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GREAT BARRIER REEF DEMERSAL FISH RESEARCH

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INTRODUCTION

The Great Barrier Reef off the coast of Queensland (Fig. 1) has an outer perimeter extending some 2300 km, is composed of 2425 individual reefs and occupies an area of 230,000 km2 of the continental margin of north east Australia (Davies, 1983). This vast region has been declared a Marine Park with the responsibility of overall management being invested in the Great Barrier Reef Marine Park Authority. Fishing and tourism are the major users of the Great Barrier Reef region and their activities have been considered in zoning plans now being prepared for the last of four Marine Park regions.

Commercial and recreational fishermen catch demersal reef fish with the Great Barrier Reef using a variety of techniques. According to Hundloe (1985) the annual recreational catch of both demersal and pelagic fish in the Barrier Reef "region" is in the order of 6,500 tonnes. Hundloe estimated that nearly 60% of the 25,000 small vessels that are based along the Queensland coastline adjacent to the Marine Park were used occasionally, if not regularly for reef fishing activities.

Commercial exploitation of the demersal fish stocks is predominantly by handline operations conducted from 7-15 m vessels especially at night, or from small dories in shallow waters during the day. Difficulties experienced with fishing in areas of high current have resulted in the development of bottom set vertical longlines (Fig. 2). Inshore prawn trawls take numbers of juvenile *Lutjanus* species (notably *L. sebae*, *L. malabaricus* and *L. erythropterus*) during late summer and autumn months. However when these *Lutjanus* species exceed about 15 cm in total length they appear to be able to avoid the low profile nets used in the northern Australian prawn trawl fishery.

While it is acknowledged that the available commercial landings of demersal and pelagic fisheries in Queensland waters are underestimates, the commercial live weight production of lutjanids, lethrinids and serranids from the Great Barrier Reef is substantially less than the total recreational catch (i.e. demersal and pelagic) for the region (Table 1).

Table 1. Commercial live weight landings of lutjanids, lethrinids and serranids from the Great Barrier Reef (calculated with available conversions from gilled/gutted and fillet landing figures) (source - Queensland Fish Board, Annual Reports).

Year	Lutjanidae/Lethrinidae (tonnes)	Serranidae (tonnes)
1973-74	278.7	186.5
1974-75	297.5	160.9
1975-76	198.1	181.2
1976-77	251.5	165.1
1077-78	177.7	90.3
1978-79	219.4	163.7
1979-80	240.5	210.7
1980-81	202.7	205.0

Future fisheries management of the Great Barrier Reef will need to address the problems of imprecise catch landing figures and the interaction between the commercial and amateur fisheries. I suspect that this combination is not a new experience to many of the fisheries officers from the SPC member countries.

The approach of the Marine Park Authority to fish stock management has been based on the periodic closing of reefs to fishing activities. Annual seasonal closure areas based on the spawning period of a species or groups of species, and longer term closures that allow resource stocks to regenerate are an integral part of the zoning plans for the regions of the Marine Park. The nature of larval fish dispersal and the movements of adult demersal fish between reefs have shown that closures of specific individual reefs would have questionable value. Applying distance closures around individual reefs for highly mobile pelagic fish would not be effective.

Information on the age, growth and reproduction of fishes is still a central element in fisheries management. In the case of seasonal closures within the Marine Park an understanding of the reproductive strategy of a species is essential to specify the period of closure. For the longer term replenishment areas, age and growth information is essential to ensure that the closure is for a sufficient time to allow the stocks to regenerate fully. Finally in a traditional population dynamic management system, an accurate knowledge of the age and growth of a species is still the most reliable method of assessing changes in mortality due to fishing pressure.

Studies on the biology of important demersal reef fish within the Marine Park are complicated by the extreme length of coastline that extends over 14o of latitude. It must be considered that aspects of growth and reproduction of fishes may vary for any species that has a continuous distribution over such a large distance. This would not be unexpected in areas where adults of the species have a discontinuous distribution and growth rates and spawning duration etc may discretely differ, however where does one draw the line for a clinal variation.

The Fisheries Research Branch (Queensland Department of Primary Industries) has commenced a programme of study on the basic biological parameters of the lutjanid, lethrinid and serranid species of major importance to commercial and recreational fishermen in north east Queensland waters. Studies commenced with the four most important species, *Lutjanus sebae* (red emperor), *Lutjanus malabaricus* (large mouthed nannygai), *Lethrinus nebulosa* (spangled emperor) and *Plectropomus leopardus* (common coral trout). A brief summary of the preliminary findings for these species are presented.

METHODS

The species chosen for this study occupy a wide range of depth profiles and continental shelf distribution (Fig. 3). Lutjanid and lethrinid samples were taken from the night inter-reef handline fishery that operates usually around the lower edges of reef slopes down to 100 fathoms. Significant samples of small Lutjanus species less than 20 cm SL were obtained from the inshore prawn trawl fishery which operates from shallow coastal waters out to about 20 fathoms. Spear fishing techniques accounted for most of the coral trout samples, with small numbers of Lethrinus sp and Lutjanus sp also being taken.

Age Determination Techniques

All fish were examined at the Northern Fisheries Research Centre laboratory in Cairns. Relevant length (standard length - SL) and weight parameters were recorded, and gonads of all fish were preserved for histological examination.

During the early stages of sampling for each species, otoliths, scales and urohyals were removed, wiped clean and either stored dry (otoliths and scales) or frozen (urohyals). When 50-100 samples of each bony part were available from the four species, and at leat 50% of samples were of small fish, an assessment of the convenience of collection, storage, preparation and ease of interpretation of annual marks was undertaken.

