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Part 1

The fishes of the genus Lutianus of the East African Coast.

Part 2

Notes on the biology of the Lutjanidae (Pisces) of the East African Coast with special reference to L. bohar (Forskal).

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THE FISHES OF THE GENUS LUTIANUS OF THE EAST AFRICAN COAST.

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[Plates IV—XII]

INTRODUCTION.

While investigating the biology of the economically important members of the genus Lutianus on the East African coastline, difficulty was experienced with the identification and the nomenclature of the group using existing literature. It was essential that adequate descriptions of the species of the genus should be available before their biology could be investigated. Routine work of the East African Marine Fisheries Research Organization has produced over 1,000 specimens for study. The Organization's vessel, the M.V. " Research ", has collected by handlines, multiple trolling lines, gill nets, deep lines and basket traps over the six hundred mile coastline of Kenya, Tanganyika and Zanzibar Protectorate, i.e. from Lat. 1° 30″ S. to 10° 30″ S. This material forms the basis of the present paper.

Underwater observations with and without a Seibe-Gorman aqualung down to seven fathoms have been made on a number of coral reefs. In this way some knowledge of the habits of certain species of the genus has been acquired, and some species rarely taken by normal fishing methods were discovered to be common. Specimens of these have been collected by spear guns. Where notes of habits of a species have been made they have been appended under the heading " Ecological note ".

Of the thirteen species of the genus found in the area, all (except the very small *L. ehrenbergi*) pass through the local markets and are considered good eating, and seven are important food fishes. Economically the genus ranks as one of the three most important groups of bottom Teleosts ; the others being the Epinephelids and the genus Lethrinus.

Measurements are based on an average of six specimens over the widest size range available.

Definition of terms.

Depth : The greatest depth of the body.

Eye : The greatest diameter of the fleshy orbit.

Head : The distance from the anterior end of the fish with mouth closed to the posterior end of the gill cover.

Interorbital distance : The shortest fleshy interorbital distance.

Length : This is measured excluding the caudal fin (body length, standard length), unless otherwise stated.

Lateral line count : Counts have been made to the end of the caudal peduncle (figures in brackets) and to the last of the lateral line scales on the caudal fin sheath (figures not in brackets).

Pectoral : Measured from the axil to the distal end of the longest ray.

Proportions : Where proportions vary directly with size the variation from the largest to the smallest fish in the size range is indicated by (l) and (s) behind the figures, and vice versa.

Snout : The snout is measured from the tip of the snout excluding the lips to the nearest point on the rim of the fleshy orbit.

Sub-orbital distance : The shortest distance between the fleshy orbital rim and the maxillary groove.

Key to the Genus *Lutianus*.

I. Scales above lateral line run parallel to dorsal profile, at least under the spinous dorsal.
  A. Distinct black lateral line spot .... *ehrenbergi* 2
  B. No lateral line spot, silvery red .... *argentimaculatus* 4
II. Scales above lateral line run obliquely upwards to dorsal profile.
  A. Blue longitudinal lines on body.
    (i) Four wide blue lines, black lateral line spot present or absent .... *kasmira* 5
    (ii) Five or more thin blue lines, some joining anteriorly, black lateral line spot present or absent .... *duodecimlineatus* 6
  B. Body red or silvery red, with or without additional distinctive markings, no lateral line spot.
    (i) Dorsal spines X.
      (*a*) Scale rows run obliquely upward above and below the lateral line. In adults, head markedly concave dorsally in profile, and upper caudal lobe distinctly rounded and larger than ventral lobe. Deep preopercular notch .... *gibbus* 7
      (*b*) Scale rows run parallel to body axis below the lateral line. Head convex or straight dorsally in profile. Two silvery spots on side which may be absent in large fish. Preopercular notch shallow or absent.................. *bohar* 8
    (ii) Dorsal spines XI.
      (*a*) Anterior nostril midway between eye and snout. Colour markings distinct in young (see Plate VIII A). Preopercular notch shallow .... *sanguineus* 10
      (*b*) Anterior nostril much nearer snout than eye. Colour markings distinct in young (see Plate IX B). Large adults develop a deep preopercular notch, and a long finger-like interopercular knob .... *sebae* 11
  C. Distinct black lateral line spot, no longitudinal blue lines, body yellow or orange.
    (i) Second anal spine shorter than snout. Vomerine teeth in a V with no elongate posterior projection .. *monostigma* 12
    (ii) Second anal spine longer than snout. Vomerine teeth in an arrowhead shape usually with an elongate posterior projection .... *fulviflamma* 13
  D. Wavy blue lines on head, pale spots on body, chalky lateral line spot, lost in large fish .... *rivulatus* 15
  E. Longitudinal yellow or fawn lines parallel to scale rows.
    (i) Dorsal spines XI. suborbital distance into eye two or more. No preopercular notch................ *lineolatus* 16
    (ii) Dorsal spines X, dorsal black sub-marginally with a fine white rim, suborbital distance into eye less than two Moderate to deep preopercular notch.. *vaigiensis* 16

Lutianus ehrenbergi (Peters). (Pl. IV A.)

Mesoprion Ehrenbergi Peters (1869) ; *Lutjanus ehrenbergi* Weber & De Beaufort (1936) ; non. *L. ehrenbergi* Blegvad (1944).

Description.

Standard lengths 44 to 98 mm.

Proportions : head 2·2 (s)–2·5 (l) ; depth 2·4 (s)–2·7 (l) ; pectoral 3·2 (l)–3·6 (s) ; all in body length. Eye 3·6 (l)–4·0 (s) ; inter-orbital

4·1 (l)–5·0 (s). Snout 3·6 (l)–4·0 (s) ; all in head length. Sub-orbital into eye 2·7 (l)–5·0 (s).

Dorsal fin count X (XI), 12 to 13 ; anal fin count III 8 (9).

Lateral line count 50 to 53 (45 to 48). Five rows of cheek scales. Six rows of scales from lateral line to mid-dorsal spines. Scales on head start behind vertical through hind end of eye. Scale rows run parallel to the body axis below the lateral line.

Pre-opercular flange serrate, finely on the vertical limb, and coarsely on the horizontal limb. Notch indistinct in the juvenile, and small but distinct in the adult. Small inter-opercular knob present.

Weak rows of conical incisors in both jaws, with the upper anterior teeth slightly enlarged to form weak canines. Thin bands of villiform vomerine teeth in a V with no posterior projection. Palatine teeth similar to the vomerine, in a small band. Lingual teeth present or absent.

Colour in formaline olive above and pale below with a yellowish tinge. Fins hyaline. Caudal pale yellow. Soft dorsal with a faint dusky tip. Large distinct lateral spot black in life and fading to brown on preservation, covering nine lateral line scales below the posterior spinous and anterior soft dorsal, more above than below the lateral line, covering three scale rows above and two below the lateral line. Faint darker spots on each scale result in pale brown longitudinal lines. In life a few golden bars are present along the body.

Maximum size seen in East Africa, 98 mm.

Ecological note. Taken from mangrove pools on Zanzibar Island. Not common, and never seen underwater about coral reefs.

Distribution. Red Sea ; East African Coast ; Indo-Pacific Region as far east as the Solomon Islands.

Note. This species seems to be closely allied to *L. johni* (Bloch), and neither Smith (1953), Barnard (1927) nor Sauvage (1891) record it from East Africa Peters (1869) and Klunzinger (1870) describe it from the Red Sea. The E.A.M.F.R.O. specimens, although close to Day's descriptions of *L. johni*, differ from them in a number of points. In his description he mentions the soft dorsal being higher than the spinous. In these fish the spinous is very much higher than the soft dorsal. This point is specifically mentioned in Peters' original description of *L. ehrenbergi*. Day mentions that in two-and-a-half inch specimens of *L. johni* a strong denticulation is present in the lower limb of the preopercle, a remnant of a large spine in post-larval fish. Two-and-a-half inch *L. ehrenbergi* in the E.A.M.F.R.O. collection lack this spine. He also mentions the dorsal spines decreasing in height to the last, whereas in *L. ehrenbergi* the penultimate spine is always shorter than the ultimate. Weber and De Beaufort (1936) mention as an additional difference the absence of occipital scaling in the latter. The species also vary in size. *L. ehrenbergi* is a small species, and matures at a small size.. Two of the E.A.M.F.R.O. specimens are fully mature females at 75 mm. This species is not recorded over 270 mm. in length. *L. johni* reaches nearly a metre in length (Weber and De Beaufort) and, if an analogy can be drawn with other large Lutianids about whose biology something is known, it must mature at about 300 mm. *L. johni* has not been taken in the area.

Lutianus argentimaculatus (Forskal). (Pl. IV B, V A.)

Sciaena argentimaculata Forskal (1775) ; *Lutianus argentimaculatus* Day (1878–1888) ; *Lutianus gembra* Barnard (1927) ; *Lutianus argentimaculatus* Fowler (1928); *Lutianus argentimaculatus* Weber & De Beaufort (1936) ; *Lutianus argentimaculatus* Smith (1949).

Description.

Standard lengths 104 to 865 mm.

Proportions : head 2·5–2·8 ; depth 2·6 (s)–3·2 (l) ; pectoral 3·4–3·7 ; all in body length. Eye 4·5 (s)–6·4 (l) ; inter-orbital 5·1–5·4 ; snout 2·8 (l)–3·2 (s) ; all in head length. Sub-orbital distance into eye 0·7 (l)–1·3 (s).

Dorsal fin count X (unusually XI) 13 to 14. Anal fin count III 8.

Lateral line scales 48 to 53 (44 to 56). Seven to eight rows of cheek scales. Scales on head start above posterior third of eye in young specimens and as far back as above the free pre-opercular edge in large adults. Scale rows above lateral line parallel to dorsal profile anteriorly, rising obliquely below the posterior end of the soft dorsal. Scale rows below lateral line parallel to the body axis.

Pre-opercle flange serrate above and in notch. with coarse, widely separated serrations below. Notch weak. No distinct interopercular knob.

Moderate conical incisors in upper jaw, with one anterior pair enlarged to form strong back-curving canines. Lower jaw with a strong row of outer canines. Villiform vomerine teeth in an arrow head, usually with a backward projection. Granular palatine teeth present in oval patch. Small patch of lingual teeth usually present.

Juvenile coloration in formalin rust red above to silver below. Pectoral fins orange, dark-tipped. Dorsal hyaline, with the spinous part dark-tipped. Anal hyaline, with the first two rays dusky. In life a wavy blue line is present on head below eye.

Adults (formalin preserved) reddish brown above to silver below. Scaly bases of unpaired fins have an orange tinge. Unpaired fins and pelvics dusky, pectorals hyaline.

Maximum size seen in East Africa up to about one metre body length.

Ecological note. Common on the Tanganyika, Kenya and Zanzibar coasts in relatively sheltered waters. Never seen under water on the exposed eastern coral reefs subject to strong wave action, but common inside the shelter of the fringing reefs in depths of two to seven fathoms, and in estuaries, mangrove inlets, and in the sheltered waters of the Zanzibar and Mafia channels. Juveniles have been taken in mangrove pools on Zanzibar Island, down to 104 mm. in length.

This species is usually seen in slowly moving shoals in water of five to seven fathoms, with about five to thirty fish per shoal. Solitary individuals, usually from six to twenty lb in weight are often seen under and about coral rock shelter.

Distribution. Natal ; Red Sea ; Indo-Pacific region as far east as the Tuamotu Archipelago and Christmas Island.

Lutianus kasmira (Forskal). (Pl. V B.)

Sciaena kasmira Forskal (1775) ; *Lutianus bengalensis* Day (1878–1888) ; *Diacope bengalensis* Sauvage (1891) ; *Lutianus kasmira* Barnard (1927) ; *Lutianus kasmira* Weber & De Beaufort (1936) ; *Lutianus kasmira* Randall (1955).

Description.

Standard lengths 170 to 190 mm.

Proportions : head 2·5–2·8 ; depth 2·8–2·9 ; pectoral 3·3–3·6 ; all in body length. Eye 4·0–4·1 ; inter-orbital 4·3–4·7 ; snout 3·0 ; all in head length. Sub-orbital distance into eye 1·6–1·8.

Dorsal fin count X (XII in Malindi specimen, see below) 14, anal fin count III 8.

Lateral line scales 56 (49 to 51) ; number of scales from the lateral line to the mid-dorsal spines seven. Seven to eight rows of cheek scales. Scales on head begin above middle to anterior third of eye, with the temporal region therefore scaly. One or two rows of scales on the sub-opercle. Scale rows run obliquely upward to the dorsal profile above the lateral line, and below it run parallel to the body axis.

Pre-opercular flange finely serrate above and just below the pre-opercular notch, which is deep and smooth. Lower curve of the free pre-opercular edge coarsely serrate. A large, often sharp, inter-opercular knob present, fitting into the notch.

Teeth of the typical Lutianid pattern, with the outer conical incisors weak, sharp, and needle-like. Two to three pairs of teeth slightly enlarged anteriorly to form weak canines. Outer row of teeth in the lower jaw moderate, only slightly enlarged half way down jaw. Villiform teeth in a band inside upper jaw, and in a small patch on either side of the symphysis in the lower jaw. Villiform vomerine teeth set in a V with no posterior projection. Similar palatine teeth set in a thin band. No lingual teeth.

Colour in formalin pale yellow, with brighter yellow about head, scaly fin sheathes, and operculum. Fins hyaline to yellow, with the dorsal strongly black tipped. Four distinct longitudinal lines, pale blue-grey, dark edged. Uppermost line from nape to ninth dorsal spine ; second from upper border of orbit to sixth or seventh soft dorsal ray ; third from upper end of free preopercular edge to last dorsal ray ; fourth from snout under eye to caudal peduncle. A distinct black lateral line spot present between the second and third longitudinal lines, below the first few soft dorsal rays, and mostly above the lateral line. In life under water this lateral line spot is often seen as a pale patch or is absent, suggesting active chromatophores as found in *L. bohar.* A wide black bar from snout to eye is also distinct underwater.

