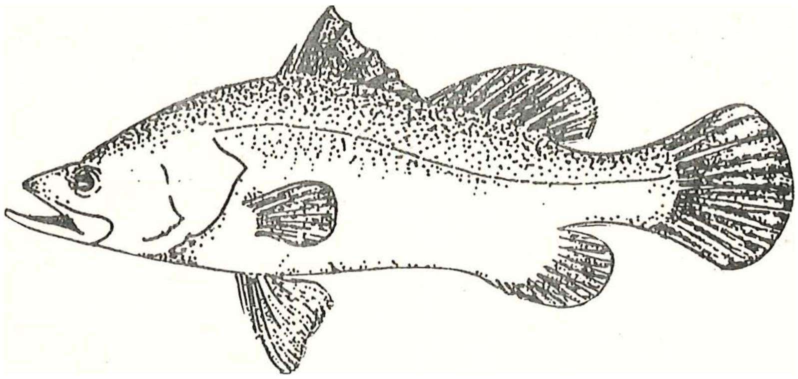
An assessment of the east Queensland inshore gillnet fishery.



D.J. Russell

Northern Fisheries Research Centre

Fisheries Research Branch

Department of Primary Industries

Post Office

Bungalow, CAIRNS Q 4870

January 1986

A report to the

Fishing Industry Research Committee

Final report to the
Fishing Industry Research Committee

An assessment of the east Queensland inshore gillnet fishery.

(Project number 81/46)

D.J. Russell
Northern Fisheries Research Centre
Fisheries Research Branch
Department of Primary Industries
c/- Post Office
BUNGALOW, CAIRNS 4870

January, 1985

CONTENTS

1. SUMMARY

The inshore gill net fishery in tropical Queensland is one of the State’s most valuable fishery resources. The fishery has been split into two entitlement zones; the Gulf of Carpentaria and north eastern coast and the remained of the east coast south to Bundaberg. While the exact quantities of fish produced by the 280 fishermen with east coast endorsements have up to now been undocumented, it is thought to be substantially less than the Gulf of Carpentaria catch which was about 700 tonnes of fillet in 1984. As a result, many east coast fishermen are involved in other fisheries (e.g. crab trapping, beam trawling and bait fishing).

The east coast gill net fishery is a multispecies fishery in which fishermen may take up to 50 different species. They commonly use monofilament gill nets of 10 to 20 cm stretched mesh but there has been a recent trend towards larger mesh sizes (i.e. to 30 cm). Barramuni (Lates calcarifer) is the single most important species of this fishery both by weight and value. It ranges over the entire east coast entitlement zone but is more commonly caught north of Rockhampton. There is evidence that many gill net fishermen target for barramundi and that catches of other fish are in many cases incidental. Studies undertaken into the biology of barramundi have largely supported management strategies already in force although minor alterations have been suggested. Biological data are also presented on the other major commercial fish species (e.g. threadfin salmons (Polynemidae) and grunter (Pomasidae)) and these will be available for use in future management strategies. A voluntary log book scheme which was initiated in 1981 amongst select commercial fishermen to collect fishery data has now been made permanent. This was regarded as an essential requisite for ongoing management of the fishery.

A series of changes to the current management strategy for the east coast gill net fishery have been recommended. These include: an increase to the present minimum legal size of barramundi to 55 cm; identification and protection of barramundi nursey areas; and a review of all estuarine netting closures. As well, it is recommended that further studies be undertaken on the economies of the fishery and the effects of coastal stream barriers. The east coast gill net fishery management plan should be regarded as dynamic and subject to regular review.

2. INTRODUCTION

Most of the world's marine fish harvest still comes from coastal waters despite the rapid development of distant water fishing fleets (McHugh, 1967). Fish yields from estuaries and lagoons are generally high, due to factors including shallowness, inflow of nutrients from rivers, and the influence of large quantities of plant materials (particularly mangroves) received from their shorelines (Makten and Polovina, 1982). Techniques developed to harvest those fish include trawling, line fishing, trapping, seine netting and gill netting.

In Queensland, commercial fishing by means of seine nets or gill nets involves a minimum of 400 fishermen or 215 of the total number of master fishermen (Qld Fish Management Authority, pers. Comm.). A substantial recreational fishery also exists for estuarine and coastal fishes. For some years, both commercial and recreational fishermen have complained of decreasing estuarine and coastal fish catches, particularly of the more commercially attractive species e.g. barramundi (Lates calcaraifer).

In response, the Queensland Government, with the aid of a Fishing Industry Research Trust Account (F.I.R.T.A.) grant, initiated a three year premanagement study of barramundi in 1978. This aimed primarily to collect the information necessary to make management decisions for the barramundi fishery. As a result of this work, certain management initiatives were implemented (see Regulations section), but there was (and still is) a need for an ongoing assessment of their impact. Further information was needed on the barramundi fishery to aid in the evaluation of these management strategies, and the effect these initiatives had on the overall east coast inshore net fishery, a multispecies fishery, was unknown. In recognition of this need for further information the Queensland Department of Primary Industries initiated a F.I.R.T.A. assisted research project in 1981.

Programme Objectives: The broad goals of this research programme were:

1) To collect, collate and analyse biological information on the east coast gill net fishery so as to accumulate a store of biological baseline data for management purposes and

2) To monitor and assess aspects of the current management regime for the fishery.

More specifically the objectives were:

- To determine catch composition with respect to species, sizes of fish, seasonality and habitat of the commercial fishery. Aspects of the biology of selected species were also to be investigated.

- To determine the effect of current gear restrictions, seasonal and area closures on catch composition and on the commercial viability of fishermen.
- To investigate alternative management, including alterations in restrictions and design of fishing gear.

Structure of the Fishery: Three important aspects of the fishery are a) the fishing methods and equipment
b) the areas fished
c) regulations governing type and use of gear

Gear: Gill nets are widely used in Queensland to catch commercial fish species in estuaries and on coastal foreshores. A gill net consists of a sheet of netting hung with floats and leads on opposite sides so that it hangs vertically in the water. The netting material used may be multifilament, kuralon or nylon but is more commonly monofilament. Mesh size is measured as stretched mesh from centre knot to centre knot. Nets are set, usually with anchors, or with one end tied to a tree or solid structure and the outer end anchored, in a place where fish are thought to move. Nets are usually set at right angles to the bank. They may be set on the surface or sunk in deep holes. Fish become tightly wedged, or enmeshed in the webbing, tangled by projecting spines or teeth or bridled with a mesh caught in the mouth. Nets are serviced at regular intervals with fish being removed, processed (filleted or gilled or gutted) and chilled on ice or placed in a freezer.

Netting Areas: In eastern Queensland, nets may be used, subject to area and seasonal closures, in estuaries, or along coastal foreshores. An estuary is defined as the part of a river or inlet up to the limit of tidal influence. In estuaries, nets are usually set in channels or in deep holes. Areas with obstructions such as rocks or in the vicinity of fallen timber are favoured as netting locations. These are mud flats, river mouths, beaches and rocky headlands.

Regulations: The inshore net fishery is controlled by regulations set out in the Fisheries Act (1976 - 1984) and the Fishing Industry Organisation and Marketing Act (1982 – 1984). Only endorsed master fishermen may participate. Management measures have been taken to conserve the fishery. These include:

(a) A closed season on the taking of barramundi from November to January inclusive.

(b) The establishment of two limited entry fisheries for the east coast and Gulf of Carpentaria.

(c) A weekend closure in most rivers and creeks on the east coast to reduce conflict between amateur and commercial fishermen.

(d) Area closures, both total fishing and partial netting bans.

(e) Identification and declaration of habitat reserves for the preservation of fish nursey grounds.

(f) A bag limit for barramundi on amateur fishermen. This applies only to the east coast.

Past commercial landings:

In 1981, a compulsory catch-log scheme was introduced into the Gulf of Carpentaria limited entry gill net fishery with a similar scheme introduced on the east coast in 1984. Prior to 1981 there was no official monitoring of total barramundi catches in Queensland. The only figures available were landings made at Queensland Fish Board Depots in major centres (Table 1) These probably bear little resemblance to actual total catches as fish were also marketed through many other outlets. The Fish Board statistics do, however, give an indication of relative landings at various east coast centres. Landings are higher in the northern centres and decrease with increasing latitude. Maryborough and Bundaberg have low landings. Total landings for all east coast centres fell from 94.4 tonnes in 1977 to 50.7 tonnes in 1981.

Landings at some centres, eg Cairns may be inflated due to transport of fish from other areas, e.g. the Gulf and Princess Charlotte Bay. It is difficult therefore to accurately gauge the relative quantities of fish caught on the east coast and Gulf of Carpentaria.

	1977		1978		1979		1980		1981	
Cairns	36468	(26.6)	22174	(13.4)	2818	(1.7)	28756	(21.3)	23378	(19.8)
Innisfail	4273	(3.1)	4791	(2.9)	3265	(1.9)	4823	(3.8)	3297	(2.7)
Townsville	27966	(20.4)	18574	(11.2)	11960	(7.1)	17560	(13.0)	8412	(7.1)
Bowen	1585	(1.2)	91	(0.1)	77	(0.1)	27	(0.1)	186	(.2)
MacKay	6362	(4.6)	5690	(3.4)	5679	(3.4)	3894	(2.9)	3342	(2.8)
Rockhampton	8028	(5.9)	9100	(5.5)	8621	(5.1)	8429	(6.2)	7256	(2.73)
Yeppoon	3921	(2.0)	3942	(2.4)	3388	(2.0)	1629	(1.2)	849	(0.7)
Rosslyn Bay	166	(0.1)	4	(0.1)	164	(0.1)	33	(0.1)	224	(.19)
Gladstone	3750	(2.7)	5444	(3.3)	5041	(3.0)	2429	(1.8)	2236	(1.9)
Bundaberg	976	(0.7)	6227	(0.4)	2257	(1.3)	496	(0.4)	568	(0.6)
Maryborough	872	(0.6)	1145	(0.7)	1493	(0.9)	930	(0.7)	911	(0.7)
Total (east coast)	94367	(69)	77182	(46.7)	44763	(26.7)	69006	(51.2)	50659	(42.9)
Total Fish Board	136948		165256		167675		134865		118019	

Table 1: Fish Board landings (kg of fillet) for the major east coast depots north of Maryborough for 1977-81. The percentage for each centre of total annual Fish Board landings is given in brackets. Weights have been rounded to the nearest kilogram. Total weights may not necessarily equal the sum of individual landing weights.

3. METHODS AND TECHNIQUES:

In order to assess the the inshore gill net fishery data were collected in two ways: catch and effort information was obtained directly from selected commercial fishermen using a voluntary log book scheme and through a research netting programme. The log book scheme was initiated in August 1981 and terminated in July 1984. It involved up to 19 fishermen completing monthly returns on their fishing activities. Details of the research netting programme are as follows.

Study sites: The topography of the eastern Queensland is dominated by the Great Dividing Range, which follows closely the coastline for most of its length. Most of the rivers and streams which flow to the east of the Dividing Range into the Coral Sea are relatively short. In the study area (Cairns to Baffle Creek), there are two major exceptions to this: the Burdekin and Fitzroy Rivers.

To achieve the objectives of this study, an intensive research field programmme was designed and implemented. Study sites were chosen in estuaries and associated foreshores of selected typical rivers. A map showing the location of all five study areas on the east Queensland coast is given in Figure 1. Within each study area, a series of sites, representative of commercial fishing grounds, were chosen for detailed examination. A number of locations and/or habitats (e.g. river, river mouth, foreshore) were examined within each site.

Fifteen permanent sites were established, while other locations were spot sampled at irregular intervals.

Sampling Period: During the period July 1981 to the end of February 1983, 10 permanent stations from Cairns south to Mackay were routinely visited at either monthly or bimonthly intervals. At the end of this period, sampling of all these locations, with the exception of the Cairns sites, was terminated. A new series of five stations from Bundaberg to Mackay was then established and sampled monthly from March 1983 until April 1984.

Netting Operations: Sampling was undertaken by a three man research team using a four wheel drive vehicle and small aluminium dinghies. At each location a selection of gillnets, which were especially designed and built for the project, were set in both estuarine and foreshore situations. Net sizes, (which ranged from 10 to 20 cm stretched mesh), type and construction were similar to those commonly used in the commercial fishery. The technique for the placement of nets was as outlined in section 2. Mainly monofilament nets were used, however a small trial was carried out with multifilament mesh. Nets were generally set in the late afternoon and retrieved the next morning. On a number of occasions however the sampling was for a shorter time, around 6 hours. Most commercial catches are made at night. Periodic checks of the net were made at about two hourly intervals to clear enmeshed fish and to ascertain if the net was functioning properly.

Processing of Catch: With the exception of certain fish (barramundi) which were tagged and then released the catch was routinely processed in the following manner. All fish were measured (total length or fork length to nearest 0.5 cm), weighed to the nearest 100 gm and then dissected to determine their sex and gonad development. In the field, the gonad development of each fish was assessed macroscopically however barramundi tissue specimens were routinely collected and processed in the laboratory for microscopic examination. This had the dual purpose of allowing for confirmation of macroscopic staging and to check for sex inversion. A gonosomatic index (percentage of gonad weight in total body weight) was also calculated for each barramundi sampled.

Tagging: Only the barramundi, Lates calcarifer, was tagged during this study. The primary method used for capturing fish to be tagged and released was gill netting. A few fish were also tagged by amateur fishermen angling with lures.

There was a set procedure for tagging. The net was carefully cut away from the fish and the fish's suitability for tagging visually assessed. Factors such as current velocity, water temperature, captive time in the net and damage sustained while in the net all contributed to the overall condition of the fish. If the fish was judged to be suitable it was immediately weighed, measured, checked for reproductive status (i.e. a running ripe fish) and then tagged and released. To minimize chances of immediate recapture, the release site was usually at least 100 metres from the net where it was captured.

Two tag types were used; dart tags and metal headed tags. Both of these were essentially tubular, coloured plastic streamers between 10 and 15 cm long which, when applied, protruded externally from the fish. Individual tags had printed on them a unique four or five digit number for identification, an address (Q'ld Fish. c/- P.O. BUNGALOW) and then the number repeated.

A dart tag has a plastic barb which holds the tag in place when it is injected through the dorsal musculature just below the posterior half of the first dorsal fin. The applicator used for this operation is a stainless steel tube sharpened at one end. The diameter of the tube is only fractionally larger than that of the tag. The tag and applicator are inserted into the fish and the applicator withdrawn leaving the tag in position. Where possible the tags were positioned in such a way to allow the anchor to lodge behind the pterygiophores associated with the dorsal spine. As this was not always possible, particularly in larger fish, efforts were made to leave the barb embedded as deeply as possible in the muscle. With the metal-headed skin tags, a blade of stainless steel (0.8 cm by 3.5 cm) was shallowly implanted into the musculature. A specially designed applicator was needed for this operation.