A large proportion of scales taken from all four species were either replacements or displayed considerable resorption, especially in L. sebae. Discontinuities were readily seen in the urohyals of all species, however regular annual checks could not be detected. Scales and urohyals were rejected for age determination in the four species studied.

Whole otoliths were examined, immersed in aniseed oil and against a black background. Criteria used for identification of annual marks or checks were established by the two otolith readers. The general appearance of the distal sides of otoliths from all species was of cloudy or milky opaque zones alternating with translucent zones. The latter were intersected by radiating striae of a pure white appearance similar to those described by Loubens (1978) for New Caledonian lutjanids and lethrinids.

Measurements of the distal face of each otolith were taken in occular micropiece units from the focus along a consistent radius, determined for each species. Annuli, or the interruption of formation of primary opaque bands, were measured along the otolith radius. As annual formation of checks could be detected on the otoliths of all four species, whole otoliths were used for age determination.

Approximately 10 otoliths from well distributed size ranges of *L. sebae*, *L. malabaricus* and *L. nebulosa* were embedded in resin. Thin transverse sections of 0.8-1.5mm thickness were cut from the central area of each otolith with an Beuhler low speed diamond saw. The sections were examined under transmitted light. The thin section displayed banding patterns consistent with those seen on the distal face of whole otoliths on fish up to five years of age.

Length at age data were backcalculated to the last annulus formed to eliminate problems from time of year of sampling and to ensure that each observation of length at age was statistically independent (Bagenal, 1978). Von Bertalanffy growth curve co-efficients and their standard curves were obtained by non linear, least-squares estimation in a manner similar to that described by Kirkwood (1983).

RESULTS

Otoliths of three species were examined three times by two readers, while the otoliths of *P. leopardus* were examined three times by one reader. Annual cycles of otolith marginal increment are apparent and suggest that the otoliths of all four species exhibit a check formation in the spring and summer months which co-incides with the spawning season of each species. The otoliths of each of the species have difficulties with interpretation of annuli, specific to that species.

If at least two age assessments of an otolith co-incided the otolith was accepted for further analysis. The rate of rejection of otoliths for ageing though difficulty of interpretation, irregular otolith profile or lack of consistency between readings was low. The numbers of otoliths accepted for age and growth studies are shown in Table 2.

Table 2. Number of otoliths accpeted for age determination studies.

Species	Total Otoliths Examined Number	Otoliths Accepted Number	Otoliths Accepted Proportion of Total
L. sebae	762	596	76%
L. malabaricus	850	744	88%
L. nebulosa	706	572	81%
P. leopardus	155	133	86%

Regressions of SL on otolith radius were calculated for each sex of the two lutjanids studied. The SL-otolith radius relationships for *L. nebulosa* and *P. leopardus* were calculated for combined sexes as these species have been shown to be protogynous hermaphrodites (Young and Martin, 1982; Goeden, 1978).

There were no significant differences in the SL-otolith radius relationship between males and females of *L. sebae* and *L. malabaricus*. The combined sex regression between SL and otolith radius was found to be linear for the *Lutjanus* species and best described by a power curve for *L. nebulosa* and *P. leopardus* (Table 3).

Table 3. Regression relationships between fish length (SL in cm) and otolith radius (R in occular micropiece units) for all species examined.

Species	Type of Relationship	n	a(±s.e.)	b(±s.e.)	r2
L. sebae	SL=a+b R	596	-6.17(±0.40)	0.42(±0.01)	0.95
L. malabaricus	SL=a+b R	744	-9.38(±0.34)	1.05(±0.01)	0.96
L. nebulosa	$SL=a\ R^b$	570	1.08(±1.12)	1.01(±.03)	0.71
P. leopardus	$SL=a\ R^b$	132	0.19(±1.32)	1.67(±0.06)	0.84

When the SL-otolith radius relationship is linear and passes through the origin, otolith growth is directly proportional to body growth (Bagenal, 1978). Therefore the length of a fish at time of annulus formation is calculated as:-

$$\frac{SLn}{SL} = \frac{Rn}{R}$$

then $$SLn \times \frac{Rn}{R} \times SL$$ - Equation 1.

where SLn = SL of fish at formation of annulus 'n'
SL = SL of fish at capture
Rn = radius of annulus 'n'
R = total otolith radius.

However the *L. sebae* SL-otolith radius regression line for *L. sebae* and *L. malabaricus* did not pass through the origin and a modification of the above direct proportion formula was used.

$$\frac{(SLn - a)}{(SL - a)} = \frac{Rn}{R}$$

then $$SLn = \frac{Rn}{R} \times (SL-a) + a$$

- Equation 2.
where a = the constant determined from the combined sex regression line (Table 3).

Where the SL-otolith radius was not linear and was best described as a power relationship, the direct preportion relationship shown in Equation 1 became:-

then $$SLn = SL \times \left(\frac{Rn}{r}\right)^b$$

- Equation 3.
where b= the power constant from the combined sex regression line (Table 3).

As the power curve passes close to the origin of the SL - otolith radius power relationship, for *L. nebulosa* and *P. leopardus* i.e. 1.08 and 0.19 cm respectively it was not necessary to correct for the curve not passing through the origin.

a) *L. sebae*

Lengths at time of annulus formation were backcalculated to the last annulus formed using Equation 2. The mean backcalculated lengths for males and females at each age are shown in Fig. 4. Analyses of variance did not show differences between the sexes in age groups 1 to 5, however males were significantly larger (at $P<0.01$) than females in age groups 6 and 7. From the limited data it would appear that age group 8 males may be larger than females, however a small sample size (males n=11, females n=1) was not sufficient to detect any statistical differences.

