THE BARRAMUNDI

IN QUEENSLAND WATERS

DIVISION OF FISHERIES AND OCEANOGRAPHY TECHNICAL PAPER NO. 5

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION, AUSTRALIA 1959

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Technical Paper No. 5

Commonwealth Scientific and Industrial Research Organization, Australia

Melbourne 1959

Printed by C.S.I.R.O., Melbourne

THE BARRAMUNDI *LATES CALCARIFER* (BLOCH) IN QUEENSLAND WATERS

By D. J. DUNSTAN *

[*Manuscript received September* 22, 1958]

Summary

The presence of vast coastal plains, often but a few feet above high tide level and traversed by rivers and creeks of considerable size with their associated swamps, is characteristic of the greater part of the north Queensland coastline along which barramundi occur in abundance.

The effect of hydrological factors and stream characteristics on the distribution of barramundi is examined. Temperature appears to limit the overall distribution, stream characteristics and climatic conditions limit the maximum availability, and salinity governs the distribution within any particular river system.

The species is carnivorous and predacious throughout the whole of its life-cycle, the diet consisting roughly of 60 per cent. teleosts and 40 per cent. crustaceans.

Growth is very variable, the mean lengths at the end of the first, second, and third year being 45, 73, and 87 cm. Generally, the species grows to maturity in the upper freshwater reaches, and journeys down the rivers, often with the assistance of floodwaters, to spawn in coastal stretches. In some localities, the severity of the wet season determines the number of spawners. The spawning season is prolonged and has two major periods, in October–January and January–March.

Major river systems with large catchment areas, low run-off, and slow but perennial freshwater discharges, support the largest stocks. The largest catches are taken during the wet season and during pre-spawning movements. Barramundi of all ages are stimulated to greater activity by river freshets; this results in greatly increased catches.

Gill meshing with set nets is the principal method used for the capture of this species.

During recent years increasingly greater catches of barramundi have been air freighted from Gulf of Carpentaria waters to inland Queensland towns. The total catch exported from this area now exceeds the marketed catch on the east Queensland coast, where the recorded catch has declined since 1947.

I. INTRODUCTION

This investigation into the state of the barramundi fishery was undertaken at the request of the Queensland Government following numerous complaints that this species was being overfished. Although the work was carried out for only the comparatively short period of four years, it is considered that the results should be placed on record. Certain aspects of the growth rate are to be dealt with in greater detail in a later paper.

The name barramundi has been applied to *Lates calcarifer* (Bloch), to *Neoceratodus forsteri* (Gunther), and to *Scleropages leichardti* (Gunther). It is generally considered by scientific workers that the vernacular name "giant perch" should be

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applied to *Lates calcarifer*, "barramundi" to *Scleropages leichardti*, and "lungfish" to *Neoceratodus forsteri*. As Queensland fishermen and fish market officials have continued to use the name barramundi for *Lates calcarifer*, and as this paper is likely to be of particular interest to them, the name barramundi has been used here.

II. Distribution

(a) General Distribution

With the exception of *Lates calcarifer*, the other six species of the genus *Lates* occur in fresh water in Africa. *L. calcarifer* is widely distributed in rivers and estuaries

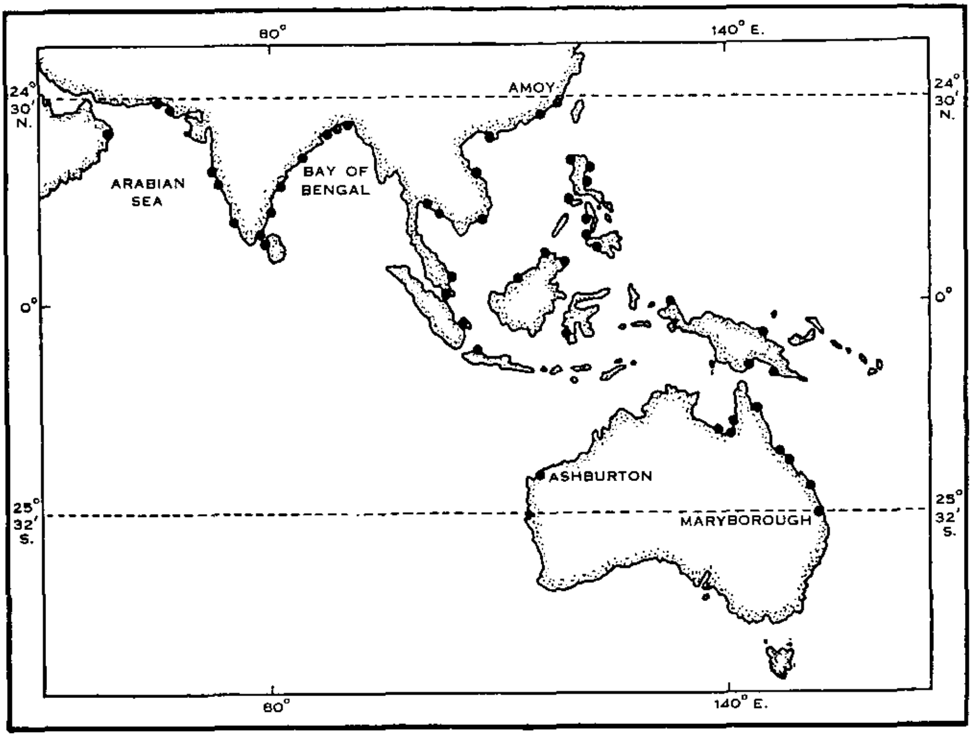

Fig. 1.—Distribution of the barramundi (*Lates calcarifer*).

in the semi-tropical and tropical regions of the Indo-Pacific, from south China to the Persian Gulf and along the coast of northern Australia. The world distribution is shown in Figure 1.

Zugmayer (1913, p. 9) records *L. calcarifer* from Mekran and Oman in the Gulf of Oman but it was not found by Blegvad and Løppenthin (1944) during the 1938–39 survey of the Iranian Gulf. The absence of *L. calcarifer* from African waterways, which appear ecologically suitable, is probably to be attributed to the hydrological barrier of the Arabian Sea with its lack of fresh water from large rivers, its high temperatures, and high evaporation rate. Chopra (1951) recorded a salinity of 36·0–36·3‰ at all times of the year and Hesse, Allee, and Schmidt (1937) recorded values as high as 45·4–46·5‰ for the Red Sea.

The limiting factors in the distribution of *L. calcarifer* appear to be temperature and chlorinity. Its extreme northern limit is Amoy, south China (lat. 24° 30′ N.), with a minimum sea temperature in March 1951 of 70°F (data from the Philippine Weather Bureau (1952)). Its southern limit is Maryborough in Queensland (lat. 25° 32′ S.) with a similar minimum sea temperature (from charts issued by the Royal Netherlands Meteorological Institute (1949)).

(*b*) *Australian Distribution*

Barramundi range from the Mary River in Queensland, around the north coast, including the Gulf of Carpentaria, to central Western Australia. The factor limiting abundance in northern Australia appears to be the absence of large rivers flowing permanently (C.S.I.R.O. Aust., unpublished data 1946). This also applies to Cape York Peninsula, where rivers flow for only a short time during the summer rainy season.

(*c*) *Queensland Distribution*

As the only fishery of commercial importance occurs in central and northern Queensland including the Gulf of Carpentaria, the investigations reported here were restricted to these areas (Fig. 2).

