Aust. J. Mar. Freshw. Res., 1985, **36**, 191-201

Early Life History of Barramundi, *Lates calcarifer* (Bloch), in North-eastern Queensland

D. J. Russell[A] *and R. N. Garrett*[B]

[A] Fisheries Research Station, Department of Primary Industries,
c/- Post Office, Burnett Heads, Qld 4670.
[B] Northern Fisheries Research Centre, Department of Primary Industries,
c/- Post Office, Bungalow, Qld 4870.

Abstract

Larval barramundi in the size range 2·8-5·2 mm were collected from plankton in two estuaries in north-eastern Queensland from 31 October 1979 until 13 February 1980. After leaving the plankton, barramundi moved into nearby brackish and freshwater swamps. These areas acted as nursery grounds, offering both protection from predators, and abundant prey in the form of insect larvae, other fish and crustaceans. These habitats exhibit a wide range of salinities (fresh water-44 $\times$ 10^3 mg l^{-1}) and surface water temperatures (23-36°C). Juvenile barramundi commenced migration from these swamps into permanent tidal creeks around April where they remained for up to 9 months before dispersal into the estuary, up rivers or along coastal foreshores. The diet of the barramundi in these tidal creeks was exclusively fish and crustaceans. Juvenile barramundi were resident in tidal creeks that had been subjected to substantial human interference through habitat alteration. Destruction of nursery swamps may pose a serious threat to local barramundi stocks near centres of human population on the eastern Queensland coast.

Introduction

Lates calcarifer (Bloch) (barramundi) is a large, predatory, percoid fish widely distributed through tropical areas of the Indo-west Pacific region (Greenwood 1976). It inhabits coastal and estuarine environments and is capable of moving long distances up rivers. Throughout northern Australia, barramundi is an important commercial and recreational fish species, and it forms the basis of a major inshore gill-net fishery.

Despite barramundi's importance, its life history in Australia is still not well documented. In particular, there have been few studies dealing specifically with reproduction and the ecology of immature phases. Dunstan (1959) undertook the first serious study of barramundi in Australia. He concluded that barramundi was a catadromous species that spawned in inshore coastal waters, just before or during the wet season, usually from October to March. In areas without major rivers, he observed postlarvae swimming up shallow gutters into waterholes on flood plains where they often became landlocked. In areas with major rivers, the postlarvae moved upstream either into freshwater lagoons adjacent to the main rivers or eventually into the freshwater reaches. Russell and Garrett (1983) found that juvenile barramundi entered supralittoral waterholes on tidal flats adjacent to a large estuary in the Gulf of Carpentaria. The histological sequence of gonad maturation in both male and female barramundi in the Northern Territory and Gulf of Carpentaria was described by Davis (1982).

The life history of barramundi has received more attention overseas. In Papua New Guinea, Moore (1980, 1982) identified a single major spawning site for barramundi in nearshore coastal waters of the south-western Gulf of Papua and observed larvae entering adjacent nursery swamps a few days after hatching. The juveniles subsequently returned

0067-1940/85/020191$02.00

to tidal waters as the nursery swamps began to dry out after the cessation of seasonal rains. Reynolds and Moore (1982) determined growth rates for barramundi in western Papua. From observations made in an Indian estuary, Ghosh (1973) found that adult barramundi spawn in the sea during the summer and early monsoon months with the larvae entering the estuary soon afterwards. Several other Indian workers, e.g. De (1971) and Patnaik and Jena (1976), have established that larval barramundi initially feed mainly on planktonic crustaceans, with prey fish assuming a greater dietary importance with age. Wongsomnuk and Manevonk (1973) discuss techniques for artificial breeding and rearing of barramundi in Thailand.

In this paper, the results of an investigation of the habitats, diet and spatial and temporal distribution of the immature stages of barramundi in north-eastern Queensland are presented. This work was a component of a wider program designed to supply biological information pertinent to the rational management of the Queensland barramundi resource.