A growth curve was fitted to individual backcalculated lengths. The mean von Bertalanffy parameters Loo and K for males and females are included in Fig. 4. As the 95% confidence intervals of these coefficients do not overlap, the data suggests that the growth rate of males may be significantly greater than for females.

b) L. malabaricus

The mean backcalculated lengths at age for males and females are shown in Fig. 5. Similar to L. sebae, analysis of variance detected differences between the sexes. There were no differences between the sexes in age groups 1 and 2. Males were significantly larger in age group 3 ($P<0.01$), while females were larger in age group 4, although only to the $P<0.05$ level. Males were larger in age groups 5 (at $P<0.01$), 6, (at $P<0.01$) and 7 (at $P<0.05$).

The least squares regression estimates of the mean von Bertalanffy growth curve co-efficients Loo and K are included in Fig. 5. The 95% confidence limits of these co-efficients do not co-incide, indicating that the growth rate of males is significantly greater than that for females.

c) Lethrinus nebulosa

The mean backcalculated lengths at age for all L nebulosa are shown in Fig. 5. The von Bertalanffy growth curve was fitted to individual observations. Least squares estimates of the mean growth curve co-efficients are included in Fig. 6.

d) P. leopardus

The mean backcalculated lengths at age for all P. leopardus are shown in Fig. 7. The von Bertalanffy growth curve was fitted to individual observations. Least squares estimates of the growth curve co-efficients are included in Fig. 7.

DISCUSSION

The present study has provided estimates of backcalculated fish lengths at age and longevity of four major demersal reef species exploited in north-east Queensland waters by commercial and amateur fishermen.

No published estimates of the lengths at age or growth rate of L. sebae or L. malabaricus are presently available for south-east Asian and Australian waters. This study has shown for the above species that the growth rate of male and female fish differs in the older year classes, males being the larger.

Studies of Lutjanus species in US and Caribbean waters have not found significant differences between the lengths at age for males and females (Mosely, 1966; Grimes, 1978; Nelson and Manooch; 1982; Johnson, 1983). Many of these studies were disadvantaged by a reliance on market outlets for larger fish where processing requirements meant that gonads were not available. The sampling strategy used in the present study ensured that the sex of the majority of samples, especially the older age classes, was known.

The calculated lengths at age, and observed lengths at capture of L. sebae and L. malabaricus was well below the calculated Loo for these species. Reports of fish larger than those sampled from the present study are available, however these reports suggest that these large invidiual fish have been taken from waters deeper than those regularly fished by the existing commercial fishery. It is therefore likely that the estimates of the von Bertalanffy growth curve co-efficients may be relevant to the present fishery which operates from 5 to about 50 fathoms.

The lengths at age for combined sexes of P. leopardus from a exploited stock in the Cairns region are presented. The low annual length increment between the 5 to 6 year age groups is difficult to explain. It is the low backcalculated average length at age 6 that influences the least squares regression estimatation of the von Bertalanffy co-efficients and produces a Loo estimate substantially lower than the maximum observed SL's from the fishery. Additional analysis of the P. leopardus data (eg mean backcalculation to all annuli formed) may eliminate this problem which could also be generated by a poor or late spawning season, when most of age group 6 fish sampled in this study entered the population.

Aldonov and Druzhinin, (1978) obtained backcalculated body lengths (thought to be equivalent to total length) of 59.2 and 63.4 cm for 10 and 12 year old L. nebulosa respectively. This compares with 61.1 and 61.8 cm total length (calculated from total length - standard length conversion in Appendix 1).

Examination of L. nebulosa gonads has confirmed a protogynous sex change for this species in north-east Queensland waters. There is evidence to show that sex change occurs over a wide range of year groups commencing from age group 1, well before the onset of maturity. The oldest female examined was 10 years of age. There was only one larger aged fish examined, a 12 year old male.

Although these results should be regarded as preliminary at this stage, they do have some implications for future management of demersal reef stocks in the Great Barrier Reef Marine Park. Analysis of *Lutjanus erythropterus* (small mouthed nannygai) and *Lutjanus carponatatus* (stripey sea perch) aged samples has yet to commence, however from initial observation it appears that like *L. sebae* and *L. malabaricus*, they too have differential growth rates (in length and weight) between the sexes. Estimates of mortality rates for fished stocks of lutjanid fish in the region may have to consider the sexes separately.

The sex change mechanisms of many of the fish families on the Barrier Reef, does and will pose problems for fishery management. Assuming that a certain fishing technique takes fish of one size group, and if this size group dominated by one sex, then the sex ratio of the population can be adversely affected. The protogynous sex change in *L. nebulosa* had originally been suggested to be a function of age, rather than by social control (Young and Martin, 1982). Some concern had been expressed that the removal of larger fish, which would tend to be males, may seriously affect the balance within this species. However in this study the sex change has been suggested to be a protracted process with both sexes being taken equally from the line fishery.

It is anticipated that research on the biology of the major demersal reef species of interest to commercial and amateur fishermen in north Queensland will continue. It is considered that the studies of age and growth of coral trout should continue, especially for larger specimens that comprise the older year groups. The age, growth and reproduction of other important species will be determined.

However the diurnal and seasonal movements, time and location of spawning still need to be identified for many of the most important demersal reef species for management purposes. Possible research approaches to these problems could involve tagging fish from early age groups taken by handline or target trawling by modified prawn trawl gear, and sonic tagging of older age groups in deeper water.