Barramundi occur in subtropical and tropical rivers, and appear able to adapt themselves to a variety of environments, but prefer the slow-moving or still, muddy water in rivers, creeks, swamps, and estuaries. They are taken in coastal waters only where these are affected by river drainage, which is extensive in the wet season, and even extend offshore to the many small islands where occasionally barramundi are caught in shallow water.

Barramundi are fished particularly in the Fitzroy, the Burdekin, the Herbert, and the Normanby Rivers on the east coast of Queensland, and in the Gilbert, the Norman, the Flinders, the Leichhardt, and the Gregory Rivers in the Gulf of Carpentaria. They occur in all rivers from the Mary to the Gregory except in those which are not permanent.

III. Factors Affecting Distribution and Abundance in Queensland

(*a*) *Temperature*

Temperature as a limiting factor of the world distribution of barramundi has already been discussed. In the upper freshwater reaches of the Fitzroy River and rivers south of the Tropic of Capricorn, lowering of the water temperature may result in the death of this species. In investigating the death of a number of fish species in the shallow waters adjacent to the coast of Florida, Miller (1940) concluded that rather rapid lowering of temperature cannot be tolerated and will result in death. Whilst the critical minimum temperature necessary for survival of barramundi is not known it would appear to be in the vicinity of 15·5°C. C.S.I.R.O. Aust. (1953) has recorded temperatures of this magnitude in the upper reaches of the Mary River, the most southern limit of the barramundi during the winter months.

(*b*) *Salinity*

Many of the tidal creeks of the Queensland coast connect with coastal waters only during the wet season, particularly in the area between latitudes 20 and 24° S. where the tidal amplitude is greatest (Endean, Kenny, and Stephenson 1956). During

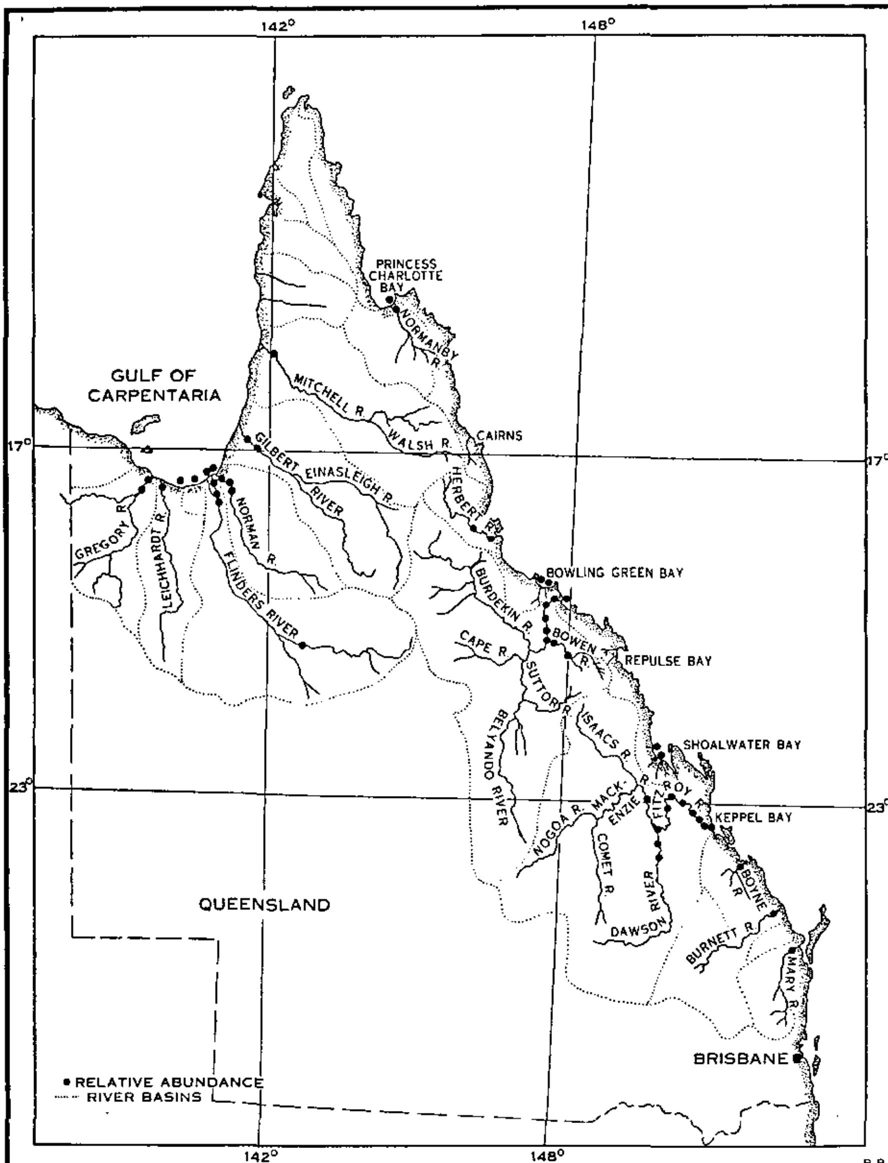

Fig. 2.—Queensland distribution of barramundi with indication of abundance.

the dry season their salinity is raised by evaporation and in some cases death of the species has followed. During the wet season (January–April) the rivers, streams, and swamps of the area are all filled and barramundi become widely distributed even to the upper reaches of the rivers. From April to December there is little rain, and barramundi are frequently isolated in small waterholes as the smaller streams and swamps dry up.

The preference for waters of different salinity by barramundi of different ages is clearly shown in the major river systems where the fish can move readily from salt to fresh water. A greater percentage of immature fish were observed in fresh water than in tidal and brackish water.

(*c*) *River Types*

Barramundi are not evenly distributed in all coastal rivers of Queensland but occur in greater abundance in certain rivers and creeks. The following classification of Queensland rivers into five categories has been drawn up to indicate these preferences.

(i) *Rivers with a Large Catchment Area and a Muddy or Sandy Bottom.*—These streams are sluggish and meandering in their middle reaches, and have a medium flow velocity and a continuous though often slow discharge which rarely falls below 15,000 ac. ft./month. The main rivers of the east coast and the Gulf are of this type.

In these rivers and adjacent waterholes barramundi find conditions suited to all stages of their life-cycle. During the dry months of the year 0+ fish are found in the lower freshwater reaches and in land-locked lagoons formed by overflow of the flooded rivers during the wet season. In the deep holes in the upper reaches of the rivers the 1+ fish are found and the mature fish inhabit the tidal reaches at the mouths of the rivers.

The 1+ group are plentiful below the falls which are about 120 miles from the mouth of the Burdekin River, but have not been recorded in the tributaries above the falls. In the Dawson River and other tributaries of the Fitzroy the 1+ group are common.

(ii) *Short, Deep, Straight, Fast-flowing Rivers.*—These rivers, rising in coastal ranges of high rainfall, have small catchment areas, with little or no storage; the rivers between Cardwell and Port Douglas are of this type. The Barron, Tully, and Johnstone River Falls present complete barriers to up-river movement of fish. There are very few barramundi in these streams.

(iii) *Impermanent Rivers.*—These streams have sandy or pebbly bottoms in their upper reaches and are reduced to a series of isolated waterholes in the dry season. Barramundi are absent from the upper reaches and scarce in the lower reaches of these streams.

(iv) *Minor Waterways.*—These are muddy streams and swamps near the coast but in contact with coastal waters during the wet season. The swamps act as reservoirs during the dry season and are usually in areas of high rainfall such as Proserpine and Ingham. Immature barramundi are plentiful and widely distributed in these permanent waterways.