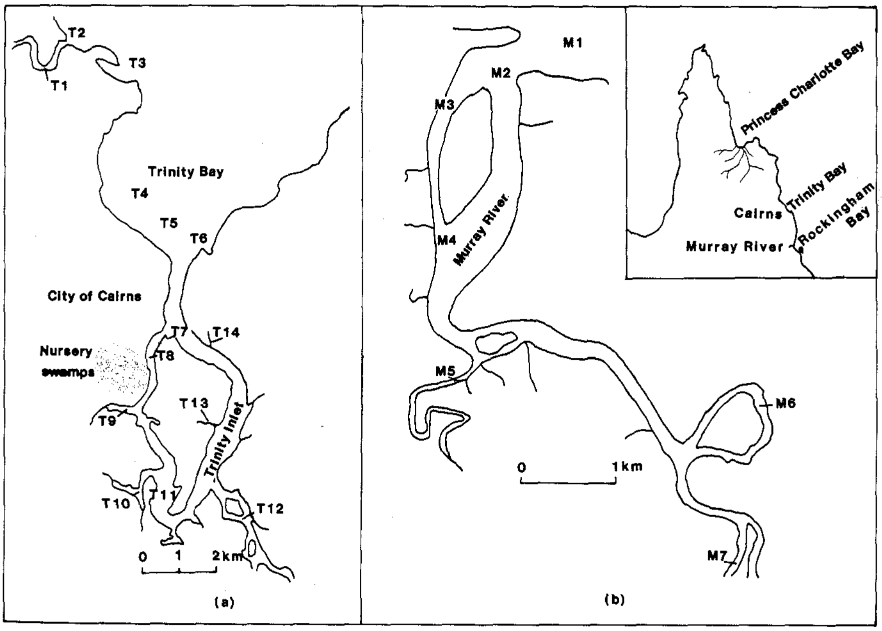

Fig. 1. Study sites in north-eastern Queensland. Plankton sampling stations in Trinity Bay (T1–T14) (*a*) and the Murray River (M1–M7) (*b*) are shown.

Study Area

Study sites for the collection of immature barramundi were established in estuarine areas of Rockingham Bay and Trinity Bay and in estuarine and freshwater habitats in Princess Charlotte Bay (Fig. 1). These sites encompass a wide range of river types, from the short streams and minor waterways common to the southern sites to the large, meandering rivers of Princess Charlotte Bay, which are more typical of river systems found in the Gulf of Carpentaria and the Northern Territory. The largest of the four major rivers that drain into the bay, the Normanby, has a mean annual discharge of $1 \cdot 24 \times 10^6$ Ml (Anon. 1980). The catchments of these rivers are mainly open eucalypt forest, which are used either as unimproved grazing land or as National Park. Lack of rain during the dry winter months may cause these large rivers to stop flowing and result in the formation of a series of isolated lagoons along the watercourse.

Intensive sampling for barramundi larvae was undertaken in two estuaries of Trinity and Rockingham Bays: Trinity Inlet and the Murray River (Figs 1*a* and 1*b*). The Murray is typical of the short, swift streams that dominate much of the north-eastern Queensland coast, and has a mean annual discharge of about $2 \cdot 26 \times 10^5$ Ml (Anon. 1980). Much of its catchment is largely undisturbed rainforest and eucalypt forest, although some areas have been cleared for agriculture. It has a maximum tidal amplitude of 3·6 m (Anon. 1981). Trinity Inlet is a relatively deep estuary opening into a large shallow bay. The inlet has little permanent freshwater inflow; however, its extensive mangrove wetlands are drained by numerous intertidal creeks. The estuary is the port for the city of Cairns, which is located on the northern bank. The maximum tidal amplitude is 3·2 m (Anon. 1981).

Estuarine systems in all three areas have both numerous small permanent tidal creeks and peripheral super- and supralittoral wetland swamps. The latter include a wide range of aquatic ecotypes, mostly shallow and less than 1 m deep. Associated plant communities are varied and appear dependent primarily on water salinity. *Melaleuca* spp. forests and *Eleocharis* spp. sedge may be dominant in freshwater habitats, and the mangrove genera *Avicennia* and *Rhizophora* in the more saline environments. Many of these swamps are ephemeral, filling with water during the high tides and seasonal rainfall of the summer months and gradually drying out with the smaller tides and low rainfall during winter. All are linked to tidal water by either freshwater flow or tidal inundation some stage during the summer months. The small permanent tidal creeks drain either into a larger estuarine system or directly into one of the above bays. Wreck Creek, which drains into Rockingham Bay 12 km south of the Murray River, is one such creek.

The creeks studied in Trinity Bay (Fig. 1), because of their close proximity to the city of Cairns, have been subjected to various degrees of human interference. This includes straightening and dredging of some sections, land filling and removal of mangrove fringes. Olsen (1983) reported that these systems did not have levels of contaminant material likely to be inimical to fisheries although other construction work had disrupted the natural watershed habitat.

Materials and Methods

A taxonomic description of barramundi larvae and juveniles has been given by Moore (1980, 1982). He found that barramundi larvae developed into juveniles at between 4·5 and 8·4 mm total length (T.L.). The juvenile stage resembled the adult fish in almost all characters except coloration. Pigmentation patterns in juvenile barramundi are described by Moore (1982). Davis (1982) found that fish first attained maturity at an average of 600 mm T.L. in the Northern Territory and 550 mm T.L. in the Gulf of Carpentaria. Reynolds and Moore (1982) calculated that 1-year-old fish had an average length of 328 mm. For the purposes of this paper, fish less than 8 mm T.L. will be described as larvae and those between 8 and 400 mm T.L. will be considered as juveniles.

