardly surprising in view of the large latitudinal distance between these two locations and, even more particularly, between the environmental conditions of those pools. The intertidal pools at Cape Keraudren contain mangrove debris, pneumatophores and roots and, at high tide, its waters become confluent with those surrounding the mangrove stands (Plate 2.2.5). In contrast, the intertidal pools at Port Smith contain bare sand and oyster-covered rocks and are essentially not associated with any form of vegetation (Plate 2.2.6). The clearer water, bare sand and greater amounts of rock at Port Smith almost certainly accounts for the greater number of sand-dwelling species, such as *Sillago vittata* and *Platycephalus endrachtensis*, and of reef-dwelling species, such as *Abudefduf septemfasciatus* and *Cephalopholis boenak*, in this location. The presence of clearer water at Dampier than in various regions in Queensland and northern Australia was also invoked by Blaber *et al.* (1985) to account for differences in the ichthyofaunal composition between those locations.

2.4.3 Intra-annual variations in the fish faunas

The distribution of the samples on the ordination plot shown in Figs 2.3.5 and 2.3.9 for gill net and seine net data, respectively, emphasised that the compositions of the fish faunas in nearshore, shallow waters in the dry and wet periods at Eighty Mile Beach differed markedly. The faunal differences between these periods were mainly attributable to the relatively far greater numbers of the catfishes *Arius proximus* and *Arius mastersi* and the engraulids *Thryssa hamiltonii* and *Thryssa setrostris* during the wet period and of *Escualosa thoracata* and *Valamugil cunnesius* during the dry period. Indeed, the two catfish species were largely caught in gill nets only during the wet period, when they were present in relatively very large numbers. This point is illustrated by the fact that the numbers of *A. proximus* caught during the wet period were over 20 times that obtained during the dry period. Since many of the catfish caught during the wet period were mature, this increase in numbers presumably reflects a movement to nearshore, shallow areas where catfish are known to form spawning aggregations (Kailola *et al.,* 1993). Conversely, the absence of small individuals of the *Arius* species in our samples from nearshore, shallow waters is attributable to the fact that the oral brooding adults of these species move offshore and deposit their eggs in deeper water (Blaber, 2002). The greater biomass recorded for fish in gill net catches during the wet period of the year was due not only to greater catches of catfish but also to an increased number of elasmobranchs. The increased number of elasmobranchs during the period when there are strong onshore winds parallels the findings of Blaber *et al*. (1985) elsewhere in Australia.

The distribution of the samples on the ordination plots demonstrated that the compositions of the fish faunas for Port Smith and Cape Keraudren in the dry and wet periods also differed, but not to the same extent as at Eighty Mile Beach. Thus, for example, on the basis of the gill net data, the composition of the samples over bare sand in the early wet season differed markedly from those in the early dry season at both Port Smith and Cape Keraudren. Likewise, on the basis of the seine net data, the samples from the late dry differed markedly from both the early wet and the early dry. Although it is evident from our data that the very marked differences in environmental conditions at different times of the year along the Pilbara and Kimberley coasts are paralleled by differences in the compositions of the fish faunas, it is not clear why the differences between the dry and wet periods are more pronounced at Eighty Mile Beach than at the other two locations.

In the case of the gill net data for both the bare sand and mangrove habitats, the compositions of the fish faunas were found to differ markedly between years only at Port Smith. This inter-annual variation was attributable, in particular, to the presence of far greater numbers of *A. proximus* in 2001 and of *V. seheli* in 2002. The ordination plot shown in Fig 2.3.6 emphasised that the main shift occurred between the late wet of 2001 and early dry of 2002. Annual variation in recruitment is a characteristic of most mullet species (Robertson & Duke, 1990b) and may explain the increase in catches of *V. seheli* during the second year. However, that ordination plot still demonstrated that the faunal composition under went a progressive cyclical change over bare sand in each year.

3.0 Fish communities of inshore waters of the Kimberley and Pilbara regions of Western Australia

Michael J. Travers, Stephen J. Newman and Ian C. Potter

3.1 Introduction

The diversity and densities of fish and the species compositions of fish assemblages typically differ among habitat types, such as unvegetated sand, seagrass, mangroves and reefs (e.g. Jenkins & Wheatley, 1998; Guidetti, 2000; Nagelkerken *et al*., 2000; Travers & Potter, 2002). Furthermore, within a particular habitat type, the above three biotic variables often change with water depth, day *vs* night and latitude (e.g. Francour, 1997; Friedlander & Parrish, 1998; Gray *et al*., 1998; Hyndes, *et al*., 1999; Williams, *et al*., 2001). The composition of the ichthyofaunas in certain environments also change throughout the year, as a result of the immigrations and emigrations of certain fish species (e.g. Hyndes *et al.,* 1999; Potter *et al.,* 2001; Travers & Potter, 2002).

As the amount of fishing taking place in areas along the north-western coast of Australia is increasing, there is a need, from a management point of view, to identify the distribution and relative abundance of the commercial and recreational fish species found along this vast length of coastline. However, prior to this FRDC project, the only published data on the ecology of the fish faunas along this coastline are those recorded by Blaber *et al*. (1985) for nearshore shallow waters (< 5 m depth) of the Dampier region and by Young *et al*. (1986) and Williams *et al*. (2001) for offshore deeper waters (> 40 m depth) at latitudes between 18 and 35ºS. There is thus no information on the species composition of the fish fauna in the two main habitat types, *i.e.* reef and unvegetated substrate, found in water depths of 5 to 30 m along this coast, and in which commercial and recreational fishing takes place. However, there are data on the fishery resources and lists of fish species found in coastal regions immediately to the south of latitude 21ºS along the north-western coast of Australia (e.g. Sainsbury, 1988; Sainsbury *et al*., 1994; Hutchins, 1995, 1996, 1997). It should also be recognised that Chapters 1 and 2 of this FRDC report provide data on the fishery resources of the Pilbara and Kimberley coasts and of the fish faunas found in the nearshore waters of this region.

The aim of this component of the project was to test the following hypotheses regarding the fish fauna found in water depths of 5 to 30 m between latitudes of 14 and 22ºS on the north-western coast of Australia. (i) The composition of the fish faunas over reefs will differ markedly from those over adjacent soft substrates. (ii) The diversity and abundance of fish over reefs and soft substrates will vary with latitude and water depth along the approximately 3,000 km of coastline in which the inshore waters were sampled. These differences will be paralleled by differences in ichthyofaunal composition. (iii) The diversity, catch rates and compositions of the fish faunas over reefs will undergo diel changes. (iv) The compositions of the fish faunas in the markedly different wet and dry periods of the year will differ. Length-frequency data will be used to determine the size compositions of the main fish species that are of commercial and recreational importance and whether they vary with water depth. For those species for which there is a minimum legal length for retention (MLL), these length-frequency data will also be used to explore broadly the extent to which those species were caught above and below that MLL.

3.2 Materials and Methods

The fish in shallow ($\bar{x}$ = 12 m) and deep waters ($\bar{x}$ = 22 m) over reefs and soft substrates were sampled at seven locations in the Kimberley and Pilbara regions. Four of the locations were in the Kimberley, *i.e.* Cape Voltaire, Hall Point, Emeriau Point and Cape Bossut, and three in the Pilbara, *i.e.* Cape Keraudren, Cape Preston and Locker Point (see Figure 3.2.1 for latitudes of these locations and Figures 3.2.2 and 3.2.3 for the position of sampling sites in each water depth at each location).

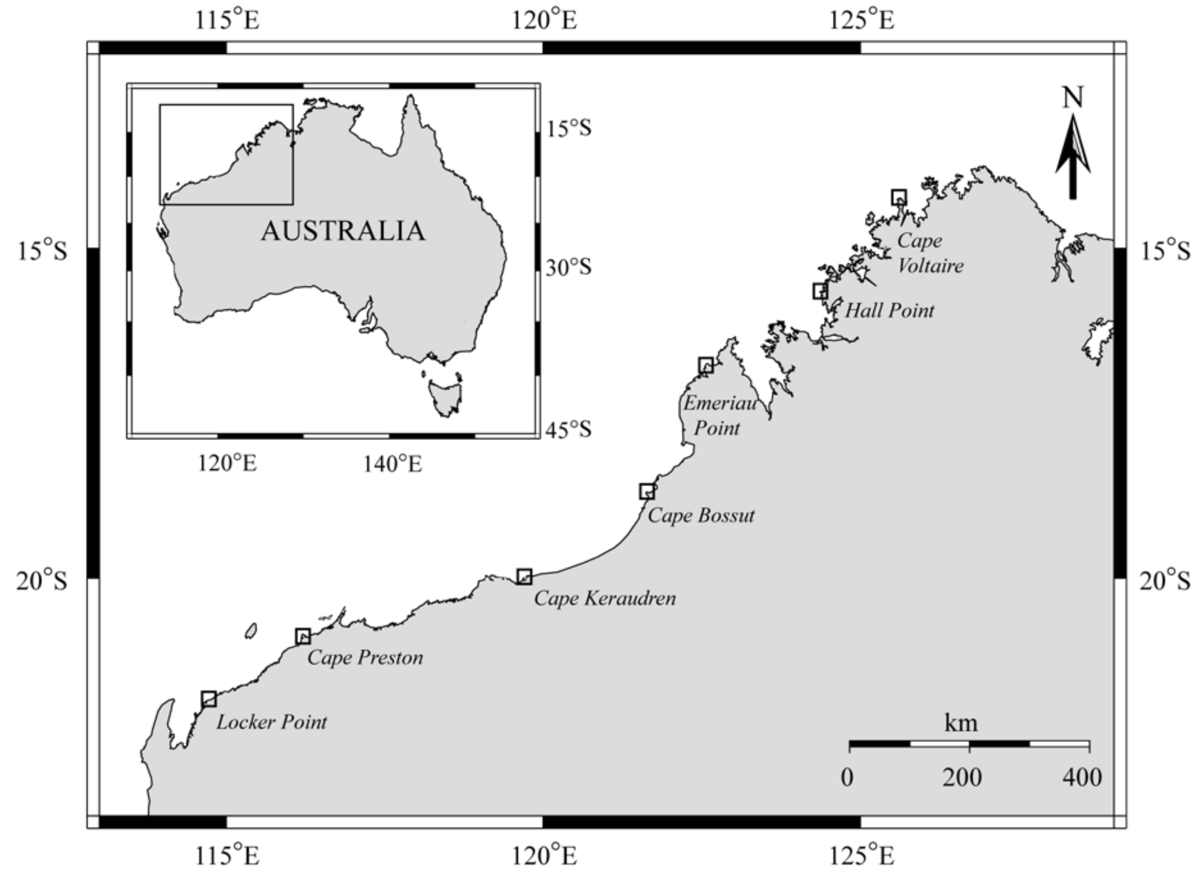

Figure 3.2.1 Map showing the seven locations sampled in north-western Australia.

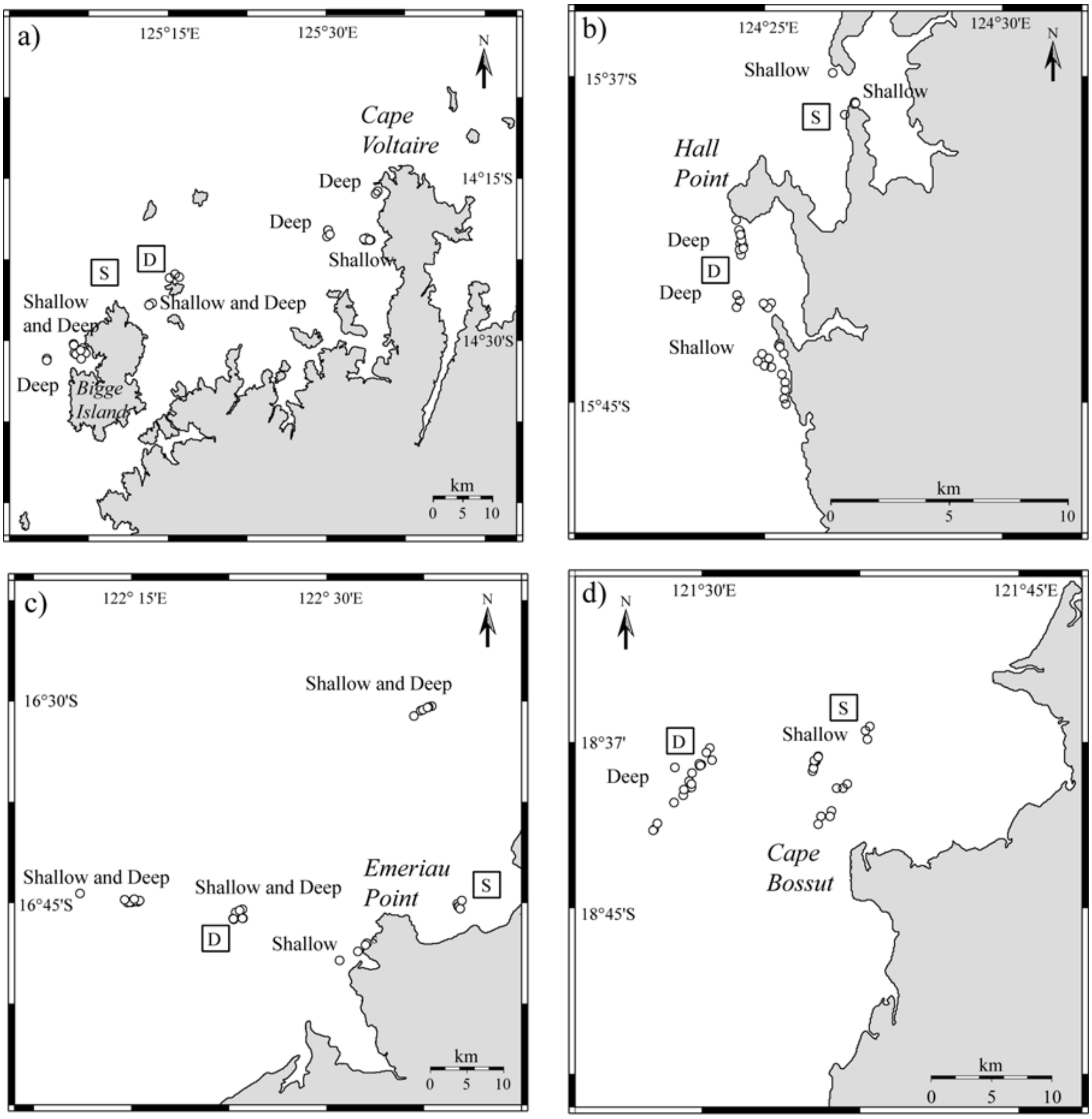

Figure 3.2.2 Map showing the locations of the trap sites in shallow and deep waters at a) Cape Voltaire, b) Hall Point, c) Emeriau Point and d) Cape Bossut in the Kimberley region of Western Australia. S and D denote where trawling was undertaken in shallow and deep waters, respectively.

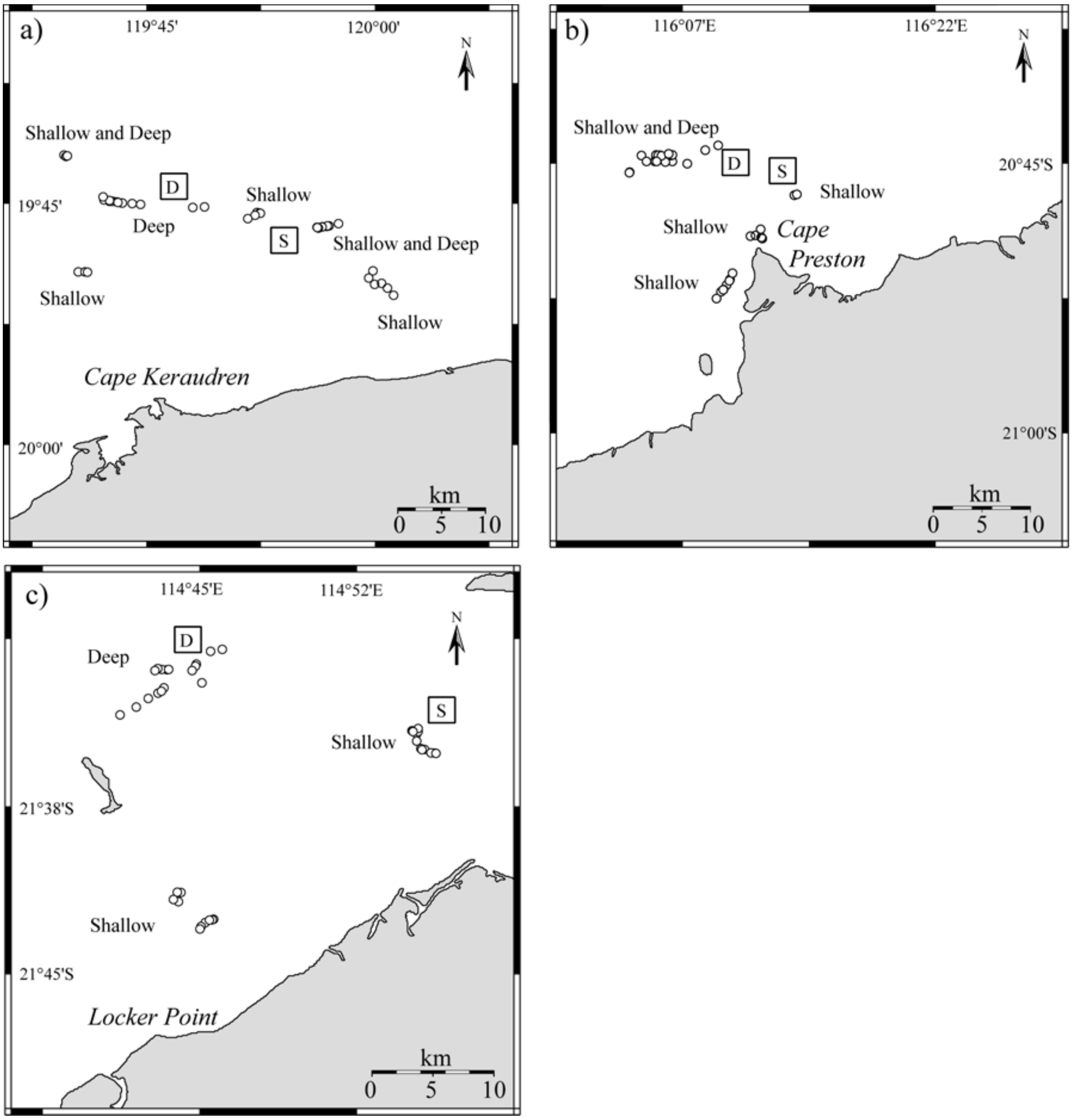

Figure 3.2.3 Map showing the locations of the trap sites in shallow and deep waters at a) Cape Keraudren, b) Cape Preston and c) Locker Point in the Pilbara region of Western Australia. S and D denote where trawling was undertaken in shallow and deep waters, respectively.

Fish were collected from over reefs during both the day and night in 2000, 2001 and 2002 using fish traps of the type employed in the Pilbara commercial trap fishery. In contrast, fish were sampled over soft substrates by otter trawling during the day during both 2001 and 2002 (Tables 3.2.1, 3.2.2). Sampling employed the Fisheries W.A. research vessels *Flinders* and *Naturaliste*.

Table 3.2.1. Details of the sampling regime conducted during dry and wet periods at the seven sampling locations in the Kimberley and Pilbara regions of north-western Australia.

Kimberley

Year	*Cape Voltaire* (14° 15´S)	*Hall Point* (15°40´S)	*Emeriau Point* (16°46´S)	*Cape Bossut* (18°42´S)	Habitat sampled	Depth sampled	Sampling equipment
2000 (Dry)	29 Jul-3 Aug	3-8 Aug	11-17 Aug	3-8 Jul	Reef	Shallow (12 m) Deep (22 m)	Fish traps
2001 (Dry)	14-20 Aug	20-25 Aug	26 Aug- 4 Sep	20-25 Jun	Reef and soft substrate	Shallow (12 m) Deep (22 m)	Fish traps and otter trawl
2002 (Wet)	10-16 Apr	17-22 Apr	23-28 Apr	11-15 Mar	Reef and soft substrate	Shallow (12 m) Deep (22 m)	Fish traps and otter trawl

Pilbara

Year	*Cape Keraudren* (19°57´S)	*Cape Preston* (20°50´S)	*Locker Point* (21°47´S)	Habitat sampled	Depth sampled	Sampling equipment
2000 (Dry)	27 Jun- 2 Jul	19-24 Jun	15-19 Jun	Reef	Shallow (12 m) Deep (22 m)	Fish traps
2001 (Dry)	14-19 Jun	6-11 Jun	2-6 Jun	Reef and soft substrate	Shallow (12 m) Deep (22 m)	Fish traps and otter trawl
2002 (Wet)	5-10 Mar	26 Feb-3 Mar	22-25 Feb	Reef and soft substrate	Shallow (12 m) Deep (22 m)	Fish traps and otter trawl

Table 3.2.2. Years, methods, time (daylight or night), duration of each sample, replication and frequency of sampling in both shallow and deep waters at each of the seven sampling locations in the Kimberley and Pilbara regions of north-western Australia in 2000, 2001 and 2002.

Year	Method	Time of sampling	Set/trawl duration	Number of replicates per day or night	Number of sampling days or nights	Total number of replicates
2000	Trap	Daylight	*ca* 4 h	2 sets of 10 traps	3	6
	Trap	Night	*ca* 10 h	2 sets of 5 traps	2	4
2001	Trap	Daylight	*ca* 4 h	2 set of 10 traps	3	6
	Trap	Night	*ca* 10 h	2 sets of 5 traps	2	4
	Trawl	Daylight	*ca* 15 min	4 trawls	1	4
2002	Trap	Daylight	*ca* 10 h	2 sets of 5 traps	3	6
	Trap	Night	*ca* 10 h	2 sets of 5 traps	2	4
	Trawl	Daylight	*ca* 15 min	4 trawls	1	4

Table 3.3.1 List of all species (families in phylogenetic order) caught by both methods during the present study. C- commercial species, R- recreational species.

Family	Scientific Name		Family	Scientific Name	
Orectolobidae	*Orectolobus ornatus*		Syngnathidae	*Hippocampus angustus*	
	Orectolobus wardi			*Hippocampus histrix*	
Stegastomatidae	*Stegostoma fasciatum*		Scorpaenidae	*Cottapistus cottoides*	
Hemiscyllidae	*Chiloscyllium punctatum*			*Cottapistus praepositus*	
	Hemiscyllium trispeculare			*Dendrochirus zebra*	
Ginglymostomatidae	*Nebrius ferrugineus*	C, R		*Hypodytes carinatus*	
Carcharhinidae	*Carcharhinus amblyrhynchos*	C, R		*Inimicus sinensis*	
	Carcharhinus brachyurus	C, R		*Minous versicolor*	
	Carcharhinus limbatus/tilstoni	C, R		*Paracentropogon longispinus*	
	Carcharhinus melanopterus	C, R		*Paracentropogon vespa*	
	Carcharhinus sorrah	C, R		*Pterois volitans*	
	Carcharinus dussumieri	C, R	Triglidae	*Lepidotrigla argus*	
	Loxodon macrorhinus	C, R		*Lepidotrigla russelli*	
	Negaprion acutidens	C, R	Aploactinidae	*Adventor elongatus*	
	Rhizoprionodon acutus	C, R	Platycephalidae	*Elates ransonnetii*	R
	Triaenodon obesus	R		*Inegocia harrisii*	R
Rhynchobatidae	*Rhina ancylostoma*			*Inegocia japonica*	R
	Rhynchobatus australiae	R		*Leviprora inops*	R
Dasyatidae	*Dasyatis annotata*			*Platycephalus arenarius*	C
	Dasyatis kuhlii			*Platycephalus endrachtensis*	R
	Dasyatis leylandi			*Sorsogona tuberculata*	R
	Himantura toshi		Dactylopteridae	*Dactyloptena papilio*	
	Taeniura lymma		Centropomidae	*Hypopterus macropterus*	
Gymnuridae	*Gymnura australis*			*Psammoperca waigiensis*	R
Myliobatidae	*Aetomylaeus nichofii*		Centrogeneidae	*Centrogenys vaigiensis*	
Clupeidae	*Anodontostoma chacunda*		Serranidae	*Cephalopholis boenack*	R
	Herklotsichthys collettei			*Cephalopholis miniata*	R
	Herklotsichthys lippa			*Cromileptes altivelis*	R
	Pellona ditchela			*Epinephelus areolatus*	C, R
	Sardinella albella			*Epinephelus bilobatus*	R
	Sardinella brachysoma			*Epinephelus bleekeri*	C, R
	Sardinella gibbosa			*Epinephelus coioides*	C, R
Engraulididae	*Stolephorus indicus*			*Epinephelus cyanopodus*	C, R
	Thryssa hamiltonii			*Epinephelus fasciatus*	R
Muraenidae	*Gymnothorax undulatus*			*Epinephelus fuscoguttatus*	C, R
	Muraenesox cinereus			*Epinephelus malabaricus*	C, R
Synodontidae	*Synodus sageneus*			*Epinephelus multinotatus*	C, R
	Synodus variegatus			*Epinephelus polyphekadion*	C, R
	Trachinocephalus myops			*Epinephelus quoyanus*	C, R
Bathysauridae	*Saurida tumbil*	R		*Epinephelus rivulatus*	R
	Saurida undosquamis	R		*Epinephelus sexfasciatus*	C, R
Ariidae	*Arius thalassinus*	C, R		*Plectropomus maculatus*	C, R
Plotosidae	*Euristhmus lepturus*			*Sacura parva*	
	Euristhmus nudiceps			*Diploprion bifasciatum*	
Batrachoididae	*Batrachomoeus occidentalis*		Pseudochromidae	*Labracinus lineatus*	
	Halophryne diemensis		Glaucosomidae	*Glaucosoma magnificum*	C, R
	Halophryne ocellatus		Terapontidae	*Pelates quadrilineatus*	R
Antennariidae	*Antennarius striatus*			*Pelates sexlineatus*	R
Holocentridae	*Myripristis hexagonus*			*Terapon theraps*	R
Veliferidae	*Velifer hypselopterus*		Priacanthidae	*Priacanthus hamrur*	R
Aulostomidae	*Fistularia commersonii*			*Priacanthus macracanthus*	R
	Fistularia petimba			*Priacanthus tayenus*	R
Centriscidae	*Aeoliscus strigatus*		Apogonidae	*Apogon albimaculosus*	
	Centriscus scutatus			*Apogon brevicaudatus*	
Syngnathidae	*Filicampus tigris*			*Apogon cavitiensis*	

Table 3.3.1 continued.

Family	Scientific Name		Family	Scientific Name	
Apogonidae	*Apogon fasciatus*		Lutjanidae	*Lutjanus fulviflamma*	C, R
	Apogon nigripinnis			*Lutjanus johnii*	C, R
	Apogon poecilopterus			*Lutjanus lemniscatus*	C, R
	Apogon rueppellii			*Lutjanus malabaricus*	C, R
	Apogon sp.1 (Sainsbury *et al.*)			*Lutjanus quinquelineatus*	R
	Apogon sp.2 (Sainsbury *et al.*)			*Lutjanus rivulatus*	C, R
	Siphamia cephalotes			*Lutjanus russelli*	C, R
Sillaginidae	*Sillago burrus*	C, R		*Lutjanus sebae*	C, R
	Sillago ingenua	C, R		*Lutjanus vitta*	C, R
	Sillago lutea	C, R		*Symphorus nematophorus*	C, R
	Sillago vittata	C, R	Caesionidae	*Caesio cuning*	R
Lactariidae	*Lactarius lactarius*			*Pterocaesio diagramma*	R
Rachycentridae	*Rachycentron canadus*	R		*Pterocaesio marri*	R
Echeneidae	*Echeneis naucrates*	R	Nemipteridae	*Nemipterus celebicus*	C
	Remora remora			*Nemipterus furcosus*	C
Carangidae	*Alectis indicus*	R		*Nemipterus hexodon*	C
	Alepes apercna			*Nemipterus peronii*	C
	Atule mate	R		*Pentapodus emeryii*	C
	Carangoides caeruleopinnatus	R		*Pentapodus porosus*	C
	Carangoides chrysophrys	R		*Pentapodus vitta*	C
	Carangoides fulvoguttatus	C, R		*Scolopsis margaritifer*	R
	Carangoides gymnostethus	C, R		*Scolopsis monogramma*	R
	Carangoides hedlandensis	R		*Scolopsis taeniopterus*	R
	Carangoides humerosus	R	Gerreidae	*Gerres filamentosus*	
	Carangoides malabaricus	R		*Gerres subfasciatus*	
	Carangoides talamparoides	R		*Pentaprion longimanus*	
	Caranx bucculentus	R	Haemulidae	*Diagramma labiosum*	C, R
	Caranx heberi	R		*Plectorhinchus gibbosus*	C, R
	Caranx ignobilis	C, R		*Plectorhinchus multivittatum*	C, R
	Caranx kleinii	R		*Plectorhinchus orientalis*	C, R
	Caranx sexfasciatus	C, R		*Plectorhinchus polytaenia*	C, R
	Caranx tille	R		*Pomadasys argenteus*	C, R
	Decapterus macarellus	R		*Pomadasys kaakan*	C, R
	Gnathanodon speciosus	C, R		*Pomadasys maculatum*	C, R
	Megalaspis cordyla	R	Lethrinidae	*Gymnocranius elongatus*	C, R
	Pantolabus radiatus	R		*Gymnocranius griseus*	C, R
	Parastromateus niger			*Lethrinus atkinsoni*	C, R
	Selar boops	R		*Lethrinus genivittatus*	C, R
	Selaroides leptolepis	R		*Lethrinus hutchinsi*	C, R
	Seriolina nigrofasciata	R		*Lethrinus laticaudis*	C, R
	Ulua aurochs	R		*Lethrinus lentjan*	C, R
	Ulua mentalis	R		*Lethrinus miniatus*	C, R
Leiognathidae	*Gazza minuta*			*Lethrinus nebulosus*	C, R
	Leiognathus bindus			*Lethrinus olivaceus*	C, R
	Leiognathus decorus			*Lethrinus ravus*	C, R
	Leiognathus equulus			*Lethrinus variegatus*	C, R
	Leiognathus fasciatus		Sparidae	*Argyrops spinifer*	C, R
	Leiognathus leuciscus			*Pagrus auratus*	C, R
	Leiognathus moretoniensis		Sciaenidae	*Johnius amblycephalus*	C, R
	Leiognathus ruconius			*Johnius borneensis*	C, R
	Leiognathus splendens			*Protonibea diacanthus*	C, R
	Secutor insidiator		Mullidae	*Parupeneus barberinoides*	C, R
Lutjanidae	*Lutjanus argentimaculatus*	C, R		*Parupeneus barberinus*	C, R
	Lutjanus bitaeniatus	C, R		*Parupeneus chryserpleuron*	C, R
	Lutjanus carponotatus	R		*Parupeneus heptacanthus*	C, R
	Lutjanus erythropterus	C, R		*Parupeneus indicus*	C, R

Table 3.3.1 continued.

Family	Scientific Name		Family	Scientific Name	
Mullidae	*Parupeneus spilurus*	C, R	Callionymidae	*Repomucenus meridionalis*	
	Upeneus asymmetricus	C, R		*Repomucenus sublaevis*	
	Upeneus luzonius	C, R	Gobiidae	*Yongeichthys nebulosus*	
	Upeneus sp.1 (Sainsbury *et al.*)	C, R	Acanthuridae	*Acanthurus grammoptilus*	R
	Upeneus sulphureus	C, R		*Acanthurus xanthopterus*	R
	Upeneus sundaicus	C, R	Siganidae	*Siganus argenteus*	
	Upeneus tragula	C, R		*Siganus doliatus*	
Ephippidae	*Platax batavianus*	R		*Siganus fuscescens*	
	Platax teira	R	Trichiuridae	*Tentoriceps cristatus*	
	Zabidius novaemaculatus	R		*Trichiurus lepturus*	
Chaetodontidae	*Chaetodon assarius*		Scombridae	*Rastrelliger kanagurta*	
	Chaetodon aureofasciatus			*Scomberomorus munroi*	C, R
	Chaetodon trifasciatus			*Scomberomorus queenslandicus*	C, R
	Chaetodontoplus meredithi		Centrolophidae	*Psenopsis humerosa*	
	Chelmon marginalis		Psettodidae	*Psettodes erumei*	C, R
	Chelmon muelleri		Bothidae	*Asterorhombus intermedius*	
	Coradion chrysozonus			*Asterorhombus osculus*	
	Heniochus acuminatus			*Bothus myriaster*	
	Parachaetodon ocellatus			*Bothus pantherinus*	
	Pomacanthus semicirculatus			*Crossorhombus kanekonis*	
Pomacanthidae	*Chaetodontoplus duboulayi*			*Engyprosopon grandisquama*	
	Chaetodontoplus personifer			*Engyprosopon maldiviensis*	
Pomacentridae	*Abudefduf bengalensis*			*Grammatobothus polyophthalmus*	
	Abudefduf septemfasciatus			*Neolaeops microphthalmus*	
	Amphiprion clarkii			*Psammodiscus ocellatus*	
	Chromis fumea			*Pseudorhombus argus*	C, R
	Pristotis obtusirostris			*Pseudorhombus arsius*	C, R
Cirrhitidae	*Cirrhitichthys aprinus*			*Pseudorhombus elevatus*	C, R
	Cirrhitichthys oxycephalus			*Pseudorhombus jenynsii*	C, R
Cepolidae	*Acanthocepola abbreviata*			*Pseudorhombus spinosus*	C, R
Sphyraenidae	*Sphyraena forsteri*	C, R	Soleidae	*Aseraggodes melanospilus*	
	Sphyraena jello	C, R		*Brachirus muelleri*	
	Sphyraena quenie	C, R		*Strabozebrias cancellatus*	
Polynemidae	*Polydactylus multiradiatus*	R		*Zebrias quagga*	
Labridae	*Anampses lennardi*	R	Cynoglossidae	*Cynoglossus macrophthalmus*	
	Bodianus bilunulatus	R		*Paraplagusia bilineata*	
	Bodianus perditio	R		*Paraplagusia longirostris*	
	Choerodon anchorago	R	Triacanthidae	*Triacanthus biaculeatus*	
	Choerodon cauteroma	C, R		*Trixiphichthys weberi*	
	Choerodon cephalotes	C, R	Balistidae	*Abalistes stellaris*	
	Choerodon cyanodus	C, R		*Sufflamen fraenatus*	
	Choerodon monostigma	R	Monacanthidae	*Anacanthus barbatus*	
	Choerodon sugillatum	R		*Cantherhines fronticinctus*	
	Choerodon vitta	R		*Chaetodermis penicilligerus*	
	Suezichthys soelae	R		*Monacanthus chinensis*	
	Xyrichtys jacksonensis			*Paramonacanthus choirocephalus*	
Scaridae	*Scarus ghobban*	C, R		*Paramonacanthus filicauda*	
Pinguipedidae	*Parapercis nebulosa*			*Paramonacanthus pusillus*	
Blenniidae	*Xiphasia setifer*			*Pseudomonacanthus elongatus*	
Congrogadidae	*Congrogadus spinifer*			*Pseudomonacanthus peroni*	
Callionymidae	*Calliurichthys australis*			*Thamnaconus tessellatus*	
	Calliurichthys grossi		Ostraciidae	*Lactoria cornuta*	
	Calliurichthys scaber			*Lactoria diaphana*	
	Dactylopus dactylopus			*Ostracion cubicus*	
	Orbonymus rameus			*Rhynchostracion nasus*	
	Pseudocalliurichthys goodladi			*Rhynchostracion rhinorhynchus*	

Table 3.3.1 continued.

Family	Scientific Name
Ostraciidae	*Stethojulis interrupta*
Tetraodontidae	*Anchisomus multistriatus*
	Arothron hispidus
	Arothron stellatus
	Canthigaster coronata
	Canthigaster rivulata
	Chelonodon patoca
	Lagocephalus lunaris
	Lagocephalus spadiceus
	Torquigener hicksi
	Lagocephalus sceleratus
	Torquigener pallimaculatus
	Torquigener whitleyi
	Tylerius spinosissimus
Diodontidae	*Cyclichthys hardenbergi*
	Cyclichthys orbicularis
	Diodon holacanthus
	Tragulichthys jaculiferus

Table 3.3.2. List of fish species caught over reefs in shallow (0 =12 m) and deep waters (0 = 22 m) at seven locations in north-western Australia using fish traps during the day on one occasion in 2000, 2001 and 2002. The rank, abundance and percentage contribution of each species overall and the percentage contributions of each species to the catches in each water depth at each location are provided.

					Kimberley								Pilbara					
			Overall		Cape Voltaire		Hall Point		Emeriau Point		Cape Bossut		Cape Keraudren		Cape Preston		Locker Point	
Family	Species	Rank	*n*	(%)	Shallow %	Deep %	Shallow %	Deep %	Shallow %	Deep %	Shallow %	Deep %	Shallow %	Deep %	Shallow %	Deep %	Shallow %	Deep %
Lethrinidae	*Lethrinus hutchinsi*	1	5562	37.3	-	0.8	7.2	-	35.1	20.8	58.8	52.6	59.5	34.9	44.6	38.2	50.5	36.7
Lutjanidae	*Lutjanus carponotatus*	2	2464	16.5	30.1	12.7	42.5	25.2	20.1	29.5	8.9	14.8	8.7	3.4	8.0	4.6	10.8	1.9
Lethrinidae	*Lethrinus laticaudis*	3	1751	11.7	25.8	15.0	26.9	18.5	5.8	28.7	7.0	1.6	8.7	15.1	9.8	5.2	13.6	-
Carangidae	*Gnathanodon speciosus*	4	666	4.4	1.2	0.2	4.8	-	18.4	2.1	3.6	5.9	2.4	0.4	0.1	-	1.1	1.7
Balistidae	*Abalistes stellaris*	5	424	2.8	-	-	-	-	0.8	1.3	1.4	6.9	2.9	8.0	4.3	13.6	0.3	2.0
Lutjanidae	*Lutjanus bitaeniatus*	6	390	2.6	1.7	22.6	-	45.5	-	-	-	-	-	-	-	-	-	-
Siganidae	*Siganus fuscescens*	7	305	2.0	2.9	-	0.1	-	1.6	1.1	5.9	0.6	4.7	1.3	2.3	-	2.9	0.7
Nemipteridae	*Pentapodus emeryii*	8	272	1.8	-	-	-	-	1.8	2.2	1.6	2.6	2.8	3.4	0.5	2.4	0.1	6.4
Lethrinidae	*Lethrinus genivittatus*	9	230	1.5	-	-	-	-	-	-	1.1	3.8	-	-	1.5	0.8	0.9	12.6
Labridae	*Choerodon cyanodus*	10”	225	1.5	2.4	0.2	2.6	-	5.3	0.8	1.8	0.2	0.1	-	2.2	0.1	1.8	-
Lutjanidae	*Lutjanus lemniscatus*	10”	225	1.5	5.0	6.1	2.9	1.0	1.5	1.7	0.3	<0.1	0.1	-	3.3	4.2	1.3	0.3
Serranidae	*Epinephelus coioides*	12	177	1.2	6.4	6.5	1.8	2.6	0.1	0.1	0.9	0.4	0.5	6.7	1.7	-	2.2	-
Lutjanidae	*Lutjanus sebae*	13	172	1.1	-	-	-	-	0.2	0.7	1.9	1.0	0.5	2.9	0.3	9.4	0.3	0.5
Haemulidae	*Diagramma labiosum*	14	161	1.1	1.0	0.8	1.6	1.5	0.2	2.0	0.4	1.1	2.2	5.5	0.4	2.4	-	0.3
Lutjanidae	*Lutjanus johnii*	15	155	1.0	8.4	23.2	0.5	1.0	-	-	-	-	-	-	-	-	-	-
Lethrinidae	*Lethrinus nebulosus*	16	149	1.0	-	-	-	-	0.5	0.2	<0.1	-	-	-	3.1	2.2	2.2	9.4
Serranidae	*Epinephelus bilobatus*	17	138	0.9	-	0.6	-	-	2.5	0.4	0.1	0.1	0.4	1.7	2.0	2.8	1.8	2.3
Lethrinidae	*Lethrinus atkinsoni*	18	131	0.9	-	-	-	-	-	-	-	-	-	-	0.9	5.5	0.1	11.0
Lethrinidae	*Lethrinus lentjan*	19	107	0.7	1.7	0.4	2.6	-	0.5	0.2	0.3	-	-	-	4.8	0.6	0.8	-
Carangidae	*Carangoides fulvoguttatus*	20	84	0.6	-	-	-	-	0.6	1.8	1.2	0.1	0.1	0.4	-	-	-	0.7
Labridae	*Choerodon cauteroma*	21	77	0.5	-	-	-	-	0.3	<0.1	<0.1	0.6	1.5	6.7	0.4	2.5	0.5	0.4
Serranidae	*Plectropomus maculatus*	22	73	0.5	1.7	0.4	0.4	0.2	0.3	0.7	<0.1	1.0	0.8	0.8	0.4	0.7	-	0.1
Glaucosomatidae	*Glaucosoma magnificum*	23	66	0.4	-	-	-	1.0	0.2	1.7	<0.1	0.8	0.4	-	-	-	-	-
Monacanthidae	*Monacanthus chinensis*	24	65	0.4	-	-	0.6	0.5	0.4	<0.1	0.5	0.8	0.4	-	1.0	-	0.3	0.5
Lutjanidae	*Lutjanus russelli*	25	60	0.4	-	-	-	0.2	-	-	-	0.7	-	-	3.1	0.3	0.7	0.7
Nemipteridae	*Scolopsis monogramma*	26	56	0.4	0.7	-	0.1	-	0.1	0.5	0.1	1.0	0.3	0.8	0.1	0.3	0.4	0.8
Lutjanidae	*Lutjanus malabaricus*	27	49	0.3	1.0	3.2	-	-	-	-	0.2	-	-	-	2.4	0.1	0.1	-
Mullidae	*Parupeneus indicus*	28	48	0.3	-	-	0.3	-	1.0	0.9	0.1	<0.1	0.1	-	0.2	0.1	0.3	-
Pomacanthidae	*Chaetodontoplus duboulayi*	29	45	0.3	0.7	0.4	0.8	1.2	0.1	0.3	0.1	0.3	0.4	0.8	-	0.3	0.5	-
Carangidae	*Caranx bucculentus*	30	39	0.3	4.8	1.5	0.4	0.7	-	0.2	-	-	-	-	-	-	0.1	-
Chaetodontidae	*Chelmon marginalis*	31”	37	0.2	-	-	-	-	0.5	0.4	-	-	0.4	0.4	0.3	0.7	1.2	-
Nemipteridae	*Pentapodus porosus*	31”	37	0.2	-	0.2	0.3	-	-	-	0.1	0.5	-	-	-	-	0.4	2.5

Table 3.3.2. continued.