(v) *Tidal Creeks.*—There are many smaller tidal creeks, particularly in the area adjacent to Hinchinbrook Channel. They discharge into mangrove swamps but they receive little fresh water. Barramundi are rarely taken in these areas.

Table 1

BODY PROPORTIONS OF BARRAMUNDI

Origin	Salinity	Number of Specimens	Body Length (mm)	Ratio of Total Length to:							
				Head Length	Snout–First Dorsal Fin	Snout–Second Dorsal Fin	Snout–Anal Fin	Snout–Pectoral Fin	Snout–Pelvic Fin	Inter-orbital Space	Maximum Depth
Gulf of Carpentaria	Brackish	7	725–798	3·35–3·70	2·53–2·88	1·69–1·81	1·65–1·73	3·50–3·84	3·17–3·55	32·2–38·5	4·34–5·0
Lagoons, east Queensland	Fresh	8	240–750	3·19–3·57	2·74–2·90	1·66–1·81	1·51–1·66	3·28–3·64	2·97–3·43	30·9–35·4	3·57–4·54
Rivers, east Queensland	Brackish	30	337–1140	3·47–4·18	2·58–2·99	1·48–1·91	1·51–1·80	3·50–4·08	3·10–3·65	20·6–37·9	3·37–4·49
Northern Territory	Brackish	2	250–281	3·09–3·12	2·63–2·69	1·77–1·82	1·71–1·81	3·51–3·62	3·53–3·57	28·1	
Torres Straits	Brackish	1	224	3·25	2·57	1·72	1·72	3·50	3·50	28·0	
Philippines	Brackish	1	155	3·37	2·72	1·82	1·85	3·86	3·52	22·1	3·78
India	Brackish	1	255	3·49	2·63	1·78	1·68	3·54	3·22	25·5	3·86
Indian Is.	Brackish	1	238	3·22	2·59	1·78	1·78	3·55	3·26	29·8	4·25

(*d*) *Pollutional Wastes from Sugar Mills*

In waterways north of the Tropic of Capricorn the effluent released from sugar mills frequently contributes to large-scale mortality of fish. In January 1956, when the flow in the Burdekin River was at a minimum, a small freshet carried the concentrated waste downstream from the Home Hill Mill. The oxygen content of this effluent was nil. A mass mortality of fish over a 5 mile stretch of the river was estimated at 100 tons (Dunstan 1955).

IV. Biology

(*a*) *Description*

Lates calcarifer has been described at different times under six different names (Fowler and Bean 1930, pp. 177–8). The description given by Weber and de Beaufort (1929) is generally applicable to Australian specimens.

There are well-marked differences between specimens from salt water and from fresh water. In the salt-water forms, the upper half of the body surface has a bluish or greenish-grey sheen, and the lower half is silvery. The upper two-thirds of the caudal fin is often yellow and the remaining fins are dark. The general body shape is elongated and the anterior head profile is pointed. There is no trace of fatty tissue in the body cavity.

The freshwater forms have a dark-coloured dorsal surface and the under surface has a golden sheen. The girth is deep, the tail is thick, and the body cavity has varying amounts of fatty tissue; in specimens from land-locked lagoons, it is practically full. The head region has a straight ventral border and a concave dorsal profile.

(*b*) *Raciation*

Data on body proportions of specimens from different localities are summarized in Table 1. While body proportions of specimens from different localities may vary greatly, these differences have also been noted to occur in specimens from the same locality and therefore cannot be regarded as racial differences.

(*c*) *Food*

The food of barramundi is varied. Generally they prey on any smaller fish or crustacean species. It is difficult to obtain food samples because barramundi tend to disgorge their stomach contents when captured. However, by placing mosquito netting downstream from a set net the regurgitated food was caught on several occasions. The stomach contents of 96 barramundi thus netted in the Ayr-Townsville rivers and estuaries during January–March 1955 are described in Table 2. The salmon catfish *Netuma thalassina* (Rüppell) was the most common teleost species. The stomach contents of barramundi from land-locked freshwater lagoons indicated a more restricted diet, including *Neosilurus hyrtlii* Steindachner, *Hypseleotris compressus* (Krefft), *Austrochanda macleayi* (Cast.), and *Harengula* sp.

(*d*) *Length–Weight Relationship*

Barramundi from fresh water have large amounts of fatty tissue and little or no trace of parasitic infection. Their movements are sluggish and their flesh is soft. They can be caught with ordinary cotton nets. Barramundi from salt water have very little fatty tissue, and a hardiness which makes them fight when captured, so that hemp or linen nets are generally used. Figure 3 shows the length–weight relationships for the east coast barramundi obtained from fresh water and from brackish and salt water. The data used for the curves were collected over a period of three years from all localities at all times of the year. The curve for barramundi from non-flowing

TABLE 2

FOOD OF THE BARRAMUNDI

Prey Species		Percentage of Stomachs Containing Prey Species
Common Name	Specific Name	
Blue-tail mullet	*Valamugil aekeli* (Forskål)	2·1
Diamond-scale mullet	*Liza vaigiensis* (Quoy & Gaimard)	6·2
Salmon catfish	*Netuma thalassina* (Rüppell)	14·6
Cooktown salmon	*Eleutheronema tetradactylum* (Shaw)	1·0
Beach salmon	*Leptobrama mulleri* Steindachner	1·0
Ox-eye herring	*Megalops cyprinoides* (Broussonet)	2·1
Mi mi	*Siganus guttatus* (Bloch)	2·1
Sand whiting	*Sillago ciliata* Cuvier	6·2
Northern pilchard	*Amblygaster sirm* (Walbaum)	1·0
Northern blue sprat	*Spratelloides delicatulus* (Bennett)	1·0
Indian anchovy	*Stolephorus indica* (Van Hasselt)	7·3
Dart	*Chorinemus lysan* (Forskål)	2·1
Bony bream	*Nematolosa come* (Richardson)	6·2
Carp gudgeon	*Hypseleotris compressus* (Krefft)	2·1
Chauda perch	*Ambassis* sp.	2·1
Pony fish	*Leiognathus* sp.	2·1
Blue swimmer crab	*Portunus neptunus* (Linnaeus)	2·1
Spotted net crab	*Matuta* sp.	6·2
Greasy back prawn	*Metapenaeus mastersii* (Haswell)	12·6
Banana prawn	*Penaeus merguiensis* (de Man)	16·8

fresh water was derived from measurements of 172 specimens and that for barramundi from brackish and salt water from 225 specimens.

The least squares method gave the regression equations:

Saltwater phase: $\log W = 2{\cdot}814 \log L - 4{\cdot}252$;

Freshwater phase: $\log W = 3{\cdot}195 \log L - 4{\cdot}905$.

(e) *Age Determination and Growth Rate*

The samples used in this investigation were caught in traps and mesh nets, except for portion of the first year group which was taken in special hauling nets.

(i) *Petersen's Method.*—In studies of age groups and year classes, sampling with mesh nets can give unreliable data owing to the selective action of the nets used. Hile (1936), working with the cisco *Leucichthys artedi* Le Sueur, has indicated that mesh nets may select certain size groups and that such data from the catches may prove unreliable. In this fishery the fisherman's knowledge of the habits of the species has dictated the use of a wide range of mesh sizes so as to partly offset the unreliability of the mesh net method. The first year group was sampled with mosquito netting — ½ in. mesh hauling nets for the smaller fish, and 2¼ and 3¼ in. hemp and linen mesh nets for the larger fish. Trap catches are not subject to this error of selection as the mesh is fixed by regulation and fish smaller than a certain size will not be taken by this gear.