Maximum size seen in East Africa 190 mm.

Ecological Note. Occasionally seen in large shoals on the outer exposed edges of coral reefs, often in conjunction with shoals of *L. fulviflamma.* Taken in local basket traps, but not a common food fish. This species does not seem to frequent the mangrove swamp areas, nor the inside of the fringing reefs, but is a species of clear water and active coral growth areas. One specimen has been taken from the research vessel in fifty fathoms off Malindi (Kenya). This deep water specimen, however, differs in a number of ways from the shallow water specimens in the E.A.M.F.R.O collection, and is described below. Schultz notes that off the Marshall and Mariana Islands *L. kasmira* is " very abundant " down to a hundred feet.

Malindi specimen. Dorsal fin count XII 13, anal fin count III 8. There is more scaling on the head, with 18 rows of cheek scales as compared with eight to ten, the scaling continuing further forward on the head, forward of the eye to below the posterior nostril. The black lateral line spot is absent.

Distribution. Natal ; East Coast of Africa ; Madagascar ; Indo-Pacific region to Tahiti.

Lutianus duodecimlineatus (C.V.). (Pl. VI A.)

Diacope duodecimlineata Cuvier & Valenciennes (1830), ? *Diacope duodecimlineata* Sauvage (1891), *Lutianus duodecimlineatus* Barnard (1927), *Lutianus duodecimlineatus* Fowler (1934), *Lutianus duodecimlineatus* Smith (1953).

Description.

Description based on one specimen of 150 mm. standard length.

Proportions : head 2·5 ; depth 2·5 ; pectoral 3·3 ; all in body length. Eye 3·7 ; inter-orbital 3·9 ; snout 3·1 ; all in head length. Sub-orbital into eye 1·4.

Dorsal fin count XI 13. Anal III 8.

Lateral line scales 54 (49). Seven scales from lateral line to mid-dorsal spines. Twelve rows of cheek scales. Scales on head begin above the front border of eye. Two rows of scales on sub-opercle. Scale rows on body run obliquely upward to dorsal profile above lateral line, below lateral line they are parallel to body axis.

Free pre-opercular edge finely serrate above and just below notch, which is deep and smooth. Lower limb of pre-opercle coarsely serrate. Inter-opercular knob distinct and pointed.

Both jaws with a weak outer row of conical incisors, slightly enlarged to form weak canines anteriorly in the upper jaw. Villiform bands inside the incisors, in the lower jaw anteriorly only. Sharp villiform vomerine teeth in a V without backward projection. A small band of villiform palatine teeth present. Tongue smooth.

Colour (preserved in formalin) pale yellow, with five dark (blue in life) lines on body ; upper most from head behind upper edge of eye to seventh dorsal spine ; second from upper edge of opercle to last dorsal spine ;

Lutianus bohar (Forskal). (Pl. VII A, B.)

Sciaena bohar Forskal (1775) ; *Mesoprion bohar* Gunther (1859) ; *Lutianus bohar* Day (1878–1888) ; *L. bohar* Barnard (1927) ; *L. bohar* Smith (1953) ; *L. gibbus* Smith (in part) (1953) ; *L. bohar* Schultz (1953) ; *L. bohar* Randall (1955).

Description.

Standard lengths 87 to 590 mm.

Proportions : depth 2·3 (s)–3·0 (l) ; head 2·6 (s)–2·8 (l) ; pectoral 3·2–3·6 ; all in body length. Eye 3·8 (s)–6·1 (l) ; inter-orbital 3·6 (l)–4·3 (s) ; snout 2·2 (l)–3·4 (s) ; all in head length. Sub-orbital into eye 0·7 (l)–2·3 (s).

Dorsal fin count X (rarely XI) 14. Anal fin count III 8 (rarely 9).

Lateral line scales 54 to 58 (48 to 50). Eight scales from the lateral line to the mid dorsal spines. Seven to eight oblique rows of cheek scales. Scales on occiput start above the posterior half of the eye. Scale rows ascend obliquely to the dorsal profile, above the lateral line under both soft and spinous dorsal fins. Scales below the lateral line run parallel to the body axis.

Pre-opercular flange serrate, finely above and coarsely below the notch, which is small, usually distinct, but sometimes wide and indistinct, always without serrations, never deep and narrow. The inter-opercular knob is a small smooth bony point facing upward and outward. Both knob and notch are faint or absent in the juvenile.

Outer strong row of conical incisors in the upper jaw, with one enlarged fanglike pair of canines anteriorly. A band of fine villiform teeth lies inside the caniniform row. Strong outer row of conical incisors in the lower jaw, with three or four pairs enlarged half way along the jaw to form strong canines. A fine villiform band lies inside the incisors anterior to the canines only Vomerine teeth fine, sharp, and backward pointing, in a V without posterior projection. Granular palatine teeth present in an elongate patch. Granular teeth present on tongue.

Colour in formalin or post mortem deep red above, shading to silver below. Two silvery spots on flanks, the anterior spot below the last four dorsal spines and the posterior pair under the last six dorsal rays, and meeting across the caudal peduncle. These spots are very distinct and large in the young, but in the adult become relatively smaller and less conspicuous, and are able to appear and disappear within short time intervals, presumably due to active chromatophores. In very large adults they may be completely absent. Eye orange-red. Spinous dorsal red, white fringed. Caudal red, fringed with white at the tips of the caudal lobes. Pectorals, upper half red, lower white, and dark brown in axils. Pelvic spine and first ray creamy white, remainder black anteriorly to pink posteriorly. Anal black anteriorly, red posteriorly.

Largest specimen seen, 20 pounds weight, 640 mm.

Ecological Note. *L. bohar* is commonly taken by handline on the outer, exposed reef edges, over bottoms with strong coral growth giving much shelter. In this type of habitat it can be found in depths from four to twelve fathoms. During underwater observation it has also often been seen inside the fringing reefs in five fathoms of water, near breaks in the fringing reef. Solitary juveniles of six inches are sometimes seen in shallow and more sheltered water and are occasionally caught by fine meshed local arrow-head traps.

L. bohar swims in small loose shoals of three to twelve fish continually on the move over and about coral shelter.

Distribution. East African Coast from the Red Sea to Natal; Indo-Pacific region as far east as the Tuamotu Archipelago and the Marquesas Islands.

Note. Smith (1953) plates under the name *L. gibbus* a large fish of about 750 mm., lacking the concave head, deeply forked tail, and deep pre-opercular notch of that species. This seems to be a typical large *L. bohar*, with its very robust body, and no margaritaceous flank patches.

Lutianus sanguineus (C.V.). (Pl. VIII A, B; IX A.)

Diacope sanguinea Cuvier & Valenciennes (1828); *Lutianus erythropterus* Day (1878–1888); *L. erythropterus* Barnard (1927); *L. sanguineus* Weber & De Beaufort (1936); ? *L. coccineus* Blegvad (1944); *L. sanguineus* Smith (1953).

Description.

Standard lengths 137 to 635 mm.

Proportions: depth 2·4 (s)–2·8 (l); head 2·4 (s)–2·9 (l); pectoral 3·3–3·7; all in body length. Eye 4·3 (s)–6·7 (l); inter-orbital 3·8 (l)–5·8 (s); snout 2·7 (l)–3·0 (s); all in head length. Sub-orbital into eye 0·6 (l)–1·09 (s).

Dorsal fin count XI 14. Anal fin count III 9 to 10.

Lateral line scales 56 to 59 (49 to 51). Eight scale rows from the lateral line to the mid-dorsal pines. Six to eight scale rows on cheek. A single row of inter-opercular scales. Scales on head begin behind vertical through posterior end of eye. Scale rows run obliquely upward above the lateral line, and parallel to the body axis or slightly upwards below the lateral line.

Pre-opercular flange finely serrate on the verticle limb above and through a shallow opercular notch. Small inconspicuous inter-opercular knob present.

Teeth very weak compared with most members of the genus, lacking the usually strong canines in the front of the upper jaw. Outer row of very weak conical incisors present in both jaws, a few slightly enlarged in the anterior part of the upper jaw. Inner bands of fine teeth in both jaws. Bristle-like vomerine teeth in a narrow V. Palatine teeth similar, in an oval patch. Lingual teeth absent.

Profile of head steep and straight in juveniles, but in adults a marked hump may develop directly above the eyes. In large specimens of 600 mm. this may be very marked, causing the head profile to become concave. (See Plate IX A.)

Colour of the adult (post mortem) a rich orange red with silver belly. Sometimes a brown bar down the occiput from the dorsal to the upper jaw, a remnant of the juvenile coloration. Eye pale red. Roof of mouth bright yellow, and yellow band inside teeth. Juvenile coloration distinct, with yellow body colour and brown occipital band marked and broad including eye. Dusky saddle on the posterior caudal peduncle, preceded by a margaritaceous patch. Sides of body covered in distinct fine red-brown lines parallel with the axis of the body.

Grows to at least 50 lb., and nearly a metre in length.

Ecological Note. Taken on certain coral banks in the Mafia group at dusk and at night from the fisheries vessel by handline, in five to seven fathoms. Never taken during the day. Juveniles caught in traps among *Cymodocea* beds in shallow water in the Zanzibar Channel and taken from the E.A.M.F.R.O. fish ponds at Chukwani, a mangrove area. Large adults taken off the southern end of Zanzibar Island in deep water (about 40 fathoms) by local fishermen in the early months of the year.

Distribution. East African Coast from Natal to the Red Sea; Indo-Pacific as far east as Melanesia ; Japan.

Lutianus sebae (C. & V.). (Pl. IX B ; X A.)

Diacope Sebae Cuvier & Valenciennes (1828) ; *Genyoroge sebae* Gunther (1859) ; *Lutjanus sebae* Day (1878–1888) ; *Lutjanus sebae* Barnard (1927) ; *Lutjanus sebae* Smith (1953).

Description.

Standard lengths 165 to 670 mm.

Proportions : depth 2·1 (s)–2·4 (l) ; head 2·3–2·6 ; pectoral 2·9 ; all in body length. Eye 4·9 (s)–8·4 (l) ; inter-orbital 4·1–5·2 ; snout 2·3 (l)–2·6 (s) ; all in head length. Sub-orbital into eye 0·4 (l)–0·8 (s).

Dorsal fin count XI 15 to 16. Anal fin count III 10.

Lateral line scales 54 to 56 (49 to 50). Six to seven scales from the lateral line to the mid-dorsal spines. Seven to eight rows of cheek scales. Scales on head begin above the posterior third of eye, or behind it in large specimens. Inter-opercle scaled, with the scales usually embedded in large specimens. Scale rows run obliquely upwards above the lateral line, and almost parallel to the body axis below it.

Preopercle finely serrate in and above notch, coarsely below it. Large adults (600 mm. body length) lose all serration. In the young, notch shallow, with inter-opercular knob small and indistinct. Both the notch and the knob develop with age, and large specimens of 20 lb. and over develop a deep smooth notch, and a blunt, finger-like inter-opercular knob.

Canines never strongly developed. Incisors conical, in a single row in each jaw, weak and sharp in the young, short and sturdy in the adult. Inner band of villiform teeth present in the upper jaw, but reduced to a small patch on either side of the symphysis in the lower jaw. Thin band of sharp, short vomerine teeth in a wide V. Similar palatine teeth in a short band. Lingual teeth absent.

Body colour (formalin preserved) silver white, with three broad, red-brown bands ; the anterior from the occiput through the eye to the upper jaw, the second band from the third to fifth to the pelvic fin and anus, and the third curving from the last two dorsal spines to the bottom of the caudal peduncle, continuing out on the lower caudal lobe. Soft dorsal and anal hyaline, black edged. Caudal hyaline with upper and lower caudal lobes black tipped. Pectorals hyaline, pelvics dusky.

With age the bands become paler, and the body colour a rich red. Large fishes show no trace of the three bands.

Grows to at least 60 lb. in East African waters.

Distribution. East coast of Africa from the Red Sea to Moçambique ; Indo-Pacific region as far east as Melanesia ; New South Wales.

Lutianus monostigma (Cuvier and Valenciennes). (Pl. X B.)

Mesoprion monostigma Cuvier & Valenciennes (1828) ; *Diacope monostigma* Klunzinger (1870) ; *Lutianus lioglossus* Day (1878–1888) ; *Lutianus monostigma* Schultz (1953).

Description.

Standard lengths 120 to 385 mm.

Proportions : depth 2·6–2·9 ; head 2·4 (s)–2·5 (l) ; pectoral 3·3–3·6 ; all in body length. Eye 4·2 (s)–5·2 (l) ; inter-orbital 5·0–5·8 ; snout 2·9 (l)–3·3 (s) ; all in head length. Sub-orbital into eye 0·8 (l)–1·3 (s).

Dorsal fin count X 12 to 13. Anal fin count III 8.

The anal and dorsal are weak spined and fairly low. Second anal spine always shorter than snout, and shorter than the third anal spine.

Lateral line scales 53 to 55 (47 to 48). Six scales from the lateral line to the mid-dorsal spines. Six rows of cheek scales. One row of inter-opercular scales. Scales on head begin above hind border of eye. Above the lateral line scale rows run obliquely upward under the dorsal fin, and below the lateral line are parallel to the body axis.

Pre-opercular flange finely and regularly serrate in juveniles, with wider serrations on the lower curve. Smooth in large adults. Notch a wide indistinct indentation, sometimes absent in adults. No inter-opercular knob.

