The effects of net fishing: addressing biodiversity and bycatch issues in Queensland inshore waters

by

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OBJECTIVES

1. To establish proportions of target catch and bycatch caught in inshore net fisheries along the Queensland east-coast and the Gulf of Carpentaria.
2. To characterise the bycatch component of net fisheries in terms of species composition, seasonal abundance, habitat type and mesh size.
3. To determine the fate of fish discarded from net catches.
4. To establish the effects of net fishing on biodiversity through intensive comparative studies of areas closed and open to commercial net fishing
5. To provide management advice on possible sustainability and biodiversity indicators and on changes in netting practices needed to reduce impacts on bycatch species and biodiversity.

NON TECHNICAL SUMMARY

Outcomes Achieved
Inshore gill netting was shown to have low bycatch rates with high proportions of the fish caught being marketed. This has allowed a greater understanding of the inshore commercial net fisheries of Queensland and their impacts on a range of fish communities. This information should allow fisheries managers to more confidently assess the impacts of commercial gill netting when considering the sustainability of these fisheries.

Four methods of gathering information on the effects of net fishing were employed to determine the possible impacts of net fishing in estuarine systems. These were:

1. a voluntary logbook filled in by commercial fishers recording bycatch and retained marketed catch;
2. an observer program that was used to extend and validate returns from the voluntary logbooks;
3. fate trials for determining short term mortality of discarded net-caught fish; and
4. a fishery independent study looking for detectable differences between fish communities in rivers that are open to commercial net fishing and those in rivers that are closed to commercial net fishing.

Seven of Queensland’s inshore net fisheries were examined. These included the southern sea mullet, whiting and small mackerel fisheries, the northern east-coast barramundi and mixed estuarine fisheries, and the Gulf of Carpentaria barramundi and mixed estuarine fisheries. Logbook and observer data were in close agreement indicating that the catch information returned by fishers participating in the voluntary logbook program was reliable.Bycatch was low in these net fisheries relative to other commercial fisheries. Bycatch, as a percentage of the total number of fish caught, was < 20 % for the fisheries examined except the whiting fishery where it was 28% of the total catch. Bycatch consisted of a multitude of species with abundances generally dominated by two or three bycatch species. Catches of undersized regulated fish were low with < 6 % of the total catch in all fisheries being individuals smaller than the legal length.

Fate trials were conducted on four species of fish commonly caught and discarded from southern whiting net fisheries. These included undersized yellowfin bream *Acanthopagrus australis* (< 230 mm TL), summer whiting *Sillago ciliata* (< 230 mm TL), dusky flathead *Platycephalus fuscus* (< 300 mm TL) and the silverbiddy, *Gerres oyeana*. These fish were caught in commercial whiting net operations and placed in cages for a period of three days. No bream died (n=48) during this experiment. Summer whiting (n = 178, mortalities = 12% ± 5%) and flathead (n = 58, 19% ± 10%) showed higher mortalities with silverbiddies having the highest mortality rates (n = 197, 67% ± 4%) after three days. Observations on the release condition of fish from within the tropical net fisheries indicates that some fish species have high mortalities before discarding while others are much more hardy to net capture.

Fishery independent sampling was carried out on the tropical Queensland east coast between Bowen and Cairns in three pairs of rivers. Each pair consisted of a river open to commercial gill netting and a similar system closed to commercial netting. Data were collected from two sites within each river (upstream and downstream) every second month from March 1998 to March 2000. Univariate analysis of the fishery independent data indicated that there were a small number of significant effects of net fishing on species that are commonly harvested. Catch rates of barramundi *Lates calcarifer*, queenfish *Scomberoides commersonianus*, estuary whalers *Carcharhinus leucas* and blue threadfin *Eleuthronema tetradactylum*, in 152 mm mesh nets indicated significantly decreased abundances in rivers open to net fishing. However, these patterns were confounded by the regional and seasonal factors considered in the analysis. Conversely, no detectable differences between open and closed rivers could be found for fish species caught in 51 mm mesh size and multipanel (19, 25 and 32 mm) mesh size nets. Seasonal factors had the greatest influence on the numbers of small fish caught.

Multivariate analysis showed no detectable differences between rivers open and closed to commercial fishing in the overall community structure. This was consistent for the following data sets: 102 mm mesh net catch data , 51 mm mesh net catch data and the multi-panel net catch data. There were significant regional effects on the species of fish likely to be caught. The 152 mm mesh net catch data showed significant differences between the community structures of the rivers open and those closed to commercial netting and among regions. The significant fishing effect with this mesh was expected because 152 mm is the minimum mesh size allowed for use by the commercial net fishery in Queensland's east coast rivers and was confined to differences in the abundances of targeted species in this fishery (ie barramundi, blue threadfin and queenfish).

Gill nets are highly selective in their ability to capture targeted species. Damage to physical environments is minimal as nets are either fished actively, being hauled across the substratum by hand, or set via anchors to passively fish a fixed position on the sea floor. Marketable catch from within these gill netting operations is high with low discard rates. The discarded component of the catch consists of a large number of species, many of which are discarded alive. These highly selective fisheries were not found to be affecting fish species that were not within the catching range of the nets allowed. Generally, the smaller the mesh size of the gill nets used in a fishery the greater the number of fish that were caught. As not all fish are marketed, particularly small ones, the bycatch component of the catch increased with decreasing mesh size.

KEYWORDS: gill netting, biodiversity, Queensland, fishery, fate, bycatch, estuaries.

2. Background

The resource managers of Australian net fisheries, conservation managers and fisheries biologists have identified a critical need for objective scientific information on the quantity and types of bycatch caught in net fishing operations and its effect on biodiversity in inshore waters. If data were available on the total catch of net fisheries, decisions on fisheries management would be greatly improved. Information on net fisheries bycatch and impacts on biodiversity would be widely applicable in Australia, delivering comprehensive and unbiased inputs into the on-going debate about the effects of inshore net fishing. This project provides essential baseline data for management decisions concerning inshore net fisheries and associated ecosystems along the Queensland east and Gulf of Carpentaria coasts.

Most fish species caught by commercial, recreational and indigenous fishers in Australia are dependent upon an estuarine habitat during part or all of their life cycle (Pollard 1976, Dredge *et al.* 1977, Quinn 1992). Estuarine fishing typically occurs in areas that contain diverse fish faunas and, sometimes, a range of icon species, such as barramundi, dugong and marine reptiles.

Fishing gear is size-selective for target species in some but not all fisheries, especially in multi-species fisheries. Target species, mesh size and fishing area all play an important role in determining the amount of bycatch caught in commercial fisheries (Alverson *et al*. 1994, Gray *et al*. 2000). Bycatch refers to individuals caught that are of no immediate value to the fisher and are returned to the water. Bycatch may include the juveniles of marketable fish as well as non-marketable fish, invertebrates, marine reptiles and marine mammals. High profile species such as sea turtles, dugong, dolphins and crocodiles are occasionally caught in net fishing operations and must be released as they are protected species.

The inshore commercial net fisheries of the Queensland east coast and Gulf of Carpentaria have an estimated wharf side value of $30 million per year (Queensland Fisheries Management Authority, QFMA 1995) with 1029 licences being held (Williams 1997). The principal species taken in these net fisheries are sea mullet (*Mugil cephalus*), whiting (*Sillago* spp.), tailor (*Pomatomus saltatrix*), bream (*Acanthopagrus australis*) and flathead (Platycephalidae) in southern Queensland and barramundi (*Lates calcarifer*), king threadfin (*Polydactylus macrochir*) and blue threadfin (*Eleutheronema tetradactylum*) in northern Queensland. The fresh fish produced from these fisheries is used almost exclusively in domestic markets with mullet roe being the only significant export. The Queensland Fisheries Service, Resource Management Division (formally Queensland Fisheries Management Authority, QFMA) collects logbook information on the part of the catch that is marketed. This compulsory logbook system has no provision for collecting data on bycatch.

The effects of net fishing in Queensland inshore waters and the problems of bycatch and resource allocation are highly contentious issues that are becoming more prominent in debates among concerned sectors of society. In the absence of this information, much of the debate relates to the need for imposition of precautionary management measures to sustain the integrity of the resource. The precautionary principles being advocated usually demand a curtailment of commercial activities and diminished access to fishing grounds.

An assessment of the likely impacts that net fishing operations have on the biodiversity of inshore marine ecosystems has been attempted in this project. This has been done by characterising commercial net catches in terms of species composition, seasonal and relative abundance, habitat, life cycle stages present, the fate of discarded bycatch, and comparisons of areas open and closed to commercial net fishing using fishery independent techniques.

This project commenced in September 1997. Co-incidentally, in response to reported declines of the Queensland east-coast dugong (*Dugong dugong*) population, a series of Dugong Protection Areas were instigated along the east coast during 1997. An unfortunate consequence of this process was the alienation of commercial fishers from management agencies and government collectively. This alienation flowed on to research initiatives, with many inshore commercial net fishers being unwilling to participate in voluntary data-gathering programs. We were successful, in part, in overcoming this impediment by making use of existing networks and research partnerships.

3. Need

There is a critical need for information to guide management decisions about inshore fisheries resources, and to address rising industry, conservation and public concern about the impact of net fishing on the sustainability and biodiversity of ecosystems and habitats associated with the fishery.

Information on the effect of gill net fishing on bycatch and biodiversity in Australia is extremely limited. While some data exist on the marketed catch from gill nets, the quantity and nature of bycatch remains virtually unknown. There is little information on the total catch characteristics of net fisheries, the proportions of species caught, and the proportion of the resource harvested each year. Similarly, little is known about the fate of fish discarded from nets, information that would help to characterise the impact of net fishing on biodiversity.

This project addresses the urgent need for information on: the total catch composition from net fishing, fate of discarded fish bycatch, impact on protected species and impact on biodiversity. Baseline data collected through both fishery-dependent and independent methods can provide a basis for long term monitoring of the fishery and will enhance the interpretation of existing commercial catch records. These data also help meet the requirements of the 'National Strategy for Conservation of Australia's Biological Biodiversity' of:

a) improving the knowledge base of fisheries,
b) improving fisheries management and
c) assessing and minimising the impact of commercial fishery practices on non-target and bycatch species, ecosystems and genetic diversity.

4. Objectives

1. To establish proportions of target catch and bycatch caught in inshore net fisheries along the Queensland east-coast and the Gulf of Carpentaria.

2. To characterise the bycatch component of net fisheries in terms of species composition, seasonal abundance, habitat type and mesh size.

3. To determine the fate of fish discarded from net catches.

4. To establish the effects of net fishing on biodiversity through intensive comparative studies of areas closed and open to commercial net fishing

5. To provide management advice on possible sustainability and biodiversity indicators and on changes in netting practices needed to reduce impacts on bycatch species and biodiversity.

5. Achievement of objectives

Establish proportions of target catch and bycatch caught in inshore net fisheries along the Queensland east coast and the Gulf of Carpentaria.

Information on the proportions of target catch and bycatch were collected for seven inshore net fisheries operating in Queensland waters. The proportion of the total catch, in numbers of fish, represented by the "target" species fluctuated widely between the fisheries (sub-tropical sea mullet 84%, whiting 35%, mackerel 68%, and tropical East Coast (EC) barramundi 39%, EC mixed estuary 64%, Gulf of Carpentaria (GoC) barramundi 36%, GoC threadfin 74%,). The "mixed species" nature of all these fisheries is evident from the high proportion of the catch that is marketed. Recorded levels of bycatch for the sub-tropical gill net fisheries targeting sea mullet (7%), whiting (28%) and mackerel (15%) together with the tropical fisheries targeting EC barramundi (16%), EC mixed estuary (15%), GoC barramundi (13%) and GoC threadfin (13%) were generally low.

Characterise the bycatch component of net fisheries in terms of their species composition, seasonal abundance, habitat type and mesh size.

In subtropical gill net catches, bycatch rates were variable with increased bycatch rates in smaller mesh nets. Generally, two or three species dominated the bycatch. Catch rates of most market and bycatch species increased during winter in the sea mullet and whiting fisheries. The small mackerel fishery is seasonal in operation. The composition of bycatch in the GoC fisheries displayed variability between locations but was largely dominated by catfish (*Arius* spp.) and bony bream (*Nematolosa erebi*). Samples collected throughout the fishing year indicated bycatch rates may fluctuate considerably on the temporal scale. Bycatch composition of the EC fisheries also displayed considerable variability, with mesh size an important factor in determining catch rates of bycatch fish.

Establish the effects of net fishing on biodiversity through intensive comparative studies of areas closed and open to commercial net fishing.

Fishery-independent sampling of rivers open and closed to net fishing was unable to detect any changes in fish biodiversity between open and closed rivers. The study found that net fishing did significantly reduce the abundance of species most commonly targeted for market in these areas (ie. barramundi, blue threadfin and queenfish), however no detectable differences were found due to net fishing on other species. No differences were found to indicate that net fishing had an effect on small fish within these systems. Regional and seasonal differences were evident for many of the marketed species within these systems.

Provide management advice on possible sustainability and biodiversity indicators and on changes in netting practices needed to reduce impacts on bycatch species and biodiversity.

Our study found that net fishing did not impact on fish biodiversity. Providing management advice to reduce the impact of net fishing on bycatch is difficult, because we found the catches of fish other than targeted marketable species were low. Few non-marketable species are caught in large enough numbers to be able to direct a change in practice to eliminate them from the catch. Recommendations on the effect of increases in size limits, particularly for southern estuarine species, are discussed in terms of the need to increase the minimum mesh size in some fisheries to allow undersized regulated fish species to pass through the meshes without causing high mortalities of these fish.

6. Catch Characteristics of Queensland Inshore Net Fisheries

6.1 Introduction

Two methods of gathering information on the catch composition of inshore gill nets were used. These were:

1. a voluntary logbook filled in by commercial fishers and which recorded retained marketed catch and bycatch; and
2. an observer program that was used to extend and validate logbook returns.

Bycatch was defined to be animals caught by nets that were not retained for legal sale or use for some other economic benefit (eg. as bait for crab potting). This included individuals of marketable species above or below the regulated size limits, non-marketable fish species, and protected species. In each of the programs listed above, net caught specimens were assigned to one of two catch categories -

- Retained – any animal retained for sale or for later use as bait (mainly crab pot bait)
- Discarded – any animal released because it was protected under legislation (such as female mud and blue swimmer crabs, grey nurse sharks), was regulated by a minimum or maximum size limit, or was of no marketable value to the fisher.

6.2 Methods for determining catch composition of Queensland inshore fisheries.

6.2.1 <u>Logbook program</u>

Compulsory logbook catch data completed by fishers and returned to the Queensland Fisheries Service, Resource Management Division (formerly Queensland Fisheries Management Authority, QFMA) contain figures for the retained and sold components of the catch only. To determine the quantities and species composition of the non-reported portion of the commercial net catch, standard data sheets were distributed to interested fishers who were asked to complete one entry (one day or night of fishing) per week. The data sheets included the following fields: date, location fished, target species identification, length and mesh size of net(s) fished, the number and/or weight of each species captured and associated fate (kept or released), and the details of any incidental capture of protected species and their condition on release. Fishers were asked to send completed log sheets to the Principal Investigator at Southern Fisheries Centre once per month in return post envelopes that were provided. A reward of a $5 scratch lotto ticket was provided for each monthly return.

The logbook program was focused on areas where project staff were based (Brisbane and Townsville) and targeted seven fisheries: the subtropical mullet, whiting and small mackerel fisheries, the tropical east coast barramundi and “mixed estuary” fisheries, and the Gulf of Carpentaria barramundi and “threadfin” fisheries.

As the logbook program was reliant on the voluntary participation of commercial fishers, structuring the data collection program on the basis of season, location and gears was not possible. All data were obtained opportunistically and were relatively unstructured.

6.2.2 Observer Program

The primary objective of the observer program was to validate the logbook returns with commercial fishers participating in the logbook program and to characterise the catch and bycatch components in detail. Again, because this part of the project was reliant on fishers agreeing to provide access to on-board observations of their fishing methods and catches the sampling regime was opportunistic and unstructured.

For each fishing event observed, all animals captured were identified to species level with numbers and/or weights together with the fate of each individual recorded. Other variables recorded by the observers on site included fishing location, target species identification, fishing practice (set netting, ring netting etc) and gear used (mesh size, net length and soak time). Observers also monitored and recorded the incidental capture of protected species on the fishing grounds.

6.2.3 Data Analysis

Individual species catch rates from the logbook program were used for the analysis of seasonality within the southern sea mullet and whiting fisheries on a per net shot basis. All data were ln(x + c), (where x = catch rate/metre of net, c = lowest non-zero catch rate/2) transformed to allow for the extremely low catch rates for many of the species. Analysis of variance with unbalanced treatment structures (Genstat 5) was used to analyse catch rates from within these fisheries. Bias corrected back transformations were performed using $e^{(x+\text{residual ms}/2)-c}$ x net length used in the fishery to give an average catch/net shot for each species (x = ln transformed mean number of fish/metre of net; c = lowest non-zero catch rate/2).

For analyses of tropical fisheries, observer data was adjusted for fishing procedure (ie. soak time and net length) and used to indicate the susceptibility of particular species to different types of fishing gear in different areas, and to determine which fishing gears and/or methods may need to be considered for modification.

The results from the logbook and observer programs were used to identify candidate species and fish sizes for fate trials (see Section 7).

6.3 Results of Observer and Logbook Programs

6.3.1 Southern Logbook Returns

Logbook information was reported by 9 fishers who returned data for periods of between 1 and 28 months from April 1998 to July 2000. A total of 1 648 net shots targeted at ten species of fish were reported (Table 1). At least 103 species of animal including fish, reptiles, birds, crustaceans and cephalopods were reported as being caught. A total of 369 362 individual animals were reported caught, of which 314 236 (85.1%) were kept for marketing or bait and 55 076 (14.9%) were discarded as bycatch. Targeting of sea mullet, sand whiting and small mackerels constituted 88% of the fishing effort reported, and the features of these fishery catches are examined in more detail in the following sections.

Table 1: Summary of southern voluntary logbook returns by targeted species from April 1998 to July 2000.

Species	Common name	Number of net shots
Mugil cephalus	sea mullet	818
Sillago ciliata	sand whiting	471
Scomberomorus sp.	mackerel	166
Carcharinidae	shark	69
Pomadasys sp.	grunter bream	50
Acanthopagrus australis	yellowfin bream	32
Hemiramphidae	gar	30
Pomatomus saltatrix	tailor	5
Siganus sp.	rabbitfish	5
Platycephalus fuscus	dusky flathead	2

6.3.2 Sea Mullet Fishery in Southern Queensland

The Fishery

The sea mullet (*Mugil cephalus*) gill net fishery in Queensland has about 400 fishers actively catching this species each year (Williams 1997). The majority of the catch is taken in southern Queensland (from Bundaberg to the NSW border) with about 10% of the annual catch caught in waters as far north as Townsville. Monthly production is about 80 t of fresh fish that is sold in local seafood markets. During the autumn and early winter, sea mullet are also sought for their roe as this brings a higher price to fishers (up to $6/kg for roe fish compared with $1 -$2/kg for the fresh fish market). To target fish for the roe market, fishers increase the mesh size of their nets from 75 mm to 87 mm or 102 mm, as the valuable female fish are generally larger than male fish (Virgona *et al.* 1998). Fishers employ active fishing techniques that involve sighting schools of mullet in shallow water. Once the schools are sighted, fishers set their net around the school and almost immediately begin to hand haul the net back into the boat. Numerous spatial and temporal closures exist in this fishery (Queensland Fisheries Act 1995) with input restrictions on the length of net used, limited mesh sizes and output restrictions in the form of minimum legal sizes on many of the species caught (Table 2).

6.3.2.1 Logbook Program in the Sea Mullet Fishery

Total Catch Composition

Voluntary logbook data was returned by 7 fishers targeting sea mullet with catches from 818 net shots recorded. At least 68 species were reported, including 5 species of crab, at least 58 species of fish, at least 2 species of reptile, 1 species of bird and 2 species of cephalopod (Table 2). Twenty-two species comprising 93.1% of the total catch were retained for market or bait to be used in other fishing operations. A bycatch rate of 6.9% was reported. The target species, sea mullet *Mugil cephalus*, dominated the catches representing 84% of the total catch. Other marketable species contributed a further 8.4% with sand whiting *Sillago ciliata* (2.2%), yellowfin bream *Acanthopagrus australis* (1.8%), dusky flathead *Platycephalus fuscus* (1.3%) and tailor *Pomatomus saltatrix* (1.0%) being the only species that contributed more than 1% of the total catch (Figure 1a).

Reported discards from the sea mullet fishery catch were dominated by undersized yellowfin bream (< 23cm total length,TL) representing 2.0% of the total catch, and undersized (< 150 mm carapace width, CW) or female mud crabs *Scylla serrata* (1.2%). Twenty species of regulated fish were discarded comprising 1.5% of the total catch (Table 2). The remaining 2.3% of the catch was made up of 31 species of fish some of which were occasionally marketed. A total of 152 marine turtles were reported in the vicinity of commercial fishers while carrying out their fishing activities. All turtles were reported to have been released alive with a number reported to have been feeding on fish caught in the net during the fishing operation. Three sea snakes, *Hydrophis* sp. (condition at release unknown) and 2 shags, *Phalacrocorax* sp. (released alive) were also reported.

Regulated Species Reported as Bycatch from Sea Mullet Logbook Program

Undersized yellowfin bream (28.6% of bycatch component in Figure 1d) were the most abundant species within the bycatch component. The discarding rate of this species was relatively high with 53% of all yellowfin bream caught being less than the legal size of 230 mm TL (Table 2). Mud crabs (17.3% of bycatch component) and blue swimmer crabs *Portunus pelagicus* (8.4% of bycatch component) were discarded at a high rate (Table 2). Ninety-eight percent of the total number of mud and blue swimmer crabs caught were discarded because they were either males less than minimum legal size or were female. Undersize sea mullet (< 30 cm TL), at 7.7% of the bycatch, was the only other regulated species that contributed more than 1% to the total bycatch. Undersized dusky flathead (1.0%), sand whiting (0.7%), and tailor (0.3%) were discarded at low rates (Figure 1b).

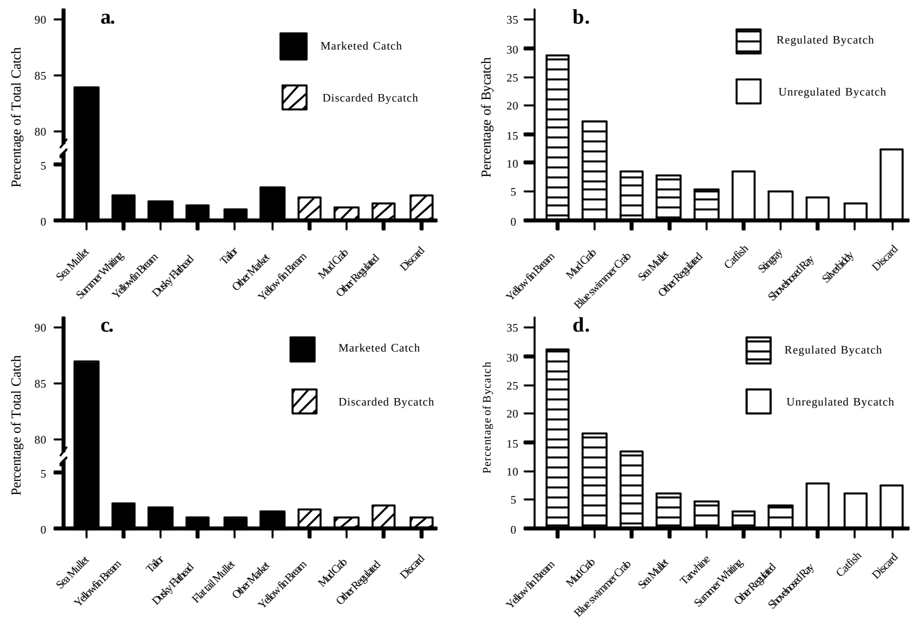

Figure 1: Sea mullet fishery catch compositions for (**a**) voluntary logbook catch, (**b**) bycatch composition from logbook returns, (**c**) observed catch and (**d**) bycatch compositon from observer data. Note differences and breaks in scales.

Unregulated Species Reported as Bycatch from Sea Mullet Logbook Program

Catfish, *Arius* spp, although not marketed for food, were occasionally kept for crab pot bait, and were discarded at a rate of 8.4% of the total bycatch (Figure 1d). All other species that were not marketed individually comprised less than 1% of the total catch.

After catfish, dasyatidid stingrays (5% of bycatch component) and shovel-nosed rays *Rhinobatus batillum* (4.1% of bycatch component) were the most abundant bycatch in sea mullet net catches. The remaining 12.3% of the bycatch comprised 25 species of fish and 3 crab species. Of these, 18 individual species were represented by less than 1% of the total bycatch (Figure 1b).

6.3.2.2 Observer Program in the Sea Mullet Fishery

Total Catch Composition

The fishing activities of 5 commercial fishers were observed in the program resulting in detailed catch records from 79 net shots. A total of 15 146 individual animals from at least 48 species were observed. They included 43 fish species, 1 cephalopod, three crab species and marine turtles (Table 2). Twenty-eight species comprising 94.4% of the total catch were retained for market. Sea mullet dominated, comprising 86.9% of the total catch. Other species that contributed to the marketable catch were yellowfin bream (2.2%), tailor (1.8%), dusky flathead (1.1%) and flat tailed mullet *Liza subviridis* (0.9%). The remaining 23 marketed species comprised 1.6% of the total catch, all of which individually represented < 0.5% of the total catch (Figure 1c). Discarded bycatch was low, representing 5.6% of the total catch. Fourteen species of regulated bycatch were discarded with undersized yellowfin bream (1.7%) and undersized male (< 150 mm carapace width) and female mud crabs (0.9%) dominant. The remaining 12 species contributed a further 2% of the total catch. Discarded fish of no economic value comprised 0.9% of the total catch. A total of 18 marine turtles were observed to be encircled by nets. All were released alive. Marine turtles caught in these actively fished nets were usually not entangled in the meshes but were encircled by the net and could not swim away from the area. This brief entrapment appears to have little adverse effect on the turtles which freely feed on fish caught in the net while they are encircled (Ian Halliday, personal observation).

Regulated Species Observed in Sea Mullet Bycatch

Undersized yellowfin bream (representing 31.3% of the observed bycatch, Figure 1b) were the most numerous species within the bycatch component. The discarding rate of this species was relatively high with 44% of all bream caught (n = 596) being undersized. Mud crabs (16.4% of the bycatch component) and blue swimmer crabs (13.5% of the bycatch component) were discarded at a high rate (97%) because individuals were either males less than the minimum legal size (< 150 mm carapace width) or were female. Sea mullet (5.9%), tarwhine *Rhabdosargus sarba* (4.6%), and sand whiting *Sillago ciliata* (3.1%) were the other main species contributing to the bycatch of regulated fish species (Figure 1d). The 7.8% attributed to other regulated bycatch comprised 11 species of fish all of which were represented by < 20 individuals each.

Unregulated Species Observed in Sea Mullet Bycatch

Shovelnosed rays *Rhinobatus batillum* (5.9% of bycatch component) and catfish *Arius* spp. (3.9% of bycatch component) were the most commonly caught unregulated species; the majority of individuals were released alive. The remaining 7.6% of the bycatch was comprised of 19 species of fish. Fifteen of these species each represented less than 1% of the discarded bycatch.

Table 2: Sea mullet fishery: species composition and discarding rates from 818 net shots reported in the voluntary logbook program, and from 79 net shots in the observer program on the sub-tropical east coast of Queensland. TL = total length, CW = carapace width, NR = Non-regulated, P = Protected species

Common Name	Species Name	Size Limit	Logbook Data (818 net shots)			Observer Data (79 net shots)		
		(cm)	Retained	Discard	% Discard	Retained	Discard	% Discard
Sea Mullet	*Mugil cephalus*	> 30 TL	135352	851	0.6	13144	50	0.4
Sand Whiting	*Sillago ciliata*	> 23 TL	3477	77	2.2	60	26	30.2
Yellowfin Bream	*Acanthopagrus australis*	> 23 TL	2835	3177	52.8	332	264	44.3
Dusky Flathead	*Platycephalus fuscus*	> 30 TL	2141	106	4.7	160	12	7.0
Tailor	*Pomatomus saltatrix*	>30 TL	1593	35	2.2	272	13	4.6
Flat tailed Mullet	*Liza subviridis*	NR	1340	0		137	0	0
Dart	*Trachinotus russelli*	NR	965	17	1.7	0	1	100
Catfish	*Arius* spp.	NR	573	937	62.1	0	33	100
Bony Bream	*Nematolosa come*	NR	434	170	28.2	0	0	
Striped Scat	*Selenotoca multifasciata*	NR	326	193	37.2	14	6	30.0
Trevally	Carangidae	NR	141	22	13.5	0	3	100
Grunter	*Pomadasys* sp.	>35 TL	123	66	35.0	44	4	8.3
Longtom	*Tylosurus* sp.	NR	175	78	30.8	0	3	100
Drummer	*Kyphosus* sp.	NR	86	0	0	0	0	
King Threadfin	*Polydactylus macrochir*	> 40 TL	46	1	2.1	0	0	
Mud Crab	*Scylla serrata*	> 15 CW	44	1916	97.8	5	138	96.5
Ludderick	*Girella tricuspidata*	> 23 TL	37	1	2.6	2	0	0
Squid	*Sepioteuthis* sp.	NR	37	1	2.7	3	0	0
Tiger Mullet	*Liza argentea*	NR	37	0		1	0	0
Mangrove Jack	*Lutjanus argentimaculatus*	> 35 TL	35	89	71.8	4	14	77.8
Diamond Scale Mullet	*Liza vaigiensis*	NR	32	6	15.7	0	1	100
Shark	*Carcharhinus* sp.	NR	26	6	18.6	0	0	
Giant Herring	*Elops* sp.	NR	25	0	0	0	0	
Tarwhine	*Rhabdosargus sarba*	> 23 TL	21	45	68.3	1	39	97.5
Blue swimmer crab	*Portunus pelagicus*	> 15 CW	20	936	97.9	4	114	96.6
Wolf Herring	*Chirocentrus dorab*	NR	20	0	0	0	0	
Rabbitfish	*Siganus* sp.	NR	19	104	84.6	0	1	100
Jew	Sciaenidae	> 45 TL	18	34	65.4	1	1	50.0
Blue Threadfin	*Eleutheronema tetradactylus*	> 40 TL	18	17	48.6	0	0	
Queenfish	*Scomberoides* sp.	NR	18	0	0	0	0	
Estuary Cod	*Epinephelis* sp.	> 35 <120 TL	9	42	82.4	1	13	92.9
Blubberlip	*Plectorhinchus* sp.	NR	9	13	59.1	1	3	75.0
Tarpon	*Megalops cyprinoides*	NR	7	32	82.1	0	3	100
Shovelnosed Ray	*Rhinobatus batillum*	NR	4	456	99.1	4	50	92.6
Bonefish	*Albula neoguinaica*	NR	4	58	93.6	0	0	
Milkfish	*Chanos chanos*	NR	4	0	0	0	0	
Black Bream	*Acanthopagrus berda*	> 23 TL	2	0		3	0	0
Octopus	*Octopus*	NR	2	0	0	0	0	
Black Sole	*Achlyopa nigra*	NR	1	182	99.5	0	11	100
Moses Perch	*Lutjanus russelli*	>	1	40	97.6	0	1	100
Tripletail	*Lobotes surinamensis*	NR	1	0	0	0	0	
Parrotfish	*Scaridae*	NR	1	0	0	0	0	
Yellowtail Kingfish	*Seriola lalandi*	> 50 TL	1	0	0	0	0	
Golden-Lined Whiting	*Sillago analis*	> 23 TL	0	0		3	3	50.0
Bar-tailed Flathead	*Platycephalus endrachtensis*	> 30 TL	0	0		2	0	0
Tongue sole	*Pseudorhombus* sp.	NR	0	0		2	0	0
Trumpter Whiting	*Sillago maculata*	NR	0	0		1	1	50.0
Soapy Jew	*Nibia soldado*	> 45 TL	0	0		1	1	50.0
Blue-Tailed Mullet	*Valamugil seheli*	NR	0	0		1	0	0
Stingray	Dasyatididae	NR	0	558	100	0	11	100
Silverbiddy	*Gerres oyeana*	NR	0	312	100	2	2	50.0
Love Crab	*Thalamita crenata*	NR	0	202	100	0	1	
Ponyfish	*Leiognathus* sp.	NR	0	87	100	0	0	
Moon Crab	Unidentified	NR	0	35	100	0	0	
Diamondfish	*Monodactylus argenteus*	NR	0	32	100	0	4	100
Bulls eye	*Priacanthus* sp.	NR	0	32	100	0	0	
Flicker Mullet	*Mugil georgii*	NR	0	31	100	80	3	3.6
Moonfish	*Mene maculata*	NR	0	27	100	0	0	
Barramundi	*Lates calcarifer*	> 58 <120TL	0	24	100	0	1	100
Rock Crab	Xanthidae	NR	0	15	100	0	0	
Scad	*Decapterus* sp.	NR	0	10	100	0	0	
Stonefish	*Synanceia horrida*	NR	0	7	100	0	0	
Emperor	*Lethrinus* sp.	> 40 TL	0	4	100	0	0	
Striped Seapike	*Sphyraena obtusata*	NR	0	4	100	0	0	
Silver Perch	*Bidyanus bidyanus*	> 30 TL	0	2	100	0	0	
Herring	*Herklotsichthys* sp.	NR	0	2	100	0	0	
Grey mackerel	*Scomberomorus semifasciatus*	> 50 TL	0	1	100	0	2	100
Grass Sweetlip	*Lethrinus fletus*	> 30 TL	0	1	100	0	0	
Conger Eel	*Muraenesox cinereus*	NR	0	1	100	0	0	
Angelfish	*Pomacanthus* sp.	NR	0	1	100	0	0	
Mackerel	*Scomberomorus* sp	> 50 TL	0	1	100	0	0	
Blue-Spotted Stingray	*Dasyatis kuhlii*	NR	0	0		0	6	100
Tripodfish	Triacanthidae	NR	0	0		0	2	100
Golden Trevally	*Gnathanodon speciosus*	NR	0	0		0	1	100
Banded Wobbegong	*Orectolobus ornatus*	NR	0	0		0	1	100
Tongue Sole	*Pseudorhombus arius*	NR	0	0		0	1	100
Turtle	Unidentified	P	0	152	100	0	18	100
Shag	*Phalacrocorax* sp.	P	0	2	100	0	0	
Sea snake	*Hydrophis* sp.	P	0	3	100	0	0	
	Total number of fish		150060	11097		14284	862	
	Percentage of Total Catch		93.1	6.9		93.3	5.7	

6.3.2.3 Seasonality of catch in Sea Mullet Fishery

Returned logbook data on catches within the sea mullet fishery indicated that there were only 5 species that were caught in sufficiently large numbers to allow statistical analysis for seasonal changes in catch rates to be carried out. Of these, three were size regulated marketable fish (sea mullet, yellowfin bream and tailor) while the others (sea mullet, yellowfin bream, blue swimmer crabs and mud crabs) were all discarded because of being under the regulated size or female.