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APPENDIX I

Relationships between total length (TL in cm) and standard length (SL in cm) (TL = a + b SL).

	n	a(±s.e.)	b(±s.e.)	r_2
Lutjanus sebae	828	1.00(±0.07)	1.24(±0.001)	0.99
Lutjanus malabaricus	1034	0.28(±.05)	1.26(±.001)	0.99
Lethrinus nebulosa	775	1.70(±0.24)	1.24(±0.005)	0.99
Plectropoma leopardus	426	0.97(±0.18)	1.22(±0.005)	0.99

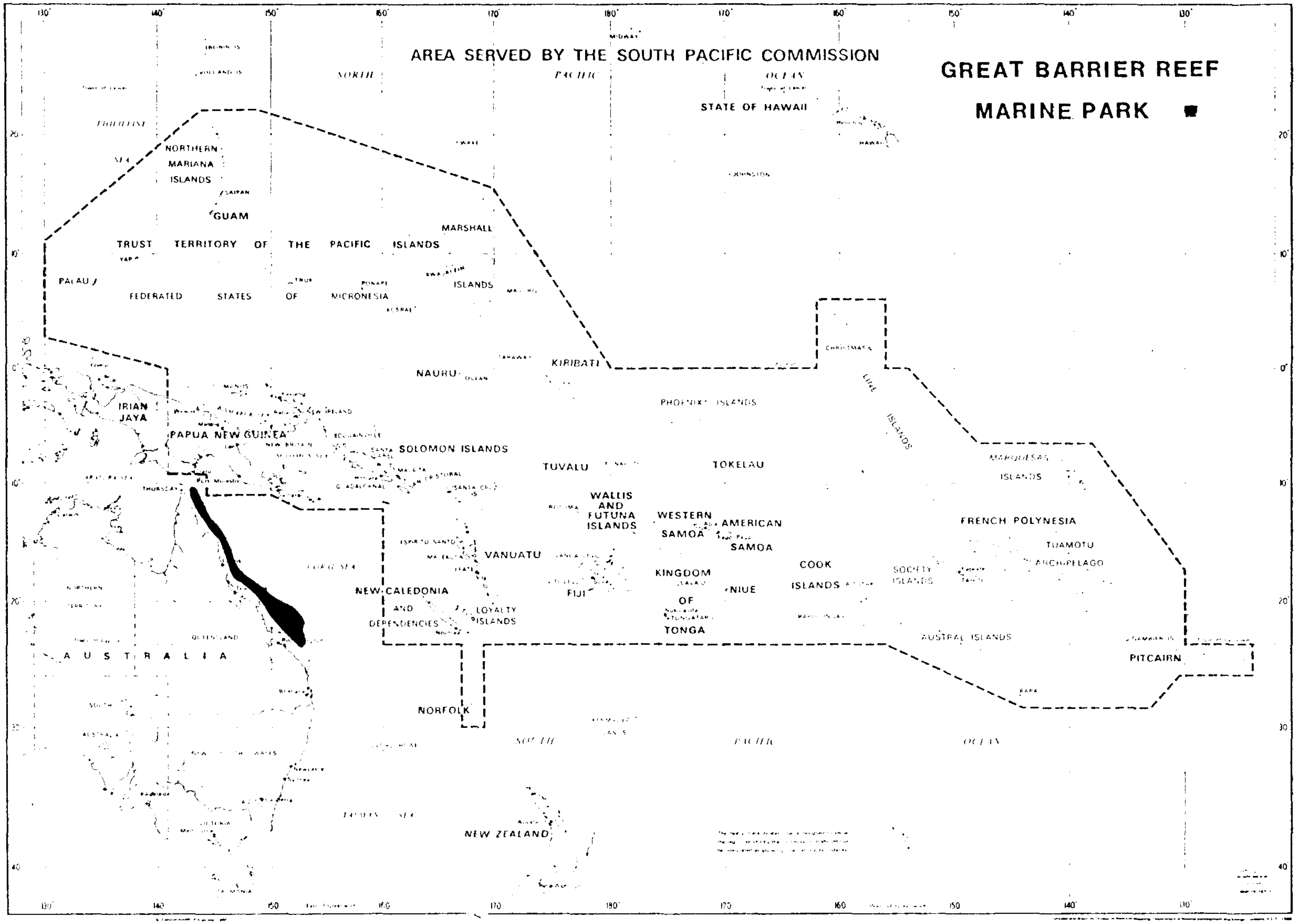

Fig. 1. Region of the Great Barrier Reef.