Successful communication with the fishing public is an essential element of tagging programmes which rely on industry and public co-operation for tag return data. Considerable effort was put into a publicity campaign involving addresses to amateur and professional fishing bodies and media releases. A reward poster was also distributed (see Appendix 1). This publicity campaign was devised to make the public aware that there was a tagging

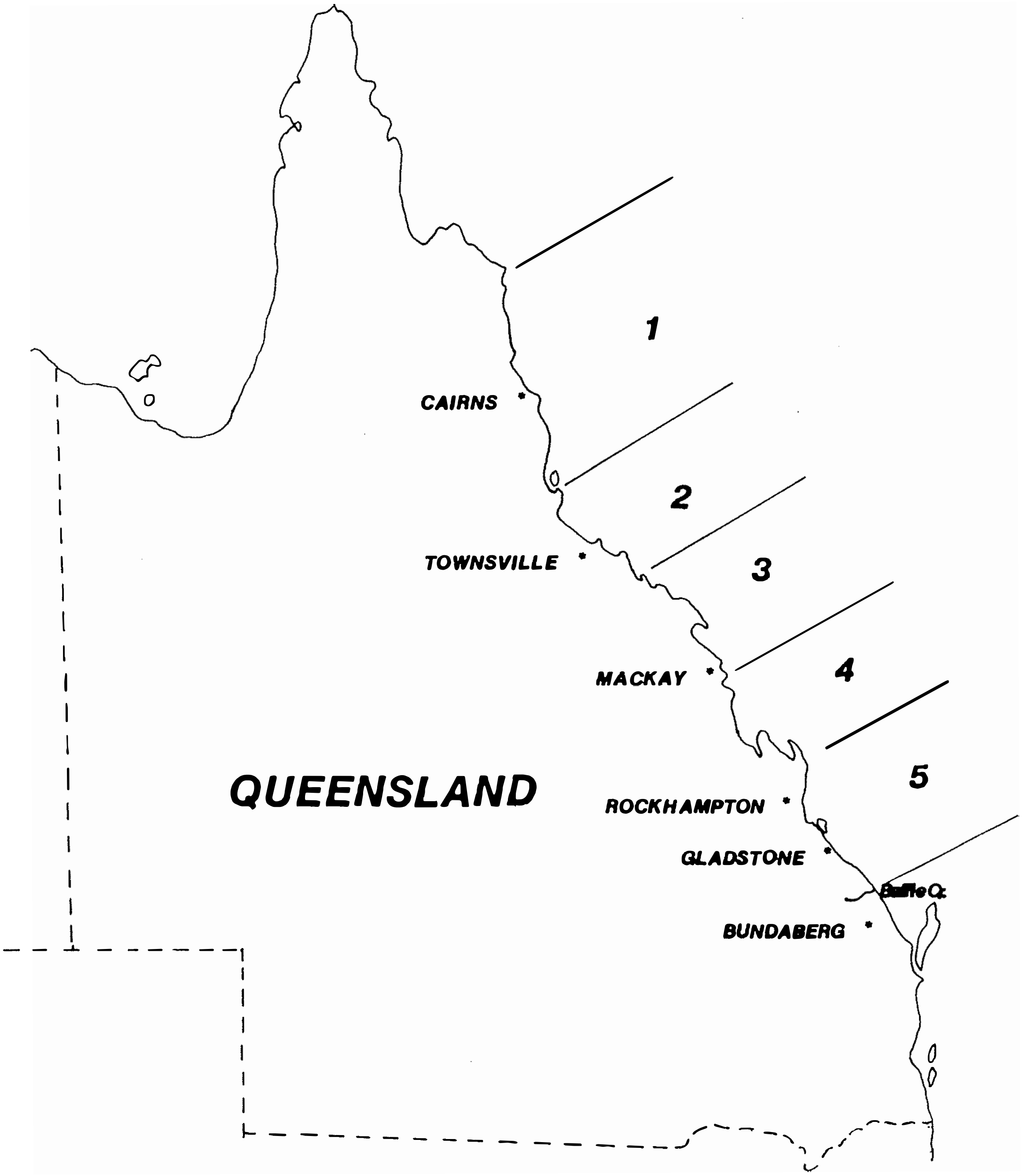


Figure 1: Location of study areas on east Queensland coast.

programme underway, and to inform them of the research objectives, where to look for tags and what to do if a tagged fish was caught. In the event of the recapture of a tagged barramundi the following information was sought.

- tag number or preferably return of the actual tag
- date and place of recapture
- length and weight of the barramundi
- sex of the fish (if easily determined)
- fishing method

A nominal reward of $5 was offered for the return of each tag. A personal letter was forwarded to each fisherman who returned tags giving details of the movements and growth of that tagged fish. As well, details of recaptures were put in an irregular newsletter to participants in the commercial log book programme.

Reproductive studies: The volumetric method of sub-sampling eggs, similar to the technique described by Moore (1980), was used to estimate barramundi fecundity. The ovary was first fixed in 10% formalin. The volume of water which it displaced was then measured to the nearest ml. The ovarian wall was then peeled off and the volume of water it displaced measured. A nett displacement (V) was calculated by subtracting the displacement of the ovarian wall from the total displacement. Eggs in the ovary were then gently teased apart, filtered and three or four samples, each displacing 0.4 ml of water, were taken. After the eggs in each sample were counted under a dissecting microscope, an average number per sample (N) was caculated. Small, underdeveloped eggs were not counted. Only mature ovaries were used. The fecundity was then calculated using the formula F = 5x(NxV).

In preparation for microscopic examination gonads were initially fixed in Bouin's solution for a period of at least two weeks. Median transverse sections of approximately 0.2 cm width were cut with a surgical blade and then placed in 'tissue tek' cassettes and allowed to wash in 70% alcohol until processed. Tissue was then placed in an automatic tissue processor for dehydration, clearing and infiltration procedures before removal and vacuum infiltration in paraffin wax for 30 minutes. Tissue samples were then placed in moulds of paraffin wax in readiness for microtome sectioning. Sections of four micron thickness were cut using a rotary microtome. After drying, slides were stained using Harris's haemotoxylin and eosin and mounted in Depex.

In the field, gonads of all commercial fish species were given an index of maturity based on a six stage classification scheme.

The scheme was as follows:

1 - immature

2 - resting / slight development

3 - maturing early

4 - mature

5 - running ripe

6 - spent

A detailed description of the morphology of barramundi gonads during each of these stages is given by Davis (1982). In a number of species, difficulty was experienced in differentiating stage 6 males from stage 2 - 3 males. When such difficulties were encountered the fish were described as stage 2.

Physical Parameters: At each netting location, measurements of surface water temperature, salinity and turbidity were made. Procedures were as follows. A mercury-in-glass thermometer was used to measure surface water temperature at each sampling location. This measurement was always made at dusk regardless of tide. A vial of water from each location was returned to the laboratory and salinity determined using an American Optical Corporation temperature compensated optical salinometer. The water sample was always taken as close to the high tide as practicable. The turbidity of this water sample was also determined using a Hach turbidity meter.

Data Processing: Data from both the research netting and log book programmes were entered onto an SR 72 micro-computer and stored electronically on floppy disks. Processing was undertaken using both off-the-shelf software and with specially designed programs written in MBASIC by staff at the Northern Fisheries Research Centre. Data were also transferred onto the PDP10 system of James Cook University for more involved analytical procedures.

4. RESULTS AND DISCUSSION:

4.1 Commercial Fishery:

Data on a total of 1571 fishing days was supplied by 19 commercial fishermen working in the seven regions of the east coast (Figure 2) Most of the commercial fishermen surveyed operated only in one area, generally close to their place of residence. Only two fishermen worked in more than one area, travelling by boat or truck to their fishing grounds. In 1982, a census of all Queensland commercial fishermen by the Queensland Fish Management Authority (Q.F.M.A.) found that there were no itinerant net fishermen. All the net fishermen were found to work in only one zone. Four of the fishermen who took part in the present survey had large displacement boats similar to those used by net fishermen in the Gulf of Carpentaria. As well as

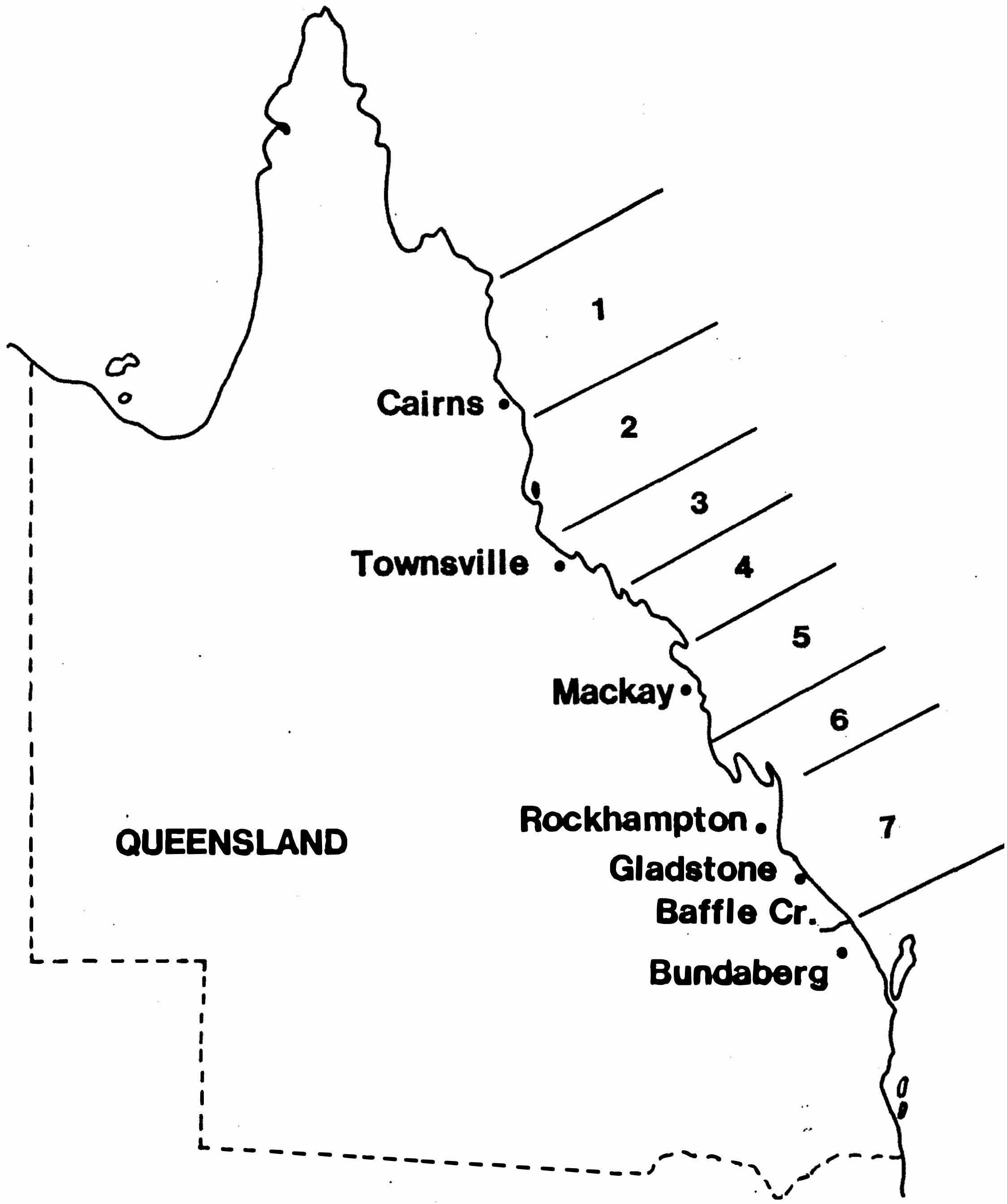


Figure 2: Location of study areas on the east Queensland coast.

gill netting these were used in other fisheries such as beam trawling and reef bottom fishing. The remaining fishermen worked out of either small, aluminium dinghies or, in two cases, larger fibreglass or aluminium speedboats. The close proximity of markets and the easy accessibility of most fishing areas made extended fishing trips unnecessary. Consequently, the number of maintenance and travelling days was relatively low at 572. For every 2.7 days spent fishing one day was spent in maintenance and travel. This however did not take into account time lost through unfavourable fishing conditions such as poor weather, presence of jellyfish and weed and unsuitable tides. Master fishermen either operated alone or with one or more assistant fishermen. It was unusual for two or more master-fishermen to work together for extended periods. Fishermen processed their catch on the fishing grounds either by filleting or by removing the viscera from the fish. The fish were then placed in a freezer or an icebox.

4.1.1 Capital Investment: Capital investment by net fishermen is low when compared to that needed in other fisheries (e.g. otter trawling). Operating expenses of this type of fishery are also relatively low. For the basic unit outlined above, variable costs would include outboard fuel, ice, and general maintenance. Fixed costs would include compulsory fees and registration, depreciation on fishing equipment and interest payments on loans. As the operation becomes more sophisticated the operating expenses increase. For example, an assistant fisherman may be employed in a larger operation. He may be paid a flat wage or, as is more common, may be given a percentage of the profits.

4.1.2 Participation in Other Fisheries: In the 1982 census of Queensland fishermen by the Q.F.M.A., 229 fishermen gave their primary fishing method as set gill netting and a further 94 gave gill netting as a non-primary fishery in which they participated. No data on participation in other fisheries were specifically asked for in the gill net catch return questionnaire, however a number did supply this information. As a result of these data and from fishermen interviews it would appear that very few fishermen, if any, were solely involved in gill netting. In fact, information available suggests that some fishermen may supplement their income by seasonally working in three or four alternate fisheries. These include ring netting, bait fishing, crab trapping, demersal and pelagic line fishing, beam trawling and even otter trawling. During this study it was not uncommon to observe commercial fishermen simultaneously involved in gill netting and other estuarine fisheries such as crab trapping.

4.1.3 Alternative Estuarine Fishing Techniques: While detailed examination of these methods was beyond the scope of this project their existence and use in the commercial fishery must be acknowledged. Other fin fishing methods presently being used in inshore waters include trapping, ring/seine netting and line fishing. These are used mainly to augment rather than to replace gill netting. Whereas gill netting can be used in a wide variety of habitats under diverse conditions these alternate techniques are somewhat limited in where and when they can be used and for what species are caught.

Trapping: Arrowhead traps, traditionally constructed from wire mesh and mangrove stakes, have been used commercially throughout

Queensland for many years. They are almost always confined to protected foreshores (e.g. beach) and are not suited for operating in creeks and rivers because of problems caused by runoff, strong currents and excess debris. Species caught in foreshore nets would be similar to those caught in arrowhead traps. If traps are not serviced regularly fish spoilage quickly results. In high tidal areas, it is difficult to locate traps with receival boxes below the low water mark. The number of operational traps has been gradually reduced, with only 11 now remaining. Under the Fisheries Act no fish traps are permitted south of Rockhampton in central Queensland.

Ring netting/seine netting: Beach seine netting can be most profitably used for species which travel inshore in large schools and which can be located visually. This technique is used very successfully on sea mullet (Mugil cephalus) in southern Queensland (see section 4.5.6). Apart from mullet and bait species, there would appear to be few commerical fishes on which the technique could be profitably and consistently used. Seine netting is very difficult in mud estuaries. Ring netting, which is a combination of seine netting and gill netting, can be used in estuaries and also in certain foreshore situations. It involves encircling with a net, areas where fish are thought to be concentrated and then disturbing the enclosed water by some means, e.g. with an outboard motor. The disturbance results in fish being frightened or chased into the net where they are enmeshed. This method is widely practised in areas 5 and 6, and success is dependent on negligible current (it is generally done on low tide inside estuaries). Threadfin salmon, barramundi, banded grunter, mullet and flathead are among the species which can be caught this way but the catch per unit of effort is generally low.

Commercial line fishing: Inshore commercial line fishing is not widespread. Much of the commercial line fishing is in estuaries, specifically for barramundi. It involves using a live bait (fish or prawn) on a hook with a heavy gauge line.

Other techniques: Other fishing methods which have potential for use in this fishery include tunnel netting and drift netting. Drift netting with small mesh nets is used successfully for bait fishing and is used to a limited extent for food fish species such as threadfin salmon and some mackerels. The author is unaware of tunnel netting being used north of the Harvey Bay area. The technique is used very successfully in catching yellow fin bream (Acanthopagrus australis). This species is not a major component in gill net catches in the study areas, and it is not known if major species of this fishery would be vulnerable to tunnel netting. Its potential should be investigated, with particular attention being given to the by-catch, which may include juveniles of commercial fish species. Both of these techniques would be suited to open flats inside large rivers or protected foreshores. In estuaries which have strong currents or which are obstructed with rocks or fallen timber, such methods would be unsuitable.

4.1.4 Commercial Gill Nets: In rivers, the most commonly set gill nets were monofilament of mesh size range 11.5cm to 21.5cm stretched mesh. On foreshores, monofilament nets from 10cm to

21.5cm stretched mesh were most widely used. Twine diameters varied according to mesh size, with the larger meshes of line 70 and 90. Two fishermen in the Burdekin region (area 3) regularly used monofilament nets of 23, 24, 25.5 and 30 cm stretched mesh in both river and foreshore situations. While net material was not specified in the gill net return form, it is known that most of the fishermen in the survey exclusively used monofilament nets. Some of the larger nets were three-stranded monofilament, which was needed to hold the larger fish. Monofilament nets have the advantages of being easily compacted, are light when wet, rot resistant and of low visibility in the water. Average length of net set varied with situations and habitats, although maximum lengths and numbers are controlled by regulations. Over the period of this study those commercial fishermen who forwarded returns set a total of 494,194m of net.

4.1.5 Target Species: A wide diversity of fish species are meshed in gill nets, particularly on foreshore sets. While gill nets are not selective in the species they catch (Clay, 1981), a fisherman may select for fish size by using different mesh sizes. Smaller species should not mesh in large mesh nets although some species do bridle. The total weights of species caught in the study area are shown in Table 2. The importance of barramundi in the commercial catch can be seen from the ratio of barramundi caught to all other species. In areas 2 and 3 the weight of barramundi and the total weight of all other fish species caught were equal or nearly equal.

Fillet Weight (kg)

Area	Period (days)	Barramundi	King Salmon	Blue Salmon	Others	Ratio of Barra to all other fish
1	1	0	5	5	0	
2	476	3887.92	329.77	1253.17	2801.32	1:1.13
3	259	2680.12	73.04	354.15	2257.97	1:1
4	101	570.54	54.98	318.98	1097.5	1:2.58
5	202	3223.65	363.24	2057.64	4501.5	1:2.14
6	301	2103	939	2513	2366	1:2.77
7	231	808	1549	31	42	1:2
TOTAL	1571	13273.23	3314.03	6532.94	13066.29	1:1.73

Table 2: Total fillet weight of species caught by commercial fishermen participating in the log book programme.