Marketable sea mullet catch rates increase significantly (LSD $P < 0.05$) from spring (160 ± 26 fish/net shot) until autumn (396 ± 42 fish/600 m net shot) (Figure 2a). Catch rates increase as sea mullet form aggregations in estuaries during autumn prior to their winter spawning run (Virgona *et al*. 1998). In conjunction with the increased catch rates of legal sized sea mullet a significantly higher catch rate (LSD $P < 0.05$) of undersized sea mullet occurs during summer and autumn in this fishery (Figure 2d). This increase although significant constitutes a very low catch rate of about 1 fish per shot. During the winter the catches of undersized sea mullet decrease as fishers concentrate effort on the larger spawning run fish by increasing the mesh size used allowing undersized fish to escape.

Catch rates of marketable yellowfin bream (>23cm TL) increased significantly (LSD $P < 0.05$) during winter in the sea mullet fishery. Yellowfin bream form schools during winter with spawning occurring mainly on surf bars from June to August (Pollock 1982). There is little difference in the catch rates for spring, summer and autumn when about 4-5 fish/shot are caught. This catch rate doubles during winter to about 10 fish/shot (Figure 2b). Undersized yellowfin bream discarded as bycatch had significantly increased catch rates (LSD $P < 0.05$) reported during summer. These catch rates are similar to catch rates for marketable yellowfin bream reaching 9.4 ± 2.0 fish/shot (Figure 2e). Changes in mesh size by fishers during winter may effectively decrease the bycatch of undersized yellowfin bream by allowing more to escape through the net meshes while still catching the larger bream.

Tailor catch rates increase significantly (LSD $P < 0.05$) from spring until winter (Figure 2c). These catch rates although significantly higher in winter were still quiet low with the winter catch rate being slightly more than 1 fish/shot. Tailor spawning patterns are similar to sea mullet in that they form large schools and move northward along ocean beaches during their spawning run (Pollock 1984). This schooling allows fishers to sometimes sight and directly target tailor in estuarine areas adjacent to ocean beaches. There are often a few tailor that travel with the mullet schools during this time of year. Increasing the mesh sizes of nets to target sea mullet during autumn and winter may not effectively decrease the catch rates of tailor because of their body morphology and their tendency to bite the net to get through rather than swimming through the mesh. Most of the tailor caught during the observer program were found with net meshes stuck between their teeth, so were “bridled” rather than being gill meshed.

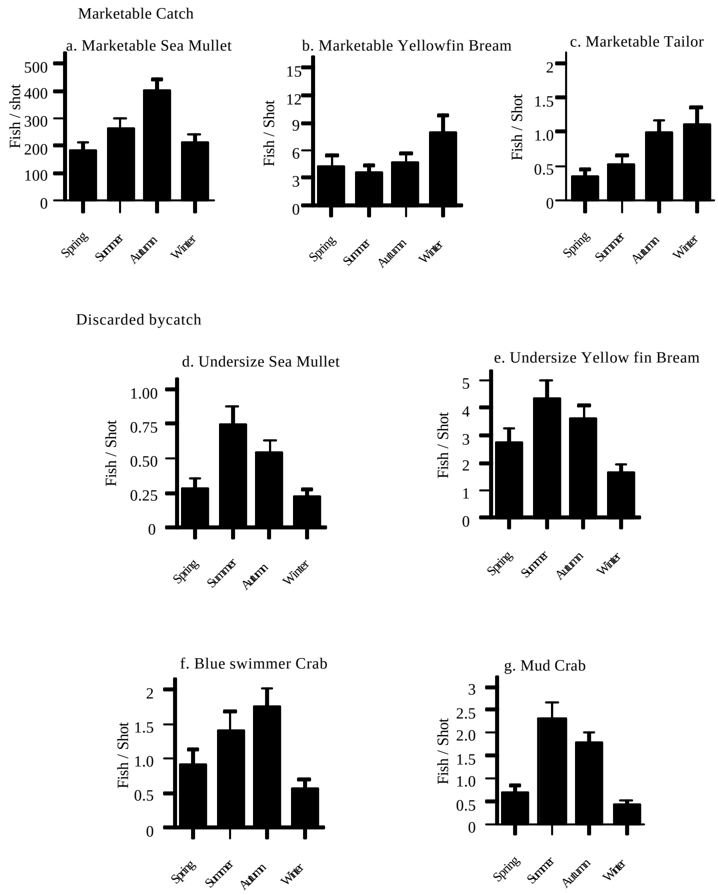

Figure 2**:** Seasonal changes in mean catch rates (± 1 S.E.) for target and bycatch species within the sea mullet fishery. Note the changes in scale for each species.

Undersized male and female blue swimmer crab catch rates were significantly higher (LSD P < 0.05) in autumn (2.2 ± 0.5 crabs /shot) than in winter and spring (0.7 ± 0.2 crabs/shot) (Figure 2f). Undersized male and female mud crabs had significantly higher catch rates reported during summer (5.3 ± 1.1 crabs/shot) with decreased catch rates occurring during winter (1.0 ± 0.2 crabs/shot) (Figure 2g). Blue swimmer and mud crabs are attracted to nets that have fish caught in them and often become entangled by their legs and claws while feeding.

6.3.3 Whiting Fisheries in Southern Queensland

The Whiting Fishery

The whiting fishery in Queensland has about 250 fishers recording catches each year and produces approximately 250 t of product (Williams 1997). Netting operations in the whiting fishery are conducted in two different ways. One involves setting a small mesh net (usually 51 mm mesh and up to 800 m long) along the edge of a bank at the low tide mark when the tide is about half down. The water then drains off the bank bringing the fish down from within the shallows and into the net. The second method is to actively use a small mesh net to form a ring, usually over intertidal or shallow sub-tidal areas. The net is then hand hauled and the fish within the ring captured by meshing.

6.3.3.1 Logbook Program in the Whiting Fishery

Total Catch Composition

Logbook sheets were returned from 7 commercial fishers fishing in the whiting fishery and represented 471 net shots. A total of 149,784 individuals from at least 54 species of animal were captured including at least 47 species of fish, 3 crab species, 2 cephalopods and 2 marine reptiles (sea snake and marine turtle) (Table 3). Thirty-one species were retained for market or as bait comprising 71.9% of the total catch. Summer whiting (55.5%) dominated the marketable catch. Two species, herring *Herklotsichthys koningsbergeri* (2.9%) and silverbiddies *Gerres oyeana* (2.8%), that are sometimes sold or retained as bait by commercial fishers, comprised a further 5.7% of the total catch. Three regulated species, dusky flathead (2.3%), sea mullet (1.9%) and yellowfin bream (1.6%) together with the unregulated species of flicker mullet *Mugil georgii* (1.6%) and flat tailed mullet *Liza subviridis* (1.5%), comprised the majority of the remaining marketed catch. The remaining 22 species retained for market comprised 1.8% of the total catch. Bycatch was reported at 28.1% with silverbiddies (18.5%) and flicker mullet (1.6%) dominating the bycatch (Figure 3a). Although both of these unregulated species are sometimes sold as bait, they often contribute major portions of the discarded bycatch. Twelve species of fish were included in the other regulated species discarded because of size restrictions with sand whiting (1.3%) and yellowfin bream (1.1%) dominating. Twenty-three species were caught but not marketed being exclusively discarded as bycatch. Sixty-four marine turtles were reported in the vicinity of commercial fishers while carrying out their fishing activities. All were reported to have been released alive with many reported to have been feeding on fish caught within the nets during the fishing operation. Two unidentified sea snakes were also reported, but their release condition is unknown.

Regulated Species Reported as Bycatch from Whiting Fishery Logbook Program

Regulated species discarded as bycatch made up 15.4% of the total discards. No individual species dominated the bycatch with sand whiting (4.5%), yellowfin bream (3.8%) and dusky flathead (2.9%) representing over two thirds of the bycatch of regulated species (Figure 3b). Blue swimmer crabs (1.6%) were discarded at a high rate, 99.5% of the total number caught (Table 3). Sea mullet (1.2%) were the only other regulated species that contributed more than 1% to the total bycatch.

Unregulated Species Reported as Bycatch from Whiting Fishery Logbook Program

Silverbiddies dominated the unregulated discards within the whiting fishery, being two thirds (65.9%) of the bycatch. This species was occasionally kept as bait. Other bait species that were sometimes kept but usually discarded included flicker mullet *Mugil georgii* (5.8%) and herring *Herklotsichthys koningsbergeri* (2.6%). The dasyatidid stingrays listed in the catch were usually not entangled by the net but rather surrounded by it. These stingrays were able to escape from the net after the fishers began hauling it from the water and are rarely landed into the boat. The remaining bycatch consisted of 23 species, none of which contributed more than 0.05% of the total bycatch.

6.3.3.2 Observer Program in the Whiting Fishery

Total Catch Composition

A total of 31 net shots by 5 different commercial fishers were observed. A combined total of 19,482 fish from 55 species of animal were captured including 50 species of fish, 2 species of crab, 2 cephalopods and marine turtles (Table 3). Thirty-six species comprising 72.5% of the total observed catch were retained for market. Six species, sand whiting (35.0%), silverbiddies (22.4%), flat-tailed mullet *Liza argentea* (4.4%), flicker mullet *Mugil georgii* (3.2%), dusky flathead (2.8%) and tailor (1.0%)

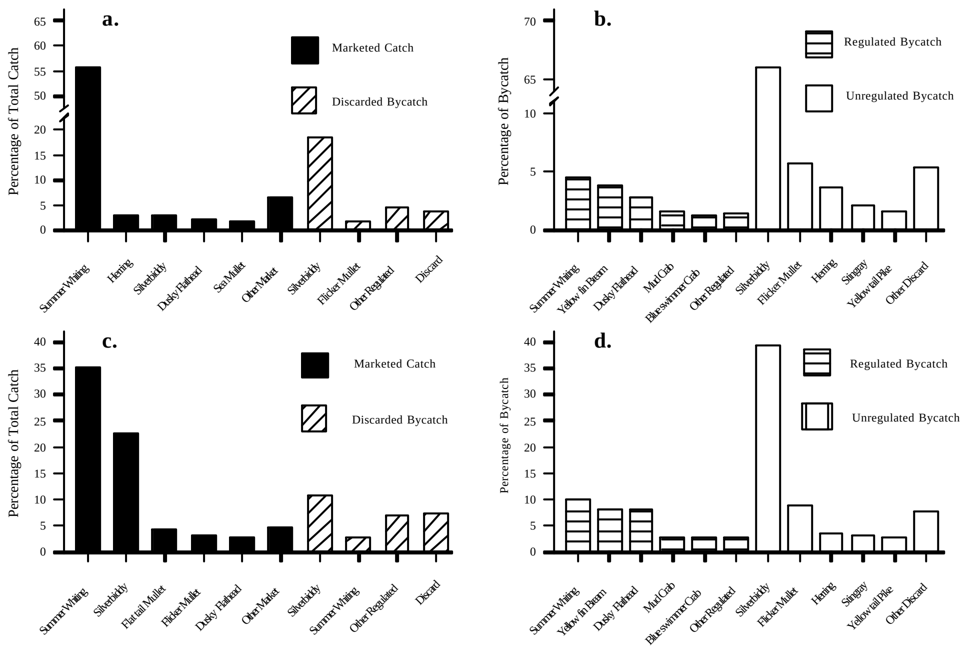

Figure 3**:** Whiting fishery catch composition for (a) voluntary logbook from 471 net shots (b) voluntary logbook bycatch, (c) observed catch from 31 net shots and (d) observed catch bycatch composition.

(Figure 3c) dominated the marketable catch. The difference in relative catch frequency of silverbiddies between the observer and logbook data (Figure 3a and c) arose from one fisher in the observer program having a local market for silverbiddies while the other fishers discarded them. This created a false impression in the observer data that silverbiddies are marketed at a reasonably high rate when they generally are not. The remaining 20 species, totalling 4.7% of the total catch, were retained for market. Bycatch was estimated at 27.5% with silverbiddies (10.8%), sand whiting (2.7%), flicker mullet (2.4%), yellowfin bream (2.2%), and dusky flathead (2.2%) dominating. No other bycatch species represented more than 1% of the total catch. Nineteen species were caught but not marketed, being exclusively bycatch. Ten sea turtles were observed being encircled by nets in this fishery during the program, and all were released alive.

Table 3: Whiting fishery: species composition and discarding rates from 471 net shots reported in the voluntary logbook program, and from 31 net shots in the observer program on the sub-tropical east coast of Queensland. TL = Total Length, CW = Carapace Width, NR = Not Regulated, P = Protected.

Common Name	Species Name	Size Limit (cm)	Logbook Data (471 Net Shots) Retained	Logbook Data Discarded	Logbook Data % Discard	Observer Data (31 Net Shots) Retained	Observer Data Discarded	Observer Data % Discard
Sand Whiting	*Sillago ciliata*	> 23 TL	83160	1898	2	6806	533	7
Herring	*Herklotsichthys koningsbergeri*	NR	4400	1513		0	192	100
Silverbiddy	*Gerres oyeana*	NR	4217	27795	87	4359	2108	33
Dusky Flathead	*Platycephalus fuscus*	> 30 TL	3377	1209	26	548	424	44
Sea Mullet	*Mugil cephalus*	> 30 TL	2782	506	15	78	25	24
Yellowfin Bream	*Acanthopagrus australis*	> 23 TL	2405	1612	40	276	433	61
Flat tailed Mullet	*Liza subviridis*	NR	2275	13	1	860	0	0
Flicker Mullet	*Mugil georgii*	NR	2351	2432		629	475	43
Tailor	*Pomatomus saltatrix*	> 30 TL	832	218	21	196	61	24
Dart	*Trachinotus russelli*	NR	678	4	1	0	0	
Tiger Mullet	*Liza argentea*	NR	377	0	0	10	0	0
Squid	*Sepioteuthis* sp.	NR	174	0	0	69	0	0
Scad	*Decapterus* sp.	NR	127	0	0	0	0	
Cuttlefish	*Sepia* sp.	NR	110	3	3	15	0	0
Sand Mullet	*Myxus elongatus*	NR	108	0	0	2	0	0
Trumpter Whiting	*Sillago maculata*	NR	70	9	11	168	0	0
Wolf Herring	*Chirocentrus dorab*	NR	45	8	15	0	0	
Gar	*Hemirhamphus quoyi*	NR	37	0	0	35	0	0
Shark	Carcharinidae	NR	28	0	0	4	0	0
Trevally	Carangidae	NR	26	41	62	12	6	33
Grunter	*Pomadasys sp.*	> 30 TL	19	50	73	0	0	
Mud Crab	*Scylla serrata*	> 15 CW	13	293	96	3	155	98
Queenfish	*Scomberoides* sp.	NR	9	2	18	0	3	100
Blue swimmer crab	*Portunus pelagicus*	> 15 CW	4	694	99	0	155	100
Striped Scat	*Selenotoca multifasciata*	NR	4	72	95	0	0	
Australian Bonito	*Sarda australis*	NR	4	0	0	0	0	
Ludderick	*Girella tricuspidata*	> 23 TL	2	0	0	0	0	
Black Sole	*Achlyopa nigra*	NR	1	52	98	0	16	100
Mackerel	*Scomberomorus* sp	> 45 TL	1	3	75	0	0	
Golden Trevally	*Gnathanodon speciosus*	NR	1	1	50	0	0	
Golden-lined Whiting	*Sillago analis*	> 23 TL	0	0		12	0	0
Blue-Spot Mullet	*Valamugil seheli*	NR	0	0		9	0	0
Diamond Scale Mullet	*Liza vaigiensis*	NR	0	0		6	5	46
Giant Herring	*Elops* sp.	NR	0	0		5	2	29
Tarpon	*Megalops cyprinoides*	NR	0	0		5	1	17
Tongue Sole	*Pseudorhombus* sp.	NR	0	0		4	15	79
Bar-tailed Flathead	*Platycephalus endrachtensis*	> 30 TL	0	0		3	7	70
Estuary Cod	*Epinephalus* sp.	> 35 < 120	0	0		1	1	50
Mangrove Jack	*Lutjanus argentimaculatus*	> 35 Tl	0	0		1	0	0
Stingray	*Dasyatididae*	NR	0	919	100	0	166	100
Striped Seapike	*Sphyraena obtusata*	NR	0	706	100	0	154	100
Shovelnosed Ray	*Rhinobatus batillum*	NR	0	494	100	0	124	100
Longtom	*Tylosurus* sp.	NR	0	368	100	0	104	100
Catfish	*Arius* spp.	NR	0	346	100	0	14	100
Ponyfish	*Leiognathus* sp.	NR	0	232	100	0	0	
Trumpeter	*Pelates* sp.	NR	0	152	100	0	6	100
Threadfin Salmon	*Polydactylus* sp.	NR	0	149	100	0	30	100
Eel-tailed Catfish	*Plotosus lineatus*	NR	0	105	100	0	35	100
Tripodfish	Triacanthidae	NR	0	98	100	0	1	100
Goatfish	*Upeneus* sp.	NR	0	47	100	0	5	100
Rabbitfish	*Siganus* sp.	NR	0	36	100	0	5	100
Pink Eyed Mullet	*Trachystoma petardi*	NR	0	20	100	0	0	
Moses Perch	*Lutjanus russelli*	> 25 Tl	0	14	100	0	7	100
Grass Sweetlip	*Lethrinus fletus*	> 30 Tl	0	9	100	0	15	100
Diamondfish	*Monodactylus argenteus*	NR	0	7	100	0	0	
Bone fish	*Albula neoguinaica*	NR	0	6	100	0	0	
Red Bullseye	*Priacanthus* sp.	NR	0	4	100	0	0	
Grinner	*Saurida* sp.	NR	0	4	100	0	0	
Love Crab	*Thalamita crenata*	NR	0	3	100	0	0	
Blue Threadfin	*Eleutheronema tetradactylum*	> 40 TL	0	2	100	0	5	100
Stonefish	*Synanceja horrida*	NR	0	1	100	0	0	
Tarwhine	*Rhabdosargus sarba*	> 23 TL	0	0		0	20	100
Rat tail ray	*Gymnura australis*	NR	0	0		0	11	100
Pufferfish	*Arothon hispidus*	NR	0	0		0	10	100
Blue-Spotted Stingray	*Dasyatis kuhlii*	NR	0	0		0	7	100
Snapper	*Pagrus auratus*	> 30 Tl	0	0		0	4	100
Estuary Stingray	*Dasyatis fluviorum*	NR	0	0		0	2	100
Reticulate Whipray	*Himantura uarnak*	NR	0	0		0	2	100
Northern Sand Flathead	*Platycephalus arenarius*	NR	0	0		0	2	100
Long-Horned Cowfish	*Lactoria cornuta*	NR	0	0		0	1	100
Fan-Bellied Leatherjacket	*Monocanthus chinensis*	NR	0	0		0	1	100
Turtle	Unidentified	P	0	64	100	0	10	100
Sea snake	Unidentified	P	0	2	100	0	0	
	Total number of fish		107635	42149		14115	5357	
	Percentage of Total Catch		71.9	28.1		72.5	27.5	

Regulated Bycatch Observed in the Whiting Fishery

Due to the small mesh size of whiting nets (usually 51 mm), higher numbers of undersized regulated fish were caught than observed in the sea mullet fishery. Thirteen species of fish and two species of crab were discarded as regulated species. Of these sand whiting (10.0% of the bycatch component), yellowfin bream (8.1% of the bycatch component), and dusky flathead (7.9% of the bycatch component) were the most abundant species. All other regulated species contributed less than 1% of the total bycatch discards.

Unregulated Bycatch Observed in the Whiting Fishery

Nineteen species were discarded as unregulated bycatch. Of these, silverbiddies (39.4% of bycatch component) and flicker mullet (8.9% of bycatch component) were the most abundant. Herring, stingrays, striped seapike *Sphyraena obtusata* and longtoms *Tylosurus* sp. were the only other species to be represented by more than 1% of the total bycatch. (Figure 3d).

6.3.3.3 Seasonality of bycatch in the Whiting Fishery.

Returned logbook data on catches within the whiting fishery indicated that there were 7 species caught in sufficient numbers to allow analysis of catch rates for seasonal trends. For marketable fish, seasonality in catches were estimated for sand whiting, sea mullet, yellowfin bream and dusky flathead. Catches of discarded undersized sand whiting, yellowfin bream, dusky flathead, blue swimmer and mud crabs were also investigated. The silverbiddy was the only unregulated species caught consistently enough to allow for investigation into seasonal changes in catch rates.

Catch rates of marketable sand whiting were significantly higher (LSD, $P < 0.05$) in autumn and winter (~350 ± 70 fish/shot) than in spring and summer (Figure 4a). This increase is associated with a significant increase (LSD, $P < 0.05$) in the catch rates of undersized whiting during winter when compared with other seasons (Figure 4e). Whiting have a cylindrical body form that allows this fishery to be highly selective in the size of the fish that are caught by changes in mesh size (Kennelly and Gray 2000). As 51 mm mesh nets are currently used in this fishery and the majority of the targeted catch is in the size range of 210-240 mm fork length, any increase in the legal size for this fish would require changes in the current legislation to increase the minimum mesh size to maintain the currently low catch rates of undersized whiting.

Marketable yellowfin bream catch rates are about 5 ± 2 fish/shot from spring until autumn and then significantly increase (LSD, $P < 0.05$) during winter to 12.4 ± 2.3 fish/shot (Figure 4b). This increase is mirrored by the catch rates of undersized yellowfin bream that are relatively stable from spring to autumn at < 3 fish/shot but increase to 11.1 ± 2.1 fish/shot in winter (Figure 4f). These higher catch rates during winter are most probably associated with the schooling/spawning behaviour of this species (see mullet section, page 18).

The catch rates of legal size dusky flathead (>300 mm TL) within the whiting fishery were significantly higher (LSD, $P < 0.05$) during winter (44.8 ± 10.7 fish/shot) than all other seasons (Figure 4d). Catch rates of undersized dusky flathead also increase significantly (LSD, $P < 0.05$) during the winter (10.0 ± 2.3 fish/shot) compared with the summer and autumn catches (~2.0 ± 0.8 fish/shot) (Figure 4g). Flathead are demersal and feed on fish and crustaceans in intertidal areas on the high tide (Dredge 1976). They are often caught in the whiting nets, particularly when intertidal banks are drained off, by their protruding opercular spines or by their mouthparts. This entangling capture means that changes in net mesh size would not have a dramatic effect on the catches of legal sized flathead but decreases in catch rates for juvenile fish may occur.

Catches of marketable sea mullet from within the whiting fishery are significantly higher in summer (24.5 ± 9.8 fish/shot) than in all other seasons (Figure 4c). This increase could be a result of summer migrations of sea mullet called “hard gut runs” (Virgona *et al*. 1998). The sea mullet that move in these runs are sexually immature and can move considerable distances without feeding. They are often seen travelling northward along surf beaches, within 10 metres of the shore, in extremely long thin schools. These schools are often only 6 or 7 fish wide with the whole school taking many hours to pass a single point. These schools move from one estuary to another presumably in the search for feeding grounds. The lean condition that they are in due to travelling long distances appears to make them more susceptible to capture in the small mesh whiting nets than at other times of the year.

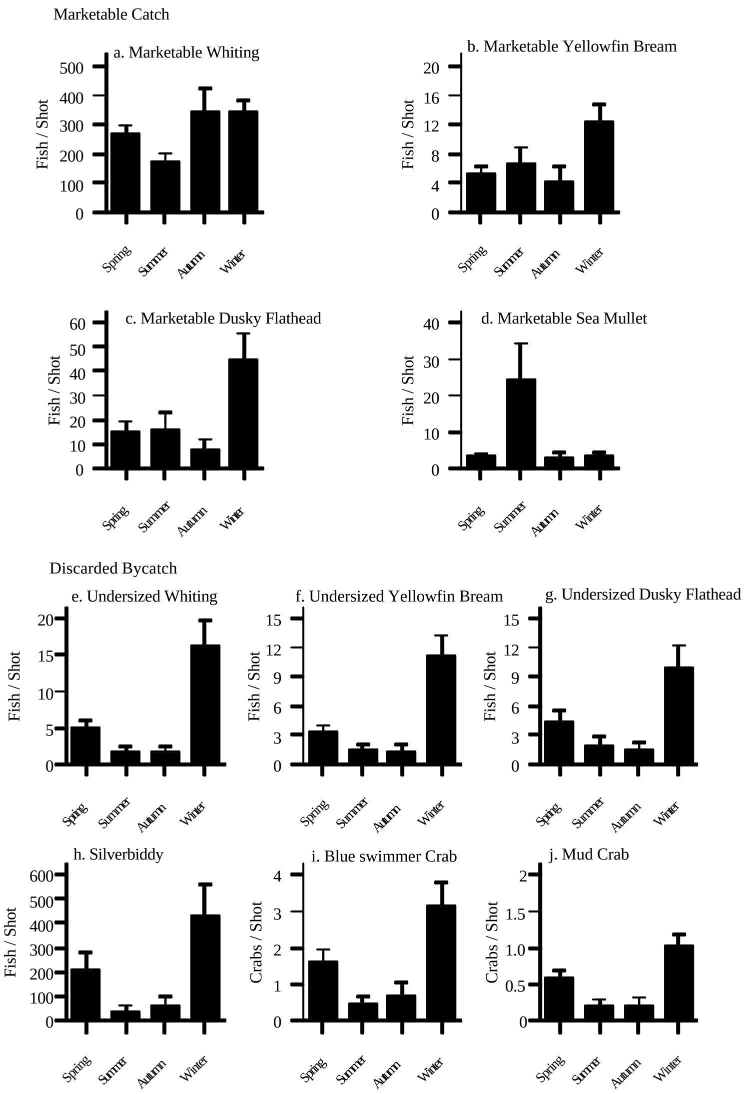

Figure 4: Seasonal changes in mean catch rates (± 1 S.E.) for target and bycatch species within the whiting fishery. Note differences in scale for all species.

Blue swimmer crab and mud crab catch rates within the whiting fishery show an opposite pattern to those recorded for the sea mullet fishery. Significantly higher catch rates for discarded crabs of both species are shown to occur during winter than in summer and autumn as in the sea mullet fishery (Figure 4I and j). Catch rates of both species of crabs is low with the highest catch rates for blue swimmer crabs being 3.1 ± 0.6 crabs/shot and 1.0 ± 0.1 crabs/shot for mud crabs

Of the unregulated species caught and discarded in the whiting fishery, only silverbiddies were caught in sufficient numbers to allow analyses of seasonal patterns in catch. Silverbiddies are small dorso-ventrally-flattened fish of similar body morphology to bream. These fish attain a maximum size of about 230 mm total length (Kailola *et al*. 1993) and are highly susceptible to "gilled" capture in 51 mm mesh nets. Silverbiddies are sometimes marketed as food or bait; however, these markets are disjointed and service an irregular demand. For this reason all reported catches of silverbiddies whether sold or discarded were pooled and included in a single analysis. High catch rates of silverbiddies were reported during winter (Figure 4h) with mean catches of 431 ± 126 fish/shot being reported. These catch rates decrease through spring and reach the lowest levels during summer (40 ± 21 fish/shot). Of all the bycatch species in the whiting fishery, the silverbiddy appears to be one species for which markets should be developed as catch rates are high and the majority of the catch is currently discarded.

6.3.4 Small Mackerel Fisheries in Southern Queensland

The Small Mackerel Fishery

Small mackerel fisheries in southern Queensland target two species, school mackerel (*Scomberomorous queenslandicus*) and spotted mackerel (*S. munroi*). About 100 fishers participate in this fishery annually with the number fluctuating markedly over the past 10 years (Williams 1997). The mackerel fishery in southern Queensland is highly seasonal, normally lasting from spring until summer. Two forms of fishing occur in this fishery. The first method is similar to the mullet fishery with fishers sighting schools of mackerel and setting their nets in a ring surrounding the school. This method is usually restricted to sheltered embayments. The second is a set net fishery where nets are set in a fixed position perpendicular to the shoreline off the surf beaches and allowed to passively fish for up to 3 hrs. Nets are usually 600 m long and have a mesh size of 112 mm to 137 mm.

6.3.4.1 Logbook Program in the southern Small Mackerel Fishery

Total Catch Composition

Logbook sheets were returned from 4 commercial fishers with a total of 166 net shots recorded. A total of 4 690 individuals from at least 45 species of fish were captured (Table 4). Of the total catch, 90.3% were reported as being retained for market. School and spotted mackerel were the most abundant fish caught in this fishery contributing a combined total of 75.2% of the total catch (Figure 5a). Dart *Trachinotus russelli* (7.2%) and carcharinid sharks (3.5%) were the only other marketable species that contributed more than 1% of the total catch. A further 20 species totalling 4.5%were retained for market. Bycatch was reported at 9.7% with lantern fish (Family: Myctophidae) (3.3%) and scads *Decapterus* sp.(1.8%) dominating. Discarding of regulated species was low

(0.4%) with 8 spanner crabs *Ranina ranina*, 7 blue swimmer crabs and 3 snapper *Pagrus auratus*, being discarded. Twenty species were caught but not marketed, being exclusively discarded as bycatch.

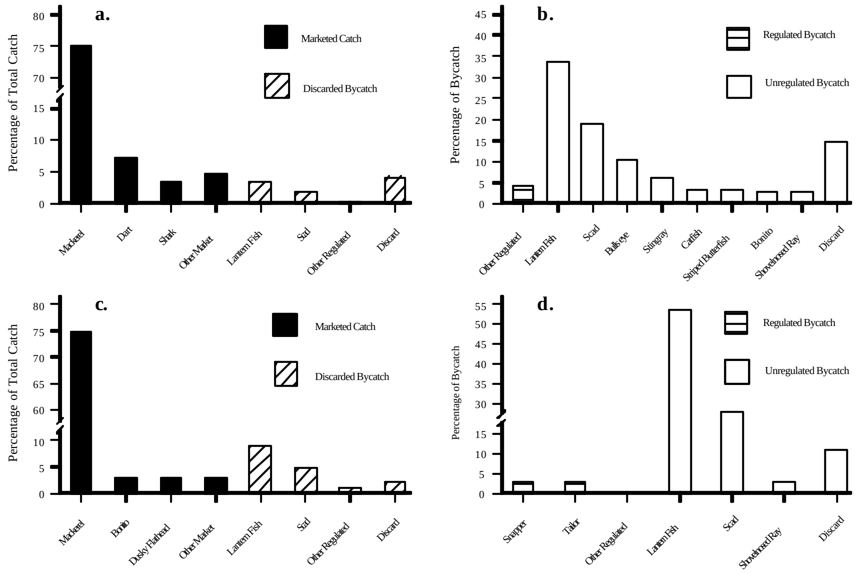

Figure 5: Small mackerel fishery catch breakdowns for (a) logbook returns catch (b) logbook bycatch composition (c) observer catch and (d) observer bycatch composition.

Regulated Species Reported as Bycatch from the Small Mackerel Logbook Program

Regulated species discarded as bycatch make up 0.4% of the total discards (Figure 5b) (Table 4).

Unregulated Species Reported as Bycatch from the Small Mackerel Logbook Program

Lantern fish (33.8% of the bycatch component) and scads (19.0% of the bycatch component) dominated the unregulated discards within the mackerel fishery. Scads were occasionally kept as bait but more often than not were discarded. Of the remaining 18 species, only bulls eyes *Priacanthus* sp.(1.03%) contributed more than 1% to the total bycatch (Figure 5b).

6.3.4.2 Observer Program in the southern Small Mackerel Fishery

Total Catch Composition

Observer data were collected from the fishing activities of one fisher in the mackerel fishery covering 19 net shots. A total of 459 fish were caught from at least 23 species (Table 4). Of the total catch 83.7% were retained for market. The small mackerel *Scomberomorus queenslandicus* was the most abundant fish caught in this fishery contributing 72.7% of the total catch (Figure 5c). Australian Bonito *Sarda australis* (3.1%), dusky flathead (3.0%) and spotted mackerel *Scomberomorus munroi* (2.0%) were the only other marketable species that individually contributed more than 1% of the total catch. Eight other species were retained for market totalling 2.8% of the total catch. Bycatch was 16.3% with lantern fish Family: Myotophidae (8.8%) and scads

Decapterus sp. (4.6%) dominating. Both of these unregulated species are small and occur seasonally in large numbers within the fishing grounds. These fish were never "gilled" and became entangled within the net by their mouthparts. Two speciments each of tailor *Pomatomus saltatrix* and snapper *Pagrus auratus* were discarded because of size limit regulations.

Table 4: Small mackerel fishery: species composition and discarding rates from 166 net shots reported in the voluntary logbook program, and from 19 net shots in the observer program on the sub-tropical east coast of Queensland. TL = Total Length, CW = Carapace Width, CL = Carapace Length, NR = Not Regulated, P = Protected

Common Name	Species Name	Size Limit (cm)	Logbook Data (166 Net Shots) Retained	Discard	% Discard	Observer Data (19 Net Shots) Retained	Discard	% Discard
Mackerel unidentified	Scomberomorus sp	> 50 TL	2655	0	0	0	0	
School Mackerel	*Scomberomorus queenslandicus*	> 50 TL	796	0	0	332	0	0
Dart	*Trachinotus russelli*	NR	340	0	0	0	0	
Shark unidentified	Charcharinidae	NR	163	2	1	2	0	0
Spotted Mackerel	*Scomberomorus munroi*	> 50 TL	74	0	0	9	0	0
Queenfish	Scomberoides sp.	NR	34	0	0	0	0	
Dusky flathead	*Platycephalus fuscus*	> 30 TL	29	0	0	14	0	0
Bonito	*Sarda australis*	NR	22	13	37	14	0	0
Snapper	*Pagrus auratus*	> 30 TL	20	3	13	1	2	67
Grey Mackerel	*Scomberomorus semifasciatus*	> 50 TL	20	0	0	0	0	
Tailor	*Pomatomus saltatrix*	> 30 TL	19	0	0	0	2	100
Blubber lip	*Plectorhinchus* sp	NR	19	0	0	6	0	0
Scad	*Decapterus* sp.	NR	12	86	88	0	21	100
Wolf herring	*Chirocentrus dorab*	NR	9	9	50	0	1	100
Grass sweetlip	*Lethrinus fletus*	> 30 TL	7	1	13	0	0	
Grunter	*Pomadasys* sp.	> 30 TL	6	0	0	0	0	
Blue swimmer crab	*Portunus pelagicus*	> 15 CW	3	7	70	0	0	
Trevally	Carangidae	TR	2	6	75	1	1	50
Estuary Cod	*Epinephalus* sp.	> 35 < 120 TL	2	0	0	0	0	
Amberjack	*Seriola dumerili*	NR	2	0	0	0	0	
Shovelnosed ray	*Rhinobatus batillum*	NR	1	12	92	0	2	100
Parrotfish	Scaridae	NR	1	0	0	1	0	0
Samson fish	*Seriola hippos*	NR	1	0	0	0	0	
Yellowtail kingfish	*Seriola lalandi*	> 50 TL	1	0	0	0	0	
Mackerel Tuna	*Euthynnus affinis*	NR	0	0		2	0	0
Bar tailed flathead	*Platycephalus endrachtensis*	> 30 TL	0	0		1	0	0
Hammerhead shark	*Sphyrna* sp.	NR	0	0		1	0	0
Lantern fish	Myctophidae	NR	0	153	100	0	40	100
Bullseye	*Priacanthus* sp.	NR	0	47	100	0	1	100
Stingray	Dasyatididae	NR	0	28	100	0	0	
Catfish	*Arius* sp.	NR	0	15	100	0	1	100
Stripey butterfish	*Selenotoca multifasciata*	NR	0	14	100	0	0	
Diamond fish	*Monodactylus argenteus*	NR	0	10	100	0	0	
Spanner crab	*Ranina ranina*	> 10 CL	0	8	100	0	0	
Grinner	*Saurida* sp.	NR	0	8	100	0	1	100
Tripod fish	Triacanthidae	NR	0	6	100	0	0	
Tarpon	*Megalops cyprinoides*	NR	0	5	100	0	0	
Moonfish	*Mene maculata*	NR	0	5	100	0	1	100
Black Trevally	*Siganus* sp.	NR	0	4	100	0	0	
Giant herring	*Elops* sp.	NR	0	2	100	0	0	
Milkfish	*Chanos chanos*	NR	0	2	100	0	0	
Red spot Crab	*Portunus sanguinolentus*	NR	0	2	100	0	0	
Herring	*Herklotsichthys* sp.	NR	0	1	100	0	0	
Silver Toadfish	*Lagocephalus scleratus*	NR	0	1	100	0	0	
Leatherjacket	Monacanthidae	NR	0	1	100	0	0	
Banded Wobbygong	*Orectolobus ornatus*	NR	0	1	100	0	1	100
Black sole	*Achlyopa nigra*	NR	0	1	100	0	0	
White spotted shovelnosed ray	*Rhynchobatus djiddensis*	NR	0	0		0	1	100
	Total number of fish		4237	453		384	75	
	Percentage of Total Catch		90.3	9.7		83.7	16.3	

Regulated Bycatch Observed in the Small Mackerel Fishery

Regulated species discarded as bycatch made up 0.9% of the total discards. Only two individuals of both tailor and snapper were caught that were discarded (Table 4).