Figure 4 shows the progression of the monthly modes of length frequency measurements of *L. calcarifer* taken in the field and in the markets over a three year period and over the greater part of its range in Queensland. The minimum legal length is 20 in., and market measurements do not include any smaller specimens.

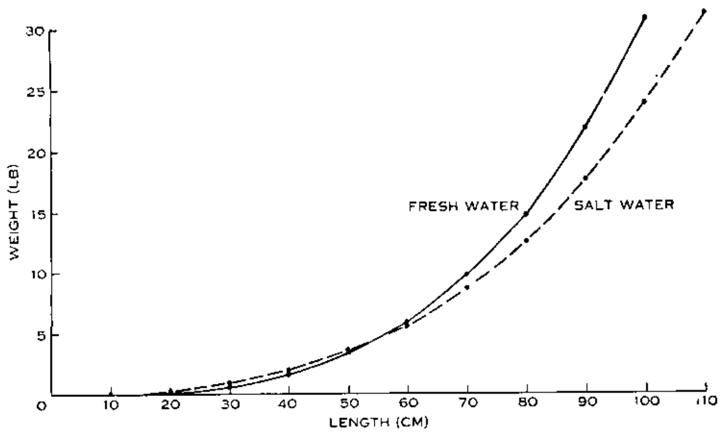

Fig. 3.—Length–weight relationship for barramundi, 225 from salt water and 172 from stagnant fresh water.

This accounts for the low frequency in the 0+ group for January. Market receivals of the older groups were insufficient in many months to indicate representative modes. The presence of double modes during certain months of the year indicates a secondary late-summer spawning period in addition to the normal November–December period. The unbroken line (Fig. 4) joining modes represents the progression for the first two years of the late spawned fingerlings, while the broken line represents the progression of the early spawned fingerlings. The large group intervals chosen, 5 cm, and the wide area from which samples were measured indicate that the adjacent maxima correspond to real modes and relate to different spawning periods (Buchanan-Wollaston and Hodgson 1928).

The February measurements plotted in Figure 4 were obtained from fish caught in the Rockhampton area. A number of year groups may be recognized. The first group (0+), consisting of fry and fingerlings of early spawned barramundi, were not taken. The second modal group (1+), containing fish ranging from 35 to 60 cm in length, would include both early (1*a*) and late (1*b*) spawned fish of the previous year and would be from 11 to 15 months old. The third group ranging from 65 to 85 cm in length would be fish of 23–27 months.

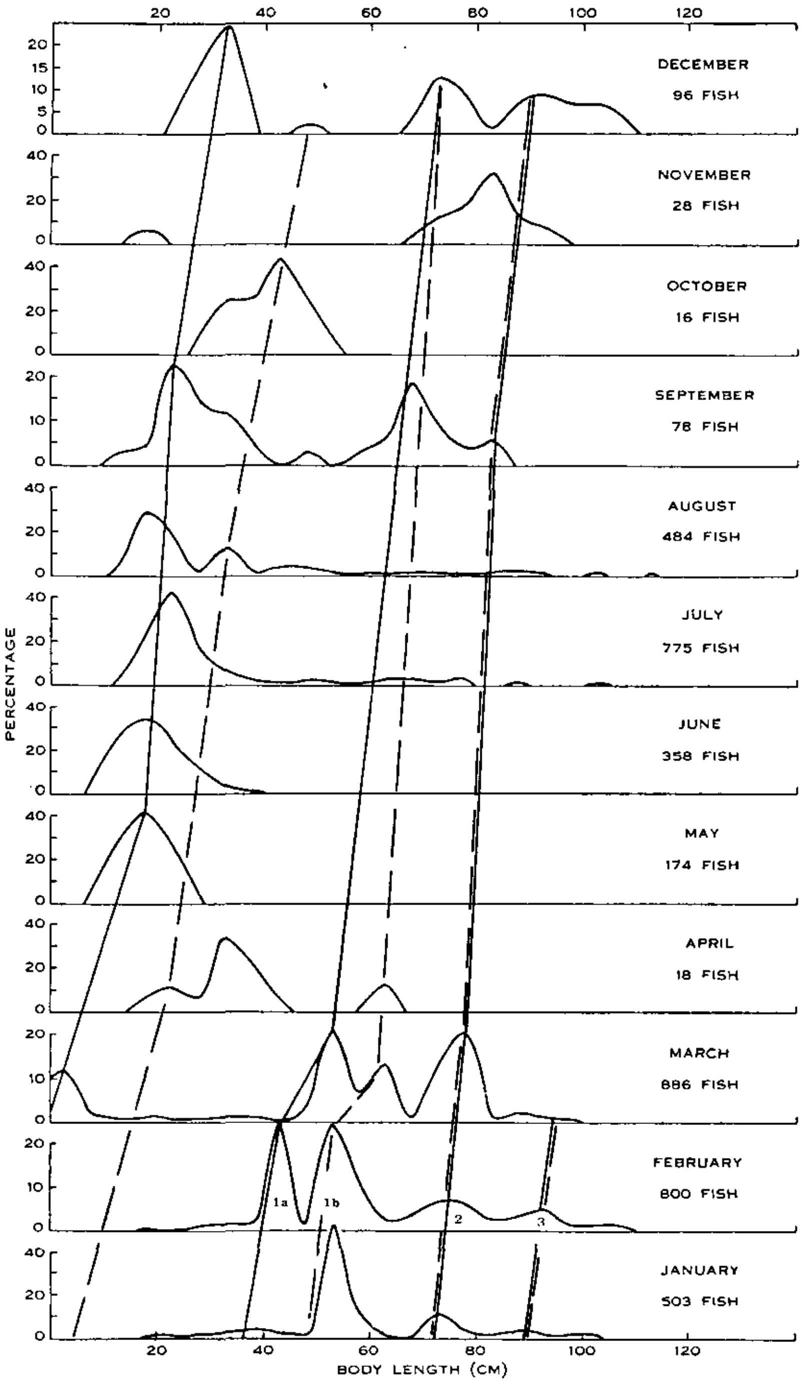

Fig. 4.—Length frequency polygons for Queensland barramundi illustrating progress of age group modes. — — — modal progression of early spawned barramundi (Nov.–Dec.) (1*a*); ——— modal progression of late spawned barramundi (Feb.–Mar.) (1*b*); ═══ modal progression of late barramundi.

A possible fourth group with modal length of 92·5 cm and a fifth group with modal length of 102·5 cm would represent fish approximately 3 and 4 years old.

In Figure 5 the modal lengths have been plotted against the months in which they occur and a curve fitted by eye to indicate the growth rate of the early and late spawned fish for two years. Subsequently there is a slower rate of growth, and because of this, the inadequacy of the sampling, and the large group interval, it is not possible to distinguish the different growth rates of the early and late spawned fish of more than two years. The line indicating growth subsequent to this period has been fitted statistically.