4.2 Catch Statistics:

4.2.1 The C.P.U.E. of commercial net fishermen: Analyses of log-book data were undertaken for the main fish categories;

barramundi, king salmon, blue salmon and all other species. Log (total weight for fish caught) was regressed on log (number of days fished). Attempts were then made to improve these models by including terms for geographic region and proportion of time involved in river fishing. After finalization of these models the coefficient of log (number of days fished) was tested for any difference from one. If the coefficient is one then the weight of the catch is proportional to the number of days fished when the other terms in the model were kept fixed. Hence C.P.U.E. is a meaningful quantity. For all fish categories the coefficient was found to be acceptable as close to one.
Point estimates and 95% confidence intervals (C.I.) of the median C.P.U.E for operators were then calculated by back-transforming sample means and confidence intervals on the log scale (Table 3).

Species	Model terms	Calculated median	95% C.I.
Barramundi		8.0	(5.44, 11.54)
King Salmon	Areas (2-4)	0.69	(0.46, 1.04)
	Areas (5-7)	3.56	(2.36, 5.38)
Blue Salmon		3.5	(1.56, 7.86)
Other Species	Percent River Fishing		
	0%	11.03	(5.79, 21.02)
	50%	5.64	(2.97, 10.11)
	100%	2.88	(0.94, 8.83)

Table 3: Median C.P.U.E. of operators for each species.

Barramundi: There was no indication of any effect on C.P.U.E. due to region or proportion of time involved in river fishing. The confidence interval was wide due to large variability in C.P.U.E. between fishermen (Table 3).

King Salmon: After deletion of a number of operators because of atypical catches, data indicated that there was a strong geographic effect on the catches. On further analysis it was clear that the study area divided itself geographically into two regions:

1) North coast - Areas 2, 3 and 4

2) South coast - Areas 5, 6 and 7

There were no apparent differences between areas within each region and no indications of any effects related to the number of river days or to the proportion of river days fished.
The C.P.U.E. for king salmon caught in southern areas (5, 6 and 7) was several times as great as that in northern waters (areas 2, 3 and 4) for the number of days fished (Table 3).

Blue Salmon: A number of fishermen were deleted from the analysis because they were either inefficient at catching blue salmon compared to most other fishermen (i.e. low catches for the number of days fished) or because reliable information on their catches was not available. There were no indications of any river days or area effects.

Other Species: After a number of deletions a total of 12 fishermen were used in the analyses. There was no evidence of any area effect. However there was evidence of an effect of proportion of days river fished on C.P.U.E.. It appeared that the median C.P.U.E. decreased as the percent of river fishing (Table 3) increased. This implies the more time spent foreshore fishing, the higher the catch of mixed species.

A comparison was made of C.P.U.E. of the foreshore and river fishing operations of individual fishermen who worked in both habitats. Sample size was too small and variability too wide to come to any definite conclusions.

4.2.2 Seasonal variation in C.P.U.E.: Log book data were analysed to determine if there were any seasonal effects associated with the catches of gill net fishermen. Catches were allocated to three seasons which were defined for the purposes of this study as:

- autumn (February to April)
- winter (May to July)
- spring (August to October)

Only a small amount of fishing was recorded for the period of November through to the end of January, the closed season on barramundi. For this reason data obtained for these three months were excluded from the analyses. Examination of data for all fish categories showed that it was acceptable to use log (catch per day), i.e. log (C.P.U.E), for seasonal effects after allowing for an operator blocking effect. These analyses were considered as a randomised blocks analysis and were completely balanced and orthogonal.

Barramundi: There was evidence of a seasonal effect ($p<.05$) due to catch per day being much greater in autumn than either winter or spring (Table 4). The autumn C.P.U.E. was almost twice that for winter or spring.

King Salmon: No evidence was found of any seasonal effect on the catches of king salmon.

Blue Salmon: There was clear evidence ($p<.05$) of a seasonal effect producing a higher blue salmon catch per day in winter. The C.P.U.E. in winter was more than double the C.P.U.E. in autumn and spring.

Other Species: After what was considered to be an unusually large catch was deleted from the data, no evidence was found of any seasonal effect on the C.P.U.E. for other species.

	Autumn	Winter	Spring	S.E.(Diff.)
Barramundi	10.02	6.26	5.32	0.2
King Salmon	1.64	1.48	1.37	0.16
Blue Salmon	3.10	7.17	2.64	0.34
Other species	7.55	11.36	10.98	0.24

Table 4: Median C.P.U.E. of operators catching the major groupings of fish by season. No data were available for summer, the period of the barramundi closed season. S.E.(Diff.) is the standard error of difference after log transformation.

4.2.3 Fishermen C.P.U.E. - differences between river and foreshores: Log book data were used to compare C.P.U.E. for gill net fishermen who undertook foreshore and river fishing. Operators who totally fished in either river or foreshore habitats were not included as they provided no information on the comparison between river and foreshore fishing within operators. No data obtained during the closed season on barramundi were included. The log(C.P.U.E.) was analysed using a paired t-test with pairing based on the operators.

Barramundi: There was no evidence that the log (catch per day) was different between those operators who undertook both river and foreshore fishing. The 95% confidence interval for the ratio of the river mean to the foreshore mean for catch per day was calculated (Table 5). As the ratio was close to one, there was a suggestion that fishermen who fished in both habitats (river and foreshore) chose whether they fished rivers or foreshores on the basis of barramundi catch.

King Salmon, Blue Salmon and Other Species: Analyses of log (catch per day) were performed for each catch type. No evidence was found for any differences between river and foreshore fishing for either of the variates. In all cases the 95% confidence intervals were too wide to be of practical use (Table 5). The river to foreshore ratios for catch per day were much more variable between operators for these three catch types than for barramundi. Again this suggested that many operators tended to treat the inshore gill net fishery as a barramundi fishery and caught other species primarily in the process of catching barramundi.

	Catch per day	
	Ratio	95% C.I.
Barramundi	1.25	0.85, 1.82
King salmon	1.36	0.47, 3.92
Blue salmon	1.57	0.35, 6.98
Other species	0.56	0.14, 2.31

Table 5: Ratio of river mean to foreshore mean C.P.U.E. (catch per day).

4.3 Catch Composition:

The species and their occurrence in the catch varied from area to area, and, within an area, from habitat to habitat. While species numbers in most areas was generally high, the bulk of the weight of the overall catch was usually attributed to only a few species.

Area 1- Cairns: Species numbers along the foreshore (30 species) were higher than the river habitats (15 species). Barramundi (Lates calcarifer) made up the bulk of the estuarine catch (75% by weight) while on the foreshores barramundi, king salmon (Polynemus sheridani) and blue salmon (Eleutheronema tetradactylum) were the major components. There was no significant difference in the mean length of barramundi ($p>.01$) and blue salmon ($p>.01$) caught on the foreshores and in the river estuary. King salmon caught on the foreshore were longer than those caught in rivers ($p<.05$).

Murray River: A total of 22 species were recorded from this river estuary and its adjacent foreshores. On the foreshore 17 species were recorded with 21 found in the river. By weight, barramundi (46%) and blue salmon (22%) accounted for most of the estuarine catch, and similarly on the foreshore the main components were barramundi (26%) and blue salmon (32%). There was no difference in the mean lengths of blue salmon ($p >.01$) caught in either habitat, however barramundi caught in the foreshore were significantly ($p<.05$) larger than those caught in the rivers.

Area 2 - Burdekin Delta: A total of 26 species were caught in the Burdekin area, with 23 of these being recorded from foreshores and 20 from rivers. Main component species of the river catch were blue salmon (15%), barramundi (58%) and banded grunter (Pomadasys kaakan) (10%), while blue salmon (30%) and barramundi (49%) dominated the foreshore landings. Mean lengths of all three main species were significantly greater ($p<.05$) on the foreshores than inside the rivers.

Area 3 - Mackay: Twenty species were caught in gill nets in the Mackay study areas, with 18 of these recorded from rivers and 14 along foreshores. In rivers, barramundi (50%), king salmon (10%) and blue salmon (12%) made up the bulk of the total catch. Similarly on the foreshores the major species were barramundi (29%), king salmon (13%) and blue salmon (24%). Mean lengths of all three species from rivers and foreshores were not significantly different (p>.01).

Area 4 - Broadsound: Of the 24 commercial species recorded from this area 16 were taken in river habitats and 16 from foreshores. Seven species were exclusive to foreshores and a further 7 exclusive to rivers. In the rivers 70% of the live weight of fish caught were barramundi, while on the foreshore barramundi (45%), king salmon (11%) and banded grunter (11%) were dominant. Mean length of barramundi caught on the foreshore was significantly higher (p<.05) than those caught in rivers, while blue salmon showed no significant difference (p>.05).

Area 5 - Fitzroy Delta and Gladstone Narrows: All netting locations for this area were within the Fitzroy delta or sheltered waters of the Narrows separating Curtis Island from the mainland. No strictly foreshore areas were sampled. Only nine species were recorded from this area with barramundi (70%) being the main component, by weight, of the catch. Minor species were blue salmon (8%), king salmon (11%) and spotted jewfish (*Johnius dicanthus*) (9%).

Baffle Creek mouth: Twenty-four species were taken in commercial sized nets from this location with barramundi (38%) and sea mullet (*Mugil cephalus*) (23%) being the major components. Surf prevented foreshore netting. It is notable that sea-mullet, which were insignificant components of the catches in other areas, are a major species in this location. Baffle creek is at the northern extremity of the eastern Australian mullet fishery. (See section 4.5.6).

4.4 Biology of Barramundi *Lates calcarifer*:

Barramundi are caught in rivers, creeks, coastal foreshores and on nearshore islands along the Queensland coast north of Maryborough in the south-east corner of the state. It is an extremely popular angling and commercial species and grows to in excess of 70 kg in weight. The average length of 845 fish caught in gill nets during this study was 69.8 cm. Figure 3 shows the length-frequency distribution of all barramundi caught during this study. Aspects of the biology of barramundi which were closely examined were reproduction and movements.

4.4.1 Tagging: A total of 552 barramundi were tagged and released in all study areas. Of these, 127 (23.0%) were subsequently recaptured by professional and amateur fishermen and the research team. Many of the fish recaptured by the last two groups were re-released, resulting in nine being recaptured for a second time and one for a third time. Table 6 is a summary of the fish tagged and recaptured in each area.

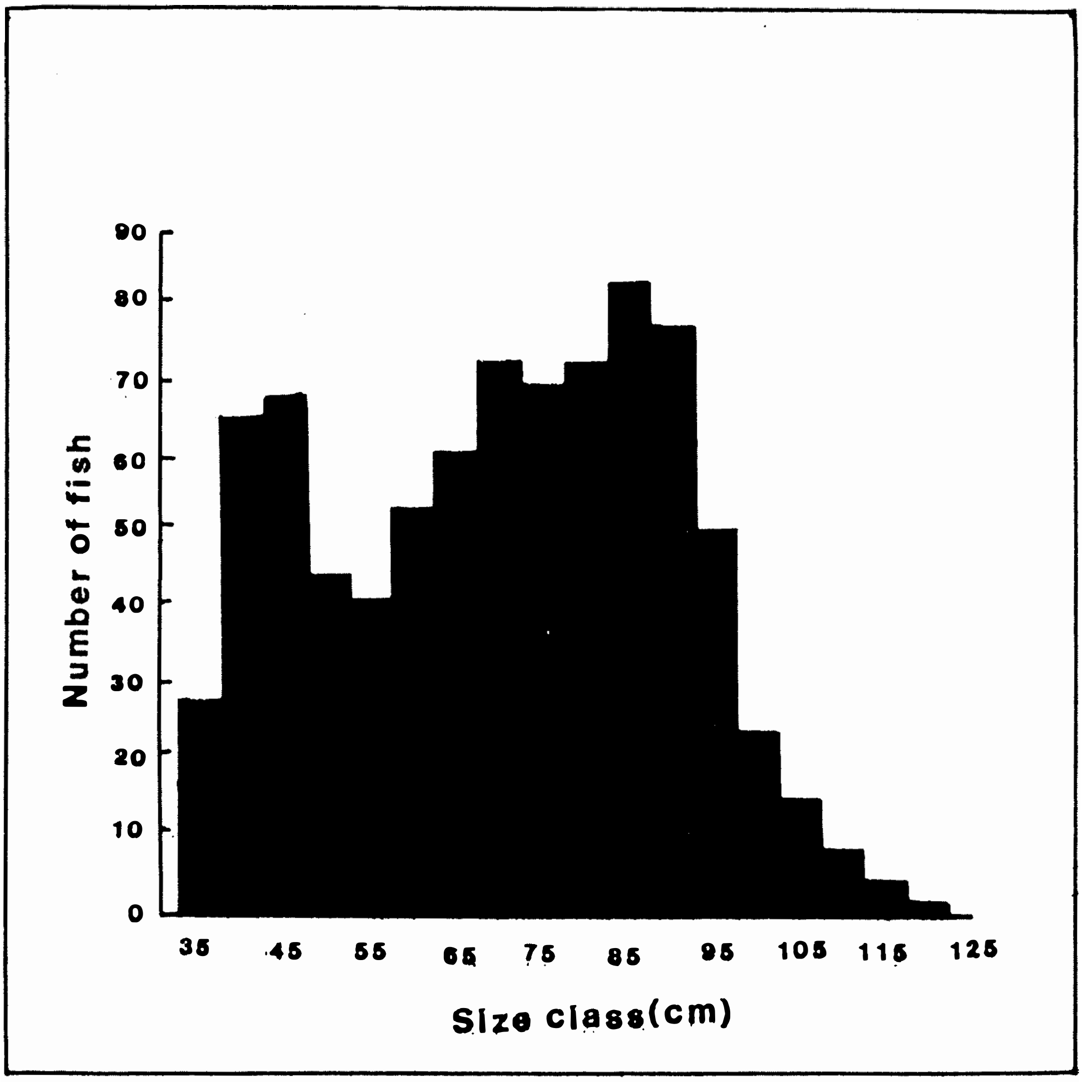


Figure 3: Size-frequency distribution of all barramundi caught in commercial gill nets during this study.

	1	2	3	4	5	6	7
Number tagged	235	140	49	77	20	4	27
Number recaptured once	57	38	14	10	4	0	4
recaptured once (%)	24.2	27.1	28.6	13.0	20	0	14.8
Number recaptured twice	5	3	0	0	0	0	1

Table 6: Statistics of barramundi tagging in eastern Queensland from January 1982 to October 1984.

In areas which were close to cities or large towns (areas 1, 2, 3, and 5) recapture rates were very high (up to 28.6%) but were lower in more sparsely populated regions (areas 4 and 7). Area 6 was not considered because of the small number of fish (4) tagged. Areas 6 and 7, at the southern end of the range of barramundi in Queensland, appeared to have smaller populations of this species.

4.4.2 Amateur versus commercial fisheries: Data on the type of fisherman who recaptured tagged fish are given in Table 7. Three categories of fishermen, amateur, commercial and the research team, are listed. Amateur fishermen used line fishing as the primary capture method while the the other two groups used mainly gill nets.

	Area							
	1	2	3	4	5	6	7	Total
Amateur anglers	21	19.5	0	9.1	0	0	20	16.7
Professional fishermen	32	53.7	78.6	27.3	25	0	0	41.3
Research team	47	26.8	21.4	63.6	75	0	80	41.3

Table 7: Percentage of tag recaptures by each of the main fishing groups by area.

The percentage of tag returns from the amateur fishery was greatest north of the Burdekin (areas 1 and 2). In southern areas (3-6) the return rate was relatively low. The high percentage of amateur returns from area 7 was exaggerated because of the low total number of returns. Only a single fish was caught by an amateur in area 7. As indicated by tag returns, the commercial fishery appeared most active from Rockhampton north (areas 1 to 5). This was supported by log book data from the fishery (see section 4.2). Tag returns from the commercial fishery were highest in the Burdekin (area 2) and at Mackay (area 3). Overall, for each tagged fish caught by a amateur fisherman, 2.5 were caught by professionals. In the Northern Territory, Griffin (1982) estimated that the amateur barramundi catch in some areas was as high as 30% of the commercial catch. In the present study the average weight of tagged fish caught was: amateurs (4.96 kg, n=15), professionals (6.47 kg, n=38) and research team (5.42 kg, n=45). For a number of reasons caution must be exercised before extrapolating these data to the overall barramundi fishery. Gill netting, the sampling technique used to capture fish for tagging, was highly selective for fish sizes. While such a technique would successfully sample fish available to the commercial fishery, it may not have supplied an unbiased sample of fish in the amateur fishery, which would be expected to include fish of a smaller average size. Another factor was non-reporting of the recapture of tagged fish. While no actual data are available, it appears that on a number of occasions professional fishermen and illegal net fishermen have recaptured tagged fish which were not subsequently reported.

