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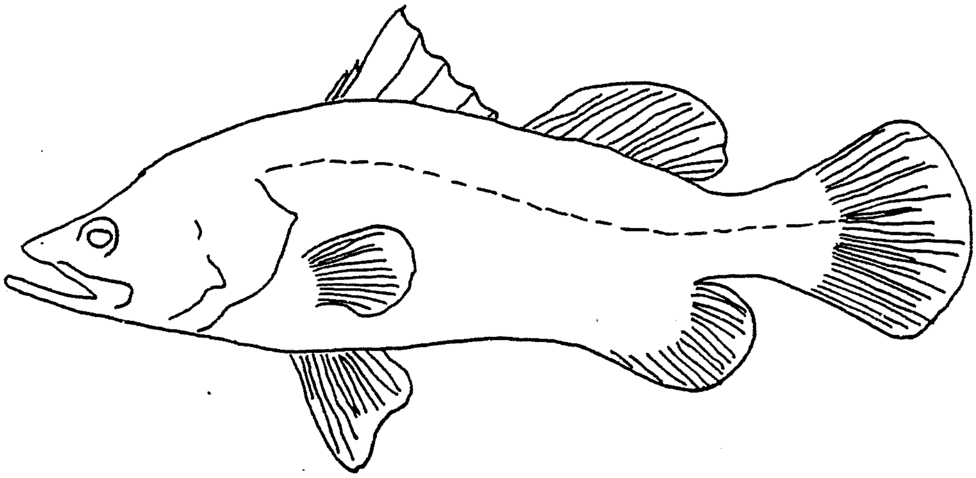

Premanagement Investigations into the Barramundi Lates calcarifer (Bloch) in Northeast Queensland Waters

1982

A Report to the Fishing Industry Research Committee

PREMANAGEMENT INVESTIGATIONS INTO THE BARRAMUNDI *Lates calcarifer* (Bloch) IN NORTHEAST QUEENSLAND WATERS : A REPORT TO THE FISHING INDUSTRY RESEARCH COMMITTEE

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1. INTRODUCTION

Barramundi, Lates calcarifer (Bloch), is a large percoid fish of the family Centropomidae that is widely distributed over the tropical Indo-West Pacific region outside of the African continent (Greenwood, 1976). It inhabits coastal and estuarine environments, but is capable of penetrating long distances up rivers. Throughout its range, it is an esteemed table fish, and is the subject of intensive commercial and artisanal fisheries. In a number of southeast Asian countries, notably Thailand, the technology has been successfully developed for the aquaculture of the species.

In northern Australia, barramundi stocks support a major inshore gill-net fishery and a large angling sportsfishery. The Queensland commercial net fishery produced about 300 tonnes in 1980/81 (Matilda and Hill, 1981) for a value of nearly $1 million. This fishery is centred on the Gulf of Carpentaria where 160 operators are involved. Barramundi catches are an important component of the east coast mixed species fishery of 400 fishermen.

The biology of the barramundi is not well known. The most significant published contributions include those of Dunstan (1959, 1962) who investigated aspects of its biology and fishery in Queensland and Papua New Guinea; of Moore (1979, 1980) who studied reproduction and migration in the Gulf of Papua; and of Ghosh (1973) on the taxonomy of larvae and juveniles from an Indian estuary. Specialized aquaculture technology in Thailand was described by Yingthavorn (1951) and more recently Wongsumnuk and Manevonk (1973).

Fishery management proposals of various sorts have been advanced in Queensland in recent years. However rational management techniques can be devised only when pertinent information for the exploited resource is available. The research effort reported in this document seeks to provide such biological information for barramundi. Investigations centred upon the movements, growth, reproduction, food habits and genetic composition of stocks in selected river systems of northeast Queensland.

The project was a major component of a study undertaken by the Fisheries Research Branch, Queensland Department of Primary Industries, the C.S.I.R.O. Division of Fisheries Research and the Northern Territory Fisheries Division, and designed to provide information on the life history attributes of barramundi over its distribution in northern Australia.

2. LOCATION OF OPERATIONS

Biological studies were conducted over the period January 1978 to June 1981. Barramundi were investigated in three main east coast localities; the Cairns region (Barron River, Trinity Inlet, Northern Beaches), the Tully area 100 km south of Cairns (Hull, Tully, Murray Rivers and Rockingham Bay) and the Princess Charlotte Bay 250 km northwest of Cairns (see map, Figure 1). The four research staff were based in Cairns.

3. PROCEDURES

(a) Sampling. Most specimens for tagging, prey organism analysis, and reproductive condition determination were taken in set gill-nets. Gill-nets were set in rivers, creeks, estuaries and along the coastal mudflats and beaches. Both nylon monofilament and multistrand nets were used. Seine-netting provided large numbers of small fish (total length less than 300mm) in tidal creeks. Angling was used to a lesser degree. Additional information was gathered from the catches of professional net fishermen and sportsfishermen.

(b) Growth and movements of fish. The growth and movements of individual fish were followed by tagging them. Fish were captured by gill-net, angling and seine-net. Floy Ft-2 dart tags were used on fish over 300mm total length (TL), and FD-67 anchor tags on smaller fish. A modified Ft-2 dart tag with a much longer external plastic streamer was used for those specimens over 700mm TL. Figure 2 depicts a small barramundi being tagged with an anchor tag.

Fish length (TL, mm) and weight (whole weight, g) were recorded at capture and a scale sample taken. Tagged fish were then released in the same area. The condition of the fish at the time of release was assessed using a scale of 0-4. The condition factor assigned was a measure of the fatigue and stress of capture, and visible damage to the fish.

Fishermen who catch tagged fish are offered a $5 reward for the return of the tag with appropriate information on length, scale sample, location and fishing method (Figure 3). The practice of returning live undersized (less than 500mm TL) tagged fish to the water with the tag in situ was encouraged to maximize movement information.

(c) Reproductive biology and food habits. Fish sacrificed for biological information were weighed, total length measured, scale samples taken, and gonad condition and gut contents noted in the field or preserved for later laboratory examination. Professional and angler catches were also examined. Gonad material was fixed in 10% formalin, vacuum embedded in paraffin, sectioned at 6-7 microns and then stained with Harris' haematoxylin and eosin.

(d) Genetic composition of Queensland stocks. Liver samples of fish taken in the Princess Charlotte Bay, Cairns and Tully areas were forwarded during 1979-80 to Dr. B. Richardson, Australian National University, Canberra for gel-electrophoretic analysis. A further collection, in co-operation with C.S.I.R.O., was made in the Gulf of Carpentaria, in June 1980.

(e) Larval, postlarval and juvenile fish studies.

(i) Larvae. Two permanent study sites were chosen for the 1979/80 larval sampling programme: the Trinity Inlet system and the Murray River. In 1980/81 Trinity Inlet alone was sampled. A total of 20 stations (all 20 in 1979/80, only six of these in 1980/81) were sampled at two week intervals until October, then at weekly intervals until February. Sampling gear consisted of a push bongo net apparatus (Figure 4) with plankton mesh sizes of 500 and 1000 microns. A diel sampling programme was implemented in 1979/80 with night tows of 5 minutes duration and 10 minute day tows. In 1980/81 day tows only were made. Measurements of water temperature, salinity and turbidity were made at every station. A total of 597 samples were collected in 1979/80 and a further 149 in 1980/81. Larval fishes were isolated from the fixed material in the laboratory, and barramundi identified from characters described by Ghosh (1973).

(ii) Juvenile Biology and Nursery Habitats. Sampling of juvenile barramundi in selected tidal creeks and tidal swamps was undertaken monthly in the Cairns and Tully study areas and less regularly in Princess Charlotte Bay. Methods for capturing these fish varied with the individual habitats and purpose of the sampling. Small-mesh (50-100 mm mesh size) nylon gill-nets and seine-nets (12-20 mm mesh) were employed in open snag-free areas and barramundi could be tagged and released. The fish poison, rotenone, was used in the more difficult habitats (eg mangrove swamps), where sampling with nets was impractical. Length/weight data were collected on all barramundi caught with additional information on gut contents from those fish which were sacrificed.

Efforts in 1980/81 were concentrated on investigating aspects of the recruitment of barramundi larvae and juveniles into nursery or sanctuary habitats. Topics of particular interest included sizes of colonizing fish, the period over which colonization took place, duration of occupation and the physical environment of the nursery areas. Study sites were established at Karumba on the southeast Gulf of Carpentaria coast and in Trinity Inlet on the east coast. Less detailed studies were conducted at selected sites in the Princess Charlotte Bay region over a two week period from the 20th November. Two methods were used for sampling fish. The first consisted of small, one-way fish traps (Figure 5) constructed of flyscreen or 1000μ plankton net, and designed to trap fish actively swimming or passively transported up tidal gutters which lead into coastal swamps. The second technique was with the fish poison rotenone. Temperature and salinity measurements were taken at every poison station and after servicing of larval traps.

4. RESULTS AND DISCUSSION

(a) Tagging

Between 1 January 1978 and 30 June 1981, a total of 3967 barramundi were captured in research operations. Of these, 3299 were tagged and released. Research personnel, anglers and professional net fishermen had recaptured by 30 June 1982 a total of 438 fish (Table 1).

Table 1. Summary of barramundi recapture data, north-east Queensland, 1978 - 1981.

Year tagged	Number tagged	Returns 1978/79	1979/80	1980/81	1981/82
1978	170	34	4	0	0
1979	1856		276	28	13
1980	1045			61	10
1981	228				12

Table 2 presents a summary of the distribution of tag returns made by anglers and net fishermen throughout the year (pooled for years and areas). If it is assumed that tagged fish are caught with the same seasonal frequency as untagged fish, then 46.2% of all barramundi are caught in the three months March - April - May, compared with 10.4% in the months of November - December - January.

Table 2. Distribution of tag returns by month from anglers and net fishermen; fish at liberty at least one year and all fish regardless of time at liberty (in parentheses).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
No.	2	9	9	6	9	5	7	3	2	2	1	2
	(7)	(21)	(37)	(31)	(28)	(7)	(18)	(17)	(13)	(13)	(9)	(6)
%	3.5	15.7	15.7	10.5	15.7	8.7	12.2	5.2	3.5	3.5	1.7	3.5
	(3.3)	(10.1)	(17.8)	(14.9)	(13.5)	(3.3)	(8.6)	(8.2)	(6.2)	(6.2)	(4.3)	(2.8)

Tagged fish are recaptured in proportion to their abundance within age groups (Figure 6). From age group two years old, professional net fishermen take the bulk of the catch.

(b) Movements

Movement data derived from tag returns (Table 3) show that 82% of fish moved less than 10 km in nett terms from the tag-release site. Fewer than 5% moved more than 50km nett before being captured.

This indicates that barramundi in the study areas constitute basically localized stocks whose movements may be characterized by a summer/monsoon season movement from the upper estuaries and freshwater areas to the coastal foreshores and inshore waters. In late summer/post monsoon, the fish disperse back into estuarine and freshwater environments. For those fish which showed extensive movement, the general pattern is one of long riverine travel and shorter coastal excursions. This pattern is exemplified by barramundi tagged in the freshwater lagoons in the Princess Charlotte Bay hinterland and recaptured on the coastal beaches.