The following techniques were developed for sampling barramundi larvae, juveniles and adults.

Larvae

A plankton sampling program was designed to determine if barramundi larvae were present in and outside two estuaries in the Rockingham and Trinity Bay study areas. Difficulty of access to and the remote location of Princess Charlotte Bay prevented any regular larval sampling regime in that area. Plankton samples were taken from seven locations in the Murray River estuary (Fig. 1*a*) between 20 September 1979 and 1 February 1980. Similarly, samples were collected from 13 stations in Trinity Inlet (Fig. 1*b*) from 28 August 1979 to 6 January 1981. Until 23 January 1980, a diel program was implemented with night tows of 5-min duration and daylight tows of 10 min. After 23 January 1980, only daylight collections were made as preliminary analyses of samples had shown that a greater proportion of the total catch of barramundi was present in daylight tows. The sampling interval was initially 2–3 weeks but was reduced to 1 week during most of the spawning season (Dunstan 1959) from November to February. Collections were made with a push bongo net apparatus similar to that described by Tarplee *et al.* (1979) with net mouths of 500 mm diameter and mesh sizes of 500 and 1000 μm. This apparatus was trawled at a speed of approximately 1 m s^{-1}, 1 m below the surface.

Surface water temperature and salinity were measured directly with a mercury-in-glass thermometer and an American Optical Corporation temperature-compensated refractometer. All plankton samples were preserved in 10% (v/v) formalin in the field for later analysis. In the laboratory, all fish were extracted from the samples and these were then sorted for barramundi larvae. Reference specimens supplied by the Papua New Guinea Department of Primary Industry were used to confirm early identifications. They were then measured (T.L., mm) and the contents of their guts examined microscopically and, where possible, identified.

Juveniles

Over a 4-year period from July 1978, juvenile fish were intensively sampled by a range of fishing techniques in a wide variety of habitats.

(*a*) *Offshore and nearshore habitats*

The fish caught by commercial otter trawlers operating on grounds inside the Great Barrier Reef off northern Queensland were examined. Research staff routinely accompanied commercial operators and were asked, over the period of the project, to look for juvenile barramundi.

(*b*) *Inshore and estuarine mudflats, eel-grass beds and beaches*

Mudflat and eel-grass areas in Trinity Bay and Inlet were intensively sampled on a monthly basis from July 1980 to April 1982 using a 1-m beam-trawl with 19-mm mesh. Spot sampling was also undertaken using a monofilament gill net of 50-mm stretched mesh (s.m.). A larval seine (5 m length, mesh size 1 mm s.m.) and a pocket seine (100 m length, mesh size 17 mm s.m.) were used at monthly intervals on beaches adjacent to Trinity Bay from July 1981 until July 1982. Spot samplings using these seine nets were made along beaches at Princess Charlotte Bay during March 1980 and November 1980 and 1981.

(*c*) *Rivers and fresh water*

Lagoons in the hinterland of Princess Charlotte Bay were sampled monthly from January 1980 to November 1980 and from March 1981 until November 1981. This sampling was undertaken by both Department of Primary Industries staff and amateur anglers. Difficulty of access to this area in the wet season prevented sampling from December 1980 to February 1981. A variety of methods, including seine netting (100 m by 15-mm s.m.), gill netting (50-, 75- and 100-mm s.m.) and angling were used to catch fish. All barramundi were measured (T.L.) and weighed and most were then tagged and released.

(*d*) *Semipermanent swamps*

As these study sites were obstructed with mangrove roots and fallen timber, the most efficient means of sampling fish was by using poison. Liquid rotenone was sprayed on the water surface with a hand-pump. All barramundi were measured (T.L.) and weighed. The gut contents of a subsample of 85 were analysed in the laboratory. A study site in Trinity Inlet (Fig. 1*a*) was sampled from late January until April 1980 when drainage and land-fill work commenced. Before this, the site was sampled only once, in June 1979. Equivalent habitats were poisoned in Princess Charlotte Bay during March and November 1980 and in Rockingham Bay during February and August 1979. Surface salinity and temperature at these sites were measured using the previously described methods.