Sharp conical incisors form the outer rows in both jaws. One large, fang-like pair of canines anteriorly in the upper jaw, and a few enlarged canines half way along the lower jaw. Vomerine teeth fine, in a V without a backward projection. Granular palatine teeth present in an elongate patch. Small patch of granular lingual teeth sometimes present.

Body colour (post mortem) grey, sometimes yellow, with faint darker lines following the scale rows. All fins yellow, the pelvics and anal a striking golden yellow. Eye silver. Distinct round black lateral line spot, more above than below the lateral line, relatively much smaller in adults and oval in shape.

Maximum size seen 385 mms. body length.

Ecological note. This species is only found about coral areas with much shelter. Unlike the closely allied *L. fulviflamma,* it is never seen in mangrove swamp and muddy creek areas. Adults are found about under large coral " rocks " in reef areas (Latham Island, Mafia Island, always close to shelter, and although a few may be found under one coral " rock " there is no clear shoaling behaviour, unlike *L. fulviflamma.* Juveniles are common about coral reefs in the Zanzibar Channel, in twos and threes. Economically not an important fish in East Africa, being rarely caught by fishermen.

Distribution. Red Sea ; East African Coast ; Seychelles ; Madagascar ; Indo-Pacific region as far east as the Tuamotu Archipelago.

Note. This species is closely allied to *L. fulviflamma* (Forskal) (see below) and to *L. russelli* (Bleeker). It differs from the latter in having 12 to 13 soft dorsal rays, not 14 to 15, and six to six-and-a-half scales between the lateral line and the median dorsal spines, not seven. Adult *L. russelli* have " six to seven longitudinal oblique golden stripes " in life, and " in young specimens three dark longitudinal bands " (Weber and De Beaufort 1936). These are absent in *L. monostigma.*

Lutianus fulviflamma (Forskal). (Pl. XI A.)

Sciaena fulviflamma Forskal (1775) ; *Mesoprion fulviflamma* Gunther (1895) ; *Lutianus fulviflamma* Day (in part) (1878–1888) ; *Lutjanus fulviflamma* Sauvage (1891).

Description.

Standard lengths 58 to 175 mm.

Proportions : depth 2·7–3·0 ; head 2·4–2·6 ; pectoral 3·2 (l)–3·9 (s) ; all in body length. Eye 3·4 (s)–3·7 (l) ; inter-orbital 4·2 (l)–6·0 (s) ; snout 3·3 (l)–4·8 (s) ; all in head length. Sub-orbital into eye 1·5 (l)–3·3 (s).

Dorsal fin count X (rarely XI) 12 to 13. Anal fin count III 7 to 8.

Second and third anal spines sub-equal. Second anal spine as long as or longer than snout.

Lateral line scales 52 to 58 (47 to 50). Six scales from the lateral line to the mid-dorsal profile. Six rows of cheek scales. One to three rows of inter-opercular scales. Scales on head begin at or behind vertical through hind border of eye. Scale rows run obliquely upward above the lateral line, and are parallel to the body axis below it.

Pre-opercular flange finely and regularly serrate on its vertical limb with the curve and lower limb coarsely serrate. Pre-opercular notch, absent, or occasionally an indistinct wide notch present. Inter-opercular knob absent.

Weak outer row of conical incisors in the upper jaw, with one or two pairs of strong canines anteriorly, and a band of sharp, back-pointing villiform teeth inside this row. Conical incisors in upper jaw moderate to weak, with three to four strong canines half way along jaw. A small patch of sharp villiform teeth present inside the incisors on either side of the symphysis. Vomerine teeth close set, sharp, and back-pointing, in an arrow-head shape, usually with an elongate posterior projection. Elongate patch of granular palatine teeth present. Tongue toothed.

Body colour (post mortem) yellow, dusky above to silvery below, with faint golden-brown longitudinal streaks following the scale rows. Head brownish above to silvery below. Eye pale yellow. Orange spot on upper pectoral base and orange on pre-opercular flange. All fins bright yellow except for posterior two pelvic rays. Caudal and dorsal faintly red-tipped. Lateral line spot oval with indistinct edges, often encircled by a pale area. Underwater photographs of adults show that in life a thick dark stripe is present from the tip of the snout to the eye. The lateral line spot is often indistinct or absent under water.

Seen up to about one and-a-half lb.

Ecological note. An abundant species in the East African coastal area, and an important food fish, taken by hand lines, traps and shore seines. It is found in mangrove swamp areas, estuaries, about coral, and inside and outside the fringing reefs. In underwater observations it is always seen in shoals, usually of ten to fifty individuals, and often in company with other Lutianids, especially *L. kasmira* and *L. lineolatus*.

Distribution. Found on the East African coast-line from the Cape (East London) to the Red Sea; Indo-Pacific region as far east as Polynesia; New South Wales.

Note. This and the preceding species are closely allied and structurally very similar, but with very different habits and habitats. *L. fulviflamma* seems able to colonise reef areas, estuaries, mangrove swamp channels, withstanding wide salinity, turbidity, and temperature ranges. It is an abundant and successful fish. *L. monostigma* is virtually restricted to coral reef areas, and then only those with large coral growths giving adequate shelter, and the numbers are a fraction of those of the former species.

Adults of the two species are very distinct, with *L. monostigma* developing a much longer snout, with relatively small growth of eye, giving ratios of eye length into head length of about five (*L. fulviflamma* 3·7) and of snout into head length of 2·9 (*L. fulviflamma* 3·3), and of sub-orbital distance into eye of 0·8 (*L. fulviflamma* 1·5). Juveniles are more difficult to distinguish however. The height of the fins is distinctive in the E.A.M.F.R.O. specimens, with *L. monostigma* having a lower dorsal and anal, commensurate with very much weaker spines. In *L. monostigma* at 120 mm. the second anal spine is shorter than the snout, in *L. fulviflamma* longer. Throughout the range of *L. monostigma* the second and third anal spines are weak, with the latter the longer. In *L. fulviflamma* the second anal spine is very sturdy, thicker and longer than the third. In this latter point the E.A.M.F.R.O. specimens do not agree with Weber and De Beaufort's descriptions.

The shape of the lateral line spot and its relation to the lateral line does not seem to be a valid difference between the two species as it is variable. In large specimens of *L. monostigma* it becomes oval, relatively smaller, and is often almost absent. It may disappear on preservation. In small specimens of *L. monostigma* up to 220 mm., the spot is large, round, and bisected about midway by the lateral line, usually leaving more black above than below the line.

L. fulviflamma has always an oval lateral line spot, usually more below than above the lateral line and often surrounded by a paler area.

Klunzinger states that the presence or absence of lingual teeth is a valid difference between these species. *L. fulviflamma* has always lingual teeth, and *L. monostigma* has usually a smooth tongue. On a few of the E.A.M.F.R.O. specimens, however, a small patch of granular teeth is present in the latter.

As noted by Klunzinger (1870) *L. monostigma* is a much larger species, reaching at least 420 mm. standard length, and maturing at about 350 mm. *L. fulviflamma* matures at 150 mm., and the largest specimens seen in East Africa were 220 mm.

Lutianus rivulatus (C.V.). (Plate XI B.)

Diacope rivulata Cuvier & Valenciennes (1828) ; *Genyoroge rivulata* Gunther (1859) ; *Lutianus rivulatus* Day (1878–1888) ; *Diacope rivulata* Sauvage (1891) ; *Lutianus rivulatus* Barnard (1927) ; *Lutianus gibbus* Blegvad (1944) ; *Lutianus rivulatus* Smith (1953).

Description.

Standard lengths 254 to 583 mm.

Proportions : depth 2·3–2·4 ; head 2·5–2·6 ; pectoral 2·8–3·0 ; all in body length. Eye 4·8–6·6 ; inter-orbital 3·8 (l)–4·2 (s) ; snout 2·4(l)–2·9 (s) ; all in head length. Sub-orbital into eye 0·5 (l)–0·9 (s).

Dorsal fin count X 15 to 16. Anal fin count III 8 to 9.

Lateral line scales 52 to 54 (47 to 49). Eight scales from the lateral line to the mid-dorsal spines. Six to eight oblique rows of cheek scales. Inter-opercle with a single row of scales, embedded in large specimens. Scales on head begin above hind end of eye. Scale rows above the lateral line run obliquely upward towards the body profile. Scale rows below lateral line parallel to the body axis.

Pre-opercular flange finely serrate above, and coarsely below the notch in small specimens, but becoming completely smooth in large adults. Notch distinct, wide and smooth, not deep and narrow. A moderate, blunt inter-opercular knob present.

Moderate outer row of conical incisors in each jaw, with a few anterior pairs slightly enlarged in the upper jaw, but without fang-like anterior canines. In large fish the incisors become blunt and peg-like. Inner bands of sharp villform teeth present inside the incisors, in the lower jaw anteriorly only. Fine vomerine teeth in a V without posterior projection. Palatine teeth villiform, in a narrow band. Lingual teeth absent.

Body colour (post mortem) grey, with a yellowish tinge dorsally, each scale with a distinct blue-grey spot. Head golden above, with fine wavy blue lines roughly parallel to the body axis. Lips white, maxilla yellow. Chalky lateral line spot present in young fish, but lost in adults.

Maximum weight seen 25 lb.

Ecological note.—This species does not appear much in the catches of the fisheries research vessel, nor in the local markets. In underwater observations, however, it is seen to be fairly common inside the fringing reef, and in the fairly sheltered water inside the southern tip of Zanzibar Island, swimming in midwater in small numbers or in larger shoals of about 15 fish, usually about large coral growths. It is often seen in composite shoals with *L. argentimaculatus* and *Spilotichthys pictus*. It has also been seen in the channel between Tutia Reef and Kibondo Island (Mafia group).

Distribution. East African coastline from the Red Sea to Natal ; Madagascar ; Indo-Pacific as far east as Polynesia ; Japan.

Note. From the blunt snout, wavy cheek lines, and blue dotted scales of Blegvad's *L. gibbus* description and plate (1944, page 107, and Plate IV, fig. 2) his fish seems to be clearly *L. rivulatus* and not *L. gibbus*.

Lutianus lineolatus (Ruppell). (Pl. XII A.)

Diacope lineolata Ruppell (1828) ; *Mesoprion lineolatus* Gunther (1859) ; *Lutianus lineolatus* Day (1878–1888) ; *Lutianus lineolatus* Blegvard (1944) ; *Lutianus lineolatus* Smith (1953).

Description.

Standard lengths 89 to 168 mm.

Proportions : depth 3·2 (l)–3·7 (s) ; head 2·6 (s)–2·8 (l) ; pectoral 3·4 ; all in body length. Eye 3·3–3·5 ; inter-orbital 3·7 (l)–4·9 (s) ; snout 3·7–4·0 ; all in head length. Sub-orbital into eye 2·8 (l)–3·7 (s).

Dorsal fin count XI 11 to 12 ; anal fin count III 8.

Lateral line scales 51 to 53 (45 to 47). Five scales from the lateral line to the mid-dorsal spines. Six to eight rows of cheek scales. Two to three rows of inter-opercular scales. Scales on head begin above the middle or the front of eye. Scales above lateral line run obliquely upward to the dorsal profile, the first few anterior scale rows often distinctly sinuous. Scales below lateral line parallel to the body axis, but curving slightly upward on the caudal peduncle.

Pre-opercular flange in young fish finely serrate on the vertical limb, and coarsely serrate on the curve and lower limb. These serrations are gradually lost in larger fish. No notch or inter-opercular knob present.

Weak outer row of conical incisors present in each jaw, the upper with one enlarged pair of canines anteriorly, the lower with two to three strong canines half way along jaw. Inside the upper incisor row is a thin villiform band of teeth, the anterior teeth of which are curved back and slightly longer than the others. Anteriorly the lower jaw has a thin band of villiform teeth inside the incisors. Vomerine teeth, villiform, sharp, and curved back, forming an arrowhead with a long posterior projection. Tongue toothed.

Colour (preserved in formalin) yellow above and silvery below, with orange-brown lines following the scale rows on the back and sides. One wider fawn line runs along the side from the upper third of the eye to the caudal peduncle. Fins hyaline. Yellow spots present at the bases of the dorsal spines.

Ecological note. This is a common species of exposed coral reef areas, usually in large shoals of thirty to a hundred, sometimes swimming together with shoals of *L. fulviflamma* and *L. kasmira*. Not seen in mangrove inlet areas, nor commonly inside the fringing reef.

Maximum size seen, about three-quarters of a lb.

Distribution. East African coastline from the Red Sea to Moçambique ; Indo-Pacific region as far east as Guam Island.

Lutianus vaigiensis (Quoy and Gaimard). (Pl. XII B.)

Diacope vaigiensis Quoy & Gaimard (1824) ; *Genyoroge marginata* Gunther (1859) ; *Lutianus marginatus* Fowler (1828) ; *Lutjanus vaigiensis* Fowler (1931) ; *Lutianus vaigiensis* Smith (1953) ; *Lutjanus vaigiensis* Schultz (1953) ; *Lutjanus vaigiensis* Randall (1955).

Description.

Standard lengths 101 to 225 mm.

Proportions : depth 2·3–2·5 ; head 2·4–2·5 ; pectoral 3·0 (l)–3·6 (s) ; all in body length. Eye 3·6–5·7 ; inter-orbital 4·5–5·3 ; snout 3·0–3·4 ; all in head length. Sub-orbital into eye 1·0–1·7.

Dorsal fin count X 13 to 15 ; anal fin count III 8.

Lateral line scales 53 to 55 (47 to 48). Seven scales from the lateral line to the mid-dorsal profile. Six to seven rows of cheek scales. Interopercle with one row of scales. Scales on head begin behind eye.

Pre-opercular flange finely serrate above and coarsely below a moderate to deep notch. Pointed inter-opercular knob present.