Table 3. Barramundi movement as deduced from tag return data

	Distance from tag-release site (km)						
	less than 1	1-10	10-20	20-30	30-40	40-50	more than 50
Number	273	87	22	14	13	10	19
Percentage	62.3	19.8	5.0	3.1	2.9	2.2	4.3

There is no apparent relationship between time at liberty and distance travelled. The greatest distance travelled to date has been approximately 120 km in 196 days exhibited by a fish tag-released in a freshwater lagoon on the Normanby River, Princess Charlotte Bay. However, a barramundi at liberty 894 days displayed a nett movement of less than 1km.

(c) Age and Growth

(i) Fish scale examination. Fish scales were found to be the most convenient hard structure for age determination. Scales were readily collected in field situations by research personnel and the fishing public, and required little preparation for laboratory examination.

(ii) Scale circuli. Barramundi have ctenoid scales (Figure 7). The upper surface of the scale is covered by ridges or circuli, usually nearly concentric about a central focus. Ridges are interrupted by radii that extend from the focus to the scale margin. No branching of radii has been noticed.

The scales of larger fish have more circuli than those of smaller fish. The relationship of total fish length to the number of circuli is linear and highly correlated ($r^2 \leq 0.952$). The data relate to fish 105-520mm TL only. Counting of circuli on scales of larger fish is a laborious task.

The scales of recaptured fish have more circuli than those scales taken at capture, indicating that the number of circuli present on a scale increases with increasing time (age).

(iii) Variation of scale size with fish length. A close relationship exists between anterior scale radius (R in mm) and total fish length (L in cm) as determined by least squares regression (Figure 8). With both sexes combined, the relationship is determined by the equation:

$$R = 0.254\ L - 1.728,\ r2 = 0.927,\ N = 658$$

When fish from the Cairns, Tully and Princess Charlotte Bay regions (tidal waters only) are treated separately, the individual area relationships appear very similar.

$$R_{Cairns} = 0.264\ L - 1.596,\ r^2 = 0.966,\ n = 220$$

$$R_{Tully} = 0.251\ L - 1.681,\ r^2 = 0.911,\ n = 203$$

$$R_{P.C.B.} = 0.236\ L - 1.726,\ r^2 = 0.942,\ n = 235$$

Correlation values are significant at the 1% level.

(iv) Scale checks. Checks are characterized by well-defined cutting across of circuli. Scales from larger fish exhibit more checks than scales from smaller fish. By back-calculation in the scale radius: total fish length equation, mean lengths (+/- one standard error) at first, second, third, fourth and fifth checks are given in Table 4. The determination of the number and position of checks on scales from large barramundi (more than 800 mm TL) using visual assessment techniques is unreliable. Erosion and resorption of material from about the scale origin is a major difficulty.

Table 4. Fish lengths at scale checks

Check	Fish length (mm TL)
1	310.1 ± 73.2
2	463.7 ± 55.1
3	578.4 ± 42.0
4	684.1 ± 69.3
5	751.2 ± 44.2

(v) Length-weight relationship. Barramundi exhibit allometric growth. The descriptive equation relating whole fish weight (W in g) to total fish length (L in mm) is

$$W = 0.00009874\ L^{2.8748},\ r^2 = 0.9812,\ N = 625$$

The size range of specimens used for computation was 41-1125mm TL. All were taken from tidal waters, and all were taken in non-breeding periods to lessen the influence of increased gonad weight with maturation.

(vi) Growth rates and age determination. Thirty-two barramundi at liberty approximately one year (range 315-412 days) have been recaptured with measurements suitable for growth evaluations. The regression of length at tagging on change (increase) in length over the year shows a linear relationship between these variables (Figure 9; r^2 = 0.848, significant at the 0.01 level). Although there is variation in size for any given age, growth decreases in rate with increasing age.

Specific growth rates are available for 75 recaptured tagged barramundi with a liberty period of approximately one year or more (range 315-894 days). The asymptotic length or theoretical maximum size limit ($L\infty$) estimate for barramundi as derived from these fish data was 1295 mm TL. Barramundi caught at a size exceeding this $L\infty$ value are occasionally reported. The von Bertalanffy growth equation was calculated as

$$L_t = 1295\ (1 - e^{-0.187\ (t-0.577)})$$

This equation was used to estimate length at age and the values used to plot a growth curve (Figure 10). The length at age values so established correlate strongly with values calculated from scale measurements for length at check formation. (table 5).

Table 5. Length (mm TL) at age in barramundi

Year	Back calculation from scales (± one s.e.)	von Bertalanffy
1	310.1±73.2	251.5
2	463.7±55.1	445.5
3	578.4±42.0	616.5
4	684.1±69.3	715.5
5	751.2±44.2	798.0

(d) Survival and mortality

Age-frequency distribution for the 1978, 1979 and 1980 year catches are adjusted in Figure 11 to reflect the relative contribution of each age group because of unequal sample sizes. Similarity of distributions suggests the northeast coast stock was sampled randomly and in proprotion to actual abundance.

As revealed by the catch curves, survival between age groups for each year is low (Table 6), indicating a high total mortality. Survival rate increases from group 0+/1 (0.418) to group 1/2 (0.692) then abruptly decreases for group 2/3 fish (0.359) as fish attain legal size (500 mm TL) and are subject to increased fishing pressure. At later ages, survival increases again, reflecting a decreased vulnerability to the fisheries.

Table 6. Survival between age classes derived from catch curves, 1978-1980

	0+/1	1/2	2/3	3/4	4/5	5/6	6/7	7/8	8/9	Mean
1978	0.394	0.692	0.148	+*	0.222	.500	*	nr**	nr	
1979	0.251	+	0.614	0.565	.160	.869	.900	+	+	
1980	0.609	+	0.317	+	.410	.472	.769	nr	+	
average	0.418	0.692	0.359	0.565	0.264	0.613	0.834			0.549

*+ = positive slope in catch curve

**nr = 0 value

The method of Youngs and Robson (1975) was used to estimate survival from recapture data (Table 7). Only three estimates are possible currently (for 1978/79, 1979/80 and 1980/81) as the fifth year has not yet elapsed.

Table 7. Survival estimated from recapture data, after the method of Youngs and Robson (1975).

Year tagged	Number tagged	Returns by year 1978/79	1979/80	1980/81	1981/82	Total Recaptures
1978	170	34	4	0	0	38
1979	1856		276	28	13	317
1980	1045			61	10	71
1981	228				12	12
C_i		34	280	89	35	
T_i		38	321	111	34	
E_i (exploitation estimate)		0.200	0.148	0.053	0.054	
S_i (survival estimate)		0.135	0.328	0.269		

The survival estimates of 0.135, 0.328 and 0.269 appear lower than expected from the catch curve analyses, suggesting either than non-reporting of tag recaptures may be a serious problem or that the fishing mortality component of total mortality is lower than expected. A plot of size at time of tagging of recaptured fish against that for unrecaptured fish (figure 12) is highly correlated (r^2 = 0.953) indicating that no particular size/age group is poorly represented in reported recaptures from any of the study areas.

If tag returns represent true fishing mortality, and noting that reported recaptures accounted for 22.3%, 17% and 6.7% of fish released in 1978, 1979 and 1980 respectively then natural mortality is 0.642 in 1978, 0.502 in 1979 and 0.664 in 1980 (Table 8).

Table 8. Mortality estimates derived from tag return data.

Year	Survival	Total Mortality	Fishing Mortality	Natural Mortality
1978	0.135	0.865	0.223	0.642
1979	0.328	0.672	0.170	0.502
1980	0.269	0.731	0.067	0.664

Natural mortality should decrease with increasing age. Non-reporting of tags may account for the difference between natural mortality values derived in Table 8 and those expected from the catch curve analyses (Table 9).

Table 9. Mortality estimates derived from catch curves

Year	Survival	Total Mortality	Fishing Mortality from tag returns	Natural Mortality
1978	0.549	0.451	0.223	0.228
1979	0.549	0.451	0.170	0.281
1980	0.549	0.451	0.066	0.385

(e) Reproduction

(i) Spawning period. Dunstan (1959) established for the central Queensland east coast that the spawning period was October-March. Two independent methods were used in this study to determine the breeding season: direct observation of the gonad activity exhibited by mature fish, and the presence of barramundi larvae in estuarine plankton.

Maturity stages in barramundi gonads were assessed in a seven point classification (after Nikolsky (1963); as quoted in Lagler (1978)). The gross morphology of the testes and ovaries has since been described by Moore (1979) and the histology of maturation by Davis (1982). The distribution of gonad activity through the year is given in Figure 13. This shows that highest levels of activity occur in the months October-January, with reproduction occurring in November-January. Larvae were identified in estuarine and nearshore plankton samples collected from both the Cairns and Tully regions through the period 31 October to 14 February. At a size of 2.8 mm to 5.3 mm TL, these larvae are about 1-2 weeks old (Wongsumnuk and Manevonk, 1973). No barramundi eggs were positively identified in plankton samples.

The evidence suggests a extended spawning period in north east Queensland of late October - mid February. It is recognized that in some years exceptional circumstances such as delayed movement of mature fish isolated upriver in freshwater lagoons to marine spawning sites may extend the breeding period.

(ii) <u>Spawning sites</u>. Barramundi with running ripe gonads were only obtained in the coastal marine habitats of lower estuary and adjacent foreshores. Fish resident in freshwater exhibited gonad activity only to the 'maturation' stage of Nikolsky (1963). Larvae were found only within the lower estuaries and immediate margins. Moore (1981) found barramundi in New Guinea spawn only in high saline coastal areas, and Dunstan (1959) suggested river mouths and shallow coastal bays as likely spawning grounds. The distribution of larvae and presence of running ripe mature adults in our study areas are indicative of lower estuarine and nearby foreshore spawning sites. Spawning appears localized and unsupportive of a single large spawning ground servicing much of the stock, as occurs in Papua New Guinea (Moore, 1980).

(iii) <u>Larvae</u>. Thirty-one larval barramundi were identified from 746 estuarine and nearshore plankton samples. Wongsomnuk and Manevonk (1973) found newly hatched larvae measured 1.5mm long. From the length range encountered, larvae collected in the study areas were 1-2 weeks old. Only a single specimen was taken outside a river mouth, and this within 200m of the immediately adjacent mangrove foreshore.

(iv) Postlarvae and Juveniles. The largest larva taken in plankton hauls was 5.3 mm TL, about two weeks old. Strikingly banded postlarval forms (Figure 14; size range 16-84 mm TL) together with juvenile barramundi (50-240 mm TL) were located during February-March in brackish and freshwater swamps along the estuarine intertidal margins in the Cairns and Princess Charlotte Bay areas. Postlarvae of 16mm TL are about one month old (Wongsomnuk and Manevonk, 1973). The swamps are typically shallow (less than 1 m deep), variable in area (less than 20 m^2 to more than 13000 m^2), vegetated by Rhizophora and Avicennia mangal (brackish habitat; Figure 15) and Melaleuca forest/sedge Eleocharis (freshwater), and are filled by high tides and seasonal rains during the summer months. Maximum tidal heights become smaller and rainfall is less in autumn and winter, resulting in drying out of many swamps. Juveniles return to permanent tidal waters from March. The swamps probably serve as sanctuaries, albeit temporary, for postlarval and juvenile barramundi by offering protection from large piscivores and an abundant food supply of other larval and juvenile fishes and crustaceans for rapid growth.