DEMERSAL VERTICAL DROPLINE

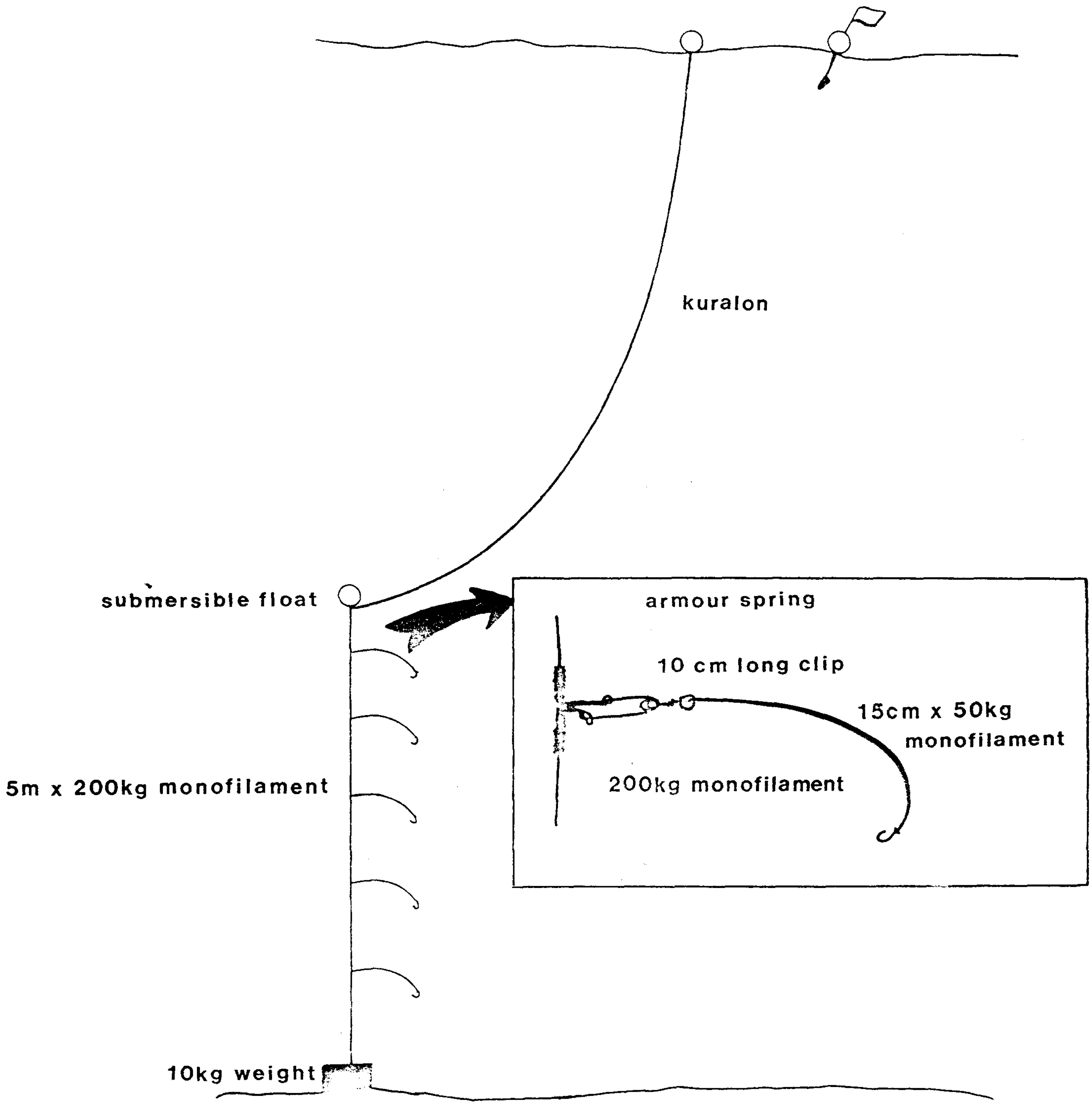

Fig. 2. Schematic diagram of vertical dropline gear developed to fish in high current areas.

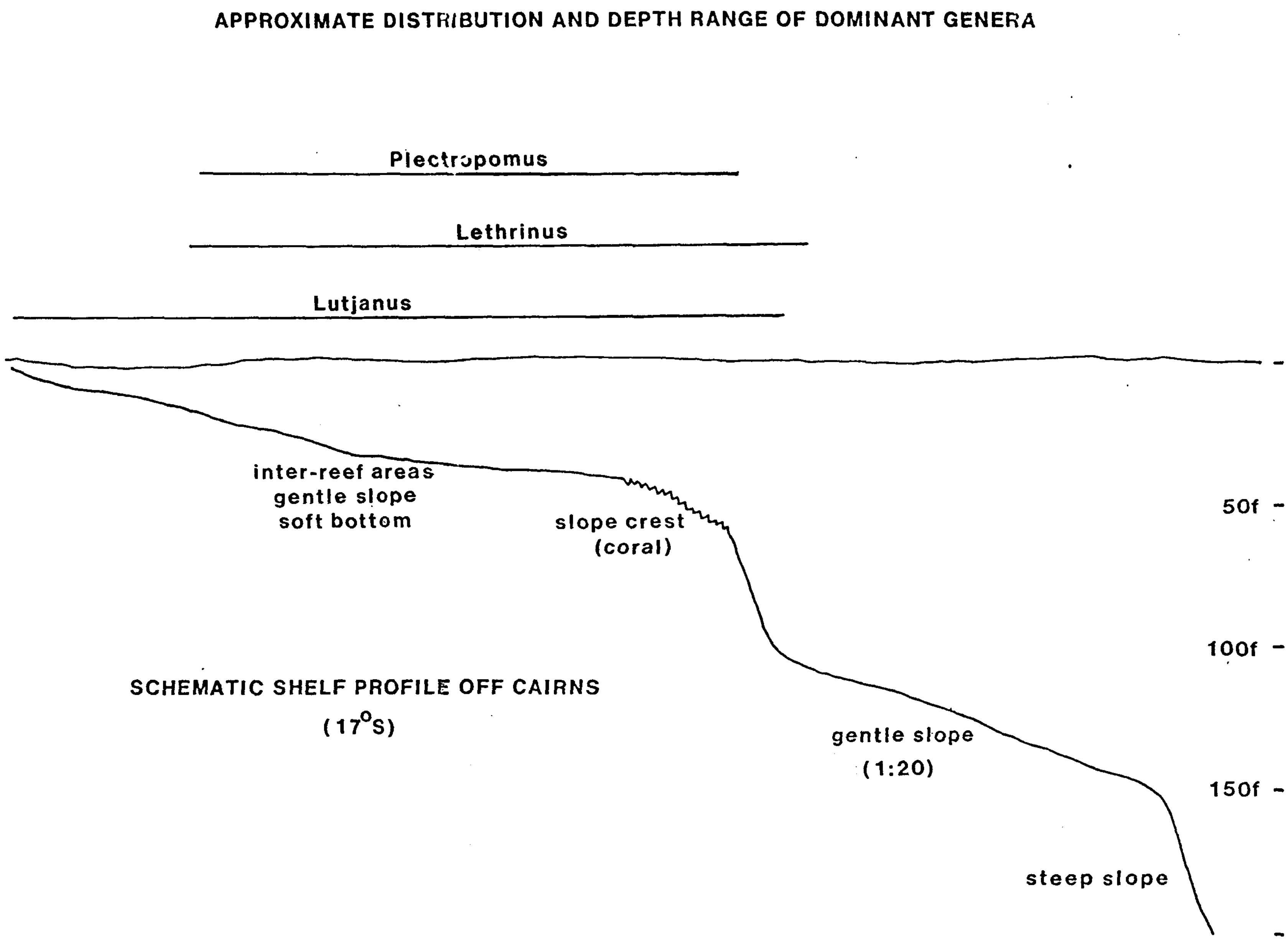

Fig. 3. Schematic diagram of approximate across shelf distribution and depth range of *Lutjanus*, *Lethrinus* and *Plectropomus* species in this study.

