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Aspects of the biology of the euryhaline Asian cichlid, *Etroplus suratensis*

Sena S. De Silva, Parakum Maitipe[1] & Ruchira T. Cumaranatunge
Department of Zoology, Ruhuna University College, Matara, Sri Lanka

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Synopsis

Aspects of the biology of the euryhaline Asian cichlid *Etroplus suratensis* in a coastal lagoon of Sri Lanka were studied for a period of 15 months. Comparisons are made from the catches from the fishery of man-made, inland freshwater reservoirs. Changes in the stock structure in the sublittoral region of the lagoon indicate that recruitment takes place twice a year, during the high rainfall/low salinity periods. The feeding habits of *E. suratensis* were different in the two habitats. In the lagoon it fed mainly on molluscs and in the freshwater reservoirs on macrophytes. Feeding chronology based on diurnal surveys indicate that it feeds mainly during the daylight hours. The dentition of *E. suratensis* is adapted for both tearing and crushing (pharyngeal teeth). Distinct differences in the mean relative intestinal length between populations from the coastal lagoon and inland reservoirs were evident and these differences are correlated to their respective feeding habits. Diurnal changes in feeding activity are associated with changes in the stomach pH. The egg-diameter distribution of mature fish indicate that *E. suratensis* is a single spawner, that it sheds its mature eggs all at once. It is inferred that *E. suratensis* breeds twice a year but that an individual female is capable of spawning only once a year.

Introduction

Etroplus suratensis (Bloch) is a euryhaline cichlid indigenous to South India and Sri Lanka (Munro 1955), and is commonly found in coastal lagoons in the region. In Sri Lanka it supports subsistance fisheries in most coastal lagoons (Ward & Wyman 1975, De Silva & Silva 1983) as well as in the inland, man-made reservoirs into which it has been introduced in the course of this century (Fernando & Indrasena 1969, De Silva & Fernando 1983). Other than some aspects of the breeding ethology (Ward & Wyman 1977, Ward & Samarakoon 1981) little is known of its biology.

In this paper aspects of the biology of *Etroplus suratensis*, including density structure and stock changes, diet, chronology, diurnal activity and reproductive biology are presented. In addition, comparisons are made of its gross morphology and feeding habits in coastal lagoons with those in inland reservoirs.

Materials and methods

E. suratensis was collected, monthly, from 1980 August to October 1981 in baited traps, a common-

[1] Present address: National Aquatic Research Agency, Crow Island, Colombo 15, Sri Lanka.

ly used fishing gear in tropical lagoons (Kapetsky 1981), in the sublittoral region of a coastal lagoon in the south western coast of Sri Lanka – the Koggala Lagoon (6′00′N 80° 15′E). The morphometry and physico-chemical characteristics of this lagoon are reported elsewhere (Silva & De Silva 1982). Rectangular traps (0.8 × 0.4 × 0.5 m) made of galvanized iron with hexagonal mesh (3 cm bar) with a single aperture (14.5 × 6.0 cm) on one of the vertical surfaces were laid in the sub-littoral region around 0500 h and hauled at 1000 h. A maximum of 20 such traps, spread over an approximate surface area of 1.0 ha, was laid in any one month from August 1980 to October 1981. Traps with different mesh sizes (0.5, 1.0, 1.5 and 2.0 cm) were also laid in the sublittoral on four different occasions in the same area, to investigate whether smaller individuals were present in the area of study. In addition samples were obtained from the gillnet (mesh size 8 cm) fishery in the lagoon, generally set in the very early hours of the morning and hauled around 1000 h. Samples from two inland reservoirs (Udawalawe 2300 ha; Muruthawela 500 ha) were also obtained from their respective gillnet fisheries and were treated as above.

The total catch from the traps and from the gillnets was brought on ice to the laboratory. The total and standard length and the gutted body weight of each individual fish were determined to the nearest mm and the nearest 0.01 g respectively. The gut was uncoiled and its length measured. Stomach contents samples were taken from the gillnet catches and preserved in 4% formalin; fish from traps were weighed to the nearest 10 mg. The detailed analyses of stomach contents were carried out according to De Silva (1973).

The feeding chronology was evaluated from gillnet catches, in an inland reservoir (Parakrama Samudra – 2662 ha at the full supply level) made at approximately 4 h intervals over a 24 h period. The nets were laid in each instance for 45 min. Each catch was brought immediately to the laboratory (4 km from the reservoir) on ice; total length, somatic weight and the weight of stomach contents (to the nearest 1 mg) were determined. In addition, the pH of the stomach fluid of at least ten individuals was determined from each 4 h catch interval using an Eil-Combination Electrode. The contents of each catch were preserved separately in 4% formalin for later analyses.