Unregulated Bycatch Observed in the Small Mackerel Fishery

Two species of fish, lantern fish Family:Myotophidae (53.3% of bycatch component) and scads *Decapterus* sp (28.0% of the bycatch component) dominated the discarded component of the catch. A further nine species were caught and discarded at low rates with only 1 or 2 individuals of each species being caught.

6.3.5 Tropical East Coast Barramundi Fishery

The Fishery

The tropical east coast (EC) barramundi gill net fishery operates in the estuarine and shallow coastal waters extending from Cape York south to the southern extent of the species range around the Mary River in southern Queensland. There are about 210 boats that report catching barramundi on the east coast each year with annual production of about 160 t (Williams 1997).

The EC barramundi seasonal closure extends for three calendar months from November 1st to February 1st each year. Each commercial net endorsement allows a fisher to operate 3 nets totalling no more than 360 m in length when fishing within creeks or rivers, or 600 m when fishing foreshores. Monofilament gill nets are used exclusively with mesh size restricted to between 150 and 215 mm for river netting operations. The product of the fishery is predominantly “iced, gilled and gutted” with large whole fish generally meeting more market resistance than smaller fish. Apart from in the far northern region of the state, most fishing effort occurs close to towns or regional centres. Fishing is predominantly conducted over-night and the product landed the next morning. Fishing generally occurs from sunset to sunrise with soak times varying between 2 and 6 hrs.

6.3.5.1 Logbook Program in the East Coast Barramundi Fishery

Five commercial fishers participated in the logbook program with catches from 95 net shots being recorded. A total of 2 362 fish from 32 species and 93 mud crabs (*Scylla serrata*) were captured (Table 5). Of the total catch, 79.6% was retained for market. The four most abundant species captured were all marketed species - barramundi *Lates calcarifer* (23.4%), blue threadfin *Eleutheronema tetradactylum* (19.2%), king threadfin *Polydactylus macrochir* (8.9%) and queenfish *Scomberoides commersonianus* (7.5%) (Figure 6a). The remaining 14 species retained for market represented a further 15.6% of the total catch. Bycatch was estimated at 20.4% with undersized barramundi (< 580 mm TL) (5.2%), mud crab (3.9%) and catfish *Arius* spp. (3.5%) dominant. Twelve species were captured but not marketed being exclusively bycatch. Fish and crabs released due to non-conformance to regulated size limits represented 9.5% of the total catch.

6.3.5.2 Observer Program in the East Coast Barramundi Fishery

Total Catch Composition

Four commercial fishers participated in the program resulting in a total of 127 net shots being observed. A combined total catch of 1 581 fish from 45 species, 31 mud crabs and four turtles from three species were captured (Table 5). Of the total catch, 84.0% was retained for market. The five most abundant species captured were all marketed species

Table 5: East coast barramundi fishery: species composition and discarding rates from 95 net shots reported in the voluntary logbook program, and from 127 net shots in the observer program on the tropical north-east coast of Queensland. TL = Total Length, CW = Carapace Width, CL = Carapace Length, NR = Not Regulated, P = Protected.

COMMON NAME	SPECIES NAME	SIZE LIMIT (cm)	LOGBOOK DATA (95 NET SHOTS)			OBSERVER DATA (127 NET SHOT)S		
			RETAINED	DISCARD	% DISCARD	RETAINED	DISCARD	% DISCARD
Barramundi	*Lates calcarifer*	> 58 <120 TL	553	122	18	621	28	4
Blue Threadfin	*Eleutheronema tetradactylum*	> 40 TL	454	4	1	263	3	1
King Threadfin	*Polydactylus macrochir*	> 40 TL	211	1	0.5	54	0	0
Queenfish	*Scomberoides commersonnianus*	NR	177	1	0.5	134	0	0
Shark unspecified	*Carcharhinus* spp	NR	117	36	24	0	0	
Sea Mullet	*Mugil cephalus*	> 30 TL	76	0	0	3	0	0
Pumpkinhead	*Trachinotus blochii*	NR	70	0	0	7	0	0
Grunter Bream	*Pomadasys kaakan*	> 30 TL	53	0	0	112	0	0
Diamond Scale Mullet	*Liza vaigiensis*	NR	44	9	17	6	0	0
Dusky Flathead	*Platycephalus fuscus*	> 30 TL	35	2	5	18	0	0
Tripletail	*Lobotes surinamensis*	NR	27	0	0	13	0	0
Giant Trevally	*Caranx ignobilis*	NR	19	6	24	0	0	
Fingermark	*Lutjanus johnii*	> 35 TL	13	0	0	10	0	0
Catfish	*Arius* spp.	NR	11	83	88	9	28	76
Mangrove Jack	*Lutjanus argentimaculatus*	> 35 TL	6	0	0	6	0	0
Moonfish	*Drepane punctata*	NR	4	5	56	0	15	100
Yellowfin Bream	*Acanthopagrus australis*	> 23 TL	3	0	0	0	0	
Shovelnose – Giant	*Rhinobatos typus*	NR	2	18	90	0	2	100
Blubberlip	*Plectorhinchus gibbosus*	NR	2	3	60	0	9	100
Parrotfish	*Scarid* sp.	NR	1	0	0	0	0	
Barracuda	*Sphyraena barracuda*	NR	1	0	0	2	0	0
Bull Shark	*Carcharhinus leucas*	NR	0	9	100	55	15	21
Mud Crab	*Scylla serrata*	> 15 CW	0	93	100	7	24	77
Wolf Herring	*Chirocentrus dorab*	NR	0	0		1	0	0
Gold Spot Cod	*Epinephilus coioides*	> 35 <120 TL	0	0		1	0	0
Black Spot Cod	*Epinephilus malabaricus*	> 35 < 120 TL	0	0		1	0	0
Bartail Flathead	*Platycephalus indicus*	> 30 TL	0	0		1	0	0
Black Jew	*Protonibea diacanthus*	> 45 TL	0	0		1	0	0
Giant Seapike	*Sphyraena jello*	NR	0	0		1	0	0
Mullet - Bluetail 1	*Valamugil buchanani*	NR	0	6	100	1	0	0
Mullet - Bluetail 2	*Valamugil seheli*	NR	0	0		1	0	0
Soapy Jew	*Nibea soldado*	> 45 TL	0	34	100	0	47	100
Diamond Trevally	*Selenotoca multifasciatus*	NR	0	20	100	0	18	100
Stingray	Dasyatididae	NR	0	15	100	0	1	100
Striped Scat	*Alectes indicus*	NR	0	7	100	0	18	100
Cownosed Ray	*Rhinoptera neglecta*	NR	0	3	100	0	1	100
Grouper	*Epinephilus lanceolatus*	> 35 < 120 TL	0	2	100	0	1	100
Scalloped Hammerhead	*Sphyrna lewini*	NR	0	1	100	0	17	100
Black Pomfret	*Parasromateus niger*	NR	0	1	100	0	0	
Wide Sawfish	*Pristis micrdon*	NR	0	1	100	0	0	
Batfish	*Platax orbicularis*	NR	0	0		0	8	100
Toadfish	*Arothron hispidus*	NR	0	0		0	5	100
Winghead Shark	*Eusphyra blochii*	NR	0	0		0	4	100
Long Nosed Shark	*Carcharhinus brevipinna*	NR	0	0		0	2	100
Bony Bream	*Nematalosa erebi*	NR	0	0		0	1	100
Tripod Fish	*Tripodichthys augustifrons*	NR	0	0		0	1	100
Grey Nurse Shark	*Carcharias taurus*	P	0	0		0	1	100
Golden Trevally	*Gnathanodon speciosus*	NR	0	0		0	1	100
Long Jaw Mackerel	*Rastrelliger kanagurta*	NR	0	0		0	1	100
Milk Shark	*Rhizoprionodon acutus*	NR	0	0		0	1	100
White Spot Shovelnose	*Rhynchobatus djiddensis*	NR	0	0		0	1	100
Spotted Scat	*Scatophagus argus*	NR	0	0		0	1	100
Loggerhead Turtle	*Caretta caretta*	P	0	0		0	1	100
Green Turtle	*Chelonia mydas*	P	0	0		0	2	100
Flatback Turtle	*Natator depressus*	P	0	0		0	1	100
	Total number of fish		1879	483		1328	198	
	Percentage of Total Catch		79.6	20.4		87.0	13.0	

- barramundi *Lates calarifer* (39.3%), blue threadfin *Eleutheronema tetradactylum* (16.6%), queenfish *Scomberoides* sp. (8.5%), grunter bream *Pomadasys kaakan* (7.1%) and king threadfin *Polydactylus macrochir* (3.4%) (Figure 6b). The remaining 16 species retained for market or bait represented a further 9.0% of the total catch numbers. Bycatch was estimated at 14.0% with soapy jew *Nibea soldado* (3.0%), catfish *Arius* spp.(1.8%) and undersized barramundi *Lates calcarifer* (<580 mm TL) (1.8%) dominant. Another twenty-two species were captured but were not marketed being exclusively bycatch.

Fish and crabs released due to non-conformance to regulated size limits represented 3.5% of the total catch and included one protected grey nurse shark (*Carcharius taurus*) that was released alive. The two green turtles (*Chelonia mydas*), one flatback turtle

(*Natator depressus*) and one loggerhead turtle (*Caretta caretta*) were all released alive after being observed entangled in nets.

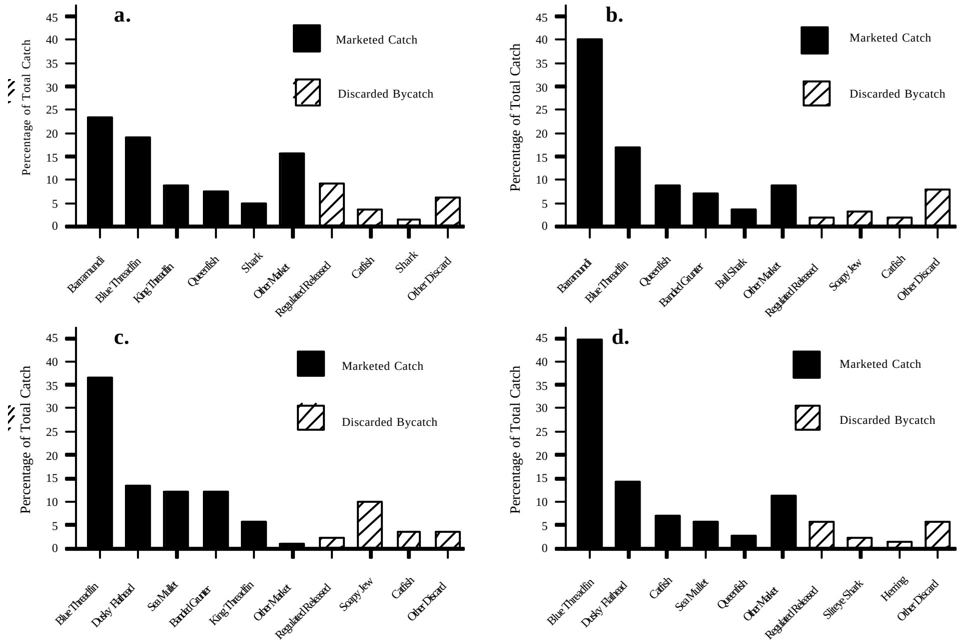

Figure 6: Catch composition for: a East Coast barramundi logbook program., b. East Coast barramundi observer program, c. East Coast mixed estuary logbook program and d. East Coast mixed estuary observer program.

6.3.6 Tropical East Coast "Mixed Estuary" Fishery

The Fishery

The tropical mixed estuary fishery operates year round and is not restricted by the seasonal barramundi closure. Gill nets of mesh sizes between 100 and 115 mm are used to target the blue and king threadfins (*Eleutheronema tetradactylum* and *Polydactylus macrochir*), grunter bream (*Pomadasys kaakan*) and dusky flathead (*Platycephalus fuscus*). Fishing occurs exclusively on foreshores, as gill nets set within estuarine or riverine waters are restricted to a minimum mesh size of 150 mm. In the fishery, set nets are fixed in static positions with soak times averaging between 4 and 5 hrs. About 200 boats report landing these four species on the east coast with annual production being about 100 t of blue threadfin, 75 t of king threadfin, 12 t of grunter bream and 50 t of dusky flathead (Williams 1997). The majority of the dusky flathead catch is caught in the south of the state with only about 10% of the annual production attributable to the tropical east coast mixed estuary fishery (Williams 1997).

6.3.6.1 Logbook Program in the East Coast "Mixed Estuary" Fishery

Logbook sheets were returned from 1 commercial fisher with only 2 net shots recorded. This fishery was severely impacted with the introduction of Dugong Protection Areas and as such many of the fishers working in it were unwilling to participate in the program. A combined total of 90 fish from nine species were captured (Table 6). Of the total catch, 81.1% were retained for market with blue threadfin (36.7%), dusky flathead

(13.3%), sea mullet (12.2%) and grunter bream (12.2%) the dominant species (Figure 6c). A further 2 species were retained for market representing 5.6% of the total catch. Bycatch was estimated at 18.9% with catfish *Arius* spp. (10.0%), striped butterfish *Scatophagus multifasciatus* (3.3%) and steelback *Leptobramma mulleri* (3.3%) dominant. Three species were captured but not marketed being exclusively bycatch. Fish released due to non-conformance to regulated size limits represented 2.2% of the total catch.

6.3.6.2 Observer Program in the East Coast "Mixed Estuary" Fishery

The fishing activities of 2 commercial fishers were observed resulting in a total of 23 net shots being recorded. A combined total of 504 fish from 26 species were captured (Table 6). Of the total catch, 84.7% was retained for market, with blue threadfin (46.6%), dusky flathead (41.7%), catfish (5.8%), sea mullet (3.6%) and queenfish (2.8%) the dominant species (Figure 6d). A further seven species representing 9% of the total catch numbers were retained for market. Bycatch was estimated at 15.3% with undersized blue threadfin (3.0%) and barramundi (2.8%) being the most abundant. Eleven species were captured but not marketed being exclusively bycatch. Fish released due to non-conformance to regulated size limits represented 6.0% of the total catch.

Table 6: East coast "mixed estuary" fishery : species composition and discarding rates from 2 net shots reported in the voluntary logbook prgram, and from 23 net shots in the observer program on the tropical north-east coast of Queensland. TL = Total Length, CW = Carapace Width, CL = Carapace Length, NR = Not Regulated, P = Protected

Common Name	Species Name	Size limit (cm)	Logbook Data (2 Shots)			Observer Data (23 Shots)		
			Retained	Discarded	%Discard	Retained	Discarded	% Discard
Blue Threadfin	*Eleutheronema tetradactylum*	> 40 TL	33	0	0	235	15	6
Dusky Flathead	*Platycephalus fuscus*	> 30 TL	12	0	0	74	2	3
Sea Mullet	*Mugil cephalus*	> 30 TL	11	0	0	18	0	0
Grunter Bream	*Pomadasys kaakan*	> 30 TL	11	0	0	8	1	11
King Threadfin	*Polydactylus macrochir*	> 40 TL	5	0	0	6	0	0
Barramundi	*Lates calcarifer*	> 58 <120 TL	1	2	67	1	14	93
Catfish	*Arius* spp.	NR	0	3	100	29	0	0
Queenfish	*Scomberoides commersonnianus*	NR	0	0		14	3	18
Steelback	*Leptobramma mulleri*	NR	0	0		14	0	0
Yellowfin Bream	*Acanthopagrus australis*	NR	0	0		7	2	22
Tripletail	*Lobotes surinamensis*	NR	0	0		7	0	0
Diamond Scale Mullet	*Liza vaigiensis*	NR	0	0		6	0	0
Striped Butterfish	*Scatophagus multifasciatus*	NR	0	3		5	0	0
Mangrove Jack	*Lutjanus argentimaculatus*	> 35 TL	0	0		2	0	0
Whiting	*Sillago analis*	> 23 TL	0	0		1	0	0
Soapy Jew	*Nibea soldado*	> 45 TL	0	9	100	0	0	
Sliteye Shark	*Loxodon macrorhinus*	NR	0	0		0	12	100
Bony Bream	*Nematalosa erebi*	NR	0	0		0	7	100
Giant Shovelnose	*Rhinobatos typus*	NR	0	0		0	5	100
Scalloped Hammerhead	*Sphyrna lewini*	NR	0	0		0	3	100
Moonfish	*Drepane punctata*	NR	0	0		0	3	100
Winghead Shark	*Eusphyra blochii*	NR	0	0		0	2	100
Tripod Fish	*Tripodichthys augustifrons*	NR	0	0		0	2	100
Hamiltons Anchovy	*Thryssa hamiltoni*	NR	0	0		0	2	100
Grinner	*Synodus* spp.	NR	0	0		0	2	100
Bony Bream	*Nematolosa come*	NR	0	0		0	1	100
Tufted Sole	*Dexillichthys muelleri*	NR	0	0		0	1	100
	Total number of fish		73	17		427	77	
	Percentage of Total Catch		81.1	18.9		84.7	15.3	

No marine mega-fauna was observed captured by fishers targeting "mixed estuary" fishes. No dugong or dolphins were captured or sighted within the vicinity of the fishing activities observed on the tropical north-east coast. However, as this data set is very small when compared to the number of participants in the fishery it is difficult draw any meaningful conclusions from this result.

6.3.6.3 Mesh Effects

Four net mesh categories were defined from the fishing activities observed on the tropical east-coast. Three mesh categories were recorded while observing fishing activities targeting barramundi (medium and large mesh categories together with the mixture category when medium and large mesh nets were fished together), with an additional mesh category recorded from fishing activities targeting “mixed estuary”.

The number of bycatch species and the proportion of the total catch varied little between mesh categories (Table 7). The lowest proportion of bycatch was observed in the catches of the large mesh category (11.7%) with the highest proportion (16.6%) observed in the medium mesh category. Reasonably strong positive correlations between catch rates of bycatch and market fish were estimated for the small, large and mixture mesh categories with a weak negative correlation estimated for the medium mesh category. Mean catch rates of bycatch decreased with increasing mesh size (Figure 7) indicating the larger mesh sizes selectively captured fewer numbers of bycatch fish.

Table 7: Summary of mesh categories, target species and number of net shots observed in the tropical east coast fisheries. The number of bycatch species observed, their percentage contribution to the total catch and the correlation coefficients of bycatch catch rates to market catch rates are listed.

MESH CATEGORY	MESH SIZE (MM)	TARGET	# NET SHOTS	% BYCATCH	# BYCATCH SPECIES	CC
SMALL	102 – 114	Mixed Estuary	22	15.3	17	0.446
MEDIUM	152 – 178	Barramundi	51	16.6	14	-0.036
LARGE	191 – 216	Barramundi	42	11.7	16	0.405
MIXTURE	152 – 216	Barramundi	34	15.0	16	0.602

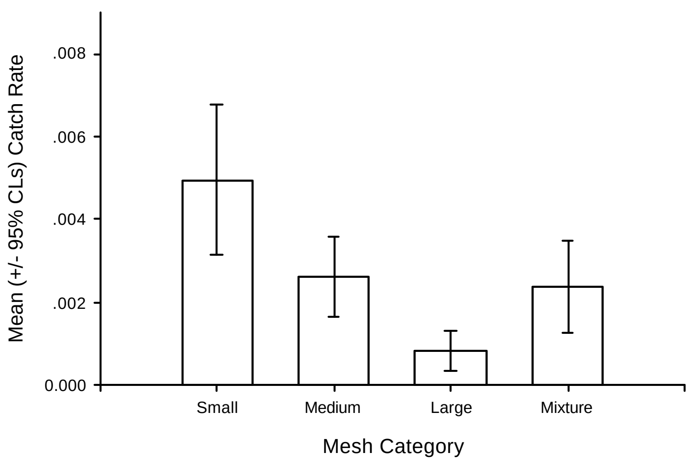

Figure 7: Mean (+/- 95% CLs) catch rates (fish/m/hr) of bycatch for each mesh category recorded from the tropical east coast observer program.

The species dominance plots of bycatch composition were similar for the three mesh categories used to target barramundi (Figure 8) with no single species clearly dominating the bycatch (Table 8). Conversely, the small mesh category used by fishers targeting “mixed estuary” fish demonstrated a strong dominance by regulated (undersized) barramundi.

Table 8: Decreasing order of dominance the ten most abundant bycatch species within the East Coast barramundi and “mixed” fisheries.

SMALL MESH	MEDIUM MESH	LARGE MESH	MIXED MESH
Barramundi	Soapy Jew	Shark	Shark
Shark	Shark	Pufferfish	Barramundi
Blue Threadfin	Catfish	Catfish	Soapy Jew
Queenfish	Barramundi	Moonfish	Scat
Moonfish	Pufferfish	Batfish	Diamond Trevally
Shovelnose	Blubberlip	Scat	Moonfish
Bony Bream	Scat	Stingray	Catfish
Bream	Batfish	Shovelnose	Blue Threadfin
Grinner	Moonfish	Tripodfish	Blubberlip
Flathead	Diamond Trevally	Grouper	Batfish

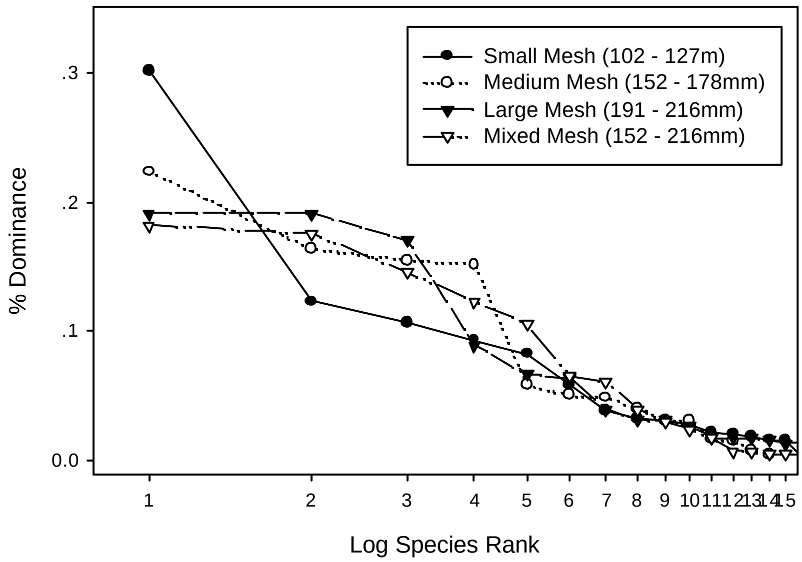

Figure 8: Dominance plots of mesh size effect on bycatch composition observed in the east-coast barramundi and mixed estuary fisheries. Mixed estuary fish are targeted with small mesh and barramundi with the medium, large and mixed mesh categories. Table 8 lists in decreasing order of dominance the ten most abundant bycatch species.

6.3.7 Gulf of Carpentaria Set Net Barramundi and “Mixed Estuary” Fisheries

The Gulf of Carpentaria (GoC) inshore gill net fishery operates in the estuarine and shallow coastal waters extending from Slade Point on Cape York Peninsula to the Queensland-Northern Territory border. Management is administered by a combination of input and output controls including limited licensing (around 90 licences exist currently), closed seasons and areas, vessel and gear restrictions, and minimum and maximum size limits. Annual production from the GoC fishery is about 380 t of barramundi, 50 t of blue threadfin, 150 t of king threadfin and 15 t of grunter bream (Williams 1997).

A sliding seasonal closure of 3½ lunar cycles (beginning 7 days prior to the first major spawning moon, usually the October full moon) protects spawning aggregations of barramundi during the monsoon season. During the open fishing season, increased catchability occurs when fish become more mobile and form predictable aggregations. Each commercial net endorsement allows a fisher to operate 6 nets totalling no more than 360 m in length when fishing within creeks or rivers, or 600 m when fishing foreshores. Monofilament gill nets are used exclusively with mesh size restricted to between 162.5 and 245 mm, though market demand for small fillet product has resulted in most fishing being conducted with 162.5 and 178 mm mesh nets. Specific net characteristics such as make, colour and strength of monofilament line strength, net length and depth, and mesh hanging ratio vary with individual fisher preferences.

Operators use arrays of static gill nets to catch target species. Nets are generally set perpendicular to riverbanks or foreshores and anchored securely at both ends. Fishing occurs 24 hrs a day with soak times varying between 4 to 12 hrs depending on water temperature, tidal cycles and catch rates. Market product is generally frozen fillet form, which is sold on the domestic market usually interstate.

Though the primary target of the fishery is barramundi (*Lates calcarifer*), various other species are also targeted at times. Most notable are the king threadfin (*Polydactylus macrochir*), blue threadfin (*Eleutheronema tetradactylum*) and grunter bream (*Pomadasys kaakan*). The GoC mixed estuary fishery is operated in a similar fashion as the east coast "mixed fishery". See Section 6.3.5 for an explanation of net setting methods. The net mesh sizes used in the GoC mixed estuary fishery are restricted to those used in the GoC barramundi fishery and the seasonal closure also applies.

6.3.7.1 Logbook Program in the Gulf of Carpentaria Barramundi Fishery

Only one fisher returned logbook data with 259 net shots being recorded. A combined total of 3 222 fish from 17 species, three mud crabs (*Scylla serrata*), and two estuarine crocodiles (*Crocodylus porosus*) were captured (Table 9). Fish from twelve species were retained for market and represented 86.0% of the total catch. Five species dominated the marketable catch; barramundi (48.1%), golden catfish *Arius thalassinus* (19.4%), king threadfin (6.1%), queenfish (4.5%), and blue threadfin (4.2%) (Figure 9a). The remaining seven species retained for market represented a further 3.7% of the total catch. Bycatch was estimated at 14.0% with catfish *Arius* spp. (3.8%) and shark *Carcharhinus* spp. (3.7%) the dominant species. Five species were caught but not marketed being exclusively bycatch. Fish and crabs released due to non-conformance to regulated size limits represented 1.6% of the total catch.

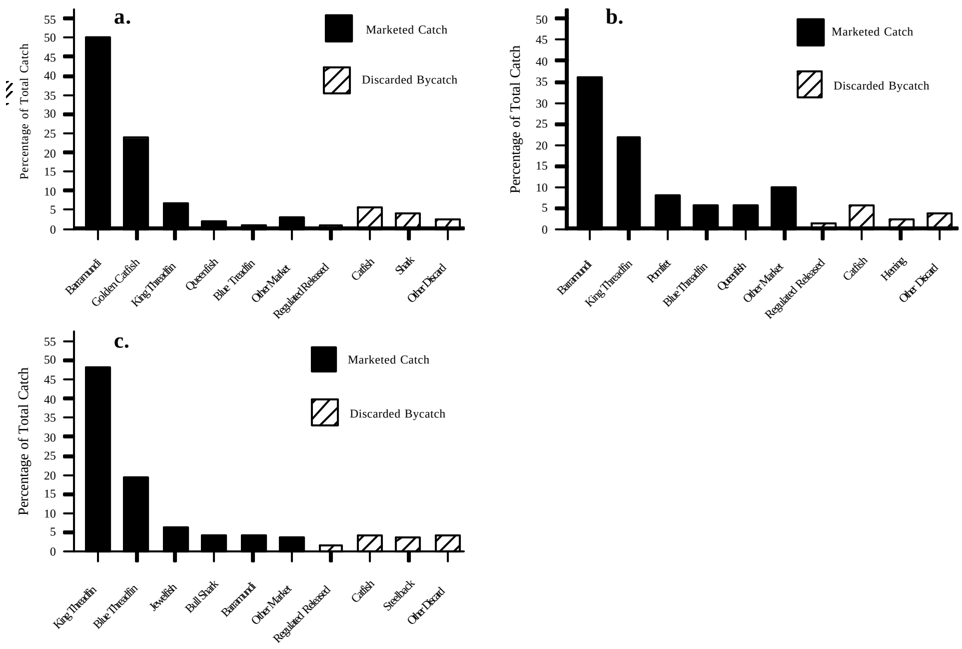

Figure 9: Catch composition from a. Gulf of Carpentaria barramundi logbook program, b. Gulf of Carpentaria barramundi observer program and c. Gulf of Carpentaria mixed estuary observer program (no logbook data was collected by fishers targeting mixed estuary fish.

6.3.7.2 Observer Program in the Gulf of Carpentaria Barramundi Fishery

The fishing activities of 4 commercial fishers were observed resulting in a total of 254 net shots being recorded. A combined total of 10,072 fish from 57 species, seven mud crabs, one turtle (*Natator depressus*) and five estuarine crocodiles (*Crocodylus porosus*) were captured (Table 9). Fish from twenty-two species were retained for market representing 86.9% of the total catch. Five species dominated the marketable catch; barramundi (36.1%), king threadfin (21.9%), black pomfret *Parastromateus niger* (8.0%), blue threadfin (5.7%) and queenfish (5.7%) (Figure 9b). The remaining 17 market species represented a further 9.8% of the total catch. Bycatch was estimated at 13.1% with catfish *Arius* spp. (5.6%) and bony bream *Nematalosa erebi* (2.0%) being the dominant species. No other species represented more than 1% of the total catch by number. Thirty-five species were captured but not marketed being exclusively bycatch. Fish and crabs released due to non-conformance to regulated size limits represented 1.4% of the total catch. The five estuarine crocodiles (*Crocodylus porosus*) and one flatback turtle (*Natator depressus*) were released alive after being observed entangled in nets.

Table 9: Gulf of Carpentaria barramundi fishery: species composition and discarding rates from 259 net shots reported in the voluntary logbook program, and from 254 net shots in the observer program in the tropical Gulf of Carpentaria, Queensland. TL = Total Length, CW = Carapace Width, CL = Carapace Length, NR = Not Regulated, P = Protected

Common Name	Species Name	Size Limit (cm)	Logbook Data (259 Net Shots) Retained	Logbook Data Discarded	Logbook Data % Discard	Observer Data (254 Net Shots) Retained	Observer Data Discarded	Observer Data % Discard
Barramundi	*Lates calcarifer*	> 60 < 120 TL	1550	380	19.7	3631	45	1.5
Golden Catfish	*Arius thalassinus*	NR	624	0	0	240	0	0
King Threadfin	*Polydactylus macrochir*	> 60 TL	197	6	3.0	2201	69	3
Queenfish	*Scomberoides commersonianus*	> 45 TL	144	16	10.0	569	0	0
Blue Threadfin	*Eleutheronema tetradactylum*	> 40 TL	137	1	0.7	570	7	1
Jewelfish	*Nibea squamosa*	> 45 TL	72	4	5.3	172	9	5
Black Jew	*Protonibea diacanthus*	> 60 < 120 TL	18	0	0	53	0	0
Black Pomfret	*Parastromateus niger*	NR	17	31	64.6	801	0	0
Grunter Bream	*Pomadasys kaakan*	>	6	0	0	245	6	2
Shark unspecified	*Carcharhinus* spp.	NR	5	119	96	58	57	50
Mud Crab	*Scylla serrata*	> 15 CW	1	2	67	5	2	29
Giant Seapike	*Sphyraena jello*	NR	1	0	0	0	2	100
Bull Shark	*Carcharhinus leucas*	NR	0	0		134	0	0
Pumpkinhead	*Trachinotus blochii*	NR	0	0		25	0	0
Steelback	*Leptobramma mulleri*	NR	0	8	100	20	0	0
Flagtail Flathead	*Platycephalus indicus*	> 30 TL	0	0		4	3	43
Diamond Scale Mullet	*Liza vaigiensis*	NR	0	0		4	0	0
Scalloped Hammerhead	*Sphyrna lewini*	NR	0	0		4	0	0
Fingermark	*Lutjanus johnii*	> 35 TL	0	0		3	0	0
Wide Sawfish	*Pristis microdon*	NR	0	4	100	2	25	93
Tripletail	*Lobotes surinamensis*	NR	0	0		2	0	0
Goldspot Cod	*Epinephilus coioides*	> 35 < 120 TL	0	0		2	0	0
Spanish Mackerel	*Scomberomorus commerson*	> 75 TL	0	0		2	0	0
Grey Mackerel	*Scomberomorus semifasciatus*	> 50 TL	0	0		2	0	0
Catfish unspecified	*Arius* spp.	NR	0	137	100	0	560	100
Bony Bream	*Nematalosa erebi*	NR	0	62	100	0	232	100
Spotted Scat	*Scatophagus argus*	NR	0	22	100	0	49	100
Winghead Shark	*Eusphyra blochii*	NR	0	0		0	95	100
Giant Shovelnose Ray	*Rhinobatos typus*	NR	0	0		0	34	100
Spotted Eagle Ray	*Aetobatus narinari*	NR	0	0		0	28	100
Striped Scat	*Selenotoca multifasciatus*	NR	0	0		0	15	100
Spotted Shovelnose Ray	*Rhynchobatus djiddensis*	NR	0	0		0	14	100
Diamondfish	*Monodactylus argenteus*	NR	0	0		0	14	100
Moonfish	*Drepane punctata*	NR	0	0		0	7	100
Giant Herring	*Elops australis*	NR	0	0		0	7	100
Narrow Sawfish	*Anoxypristis cuspidata*	NR	0	0		0	6	100
Soapy Jew	*Nibea soldado*	> 30 TL	0	0		0	6	100
Wolf Herring	*Chirocentrus dorab*		0	0		0	3	100
Tarpon	*Megalops cyprinoides*	NR	0	0		0	3	100
Striped Catfish	*Plotosid* spp.	NR	0	0		0	3	100
Bluetail Mullet	*Valamugil seheli*	NR	0	0		0	2	100
Milk Shark	*Rhizoprionodon acutus*	NR	0	0		0	2	100
Dwarf Sawfish	*Pristis clavata*	????	0	0		0	2	100
Giant Hammerhead	*Sphyrna mokarran*	NR	0	0		0	2	100
Catfish	*Cinetodus froggatti*	NR	0	0		0	1	100
Stingray	Dasyatididae	NR	0	0		0	1	100
Black Bream	*Acanthopagrus berda*	> 23 TL	0	0		0	1	100
Catshark	*Atelomycterus* spp.	NR	0	0		0	1	100
Giant Trevally	*Caranx ignobilis*	NR	0	0		0	1	100
Milkfish	*Chanos chanos*	NR	0	0		0	1	100
Tufted Sole	*Dexillichthys muelleri*	NR	0	0		0	1	100
Batfish	*Ephippid* spp.	NR	0	0		0	1	100
Leopard Whipray	*Himantura undulata*	NR	0	0		0	1	100
Tawny Nurse Shark	*Nebrius ferrugineus*	NR	0	0		0	1	100
Lemon Shark	*Negaprion acutidens*	NR	0	0		0	1	100
Archerfish	*Toxotes chatareus*	NR	0	0		0	1	100
Longtom	*Tylosurus crocodilus*	NR	0	0		0	1	100
Mangrove Jack	*Lutjanus argentimaculatus*	> 35 TL	0	0		0	1	100
Flatback Turtle	*Natator depressus*	P	0	0		0	1	100
Saltwater Crocodile	*Crocodylus porosus*	P	0	2	100	0	5	100
	Total Number of fish		2772	450		8749	1323	
	Percentage of total catch		86.0	14.0		86.9	13.1	

6.3.7.3 Logbook Program in the Gulf of Carpentaria Mixed Estuary Fishery.

No commercial fishers participated in this part of the project.