Upper jaw with a weak outer row of conical incisors, three pairs enlarged to form weak, back-curved canines. Inside this row a band of villiform teeth, four to five rows deep. The lower jaw with a weak outer conical incisor row, close-set posteriorly, with two to four pairs slightly enlarged half way down the jaw, and a small patch of fine villiform teeth on either side of the symphysis anteriorly. Vomerine teeth sharp, back-curved, fine, set in a V. Villiform palatine teeth present in an elongate patch. No lingual teeth present.

Body colour (post mortem) : Bronze or roseate, with longitudinal narrow golden lines, six strongly defined, with thinner ones between these. The longitudinal lines are also clearly seen in underwater photographs of living fish. Flecks of gold on the cheeks. Pectoral, pelvics, and anal yellow, the latter white edged. Dorsal and caudal dark grey, the soft dorsal and caudal dusky sub-marginally, and with a distinct white marginal rim. Juvenile coloration (100 mm. standard length) as in the adult, but with the pectorals hyaline, pelvics bright yellow, and the whole dorsal black beneath the white marginal rim, not proximally paler.

With formalin preservation the golden body lines fade, but the submarginal duskiness and the white rim remain distinct.

Maximum size seen in East Africa, about one lb.

Ecological Note. Not a common fish in this area. Occasional specimens are caught by local fishermen. Occasionally seen about coral reefs in the Zanzibar Channel, and inside the fringing reef on the Zanzibar east coast. Seen in the Mafia area in exposed coral areas, but not common. Usually seen singly or in pairs, and sometimes in conjunction with small numbers of *L. monostigma.* Juveniles have been taken from fish ponds at Chukwani (Zanzibar), a mangrove area.

Distribution. East African coastline as far south as Natal ; Indo-Pacific to the Tuamotu Archipelago ; northern Australia.

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EXPLANATION OF PLATES.

PLATE IV.

A. *Lutianus ehrenbergi* (Peters). Length 70 mm.
B. *Lutianus argentimaculatus* (Forskal). Length 140 mm.

PLATE V.

A. *Lutianus argentimaculatus* (Forskal). Length 730 mm.
B. *Lutianus kasmira* (Forskal). Length 200 mm.

PLATE VI.

A. *Lutianus duodecimlineatus* (C. V.). Length 155 mm.
B. *Lutianus gibbus* (Forskal). Length 305 mm.

PLATE VII.

A. *Lutianus bohar* (Forskal). Length 228 mm.
B. *Lutianus bohar* (Forskal). Length 585 mm.

PLATE VIII.

A. *Lutianus sanguineus* (C. V.). Length 114 mm.
B. *Lutianus sanguineus* (C. V.). Length 230 mm.

PLATE IX.

A. *Lutianus sanguineus* (C. V.). Length 600 mm.
B. *Lutianus sebae* (C. V.). Length 270 mm.

PLATE X.

A. *Lutianus sebae* (C. V.). Length 595 mm.
B. *Lutianus monostigma* (C. V.). Length 385 mm.

PLATE XI.

A. *Lutianus fulviflamma* (Forskal). Length 200 mm.
B. *Lutianus rivulatus* (C. V.). Length 480 mm.

PLATE XII.

A. *Lutianus lineolatus* (Ruppell). Length 175 mm.
B. *Lutianus vaigiensis* (Quoy & Gaimard). Length 250 mm.

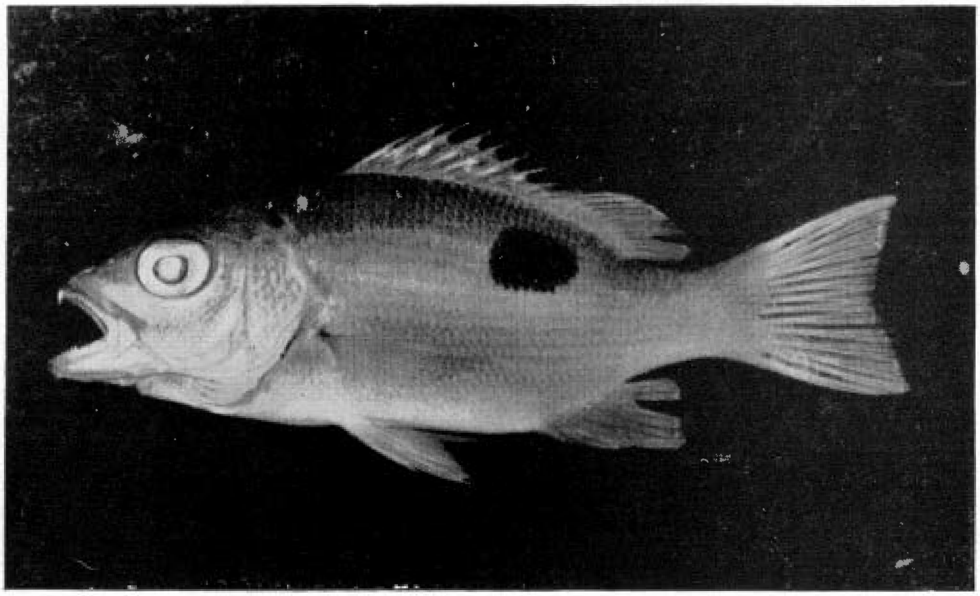
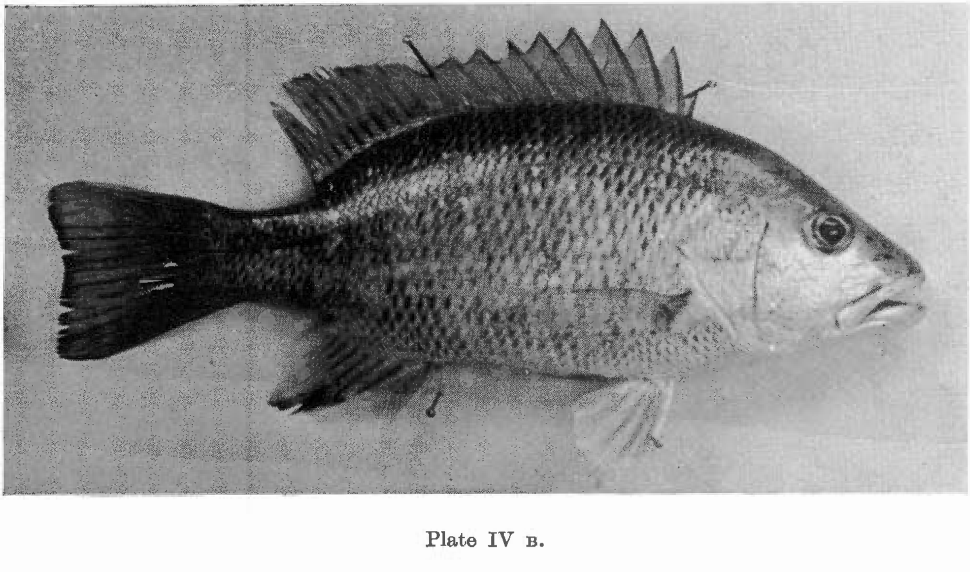


Plate IV A.



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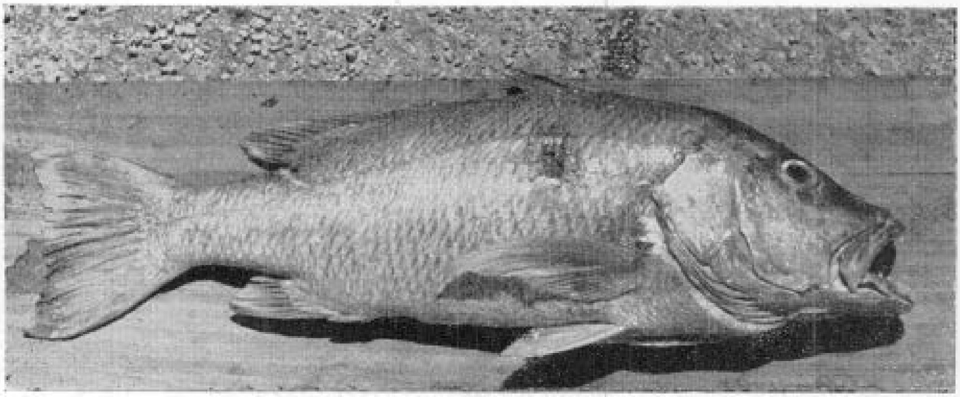

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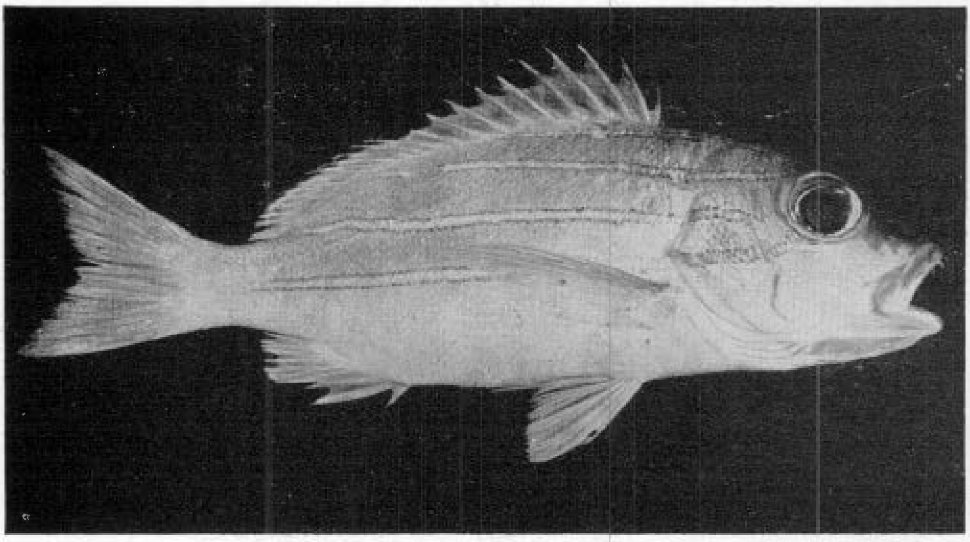

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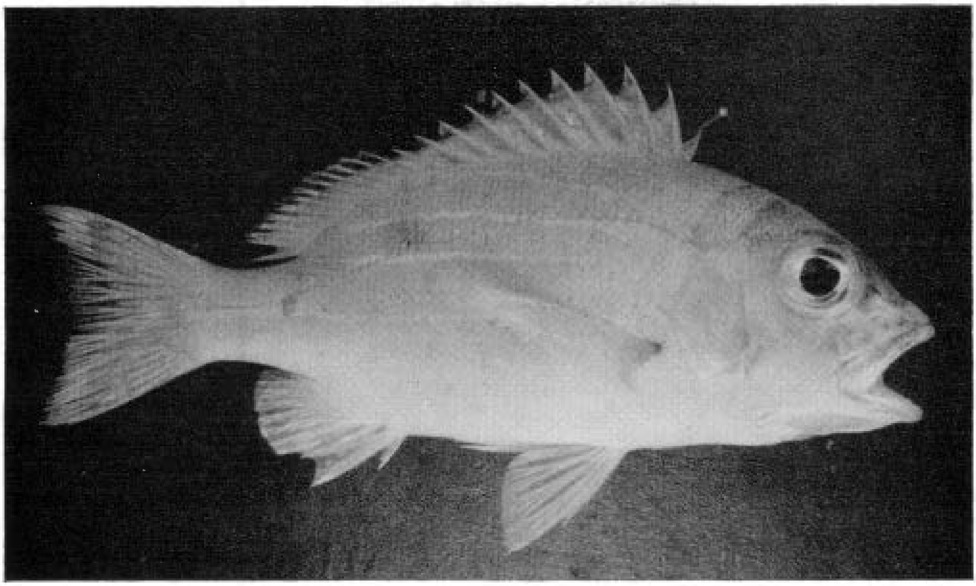

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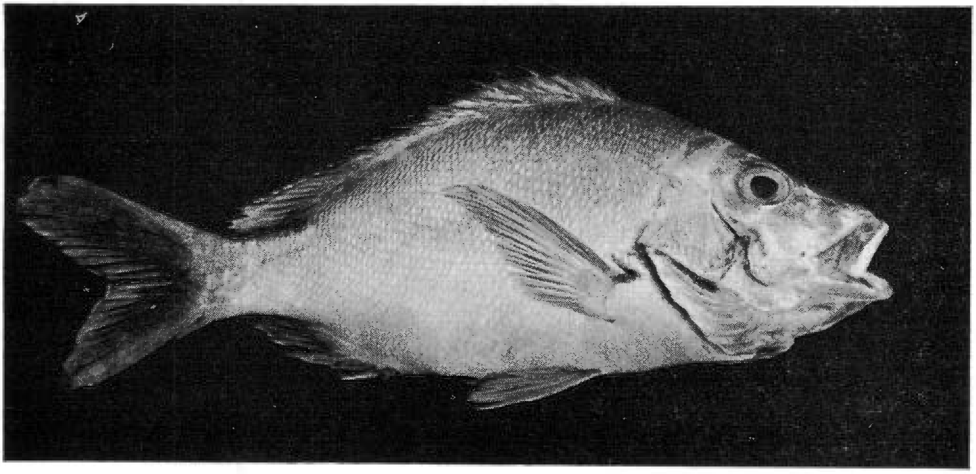
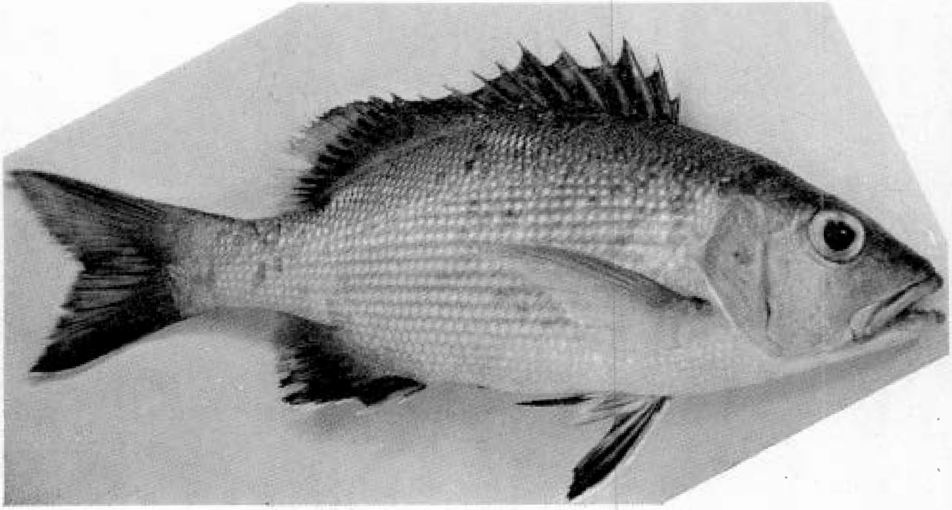


Plate VI B.