(*e*) *Tidal creeks*

Monthly samplings were made of creeks draining into Trinity Bay (August 1978 to June 1980) and Rockingham Bay (September 1979 to January 1980) using both seine nets (5-, 12- and 19-mm s.m.) and monofilament gill nets (25–100-mm s.m.). Barramundi were weighed, measured (T.L.) and most subsequently tagged and released. The results of this tagging program will be reported elsewhere. A small number ($n = 79$) was retained for gut analysis. The period of occupation of tidal creeks was gauged by two methods. At Rockingham Bay, where gill netting was used exclusively as the capture technique, units of relative abundance were calculated using catch per unit effort data. These were the number of fish caught per net per hour. Pooled length–frequency data from Trinity Bay, where seine netting was the dominant sampling method, and from Rockingham Bay also provided an indication of period of occupancy. Surface water temperatures and salinities were also recorded using the above described methods.

Adults

Over the period January 1979 to December 1980, mature barramundi were collected with commercial gill nets (100–200-mm s.m.) from estuaries and coastal foreshores in all study areas. The reproductive activity of these barramundi was assessed by dissecting the fish and assigning their gonads an index of maturity. The indices used were based on the seven-point classification scheme of Nikolsky (1963) as quoted by Lagler (1978).

Results

Field sampling operations resulted in the capture of both larval and juvenile barramundi and also adult fish at various stages of maturity.

Table 1. Data on location, numbers of larvae, plankton net mesh size, surface water temperature and salinity for days when larval barramundi were sampled

Station locations for Trinity Inlet (T stations) and the Murray River (M stations) are given in Fig. 1. n.r., data not recorded

Date	Station	Mesh size (μm)	No. caught	T.L. of larvae (mm)	$10^{-3}\times$ salinity (mg l^{-1})	Temperature (°C)
31.x.79	M1	500	1	n.r.	30	28
31.x.79	M2	500	2	4·2, 4·7	32	28
31.x.79	M3	500	1	2·8	32	26·5
31.x.79	M5	500	1	5·1	22	28
31.x.79	M7	1000	1	5·2	16	27·5
29.xi.79	M5	500	2	3·1, 3·6	29	31
18.xii.79	T7	500	3	n.r.	34	32
18.xii.79	T8	500	1	4·8	37	30·5
18.xii.79	T11	1000	2	4·5, n.r.	36	30·5
19.xii.79	T7	500	1	4·7	34	29·5
19.xii.79	T12	1000	1	n.r.	31	29
19.xii.79	T13	1000	2	4·6, 4·6	32	30
19.xii.79	T13	500	2	5·3, 5·3	32	30
19.xii.79	T13	500	4	3·9, 4·2, 4·7, 4·6	30	29·5
19.xii.79	T13	1000	3	4·8, 4·8, 5·3	30	29·5
19.xii.79	T14	500	1	5·1	27	31·5
27.xii.79	T7	500	1	4·8	31	30
13.ii.80	T8	500	1	4·7	n.r.	29
18.xii.80	T7	500	1	4·2	28	29

Larvae

Between 28 August 1979 and 6 January 1981, 31 barramundi larvae, ranging in size from 2·8 to 5·2 mm T.L., were collected from 744 plankton samples. In the 1979–1980 spawning season, 30 larvae were collected in the Murray River and Trinity Inlet estuaries between 31 October and 13 February. Peak numbers were taken during December (see Table 1). In the 1980–1981 season, only one larva was collected. In both areas, larvae were distributed throughout the estuaries, being found in both tributary creeks and the main channels. No larvae were collected in Trinity Bay although one was collected outside the mouth of the Murray River. Of the 31 barramundi larvae caught, 9 were taken with the 1000-μm plankton net and the remainder with the 500-μm net. This is probably a result of mesh selectivity, with a proportion of larvae not being retained in the larger mesh [as discussed by Bowles *et al.* (1978)].

The stomachs of all the larvae were either empty, perhaps because many had not yet commenced feeding, or the contents were generally impossible to identify. Of two specimens collected on 19 December 1979, one had two copepods in its gut and the other had an unidentified crustacean.

Surface water temperatures at the locations from which larval barramundi were taken ranged from 26·5 to 32·0°C and salinities were generally high (Table 1).

Juveniles

During this study there was no evidence of juvenile barramundi in offshore habitats, or of many over inshore and estuarine mudflats, sea-grass beds and along beaches. Large numbers of juveniles were only located in semipermanent coastal swamps, tidal creeks and the freshwater reaches of rivers.