4.4.3 Movements: In 49% of reported recaptures of tagged fish, some nett movement occurred between tagging and recapture sites. However, in most instances (79.5%) this nett movement was small, usually within the estuary or to or from an adjacent coastal foreshore. This was in agreement with the results of other studies being conducted simultaneously in north-eastern Queensland and in the Gulf of Carpentaria (R. Garrett, pers comm). There were, however, instances of fish movement into adjacent estuaries, into freshwater, or along coastal foreshores. Studies conducted in the Burdekin delta in particular showed such movements and these are illustrated in Figure 4. The general trend of these movements appeared to be southwards, towards the mouth of the Burdekin River. Two fish moved 50km up the Burdekin into freshwater and were recaptured below the Clare Weir. No tagged fish were recaptured upstream of this weir despite the presence of a fish ladder.

In this study most of the fish were tagged either in an estuary or on a coastal foreshore adjacent to an estuary. Little tagging was done in other habitats such as nearshore islands and rocky headlands, which are known to support populations of barramundi. Consequently, while the results suggest a non-migratory behaviour of barramundi resident in estuaries, no such conclusions can be reached about fish in other habitats. In earlier work on barramundi in Queensland, Dunstan (1959) documented an annual spawning migration from freshwater to coastal areas. As well as for spawning, this behaviour may also act to replenish estuarine stocks of barramundi resident in estuaries. It is likely that fish from other habitats mentioned above may also enter estuaries at certain times, e.g. for spawning. This could be an important replenishment mechanism for areas without large freshwater catchments.

4.4.4 Recapture intervals: Table 8 shows the period from release to date of first recapture for barramundi tagged during the study.

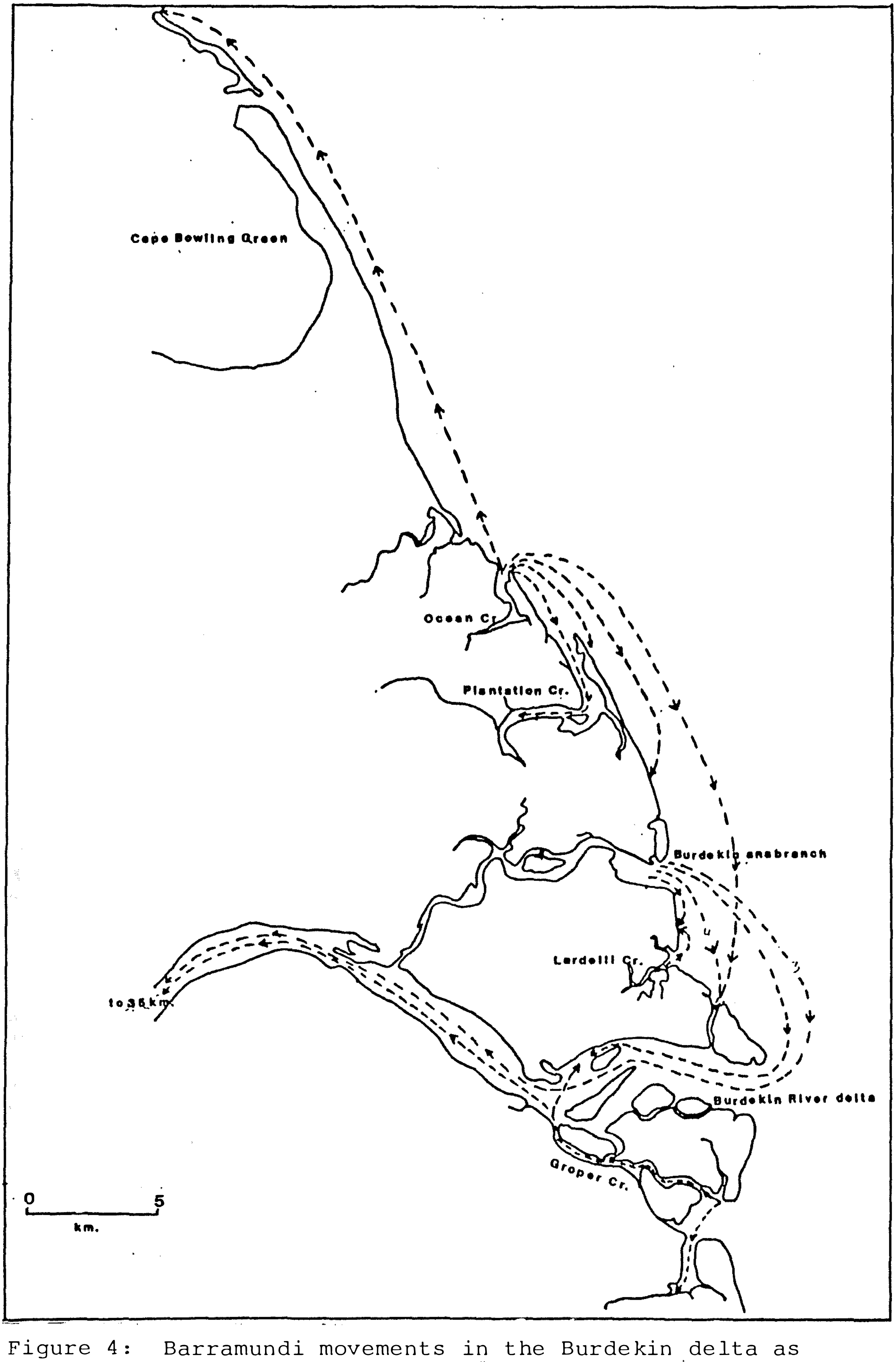


Figure 4: Barramundi movements in the Burdekin delta as determined by tag recoveries. Broken lines represent the movements of individual fish or groups of fish.

	Area							
Period (Days)	1	2	3	4	5	6	7	Total (%)
0 - 90	19	12	3	5	2	0	1	47 (37.0)
91 - 180	11	7	5	3	1	0	2	26 (20.5)
181 - 365	12	14	1	2	1	0	0	32 (25.2)
366 - 545	13	4	0	0	0	0	1	17 (13.4)
546 - 730	1	1	0	0	0	0	0	4 (3.1)
>731	1	0	0	0	0	0	0	1 (0.08)

Table 8: Number of barramundi recaptured at given intervals tagging for each of the study areas. Periods are approximately equal to three, six or 12 months.

Most of the recaptures (82.7%) occurred within a year of being tagged and during that period 37% of the recaptures were made within the first three months. Of the fish which were at liberty for more than a year only one (0.08%) was at large for more than two years.

Average time of liberty for all 127 barramundi recaptured once was 186.4 ± 158 days. For the Cairns area where 57 fish were recaptured, the average release period was 216.9± 182.6 days and for the Burdekin it was slightly less at 197.7 ± 141.0 days. Kesteven (1953) proposed a method of estimating average life expectancy by adding the average age at release to the average period of liberty. This was interpreted as the average life expectancy of the fish beyond the release age. The average age of fish tagged during this study using age-length data from barramundi in the Gulf of Carpentaria (Davis, 1984) was 3.27 years. Using Kesteven's method, an estimate of average life expectancy for east coast barramundi was about 3.8 years.

4.4.5 Tag shedding and tag mortality: No attempt was made to estimate tag shedding rates for either of the tag types used. Sufficient information is available in the literature on tag shedding of dart tags (Floy Ft-2) from barramundi. Davis and Reid (1982), using a double tag experiment, determined that immediate tag shedding of dart tags was negligible and the instantaneous daily shedding rate was 0.00057. Davis and Reid (1982) concluded that Ft-2 dart tags were most suitable for the size range of barramundi on which they were used (i.e. larger fish) and appeared to have a much lower shedding rate when compared with opercular tags. No data were available on tag shedding from metal-headed skin tags, but it was assumed to be low. No data were available on mortality due to tagging in barramundi. Every effort was made to screen for fish which had suffered major damage during the capture process and these were not tagged. An indication that tagging mortality was low was given by the high recapture rates.

4.4.6 Reproductive biology: Work undertaken in Papua-New Guinea (Moore, 1979), and later in the Northern Territory and eastern Gulf of Carpentaria (Davis, 1982), suggested that barramundi undergo natural sex inversion from male to female. Garrett and Russell (1982) found indirect evidence for sex inversion in barramundi stocks in north-eastern Queensland. The present study confirmed the wider occurrence of sex inversion in east Queensland barramundi stocks.

Figure 5 shows that the percentage of female fish present in a given size class changed with size. The percentage of females in the lower size classes was small, but the percentage progressively increases with size until in the 105 cm size group all fish were female. This distribution is an indication of sex inversion. Histological examination of gonads collected over the period of the study identified three transitional testes, direct supporting evidence for sex inversion.

During the study tagged fish were always checked for reproductive activity (i.e. running ripe with milt or eggs) before being released. Two fish, identified as running males at time of tagging, were recaptured, after a periods of 13 and 18 months, as females.

Length at first maturity: There was little variation in gonosomatic indices of fish with total lengths of less than 55cm. The smallest sexually active male found during this study was 54.5 cm, indicating that the median length at first maturity was greater than the present 50 cm minimum legal length. Davis (1982) found that in the Gulf of Carpentaria, mature males first appeared at 55cm length.

Fecundity: Estimates were made of the fecundity of eight barramundi ranging from 14.4 to 20kg in total weight. Figure 6 is a plot of total weight against fecundity. The fecundity of barramundi is very high.

Reproductive seasonality: An accurate knowledge of the reproductive processes and spawning season of barramundi is of great importance to current management strategies. While some small, local variations in spawning times were recorded, the main spawning period in all areas was from about November to February. Figure 7 shows the gonosomatic indices for male and female barramundi gradually increasing from September and peaking in November and December. This is supported by the monthly data on gonadal development of barramundi shown in Figure 8.

Spawning aggregations and sites: On a number of occasions during this study small groupings or schools of near ripe or running ripe barramundi (both males and females) were encountered, usually in or just outside the mouths of creeks and rivers. Such locations were reported as barramundi spawning grounds in earlier studies (e.g. Dunstan, 1959). These aggregations were characterized by a high ratio of male to female fish. On one occasion, seven males were caught to each female. Several

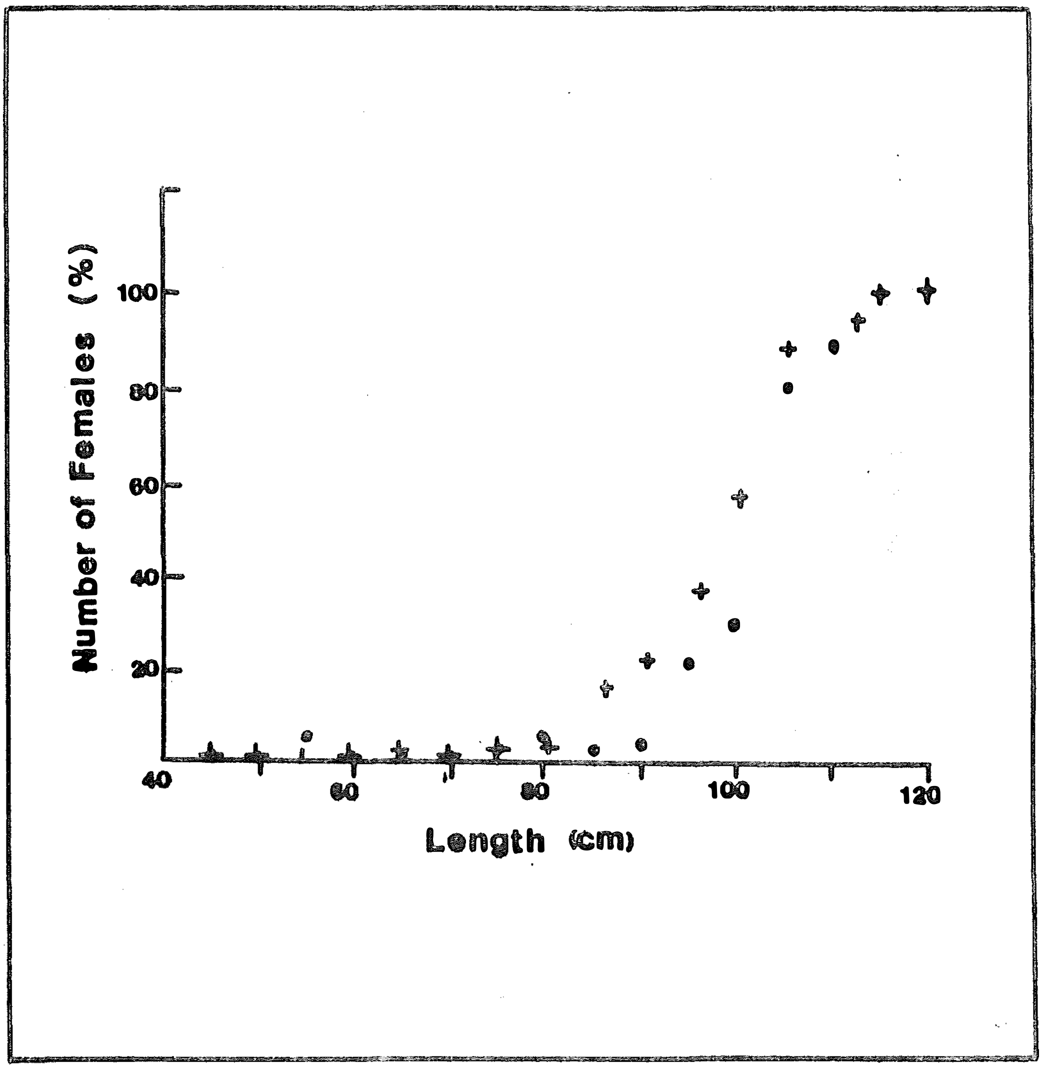


Figure 5: The percentage of female barramundi in each 5 cm size class. (● are data obtained from this study and ✣ are from Davis' (1982) work in the Gulf of Carpentaria.)

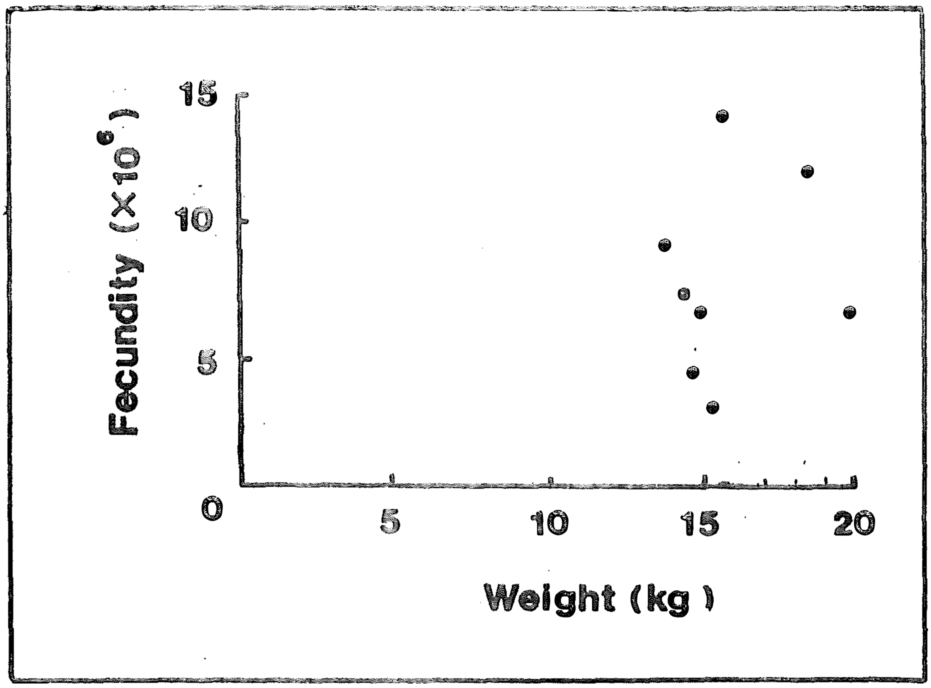


Figure 6.: Plot of total weight of individual barramundi against their estimated fecundity.