Family	Species	Overall Rank	Overall *n*	Overall (%)	Kimberley: Cape Voltaire Shallow %	Kimberley: Cape Voltaire Deep %	Kimberley: Hall Point Shallow %	Kimberley: Hall Point Deep %	Kimberley: Emeriau Point Shallow %	Kimberley: Emeriau Point Deep %	Kimberley: Cape Bossut Shallow %	Kimberley: Cape Bossut Deep %	Pilbara: Cape Keraudren Shallow %	Pilbara: Cape Keraudren Deep %	Pilbara: Cape Preston Shallow %	Pilbara: Cape Preston Deep %	Pilbara: Locker Point Shallow %	Pilbara: Locker Point Deep %
Carangidae	*Carangoides gymnostethus*	33	36	0.2	-	-	-	-	0.6	0.2	0.9	-	-	-	-	0.1	-	-
Lutjanidae	*Lutjanus vitta*	34	27	0.2	-	-	-	-	-	-	0.4	0.3	-	-	0.1	0.3	-	1.2
Pomacentridae	*Abudefduf bengalensis*	35	21	0.1	0.2	-	-	-	0.2	-	<0.1	-	-	-	0.1	0.6	1.2	0.1
Serranidae	*Epinephelus multinotatus*	36	20	0.1	-	-	-	-	-	-	0.1	0.3	0.5	1.7	-	0.1	0.3	0.1
Chaetodontidae	*Coradion chrysozonus*	37"	17	0.1	0.2	-	-	-	0.2	<0.1	0.2	0.4	-	-	-	-	-	-
Serranidae	*Epinephelus fasciatus*	37"	17	0.1	-	-	-	-	-	-	-	0.4	0.1	-	-	0.4	-	0.5
Nemipteridae	*Nemipterus furcosus*	37"	17	0.1	-	-	-	-	-	<0.1	<0.1	0.1	-	-	-	-	-	1.6
Lutjanidae	*Symphorus nematophorus*	37"	17	0.1	-	-	-	-	-	0.1	-	-	0.5	2.5	0.2	0.1	-	0.1
Carangidae	*Caranx ignobilis*	41	16	0.1	1.4	-	1.0	-	0.1	<0.1	-	-	-	-	-	-	-	-
Carangidae	*Caranx sexfasciatus*	42"	15	0.1	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-
Haemulidae	*Pomadasys kaakan*	42"	15	0.1	-	3.2	-	-	-	-	-	-	-	-	-	-	-	-
Lethrinidae	*Lethrinus olivaceus*	44	14	<0.1	-	-	-	-	0.2	0.1	-	-	0.1	-	0.1	-	0.4	0.3
Tetraodontidae	*Anchisomus multistriatus*	45	11	<0.1	-	-	-	-	-	<0.1	0.3	0.1	-	-	-	-	-	0.1
Chaetodontidae	*Parachaetodon ocellatus*	46"	10	<0.1	-	-	0.1	-	-	-	-	0.3	-	-	-	0.1	0.1	-
Haemulidae	*Plectorhinchus polytaenia*	46"	10	<0.1	-	-	-	-	0.1	0.3	<0.1	-	-	-	-	-	-	-
Mullidae	*Parupeneus spilurus*	48"	9	<0.1	-	-	-	-	-	-	-	-	-	-	-	0.3	0.4	0.5
Scaridae	*Scarus ghobban*	48"	9	<0.1	-	-	0.4	-	-	-	-	-	-	-	0.6	-	-	-
Carangidae	*Caranx tille*	50"	8	<0.1	1.2	-	-	-	-	-	0.1	-	-	-	-	-	-	-
Serranidae	*Epinephelus bleekeri*	50"	8	<0.1	-	-	-	0.2	-	-	-	-	-	-	0.7	-	-	-
Chaetodontidae	*Heniochus acuminatus*	50"	8	<0.1	-	-	0.3	-	0.1	<0.1	-	-	-	-	-	0.3	-	0.1
Lutjanidae	*Lutjanus erythropterus*	50"	8	<0.1	-	-	-	-	-	-	-	0.2	-	-	0.3	-	-	-
Haemulidae	*Plectorhinchus gibbosus*	50"	8	<0.1	0.2	0.2	0.3	-	-	0.1	-	-	0.1	-	-	-	-	-
Haemulidae	*Plectorhinchus multivittatum*	50"	8	<0.1	-	-	-	-	0.1	0.1	0.2	-	-	-	-	-	-	-
Centropomidae	*Psammoperca waigiensis*	50"	8	<0.1	-	0.4	-	0.2	-	-	0.2	-	-	-	-	-	-	-
Caesionidae	*Caesio cuning*	57	7	<0.1	0.2	0.2	0.4	0.2	0.1	-	-	-	-	-	-	-	-	-
Percichthyidae	*Epinephelus rivulatus*	58"	6	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.7	0.1
Lethrinidae	*Lethrinus miniatus*	58"	6	<0.1	-	-	-	-	-	-	0.1	-	-	-	-	-	-	0.5
Ephippidae	*Platax batavianus*	58"	6	<0.1	-	-	-	-	-	0.1	-	0.1	-	0.4	-	-	-	-
Ephippidae	*Platax teira*	58"	6	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	0.1	0.4	0.1
Sphyraenidae	*Sphyraena jello*	58"	6	<0.1	0.2	-	-	-	0.1	0.1	<0.1	-	-	-	-	-	-	-
Balistidae	*Sufflamen fraenatus*	58"	6	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8
Hemiscyllidae	*Chiloscyllium punctatum*	64"	5	<0.1	-	-	0.1	-	0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-
Serranidae	*Epinephelus malabaricus*	64"	5	<0.1	-	-	0.1	-	0.1	-	-	-	-	0.8	-	-	-	0.1
Siganidae	*Siganus doliatus*	64"	5	<0.1	-	-	-	-	0.2	-	-	-	-	-	0.2	-	-	-

Table 3.3.2. continued.

					Kimberley								Pilbara					
			Overall		Cape Voltaire		Hall Point		Emeriau Point		Cape Bossut		Cape Keraudren		Cape Preston		Locker Point	
Family	Species	Rank	*n*	(%)	Shallow %	Deep	Shallow %	Deep	Shallow %	Deep	Shallow %	Deep	Shallow %	Deep	Shallow %	Deep	Shallow %	Deep
Acanthuridae	*Acanthurus xanthopterus*	67”	4	<0.1	-	-	0.1	-	0.2	-	-	-	-	-	-	-	-	-
Labridae	*Bodianus bilunulatus*	67”	4	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.4
Chaetodontidae	*Chaetodon aureofasciatus*	67”	4	<0.1	-	-	-	-	-	<0.1	-	<0.1	-	-	-	-	0.3	-
Serranidae	*Epinephelus quoyanus*	67”	4	<0.1	-	-	-	-	-	-	<0.1	0.1	0.1	-	-	-	-	-
Balistidae	*Pseudomonacanthus peroni*	67”	4	<0.1	-	-	0.1	-	-	0.1	-	-	-	-	0.1	-	-	-
Carcharhinidae	*Triaenodon obesus*	67”	4	<0.1	-	-	0.3	-	-	-	-	-	0.3	-	-	-	-	-
Carcharhinidae	*Carcharhinus amblyrhynchos*	73”	3	<0.1	0.2	-	0.3	-	-	-	-	-	-	-	-	-	-	-
Balistidae	*Chaetodermis penicilligerus*	73”	3	<0.1	-	-	-	-	-	-	0.1	<0.1	-	-	-	-	-	-
Echeneidae	*Echeneis naucrates*	73”	3	<0.1	-	-	-	-	-	<0.1	0.1	-	-	-	-	-	-	-
Mullidae	*Parupeneus barberinus*	73”	3	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-
Ariidae	*Arius thalassinus*	77”	2	<0.1	-	-	0.1	-	-	<0.1	-	-	-	-	-	-	-	-
Serranidae	*Cephalopholis miniata*	77”	2	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3
Pomacanthidae	*Chaetodontoplus personifer*	77”	2	<0.1	-	-	-	-	-	-	-	<0.1	-	-	-	-	-	0.1
Serranidae	*Cromileptes altivelis*	77”	2	<0.1	-	-	0.1	-	0.1	-	-	-	-	-	-	-	-	-
Serrinidae	*Epinephelus areolatus*	77”	2	<0.1	0.2	-	-	-	-	-	-	-	-	-	-	-	0.1	-
Serranidae	*Epinephelus polyphekadion*	77”	2	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3
Lutjanidae	*Lutjanus quinquelineatus*	77”	2	<0.1	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-
Ginglymostomatidae	*Nebrius ferrugineus*	77”	2	<0.1	-	0.2	-	-	0.1	-	-	-	-	-	-	-	-	-
Mullidae	*Parupeneus heptacanthus*	77”	2	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3
Pomacentridae	*Abudefduf septemfasciatus*	86”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
Acanthuridae	*Acanthurus grammoptilus*	86”	1	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Carangidae	*Alepes apercna*	86”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
Tetraodontidae	*Arothron hispidus*	86”	1	<0.1	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-
Carangidae	*Carangoides talamparoides*	86”	1	<0.1	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Carcharhinidae	*Carcharhinus limbatus*	86”	1	<0.1	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Carcharhinidae	*Carcharhinus melanopterus*	86”	1	<0.1	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Carcharhinidae	*Carcharhinus sorrah*	86”	1	<0.1	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chelmon muelleri*	86”	1	<0.1	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-
Labridae	*Choerodon anchorago*	86”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
Labridae	*Choerodon cephalotes*	86”	1	<0.1	-	-	-	-	-	-	-	<0.1	-	-	-	-	-	-
Dasyatidae	*Dasyatis kuhlii*	86”	1	<0.1	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-
Serranidae	*Epinephelus cyanopodus*	86”	1	<0.1	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-
Serranidae	*Epinephelus fuscoguttatus*	86”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
Lethrinidae	*Lethrinus ravus*	86”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1

Table 3.3.2. continued.

					Kimberley								Pilbara					
		Overall			Cape Voltaire		Hall Point		Emeriau Point		Cape Bossut		Cape Keraudren		Cape Preston		Locker Point	
Family	Species	Rank	*n*	(%)	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
					%		%		%		%		%		%		%	
Nemipteridae	*Nemipterus hexodon*	86"	1	<0.1	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Orectolobidae	*Orectolobus ornatus*	86"	1	<0.1	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-
Mullidae	*Parupeneus chryserpleuron*	86"	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
Haemulidae	*Plectorhinchus orientalis*	86"	1	<0.1	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-
Chaetodontidae	*Pomacanthus semicirculatus*	86"	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
Scorpaenidae	*Pterois volitans*	86"	1	<0.1	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-
Echeneidae	*Remora remora*	86"	1	<0.1	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-
Ostraciidae	*Rhynchostracion nasus*	86"	1	<0.1	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-
Siganidae	*Siganus argenteus*	86"	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraenidae	*Sphyraena quenie*	86"	1	<0.1	-	-	0.2	-	-	-	-	-	-	-	0.1	-	-	-
Dasyatidae	*Taeniura lymma*	86"	1	<0.1	0.2	-	-		-	-	-	-	-	-	-	-	-	-
Ephippidae	*Zabidius novaemaculatus*	86"	1	<0.1	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-
Total			14916		419	474	793	607	1763	2096	2309	2202	781	238	1016	712	760	746
Total species		112			27	26	32	20	42	45	45	39	30	24	35	33	40	44

Plate 3.2.1 The fish traps used for sampling reef habitats.

The traps, which have a curved arrowhead design, have a diameter of 1500 mm, a height of 600 mm and a mesh size of 50 mm (Plate 3.2.1). In each of the seven sampling locations in 2000 and 2001, one group of ten traps was set twice during daylight for *ca* 4 hours on the three days of daylight sampling and two groups of five traps were set once overnight for *ca* 11 hours on the two nights of nocturnal sampling. In 2002, two groups of five traps were set once for *ca* 11 hours during both daylight and night on three days at each location (Table 3.2.2). The above sampling regimes for 2000, 2001 and 2002 were repeated in both shallow and deep waters at each location. To ensure that the field of capture of a trap did not overlap that of any other trap, each trap was set at distances from each other of at least 50 m (Eggers *et al*., 1982). Water temperature was recorded after each group of traps had been set. Records were also kept of the time of sampling, the state of the tide, lunar period and weather conditions.

Traps were retrieved one at a time. Each fish was identified to species and its fork length measured to the nearest 1 mm and then released live. The fork length, rather than total length was measured as the tips of the caudal lobes of fish caught in traps tend to be fragmented (S.J. Newman pers. comm.).

The otter trawls used to sample the fish over soft substrates close to reefs were of the type employed in the north-western Australian prawn fisheries. The port and starboard nets each have a 30.5 m foot rope and a cod-end made of 45 mm mesh (Plate 3.2.2). Four replicate trawls of 15 min duration were carried out in each water depth at each location during the day in 2001 and 2002 at an approximate boat speed of 3-4 km h^{-1}. All fish were identified to species and the total number and wet weight of each species in each sample were recorded. Due to logistical difficulties, only three replicate trawls were carried out in each water depth at Cape Keraudren in 2001.

Plate 3.2.2 The otter trawl net used for sampling soft substrate habitats.

Univariate analyses

The mean number of fish species and the mean catch rates of fish recorded using traps in both shallow and deep waters at each location during the day and night, and the mean number of species, mean densities and biomass of fish derived from trawl catches obtained from the two water depths at each location during the day, were subjected to either two or three-way Analysis of Variance (ANOVA). The number of fish in each trap were standardised to a catch rate of fish 4 h^{-1} per trap for each daylight sample in 2000 and 2001 and to a catch rate of fish 10 h^{-1} per trap for each daylight and night sample in 2002. The numbers and wet weight of each fish species collected by trawling were standardised to a density (number of fish 10,000 m^{-2}) and biomass (kg of fish 10,000 m^{-2}), respectively. Plots of the relationships between the $\log_{10}$ transformed means and associated standard deviations for both the mean number of species and the catch rates of fish in each depth at each location during both the day and night demonstrated that prior to subjecting the data for these dependent biotic variables to ANOVA, the number of species and catch rates required a square root and a $\log_{10}(n+1)$ transformation, respectively (see Clarke & Warwick, 2001 for rationale for this approach). When the data derived from trawling were subjected to the same procedure, the plots demonstrated that the mean number of species, densities and biomass of fish should each be $\log_{10}(n+1)$ transformed. Location, depth, time of day and period (wet and dry) are considered fixed factors (Underwood, 1981) and differences were considered significantly different at $P < 0.01$. When ANOVA showed that there was a significant difference between the mean values for a variable, and there was no significant interaction associated with that variable, Scheffe's *a posteriori* test was used to determine where the differences resided. Note that since a full suite of samples could not be collected from deep waters over reefs at Cape Keraudren, the limited data for this location were excluded from univariate analyses.

Multivariate analyses

Emphasis was initially placed on exploring whether there were marked differences between the compositions of the fish in catches obtained using fish traps over reefs and those obtained using otter trawls over soft substrates. For this purpose, the mean percentage contributions of each species on each sampling occasion in each water depth in each habitat type at each location were calculated.

The above percentage contributions of the various species in both the trap and trawl samples were ordinated using non-metric Multi-dimensional scaling ordination (MDS) techniques as described in the PRIMER *v*5 statistical package (Clarke & Gorley, 2001). Subsequently, the catch rates over reefs and then the densities over soft substrates in each water depth at each locality on each sampling occasion were each subjected to MDS ordination separately. Because the time over which traps were set during daylight and the night in 2000 and 2001 differed, *i.e.* 4 *vs* 10 h, the analyses of the daylight and night-time data were carried out separately. However, the daylight and night-time data were analysed together in 2002 when the traps were set for the same time during daylight and the night, *i.e.* 10 h.

Prior to the above MDS analyses, the percentage contributions, catch rates and densities of each species were square-root transformed and the Bray-Curtis similarity measure used to construct the similarity matrices. One-way and two-way crossed analysis of similarity (ANOSIM, Clarke, 1993) were employed to test whether the species compositions over reefs and soft substrates differed significantly between water depths and among locations, and also between day and night in the case of reefs in 2002. When appropriate, the R-statistic values determined by ANOSIM for pair-wise comparisons were used to ascertain the degree to which the *a priori* groups of samples were dissimilar. R-statistic values close to unity show that the compositions of the samples in each group are very different, whereas those that are close to zero demonstrate that they are very similar. Similarity of Percentages (SIMPER; Clarke & Gorley, 2001) was used to ascertain which species best typify faunal assemblages and/or contribute most to any differences between samples (Clarke, 1993).

3.3 Results

3.3.1 Environmental variables

Mean surface water temperatures were generally *ca* 4-6°C higher in the wet period of 2002 (February to April) than in the dry periods of both 2000 and 2001 (June to August or September), which were similar (Fig. 3.3.1). In 2002, water temperature was greatest at the three most northern locations and declined sequentially from a maximum of *ca* 32°C at Hall Point to a minimum of *ca* 27°C at the most southern location, *i.e.* Locker Point (Fig. 3.3.1). In both 2000 and 2001, water temperatures declined from *ca* 26°C at Hall Point to *ca* 22°C at Cape Keraudren and then rose to *ca* 24°C at Locker Point (Fig. 3.3.1).

3.3.2 Comparisons of species compositions over reefs and soft substrates

Fish trapping and otter trawling in shallow ($\bar{x}$ = 12 m) and deeper waters ($\bar{x}$ = 22 m) at the seven sampling locations along the north-western Australian coast between 2000 and 2002 yielded 352 species of fish, representing 194 genera and 82 families (Table 3.3.1). Overall, the most speciose families were the Carangidae, Serranidae, Bothidae, Lutjanidae and Tetraodontidae (Table 3.3.1). The Serranidae, Lutjanidae, Lethrinidae and Carangidae, which were represented in the catches taken by trapping over reefs by 15, 14, 9 and 9 species, respectively, contributed 86.1 and 91.5% to the catches in this habitat during the day and night, respectively (Tables 3.3.2, 3.3.3). The Carangidae, Bothidae, Tetraodontidae, Mullidae and Leiognathidae were the most speciose families collected by trawling over soft substrates during the day, with 17, 15, 13, 11 and 10 species being recorded in the catches obtained by that method (Table 3.3.4). Collectively, these five families contributed more than 46.4% to the total number of fish caught over soft substrates, with the Leiognathidae (21.9%) and Carangidae (16.4%) being the most abundant and the Pomacentridae and Terapontidae each contributing a further 7.1% to the catch (Table 3.3.4). [Note that only those species that contributed > 0.1% are recorded in Table 3.3.4].

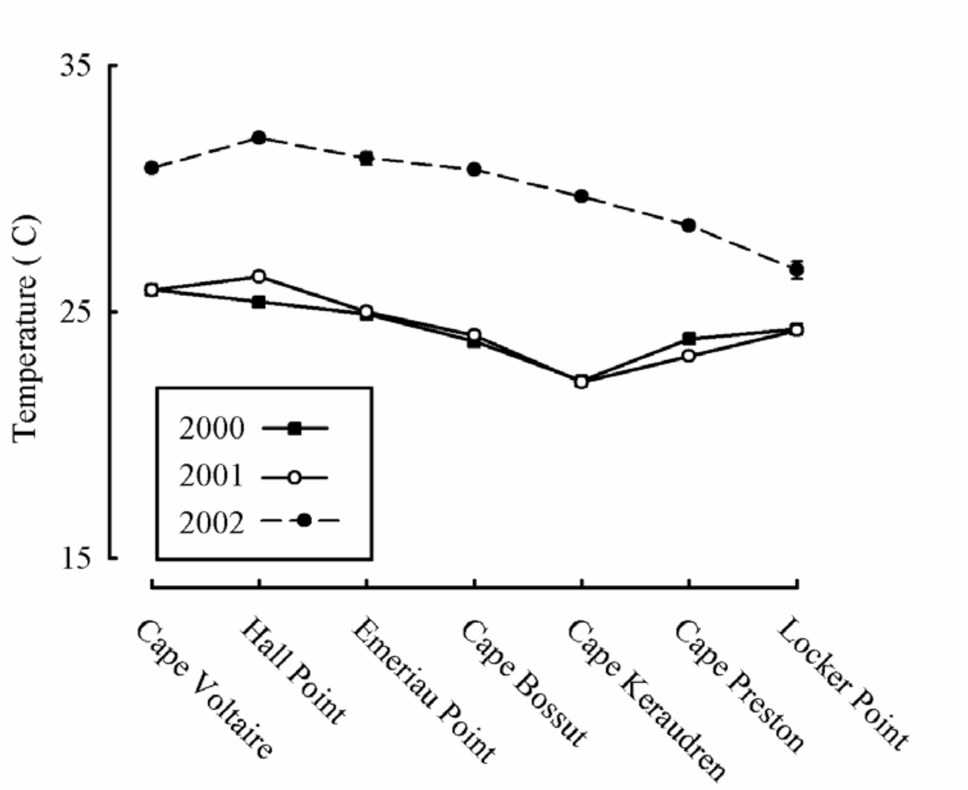

Figure 3.3.1 Mean values ±SE for water temperatures at the seven sampling locations in north-western Australia in June to August 2000, June to September 2001 and February to April 2002.

When the percentage contributions of the various fish species collected by trawling over soft substrates and by fish trapping over reefs in shallow and deep waters during the day in 2001 and 2002 were ordinated, all of the samples collected over reefs lay to the left of all of those collected over soft substrates (Fig. 3.3.2). Furthermore, the samples obtained using both methods were distributed on the plot in a manner that very largely reflected the latitude of these locations. Thus, irrespective of the habitat sampled, the samples from the most northern locations, *i.e.* Cape Voltaire and Hall Point, lay in the top of the plot, whereas those from the more southern locations, *i.e.* Emeriau Point, Cape Bossut, Cape Keraudren, Cape Preston and Locker Point, lay towards the bottom of the plot (Fig. 3.3.2). Furthermore, the samples collected from deep water over reefs at Cape Bossut, Cape Preston, and even more particularly Locker Point, the three most southern localities, lay very largely below those from over reefs in both water depths at all other locations. The question of whether the compositions of the fish faunas at each location and in shallow and deep waters at each location are significantly different is now addressed by subjecting separately to MDS ordination, the catch rates of fish over reefs and the densities of fish over soft substrates.

3.3.3 The compositions of the fish faunas over reefs

Fish trapping in shallow and deeper waters in each of the seven sampling locations in north-western Australia in 2000, 2001 and 2002 during the day and night yielded 14,916 and 10,823 fish, respectively (Tables 3.3.2, 3.3.3). The samples collectively contained 133 species, representing 38 families and 66 genera, with those obtained during daylight and night-time yielding 112 and 100 species, respectively (Tables 3.3.2, 3.3.3).

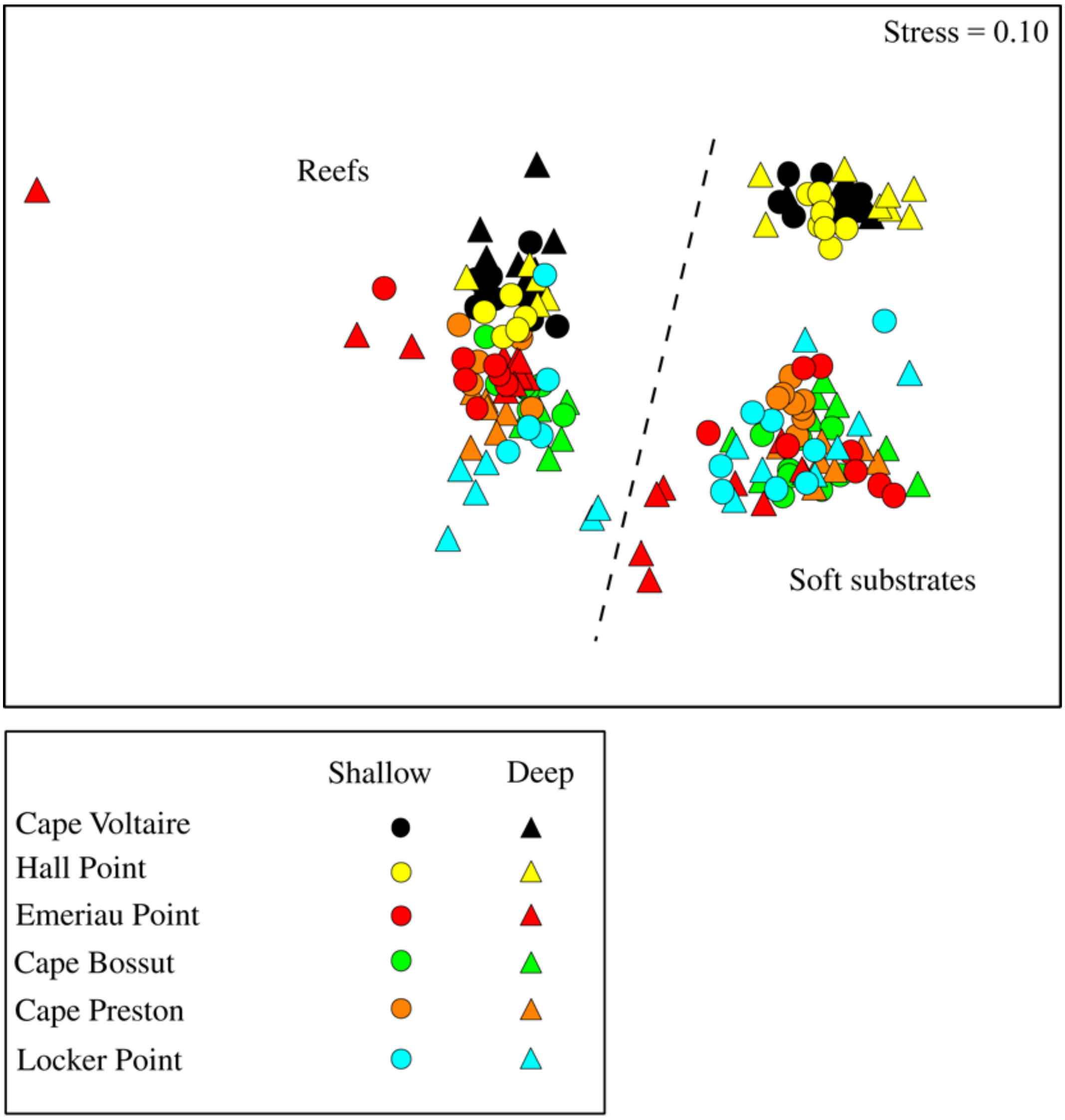

Figure 3.3.2 Nonmetric multidimensional scaling ordination of the percentage contributions of the various fish species caught by fish trapping over reefs and by trawling over soft substrates in shallow $\bar{x}$ = 12m) and deep waters ($\bar{x}$ = 22m) during the day at six locations in north-western Australia on one occasion in both 2001 and 2002.

Blue-spot emperor (*Lethrinus hutchinsi*) was the most abundant species overall in the samples obtained during both the day and night, contributing 37.3 and 35.0% to those samples, respectively, followed by the stripey snapper (*Lutjanus carponotatus*) and grass emperor (*Lethrinus laticaudis*), which respectively contributed 16.5 and 11.7% during the day and 25.5 and 10.3% at night (Tables 3.3.2, 3.3.3). These three species thus collectively accounted for over 65 and 70% of the total catches obtained by trapping during the day and night, respectively. *Lethrinus hutchinsi* was the second most abundant fish species in the trap and trawl catches of the Pilbara Demersal Finfish Fishery (PDF), with the majority of the catch being obtained offshore from the Dampier region (see Chapter 1). *Lutjanus carponotatus* and *L. laticaudis* are the first and second most frequent of the species in the catches of recreational anglers in the Pilbara and west Kimberley region (P. Williamson *et al.*, in prep.).

Table 3.3.3. List of fish species caught over reefs in shallow ($\bar{x}$ = 12 m) and deep waters ($\bar{x}$ = 22 m) at seven locations in north-western Australia using fish traps during the night on one occasion in 2000, 2001 and 2002. The ranking by abundance and percentage contribution of each species overall and the percentage contributions of each species to the catches in each depth at each location are provided.

					Kimberley								Pilbara					
		Overall			Cape Voltaire		Hall Point		Emeriau Point		Cape Bossut		Cape Keraudren		Cape Preston		Locker Point	
Family	Species	Rank	*n*	(%)	Shallow %	Deep %	Shallow %	Deep %	Shallow %	Deep %	Shallow %	Deep %	Shallow %	Deep %	Shallow %	Deep %	Shallow %	Deep %
Lethrinidae	*Lethrinus hutchinsi*	1	3788	35.0	-	1.9	2.0	-	47.8	21.4	51.2	51.0	58.9	24.6	52.9	49.2	52.9	23.5
Lutjanidae	*Lutjanus carponotatus*	2	2758	25.5	32.2	25.0	60.7	24.3	26.6	38.7	22.3	29.5	23.5	15.7	19.3	14.4	11.3	3.9
Lethrinidae	*Lethrinus laticaudis*	3	1119	10.3	21.3	17.0	21.7	13.3	10.0	24.9	6.4	2.5	4.6	7.7	7.5	2.9	9.3	-
Lutjanidae	*Lutjanus bitaeniatus*	4	537	5.0	2.0	16.1	-	52.2	-	-	-	-	-	-	-	-	-	-
Lutjanidae	*Lutjanus johnii*	5	265	2.4	22.0	21.9	-	5.9	-	-	-	-	-	-	-	-	-	-
Lutjanidae	*Lutjanus russelli*	6	185	1.7	0.2	-	-	-	-	-	0.5	0.4	1.2	4.2	7.6	2.1	6.3	3.4
Haemulidae	*Diagramma labiosum*	7"	173	1.6	2.3	2.0	4.6	3.1	-	0.7	0.5	0.6	0.8	20.1	0.1	0.6	0.3	0.2
Lethrinidae	*Lethrinus nebulosus*	7"	173	1.6	-	-	-	-	0.7	0.1	0.2	-	-	-	0.3	5.0	1.5	20.1
Lethrinidae	*Lethrinus atkinsoni*	9	147	1.4	-	-	-	-	-	-	-	-	-	-	-	3.0	-	22.5
Lethrinidae	*Lethrinus genivittatus*	10	129	1.2	-	-	-	-	-	-	2.1	1.9	0.9	-	0.1	2.7	3.7	4.8
Lutjanidae	*Lutjanus lemniscatus*	11	121	1.1	8.8	2.8	1.8	0.1	1.5	1.6	0.2	-	0.2	-	0.3	0.8	0.5	1.3
Siganidae	*Siganus fuscescens*	12	119	1.1	0.2	0.2	0.4	-	0.4	2.3	6.3	1.2	0.2	-	2.0	0.3	0.1	-
Balistidae	*Abalistes stellaris*	13	115	1.1	-	-	-	-	-	0.1	0.6	2.3	1.5	5.4	0.3	4.3	0.1	0.6
Serranidae	*Epinephelus coioides*	14	100	0.9	5.2	2.6	2.0	0.6	-	-	0.3	0.1	1.8	3.2	0.8	-	1.1	-
Nemipteridae	*Pentapodus emeryii*	15	99	0.9	-	-	-	-	2.4	0.9	0.5	2.3	0.5	1.0	-	0.9	-	3.4
Lutjanidae	*Lutjanus sebae*	16	95	0.9	-	0.4	-	-	-	1.2	1.1	1.0	0.4	1.9	0.2	3.8	0.3	1.9
Lethrinidae	*Lethrinus lentjan*	17	74	0.7	0.5	0.7	0.9	-	0.7	0.5	-	-	-	-	4.4	1.0	0.5	-
Carangidae	*Gnathanodon speciosus*	18	64	0.6	1.6	-	0.4	-	0.3	0.8	-	2.6	0.3	-	-	0.2	0.1	-
Glaucosomidae	*Glaucosoma magnificum*	19	60	0.6	-	-	-	-	0.1	0.2	3.2	0.7	1.1	2.9	-	-	0.8	-
Labridae	*Choerodon cyanodus*	20	58	0.5	-	0.2	1.6	-	4.0	0.5	0.9	-	-	-	0.4	0.1	0.1	-
Serranidae	*Epinephelus bilobatus*	21	56	0.5	-	-	-	-	1.5	0.6	0.8	-	0.4	0.3	0.2	0.8	1.1	1.9
Lutjanidae	*Lutjanus malabaricus*	22	55	0.5	-	2.4	-	-	-	0.5	0.3	-	-	-	0.3	-	4.0	-
Lutjanidae	*Lutjanus quinquelineatus*	23	52	0.5	-	-	-	-	-	-	0.3	-	-	-	-	3.1	1.7	1.9
Lutjanidae	*Lutjanus vitta*	24	38	0.4	-	-	-	-	-	-	0.3	0.1	0.6	-	0.3	0.9	0.4	2.8
Labridae	*Choerodon cauteroma*	25	32	0.3	0.2	-	-	-	-	-	0.5	0.3	0.3	2.9	-	1.0	0.3	0.2
Serranidae	*Plectropomus maculatus*	26	30	0.3	0.5	0.4	-	-	0.1	0.3	-	0.6	0.7	0.6	0.2	0.1	0.1	-
Pomacentridae	*Abudefduf bengalensis*	27	24	0.2	-	-	-	-	1.3	-	-	0.5	-	-	0.1	0.3	0.5	-
Haemulidae	*Plectorhinchus polytaenia*	28	23	0.2	-	-	-	-	-	1.5	0.2	0.1	0.1	0.3	-	-	-	-
Serranidae	*Epinephelus fasciatus*	29	22	0.2	-	-	-	-	-	-	-	0.7	0.3	-	-	0.2	0.1	1.1
Haemulidae	*Pomadasys kaakan*	30"	18	0.2	0.7	2.8	-	-	-	-	-	-	-	-	-	-	-	-
Nemipteridae	*Scolopsis monogramma*	30"	18	0.2	-	-	0.2	-	-	0.3	0.3	0.4	0.1	1.0	-	0.1	-	0.2
Nemipteridae	*Pentapodus porosus*	32	17	0.2	-	-	-	-	-	-	-	0.1	-	2.2	-	0.3	0.3	0.6

Table 3.3.3. continued.

					Kimberley								Pilbara					
		Overall			Cape Voltaire		Hall Point		Emeriau Point		Cape Bossut		Cape Keraudren		Cape Preston		Locker Point	
Family	Species	Rank	*n*	(%)	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
					%		%		%		%		%		%		%	
Ginglymostomatidae	*Nebrius ferrugineus*	33	15	0.1	-	0.2	0.4	-	0.3	0.2	-	-	0.4	0.3	0.1	0.1	0.1	-
Carangidae	*Caranx bucculentus*	34	14	0.1	0.5	1.3	0.4	-	-	0.2	-	-	-	-	-	-	-	-
Monacanthidae	*Monacanthus chinensis*	35"	12	0.1	-	-	-	-	0.1	-	0.5	0.2	0.1	-	0.2	-	0.1	0.2
Centropomidae	*Psammoperca waigiensis*	35"	12	0.1	0.7	0.6	-	0.1	-	-	-	0.1	0.1	-	-	0.1	0.1	-
Sphyraenidae	*Sphyraena jello*	37	11	0.1	-	-	0.2	-	0.6	0.2	-	-	-	-	0.2	0.1	-	-
Caesionidae	*Caesio cuning*	38"	10	0.1	-	-	0.5	-	-	0.1	-	-	-	-	-	0.6	0.1	-
Pomacanthidae	*Chaetodontoplus duboulayi*	38"	10	0.1	-	-	0.4	-	-	0.4	-	-	0.2	-	-	0.1	-	-
Serranidae	*Epinephelus bleekeri*	38"	10	0.1	-	-	-	-	-	-	-	-	-	-	1.1	-	-	-
Chaetodontidae	*Chelmon marginalis*	41"	9	0.1	-	0.2	0.4	-	-	0.3	-	0.1	-	-	0.1	-	-	-
Lutjanidae	*Lutjanus erythropterus*	41"	9	0.1	-	0.6	-	-	-	-	-	0.1	-	-	0.4	-	0.1	-
Lutjanidae	*Lutjanus fulviflamma*	41"	9	0.1	-	-	-	-	-	-	-	-	-	-	-	0.1	-	1.5
Haemulidae	*Plectorhinchus multivittatum*	41"	9	0.1	-	-	-	0.1	-	0.1	0.3	0.1	0.1	0.6	-	-	-	-
Lutjanidae	*Symphorus nematophorus*	45	8	0.1	-	-	-	-	-	0.1	-	-	0.1	1.6	-	-	-	0.2
Serranidae	*Epinephelus multinotatus*	46"	7	0.1	-	-	-	-	-	-	0.2	-	-	1.9	-	-	-	-
Serranidae	*Epinephelus polyphekadion*	46"	7	0.1	-	-	-	-	-	-	-	-	-	-	-	0.1	-	1.1
Serranidae	*Epinephelus quoyanus*	48"	6	0.1	-	-	-	-	-	0.1	0.2	0.1	0.1	-	-	0.1	-	-
Serranidae	*Epinephelus rivulatus*	48"	6	0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.7	0.2
Balistidae	*Pseudomonacanthus peroni*	48"	6	0.1	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-
Nemipteridae	*Nemipterus furcosus*	51"	5	<0.1	-	-	-	-	-	-	-	0.2	-	-	-	-	-	0.4
Sciaenidae	*Protonibea diacanthus*	51"	5	<0.1	0.5	0.2	-	-	-	0.2	-	-	-	-	-	-	-	-
Ariidae	*Arius thalassinus*	53"	4	<0.1	-	-	-	-	0.3	0.2	-	-	-	-	-	-	-	-
Hemiscyllidae	*Chiloscyllium punctatum*	53"	4	<0.1	-	0.2	0.4	0.1	-	-	-	-	-	-	-	-	-	-
Lethrinidae	*Lethrinus miniatus*	53"	4	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7
Lethrinidae	*Lethrinus olivaceus*	53"	4	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.4
Acanthuridae	*Acanthurus grammoptilus*	57"	3	<0.1	-	-	-	-	-	0.2	-	-	-	-	-	-	-	-
Carangidae	*Carangoides fulvoguttatus*	57"	3	<0.1	-	-	-	-	0.4	-	-	-	-	-	-	-	-	-
Carcharhinidae	*Negaprion acutidens*	57"	3	<0.1	-	-	-	-	-	-	0.2	-	-	0.6	-	-	-	-
Orectolobidae	*Orectolobus wardi*	57"	3	<0.1	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-
Mullidae	*Parupeneus indicus*	57"	3	<0.1	-	-	-	-	-	-	-	0.1	-	-	-	-	0.3	-
Balistidae	*Sufflamen fraenatus*	57"	3	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6
Chaetodontidae	*Chaetodon trifasciatus*	63"	2	<0.1	-	-	-	-	-	-	-	-	0.2	-	-	-	-	-
Chaetodontidae	*Coradion chrysozonus*	63"	2	<0.1	-	-	-	-	0.1	-	-	-	-	-	0.1	-	-	-
Serranidae	*Epinephelus malabaricus*	63"	2	<0.1	-	-	0.2	-	0.1	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Heniochus acuminatus*	63"	2	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	0.1	-
Lutjanidae	*Lutjanus argentimaculatus*	63"	2	<0.1	0.2	-	0.2	-	-	-	-	-	-	-	-	-	-	-

Table 3.3.3. continued.