In Figure 5 the broken line represents the growth for two years of fish spawned during November–December, the unbroken line for fish spawned during February–March. During the winter months of the first two years the curves flatten out indicating

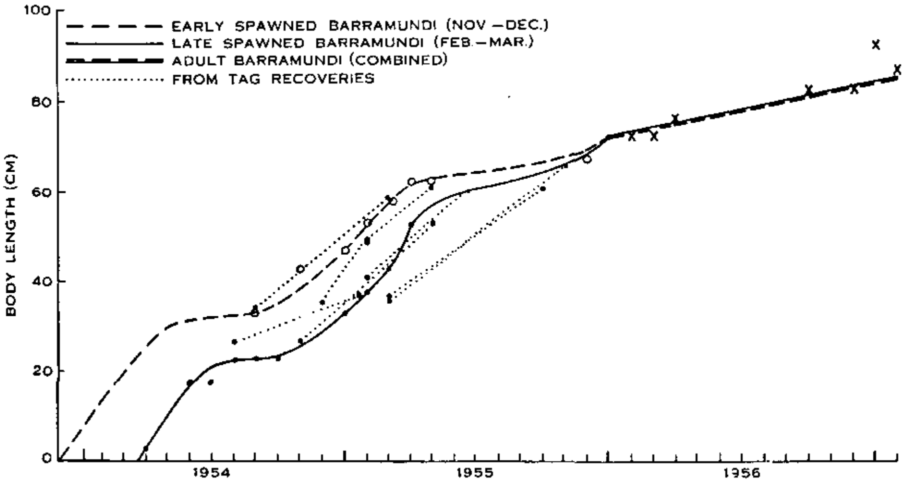

Fig. 5.—Scheme of general growth rate. Growth increments from reliable tag recoveries are indicated.

a slowing down of the growth rate. During the winter of the third year the growth rate appears to remain practically constant. This difference may be related to the more uniform environment of the mature specimens.

(ii) *Evidence from Tagging*.—More than 2000 barramundi were tagged between January 1953 and January 1956, over an area extending from Gladstone to Ingham in fresh, brackish, and salt water. Most were immature because it was difficult to catch the mature fish in sufficient numbers in salt and brackish water. Opercular-type clip tags were used. To date, only 16 tags (0·8 per cent.) have been recovered, the longest period between release and recovery being 7 months. This low return may be due to the loss of the tag because of a fungal infection of the operculum or because fishermen have not noticed them or have not returned them. No adult fish tagged were recovered. Very few lengths at capture were recorded.

Growth increments from nine reliable tag recoveries are shown in Figure 5. Of the 1+ group, four tagged fish were returned. One measured 49 cm when released at the mouth of the Fitzroy River in January 1953. When recovered in mid April, 35 miles up-river, the length was 61 cm. The second recovery was a fish tagged and released in Lake Iris, a freshwater, land-locked lagoon in the Proserpine area, prior to the commencement of the wet season in January 1956. When recaptured in mid June at Balmunda Bay, it measured 61 cm.

The other recoveries of this year group were barramundi tagged in the shallow coastal waters of Cleveland Bay in mid autumn. Their length was 36 cm, which indicated either a very rapid growth during the first few months after hatching or a subnormal growth during the first year. The restricted habitat of the immature fish and the late spawning of the bulk of the mature fish in this locality indicate that these fish were in their second year and that growth had been retarded by adverse environmental conditions. Their length on recapture 6 months later in the same area was 65 cm.

(iii) *Evidence from Scale Reading*.—Hardenberg (1938) has suggested that the absence of marked seasonal fluctuations in temperature in tropical waters would permit uninterrupted growth and promiscuous breeding, thus making it difficult to determine year classes or to find age marks on scales. Chevey (1930), however, has discussed periodicities other than temperature which could cause age marks on the scales of fish. More recently, Chacko and Krisnamurthi (unpublished data, 1951) and Jhingran (1957) found breaks on the scales of two different species of freshwater carp. They suggested that the breaks were formed annually and possibly related to cessation of feeding. Seshaffa and Bhimachar (1954) have demonstrated an annual ring in the Malabar sole, *Cynoglassus semifasciatus* Day, which is a marine but coastal fish. This they called a "monsoon" ring because it appeared to be related to the periodicity of the monsoon rather than to temperature as in temperate regions.

If a neritic species could be influenced by the monsoon in this way, it seems even more likly that a catadromous tropical species such as *Lates calcarifer* would also be influenced by the monsoon's effects. Consequently, when this investigation was commenced, scales were collected and examined. Frequently more than one ring appeared to be formed during each of the first two years of life in coastal rivers, whereas, upon attainment of sexual maturity, only one ring is formed each year. It is suggested that this is because the mature fish live in a more uniform environment. This aspect of growth studies is to be dealt with in a separate paper.

(*f*) *Gonad Maturation, Spawning, and Larval Life*

Maturation of the gonads commences in early spring, and by late spring, female fish with enlarged gonads weighing up to 6·6 per cent. of the total weight, and approaching stage IV (Kesteven 1942), are occasionally taken in deep holes at the river mouths. Large adults with ovaries weighing up to 19 per cent. of the total body weight were taken during late spring and early summer in coastal traps located in backwaters of bays and estuaries. These are the typical "salt-water" barramundi, the narrow elongated fish. During this investigation barramundi with ovaries approaching maturity (stage V) were observed only in brackish or salt water.

In years when the wet season is not pronounced, and floodwaters are insufficient to release land-locked adult barramundi, the number of spawning fish at sea is greatly reduced. No adult fish with well-developed gonads were taken in non-flowing freshwater, or land-locked coastal lagoons. These fish preserve the characteristics of the freshwater fish, and appear plump and dark in colour. If the wet season is delayed, some lagoons do not become joined to the main water systems till late in the rainy period. This prolonged spawning period together with the fast early growth rate accounts for the large range of intermediate sizes throughout the year and for the submodes in the length frequency analysis.

Delsman and Hardenberg (1934) estimated 7·5 million eggs in the two ovaries of a 107 cm (approx. 27 lb) barramundi. In this investigation on Queensland barramundi counts of 8·5 million and 17 million eggs were obtained in the ovaries of a 42 and a 48 lb barramundi. Yingthavorn (unpublished data, 1951) believed that the eggs are demersal, but the large number of eggs present in the ovaries and their small size (less than 0·5 mm at stage V) would suggest that they are probably pelagic.

Indian workers (Indian Council for Agricultural Research 1950) stated that the mature specimens of this species in Madras range in size from 51 to 61 cm. Yingthavorn (unpublished data, 1951) found the breeding size in Thailand to be slightly less than 70 cm in length and 8 lb in weight. In Queensland waters the smallest female barramundi with well-developed gonads was 76 cm in length, 11 lb in weight, and 2 years of age.

Jones and Suyansingani (1954) found that fish about to spawn leave Chilka Lake and spawn at sea in the Bay of Bengal. In Queensland a down-river migration to coastal waters of maturing fish, usually in pairs as shown in net catches, takes place in spring. However, not all adult fish spawn each year. The majority of the 2+ fish examined during the spawning season showed no sign of gonad development.

Fishermen's reports indicate that barramundi occasionally school in small numbers prior to spawning and migrate to suitable spawning areas. Spawning of the river fish occurs just prior to or during the wet season, usually in October–January. The barramundi land-locked in coastal lagoons and swamps are released when the wet season floodwaters connect these areas with the estuaries or the open sea, and they usually spawn from January to March, thus giving two spawning peaks.