A second diurnal survey was carried out in the Koggala Lagoon to coincide with the 1982 spring equinox. In this survey baited traps (average of six) were laid at approximately 4 h intervals in the sublittoral region. As the fish entrapped (over 99% were *Etroplus suratensis*) tended to feed on the bait (3 coconut meal: 1 wheat flour) the stomach contents of these catches could not be used for assessment of the feeding chronology. However, for each catch the total number trapped and their length distribution was evaluated.

The stomach contents of the monthly samples from the Koggala Lagoon as well as those obtained from the reservoir were initially assessed qualitatively; the stomach contents being identified into major taxonomic groups, such as diatoms, crustaceans, etc. Subsequently, the relative contribution of each of the major taxa was assessed quantitatively according to the volume of each item as described elsewhere by De Silva (1973).

In addition the sex and the stage of maturity of each individual fish was determined macroscopically according to the maturity scale suggested by Chandrasoma (1981). Gonads of females in Stage II

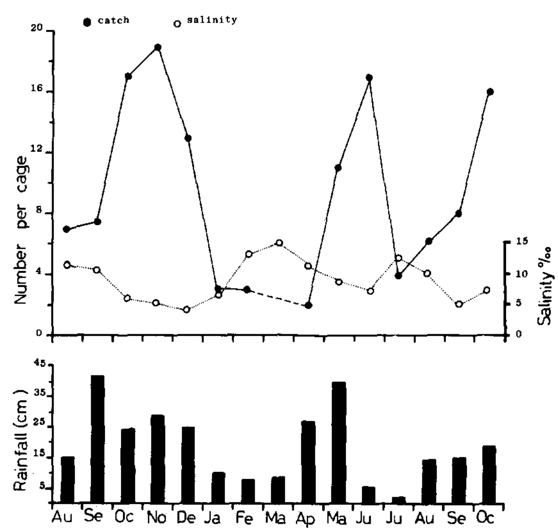

Fig. 1. Seasonal changes in the number of fish trapped per cage, together with the changes in the mean salinity in the Lagoon and the mean rainfall in the catchment.

and above were weighed to the nearest 0.01 g and preserved in Gilson's Fluid, shaken vigorously and kept in the dark for further study. The egg-diameter distribution of a minimum of 5 females at each maturity stage was determined.

Results

Stocks

The mean monthly number of *E. suratensis* trapped per cage appears to reach a maximum around October–November and May–June. During the period January to April numbers were minimal (Fig. 1). The modal length of the stocks varied between 70–100 mm except in July 1981 when a second mode between 140–150 mm was present (Fig. 2). The smallest length groups in the catches (50–60 and 60–70 mm) occured in August/October 1980, April/May/June 1981, and once again in August/September 1981. The appearance of these size groups is coincident with the time(s) of increased catches. The monthly changes in the mean length of three cohorts for the period August to February which were separable into discrete units from prob-