Some 600 juvenile barramundi (105-380 mm TL) were collected in permanent tidal creeks. Tagging results show a residence time in such creeks of up to one year. Subsequently there is wider dispersal through the estuary and inshore waters (Figure 16).

In the southeast Gulf of Carpentaria, river estuaries are fringed by a thin veneer of mangroves behind which are extensive saltpans. Freshwater or brackish swamps of the type utilized by postlarvae and juveniles on the northeast coast are rare. Instead, these utilize temporary pools created by high seasonal tides, which occur from October until April, on the saltpans and littoral margins of the estuaries. Temperatures and salinities in such habitats investigated in 1980/81 on the Norman River were, in some instances, extreme; with salinities ranging from 94‰ to less than 1‰ and temperatures reaching 36°C. Juvenile fishes of 37 species colonized the pools. Barramundi collected ranged from 9.5 to 210 mm TL. Residency period is limited, with a tidal regime unfavourable for egress commencing in mid-April. In some years freshwater run-off may extend this period. The movements of juvenile barramundi following departure from these sanctuary/nursery habitat was not investigated.

(v) Sub-Adults and Adults

These are distinguished on the basis of activity exhibited by the gonads. Adult fish have mature,reproducing gonads. For the months of greatest observed gonad activity, October to March (Figure 13), 439 fish with a size range of 150-1195 mm TL were examined. Specimens were obtained from research, angler and commercial fishermen's catches. The relationship in rounded percentage form between gonad maturation state and size of male fish is presented in Table 10 and that for female fish in Table 11. In 136 fish, sex could not be determined from the undifferentiated gonad. Such fish were nearly all in the 150-345 mm TL size range.

Table 10. Effect of total length on testes maturation

Total length Interval (mm)	Percent Contribution by Maturity Stage: Undifferentiated	Virgin	Developing	Advanced	Number
150 - 195	100				34
200 - 245	100				28
250 - 295	100				54
300 - 345	56	44			27
350 - 395	27	64	9		11
400 - 445	8	83	8		12
450 - 495	6	89	6		18
500 - 545		84	11	5	19
550 - 595		8	75	17	24
600 - 645			78	22	32
650 - 695			55	45	11
700 - 745			39	61	18
750 - 795			21	79	24
800 - 845			7	93	15
850 - 895			7	93	14
900 - 945				100	14
950 - 995				100	3
1000 - 1045				100	2

Male fish were first recognizable (as virgins) at 300 mm TL with the testes small thin strap-like and transparent. Advanced testicular development where milt could be extruded under pressure first appeared in substantial numbers at the 550-595 mm TL interval. These fish are regarded as mature adults. By 800 mm TL, over 90% of male fish are mature.

Table 11. Effect of total length on ovary maturation

Total Length Interval (mm)	Percent Contribution by Maturity Stage Virgin	Developing	Advanced	Number
500 - 545	100			1
550 - 595	100			1
600 - 645		50	50	2
650 - 695		50	50	2
700 - 745		33	67	3
750 - 795			100	3
800 - 845			100	7
850 - 895			100	10
900 - 945			100	17
950 - 995			100	9
1000 - 1045			100	11
1050 - 1095			100	8
1100 - 1145			100	4
1150 - 1195			100	1

Only small numbers of female fish were sampled, so data are to be treated with caution. Two small (545 mm TL and 575 mm TL) females with small transparent pale orange ovaries are considered virgin. A further three fish (600 - 735 mm TL) had eggs visible only when magnified. The presence of clearly discernable eggs in an enlarged ovary was considered indicative of advanced maturation, and occurred from 600 mm TL on. The largest size classes (equal to and more than 1050 mm TL) appear to be of female fish only, but this may be merely an artefact of small sample size.

(vi) Sex Ratios

Of 824 sampled barramundi for which sex could be determined, 686 were males and 138 were female, giving a sex ratio of 4.97:1 (Table 12).

Table 12. Sex ratio of barramundi taken northeast Queensland

Locality	Habitat	No. of Males	No. of Females	Male/Female Ratio
Cairns	marine	147	15	9.80:1
Tully	marine	165	16	10.31:1
Princess Charlotte Bay	marine	307	103	2.98:1
Princess Charlotte Bay	freshwater	67	4	16.75:1

The above figures include catches taken in both spawning and non-spawning times. Dunstan (1962) established that sex ratio alters with time of the year. He reported that at commencement of the Papuan spawning season, the ratio of males to females was 3.4:1. During the spawning season the ratio was about 1:1, indicating that a greater proportion of female fish remain in coastal waters for a longer period after spawning.

If we consider the immediate post-spawning period only (February to April), and make a distinction between river catches and foreshore catches, the ratios are:

Table 13. Sex ratio in post-spawning period

Locality	Habitat	Sex Ratio
Cairns	foreshore	5.54:1
	river	8.53:1
Tully	foreshore	5.62:1
	river	10.71:1
Princess Charlotte Bay	foreshore	4.78:1
	river	10.80:1

For this period there are marked differences in sex ratios between river and coastal foreshore catches, with foreshore catches showing lower preponderance of males. This suggests a greater proportion of female barramundi remain outside the rivers for a longer time after spawning.

(vii) Sex Reversal

Moore (1979) found that females are normally derived from males by sex inversion. In this study, the transitional stage from male to female could not be detected macroscopically. The examination of histological preparations of gonad material routinely gathered through the yearly period is not yet complete, with a backlog to be placed on microscope slides. However, there is some indirect evidence for sex reversal. In Figure 17, the total length frequencies of 167 mature adult fish (as per Tables 10, 11) are given. The female mode is displaced to the right of the male mode. The male peak in length frequency occurs at 750 - 795 mm TL, of which length class female fish contribute only 13.6%. The female peak is at 900 - 945 mm TL, when 45.1% of the class are males. Davis (1982) found the mean length of transitional males in the southeast Gulf of Carpentaria was 820 mm (range 680 - 900 mm).

(f) Feeding Habits

Dunstan (1959, 1962) established that barramundi are carnivorous and predacious throughout the whole of their life cycle. Generally, they will prey on any fish or crustacean species smaller than themselves. The food preferences of larval barramundi were not fully established, although examination of the gut contents of 2 specimens suggests they feed predominately on zooplankton. Postlarval and juvenile barramundi in nursery habitats prey on a wide variety of organisms including insect larvae, fish and crustaceans.

In Table 14, the stomach contents of 648 barramundi, length range 235 - 1125 mm TL, taken from both marine and freshwater habitats, are given. Sixty-nine percent of all stomachs examined were empty. Fish, penaeid prawns and decapod crustaceans were the most frequently taken prey items.

Table 14. Stomach Contents of Barramundi

Stomach Content	Frequency of Occurence (number, percentage)	
	Marine Habitat	Freshwater Habitat
empty	394, 67.5	55, 84.6
fish	130, 22.2	6, 9.2
Penaeid prawns	66, 11.3	2, 3.0
Alpheid prawns	1	0
decapod crabs	15	1
stomatopods	2	0
molluscs	2	0
plant material	1	1
coral	3	0

(g) Genetic Stock Analyses

Frozen liver material from the study areas was airfreighted in 1979 and 1980 to Dr. B. Richardson, Australian National University, for gel-electrophoresis analyses as part of the northern Australian barramundi stock delineation programme. The number and relative mobility of liver serum protein fractions was determined for the species in each area and compared.

The examination of such fractions has shown both similarities and divergences. Expressed as protein gene frequencies, Dr Richardson found only minor differences in frequencies among Queensland east coast samples. The gene frequency differences appear greater between east coast and Gulf of Carpentaria samples. Significant differences are exhibited between Queensland and the Northern Territory samples. It seems likely then that Queensland and the Northern Territory support genetically distinct barramundi stocks. Further work is required before the existence of discrete separate sub-stocks may be ascertained.

5. SUMMARY OF LIFE HISTORY (See Figure 18)

Spawning and larvae. Spawning occurs in inshore waters probably at the mouths of rivers and large creeks, and along the coastline in sheltered embayments. Spawning usually occurs just prior to and during the wet season. In northeast Queensland, spawning commences in November and proceeds to January, perhaps into March if the monsoon is delayed. Eggs and larvae are probably transported by currents into and within estuaries. At hatching the larvae are 1.5mm long. Within one to two weeks, larvae move into small tidal creeks and flooded coastal swamps where they feed initially on plankton and aquatic insect larvae. In about a month they reach a size of 10 to 20mm and feed predominately on small prawns and fish.

Juveniles. The term applies to fish about one month to one year old, at which time they are about 300mm long. Juveniles progressively occupy a wide range of habitats, from tidal creeks and mangrove swamps adjacent to the river mouth, to brackish water streams, canals and drains in the upper reaches of the estuary, into freshwater areas. Growth of juveniles averages a little less than one millimetre per day during the first year of life.

Adults. After the first year, barramundi enter a sexually immature subadult phase which may last a further two years. In this time they grow to about 580mm. Barramundi typically become mature as males in their fourth year. Female fish are usually older than six years (850mm long), and most are probably derived from male fish through a process of sex reversal. Maximum age is beyond 25 years. Adult growth is highly variable, but decreases in rate with increasing age. Barramundi appear to be essentially non-migratory, but may travel great distances from freshwater and estuarine environments to marine environments during the summer spawning season. At this time they are especially vulnerable to fishing pressure.

6. MANAGEMENT INITIATIVES

The investigations indicated that additional management of the Queensland barramundi resource was desirable. The tag-release programme revealed that a minimum of 7% (Princess Charlotte Bay) to 29% (Cairns, Tully) of legal sized barramundi are captured annually by amateur and commercial fishermen. These are minimum figures because not every tagged fish that is recaptured by fishermen is reported. About 10% of the annual catch may be taken during the spawning season.

Most recaptured fish are caught within the same river system as release, thus arguing for the existence of localized sub-populations within a total northeast Queensland stock. This concept is supported by the A.N.U. genetic analysės to some extent. Local differences in levels of fishing pressure will produce, then, different responses in local sub-populations.

As a direct result of this work, and in consultation with commercial and ameteur fishermen's organisations, the Queensland Government in January 1981 implemented a number of measures designed to allow for more rational use of the State's barramundi resource. These initiatives are:

(a) a closed fishing season from November to January, the peak spawning period.

(b) the establishment of separate limited licence commercial fisheries in the Gulf and on the east coast with difference eligibility criteria.

(c) an increase to 150mm in the minimum mesh size for all set gill-nets used in the barramundi fishery.

(d) a bag limit on all amateur fishermen and commercial fishermen not holding a endorsed licence.

(e) the establishment of a number of legislated habitat reserves, fish sanctuaries and fish refuge areas, primarily to protect barramundi nursery habitats.

Evaluations of the effectiveness of the management plan are presently in progress. This research effort is, in part, being financed through a further grant from the Fishing Industry Research Trust Account.

7. ACKNOWLEDGEMENTS

We thank G.M. French, I.R. Hocking, N.A. Newton, G.J. Pomroy and L.C. Squire for their assistance in collecting field data. The financial support provided from the Fishing Industry Research Trust Account is gratefully acknowledged.