Very few fish with ripe gonads were caught, nor were fertilized eggs or early larvae collected during this investigation, but it seems likely that the fish move to more saline waters to spawn because of the very great dilution of the water in estuaries and bays caused by floodwater from rivers. Orr (1933) found that during the summer wet season in 1929, in the vicinity of Low Island the salinity of the seawater fell from 35·47 to 31·32‰.

In areas without major rivers, post-larvae of less than 1 in. in length were observed swimming up shallow gutters into waterholes on flood-plains usually in close proximity to coastal waters. With the recession of floodwaters the fish become land-locked until the following wet season.

In the major rivers the post-larvae were observed swimming up-river along the banks out of the main run of the current. Many of these fish become stranded in the freshwater lagoons which form backwaters of the main rivers. The young fish grow quickly and move into the freshwater zones of the rivers during the dry season. They were occasionally observed even in the headwaters of the rivers.

The population fluctuations of barramundi in two creeks of the Goorganga Plains area (lat. 20° 45′ S.) were followed closely over a period of four years. These plains contain a number of small creeks supporting large numbers of immature barramundi. During the wet season the plains are covered by floodwaters to a depth of several feet, but at the end of the wet season the individual creeks are separated and some contain only fresh water in their upper reaches. With the recession of the floodwaters Goorganga Creek is isolated from coastal waters and throughout the period of the investigation contained large numbers of barramundi. When first examined in June 1953 Thomson's Creek, which runs almost parallel to Goorganga Creek, was affected only by larger tides. It then contained large numbers of the 0+ barramundi in the upper waters. In 1955 floodwater eroded the bar at the mouth of the creek and thereafter even the upper reaches of the creek were affected by the tides. Evaporation during 1955 increased the salinity of the creek water above that of the nearby coastal waters, and no barramundi were found in this creek although the neighbouring freshwater Goorganga Creek was unaffected and still carried numbers of young barramundi.

TABLE 3

AVERAGED HYDROLOGICAL DATA OF THE EAST QUEENSLAND RIVERS AND AVERAGED BARRAMUNDI MARKET RECEIVALS FOR ALL AVAILABLE YEARS AND FROM ALL AVAILABLE EAST QUEENSLAND DISTRICTS

Marketing District	Principal Streams of Basin	Catchment Area of Basin (sq. miles)	Estimated Total Annual Discharge from Each Basin (x) (1000 ac.ft.)	Average Annual Run-off (y) (in.)	x/y	Annual Production Barramundi* (lb)	Years
Cairns	Barron Mulgrave Russell North Johnstone South Johnstone	2,546	3810	21·29	179	3,137†	1
Maryborough	Mary	3,666	1587	9·02	176	3,800	9
Bundaberg	Burnett	12,888	1323	1·9	696	5,014	9
Mackay	Don Proserpine O'Connell Pioneer Styx	8,796	8322	16·95	491	19,755	9
Rockhampton	Fitzroy	54,522	4200	1·29	3256	38,352	3
Ayr	Burdekin	50,489	6210	2·3	2696	50,836	9

* Fish Board market receivals.

† Figures for one year because previously 80 per cent. of fish marketed at Cairns came from Gulf of Carpentaria and Princess Charlotte Bay.

The movements of mature fish appear to be associated with the salinity of the water. During the dry season, when there is an increase in salinity in estuarine waters, barramundi move upstream. With the decrease in surface salinity in the estuaries and coastal waters during the wet season, particularly north of latitude 25° S. (Endean, Kenny, and Stephenson 1956), barramundi move into these areas. Adult specimens are rarely taken in flowing fresh water, though they are sometimes found stranded in land-locked lagoons.

V. The Fishery

(a) *Abundance*

The abundance of barramundi in Queensland waters should not be judged only from the total figures of receivals at the Fish Board depots and markets. Those figures indicate that it forms 1·7 per cent. of the total fish marketed in Queensland. A large part of the catch in eastern Queensland is made by part-time fishermen, who do not generally market through the Board. The expanding catch of this species in the Gulf of Carpentaria is not shown in the Fish Board totals used in Table 3.

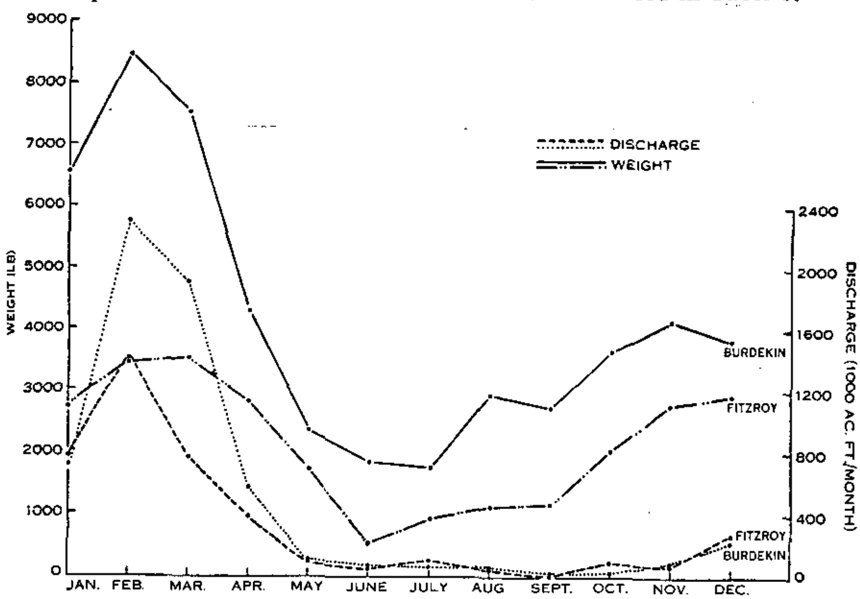

Fig. 6.—Monthly catch and monthly river discharge for the Burdekin and Fitzroy Rivers.

(i) *East Queensland Waters.*—The abundance of barramundi in east Queensland rivers appears to be closely associated with the flow of fresh water. The available hydrological data (Queensland Irrigation and Water Supply Commission 1952–56) are summarized in Table 3 for the east Queensland rivers in which barramundi occur. The discharge per inch run-off (x/y in Table 3) was estimated from the mean monthly and annual run-off figures for the years 1921–50.

In rivers with a large catchment area and muddy and sandy bottoms, water from rainfall is stored, and the run-off is low when compared with that from short swift-flowing rivers. The slow rates of flow and the low run-off from the Burdekin and the Fitzroy Rivers are noteworthy. They have large swampy areas and extensive lagoons near their mouths. These factors are favourable to barramundi distribution as can be seen from a comparison of average run-off and barramundi catch (Queensland

Fish Board 1946–54) in Table 3. The Fitzroy and the Burdekin are clearly the rivers with the highest holding capacity, a slow but perennial freshwater discharge, and a large area of brackish tidal water.

In the major river systems fish are caught following a freshwater flow or during pre-spawning movements. Small local freshets are usually followed by downstream movements of fish. There is a significant correlation between average monthly river discharges (40 readings for the Fitzroy and 31 for the Burdekin) and average monthly catch of barramundi (from 1946 to 1953 inclusive) for these two rivers (Fig. 6). The respective correlation coefficients are for the Fitzroy, $0{\cdot}704 \pm 0{\cdot}159$ (significant at the 5 per cent. level), and for the Burdekin, $0{\cdot}909 \pm 0{\cdot}055$ (significant at the 1 per cent. level).