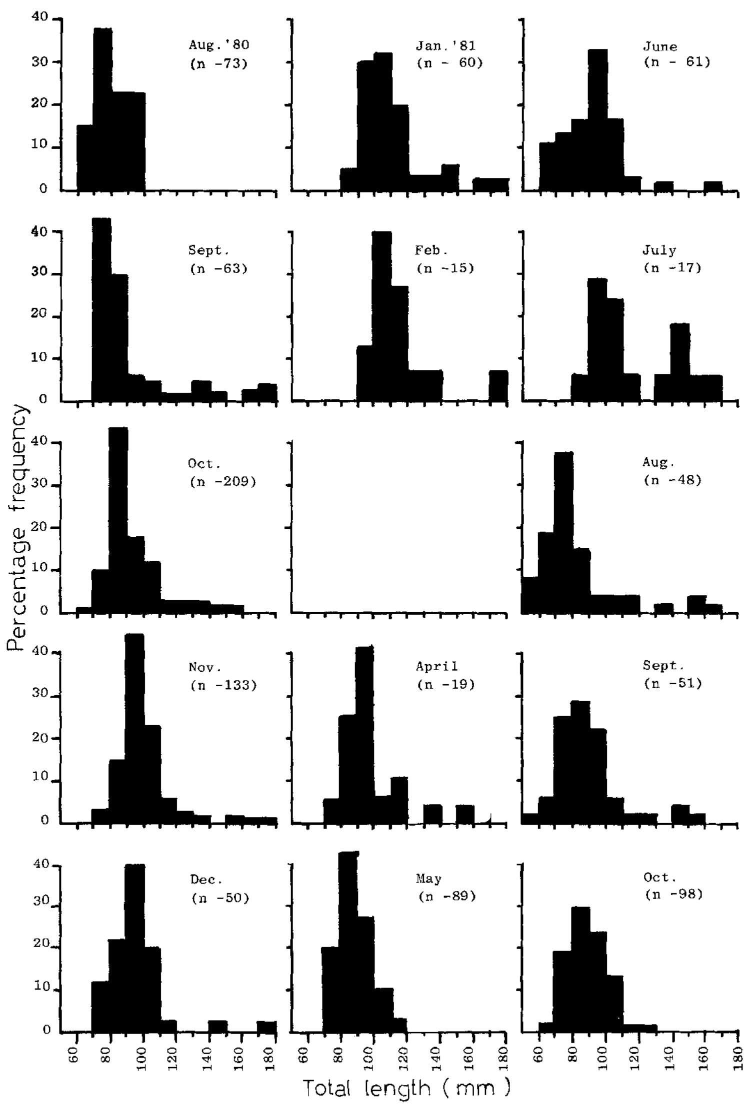

Fig. 2. Monthly length frequency distribution of the *E. suratensis* catches. The number sampled in each month is given in parentheses.

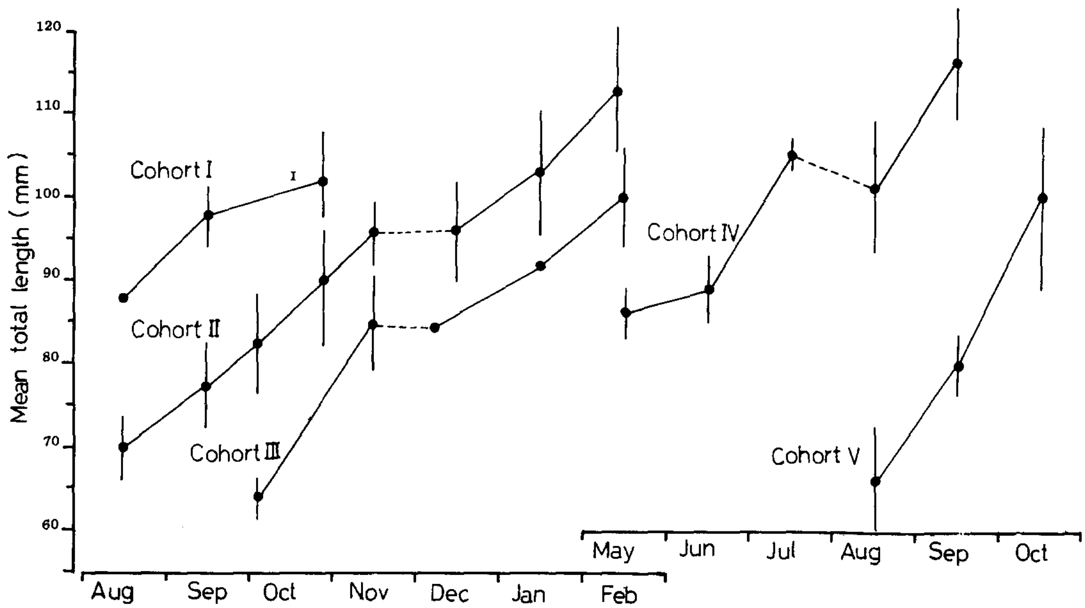

Fig. 3. The monthly mean length of different stocks of *E. suratensis*. The vertical lines indicate ±2SD. The individual points have been connected by eye.

ability paper analysis (Harding 1946) is shown in Figure 3. Similarly, changes in the mean length from May 1981 to October 1981 are also shown. Using the data on the growth of each cohort (stock) and the data from Figure 2 the probable time of recruitment, growth and the time of origin of each brood was inferred (Table 1). The average increase in length for these stocks was 1.76 mm per week with a range of 1.64 to 1.87 mm per week (Table 1), while the mean rate of growth from the probable time of hatching was 3.11 mm per week.

Table 1. The probable time of recruitment of different stocks of *E. suratensis*, their observed mean rate of growth (mm per week) for the study-period (*a*), and the probable overall rate of growth (mm per week) from the time of hatching until recruitment into the deeper waters (*b*); the stocks are numbered I to V for convenience.

Stock	Recruitment	*a*	Brood	*b*
I	May–June 1980	1.64	Feb.–March 1980	3.20
II	Aug. 1980	1.68	June–July 1980	2.94
III	Oct. 1980	1.87	July–Aug. 1980	2.92
IV	April–May 1981	1.75	Jan.–Feb. 1981	3.09
V	August 1981	1.87	June–July 1981	3.40
Mean		1.76		3.11

The length-weight relationship for *E. suratensis* ranging in length from 50 to 220 mm from the euryhaline Koggala Lagoon was $W = 44.87 \times 10^{-6} L^{2.8703}$ (n = 86), and from the fresh-water reservoirs $W = 31.26 \times 10^{-6} L^{2.9522}$ (n = 320) (W = weight in g and L = total length in mm). These relationships were statistically significant (r = 0.95) but they were not significantly different ($p > 0.01$) from each other.