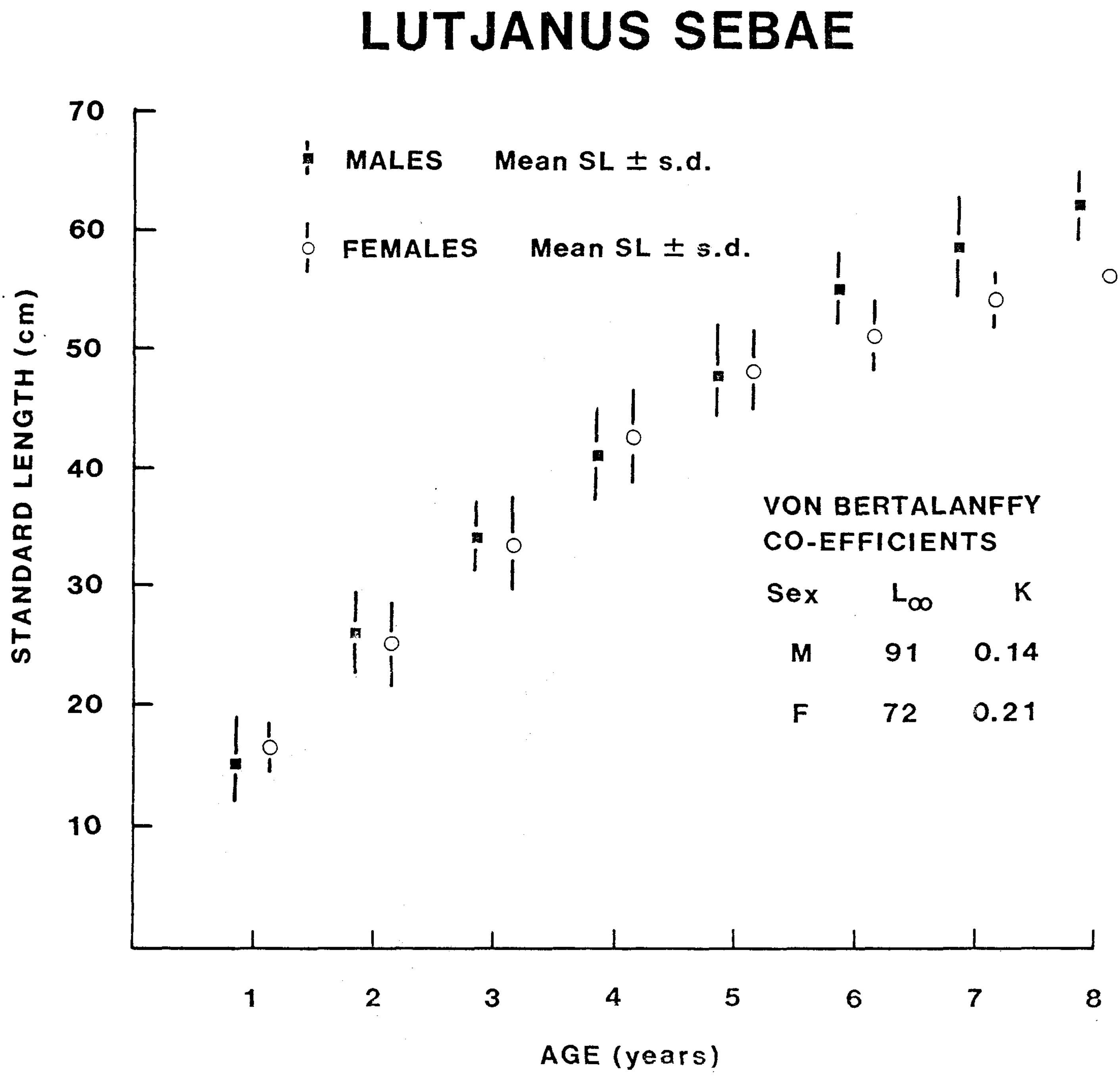

Fig. 4. Length at age estimates (in cm) and von Bertalanffy growth co-efficients for Lutjanus Sebae.