TALBOT. *Ann. & Mag. Nat. Hist. Ser. 12. Vol. X. Pl. VII.*



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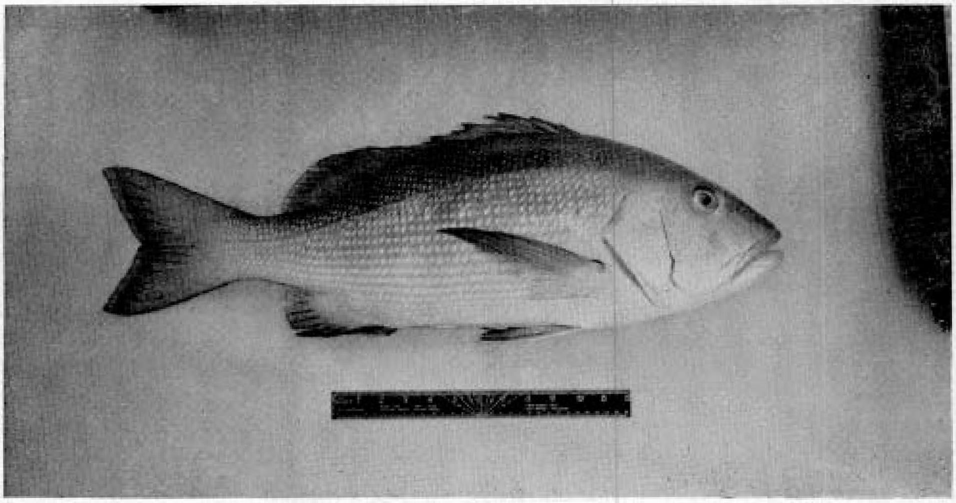
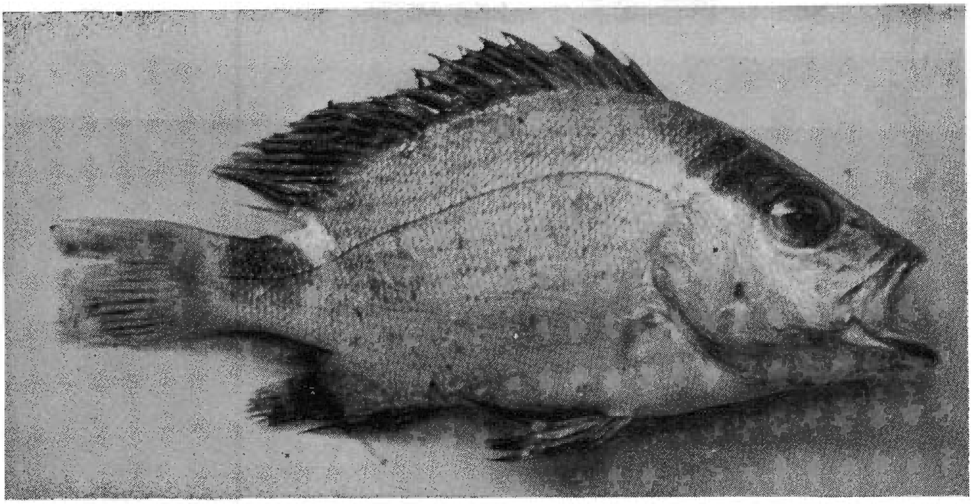


Plate VII B.



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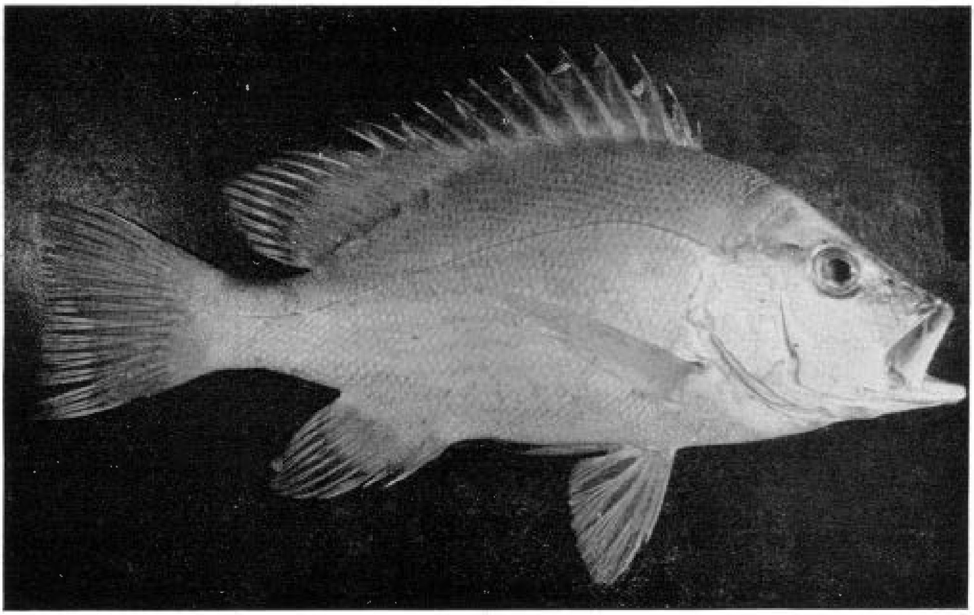


Plate VIII B.

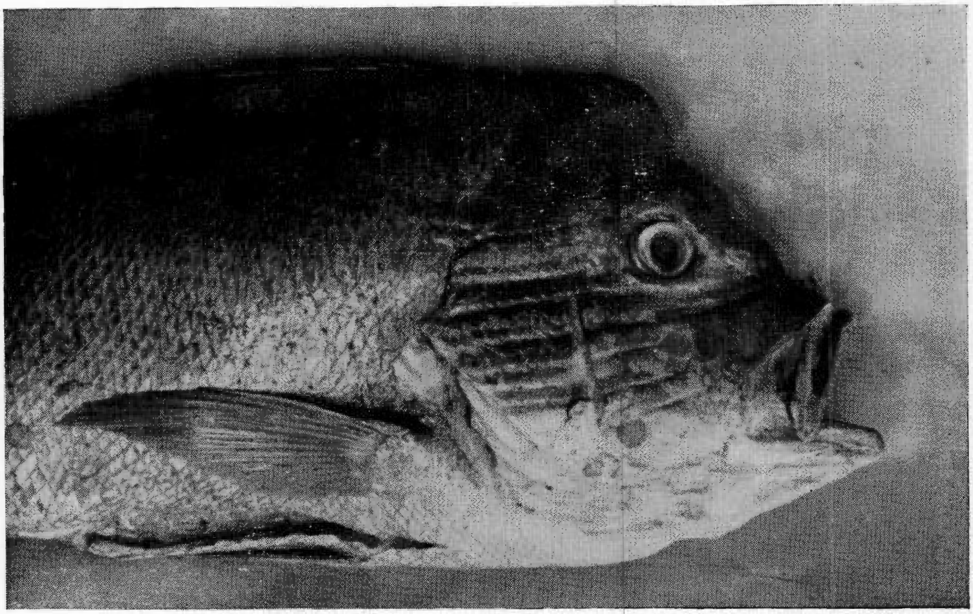


Plate IX A.

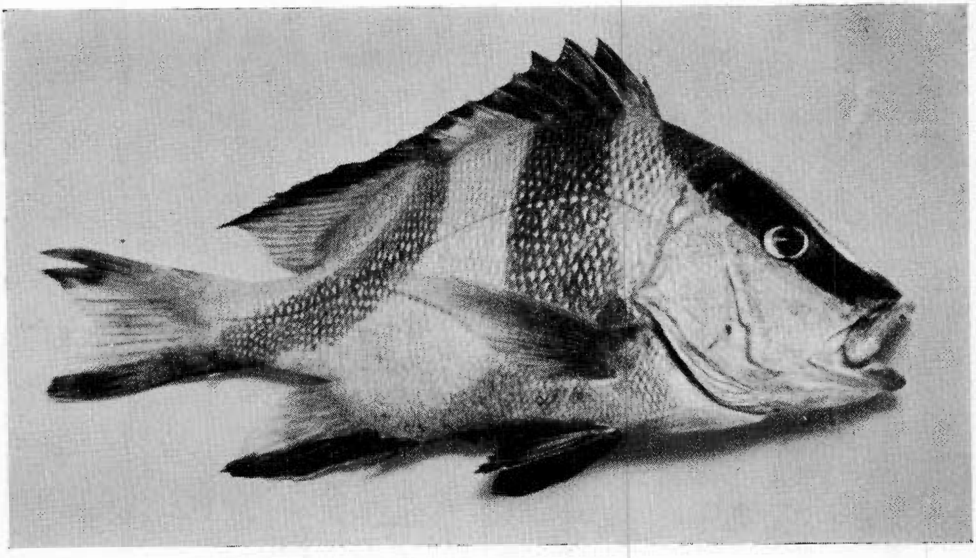


Plate IX B.

TALBOT. *Ann. & Mag. Nat. Hist. Ser. 12. Vol. X. Pl. X.*

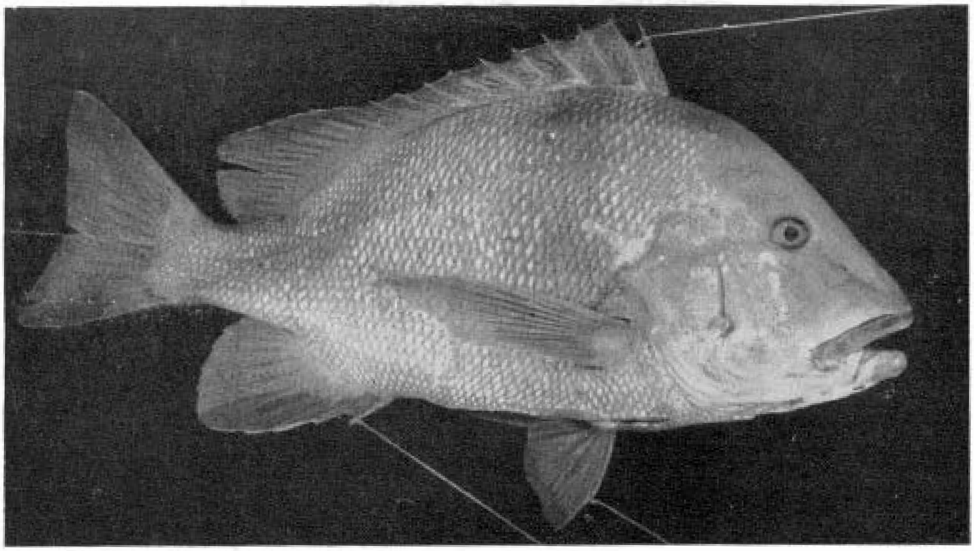


Plate X A.

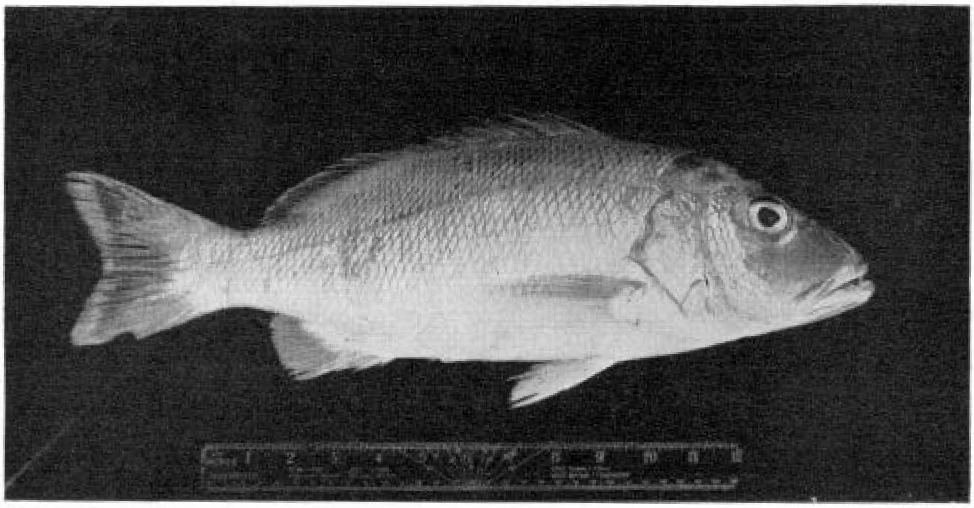


Plate X B.