					Kimberley						Pilbara							
			Overall		Cape Voltaire		Hall Point		Emeriau Point		Cape Bossut		Cape Keraudren		Cape Preston		Locker Point	
Family	Species	Rank	*n*	(%)	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
					%		%		%		%		%		%		%	
Lutjanidae	*Lutjanus rivulatus*	63”	2	<0.1	-	-	-	-	-	0.1	-	-	-	0.3	-	-	-	-
Ephippidae	*Zabidius novaemaculatus*	63”	2	<0.1	0.2	-	-	0.1	-	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Anchisomus multistriatus*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-
Tetraodontidae	*Arothron stellatus*	70”	1	<0.1	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-
Labridae	*Bodianus bilunulatus*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2
Labridae	*Bodianus perditio*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2
Carangidae	*Carangoides gymnostethus*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
Carangidae	*Caranx ignobilis*	70”	1	<0.1	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Carcharhinidae	*Carcharhinus amblyrhynchos*	70”	1	<0.1	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Carcharhinidae	*Carcharhinus melanopterus*	70”	1	<0.1	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-
Serranidae	*Cephalopholis miniata*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2
Balistidae	*Chaetodermis penicilligerus*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-
Chaetodontidae	*Chaetodon aureofasciatus*	70”	1	<0.1	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-
Chaetodontidae	*Chelmon muelleri*	70”	1	<0.1	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Serranidae	*Cromileptes altivelis*	70”	1	<0.1	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-
Haemulidae	*Dasyatis kuhlii*	70”	1	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Diodontidae	*Diodon holacanthus*	70”	1	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Grammistidae	*Diploprion bifasciatum*	70”	1	<0.1	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-
Echeneidae	*Echeneis naucrates*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-
Batrachoididae	*Halophryne diemensis*	70”	1	<0.1	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-
Batrachoididae	*Halophryne ocellatus*	70”	1	<0.1	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-
Hemiscyllidae	*Hemiscyllium trispeculare*	70”	1	<0.1	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-
Lethrinidae	*Lethrinus ravus*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2
Platycephalidae	*Leviprora inops*	70”	1	<0.1	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-
Carcharhinidae	*Loxodon macrorhinus*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
Holocentridae	*Myripristis hexagonus*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-
Nemipteridae	*Nemipterus hexodon*	70”	1	<0.1	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Sparidae	*Pagrus auratus*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
Ephippidae	*Platax batavianus*	70”	1	<0.1	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-
Haemulidae	*Plectorhinchus gibbosus*	70”	1	<0.1	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-
Ostraciidae	*Rhynchostracion rhinorhynchus*	70”	1	<0.1	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-
Diodontidae	*Tragulichthys jaculiferus*	70”	1	<0.1	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-
Carcharhinidae	*Triaenodon obesus*	70”	1	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Total			10823		441	540	549	845	718	1288	656	1426	994	313	893	874	749	537
Total species		100			20	25	23	12	25	35	28	33	31	24	27	35	37	31

The next most abundant species in the daytime trap catches were golden trevally (*Gnathanodon speciosus*), starry triggerfish (*Abalistes stellaris*), Indonesian snapper (*Lutjanus bitaeniatus*) and black spine-foot (*Siganus fuscescens*), which each contributed between 2.0 and 4.4% to the total catch during the day. The only other two species to contribute more than 2.0% to the total catches during the night were Indonesian snapper (*Lutjanus bitaeniatus*) and golden snapper (*Lutjanus johnii*), with contributions of 5.0 and 2.4%, respectively (Tables 3.3.2, 3.3.3). *Lutjanus johnii* and *G. speciosus* are important commercial and recreational species, respectively, on the Pilbara and west Kimberley coasts, with the latter species ranking fourth by number in the recreational catch of the former region (Sumner *et al*, 2002; Chapter 1).

Despite the overall dominance of the catches obtained by traps by 3 species, namely *Lethrinus laticaudis*, *L. hutchinsi* and *Lutjanus carponotatus*, the contributions of each of these species to catches varied among locations and between depths and between day and night. Thus, although *L. hutchinsi* contributed more than 20.8% to the catches obtained from both shallow and deep waters during both the day and night at the five most southern locations, it contributed less than 7.2% to the catches taken from both shallow and deep waters during both the day and night at the two most northern locations, *i.e.* Cape Voltaire and Hall Point. In contrast, the contributions made by *L. carponotatus* and *L. laticaudis* to the catches in both water depths during both the day and night were greatest at the three and two most northern locations, respectively (Tables 3.3.2, 3.3.3). Furthermore, *L. bitaeniatus* and *L. johnii* were caught only at the two most northern sites, *i.e.* Hall Point and Cape Voltaire, whereas spangled emperor (*Lethrinus nebulosus*) and purple threadfin bream (*Pentapodus emeryii*) were not caught at these locations, but were abundant in samples from the other five more southern locations (Tables 3.3.2, 3.3.3). *Lutjanus johnii* made a far greater contribution to the catches in both shallow and deep waters at Cape Voltaire than to those in both water depths at Hall Point (Tables 3.3.2, 3.3.3). *Lethrinus nebulosus* is an important commercial and recreational species in the region. It is the third most frequently caught species by recreational fishers in the Pilbara region and ranks in the top ten in the PDF and NDSF fisheries (Chapter 1).

At the two most northern locations, *L. bitaeniatus* made a substantial contribution to the catches in deep waters during both the day and night, *i.e.* 16.1 to 52.2%, but was either absent or made only a small contribution to those in shallow waters. Furthermore, *A. stellaris* was always more abundant in deep than in shallow water and sometimes markedly so. *Lutjanus carponotatus* was typically caught in greater numbers during the night than day and, in four of the seven locations, was at least twice as abundant in the night-time catches (Table 3.3.5). In contrast, *L. laticaudis* was caught in greater numbers during the day than night at five of the seven locations sampled (Table 3.3.5).

3.3.4 Ichthyofaunas of reefs during the day

ANOVA showed that the mean number of fish species and mean catch rate of fish, derived from samples collected by trapping over reefs, differed significantly among locations and between water depths (Table 3.3.6). The mean squares for location and depth were similar for the numbers of species and were greater for location than depth in the case of catch rates. The overall mean number of species and catch rates increased sequentially in a southwards direction from 1.3 species and 2.2 fish $4h^{-1}$ at the most northern location, *i.e.* Cape Voltaire, to 4.3 species and 19.2 fish $4h^{-1}$ at Cape Bossut, before declining to 1.9 species and 4.9 fish $4h^{-1}$ at the most southern location, *i.e.* Locker Point (Fig. 3.3.3a,c). Scheffe's *a posteriori* test demonstrated that the mean number of species was significantly greater at Cape Bossut than at Cape Voltaire and Locker Point and that the catch rates at Cape Bossut were significantly greater than at all other locations and those at Emeriau Point were significantly greater than at Cape Voltaire (Fig 3.3.3a,c). The overall mean number of species and catch rates in deep water, *i.e.* 2.8 and 6.4 fish $4h^{-1}$, were greater than those in shallow water, *i.e.* 1.9 and 4.5 fish $4h^{-1}$ (Fig 3.3.3b,d).

Table 3.3.4. List of fish species caught over soft substrate habitats in shallow ($\bar{x}$ = 12 m) and deep waters ($\bar{x}$ = 22 m) at seven locations in north-western Australia using an otter trawl net during the day on one occasion in both 2001 and 2002. The ranking by density and percentage contributions by numbers and biomass of each species overall after catches in each sample had been adjusted to a constant area of $10000m^2$; and the percentage contributions by density of each species to the catches in each water depth at each location are provided. Data have been restricted to those species that contributed ≥0.1% to the total catch.

						Kimberley								Pilbara					
		Overall				Cape Voltaire		Hall Point		Emeriau Point		Cape Bossut		Cape Keraudren		Cape Preston		Locker Point	
Family	Species	Rank	*n*		Wt.	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
				(%)		%		%		%		%		%		%		%	
Leiognathidae	*Leiognathus splendens*	1	4496.3	11.9	9.0	34.0	37.6	4.3	14.4	-	-	-	-	-	-	-	-	-	-
Carangidae	*Selaroides leptolepis*	2	3934.4	10.4	5.7	0.3	1.6	5.9	-	6.3	1.9	0.3	27.7	29.3	41.3	5.4	-	0.1	11.5
Pomacentridae	*Pristotis obtusirostris*	3	2708.7	7.1	1.5	-	-	-	-	14.7	3.8	62.0	3.8	0.1	27.3	2.7	8.7	14.9	3.9
Terapontidae	*Terapon theraps*	4	2679.9	7.1	10.7	5.3	17.4	27.6	23.4	0.1	-	-	-	-	-	-	-	0.5	-
Harpodontidae	*Saurida undosquamis*	5	2362.7	6.2	7.1	0.6	1.3	0.5	0.9	21.3	0.6	7.5	19.1	5.8	2.7	7.5	44.2	5.8	12.2
Monacanthidae	*Paramonacanthus choirocephalus*	6	2302.5	6.1	1.4	-	-	-	-	37.6	0.7	1.0	2.6	8.7	2.0	37.8	12.6	6.7	1.2
Leiognathidae	*Leiognathus leuciscus*	7	1644.8	4.3	2.8	12.2	2.3	11.6	2.2	-	-	-	8.4	9.4		<0.1	-	<0.1	-
Lethrinidae	*Lethrinus genivittatus*	8	1488.6	3.9	1.7	-	-	-	-	0.1	1.6	0.2	0.3	3.1	0.2	0.1	-	47.4	4.2
Leiognathidae	*Secutor insidiator*	9	1127.9	3.0	2.8	18.0	1.1	0.1	1.2	-	-	-	-	-	-	-	-	-	-
Carangidae	*Carangoides malabaricus*	10	966.0	2.5	2.0	4.2	10.4	1.1	1.6	-	-	-	0.3	2.5	-	-	-	-	-
Carangidae	*Caranx bucculentus*	11	917.4	2.4	5.6	1.6	1.3	18.9	5.5	0.8	-	-	-	0.9	-	-	-	-	-
Mullidae	*Upeneus sulphureus*	12	808.2	2.1	3.6	3.6	5.2	7.7	1.6	-	-	-	-	-	-	-	-	1.6	-
Tetraodontidae	*Torquigener pallimaculatus*	13	727.4	1.9	0.5	<0.1	-	0.2	0.2	0.1	0.2	4.8	5.5	1.7	6.3	2.4	6.0	3.3	1.0
Mullidae	*Upeneus asymmetricus*	14	661.7	1.7	0.7	-	-	-	-	-	-	-	3.0	7.6	1.8	5.2	0.2	3.0	3.2
Leiognathidae	*Leiognathus equulus*	15	485.8	1.3	1.7	1.3	6.9	<0.1	1.4	-	-	-	-	-	-	-	-	-	<0.1
Bothidae	*Engyprosopon grandisquama*	16	475.8	1.3	0.3	<0.1	-	<0.1	-	0.3	0.8	1.0	2.7	1.7	0.1	6.5	3.2	0.9	4.9
Bothidae	*Engyprosopon maldiviensis*	17	43<0.1	1.1	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	17.7
Siganidae	*Siganus fuscescens*	18	403.4	1.1	0.6	-	-	-	<0.1	-	0.4	-	0.3	0.4	0.5	8.1	1.3	4.3	0.3
Labridae	*Choerodon cephalotes*	19	374.0	1.0	2.1	<0.1	-	-	-	0.5	9.0	1.9	2.7	2.2	1.7	<0.1	0.3	2.4	0.8
Harpodontidae	*Saurida tumbil*	20	350.9	0.9	4.2	2.0	2.3	2.3	0.6	0.1	-	0.4	-	0.4	<0.1	0.1	0.1	-	0.2
Pinguipedidae	*Parapercis nebulosa*	21	340.5	0.9	0.8	<0.1	-	-	-	1.2	1.2	1.3	2.1	0.5	0.1	3.4	7.5	1.1	0.8
Nemipteridae	*Pentapodus porosus*	22	334.8	0.9	0.9	-	-	-	-	1.3	8.1	1.1	4.9	0.4	1.7	0.6	0.4	0.9	1.8
Nemipteridae	*Nemipterus furcosus*	23	323.9	0.9	0.7	-	-	-	-	0.3	0.7	-	0.9	0.2	1.6	1.9	0.6	0.1	6.8
Sillaginidae	*Sillago ingenua*	24	282.6	0.7	0.6	0.1	<0.1	-	0.2	0.3	-	4.1	0.3	0.9	4.2	0.3	0.2	<0.1	-
Haemulidae	*Pomadasys maculatum*	25	273.4	0.7	1.9	4.2	0.3	0.3	0.1	-	-	-	0.1	-	-	-	-	-	-
Tetraodontidae	*Lagocephalus sceleratus*	26	234.7	0.6	0.4	0.2	0.1	0.1	-	0.3	0.1	1.0	1.1	3.3	0.7	1.2	0.2	0.2	0.3
Sciaenidae	*Johnius borneensis*	27	221.7	0.6	0.4	0.1	0.2	-	8.4	-	-	-	-	-	-	-	-	-	-
Pomacanthidae	*Chaetodontoplus duboulayi*	28	214.8	0.6	1.2	-	-	-	<0.1	0.1	11.7	2.5	0.6	1.1	0.9	-	-		0.1
Apogonidae	*Apogon poecilopterus*	29	198.2	0.5	0.1	0.1	0.6	<0.1	6.7	-	-	0.1	-	-	-	-	-	-	-
Leiognathidae	*Leiognathus bindus*	30	187.3	0.5	0.1	0.7	0.3	1.2	3.9	-	-	-	-	-	-	-	-	-	-
Bothidae	*Pseudorhombus arsius*	31	185.6	0.5	1.0	0.3	0.2	1.0	1.7	0.1	-	0.1	1.1	0.7	<0.1	1.4	0.1	0.2	0.2
Priacanthidae	*Priacanthus tayenus*	32	181.0	0.5	0.4	0.1	0.1	0.3	<0.1	0.2	-	-	1.0	1.1	-	4.1	0.1	-	-
Labridae	*Choerodon vitta*	33	169.1	0.4	0.4	-	-	-	-	0.6	12.9	-	1.1	0.3	0.4	-	0.3	-	<0.1
Synodontidae	*Trachinocephalus myops*	34	166.9	0.4	0.4	-	-	-	-	0.3	-	1.2	0.9	0.3	<0.1	0.6	2.8	0.9	2.0
Lutjanidae	*Lutjanus vitta*	35	162.1	0.4	0.2	-	-	-	-	1.2	12.1	0.3	0.1	<0.1	0.7	-	-	-	0.1
Carangidae	*Carangoides humerosus*	36	158.3	0.4	0.7	0.1	0.5	4.0	<0.1	-	-	-	-	-	-	-	-	-	-
Gerreidae	*Gerres filamentosus*	37	143.3	0.4	0.6	0.8	1.4	0.8	<0.1	-	-	-	-	-	-	-	-	-	-

Table 3.3.4. continued.

Family	Species	Rank	Overall n	(%)	Wt.	Kimberley: Cape Voltaire Shallow %	Cape Voltaire Deep %	Hall Point Shallow %	Hall Point Deep %	Emeriau Point Shallow %	Emeriau Point Deep %	Cape Bossut Shallow %	Cape Bossut Deep %	Pilbara: Cape Keraudren Shallow %	Cape Keraudren Deep %	Cape Preston Shallow %	Cape Preston Deep %	Locker Point Shallow %	Locker Point Deep %
Leiognathidae	*Leiognathus ruconius*	38	141.5	0.4	0.1	1.9	<0.1	-	1.1	-	-	-	-	-	-	-	-	-	-
Bothidae	*Pseudorhombus argus*	39	138.9	0.4	0.3	-	-	-	-	0.3	1.6	0.7	1.6	0.8	0.3	0.1	1.7	0.1	1.2
Apogonidae	*Apogon sp.1* (Sainsbury *et al.*)	40	123.4	0.3	0.1	0.1	0.6	0.9	2.2	-	-	-	-	-	-	-	-	0.2	0.1
Sillaginidae	*Sillago burrus*	41	118.9	0.3	0.3	<0.1		-	-	0.2		-	-	1.8	-	2.1	-	-	-
Nemipteridae	*Nemipterus hexodon*	42	110.4	0.3	0.4	0.3	1.3	0.6	0.1	-	-	-	-	-	-	-	-	-	-
Clupeidae	*Pellona ditchela*	43	109.9	0.3	0.1	0.1	0.5	-	3.3	-	-	-	-	-	-	-	-	-	-
Diodontidae	*Cyclichthys orbicularis*	44	109.6	0.3	0.1	-	-	-	-	-	-	0.3	0.2	3.3	-	-	-	-	-
Gerreidae	*Pentaprion longimanus*	45	108.5	0.3	0.1	0.4	0.4	1.6	-	-	-	-	-	-	-	0.4	-	-	0.1
Apogonidae	*Apogon fasciatus*	46	105.6	0.3	0.1	0.2	1.2	0.5	0.6	-	-	-	-	-	-	-	-	-	-
Priacanthidae	*Priacanthus macracanthus*	47	102.3	0.3	0.2	-	-	-	0.2	-	1.3	-	-	-	1.9	-	-	<0.1	-
Leiognathidae	*Leiognathus fasciatus*	48	98.5	0.3	0.5	1.7	-	<0.1	-	-	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Coradion chrysozonus*	49	95.3	0.3	0.1	-	-	-	-	0.1	4.8	0.1	0.1	1.2	0.2	-	-	-	0.1
Bothidae	*Crossorhombus kanekonis*	50	92.8	0.2	0.1	-	-	-	-	-	-	-	-	-	-	<0.1	2.4	0.1	2.2
Platycephalidae	*Inegocia japonica*	51	9<0.1	0.2	0.2	<0.1	0.1	<0.1	0.9	-	0.2	-	0.2	0.4	<0.1	0.6	0.5	0.3	0.4
Mullidae	*Upeneus tragula*	52	87.7	0.2	0.1	-	-	-	-	0.1	5.4	1.2	0.1	0.3		<0.1	-	<0.1	0.6
Lutjanidae	*Lutjanus malabaricus*	53	87.6	0.2	0.2	0.3	-	0.2	-	0.7	-	-	-	<0.1	<0.1	2.0	-	0.1	-
Callionymidae	*Callionymus goodladi*	54	87.1	0.2	0.1	-	-	<0.1	-	1.8	-	0.1	-			2.0	0.6	-	-
Nemipteridae	*Pentapodus vitta*	55	83.9	0.2	0.2	-	-	-	-	1.1	-	-	-	1.9	0.2	-	-	-	-
Engraulididae	*Thryssa setirostris*	56	77.2	0.2	0.1	0.1	-	-	3.1	-	-	-	-	-	-	-	-	-	-
Mullidae	*Upeneus sundaicus*	57	75.6	0.2	0.2	0.2	0.1	0.1	0.1	-	-	-	-	-	-	-	-	0.7	1.4
Pomacentridae	*Chromis fumea*	58	73.5	0.2	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	3.0
Carangidae	*Ulua aurochs*	59	72.1	0.2	0.2	-	-	1.6	-	-	-	0.2	0.9	0.1	-	0.3	0.1	-	-
Sillaginidae	*Sillago lutea*	60	68.7	0.2	0.1	<0.1	0.1		0.7	0.1	-	-	0.1	1.3	-	-	-	0.1	-
Bothidae	*Pseudorhombus spinosus*	61	68.3	0.2	0.2	-	-	<0.1	-	0.4	0.1	1.6	0.4	0.4	0.1	0.1	0.9	-	0.4
Monacanthidae	*Paramonacanthus filicauda*	62	66.9	0.2	0.1	0.3	0.7	-	0.6	-	-	-	-	-	-	-	-	-	-
Cynoglossidae	*Paraplagusia longirostris*	63	64.8	0.2	0.2		<0.1	-	2.7	-	-	-	-	-	-	-	-	-	-
Diodontidae	*Tragulichthys jaculiferus*	64	64.2	0.2	0.9	-	-	-	0.1	1.2	2.2	0.9	0.1	0.4	0.1	-	0.2	-	0.1
Labridae	*Xyrichtys jacksonensis*	65	62.0	0.2	0.2	-	-	-	-	0.1	0.6	0.5	0.6	<0.1	<0.1	0.3	2.0	-	0.1
Carangidae	*Pantolabus radiatus*	66	61.5	0.2	0.4	0.3	0.2	1.0		-	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chelmon marginalis*	67	61.1	0.2	0.1	-	-	-	-	-	3.9	-	-	0.4	0.2	-	-	0.1	0.1
Aulostomidae	*Fistularia commersonii*	68	58.9	0.2	0.1	0.2	0.2	0.1	-	-	-	-	0.1	0.5	-	-	-	0.2	0.4
Leiognathidae	*Leiognathus decorus*	69	54.7	0.1	0.2	0.5	-		0.8	-	-	-	-	0.2	-	-	-	-	-
Leiognathidae	*Leiognathus moretoniensis*	70	54.3	0.1	0.1	0.3	0.2	0.3	0.8	-	-	-	-	-	-	-	-	-	-
Mullidae	*Parupeneus chryserpleuron*	71	53.3	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	2.2
Psettodidae	*Psettodes erumei*	72	52.4	0.1	0.6	0.3	0.4	0.4	-	-	-	-	-	<0.1	-	<0.1	-	<0.1	-
Polynemidae	*Polydactylus multiradiatus*	73	50.5	0.1	0.5	0.5	0.3		0.3	-	-	-	-	-	-	-	-	-	-
Carangidae	*Carangoides talamparoides*	74	45.7	0.1	0.2	<0.1	0.1	1.2	-	-	-	-	-	<0.1	-	-	-	-	-
Apogonidae	*Apogon albimaculosus*	75	44.8	0.1	<0.1	-	-		1.9	-	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon assarius*	76	43.9	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8
Synodontidae	*Synodus sageneus*	77	41.2	0.1	0.1	-	-	-	-	0.5	0.7	-	-	-	-	0.4	0.5	0.2	0.1

Table 3.3.4. continued.

						Kimberley								Pilbara					
		Overall				Cape Voltaire		Hall Point		Emeriau Point		Cape Bossut		Cape Keraudren		Cape Preston		Locker Point	
Family	Species	Rank	*n*		Wt.	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
				(%)		%		%		%		%		%		%		%	
Carangidae	*Carangoides hedlandensis*	78	40.7	0.1	0.1	-	0.1	0.3	-	-	-	-	-	0.8	0.1	-	-	-	-
Engraulididae	*Thryssa hamiltonii*	79	40.3	0.1	0.2	0.1	0.1	-	1.2	-	-	-	-	-	-	-	-	-	-
Labridae	*Choerodon monostigma*	80	40.2	0.1	0.2	-	-	-	0.5		3.1	-	-	-	-	-	-		<0.1
Carangidae	*Carangoides fulvoguttatus*	81	39.7	0.1	0.1	-	-	-	-	-	-	-	-		0.8	-	0.1	<0.1	0.1
Triacanthidae	*Trixiphichthys weberi*	82	38.3	0.1	0.1	0.1	0.2	0.6	0.2	-	-	-	-	0.1	-	-	-	-	-
Total			37908.1			5792.9	5455.2	3049.2	2412.9	1272.8	889.2	843.1	1293.7	3137.3	4457.4	2683.0	1543.5	2652.8	2425.0
Total species		279				90	74	69	78	56	59	43	61	81	56	61	46	76	107

Table 3.3.5. List of fish species caught in reef habitats in shallow ($\bar{x}$ = 12 m) and deep ($\bar{x}$ = 22 m) waters at seven locations in north-western Australia using fish traps during the day and during the night on one occasion in 2002. The ranking, abundance and percentage contribution of each species overall and the percentage contributions of each species to the catches in each diel period at each location are provided.

					Kimberley								Pilbara					
		Overall			Cape Voltaire		Hall Point		Emeriau Point		Cape Bossut		Cape Keraudren		Cape Preston		Locker Point	
Family	Species	Rank	*n*	(%)	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
					%		%		%		%		%		%		%	
Lutjanidae	*Lutjanus carponotatus*	1	2,108	35.1	16.7	29.3	46.7	51.6	44.0	42.5	29.3	60.5	17.2	45.1	4.2	21.5	6.3	14.8
Lethrinidae	*Lethrinus hutchinsi*	2	1,065	17.7	-	-	0.2	-	14.8	35.1	14.5	19.1	20.5	20.8	25.6	42.9	16.1	32.7
Lethrinidae	*Lethrinus laticaudis*	3	495	8.2	12.6	7.3	18.6	10.5	7.0	12.0	9.6	4.8	11.5	6.2	5.0	2.1	2.2	2.8
Carangidae	*Gnathanodon speciosus*	4	387	6.4	-	-	-	-	19.0	1.3	10.6	-	5.2	-	-	-	-	-
Lutjanidae	*Lutjanus bitaeniatus*	5	238	4.0	10.7	16.4	16.6	27.1	-	-	-	-	-	-	-	-	-	-
Lutjanidae	*Lutjanus lemniscatus*	6	139	2.3	6.1	4.5	1.6	1.6	2.1	2.2	0.5	-	0.3	-	11.2	0.6	4.0	0.6
Lutjanidae	*Lutjanus johnii*	7	137	2.3	26.5	29.0	0.8	4.0	-	-	-	-	-	-	-	-	-	-
Balistidae	*Abalistes stellaris*	8	109	1.8	-	-	-	-	0.8	0.2	6.0	1.4	4.5	-	12.3	2.5	0.5	0.3
Lutjanidae	*Lutjanus russelli*	9	109	1.8	-	-	-	-	-	-	-	-	-	1.6	9.2	6.1	2.0	15.6
Lutjanidae	*Lutjanus sebae*	10	97	1.6	-	-	-	-	0.7	0.1	1.5	0.6	2.2	2.8	9.9	7.3	0.9	1.8
Serranidae	*Epinephelus coioides*	11	96	1.6	10.3	3.4	2.9	0.8	-	-	3.3	0.3	3.7	2.8	1.3	0.9	3.4	0.9
Haemulidae	*Diagramma labiosum*	12	84	1.4	0.4	-	3.0	2.3	0.9	-	3.0	0.9	4.4	3.6	1.6	0.6	-	0.9
Siganidae	*Siganus fuscescens*	13	78	1.3	-	-	-	-	1.1	1.0	2.3	1.7	10.6	-	-	-	3.7	-
Nemipteridae	*Pentapodus emeryii*	14	62	1.0	-	-	-	-	0.9	0.6	1.9	0.8	2.6	-	0.6	0.3	8.3	0.9
Glaucosomatidae	*Glaucosoma magnificum*	15	59	1.0	-	-	1.0	-	2.4	-	0.3	0.9	1.0	5.0	-	-	-	1.2
Lethrinidae	*Lethrinus nebulosus*	16	58	1.0	-	-	-	-	0.2	-	-	-	-	-	1.6	0.6	14.6	4.2
Lethrinidae	*Lethrinus atkinsoni*	17	42	0.7	-	-	-	-	-	-	-	-	-	-	0.9	1.2	5.7	6.4
Serranidae	*Epinephelus bilobatus*	18	41	0.7	-	-	-	-	0.4	0.3	-	-	0.7	0.6	2.7	-	6.7	1.2
Lutjanidae	*Lutjanus malabaricus*	19	38	0.6	5.2	1.6	-	-	-	-	-	0.6	-	-	4.4	0.6	0.4	0.9
Lutjanidae	*Lutjanus quinquelineatus*	20	37	0.6	-	-	-	-	-	-	-	-	-	-	0.6	6.4	-	3.9
Labridae	*Choerodon cyanodus*	21	36	0.6	0.8	-	0.4	0.3	0.6	1.0	1.5	0.6	0.4	-	1.2	0.6	-	-
Labridae	*Choerodon cauteroma*	22	32	0.5	-	-	-	-	0.1	-	0.9	0.3	5.6	-	1.6	-	1.9	0.3
Chaetodontidae	*Chaetodontoplus duboulayi*	23	28	0.5	0.4	-	1.8	-	0.2	-	1.4	-	1.1	-	0.6	-	1.9	-
Lutjanidae	*Lutjanus vitta*	24	25	0.4	-	-	-	-	-	-	0.2	0.3	-	1.6	-	1.4	2.8	2.4
Lethrinidae	*Lethrinus lentjan*	25"	24	0.4	0.5	-	0.8	0.3	0.1	0.4	-	-	-	-	2.9	0.8	-	0.3
Mullidae	*Parupeneus indicus*	25"	24	0.4	-	-	-	-	1.3	-	-	-	-	-	-	-	0.9	-
Haemulidae	*Plectorhinchus polytaenia*	25"	24	0.4	-	-	-	-	0.6	1.8	0.3	0.6	-	-	-	-	-	-
Serranidae	*Plectropomus maculatus*	28	23	0.4	1.8	-	0.8	-	0.2	-	0.7	1.1	0.4	0.5	-	0.9	-	-
Pomacentridae	*Abudefduf bengalensis*	29	21	0.3	-	-	-	-	-	-	0.3	2.0	-	-	-	0.3	3.7	1.2
Monacanthidae	*Monacanthus chinensis*	30	19	0.3	-	-	1.3	-	-	-	2.4	0.6	-	-	-	-	-	-
Nemipteridae	*Scolopsis monogramma*	31	16	0.3	-	-	0.2	-	0.2	-	1.4	-	0.4	-	-	-	2.2	-
Serranidae	*Epinephelus fasciatus*	32	15	0.2	-	-	-	-	-	-	1.2	0.3	-	-	-	0.3	1.6	1.2
Ginglymostomatidae	*Nebrius ferrugineus*	33"	14	0.2	0.5	0.6	-	0.5	-	0.3	-	-	-	2.8	-	0.6	-	0.3
Centropomidae	*Psammoperca waigiensis*	33"	14	0.2	-	2.8	0.2	-	-	-	1.3	0.3	-	-	-	0.3	-	0.3
Chaetodontidae	*Chelmon marginalis*	35"	13	0.2	-	-	-	-	0.4	-	-	-	1.0	-	0.6	-	0.9	-
Haemulidae	*Pomadasys kaakan*	35"	13	0.2	2.7	3.5	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	*Plectorhinchus multivittatum*	37	12	0.2	-	-	-	0.3	0.2	-	1.3	0.5	-	0.6	-	-	-	-
Caesionidae	*Caesio cuning*	38"	11	0.2	0.5	-	0.8	0.5	0.1	-	-	-	-	-	-	0.9	-	-
Sphyraenidae	*Sphyraena jello*	38"	11	0.2	0.4	-	-	-	0.3	0.7	0.3	-	-	-	-	-	-	-

Table 3.3.5. continued.

Family	Species	Overall Rank	Overall *n*	Overall (%)	Kimberley: Cape Voltaire Day %	Cape Voltaire Night %	Hall Point Day %	Hall Point Night %	Emeriau Point Day %	Emeriau Point Night %	Cape Bossut Day %	Cape Bossut Night %	Pilbara: Cape Keraudren Day %	Cape Keraudren Night %	Cape Preston Day %	Cape Preston Night %	Locker Point Day %	Locker Point Night %
Carangidae	*Caranx tille*	40"	8	0.1	2.0	-	-	-	-	-	0.8	-	-	-	-	-	-	-
Serranidae	*Epinephelus multinotatus*	40"	8	0.1	-	-	-	-	-	-	0.5	-	1.5	1.2	-	-	-	-
Lethrinidae	*Lethrinus genivittatus*	40"	8	0.1	-	-	-	-	-	-	0.4	0.6	-	-	-	-	0.5	0.9
Nemipteridae	*Pentapodus porosus*	40"	8	0.1	-	-	-	-	-	-	-	-	-	3.6	-	-	-	0.3
Lethrinidae	*Lethrinus olivaceus*	44"	7	0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	1.8	0.6
Chaetodontidae	*Parachaetodon ocellatus*	44"	7	0.1	-	-	-	-	-	-	1.5	-	-	-	-	-	-	-
Carangidae	*Carangoides fulvoguttatus*	46"	6	0.1	-	-	-	-	0.4	-	-	-	0.4	-	-	-	-	-
Ephippidae	*Platax teira*	46"	6	0.1	-	-	-	-	0.1	-	-	-	-	-	0.3	-	1.9	-
Serranidae	*Epinephelus rivulatus*	48"	5	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5
Mullidae	*Parupeneus spilurus*	48"	5	0.1	-	-	-	-	-	-	-	-	-	-	0.6	-	1.4	-
Haemulidae	*Plectorhinchus gibbosus*	48"	5	0.1	0.4	-	-	-	0.1	-	-	-	0.4	0.5	-	-	-	-
Siganidae	*Siganus doliatus*	48"	5	0.1	-	-	-	-	0.2	-	-	-	-	-	0.6	-	-	-
Acanthuridae	*Acanthurus xanthopterus*	52"	4	0.1	-	-	0.2	-	0.2	-	-	-	-	-	-	-	-	-
Serranidae	*Epinephelus malabaricus*	52"	4	0.1	-	-	0.2	-	-	-	-	-	0.7	-	-	-	0.4	-
Serranidae	*Epinephelus quoyanus*	52"	4	0.1	-	-	-	-	-	-	-	0.3	0.4	0.5	-	0.3	-	-
Lethrinidae	*Lethrinus miniatus*	52"	4	0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.8	0.6
Lutjanidae	*Symphorus nematophorus*	52"	4	0.1	-	-	-	-	-	-	-	-	1.4	-	-	-	-	-
Carcharhinidae	*Triaenodon obesus*	52"	4	0.1	-	-	0.4	-	-	-	-	-	0.8	-	-	-	-	-
Carcharhinidae	*Carcharhinus amblyrhynchos*	58"	3	<0.1	0.4	-	0.4	-	-	-	-	-	-	-	-	-	-	-
Scaridae	*Scarus ghobban*	58"	3	<0.1	-	-	0.4	-	-	-	-	-	-	-	0.3	-	-	-
Chaetodontidae	*Zabidius novaemaculatus*	58"	3	<0.1	-	0.6	-	0.3	0.1	-	-	-	-	-	-	-	-	-
Carangidae	*Carangoides gymnostethus*	61"	2	<0.1	-	-	-	-	-	-	0.3	-	-	-	0.3	-	-	-
Serranidae	*Cromileptes altivelis*	61"	2	<0.1	-	-	0.2	-	0.1	-	-	-	-	-	-	-	-	-
Serranidae	*Epinephelus areolatus*	61"	2	<0.1	0.4	-	-	-	-	-	-	-	-	-	-	-	0.5	-
Serranidae	*Epinephelus polyphekadion*	61"	2	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.9	-
Chaetodontidae	*Heniochus acuminatus*	61"	2	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Lutjanidae	*Lutjanus fulviflamma*	61"	2	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6
Ephippidae	*Platax batavianus*	61"	2	<0.1	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-
Sciaenidae	*Protonibea diacanthus*	61"	2	<0.1	-	1.1	-	-	-	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Anchisomus multistriatus*	69"	1	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Arothron hispidus*	69"	1	<0.1	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Arothron stellatus*	69"	1	<0.1	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-
Carangidae	*Caranx bucculentus*	69"	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-
Carangidae	*Caranx ignobilis*	69"	1	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Carcharhinidae	*Carcharhinus limbatus*	69"	1	<0.1	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-
Carcharhinidae	*Carcharhinus sorrah*	69"	1	<0.1	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
Monacanthidae	*Chaetodermis penicilligerus*	69"	1	<0.1	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon aureofasciatus*	69"	1	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chelmon muelleri*	69"	1	<0.1	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-
Labridae	*Choerodon cephalotes*	69"	1	<0.1	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-
Dasyatidae	*Dasyatis kuhlii*	69"	1	<0.1	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-
Diodontidae	*Diodon holacanthus*	69"	1	<0.1	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-

Table 3.3.5. continued.

					Kimberley								Pilbara					
		Overall			Cape Voltaire		Hall Point		Emeriau Point		Cape Bossut		Cape Keraudren		Cape Preston		Locker Point	
Family	Species	Rank	*n*	(%)	Day %	Night %	Day %	Night %	Day %	Night %	Day %	Night %	Day %	Night %	Day %	Night %	Day %	Night %
Grammistidae	*Diploprion bifasciatum*	69"	1	<0.1	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-
Echeneidae	*Echeneis naucrates*	69"	1	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Serranidae	*Epinephelus fuscoguttatus*	69"	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-
Lutjanidae	*Lutjanus rivulatus*	69"	1	<0.1	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-
Holocentridae	*Myripristis hexagonus*	69"	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-
Haemulidae	*Plectorhinchus orientalis*	69"	1	<0.1	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-
Haemulidae	*Pomacanthus semicirculatus*	69"	1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-
Scorpaenidae	*Pterois volitans*	69"	1	<0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Ostracidae	*Rhynchostracion nasus*	69"	1	<0.1	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-
Ostracidae	*Rhynchostracion rhinorhynchus*	69"	1	<0.1	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-
Sphyraenidae	*Sphyraena quenie*	69"	1	<0.1	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-
Diodontidae	*Tragulichthys jaculiferus*	69"	1	<0.1	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-
Total			6059		244	184	488	382	1591	670	422	356	283	193	334	343	236	333
Total species		96			23	13	27	14	40	18	34	28	30	18	26	26	34	32

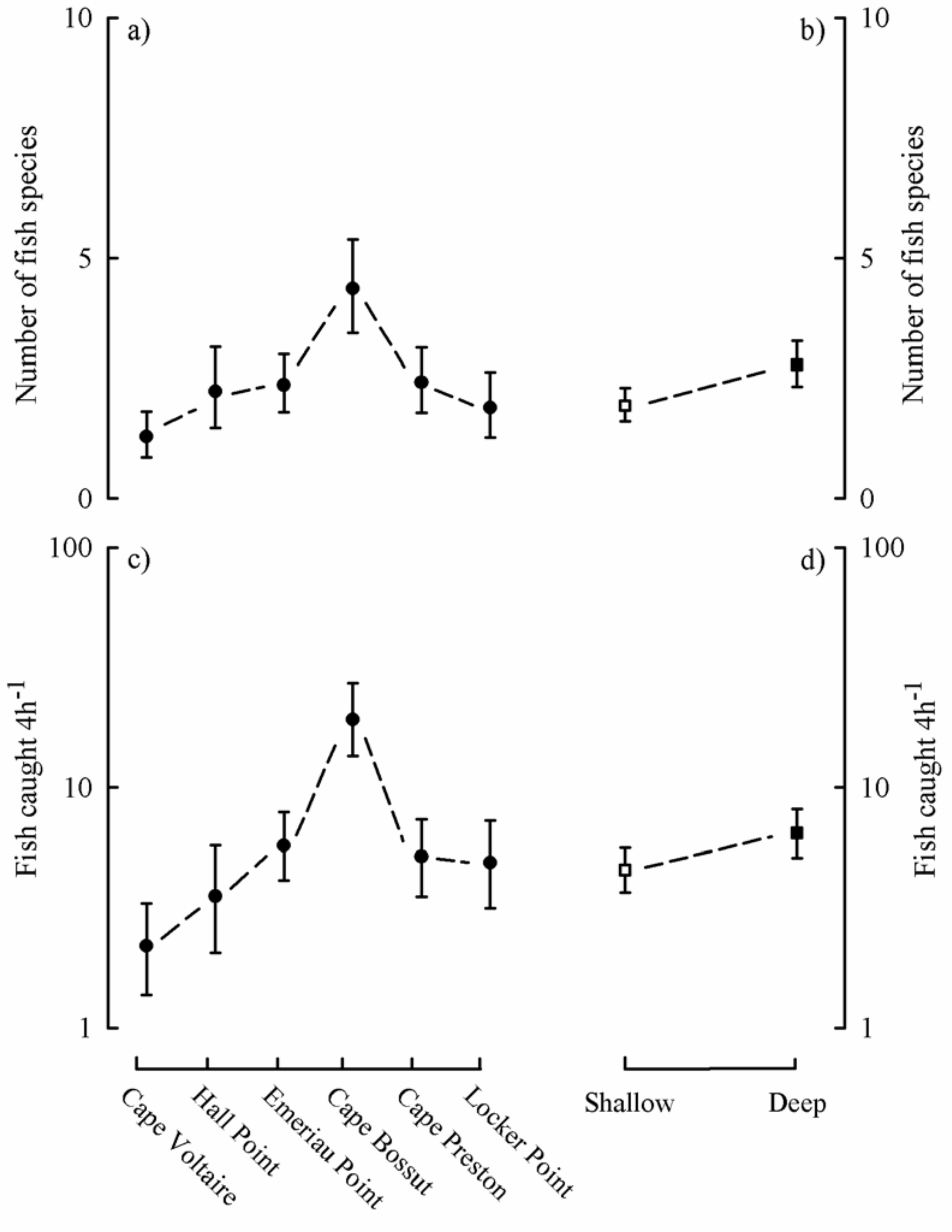

Figure 3.3.3 Mean numbers of fish species and catch rates of fish ±95% CIs over reefs at the different locations during the day (a and c) and in shallow and deep waters (b and d) on one occasion in both 2000 and 2001.