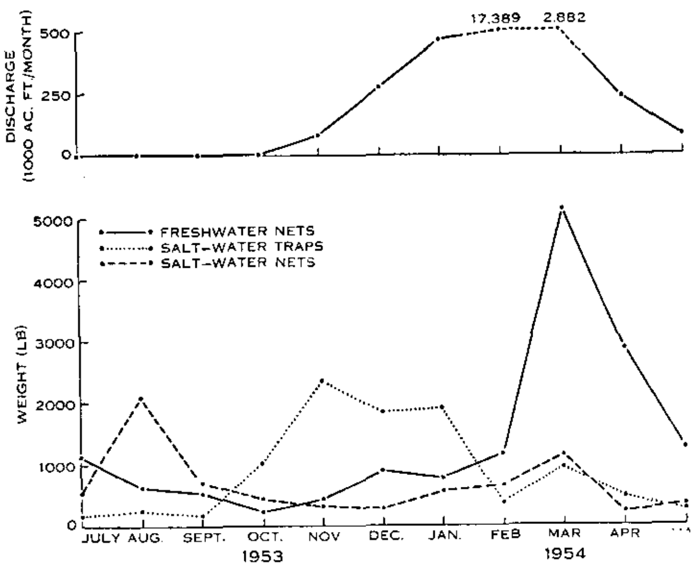

Fig. 7.—Dissected catch statistics and monthly river discharge for the Rockhampton district.

For both rivers the smallest catches are generally taken during June and July although the driest month is September. Catches increase from September because of the downstream migration to spawning grounds of mature barramundi. In the Burdekin River system approximately 45 per cent. of the total yearly catch is taken during the wet season, January–March. At this period the discharge is 80 per cent. of the total yearly discharge. In the Fitzroy River for these months the catch is 37·4 per cent. and the discharge 72 per cent. of the yearly total.

Though it was possible to determine the exact locality of capture of only a portion of the total catch for the Rockhampton area, dissected catch statistics for July 1953–May 1954 give interesting information on the distribution of fish during each month of the year (Fig. 7). Of the total catch in this period 44·1 per cent. was taken with nets in fresh water. The bulk of this was taken from February to April when the velocity of the current in the Fitzroy had decreased sufficiently to allow fishing in the river and in adjacent lagoons. About 50 salt-water traps are located in the vicinity of the mouth of the Fitzroy River. The catch of barramundi from them for this period represents 28·9 per cent. of the total. This catch rose in October, reached a peak in November, and rose again in January. The first peak represents mature fish which had travelled down the river to spawn and the secondary peak represents a movement of mature fish released from coastal lagoons and waterholes connected to the river by the wet season floodwaters. Salt-water nets took 27 per cent. of the total catch in this period; these were large mature fish in the brackish tidal waters throughout the year. These catches increase when freshets or floodwaters stimulate the fish to greater activity. The limited information from tagging does not indicate large-scale migrations between rivers (Section V(*b*)).

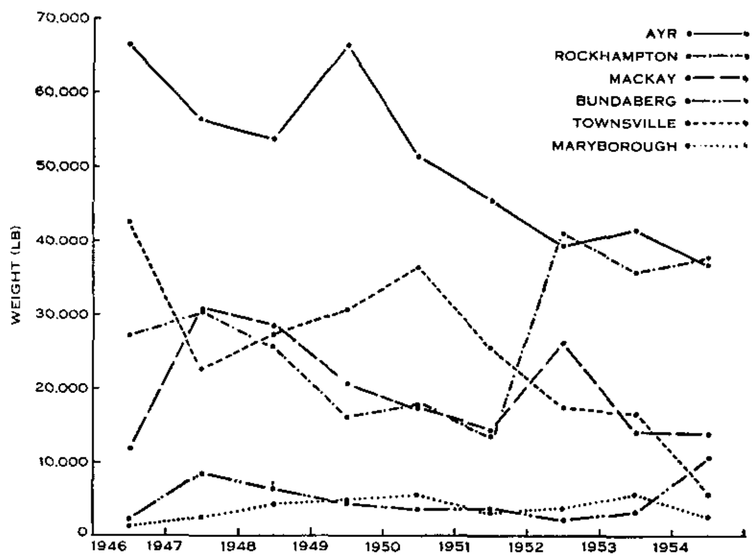

Fig. 8.—Market receivals at the various fishing centres.

(ii) *Gulf of Carpentaria Waters*.—In 1953 a survey was carried out in conjunction with the officers of the Queensland Department of Harbours and Marine to determine the fishing potential for barramundi in the Gulf of Carpentaria waters. Since that time the fish catch air-freighted to Cairns and inland western and north-western towns has greatly increased, and although exact figures are not available the annual catch marketed was estimated as being higher than that of eastern Queensland (Dunstan 1956). As the fishermen in this area are operating on a franchise, they deal directly with the public and the catches are not recorded by the Queensland Fish Board.

The fishermen operate in the upper reaches of the rivers and creeks in close proximity to Normanton and Burketown and in the mouths of the rivers flowing into the Gulf, particularly at Karumba on the Norman River.

(*b*) *Catch*

Figures for the monthly market receivals at the various fishing centres have been obtained from mid 1946 to 1954. Figure 8 indicates the total weight of fish marketed at centres from Maryborough to Townsville. Figure 9 shows the total Queensland catch of barramundi and its percentage of the total Queensland fish production.

From Figure 9 it can be seen that there has been a downward trend from the peak figure of 185,644 lb for 1947 except for a rise to 151,822 lb in 1952. This rise was due to the increased supply of air-freighted barramundi from the Gulf and the enforcement of Fish Board marketing regulations in the Rockhampton area. The total weight of fish marketed represents only part of the total catch, but it is a constantly related part and the figures can thus be used as an accurate indication of overall yearly trends.

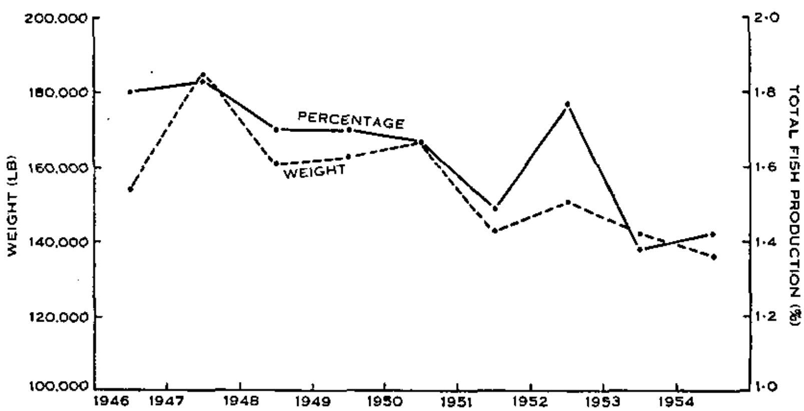

Fig. 9.—Total barramundi catch and catch as percentage of total fish catch.

The Gulf of Carpentaria fishery has developed greatly since 1955. The catch for the year ended August 1955 was air freighted to Cairns and totalled 22,389 lb. For the year ended June 1957 the total catch exported from the Gulf was approximately 200,000 lb of headed and gutted fish, of which 70 per cent. was barramundi.

In Queensland no distinction is made between full- and part-time fishermen so that comparisons of annual catches per man are meaningless. A considerable portion of the barramundi catch is taken by these part-time fishermen either with fish traps or set nets. Between 1946 and 1954 the number of licensed traps increased from 253 to 294 and the number of licensed fishermen north of the Tropic of Capricorn rose from 2118 to 5468 (Queensland Department of Harbours and Marine 1946–54).