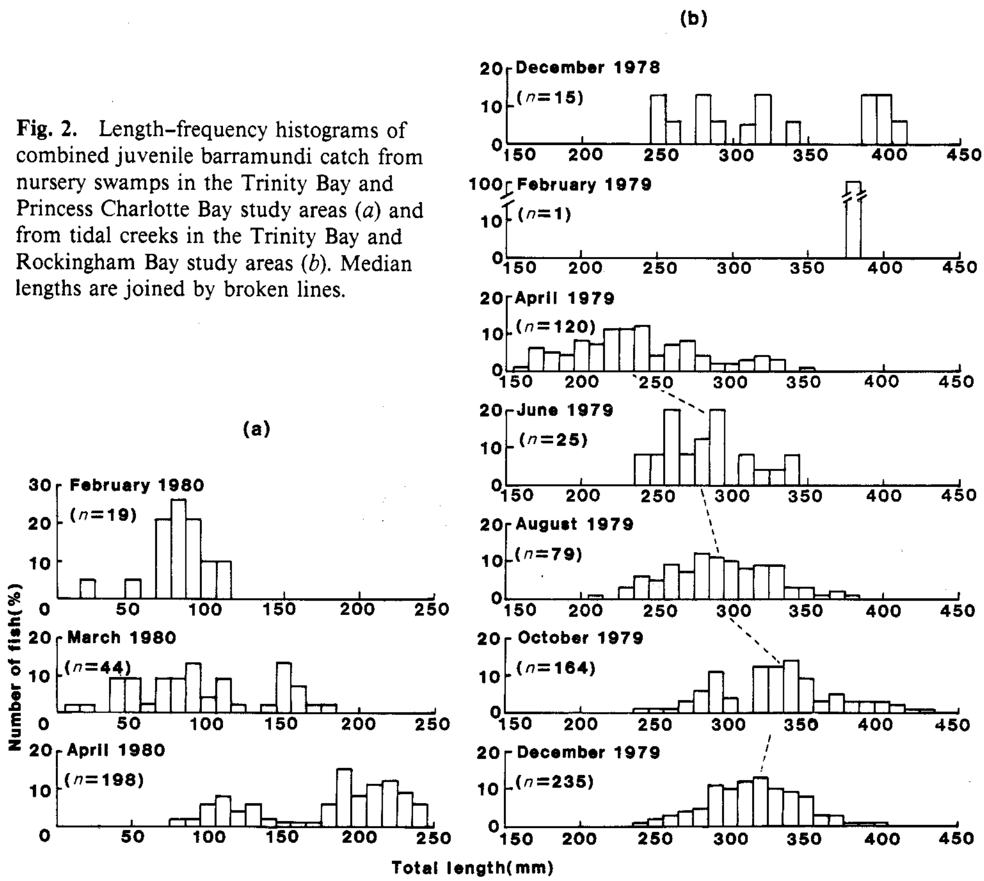

Fig. 2. Length–frequency histograms of combined juvenile barramundi catch from nursery swamps in the Trinity Bay and Princess Charlotte Bay study areas (*a*) and from tidal creeks in the Trinity Bay and Rockingham Bay study areas (*b*). Median lengths are joined by broken lines.

In the freshwater lagoons of Princess Charlotte Bay, a total of 96 barramundi of less than 400 mm T.L. was sampled from January 1980 to November 1981. Of these 19 (19·8%) were shorter than 300 mm T.L. and none shorter than 200 mm T.L. There are insufficient data available in this study to determine when or at what size juvenile fish migrate into freshwater reaches of the Princess Charlotte Bay rivers although it is before the many ephemeral streams stop flowing in winter.

In estuaries, juvenile (0+) barramundi appeared first in the swamp habitats in February and later, around April, in the tidal creeks. The size-frequencies of juvenile barramundi found in coastal swamp habitats and in permanent tidal creeks are given in Figs 2*a* and 2*b*. Sampling in the swamp systems adjacent to Trinity Inlet ceased on 10 April 1980 when land reclamation work commenced, thus preventing determination of the occupancy time.

In the previous year, however, no juveniles were captured during a sampling in June. Similar habitats in Princess Charlotte Bay were found to be populated with juvenile barramundi in mid-March 1980 but contained no fish life in November 1980.

The bimonthly length distribution of barramundi in tidal creeks over a year is shown in Fig. 2*b*. Changes in the median size of these samples indicates a steady growth of barramundi throughout most of the year. The decrease of median length in December is probably due to emigration. Intensive netting of the Trinity Inlet tidal creeks in February produced only one juvenile, suggesting that evacuation was largely completed by January. Similarly, in the Wreck Creek study site of Rockingham Bay, catch per unit effort was relatively constant in September (7·0), October (5·6) and December (6·9) but declined suddenly to 0·2 in January, suggesting a movement of juveniles out of tidal creeks.