8. LITERATURE CITED

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

Dunstan, D.J. (1959). The barramundi in Queensland waters. *CSIRO Aust.*, Division of Fisheries and Oceanography Technical Paper No. 5.

Dunstan, D.J. (1962). The barramundi in New Guinea waters. *Papua New Guinea Agric. J.* *15*, 23-31.

Ghosh, A. (1973). Observations of the larvae and juveniles of the "bhekti" *Lates calcarifer* (Bloch) from the Hooghly-Matlah estuarine system. *Indian J. Fish.* *20*, 372-9.

Greenwood, P.H. (1976). A review of the family Centropomidae (Pisces, Perciformes). *Bull. British Museum (Nat. Hist.) ZOOL.* *29*, 4-81

Lagler, K.F. (1978). Capture, sampling and examination of fishes. In "Methods for assessment of fish production in fresh waters", ed. T. Bagenal. (third edition). pp. 7-47 (Blackwell Scientific Publications:Oxford).

Matilda, C.E. and B.J. Hill (1981). Commercial landings of fish in Queensland. *Qld. Dep. Primary Ind.* Miscellaneous Publication No. 81018 .

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

Moore, R. (1980). Reproduction and migration in *Lates calcarifer* (Bloch). Ph. D. Thesis, University of London.

Wongsumnuk, S. and S. Manevonk (1973). Results of experiments on artificial breeding and larval rearing of the sea bass (*Lates calcarifer* Bloch). Thailand Division of Research and Investigations, Department of Fisheries, Songkla Marine Fisheries Station Contribution No. 5.

Yingthavorn, P. (1951). Notes on pla-kapong (*Lates calcarifer* Bloch) culturing in Thailand. IPFC/C511 Technical Paper No. 20.

Youngs, W.D. and D.S. Robson (1975). Estimating survival rate from tag returns:model tests and sample size determination. *J. Fish. Res. Board Can.* *32*, 2365-71.

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FIGURE 1 Location of sampling areas, northeast Queensland

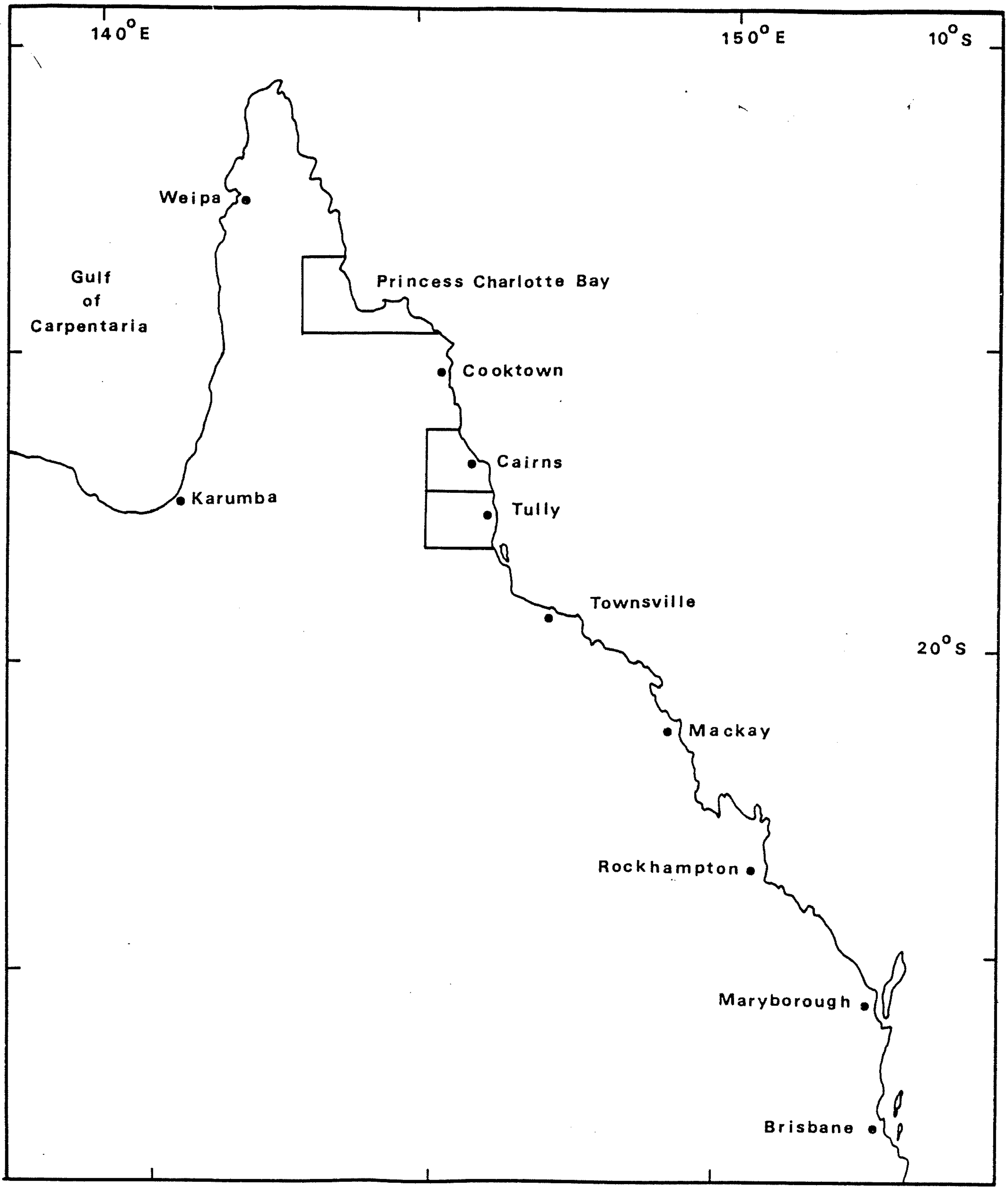


FIGURE 2 A small (300 mm TL) barramundi being tagged with an FD-67 anchor tag. The yellow streamer of the tag is seen adjacent to the trigger piece of the tag gun (photograph G. Pomroy)

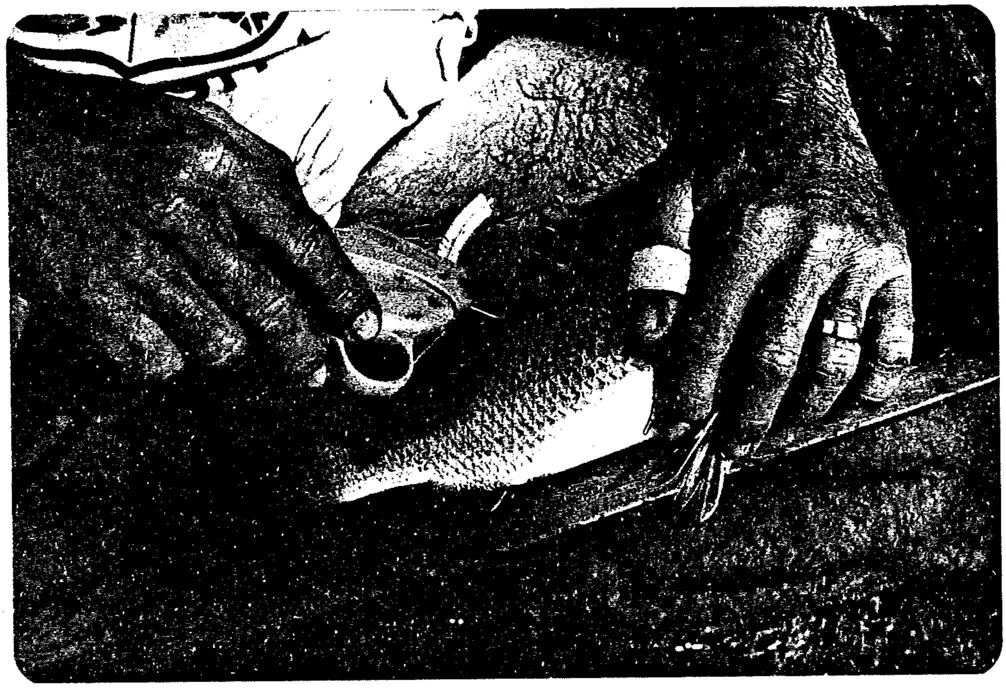
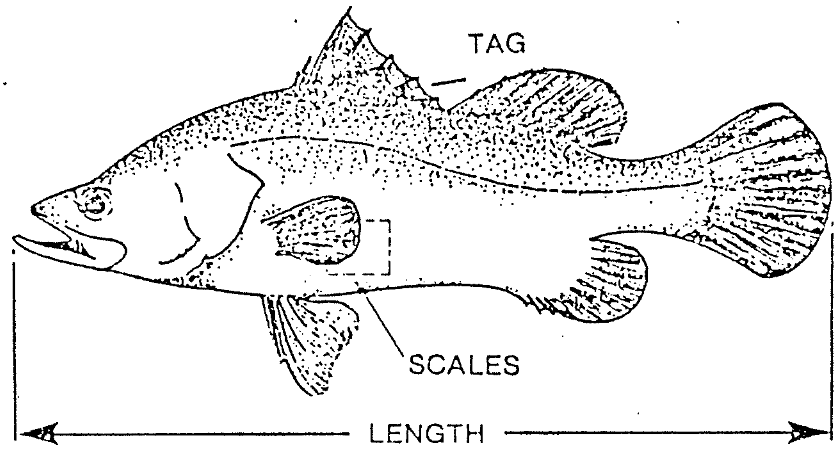


FIGURE 3 Reward notification for recapture of tagged barramundi

REWARD

TAGGED BARRAMUNDI



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

WHAT TO DO:

RETURN TAG TO — NORTHERN FISHERIES STATION,
QUEENSLAND FISHERIES SERVICE,
C/- POST OFFICE, BUNGALOW, QLD., 4870.

OR — CSIRO, P.O. BOX 3998,
WINELLIE, N.T., 5789.

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) SEX OF FISH.

iv) ABOUT 10 SCALES FROM LEFT HAND SIDE OF BODY AS SHOWN IN DIAGRAM.

BARRAMUNDI ARE BEING TAGGED BY THE QUEENSLAND FISHERIES SERVICE AND THE CSIRO TO STUDY GROWTH RATE, POPULATION DENSITY, FISHING EXPLOITATION AND MIGRATORY PATTERNS.