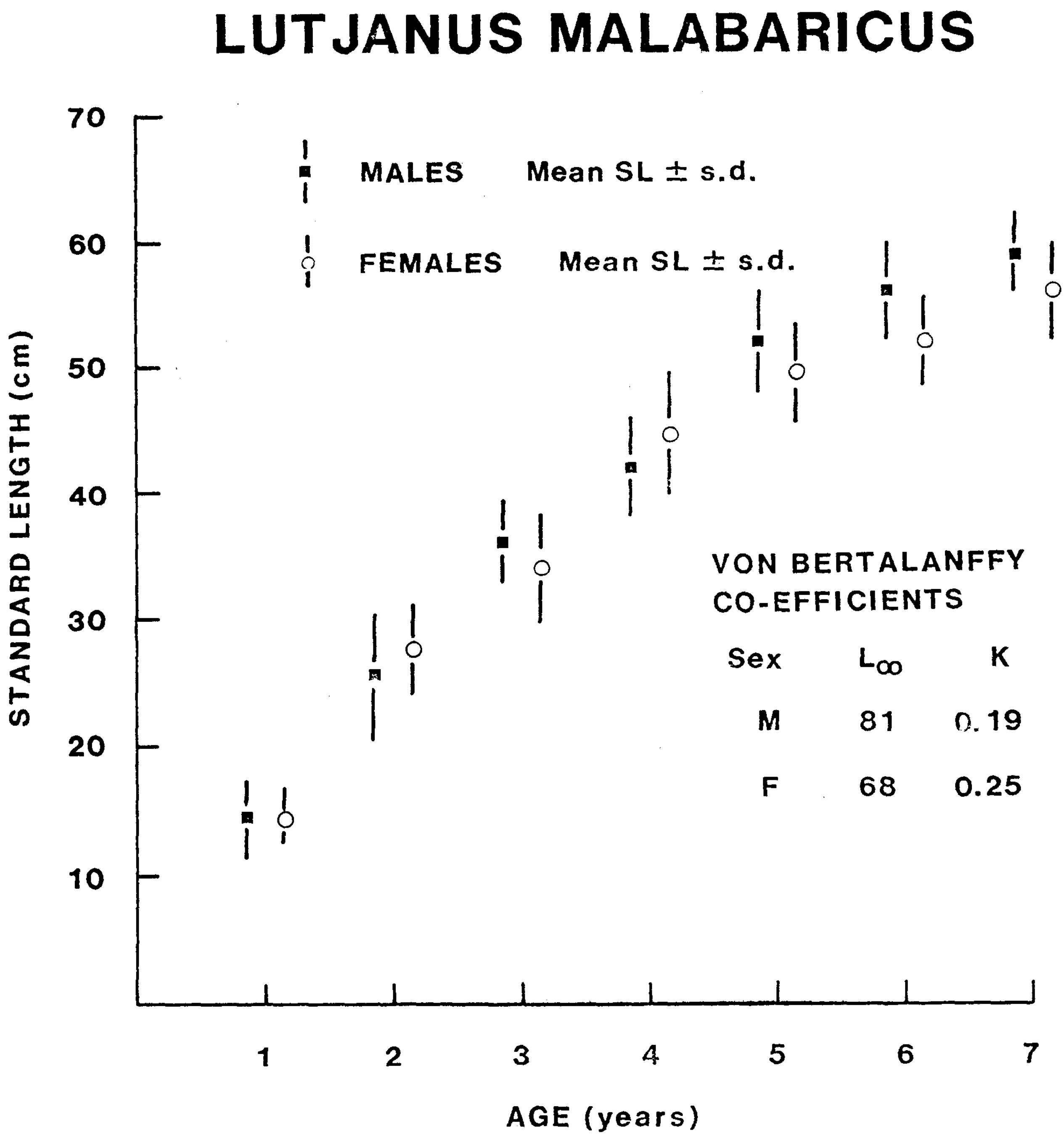

Fig. 5. Length at age estimates (in cm) and von Bertalanffy growth co-efficients for Lutjanus Malabaricus.