Food and feeding

Morphological features

Dentition. – *E. suratensis* is equipped with three rows of incisiform teeth in each jaw, one behind the other numbering approximately 30 and 20 in each row in the upper and lower jaws respectively (Fig. 4). The back rows of teeth are shorter and smaller with serrated edges (3 to 4 serrations) whilst the middle ones in the front row of teeth have a flat sharp cutting surface (Fig. 4E). These teeth fit very closely to each other. The pharyngeal teeth are molariform. The upper and lower floors of the pharynx are equipped with grinding and crushing teeth, with flat hard surfaces, arranged in 6 apparent rows. The middle row of each half of (Fig. 4C,

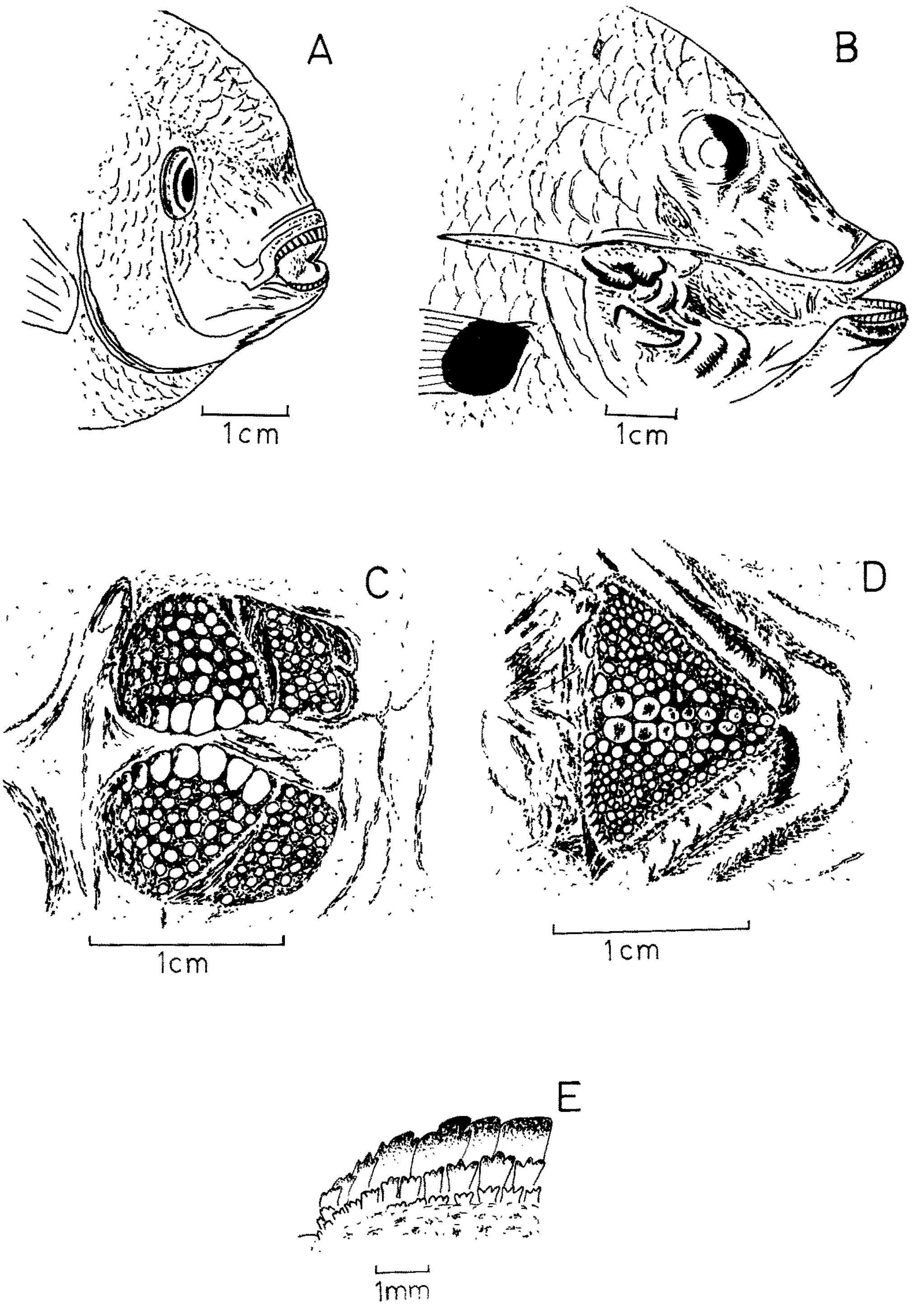

Fig. 4. The position of the mouth with the incisiform teeth (A), the location of pharyngeal teeth (B), the nature of upper (C), and lower (D) pharyngeal teeth and details of the incisiform teeth (E) on the lower jaw as viewed from inside.