G. K. BOLTON, PRINTERS, CAIRNS.

FIGURE 4 Larval barramundi are collected in plankton nets suspended from the bow of a small dinghy (photograph G. French)

FIGURE 5 Design of one-way tidal fish trap

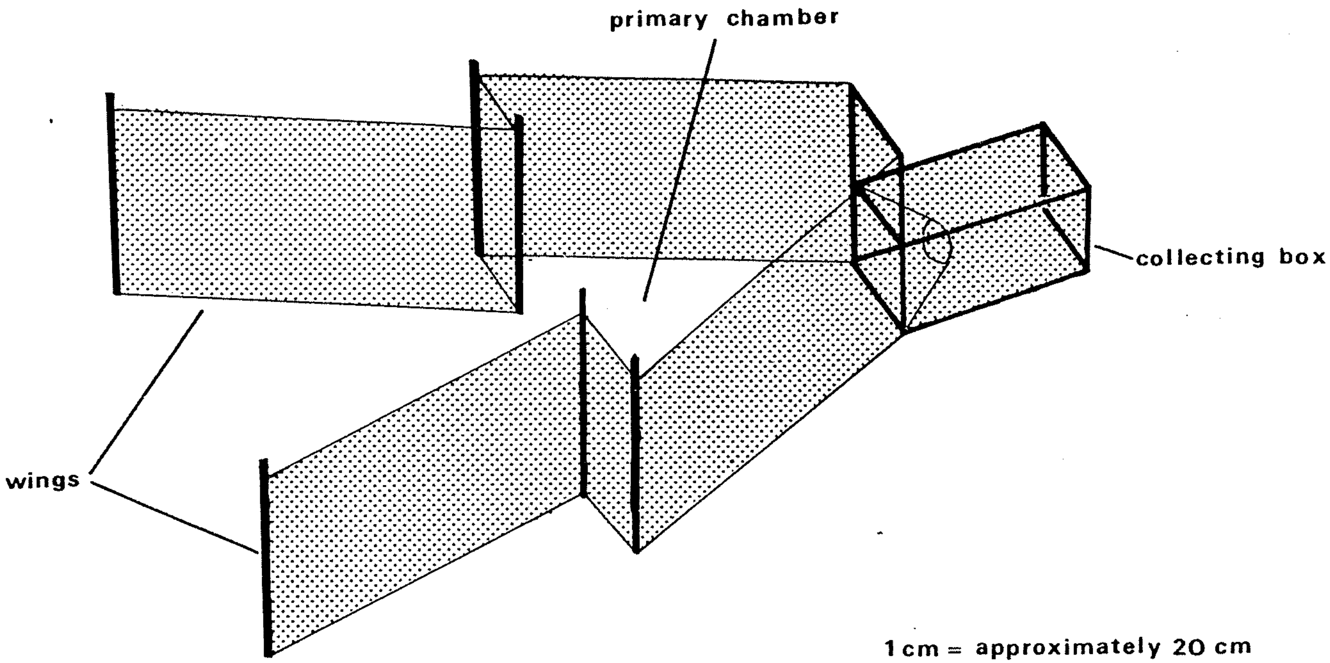


FIGURE 6 Proportions of tagged barramundi subsequently recaptured by anglers and net fishermen 1978 – 1982. Age of fish assigned on the basis of Section 4(c)(vi).

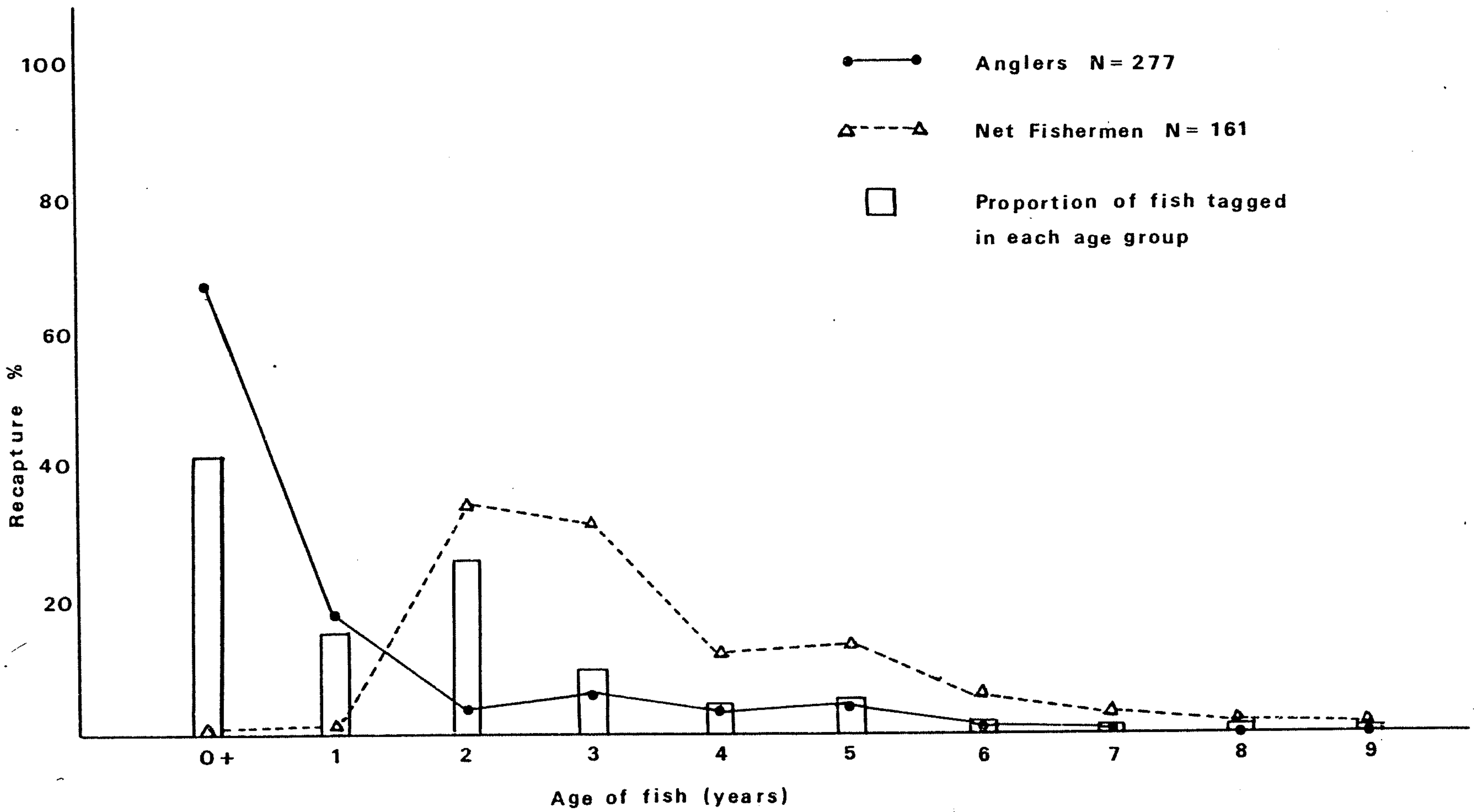


FIGURE 7 Pectoral region body scale from a 400 mm TL barramundi. The fine, almost concentric lines are circuli (photograph G. French)

f	=	Central focus
r	=	Radius
x	=	Crossover of circli or check
m	=	Anterior scale margin
f - m	=	Anterior scale radius