LETHRINUS NEBULOSA

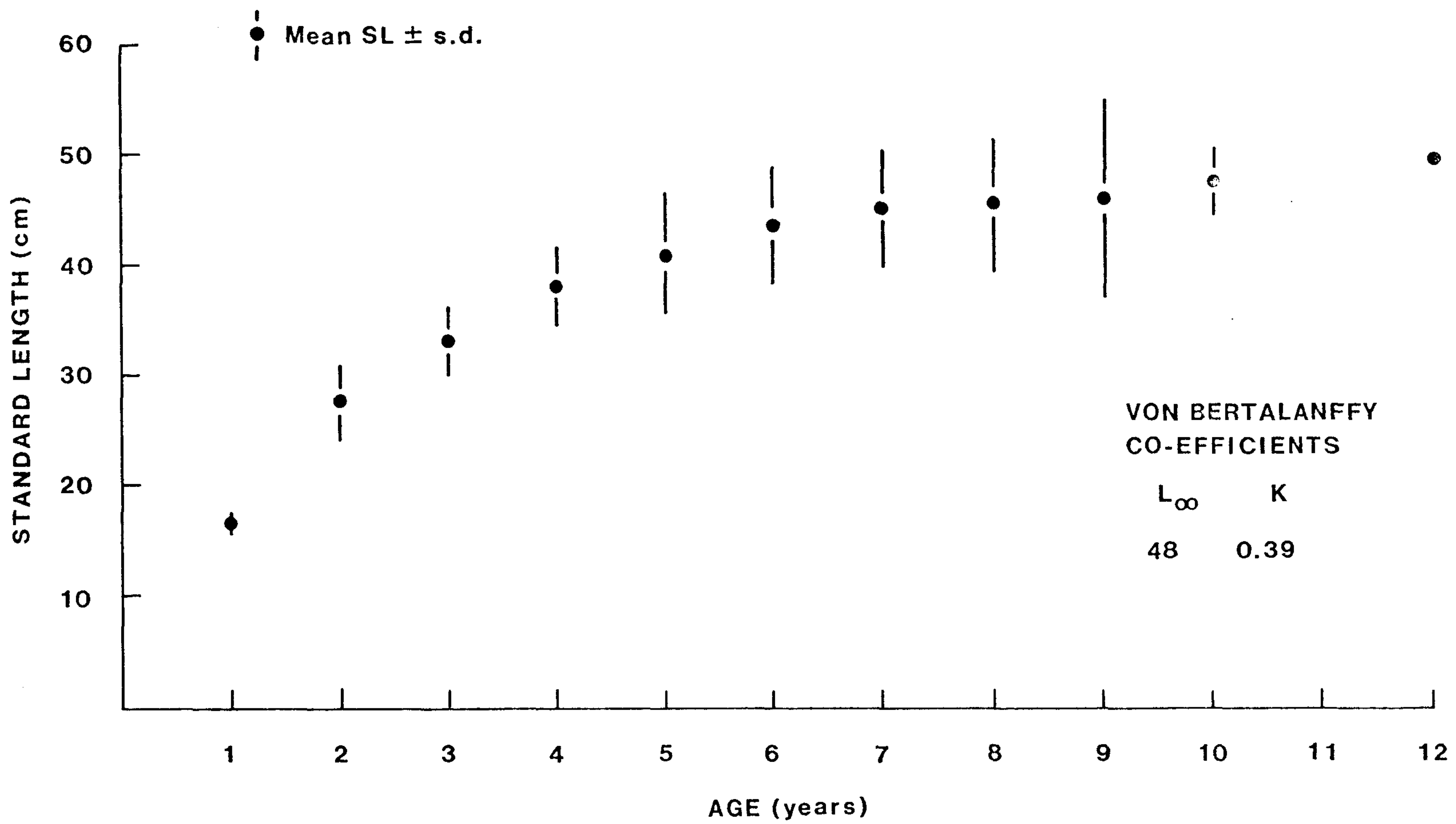

Fig. 6. Length at age estimates (in cm) and von Bertalanffy growth co-efficients for Lethrinus Nebulosa.

PLECTROPOMUS LEOPARDUS

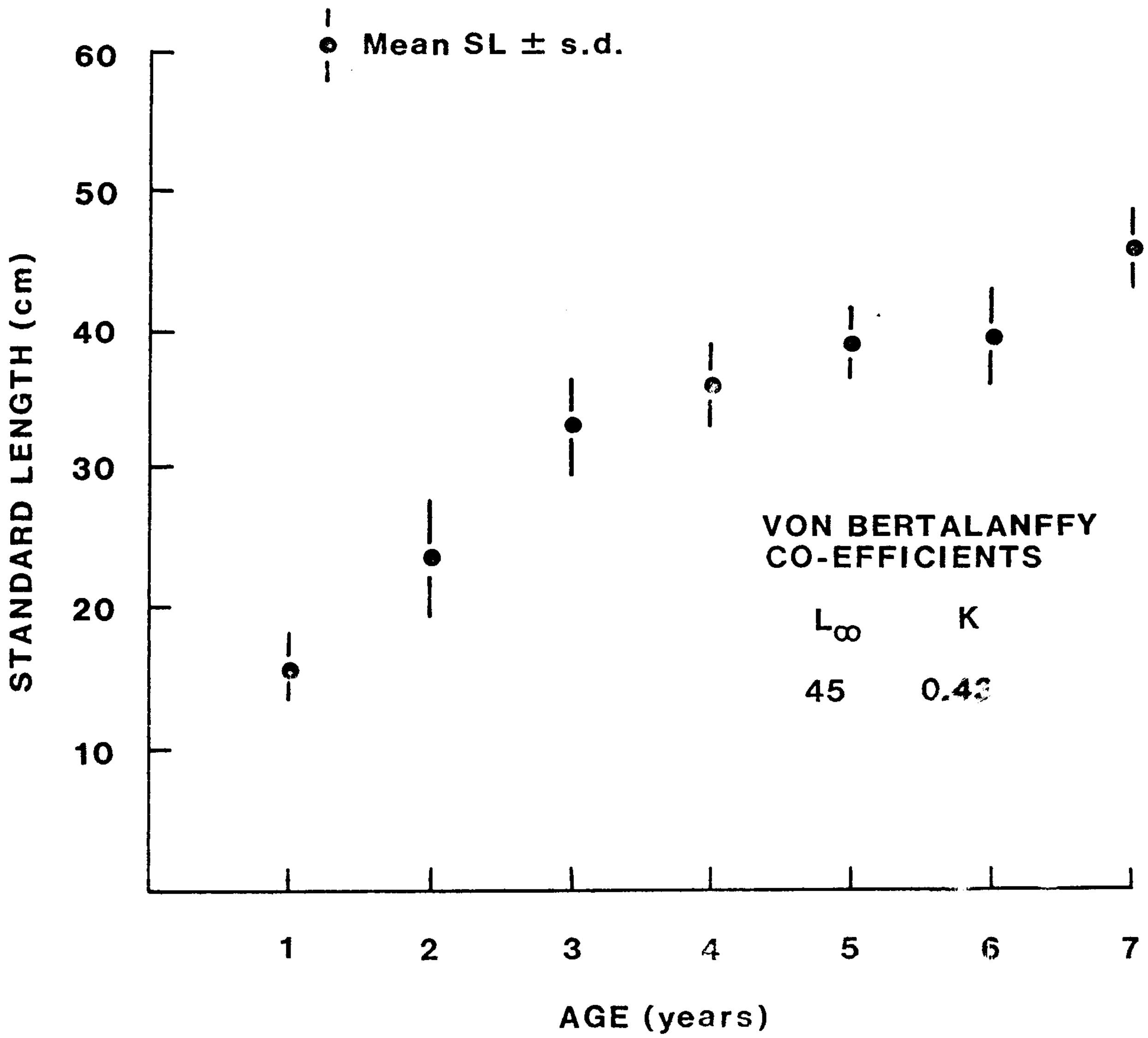

Fig. 7. Length at age estimates (in cm) and von Bertalanffy growth co-efficients for Plectropomus Leopardus.