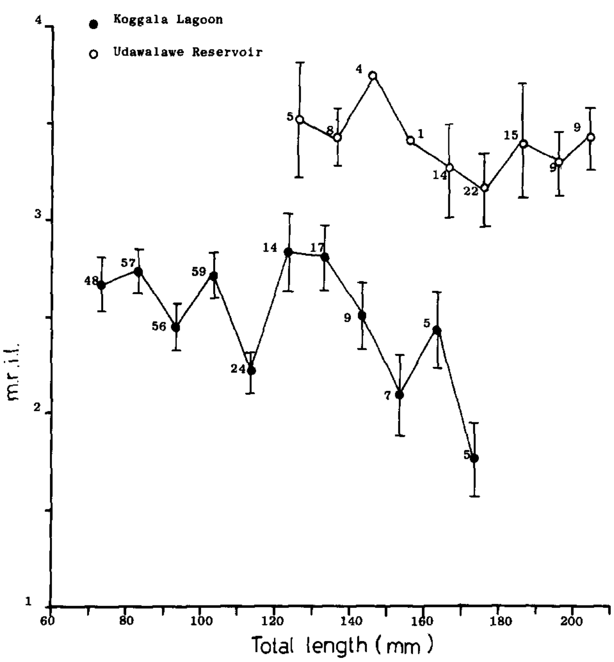

Fig. 5. Relationship of the mean relative intestinal length with increasing length in *E. suratensis* from the euryhaline Koggala Lagoon and the freshwater inland reservoirs. The vertical lines indicate ±2SE. The number of observations made for each length group is also indicated.

D) the upper and lower pharyngeal teeth are much larger than the rest. Also all the lower pharyngeal teeth are arranged in the form of an equilateral triangle while those on the upper palate are arranged in two distinct groups, each group being further divisible into two.

Gut length. – The ratio of the intestinal length (devoid of caecum/stomach) to the total length (= mean relative intestinal length – m.r.i.l.) ranged from 1.02 to 4.95 in fish from 65 to 200 mm long in the euryhaline Koggala Lagoon, and from 2.45 to 5.54 in fish from 100 to 220 mm long from the freshwater reservoirs. There is an apparent trend for the m.r.i.l. to decrease with increasing body length of *E. suratensis* from the lagoon (Fig. 5). The results of fitted regressions for the two groups are, for lagoon fish $Y = -0.005X + 3.03$ ($r = 0.64$; $p<0.05$) and, $Y = -0.004X + 4.18$ ($r = 0.56$; $p<0.05$) for reservoir fish (Y = fish length and X = m.r.i.l.).

Diet

The composition of the diet of *E. suratensis*, of different size groups from different environments is given in Table 2. Qualitatively the diet ranges widely from microscopic plants to animals. Only minor seasonal variations in the diet were observed. Macrophyte material in the gut was found to be shredded while molluscs were found to be crushed.

Quantitatively, the relative contributions of major taxa did not greatly differ among age groups within a habitat. The relative contribution of each major taxa to the diet of *E. suratensis* of two size groups, from the two habitats under consideration is shown in Figure 6. In the coastal lagoon, molluscs, predominantly bivales such as *Modiolus* sp., ranging in shell length from 2 to 4 mm, constitute the major part of the diet, while in the reservoirs macrophytes predominate. In both habitats desmids, diatoms, etc. contribute only slightly to the diet and their

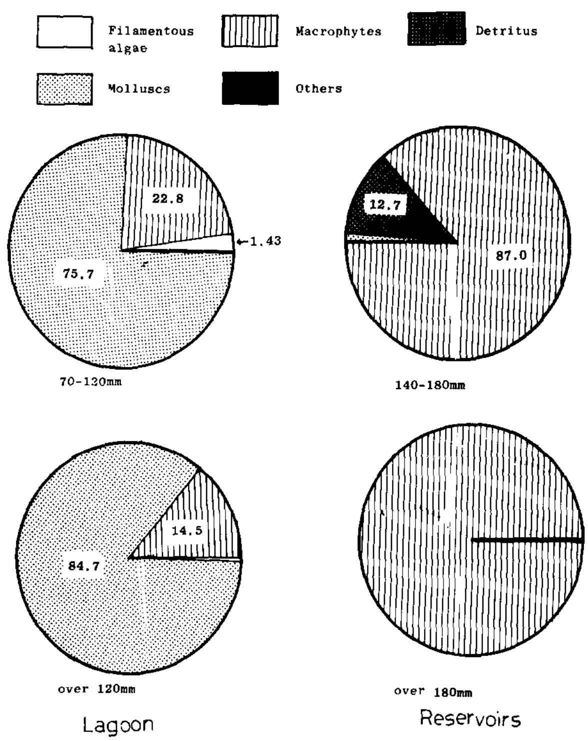

Fig. 6. The relative contribution of the major food items to the diet of *E. suratensis*, of two size groups, from the Koggala Lagoon and the inland reservoirs ('others' refer to those items contributing less than 1% to the diet).