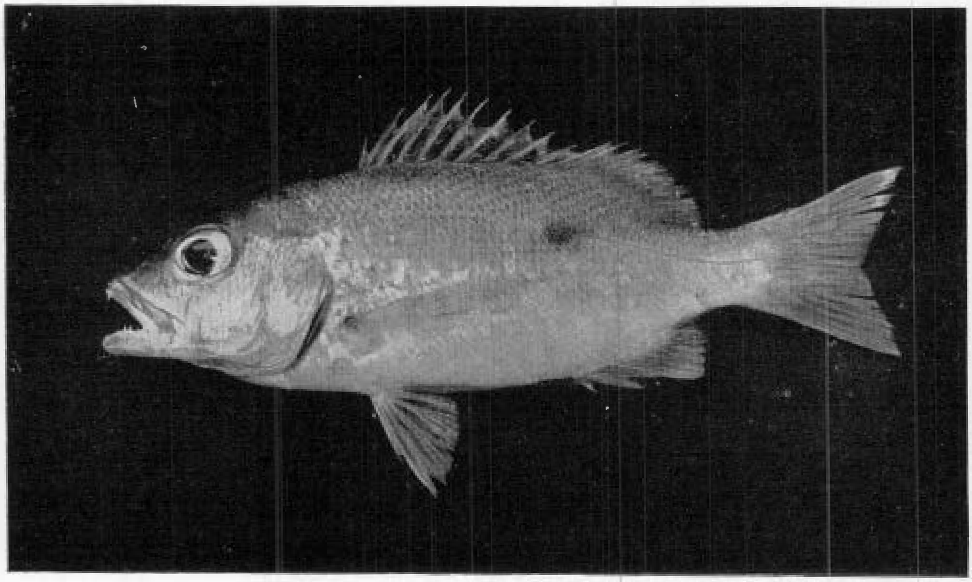
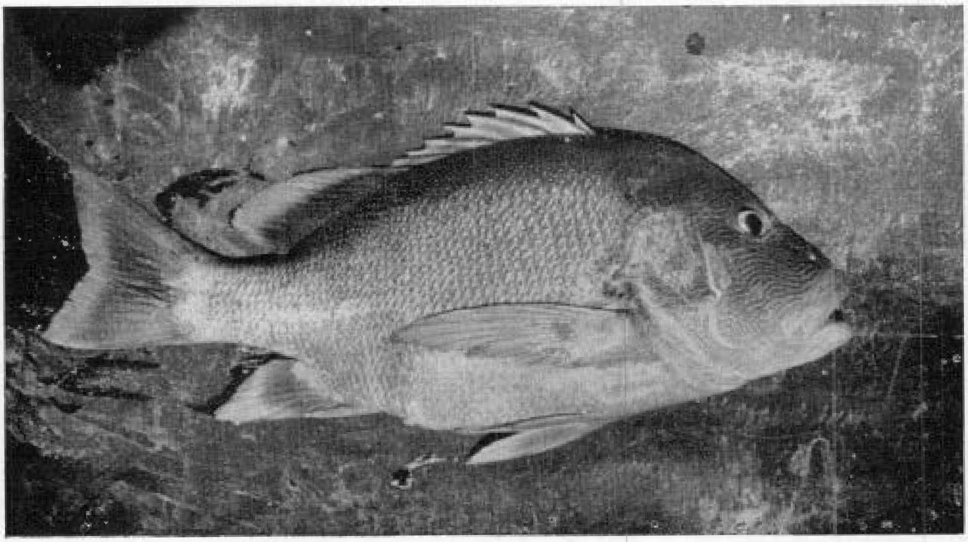


Plate XI A.



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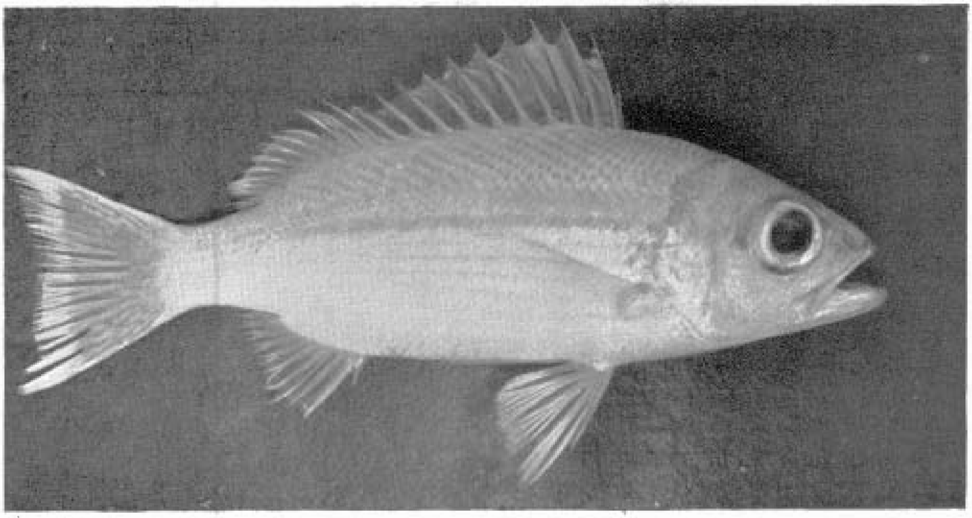

Plate XII A.

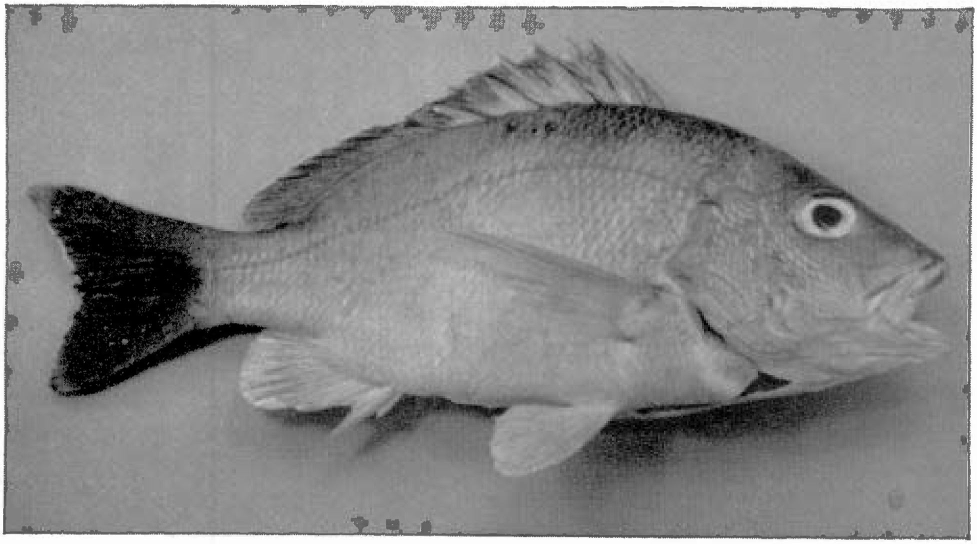

Plate XII B.

ANNALS

OF THE

SOUTH AFRICAN MUSEUM

VOLUME XLV

PART V, *containing*:—

Notes on the Biology of the Lutjanidae (Pisces) of the East African Coast, with special reference to L. bohar (*Forskal*). By F. H. Talbot, M.Sc. (With 5 figures in the text.)

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NOTES ON THE BIOLOGY OF THE LUTJANIDAE* (PISCES) OF THE EAST AFRICAN COAST, WITH SPECIAL REFERENCE TO *L. BOHAR* (FORSKAL)

By F. H. Talbot, M.Sc.

(With 5 figures in the text)

INTRODUCTION

Lutjanid material for this study has been obtained during routine fishing from 1954 to 1957 inclusively, by the research ship M.V. *Research* and her replacement the M.V. *Manihine* of the East African Fisheries Research Organization, Zanzibar, while the author was a member of this Organization. During this period a study of bottom fishes was made, mainly in coral reef areas of from 3 to 14 fathoms, and also to a lesser extent in deeper water below the coral reef zone down to 100 fathoms. The work has centred on the reefs off Lamu on the Kenya coast, in the Mafia Archipelago off the Tanganyika coast, and on Latham Bank, a shallow bank surrounding a small island south-west of Zanzibar (see fig. 1). Handlines, gill-nets, trammel-nets, set-lines, basket-traps, underwater spearing, and explosives have been used for collecting. In addition fish were occasionally obtained from the local markets on Zanzibar Island. Information on Lutjanids from the unpublished East African Marine Fisheries Research Organization records from 1951 to 1953, and for 1958, has also been used by courtesy of the Director.

This paper is one of a series on hydrographic conditions, Newell (1957, 1959); fish systematics, Morgans (1958), Talbot (1957, 1958), Talbot and Williams (1956), Williams (1958a, 1959a and b); and fish biology, Talbot and Newell (1956), Williams (1953, 1956, 1958b), Williams and Newell (1957), providing some preliminary data on the systematics, distribution and biology of East Coast fishes of economic importance. A full description of the topography of the area is given in Williams, 1956. In this paper the systematics of the genus *Pristipomoides* is based on Smith (1954) and the systematics of the genus *Lutjanus* follows that used in a previous communication (Talbot, 1957).

The East African coastal area over which this study was made is markedly affected by the monsoon winds. In all seasons of the year it is bathed by the

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* Both the spellings *Lutjanus* and *Lutianus* are in current use. The first nomenclatorially valid use of the generic name is in Bloch, 1790, *Nat. ausl. Fische*, **4**, p. 107, in the description of *Lutjanus lutjanus*. Cuvier, 1798, *Table. elem.*, pp. 357 and 705, uses *Lutianus* (as does Bloch occasionally after this date), and this is the form used by Jordan and Everman in their *Genera of Fishes*, Stanford Univ., 1917, with the footnote 'Also spelled *Lutjanus*'. As *Lutianus* has not been universally accepted it seems better to return to the original form *Lutjanus*.

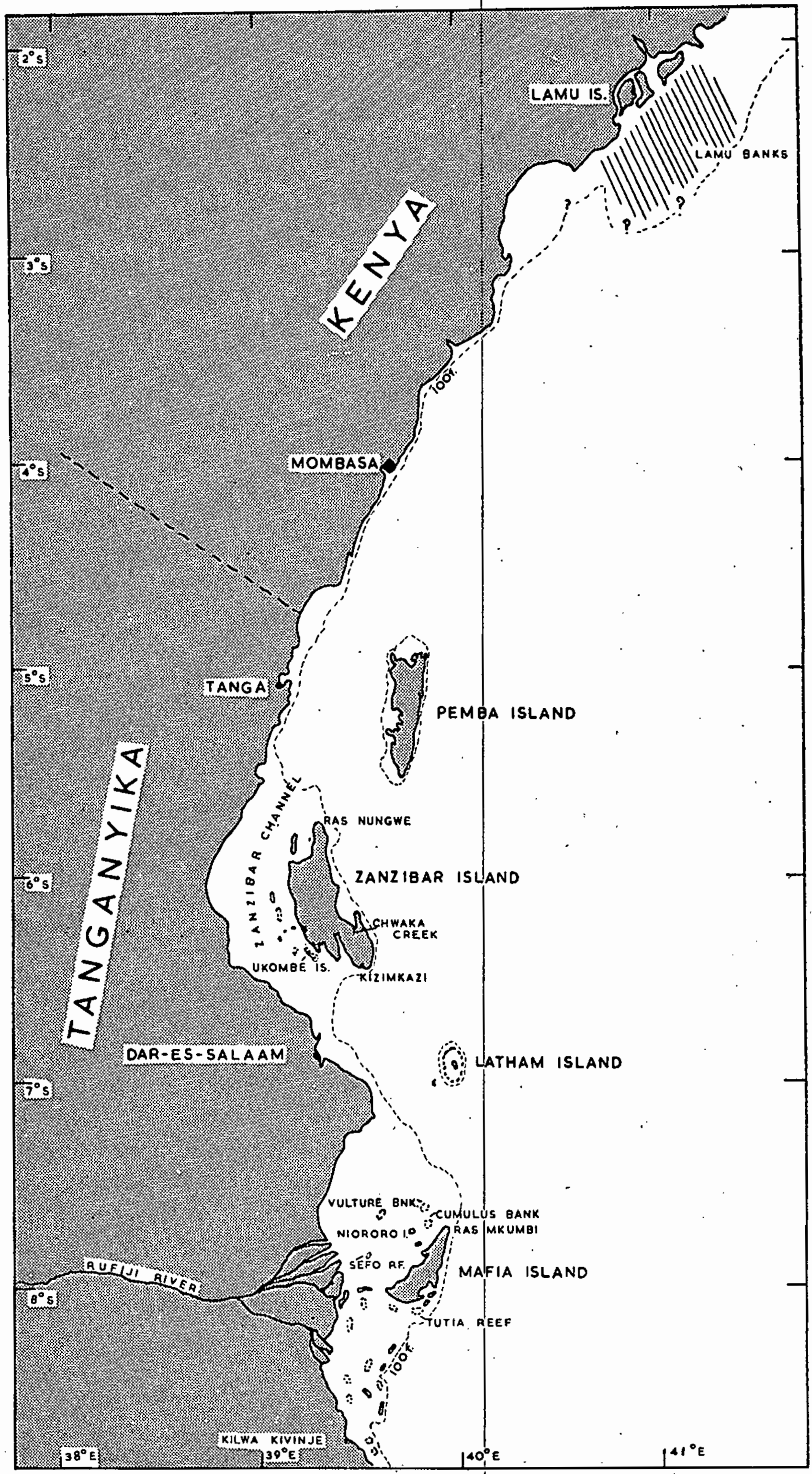

Fig. 1

Chart of the coastal areas where Lutjanids were collected. (From British Admiralty Chart 597.)

north-flowing East African Coastal Current, but from May to October ('winter', if one may talk of summer and winter so close to the equator) the strong south-east monsoon wind speeds up the current to 3–4 knots, and increases vertical mixing of the upper layers, lowering the thermocline to 50 fathoms. The surface temperature in this period is about 24°C.–25°C. In summer (November to April) the wind system is reversed, and the moderate north-east monsoon wind slows up the East African Coastal Current to 1–2 knots. Much less surfacing mixing takes place, and a very stable surface layer is formed with a marked thermocline at about 25 fathoms, and a surface temperature of 27°C.–29°C.