6.3.7.4 Observer Program in the Gulf of Carpentaria Mixed Estuary Fishery.

The fishing activities of 2 commercial fishers were observed while targeting mixed estuary fish with a total of 30 net shots observed. A combined total of 1 315 fish from 23 species and two marine turtles of two species (*Chelonia mydas* and *Natator* *depressus*) were captured (Table 10). Ten species were retained for market and represented 86.6% of the total catch. King threadfin and blue threadfin dominated the marketable catch representing 50.4% and 23.9% of the total catch respectively (Figure 9c). The remaining eight species retained for market contributed a further 12.4% to the total catch. Thirteen species were recorded as bycatch with catfish *Arius* spp. (5.8%) and steelback *Leptobrama mulleri* (4.1%) the dominant species. Fish released due to non-conformance to regulated size limits represented 1.2% of the total catch and included two protected grey nurse sharks *Carcharius taurus* that were both released alive. The two marine turtles observed caught in nets set by fishers targeting mixed estuary fish were released alive. No crocodiles, dugong or dolphins were captured or sighted within the vicinities of the fishing activities observed.

Table 10: Gulf of Carpentaria mixed estuary fishery: species composition and discarding rates from 30 net shots in the observer program in the Gulf of Carpentaria, Queensland. TL = Total Length, CW = Carapace Width, CL = Carapace Length, NR = Not Regulated, P = Protected

COMMON NAME	SPECIES NAME	SIZE LIMIT (cm)	OBSERVER DATA (30 SHOTS)		
			RETAINED	DISCARDED	% DISCARD
King Threadfin	*Polydactylus macrochir*	> 60 TL	663	9	1
Blue Threadfin	*Eleutheronema tetradactylum*	> 40 TL	314	0	0
Jewelfish	*Nibea squamosa*	> 45 TL	91	0	0
Bull Shark	*Carcharhinus leucas*	NR	29	0	0
Barramundi	*Lates calcarifer*	> 60 < 120 TL	14	4	22
Steelback	*Leptobramma mulleri*	NR	9	54	86
Shark unspecified	*Carcharhinus* spp.	NR	9	0	0
Black Pomfret	*Parastromateus niger*	NR	6	0	0
Black Jew	*Protonibea diacanthus*	> 60 < 120 TL	3	0	0
Tripletail	*Lobotes surinamensis*	NR	2	0	0
Catfish	*Arius* spp.	NR	0	76	100
Eagle Ray	*Aetobatus narinari*	NR	0	17	100
White Spot Shovelnose	*Rhynchobatus djiddensis*	NR	0	3	100
Wide Sawfish	*Pristis microdon*	NR	0	2	100
Grey Nurse Shark	*Carcharius taurus*	P	0	2	100
Giant Shovelnose	*Rhinobatos typus*	NR	0	1	100
Milk Shark	*Rhizoprionodon acutus*	NR	0	1	100
Frogfish	*Cinetodus froggatti*	NR	0	1	100
Stingray	Dasyatididae	NR	0	1	100
Bombay Duck	*Harpodon translucens*	NR	0	1	100
Bluetail Mullet	*Valamugil seheli*	NR	0	1	100
Toad Fish	*Tetradontid* spp.	NR	0	1	100
Grouper	*Epinephelus lanceolatus*	> 35 < 120 TL	0	1	100
Green Turtle	*Chelonia mydas*	P	0	1	100
Flatback Turtle	*Natator depressus*	P	0	1	100
	Total Number of fish		1140	177	
	Percentage of total catch		86.6	13.4	

6.3.7.5 Locality and Seasonal Effects in Gulf of Carpentaria Fisheries.

Observers conducted twelve trips collecting information on GoC river fishing targeting barramundi and foreshore fishing targeting mixed estuary fish. Temporally displaced samples were collected from some locations though not others, with the number of net shots observed also varying between trips (Table 11). The bycatch component of the total recorded catch varied between trips with a low of 4.2% in the South River 2 location and a high of 29.9% at North Foreshore 2. The highest number of bycatch species (18) was recorded at North Foreshore 2, while only two bycatch species were recorded at North River 1. Correlations between catch rates of bycatch fish and catch rates of market fish did not display a consistent pattern between samples. For both samples collected from fishers targeting mixed estuary fish, catch rates of bycatch species were negatively correlated with the catch rates of market fish (Table 11). Conversely, 8 of 10 samples collected from fishers targeting barramundi had positive correlations, although most were weakly correlated, with the remaining two displaying weakly negative correlations.

Table 11: Summary of the locations, dates, target species and number of replicate net shot samples collected by the Gulf of Carpentaria observer program. The number of bycatch species, their contribution to the total catch and correlation coefficients (CC) of bycatch catch rates to market catch rates are given.

LOCATION	DATE	TARGET	# NET SHOTS	% BYCATCH	# BYCATCH SPECIES	CC
South Foreshore 1	May 1998	Mixed Estuary	22	8.8	9	- 0.13
South Foreshore 2	Aug 1998	Mixed Estuary	8	21.5	8	- 0.56
South River 1	June 1998	Barramundi	33	11.7	7	0.65
	July 1999	Barramundi	33	14.1	8	0.14
	Feb 2000	Barramundi	72	10.1	12	0.40
South River 2	Aug 1998	Barramundi	6	4.2	7	0.21
South River 3	Aug 1998	Barramundi	18	14.4	6	0.19
North River 1	Sept 1998	Barramundi	6	12.2	2	- 0.07
	Aug 1999	Barramundi	32	14.5	14	0.28
North Foreshore 1	Sept 1998	Barramundi	20	9.1	9	0.32
	Aug 1999	Barramundi	14	29.9	12	- 0.07
North Foreshore 2	Sept 1998	Barramundi	20	16.9	18	0.12

Variability was observed in the catch rates of bycatch between locations and between times for locations sampled more than once (Figure 10). The lowest mean catch rates of bycatch were estimated for trips undertaken during June and July, the coolest months of the year. Higher rates of bycatch were estimated for trips undertaken during the warmer months. Given this seasonal variability, catch rates generally remained at around a level of 0.001 and 0.003 fish/metre/hour.

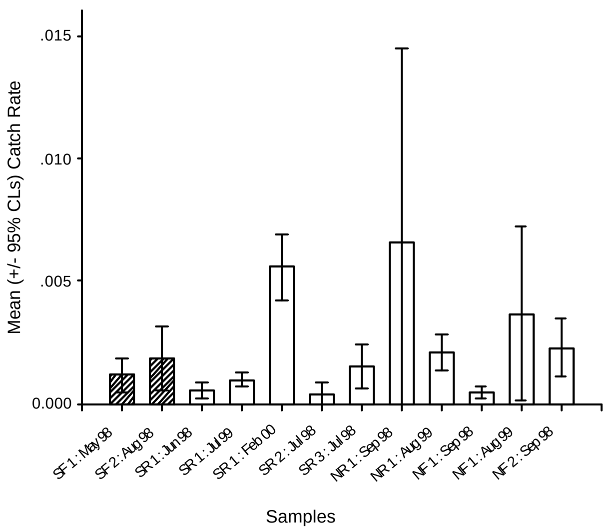

Figure 10: Mean (+/- 95% CLs) catch rates (fish/m/h) of bycatch recorded for each sampling event recorded from the Gulf of Carpentaria. S: southern gulf; N: northern gulf; R: river; F: foreshore. Hashed bars represent samples where mixed estuary fish were targeted; clear bars where barramundi was targeted.

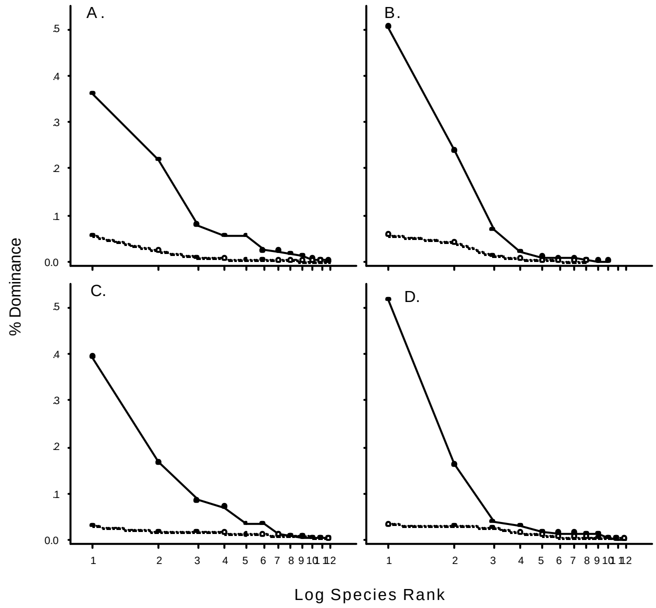

Figure 11: Dominance plots showing the relative contribution of market and bycatch components of the total catches recorded in the observer program for tropical set net fisheries targeting A. GoC barramundi, B. GoC mixed estuary, C. EC barramundi and D. EC mixed estuary (Market = solid dots and lines; Bycatch = hollow dots and broken lines).

Table 12: The ten most abundant bycatch species observed at each location in decreasing order of abundance for dominance plots of Gulf of Carpentaria barramundi and mixed estuary fisheries.

June 1998	South River 1 July 1999	Feb 2000	South Foreshore 1 May 1998	South Foreshore 2 Aug 1998	North Foreshore 2 Sept 1998
Bony Bream	Catfish	Catfish	Catfish	Steelback	Catfish
Catfish	Bony Bream	Bony Bream	Eagle Ray	Catfish	Eagle Ray
Sawfish	King Threadfin	King Threadfin	King Threadfin	Shovelnose	Scat
Barramundi	Scat	Barramundi	Barramundi	Stingray	Grunter
Scat	Barramundi	Scat	Shark	Pufferfish	Barramundi
King Threadfin	Soapy Jew	Shovelnose	Sawfish	Mullet	Blue Threadfin
Soapy Jew	Blue Threadfin	Soapy Jew	Grouper	Bombay Duck	Moonfish
	Stingray	Giant Herring	Shovelnose		Shovelnose
		Sawfish			Sawfish
		Gar			Giant Herring

North River 1		North Foreshore 1		South River 2	South River 3
Sept 1998	Aug 1999	Sept 1998	Aug 1999	Aug 1998	Aug 1998
Catfish	Catfish	Catfish	Shark	Catfish	Catfish
Barramundi	Bony Bream	Shovelnose	Catfish	Batfish	Barramundi
	Shark	Sawfish	Shovelnose	Barramundi	Sawfish
	Diamondfish	Shark	Sawfish	Bony Bream	Scat
	Scat	Barramundi	Mullet	King Threadfin	Barracuda
	Barramundi	King Threadfin		Scat	Archerfish
	Soapy Jew	Stingray			
	Wolf Herring	Sole			
	Sawfish				
	Shovelnose				

The composition of bycatch indicated selective capture by the gears used. In all samples, the two most abundant species represented at least 60% of the total bycatch (Figure 11). Catfish were the most abundant bycatch species in nine of the twelve samples collected (Table 12). Bony bream *Nematalosa erebi* (the second most abundant bycatch species overall) were a consistent bycatch component at South River 1. Regulated species released (mostly undersized barramundi and king threadfin) contributed to the bycatch of most samples, though representing only a minor proportion of the total bycatch.

6.4 Discussion of Bycatch in Net Fisheries

The low bycatch rates within the inshore gill net fisheries of Queensland indicate that the targeting of specific species is effective. As each species for market is generally targeted using particular mesh sizes, the effects of differing mesh sizes on the catch rates within each fishery could not be determined. It is interesting to note that the bycatch levels within all the net fisheries are similar (7 – 28%) even though the size ranges of species targeted differ considerably.

From the logbook and observer data it can be seen that the sea mullet fishery is effective at targeting the desired species and good use is made of some of the other estuarine fish that are also caught in large numbers. Bycatch rates are low and are comprised of many species that occur only occasionally in catches. Previous studies of sea mullet fisheries have shown through both fishery-dependent and fishery-independent methods (Hale *et al.* 1996, Pierce *et al.* 1998) that targeting of sea mullet schools is one of the most effective means of catching this species. Even with low reported bycatch rates within the fishery in Florida, where sea mullet as a percentage of total catch was calculated at 99% (Hale *et al.* 1996) and between 16-100% (Pierce *et al.* 1998), the fishery was closed due to legislation effectively banning gill net fishing throughout the state due to a community-based referendum with bycatch of sport fish as the major issue (see Hale *et al.* 1996 for a description of events). Based on this outcome, it would appear that it is necessary to change the public image of commercial net fisheries if they are to continue to exist in the future. The misconceptions generated in the general public of how effectively net fishers can target their selected species have become one of the major problems facing the commercial industry. The low bycatch rates and high proportion of marketable species caught in the Queensland fisheries, as demonstrated by our study, should provide a more informed basis on which the effects of net fishing on ecological systems can be debated.

The Queensland whiting fishery catches a greater number of fish species and a higher proportion of bycatch than the sea mullet fishery. The whiting fishery can be considered to be a true “mixed species” fishery. Fishers target whiting as this is the highest priced fish that they catch in southern Queensland waters, but they also expect to catch bream, sea mullet, dusky flathead and tailor of marketable quality. Along with these species there are a number of other species caught that are not targeted (such as tarpon, estuary cod and gar) that are often sold if caught. Silverbiddies are marketed in considerable quantities in NSW where about 150 t per annum are sold (Pease 1999). This represents an area where potential markets for Queensland product could be further developed. If a consistent demand for this species eventuated this would result in an approximate 40% decrease in the bycatch currently discarded in this fishery. Developing markets for stingrays, that are currently not utilitised at all, has the potential of reducing the amount of bycatch taken within this fishery even further.

The inshore net fisheries of southern Queensland tend to have increased catch rates during the autumn and winter and significant increases occur in the catch rates of many of the marketable species. This increase occurs at the time when there is an influx of spawning sea mullet, whiting, yellowfin bream and tailor into the lower reaches of estuaries. Increased catches in dusky flathead during winter, may be related to their increased access to littoral zones during winter night-time spring tides and is probably not related to reproductive behaviour as flathead spawn in similar areas during summer (Dredge 1976).

Another possible factor for this increase could be the preference of many fishers to fish at night. Night fishing is preferred for a number of reasons, including better product quality, interactions with the general public and the recreational fishing community are minimised and catch rates at night are generally higher than during the day. It may be that another factor is the influencing catch rates during winter is the height of the tide at night. In southern areas of Queensland the tidal range usually causes the highest night time high tide of the year to be during winter and the highest day-time tides to occur during the summer. These spring tides in winter allow a much greater access to the littoral zone during the night attracting more fish into these areas to feed. Greater numbers of fish on the banks increases the number of fish available to be caught while net fishing in these areas. During the summer, with lower night-time high tides than in winter, fish access to the littoral zone is restricted and not as many fish occupy these areas. The added effect of fish that are schooling as part of their spawning behaviour with many congregating in or around the mouths of estuaries to spawn, would provide opportunities for greater catch rates to occur.

If Queensland's fisheries managers consider implementing an increased size limit on species such as yellowfin bream (currently 23 cm TL) sand whiting (23 cm TL) and dusky flathead (currently 30 cm TL) aligning with New South Wales legislation, there would be a good argument for an increase in the minimum mesh size used to target whiting as most whiting caught are at or just above the legal size. Kennelly and Gray (2000) showed that increasing the mesh size in the bunt and cod-end of whiting seine nets from 50 to 57mm resulted in significant increases in the length frequency of whiting caught with significant decreases in the proportion of undersized sand whiting caught. These authors did warn that such an increase in mesh size may increase the bycatch of undersized regulated species if fishers were not directly targeting sand whiting (*Sillago ciliata*). Management intervention to increase the minimum size of bream and flathead would also warrant consideration of the effect that this would have on the harvest fishery production.

In the tropical Queensland net fisheries our investigations showed that the fishing gears and methods employed by the fishers were selective in harvesting the nominated target species. The East Coast (EC) and Gulf of Carpentaria (GoC) inshore set net fisheries are commonly referred to as barramundi fisheries, but would be better described as multi-species fisheries as barramundi is often not the only species actively targeted. Along with barramundi, three other species are actively targeted during the fishing year – the king and blue threadfins, *Polydactylus macrochir* and *Eleutheronema tetradactylum*, and grunter bream *Pomadasys kaakan*. When the catch of these "additional" target species is considered, both the tropical EC and GoC fisheries display highly selective characteristics. Similarly, the catches of fishers targeting “mixed estuary” on the EC or in the GoC also display high selectivity. The dominance of catches by market species is better highlighted when the relatively low representation of the bycatch species in net catches is considered (Figure 8, Figure 11).

The low rates of bycatch that were established for each of the Queensland net fisheries indicates that levels of bycatch and its composition should not be an issue in relation to ecological impacts of the fisheries concerned. Generally, catch rates of bycatch are low when compared with other commercial fisheries including northern Australian prawn trawling bycatch to target weight ratios of between 3.3:1 (Harris and Poiner 1990) and 21:1 (Pender 1992) and estuary seine netting where 44% of individuals are discarded (Gray *et al*.). Six of the seven fisheries that were investigated would be ranked in the ten lowest “observed numbers-based discard ratios other than shrimp” as reported by the FAO (Alverson *et al*. 1994).

The Environment Protection and Biodiversity Conservation Act which came into place in July 2000 requires that all fisheries which export their product are examined with respect to the sustainability of the target species, bycatch species and their impacts on the environment. Sea mullet roe is the only product exported from the net fisheries examined and the sea mullet fishery that will need to meet the requirements of this Act if the export of roe is to continue. This highly targeted fishery is part of a long term monitoring project carried out by the Queensland Fisheries Service measuring the age structure of the sea mullet catch for use in age based stock assessments, has low levels of bycatch and has little impact on the environment. These sources of information should allow the sea mullet fishery to substantially meet the requirements of this Act.

Catches of protected species within all observed net fisheries was low with no capture resulting in immediate death. We would consider that net fishing is not a major threat to any of the species encountered during the observer program however in cases where species are considered to be endangered a more directed approach to estimating the actual catch rates should be undertaken.

The issue with bycatch is often that many undersized fish of the targeted species are caught and discarded dead as a result of the capture process. Although discarding of undersized individuals was low in all the net fisheries examine we attempted to establish estimates of the fate, after discarding, of some of the more abundant species caught in these net fisheries. This was done using the undersized regulated fish and bycatch species from within the whiting fishery (this was the only fishery examined where large enough quantities of undersized fish were caught to conduct meaningful trials) with some estimates of the immediate fate of fish discarded from within the other fisheries examined during observer trips.

7. FATE OF FINFISH DISCARDED FROM NET CATCHES

7.1 Methods for determining the fate of discarded bycatch

Fate trials were conducted to determine the mortality of individuals after capture and subsequent discarding. Fish species used in the fate trials were determined from information on bycatch species collected in the logbook and observer programs. This information precluded the use of any of the northern species in these experiments due to the very low catch rates recorded for those species of interest (undersized fish of commercial and/or recreational importance such as barramundi, blue threadfin, king threadfin, dusky flathead and grunter bream, see Chapter 6 Tables 5, 6, 9 and 10). In lieu of dedicated fate trials for northern species, the condition (alive or dead) of all net caught regulated fish was recorded at the time of release during the observer program.

In contrast, higher bycatch rates of a number of regulated species within the southern net fisheries allowed sufficient numbers to be obtained for fate trials. Fish of four species, yellowfin bream *Acanthopagrus australis,* dusky flathead *Platycephalus fuscus*, sand whiting *Sillago ciliata*, and silverbiddy *Gerres oyeana* were collected on three occasions from the catch of a commercial fisher targeting sand whiting in Tin Can Bay, Queensland. One net, 800 m long and 51 mm mesh size was set about 3 hrs after high tide along the line of the low water mark on the edge of seagrass and sandbanks. After most of the water had drained off the bank, fish were collected from the net starting at one end and working towards the other.

As this experiment was designed to estimate the mortality of fish after their removal from a net by commercial operators, only the commercial fisher removed fish from the net. This usually involved the fish being forced headfirst through the meshes of the net and then being pulled free. Fish removed from the net were measured and undersized fish of the desired species as well as silverbiddies were transferred into a 200 litre holding tank half filled with water. Water exchange was carried out about every 15 minutes by replacing half of the water in the holding tank with clean water bucketed into the tank. Once approximately ¼ of the net had been cleared (30 minutes), fish from the holding tank were transferred into specially designed holding cages placed on the substratum below the low tide level. Sites were carefully selected to allow the holding cages to be placed in areas of low current flow and minimal exposure to prevailing south-east winds minimising their exposure to wave action. Fish were placed in these cages at a maximum stocking rate of 10 fish per cage for the yellowfin bream, summer whiting, and flathead and at 20 fish per cage for silverbiddies. Each cage contained only the one species. During each collection the number of each species of fish used varied and therefore the numbers of cages used in the experiment for each species differed between trips.

Two types of holding cages were used during this experiment. One type was made of a cylindrical steel frame 900 mm in diameter and 400 mm deep and covered with 5 mm square plastic mesh. This type of cage sunk to the bottom resting on the substratum. The other cage type floated, had PVC framing and was covered with 1 mm mesh with overall dimensions being the same as for the sinking cage type. Over the three days of each experiment, each cage was checked daily and any dead or near dead fish removed. Experiments were carried out during February, April and July 2000 to determine seasonal influence on the mortality rates with changes in water temperatures. Water temperature and tidal height were recorded every 5 minutes using a Vemco datalogger placed in the bottom of one of the sinking cages over the three days of each experiment.

These data were analysed using a linear regression with a maximal model of site (time in net)+ fish length + cage type + season. Because of the unbalanced nature of the sample numbers over different times, higher order interactions were not analysed. For yellowfin bream, whiting and dusky flathead the model was reduced to season as all other factors did not significantly improve the percentage of variability explained. All major factors were included in the analysis of silverbiddy data.

Cage trials to determine the fate of discarded bycatch were carried out under "Animal Ethics Approval No: BRIBIE/24/1999".

7.2 Results of Fate of Discarded Bycatch

7.2.1 Southern Fish Species

During the three day fate trials no undersized yellowfin bream died (n = 48 cumulative number over all three times). Undersized dusky flathead had estimated three day mortalities of 19 ± 10% (n = 58), undersized sand whiting 12 ± 5% (n = 178) and silverbiddies an estimated rate of 67 ± 4% (n = 197). Mortality rates of silverbiddies were, cage type, size and seasonally dependent. Mortality rates were highest for small silverbiddies during winter with lower mortalities occurring in the sunken cages. Undersized yellowfin bream, whiting and flathead did not show any length, cage type or seasonal variation in their mortality rates after discarding from the nets. Although no control experiments were conducted caging effects appeared small. With mortality rates expected to increase as a result of caging effect the relatively low mortality rates for sand whiting and dusky flathead indicate that for some species at least this caging effect was not large.

The survival of all the yellowfin bream indicated that post-release mortalities due to capture and handling are probably low. This is important as about half the yellowfin bream caught in the sea mullet and whiting fisheries are discarded because they are under the legal size. Broadhurst *et al.* (1999) reported negligible mortalities in yellowfin bream 30 days after simulated escape from a Nordmore-grid guiding panel designed to exclude bycatch from trawl fisheries. Many of the yellowfin bream were removed from gill nets tail-first as their body morphology makes gilled fish easier to remove this way rather than forcing the whole fish forwards through the net. Bream caught in net fisheries are unlikely to experience the same physical stresses as trawl caught fish. The static use of gill nets does not cause crushing of each individual as the net is hauled and a reduced time out of the water probably help reduce this mortality.

Mortality rates of undersized dusky flathead caught in gill nets were estimated at 19 ± 10% of discarded fish. Discarding rates of undersized flathead peak in winter with 10 ± 2 fish/shot and are much lower, 2-5 fish/shot, for the other seasons (Figure 4g). Mortalities may be higher than this over a longer time period as abrasions and scale loss caused by removal from the net were evident in all fish surviving the three day trial.

Mortalities of discarded undersized sand whiting were estimated to be 8-17%. Undersized sand whiting were reported to be discarded at 2-7% (Table 3). Highest catch rates of undersized whiting were recorded during winter with an estimated 15 ± 3 fish/shot caught. During other seasons, between 1-5 fish/shot were caught. Kennelly and Gray (2000) estimated a 40% mortality rate for undersized summer whiting (< 25 cm FL in NSW) held in laboratory conditions for 24 days after being caught and gilled in 50 mm mesh nets. These authors noted that the greatest mortality rates were recorded between the 5^{th} and 11^{th} days of the experiment by which time 36.3% had died. This higher rate of mortalities occurred at a time long after our experiment was terminated. It is feasible that the mortality rate of sand whiting would have continued to increase had our experiment been run for a longer time period as abrasion and scale loss from around the maximum girth of net caught whiting was evident in all individuals caged.

Silverbiddies showed considerably higher three day mortalities than any of the three regulated fish species investigated. With high three-day mortalities of 67 ± 4% it would appear that the majority of silverbiddies caught and then discarded in the whiting fishery would die soon after release. With winter catches of this species being high (430 ± 126 fish/shot) it would appear that better use could be made of these net captures. Being soft bodied, with scales that are easily shed and being susceptible to gill meshing in a 51 mm net many of the silverbiddies removed from the net are already in poor condition or dead. Silverbiddies held in the cages were observed to shed many scales presumably because of their continued contact with the sides of the cage while daily checks on fish condition were carried out.

7.2.2 Tropical Inshore Net fisheries

Though dedicated fate trials were not conducted on fish species discarded from the tropical net fisheries, observed on board commercial vessels recorded the condition of every fish released because of legal size constraints or because of the species protected status. Some patterns worthy of mention were observed within bycatch composition of both the EC and GoC fisheries.

For the barramundi and mixed estuary fisheries observed on the east coast, four categories of mesh size were defined and their effects on bycatch composition and bycatch catch rates were investigated. Within the GoC, the fishing activities observed were mostly conducted with nets of 165 and 178 mm mesh size with a minor amount of fishing effort with larger mesh nets (216 mm) occurring irregularly. As such, mesh size was considered to remain fixed between locations, times and target species allowing the effect of each of these factors on bycatch composition to be considered.

The commercial fishers who voluntarily participated in this project did so on the condition that absolute catch rates of market species and the specific locations fished would be confidential. As such, any discussion of market catch components do not present absolute catch rate information, and the locations where fishing was observed will be referred to as general areas.

7.2.2.1 Observed fate of discarded fish from Tropical East Coast Fisheries

In the EC barramundi fishery, a total of 31 captured fish from two species were returned to the water as regulated individuals (Table 13). None of the three regulated blue threadfin captured were alive when released, while all but one of the 28 regulated barramundi were live when released. The discard rates (proportion of the total number of fish from each species captured that had to be released due to non-conformance to size limits) of both species was very low (4.3% of the barramundi caught and 1.1% for the blue threadfin (Table 13)). The twenty-four mud crabs observed entangled in nets were all released alive. A single grey nurse shark (a protected species in Australian waters) was released alive after being observed entangled in a net.

Thirty regulated fish from three species were captured during the observed target fishing for mixed estuary species on the Queensland East Coast (Table 13). All 15 of the blue threadfin captured were dead when released, while all 14 barramundi and the single grunter bream were live when released. Discard rates were low for blue threadfin (6.0%) and grunter bream but high for barramundi (93.3%).

Table 13: Regulated species observed caught in the tropical inshore net fisheries showing size limits, % of each species discarded due to non-conformance to these limits, the total number of fish captured and the % of discarded fish that were alive when returned to the water.

SPECIES	SIZE LIMITS Min	Max	% DISCARD	# REGULATED FISH	% ALIVE AT RELEASE
EC BARRAMUNDI					
Lates calcarifer	58	120	4.3	28	96.4
Eleutheronema tetradactylum	40	na	1.1	3	0
Scylla serata	15		77	24	100
Carcharias taurus	Protected		100	1	100
EC MIXED ESTUARY					
Eleutheronema tetradactylum	40	na	6.0	15	0
Lates calcarifer	58	120	93.3	14	100
Pomadasys kaakan	30	na	11.1	1	100
GoC BARRAMUNDI					
Polydactylus macrochir	60	na	3.0	69	36.2
Lates calcarifer	60	120	1.2	45	88.9
Nibea squamosa	45	na	5.0	9	55.6
Eleutheronema tetradactylum	40	na	1.2	7	0
Pomadasys kaakan	40	na	2.4	6	100
Platycephalus indicus	30	na	20.0	1	100
Lutjanus argentimaculatus	35	120	100	1	100
GOC MIXED ESTUARY					
Polydactylus macrochir	60	na	1.3	9	22.2
Lates calcarifer	60	120	22.2	4	75.0
Epinephelus lanceolatus	35	120	100	1	100
Carcharias taurus	Protected		100	2	100

7.2.2.2 Observed fate of discarded fish in the Gulf of Carpentaria Fisheries

In the GoC barramundi fishery, a total of 138 fish from seven species were returned to the water as regulated individuals. The discard rates of each of the regulated species was generally very low (Table 13), with regulated king threadfin and barramundi the most frequently captured. The survival rates recorded displayed species specificity with the blue and king threadfins recording the lowest survival rates (36.2% and 0% respectively, Table 13). Undersized barramundi were much more robust to capture in the nets with 88.9% of fish alive when released.

Fishers captured 14 individuals from three species that were size-regulated fish when targeting mixed estuary species in the Gulf of Carpentaria (Table 13). Of the 9 undersized king threadfin caught only two were released from the net and returned to the water alive. Four barramundi were captured with one fish exceeding the maximum size limit. This fish was tagged and released alive by the fisher. One of the three under sized barramundi was dead when returned to the water. One Queensland Grouper that also exceeded the maximum size limit for the species was captured and released alive. Two captured grey nurse sharks were also released alive from the netsFrom the direct observation of the fate of discards it is clear that softer bodied fish with small scales (blue threadfin, king threadfin and jewelfish) are likely to have high mortality caused by the capture process alone. This indicates that future stock assessments of threadfins should take the discarding rates as added fishing induced mortality. This is in direct contrast to more robust species with large scales, such as barramundi and banded grunter, that have a high probability of being discarded alive. Estimating the post-release mortality for barramundi would require a directed fishing independent study to collect undersized fish with gill nets as commercial catches rates of undersized barramundi are too low for sufficient numbers to be collected for valid trials to be carried out. Very few specimens of protected species were observed caught with all being released alive.

8. FISHERY-INDEPENDENT SAMPLING

8.1 Methods

8.1.1 Site Selection Procedures

Our design objective was to collect samples that were as similar as possible except for the fact that they were from commercially gill netted versus not commercially gill netted rivers. Extraneous sources of variation were minimised in the design process. Primary temporal sources of variation were identified as tidal cycles/moon phases, seasons, and known spawning seasons of target fish species. Spatial sources of variation included rainfall distribution patterns, proximity to offshore features, latitudinal changes in tidal range, and catchment features. These parameters interacted across the study area (Figure 12) generating a complex set of environmental conditions.

Closed river systems selected as candidate rivers were all pre-existing and had been closed to commercial netting for a minimum of 5 years. Paired river systems (open and closed) were selected using the physical characteristics of their catchments. These were:
(1) area of catchment/length of main channel,
(2) land elevations,
(3) direction of river course with respect to the coast,
(4) land use and extent of native riparian habitat, and
(5) extent and characteristics of mangrove wetlands.
One pair of rivers in three geographic regions (north, middle and south) were selected. The three geographic regions were distinguished from one another by average annual rainfall (Table 14).

8.1.2 Characteristics of the research nets.

In each study system, two identical “fleets” of gill nets were used to sample upstream and downstream sites simultaneously. Each “fleet” consisted of two identical/replicate 102 mm and 152 mm mesh nets, together with a single 51 mm mesh net and a smaller mesh multi-panel net. The multi-panel net comprised panels of 19 mm, 25 mm and 32 mm mesh joined end to end to make one continuous net. Each net was constructed by hanging the mesh panels on 12 mm cored float and lead line. The cored lead line weighed 0.4 kilograms/metre, and was sufficiently heavy to ensure each net fished from the substrate to the surface at each site. The cored float line was supplemented with small torpedo floats at a spacing of 1.5 metres. Specifications of nets are given in Table 15. All research activities were carried out under “General Fisheries Permit No: 5900”, “General Fisheries Permit No: PRM00686F” and “Animal Ethics Approval No: BRIBIE/22/1999”.

8.1.3 Sampling periods

Survey sampling was undertaken every second month from March 1998 until March 2000 and unfortunately could not be uniformly structured with respect to lunar phase (Table 16). The Bowen to Cairns region has a semi-diurnal tidal cycle with the unusual characteristic of having larger high tides at night during the summer months and larger high tides during the day throughout the winter months. As effective sampling with fixed gill nets is not possible during large tidal flows, the “best set” of neap tides available within each second calendar month was chosen for the sampling.

8.1.4 Sampling Regime

On each sampling day, the replicate 102 mm and 152 mm mesh nets were set at each of the upstream and downstream sites from a research netting vessel between 1430 and 1500 hrs. Soak time for these large mesh nets was ~6 hrs with all nets being retrieved as close to 2100 hrs as possible. Large mesh nets were set predominantly off deep eroded banks with a distance of at least 100 m between each net, so the possible competition or interaction between the nets was assumed to be negligible. Where possible, the nets were also staggered from opposing banks at the sites. One end of the net was fixed securely to the bank (usually by the float line being tied to the base of a large mangrove), the net was then deployed perpendicularly to the bank (and hence, tidal flow). The outer end of the net was fixed in position by attaching an anchor and chain with 15 m of line to the float rope allowing the mesh panels to be vertically suspended in the water. Light-sensitive strobe lights marked the extreme ends of all nets in the hours of darkness. During each sampling trip we tried to maintain a high degree of site fidelity by setting all nets as near as possible to the same location.