Table 2. Dietary composition of different size groups of *E. suratensis* from the Koggala Lagoon and Inland Reservoirs.

	Koggala Lagoon				Inland reservoirs	
	Length group (mm)					
Food item	61–100	101–140	141–180	>181	141–180	181–220
Diatoms						
Cocconeis		+	+			
Cymbella	+				+	
Diatoma		+	+		+	+
Frustulia		+			+	+
Navicula		+	+		+	+
Nitzschia	+	+	+		+	+
Pinnularia		+				+
Rhopaloidea					+	
Surirella					+	
Synedra	+	+	+			+
Tabellaria						+
Desmids						
Closterium					+	
Cosmarium	+				+	
Staurastrum					+	
Blue green algae						
Anabaena	+		+		+	+
Coelosphaerium					+	
Gleotheca	+	+	+		+	
Lyngbya					+	
Oscillatoria		+			+	+
Merismopedia		+			+	
Spirulina					+	+
Green algae						
Ankistrodesmus					+	+
+ *Chara*			+		+	
Chlorella	+				+	+
+* *Cladophora*			+			
* *Mougoetia*	+	+	+		+	+
+ *Nitella*						
+* *Oedogonium*	+	+			+	
Scenedesmus					+	+
* *Spirogyra*	+	+	+			+
Trochiscia	+				+	+
* *Ulothrix*	+				+	
Brown algae						
@ *Ectocarpus*					+	+
Higher plant matter						
Monocots	+	+	+	+	+	+
Dicots					+	+
Animal matter						
Bivalves	+	+	+	+		
Gastropoda				+	+	
Crustacean appendages			+	+		
Detritus	+	+	+	+	+	+

+ = rooted algae; * = filamentous algae; @ = epiphytic presence in the stomach appears to be incidental. It is also important to note the increased dependence on molluscs with increasing size in the diet of lagoon stocks whilst in the reservoirs the shift is towards an increased dependence on plant material.

Feeding chronology

The feeding chronology was evaluated on the basis of the changes in the stomach fullness, quantified as the changes in the mean of the ratio of the weight of stomach contents to body weight (see Keast 1970, De Silva 1973, De Silva & Wijeyaratne 1977), together with the changes in percent occurrence of non-feeding individuals, through the 24 h cycle. The results, together with the changes in the pH of the stomach and intestinal (mid) fluid, are shown in Figure 7A. Changes in mean stomach content weight to body weight are complimentary to changes in the occurrence of non-feeding individuals in the 24 h period; the former reached a maximum in the evening and began to show a decline after dark, when feeding activity ceases almost completely. Feeding activity commenced again at dawn. Thus it is seen that in *E. suratensis* the main feeding activity occurs in the daylight hours.

The pH of the stomach changes significantly through the diel cycle but not in the intestine which remained near neutral. The stomach pH became increasingly acidic with increasing feeding activity while during the night when feeding activity is minimal the pH remained only slightly acidic.

The results of the diel survey in the Koggala Lagoon (Fig. 7B) indicates that the number of *E. suratensis* trapped per cage reached a peak towards late afternoon, after dark catches were zero. Catches increased after dawn. The mean size of the fish trapped was not significantly different from one time period to another ($p > 0.05$).