Table 2. Gut contents of juvenile barramundi from nursery swamp and tidal creek habitats
Number of guts containing a particular food item and that item's frequency of occurrence in all stomachs that *contained* food are shown

Prey item	Nursery swamp (n = 85)		Tidal creek (n = 79)	
	No.	Frequency	No.	Frequency
INSECTA				
Chironomidae (larvae)	14	0·28	0	0
Culicidae (larvae)	4	0·08	0	0
Trichoptera (larvae)	1	0·02	0	0
Unidentified Insecta	4	0·08	0	0
CRUSTACEA				
Penaneidea	12	0·24	24	0·59
Portunidae	0	0	2	0·05
OSTEICHTHYES				
Hemirhamphidae				
Zenarchopterus dispar	1	0·02	0	0
Chandidae				
Ambassis sp.	1	0·02	13	0·32
Theraponidae				
Amphitherapon caudavittatus	2	0·04	0	0
Therapon jabua	1	0·02	0	0
Scatophagidae				
Selenotoca multifasciata	0	0	1	0·02
Melanotaeniididae				
Melanotaeniididae sp.	0	0	1	0·02
Gobiidae				
Gobiidae sp.	9	0·18	4	0·10
Eleotridae				
Eleotridae sp.	1	0·02	1	0·02
Hypseleotris sp.	0	0	12	0·29
Siganidae				
Siganus sp.	1	0·02	0	0
Unidentified fish	8	0·16	19	0·46
Unidentified contents	2	0·04	0	0
No contents	35	—	38	—

Stomach contents of juveniles taken from both swamp and tidal creek habitats are shown in Table 2. Many of the fish examined (41% of swamp fish and 48% of tidal creek fish) had empty stomachs. This situation is not uncommon among predatory fish [see Randall and Brock (1960), Choat (1968), and Goeden (1978)]. Also, Dunstan (1959) observed a tendency for barramundi to disgorge gut contents when caught in a net. In the present study, many of the barramundi caught in nets were found to have regurgitated food in their mouths. The diet of barramundi captured in the swamp habitats varied, with fish and insects being the main components. The fish component of the diet comprised representatives from at least seven families; the crustaceans were relatively minor and the insect prey were predominantly Chironomidae larvae. In tidal creeks, fish were the dominant food item of barramundi. Crustaceans were also eaten, but insects were entirely absent from the diet.

The swamp habitats and tidal creeks containing barramundi exhibited a wide range of surface salinities, with the former ranging from fresh water to 44×10^3 mg l^{-1} and the latter from fresh water to 38×10^3 mg l^{-1}. Surface water temperatures of both habitats varied from 23 to 36°C.

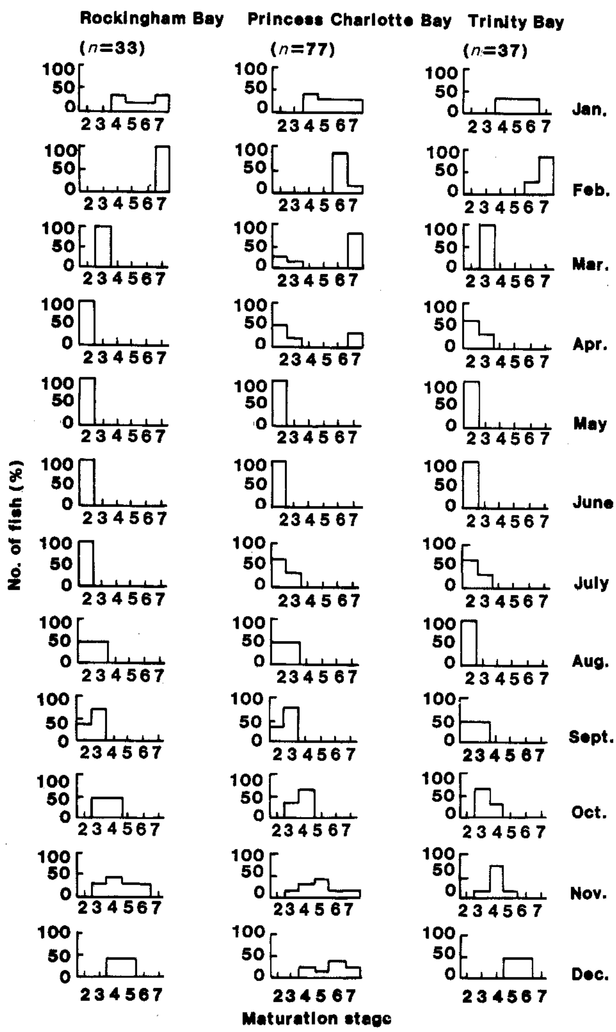

Fig. 3. Grouped monthly ovarian maturation stages of 147 barramundi from gill-net catches in all study areas from January 1979 to December 1981. Stage 2 is slight development, stages 3 and 4 are developing, stage 5 is spawning, stage 6 is spent, and stage 7 is resting.

Adults

A total of 147 adult barramundi was examined for gonad development during this study. The period of maximum gonad activity was from October to February with evidence of the commencement of spawning (presence of stage 5–6 gonads) in November (Fig. 3).