In order to avoid catching excessively large catches of shoaling bait-fishes, such as clupeids and engraulids, the 51 mm and multi-panel nets were "fished" for one hour either side of dusk. For the daytime soak, both nets were set between 1630 and 1700 hrs and retrieved between 1730 and 1800 hrs. The nets were re-set for the night-time soak between 1830 and 1900 hrs, with final retrieval between 1930 and 2000 hrs.

Table 14: Summary of site evaluations for riverine estuaries selected for use in the fishery-independent sampling program.

Criteria	Units	Russell	Hull	Haughton	Barrattas	Yellow Gin	Nobbies Inlet
Region		North	North	Middle	Middle	South	South
Commercial net fishing policy		Closed	Open	Closed	Open	Closed	Open
Sampling locations		Side branch west of confluence of Rivers & Maturo Inlet	West branch & lower main branch	Main channel	Short Cut & main channel	Sugarloaf & Saltwater Creek branches	Cape Creek
Latitude	Deg/Min S	17° 14'	18° 00'	19° 15'	19° 25'	19° 45'	19° 50'
Longitude	Deg/Min E	145° 58'	146° 05'	147° 08'	147° 17'	147° 35'	147° 45'
Basin name	Basin	Russell-Mulgrave	Tully	Haughton	Haughton	Don	Don
Receiving waters		Coral Sea	Coral Sea	Bowling Green Bay	Bowling Green Bay	Upstart Bay	Upstart Bay
Aspect of Flow	upstream to down	west - east	nw to se	south to north	south to north	west to east	south to north
Main navigable channel	kilometres	7	9	15	10	15	12
Obstructions				low weir	low weir	low weir	
Maximum Elevations	metres	250	100	50	50	50	50
Topography		Rolling hills	Rolling hills	Flat	Flat	Flat	Flat
Land use		Sugar cane / National Park	Sugar cane / National Park	Cattle grazing / sugar cane	Cattle grazing / sugar cane	Cattle grazing / sugar cane	Cattle grazing / sugar cane
Native communities		Rainforest	Rainforest	Dry eucalypt / salt flats / intermittent lagoons	Dry eucalypt / salt flats / intermittent lagoons	Dry eucalypt / salt flats / intermittent lagoons	Dry eucalypt / salt flats / intermittent lagoons
Mangrove habitat		Diverse	Diverse	*Rhizophora / Avicennia*	*Rhizophora / Avicennia*	*Rhizophora / Avicennia*	*Rhizophora / Avicennia*
Wetland width in km at:	1 km from mouth	0.5	1	4	3	1.5	1
	3 km from mouth	2.5	2.5	2.5	2.5	2.4	3
	10 km from mouth	na	na	2.5	0.5	fringe	fringe

Table 15: Specifications of the gill nets used in the fishery-independent study. (Note the 19, 25 and 32 mm mesh panels were hung end to end to make one continuous multipanel net of 38.1 m long).

Mesh Size (mm / inches)		Ply	# meshes deep	# meshes long	Hanging Ratio	Fishing Depth (m)	Fishing Length (m)
152	6	40	33	650	0.4	4.6	38.5
102	4	24	50	500	0.4	4.7	21.2
51	2	16	50	950	0.5	2.2	24.1
32	1 ¼	12	100	700	0.6	2.5	12.7
25	1	8	100	910	0.6	2.0	13.2
19	¾	6	100	1120	0.6	1.5	12.2

Table 16: Dates and site sampling sequences of the 13 fishery-independent sampling trips. After the second trip, a rest day was incorporated into the sampling program (dates shown shaded). Abbreviations are: Sth, southern rivers; Mid, middle rivers; Nth, northern rivers; O, open to commercial net fishing; C, closed to commercial net fishing; Q, quarter moon; NEW, new moon.

Trip No.								
1	Date:	16-Mar-98	17-Mar-98	18-Mar-98	19-Mar-98	20-Mar-98	21-Mar-98	
	Location:	**Sth-O**	**Sth-C**	**Mid-O**	**Mid-C**	**Nth-O**	**Nth-C**	
	Moon:						LAST Q	
2		13-May-98	14-May-98	15-May-98	16-May-98	17-May-98	18-May-98	
		Nth-C	**Nth-O**	**Mid-C**	**Mid-O**	**Sth-O**	**Sth-C**	
								LAST Q
3		27-Jul-98	28-Jul-98	29-Jul-98	30-Jul-98	31-Jul-98	1-Jul-98	2-Jul-98
		Mid-O	**Mid-C**	**Sth-O**	**Sth-C**		**Nth-O**	**Nth-C**
						FIRST Q		
4		23-Sep-98	24-Sep-98	25-Sep-98	26-Sep-98	27-Sep-98	28-Sep-98	29-Sep-98
		Nth-C	**Nth-O**		**Sth-O**	**Sth-C**	**Mid-O**	**Mid-C**
								FIRST Q
5		19-Nov-98	20-Nov-98	21-Nov-98	22-Nov-98	23-Nov-98	24-Nov-98	25-Nov-98
		Mid-C	**Mid-O**	**Sth-O**	**Sth-C**		**Nth-C**	**Nth-O**
		NEW						
6		18-Jan-99	19-Jan-99	20-Jan-99	21-Jan-99	22-Jan-99	23-Jan-99	24-Jan-99
		Sth-O	**Sth-C**	**Mid-C**	**Mid-O**		**Nth-C**	**Nth-O**
		NEW						
7		5-Mar-99	6-Mar-99	7-Mar-99	8-Mar-99	9-Mar-99	10-Mar-99	11-Mar-99
		Sth-O	**Sth-C**	**Mid-O**	**Mid-C**		**Nth-C**	**Nth-O**
							LAST Q	
8		4-May-99	5-May-99	6-May-99	7-May-99	8-May-99	9-May-99	10-May-99
		Nth-C	**Nth-O**		**Mid-C**	**Sth-O**	**Mid-O**	**Sth-C**
							LAST Q	
9		17-Jul-99	18-Jul-99	19-Jul-99	20-Jul-99	21-Jul-99	22-Jul-99	23-Jul-99
		Nth-C	**Nth-O**		**Sth-O**	**Sth-C**	**Mid-O**	**Mid-C**
					FIRST Q			
10		13-Sep-99	14-Sep-99	15-Sep-99	16-Sep-99	17-Sep-99	18-Sep-99	19-Sep-99
		Nth-C	**Nth-O**		**Mid-C**	**Mid-O**	**Sth-O**	**Sth-C**
							FIRST Q	
11		9-Nov-99	10-Nov-99	11-Nov-99	12-Nov-99	13-Nov-99	14-Nov-99	15-Nov-99
		Mid-O	**Mid-C**	**Sth-O**	**Sth-C**		**Nth-C**	**Nth-O**
								FIRST Q
12		10-Jan-00	11-Jan-00	12-Jan-00	13-Jan-00	14-Jan-00	15-Jan-00	16-Jan-00
		Sth-O	**Sth-C**	**Mid-C**	**Mid-O**		**Nth-C**	**Nth-O**
						FIRST Q		
13		9-Mar-00	10-Mar-00	11-Mar-00	12-Mar-00	13-Mar-00	14-Mar-00	15-Mar-00
		Sth-O	**Mid-C**	**Sth-C**	**Mid-O**		**Nth-C**	**Nth-O**
						FIRST Q		

8.1.5 Checking Nets

The replicate large mesh nets were checked for the presence of fish in the meshes every 1 to 1.5 hrs after setting. This check frequency enabled captured animals to be released alive after processing. On each net check, the entire length of each net was “run” from the research vessel with all captured animals removed. Checking of each net was most effectively achieved by hand-hauling the vessel along the net. This method prevented dragging or moving the net from the fixed position.

As the smaller mesh nets were “fished” for discrete periods, checking was achieved by retrieving the nets back aboard the research vessel and removing all captured animals by hand.

8.1.6 Fish Removal and Identification

In order to minimise the effects of the research netting on the fish fauna present at the sites, as many as possible of the captured fish were released after identification and measuring. To prevent unnecessary damage to the fish, net shears were used to cut any tight meshes that were caught behind the operculum. Most species of fish captured could be identified in the field. In cases of uncertainty, photographs were taken or a specimen retained for later identification in the laboratory.

8.1.7 Design of sampling program

The final design (Figure 12) integrated the dynamics associated with the six selected rivers into four spatial and temporal factors:

- *Region.* Three regions defined by environmental factors that changed across the latitudinal gradient, including rainfall, tidal range, and distance to the Great Barrier Reef: (a) northern sector (Cardwell to Cairns), (b) middle (Giru to Cardwell), (c) southern (Bowen to Giru).
- *Fishing.* Two fishing policies relative to commercial net fishing closures: (a) rivers closed to commercial net fishing versus (b) rivers open to commercial net fishing.
- *Position.* Two sites in each river encompassing habitat changes along the estuarine gradient: (a) upstream sites near the source of freshwater inflow (5 – 7 km from the mouth), and (b) downstream sites within 1 km of the mouth.
- *Trip.* Bimonthly sampling encompassing the temporal variation expected in the region over at least two years.

Throughout the text the spatial factors above are used to reference each site (ie north – open –upstream (Hull River) = NOU, north – closed – downstream (Russell River) = NCD, middle – closed-downstream (Haughton River) = MCD, mid-open-upstream (The Barrattas) = MOU, south-closed-upstream (Yellow Gin Creek) = SCU and south-open-downstream (Nobbies Inlet) = SOD.

8.1.8 Environmental Parameters

During the first year of sampling a HYDROLAB® datasonde 3 datalogger was deployed at the downstream site of each river during sampling that recorded water temperature, salinity and dissolved oxygen at 5 minute intervals. During the second year of sampling, two dataloggers were used in each river one at the upstream and one at the downstream site.

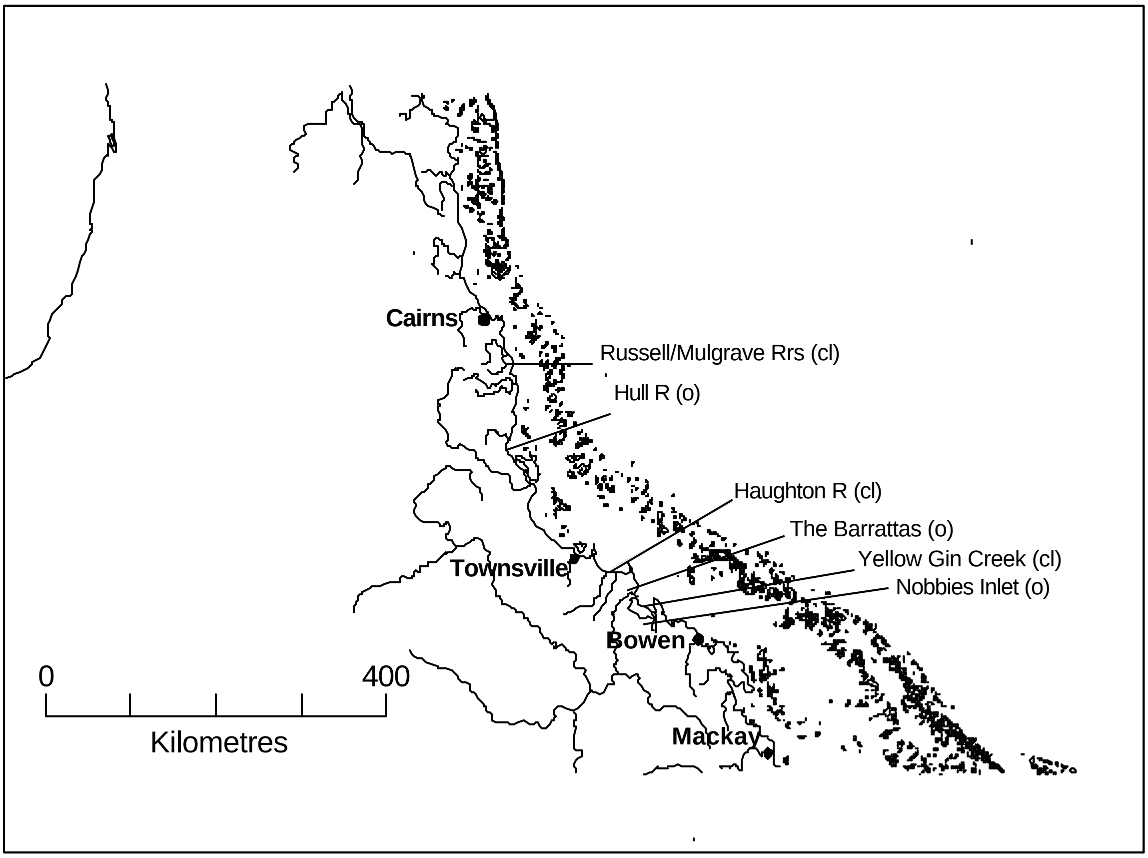

Figure 12: Map of study area showing pairs of open and closed riverine estuaries: North: Russell/Mulgrave (closed) versus Hull (open); Middle: Haughton (closed) vs Barrattas (open); South: Yellow Gin (closed) vs Nobbies Inlet (open).

8.1.9 Statistical Analysis

The range of mesh sizes used in the research gill nets effectively targeted different segments of the fish species population, and analyses were conducted separately for each mesh size. The experimental design was a complete factorial structure with three geographic regions (north, middle, south), two fishing policies regarding commercial net fishing (open, closed), two positions along the estuarine gradient (upstream, downstream), 13 points in time (bimonthly), with two replicates each time (n = 312 samples). All 3-way interactions were estimated with 4 and 5-way interactions pooled into the respective error lines. Key variables chosen for analyses were: diversity measures (four indices and number of species), total abundance and total biomass of all fish, and abundance and biomass of the 20 most common species. Calculations of diversity indices were made using the PRIMER version 5.2.2 computer software package and the following indices used.

Margelef Species Richness Index $d = S - 1 / \ln N$
Shannon-Wiener Diversity Index: $H' = - \sum_i p_i(\ln p_i)$
Pielou's Evenness Index $J' = H'_{(observed)} / H'_{max}$
Simpson's dominance Index $SI = \sum_i p_i^{\ 2}$

In these equations for diversity measures, symbols represent: number of species (*S*); number of individuals (N); and proportion of total species count arising from the *i*th species (p_i). These measures of diversity are the most commonly used indicators of community conditions in ecology (Clarke and Warwick 1994).

8.1.10 Model development and testing

Prior to analyses, catch data (fish per sample) were natural log (x + 0.5) transformed and biomass data (grams per sample) were square root (x + 0.5) transformed (Yamamura 1999). The post-analysis residuals were inspected graphically, and checked for skewness, normality and homogeneity of variances. Some problems remained due to an inflated zero-class for some species, but these analyses were accepted as they represent true data patterns, which were largely accommodated by the fitted model. In reporting results, main effect and interaction means were all back-transformed from the natural log and square root scales (with the bias-correction adjustment, Kendall *et al.* 1983) to the original scale (fish per sample).

Consistently across these data sets for different mesh sizes, split-plot analyses of repeated measures over time (using AREPMEASURES in Genstat, Payne *et al.* 1993) showed a reasonably degree of autocorrelation. The Greenhouse-Geisser epsilon averaged 0.35, and this overall value was applied as a constant correction factor to the degrees of freedom below the split (ie for time related factors) (Greenhouse and Geiser 1959). This factor was applied to all analyses (rather than using individual epsilons, as these tended to be inconsistent).

For the final model, the covariate soak time was added. It was included for all models to provide a consistent adjustment method for all reported means. Adequate degrees of freedom existed to accommodate this. Exploratory analyses trialed a second covariate, tide phase. This had little correlation with catch rates and caused estimation problems due to its partial aliasing with other design factors, and so was omitted in the final model.

Post hoc multiple comparison tests were conducted for all *F*-tests which were significant at the 5% level. The LSD (Least Significant Difference) multiple comparison method was used to compare each treatment mean to every other treatment mean (Milliken and Johnson 1992).

8.1.11 Multivariate Analyses

Multivariate statistics were used to identify patterns among the sites based on assemblages of fishes caught by each mesh type using PRIMER version 5.2.2. The square root of abundance for the 20 most abundant species averaged over time (n = 12 sites) was used in the analyses for each net type. A similarity matrix based on Bray-Curtis indices representing species abundances was calculated. These values were used in cluster analyses, using group average linking, to separate spatial groups. Significance of these spatial groups was tested using one way analysis of similarities (ANOSIM). SIMPER analysis was carried out to identify the species determining the spatial groups. For each species this analysis calculates the ratio of average contribution to similarity between groups to the standard deviation of similarity between groups. The higher the value of the discrimination index the more useful the species is for discriminating between groups.

Multidimensional scaling (MDS) was used to ordinate and view the spatial relationships identified in the cluster analysis. MDS is a procedure that iteratively rearranges points from the similarity matrix to generate graphs that can be visually inspected for gradients along the axes and clusters among sites. The MDS procedure uses established techniques of numerical optimisation to compress coordinates from higher to lower multidimensional space while still maintaining the relationships in the original higher dimensional matrix to the maximum degree possible (Clarke and Warwick 1994). A matrix representing 20 species at 12 sites would generate a plot in 20 dimensions, and thus be impossible to visually inspect and evaluate for patterns. The MDS procedure produces a 2 - or 3-dimensional graph based on the original relationships in 20 dimensional space and then calculates a measure of goodness of fit (or stress) between the original and reduced configurations of points. The lower the stress value the better the fit. If the stress level was less than 0.20, the plots were inspected for the possible influences of the three main effects (region, fishing, and position).

8.2 Results of Intensive Fishery Independent Survey

8.2.1 Overall Catch

The cumulative total catch in all nets from the 13 sampling trips was 24 908 fish, with one-third more specimens caught in the closed rivers than in the open rivers (Appendix 1). Furthermore, of the 10 350 kg of fish caught, the biomass from closed systems was twice that caught in the open systems. The number of species (141 overall) was not significantly different between rivers open to net fishing (111 species) versus closed systems (129 species). The three most abundant species in rivers closed to net fishing were *Herklotsichthys castelnaui*, *Lates calcarifer*, and *Thryssa hamiltoni*. In the open rivers, *H. castelnaui* was also most abundant, followed by *T. hamiltoni*, and *Arius* spp.

The total number of species caught in an individual river ranged from 75 at Yellow Gin Creek (south closed) to 94 in the Russell River (north closed) (Table 17). Abundance ranged from 3,304 fish netted in Nobbies Inlet (south open) to 5,607 in the Russell River (north closed). Biomass ranged from a low of 738 kg again at Nobbies Inlet (south open) to a high of 2,757 kg in the Haughton River (mid closed).

8.2.2 Environmental Conditions

Water temperature remained above 20^{o} C throughout the period, with no north to south differences detected over the 400 km study area (Table 18). The water temperature ranged by about 12^{o} C in all the rivers. Highest salinities were recorded at the southern sites, decreasing through the middle region and being lowest in the north. Upstream sites were consistently lower than downstream salinities. Salinity patterns reflect the gradient in rainfall conditions from the rainy north to the drier south as recorded at rain gauges near the study sites (Figure 13). Each pair of rivers lies within a similar rainfall

Table 17: Comparison of species numbers, abundance and biomass for the six estuarine river systems sampled in the fishery-independent study.

Region	Fishing	River	Position	No. Species	Abundance	Biomass (kg)
North	Closed	Russell	Upstream	63	2,978	939
			Downstream	78	2,629	1,149
			All	*94*	*5,607*	*2,088*
North	Open	Hull	Upstream	58	2,284	603
			Downstream	61	1,192	334
			All	*78*	*3,476*	*938*
Middle	Closed	Haughton	Upstream	61	2,292	1,885
			Downstream	65	1,368	872
			All	*85*	*3,660*	*2,757*
Middle	Open	Barrattas	Upstream	59	1,879	803
			Downstream	64	1,981	636
			All	*77*	*3,860*	*1,439*
South	Closed	Yellow Gin	Upstream	57	2,341	1,497
			Downstream	63	2,624	894
			All	*75*	*4,965*	*2,390*
South	Open	Nobbies	Upstream	59	1,278	379
			Downstream	76	2,062	359
			All	*90*	*3,340*	*738*

region, and this design feature is reflected in the observed salinity trends. Similar temporal patterns were evident between pairs of rivers within regions over most of the months. Salinity fell dramatically in direct response to storms and at the onset of the rainy season (Figure 14 a, b & c).

Following major storm events, we observed run-off laden with silt from the surrounding catchments washing into the rivers. Consequently, oxygen levels occasionally dropped below the 4 mg/L concentration level considered critical to survival of fishes and other fauna and fish kills were observed (e.g. March 1999) (Table 14).

Table 18: Summary of environmental conditions for each of the river systems in the fishery-independent study as measured using a Datasonde3 datalogger. The number of samples varied due to the deployment of only one hydrolab on some of the trips.

Region	Fishing	River	Position	Temperature				Salinity				Dissolved Oxygen (mg/L)			
				Average	Minumum	Maximum	Samples	Average	Minumum	Maximum	Samples	Average	Minumum	Maximum	Samples
North	Closed	Russell	Upstream	25.8	22.6	29.6	159	12.4	0.2	34.1	159	7.1	3.4	14.3	91
			Downstream	25.9	22.8	29.1	48	16.3	0.6	34.1	48	6.1	4.6	7.6	32
North	Open	Hull	Upstream	26.4	23.3	29.8	48	12.3	0.1	26.3	48	5.4	3.6	6.5	32
			Downstream	26.4	20.9	30.8	152	17.2	0.1	31.0	152	5.8	4.3	7.4	72
Middle	Closed	Haughton	Upstream	27.8	23.8	31.8	48	15.5	0.2	36.9	48	6.2	4.8	8.6	32
			Downstream	27.0	20.0	31.1	160	25.7	3.9	39.2	160	5.6	4.3	6.6	80
Middle	Open	Barrattas	Upstream	28.0	23.7	31.3	48	17.6	0.6	37.4	48	5.5	3.2	9.2	32
			Downstream	27.2	22.8	30.9	152	24.4	3.6	38.6	152	6.9	2.7	13.1	80
South	Closed	Yellow Gin	Upstream	27.5	23.8	31.3	48	18.0	0.5	40.6	48	6.1	4.6	8.1	32
			Downstream	26.0	22.5	30.8	144	28.2	3.0	39.0	144	6.3	1.8	13.6	80
South	Open	Nobbies	Upstream	27.4	23.0	31.3	48	29.8	12.3	41.4	48	5.4	3.4	8.2	32
			Downstream	26.6	21.6	31.5	160	33.6	16.7	42.7	160	6.1	2.9	13.0	94
Overall				***26.8***	***20.0***	***31.8***		***20.9***	***0.1***	***42.7***		***6.0***	***1.8***	***14.3***	

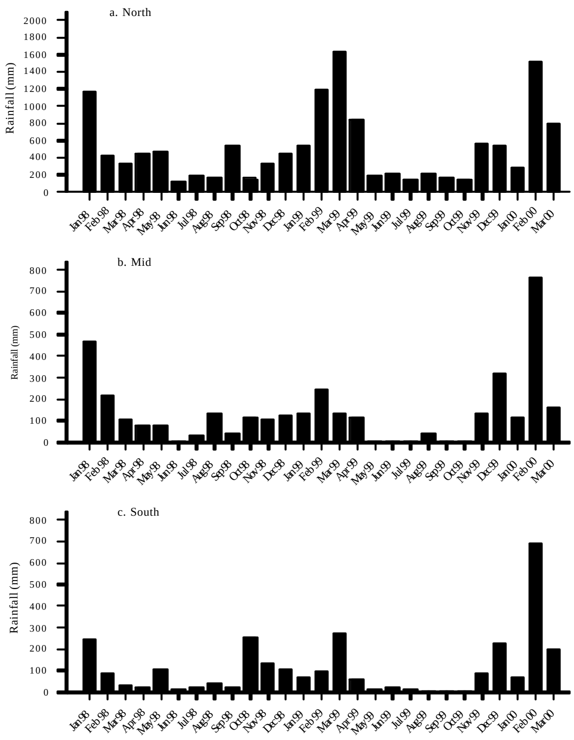

Figure 13: Monthly rainfall by station (South: Home Hill, Middle: Giru, North average of Tully and Babinda). Source: Australian Bureau of Meteorology (2000).

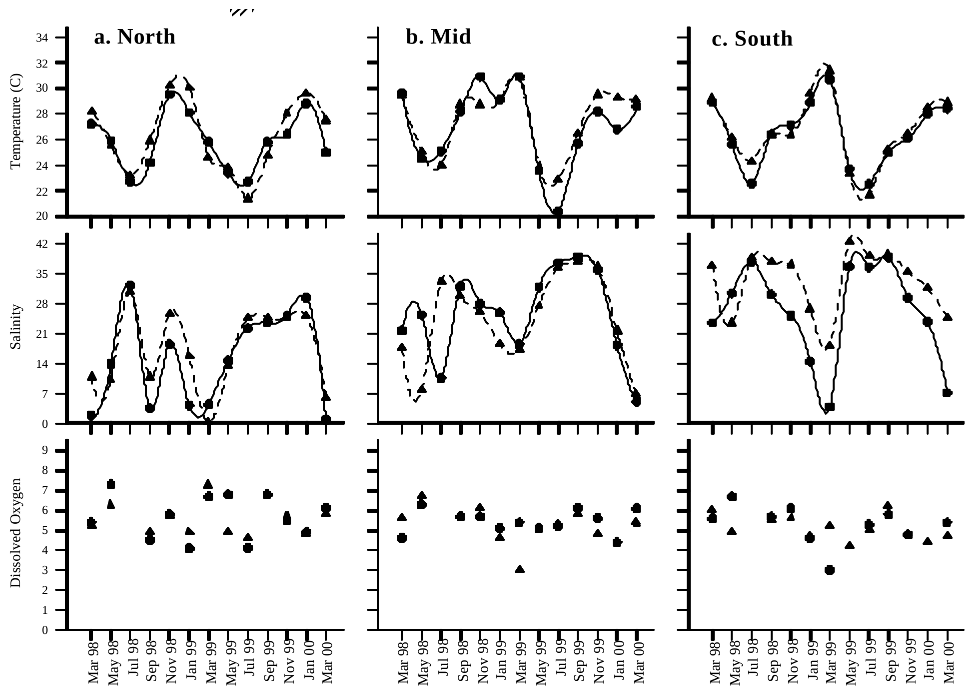

Figure 14: Average/trip temperature, salinity and dissolved oxygen concentrations recorded by datalogger with readings taken every five minutes while nets were fishing at the downstream sites. A. Northern rivers Russell River closed to net fishing = circles, Hull River open to net fishing = triangle. B. Haughton River closed to net fishing = circles, Barrattas River open to net fishing = triangles. C. Yellow Gin Creek closed to net fishing = circles, Nobbies Inlet open to net fishing = triangles.

8.2.3 Variance in Fish Catch

The mesh size of the research nets dictated the size portion of the overall population sampled (Figure 15). Catch in the multipanel nets was comprised of 13 750 fish from 91 species, with the majority of fish in the 50 -100 mm fork length (FL) range. Over 65% of the fish numbers caught in these fine mesh nets were *Herklotsichthys castelnaui* and *Thryssa hamiltoni*. The 51 mm mesh nets caught 3 560 fish from 62 species, mostly in the range 150 – 300 mm FL. Most of the fish caught in these nets were from the families Mugilidae and Ariidae. Catches in the 102 mm mesh nets were dominated by catfish (*Arius* spp.) and barramundi (*Lates calcarifer*), and the overall catch of 5 916 fish was from 68 species, most in the 150 to 500 mm size range. Barramundi dominated the catch in the 152 mm mesh nets. The 1 682 fish sampled in these large mesh nets were from 52 species representing a wide range of fish sizes, peaking in abundance in the 600 to 800 mm length range. Due to these selective sampling features, further analyses were conducted on catches from each mesh size separately.

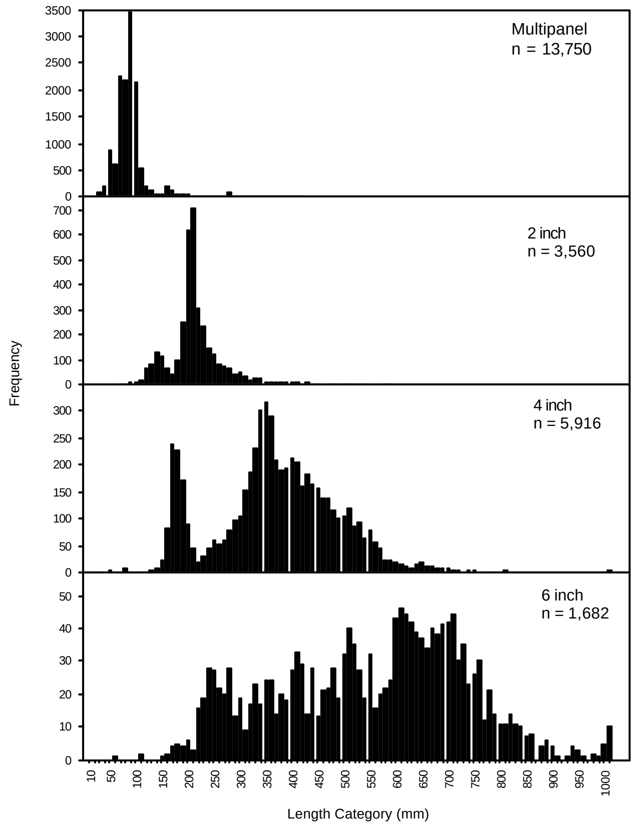

Figure 15: Length-frequency histograms for fish caught in each net-type used in the fishery-independent study pooled for all rivers.

152 mm mesh Nets. The broad size range of fish (150 – 1520 mm) captured in these large mesh nets included massive, deeper bodied species. Of the 52 species caught, the seven most abundant represented over 72% of the total catch. Taxa included sharks, barramundi, trevally, grunters, threadfins, scats and the occasional ray (Table 19).

Total abundance and species diversity were significantly greater ($P < 0.001$) in the closed than open systems for all comparisons (Table 20, Figure 16). Although the statistical analysis indicated a significant interaction among spatial factors (Fishing*Position*Region, $P < 0.001$), closed rivers had significantly greater biomass for each pair of systems than the open rivers (Figure 17a).

Table 19: Total catch for 152 mm nets for all 13 sampling periods during the fishery independent study.

Family	**Species**	**Abundance**	**Biomass (gr)**	**Length Range (mm)**	**Family**	**Species**	**Abundance**	**Biomass (gr)**	**Length Range (mm)**
Centropomidae	*Lates calcarifer*	527	2,141,627	385-1020	Elopidae	*Elops australis*	3	2,584	440-461
Ariidae	*Arius spp.*	156	267,511	215-735	Sphyrnidae	*Sphyrna lewini*	3	2,270	356-470
Carcharhinidae	*Carcharhinus leucas*	144	148,356	590-1520	Carangidae	*Scomberoides tala*	3	1,693	311-395
Polynemidae	*Eleutheronema tetradactylum*	143	226,416	240-900	Tetraodontidae	*Tetraodontidae*	2	4,100	420
Carangidae	*Scomberoides*	140	284,612	355-990	Platycephalidae	*Platycephalus fuscus*	2	3,240	590-660
Ephippidae	*Drepane punctata*	110	52,938	200-380	Haemulidae	*Pomadasys argenteus*	2	2,615	280-520
Sciaenidae	*Nibea soldado*	72	22,337	220-400	Mugilidae	*Valamugil buchanani*	2	2,357	370-440
Polynemidae	*Polydactylus macrochir*	69	351,575	438-860	Platycephalidae	*Platycephalus indicus*	2	1,658	500
Carangidae	*Caranx ignobilis*	48	55,501	256-545	Haemulidae	*Pomadasys* sp.	2	679	265-285
Haemulidae	*Pomadasys kaakan*	44	92,922	283-630	Echeneidae	*Echeneis naucrates*	2	16	143-157
Carangidae	*Trachinotus blochi*	24	48,878	290-720	Serranidae	*Epinephelus lanceolatus*	1	13,001	1000
Leiognathidae	*Leiognathus equulus*	21	3,899	160-235	Dasyatidae	*Himantura granulata*	1	5,821	600
Mugilidae	*Liza vaigiensis*	20	61,937	500-650	Sphyraenidae	*Sphyraena barracuda*	1	5,195	1160
Haemulidae	*Plectorhynchus gibbosus*	19	55,299	365-680	Dasyatidae	*Himantura sp.*	1	3,545	500
Carcharhinidae	*Carcharhinus* sp.	13	11,971	650-1000	Carangidae	*Gnathanodon speciosus*	1	2,156	520
Scatophagidae	*Scatophagus argus*	13	9,144	255-340	Chanidae	*Chanos chanos*	1	1,156	430
Mugilidae	*Mugil cephalus*	12	30,987	480-620	Rhinobatidae	*Aptychotrema rostrata*	1	885	750
Megalopidae	*Megalops cyprinoides*	11	11,967	320-490	Dasyatidae	*Himantura uarnak*	1	883	300
Scatophagidae	*Scatophagus multifasciatus*	9	4,679	220-345	Ephippidae	*Platax orbicularis*	1	869	315
Lutjanidae	*Lutjanus johnii*	8	22,697	515-880	Sparidae	*Acanthopagrus berda*	1	505	270
Tetraodontidae	*Arothron hispidus*	8	17,222	320-515	Ephippidae	*Platax novemaculeatus*	1	436	232
Carangidae	*Alectis indicus*	8	7,537	265-500	Carcharhinidae	*Rhizoprionodon acutus*	1	368	575
Lutjanidae	*Lutjanus argentimaculatus*	6	10,406	405-520	Chirocentridae	*Chirocentrus dorab*	1	360	445
Tetraodontidae	*Arothron reticularis*	6	9,040	300-442	Clupeidae	*Nematalosa come*	1	323	235
Stromateidae	*Parastromateus niger*	6	7,510	300-360	Sciaenidae	*Otolithes ruber*	1	318	320
Myliobatidae	*Aetobatus narinari*	6	6,763	390-540	Ephippidae	*Platax teira*	1	316	205
Total							***1682***	***4,021,081***	

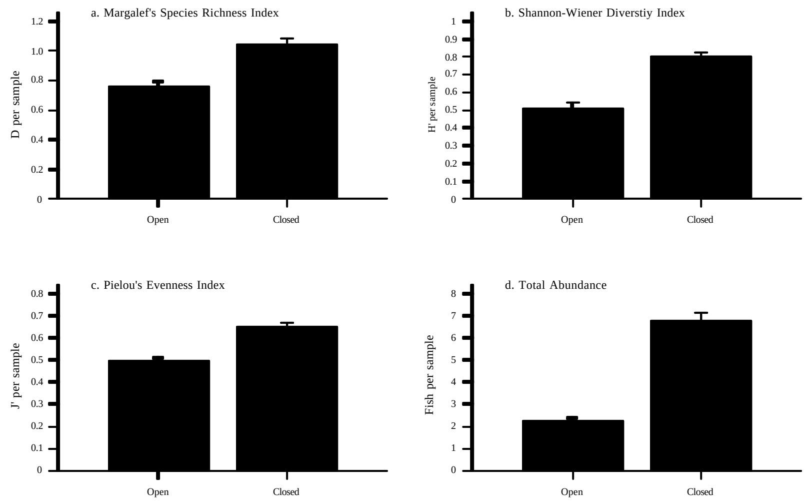

Figure 16: Diversity indices (± 1 SE) and overall abundance (± 1 SE) for catch in the 152 mm mesh nets. Significant effects ($P < 0.001$) were consistent among sites and for all trips.