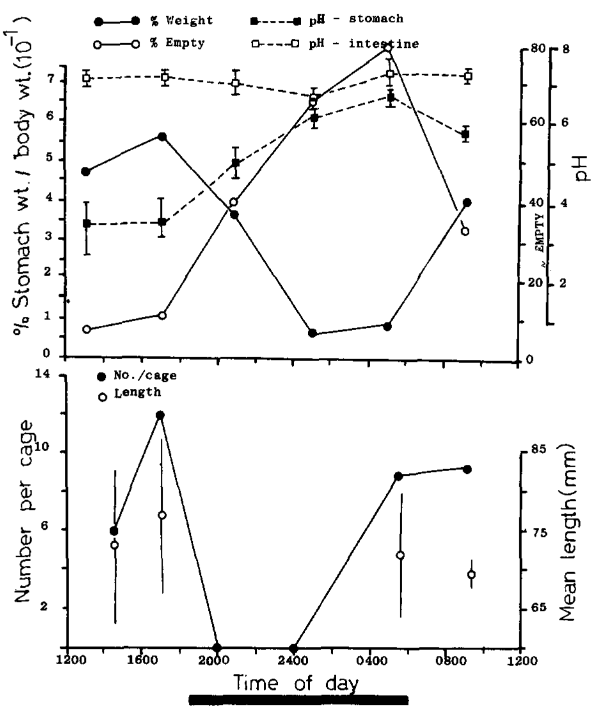

Fig. 7. The results of two diel surveys. (A) Diel changes in the mean stomach weight, expressed as a percentage of the body weight, the percentage of non-feeding individuals, and the changes in the mean pH of the stomach and mid-intestinal fluid. (B) Diel changes in the number of fish trapped per cage and the mean and the range in length of the catches.

Discussion

The gear used in this study was a common and a popular method adopted in coastal lagoons in the tropics by subsistence fishermen (Kapetsky 1981, Bwathondi 1982). The use of this gear in Sri Lanka is now prohibited. The traps of smaller mesh size did not yield individuals smaller than 50 cm and the range in length of those catches was also 50–120 mm, suggesting the gear utilized was nonselective. The sub-littoral region, close to the edge of the marginal vegetation, is known to be the habitat of young *Etroplus suratensis* as well as the breeding grounds for the adults (Ward & Wyman 1975, Ward & Samarakoon 1981). Therefore, seasonal changes in catch per effort observed in the present study reflect changes in the abundance of young in the littoral region of the lagoon. It is also possible that brooding individuals either avoid the gear because of their non-foraging habit during brooding (Ward & Samarakoon 1981) or that the area in which the traps were laid is not suitable for breeding.

Variations in abundance of young *E. suratensis* bear a distinct relationship to the salinity/rainfall pattern in the Lagoon (Fig. 1). Recruitment into the sublittoral takes place from the breeding grounds at a mean length of about 50 mm nearly 2–3 months after hatching. Ward & Samarakoon (1981) concluded from observations on the intensity of nest building in another coastal lagoon in Sri Lanka that *E. suratensis* breeds during the periods (two) when the lagoon salinity is high and the turbidity is minimal. The appearance of the youngest size classes approximately 2–3 months after the high salinity periods and the consequent increase in abundance in the catches indicate that *E. suratensis* in the Koggala Lagoon also probably breed when conditions similar to those described earlier prevail and that it takes 2–3 months for *E. suratensis* to reach a size of 60 mm — an approximate rate of growth of 3.9 to 5.6 mm per week.

In most of the monthly catches length-classes above 110 mm are very sparsely represented. This is not likely to be due to selection of the gear as experimental traps of bigger mesh size, laid together with the normal trap (in October 1981 and March 1982), did not indicate a difference in length distribution. Fish beyond 110 mm length possibly tend to get recruited into the fishery in the deeper regions of the lagoon, thereby indicating a change in the habitat preference with size.

The dentition and the position of the mouth of *E. suratensis* shows mixed characteristics. The frontal incisiform sharp teeth are similar to those found in cichlids such as *Tilapia rendalli*, *Tilapia zilli* and *Haplochromis similis* that feed on higher plants (Fryer & Iles 1972), whilst the pharyngeal teeth are similar to those found in the cichlid *Haplochromis placodon* (Greenwood 1952) which is a typical mollusc eater. It is, therefore, apparent that the dentition of *E. suratensis* is well suited to exploitation of two food resources generally abundant in tropical, coastal lagoons (Barnes 1980). The crushing teeth may also assist the trituration of the macrophytic material ingested, thereby expediting its digestion by rupturing the cell walls.

Contrary to the earlier reports we have found *E. suratensis* to be predominantly a macrophyte feeder in certain habitats but most certainly not a complete herbivore as reported by Ward & Samarakoon (1982). The relatively high proportion of detritus in the diet of stocks in the reservoirs, in contrast to the complete absence of detritus in those from the coastal lagoon, may be indicative of selective feeding on detritus. Detritus is known to play a significant role in the diet of certain freshwater cichlids (Bowen 1981). *Sarotherodon niloticus* (Moriarty 1973) and *Tilapia rendalli* (Caulton 1976), amongst others, have been shown to have the ability to digest plant material. Such species are known to have mechanisms for either physical breakdown of the cellulose wall or to cause lysis of the cellulose material by a distinctly lower stomach pH than in non-herbivorous species. The mean stomach pH in *E. suratensis* showed significant changes with feeding activity, tending to be acidic during peak feeding activity. The mean stomach pH during peak periods however, was less than that reported either for *T. rendalli* or *S. niloticus*. It is possible that the efficient triturating mechanism in *E. suratensis* makes acid lysis unnecessary.