(c) *Fishing Methods*

(i) *Trap Fishing*.—The Queensland Department of Harbours and Marine issues licences for traps and regulates their dimensions and plan. Traps are permitted only in areas north of the mouth of the Fitzroy River. In sheltered localities adjacent to the mouths of rivers in this region large areas of mangroves prevent the use of seine nets. The traps are of arrow head formation usually of 16 gauge wire netting with the shaft extending out from high-water mark and terminating in a cage. From this, two wings extend back towards the shore at 45° angles. The extremities of the wings are recurved and directed towards the funnel-shaped opening to the cage. The traps account for a large proportion of the barramundi catch from November to March. In the Mackay-Townsville area there are 175 licensed traps. In the Townsville area alone there are 95 traps and for the year ended June 1954, 58 per cent. of the total catch of barramundi marketed in Townsville was taken from the traps.

(ii) *Net Fishing.*—Owing to the soft nature of the bottom, the lack of hauling grounds, and the non-schooling behaviour of the species, mesh netting is the usual method of capture. Barramundi are able to expand their opercula and thus break ordinary cotton nets; therefore nets of linen, hemp, or seaming twine with a breaking strain of up to 200 lb are used. The mesh sizes range from 3 to 10½ in.

Set nets are often placed across rivers and creeks in the vicinity of well-known barramundi feeding grounds. This method is used particularly during small local freshets. Net fishing in freshwater is illegal, but it is known that barramundi are netted at the end of the wet season in these areas.

(iii) *Fishing in Gulf of Carpentaria.*—There are several shore-based units operating from Normanton and Burketown with refrigerated trucks and dinghies working in the upper reaches of the rivers and creeks. A sea unit based at Karumba at the mouth of the Norman River has a 10,000 lb freezer and ranges over a large area at the mouths of the rivers.

VI. Conclusions

The barramundi is a catadromous species spawning in inshore coastal waters. Its immature stages are passed in the freshwater areas of central and north Queensland rivers.

It is fast growing during the first two years, and when mature it moves into the brackish areas of the rivers where a large proportion of the catch is taken.

The recorded catch of barramundi in east Queensland waters has declined since 1947 (Fig. 9). It is suggested that the very great increase in the number of licensed fishermen and licensed fish traps and the increase of fishing for barramundi in fresh water may have contributed to a decline in the abundance of this species.

In both eastern Queensland and the Gulf of Carpentaria areas suitable for commercial fishing are limited. On the east coast, fishing for barramundi is an economic proposition only in the waterways between and including the Fitzroy and the Herbert Rivers and possibly in the rivers flowing into Princess Charlotte Bay. In the Gulf of Carpentaria operations in the sheltered lower waters in the area from the Gregory to the Gilbert can probably give good results. At present, operations are confined to areas in reasonable proximity to airfields from which the catch can be air freighted to markets in the south.

VII. Acknowledgments

The author is indebted to officers of the Department of Harbours and Marine, Qld, for assistance in the field, in particular to Inspectors R. Jondahl of Mackay and M. Pollard of Townsville. The managers of the Queensland Fish Board markets and depots assisted throughout the investigation. Grateful acknowledgment is made of the assistance given by Mr. H. Hansen of the Rockhampton Fish Board and by Mr. F. Breuer of Townsville.

VIII. References

Blegvad, H., and Løppenthin, B. (1944).—Fishes of the Iranian Gulf. *Dan. Sci. Invest. Iran* **3**: 1–247.

Buchanan-Wollaston, H. J., and Hodgson, W. C. (1928).—A new method of treating frequency curves in fisheries statistics, with some results. *J. Cons. Int. Explor. Mer* **4**: 207–25.

Chevey, P. (1930).—Sur la valeur de la méthode de la lecture des écailles appliquées aux poissons de la zone intertropicale. *C. R. Acad. Sci. Paris* **190**: 207–8.

Chopra, B. N. (1951).—"Handbook of Indian Fisheries." (Survey of India Offices: Calcutta.)

C.S.I.R.O. Aust. (1953).—Estuarine hydrological investigations in eastern and south-western Australia, 1952. *C.S.I.R.O. Aust. Oceanogr. Sta. List* **15**: 1–100.

Delsman, H. C., and Hardenberg, J. D. F. (1934).—"De Indische Zievisschen en Zeevisschery." (Bibliotheek Nederlandische: Batavia.)

Dunstan, D. J. (1955).—Effects of sugar mill effluent on fish life. *Fish. News Lett. Aust.* **14** (5): 15.

Dunstan, D. J. (1956).—Fishing Gulf of Carpentaria waters. *Fish. News Lett. Aust.* **15** (5): 17.

Endean, R., Kenny, R., and Stephenson, W. (1956).—The ecology and distribution of intertidal organisms on the rocky shores of the Queensland mainland. *Aust. J. Mar. Freshw. Res.* **7**: 88–146.

Fowler, H. W., and Bean, B. A. (1930).—Fishes of the Philippine Islands and adjacent seas. *Bull. Amer. Mus. Nat. Hist.* **100** (10): 177–9.

Hardenberg, J. D. F. (1938).—Marine biological fishery problems in the tropics. *Arch. Neerl. Zool.* **3**: 65–73.

Hesse, R., Allee, W. C., and Schmidt, K. P. (1937).—"Ecological Animal Geography." (J. Wiley & Sons: New York.)

Hile, R. (1936).—Age and growth of the cisco. *Bull. U.S. Bur. Fish.* **48** (19): 211–317.

Indian Council for Agricultural Research (1950).—Madras rural pisicultural scheme. Prog. Rep. Apr. 1950–Mar. 1951. 10 pp.

Jhingran, V. G. (1957).—Age determination of the Indian major carp. *Nature* **179**: 468–9.

Jones, S., and Suyansingani, K. H. (1954).—Fish and fisheries of the Chilka Lake, with statistics. *Indian J. Fish.* **1**: 276.

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

Miller, E. (1940).—Mortality of fishes due to cold on the south-east Florida coast. *J. Ecol.* **21**: 420–2.

Orr, A. P. (1933).—Physical and chemical conditions in the sea in the neighbourhood of the Great Barrier Reef. *Sci. Rep. Gt. Barrier Reef Exped.* **2**: 37.

Philippine Weather Bureau (1952).—Recordings of sea temperature from 1949–1952. (Bureau of Fisheries: Manila.)

Queensland Department of Harbours and Marine (1946–54).—Annual reports. (Queensland Govt. Printing Office: Brisbane.)

Queensland Fish Board (1946–54).—Annual reports. (Queensland Govt. Printing Office: Brisbane.)

Queensland Irrigation and Water Supply Commission (1952–56).—Annual reports. Hydrological data. (Queensland Govt. Printing Office: Brisbane.)

Royal Netherlands Meteorological Institute (1949).—Sea areas around Australia. Oceanogr. Met. Data No. 124.

Seshaffa, G., and Bhimachar, B. S. (1954).—Age and growth of the Malabar sole. *Indian J. Fish.* **1**: 145–62.

Weber, M., and de Beaufort, L. F. (1929).—"The Fishes of the Indo-Australian Archipelago." Vol. 5. pp. 396–8. (E. G. Brill Ltd.: Leiden.)

Zugmayer, E. (1913).—Die Fische von Balutischistan. *Münch. Abh. Ak. Wiss.* **26** (6). 35 pp.