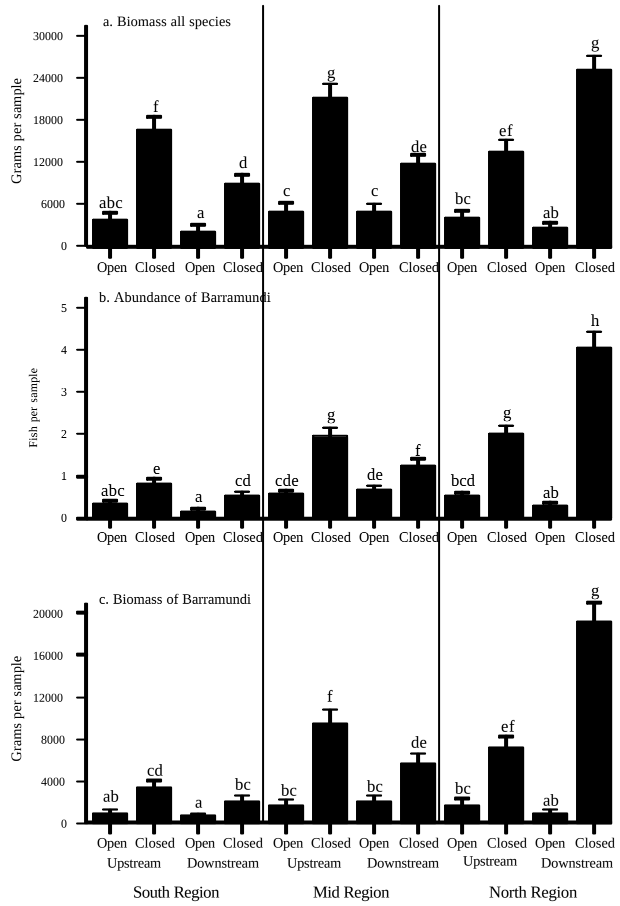

Figure 17: a. Total biomass (all species) (± 1 SE), caught in the 152 mm mesh nets where significant effects of fishing were found. Letters indicate significant differences for LSD = 0.05.

Nine species were selected for detailed analysis due to their high abundance. The ANOVA results indicated highly significant ($P < 0.001$) effects of fishing for three species (barramundi, estuary whalers *Carcharinus leucus* and queenfish *Scomberoides commersonianus*) and in each case, closed systems had greater abundance and biomass levels. For barramundi, the most abundant species caught in the 152 mm mesh nets, closed rivers consistently had greater abundance and biomass levels (Figure 17b and c). Although barramundi less than 750 –800 mm were commonly captured in both open and closed rivers, very few barramundi larger than 800 mm were caught in the open rivers (Figure 18).

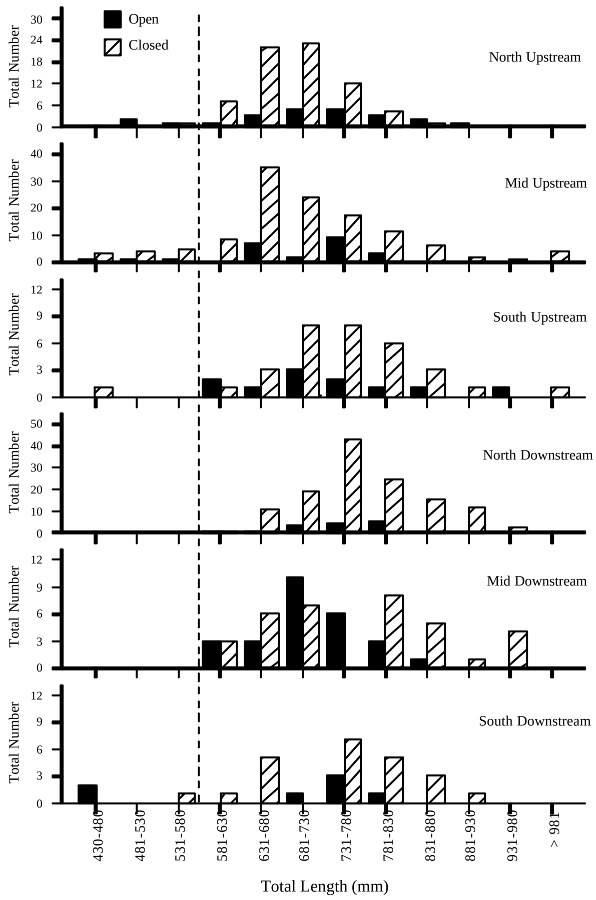

Figure 18: Length-frequency of barramundi caught with 152 mm mesh nets. Dashed line indicates minimum legal length. Note change in scale on some figures.

For queenfish and estuary whalers, spatial variations generated some inconsistent patterns among open versus closed systems (Figure 20). In most comparisons, however, closed systems had greater numbers and biomass (Figure 19 a and b). The occurrence of estuary whalers was highly seasonal (Figure 20). In the northern and middle region rivers, abundances increased in January 1998; but in January 1999 the peak abundance occurred in the southern closed river alone (Yellow Gin). These peaks in abundance were the result of the seasonal pattern of pupping and use of these riverine systems as nursery areas with few sharks being caught at other times of the year. The observed effect of fishing in this case may be an artefact of the sampling design as the times that these small sharks were caught in all samples was during the annual commercial netting closure (from November to February see Section 6.3.4.1). Therefore it is reasonable to assume that the seasonal changes in abundance were much greater than the effect of fishing on this species.

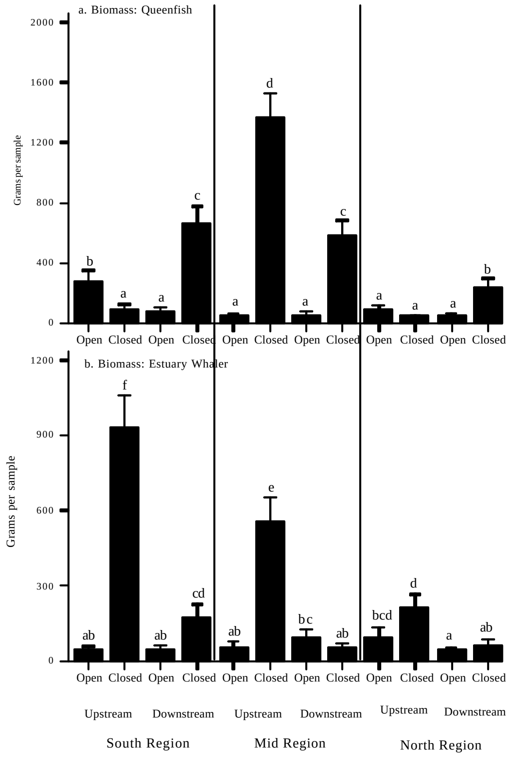

Figure 19: Biomass (± 1 SE) of queenfish and estuary whalers caught in the 152 mm mesh nets. Letters indicate significant differences for LSD = 0.05.

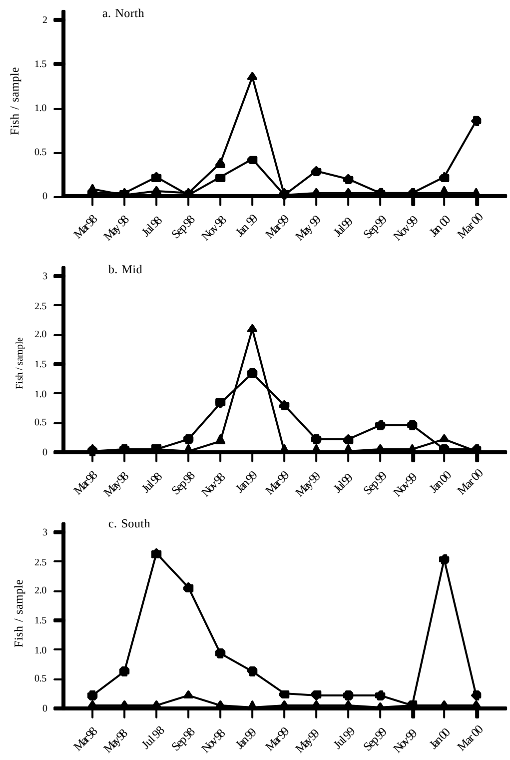

Figure 20: Abundance of estuary whalers caught in the 152 mm mesh nets showed significant effects (P < 0.001) of fishing. Circles = Closed, Triangles = Open.

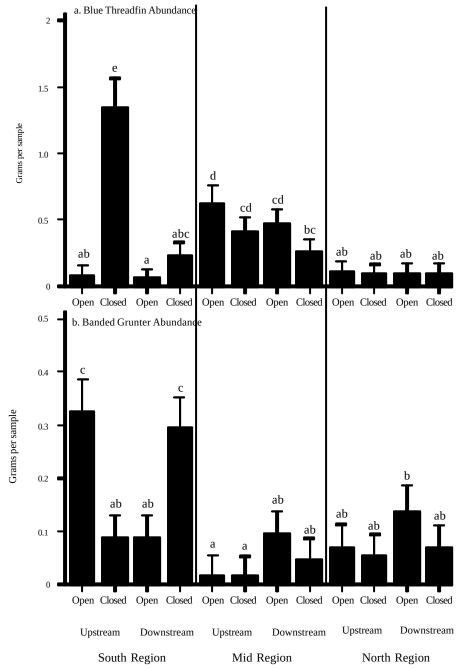

Figure 21: Abundances (± 1 SE) of blue threadfin and banded grunter caught in 152 mm mesh nets. Significant effects of fishing were found for blue salmon ($P < 0.04$) but not for banded grunter ($P < 0.32$). Significant three-way interactions were found among the spatial factors (fishing, position, region, $P < 0.05$) for both of these commercial species. Letters indicate significant differences for LSD = 0.05.

For blue threadfin *Eleutheronema tetradactylum*, an important market species, effects of fishing were significant ($P = 0.044$), but inconsistently among the sites (Figure 20). One sampling site (south-closed-upstream) had high abundances of this species during the winter (Figure 21a). Banded grunter *Pomadasys kaakan*, showed a similar abundance pattern: ie among all the sampling sites, two had very high numbers (Figure 21b). Both of these sites were located in the southern region, with one site closed (upstream) and the other open (downstream).

Table 20: Summary of split plot analysis of variance for catch in the 152 mm mesh nets with Fishing (F), Position (P) and Region (R) as main effects, and Tripno (T) as repeated effect. Interactions abbreviated as F*P etc. Significance of effects designated as *** for P < 0.001; ** for P < 0.01; * for P < 0.05.

Net – Data type	Spatial Parameters							Temporal/Temporal*Spatial Parameters						
Parameter	Fishing	Position	Region	F*P	F*R	P*R	F*P*R	Tripno	T*F	T*P	T*R	T*F*P	T*F*R	T*P*R
152 mm mesh - Diversity Indices														
Margelef Species Richness	***		***					*			*			
Shannon-Wiener Diversity	***		**					*			*			
Pielou's Evenness	***		**					*						
Simpson's Dominance			*											
Total species	***							*						
152 mm mesh - Abundance Data														
Total Abundance	***	*						*		*				
Arius spp.		**			**			**				**	*	
Carcharhinus leucas	***	***	**				**	***		*	*		*	
Eleutheronema tetradactylum	*	**	***				*	**						
Lates calcarifer	***	*	***				***							
Leiognathus equulus			*							*			*	*
Liza vaigiensis			*				*					*	*	*
Nibea soldado			*		*									
Pomadasys kaakan			***				**				*			
Scomberoides commersonianus	***		**				**					*		
152 mm mesh - Biomass Data														
Total catch	***	**	*				***			*				
Arius spp.	**	***		**	**			***				*	***	**
Carcharhinus leucas	***	***					**	*			*	*	*	*
Eleutheronema tetradactylum		**	**				*	***						
Lates calcarifer	***		***				***							
Leiognathus equulus			**	*									*	*
Liza vaigiensis			*				*						*	*
Nibea soldado			*											
Pomadasys kaakan			***				**				*	**		
Scomberoides commersonianus	***		***				***							

Table 21: Comparisons of groups identified by cluster analysis by the top three discriminating species based on SIMPER analyis of species data.

Comparison of Abundance Data	Probability from ANOSIM test	Main Contributing Species (discrimination value)
152mm mesh net		
Cluster		
G1 vs G2	0.029	Barramundi (3.49), King threadfin (3.33) Queenfish (1.89)
G2 vs G3	0.036.	Barramundi (2.06), Soapy Jew (2.30), Queenfish (1.89)
G1 vs G3	0.008.	King threadfin (2.30), Blue threadfin (1.62), Estuary whaler (1.62)
Open vs Closed	0.017	Queenfish (1.77), Giant trevally (1.77), Barramundi (1.57)
102mm mesh net		
Cluster		
North vs Middle/South combined	0.002	Leiognathus equulus (4.69), Scomberoides tala (3.22), Megalops cyprinoides (2.13)
51mm mesh net		
Cluster		
G1 vs G2	0.002	Liza subviridis (2.09), Thryssa hamiltoni (1.79), Blue threadfin (1.71)
G2 vs G3	0.143 n.s.	
G1 vs G3	0.167 n.s.	
Multi panel net		
Cluster		
G1 vs G2	0.002	Liza subviridis (2.33), Herklotsichthys castelnaui (1.68) Thryssa hamiltoni (1.58)

Fish Community Distribution Patterns from 152 mm Mesh Net Catches

Cluster analysis (Figure 22a) and the resulting MDS ordinations of the 20 most abundant species caught in the 152 mm mesh nets indicated that three groups of sites could be distinguished in the data. One group contained four sites open to net fishing (G1), the second, three sites closed to net fishing (G2) and the third, a combination of both open and closed sites (G3) at a Bray-Curtis similarity of 57% (Figure 22b). Pairwise ANOSIM showed that these three groups were significantly different in the abundances of fish caught (Table 21). Pairwise SIMPER analysis of the three groups (G1 vs G2, G2 vs G3 and G1 vs G3) showed that higher abundances of barramundi in G2 were a major contributor to the differences between G2 and both G1 and G3 with a discrimination index of 3.49 and 2.06 for each comparison respectively. Figure 22d shows the relative catch of barramundi in all 12 sites clearly indicating that the sites within G2 contained the highest abundances of barramundi. When comparing G1 versus G2, high discrimination indices were also found for king threadfin (3.33) and queenfish (1.89) both occurring in higher abundances in the G2 group of sites (Figure 22e and f). Comparing G2 and G3, barramundi (2.06), soapy jew (2.30) and queenfish (1.89) had the highest discrimination indices with barramundi and queenfish being more abundant in G2 and soapy jew having higher abundances in the G3 group of sites (Figure 22g). In the G1 vs G3 comparison, king threadfin (2.30), blue threadfin (1.62) (Figure 22h) and estuary whalers (1.62) (Figure 22i) had the highest discrimination indices. All three of these species occurred in greater abundances in the G3 group of sites.

Comparisons between sites open and closed to commercial fishing using ANOSIM indicated that there was a significant difference (P = 0.017) between the catches (Figure 22c). SIMPER analysis showed that queenfish *Scomberoides commersonianus* (1.77), giant trevally *Caranx ignobilis* (1.77) and barramundi (1.57) had the highest discrimination indices with all species being caught in greater abundances in the closed sites (Figure 22f, j and d).

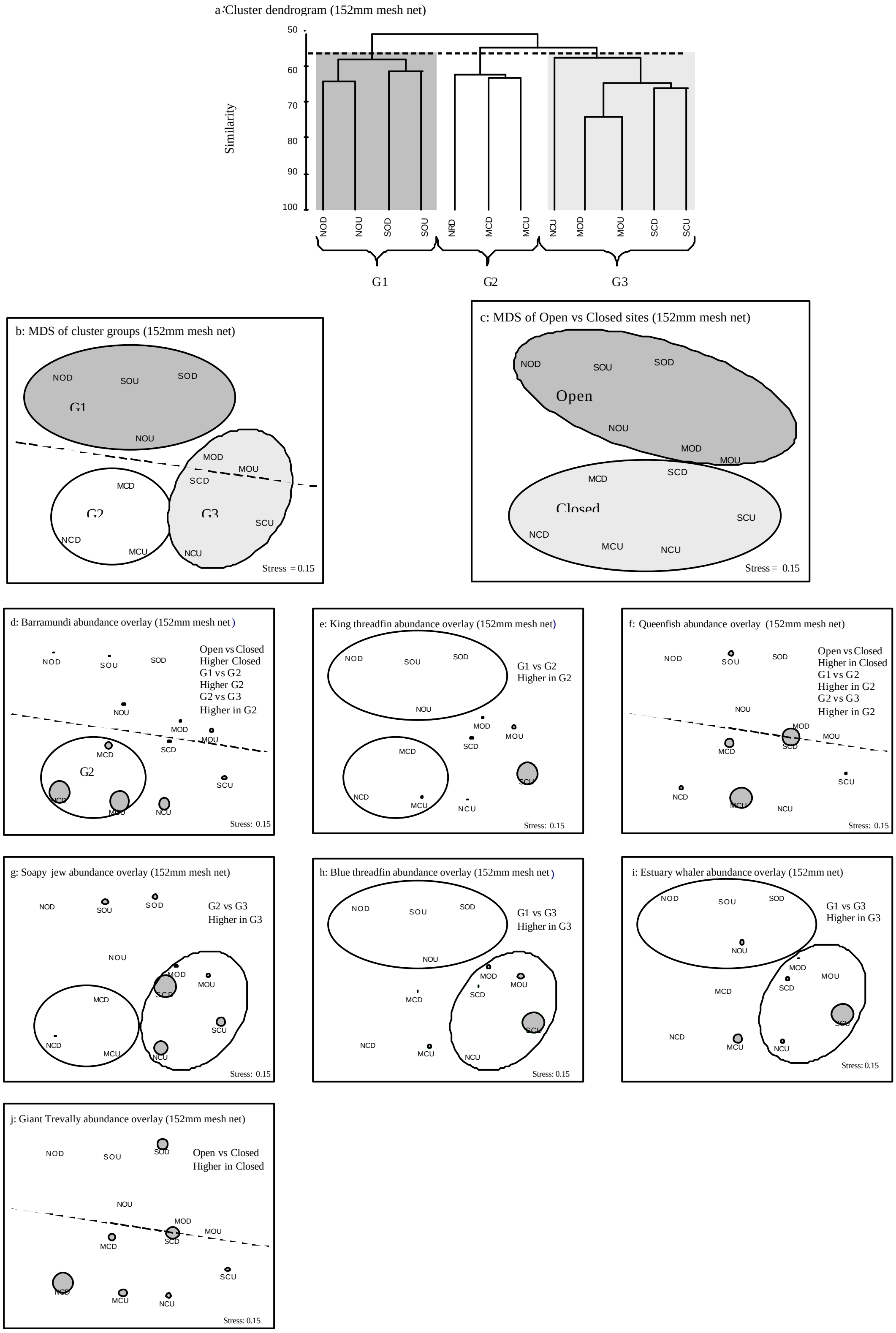

Figure 22: (a) Dendrogram showing group average clustering of 12 sites based on the twenty most abundant species caught in the 152mm mesh nets. Shading delineates groups at a similarity of 57%; (b) MDS ordination (stress = 0.15) of 12 sites based on twenty most abundant species. Boundaries and shaded areas indentify by cluster; (c) MDS ordination (stress = 0.15) of 12 sites based on twenty most abundant species grouped by open vs closed to net fishing. Bubble plots of average abundance per site for (d) barramundi, (e) king threadfin, (f) queenfish, (g) soapy jew, (h) blue threadfin, (i) estuary whaler and (j) giant trevally. The symbol codes for sites are: N = North, M = Middle, S = South, O = Open, C = Closed, D = Downstream, U = Upstream.

102 mm mesh Nets. The species sampled with 102 mm mesh nets included some of the same taxa that dominated the 152 mm mesh nets, including barramundi, blue threadfin, and trevally (Table 22). Slender-bodied species were also caught such as soapy jew *Nibea soldado*, tarpon *Megalops cyprinoides*, mullets Family: Mugilidae, and milkfish *Chanos chanos*, as were shorter-bodied fish with substantial spines such as catfish *Arius* spp., archer fish *Toxotes chatareus* and ponyfish *Leiognathus equulus*. The catches from these nets are not typical of the commercial catches from within the open systems as 152 mm mesh nets are the smallest mesh size allowed to be fished in these areas (see Section 6.3.4).

Catches in the 102 mm mesh nets showed significant differences between rivers open to commercial netting and those closed to commercial netting for Margelf species richness ($P < 0.01$), Shannn-Wiener diversity ($P < 0.001$) and total number of species ($P < 0.001$), but Pielou's eveness and Simpson dominance measures were only significantly different with respect to the position within the river (Table 23). Overall diversity, abundance and biomass were greater in the closed systems for each pair of systems, with the exception of the mid-down comparison (Figure 23a - e). Among the 8 species selected for detailed analysis, diamond scale mullet *Liza vaigiensis* was consistently more abundant in the closed sites (Figure 24a and c). Catches of ponyfish *Leiognathus equulus* in the closed sites were significantly greater than in open sites (Figure 24b and d). This species showed a high degree of sites selectivity with abundances being orders of magnitude higher in the northern sites.

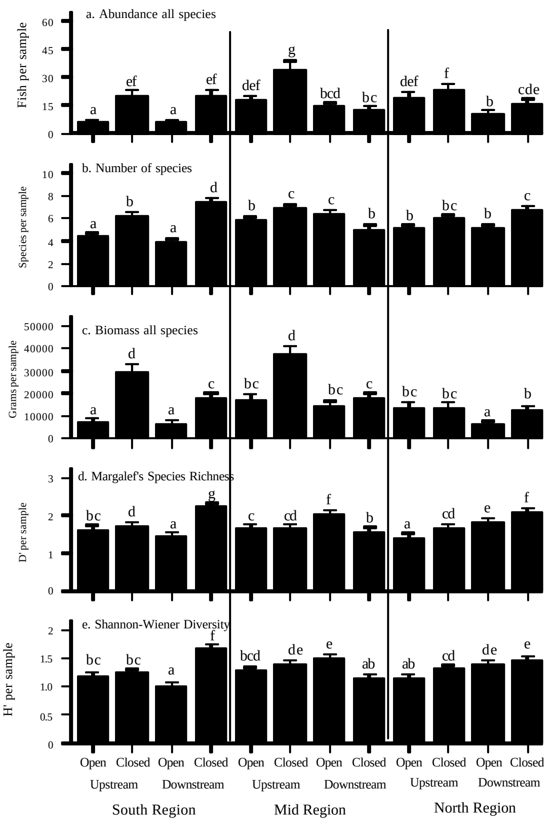

Figure 23: Catches in the 102 mm mesh nets had significant effects of fishing ($P < 0.01$) for several community indicators (a – e). Levels at sites closed to net fishing were generally greater than open sites. Letters indicate significant differences for LSD = 0.05.

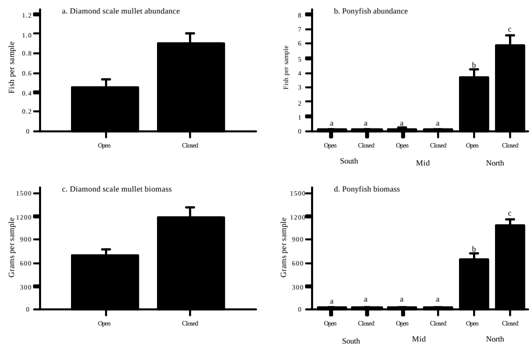

Figure 24: Catches (± 1 SE) in the 102 mm mesh nets for a.diamond scale mullet abundance b. ponyfish abundance, c. diamond scale mullet biomass and d. ponyfish biomass were greater in the closed than open systems. Letters indicate significant differences for LSD = 0.05.

Table 22: Catch composition for 102 mm mesh nets from all sites on all sampling trips during the fishery independent sampling.

Family	Species	Abundance	Biomass (gr)	Length Range (mm)	Family	Species	Abundance	Biomass (gr)	Length Range (mm)
Ariidae	*Arius* spp.	1,537	1,351,470	190-620	Sparidae	*Acanthopagrus australis*	5	1,680	220-250
Centropomidae	*Lates calcarifer*	1,057	1,648,670	290-820	Gerreidae	*Gerres abbreviatus*	5	1,331	185-220
Leiognathidae	*Leiognathus equulus*	785	122,659	75-215	Sphyraenidae	*Sphyraena jello*	4	11,615	114-1430
Polynemidae	*Eleutheronema tetradactylum*	297	402,645	220-635	Toxotidae	*Toxotes* sp.	4	1,387	250-260
Sciaenidae	*Nibea soldado*	271	125,171	215-475	Soleidae	*Achlyopa nigra*	4	927	195-230
Mugilidae	*Liza vaigiensis*	256	411,675	280-650	Carangidae	Carangidae	3	1,417	295-305
Haemulidae	*Pomadasys argenteus*	247	112,664	165-495	Chirocentridae	*Chirocentrus dorab*	3	1,319	405-495
Haemulidae	*Pomadasys kaakan*	232	140,923	160-530	Carangidae	*Trachinotus blochi*	3	1,095	193-290
Megalopidae	*Megalops cyprinoides*	192	222,391	175-525	Tetraodontidae	*Arothron manilensis*	3	637	195-240
Carangidae	*Scomberoides commersonianus*	192	128,667	230-705	Sphyraenidae	*Sphyraena* sp.	3	371	105-395
Carangidae	*Caranx ignobilis*	118	64,760	25-1040	Mugilidae	*Valamugil seheli*	2	4,542	455-535
Mugilidae	*Mugil cephalus*	105	133,537	325-580	Tetraodontidae	*Arothron reticularis*	2	3,317	380-386
Polynemidae	*Polydactylus macrochir*	102	254,228	340-740	Mugilidae	*Valamugil* sp.	2	2,784	420-625
Carangidae	*Scomberoides tala*	55	33,950	280-510	Platycephalidae	*Platycephalus indicus*	2	2,595	510-645
Toxotidae	*Toxotes chatareus*	55	22,814	230-320	Carangidae	*Scomberoides* sp.	2	2,241	380-515
Mugilidae	*Valamugil buchanani*	31	66,078	400-600	Carcharhinidae	*Carcharhinus ambionensis*	2	1,161	670
Lutjanidae	*Lutjanus argentimaculatus*	30	26,321	300-430	Serranidae	*Epinephelus coioides*	2	1,115	355-362
Chanidae	*Chanos chanos*	29	31,292	265-510	Sillaginidae	*Sillago analis*	2	762	320-333
Scombridae	*Scomberomorus semifasciatus*	23	12,325	315-440	Batrachoididae	*Halophryne diemensis*	2	638	235-285
Lutjanidae	*Lutjanus johnii*	19	14,141	190-615	Sciaenidae	Sciaenidae	2	564	285
Engraulidae	*Thryssa hamiltoni*	19	1,771	165-225	Gerreidae	*Gerres filamentosus*	2	379	200
Ephippidae	*Drepane punctata*	18	3,961	130-320	Leptobramidae	*Leptobrama mulleri*	2	322	250-260
Scatophagidae	*Scatophagus multifasciatus*	17	3,606	140-212	Teraponidae	*Mesopristes argenteus*	2	261	155-240
Monodactylidae	*Monodactylus argenteus*	17	2,025	145-180	Serranidae	*Epinephelus lanceolatus*	1	4,947	730
Mugilidae	Mugilidae	16	27,794	410-490	Sphyraenidae	*Sphyraena barracuda*	1	4,135	1,060
Scatophagidae	*Scatophagus argus*	15	4,818	150-335	Stromateidae	*Parastromateus niger*	1	1,664	355
Lactariidae	*Lactarius lactarius*	14	5,491	210-385	Rhinobatidae	*Aptychotrema rostrata*	1	1,101	505
Sparidae	*Acanthopagrus berda*	12	4,030	220-265	Mugilidae	*Valamugil cunnesius*	1	1,044	380
Tetraodontidae	*Arothron hispidus*	9	11,512	240-485	Serranidae	*Epinephelus malabaricus*	1	831	390
Carcharhinidae	*Carcharhinus leucas*	9	9,708	630-1200	Carcharhinidae	*Rhizoprionodon acutus*	1	766	510
Mugilidae	*Liza subviridis*	9	4,485	198-390	Carangidae	*Caranx sexfasciatus*	1	755	335
Haemulidae	*Plectorhynchus gibbosus*	8	16,040	245-610	Haemulidae	*Pomadasys* sp.	1	607	335
Clupeidae	*Nematalosa come*	8	2,893	210-315	Carangidae	*Caranx bucculentus*	1	548	275
Platycephalidae	*Platycephalus fuscus*	6	6,730	495-640	Centropomidae	*Psammoperca waigiensis*	1	522	340
Elopidae	*Elops australis*	6	5,120	320-506	Carangidae	*Carangoides hedlandensis*	1	303	226
Carangidae	*Trachinotus bailloni*	6	2,603	235-320	Siganidae	*Siganus lineatus*	1	290	225
Leiognathidae	*Leiognathus* sp.	6	30	80	Bothidae	*Pseudorhombus* sp.	1	245	220
Clupeidae	*Nematalosa erebi*	5	3,106	265-350	Gerreidae	*Gerres oyena*	1	220	210
Toxotidae	*Toxotes jaculatrix*	5	2,508	250-285					
Total							***5,916***	***5,505,049***	

Table 23: Summary of split plot analysis of variance for catch in 102 mm mesh nets with Fishing (F), Position (P) and Region (R) as main effects, and Trip no (T) as repeated effect. Interactions abbreviated as F*P etc. Significance of effects designated as : *** for P < 0.001; ** for P < 0.01; * for P < 0.05.

Net - Data type	Spatial Parameters							Temporal/Temporal*Spatial Parameters						
Parameter	Fishing	Position	Region	F*P	F*R	P*R	F*P*R	Tripno	T*F	T*P	T*R	T*F*P	T*F*R	T*P*R
102 mm mesh - Diversity														
Margelf Species Richness	**	***					**	*			*			
Shannon-Wiener Diversity	***	**					***	*						
Pielou's Evenness		***					*	*				*	*	*
Simpson Dominance		*					**							
Total species	***		**		***		**	***		***	**	*		**
102 mm mesh - Abundance Data														
Total Abundance	***	***	***				**	***						**
Arius sp.		***	***		***	**		***						
Eleutheronema tetradactylum	*		**	*	**			**				*	**	*
Lates calcarifer	***		***				*	***			*			
Leiognathus equulus	*	**	***		*	***								*
Liza vaigiensis	**	**									*			
Nibea soldado					***			*					*	
Pomadasys argenteus		*	***				***	*			*			
Pomadasys kaakan			**				*							
102 mm mesh - Biomass Data														
Total Catch	***	***	***				*	*		**	*			
Arius sp.		***	***		***	**		***		*				
Eleutheronema tetradactylum	**	*	**	**	***			***				**	***	***
Lates calcarifer	***	*	***				***	***						
Leiognathus equulus	**	***	***		**	***								*
Liza vaigiensis	**	**	*											
Nibea soldado					***			*					*	
Pomadasys argenteus		*	***				***							
Pomadasys kaakan			***				*							

Abundance and biomass of barramundi were greater in the closed rivers than in the open rivers for all comparisons except at the mid-downstream pair of sites which had similar numbers (Figure 25 a and b). The majority of barramundi caught in the 102 mm mesh nets were less than the legal size limit of 580 mm (Figure 26). Closed systems had greater numbers for all size classes quite consistently, but barramundi abundance varied widely over the study period (Figure 27). For example, at the mid-closed site where we consistently caught numerous barramundi (> 20 per trip), the September 1999 catch of this species was zero.

For blue threadfin, a valuable commercial and recreational species, statistically significant effects of fishing (P = 0.042) were confounded by complex spatial and temporal patterns (Table 23). The middle region had higher abundances in the open river sites during May 1998 and March 1999 when peak abundances were caught (Figure 28). Conversely, the southern region had higher levels in the closed system during the peak months of May 1998 and July 1999. Notably, however, abundances in the southern region were about 4 times the level in the middle region. Significantly lower numbers of blue threadfin were caught in the northern region than elsewhere.

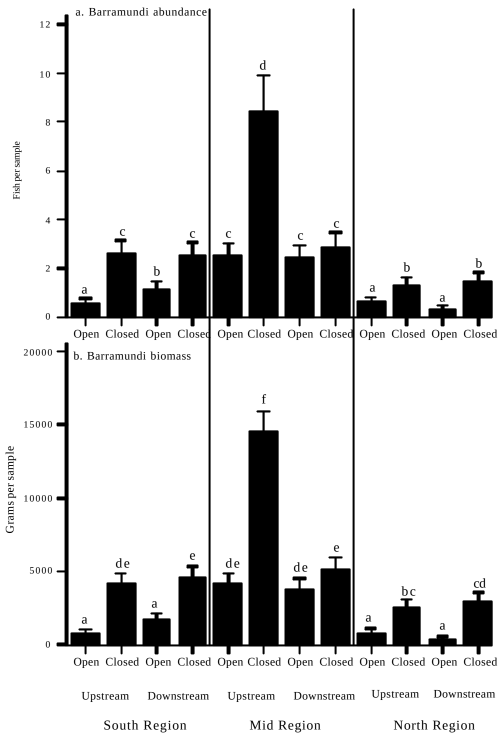

Figure 25: Total abundance (± 1 SE) and total biomass (± 1 SE) of barramundi caught by site in the 102 mm mesh nets. In all cases, closed rivers had significantly greater abundances than open systems. Letters indicate significant differences for LSD = 0.05.

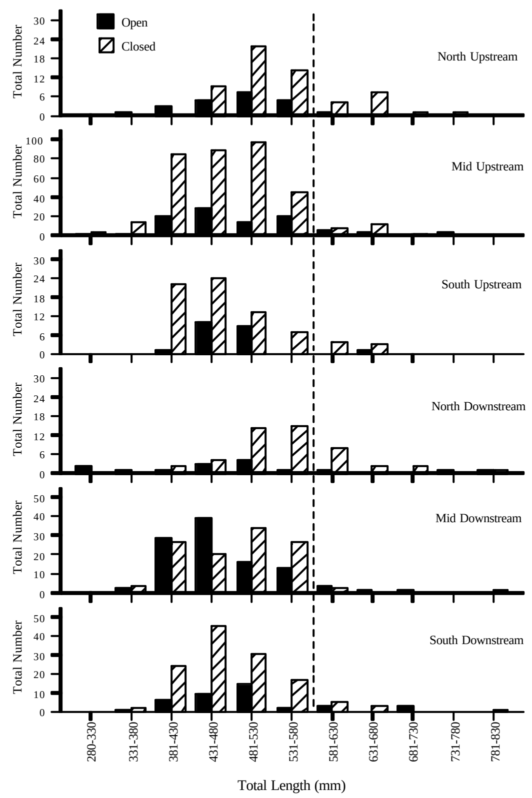

Figure 26: Length-frequency of barramundi sampled using 102 mm mesh nets, comparing open versus closed systems. Dashed line indicates minimum legal length.