The mean catch rates of *L. hutchinsi*, *L. laticaudis* and *L. carponotatus* differed significantly among locations and there were significant interactions between location and depth with the latter two species (Table 3.3.6). The mean catch rate of *L. hutchinsi* was significantly greater at Cape Bossut ($P < 0.001$) than at all other locations and was also significantly greater at Emeriau Point, Cape Preston and Locker Point than at Cape Voltaire (Fig. 3.3.4a). The interaction between location and depth for *L. carponotatus* and *L. laticaudis* is explained by the fact that, while the catch rates were greater in shallow than deep waters in four and five of the six locations, respectively, the reverse pertained at the other two and one locations, respectively (Fig. 3.3.4b,c).

Table 3.3.6 Mean squares and significance levels for two-way ANOVAs of the mean number of fish species and the mean catch rates of fish and of the three most abundant fish species derived from the catches obtained by fish trapping over reef habitats during the day at six locations in north-western Australia on one occasion in both 2000 and 2001.

	Main effects		Interactions	
	Location (L)	Depth (D)	L x D	Residual
	DF (5)	(1)	(5)	(91)
Mean number of species	1.633***	1.797**	0.208	0.214
Mean catch rate	1.178***	0.385**	0.081	0.081
Lethrinus hutchinsi	1.733***	0.007	0.149	0.079
Lutjanus carponotatus	0.210***	0.002	0.088**	0.023
Lethrinus laticaudis	0.149**	0.028	0.303***	0.032

DF, degrees of freedom; $^{**}P < 0.01$; $^{***}P < 0.001$.

On the ordination plot derived from the trap catch rates for species in shallow and deep waters at the different sampling locations, the samples from the two most northern latitudes, *i.e.* Cape Voltaire and Hall Point, formed a group in the upper region of the plot, whereas those from deep water at the most southern latitude, *i.e.* Locker Point, were mainly located towards the bottom of the plot and those from Emeriau Point occupied an intermediate position (Fig. 3.3.5a). One-way ANOSIMs showed that the species compositions of the fish fauna over reefs were significantly influenced by both location and water depth ($P<0.001$), with the *R*-statistic for location (0.353) being more than twice that for depth (0.147). The main typifying species for the shallow and deep waters at each location are shown in Table 3.3.7. For example, the shallow waters at Cape Voltaire and Hall Point were typified by *L. carponotatus*, *L. laticaudis* and either the estuary cod (*Epinephelus coioides*) or the dark-tailed snapper (*Lutjanus lemniscatus*), whereas the deeper water at these two locations were typified by the former two species and *L. bitaeniatus*. However, at each of the other locations, the fish faunas over reefs in shallow waters were typified by *L. hutchinsi* and *L. carponotatus* or *L. laticaudis*, whereas those in deeper waters were typified by *L. hutchinsi* and either *L. laticaudis*, *L. carponotatus, A. stellaris* or *L. nebulosus.*

Since the one-way ANOSIM demonstrated that location had the greatest influence on the species compositions of the samples, the effect of location was examined in each depth separately. The samples collected from shallow water at most locations tended to form groups in different parts of the plot (Fig. 3.3.5b). One-way ANOSIM demonstrated that the species compositions in the shallow waters of the different locations were significantly different ($P<0.001$, R-statistic = 0.426). Pair-wise ANOSIM comparison tests showed that the samples from each location were significantly different from that in each other location in all cases except for Emeriau Point *vs* Locker Point and Cape Preston *vs* Locker Point. The species that distinguished between the faunas of each pair of locations in shallow water, except for those two pairs of locations where the difference was not significant, are shown in Table 3.3.8. For example, the fauna at Cape Bossut was distinguished from those at all other locations by a greater contribution of *L. hutchinsi* and red emperor (*Lutjanus sebae*), whereas the fauna in shallow water at Hall Point was distinguished from that at each other location by a greater contribution of *L. laticaudis* (Table 3.3.8).

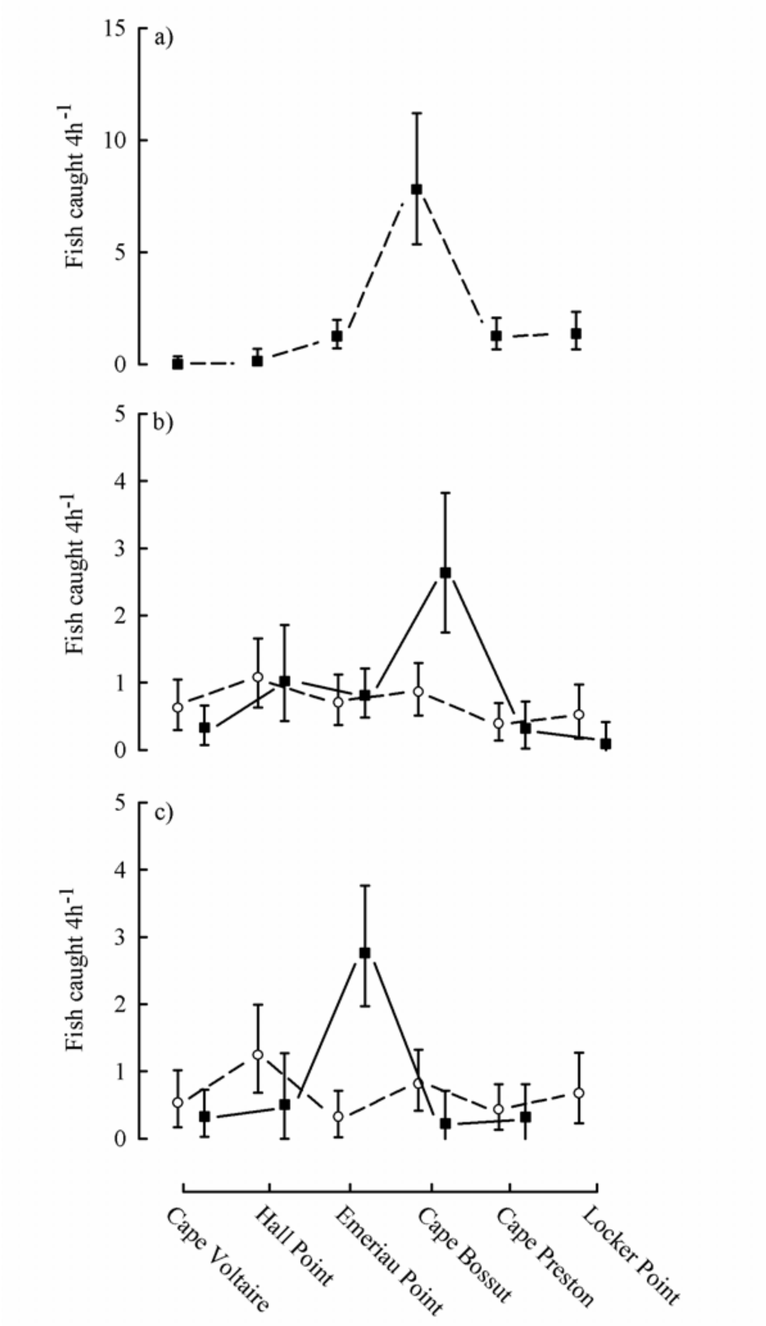

Figure 3.3.4 Mean catch rates ±95% CI for a) *Lethrinus hutchinsi* in shallow and deep waters at six locations in north-western Australia and mean catch rates ±95% CIs of b) *Lutjanus carponotatus* and c) *Lethrinus laticaudis* in shallow (O) and deep (■) waters at six locations during the day in north-western Australia on one occasion in both 2000 and 2001.

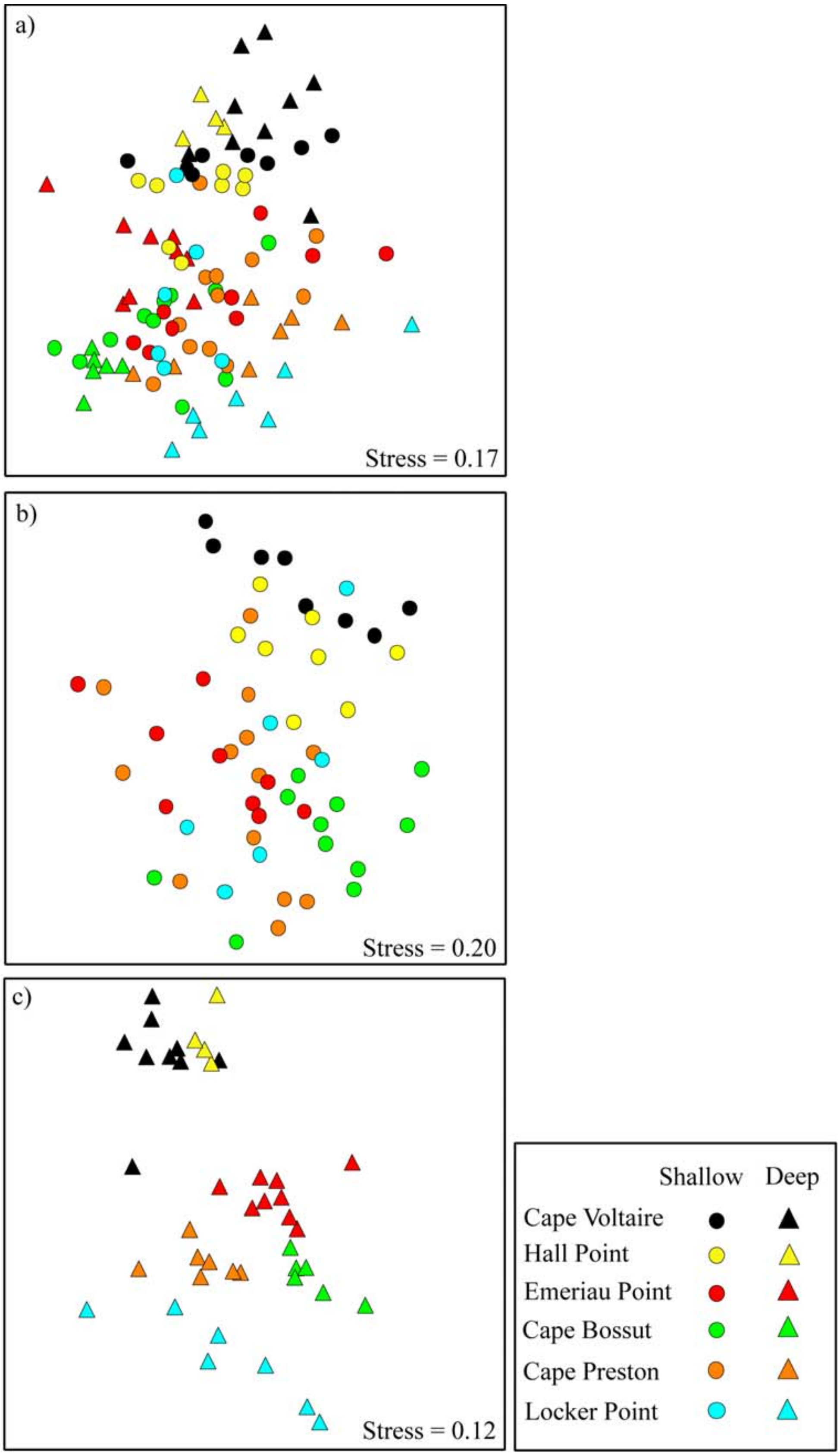

Figure 3.3.5 Nonmetric multidimensional scaling ordinations of the catch rates of the various fish species caught by fish trapping over reefs in a) shallow ($\overline{x}$ = 12m) and deep ($\overline{x}$ = 22m) waters and b) shallow and c) deep waters separately at six locations during the day in north-western Australia on one occasion in both 2000 and 2001.

Table 3.3.7 Species shown by SIMPER to typify the fish communities over reef in shallow and deep waters at six locations in north-western Australia during the day on one occasion in both 2000 and 2001.

	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Preston	Locker Point
Shallow	*Lutjanus carponotatus* *Lethrinus laticaudis* *Epinephelus coioides* *Lutjanus lemniscatus*	*Lutjanus carponotatus* *Lethrinus laticaudis* *Lutjanus lemniscatus* *Lethrinus hutchinsi* *Choerodon cyanodus*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Choerodon cyanodus* *Lethrinus laticaudis* *Pentapodus emeryii*	*Lethrinus hutchinsi* *Lethrinus laticaudis* *Lutjanus carponotatus* *Lutjanus sebae* *Choerodon cyanodus* *Gnathanodon speciosus*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lethrinus laticaudis* *Abalistes stellaris* *Lutjanus lemniscatus*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lethrinus laticaudis* *Lethrinus nebulosus* *Epinephelus coioides*
Deep	*Lethrinus laticaudis* *Lutjanus carponotatus* *Lutjanus bitaeniatus* *Lutjanus lemniscatus* *Lutjanus johnii* *Epinephelus coioides*	*Lutjanus bitaeniatus* *Lutjanus carponotatus* *Lethrinus laticaudis*	*Lethrinus laticaudis* *Lethrinus hutchinsi* *Lutjanus carponotatus* *Diagramma labiosum* *Pentapodus emeryii*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Abalistes stellaris* *Gnathanodon speciosus* *Pentapodus emeryii*	*Lethrinus hutchinsi* *Abalistes stellaris* *Lethrinus laticaudis* *Lutjanus sebae* *Lutjanus carponotatus* *Lethrinus nebulosus* *Lethrinus atkinsoni*	*Lethrinus hutchinsi* *Lethrinus nebulosus* *Lethrinus genivittatus* *Lethrinus atkinsoni* *Pentapodus emeryii* *Sufflamen fraenatus*

Table 3.3.8 Species shown by SIMPER that distinguish the fish communities over reefs in shallow water at six locations in north-western Australia during the day between 2000 and 2001. The species shown make a relatively greater contribution at the location at the top of each column.

Location	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Preston	Locker Point
Locker Point	*Lutjanus lemniscatus*	*Lethrinus laticaudis* *Lutjanus lemniscatus*		*Lethrinus hutchinsi* *Abalistes stellaris* *Lutjanus sebae* *Pentapodus emeryii*		
Cape Preston	*Lethrinus laticaudis*	*Lethrinus laticaudis* *Lutjanus carponotatus*	*Lethrinus hutchinsi* *Choerodon cyanodus* *Lutjanus carponotatus*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lutjanus sebae* *Pentapodus emeryii*		
Cape Bossut			*Lutjanus lemniscatus*			*Lethrinus nebulosus*
Emeriau Point	*Epinephelus coioides*	*Lethrinus laticaudis*		*Lethrinus hutchinsi* *Lutjanus sebae* *Abalistes stellaris*	*Abalistes stellaris* *Lethrinus laticaudis*	
Hall Point	*Epinephelus coioides*		*Lethrinus hutchinsi* *Choerodon cyanodus* *Pentapodus emeryii*	*Lethrinus hutchinsi* *Lutjanus sebae* *Abalistes stellaris* *Pentapodus emeryii*	*Lethrinus hutchinsi* *Abalistes stellaris*	*Lethrinus hutchinsi* *Lethrinus nebulosus*
Cape Voltaire		*Lethrinus laticaudis* *Lutjanus carponotatus*	*Lethrinus hutchinsi* *Choerodon cyanodus*	*Lethrinus hutchinsi* *Lutjanus sebae* *Abalistes stellaris* *Pentapodus emeryii*	*Lethrinus hutchinsi* *Abalistes stellaris*	*Lethrinus hutchinsi* *Lethrinus laticaudis* *Lethrinus nebulosus*

When the catch rates for species in deep water were ordinated separately, the samples from each location tended to form discrete groups (Fig. 3.3.5c). All of the samples from Hall Point and Cape Voltaire lay in the top of the plot, while those from Locker Point were located in the bottom of the plot and those from Emeriau Point, Cape Bossut and Cape Preston lay in the middle of the plot (Fig. 3.3.5c). One-way ANOSIM demonstrated that the species compositions in deep water in the different locations were significantly different ($P<0.001$, R-statistic = 0.808). Pair-wise ANOSIM tests demonstrated that the samples from each location were significantly different from each other in all cases except for those at the two most northern locations, Cape Voltaire and Hall Point. The species that distinguished between the faunas in deep water at each pair of locations, except for Cape Voltaire *vs* Hall Point, are shown in Table 3.3.9. As an example, the fauna at Hall Point was distinguished from those at all other locations by relatively greater catch rates of *L. bitaeniatus*, whereas those at Emeriau Point and Cape Bossut were distinguished from those at all other locations by relatively greater catch rates of *L. laticaudis* and *L. hutchinsi*, respectively (Table 3.3.9).

Table 3.3.9 Species shown by SIMPER that distinguish the fish communities over reefs in deep water at six locations in north-western Australia during the day between 2000 and 2001. The species shown make a relatively greater contribution at the location at the top of each column.

Location	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Preston	Locker Point
Locker Point	*Lutjanus bitaeniatus* *Lutjanus johnii* *Lethrinus laticaudis* *Epinephelus coioides*	*Lutjanus bitaeniatus* *Lutjanus carponotatus* *Lethrinus laticaudis*	*Lethrinus laticaudis* *Lutjanus carponotatus* *Diagramma labiosum*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Abalistes stellaris* *Gnathanodon speciosus*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lethrinus laticaudis*	
Cape Preston	*Lutjanus bitaeniatus* *Lutjanus johnii* *Epinephelus coioides*	*Lutjanus bitaeniatus*	*Lethrinus laticaudis* *Lutjanus carponotatus* *Diagramma labiosum*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Gnathanodon speciosus*		*Lethrinus atkinsoni* *Lethrinus nebulosus*
Cape Bossut	*Lutjanus bitaeniatus* *Lutjanus johnii*	*Lutjanus bitaeniatus*	*Lethrinus laticaudis* *Diagramma labiosum*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Gnathanodon speciosus*	*Lethrinus atkinsoni* *Lutjanus sebae*	*Lethrinus nebulosus*
Emeriau Point	*Lutjanus bitaeniatus* *Lutjanus johnii*	*Lutjanus bitaeniatus*		*Lethrinus hutchinsi* *Abalistes stellaris* *Gnathanodon speciosus* *Pentapodus emeryii*	*Lethrinus atkinsoni* *Lutjanus sebae* *Choerodon cauteroma*	*Lethrinus nebulosus*
Hall Point			*Lethrinus laticaudis* *Lethrinus hutchinsi* *Pentapodus emeryii* *Lutjanus carponotatus* *Diagramma labiosum*	*Lethrinus hutchinsi* *Abalistes stellaris* *Gnathanodon speciosus* *Lutjanus carponotatus* *Pentapodus emeryii*	*Lethrinus hutchinsi* *Abalistes stellaris* *Lutjanus sebae* *Lethrinus atkinsoni* *Choerodon cauteroma*	*Lethrinus hutchinsi* *Lethrinus nebulosus*
Cape Voltaire			*Lethrinus laticaudis* *Lethrinus hutchinsi* *Lutjanus carponotatus* *Pentapodus emeryii* *Diagramma labiosum*	*Lethrinus hutchinsi* *Abalistes stellaris* *Lutjanus carponotatus* *Gnathanodon speciosus*	*Lethrinus hutchinsi* *Abalistes stellaris* *Lutjanus sebae* *Choerodon cauteroma* *Lethrinus atkinsoni*	*Lethrinus hutchinsi* *Lethrinus atkinsoni*

In order to determine whether there were consistent differences between faunal compositions in shallow and deep waters at each location, the catch rates for both water depths during the day were ordinated separately for each of the different locations. In the case of each location, the samples from shallow and deep waters lay on the left and right sides of the ordination plots, respectively, and showed little or no overlap (Fig. 3.3.6a-f). One-way ANOSIM tests demonstrated that the species compositions in shallow and deep waters at each location were significantly different, with R-statistic values ranging from 0.208 at Cape Preston to 0.833 at Hall Point (Table 3.3.10).

Table 3.3.10 One-way ANOSIM results for the trap catches during the day for shallow *vs* deep waters at each location separately on one occasion in both 2000 and 2001. Significant results are highlighted in bold type.

	p (%)	R
Cape Voltaire	**0.2**	**0.427**
Hall Point	**0.2**	**0.833**
Emeriau Point	**0.1**	**0.478**
Cape Bossut	**3.8**	**0.248**
Cape Preston	**3.2**	**0.208**
Locker Point	**0.3**	**0.628**

Table 3.3.11 Mean squares and significance levels for two-way ANOVAs of the mean number of species, mean catch rates of fish and the mean catch rates of the three most abundant fish species caught by fish trapping over reef habitats during the night at six locations in north-western Australia on one occasion in 2000, 2001 and 2002.

	Main effects			Interactions				
	Location (L)	Depth (D)	Period (P)	L x D	L x P	D x P	L x D x P	Residual
	DF (5)	(1)	(1)	(5)	(5)	(1)	(5)	(167)
Species	0.423**	0.811**	1.735***	0.121	0.500	0.036	0.278	0.104
Catch rate	0.472***	0.404	0.517**	0.170	0.376	0.001	0.115	0.069
Lethrinus hutchinsi	2.334***	0.005	0.472**	0.366***	0.611***	0.001	0.050	0.063
Lutjanus carponotatus	1.153***	0.001	0.246	0.285***	0.257***	0.170	0.078	0.046
Lethrinus laticaudis	0.256***	0.030	0.596***	0.130**	0.076**	0.048	0.019	0.039

DF, degrees of freedom; $^{**}P < 0.01$; $^{***}P < 0.001$.

3.3.5 Ichthyofaunas of reefs during the night

ANOVA showed that the mean number of fish species and mean catch rates of fish in traps at night differed significantly among locations and periods and, in the case of the number of species, between water depths, and that there were no significant interactions at $P<0.01$ (Table 3.3.11). The mean square was greatest for period in the case of both biotic variables (Table 3.3.11). The mean number of species was greater in the dry period than wet period, 3.1 *vs* 2.4, respectively, and was greater in deep water than shallow water, 2.9 *vs* 2.5, respectively, and ranged from 2.2 at Cape Voltaire to 3.3 at Cape Bossut (Fig. 3.3.7a-c). The mean catch rate ranged from 4.3 fish $10h^{-1}$ at Cape Voltaire to 11.7 fish $10h^{-1}$ at Cape Bossut and was greater in the dry period (8.8 fish $10h^{-1}$) than wet period (6.6 fish $10h^{-1}$) (Fig. 3.3.8a,b). Scheffe's *a posteriori* test demonstrated that the mean number of fish species was significantly greater at Cape Bosssut than at Cape Voltaire and that the mean catch rate of fish was significantly greater at Cape Bossut than at either Cape Voltaire or Hall Point.

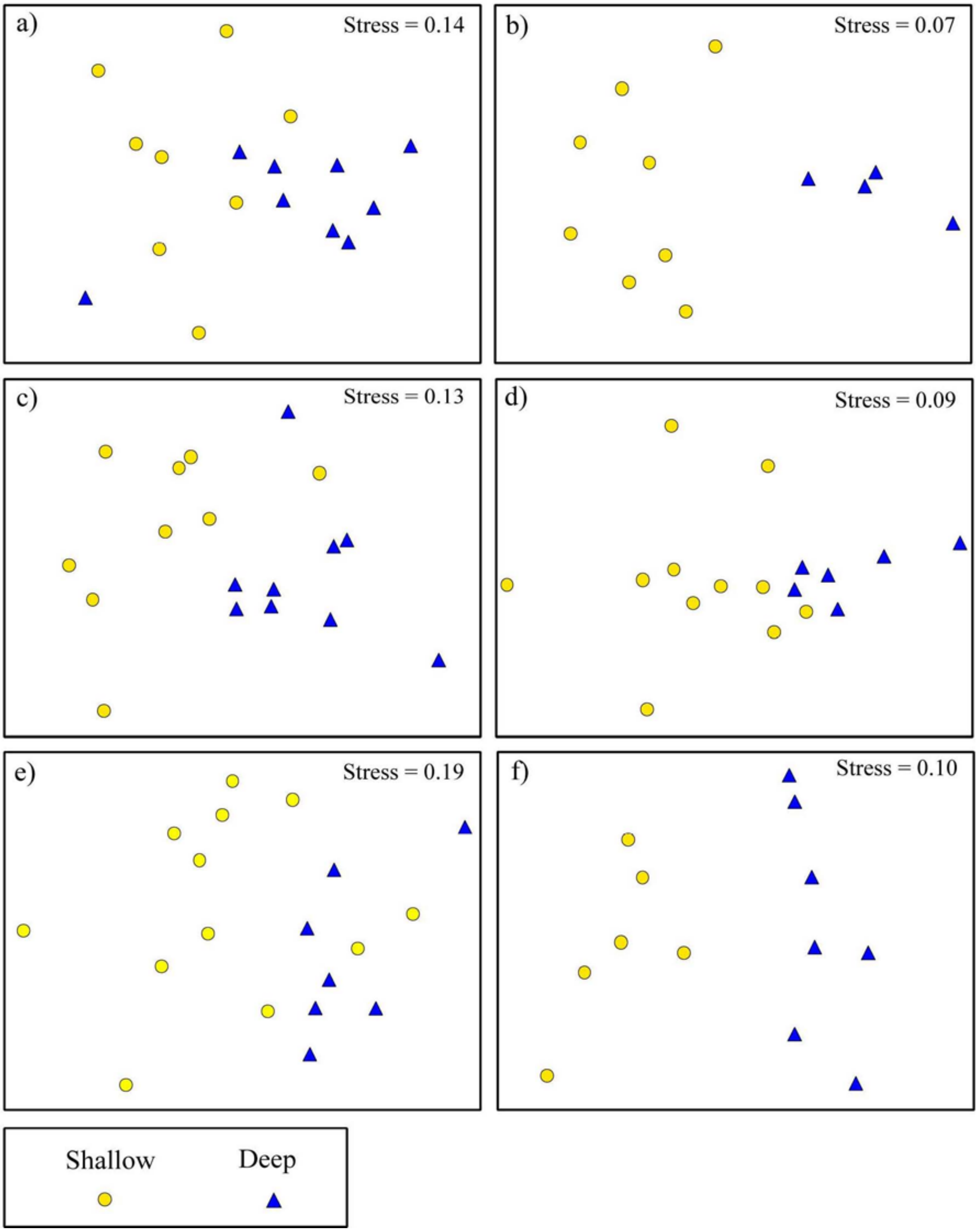

Figure 3.3.6 Nonmetric multideimensional scaling ordinations of the catch rates of the various fish species caught by fish trapping over reef in shallow ($\overline{x}$ = 12m) and deep ($\overline{x}$ = 22m) waters during the day at a) Cape Voltaire, b) Hall Point, c) Emeriau Point, d) Cape Bossut, e) Cape Preston and f) Locker Point on one occasion in both 2000 and 2001.

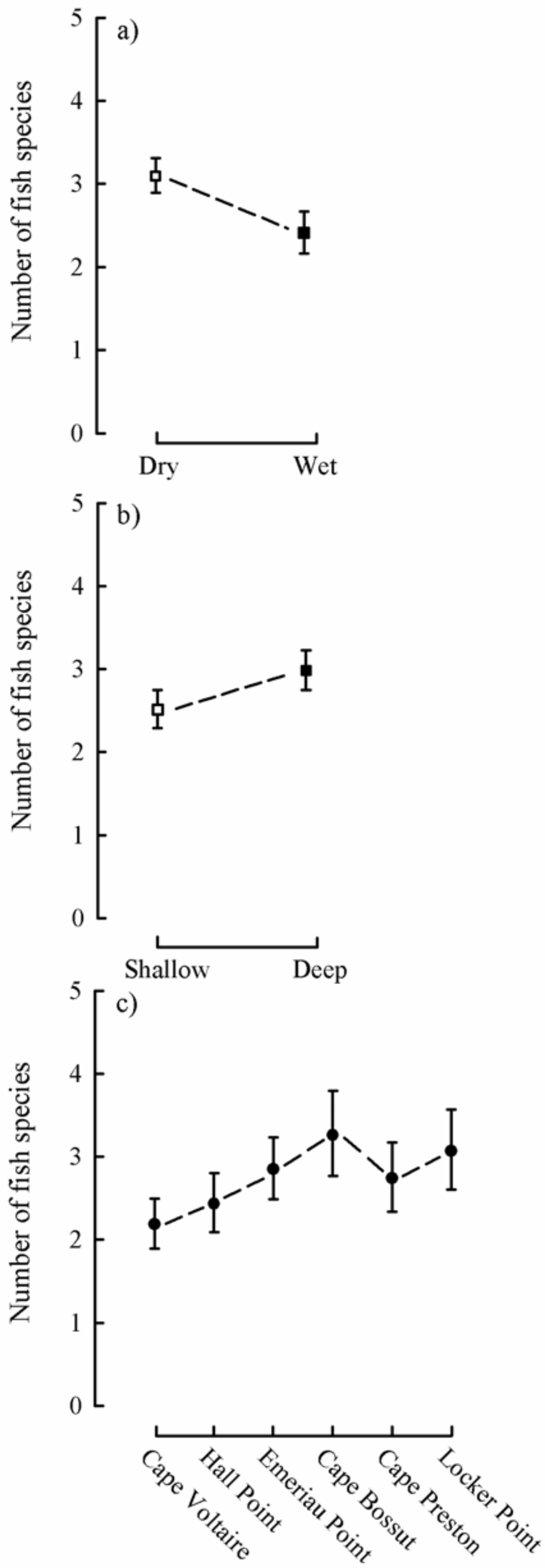

Figure 3.3.7 Mean numbers of fish species ±95% CIs over reefs during the night in a) the dry and wet periods b) shallow and deep waters and c) at each of the six locations on one occasion in 2000, 2001 and 2002.

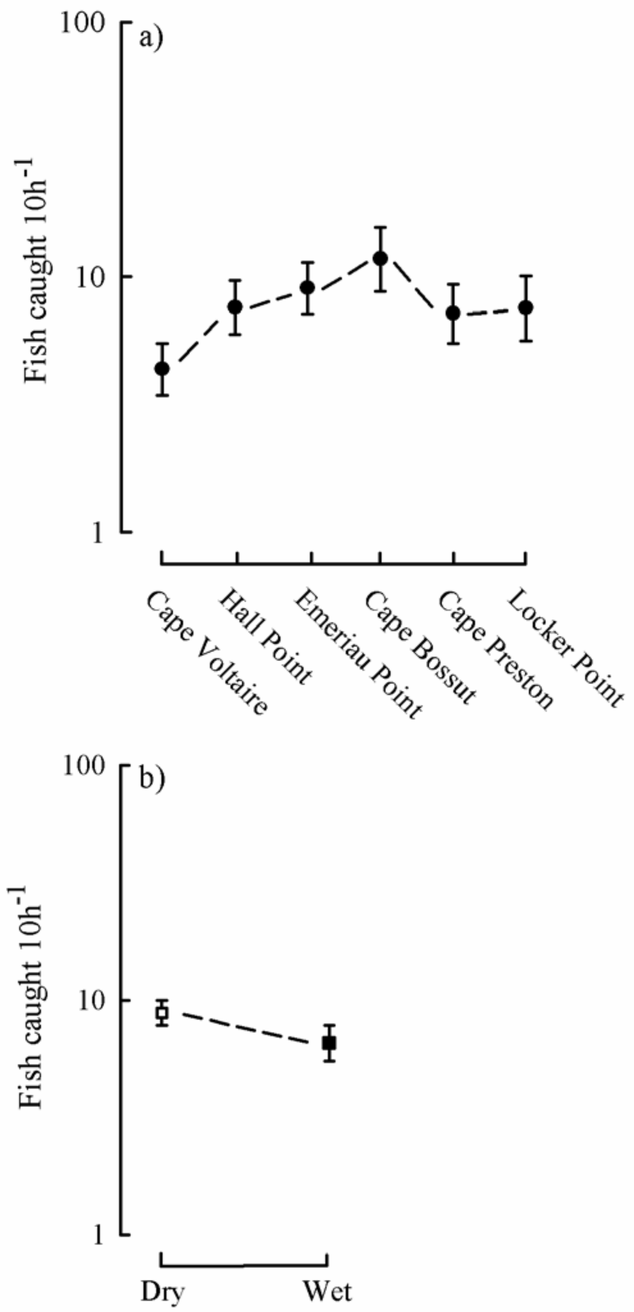

Figure 3.3.8 Mean catch rates of fish ±95% CIs over reefs during the night a) at each location and b) during the dry and wet periods at each of the six locations on one occasion in 2000, 2001 and 2002.

The mean catch rates of *L. hutchinsi*, *L. carponotatus* and *L. laticaudis* differed significantly among locations and, in the case of the first and third species, also between periods and that there were significant interactions between both location and depth and between location and period for each species (Table 3.3.11). The interaction between location and depth is explained by the fact that the catch rates were greater in shallow than deep waters at some locations and greater in deep than shallow waters at other locations (Fig. 3.3.9a,b,c). However, there were no clear trends for the catch rates of any of these three species to be greater in either shallow or deeper water at any location.

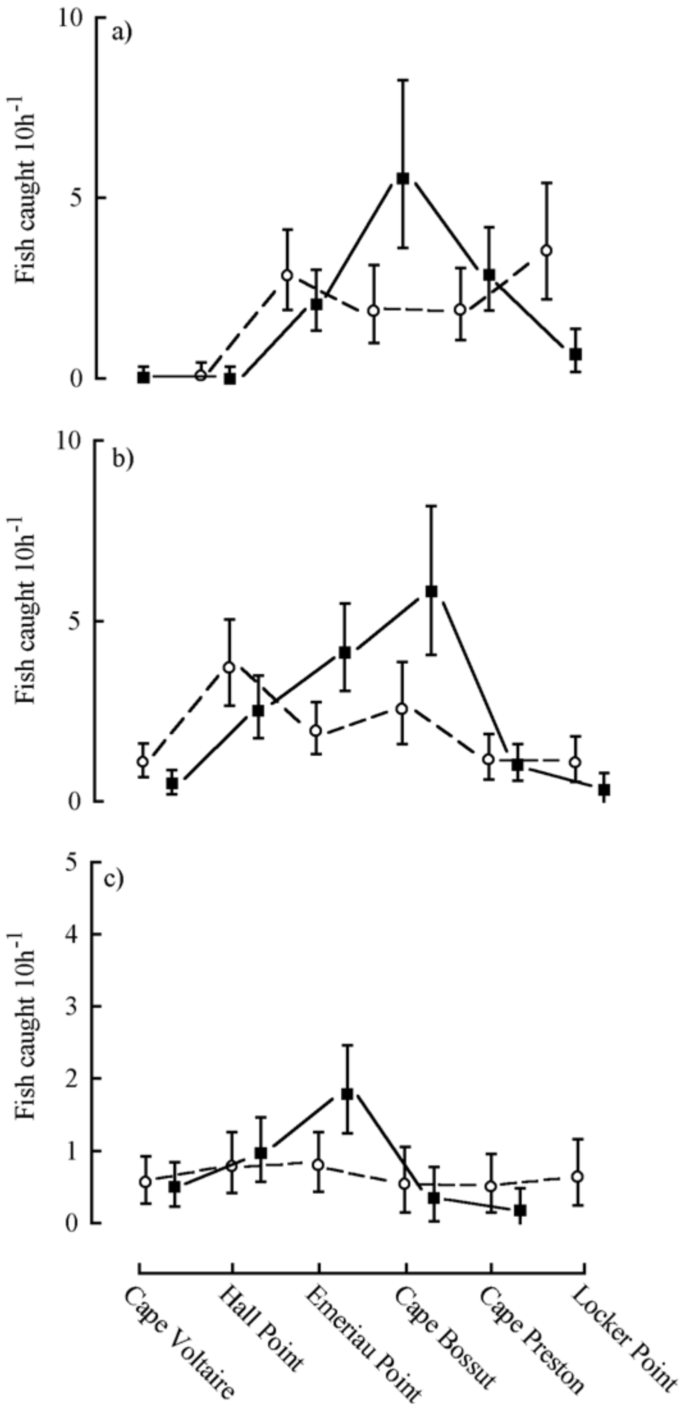

Figure 3.3.9 Mean catch rates ±95% CIs for a) *Lethrinus hutchinsi*, b) *Lutjanus carponotatus* and c) *Lethrinus laticaudis* over reefs in shallow (O) and deep (■) waters during the night at each of the six locations on one occasion in 2000, 2001 and 2002.

Following ordination of the catch rates for species in shallow and deep waters over reefs during the night at the different sampling locations, the samples from the two most northern latitudes, *i.e.* Cape Voltaire and Hall Point, lay in the upper half of the plot, whereas those from deep water at the most southern latitude, *i.e.* Locker Point, were mainly located towards the bottom of the plot and those from Emeriau Point, Cape Bossut and Cape Preston lay in the middle right of the plot (Fig. 3.3.10a). One-way ANOSIMs showed that the species compositions of the fish fauna over reefs during the night were significantly influenced by location ($P<0.001$), water depth ($P<0.01$) and period ($P<0.05$), with the R-statistic being far greater for location (0.467) than for the very low values for both depth (0.070) and period (0.058). The main typifying species in shallow and deep waters at each location are shown in Table 3.3.12. Although the faunas in both shallow and deep water at Cape Voltaire were typified by *L. carponotatus*, *L. johnii*, and *L. laticaudis*, the fauna in shallow water at this location was also typified by *L. lemniscatus* and *E. coioides* and that in deep water was also typified by *L. bitaeniatus*. Furthermore, the sequence of the three first species in terms of importance varied between shallow and deeper waters. The types of trend just described for differences between shallow and deeper waters were repeated at the other locations (Table 3.3.12).

Table 3.3.12 Species shown by SIMPER that typify the fish communities over reefs in shallow and deep waters at six locations in north-western Australia during the night in 2000, 2001 and 2002.

	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Preston	Locker Point
Shallow	*Lutjanus carponotatus* *Lutjanus johnii* *Lethrinus laticaudis* *Lutjanus lemniscatus* *Epinephelus coioides*	*Lutjanus carponotatus* *Lethrinus laticaudis* *Diagramma labiosum*	*Lutjanus carponotatus* *Lethrinus hutchinsi* *Lethrinus laticaudis*	*Lutjanus carponotatus* *Lethrinus hutchinsi* *Lethrinus laticaudis*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lethrinus laticaudis* *Lethrinus lentjan* *Lutjanus russelli*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lethrinus laticaudis* *Lutjanus russelli*
Deep	*Lutjanus johnii* *Lutjanus bitaeniatus* *Lethrinus laticaudis* *Lutjanus carponotatus*	*Lutjanus bitaeniatus* *Lutjanus carponotatus* *Lethrinus laticaudis* *Lutjanus johnii*	*Lutjanus carponotatus* *Lethrinus laticaudis* *Lethrinus hutchinsi*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Abalistes stellaris* *Lethrinus laticaudis* *Pentapodus emeryii*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Abalistes stellaris* *Lutjanus sebae*	*Lethrinus atkinsoni* *Lethrinus nebulosus* *Lethrinus hutchinsi* *Lutjanus carponotatus* *Lutjanus sebae*

Since one-way ANOSIM demonstrated that location had the greatest influence on the species compositions of the samples, the effect of location on species composition was next examined separately for both water depths.