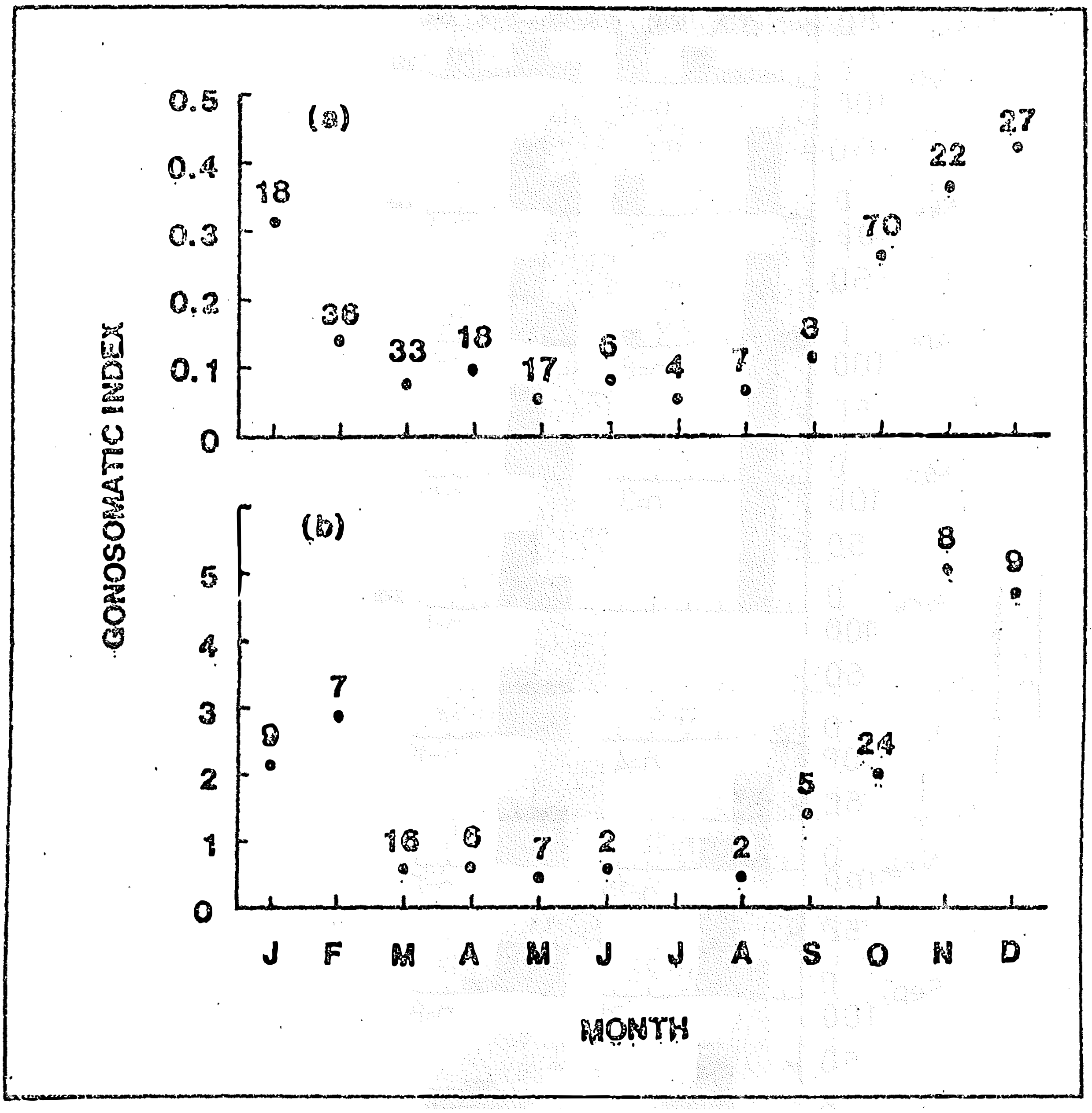


Figure 7: Monthly average gonosomatic indices of male (a) and female (b) barramundi

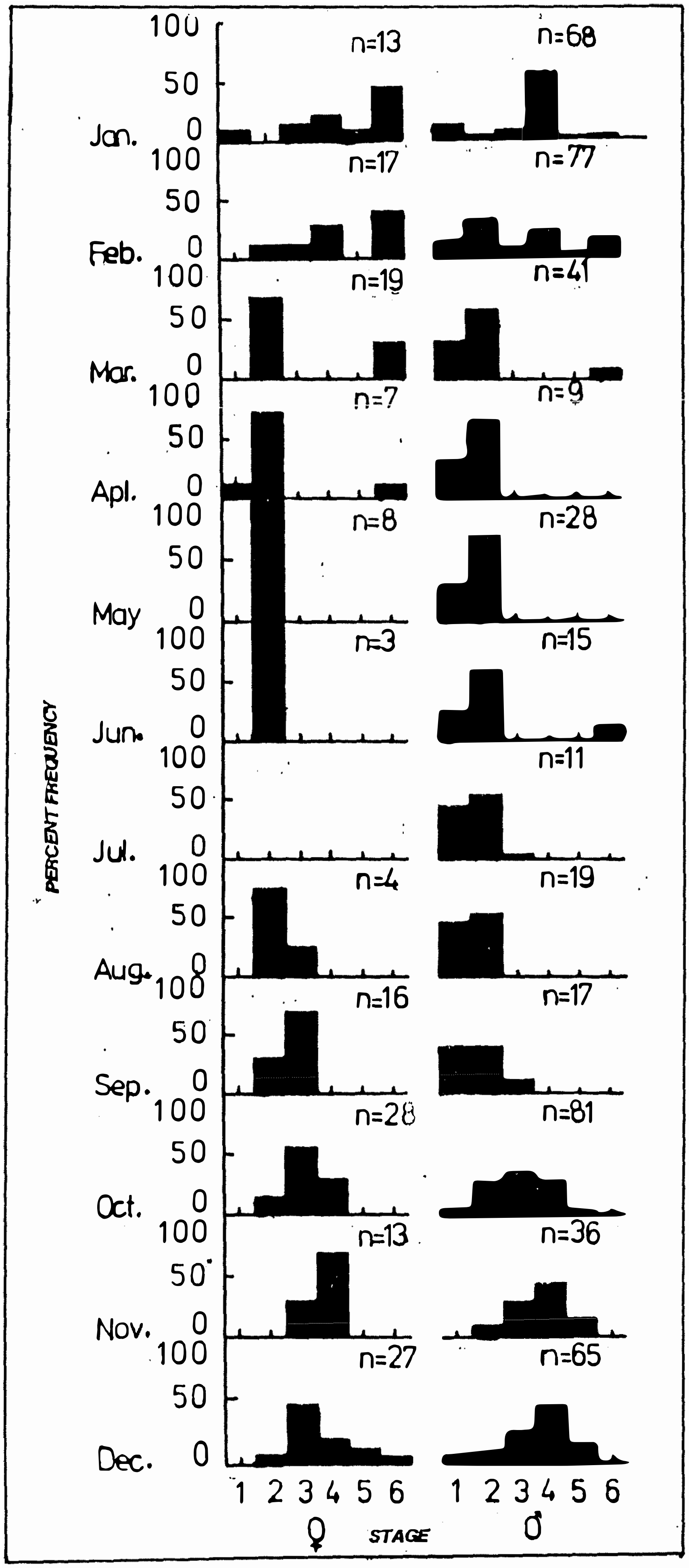


Figure 8: Grouped monthly gonad maturation stages of 622 mature *Lates calcarifer* from gill net catches in all study areas.

females discharged eggs while being released from nets. These unfertilized eggs were rounded, translucent, contained a single oil globule and measured about 0.8 mm in diameter. They had only a slight negative bouyancy but normal water movements would have been enough to keep eggs in suspension.

4.5 Biology of other major species:

In a management context, a knowledge of elements of the biology of other major target species besides barramundi is also essential. Aspects of the biology of six of the more important species of inshore mixed fishery are discussed below.

4.5.1 King Salmon <u>Polynemus sheridani</u>: In terms of value to the fishery king salmon is second only to barramundi. Its range extends from south-eastern Queensland through tropical Australia and possibly into Papua New-Guinea (Grant, 1982). It is caught by both anglers and commercial net fishermen on foreshores and less commonly, in rivers. It is also taken in upper estuaries using both set and ring netting techniques.

The largest fish caught during this study was 120 cm length at caudal fork (L.C.F.). Unconfirmed reports from fishermen indicate the species may uncommonly exceed 150 cm L.C.F.. Figure 9(a) shows the length-frequency distribution of the 254 fish caught during this study. The mean length was 59 $\pm$ 19 cm.

Hermaphrodism (both male and female tissue in the one gonad) occurs in this species, as it does in many of the Polynemids (Kagwade, 1970). Three hermaphrodites in the size range 78 to 84.5 cm were sampled. The ratio of males to females was 1:6.8. About 44% of all males were immature. The size at first maturity is about the present minimum legal length of 40 cm.

The large number of immature fish in the catch made determination of the spawning season difficult, but it is probably in summer from about October/November to March (see Figure 10).

4.5.2. Blue Salmon <u>Eleutheronema tetradactylum</u>: Blue salmon are caught along coastal foreshores and in estuaries over the entire study area. Blue salmon are the mainstay of the mixed fish catch in foreshore gillnets. They are known to grow up to 122 cm (Grant, 1982) although during this study the largest specimen caught was 65 cm. The average size was 36 $\pm$ 6cm. Figure 9(b) shows the length-frequency distribution of 1633 blue salmon caught during the study.

The occurrence of hermaphroditism in this species is well documented (Kagwade, 1970, Patnaik, 1967 and Stanger, 1974). In north-eastern Australia, inversion from males to hermaphrodites occurs around April/May with the hermaphrodite condition being maintained until after the spawning season when inversion to females is thought to occur (Stanger, 1974). This prolonged period of transition explains the high proportion of hermaphrodites (16%) in the catch during this study. Mean length of males was 30.2 cm, hermaphrodites 34.4 cm and females 40.2 cm.

Many of the hermaphrodites were functional males. The ratio of males to females in the catch was 1:1.86, however if all hermaphrodites are included with the males then the ratio is reduced to 1:1.18.

Stanger (1974) suggested that the spawning season could be prolonged. Data from this study supports this with spent females being found from August until April (Figure 11). October to December appears to be the peak spawning time.

4.5.3 Mud Flathead Platycephalus fucus: Platycephalus fucus was taken in gill nets over the entire study area from Cairns to Baffle Creek. It was most commonly caught in lower estuaries and on coastal flats usually in shallow water over a sandy bottom. Occasional specimens were caught in the upper reaches of estuaries. It is a demersal, non-schooling species usually taken in the bottom of gill nets near the lead line.

A total of 278 mud flathead were sampled, with data on gonad maturation available from 267. Figure 12 shows length-frequency distributions for male and female flathead. The mean size of females was 55.7cm. and males was 46.3cm. These mean values are significantly different ($p<.01$). The ratio of males to females caught during the study was 1:6.85. Similar observations were made by Dredge (1976) who concluded that sex ratios in age 4+ fish (ie. a mean length for males of 44.5cm and for females 43.2cm) were heavily biased towards females, with no males older than 4+ being taken during his study.

Dredge (1976) also suggested that mud flathead are protandrous and cites studies by Lewis (1971) describing protrandry in two of the five species of Platycephalidae found in Moreton Bay. Whilst no direct (histological) evidence of protandry was uncovered in this study, the high male to female sex ratio and the significant difference in mean sizes indirectly support the theory of sex reversal. The possibility of different growth rates in male and female flathead cannot be discounted.

Only two female flathead taken during this study were considered immature. This suggests that the average length at first maturity is probably below the size that is commonly caught in commercial gill nets in Queensland. The legal minimum size of flathead in Queensland is 30cm, which is smaller than any flathead caught during this study.

The presence of stage 5 and 6 ovaries indicated that spawning occurred in the period September through to March (see Figure 13). Dredge (1976) identified the spawning season of mud flathead in Moreton Bay to be between November and February. If the spawning season of this species is temperature dependent, then it is conceivable that spawning in tropical waters commences several months earlier than in the more temperate Moreton Bay. The data presented in Figure 13 supports that hypothesis.

In the non-spawning months (April to August) ovarian development was shown not to be static at Stage 2 but to progressively develop to Stage 4.

No spawning sites were positively identified, although running ripe fish were found in shallow water in the lower estuaries and on coastal foreshores.

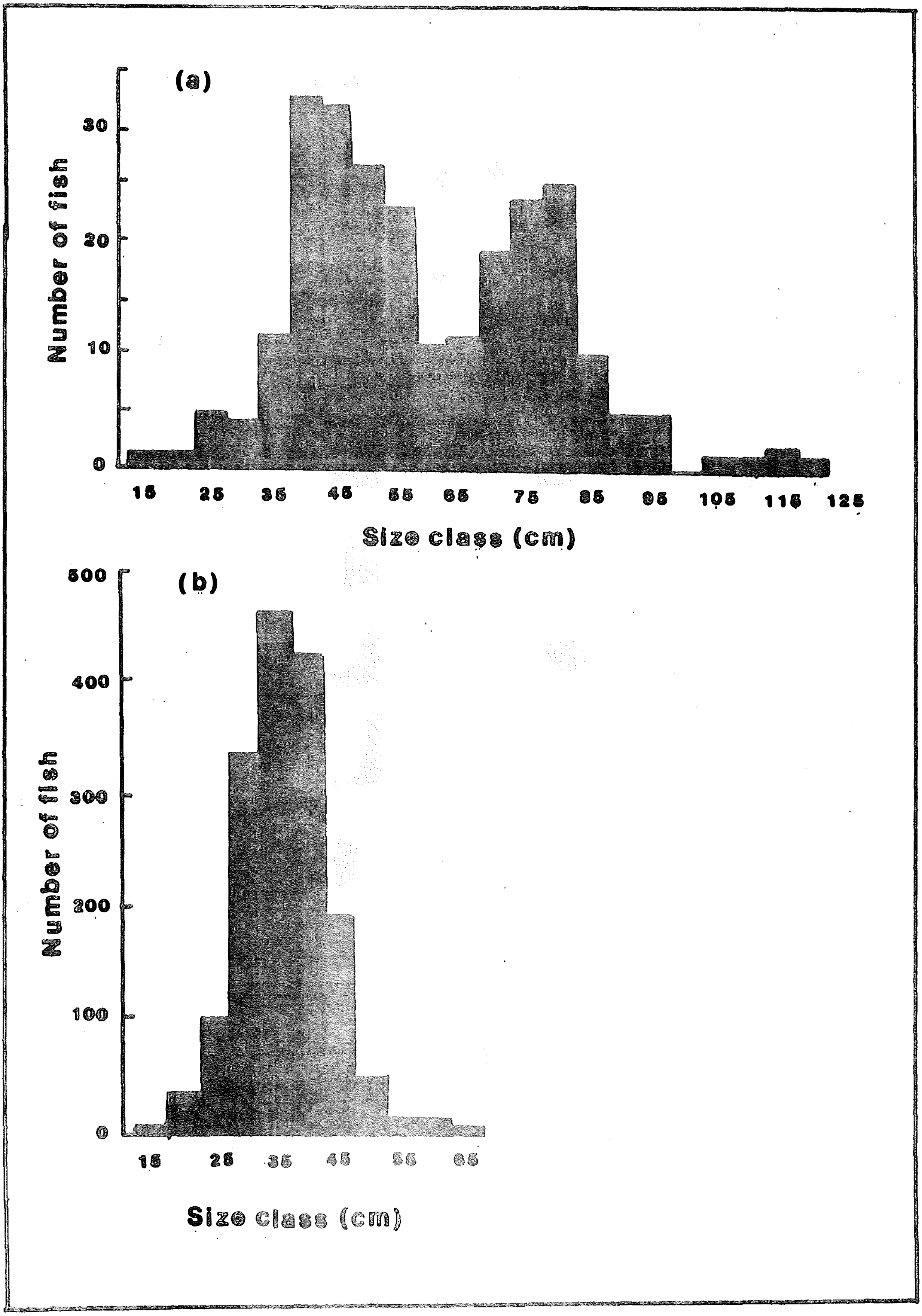


Figure 9: Length frequency of (a) king salmon and (b) blue salmon caught during this study.