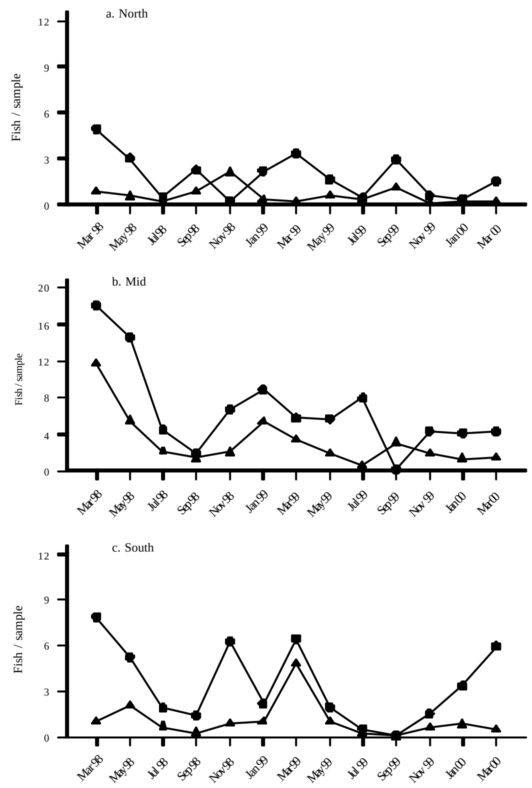

Figure 27: Seasonal variation in the abundances of barramundi caught in the 102 mm mesh nets for the six rivers sampled. Triangles = Open, Circles = Closed.

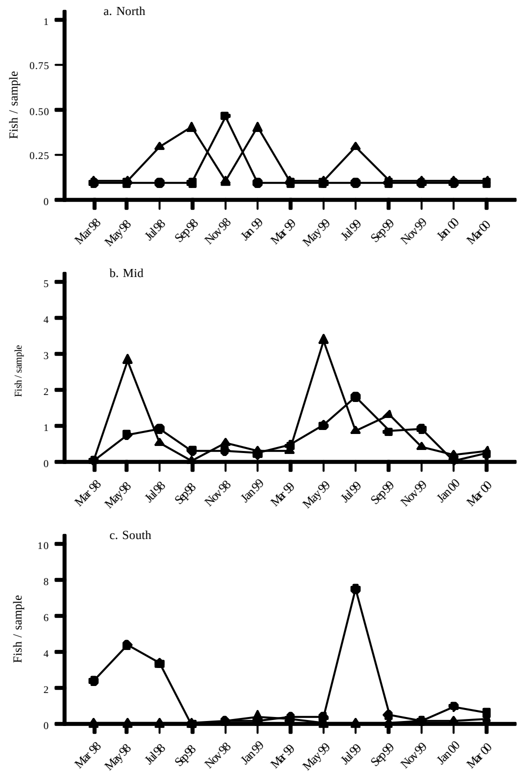

Figure 28: Seasonal abundance of blue threadfin caught in the 102 mm mesh nets by river. Triangles = Open, Circles = Closed.

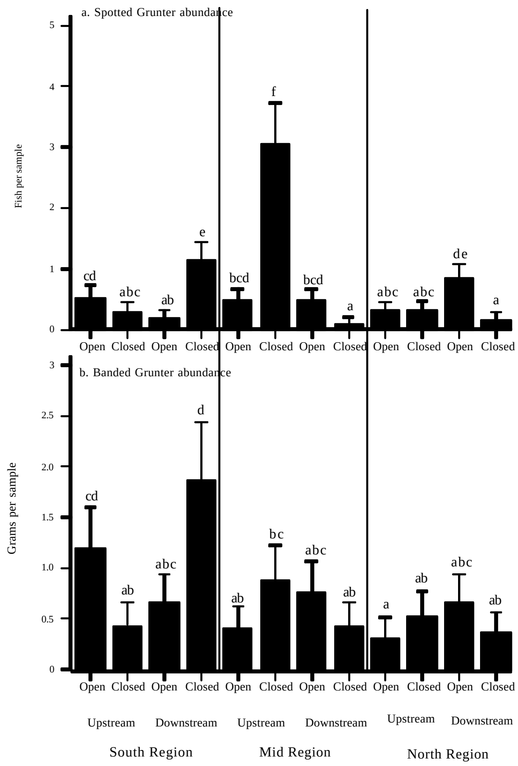

Figure 29: Abundance of spotted grunter and banded grunter caught in 102 mm mesh nets by river and position. Letters indicate significant differences for LSD = 0.05.

For the two species of commercially exploited haemulids caught in the research nets (spotted grunter *Pomadasys argenteus* and banded grunter *Pomadasys kaakan*), differences between closed and open river were not statistically significant (Table 23). The distribution patterns for spotted grunter were complex, with one site (mid-up-closed) producing most of the catch (Figure 29a). Similarly, banded grunter were widely distributed but markedly abundant at only two sites (south-open-upstream, south-closed-downstream) (Figure 29b).

Fish Community Distribution Patterns from 102 mm Mesh Net Catches

Cluster analysis (Figure 30a) and the resulting MDS ordinations of the 20 most abundant species caught in the 102 mm mesh nets showed a clear separation between the northern region (G1) and the southern and middle regions at a Bray-Curtis similarity of 65%. The middle and southern regions formed a single mixed group that could not be further separated (Figure 30b). ANOSIM analyses of the northern vs middle/southern groups showed significant differences (P = 0.002) between the groups (Table 21). SIMPER analysis revealed that *Leiognathus equulus*, *Scomberoides tala* and *Megalops cyprinoides* had the highest discrimination indices (4.69, 3.22, 2.13 respectively) These species were most abundant in the northern sites (Figure 30c, d and e). It is interesting to note that in all three of these species, very few if any individuals were caught outside of the northern region. ANOSIM of open vs closed sites did not reveal any significant differences.

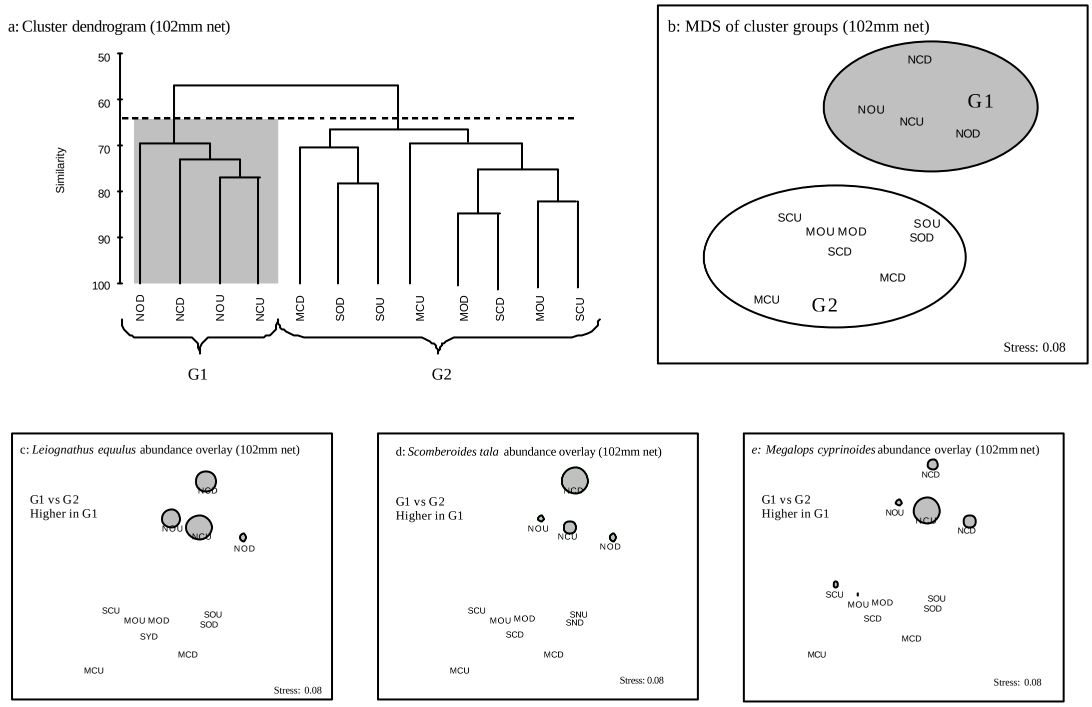

Figure 30: (a) Dendrogram showing group average clustering of 12 sites based on the twenty most abundant species caught in the 102 mm mesh nets. Shading delineates groups at a similarity of 65%; (b) MDS ordination (stress = 0.08) of 12 sites based on twenty most abundant species. Boundaries and shaded areas identified by cluster; Bubble plots of average abundance per site for (c) *Leiognathus equulus*, (d) *Scomberoides tala* and (e) *Megalops cyprinoides*. Three symbol codes for sites are: N = North, M = Middle, S = South, O = Open, C = Closed, D = Downstream, U = Upstream.

51 mm mesh Nets. Hamilton's anchovy *Thryssa hamiltoni* and bony bream *Nematalosa come* were abundant in catches of the 51 mm mesh nets. These nets were especially effective at catching mullet, comprising over half the catch (Table 24). Significant effects of fishing could not be detected for any of the parameters analysed (Table 25). Inconsistent patterns and temporal variation occurred for all key parameters and species as exemplified by the patterns in catfish and blue salmon (Figure 32). Temporal patterns in abundance were significant for total abundance of all species, as well as abundance of *Thryssa hamiltoni*, *Valamugil cunnesius*, *Liza subviridis* and *Arius* spp. (Figure 32).

Table 24: Total catch from the 51 mm mesh nets from all sites on all sampling trips during the fishery-independent sampling.

Family	Species	Abundance	Biomass (gr)	Length Range (mm)	Family	Species	Abundance	Biomass (gr)	Length Range (mm)
Engraulidae	*Thryssa hamiltoni*	683	65,048	140-240	Teraponidae	*Terapon jarbua*	5	374	150-155
Mugilidae	*Valamugil cunnesius*	552	75,187	119-330	Carangidae	*Caranx sexfasciatus*	5	332	130-150
Mugilidae	*Liza subviridis*	518	83,485	155-352	Mugilidae	*Mugil cephalus*	4	950	221-248
Ariidae	*Arius* spp.	374	101,766	160-419	Clupeidae	*Herklotsichthys koningsbergi*	4	233	130-140
Clupeidae	*Nematalosa come*	295	20,218	100-220	Lutjanidae	*Lutjanus russelli*	4	219	140-158
Mugilidae	*Valamugil buchanani*	272	43,949	170-370	Haemulidae	*Pomadasys argenteus*	4	181	130-150
Mugilidae	*Valamugil seheli*	119	25,932	180-308	Clupeidae	*Anodontostoma chacunda*	4	141	105-130
Clupeidae	*Herklotsichthys castelnaui*	80	3,759	73-150	Sillaginidae	*Sillago analis*	3	545	240-280
Polynemidae	*Eleutheronema tetradactylum*	74	32,086	170-515	Polynemidae	*Polynemus heptadactylus*	3	485	140-212
Centropomidae	*Lates calcarifer*	66	43,719	215-590	Scombridae	Scombridae	3	14	68-72
Leptobramidae	*Leptobrama mulleri*	58	7,777	177-300	Scatophagidae	*Scatophagus argus*	2	726	225-235
Elopidae	*Elops australis*	46	14,498	234-480	Lutjanidae	*Lutjanus argentimaculatus*	2	378	155-260
Sciaenidae	*Nibea soldado*	37	5,431	170-320	Gerreidae	*Gerres oyena*	2	101	118-125
Leiognathidae	*Leiognathus equulus*	35	3,926	75-220	Batrachoididae	*Halophryne diemensis*	2	97	132-142
Sillaginidae	*Sillago sihama*	34	5,115	208-280	Leiognathidae	*Gazza achlamys*	2	56	100-112
Mugilidae	*Valamugil* sp.	32	3,552	171-295	Congridae	*Muraenesox cinereus*	1	3,278	1,330
Scombridae	*Scomberomorus semifasciatus*	29	6,851	195-372	Ephippidae	*Platax batavianus*	1	2,545	426
Gerreidae	*Gerres filamentosus*	24	923	103-160	Polynemidae	*Polydactylus macrochir*	1	2,544	565
Clupeidae	*Nematalosa erebi*	23	1,400	100-165	Gobiidae	*Periophthalmus* sp.	1	981	200
Carangidae	*Scomberoides tala*	19	4,029	198-395	Tetraodontidae	*Arothron reticularis*	1	937	320
Sphyraenidae	*Sphyraena jello*	17	7,898	305-538	Belonidae	*Tylosurus crocodilus*	1	405	580
Haemulidae	*Pomadasys kaakan*	17	927	152-170	Belonidae	*Tylosurus* sp.	1	347	574
Carangidae	*Scomberoides commersonianus*	13	1,845	147-465	Siganidae	*Siganus guttatus*	1	196	200
Carangidae	*Caranx ignobilis*	11	1,754	111-392	Teraponidae	*Mesopristes argenteus*	1	185	210
Sphyraenidae	*Sphyraena barracuda*	9	3,496	350-505	Carangidae	*Scomberoides tol*	1	101	230
Platycephalidae	*Platycephalus fuscus*	9	3,380	265-520	Toxotidae	*Toxotes jaculatrix*	1	82	155
Platycephalidae	*Platycephalus indicus*	9	3,125	300-420	Sparidae	*Acanthopagrus berda*	1	74	140
Chirocentridae	*Chirocentrus dorab*	7	2,038	300-515	Lutjanidae	*Lutjanus* sp.	1	56	160
Carangidae	*Scomberoides lysan*	6	512	185-210	Sciaenidae	*Sciaenidae*	1	55	197
Mugilidae	*Liza vaigiensis*	5	6,029	204-580	Scorpaenidae	*Notesthes robusta*	1	38	150
Megalopidae	*Megalops cyprinoides*	5	1,026	190-330	Leiognathidae	*Gazza* sp.	1	37	110
Sillaginidae	*Sillago ciliata*	5	915	250-270	Siganidae	*Siganus lineatus*	1	24	102
Plotosidae	*Paraplotosus albilabris*	5	824	255-268	Monodactylidae	*Monodactylus argenteus*	1	14	80
Chanidae	*Chanos chanos*	5	637	179-250					
Total							3,560	599,792	

Table 25: Summary of split plot analysis of variance for catch in 51 mm mesh nets with Fishing (F), Position (P) and Region (R) as main effects, and Tripno (T) as repeated effect. Interactions abbreviated as F*P etc. Significance of effects designated as : *** for P < 0.001; ** for P < 0.01; * for P < 0.05.

Net - Data type	Spatial Parameters							Temporal/Temporal*Spatial Parameters						
Parameter	Fishing	Position	Region	F*P	F*R	P*R	F*P*R	Tripno	T*F	T*P	T*R	T*F*P	T*F*R	T*P*R
51 mm mesh - Diversity Indices														
Margelef Species Richness								***						
Shannon-Wiener Diversity								***						
Pielou's Evenness								**			*			
Simpson Dominance														
Total No. Species					*			***						
51 mm mesh - Abundance Data														
Total Abundance					**			***			*			
Arius spp.			*		**			*						
Eleutheronema tetradactylum					**									
Lates calcarifer														
Liza subviridis							*	***	*					
Nematalosa come								***					*	*
Thryssa hamiltoni								*						
Valamugil buchanani								***				*	*	
Valamugil cunnesius			*					**			*			
Valamugil seheli											*			
51 mm mesh - Biomass Data														
Total Abundance					**			***			*			
Arius spp.					*			*						
Eleutheronema tetradactylum					*									
Lates calcarifer														
Liza subviridis			***				**	***					*	
Nematalosa come			*					***						**
Thryssa hamiltoni											*			
Valamugil buchanani								***				*	*	
Valamugil cunnesius			*					**			*			
Valamugil seheli											*			

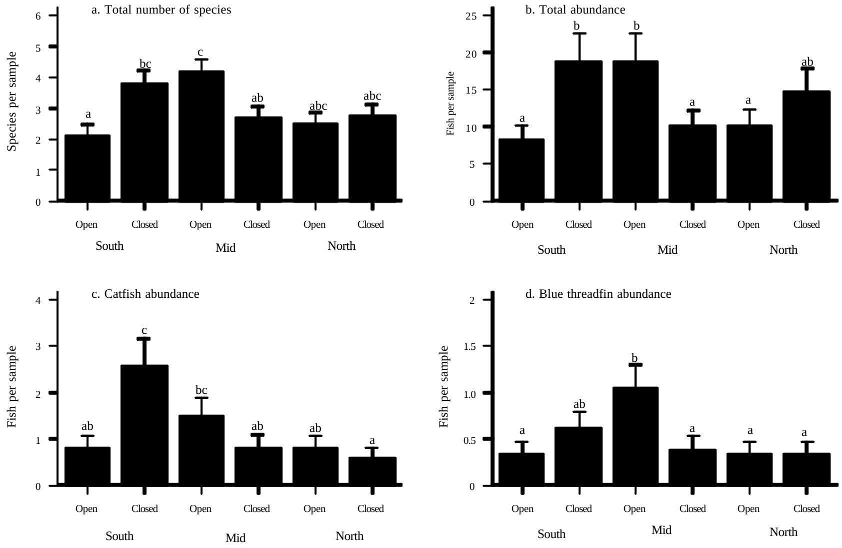

Figure 31: Catches (± 1 SE) in the 51 mm mesh nets showed no significant differences between closed and open sites. Significant two way interaction (Region x Fishing) are shown in the catches of *Arius* spp. and *Eleutheronema tetradactylum*. Letters indicate significant differences for LSD = 0.05.

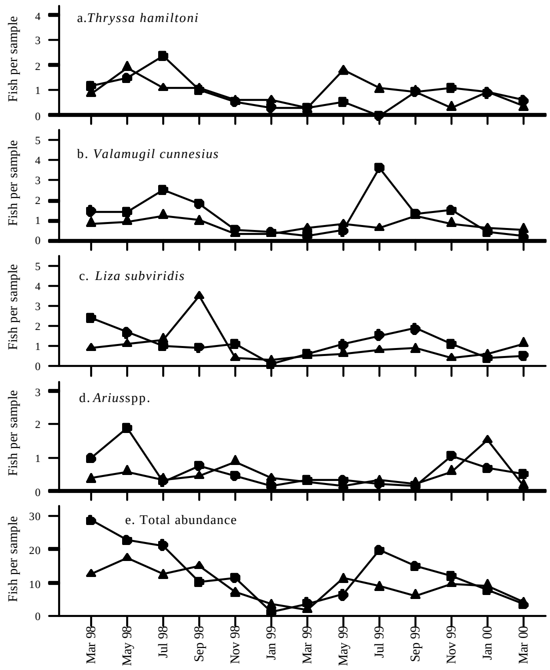

Figure 32: Catches (± 1 SE) in the 51 mm mesh nets showed no significant differences between closed and open sites. Temporal variations were significant for total abundance and abundance of *Thryssa hamiltoni*, *Valamugil cunnesius*, *Liz subviridis* and *Arius* spp. Triangles = Open, Circles = Closed.

Fish Community Distribution Patterns for 51 mm Mesh Net Catches

Cluster analysis (Figure 33a) and the resulting MDS ordinations of the 20 most abundant species caught in the 51mm mesh nets showed separation into three different regions at a Bray-Curtis similarity of 53%. The first group (G1) contains all the middle region sites as well as the two southern closed sites. The second (G2) contains three northern sites and the two southern open sites, while the third (G3) is a single northern site (Figure 33b). Pairwise ANOSIM analyses of G1 vs G2 indicated that there was a significant difference (P = 0.002) with the other combination of G2 vs G3 and G1 vs G3 not being significantly different (Table 21). SIMPER analysis of G1 and G2 groups revealed that *Liza subviridis* (2.09), *Thryssa hamiltoni* (1.79) and blue threadfin (1.71) had the highest discrimination indices. Figure 33c, d and e show the relative abundances between sites for these three species with *Liza subviridis* and blue threadfin being more abundant in G1 while *Thryssa hamiltoni* was caught in higher abundances in the G2 sites. ANOSIM of open vs closed sites did not reveal any significant differences.

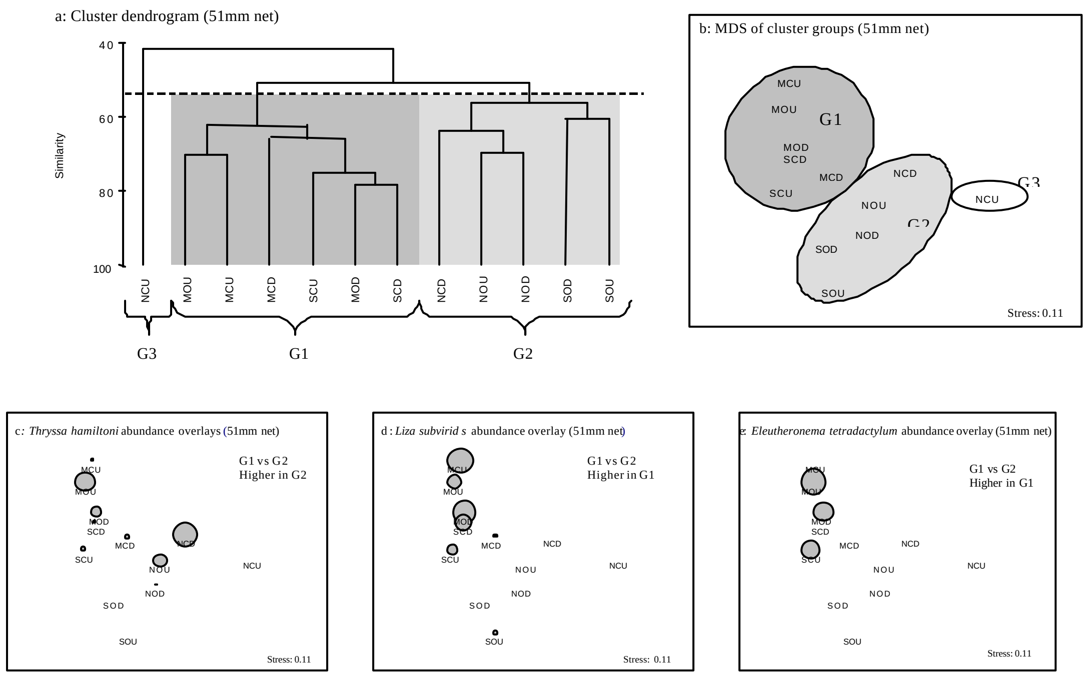

Figure 33: (a) Dendrogram showing group average clustering of 12 sites based on the twenty most abundant species caught in the 51mm mesh nets. Shading delineates groups at a similarity of 53%; (b) MDS ordination (stress = 0.11) of 12 sites based on twenty most abundant species. Boundaries and shaded areas indentify by cluster. Bubble plots are MDS ordinations overlaid with the average abundance per site for (c) *Liza subviridis*, (d) *Thryssa hamiltoni* and (e) blue threadfin. Three symbol codes for sites are: N = North, M = Middle, S = South, O = Open, C = Closed, D = Downstream, U = Upstream.

Multipanel (19/25/32 mm mesh) Nets. The catch in the multipanel nets were dominated by *Herklotsichthys castelnaui* (over half the catch) (Table 26). However, 90 other species were caught, far more than in any of the other nets. Herrings, ambassids, anchovies, silverbiddies, longtoms and juvenile mullet were all abundant. As with the 51 mm mesh nets, no detectable differences could be found between rivers closed and open to commercial gill netting (Table 27). For the single species showing significant differences between rivers closed and open to net fishing, *Escualosa thoracata*, significant seasonal and regional differences in abundance were evident (Figure 34). Regional differences in abundance were significant for 7 of the 9 species examined however abundances of each species peaked at different times of the year (Figure 34).

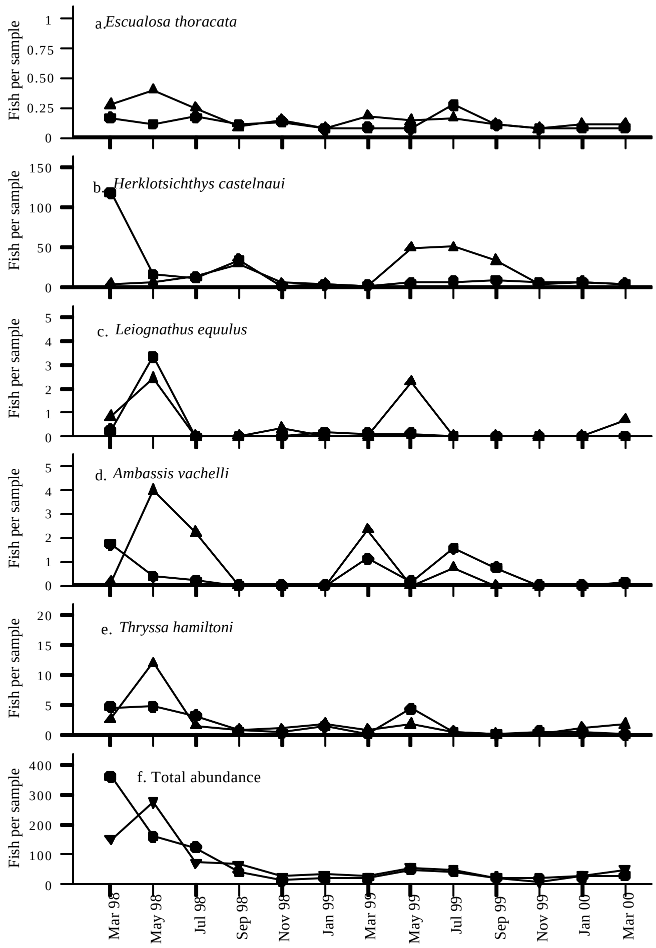

Figure 34: Catches of the most abundant species caught in the multipanel (19/25/32 mm mesh) nets. Temporal variation generated inconsistencies in fishing effects among the regions. Triangles = Open, Circles = Closed.

Table 26: Total catch in multipanel (19/25/32 mm mesh) nets for all catch within the fishery-independent survey.

Family	Species	Abundance	Biomass (gr)	Length Range (mm)	Family	Species	Abundance	Biomass (gr)	Length Range (mm)
Clupeidae	*Herklotsichthys castelnaui*	7,414	75,333	49-125	Chirocentridae	*Chirocentrus dorab*	4	977	373-410
Engraulidae	*Thryssa hamiltoni*	1,561	20,274	42-215	Carangidae	*Scomberoides tol*	4	38	83-105
Leiognathidae	*Leiognathus equulus*	542	2,369	21-205	Engraulidae	*Thryssa baelama*	4	22	67-100
Ambassidae	*Ambassis vachelli*	536	1,201	32-67	Leiognathidae	*Gazza* sp.	4	22	50-65
Clupeidae	*Nematalosa come*	457	5,524	44-198	Ambassidae	*Ambassis* spp.	4	16	53-58
Mugilidae	*Valamugil cunnesius*	444	8,070	54-223	Tetraodontidae	*Chelonodon patoca*	4	16	48-53
Belonidae	*Strongylura strongylura*	328	13,462	220-450	Leiognathidae	*Leiognathus blochi*	4	5	35-40
Clupeidae	*Escualosa thoracata*	248	1,032	58-84	Leptobramidae	*Leptobrama mulleri*	3	467	199-273
Mugilidae	*Liza subviridis*	223	4,486	52-245	Mugilidae	*Valamugil buchanani*	3	234	120-203
Hemiramphidae	*Arrhamphus sclerolepis*	213	7,120	58-230	Belonidae	*Strongylura* sp.	3	117	220-391
Clupeidae	*Anodontostoma chacunda*	200	1,405	42-101	Chanidae	*Chanos chanos*	3	80	120-125
Clupeidae	*Sardinella brachysoma*	179	1,217	50-95	Polynemidae	*Polynemus heptadactylus*	3	27	74-92
Polynemidae	*Eleutheronema tetradactylum*	177	8,553	80-405	Haemulidae	*Pomdasys maculatum*	3	20	66-74
Ambassidae	*Ambassis gymnocephalus*	151	656	35-74	Tetraodontidae	*Marilyna pleurosticta*	3	17	60-65
Leiognathidae	*Leiognathus brevirostrus*	143	387	20-65	Gerreidae	*Gerres acinaces*	3	14	42-65
Engraulidae	*Stolephorus* sp.	89	536	68-95	Scombridae	Scombridae	3	14	68-72
Ariidae	*Arius* spp.	77	23,350	151-410	Gerreidae	*Gerres oblongus*	3	10	42-55
Sillaginidae	*Sillago sihama*	75	1,524	87-180	Carangidae	*Caranx sexfasciatus*	3	8	45-61
Engraulidae	*Stolephorus commersoni*	72	519	70-121	Belonidae	*Tylosurus crocodilus*	2	1,467	703-722
Haemulidae	*Pomadasys kaakan*	59	2,522	48-505	Platycephalidae	*Platycephalus fuscus*	2	1,280	460
Hemiramphidae	*Zenarchopterus buffonis*	48	682	53-240	Lutjanidae	*Lutjanus argentimaculatus*	2	1,074	260-355
Mugilidae	*Valamugil seheli*	45	1,692	65-345	Hemiramphidae	*Hyporhamphus regularis*	2	75	195-218
Leiognathidae	*Leiognathus splendens*	42	104	32-56	Clupeidae	*Nematalosa erebi*	2	23	65-85
Mugilidae	*Valamugil* sp.	37	274	61-95	Lutjanidae	*Lutjanus russelli*	2	20	85-86
Haemulidae	*Pomadasys argenteus*	31	2,686	65-325	Carangidae	*Gnathanodon speciosus*	2	11	58-69
Carangidae	*Scomberoides commersonianus*	21	9,959	46-755	Scatophagidae	*Scatophagus multifasciatus*	2	7	42-53
Clupeidae	*Sardinella albella*	20	188	47-115	Apogonidae	*Apogon hyalosoma*	2	6	60
Engraulidae	*Stolephorus nelsoni*	18	73	57-95	Leiognathidae	*Secutor insidiator*	2	3	31-43
Leiognathidae	*Gazza minuta*	17	32	21-60	Congridae	*Muraenesox cinereus*	1	2,171	1,250
Carangidae	*Scomberoides lysan*	15	162	73-142	Dasyatidae	*Himantura uarnak*	1	2,066	410
Gerreidae	*Gerres filamentosus*	15	89	43-85	Belonidae	*Tylosurus punctatus*	1	516	145
Leiognathidae	*Leiognathus* sp.	13	32	35-61	Dasyatidae	*Himantura toshi*	1	509	245
Gerreidae	*Gerres abbreviatus*	12	800	44-170	Serranidae	*Epinephelus malabaricus*	1	264	270
Gerreidae	*Gerres oyena*	11	51	46-63	Belonidae	*Strongylura incisa*	1	130	485
Atherinidae	Atherinidae	10	41	64-75	Teraponidae	*Mesopristes argenteus*	1	106	185
Leiognathidae	*Secutor ruconius*	10	20	26-45	Belonidae	*Strongylura leiura*	1	49	330
Leiognathidae	*Leiognathus bindus*	9	41	35-70	Trichiuridae	*Trichiurus lepturus*	1	34	210
Elopidae	*Elops australis*	8	2,446	127-455	Carangidae	Carangidae	1	30	120
Clupeidae	*Herklotsichthys koningsbergi*	8	460	130-145	Hemiramphidae	*Zenarchopterus gilli*	1	19	200
Sphyraenidae	*Sphyraena jello*	7	2,320	355-414	Lutjanidae	*Lutjanus johnii*	1	8	78
Hemiramphidae	*Hemiramphus robustus*	7	217	184-284	Ambassidae	*Ambassis nalua*	1	7	70
Centropomidae	*Lates calcarifer*	6	4,114	170-475	Hemiramphidae	*Zenarchopterus* sp.	1	5	163
Sphyraenidae	*Sphyraena barracuda*	6	2,127	250-545	Carangidae	*Caranx ignobilis*	1	4	57
Plotosidae	*Paraplotosus albilabris*	6	857	240-260	Gobiidae	*Glossogobius biocellatus*	1	4	69
Platycephalidae	*Platycephalus indicus*	6	751	80-340	Leiognathidae	*Leiognathus semifasciatus*	1	4	51
Scombridae	*Scomberomorus semifasciatus*	6	228	76-245	Leiognathidae	*Gazza achlamys*	1	3	57
Carangidae	*Scomberoides tala*	6	42	76-102	Cynoglossidae	*Paraplagusia unicolor*	1	2	62
Hemiramphidae	Hemiramphidae	5	297	130-235	Sparidae	*Acanthopagrus berda*	1	2	38
Hemiramphidae	*Hyporhamphus quoyi*	5	134	185-192	Gerreidae	*Gerres macrosoma*	1	1	42
Leiognathidae	*Leiognathus daura*	5	12	35-47	Leiognathidae	*Gazza insidiator*	1	1	30
Sciaenidae	*Nibea soldado*	4	1,063	195-315					
Total							***13,750***	***223,538***	

Table 27: Summary of split plot analysis of variance for catch in Multipanel (19/25/32 mm mesh) nets with Fishing (F), Position (P) and Region (R) as main effects, and Tripno (T) as repeated effect. Interactions abbreviated as F*P etc. Significance of effects designated as : *** for P < 0.001; ** for P < 0.01; * for P < 0.05.

Net - Data Type	Spatial Parameters							Temporal/Temporal*Spatial Parameters						
Parameter	Fishing	Position	Region	F*P	F*R	P*R	F*P*R	Tripno	T*F	T*P	T*R	T*F*P	T*F*R	T*P*R
Multpanel Net - Diversity														
Margelef Species Richness		*						***		*				
Shannon-Wiener Diversity		*						**		*				
Pielou's Evenness														
Simpson's Dominance		*												
Total No. species		*						*						
Multi - Abundance Data														
Total abundance		*						***						
Ambassis vachelli								***	*					
Eleutheronema tetradactylum			***		**			***					*	*
Escualosa thoracata	*		***		**	**		**					*	*
Herklotsichthys castelnaui			***					**			*			*
Leiognathus equulus								***						
Liza subviridis			**					*						
Nematalosa come			**		**			**					*	
Strongylura strongylura		*	*					**					*	
Thryssa hamiltoni			**		**			*						
Multi - Biomass Data														
Total abundance								***			*			
Ambassis vachelli								**	*					
Eleutheronema tetradactylum			***		***									
Escualosa thoracata			***		**	*		*						*
Herklotsichthys castelnaui			***					**					*	
Leiognathus equulus			*					*						
Liza subviridis		*	**	*							*			
Nematalosa come			**		*			***					*	
Strongylura strongylura								**	*					
Thryssa hamiltoni					*			*						

Fish Community Distribution Patterns for Multipanel Net Catches

Cluster analysis (Figure 35a) and the resulting MDS ordinations of the 20 most abundant species caught in the multipanel nets showed all sites within the northern region (G1) separated from a combined set of all middle and southern region sites (G2) at a Bray-Curtis similarity of 58%. The middle and southern regions formed a single mixed group that could not be further separated (Figure 35b). ANOSIM analysis of the northern vs middle/southern groups showed significant differences between the groups (P = 0.002). SIMPER analysis revealed that *Liza subviridis* (2.33), *Herklotsichthys castelnaui* (1.68) and *Thryssa hamiltoni* (1.58) had the highest discrimination indices between the two groups (Table 21). Abundances of *Liza subviridis* (Figure 35c) and *Thryssa hamiltoni* (Figure 35d) were highest in the middle/southern region while *Herklotsichthys castelnaui* (Figure 35e) had higher abundances in the northern region. ANOSIM of open vs closed sites did not reveal any significant differences.