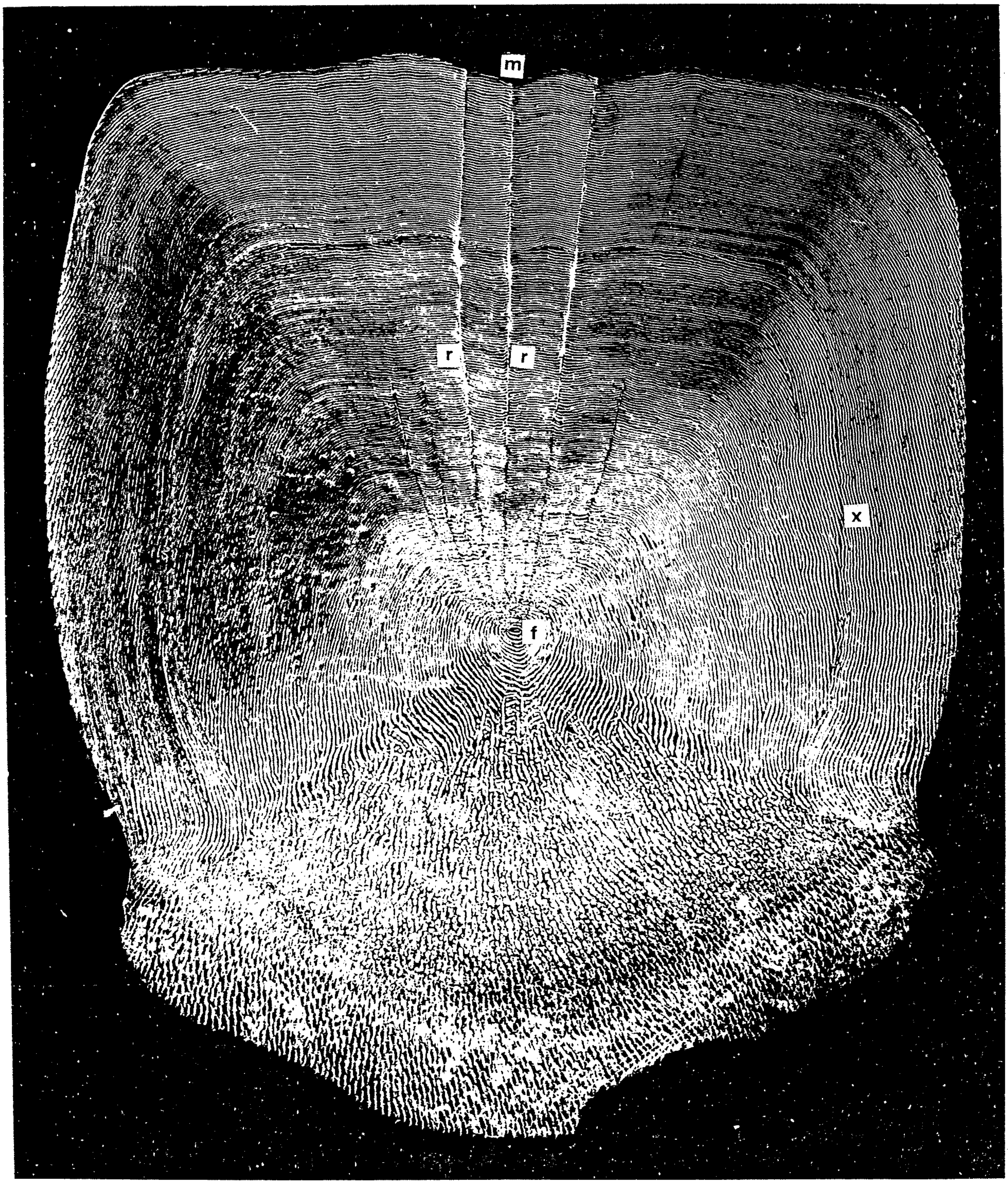


FIGURE 8 Variation of anterior scale radius with fish length

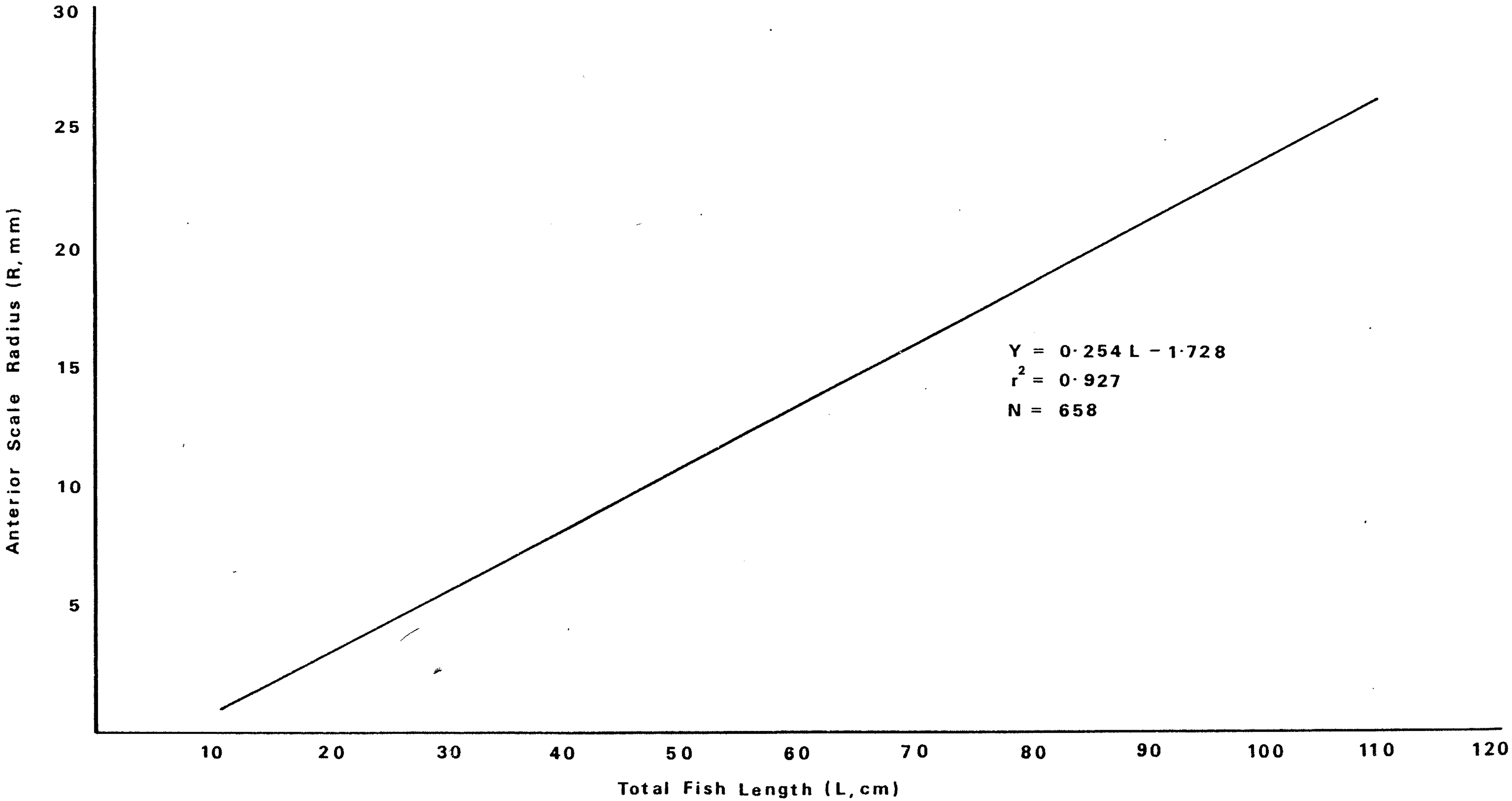


FIGURE 9 Regression of length at tagging on change in length for barramundi at liberty for one year

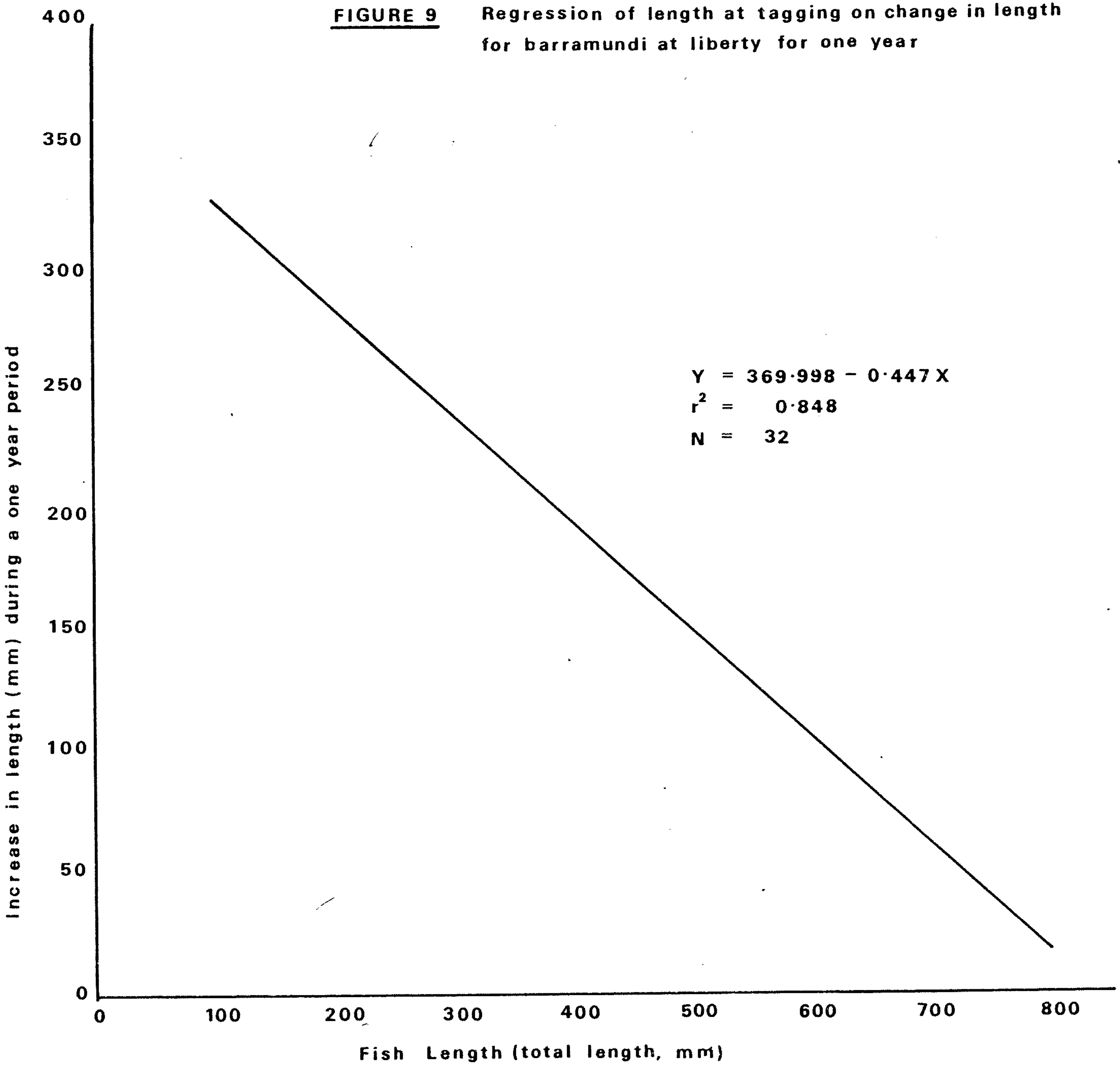


FIGURE 10 Von Bertalanffy growth curve for recaptured barramundi

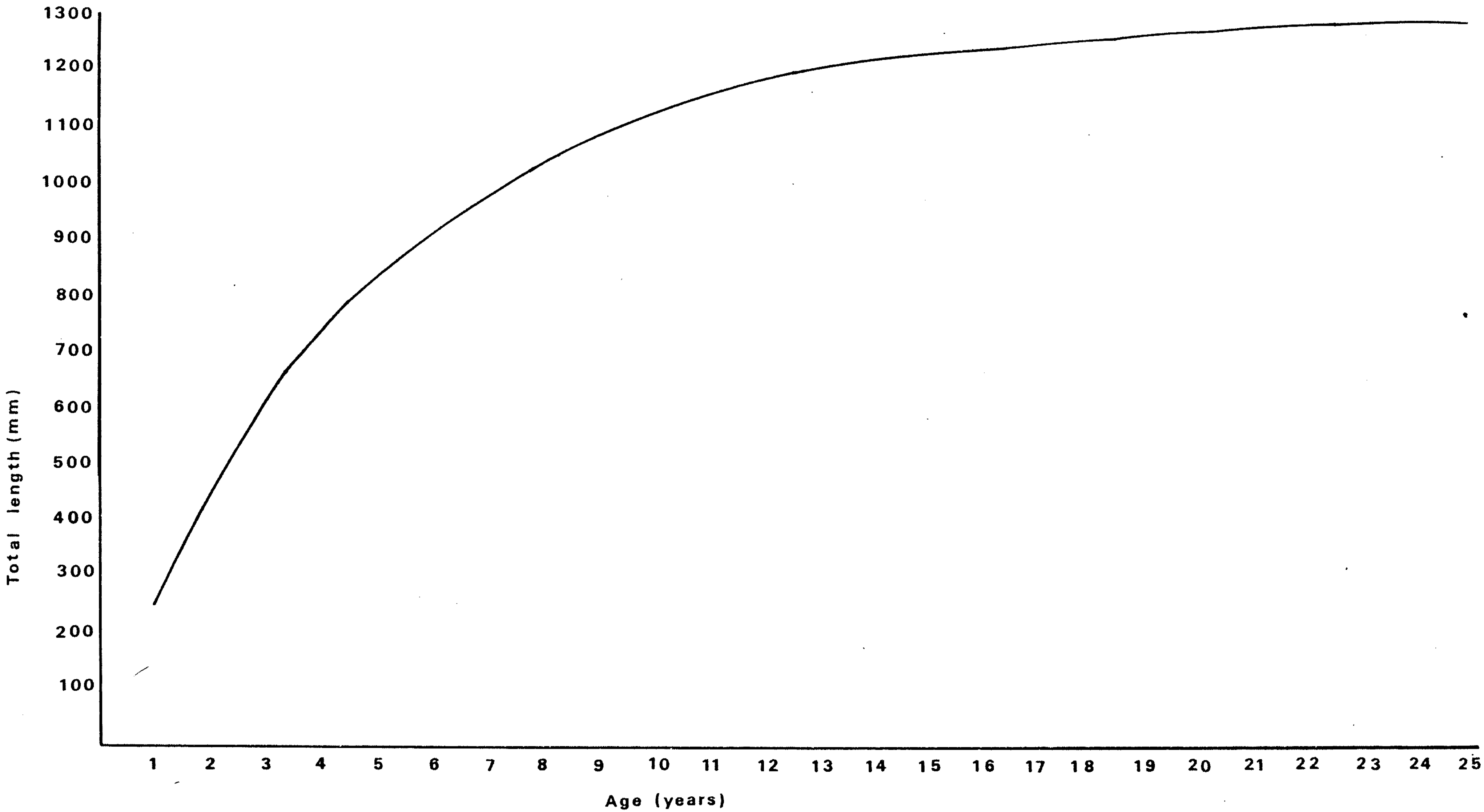


FIGURE 11 Relative contribution of age groups of barramundi in research catches 1978 to 1980