Discussion

In western Papua, Moore (1982) reported a substantial migration of barramundi to a specific spawning ground. Despite extensive surveys involving the poisoning of coastal swamp systems and the netting of foreshores he found no evidence of any other major spawning sites, although at least one other, smaller site was identified. In contrast, it would appear that there is no single major spawning site in north-eastern Queensland. Local spawning activity, as indicated by the presence of larvae and/or the discovery of juvenile nursery grounds was evident in all three study areas. Adult barramundi exhibiting an advanced state of gonad development were also present. The inclusion of running ripe females (gonad stage 5) in gill-net catches made in lower estuaries and on coastal foreshores suggests that spawning takes place nearby. Moore (1980, 1982) suggested a close relationship between known spawning grounds of barramundi and high salinity and that the huge discharge of the Fly River (average discharge of 8000 $m^3 s^{-1}$) into the Gulf of Papua precluded local spawning, necessitating a migration to more suitable grounds. The rivers of north-eastern Queensland, particularly the short streams, have a comparatively insignificant discharge, thus creating conditions for localized spawning.

A strategy for avoiding estuarine and coastal waters of low salinity could be the commencement and completion of a major part of the breeding cycle before the onset of the northern monsoon, which usually occurs from late December to March. In this study, gonadal activity was highest between October and February, with larvae being recorded over the same period. Davis (1982) found that the months of greatest gonadal activity for barramundi in the Northern Territory were October to December and in the Gulf of Carpentaria, October to January.

The salinities of surface water in the Murray River and Trinity Inlet where larvae were sampled were generally high. However, in one instance a larva was found in the Murray River, 8 km from the mouth at a salinity of 16×10^3 mg l^{-1}. This single, but important, instance suggests that although high salinities may be critical for spawning sites, larvae are subsequently passively transported by tidal currents into areas of various salinities. In rearing trials on barramundi larvae in Thailand, Wongsomnuk and Manevonk (1973) concluded that survival was optimal at salinities of between 20×10^3 and 25×10^3 mg l^{-1}.

Temporal distribution of barramundi larvae is very sporadic, with fish being sampled on only 7 days during the study. Bowles *et al.* (1978) suggested that such temporal patchiness in larval occurrence may be due to temporal variations in spawning, diel movement of larvae and fluctuations in the tidal cycle.

Observations on larval stomach contents, although very limited, support the findings of De (1971) and Patnaik and Jena (1976) that barramundi larvae are entirely planktophagous.

The movements of postlarval barramundi appear to be directly influenced by the availability of freshwater habitats. In this study, juvenile fish from 16 mm T.L. were found in swamps and lagoons adjacent to estuaries and the coast. Specimens as small as 9·5 mm T.L. were found in equivalent localities in the Gulf of Carpentaria (Russell and Garrett 1983), and specimens shorter than 5 mm in Papua New Guinea (Moore 1982). Although a postlarval (and possibly larval) movement into these swamp systems occurs on an apparently large scale, it is also likely that some fish, particularly in rivers with high discharges and large catchments, move upstream into freshwater habitats. Dunstan (1959) observed postlarvae swimming upstream in large rivers either into freshwater lagoons adjacent to the main river or eventually into its freshwater reaches. In the hinterland of Princess Charlotte Bay, which contains extensive freshwater lagoon and river systems, no barramundi shorter than 200 mm T.L. was caught. It is feasible that much smaller fish were present in the immediate postspawning period but were not sampled. This may have been due to inaccessibility of sites during the wet season and/or bias in sampling methods. Gill netting is a particularly size-selective sampling technique (Clay 1981).

In areas of north-eastern Queensland without large river systems, coastal swamps form the predominant nursery habitat for postlarval barramundi. These are sheltered and presumably highly productive environments that allow for rapid growth of juveniles to a size where they may compete successfully in the open estuary. These habitats are occupied simultaneously by a range of other juvenile fish and crustaceans. The barramundi in these swamps are entirely carnivorous, with a varied diet including prey such as other fish, crustaceans and insect larvae. No evidence of cannibalism was found although the range of size classes and the voracious appetite (Moore 1980) of barramundi make it probable. Indeed, Moore (1980) recorded cannibalism in similar habitats in New Guinea.

The lowering of water levels in these swamps at the onset of the winter dry season, coupled with a depletion of food are likely to stimulate an exit of juveniles into more permanent habitats. Moore (1980, 1982) and Russell and Garrett (1983) discussed similar escape strategies for barramundi from nursery grounds. Of the fish that remain in the swamps some perish as isolated pools dry out during winter, whereas others, trapped in more permanent waters, may survive until the next flood rains.