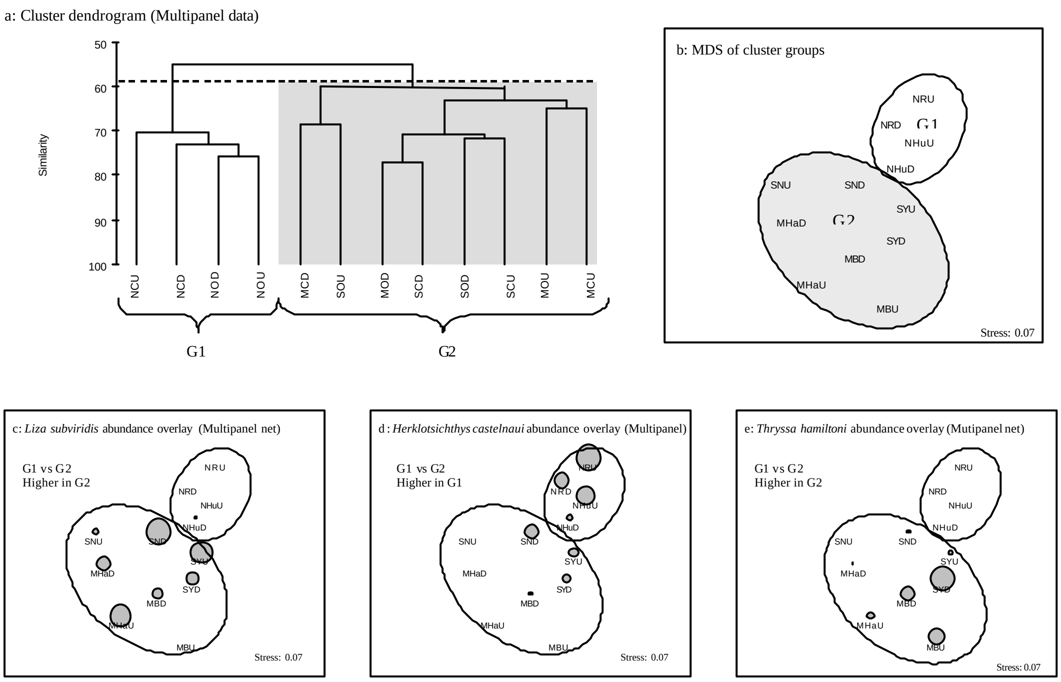

Figure 35: (a) Dendrogram showing group average clustering of 12 sites based on the twenty most abundant species caught in the multipanel nets. Shading delineates groups at a similarity of 58%; (b) MDS ordination (stress = 0.07) of 12 sites based on twenty most abundant species. Boundaries and shaded areas indentify by cluster. Bubble p lots are MDS ordinations overlaid with the average abundance per site for (c) *Liza subviridis*, (d) *Herklotsichthys castelnaui* and (e) *Thryssa hamiltoni*. Three symbol codes for sites are: N = North, M = Middle, S = South, O = Open, C = Closed, D = Downstream, U = Upstream

8.3 Fishery Independent Discussion

8.3.1 Comparison of Six Riverine Estuaries

Direct Effects. The overall trends of the research surveys indicated that riverine estuaries closed to commercial net fishing had higher diversity, biomass and relative abundance of large but not of small fish. Although fishing effects were detected for some commercially important species captured by the large survey nets (152 mm mesh), similar fishing effects were not detected in the catches of smaller survey nets.

Although the research surveys demonstrated overall fishing effects for barramundi, queenfish, estuary whalers and blue threadfin, consistency of the fishing effect between distinct geographical regions (varying in environmental conditions) surveyed were only present for barramundi and queenfish. Further, eight of the nine most abundant species surveyed by the 152 mm mesh nets, demonstrated significant regional trends in abundance. Fishing effects were not demonstrated in the catches of the small mesh survey nets, similar distinct regional patterns in abundance were observed for some species.

Very few of the differences the surveys detected between open and closed systems can be directly attributed to the removal of certain components of fish populations by commercial gill net fishing operations. This pattern was consistent for barramundi and queenfish however it was somewhat more complicated when estuary whalers, which are highly seasonal and abundant during the commercial net fishing closure is in force, and blue threadfin which are seasonal and abundant in only one region, are considered.

Barramundi in the 600 - 800 mm size classes were commonly caught at all sites with larger fish (> 800 mm) being caught predominantly in the rivers closed to net fishing. The majority of barramundi in the 600 – 800 range are immature or male (Garrett 1997, Milton *et al.* 1998) with a small proportion having completed sex reversal to female (Davis 1986). The removal of large barramundi (> 900 mm) from within a system may reduce the available spawners from within an area (Milton *et al.* 1998) but it may also reduce the predation on small barramundi by removing large cannibalistic predators (Griffin 1988). Barramundi are highly fecund and recruitment into river systems depends largely on the successful spawning of highly localised populations (Davis 1986). Spawning aggregations occur just before the onset of the wet season at estuarine river mouths, and juveniles can subsequently take advantage of the aquatic habitat that results from flooding (Davis 1986). As they grow, barramundi occupy several habitat types throughout the estuarine system, including temporary supralittoral habitats, billabongs, tidal creeks, and open channels (Russell and Garrett 1983, Davis 1986). A critical factor in maintaining recruitment is assuring that enough females are present in the spawning aggregations. In recognition of the need to protect these critical components of the populations, specific regulations have been developed. In addition to minimum size limits of 580 mm on the Queensland east coast, maximum legal size limits of 1 200 mm are in effect in Queensland (ie to protect large females) (Williams 1997). Furthermore, seasonal closures for harvesting barramundi along the Queensland coast are in effect during the time when barramundi spawning is predicted to take place (Fisheries Regulation 1995).

Queenfish were less abundant in the commercially fished rivers. Rarely targeted, this species is often part of the mixed catch from these net fisheries that are frequently marketed (Yearsley *et al.* 1999). Although their life history is not well documented, larger individuals are common on offshore reefs (Randall *et al.* 1997). They ranged from 46 to 990 mm fork length in our sampling nets, indicating possible nursery use of the riverine systems. This result coincides with findings from north-western Queensland where, based on large catch rates and similar size ranges (30 to 950 mm), the Embley River estuary was identified as a nursery ground for this species (Blaber *et al.* 1989). Queenfish were consistantly more abundant in the river closed to commercial gill netting. The majority of the queenfish caught in the 152 mm mesh nets died before they could be released. This indicates that net fishing has the potential to impact on the larger size classes of the populations regardless of whether they are retained for market or discarded.

Estuary whalers are distributed in tropical seas around the world and are common in estuarine rivers (Compagno 1984). As live-bearers, females give birth to their young at the mouths of estuarine rivers. The newborn sharks generally proceed to upstream habitats, but their body shape and size at birth (550 mm fork length) make these sharks easily caught in large mesh gill nets. Catch in the 152 mm nets was seasonal, localised and mostly comprised of sharks in their first year of life. The differential peaks among the rivers during January may indicate that different rivers are used for pupping from year to year, but that young sharks can be expected to regularly peak in abundance during January. The occurrence of these small sharks in the estuaries coincides with the commercial netting closure meaning that the rapid decrease in abundance of these small sharks is most likely linked with their behaviour than their removal by gill nets.

Substantial quantities of blue threadfin (~ 80 t per year) are marketed by commercial net fishers in the Queensland east coast fishery (about half the weight of the barramundi catch, Williams 1997). The significantly higher abundances of blue threadfin caught in our 152 mm mesh nets in closed rivers indicated that net fishing may contribute to this decrease in abundance in the open rivers. Little work has been conducted on this species, but blue threadfin are known to reach sexual maturity as males at about 200 mm fork length and then undergo sex reversal from male to female (Garrett 1997). Due to the 400 mm total length minimum legal size limit, the commercial catch is mainly composed of females. The net sizes used in the river fishery (minimum of 150 mm in rivers) effectively selects against small blue salmon (< 400 mm TL) however this species tends to become bridled in the net meshes and most are dead if discarded (see Section 7.2.2.1). Commercial catch is mostly concentrated in the estuaries in the middle to southern parts of Queensland, explaining our higher catch rates for the southern and middle regions. In both sampling years, our catch peaked (16 fold) in the southern-closed system in the dry cool season, corresponding with the time of peak commercial catch (Garrett 1997). It is clear from our survey results that blue threadfin have complex seasonal distribution patterns probably attributable to spawning behaviour and specific habitat preferences. These habitat preferences are illustrated by the finding that blue salmon were one of only a few species that were caught in the full range of our nets. Juvenile blue salmon were only caught in three of our sites, middle open, middle closed and southern closed. The majority (96%) of adult fish caught was caught at these same sites. The highest abundances of juvenile blue threadfin caught in the multipanel net were during March and May 2000. A more directed study into the life cycle and habitat preferences of blue threadfin based around the mid-open, mid-closed and southern closed sites would provide clarification of the specific environmental needs ofr this species.

The weight of commercially caught banded grunter (10 – 15 t per year) is about 10% of the barramundi tonnage sold from the east coast fishery (Garrett 1997). Although no significant differences between sites open and closed to commercial gill netting were found for this species, significant regional differences in abundance were evident. As with blue threadfin, particular sites produced higher catches of banded grunter regardless of fishing policy. As banded grunter were also more abundant in our more southerly sites and with peak commercial catch occurring south of the study area, further investigation of the effects of commercial net fishing on banded grunter would best be conducted in more southern locations.

In summary, direct effects of commercial net fishing were observed for few of the species of commercially targeted fish in the open systems. Survey results indicated that four of six species marketed by net fishers had significantly greater abundance and biomass levels in the closed rivers. Of the four species only two, barramundi and queenfish, showed consistent patterns across all regions (ie higher abundance in rivers closed to commercial netting). For estuary whaler the differences in abundance between open and closed rivers occur at a time when no commercial fishing occurs making it likely that this result is an artefact of our sampling regime. Blue threadfin are highly site specific with low catches of undersized fish that are dead when discarded.

Indirect Effects. One of the most widely expressed concerns about intensive and selective fishing activities is that they will lead to imbalances in ecosystem function, and this has ramifications for non-target species (Jennings and Kaiser 1998). Thus, we tested two hypotheses concerned with indirect effects of fishing. Firstly, we hypothesised that other predatory species may take advantage of available prey and therefore be more abundant in the rivers where substantial numbers of barramundi, queenfish, sharks and blue threadfin were selectively removed by net fishing. In estuaries, top level consumers tend to be opportunistic and have overlapping diets (McHugh 1967). Among the competing predators, three species were sufficiently abundant for statistical comparison between open and closed systems: ie *Arius* spp., *P. kaakan* and *Nibea soldado*. However, contrary to our hypothesis, none of these species were consistently more abundant in the open rivers than in rivers closed to commercial netting. None of the competitor taxa listed in Table 20 were sampled in large enough numbers for statistical analysis. Due to the selectivity of gill nets and the non-susceptibility of to net capture some piscivorous estuarine fish species because of their behaviour, they may not have appeared or were rarely encountered in our samples. Lutjanids, sparids and serranids seldom range far from the structure provided by mangrove prop roots and snags (Sheaves 1993 and 1996), and thus rarely encounter set gill nets. Despite this lack of data, our results appear consistent with the views expressed in a major recent review of published studies on the effects of fishing by Jennings and Kaiser (1998). Based on relevent studies in a range of marine ecosystems (but not including estuaries or reefs), these authors concluded that compensatory species replacements seldom occur in response to fishing a particular species guild. Thus, our results may be interpreted as supporting and extending this conclusion for Queensland's tropical estuaries.

For the second indirect effect of fishing tested, we had hypothesized that by reducing numbers of upper level consumers through fishing, abundances of their prey might increase. If this were true, we would have expected to find grater abundances of prey species in the open systems using the smaller mesh nets. However, we found no evidence that prey numbers were higher in the open rivers than in rivers closed to net fishing. In several tests of this theory on coral reefs, the results obtained were similar to ours: reduced abundances of piscivorous target species did not correspond with any detectable increase in the abundance of their prey (see review in Jennings and Kaiser, 1998). In studies of the consequences of predator removal in freshwater systems, strong cascading effects from top predators to lower trophic levels have been empirically demonstrated (Carpenter *et al*. 1985, Power 1990). Apparently the indirect effects of fishing on coral reef and estuarine fish communities are less easily discerned, are less predictable, and may be smaller than in strictly freshwater systems.

If there had been any effect of increased predation in the closed systems, we expected to detect the effect for several reasons. Firstly, diets of barramundi gradually change from penaeid prawns when they are small (200 to 400 mm TL), to mostly fish at larger sizes (400 – 1200 mm TL) (Davis 1985). Ninety-one percent of the barramundi caught in all nets were in this larger size class, and so likely to be mainly piscivorous. Secondly, the prey fishes consumed were most likely to be dominated by engraulids, clupeids, mugillids, and ariids (Davis 1985), the same taxa that were most abundant in our small mesh nets. Perhaps the difference in numbers of predators between open and closed rivers was not great enough to generate detectable differential effects on their main prey. Independently of predation, numbers of the short-lived planktivorous fishes capable of rapid population growth such as clupeids and engraulids may be more closely linked with availability of their food supply, mainly zooplankton (Robertson and Duke 1990). In such riverine estuaries, zooplankton abundances respond to changes in physical forcing functions (eg tidal state, input of freshwater) which are relatively unpredictable (McKinnon and Klumpp 1998). The asynchronous variations in peak abundances of baitfish species observed in our study may well be the result of these dynamics differentially affecting the various species. Thus, contrary to our original hypothesis, the number of predators removed by commercial net fishing did not measurably affect prey abundance levels. The reverse is probably also true: numbers of prey are probably not a limiting factor for populations of barramundi and similar piscivores in these riverine estuaries.

Thus, both hypotheses concerning the indirect of effects net fishing tested false. Neither abundances of prey or abundances of alternative competitors were greater in the commercially fished. Marine ecosystems are said to be well adapted to fluctuations in component species (Jennings and Kaiser 1998). The fishing pressure imposed on our study systems may cause population depletion that is well within the range of variation experienced within the ecosystem naturally. However, as observed in other fished systems, a threshold can be reached where further removals of critical population components from a particular stock leads to an irreversible shift in ecosystem structure and function. Responses to such gross population losses can be switches in species composition to less valuable alternatives (Steele 1998)

Regional effects. Aside from fishing, region had the biggest effect on the spatial distribution patterns of abundant species. The northern region, in particular, was distinctly different from the middle and southern regions. The northern rivers, located in steep rainforest-dominated catchments, supported numerous large ponyfish *Leiognathus equulus* but fewer catfish and barramundi. In contrast, the southern rivers that were associated with flatter eucalypt forest catchments, supported numerous catfish and barramundi. Variation in the aquatic and floodplain habitats may have contributed to variation in the fish communities inhabiting the rivers. Firstly, downstream salinities were lower in the northern rivers and the distribution of estuarine fishes may be strongly influenced by salinity conditions (Sheaves 1998). Other factors such as primary and secondary productivity may also explain the observed differences in the fish assemblages. Secondly, in the flatter topography of the southern systems, expansive floodplains provide alternative habitats that become available to mobile riverine biota when the rivers overflow during floods. These seasonally accessible habitats increase the nursery area for species like barramundi; in contrast, the northern rivers with steeper catchments have only limited wetlands and waterholes suitable as juvenile habitat (Dunstan 1959).

8.3.2 Value of Long Term Fishery Replenishment Zones

This study indirectly addressed one of the main questions involving the integration of fisheries and ecosystems management objectives: what happens to biota in reserves protected from all types of harvest? The effectiveness of reserves has received much attention in the recent ecological and fishery management literature (Bohnsack 1993, Allison *et al.* 1998, Lauck *et al.* 1998, Murray *et al.* 1999). Empirical evidence from several case studies demonstrates that reserves can harbour more diversity, higher abundance, and notably different community structures (see Allison *et al.* 1998). The current study supports the notion that commercial closures could benefit the non-commercial fishery within the reserve. Because we were able to show differences in abundance for some of the target species among replicate protected estuaries; our results may significantly strengthen the case in favour of the effectiveness of no-harvest reserves. The lower abundances of large legal size fish in the systems open to commercial net fishing may not only be due to capture by nets but also because of recreational catches. Although not measured as part of this study, it was observed that recreational effort in closed rivers was higher than in rivers open to commercial netting, however some recreational effort did occur in all rivers sampled. Given the selectivity of gill nets allowed to be used in rivers on the east coast of Queensland it would appear that differences in the abundances of undersized commercially targeted species between sites are not caused by the commercial netting in these areas. Very few of the fish caught in nets smaller than 152 mm mesh would have been captured in these large nets because of their size. In the tropical Queensland rivers studied, closed rivers may serve as stock refugia where numbers of spawning individuals are greater, more larger females potentially produce more eggs, and suitable habitat is present juveniles can survive to a reproductive age. This would all lead to an enhanced level of recruitment to the fishery within the closure,that may possibly extend to areas outside the closure.

To protect and enhance fishery resources, a frequently promoted initiative is to establish permanent reserves in which all resources are protected from all forms of fishing and other harvesting. In such reserves, biodiversity can return to a more natural condition (Bohnsack 1993). Our study did not include sites closed to all types of exploitation, but fishery-independent surveys in locations closed to both recreational and commercial fishing for 25 years in Florida showed greater abundance and larger size classes of all exploitable species than did adjacent fished areas (Johnson *et al.* 1999). Thus, establishing no-take estuarine refugia in Queensland may benefit the broad range of species targeted by both commercial fishers and recreational anglers (eg Lutjanidae, Serranidae, Centropomidae, Polynemidae, Haemulidae) in adjacent fishing grounds.

Table 28: Details of tagged sportfish recaptured in the research gill nets. Source of tags and details: Bill Sawynok, Sportfish Tagging Coordinator, Australian National Sportfishing Association Queensland.

Tag no.	Species	Tagging Details			Recapture Details					
		Original River	Release Date	Total Length mm	Recapture Mon-Yr	Recapture River	Recapture Position	Mesh	Total Length mm	Condition
Z02707	*Lates calcarifer*	Russell	Apr-90	455	Jul-98	Russell	Down	6	830	Live
K25895	*Scomberoides commersonianus*	Haughton	Feb-98	500	Sep-98	Haughton	Down	6	603	Dead
J16216	*Lates calcarifer*	Haughton	Aug-98	430	Sep-98	Haughton	Up	6	460	Live
J02395	*Lutjanus argentimaculatus*	Wallace Creek	Sep-98	375	Nov-98	Yellow Gin	Down	4	380	Live
K13040	*Lates calcarifer*	S. Johnstone	Oct-98	520	Mar-99	Russell	Down	6	766	Live
J16207	*Lates calcarifer*	Ross River	Mar-99	450	May-99	Haughton	Up	4	455	Live
J27233	*Lates calcarifer*	Haughton	May-99	450	Jul-99	Haughton	Up	4	445	Live
K15080	*Lates calcarifer*	Russell	Apr-95	540	Sep-99	Russell	Down	6	830	Live
JO7490	*Lates calcarifer*	Haughton	Apr-98	430	Nov-99	Haughton	Up	4	565	Live
K87241	*Lates calcarifer*	Haughton	Sep-98	530	Nov-99	Haughton	Up	4	635	Live
J44893	*Lates calcarifer*	Unknown	Unknown	Unk	Mar-00	Barrattas	Up	4	560	Live
J17448	*Lates calcarifer*	Unknown	Unknown	Unk	Mar-00	Russell	Down	6	635	Live

In our study we did not address the question of whether areas closed to net fishing potentially affect surrounding fishing grounds. Such an exercise would have involved conducting a concurrent program of tagging and recovery considered beyond the scope and resources of this project. Two of the ten barramundi tagged by recreational fishers (as part of the Queensland ANSA/SUNTAG tagging program) and recaptured in our nets, were shown to have travelled from elsewhere (Table 28). Barramundi are more likely to migrate along the coastline if continuous suitable habitat (eg. numerous creeks, rivers, and extensive mangrove wetlands) occurs in the intervening coastal area (Russell and Garrett 1983). Some movements are likely to occur between closed and open rivers designated as pairs in the current study, especially for the southern and middle regions because of their close proximity and relatively unmodified coastal habitats. Tagging results from the study of a 25-year closure to all forms of fishing in Florida verified substantial fish movements from unfished to fished areas, and documented several catches of trophy-sized gamefish by anglers "fishing the edge" of the refuge (Johnson *et al.* 1999). A system of commercial netting closures is already in place in Queensland estuarine rivers, however there are very few areas totally protected under Queensland legislation. Thus, an approach that merits further consideration is the upgrading some of these already partially closed areas to areas totally protected from all forms of fishing throughout the tropical coast. Such a network could help maintain a flow of commercially and recreationally targeted species into the fished systems.

Evidence from our surveys suggests that unique conditions exist within individual estuarine ecosystems that generate especially beneficial habitats suitable for particular species. For example, the mid-closed river (Haughton) featured far more barramundi than any other rivers sampled. Similarly, the south-closed river (Yellow Gin) produced many more blue threadfin. Other systems appeared to be particularly well-suited to production of haemulids. Identifying the habitat features associated with these distribution patterns would generate criteria for implementing a reserve network strategy with multi-species benefits.

In summary, riverine estuaries open to commercial net fishing had lower diversity, biomass and abundances of larger predatory fish species targeted by the fishery than rivers closed to commercial netting. These effects were similar over a wide range of habitat and environmental conditions with different associated fish assemblages. The findings represent some of the first objective scientific information about the effects of gill net fishing on fish communities in tropical Australian estuaries. Establishing the impacts of net fishing on fish populations outside particular river systems is an important area of research that should be undertaken, if an understanding of the overall effects in connected habitats is to be achieved. From the data presented in this study it is apparent that the use of gill netting is one of the most environmentally sensitive forms of fishing used in commercial fisheries. The ability of fishers using these apparatus to capture high proportions of targeted and marketable catches using techniques that are non-destructive to habitats, and have no detectable effect on the overall species diversity of particular areas indicate that efforts to achieve further meaningful reductions in bycatch should be focused on developing markets for only a few select species.

9. Benefits

The project:

- Provided observer validated information on the bycatch rates and species composition of seven inshore commercial gill net fisheries in Queensland.

- Demonstrated that commercial net fishing operations are very effective at targeting marketable species without having major impacts on bycatch species. Very little of the catch is not marketed and interactions with protected wildlife species were uncommon with no deaths reported or observed.

- Made available information on the proportion of bycatch taken in Queensland net fisheries, essential for understanding the scope of the bycatch issue. This will allow more informed management decisions when catch allocation and biodiversity issues are being debated. It will also provide the commercial industry with a factual basis to defend a currently weak position due to the lack of data on their impacts.

- Made available information on the fate of fish discarded from net catches at least in the short term. These data will directly benefit all state fisheries where similar species and netting methods occur.

- Identified some species where market development opportunities should be sought to further reduce bycatch within the fishery.

- Provided information on the effect of net fishing on inshore biodiversity and options for diminishing unacceptable impacts. These will assist in reviewing current net fishing practices and development of codes of practice.

- Data gathered will be of benefit to the current Queensland stock assessment programs (TRAP and Queensland Fisheries Service, Long Term Monitoring Program) by providing an extended data base.

- Provided information to educate stakeholders about the effects of net fishing allowing a rational debate in resource management decisions, especially those involving bycatch reduction and the maintenance of biodiversity.

- Identified necessary research investigations that should be undertaken to obtain the necessary ecosystem wide understanding of fishery impacts.

10. Intellectual property

Results from this project will be published in a wide variety of scientific and popular journals as well as in open discussions with managers and the general public. Articles will contain information useful in the development of commercial netting practices and improve the current knowledge base on gill netting and its potential affects on sustainability of this fishery. No patents are expected from this project.

11. Further development

Potential future developments building on the information gathered in this project would be to:

- Examine the impacts of net fishing outside the immediate systems in which they occur.
- Develop new markets for currently underutilized bycatch species.
- Examine the why certain locations maintain higher populations of particular species with a view to protecting specific habitats for particular species.
- Monitor areas where extended closures to all types of fishing provide the opportunity to examine post-closure changes in population structures of key species and the effectiveness of the closures at enhancing fisheries outside of the closure area.
- Develop a model to predict how the introduction of a system of closures may function in ensuring the future of associated fisheries.

Comment.
If a viable and sustainable barramundi fishery is to be maintained in the northern coast places such as the Haughton River, Barrattas River and Yellow Gin Creek should be viewed as a "safety deposit box". Many of the areas that were traditionally barramundi strongholds have become less productive in a fisheries sense while increasing the production of agricultural commodities. With further habitat modification and restriction of access to wet lands barramundi populations will continue to decline. The Haughton River has the highest abundances of many of the fish species commonly caught during the fishery independent study and would be a prime example of the value of maintaining continuity of access to juvenile and adult barramundi habitat. Protection of the surrounding habitats will be the most important aspect of maintaining a healthy barramundi population in the future.

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Ian Halliday (80%)	Principal Investigator	QDPI, AFFS Fisheries	1st Sept 1997 to 31st Dec 2000
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15. Appendices

Appendix 1: Total catch by species for rivers closed to commercial net fishing, versus open rivers (all nets combined).

Family / Species	Abundance Closed	Abundance Open	Weight (gr) Closed	Weight (gr) Open
Carcharhinidae (whaler sharks)				
Carcharhinus ambionensis	2	0	1,161	0
Carcharhinus leucas	122	31	126,126	31,938
Carcharhinus sp.	13	0	11,971	0
Rhizoprionodon acutus	0	2		1,134
Sphyrnidae (hammerhead sharks)				
Sphyrna lewini	0	3	0	2,270
Rhinobatidae (shovelnosed Ray)				
Aptychotrema rostrata	1	1	1,101	885
Dasyatidae (stingrays)				
Himantura granulata	1	0	5,821	0
Himantura sp.	1	0	3,545	0
Himantura toshi	1	0	509	0
Himantura uarnak	1	1	883	2,066
Myliobatidae (eagle rays)				
Aetobatus narinari	1	5	1,387	5,377
Clupeidae (herrings, sardines)				
Anodontostoma chacunda	61	143	664	882
Escualosa thoracata	83	165	358	674
Herklotsichthys castelnaui	4,366	3,128	50,530	28,562
Herklotsichthys koningsbergi	0	12	0	693
Nematalosa come	250	511	13,848	15,110
Nematalosa erebi	27	3	4,428	101
Sardinella albella	8	12	62	126
Sardinella brachysoma	80	99	531	686
Engraulidae (anchovies)				
Stolephorus commersoni	52	20	383	136
Stolephorus nelsoni	0	18	0	73
Stolephorus sp.	79	10	477	59
Thryssa baelama	3	1	18	4
Thryssa hamiltoni	1,115	1,148	40,557	46,537
Chirocentridae (wolf herrings)				
Chirocentrus dorab	7	8	2,085	2,609
Megalopidae (tarpon)				
Megalops cyprinoides	125	83	145,724	89,660
Elopidae (giant herring)				
Elops australis	25	38	9,170	15,477
Muraenesocidae (pike congers)				
Muraenesox cinereus	2	0	5,449	0
Chanidae (milkfish)				
Chanos chanos	25	13	21,066	12,099
Ariidae (sea catfish)				
Arius sp.	1,112	1,032	963,432	780,665
Plotosidae (eeltail catfish)				
Paraplotosus albilabris	0	11	0	1,681
Batrachoididae (toadfishes)				
Halophryne diemensis	4	0	735	0
Belonidae (long toms)				
Strongylura incisa	0	1	0	130
Strongylura leiura	0	1	0	49
Strongylura sp.	0	3	0	117
Strongylura strongylura	199	129	7,800	5,661
Tylosurus crocodilus	0	3	0	1,872
Tylosurus punctatus	0	1	0	516
Tylosurus sp.	0	1	0	347

Family / Species	Abundance Closed	Abundance Open	Weight (g) Closed	Weight (g) Open
Hemiramphidae (halfbeaks)				
Arrhamphus sclerolepis	122	91	4,233	2,888
Hemiramphidae	5	0	297	0
Hemiramphus robustus	6	1	190	27
Hyporhamphus quoyi	1	4	20	114
Hyporhamphus regularis	1	1	27	48
Zenarchopterus buffonis	14	34	189	494
Zenarchopterus gilli	1	0	19	0
Zenarchopterus sp.	1	0	5	0
Atherinidae (silversides, hardyheads)				
Atherinidae	0	10	0	41
Scorpaenidae (scorpion fish)				
Notesthes robusta	1	0	38	0
Platycephalidae (flatheads)				
Platycephalus fuscus	10	9	9,585	5,045
Platycephalus indicus	8	11	4,709	3,420
Centropomidae (barramundi, sandbass)				
Lates calcarifer	1,226	430	2,975,304	862,826
Psammoperca waigiensis	1	0	522	0
Ambassidae (glassfish)				
Ambassis gymnocephalus	119	32	533	123
Ambassis nalua	1	0	7	0
Ambassis spp.	3	1	12	4
Ambassis vachelli	203	333	523	678
Serranidae (rock-cod, groper)				
Epinephelus coioides	0	2	0	1,115
Epinephelus lanceolatus	1	1	4,947	13,001
Epinephelus malabaricus	1	1	831	264
Teraponidae (trumpeter, tiger perch)				
Mesopristes argenteus	4	0	552	0
Terapon jarbua	0	5	0	374
Apogonidae (cardinal fish)				
Apogon hyalosoma	0	2	0	6
Sillaginidae (whitings)				
Sillago analis	5	0	1,307	0
Sillago ciliata	5	0	915	0
Sillago sihama	44	65	2,662	3,977
Echeneidae (remora)				
Echeneis naucrates	2	0	16	0
Carangidae (trevally, queenfish)				
Alectis indicus	4	4	2,096	5,441
Carangidae	2	2	472	975
Carangoides hedlandensis	0	1	0	303
Caranx bucculentus		1		548
Caranx ignobilis	106	72	83,998	38,021
Caranx sexfasciatus	7	2	953	142
Gnathanodon speciosus	2	1	11	2,156
Scomberoides commersonianus	290	76	352,628	72,454
Scomberoides lysan	17	4	492	182
Scomberoides sp.	2	0	2,241	0
Scomberoides tala	59	24	25,827	13,887
Scomberoides tol	2	3	19	120
Trachinotus bailloni	5	1	2,330	273
Trachinotus blochi	25	2	41,504	8,470

Family	Abundance		Weight (g)	
	Closed	Open	Closed	Open
Lactariidae (false trevally)				
Lactarius lactarius	14	0	5,491	0
Leiognathidae (ponyfish)				
Gazza achlamys	3	0	59	0
Gazza insidiator	0	1	0	1
Gazza minuta	2	15	7	25
Gazza sp.	5	0	59	0
Leiognathus bindus		9		41
Leiognathus blochi	4	0	5	0
Leiognathus brevirostrus	77	66	154	232
Leiognathus daura	5	0	12	0
Leiognathus equulus	833	550	83,737	49,116
Leiognathus semifasciatus	0	1	0	4
Leiognathus sp.	10	9	21	41
Leiognathus splendens	20	22	41	63
Secutor insidiator	0	2	0	3
Secutor ruconius	10	0	20	0
Lutjanidae (snappers, sea-perch, jacks)				
Lutjanus argentimaculatus	25	15	24,622	13,557
Lutjanus johnii	11	17	13,468	23,379
Lutjanus russelli	0	6	0	239
Lutjanus sp.	1	0	56	0
Gerreidae (silver biddies)				
Gerres abbreviatus	1	16	2	2,130
Gerres acinaces	1	2	8	6
Gerres filamentosus	26	15	1,011	381
Gerres macrosoma	1	0	1	0
Gerres oblongus	1	2	3	7
Gerres oyena	9	5	261	111
Haemulidae (grunts)				
Plectorhynchus gibbosus	16	11	50,102	21,236
Pomadasys argenteus	190	94	74,322	43,823
Pomadasys kaakan	194	158	115,885	121,409
Pomadasys sp.	3	0	1,286	0
Pomdasys maculatum	3	0	20	0
Sparidae (bream)				
Acanthopagrus australis	3	2	1,086	594
Acanthopagrus berda	12	3	3,414	1,198
Sciaenidae (jewfish)				
Nibea soldado	195	189	78,509	75,492
Otolithes ruber	0	1	0	318
Sciaenidae	0	3	0	619
Monodactylidae (diamond fish)				
Monodactylus argenteus	14	4	1,673	366
Leptobramidae (beach salmon)				
Leptobrama mulleri	37	26	4,903	3,663
Toxotidae (archer fish)				
Toxotes chatareus	31	24	13,040	9,773
Toxotes jaculatrix	4	2	1,583	1,007
Toxotes sp.	2	2	815	572

Family	Abundance		Weight (g)	
Species	Closed	Open	Closed	Open
Ephippidae (batfish, sickle fish)				
Drepane punctata	72	56	32,370	24,528
Platax batavianus	0	1	0	2,545
Platax novemaculeatus	0	1	0	436
Platax orbicularis	1	0	869	0
Platax teira	0	1	0	316
Scatophagidae (scat, butterfish)				
Scatophagus argus	22	8	11,319	3,369
Scatophagus multifasciatus	12	16	3,875	4,416
Mugilidae (mullets)				
Liza subviridis	415	335	45,878	46,578
Liza vaigiensis	218	63	367,136	112,505
Mugil cephalus	97	24	138,527	26,947
Mugilidae	16	0	27,794	0
Valamugil buchanani	136	172	52,668	59,949
Valamugil cunnesius	606	391	52,662	31,639
Valamugil seheli	71	95	9,569	22,598
Valamugil sp.	38	33	4,061	2,548
Sphyraenidae (barracuda)				
Sphyraena barracuda	3	14	9,608	5,345
Sphyraena jello	11	17	13,077	8,756
Sphyraena sp.	2	1	31	339
Polynemidae (threadfin salmon)				
Eleutheronema tetradactylum	462	229	511,008	158,693
Polydactylus macrochir	146	26	499,153	109,193
Polynemus heptadactylus	4	2	231	281
Gobiidae (gobies)				
Glossogobius biocellatus	0	1	0	4
Periophthalmus sp.	1	0	981	0
Siganidae (spinefoot, rabbitfish)				
Siganus guttatus	1	0	196	0
Siganus lineatus	1	1	290	24
Trichiuridae (hairtail)				
Trichiurus lepturus	1	0	34	0
Scombridae (mackerel)				
Scomberomorus semifasciatus	32	26	10,291	9,113
Scombridae	0	6	0	28
Stromateidae (pomfret)				
Parastromateus niger	7	0	9,174	0
Bothidae (flounder)				
Pseudorhombus sp.	0	1	0	245
Cynoglossidae (sole)				
Paraplagusia unicolor	1	0	2	0
Soleidae (sole)				
Achlyopa nigra	2	2	450	477
Tetraodontidae (toadfish, puffers)				
Arothron hispidus	9	8	15,768	12,966
Arothron manilensis	2	1	383	253
Arothron reticularis	2	7	2,559	10,734
Chelonodon patoca	3	1	12	4
Marilyna pleurosticta	3	0	17	0
Tetraodontidae	0	2	0	4,100
Totals				
51 families ***141 total species (129 closed, 111 open)***	**14,232**	**10,676**	**7,235,506**	**3,113,954**