Differences in the gut morphology, with increasing size have been reported by Braber & De Groot (1973) for five species of pleuronectids. More recently, morphological changes in isolated population of the estuarine clupeid *Gilchristella aestuarius*

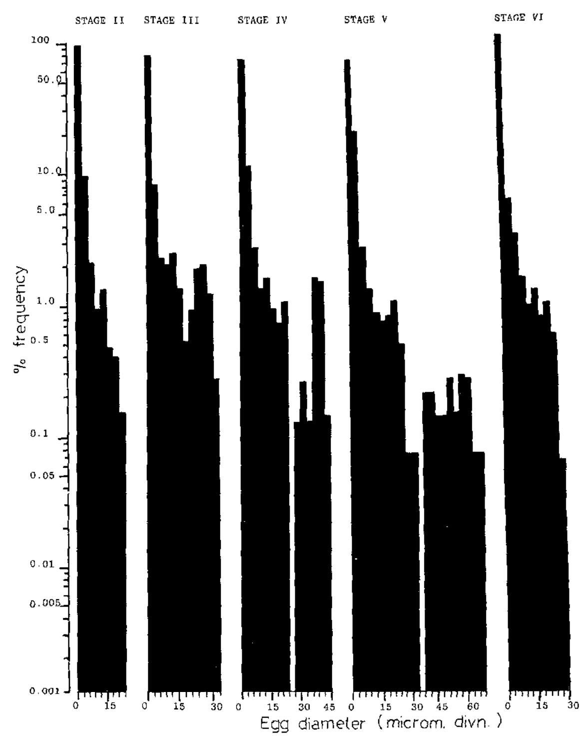

Fig. 8. The egg diameter frequency distribution of female *E. suratensis* at different stages of maturity (1 micrometer division = 0.043 mm).

have been correlated to differences in the zooplankton food resources (Blaber et al. 1981). The differences in the m.r.i.l. of fish from the euryhaline lagoon from that of the reservoirs possibly indicates the adaptability of this species to different food resources. The differences observed presently have not been reported to our knowledge for other fish species. Mendis (1965) has reported a general paucity of the molluscan fauna in inland reservoirs. The m.r.i.l. in reservoir populations may be an adaptation to this paucity of the molluscan fauna, and its consequent dependence on macrophytes and on detritus. The phenotypic nature of m.r.i.l. has been reported for anuran tadpoles; the same progeny when exposed to different food resources resulted in different gut lengths (Altig & Kelly 1974). It may well be that m.r.i.l. is an entirely phenotypic feature in fishes also.

Feeding chronologies of tropical fish species are scarcely known (Odum 1970, De Silva & Wijeyaratne 1977, Collins 1981). The present study indirectly indicates that *Etroplus suratensis* is a visual feeder and the same is suggested by its daily pattern of activity indicated by the catch per trap. *E. suratensis* is an important constituent of the fisheries in most lagoons in Sri Lanka (Ward & Wyman 1975, De Silva & Silva 1983) as well as in certain inland reservoirs (De Silva & Fernando 1983). The main method of capture of this species is by angling and cast netting, during daylight hours, whilst the catches from the gillnet fishery are very small, particularly in the inland reservoirs. This is possibly a reflection of its daily activity pattern which has emerged from the present study and it may be that laying of gillnets in the early hours of the day may be more effective. The diel variation in the number of trapped fish in the Lagoon which is indicative of their degree of activity through the day is very similar to the pattern of diurnal feeding activity shown in an inland reservoir. Thus it appears that there is no difference in the activity patterns of *E. suratensis* in distinctly different environments.

The egg-diameter distribution indicates, that in all probability *E. suratensis* is a single spawner (Hickling & Rutenberg 1936), i.e. eggs destined to be spawned are shed all at once as in certain other cichlids, e.g., *Sarotherodon mossambicus* and *Tilapia rendalli* (De Silva & Chandrasoma 1980, Chandrasoma & De Silva 1981). It has been shown earlier that this cichlid tends to breed twice a year in lagoons (Ward & Samarakoon 1981) and this is confirmed by indirect evidence from the present study. Ward & Samarakoon stipulated that in *E. suratensis* both parents are engaged in guarding a brood, and that they do not forage until the young are released. The time difference between the two high salinity periods on the west-coastal lagoons of Sri Lanka is approximately 5 months (February to August, De Silva & Silva 1983). Thus it is unlikely that an individual will be able to undergo two spawning cycles within a year and as such during the two seasons two different sets of mature individuals breed.

The adaptability of *E. suratensis* together with the relatively fast growth makes it a strong candidate for aquaculture. The observed rate of growth of *E. suratensis* compares well with other euryhaline species, such as *Siganus canalicullatus* (Bwathondi 1982), considered as candidates for culture in the tropics.

Acknowledgements

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