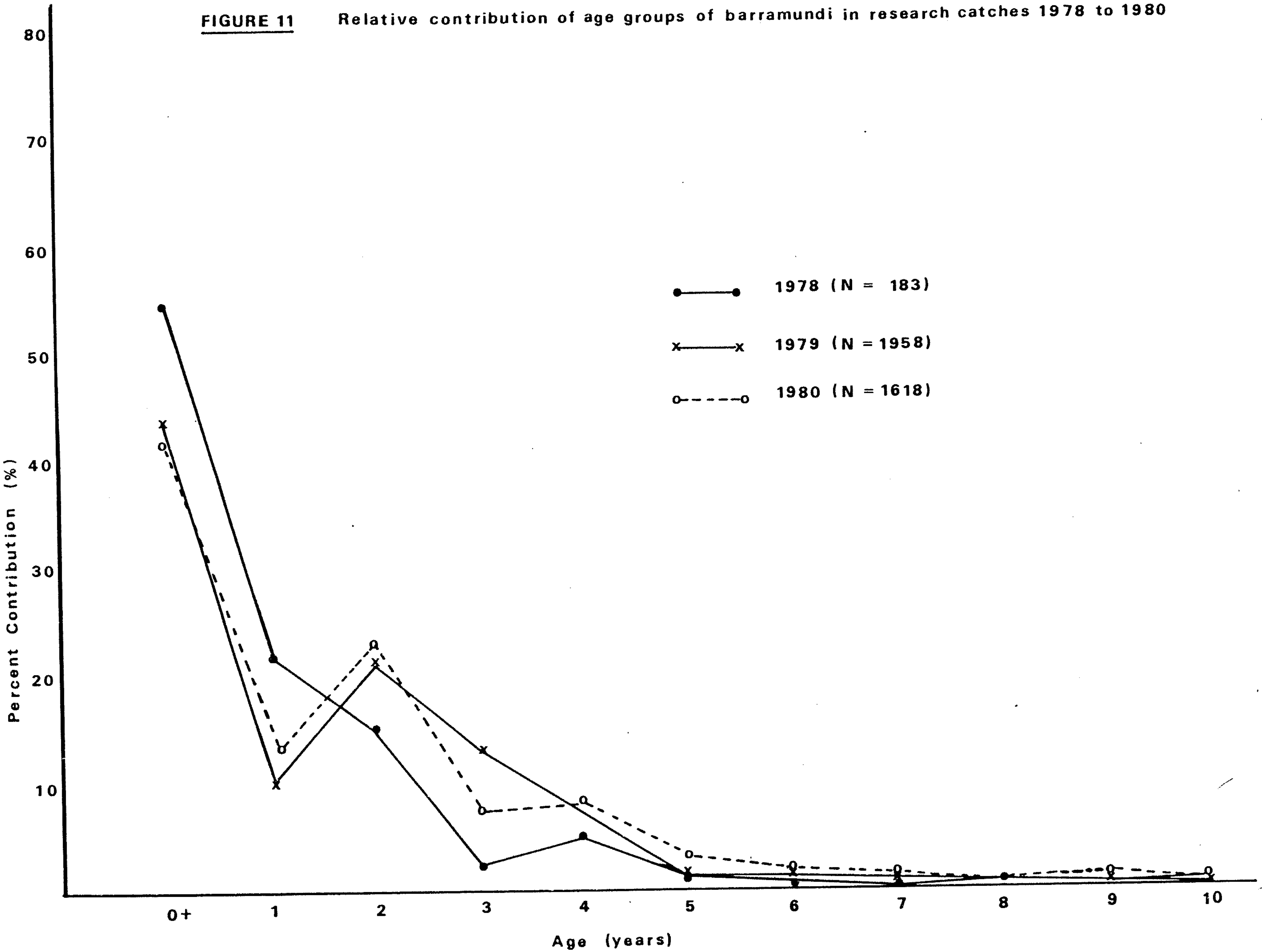


FIGURE 12 Comparison of mean length at time of tagging for recapture and unrecaptured barramundi

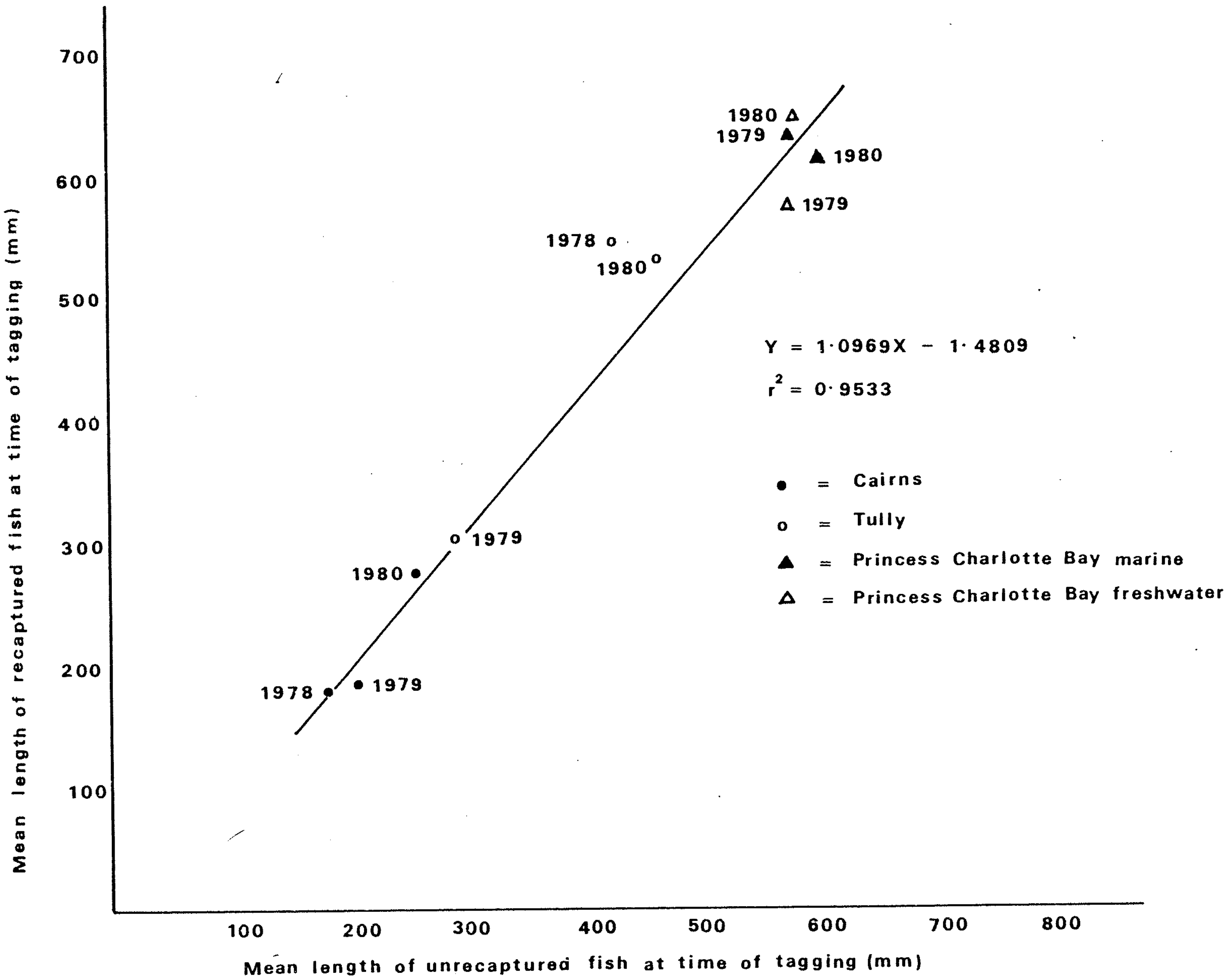


FIGURE 13 Distribution of Gonad Activity through the year

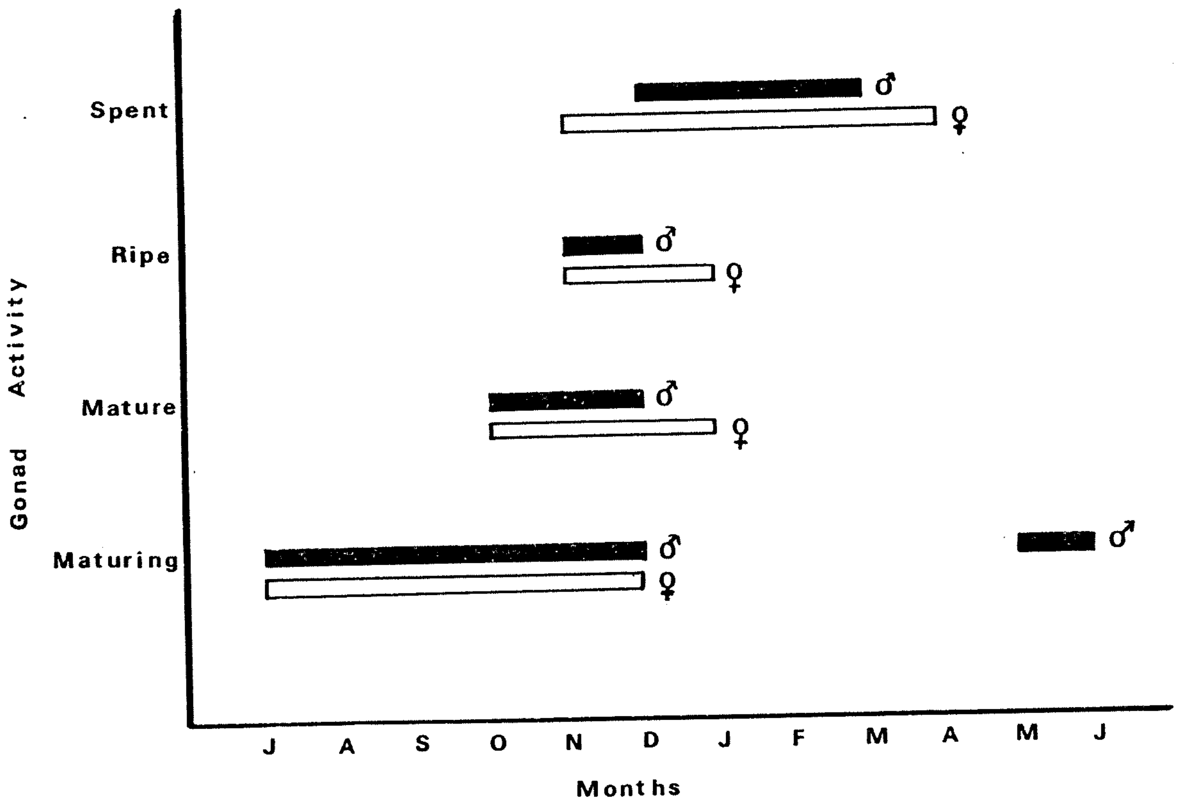


FIGURE 14 Postlarval and juvenile barramundi from a Cairns area nursery habitat (photograph G, French)