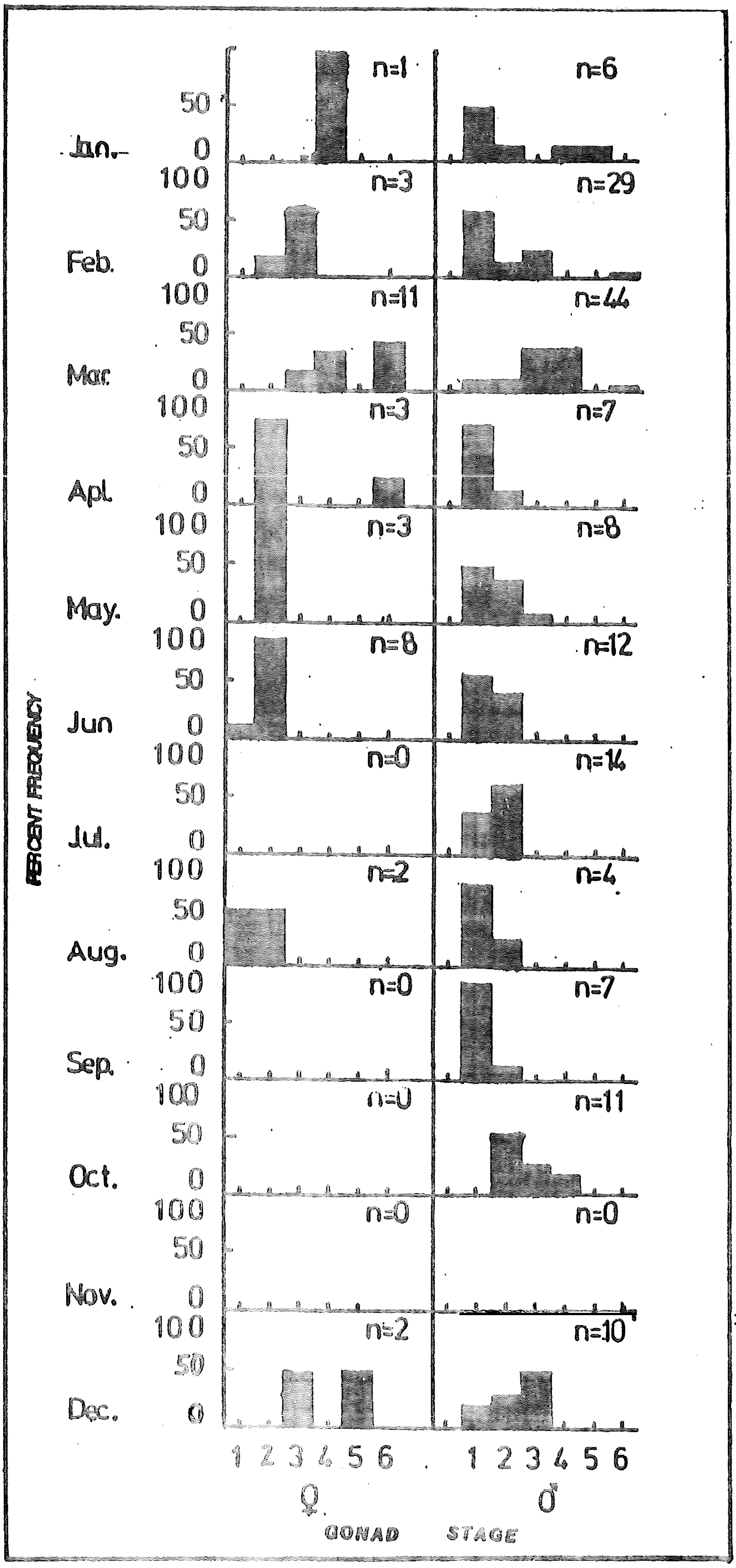


Figure 10 : Pooled monthly gonad maturation stages of 185 Polynemus sheridani caught in the gill net sampling.

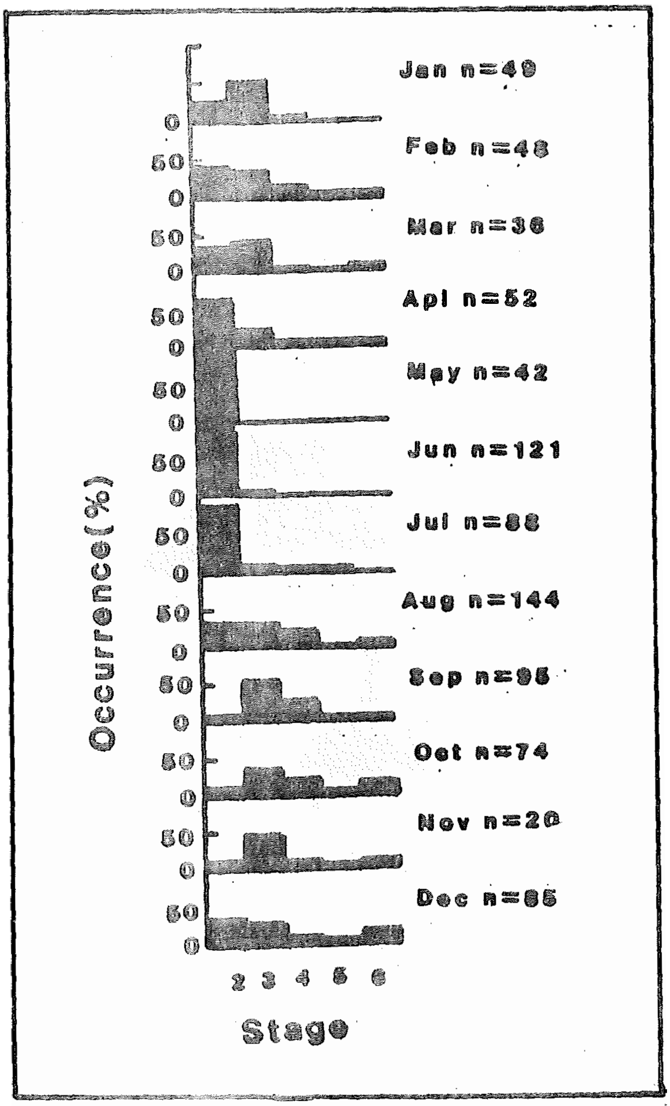


Figure 11: Pooled monthly female gonad maturation stages for blue salmon taken from gill net catches in all areas.

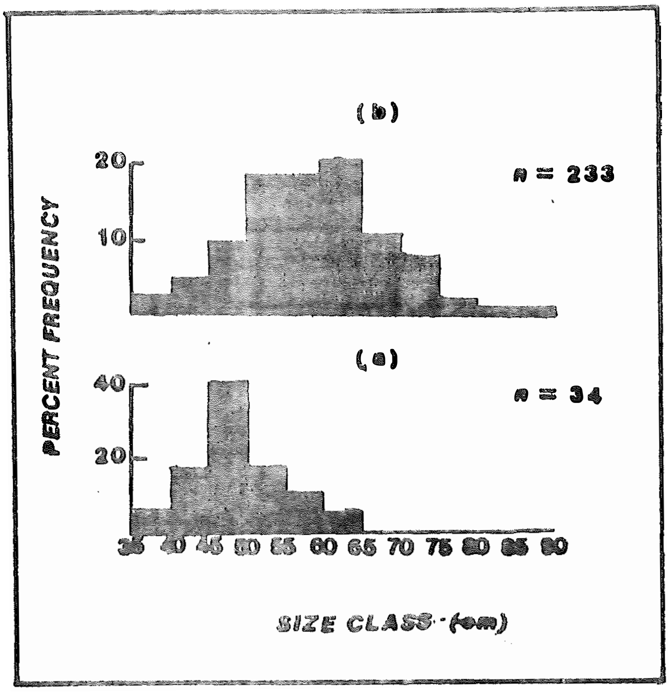


Figure 12: Length frequency distributions for 267 (a) male and (b) female flathead caught during the study.

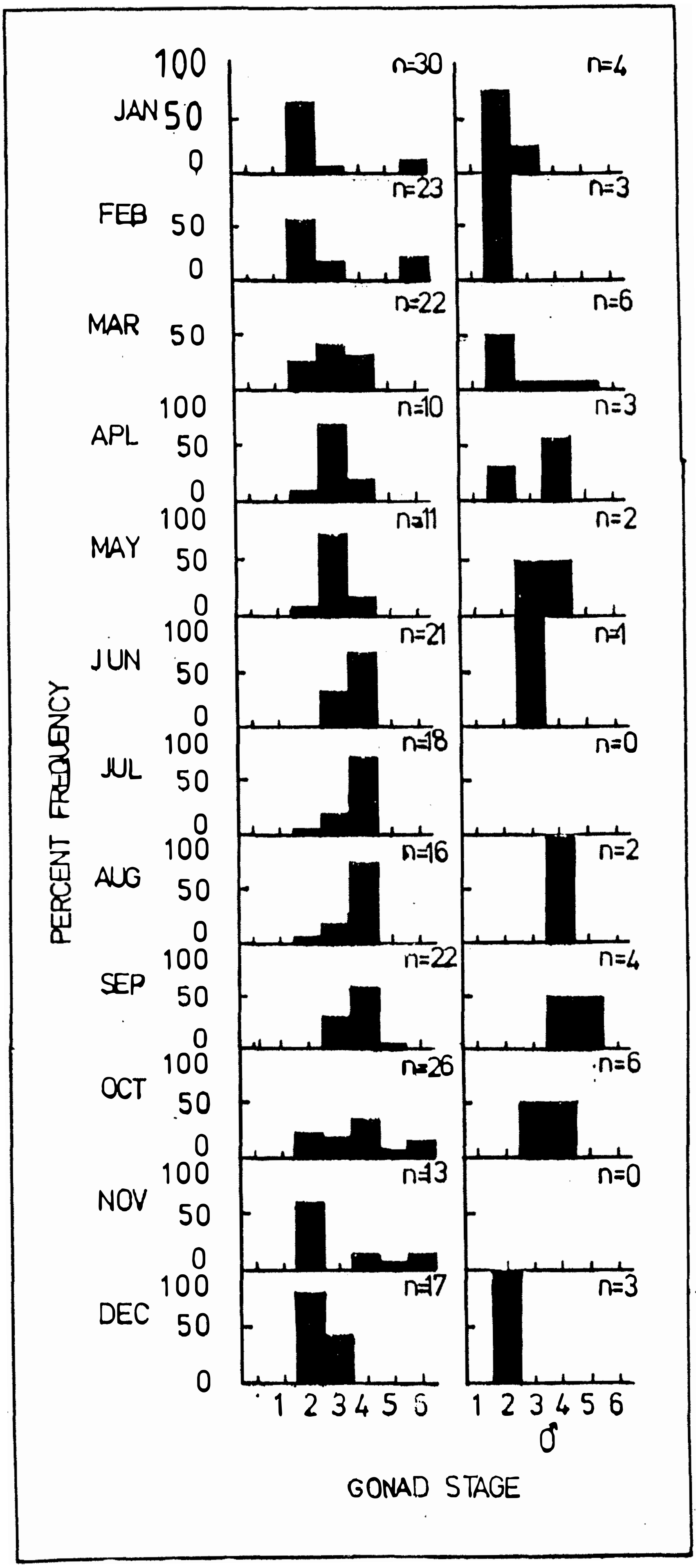


Figure 13: Pooled monthly gonad maturation stages for all mature flathead caught in gill net sampling.

4.5.4 Banded Grunter **Pomadasys kaakan:** Banded grunter are a valuable recreational and commercial species caught in lower estuaries and along coastal foreshores, particularly rocky headlands (Grant, 1982). Schools of banded grunter were frequently netted along beaches in the Burdekin district. Individual, mostly larger, specimens were caught in large mesh nets set in the middle and upper reaches of estuaries. The species ranged over the entire study area, although it was more commonly taken north of Broadsound. Grant (1982) considers it a northern species but has recorded occasional specimens as far south as the Noosa River. In this study specimens were caught in Baffle Creek, the most southerly sampling station. This species feeds on fish, crustaceans and molluscs. Gut contents were often found to include mollusc shells which had been crushed by the fishes strong pharyngeal teeth. Grant(1982) has recorded specimens to 60 cm T.L..

A total of 383 specimens were caught, with gonad maturation records available on 354. Length-frequency distributions (in 5cm size classes) for male and females are given in Figure 14. Mean sizes of males and females were 32.0 cm and 37.6 cm respectively. The mean size of females was significantly higher than males ($p<.01$). The ratio of males to females was 1:4.6. Only six female banded grunter were considered sexually immature, suggesting that average length at first maturity was well below the average size of fish caught in commercial catches. The minimum legal length of this species in Queensland is 30cm.(T.L.), while the median length of fish caught in this study was 34cm (L.C.F.). No conversion between fork and total length is available. The above data suggest that, with present commercial gear, fewer than half, and probably only a small fraction of the commercial catch is less than the statutory minimum legal size.

Figure 15 illustrates monthly gonad stages for 354 mature banded grunter. The presence of advanced female gonad stages (5 and 6) suggests a prolonged summer spawning season between September and March. A lack of stage 5 and 6 gonads in November and February could simply be a result of the small sample sizes in those months or could indicate spawning peaks or pulses.

4.5.5 Silver Jewfish **Nibea soldado:** This small sciaenid is found mainly over sand or mud substrates along northern coastal foreshores and also in lower estuaries. It is caught by both recreational anglers and net fishermen. The latter catch silver jewfish with long foreshore set nets usually of 10 to 12cm stretched mesh. Some commercial fishermen do not regard them as a worthwhile target species (mainly because of low market value), but they are generally processed and marketed as part of the mixed fish catch.

The silver jewfish has a broad geographic distribution (Indo-Pacific) and while it is found over the entire study area, it appears more abundant north of the Burdekin River. Some confusion exists about the taxonomy of the family. Grant (1982) described another sciaenid, Johniops vogleri, as being similar in appearance, but having a distribution in rivers and estuaries from Rockhampton south to Brisbane. Only small numbers of silver jewfish were sampled in this geographic region and no attempt was made to separate the latter species.

A total of 404 silver jewfish were sampled, 305 of which were mature females and 82 mature males. Of the remainder, nine were immature (both males and females) and eight were not sexed. Size-frequency distributions of males and females are illustrated in Figure 16. Mean lengths of male and female components of the sample were 25.1 cm and 32.9 cm respectively. Female fish were found to be significantly longer than males ($p<.01$). The ratio of male to female to immature fish was 1:3.7:0.1. The reason for such a high male to female ratio in the catch is unclear. It is possible that there was a differential size structure between sexes and net selectivity tended to mask the true sex ratio. Another possible reason for this high ratio is sex inversion. Although this phenomenon is known to occur in many Australian estuarine fish species (Dredge (1976); Davis (1982); Pollock (1984)), there is little evidence supporting its occurrence in this species.

The low number of immature fish in the catch showed most individuals were sexually mature at the size at which they entered the fishery. Figure 17 illustrates the monthly progression of gonad development in silver jewfish. The presence of stage 5 and/or stage 6 gonads during most months from August to March inclusive was evidence of a prolonged spring/summer spawning season. In only four months of the year was there no spawning, with increased gonadal activity in July.

4.5.6 Sea Mullet <u>Mugil</u> <u>cephalus</u>: While catches of mullet were made in all study areas, large numbers were recorded only at the southern sites, particularly Baffle Creek. Commercial mullet fishermen use ring nets in the estuaries and seine nets along beaches to capture mullet. Gill netting is not a popular technique for commercial mullet fishing, as ring netting appears to be more efficient probably because of the predictable nature of mullet schools. During autumn, mullet descend out of freshwater into estuaries, where they congregate into shoals before their northward breeding migration in winter (Grant, 1982). It is from this movement that beach fishermen take most of their catch. While extraordinary individual hauls of up to 25 tonnes (Grant 1982) may be taken, lesser catches are more common. During this study, a commercial 'gang' at Rule's Beach north of Baffle Creek, made a catch of 5 tonnes. Rule's Beach was the most northerly known location where specialist mullet fishing gangs operate. Large catches of sea mullet were made occasionally in the vicinity of Gladstone and as far north as Mackay. Kesteven (1942) identified Mackay as the northern limit of commercial sea mullet stocks.

While gill nets are not recognised as commercial gear for target mullet fishing, one large catch was made with research nets during the course of this study.

4.6 Mesh Selectivity:

Fish are normally caught in gill nets by either gilling or wedging and tangling. Tangling is more important in species with

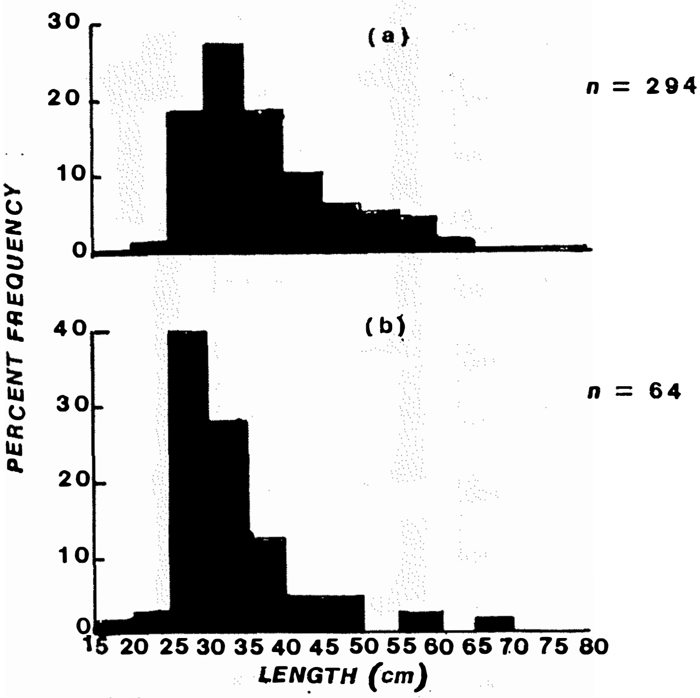


Figure 14: Length-frequency distributions of 358 (a) female and (b) male Pomadasys kaakan.