The samples from shallow water at each location showed a marked tendency to progress downwards on the ordination plot in a manner that paralleled their latitudinal position (*c.f.* Fig. 3.3.10b; Fig. 3.2.1). Thus, those from Cape Voltaire lay at the top of the plot and those from Cape Preston and Locker Point were located at the bottom of the plot (Fig. 3.3.10b). Although the same trends were exhibited by the samples from deep water (Fig. 3.3.10c), the samples from deep water at each location formed more discrete groups than was the case with those from shallow water (Figs. 3.3.10b,c). One-way ANOSIM demonstrated that the species compositions in shallow waters at the different locations were significantly different (P<0.001; R-statistic = 0.453). Pair-wise comparisons showed that the samples from each location were significantly different from each other in all cases except for Emeriau Point *vs* both Cape Bossut and Locker Point and for Cape Preston *vs* Locker Point. The species that distinguish between the ichthyofaunas in the shallows of each pair of locations in which the compositions were found to be significantly different are shown in Table 3.3.13. For example, the ichthyofauna at Cape Voltaire was distinguished from that at each of the other locations by relatively greater catch rates of *L. johnii*, whereas the ichthyofauna at Cape Preston was distinguished from those at all other locations by consistently greater contributions of Moses snapper (*Lutjanus russelli*) and/or *Lethrinus lentjan*, the purple headed emperor (Table 3.3.13).

Table 3.3.13 Species shown by SIMPER that distinguish the fish communities over reefs in shallow water at six locations in north-western Australia during the night in 2000, 2001 and 2002. The species shown make a relatively greater contribution at the location at the top of each column.

Location	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Preston	Locker Point
Cape Voltaire		*Lutjanus carponotatus* *Lethrinus laticaudis*	*Lethrinus hutchinsi* *Lethrinus laticaudis* *Lutjanus carponotatus*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Siganus fuscescens*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lutjanus lentjan*	*Lethrinus hutchinsi* *Lethrinus laticaudis*
Hall Point	*Lutjanus johnii*		*Lethrinus hutchinsi*	*Lethrinus hutchinsi*	*Lethrinus hutchinsi* *Lutjanus lentjan*	*Lethrinus hutchinsi*
Emeriau Point	*Lutjanus johnii*	*Lutjanus carponotatus* *Lethrinus laticaudis*			*Lethrinus hutchinsi* *Lutjanus russelli*	
Cape Bossut	*Lutjanus johnii* *Lethrinus laticaudis* *Lutjanus lemniscatus*	*Lutjanus carponotatus* *Lethrinus laticaudis*			*Lethrinus hutchinsi* *Lutjanus russelli* *Lutjanus lentjan* *Lethrinus laticaudis*	*Lethrinus hutchinsi* *Lutjanus russelli* *Lethrinus laticaudis*
Cape Preston	*Lutjanus johnii* *Lethrinus laticaudis*	*Lutjanus carponotatus*	*Lutjanus carponotatus*	*Lutjanus carponotatus* *Siganus fuscescens*		
Locker Point	*Lutjanus johnii*	*Lutjanus carponotatus* *Lethrinus laticaudis*		*Lutjanus carponotatus*		

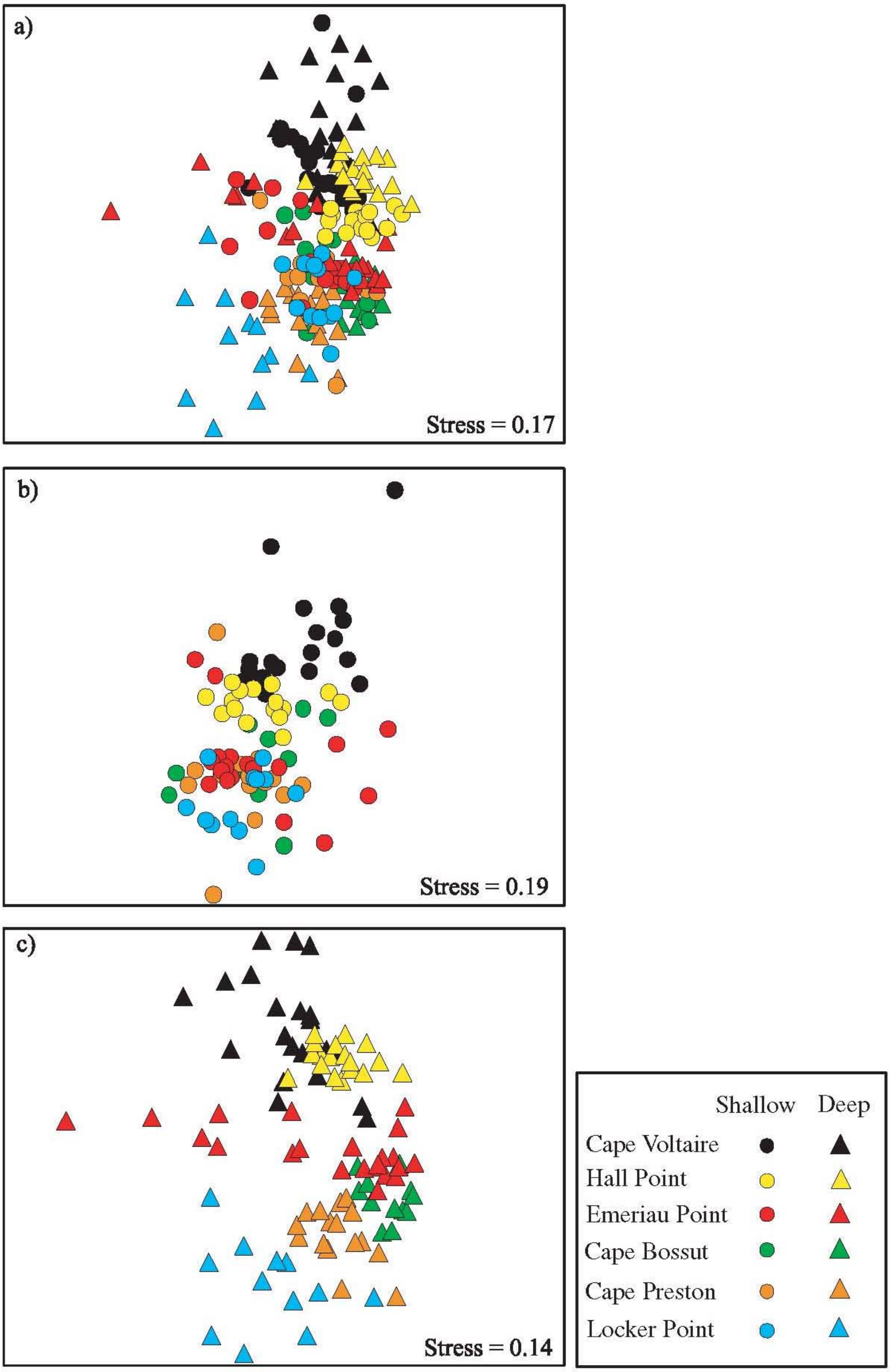

Figure 3.3.10 Nonmetric multidimensional scaling ordinations of the catch rates of the various fish species collected over reefs in a) shallow ($\overline{x}$ = 12m) and deep ($\overline{x}$ =22m) water depths and b) shallow and c) deep water separately at six locations during the night on one occasion in 2000, 2001 and 2002.

One-way ANOSIM demonstrated that the species compositions in deeper water at the various locations were significantly different (P<0.001; R-statistic =0.636). Pair-wise tests showed that the species compositions of the samples from each location were significantly different from each other in all cases except for Cape Bossut *vs* Emeriau Point. However, even with that one exception, the samples for the two locations showed minimal overlap on the ordination plot and the P value was close to significance, *i.e.* 5.2%. The species that distinguish between the ichthyofaunas in deeper waters at each pair of locations in which the faunas were significantly different are shown in Table 3.3.14. For example, the ichthyofauna at Cape Voltaire was distinguished from those at all other locations by relatively greater catch rates of *L. johnii* and either *L. bitaeniatus* or *L. lemniscatus*, whereas that in deep water at Locker Point was distinguished from those at all other locations by relatively greater catch rates of yellow-tailed emperor (*Lethrinus atkinsoni*) and *L. nebulosus* (Table 3.3.14).

To explore the differences in the compositions in shallow and deep waters and during the dry and wet periods in greater detail, the catch rates of the species over reefs during the night were ordinated separately for each location. On the resultant plots, the samples from shallow water at Hall Point, Cape Preston and Locker Point formed a group on the left of the ordination plots that showed little or no overlap with the corresponding samples from deep water on the right of the plots (Fig. 3.3.11b,e,f). A similar but less marked trend was present in the ordination plots for Cape Bossut (Fig. 3.3.11d). The samples from shallow water in the dry period formed tight and largely discrete groups at Hall Point, Cape Preston and Locker Point and the same was true for the samples from shallow water in the wet period at Hall Point, Cape Bossut and Locker Point and for the samples from the deep water during the dry period at Hall Point, Cape Bossut, Cape Preston and Locker Point (Fig. 3.3.11b,d,e,f).

Table 3.3.14 Species shown by SIMPER that distinguish the fish communities over reefs in deep water at six locations in north-western Australia during the night in 2000, 2001 and 2002. The species shown make a relatively greater contribution at the location at the top of each column.

Location	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Preston	Locker Point
Cape Voltaire		*Lutjanus bitaeniatus* *Lutjanus carponotatus* *Lethrinus laticaudis* *Diagramma labiosum*	*Lutjanus carponotatus* *Lethrinus laticaudis* *Lethrinus hutchinsi*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Abalistes stellaris* *Pentapodus emeryii* *Lutjanus sebae*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Abalistes stellaris* *Lutjanus sebae*	*Lethrinus atkinsoni* *Lethrinus nebulosus*
Hall Point	*Lutjanus johnii* *Lutjanus lemniscatus*		*Lutjanus carponotatus* *Lethrinus hutchinsi* *Lethrinus laticaudis*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Abalistes stellaris* *Pentapodus emeryii*	*Lethrinus hutchinsi* *Abalistes stellaris* *Lutjanus sebae*	*Lethrinus atkinsoni* *Lethrinus nebulosus* *Lethrinus hutchinsi*
Emeriau Point	*Lutjanus johnii* *Lutjanus bitaeniatus*	*Lutjanus bitaeniatus* *Lutjanus johnii* *Diagramma labiosum*		*Lethrinus hutchinsi* *Lutjanus carponotatus* *Abalistes stellaris* *Pentapodus emeryii*	*Lethrinus hutchinsi* *Abalistes stellaris* *Lutjanus sebae* *Lutjanus russelli*	*Lethrinus atkinsoni* *Lethrinus nebulosus*
Cape Bossut	*Lutjanus johnii* *Lutjanus bitaeniatus* *Lethrinus laticaudis*	*Lutjanus bitaeniatus* *Lutjanus johnii* *Lethrinus laticaudis*	*Lethrinus laticaudis*		*Lutjanus russelli*	*Lethrinus atkinsoni* *Lethrinus nebulosus*
Cape Preston	*Lutjanus johnii* *Lutjanus bitaeniatus* *Lethrinus laticaudis*	*Lutjanus bitaeniatus* *Lutjanus carponotatus* *Lethrinus laticaudis* *Lutjanus johnii*	*Lutjanus carponotatus* *Lethrinus laticaudis*	*Lutjanus carponotatus* *Lethrinus hutchinsi* *Pentapodus emeryii* *Lethrinus laticaudis*		*Lethrinus atkinsoni* *Lethrinus nebulosus*
Locker Point	*Lutjanus johnii* *Lutjanus bitaeniatus* *Lethrinus laticaudis* *Lutjanus lemniscatus*	*Lutjanus bitaeniatus* *Lutjanus carponotatus* *Lethrinus laticaudis* *Lutjanus johnii*	*Lutjanus carponotatus* *Lethrinus laticaudis* *Lethrinus hutchinsi*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lethrinus laticaudis* *Abalistes stellaris*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Abalistes stellaris*	

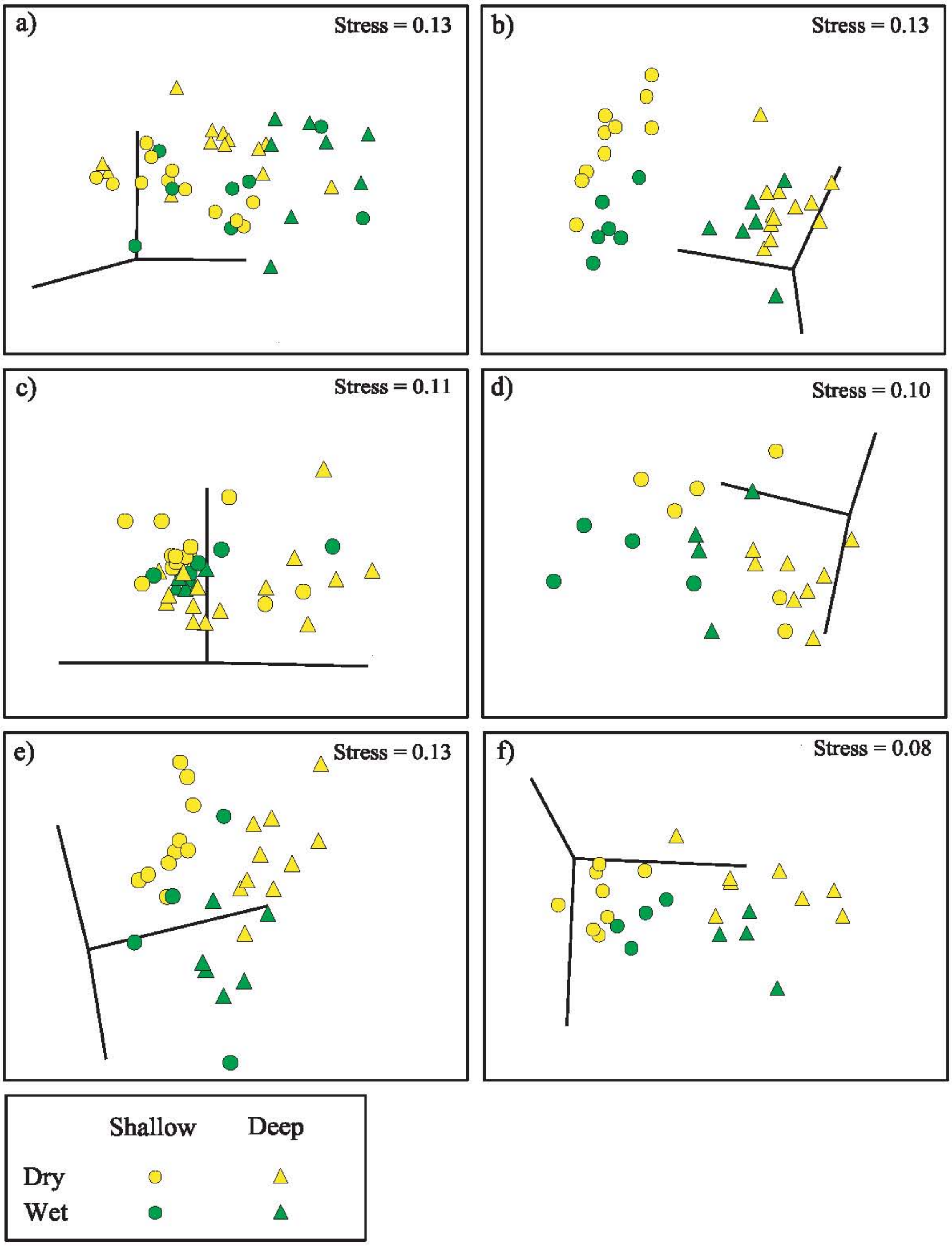

Figure 3.3.11 Nonmetric multidimensional scaling ordinations of the catch rates of the various fish species caught by fish trapping over reefs in shallow ($\overline{x}$ = 12m) and deep ($\overline{x}$ = 22m) waters during the night at a) Cape Voltaire, b) Hall Point, c) Emeriau Point, d) Cape Bossut, e) Cape Preston and f) Locker Point on two occasions in the dry period (2000 and 2001) and one occasion in the wet period (2002).

Two-way crossed ANOSIM, using data for water depth and period at each location, demonstrated that the species compositions of the fauna in shallow waters differed significantly from those in deeper waters at each location. However, while the R-statistic values for these differences at Cape Bossut, Cape Preston, Locker Point and Hall Point ranged from 0.464 to 0.874, they were low for Cape Voltaire (0.201) and essentially negligible for Emeriau Point (0.097) (Table 3.3.15). Furthermore, except in the cases of Hall Point and Emeriau Point, the species compositions of the fish fauna in the dry period differed significantly from those in the wet period at each location, with R-statistic values ranging from 0.268 at Locker Point to 0.594 at Cape Bossut (Table 3.3.15).

Table 3.3.15 Significance values (p%) and R-statistics (R) detected by two-way crossed ANOSIM between the compositions of the ichthyofauna over reefs in each water depth, *i.e.* shallow and deep, and each period, *i.e.* dry and wet at each of the six locations during the night in 2000 (dry period), 2001 (dry period) and 2002 (wet period). Significant results are highlighted in bold type.

Cape Voltaire

	p %	R
Depth	**0.3**	**0.201**
Period	**0.1**	**0.344**

Hall Point

	p %	R
Depth	**0.1**	**0.874**
Period	6.5	0.125

Emeriau Point

	p %	R
Depth	**2.8**	**0.097**
Period	75.9	-0.083

Cape Bossut

	p %	R
Depth	**0.1**	**0.464**
Period	**0.1**	**0.594**

Cape Preston

	p %	R
Depth	**0.1**	**0.653**
Period	**0.1**	**0.553**

Locker Point

	p %	R
Depth	**0.1**	**0.812**
Period	**1.2**	**0.268**

The species that distinguished between the compositions of the fish faunas in shallow and deeper waters at Hall Point and Emeriau Point, localities at which the composition did not differ significantly between periods, are shown in Table 3.3.16a,b. The species that distinguish the dry and wet periods in shallow and deep water separately are shown for Cape Voltaire and Cape Bossut in Table 3.3.17 and the species that distinguish the shallow and deeper waters in both the dry and wet periods separately, at Cape Preston and Locker Point are shown in Table 3.3.18. For example, the ichthyofaunas in deep waters at Hall Point was distinguished from that in shallow water by greater contributions of *L. bitaeniatus*, *L. johnii and L. laticaudis*, whereas the deep water at Emeriau Point was distinguished from that in shallow water by greater contributions of *L. carponotatus* and *L. laticaudis* (Table 3.3.16a,b). In shallow waters over reefs at Cape Preston, the ichthyofauna in the dry period was distinguished from that in the wet period by relatively greater contributions of *L. laticaudis*, *L. johnii* and *L. carponotatus*, whereas, during the wet period, *L. bitaeniatus* made a greater contribution to the catches in this depth (Table 3.3.17c). However, in deep water at this location, *L. bitaeniatus* made a greater contribution to the catches in the dry period.

Table 3.3.16 Species shown by SIMPER analysis as typifying the fish communities in each depth (diagonal cells, *i.e.* Shallow *vs* Shallow, Deep *vs* Deep) and distinguishing between each of those depths (vertical cells) over reefs at a) Hall Point and b) Emeriau Point during the night in 2000, 2001 and 2002. * Indicates that a species is most abundant in the depth marked *, *i.e.* deep waters.

a) Hall Point

	Shallow	**Deep**
Shallow	*Lutjanus carponotatus* *Lethrinus laticaudis* *Diagramma labiosum*	
Deep*	*Lutjanus carponotatus* *Lutjanus bitaeniatus** *Lutjanus johnii** *Lethrinus laticaudis**	*Lutjanus bitaeniatus* *Lutjanus carponotatus* *Lethrinus laticaudis* *Lutjanus johnii*

b) Emeriau Point

	Shallow	**Deep**
Shallow	*Lutjanus carponotatus* *Lethrinus hutchinsi* *Lethrinus laticaudis*	
Deep*	*Lethrinus hutchinsi* *Lutjanus carponotatus** *Lethrinus laticaudis**	*Lutjanus carponotatus* *Lethrinus laticaudis* *Lethrinus hutchinsi*

Table 3.3.17 Species shown by SIMPER analysis as typifying the fish communities in each season (diagonal cells, *i.e.* Dry *vs* Dry, Wet *vs* Wet) and distinguishing between each of those seasons (vertical cells) over reefs in shallow and deep waters separately at a) Cape Voltaire and b) Cape Bossut during the night in 2000 (dry period), 2001 (dry period) and 2002 (wet period). * Indicates that a species is most abundant in the period marked *, *i.e.* wet period.

a) Cape Voltaire

	Shallow			Deep	
	Dry	**Wet**		**Dry**	**Wet**
Dry	*Lutjanus carponotatus* *Lethrinus laticaudis* *Lutjanus johnii* *Lutjanus lemniscatus* *Epinephelus coioides*		**Dry**	*Lutjanus johnii* *Lethrinus laticaudis* *Lutjanus carponotatus* *Lutjanus bitaeniatus* *Lutjanus lemniscatus*	
Wet*	*Lethrinus laticaudis* *Lutjanus johnii* *Lutjanus carponotatus* *Lutjanus lemniscatus* *Epinephelus coioides* *Lutjanus bitaeniatus**	*Lutjanus johnii* *Lutjanus carponotatus* *Lutjanus lemniscatus* *Lethrinus laticaudis*	**Wet***	*Lethrinus laticaudis* *Lutjanus carponotatus* *Lutjanus bitaeniatus* *Lutjanus johnii*	*Lutjanus johnii* *Lutjanus bitaeniatus* *Lutjanus carponotatus*

b) Cape Bossut

	Shallow			Deep	
	Dry	**Wet**		**Dry**	**Wet**
Dry	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lethrinus laticaudis*		**Dry**	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Abalistes stellaris* *Pentapodus emeryii* *Lethrinus laticaudis*	
Wet*	*Lethrinus hutchinsi* *Siganus fuscescens* *Lethrinus laticaudis* *Lutjanus carponotatus**	*Lutjanus carponotatus* *Lethrinus laticaudis* *Siganus fuscescens*	**Wet***	*Lethrinus hutchinsi* *Pentapodus emeryii* *Lutjanus sebae* *Lethrinus laticaudis* *Lutjanus carponotatus**	*Lutjanus carponotatus* *Lethrinus hutchinsi* *Lethrinus laticaudis* *Abalistes stellaris*

Table 3.3.18 Species shown by SIMPER analysis as typifying the fish communities in each depth (diagonal cells, *i.e.* Shallow *vs* Shallow, Deep *vs* Deep) and distinguishing between each of those depths (vertical cells) over reef habitats at a) Cape Preston and b) Locker Point during the night in 2000 (dry period), 2001 (dry period) and 2002 (wet period). * Indicates that a species is most abundant in the depth marked *, *i.e.* deep waters.

a) Cape Preston

Dry period	Shallow	Deep
Shallow	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lethrinus laticaudis* *Lethrinus lentjan*	
Deep*	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lethrinus lentjan* *Lutjanus russelli* *Abalistes stellaris** *Lethrinus nebulosus**	*Lethrinus hutchinsi* *Abalistes stellaris* *Lutjanus carponotatus* *Lethrinus laticaudis* *Lutjanus russelli* *Lethrinus nebulosus*

Wet period	Shallow	Deep
Shallow	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lutjanus russelli* *Lethrinus laticaudis* *Epinephelus coioides*	
Deep*	*Lutjanus russelli* *Lethrinus hutchinsi** *Lutjanus carponotatus** *Lutjanus sebae** *Abalistes stellaris**	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lutjanus sebae* *Abalistes stellaris* *Lutjanus quinquelineatus*

b) Locker Point

Dry period	Shallow	Deep
Shallow	*Lethrinus hutchinsi* *Lethrinus laticaudis* *Lutjanus carponotatus*	
Deep*	*Lethrinus hutchinsi* *Lethrinus laticaudis* *Lutjanus carponotatus* *Lethrinus atkinsoni** *Lethrinus nebulosus**	*Lethrinus nebulosus* *Lethrinus atkinsoni* *Lethrinus hutchinsi* *Lutjanus sebae*

Wet period	Shallow	Deep
Shallow	*Lethrinus hutchinsi* *Lutjanus carponotatus* *Lutjanus russelli* *Lethrinus laticaudis*	
Deep*	*Lethrinus hutchinsi* *Lutjanus russelli* *Lethrinus laticaudis* *Lutjanus carponotatus* *Lethrinus atkinsoni**	*Lethrinus atkinsoni* *Lutjanus carponotatus* *Lutjanus sebae* *Lutjanus russelli* *Lethrinus hutchinsi*

3.3.6 Ichthyofaunas of reefs during the day and night

ANOVA showed that both the mean number of fish species and the mean catch rates of fish over reefs during the day and night in 2002 differed significantly between locations and day *vs* night, and also with water depth for the number of species and that, for both variables, there was a significant interaction between location and depth (Table 3.3.19). The mean squares were greatest for water depth for the number of species and for location for catch rate. The interactions between location and water depth for both the number of species and catch rates is explained by the fact that the values for these two variables were greater in deep than shallow waters at four of the locations, whereas the reverse trend was exhibited at the other two locations (Fig. 3.3.12a,c). The mean number of species and catch rates were greater during the day, *i.e.* 2.9 species and 6.6 fish $10h^{-1}$, than during the night, *i.e.* 2.3 species and 4.7 fish $10h^{-1}$ (Fig. 3.3.12b,d).

Table 3.3.19 Mean squares and significance levels for three-way ANOVAs of the mean number of species, mean catch rates of fish and the mean catch rates of the three most abundant fish species derived from the data obtained by fish trapping over reef habitats during the day and night at six locations in north-western Australia in 2002.

	Main effects			Interactions				
	Location (L)	Depth (D)	Diel (T)	LxD	LxT	DxT	LxDxT	Residual
	DF (5)	(1)	(1)	(5)	(5)	(1)	(5)	(91)
Mean number of species	0.567**	1.196**	1.085**	0.603**	0.235	0.041	0.047	0.152
Mean catch rate	0.660***	0.300	0.435**	0.217**	0.073	0.009	0.048	0.057
Lethrinus hutchinsi	1.212***	0.021	0.096	0.184**	0.039	0.052	0.062	0.056
Lutjanus carponotatus	1.590***	0.044	0.029	0.445***	0.124	0.001	0.035	0.039
Lethrinus laticaudis	0.345***	0.019	0.261***	0.131***	0.025	0.002	0.016	0.017

DF, degrees of freedom; ***P* < 0.01; ****P* < 0.001.

The mean catch rates of *L. hutchinsi*, *L. carponotatus* and *L. laticaudis* differed significantly among locations and between day and night with the last species and there were significant interactions between location and depth for each species (Table 3.3.19). The interaction between location and depth is explained by the fact that the catch rates of each species were greater in shallow than deep waters at some locations and greater in deep than shallow waters at other locations (Fig. 3.3.13a,b,c). Indeed, there were no clear trends for the catch rates of any of these three species to be greater in one depth than another in any location. The mean catch rate of *L. laticaudis* was greater during the day than during the night (Fig. 3.3.13d).

On the ordination plot derived from the catch rates for species in shallow and deep waters over reefs during the day and night at the different locations, the samples from the two most northern locations, *i.e*. Cape Voltaire and Hall Point, lay very largely in the upper one third of the plot, whereas those from the two most southern locations, *i.e*. Cape Preston and Locker Point, lay predominantly in the bottom two thirds of the plot (Fig. 3.3.14a). When the data for the same samples were coded separately for water depth, the samples from shallow waters formed a group in the centre of the ordination plot and were less widely dispersed than those from deep waters, with which they intermingled (Fig.3.3.14b). The daytime samples were more widely dispersed than the night-time samples, with which they overlapped markedly (Fig. 3.3.14c).

One-way ANOSIM showed that the species compositions of the fish fauna over reefs were significantly influenced by location, water depth and day *vs* night (P<0.001). However, while the R-statistic for location was relatively high (0.568), those for day *vs* night (0.093) and water depth (0.073) were very low. Pair-wise ANOSIM comparisons showed that the composition of the samples from each location were significantly different from that at each of the other locations.

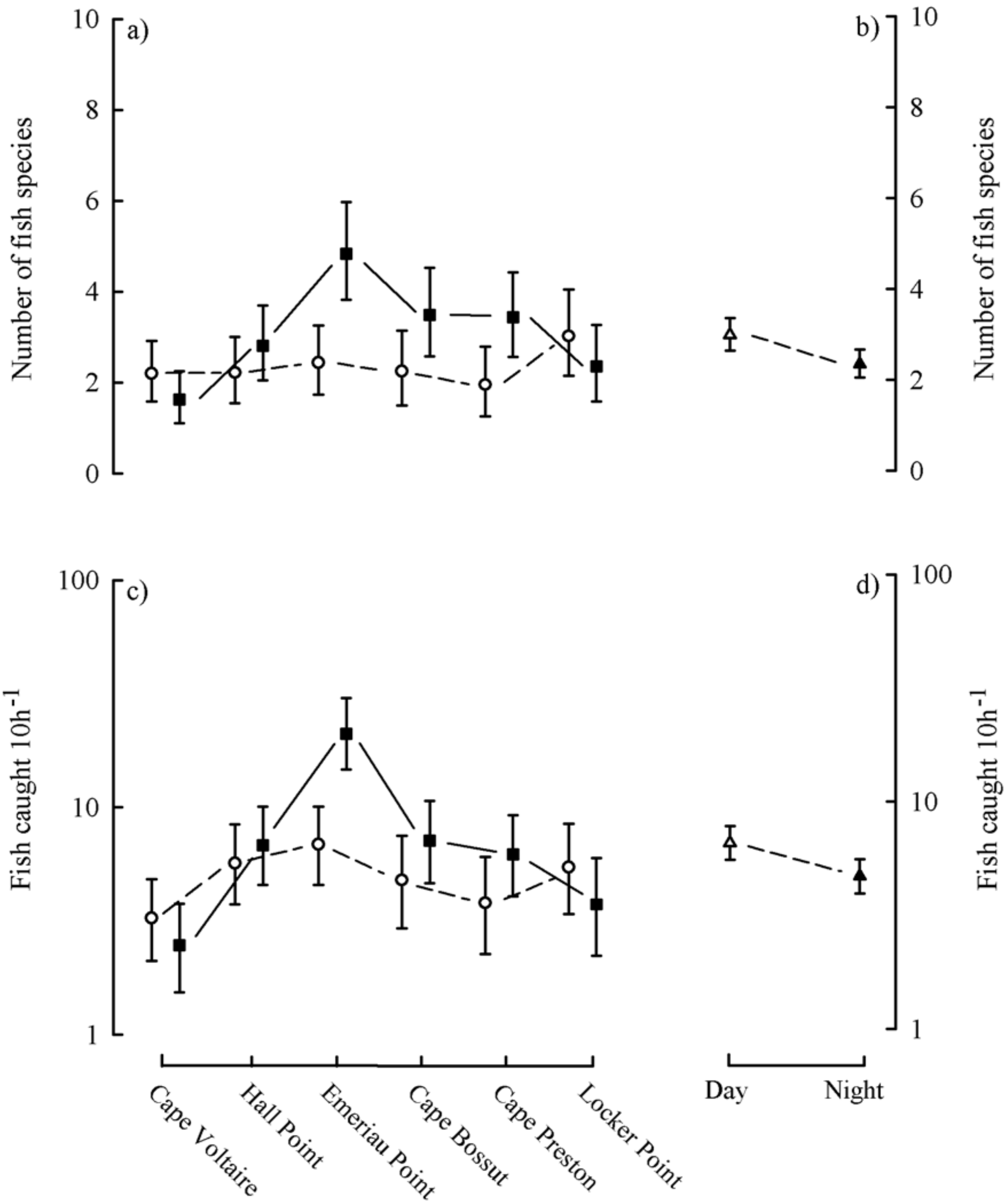

Fig. 3.3.12. a) Mean numbers of fish species and c) mean catch rates of fish ±95% CIs collected over reefs during the day and night in shallow (○) and deep waters (■) and b) and d) during the day (△) and during the night (▲) at each of the six locations in 2002.

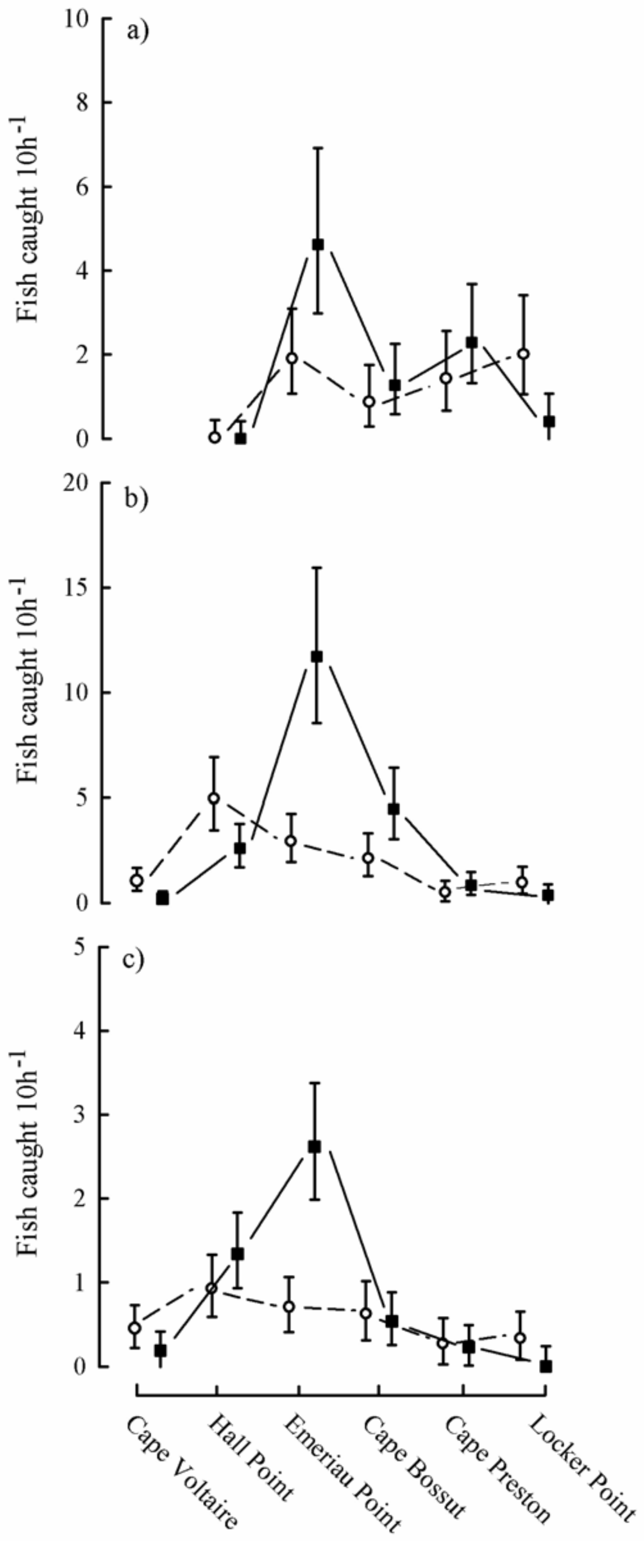

Fig. 3.3.13. Mean catch rates ±95% CIs of a) *Lethrinus hutchinsi,* b) *Lutjanus carponotatus* and c) *Lethrinus laticaudis* in shallow (○) and deep (■) water during the day and night and d) mean catch rates ±95% CIs of *Lethrinus laticaudis* during the day (△) and night (▲) in shallow and deep waters over reefs at six locations in 2002.

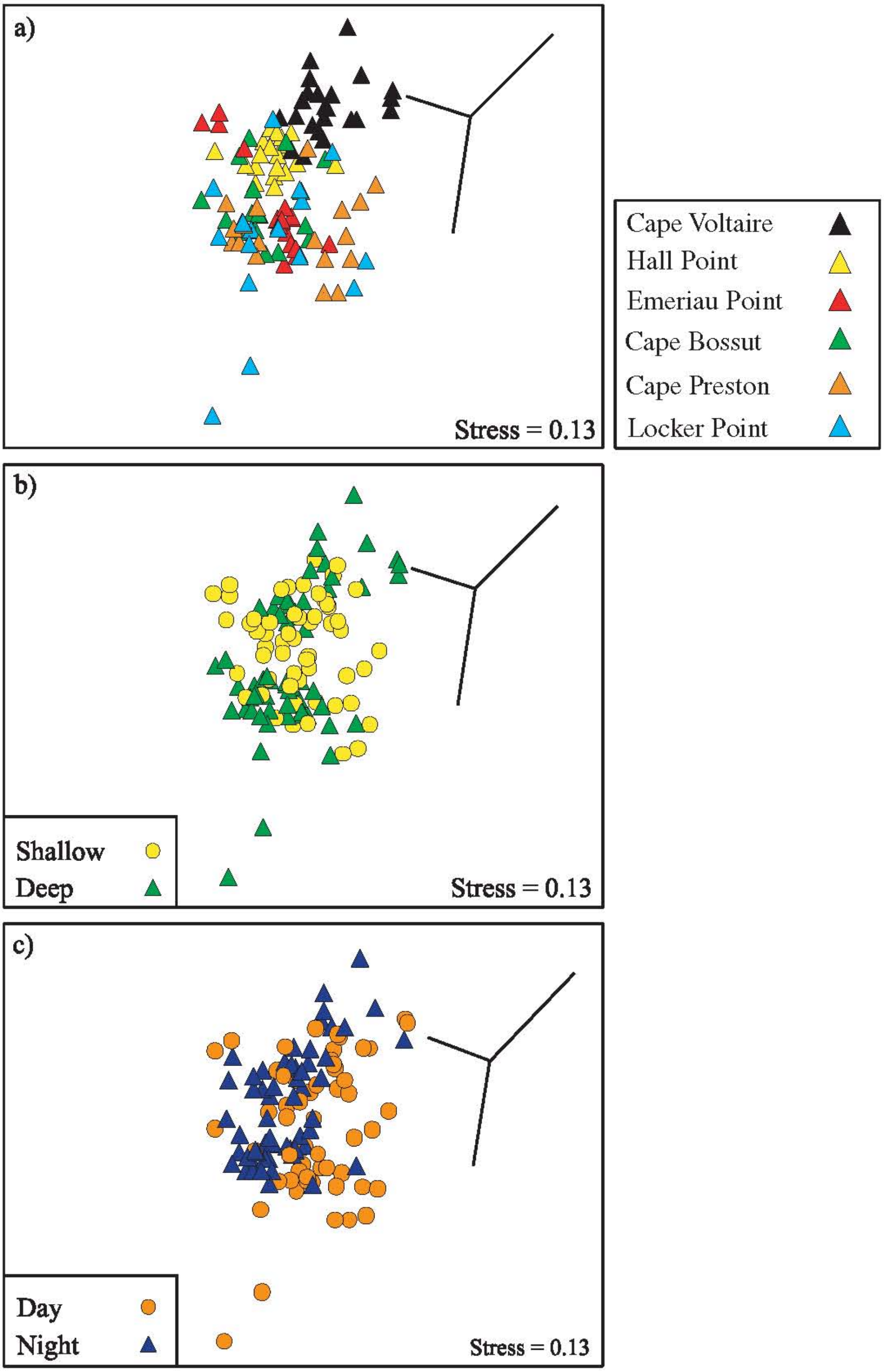

Fig. 3.3.14. Nonmetric multidimensional scaling ordinations of the catch rates of the various fish species caught by fish trapping over reefs in shallow ($\bar{x}$ = 12 m) and deep ($\bar{x}$ = 22 m) waters at six locations during the day and during the night in north-western Australia in 2002, coded separately for a) location, b) depth and c) time of sampling (day or night).

Since location exerted a far greater overall influence on the ichthyofaunal composition over reefs than either water depth or time of day, the influence of the latter two variables on the ichthyofaunal composition at each location was next explored. On the ordination plots for each location, there was a very pronounced tendency for the samples from shallow water during the day and night to lie to the left and/or above those from deep water during the day and night (Fig. 3.3.15a-f). The samples from deep water during both the day and night almost invariably formed tight and, in most cases, relatively discrete groups. The same was true for the samples from shallow water during the day and night at Hall Point and from shallow water during the night at Locker Point (Fig. 3.3.15b,f).