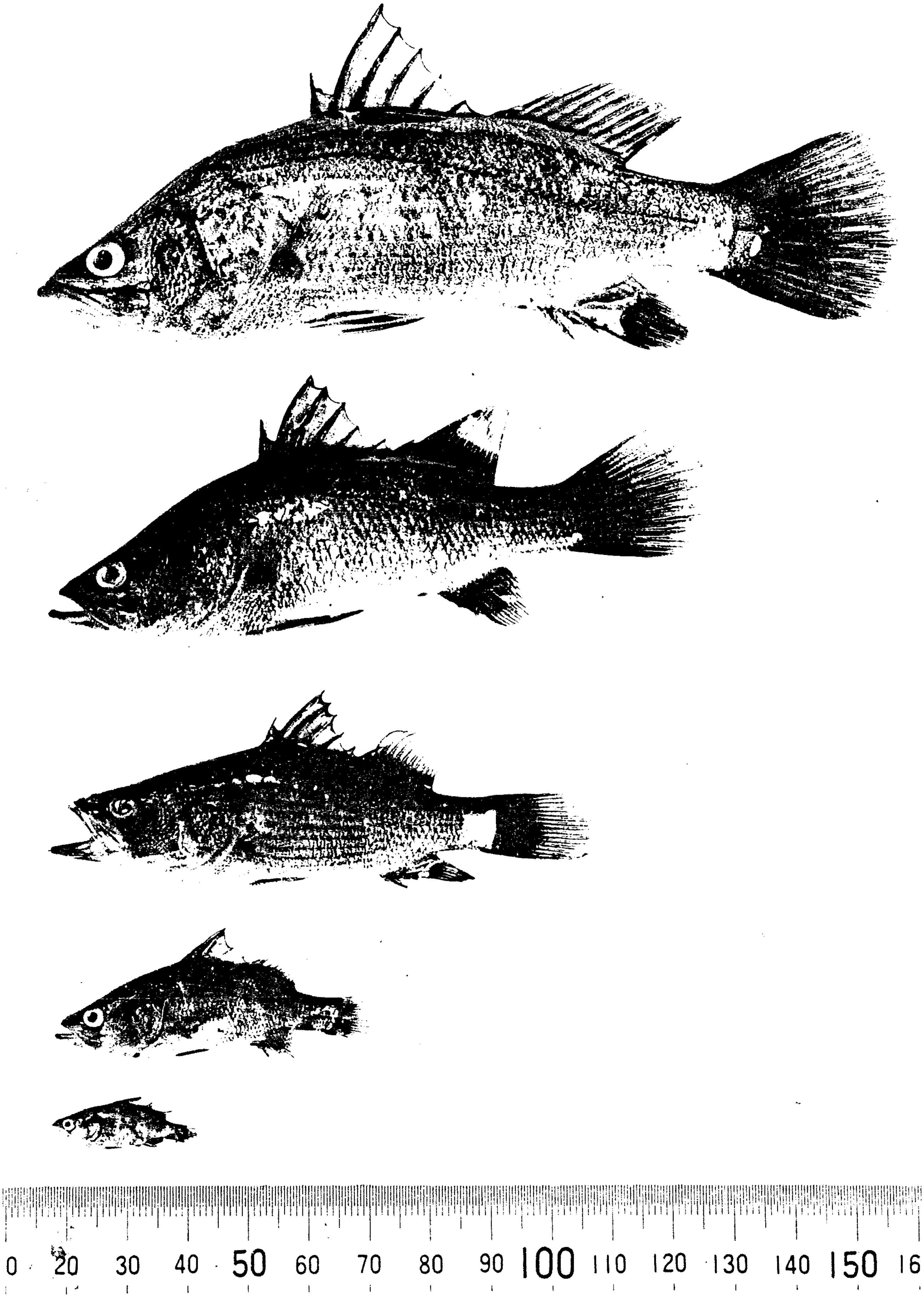


FIGURE 15 Section of a Cairns region nursery swamp. Waterway in background is a tidal creek. Swamp has *Rhizophora* mangal margins. *Avicennia* in left and right foreground (photograph J. Russell)

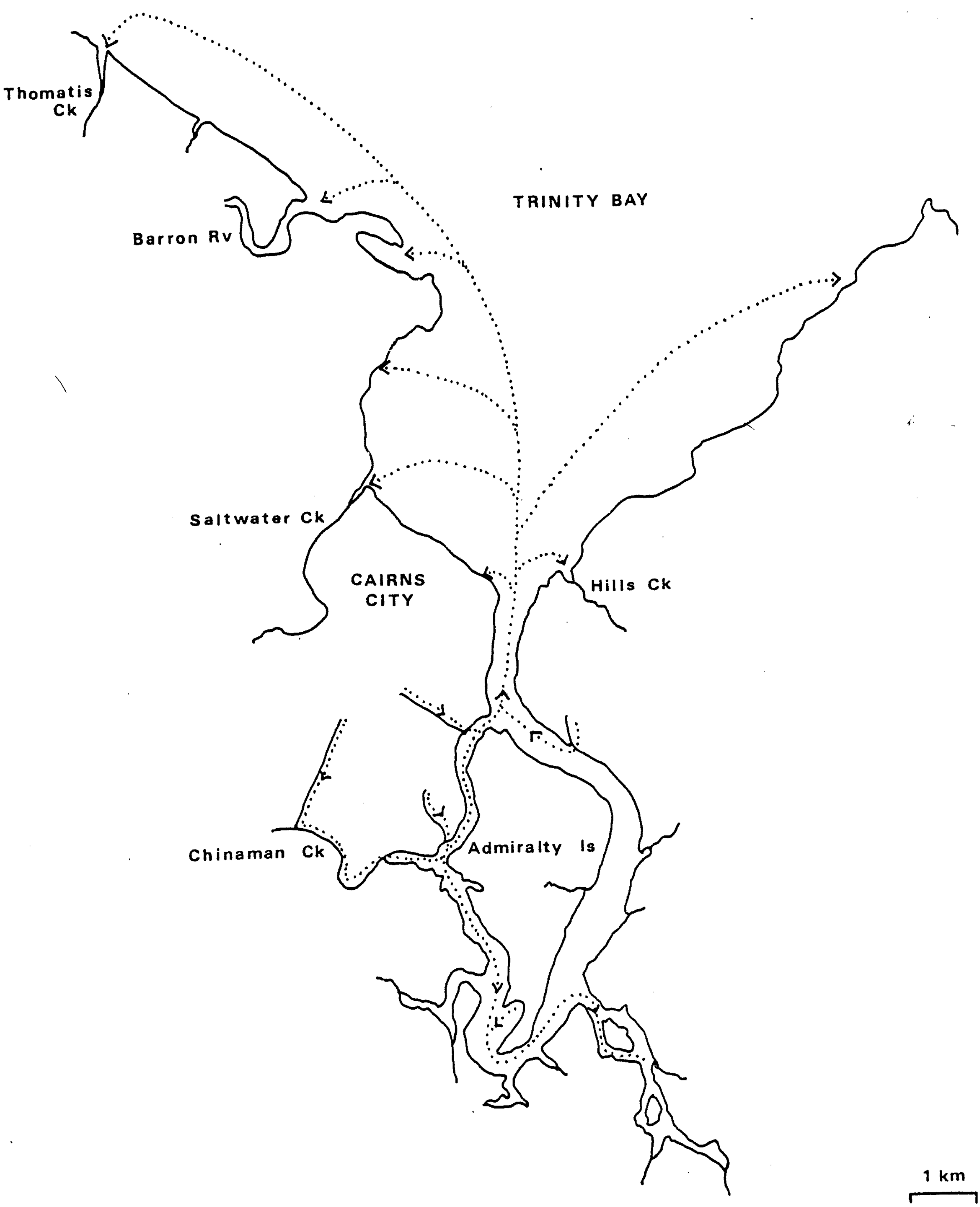


FIGURE 16 Movements of tagged one year old barramundi from tidal creeks in the Cairns area.

FIGURE 17 Total length frequencies of male and female barramundi from 167 mature adult specimens expressed as a percentage of the total samples of each sex. • male o female

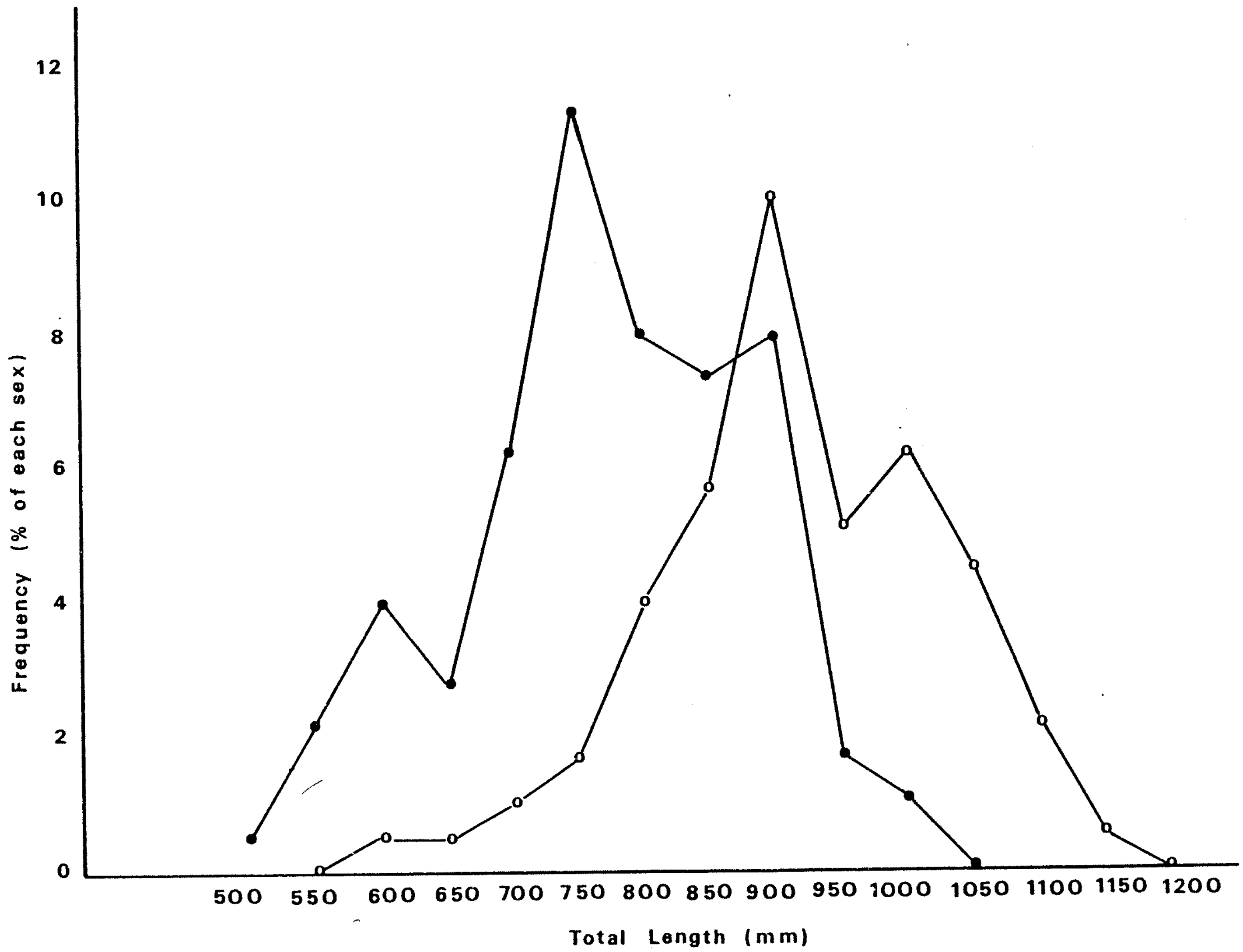


FIGURE 18 Outline life history of barramundi