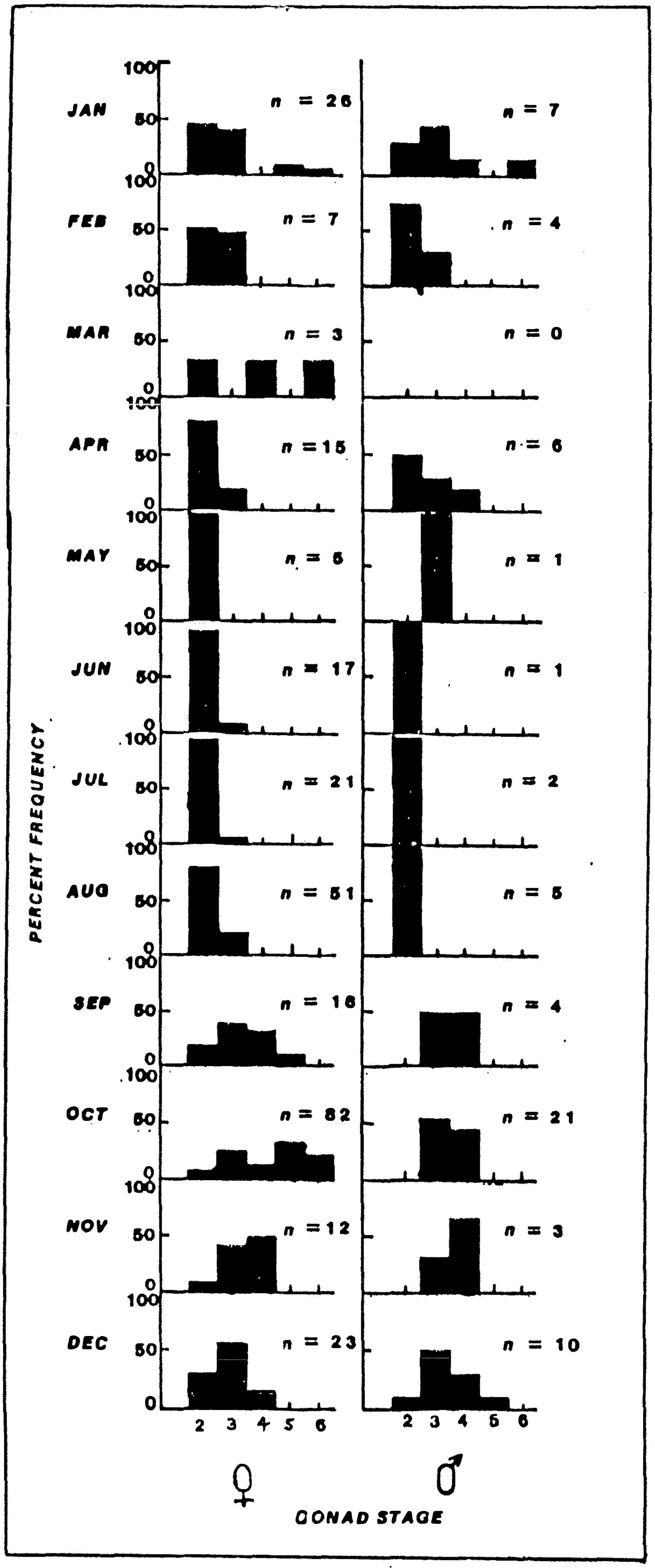


Figure 15: Pooled monthly gonad ~~maturation~~ stages for 354 P. kaakan caught in the gill net sampling.

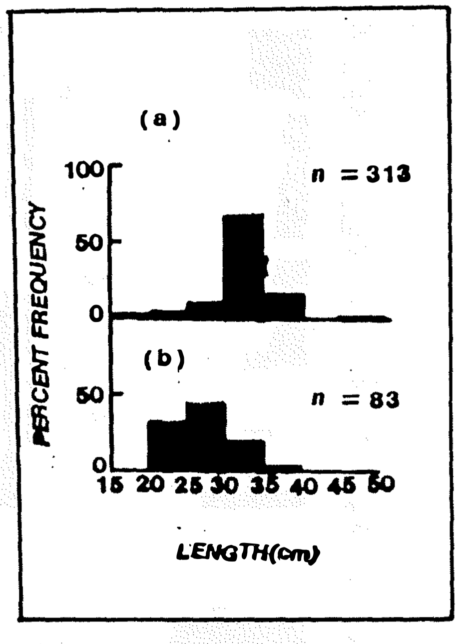


Figure 16: Length frequency distribution of (a) female and (b) male silver jewfish

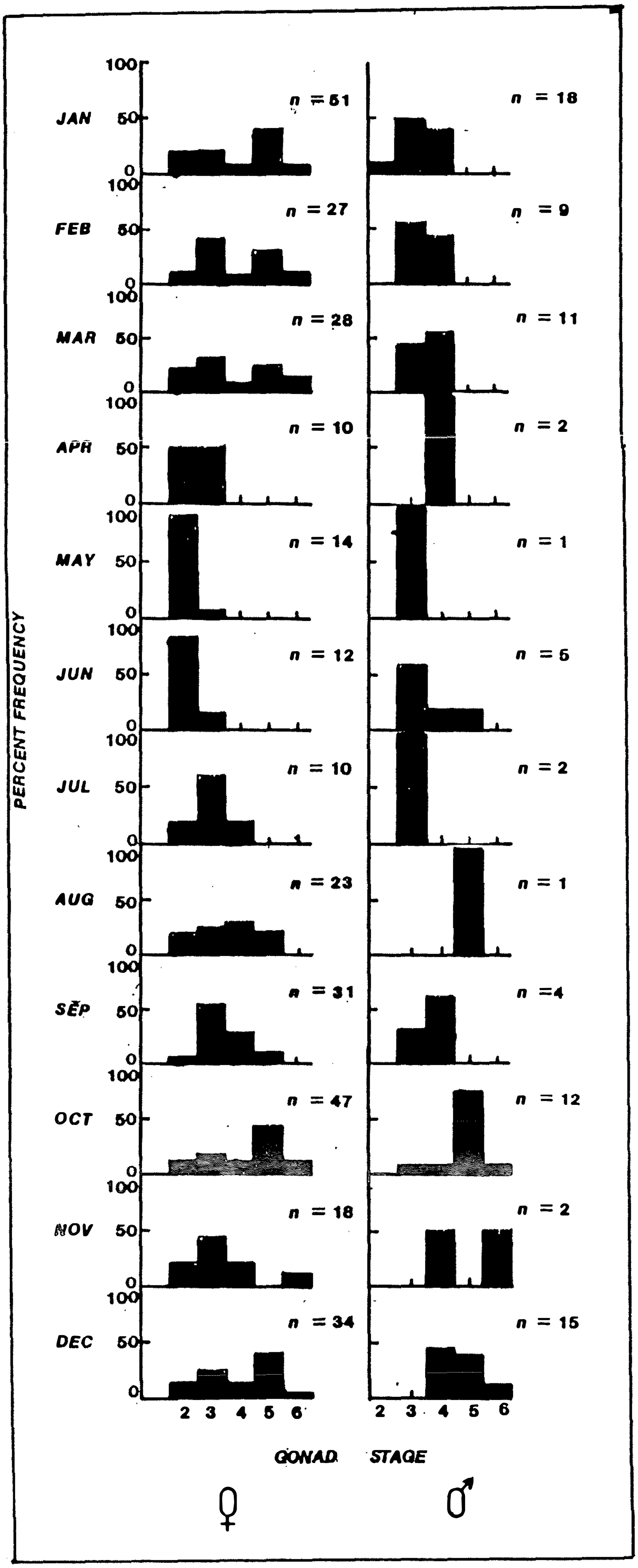


Figure 17: Pooled monthly gonad maturation stages for male and female jewfish.

spines (e.g. catfish) than smooth bodied fish (e.g. salmon and barramundi) which make up the bulk of the east coast fishery. For the purposes of mesh selectivity analyses tangling has been ignored. A third way by which nets catch fish is by bridling or 'lipping' of fish. Fish caught in this way are usually insecurely hooked by mouth parts. Threadfin salmons are commonly bridled in the net.

Gill nets catch fish of varying size with unequal success. For each species there is an optimum size of fish that will be retained by a net of a particular mesh size. Above and below this optimum length, the ability of the net to catch fish decreases. Smaller fish pass through the meshes, while larger fish can either break through the net or may not become properly enmeshed. Net mesh size regulations can, and have been, used as an effective management tool for controlling the size and numbers of fish caught.

The relationship between mean lengths for four species (barramundi, King salmon, blue salmon and banded grunter) and mesh size is shown in Table 9.

Species	Mesh Size (cm)						
	10	11.5	12.5	15	16.2	18	20
Barramundi	46.4(12.3)	45.3(7.2)	55.1(11.8)	68.3(10.6)	74.5(12.6)	84.3(6.4)	92.1(9.1)
King salmon	44.7(11.0)	n.a.	55.7(13.5)	70.4(16.5)	n.a.	68.0(23.8)	n.a.
Blue salmon	37.3(6.3)	37.7(8.0)	35.4(7.7)	33.9(6.7)	35.8(5.6)	37.2(6.7)	n.a.
Banded grunter	28.8(4.8)	n.a.	37.5(8.8)	48.8(8.1)	n.a.	n.a.	n.a.

Table 9: Mean length (cm) ± S.D. (in brackets) of fish caught in various mesh sizes. n.a. indicates not enough data were available for analyses. Data were pooled by site and sex.

The mean length of barramundi and banded grunter generally increased with increasing mesh size, but this is not the case for the threadfin salmons, particularly blue salmon. This was probably because of a disproportionate number of smaller fish being caught by bridling, rather than by wedging.

Relationship between minimum legal length and mesh size: A large proportion of the barramundi caught in the 10 cm mesh (71%) and the 11.5 cm mesh (75%) were below the statutory legal size of 50 cm. With increasing mesh size this proportion decreased to 23% for 12.5 cm mesh and to 2% for 15 cm mesh. In blue salmon, and king salmon the miniumum legal length is taken as the total overall length whereas this study measured L.C.F. for these species. In both species the L.C.F. is roughly 85% of the T.L.. The mean L.C.F's for King salmon caught in all mesh sizes were certainly all well above the minimum legal size (40 cm). The minimum legal length of 40 cm for blue salmon approximates 34 cm L.C.F., which is below all the mean values obtained for all mesh sizes. The mean length of banded grunter caught in 10 cm nets (28.8 cm T.L.) is slightly less than the statutory legal length of 30 cm T.L.. Mean lengths obtained for other mesh sizes (12.5 and 15 cm) were well above 30 cm.

Sex selectivity: As discussed in sections 4.4.6 and 4.5 sex reversal has been established or suspected in a number of the key target species including barramundi, blue salmon and mud flathead. In all these species fish mature as males and later change to females. It was expected that mesh selectivity would result in more males being caught in smaller mesh sizes and females to dominate in the catches of larger mesh nets. This was certainly the case for barramundi (See Table 10), and in fact many of the fish caught in the 10 to 12.5 cm mesh sizes were not mature.

	Mature Barramundi		
Mesh Size (cm)	Female	Male	Total Number
10	0.1	0.9	5
11.5	0.1	0.9	2
12.5	0.0	1.0	7
15	0.01	0.99	81
16.2	0.11	0.89	14
18	0.2	0.8	165
20	0.44	0.66	35

Table 10: Frequency of occurrence of mature male and female barramundi in different mesh sizes. If larger mesh sizes were to be trialled it would be expected that a higher percentage of females would be caught.

Table 11 shows the relationship between mesh size and sex of blue salmon caught during the study. With the exception of the 15 cm mesh size group, females made up the highest proportion of the catch. Males made up only a small fraction of the catch in most mesh sizes. This was most certainly related to the small size at which sex inversion occurs.

Smaller sample sizes for the other major target species prevented the establishment of similar relationships between sex and mesh size.

	Blue salmon			
Mesh size (cm)	Female	Male	Hermaphrodite	Total Number
11	0.63	0.22	0.15	643
11.5	0.62	0.21	0.16	66
12.5	0.51	0.31	0.17	334
15	0.36	0.47	0.16	348
16.2	0.5	0.17	0.33	12
18	0.6	0.24	0.15	145
20	0.68	0.09	0.23	22

Table 11: Frequency of occurrence of mature male, mature female and hermaphrodite blue salmon in a range of gill nets.

Relative efficiency of multifilament and monofilament nets: Monofilament and multifilament nylon were the two most common webbings used in the inshore gill net fishery. In recent years monofilament has become the dominant webbing. Monofilament nets have advantages over multifilament nets; they can be set and retrieved faster and they are lighter which makes them easier to transport and allows a greater length of net to be set. Fish can be removed more efficiently and apparently the incidental catch of crabs and debris is reduced. Pristas and Trent (1977), using a technique for assessing damage to nets from normal fishing activity, found the average damage was 0.16% for monofilament and 0.24% for multifilament webbing. The disadvantages of monofilament compared to multifilament nets were: greater cost per kilogram; more storage room required and problems with repairing webbing due to knot slippage (Pristas and Trent, 1977).

The biggest advantage of monofilament over multifilament nets is its higher catch per unit length of net. Collins (1979) when comparing the two gears for catching lake whitefish found monofilament nets were 1.8 times more efficient. Pristas and Trent (1977) found in Florida that catches of fishes were higher in monofilament webbing than multifilament webbing for eight of the 12 most abundant species. Over 58% of the 12 most abundant species and over 71% of the four most abundant food and recreational fishes were caught in monofilament nets. In the United Kingdom the use of monofilament nets increased the C.P.U.E. on bass (Dicentrachris labrax) from around 200 lb/boat/day to around 6000 lb/boat/day, an increase of about 3000% (Lilygreen and Meade, 1982). The superior efficiency of monofilament netting has prompted some governments to plan for or to actually place severe restrictions on its usage in inshore waters (e.g. Lilygreen and Meade, 1982)

5. FISHERY MANAGEMENT:

The east coast gill net fishery is a multi-species fishery composed of nearly 50 different species, with barramundi, threadfin salmons and banded grunters being the main target fish. Of these, barramundi was the most important species both by weight and value. With the exception of the south-east corner, it is commercially caught along the entire Queensland coast.

The problems associated with effectively managing such a multispecies fishery are considerable. Beddington and Rettig (1984) discuss problems associated with tropical multispecies trawl fisheries. Problems they identified included declining catch rates with an increased effort and ecosystem overfishing where the species composition of the community moves from one dominated by large teleostean fish to one dominated by smaller fish and invertebrates. While there was no direct evidence that either of these processes was occurring in the east coast gill net fishery, (mainly because of lack of long term fishery statistics), there was some indirect evidence (see section 2), and considerable anecdotal evidence that total catches, particularly barramundi catches had declined in the period prior to be introduction of the current fishery management strategies in 1981. Management of the east coast gill net fishery has been essentially a strategy of controlling fishing effort. Controls have been placed on the number, mesh sizes and length of nets that may be used and the areas where and times when fishing may be conducted. Limits have also been placed on the number of participants in the fishery.

The main intention of the present management strategy has been directed towards conserving stocks of the primary target species, barramundi. However a prudent combination of area and gear restrictions, particularly regarding the mesh sizes which can be used in rivers and along foreshores, has resulted in little impediment to the harvesting of other target species.

There was no evidence that the stocks of any other fish species beside barramundi were under heavy fishing pressure. This situation is probably the result of a number of factors. Barramundi is predominantly estuarine and is subject to higher fishing intensity than the other species, which are mainly caught in foreshore coastal habitats. Log book data indicated that most commercial gill net fishermen target specifically for barramundi. Barramundi also commanded a higher price which undoubtedly contributed to fishing intensity. Barramundi is a relatively long-lived fish not maturing as a male until about 3-4 years, while in general the other target species have a relatively short life span and therefore are less vulnerable to fishing pressure. While this present management strategy has an inherent bias towards the barramundi component of the fishery, it should be recognised that the fishery is dynamic, and future pressure on stocks of other species may necessitate major management changes. Biological and fishery data in this report should provide a basis for making such decisions.