Two-way crossed ANOSIMs demonstrated that, at each location except Cape Bossut, the species composition in shallow water differed significantly from that in deeper waters, with *R*-statistic values ranging from 0.162 at Cape Voltaire to as high 0.692 at Hall Point and 0.818 at Locker Point (Table 3.3.20). Furthermore, these tests showed that, at each of the different locations, the species composition differed significantly between day and night, with R-statistic values ranging from 0.199 at Cape Voltaire to 0.412 at Cape Preston (Table 3.3.20). The species that typify the ichthyofaunas during the day and night and also those that distinguish between the fish faunas during the day and night at each location are shown in Table 3.3.21. As an example, the catch rates of *L. nebulosus* were relatively greater during the day than during the night at Locker Point, whereas the reverse pertained with *L. hutchinsi* and *L. carponotatus* during the night at this location (Table 3.3.21).

3.3.7 Ichthyofaunas over soft substrates

Trawling in shallow ($\bar{x}$ = 12m) and deep ($\bar{x}$ = 22m) waters at seven locations in north-western Australia during the present study yielded 43 214 fishes. This corresponded to a total of 37 908 fishes, after the numbers in each sample had been standardised to an area of 10,000m^2 and then summed (Table 3.3.4). These samples contained 279 species, representing 184 genera and 74 families (Table 3.3.4). *Leiognathus splendens* was the most abundant species, contributing 11.9% to the total catch, with *Selaroides leptolepis, Pristotis obtusirostris*, *Terapon theraps*, *Saurida undosquamis* and *Paramonacanthus choirocephalus*, which were the next most abundant species, contributing between 6.1 and 10.4% to the total catch, respectively (Table 3.3.4). These six species, which were the only species that contributed more than 5% to the total catch, collectively accounted for 48.8% of the catch.

Two of the 12 species, that contributed more than 2% to the total catch from all locations, *i.e.* the leiognathids *L. splendens* and *Secutor insidiator*, were recorded only at the two most northern locations. In contrast, the pomacentrid *P. obtusirostris*, the monacanthid *P. choirocephalus* and the lethrinid *Lethrinus genivittatus* were never caught at these two locations (Table 3.3.4).

Terapon theraps and *L. splendens* made the greatest contributions in terms of biomass, contributing 10.7 and 9.0%, respectively. The only other species to contribute more than 5% to the total biomass were *S. leptolepis*, *S. undosquamis* and *Caranx bucculentus*, which contributed 5.7, 7.1 and 5.6%, respectively (Table 3.3.4).

ANOVA showed that the mean number of fish species, densities of fish and biomass of fish differed significantly among locations and, in the case of density, between periods, and that there were two-way and/or three-way interactions between these main effects (Table 3.3.22). The mean squares were greater for the main effects than the interactions for both of the biotic variables.

Table 3.3.20 Two-way crossed ANOSIM results for each location from the trap catches during the day and night in 2002. Significant results are highlighted in bold type.

Cape Voltaire

	p %	R
Depth	**2.9**	**0.162**
Diel	**1.1**	**0.199**

Hall Point

	p %	R
Depth	**0.1**	**0.692**
Diel	**0.1**	**0.362**

Emeriau Point

	p %	R
Depth	**0.3**	**0.296**
Diel	**2.3**	**0.324**

Cape Bossut

	p %	R
Depth	11.1	0.133
Diel	**3.9**	**0.205**

Cape Preston

	p %	R
Depth	**0.9**	**0.359**
Diel	**0.9**	**0.412**

Locker Point

	p %	R
Depth	**0.1**	**0.818**
Diel	**1.2**	**0.359**

Table 3.3.21. Species shown by SIMPER that typify the fish communities over reefs during daylight and during the night at each location in 2002. * indicates that a species is most abundant in the diel period in the left hand row

	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Preston	Locker Point
Day	*Lutjanus johnii** *Epinephelus coioides** *Lutjanus carponotatus* *Lutjanus lemniscatus** *Lethrinus laticaudis** *Lutjanus bitaeniatus*	*Lutjanus carponotatus* *Lethrinus laticaudis** *Epinephelus coioides** *Lutjanus bitaeniatus* *Diagramma labiosum*	*Lutjanus carponotatus** *Lethrinus hutchinsi* *Lethrinus laticaudis* *Lutjanus lemniscatus** *Gnathanodon** *speciosus*	*Lutjanus carponotatus* *Lethrinus laticaudis* *Lethrinus hutchinsi* *Epinephelus coioides* *Gnathanodon speciosus** *Abalistes stellaris**	*Lethrinus hutchinsi* *Abalistes stellaris** *Lutjanus lemniscatus** *Lethrinus laticaudis** *Lutjanus carponotatus*	*Lethrinus nebulosus** *Lutjanus carponotatus* *Pentapodus emeryii* *Lethrinus hutchinsi* *Epinephelus bilobatus*
Night	*Lutjanus johnii* *Lutjanus carponotatus* *Lutjanus bitaeniatus* *Lethrinus laticaudis*	*Lutjanus carponotatus* *Lethrinus laticaudis* *Lutjanus bitaeniatus** *Diagramma labiosum*	*Lutjanus carponotatus* *Lethrinus hutchinsi* *Lethrinus laticaudis*	*Lutjanus carponotatus** *Lethrinus hutchinsi* *Lethrinus laticaudis*	*Lethrinus hutchinsi** *Lutjanus carponotatus** *Lutjanus sebae*	*Lethrinus hutchinsi** *Lutjanus carponotatus** *Lutjanus russelli** *Lethrinus atkinsoni*

Table 3.3.22. Mean squares and significance levels for three-way ANOVAs of the mean number of species, densities and biomass of fish and mean densities of the three most abundant fish species derived from the data obtained by trawling over soft substrates during the day at seven locations in north-western Australia in 2001 and 2002.

	Main effects			Interactions				
	Location (L)	Depth (D)	Period (P)	L x D	L x P	D x P	L x D x P	Residual
	DF (6)	(1)	(1)	(6)	(6)	(1)	(6)	(82)
Mean number of species	0.157***	0.014	0.006	0.044	0.067**	<0.001	0.034	0.015
Mean density	1.278***	0.081	0.624**	0.029	0.308***	0.103	0.310***	0.062
Mean biomass	0.652***	0.100	0.055	0.182	0.256	0.436	0.335***	0.065
Selaroides leptolepis	1.245***	0.396	12.437***	1.881***	2.866***	<0.001	0.993***	0.154
Pristotis obtusirostris	3.598***	0.053	0.005	2.837***	0.016	0.008	0.173	0.292
Saurida undosquamis	2.394***	0.095	1.396**	1.607***	0.060	0.156	0.497**	0.109

DF, degrees of freedom; $**P < 0.01$; $***P < 0.001$.

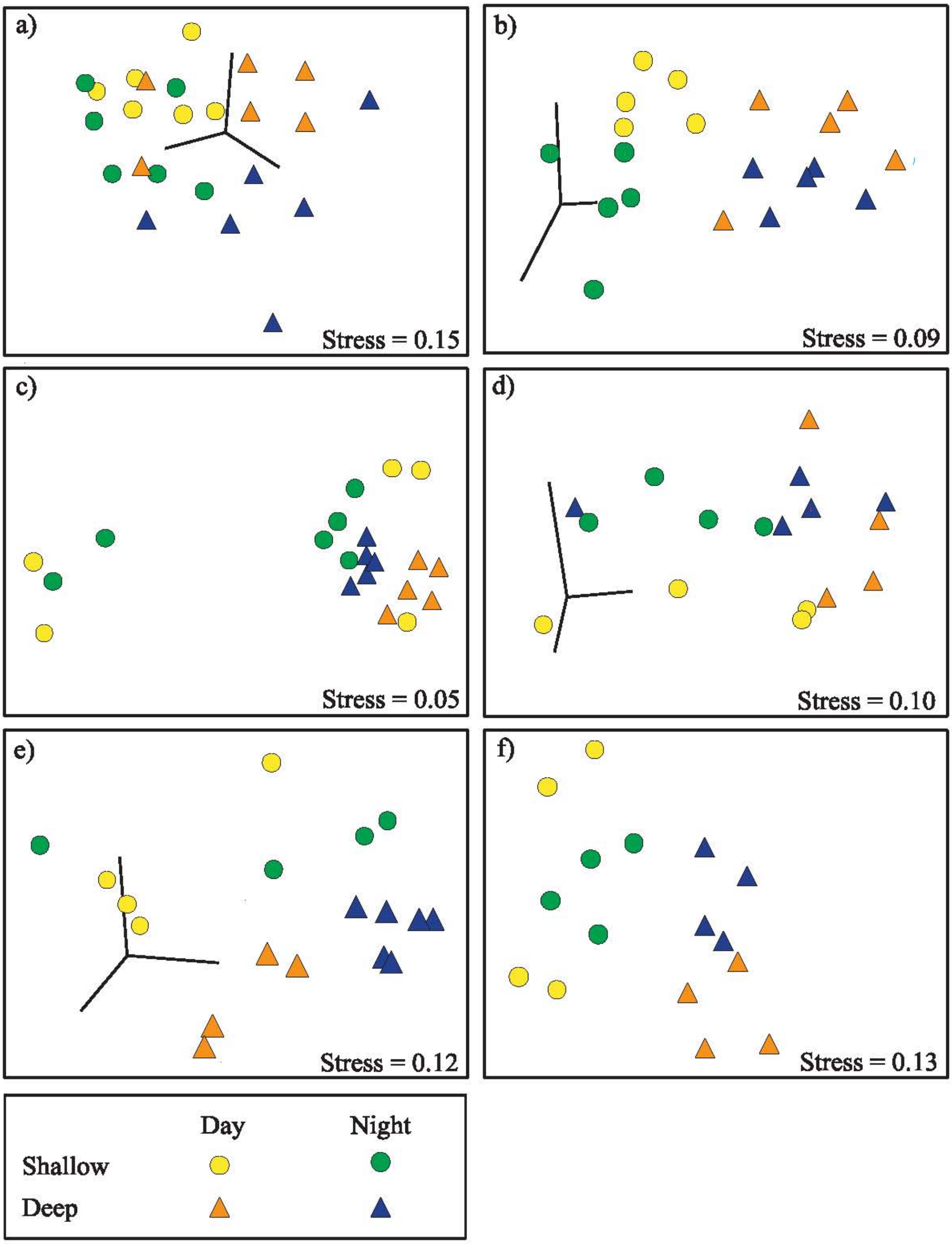

Fig. 3.3.15. Nonmetric multidimensional scaling ordinations of the catch rates of the various fish species caught by fish trapping over reefs in shallow ($\bar{x}$ = 12 m) and deep ($\bar{x}$ = 22 m) waters during the day and night at a) Cape Voltaire, b) Hall Point, c) Emeriau Point, d) Cape Bossut, e) Cape Preston and f) Locker Point in 2002.

The interaction between location and period for the number of species is explained by the fact that the mean values for this variable were greater in the wet than dry periods at four locations and greater in the dry than wet periods at the other locations (Fig. 3.3.16a). The densities and biomass of fish in neither shallow nor deep waters were consistently greater in either the dry or wet period across all locations (Fig. 3.3.16b,c,d,e).

The mean densities of *S. leptolepis*, *P. obtusirostris* and *S. undosquamis* differed significantly among locations and, in the case of the first and third species, also between periods (Table 3.3.22). There were two-way and/or three-way interactions between the main effects for each species.

The interaction between location and period for *S. leptolepis* is explained by the fact that, while this species was caught at all or most locations during the wet period, it was only caught at the two most northern locations, Cape Voltaire and Hall Point, during the dry period (Fig. 3.3.17a,b). Furthermore, the fact that the trends exhibited by the mean densities of *S. leptolepis* in shallow and deep water across all locations were not entirely consistent explains the interaction between location and depth. The interaction between location and depth for the densities of *S. undosquamis* is explained, in part, by the fact that, at Emeriau Point, the densities of this species in the dry and wet periods were relatively high in shallow water but relatively low in deep water (Fig. 3.3.17c,d). In the case of *P. obtusirostris*, the interaction between location and depth is explained by the densities being greater in shallow than deep waters at three of the locations, whereas the reverse pertained at the other two locations (Fig. 3.3.17e).

Following ordination of the densities of species in shallow and deep waters at the seven locations during the day, the samples from Cape Voltaire and Hall Point formed a very discrete group at the top of the plot, whereas those from the other five locations lay at the bottom of the plot (Fig. 3.3.18a). One-way ANOSIM showed that the species compositions of the fish faunas over soft substrates were significantly influenced by both location ($P<0.001$) and water depth ($P<0.05$), with the R-statistic being far greater for location (0.616) than for depth (0.047). The main typifying species in shallow and deep waters at each location are shown in Table 3.3.23.

Since one-way ANOSIM demonstrated that location had the greatest influence on the species compositions of the samples, the effect of location was further examined for each depth separately. On the ordination plot for shallow water, the samples for Hall Point formed a tight and discrete group between those for Cape Voltaire at the top of the plot, while those for Cape Keraudren and Cape Preston formed a group above those for Locker Point and Cape Bossut and most of those for Emeriau Point in the bottom of the plot (Fig. 3.3.18b). One-way ANOSIM demonstrated that the species compositions in shallow water differed significantly among locations ($P<0.001$; R-statistic = 0.767). Pair-wise ANOSIM tests showed that the composition of the samples from each location were significantly different from that at each other location, with R-statistic values ranging from 0.241 for Cape Keraudren *vs* Cape Preston to 1.000 for both Cape Voltaire and Hall Point *vs* Cape Bossut. The species compositions that distinguished between the faunas in shallow water at each location are shown in Table 3.3.24. As an example, the fauna at Cape Voltaire was distinguished from that at each of the locations south of Hall Point by relatively greater densities of *Leiognathus leuciscus* and *L. splendens*, whereas the fauna at Locker Point was distinguished from those of all other locations by relatively greater densities of *L. genivittatus* and *P. obtusirostris* (Table 3.3.24).

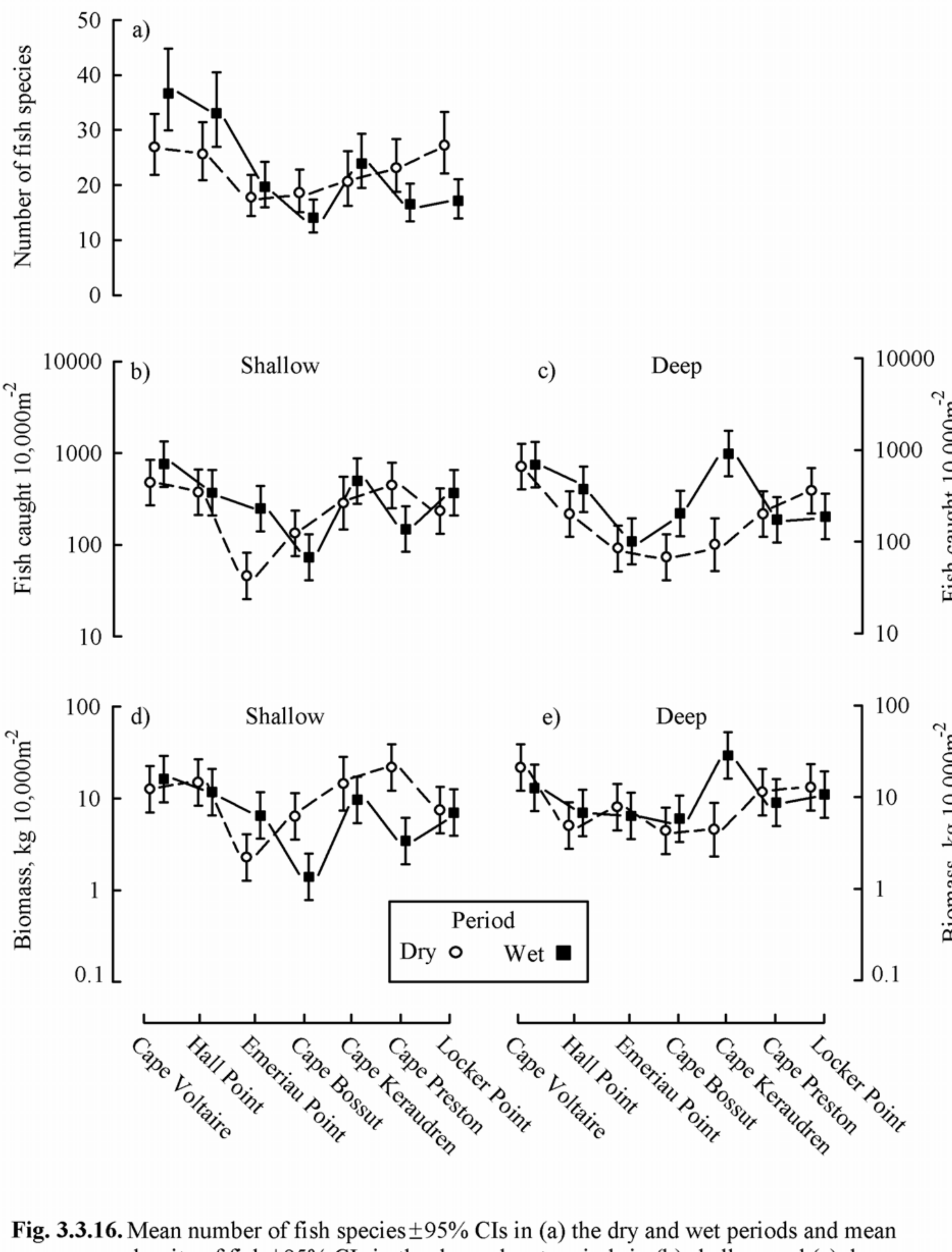

Fig. 3.3.16. Mean number of fish species ± 95% CIs in (a) the dry and wet periods and mean density of fish ± 95% CIs in the dry and wet periods in (b) shallow and (c) deep waters and mean biomass of fish ± 95% CIs in the dry and wet periods in (d) shallow and (e) deep waters. Derived from data obtained by trawling over soft substrates in shallow and deep waters at seven locations in north-western Australia during the day in the dry period of 2001 and in the wet period of 2002.

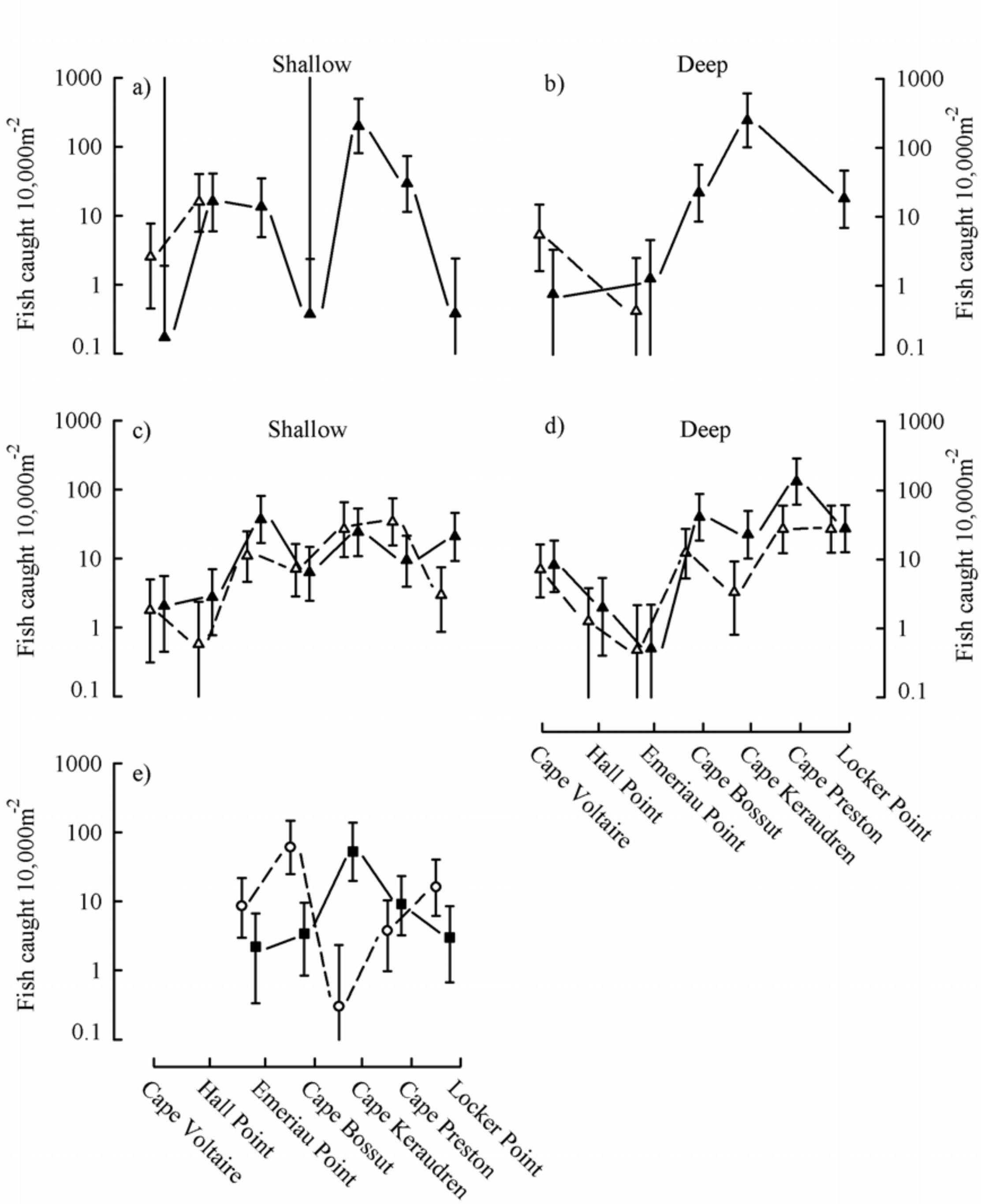

Fig. 3.3.17. Mean densities ±95% CIs in the dry (▵) and wet periods (▲) for *Selaroides leptolepis* in shallow (a) and deep waters (b) and *Saurida undosquamis* in shallow (c) and deep waters (d) and *Pristotis obtusirostris* in (e) the dry and wet periods in shallow (○) and deep waters (■). Derived from data obtained by trawling over soft substrates during the day in shallow and deep waters at seven locations in north-western Australia in the dry period of 2001 and in the wet period of 2002.

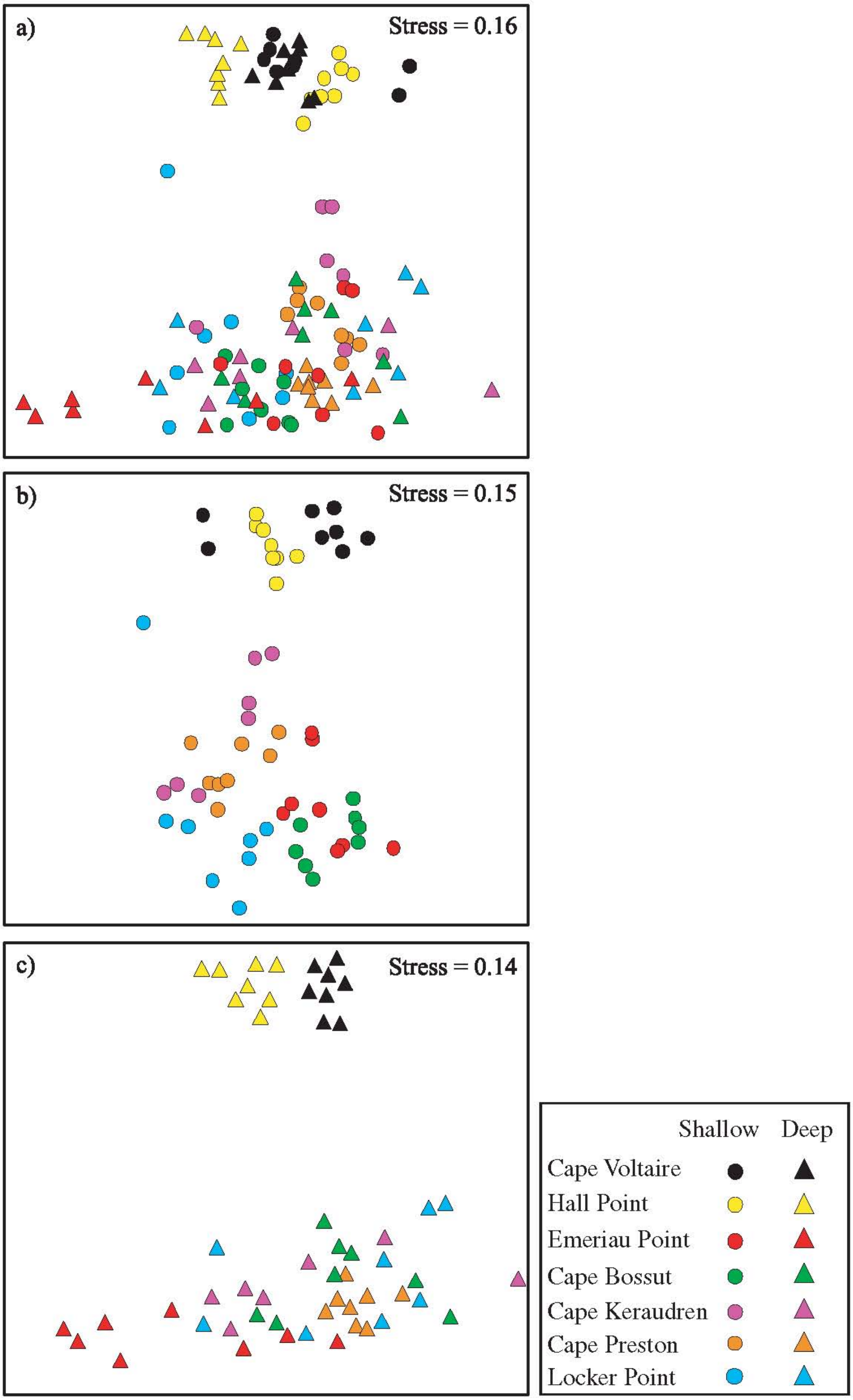

Fig. 3.3.18. Nonmetric multidimensional scaling ordinations of the densities of the various fish species caught by trawling over soft substrates in a) shallow ($\bar{x}$ =12 m) and deep ($\bar{x}$ =22 m) water and b) shallow and c) deep waters separately at seven locations during the day in north-western Australia in 2001 and 2002.

Table 3.3.23. Species shown by SIMPER to typify the fish communities over soft substrates in shallow and deep waters at seven locations in north-western Australia during the day in 2001 and 2002.

	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Keraudren	Cape Preston	Locker Point
Shallow	*Leiognathus leuciscus*	*Terapon theraps*	*Saurida undosquamis*	*Pristotis obtusirostris*	*Saurida undosquamis*	*Saurida undosquamis*	*Pristotis obtusirostris*
	Leiognathus splendens	*Caranx bucculentus*	*Pristotis obtusirostris*	*Saurida undosquamis*	*Upeneus assymetricus*	*Siganus fuscescens*	*Saurida undosquamis*
	Saurida tumbil	*Leiognathus leuciscus*	*Paramonacanthus choirocephalus*	*Torquigener pallimaculatus*	*Selaroides leptolepis*	*Lethrinus genivittatus*	*Choerodon cephalotes*
	Terapon theraps	*Selaroides leptolepis*	*Callionymus goodladi*	*Chaetodontoplus duboulayi*	*Torquigener pallimaculatus*	*Parapercis nebulosa*	*Lethrinus genivittatus*
	Gerres filamentosus	*Saurida tumbil*	*Tragulichthys jaculiferus*		*Paramonacanthus choirocephalus*	*Torquigener pallimaculatus*	*Siganus fuscescens*
	Carangoides malabaricus	*Carangoides humerosus*	*Parapercis nebulosa*		*Leiognathus leuciscus*	*Pseudorhombus arsius*	*Paramonacanthus choirocephalus*
	Upeneus sulphureus	*Ulua aurochs*	*Pentapodus vitta*			*Paramonacanthus choirocephalus*	*Upeneus assymetricus*
						Nemipterus furcosus	*Torquigener pallimaculatus*
Deep	*Leiognathus splendens*	*Terapon theraps*	*Chaetodontoplus duboulayi*	*Saurida undosquamis*	*Pristotis obtusirostris*	*Saurida undosquamis*	*Saurida undosquamis*
	Terapon theraps	*Leiognathus splendens*	*Choerodon cephalotes*	*Paramonacanthus choirocephalus*	*Saurida undosquamis*	*Torquigener pallimaculatus*	*Nemipterus furcosus*
	Carangoides malabaricus	*Leiognathus bindus*	*Choerodon vitta*	*Parapercis nebulosa*	*Upeneus assymetricus*	*Pristotis obtusirostris*	*Engyprosopon maldiviensis*
	Saurida tumbil	*Johnius borneensis*	*Nemipterus porosus*	*Pseudorhombus argus*	*Torquigener pallimaculatus*	*Parapercis nebulosa*	
	Upeneus sulphureus	*Thryssa setirostris*	*Coradion chrysozonus*	*Torquigener pallimaculatus*	*Selaroides leptolepis*	*Paramonacanthus choirocephalus*	
	Caranx bucculentus			*Nemipterus porosus*	*Paramonacanthus choirocephalus*	*Crossorhombus kanekonis*	
	Saurida undosquamis			*Pristotis obtusirostris*	*Nemipterus furcosus*	*Trachinocephalus myops*	
	Leiognathus bindus				*Nemipterus porosus*		

Table 3.3.24 Species shown by SIMPER that distinguish the fish communities over soft substrates in shallow water at seven locations in north-western Australia during the day in 2001 and 2002. The species shown make a relatively greater contribution at the location at the top of each column.

	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Keraudren	Cape Preston	Locker Point
Cape Voltaire		*Caranx bucculentus* *Selaroides leptolepis* *Ulua aurochs* *Carangoides humerosus*	*Pristotis obtusirostris* *Callionymus goodladii* *Tragulichthys jaculiferus*	*Pristotis obtusirostris* *Torquigener pallimaculatus*	*Upeneus assymetricus* *Selaroides leptolepis* *Saurida undosquamis* *Torquigener pallimaculatus*	*Lethrinus genivittatus* *Parapercis nebulosa* *Torquigener pallimaculatus*	*Lethrinus genivittatus* *Pristotis obtusirostris* *Choerodon cephalotes*
Hall Point	*Leiognathus splendens* *Carangoides malabaricus*		*Pristotis obtusirostris* *Paramonacanthus choirocephalus* *Saurida undosquamis*	*Pristotis obtusirostris* *Torquigener pallimaculatus* *Saurida undosquamis*	*Upeneus assymetricus* *Selaroides leptolepis* *Saurida undosquamis*	*Siganus fuscescens* *Paramonacanthus choirocephalus* *Upeneus assymetricus* *Parapercis nebulosa* *Saurida undosquamis* *Nemipterus furcosus* *Torquigener pallimaculatus*	*Lethrinus genivittatus* *Pristotis obtusirostris* *Siganus fuscescens* *Choerodon cephalotes*
Emeriau Point	*Leiognathus leuciscus* *Leiognathus splendens* *Terapon theraps* *Saurida tumbil* *Gerres filamentosus*	*Terapon theraps* *Caranx bucculentus* *Leiognathus leuciscus* *Carangoides humerosus* *Saurida tumbil* *Ulua aurochs* *Pseudorhombus arsius*		*Torquigener pallimaculatus* *Chaetodontoplus duboulayi*	*Upeneus assymetricus* *Selaroides leptolepis* *Leiognathus leuciscus* *Torquigener pallimaculatus* *Pseudorhombus arsius*	*Siganus fuscescens* *Paramonacanthus choirocephalus*	*Lethrinus genivittatus* *Siganus fuscescens* *Pristotis obtusirostris* *Choerodon cephalotes*
Cape Bossut	*Leiognathus leuciscus* *Leiognathus splendens* *Terapon theraps* *Saurida tumbil* *Gerres filamentosus* *Caranx bucculentus*	*Terapon theraps* *Caranx bucculentus* *Leiognathus leuciscus* *Selaroides leptolepis* *Carangoides humerosus* *Saurida tumbil* *Ulua aurochs* *Pseudorhombus arsius*	*Pristotis obtusirostris* *Paramonacanthus choirocephalus* *Saurida undosquamis* *Callionymus goodladii* *Pentapodus vitta*		*Upeneus assymetricus* *Selaroides leptolepis* *Leiognathus leuciscus* *Paramonacanthus choirocephalus* *Pseudorhombus arsius* *Saurida undosquamis*	*Siganus fuscescens* *Upeneus assymetricus* *Paramonacanthus choirocephalus* *Priacanthus tayenus* *Parapercis nebulosa* *Nemipterus furcosus* *Pseudorhombus arsius*	*Lethrinus genivittatus* *Siganus fuscescens* *Paramonacanthus choirocephalus* *Upeneus assymetricus*

Table 3.3.24 continued.

	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Keraudren	Cape Preston	Locker Point
Cape Keraudren	*Leiognathus leuciscus* *Leiognathus splendens* *Terapon theraps* *Saurida tumbil* *Gerres filamentosus*	*Terapon theraps* *Caranx bucculentus* *Carangoides humerosus* *Ulua aurochs*	*Paramonacanthus choirocephalus* *Pristotis obtusirostris* *Callionymus goodladii*			*Paramonacanthus choirocephalus* *Siganus fuscescens* *Engyprosopon grandisquama* *Priacanthus tayenus* *Nemipterus furcosus*	*Lethrinus genivittatus* *Pristotis obtusirostris*
Cape Preston	*Leiognathus leuciscus* *Leiognathus splendens* *Terapon theraps* *Saurida tumbil* *Carangoides malabaricus* *Gerres filamentosus*	*Caranx bucculentus* *Terapon theraps* *Leiognathus leuciscus* *Carangoides humerosus* *Saurida tumbil* *Ulua aurochs*	*Tragulichthys jaculiferus* *Pristotis obtusirostris*	*Pristotis obtusirostris* *Chaetodontoplus duboulayi*	*Selaroides leptolepis* *Leiognathus leuciscus* *Engyprosopon grandisquama* *Lagocephalus scleratus*		*Lethrinus genivittatus* *Pristotis obtusirostris* *Choerodon cephalotes*
Locker Point	*Leiognathus leuciscus* *Leiognathus splendens* *Terapon theraps* *Saurida tumbil* *Carangoides malabaricus* *Gerres filamentosus*	*Caranx bucculentus* *Terapon theraps* *Leiognathus leuciscus* *Selaroides leptolepis* *Carangoides humerosus* *Saurida tumbil* *Ulua aurochs* *Pentaprion longimanus*	*Paramonacanthus choirocephalus* *Saurida undosquamis* *Callionymus goodladii* *Tragulichthys jaculiferus* *Pentapodus vitta*	*Chaetodontoplus duboulayi* *Pristotis obtusirostris*	*Selaroides leptolepis* *Leiognathus leuciscus* *Paramonacanthus choirocephalus* *Choerodon cephalotes* *Upeneus assymetricus*	*Paramonacanthus choirocephalus* *Selaroides leptolepis* *Priacanthus tayenus* *Pseudorhombus arsius*	

When the densities of species in deep water were ordinated, the samples from Cape Voltaire and Hall Point each formed tight and discrete groups at the top of the plot, that were well separated from those at the more southern locations, which intermingled and formed a band along the bottom of the plot (Fig. 3.3.18c). One-way ANOSIM demonstrated that the species compositions in deep water differed significantly among locations ($P < 0.001$; R-statistic = 0.771). Pair-wise tests showed that the compositions of the samples from each location were significantly different from those at each other location, with R-statistic values ranging from 0.2 in the case of Cape Bossut *vs* Cape Preston to 1.0 for both Cape Voltaire and Hall Point *vs* Cape Preston. The species compositions that distinguished between locations in deep water are shown in Table 3.3.25. As an example, the fauna at Cape Voltaire was distinguished from those at all other locations except Hall Point by relatively greater densities of *L. splendens* and *T. theraps*, whereas, in deep water at Emeriau Point, the species composition was distinguished from all other locations by a greater contribution of *Chaetodontoplus duboulayi*, *Choerodon vitta* and *Choerodon cephalotes* or *Lutjanus vitta* (Table 3.3.25).

On the separate 3D ordination plots, derived from the densities of fish at each of the seven locations, the samples from shallow water formed a group that was located largely or entirely to the left of those from deep water, except in the case of those from Cape Voltaire (Fig. 3.3.19a-g). Furthermore, the samples from the wet and dry periods formed largely or entirely discrete groups. Two-way crossed ANOSIMs demonstrated that the species compositions in both shallow and deep waters at each location were significantly different, except in the case of Cape Voltaire, with the R-statistic values for water depth in each location other than Cape Voltaire ranging from 0.547 at Locker Point to 0.948 at Hall Point (Table 3.3.26). Furthermore, at each location, the species compositions in the dry and wet periods were significantly different, with R-statistic values ranging from 0.391 at Cape Voltaire and Emeriau Point to 0.969 at Cape Preston (Table 3.3.26).

The species that distinguish between the compositions of the fish faunas in the dry and wet periods at Cape Voltaire, at which locality the composition did not differ significantly, are shown in Table 3.3.27. The species that distinguish the fauna in the dry and wet periods in shallow and deep waters separately are shown for Hall Point, Emeriau Point, Cape Preston and Locker Point in Table 3.3.28 and the species that distinguish the shallow and deeper waters in both the dry and wet periods separately, at Cape Bossut and Cape Keraudren are shown in Table 3.3.29.

3.3.8 Length-frequency distributions

The length-frequency distributions for those twelve fish species that were taken in traps over reefs in shallow and deep waters and were the most important commercial and/or recreational species, are shown in Figs 3.3.20 to 3.3.23. In the case of seven of these species, the mean fork lengths of fish caught in deeper waters were significantly greater than those of fish collected from shallow waters. For those species which the Department of Fisheries W.A. lists a minimum legal length (MLL) for retention, a relatively small component of the catch lay below that length in the cases of *L. laticaudis* (Fig. 3.3.20b) and *Lethrinus nebulosus* (Fig. 3.3.20c), whereas *ca* 80% of the catch lay below that length in the cases of *L. hutchinsi* (Fig. 3.3.20a) and *Lutjanus sebae* (Fig. 3.3.21c), respectively. In the case of *Plectropomus maculatus*, there were similar numbers above and below that length (Fig. 3.3.22b).

Table 3.3.25 Species shown by SIMPER that distinguish the fish communities over soft substrates in deep water at seven locations in north-western Australia during the day in 2001 and 2002. The species shown make a relatively greater contribution at the location at the top of each column.