In Trinity Inlet, 0+ barramundi first appear outside nursery swamps in nearby tidal creeks from around April. Populations of these juvenile fish are found in the tidal creeks up until about December or January. Tagging experiments (Russell and Garrett, unpublished data) have shown that they then disperse into the estuary, moving upstream and along the coast. The diet of barramundi living in these tidal creeks included crustaceans and fish, with the latter the dominant component. This may reflect opportunism rather than any active prey selection.

In developed coastal regions, many of the tidal creeks and swamps occupied by juvenile barramundi have been or are threatened with various types of human interference. Although the fish still use tidal creeks of Trinity Inlet that have been dredged, straightened and had their mangrove fringes removed, they may not tolerate more severe habitat disruption. Nursery swamps appear critical to the life cycle of the barramundi in some areas and their destruction could lead to a decline in local barramundi stocks and their attendant fisheries.

Acknowledgments

The help of the many amateur anglers and other staff of the Department of Primary Industries Fisheries Research Branch who assisted with collecting field data is gratefully acknowledged. We would especially like to thank Messrs G. M. French, I. R. Hocking, G. J. Pomroy and L. C. Squire. We also thank Dr G. Goeden for his advice on earlier drafts of the manuscript, Dr R. Moore for supplying larval reference specimens, and Mr D. Mayer for drafting the figures. This research was funded by a Fishing Industry Trust Account Grant.

References

Anon. (1980). 'Queensland Stream Flow Records to 1979. Vol. 3. Queensland.' (Water Resources Commission: Brisbane.)

Anon. (1981). Official tide tables with notes on boating—1982. Department of Harbours and Marine, Brisbane.

Bowles, R. R., Merriner, J. V., and Grant, G. C. (1978). Factors associated with accuracy in sampling fish eggs and larvae. United States Department of the Interior, FWS/OBS-78/83.

Choat, J. H. (1968). Feeding habits and distribution of *Plectropomus maculatus* (Serranidae) at Heron Island. *Proc. R. Soc. Queensl.* **80**, 13–17.

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

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**, 529–46.

De, G. K. (1971). On the biology of postlarval and juvenile stages of *Lates calcarifer* (Bloch). *J. Indian Fish Assoc.* **1**, 51–64.

Dunstan, D. J. (1959). The barramundi, *Lates calcarifer* (Bloch) in Queensland waters. CSIRO Div. Fish. Oceanogr. Tech. Pap. No. 5.
Ghosh, A. (1973). Observations on the larvae and juveniles of the 'bhekti', *Lates calcarifer* (Bloch), from the Hooghly-Matlah estuarine system. *Indian J. Fish.* **20**, 372–9.
Goeden, G. B. (1978). A monograph of the coral trout *Plectropomus leopardus* (Lacepede). Queensl. Fish. Serv., Res. Bull. No. 1.
Greenwood, P. H. (1976). A review of the family Centropomidae (Pisces, Perciformes). *Bull. Br. Mus. (Nat. Hist.) Zool.* **29**, 4–81.
Lagler, K. F. (1978). Capture, sampling and examination of fishes. In 'Methods for Assessment of Fish Production in Freshwater'. (Ed. T. Bagenal.) pp. 7–47. (Blackwell Scientific: Oxford.)
Moore, R. (1980). Migration and reproduction in the percoid fish *Lates calcarifer* (Bloch). Ph.D. Thesis, University 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**, 647–61.
Olsen, H. F. (1983). Biological resources of Trinity inlet and bay. Queensl. Dep. Primary Ind. Bull. No. QB83004.
Patnaik, S., and Jena, S. (1976). Some aspects of biology of *Lates calcarifer* (Bloch) from Chilka Lake. *Indian J. Fish.* **23**, 65–71.
Randall, J. E., and Brock, V. E. (1960). Observations on the ecology of epinepheline and lutjanid fishes of the Society Islands, with emphasis on food habits. *Trans. Am. Fish. Soc.* **89**, 9–16.
Reynolds, L. F., and Moore, R. (1982). Growth rates of barramundi, *Lates calcarifer* (Bloch), in Papua New Guinea. *Aust. J. Mar. Freshw. Res.* **33**, 663–70.
Russell, D. J., and Garrett, R. N. (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.
Tarplee, W. H., Bryson, W. T., and Sherfinski, R. G. (1979). Portable push net apparatus for sampling ichthyoplankton. *Prog. Fish Cult.* **41**, 213–15.
Wongsomnuk, S., and Manevonk, S. (1973). Results of experiments on artificial breeding and larval rearing of the sea bass *Lates calcarifer* (Bloch). (In Thai.) Contribution of Songkhla Marine Fisheries Station No. 5.

Manuscript received 8 November 1983, accepted 8 October 1984