Although the majority of species mentioned here are widespread over the Indo-Pacific region, and many are found from the South African coast up to the Red Sea and across to Polynesia and the Tuamotu Archipelago, some 10,000 miles to the eastward, apart from systematics little or nothing has been published about their biology except some recent data on habits and habitats in systematic papers by American workers aided by U.S. Navy grants (Randall 1955, Schultz 1953, Harry 1953), and the Mauritius Seychelles Fisheries Survey undertaken by Wheeler and Ommanney (1953).

The latter authors, in a survey of the coral reef areas lying between Mauritius and Seychelles, obtained seven species of Lutjanids, all of which are also found on the East African coastline. Of these seven species four were seldom caught, but useful data were obtained on the remaining three: *L. bohar* (Forskal) (*L. civis* (C. & V.) of their report), *Aprion virescens* Valenciennes, and *L. sebae* (Cuvier).

In tropical coral areas the catches comprise many more species than do those of temperate waters, but the numbers of fish of each species are far smaller. In this survey it was difficult to obtain large enough samples of each species. With small numbers many established fishery techniques (such as deductions from length-frequency distribution) cannot be used.

Underwater observations using a Seibe-Gorman aqualung were made on Latham Bank, about Zanzibar Island, in the Zanzibar channel, and in the Mafia Archipelago, and showed that two species (*L. monostigma* and *L. vaigiensis*) were common on these reefs although they were very rarely taken by normal fishing methods. Small samples of these were collected by spear-guns. These observations also gave a much more accurate picture of relative abundance of species than did the use of handlines, nets, traps, etc., and some notes on habits were obtained. It was found that the method was strictly limited in its usefulness however, for an underwater observer with his trail of bubbles could not remain hidden, and had a marked effect on the fishes. Many of the smaller reef species are attracted by the aqualunger, who may become surrounded by shoals of small fishes. Often also the larger predators such as *Plectropomus maculatus* will come closer and inspect the unusual object from mid-water. Among the Lutjanids these effects can also be seen. *Aprion virescens* will often approach close to the diver before continuing down the reef. A shoal of

L. gibbus will move off or take shelter. *L. bohar* after a short time will usually leave the immediate reef area. Observation is therefore not of a normal undisturbed reef and its fish fauna—the 'observer' has influenced the fish population, and normal movements and feeding may not be taking place. This does not imply that the method of underwater observation is not useful. On the contrary, it is an obvious and developing method which will have important uses in ecology and ethology (see Reidle 1956). For coral reef observation however some 'hide' method must be used.

That scale rings occur in tropical marine fishes has been shown by a number of workers (summarized in Menon, 1953). The variation in surface temperatures from 24°C. to 29°C. between summer and winter in the East African area might be reasonably considered to be enough environmental change to affect the formation of annual rings. As is shown below, however, consideration of *L. bohar* scale edges with season did not bear this out.

Both scales and otoliths of *L. bohar* were examined for ringing. The otoliths showed no clear opaque and translucent zones even on grinding, and although the surface of the otoliths showed concentric ridges which gave the same counts as the scale rings in young fishes, in older fishes they were difficult to count due to crowding towards the periphery, and were also possibly covered over near the nucleus by further growth. Only the scales are therefore considered here. Scales of 273 *L. bohar* were examined, and of these approximately one in four showed rings considered clear enough to be counted, although rings of more or less clarity were present in all fish. On an average four scales per fish were counted, and scales from the same fish with few exceptions showed the same number of rings at similar relative distances from the scale nucleus. It was found that individuals of a single sample of fish, taken from the same bank at the same time did not necessarily have the outermost ring at a similar distance from the periphery, showing that the rings were not all formed at the same time of year in all fish. This suggests that the rings that do form are due to spawning, and not to seasonal changes. With checks forming at different times of year with different fish it is impossible to test whether the rings are annual by the method of watching the periphery of the scales of samples of fish periodically during the year.

Forty scales were re-read a year after first reading to check error. Of these 19 were re-read exactly as in the first reading, 12 disagreed by one year, and 9 by more than one year. These discrepancies are due to faint rings being either considered as false checks or true annuli. This error can be stated thus: in about 47% of scales used here reading error is negligible; and in about 78% of scales an error of ± 1 ring may be present. If it is realized that the scales being read here are already only those showing the clearest rings (one-quarter of the total) it is obvious that the clarity of ringing does not approach that of many temperate species. Clark (1958) for example in the re-reading of young haddock samples by the same worker obtained 90% and 93% similarity. Nevertheless in many specimens of *L. bohar* consistent ringing is present in the scale structure, due to some regular change in the metabolism of the fishes. It is possible that these periodic changes are not annual, but their regularity suggests that they will be found to be connected with the spawning cycle or be due to periodic feeding changes. As has been suggested above, the former is the more likely answer. Wheeler (in Wheeler and Ommanney, 1953) has suggested that *L. bohar* spawns twice a year. As will be seen in this report the results from East African coastal fish rather suggest an extended breeding season in the warmer months. Lacking evidence to the contrary the ringing here seen is considered as annual.

Description of Gonad Condition

Gonads were described macroscopically in the fresh condition as the fish were gutted on board. For females a system based on seven stages was used (after Bowers, 1954). For males five stages were discernible.

Males:
- I. *Immature.* Gonad small, usually threadlike, no sperm extruded on cutting and squeezing.
- II. *Mature unripe.* Gonad small, sperm extruded on cutting and squeezing.
- III. *Ripe.* Gonad enlarged and full of sperm.
- IV. *Ripe running.* As above, but milt extruded on pressure to flank.
- V. *Spent.* Testis shrunken, not full and round, little sperm.

Females:
- I. *Immature.* Ovaries small and threadlike, eggs microscopic.
- II. *Mature unripe*, or *Virgin maturing.* Gonad of moderate size, eggs microscopic, gonad often translucent. The two stages may sometimes be distinguished as there may be remains of corpora lutea in the mature fish visible as small orange flecks in the ovary.
- III. *Mature ripening.* Ovary of moderate size, eggs visible to the naked eye, opaque.
- IV. *Nearly ripe.* Ovary enlarged and extended, eggs clearly visible, opaque.
- V. *Ripe.* Ovary enlarged and distended, tunica breaks easily, some eggs transparent.
- VI. *Ripe running.* Nearly all eggs transparent, eggs extrude on slight pressure to flank.
- VII. *Spent.* Ovary flaccid, shrunken, and with some residual eggs.

Although stage II males are called mature unripe it seems probable that sperm may be present in the testis before the fish are capable of mating, as in *L. bohar* a very small gonad holding some sperm may be found in fish of about

200 mm. but the first males found with enlarged ripe gonads were of a much greater size than this. State II contains both virgin developing males, and mature males in resting condition. No macroscopic difference was noticed between the two.

Species	*No. Examin.*	*Immature*	*Mature*
Lutjanus bohar (Forskal)	854	443 (150–439 mm.)	411 (440–660 mm.)
Aprion virescens Valenciennes	259	18 (202–452 mm.)	241 (460–800 mm.)
Lutjanus rivulatus (Cuvier)	129	4 (395–449 mm.)	125 (450–640 mm.)
L. fulviflamma (Forskal)	126	41 (51–159 mm.)	85 (160–220 mm.)
L. gibbus (Forskal)	121	10 (170–219 mm.)	111 (220–355 mm.)
L. sanguineus (Cuvier)	102	39 (170–479 mm.)	63 (480–650 mm.)
L. kasmira (Forskal)	77	—	77 (125–205 mm.)
L. sebae (Cuvier)	27	12 (128–489 mm.)	15 (490–665 mm.)
L. monostigma (Cuvier)	18	7 (275–349 mm.)	11 (350–420 mm.)
L. argentimaculatus (Forskal)	13	9 (300–459 mm.)	4 (460–630 mm.)
		Size Range	
Pristipomoides microlepsis Bleeker	12	260–640 mm.	
Lutjanus ehrenbergi (Peters)	6	44–98 mm.	
L. vaigiensis (Quoy and Gaimard)	6	200–250 mm.	
L. lineolatus (Ruppell)	5	120–175 mm.	
Pristipomoides typus (Bleeker)	1	525 mm.	
Aphareus rutilans Cuvier	1	780 mm.	
Lutjanus duodecimlineatus	1	150 mm.	

TABLE I

A list of the Lutjanids taken during the survey, with the proportions of mature to immature fish. (For the commoner species the smallest length at which mature fish were found is used for a division into 'mature' and 'immature' fishes in the table.)

Lutjanus bohar (Forskal)

L. bohar is one of the commonest predators of exposed coral reefs in the East African coastal area. The majority of specimens were taken by handline, but the species was also taken in basket traps, trammel nets, and very occasionally on trolled lures. It is fairly common in local markets, seldom in abundance, but present in regular quantities throughout the year. Wheeler and Ommanney (1953) took larger numbers and a greater total weight of this species than any other on the Mauritius-Seychelles banks.

This species sometimes causes ciguatera poisoning in the Mauritius area and is banned in the markets there. Harry (1953) states that in Raroia Atoll of the Tuamotu Archipelago 'large adults of *L. bohar* are poisonous, and natives know to a few inches of length when an individual is poisonous or not'. Randall (1958) in his review of ciguatera mentions this species as causing poisoning in a number of areas. Whitley (1943) in his list of poisonous fishes of Australia includes the closely allied (perhaps synonymous) *L. coatsi*. In spite of this there is no record known to the author of this species being considered poisonous in the East African coastal region, and both there and in the Seychelles (Wheeler and Ommanney, 1953) *L. bohar* is considered a prime market species. Randall's suggestion that this type of poison enters the fish through one of its foods, probably a blue-green alga, is consistent with the species being poisonous in some areas and not in others.

Handlining showed this species to be common on exposed areas with actively growing coral in from 4 to 15 fathoms. Adults were seen underwater on the outer slope of the fringing reef, and entering into gaps in the fringing reef where these were deep (five to seven fathoms), but were not seen in areas where the channel was shallower than this, or on the reef flat at high tide, (see figs. 4 and 5). Juveniles of about 100 mm. were seen in and about coral where the fringing reef channel was under 5 fathoms deep. On the outer edge of Tutia Reef and on Latham Bank the species was usually seen in loose and actively moving shoals of about two to seven fish, over coral in mid-water in 3 to 10 fathoms. Underwater observation did not go deeper than this. Shoals were loosely knit, and seemed to break up and rejoin, with no tight cohesion as with many other species of the genus. What shoaling instinct there was, however, results in the species being more often seen in twos and threes than singly. Unlike many related species which may stay around one coral head for the time observed (maximum 2 hours), *L. bohar* is continually on the move, as though actively searching for food over wide areas. Actual feeding has not been observed underwater.

L. bohar was also found to be common in deep water of the Kenya coast in the region of Lamu (see fig. 1). In this area the continental shelf is wider than in most of the East African coastal region, and rich populations of fishes were found on grounds approximately 25 to 65 fathoms deep. *L. bohar* was caught from 25 to 46 fathoms, but where a bathythermograph was used while fishing it was never found below the major thermocline, which varies from 25–50 fathoms with season (Newell, 1957). The dominant species in these rich populations were *Lutjanus bohar*, *Lutjanus rivulatus*, *Epinephelus undulosus*, *Lutjanus sanguineus*, *Lethrinus waigiensis*, and *Lethrinus kallopterus*, in order of abundance (Williams, 1958).

Sampling showed that this species is present on the reefs at all times of year and showed no evidence of migrations. Underwater observations proved that on certain small reefs the species could be present at one visit and not at the next.

FEEDING

Of the 854 *L. bohar* examined, 58% of the fish caught had empty stomachs or contained only bait. Table II lists the food organisms found in *L. bohar* stomachs. The species is a euryphagous predator, feeding basically on fish (see fig. 2), but capable of eating crawfish, crab, prawn, squid, octopus, ophiuroids and even pelagic pteropods, doliolids and pyrosomas when these are abundant in the plankton. Although a wide variety of small reef fishes was the main food over the period of study, at certain times when there was an abundance of any one organism the samples contained nothing but these organisms. This was clearly seen in two samples from North Mafia Bay

(Cumulus Bank), and once in a deep-water sample from Lamu. In December 1952 a large proportion of the samples from these two banks was packed with Penaeid prawns, probably migrating to or from the mangrove areas of the huge Rufiji delta. In November 1953 there was an unusually large amount of a larval Stomatopod in the Mafia-Latham Island area. These were seen swimming on the surface at night, and almost everything caught from bottom-dwelling Epinephelids to pelagic Sphyraenids contained them. All *Lutjanus* *bohar* from Vulture, Cumulus and Latham Banks were full of Stomatopod remains. In one particular sample (14–19 November 1956) of the many taken from deep water off Lamu, *L. bohar*, *L. sanguineus*, *L. rivulatus*, *Aprion virescens* and one species of *Ephinephelus* all contained salp tests. Otherwise salps were not a common item of food in any of these species. *L. bohar* then follows the general pattern that most predatory species at any one time will eat the commonest foods available to them in their particular habitats (Stephen 1930, Allee *et al.* 1949).