	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Keraudren	Cape Preston	Locker Point
Cape Voltaire		*Johnius borneensis* *Thryssa setirostris* *Paraplagusia longirostris* *Leiognathus bindus* *Caranx bucculentus*	*Chaetodontoplus duboulayi* *Choerodon vitta* *Choerodon cephalotes* *Pentapodus porosus*	*Selaroides leptolepis* *Pentapodus porosus* *Paramonacanthus choirocephalus*	*Pristotis obtusirostris* *Selaroides leptolepis* *Upeneus assymetricus* *Paramonacanthus choirocephalus*	*Torquigener pallimaculatus* *Pristotis obtusirostris* *Paramonacanthus choirocephalus* *Saurida undosquamis* *Parapercis nebulosa* *Trachinocephalus myops* *Crossorhombus kanekonis*	*Engyprosopon maldiviensis* *Nemipterus furcosus* *Selaroides leptolepis* *Saurida undosquamis*
Hall Point	*Carangoides malabaricus* *Leiognathus splendens* *Leiognathus equulus* *Upeneus sulphureus* *Saurida tumbil* *Saurida undosquamis*		*Chaetodontoplus duboulayi* *Choerodon vitta* *Choerodon cephalotes* *Pentapodus porosus* *Lutjanus vitta* *Coradion chrysozonus*	*Saurida undosquamis* *Leiognathus leuciscus* *Selaroides leptolepis* *Paramonacanthus choirocephalus* *Parapercis nebulosa*	*Pristotis obtusirostris* *Selaroides leptolepis* *Torquigener pallimaculatus* *Upeneus assymetricus* *Paramonacanthus choirocephalus* *Saurida undosquamis*	*Saurida undosquamis* *Pristotis obtusirostris* *Paramonacanthus choirocephalus* *Torquigener pallimaculatus* *Parapercis nebulosa*	*Saurida undosquamis* *Engyprosopon maldiviensis* *Nemipterus furcosus* *Engyprosopon grandisquama* *Pristotis obtusirostris*
Emeriau Point	*Leiognathus splendens* *Terapon theraps* *Carangoides malabaricus* *Upeneus sulphureus* *Saurida tumbil* *Leiognathus leuciscus* *Caranx bucculentus*	*Terapon theraps* *Leiognathus splendens* *Johnius borneensis* *Leiognathus bindus* *Thryssa setirostris* *Paraplagusia longirostris*		*Saurida undosquamis* *Paramonacanthus choirocephalus* *Pseudorhombus argus* *Selaroides leptolepis* *Torquigener pallimaculatus*	*Pristotis obtusirostris* *Selaroides leptolepis* *Torquigener pallimaculatus* *Upeneus assymetricus* *Paramonacanthus choirocephalus* *Saurida undosquamis* *Nemipterus furcosus*	*Saurida undosquamis* *Torquigener pallimaculatus* *Paramonacanthus choirocephalus* *Pristotis obtusirostris* *Trachinocephalus myops* *Crossorhombus kanekonis*	*Saurida undosquamis* *Engyprosopon maldiviensis* *Pristotis obtusirostris* *Canthigaster rivulata*
Cape Bossut	*Leiognathus splendens* *Terapon theraps* *Carangoides malabaricus* *Upeneus sulphureus* *Leiognathus equulus* *Saurida tumbil* *Caranx bucculentus*	*Terapon theraps* *Leiognathus splendens* *Johnius borneensis* *Leiognathus bindus* *Thryssa setirostris* *Paraplagusia longirostris*	*Chaetodontoplus duboulayi* *Choerodon vitta* *Choerodon cephalotes* *Coradion chrysozonus*		*Pristotis obtusirostris* *Selaroides leptolepis* *Torquigener pallimaculatus* *Upeneus assymetricus*	*Paramonacanthus choirocephalus* *Crossorhombus kanekonis* *Torquigener pallimaculatus* *Trachinocephalus myops* *Pseudorhombus argus*	*Engyprosopon maldiviensis* *Engyprosopon grandisquama* *Pristotis obtusirostris* *Canthigaster rivulata*

Table 3.3.25 continued.

	Cape Voltaire	Hall Point	Emeriau Point	Cape Bossut	Cape Keraudren	Cape Preston	Locker Point
Cape Keraudren	*Leiognathus splendens* *Terapon theraps* *Carangoides malabaricus* *Upeneus sulphureus* *Saurida tumbil* *Leiognathus leuciscus* *Caranx bucculentus*	*Terapon theraps* *Leiognathus splendens* *Johnius borneensis* *Leiognathus bindus* *Thryssa setirostris* *Paraplagusia longirostris*	*Choerodon vitta* *Lutjanus vitta* *Chaetodontoplus duboulayi*			*Saurida undosquamis* *Parapercis nebulosa* *Crossorhombus kanekonis* *Trachinocephalus myops*	*Engyprosopon maldiviensis* *Nemipterus furcosus*
Cape Preston	*Leiognathus splendens* *Terapon theraps* *Carangoides malabaricus* *Upeneus sulphureus* *Saurida tumbil* *Leiognathus equulus* *Leiognathus leuciscus* *Caranx bucculentus*	*Terapon theraps* *Leiognathus splendens* *Johnius borneensis* *Leiognathus bindus* *Thryssa setirostris* *Paraplagusia longirostris*	*Chaetodontoplus duboulayi* *Choerodon vitta* *Choerodon cephalotes* *Pentapodus porosus* *Coradion chrysozonus*	*Selaroides leptolepis* *Pentapodus porosus* *Upeneus assymetricus*	*Pristotis obtusirostris* *Selaroides leptolepis* *Torquigener pallimaculatus* *Upeneus assymetricus*		*Engyprosopon maldiviensis* *Nemipterus furcosus* *Selaroides leptolepis* *Crossorhombus kanekonis*
Locker Point	*Leiognathus splendens* *Terapon theraps* *Carangoides malabaricus* *Upeneus sulphureus* *Saurida tumbil* *Leiognathus equulus* *Leiognathus leuciscus* *Caranx bucculentus*	*Terapon theraps* *Leiognathus splendens* *Johnius borneensis* *Leiognathus bindus* *Thryssa setirostris* *Paraplagusia longirostris*	*Chaetodontoplus duboulayi* *Choerodon vitta* *Choerodon cephalotes* *Pentapodus porosus* *Coradion chrysozonus*	*Selaroides leptolepis* *Pentapodus porosus*	*Pristotis obtusirostris* *Selaroides leptolepis* *Torquigener pallimaculatus* *Upeneus assymetricus*	*Pristotis obtusirostris* *Paramonacanthus choirocephalus* *Torquigener pallimaculatus* *Parapercis nebulosa*	

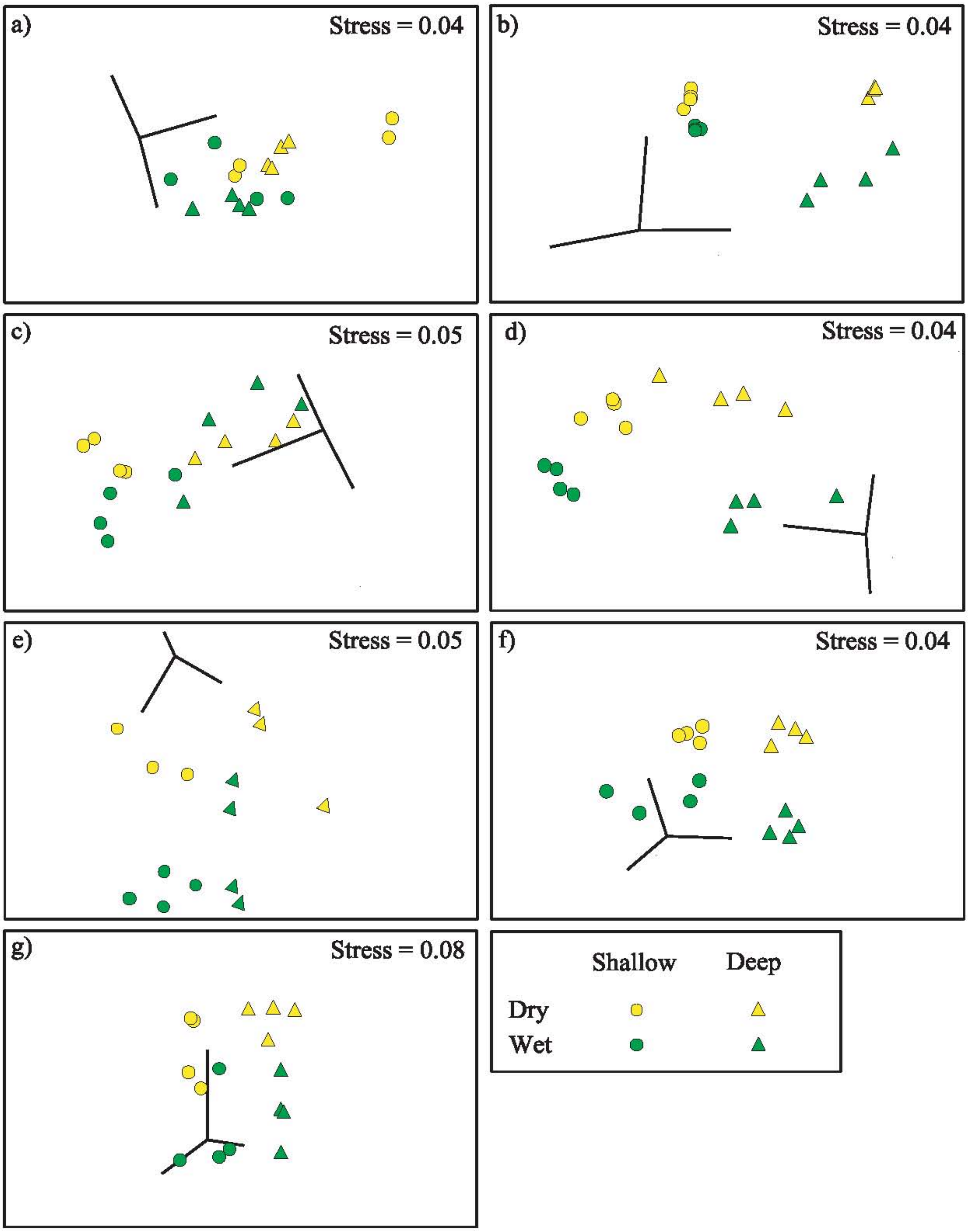

Fig. 3.3.19. Nonmetric multidimensional scaling ordinations of the densities of the variousfish species caught by trawling over soft substrates in shallow ($\bar{x}$ =12 m) and deep waters ($\bar{x}$ =22 m) during the day at a) Cape Voltaire, b) Hall Point, c) Emeriau Point, d) Cape Bossut, e) Cape Keraudren, f) Cape Preston and g) Locker Point in the dry period of 2001 and wet period of 2002.

Table 3.3.26 Significance values (p%) and R-statistics (R) detected by two-way crossed ANOSIM between the compositions of the ichthyofauna over soft substrates in each water depth, *i.e.* shallow and deep and in each period, *i.e.* dry and wet, at each of the seven locations during the day in 2001 and 2002. Significant results are highlighted in bold type.

Cape Voltaire

	p %	R
Depth	14.7	0.161
Period	**1.0**	**0.391**

Hall Point

	p %	R
Depth	**0.1**	**0.948**
Period	**0.2**	**0.833**

Emeriau Point

	p %	R
Depth	**0.2**	**0.750**
Period	**3.5**	**0.391**

Cape Bossut

	p %	R
Depth	**0.1**	**0.724**
Period	**0.3**	**0.870**

Cape Keraudren

	p %	R
Depth	**0.6**	**0.593**
Period	**0.2**	**0.741**

Cape Preston

	p %	R
Depth	**0.3**	**0.984**
Period	**0.4**	**0.969**

Locker Point

	p %	R
Depth	**0.3**	**0.547**
Period	**0.4**	**0.458**

Table 3.3.27 Species shown by SIMPER analysis as typifying the fish communities in each period (diagonal cells, *i.e.* dry *vs* dry, wet *vs* wet) and distinguishing between each of those periods (vertical cells) over soft substrates in shallow and deep waters at Cape Voltaire during the day in 2001 and 2002. * indicates that a species is most abundant in the period marked *, *i.e.* wet period.

	Dry	**Wet**
Dry	*Leiognathus leuciscus* *Carangoides malabaricus* *Saurida tumbil* *Terapon theraps* *Leiognathus splendens* *Leiognathus equulus* *Gerres filamentosus*	
Wet*	*Leiognathus equulus* *Carangoides malabaricus* *Gerres filamentosus* *Carangoides humerosus* *Upeneus sulphureus** *Secutor insidiator** *Leiognathus bindus**	*Leiognathus splendens* *Terapon theraps* *Upeneus sulphureus* *Saurida tumbil*

Table 3.3.28 Species shown by SIMPER analysis as typifying the fish communities in each depth (diagonal cells, *i.e.* Shallow *vs* Shallow, Deep *vs* Deep) and distinguishing between each of those depths (vertical cells) over soft substrates at a) Hall Point b) Emeriau Point c) Cape Preston and d) Locker Point during the day in 2001 (dry period) and 2002 (wet period). * Indicates that a species is most abundant in the depth marked *, *i.e.* deep waters.

a) Hall Point

	Dry period	
	Shallow	**Deep**
Shallow	*Caranx bucculentus* *Terapon theraps* *Carangoides humerosus* *Selaroides leptolepis* *Saurida tumbil*	
Deep*	*Caranx bucculentus* *Carangoides humerosus* *Selaroides leptolepis* *Leiognathus splendens* *Johnius borneensis** *Terapon theraps**	*Terapon theraps* *Johnius borneensis* *Leiognathus bindus* *Leiognathus leuciscus* *Leiognathus splendens*

	Wet period	
	Shallow	**Deep**
Shallow	*Terapon theraps* *Leiognathus leuciscus* *Upeneus sulphureus* *Caranx bucculentus*	
Deep*	*Leiognathus leuciscus* *Upeneus sulphureus* *Selaroides leptolepis* *Leiognathus splendens** *Apogon poecilopterus**	*Terapon theraps* *Apogon poecilopterus* *Caranx bucculentus* *Upeneus sulphureus*

b) Emeriau Point

	Dry period	
	Shallow	**Deep**
Shallow	*Saurida undosquamis* *Pristotis obtusirostris* *Tragulichthys jaculiferus*	
Deep*	*Pristotis obtusirostris* *Saurida undosquamis* *Chaetodontoplus duboulayi** *Choerodon vitta** *Choerodon cephalotes** *Coradion chrysozonus**	*Chaetodontoplus duboulayi* *Choerodon vitta* *Choerodon cephalotes* *Pentapodus porosus*

	Wet period	
	Shallow	**Deep**
Shallow	*Paramonacanthus choirocephalus* *Saurida undosquamis*	
Deep*	*Paramonacanthus choirocephalus* *Saurida undosquamis* *Selaroides leptolepis* *Lutjanus vitta** *Choerodon vitta** *Chaetodontoplus duboulayi**	*Choerodon cephalotes* *Chaetodontoplus duboulayi* *Pentapodus porosus* *Choerodon vitta* *Coradion chrysozonus*

Table 3.3.28 continued.

c) Cape Preston

	Dry period	
	Shallow	**Deep**
Shallow	*Paramonacanthus choirocephalus* *Saurida undosquamis* *Engyprosopon grandisquama* *Siganus fuscescens* *Parapercis nebulosa* *Priacanthus tayenus* *Pseudocalliurichthys goodladi*	
Deep*	*Paramonacanthus choirocephalus* *Priacanthus tayenus* *Siganus fuscescens* *Engyprosopon grandisquama* *Pristotis obtusirostris** *Crossorhombus kanekonis**	*Paramonacanthus choirocephalus* *Saurida undosquamis* *Parapercis nebulosa* *Torquigener pallimaculatus* *Trachinocephalus myops* *Xyrichtys jacksonensis* *Engyprosopon grandisquama* *Crossorhombus kanekonis* *Pristotis obtusirostris*

	Wet period	
	Shallow	**Deep**
Shallow	*Selaroides leptolepis* *Upeneus asymmetricus* *Saurida undosquamis* *Lagocephalus scleratus* *Sillago burrus* *Parapercis nebulosa* *Pseudorhombus arsius*	
Deep*	*Selaroides leptolepis* *Upeneus asymmetricus* *Siganus fuscescens* *Sillago burrus* *Lagocephalus scleratus* *Saurida undosquamis** *Pristotis obtusirostris**	*Saurida undosquamis* *Torquigener pallimaculatus* *Pristotis obtusirostris* *Parapercis nebulosa*

Table 3.3.28 continued.

d) Locker Point

Dry period		
	Shallow	**Deep**
Shallow	*Paramonacanthus choirocephalus* *Choerodon cephalotes* *Upeneus asymmetricus* *Pristotis obtusirostris* *Parapercis nebulosa* *Torquigener pallimaculatus*	
Deep*	*Lethrinus genivittatus* *Paramonacanthus choirocephalus* *Pristotis obtusirostris* *Upeneus asymmetricus* *Torquigener pallimaculatus* *Choerodon cephalotes* *Engyprosopon maldiviensis** *Saurida undosquamis** *Engyprosopon grandisquama** *Pseudorhombus argus** *Trachinocephalus myops**	*Engyprosopon maldiviensis* *Saurida undosquamis* *Engyprosopon grandisquama* *Trachinocephalus myops* *Pseudorhombus argus* *Paramonacanthus choirocephalus* *Torquigener pallimaculatus*

Wet period		
	Shallow	**Deep**
Shallow	*Lethrinus genivittatus* *Saurida undosquamis* *Pristotis obtusirostris* *Siganus fuscescens* *Choerodon cephalotes*	
Deep*	*Lethrinus genivittatus* *Pristotis obtusirostris* *Siganus fuscescens* *Nemipterus furcosus** *Selaroides leptolepis** *Parupeneus chrysopleuron**	*Saurida undosquamis* *Nemipterus furcosus* *Selaroides leptolepis* *Parupeneus chrysopleuron* *Canthigaster rivulata*

Table 3.3.29 Species shown by SIMPER analysis as typifying the fish communities in each period (diagonal cells, *i.e.* dry *vs* dry, wet *vs* wet) and distinguishing between each of those periods (vertical cells) over soft substrates in shallow and deep waters separately at a) Cape Bossut and b) Cape Keraudren during the day in 2001 (dry period) and 2002 (wet period). * Indicates that a species is most abundant in the period marked *, *i.e.* wet period.

a) Cape Bossut

Shallow

	Dry	**Wet**
Dry	*Pristotis obtusirostris* *Saurida undosquamis* *Chaetodontoplus duboulayi* *Torquigener pallimaculatus* *Synodus variegatus* *Paramonacanthus choirocephalus* *Choerodon cephalotes* *Pseudorhombus spinosus*	
Wet*	*Pristotis obtusirostris* *Pseudorhombus spinosus* *Choerodon cephalotes* *Synodus variegatus* *Paramonacanthus choirocephalus* *Sillago ingenua** *Torquigener pallimaculatus** *Lagocephalus scleratus**	*Pristotis obtusirostris* *Torquigener pallimaculatus* *Saurida undosquamis* *Sillago ingenua* *Chaetodontoplus duboulayi*

Deep

	Dry	**Wet**
Dry	*Saurida undosquamis* *Engyprosopon grandisquama* *Pseudorhombus argus* *Trachinocephalus myops* *Paramonacanthus choirocephalus* *Xyrichtys jacksonensis* *Pseudorhombus spinosus*	
Wet*	*Lagocephalus lunaris* *Choerodon cephalotes* *Trachinocephalus myops* *Selaroides leptolepis** *Torquigener pallimaculatus** *Saurida undosquamis** *Leiognathus leuciscus** *Ulua aurochs**	*Saurida undosquamis* *Torquigener pallimaculatus* *Selaroides leptolepis* *Parapercis nebulosa* *Paramonacanthus choirocephalus* *Pentapodus porosus* *Pristotis obtusirostris*

Table 3.3.29 continued.

b) Cape Keraudren

	Shallow	
	Dry	**Wet**
Dry	*Saurida undosquamis* *Cyclichthys orbicularis* *Upeneus asymmetricus* *Sillago burrus* *Engyprosopon grandisquama* *Pentapodus vitta* *Sillago lutea*	
Wet*	*Cyclichthys orbicularis* *Paramonacanthus choirocephalus* *Engyprosopon grandisquama* *Sillago lutea* *Sillago burrus* *Pentapodus vitta* *Selaroides leptolepis** *Leiognathus leuciscus** *Lagocephalus scleratus** *Caranx bucculentus** *Carangoides hedlandensis**	*Selaroides leptolepis* *Saurida undosquamis* *Upeneus asymmetricus* *Leiognathus leuciscus* *Lagocephalus scleratus*

	Deep	
	Dry	**Wet**
Dry	*Pristotis obtusirostris* *Upeneus asymmetricus* *Saurida undosquamis* *Pseudorhombus argus* *Anampses lennardi* *Choerodon cephalotes*	
Wet*	*Choerodon cephalotes* *Pseudorhombus argus* *Pentapodus vitta* *Selaroides leptolepis** *Pristotis obtusirostris** *Torquigener pallimaculatus** *Sillago ingenua** *Paramonacanthus choirocephalus** *Carangoides fulvoguttatus**	*Selaroides leptolepis* *Torquigener pallimaculatus* *Pristotis obtusirostris* *Saurida undosquamis* *Paramonacanthus choirocephalus* *Carangoides fulvoguttatus* *Sillago ingenua*

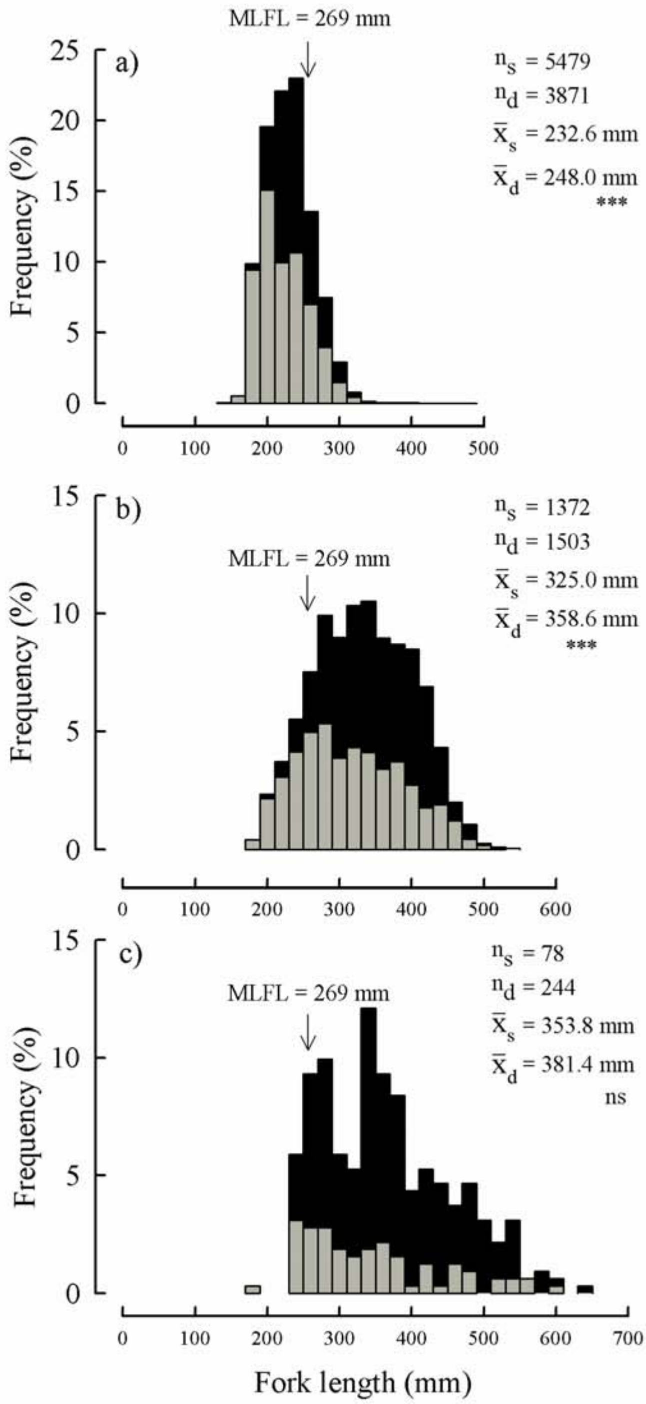

Fig. 3.3.20. Length-frequency histograms for a) *Lethrinus hutchinsi*, b) *Lethrinus laticaudis* and c) *Lethrinus nebulosus* caught in fish traps over reefs in shallow (▨) and deep (■) waters in north-western Australia. *** and ns = mean lengths in shallow and deep waters significantly different ($P < 0.001$) and not significantly different ($P > 0.05$), respectively. MLFL = mimimum legal fork length for retention. In this Fig. and Figs 3.3.21 to 3.3.23, n_s and n_d = number of fish caught in shallow and deep waters, respectively, and $\bar{x}_s$ and $\bar{x}_d$ = mean fork length of fish in shallow and deep waters, respectively.

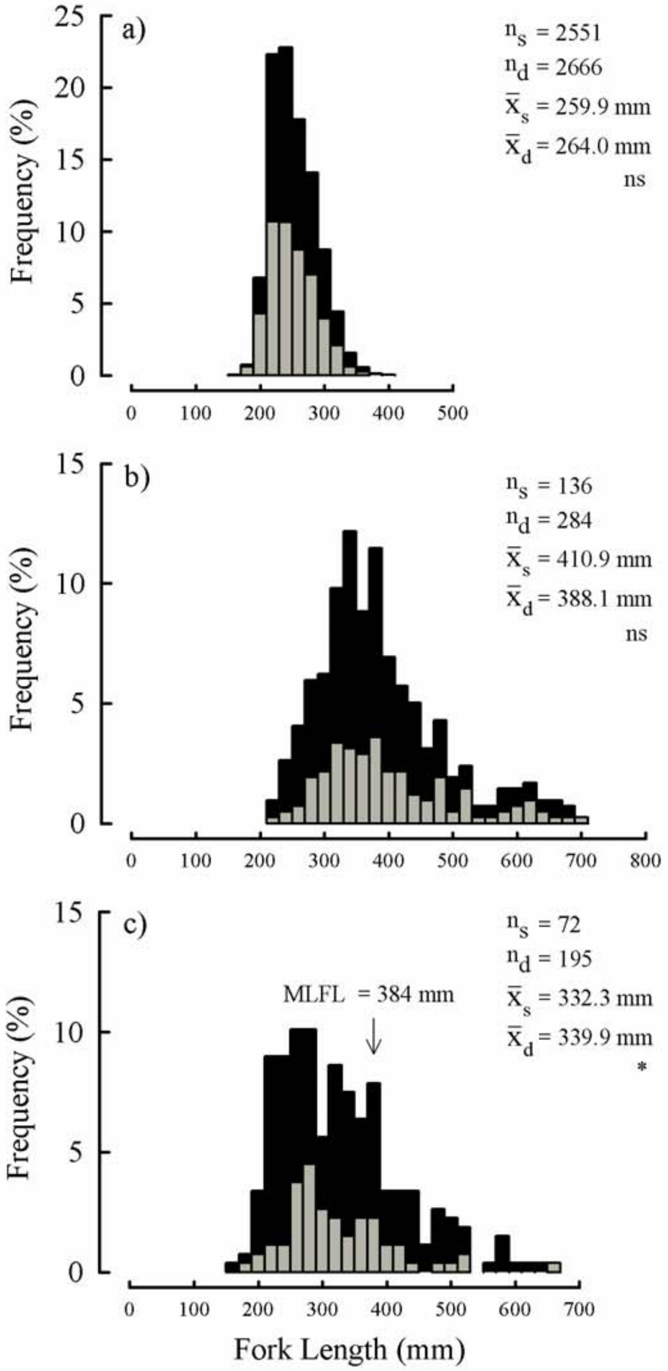

Fig. 3.3.21. Length-frequency histograms for a) *Lutjanus carponotatus*, b) *Lutjanus johnii* and c) *Lutjanus sebae* caught in fish traps over reefs in shallow (■) and deep (■) waters in north-western Australia. * and ns = mean lengths in shallow and deep waters significantly different ($P < 0.05$) and not significantly different ($P > 0.05$), respectively. MLFL = mimimum legal fork length for retention.

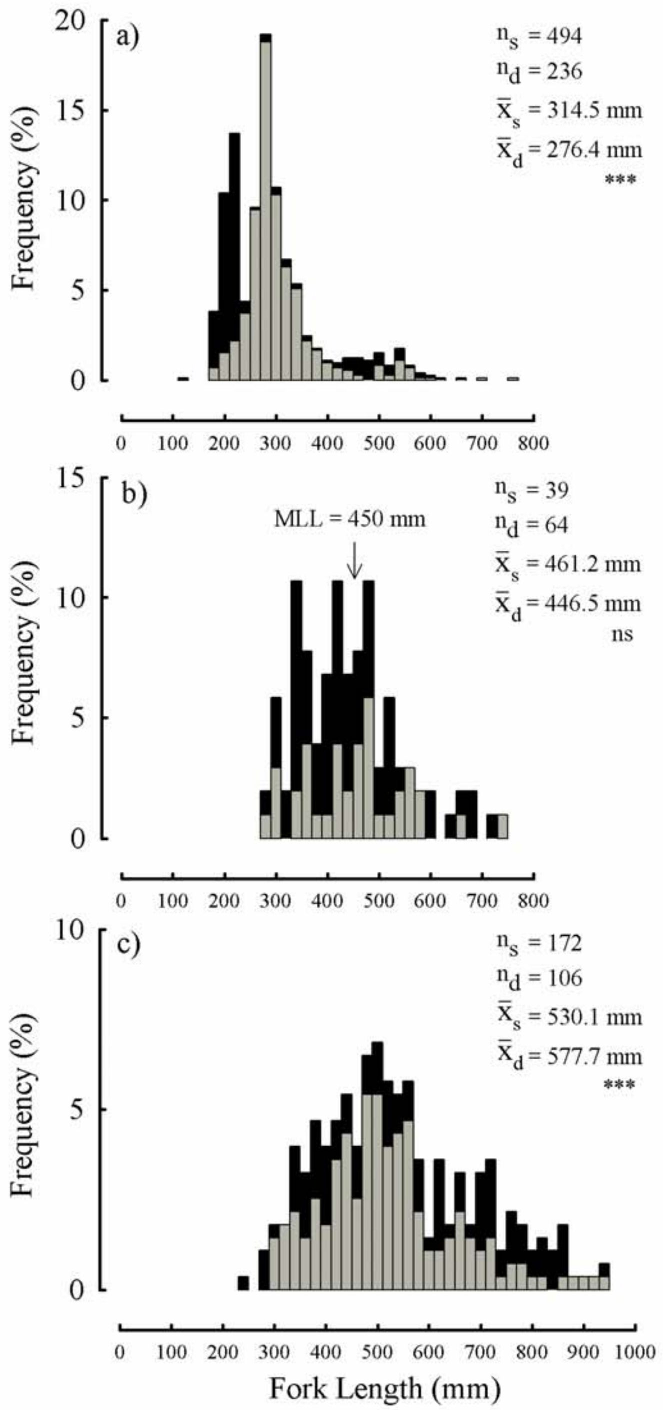

Fig. 3.3.22. Length-frequency histograms for a) *Gnathanodon speciosus,* b) *Plectropomus maculatus* and c) *Epinephelus coioides* caught in fish traps over reefs in shallow (▢) and deep (■) waters in north-western Australia. *** and ns = mean lengths in shallow and deep waters significantly different ($P < 0.001$) and not significantly different ($P > 0.05$), respectively. MLL = mimimum legal length for retention.

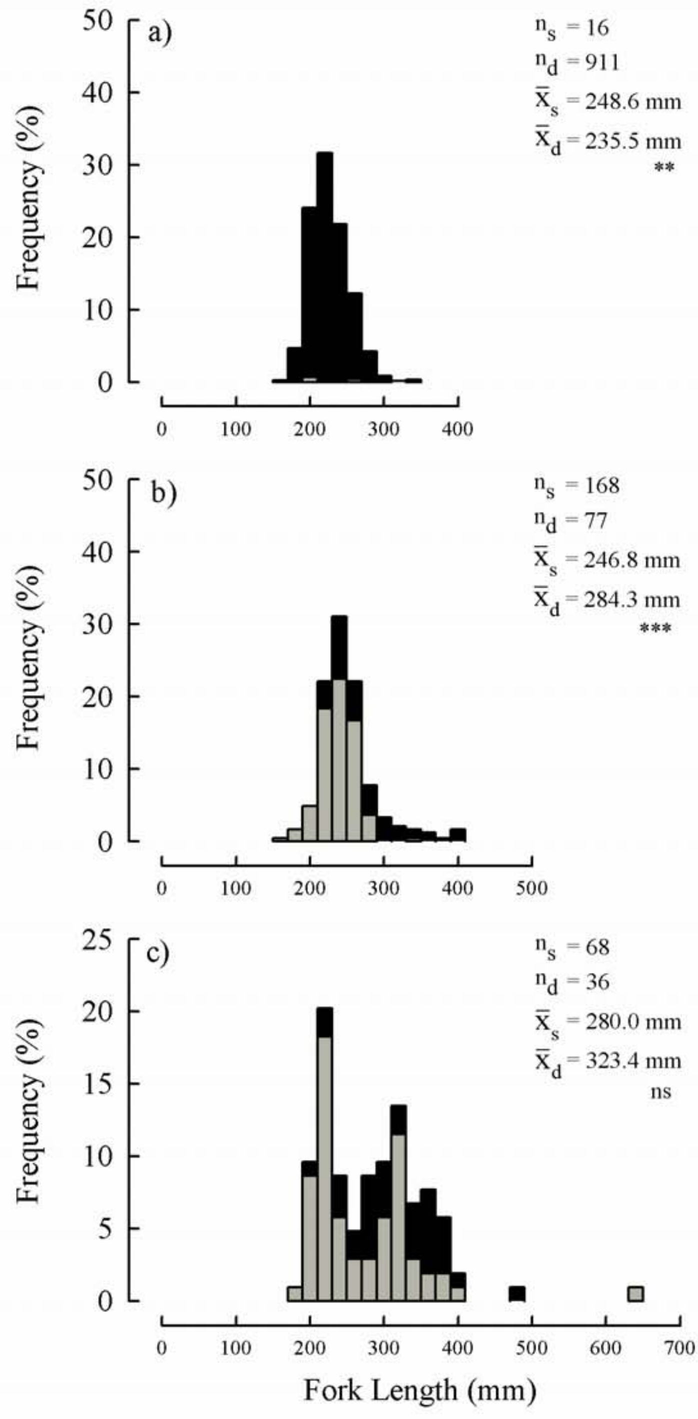

Fig. 3.3.23. Length-frequency histograms for a) *Lutjanus bitaeniatus*, b) *Lutjanus russelli* and c) *Lutjanus malabaricus* caught in fish traps over reefs in shallow (▢) and deep (■) waters in north-western Australia. **, *** and ns = mean lengths in shallow and deep waters significantly different at $P<0.01$, $P<0.001$ and not significantly different at $P<0.05$, respectively .

3.4 Discussion

3.4.1 Comparisons of ichthyofaunas over reefs and soft substrates

This study provides the first account of the characteristics of the fish faunas associated with reefs and soft substrates in water depths of 5 to 30 m along *ca* 3,000 km of coastline in north-western Australia. The fish caught in these inshore waters of the Pilbara and Kimberley coasts, using two different sampling methods, comprised 352 fish species representing 194 genera and 82 families. The number of fish species and families recorded over soft substrates (279 species and 74 families) were more than twice those recorded over reefs (132 species and 36 families).

The species composition of the fish fauna caught by trapping over reefs differed markedly from that collected by trawling over soft substrates in each water depth at each location. This very pronounced difference in species composition between habitat types is illustrated by the fact that the three most abundant species over reefs, *i.e. Lethrinus hutchinsi*, *Lutjanus carponotatus* and *Lethrinus laticaudis,* and which accounted for more than 65% of the catch in this habitat type, differed from the six most abundant species caught over soft substrates, *i.e. Leiognathus splendens*, *Selaroides leptolepis*, *Pristotis obtusirostris*, *Terapon theraps*, *Saurida undosquamis* and *Paramonacanthus choirocephalus*, and which contributed nearly half of the catch of fish obtained from this habitat type.

The most speciose families over reefs were the Serranidae, Lutjanidae and Lethrinidae, thereby largely paralleling the situation with reefs in tropical and sub-tropical waters elsewhere (e.g. Heemstra & Randall, 1993; Newman *et al*., 1997; Rooker *et al*., 1997; Connell & Kingsford, 1998; Rocha *et al*., 1998; Smith-Vaniz, 1999). Most of the abundant fish species collected over reefs in this study were carnivores, which accounts for the fact that these species were attracted to the pilchards used as bait in the traps (Hobson, 1974; St John, 2001; Nakamura *et al.,* 2003). In contrast, the most speciose families over soft substrates were the Carangidae, Bothidae, Tetraodontidae, Mullidae and Leiognathidae, which are typically associated with soft substrates in tropical and sub-tropical waters elsewhere (e.g. Blaber *et al*., 1990, 1995; Watson *et al*., 1990). Many of the species in these families feed on benthic macroinvertebrates and cryptic benthic fish species (Jayabalan & Ramamoorthi, 1985; Rajaguru *et al*., 1987; Brewer *et al*., 1994; McCormick, 1995; Potter *et al*, 1988; Platell & Potter, 2001).

3.4.2 Latitudinal comparisons of species composition

The use of multidimensional scaling ordination emphasizes that the species compositions of the fish faunas over reefs changed in an essentially progressive manner from Cape Voltaire in the Kimberley southwards to Cape Preston and Locker Point in the Pilbara. This progressive change with latitude is hardly surprising in view of the vast distance of *ca* 1800 km that separated these most northerly and southern sampling locations and that these locations differed in latitude by as much as *ca* 8 degrees. The distribution of the samples on the ordination plots also indicated that, at least in deeper water, there was a "faunal break" between Cape Voltaire and Hall Point in the north and all of the other more southern locations. This difference is exemplified by, *inter alia,* the fact that, in deep water, relatively greater numbers of *Lutjanus bitaeniatus* and *Lutjanus johnii* distinguished the fish fauna at Cape Voltaire from those at each location south of Hall Point, and that the same was true for the former species at Hall Point *versus* all of those more southern locations. In contrast, relatively greater numbers of species such as *Lethrinus hutchinsi* distinguished the deep water faunas at most of the southern locations from those at the two most northern locations.

The number of fish species and relative abundance of fish over reefs were least at Cape Voltaire and were also relatively low at Hall Point. It is thus almost certainly relevant that the very large tides and the presence of large rivers along the region of the coastline where the two more northern locations are situated leads to the suspension of large amounts of sediment in the water column (Hutchins, 1997) and thus a reduction in the substrate available to coral propagules and a reduction in the amount of light for algae (Walker, 1995). Furthermore, Hutchins (1995) suggests that the majority of the fish species found in the waters of the southern Kimberley region are particularly well adapted to living in turbid water.

The number of fish species and abundance of fish in both the shallow and deep waters over reefs were both found to be greater at Cape Bossut than at all other locations. It may thus be relevant that Cape Bossut is characterised by numerous patches of reefs and thus a large area for colonisation by fish species that occupy this type of habitat. Furthermore, heavy predation by large numbers of reef species on the fish occupying the waters over adjacent soft substrates could account for the relatively low densities of fish found in these waters.

The compositions of the fish faunas over soft substrates were also influenced markedly by latitude and, in the case of this habitat type, the distinction between the fish faunas at Cape Voltaire and Hall Point and those further to the south were even more pronounced than was the case over reefs. This difference in faunal composition is emphasized by, for example, the fact that the leiognathids *Leiognathus splendens* and *Secutor insidiator* were relatively abundant at Cape Voltaire and Hall Point, but were not caught at the more southern locations. In contrast, the pomacentrid *Pristotis obtusirostris*, the monacanthid *Paramonacanthus choirocephalus* and the lethrinid *Lethrinus genivittatus*, which were relatively abundant at the southern locations, were never caught at Cape Voltaire and Hall Point.

3.4.3 Comparisons between water depths

The greater number of species and greater catch rates of fish over reefs in deep waters than shallow waters along the Pilbara and Kimberley coasts parallel the situation found with reefs in some other regions (e.g. Roberts & Ormond, 1987; Rooker *et al*., 1997; Kulbicki *et al*., 2000; Newman & Williams, 2001). These differences were paralleled by pronounced differences in the species compositions in shallow and deeper waters at each location and particularly at Hall Point and Locker Point. In reefs at the latter location, the fish faunas in shallow water were distinguished from those in deeper waters by relatively greater numbers of *Lethrinus laticaudis* and *Epinephelus coioides* and relatively lower numbers of *Lethrinus genivittatus* and *Lethrinus nebulosus*.

Water depth also had a marked influence on the species composition of the fish faunas over soft substrates, as has also been found to be the case in areas such as the Gulf of Carpentaria (Rainer & Munro, 1982; Rainer, 1984). Thus, at locations where particular species were abundant, the densities of species such as *Paramonacanthus choirocephalus* and *Leiognathus leuciscus* tended to be greater in shallow than deeper water, whereas the reverse pertained with *Upeneus assymetricus*. However, several species, e.g. *Pristotis obtusirostris* and *Saurida undosquamis*, were present in greater densities in shallow than deep waters in one or more locations and to exhibit the opposite trend at other locations.

3.4.4 Diel and period comparisons

The numbers of species and catch rates of fish over reefs were both greater during the day than night, which clearly implies that the fish that enter traps show a greater tendency to feed during the day than at night. In the context of densities, it is relevant that the lethrinid *Lethrinus laticaudis*, which was the third most abundant species, was far more numerous in trap catches obtained during the day than night. The same situation pertained with the serranids *Epinephelus coioides* and *Epinephelus bilobatus*, the balistid *Abalistes stellaris* and another lethrinid, *Lethrinus nebulosus*. Newman & Williams (1995) report that, in their study on fish caught using traps on the Great Barrier Reef, *Lethrinus ravus* and *A. stellaris* were both caught in greater numbers in traps set during the day than at night and species of serranids also tend to feed mainly during daylight hours (Parrish, 1987). Although lethrinids dominated the trap catches during the day off the north-west coast of Australia (Whitelaw *et al*., 1991) *L. laticaudis* and *L. nebulosus* were the only lethrinid species in our study, to show a conspicuous tendency to be caught in greater numbers during the day than night.