5.1 Changes to the management plan:

The current management strategy can benefit from some 'finetuning'. There are also some areas which require further investigation. These are:

Minimum mesh sizes in rivers: At present, 11.5cm is the minimum mesh size allowed for set nets inside river estuaries. It may only be used from April to September and is ostensibly for catching threadfin salmon. When used in rivers this mesh size caught more undersized barramundi than any other species (see section 4.6). The log book data showed that this mesh size was rarely used inside rivers by those commercial fishermen who participated in the voluntary scheme. The general minimum mesh size for river set nets should be universally increased to 15 cm bringing it into line with regulations in the Gulf of Carpentaria fishery. It should be left to the industry to nominate for exemption important salmon fishing areas (if any) which are presently subject to river fishing regulations. No such areas were identified during this study. It may be necessary to re-assess the criteria used for determining where river fishing regulations take force in areas such as Broadsound and Shoalwater Bay where river mouths are very large.

Minimum legal size of barramundi: Size at first maturity of barramundi is well above the present minimum legal size for the species. In other fisheries, and indeed in the barramundi fishery in the Northern Territory, size at first maturity is an important criterion for determining minimum legal size. Data presented by Davis (1982) showed that the size of earliest maturity in the Gulf of Carpentaria was 55 cm T.L., a finding supported in this study, where the smallest sexually active male found was 54.5 cm.

Maximum size of barramundi: Management of the barramundi fishery is complicated by sex inversion whereby males change to females. Fish of lengths greater than 110 cm were generally females (see section 4.4.6). Arguments have been advanced to enforce a maximum size limit on barramundi thus protecting breeding females and ensuring adequate recruitment to the fishery. Conversely it has been argued that females should be afforded no special protection as the huge fecundity of the species means only a relatively few fish are needed to ensure maximum recruitment.

Mathematical models of recruitment are commonly used in fisheries research. Theoretical consideration of these models recognize that there is an upper limit to recruitment regardless of how large is the population of spawners (Tyler and Gallucci, 1980). There is also a critical stock size below which reproductive processes may be density-independent and which can result in inadequate recruitment to perpetuate the stock (Tyler and Gallucci, 1980). There is anecdotal information that crashes have occurred in barramundi stocks in India due to overfishing. No Australian barramundi stocks are known to be under such a threat.

It is worth noting that there is increased interest amongst fishermen on the east coast and in the Gulf of Carpentaria in using large mesh gill nets, in some cases up to 30 cm stretched mesh. At the moment, the overall capital invested in these nets is small. Large mesh nets target specifically for large female barramundi, which normally would have a reasonable chance of avoiding capture in smaller nets. Barramundi stocks in east coast areas already heavily fished and/or under pressure from other factors such as environmental degradation, may well be particularly susceptible to an increased fishing pressure on female barramundi. In the event of measures being introduced to protect female barramundi, rather than imposing a politically unpopular and virtually unenforceable maximum legal size on barramundi, it would be more efficient to control effort by selecting a maximum mesh size to be used in inshore waters and estuaries. While a few east coast fishermen have always used large mesh nets most use mesh sizes up to 20 or 21.5 cm. A maximum mesh size of 20 cm would ensure that most barramundi caught would be males (see section 4.6).

Area closures: In Queensland all freshwaters are closed to commercial fishing, a weekend netting closure is enforced for most east coast estuaries, and certain estuaries or sections of estuaries have been closed to all net fishing or in rare instances, to all forms of fishing. The weekend closure and many of the estuarine closures were introduced to limit potential conflicts between amateur and professional fishermen. Such closed areas are usually adjacent to large towns or cities. After representations from commercial fishermen the Q.F.M.A. reviewed the weekend closure in central Queensland. This review identified areas which were sufficiently isolated to allow them to be re-opened to net fishing on the weekends.

Rivers, in the past, have been closed to netting using the rationale that they may then act as replenishment areas for the fish fauna of surrounding streams. Movement studies on barramundi, the dominant species of the estuarine gill net fishery, have shown that there is minimal movement between rivers. In view of this and the contention that closed rivers are more susceptable to illegal fishing, such replenishment strategies must be questioned.

Area closures can be used effectively in protecting certain stages in the life history of fish. An example is some estuarine supralittoral swamps and lagoons which have been identified as nursery grounds for barramundi (Moore, 1982; Russell and Garrett, 1983,1985). Some such nursery areas have been protected as habitat reserves or wetland reserves, but there is a need for more work to identify such habitats, particularly along the more densely populated section of the east coast where there is a high risk of environmental degradation.

Physical barriers: Another area where habitat disruption is an issue for concern on the east coast is the construction of coastal steam barriers. These interfere with the migratory patterns of commerical fish species such as barramundi and sea mullet. Many have incorporated into their design fish ladders which are supposed to allow for fish movement in both directions. This may in fact not be happening and the suitability of the designs of some ladders to Australian native fish has been questioned. Stream barriers with an ineffective fish ladder or no fish ladder prevent many migratory fish from utilizing large areas of freshwater habitat. Kowarsky and Ross (1981) in a year long study of fish movements in the fish ladder on the Fitzroy River Barrrage near Rockhampton found only five sub-adult barramundi moving upstream. There is a need to assess the effectiveness of other coastal fish ladders and to determine which design is most suitable for native fishes. Fish often congregatate in sections of rivers immediately upstream and downstream of coastal stream barriers on their migratory routes where they are especially vulnerable to fishing. While some closures are already in effect, consideration should be given to placing a moratorium on all fishing within a determined distance of coastal stream barriers, including the fish ladders.

Closed Season: Spawning grounds can be protected by area closures, but this is probably more appropriate in the fisheries where there are central spawning grounds. Most of the species in the fishery apparently do not have central spawning grounds to which they migrate. Very little is known about the spawning grounds and requirements of most east coast commercial fish species. Spawning stocks of barramundi are protected by the closed season and by a closure of all rivers to fishing during that season. Data obtained during this study suggest that a river closure does not greatly affect the fishery for other species. The period set aside for the barramundi closed season generally coincided with the peak spawning periods of many of these other species. While there are some regional differences, no consideration should be given at this time to staggered geographical closures.

Fishery Statistics: The establishment of a sound database for the fishery is essential for future management. This seems assured as the voluntary log book programme initiated in 1981 as part of this research project has now been replaced by a compulsory scheme. Until adequate fishery statistics are available it is recommended that there be no new increases in effort in the fishery.

Fishery Economics: This project has dealt primarily with the biology of species and the gear used in the east coast gill net fishery. Management should not be based solely on these factors. Sociological considerations and particularly economics of the fishery should be integrated into management programmes. There is a need for a detailed study to define economic parameters of the fishery.

5.2 Stock enhancement:

The present management strategy for the east coast gill net fishery has been in force for about four and a half years. During this time there have been reports by fishermen of large numbers of juvenile barramundi in estuaries, a pointer that the strategy is working. There is a considerable lag between the time of recruitment of juvenile fish into the stock and the time at which they subsequently become available to the fishery. It may be some years yet before the effects of the 1981 management measures follow through to the fishery. The concept of stock enhancement using hatchery reared barramundi fry is, on the surface, an attractive proposition. The cost of such estuarine stocking would be considerable and prior research would be required to determine optimal stocking rates. There is also a possibility of some type of genetic contamination of the indigenous population. Very serious consideration should be given to the economic and possible biological consequences of such a proposition.

6. RECOMMENDATIONS:

The strategy of using effort restrictions to regulate the fishery should be retained.

- Moves to increase effort in the fishery at this time should be resisted.

- The management plan should be regarded as dynamic and subject to regular review.

- The compulsory log book scheme should be a permanent part of the management plan.

- An economic survey of the fishery should be undertaken.

- The minimum mesh size for use in east coast estuaries should be conditionally increased to 150 mm stretched mesh.

- All river closures to the commerical fishery should be assessed.

- The closed season on barramundi should be retained as a key component of the overall strategy.

- Potential effects of an increased usage of large mesh nets on numbers of female barramundi should be carefully investigated.

- Consideration should be given to increasing the minimum legal size of barramundi to at least 55 cm T.L. to correspond to size at first maturity.

- There is a need to identify and protect important nursery habitats for barramundi.

- The effect of coastal stream barriers on migratory fish and the effectiveness of fish ladders needs to be investigated.

- Consideration should be given to a total fishing closure on sections of river immediately upstream and downstream of coastal fish ladders.

7. PUBLICATION OF RESULTS:

Results and data generated from this study have been made available to the industry, particularly participants in the logbook scheme, through a series of irregular newsletters. An expanded edition of this report will be published by the Q.D.P.I. as a technical report. Over the duration of the project efforts have been made to inform the industry and general public of the progress of research work. A seminar on the project was presented to the annual meeting of the Australian Society of Fish Biology in August 1985.

8. ACKNOWLEDGEMENTS:

I gratefully acknowledge the technical assistance given by Messrs P.R. Cooper and C. Turnbull and Ms M. Reid. Messrs R.N. Garrett, R. Pearson and Dr R. Coles provided useful comments on earlier drafts of this manuscript. Mr K. Butler did the analyses of the log book statistics.

9. REFERENCES:

Beddington J.R. and R.B. Rettig, (1984) Approaches to the regulation of fishing effort F.A.O. Technical Paper 243: 39p.

Clay, D. (1981) A new technique for estimation of gill net selectivity and reanalysis of data for several species. N.A.F.O. Sci. Counc. Studies. No. 1, pp 7-22.

Collins, J.J., (1979) Relative efficiency of multifilament and monofilament nylongill nets towards lake whitefish Coregonus clupleformes in Lake Huron. J. Fish Res. Board Can. 36:1180-1185.

Davis, T.L.O., and D.D. Reid, (1982) Estimates of tag shedding rates for Floy FT-2 dart and FD-67 anchor tags in barramundi, Lates calcarifer (Bloch). Aust. J. Mar. Freshw. Res. 33, 1113-1118.

Davis, T.L.O., (1982) Maturity and sexuality in barramundi, Lates calcarifer (Bloch), in the Northern Territory and south-eastern Gulf of Carpentaria. Aust. J. Mar. Freshw. Res. 33, 529-45.

Davis, T.L.O., (1984) Age and growth studies on barramundi, Lates calcarifer (Bloch) in northern Australia. Aust. J. Mar. Freshw. Res. 35,673-690.

Dredge, M.L.C., (1976) Aspects of the ecology of three estuarine-dwelling fish in south-east Queensland. Unpub. M.Sc. Thesis, Uni of Q.

Dunstan, D.J., (1959) The barramundi Lates calcarifer in Queensland waters. C.S.I.R.O. Div. Fish. Oceangr. Tech. Pap. No.5.

Garrett, R.N. and D.J. Russell (1982) Premanagement investigationsinto the barramundi Lates calcarifer (Bloch) in northeast Queensland waters. Unpubl. rept. to F.I.R.T.A. 40p.

Grant, E.M., (1982) Guide to Fishes. Dept of Harb. Marine, Brisbane 896p.

Griffin, R.K., (1982) A survey of amateur angling for barramundi (Lates calcarifer) in the Northern Territory. Tech. Rpt. No. 2. Fisheries Div. N.T. Dept of Primary Prod. 37p.

Kagwade, P.V.,(1970) The Polynemid fishes of India. Bull. Cent. Mar. Fish. Res. Inst. I.C.A.R. no.18, 69p

Kesteven, G.L., (1942) Studies in the biology of Australian mullet. 1.- Account of the fishery and preliminary statement of the biology of Mugil dobula Gunther. Coun. Sci. Industr. Res. Aust. Bull. No. 157.

Kesteven, G.L., (1953) Further results of tagging sea mullet, Mugil cephalus. (Linnaeus) of the eastern Australian coast. Aust. J. Mar. Freshw. Res. 4:251-306.

Kowarsky, J. and A.H. Ross, (1981) Fish movement upstream through a central Queensland (Fitzroy River) coastal fishway. Aust. J. Mar. Freshw. Res. 32:93-110

Lilygreen, V and B. Meade, (1982) Fish stocks under pressure from monofilament gill nets. Mar. Poll. Bull. 13(8):263-265.

McHugh, J.L., (1967) Estuarine nekton in estuaries (ed. G.D. Lauff) pp.581-62. Am. Ass. Adv. Sci. Publ No. 83.

Makten, G.G. and J.J. Palovina (1982) A comparative study of fish yieldsfrom various tropical ecosystems. In 'Theory and Management of Tropical Fisheries' (eds D. Pauly and G.I. Murphy). Proc. ICLARM/CSIRO Workshops on Theory and Management of Tropical Mutlispecies Stocks, 12-21 January, 1981.

Moore, R., (1979) Natural sex inversion in the giant perch (Lates calcarifer). Aust. J. Mar. Freshw. Res. 30:803-13.

Moore, R., (1980) Migration and reproduction in the percoid fish Lates calcarifer (Bloch). Ph.D. Thesis, Uni. of London.

Moore, R., (1982) Spawning and early life history of barramundi, Lates calcarifer (Bloch) in Papua New Guinea. Aust. J. Mar. Freshw. Res. 33:663-70.

Patnaik, S., (1967) Hermaphroditism in the Indian salmon Eleutheronema tetradactylum (Shaw). Curr. Sci. 36:525.

Pollock, B.R., (1984) Relations between migration, reproduction and nutrition in yellowfin bream Acanthopagrus australis. Marine Ecology. 19:17-23.

Pristas P.J. and L. Trent, (1977) Comparision of catches of fishesin gill nets in relation to webbing material, time of day and depth in St.Andrew Bay, Florida. Fish. Bull. U.S. 75:103-108.

Russell, D.J. and R.N. Garrett, (1983) Use by juvenile barramundi, Lates calcarifer (Bloch), and other fishes of temporary supralittoral habitats in a tropical estuary in northern Australia. Aust. J. Mar. Freshw. Res. 34, 805-11.

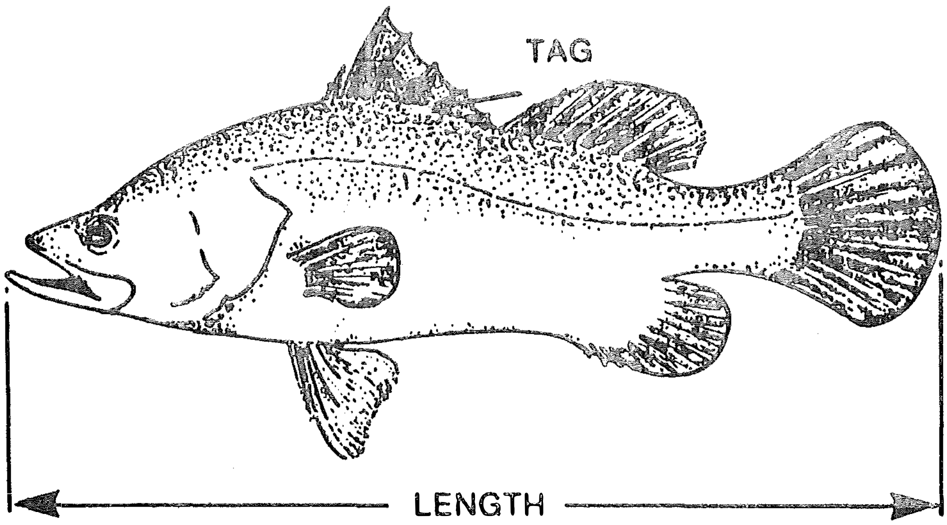
Russell, D.J. and R.N. Garrett, (1985) Early life history of barramundi, Lates calcarifer (Bloch) in north-eastern Queensland. Aust. J. Mar. Freshw. Res. 36,191-201.

Stanger, J.D.,(1974) A study of the growth, feeding and reproduction of the threadfin Eleutheronema tetradactylum (Shaw) Unpubl. thesis J.C.U.N.Q.

Tyler, A.V. and V.F. Gallucci (1980) Dynamics of fished stocks in Fisheries Management. R.T. Luckly and L.A. Neilsen (eds). Blackwell Scientific Publications. 422 p.

REWARD

TAGGED BARRAMUNDI



A REWARD OF $5.00 IS PAID FOR EACH TAG RETURNED WITH INFORMATION

What to do:

RETURN TAG TO — NORTHERN FISHERIES RESEARCH CENTRE,
QUEENSLAND FISHERIES SERVICE,
C/- POST OFFICE, BUNGALOW, QLD., 4870
PHONE CAIRNS 51 5588

OR — CONTACT NEAREST FISHERIES INSPECTOR.

AND PROVIDE

i) PLACE AND DATE OF CAPTURE.
ii) LENGTH OF FISH FROM TIP OF LOWER JAW TO TAIL.
iii) WEIGHT OF FISH, IF POSSIBLE.

BARRAMUNDI ARE BEING TAGGED BY THE NORTHERN FISHERIES RESEARCH CENTRE TO STUDY GROWTH RATE, POPULATION DENSITY, FISHING EXPLOITATION AND MIGRATORY PATTERNS.

Printers — The Stationery Warehouse.