In contrast to the situation with our trap catches, the number of fish caught by the same method over reefs in the Great Barrier Reef was greater during the night than day (Newman & Williams, 1995). However, this may have reflected the shorter period of time that the traps were set during the day than night in that study, *i.e.* 6-9 h *vs* 10-14 h. Although the compositions of the fish faunas over reefs did differ significantly between day and night at each location, the R-statistic values for the ANOSIM test for day *versus* night were less than 0.36 in all but one case, which implies that the differences were not particularly pronounced.

The fact that overall the number of fish species and abundance of fish over reefs were both greater during the dry than wet periods probably reflects either a tendency for fish, during the dry period, to be more dispersed and/or differences related to the reproductive movements of certain species. It has been suggested that seasonal variations in reef fish abundances can be related to movements of fish in response to physical stresses (Coles & Tarr, 1990) and to movements associated with reproduction (Johannes, 1978; Robertson, 1983), including those of certain serranid and lutjanid species (Shapiro, 1987; Beets & Friedlander, 1992; Sadovy, 1996).

The lower number of fish species and abundances of fish during the wet period may also reflect the extreme weather patterns that are experienced along the Kimberley and Pilbara coastlines during the wet season. This coast of Australia, which is one of the most cyclone-prone coasts anywhere in the world, experiences more cyclones than any other coast in Australia. Indeed, Cyclone Chris, one of the most severe cyclones ever experienced in Australia crossed between Cape Bossut and Cape Preston three weeks prior to the wet season sampling trip in 2002. The studies of Friedlander & Parrish (1998) and Syms & Jones (2000) have demonstrated that disturbances in the forms of heavy weather or extreme temperatures can have a substantial influence on reef fish assemblages, e.g. number of species was negatively correlated with wave height. It is thus noteworthy that, although R-statistic values for ANOSIM tests (Table 3.3.15) demonstrated that the extent to which period (dry *vs* wet) influenced faunal composition over reefs at night varied greatly with location, the influence of period was particularly pronounced only at Cape Bossut and Cape Preston, the locations that lay to either side of the region where Cyclone Chris, crossed the coast.

3.4.5 Comparisons between research catches and the commercial and recreational catches

Lethrinus hutchinsi, which was the most abundant species overall in the catches obtained by our trapping over reefs, was the second ranked species by weight overall in the catches obtained by the commercial trap and trawl fisheries that is based in the Pilbara and centred around Dampier. Furthermore, this lethrinid ranked as high as nineteenth in terms of numbers amongst the numerous recreational species recorded in the Pilbara and West Kimberley creel survey (Chapter 1). Since no commercial trapping or trawling is permitted in water depths less than 30 m in the Pilbara, it is particularly relevant that over 80% of the individuals of *L. hutchinsi* that were caught during our trapping and trawling, which was conducted in waters shallower then 30 m, were less than the MLL. Thus, large numbers of the smaller individuals of this species are protected from capture by commercial fishers.

The second most abundant species in our trap catches, *Lutjanus carponotatus*, was a very important species for recreational anglers and charter boat fishers (Chapter 1). Since this species was caught in large numbers at each of our sampling locations, it was clearly well adapted to the range of environmental conditions found along the Pilbara and Kimberley coasts.

Lethrinus laticaudis, which ranked third in our trap catches and was abundant at all of our sampling locations, is a major species in Zone 1 of the NDSF and ranked second in the Pilbara and West Kimberley recreational catch (Chapter 1). Unlike *L. hutchinsi*, the majority of the individuals of this species in our catches lay above the MLL. The contrast between the large numbers of the adults of this species in our catches and the paucity of this species in the commercial catches, reflects the fact that this species is essentially confined to shallower waters.

Our trap catches of *Lutjanus johnii* were abundant in and restricted to the two most northern locations, *i.e.* Cape Voltaire and Hall Point in the Kimberley. This is consistent with the commercial catches for this species being centred in Zone 1 of the NDSF, which is located in the Kimberley region, and ranked third in the charter boat fishery of that region (Chapter 1).

The coral trout *Plectropomus maculatus* was caught at all of our sampling locations and is also caught by commercial fishers throughout the length of coastline over which we sampled (Chapter 3). It is considered an icon angling species, ranking sixteenth in the recreational catches obtained from the Pilbara and West Kimberley regions (Chapter 1). Since the lengths of the individuals of this species in our catches lay to either side of the MLL, the legislation preventing commercial fishing in water depths less than 30 m is protecting substantial numbers of both the smaller and larger individuals of this species from capture by commercial fishers. Although this species is targeted by anglers in shallower waters, the individuals less than the MLL are more likely to survive release in these shallower waters than in deeper waters further offshore.

The Moses snapper *Lutjanus russelli* is one of the few species that was numerous in our trap catches that was also abundant in nearshore waters and particularly in rock pools (Chapter 2). It is clear that the latter environment provides an important nursery area for this lutjanid. *Lutjanus russelli* is an important commercial and recreational fish species along the Pilbara and Kimberley coasts (Chapter 1). Although the restriction of commercial fishing to waters deeper than 30 m protects large numbers of the juveniles from capture by commercial fishers, *L. russelli* is targeted by recreational anglers in shallower waters.

4.0 Fish by-catch in the Exmouth Gulf Prawn Fishery

Michael J. Travers, Stephen J. Newman and Ian C. Potter

4.1 Introduction

The Exmouth Gulf Prawn Managed Fishery (EGPMF) is the second largest prawn fishery in Western Australia, with the catch in 2001 weighing 670 t and having a value of $10 million (Kangas & Sporer, 2003). This large fishery, which has been based in Exmouth Gulf on the central-west coast of Australia since 1963, operates in four fishing areas (A, B, C, D) in this embayment (Fig. 4.1.1). The EGPMF is located adjacent to the Ningaloo Marine Park, in which recreational fishers catch over 100 t of fish each year and a substantial charter boat industry is located (Sumner *et al*., 2002).

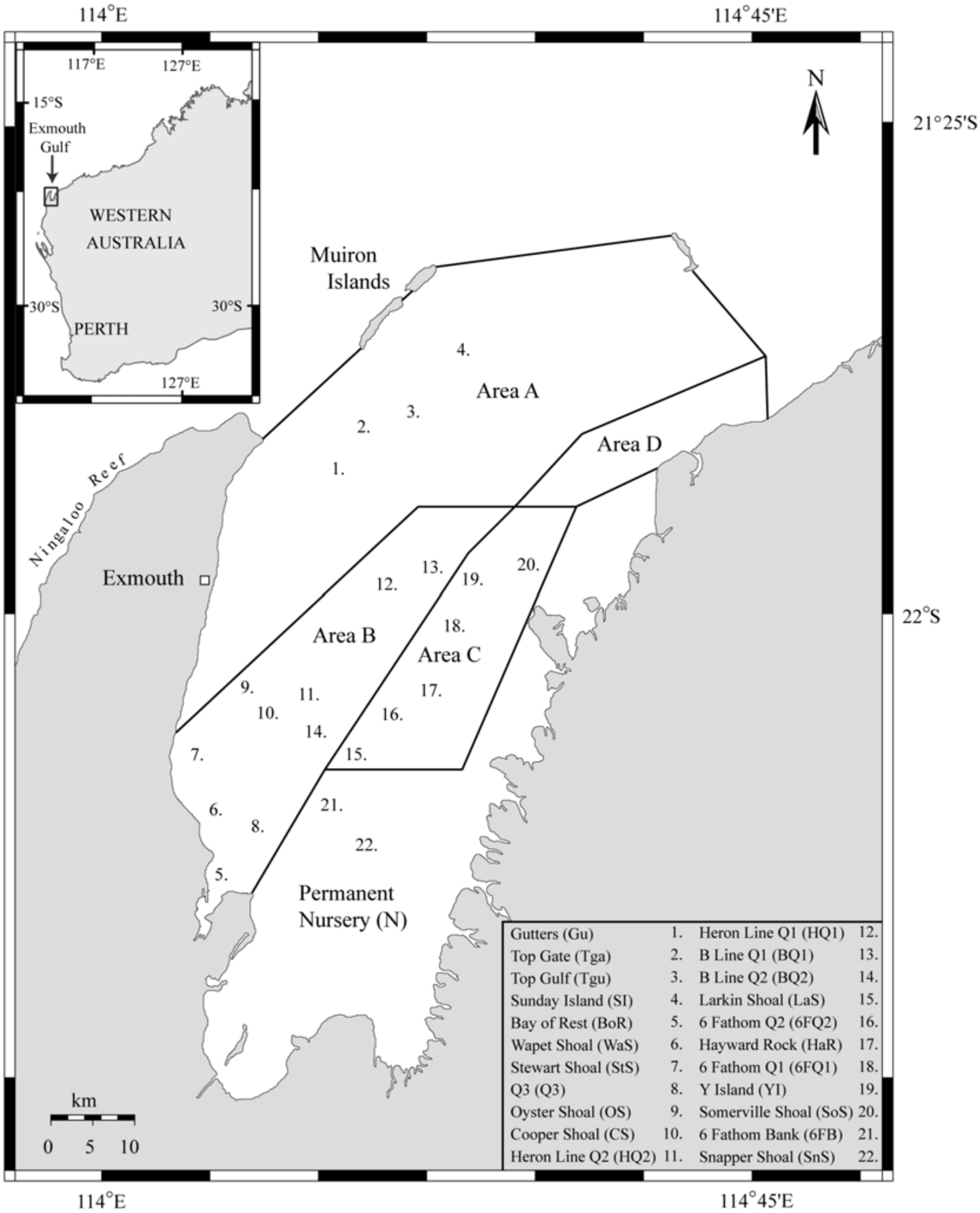

Figure 4.1.1 Map showing the location of the sites sampled in the prawn fishing areas A, B, C and D and the permanent nursery area N in Exmouth Gulf.

The EGPMF operates under management advice from the Exmouth Gulf Prawn Management Advisory Committee (EGPMAC), which determines gear controls. The committee also determines the period of the year when each of the four fishing areas is open to fishing, which overall extends for a period between the beginning of April and the end of November. The closure of these fishing areas at other times is aimed at allowing the prawns in each area to grow to their optimal marketable size (Fisheries W.A., 2002). The EGPMAC is also responsible for initiating closures within each month, which usually last for four nights around the time of each full moon and are aimed at protecting the prawns that moult at that time and are thus soft-shelled. An area on the eastern side of the gulf is permanently closed to fishing (Fig. 4.1.1) in order to conserve the seagrass and other sensitive habitats in that area, which are occupied by juvenile prawns (Fisheries W.A., 2002).

This fishery operates only during the night, at which time the western king prawn (*Penaeus latisulcatus*), brown tiger prawn (*Penaeus esculentus*), endeavour prawn (*Metapenaeus* spp.) and banana prawn (*Penaeus merguiensis*) are at their most active. Thirteen licensed boats, each employing 4.5-fathom quad demersal otter trawl gear, fish in the Gulf throughout each "fishing season".

Prawn trawling is one of the least selective methods of fishing, and consequently the weight of the by-catch of fish, cephalopods and other crustaceans can far outweigh that of the targeted prawns (e.g. Stobutzki *et al*., 2001). Indeed, it has been estimated that a third of all fisheries discards worldwide result from prawn trawling and that the northern Australian prawn trawl fishery (NPF) has the third highest discard ratio of by-catch to targeted species in the world (Alverson *et al*., 1994). Stobutzki *et al*. (2000) found that, in the NPF, the trawl catch per unit effort for the trawl by-catches were as high as 145 kg h^{-1}, whereas those of prawns were only 2.8 to 11.0 kg h^{-1}. The by-catch taken by prawn trawl fisheries includes the juveniles of many commercially and/or recreationally important fish species, which have been shown to suffer very heavy mortality prior to or just after being returned to the water (Hill & Wassenberg, 1990, 2000). Fisheries managers within Australia now acknowledge the importance of determining the amount and composition of fishery by-catch so that they can ascertain the potential impact of trawling on populations of non-target species.

The amount and/or composition of the by-catch taken by other Australian prawn trawl fisheries have been well documented. These include the fisheries in northern Australia (Pender *et al*., 1992; Stobutzki *et al*., 2000), Queensland (Dredge, 1989a; 1989b; Stobutzki *et al*., 2000) and south-eastern Australia (Gray *et al*., 1990; McShane *et al*., 1999). Although the available data indicate that the total by-catch of the EGPMF is relatively low by tropical trawl fisheries standards (Fisheries WA, 2002; Kangas & Sporer, 2003), there is a paucity of data on the composition of the fish by-catch taken by this fishery.

The fleet trialled bycatch reduction devices (BRDs) during 2001 and 2002 and their use became mandatory in the 2003 season. These devices are modified Nordmøre-grids, in which the codend has been modified so that it significantly reduces the fish by-catch, while maintaining the catch of prawns (Broadhurst & Kennelly, 1996; Broadhurst *et al*., 1996).

The aim of this component of the FRDC project was to determine the relative abundances and size compositions of the commercial and/or recreational fish species that are taken as by-catch by the EGPMF.

4.2 Material and methods

Fish collected as by-catch by prawn trawlers operating at night in areas A, B and C and the nursery area N in Exmouth Gulf (see Fig. 4.1.1 for location of areas) were sampled opportunistically between March 2001 and June 2003 (see Table 4.2.1 for details of sampling). Each boat deployed quad demersal otter trawl gear, with each of the four nets having a headrope length of 4.5 fathoms and a 45 mm mesh codend that is 100 meshes around. Each trawl lasted between 30 min and 3 h and was undertaken at a boat speed of *ca* 3-4 km h^{-1}. Samples were obtained from 108 trawls, which were conducted from boats using the by-catch reduction devices (BRDs) that became mandatory for this fishery in 2003.

Table 4.2.1 The months and number of times that trawls from the different trawl sites in fishing areas A, B and C and the prawn nursey area N in Exmouth Gulf were sampled for fish by-catch. The code for trawling sites and the location of the fishing and nursery areas are shown in Figure 4.1.1.

			A				B										C						N	
Year	Month	(*n*)	Gu	SI	Tga	Tgu	BoR	BQ1	BQ2	CS	HQ1	HQ2	OS	Q3	StS	WaS	6FQ1	6FQ2	HaR	LaS	YI	SoS	6FB	SnS
2001	March	10					1							3	1	1	2						2	
2001	September	19	11			2						1			1	1				2		1		
2002	April	14					1	2	1		2	2			1	1	1						1	2
2002	August	16	5	1	2		1									1	1	1	1	1	1	1		
2002	September	15	6			1			1						1	1	1	1	1		1	1		
2002	October	5							1					2	1	1								
2002	November	10	3							1			1		2	1	1			1				
2003	April	11					1	1			1	1			1	1		1		1		1	1	1
2003	June	8	7									1												
Total		108	32	1	2	3	4	3	3	1	3	5	1	5	8	8	6	3	2	5	2	4	4	3

The entire catch collected by each of the four nets during each trawl, and which mainly comprised fish, sponges, prawns and other crustaceans, was emptied on to a sorting tray where the crew then selected all marketable prawns and placed the by-catch to the side. All of the fish in the by-catch of each trawl were separated out. Ten-litre containers were then repeatedly filled with the fish by-catch until the entire catch had been subjected to this procedure and the number of containers that this required was recorded. Four 10 L containers were then filled randomly with fish from the by-catch, and the numbers and weights of fish in each of these four containers were recorded and meaned. These mean values were then multiplied by the number of containers to provide an estimate of the total number and weight of all fish caught in each trawl.

All of the individuals of each fish species, that contribute to commercial and/or recreational fisheries in Western Australia, were then separated from the entire fish catch obtained during each trawl and counted and their fork lengths measured to the nearest 1 mm. This enabled the percentage contribution made to the overall catch of trawled fish by each of those recreational and/or fish species to be calculated.

4.3 Results and Discussion

4.3.1 Species composition of fish by-catch in the Exmouth Gulf Prawn Fishery

Sampling of the fish by-catch from 108 trawls in the Exmouth Gulf prawn fishery in 2001, 2002 and 2003 yielded an estimated 396,725 fish, of which 2774 (0.64%), representing 22 species, are fished by commercial and/or recreational finfish fisheries in Western Australia (Table 4.3.1). The most abundant of the commercial and/or recreational fish species collected were threadfin emperor (*Lethrinus genivittatus*) and Australian threadfin (*Polydactylus multiradiatus*), with 1396 and 681 individuals, respectively, which represented 0.35 and 0.17%, respectively, of the total number of fish caught (Table 4.3.1). Nether of these two species are of particular commercial or recreational importance in Western Australia.

Saddle-tailed snapper (*Lutjanus malabaricus*), grass emperor (*Lethrinus laticaudis*), stripey snapper (*Lutjanus carponotatus*) and Moses snapper (*Lutjanus russelli)*, with 347, 85 and 65 individuals being caught, respectively, were the only other important commercial and/or recreational species to account for at least 0.01% of the total catch (Table 4.3.1). The saddle tailed snapper ranked sixth by weight in the Pilbara demersal finfish fisheries in 2001 (Stephenson & King, 2003). In creel surveys of recreational fisheries, grass emperor and stripey snapper ranked fourth and fourteenth in the Ningaloo Marine Park, respectively (Sumner *et al*., 2002) and second and first in the Pilbara, respectively (Williamson *et al*., in prep.). Other species of particular commercial and/or recreational importance, e.g. blue-spotted emperor, tropical snapper, crimson snapper, golden trevally, red emperor and Rankin's cod, were caught only in low numbers.

From the above data, it is concluded that no commercial and/or recreational fish species constituted a major component of the by-catch of the Exmouth Gulf Prawn Fishery between 2001 and 2003.

Table 4.3.1 Fish species that were a by-catch of the Exmouth Gulf Prawn Fishery in 2001, 2002 and 2003 and are of commercial and/or recreational importance. Data are also provided on the number of each species caught and its contribution to the total catch of all fish, the frequency of occurrence of each species in all trawls and the range and mean for the fork length of each species. * denotes species that are particularly important from a commercial and/or recreational perspective.

Species	Common name	*n*	Contribution %	Frequency %	Fork length (mm) Range	Mean
Lethrinus genivittatus	Threadfin emperor	1396	0.35	71.3	20-217	131.8
Polydactylus multiradiatus	Günther's threadfin	681	0.17	38.9	117-243	178.4
Lutjanus malabaricus	Saddle-tail snapper*	347	0.09	37.0	61-258	123.3
Lethrinus laticaudis	Grass emperor*	85	0.02	29.6	114-322	217.5
Lutjanus carponotatus	Stripey snapper*	65	0.02	16.7	133-234	184.3
Lutjanus russelli	Moses perch*	43	0.01	6.5	119-311	193.1
Epinephelus sexfasciatus	Six-banded rockcod	31	0.01	5.6	108-226	165.6
Lethrinus hutchinsi	Blue-spotted emperor*	19	<0.01	3.7	20-217	131.8
Scomberomorus queenslandicus	Queensland school mackerel	18	<0.01	4.6	228-351	291.7
Caranx bucculentus	Blue-spotted trevally	16	<0.01	1.9	151-195	175.9
Lutjanus vitta	Tropical snapper*	15	<0.01	6.5	111-219	165.8
Lutjanus erythropterus	Crimson snapper*	14	<0.01	8.3	54-216	82.8
Gnathanodon speciosus	Golden trevally*	13	<0.01	4.6	81-164	126.2
Scomberomorus semifasciatus	Grey mackerel	8	<0.01	0.9	271-353	321.7
Lutjanus sebae	Red emperor*	6	<0.01	5.6	61-126	98.2
Carcharinus sp.	Blacktip reef shark	4	<0.01	3.7	700-900	817.7
Epinephelus multinotatus	Rankin's cod*	4	<0.01	2.8	130-226	162.5
Rhynchobatus djidensis	White-spotted shovelnose ray	3	<0.01	2.8	825-950	895.0
Acanthopagrus latus	Yellowfin bream*	2	<0.01	0.9	165-177	171.0
Pagrus auratus	Pink snapper*	2	<0.01	0.9	136-145	140.5
Lethrinus rubrioperculatus	Spotcheek emperor	1	<0.01	0.9	170	-
Protonibea diacanthus	Black jewfish	1	<0.01	0.9	782	-
Total		2774	0.64		20-900	238.7
Total of all fish		396725				

4.3.2 Size composition of by-catch fish species in the Exmouth Gulf Prawn Fishery

The range and mean for the fork lengths of each fish species that was caught as by-catch by the prawn trawlers and is fished commercially and/or recreationally are shown in Table 4.3.1. The length-frequency distributions of the six most abundant commercial and/or recreational fish species in the by-catch, including *Lutjanus malabaricus*, *Lethrinus laticaudis* and *Lutjanus carponotatus*, which are particularly important commercial and/or recreational fish species, are shown in Figs 4.3.1 and 4.3.2. These data demonstrate that the maximum fork lengths of. *L. laticaudis*, *L. malabaricus* and *L. russelli* were well below those recorded in Carpenter & Allen (1989) and Allen (1985), and that those for *L. genivittatus*, *P. multiradiatus* and *L. carponotatus*, approached those recorded in these references. A large percentage (87.2 %) of the catch of *L. laticaudis*, lay below the minimum legal length for that species.

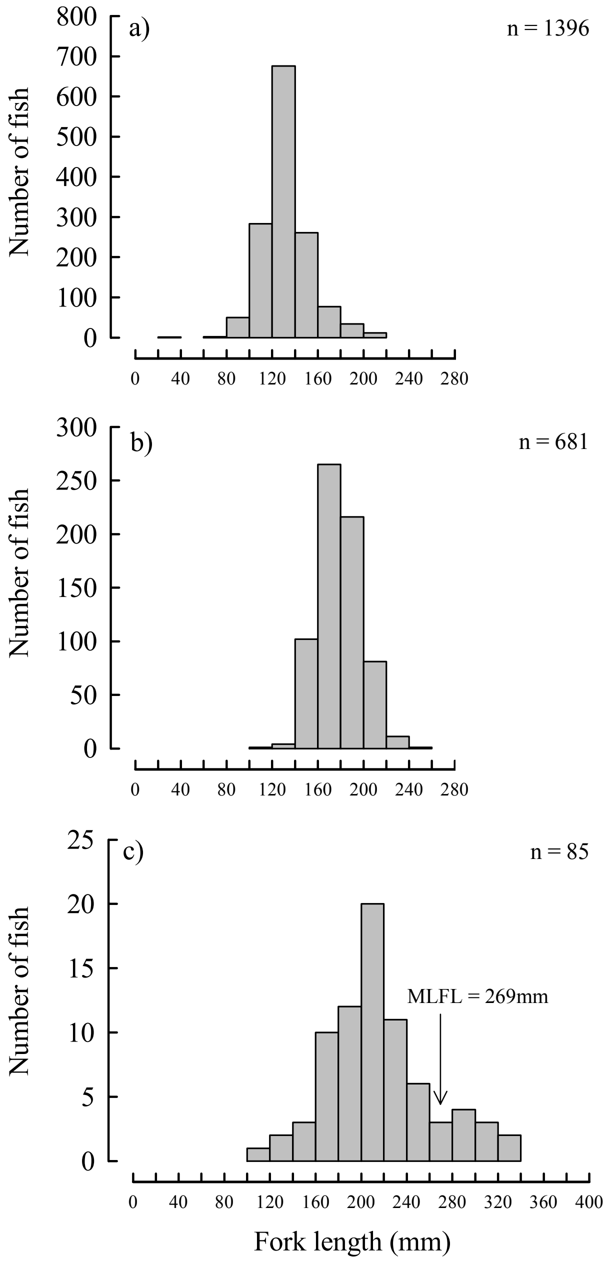

Figure 4.3.1 Length-frequency histograms for a) *Lethrinus genivittatus*, b) *Polydactylus multiradiatus* and c) *Lethrinus laticaudis* obtained in by-catch samples from the Exmouth Gulf prawn trawl fishery.

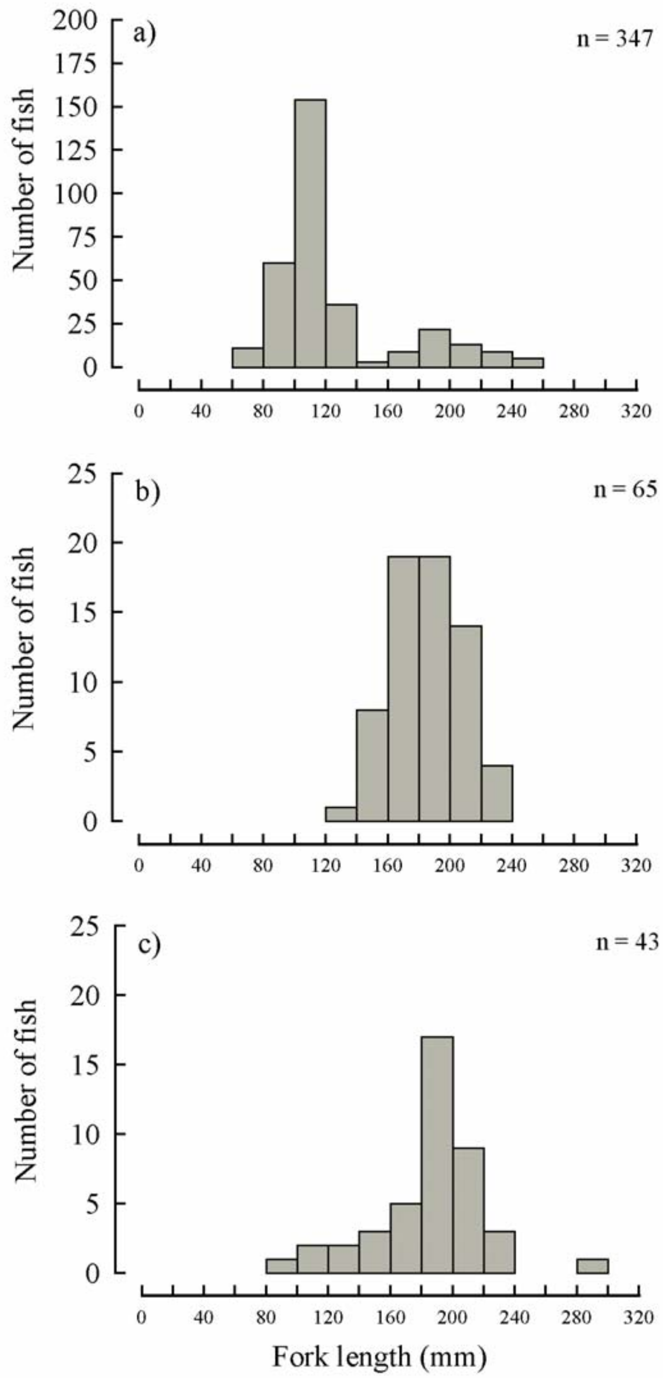

Figure 4.3.2 Length-frequency histograms for a) *Lutjanus malabaricus*, b) *Lutjanus carponotatus* and c) *Lutjanus russelli* obtained in by-catch samples from the Exmouth Gulf prawn trawl fishery.

Benefits and adoption

The outcomes from this project will assist in the development of sustainable management plans for the inshore fishery resources of both the Pilbara and Kimberley region. The beneficiaries of this information are primarily commercial and recreational fishers, related support industries and natural resource managers in Western Australia. The direct benefit to fishers will ultimately be the sustainability of the inshore fishery area.

Another major beneficiary of this project are the environmental managers of the nearshore marine environment of north-western Australia. This project has identified nursery habitats for species of commercial and recreational fishing significance. This information provides a basis for decisions by the community on issues such as minimising the impacts of coastal developments and the protection of important mangrove-creek ecosystems. In addition, it provides a basis for the future protection of fish habitat areas including those critical nursery habitats of species of commercial and recreational fishing significance across north-western Australia.

Further Development

The project has synthesised the available data from commercial, recreational and charter boat fisheries with baseline survey data throughout the region. In order to build on the outcomes of this project we have identified a number of priority research areas for this nearshore zone. These include:

1. Estimation of biological parameters of key species for fisheries management

There is a need to obtain detailed information on crucial aspects of the biology of key target species in order to rationalise appropriate management plans for conserving these species.

The collection of size and age at maturity data and other biological attributes for these key species such as longevity, growth and reproduction are all-important factors for underpinning legal minimum length and bag limit recommendations. The provision of this information would provide strategically valuable data that is needed to underpin the current size and bag limit review process along the coast of north-western Australia.

The recreational, commercial and aboriginal fisheries and the charter boat and “fishing safari” operations collectively generate seafood income, jobs and tourism that are of vital importance to the economies of the small and isolated communities of the region.

Key species in order of priority for research purposes have been divided into two broad areas; (i) reef associated fishes; and (ii) open shore and/or mangrove-creek associated fishes. It should be noted that there is some overlap among groups, and that species are listed in one group only, although they may have a juvenile or adult phase in another category.

(i) Reef associated fishes in order of research priority (top ten only);

- Stripey seaperch (*Lutjanus carponotatus*)
- Blue-lined emperor (*Lethrinus laticaudis*)
- Bar-cheeked coral trout (*Plectropomus maculatus*)
- Golden snapper or fingermark (*Lutjanus johnii*)
- Moses perch (*Lutjanus russelli*)
- Chinaman fish (*Symphorus nematophorus*)
- Spangled emperor (*Lethrinus nebulosus*)
- Blue-spot emperor (*Lethrinus hutchinsi*)

- Blackspot tuskfish (*Choerodon shoenleinii*)
- Giant trevally (*Caranx ignobilis*)

(ii) Open shore and mangrove-creek associated fishes in order of research priority (top ten only);

- Giant threadfin salmon (*Polydactylus macrochir*)
- Bluenose threadfin salmon (*Eleutheronema tetradactylum*)
- Estuary cod (*Epinephelus coioides*)
- Malabar grouper (*Epinephelus malabaricus*)
- Mangrove jack (*Lutjanus argentimaculatus*)
- Black jewfish (*Protonibea diacanthus*)
- Tripletail (*Lobotes surinamiensis*)
- Barramundi (*Lates calcarifer*)
- Western yellowfin bream (*Acanthopagrus latus*)
- Big-eye trevally (*Caranx sexfasciatus*)

2. Evaluation and assessment of recreational and aboriginal netting in the Pilbara/Kimberley bioregion of north-western Australia

The Pilbara/Kimberley region of Western Australia has recently been re-opened to recreational haul netting. The decision was made following discussions with aboriginal communities in the region, many of which were significantly disadvantaged by the ban, since haul netting was widely used as the primary method of catching food for themselves and their families. In addition, haul netting is popular amongst the non-indigenous community in the region, both to provide a source of food and as a recreational pastime. The reversal of the ban has once again fuelled conflict between the divergent user groups of the inshore fisheries resources in this region. There is thus an urgent need to further explore the issues and impacts surrounding the netting for fish so that the integrated management of fisheries in the Pilbara/Kimberley will be successful.

Since many aboriginal people in this region use haul nets as a means to catch their food and the 2003 Aboriginal Fishing Strategy recommends that aboriginal fishers be exempt from bag and size limits while fishing within aboriginal fishing zone 1 (La Grange Bay north to Wyndham);

- There is a need to determine the composition, size range and quantity of fish caught to ensure, not only effective integrated management of the resource, but the sustainability of an important food resource for aboriginal people.
- Evaluation of the selectivity of the mesh sizes used by each of the user groups and assessment of their impacts across sectors and their effectiveness in targeting specific species or species groups.
- Assessment of the by-catch component of netting activities and its impact on biodiversity and conservation values within the region, particularly in relation to protected and/or vulnerable species.

3. Determination of the genetic stock structure of key species of commercial and recreational fishing significance throughout north-western Australia

The assessment of genetic stock structure and the amount of gene flow and linkage among locations are important considerations both for the development of suitable management plans, the appropriate spatial scale for fisheries management and for assessments of the resource status of key species of recreational or commercial fishing significance. This research area represents a significant gap in our current knowledge base.

4. Refinement of commercial and recreational data collection programs in the Pilbara/Kimberley bioregion of north-western Australia

The development of suitable identification guides for both commercial and recreational fishers that will facilitate more detailed compilations of the recreational and commercial catch data and prevent the need for the amalgamation of data into similar species groups for reporting purposes. This has a flow on benefit in proving more accurate data for stock assessment purposes.

Planned Outcomes

The principal outcome that this project has delivered is a major contribution towards our understanding of the spatial and temporal distribution and abundance of the nearshore fish fauna of north-western Australia and the level of exploitation of those species of commercial and recreational fishing significance. The information provided by this work forms the basis for the ecologically sustainable development of the nearshore demersal fish resources of north-western Australia.

A number of key outputs have specifically contributed to the principal outcome described above. The key outputs are:

- Knowledge of the level of the commercial, recreational and charter vessel catch.
- A detailed knowledge of the species composition and relative abundance of the inshore demersal finfish resource from the shoreline outward to a depth of 30 metres along the inner-continental shelf in north-western Australia.
- An understanding of the nursery areas of fish species of commercial and recreational significance in the Pilbara/Kimberley bioregion.
- This work provides a detailed reference work for future marine planning in north-western Australia. Moreover, this work provides a baseline for any future research programs along the inner-continental shelf in north-western Australia.
- This project has clearly identified the key species of both commercial and recreational fishing significance in the nearshore sector for which we require a detailed biological understanding.
- This project provides fishery managers with the information required to develop suitable management plans for the sustainable exploitation of the demersal fish resources shared by both recreational and commercial fishers in the Pilbara/Kimberley bioregion.
- This project has collected baseline information on the fishery resources in some of the areas nominated as future marine reserve sites. Thus, it is now possible to assess the likely impacts on commercial and recreational fishers should access to these areas become restricted.
- Extensive collaboration and personal contact between research staff and commercial fishers, recreational fishers and related interest groups during the project has directly contributed to the success of the project. These cross-sectoral relationships form the basis for effective future collaborations that are required to ensure effective project outcomes in any future work.

Conclusions

The catches of the main fish species of commercial, recreational and charter boat fishers along the Pilbara and Kimberley coasts have been determined by analysing the Department of Fisheries (Western Australia) Catch and Effort Database System (CAES), the results of a recreational creel survey and the statutory monthly reports of catch and effort by charter boat operators. The combined weight of finfish caught by nearshore and inshore commercial fisheries and as a by-product of the prawn trawl fisheries in 2002 was approximately 590 tonnes. The reported recreational fishing catch between Onslow and Broome in the 12-month period from 1999-2000 was estimated at approximately 320 tonnes of fish. The 111 licensed charter boat operators undertook 3628 tours in 2002, during which they caught 53 tonnes of fish. Thus, the total weight of fish caught in 2002 across all three fishing sectors is likely to have approached 1000 tonnes. In addition, the species targeted by commercial, recreational and charter boat fishers overlap markedly and thus there is direct competition by these sectors for the shared inshore demersal fishery resources.

Sampling by gill net, seine net and the ichthyocide rotenone in three separate locations (Cape Keraudren, Eighty Mile Beach and Port Smith) demonstrated that several fish species are abundant in the nearshore, shallow waters, including intertidal pools, along the Pilbara and Kimberley coasts. Fifty three of the 170 species caught in these nearshore, shallow waters are fished commercially and recreationally and a further 17 species are fished solely by recreational fishers. Species such as *Polydactylus macrochir, Eleutheronema tetradactylum*, *Carcharinus cautus* and *Rhizoprionodon taylori* complete their life cycles in nearshore shallow waters, *i.e* are residents. Other species, such as *Epinephelus coioides, Epinephelus malabaricus, Lutjanus russelli, Lutjanus argentimaculatus, Negaprion acutidens* and *Pristis zijsron*, move offshore as they approach adulthood. Some species are found predominantly over bare sand, *e.g. P. macrochir, E. tetradactylum, P. zijsron* and *Sillago analis*, while others occupy mainly mangroves, *e.g. Lutjanus argentimaculatus*, *Liza macrolepis* and *C. cautus*. Intertidal pools constitute a particularly important habitat for the juveniles of *L. russelli*, *Acanthopagrus latus* and *E. coioides*.

The compositions of the fish faunas at Cape Keraudren, Eighty Mile Beach and Port Smith were significantly different, reflecting *inter alia* differences in latitude and the extent of exposure to tidal action and level of turbidity. The compositions of the fish faunas in each location differed between the wet and dry times of the year. This was particularly the case at Eighty Mile Beach, where there was a large immigration of mature *Arius proximus* and *Arius mastersi* in the wet season.

Sampling over reefs using fish traps and over soft substrates using an otter trawl net in both shallow (*ca* 15 m) and deeper inshore waters (*ca* 22 m) at seven locations yielded data on the species composition and relative abundances of the main commercial and recreational fish species in these waters along the Pilbara and Kimberley coasts. A total of 133 fish species were caught over reefs and 279 species over soft substrates, of which 53 and 9% were of commercial and/or recreational importance. The most abundant commercial and/or recreational fish species over reefs were *Lethrinus hutchinsi*, *Lutjanus carponotatus*, *Lethrinus laticaudis*, *Gnathanodon speciosus*, *Lutjanus bitaeniatus*, *E. coioides* and *Lutjanus johnii*, which, during the day, collectively comprised *ca* 75% of the total catch. In contrast, the most abundant commercial and/or recreational fish species over soft substrates, *Lethrinus genivittatus*, *Caranx bucculentus*, *Upeneus sulphureus*, *Upeneus asymmetricus*, *Choerodon cephalotes* and *Nemipterus furcosus*, collectively contributed only *ca* 11% to the total catch. The most abundant fish species in the trawl catches were *Leiognathus splendens* (11.4%), *Selaroides leptolepis* (10.4%), *Pristotis obtusirostris* (7.1%) and *Terapon theraps* (7.1%).

Species composition was strongly influenced by latitudinal position, with, for example, species such as *L. johnii* and *L. bitaeniatus* being far more abundant over reefs in the northern locations, whereas the reverse was the case for species such as *L. hutchinsi*, *Lethrinus atkinsoni* and *Abalistes stellaris*. Species such as *L. hutchinsi* and *Lutjanus lemniscatus* were abundant in both shallow and deeper waters, whereas *L. laticaudis* and *G. speciosus* were relatively more numerous in shallow water and *Siganus fuscescens* and *L. bitaeniatus* are more abundant in deeper water.

Species composition in the wet and dry periods differed markedly, with, for example at Cape Voltaire, species such as *L. bitaeniatus* being more common during the wet, whereas the reverse was true for *L. laticaudis* and *L. johnii*. The numbers of species and numbers of individuals caught in traps over reefs were both greater during the day than night, reflecting greater feeding activity by particularly lethrinid species. In the catches from over reefs, most *L. hutchinsi* and *Lutjanus sebae* were < the MLL, whereas most *L. laticaudis* and *Lethrinus nebulosus* were > the MLL and considerable numbers of *Plectropomus maculatus* were caught both above and below the MLL.

Inshore demersal fish stocks in north-western Australia are facing increased exploitation by recreational fishers, who are thus in direct competition with commercial and charter boat fishers. Thus, this inshore demersal finfish resource will require careful management both to ensure its sustainability and to avoid conflict among the competing fishing sectors. The baseline information provided on the nearshore fishery resources of north-western Australia by the results of the present study will be invaluable for developing fisheries management plans for these resources and for assessing the impact of any proposed access restrictions that may be imposed in areas nominated as future Marine Parks and Reserves.

The tropical inshore fish species requiring future detailed stock status advice for fisheries management have been identified by this project. Furthermore, resource managers should note that only 0.6% of the fish by-catch of the Exmouth Gulf prawn fishery comprised commercial and/or recreational fish species.

All of the objectives of this project have been met by documenting the following; the overall catch of the key commercial, recreational and charter boat fish species; the species composition and relative abundance of the inshore demersal finfish resource from the shoreline outward to a depth of 30 m along the inner continental shelf in north-western Australia; and the nursery areas of the major commercial and recreational fish species in the Pilbara and Kimberley regions.

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Appendix 1: Intellectual Property

Nil

Appendix 2: Staff

Dr. S. Newman

Dr. G. Young

Prof. I. Potter

Mr. M. Travers

Mr. M. Pember

Mr. C. Skepper

Ms. P. Williamson