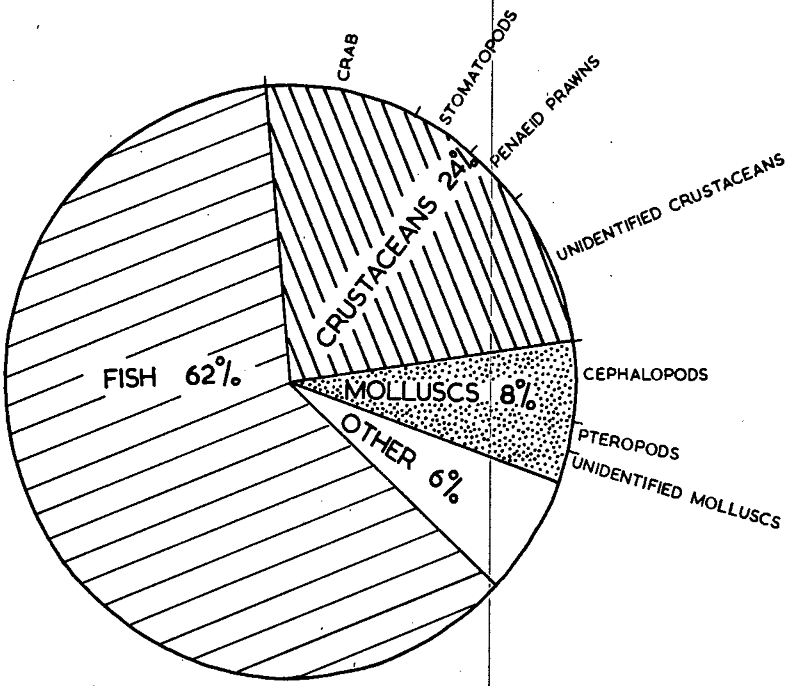

FIG. 2
Relative abundance of food organisms found in *Lutjanus bohar*.

Some change of diet with size was shown. The smallest *L. bohar* taken (150 mm.) were already fish predators and fish was the predominant food throughout the size range investigated. Crabs were first found in fish over 200 mm. in length, and Cephalopods only in fish over 250 mm. As the fish increased in size above this Cephalopods became an increasingly important food.

Wheeler (in Wheeler and Ommanney, 1953) found essentially similar feeding for *L. bohar* of the Mauritius-Seychelles banks, although a greater frequency of crustacean and plankton food was found (Fish 114, Crustaceans 117, Plankton 116, Molluscs 83, other 31). Wheeler also concluded that plankton is taken only in times of special density.

Reptilia
- Green Turtle (*Chelone midas* L.) juvenile.

Pisces
- Carangid fish
- *Holocentrus* sp.
- *Ostracion* sp. juvenile
- Echidnid eel.
- Scaridae (many unident. species)
- *Lethrinus chaerorhynchus*
- *Lethrinus latifrons* Ruppell
- Syngnathid fish
- *Canthidermis* sp.
- Monacanthid fish juvenile
- Clupeidae
- Mullidae.

Tunicata
- *Pyrosoma*
- *Doliolid.*

Echinodermata
- Ophiuroids.

Mollusca
- *Cavolinia* sp.
- *Turbo* sp. ('Green Snail')
- Octopus
- Squid
- *Tectibranch* rem.

Crustacea
- *Charybdis natator* (Herbst)
- *Calappa* sp.
- *Charybdis* sp.
- *Lupa sanguinolenta* (Herbst)
- *Achelous* sp.
- *Thalamita* sp.
- *Monomia* sp.
- Xanthid crab
- Oxyrhynchid crab
- *Panulirus* sp.
- *Penaeus* sp.
- *Pagurus* sp.
- *Metapenaeus* sp.
- Scyllarid larva
- Megalopa larvae
- Sphaeromid Isopod
- Amphipods
- Stomatopod
- Stalked cirripede.

Polychaeta
- Polychaete bristles.

Plants
- *Cymodocea* leaves
- Green alga.

TABLE II

Food organisms found in *Lutjanus bohar.*

GROWTH RATE

Wheeler (op. cit.) has estimated the growth rate of *L. bohar* on the Chagos Bank (Seychelles) from length-frequency curves, and has suggested that the one-year group is 180 mm. total length (136 mm. standard length), with additions of 120 mm. and 110 mm. in the second and third years respectively. He estimated that on the Seychelles plateau and the Amirantes 510 mm. total length (425 mm. standard length) was attained in four years. The Peterson method of age determination is dependent on a short spawning period and roughly equal growth rate of the individuals of each spawning. Wheeler found, in over 2,000 fishes taken during 1948–9, that ripe females were present only in October and November and again in March, suggesting that the first of these tenets is satisfied, with due allowance made for the addition of a new group every six months and not every year. As different banks were considered separately there is every reason to suppose that growth rate is approximately the same and that the method is valid for *L. bohar* in the Seychelles-Mauritius area. In the East African coastal region, however, the breeding season seems to be an extended one, ripe female fish being taken over most of the year. This and the small size of samples has precluded the use of the Peterson method here.

Wide, diffuse rings (formed of a group of fine rings) were present in juveniles, but in adults the scale checks were often sharp, with the lamellae after the check beginning at different angles, as though either resorption had taken place, or growth had begun again after complete cessation. If the checks in the adults are spawning checks, the diffuse rings in the juveniles are possibly due to a physiological sex rhythm already existing in the juvenile, as suggested for the Hake by Hickling (1933).

Peripheral checks were seen in September, November, January, February, March, April, and May. This is mainly in the north-east monsoon period, which lasts from November to April, when the water temperatures are higher than the period of the strong south-east monsoon from May to October. The largest *L. bohar* taken during this survey and aged was 660 mm. standard length, and showed 12 growth rings. On one fish of 615 mm. 13 rings were found. The smallest fish whose scales were read was 200 mm., and showed three growth checks. Increments were 70 mm. and 60 mm. in the fourth and fifth year, and then gradually reduced to approximately 35 mm. per year (see Table III). Maturity was reached about the sixth to seventh year (450 mm.) and no difference in growth rate was seen between the sexes.

This is a very much slower growth rate than that given by Wheeler, increments being about half as much from scale ringing. The possibility cannot be excluded that two rings are laid down per year, although at present there seems no obvious reason for such double ringing in the coastal fishes.

Age	*St. Length to nearest 5 mm.*	*Annual Increment*
0–2	?	?
3	240	?
4	310	70
5	370	60
6	420	50
7	465	45
8	510	45
9	550	40
10	585	35
11	620	35

TABLE III

Average lengths and increments for different age groups of *L. bohar*. Maturity reached at 6–7 years.

MATURITY AND SPAWNING

No distinct spawning periods were found in *L. bohar*. Few ripe (Stage V) females were found, these being taken in July, September, November, February and March. This suggests an extended breeding season over most of the year. The double spawning period suggested by Wheeler (op. cit.) for *L. bohar* in the Seychelles area is not proved for coastal fish by these results. The smallest females with enlarged gonads (recorded as ripe or nearly ripe) were 445 mm. Although sperm was seen in males as small as 270 mm., when the testes are still threadlike, the first ripe (Stage III) males were found at 450 mm.

Aprion virescens Valenciennes

Aprion virescens is a fast-moving predator common over coral areas in 3 to 15 fathoms, feeding from the surface through the mid-water region to the bottom. It is the only Lutianid species to be regularly taken by surface lures. 259 specimens were taken by handline and surface lure from 202 mm. to 800 mm. standard length (25 lb.). This species was often taken when handlining for *L. bohar*, usually on non-weighted lines. Over coral reefs in from 4 to 14 fathoms *L. bohar* is typically caught from mid-water to the bottom, and *Aprion virescens* from the surface to mid-water. They therefore occupy distinctly different, but overlapping habitats. *A. virescens* has been caught on handlines fishing down to 50 fathoms. The statement by Williams (1956 p. 37) of this species being taken on lines fishing from 75–80 fathoms is an error, and refers to a specimen taken fishing at 50 fathoms off the north end of Pemba Island on 23 October 1953. More than once this species has followed handlines being hauled in from deep water (50–60 fathoms) to the surface. It is possible that the species, which is mainly known as pelagic, may take the bait as the lines are being hauled in, and not at the bottom. There is no proof at present of the species occurring below the major thermocline in the colder sub-surface water.

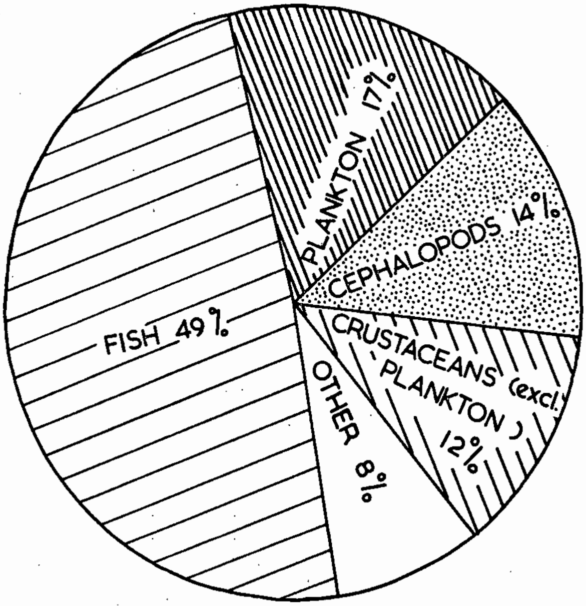

Fig. 3
Relative abundance of food organisms found in *Aprion virescens*.

A. virescens is considered a prime food fish, and occurs in the local markets throughout the year in small numbers.

Underwater, *A. virescens* is commonly seen in coral areas (Mafia, Latham, Cumulus, Zanzibar Channel), always actively moving in mid-water, never sheltering in coral. It is usually in loose and widely spaced shoals of two to five fish, but occasionally solitary.

FEEDING

A. virescens seems able to feed from the surface to the bottom. Fish was the most important food taken, and comprised *Lethrinus microdon*, *Iniistius* sp., Siganids, Tetraodonts, Scarids, Balistids, Labrids, Synodontids and Atherinids. Plankton was also often found in the stomachs of even the largest fishes, and included fish eggs, larval fish, stomatopod larvae, salps and zoeae larvae. Crustaceans, mainly Portunid crabs, and to a lesser extent Penaeid prawns, were also important. Squid was occasionally taken. (See fig. 3.)

MATURITY AND SPAWNING

The smallest female recorded as ripe (Stage V) was 465 mm. standard length, and another female of the same length as mature ripening (State IV). Gonads of males were seen with sperm at 410, 420, 455 and 460 mm., but the smallest males recorded with enlarged full testes were just under 500 mm.

Ripe females were found only in December, January and February, suggesting a breeding season during the warmer water of the north-east monsoon period. Nearly ripe fish (Stage IV) were recorded in most months, and more information will probably prove an irregular extended breeding season.

Lutjanus rivulatus (Cuvier)

One hundred and twenty-nine specimens were taken by handline and underwater spearing, ranging from 395–640 mm. (maximum weight of 19 lb.). This species had rarely been taken from the E.A.M.F.R.O. research vessels until the rich fish populations at Lamu off the Kenya coast had been found (mentioned under *L. bohar*) in 25–65 fathoms. *L. rivulatus* formed about 20% of the catch in these areas. Underwater observation has shown that although seldom caught by handline over shallow coral reefs, *L. rivulatus* is common in certain sheltered coral areas such as Tutia Gap (Mafia) and inside the fringing reef in 5–7 fathoms with *L. bohar* on the east coast of Zanzibar Island, and also at Ras Kizimkazi at the southern tip of Zanzibar Island. At these places occasional mid-water shoals of five to ten fish, often in conjunction with *L. bohar* and *L. argentimaculatus* are present. The species has also been seen singly sheltering under dense beds of the 'platform coral' (*Acropora hyacinthus* [Dana]) on Tutia Reef, and in rocky areas at 5 fathoms on Latham Bank.

FEEDING

L. rivulatus is predominantly a fish predator, also taking crabs, polychaetes, squid, octopus, echinoids, ascidians and polyzoa. It is chiefly a bottom feeder. One sample from deep water contained many fishes filled with salps.

MATURITY AND SPAWNING

Maturity is reached in both males and females at about 450 mm. standard length. Ripe females were found in February, March, April, November and December, and ripe males in March, April, August, November and December, suggesting an extended breeding season in the warm north-east monsoon period.

Lutjanus fulviflamma (Forskal)

This species is abundant over the whole East African coastline extending as far south as South Africa (33°S.), and although small in size is an important species economically, always present in the local fish markets, often in large numbers. It is common in the fringing reef channels, the outer reef slope, mangrove areas, the reefs of Zanzibar channel, the Mafia area and in estuaries (see figs. 4 and 5). Juveniles have been seen in pools on the reef flat, and in shallow water of from six inches to a foot around Zanzibar town over both sandy and weedy bottoms. No other Lutjanid species has as wide a distribution of habitats as *L. fulviflamma*.

One hundred and twenty-six specimens were examined, taken by basket-trap, handlines, trammel-nets, and bought from the local markets. The size range was from 51–220 mm.

FEEDING

Crustaceans were the predominant foods; being mainly crabs (including Portunids and Callapids) and also Eupagurids, Sphaeromid isopods, Penaeid prawns and Stomatopods. Fish remains included Engraulids, Fistularids and gobies.

Different samples often contained foods of one type, presumably indicating local abundance of one particular food organism in the area in which the sample was obtained. Most of the food organisms found were bottom animals.

The investigation of small samples of this species in Durban Bay (South Africa) by the Zoology Department, University of Cape Town, has shown very similar results. Bottom-dwelling crustaceans (mainly *Hymnosoma orbiculare* Dem. and Penaeid prawns) predominated in the stomachs, with fish (Eleotrids, gobies and *Lutjanus* sp.) next in importance (from unpublished records by courtesy of Professor J. H. Day).

MATURITY AND SPAWNING

Of 112 fishes whose gonads were examined, 36 were immature and unsexed, of the remaining 76, 51 were female and 25 male. Of one sample of 13 fish, 12 were female and 1 male. Males were recorded with sperm as small as 145 mm., and the first fully ripe male was found at 170 mm. Ripe females were recorded as small as 160 mm.

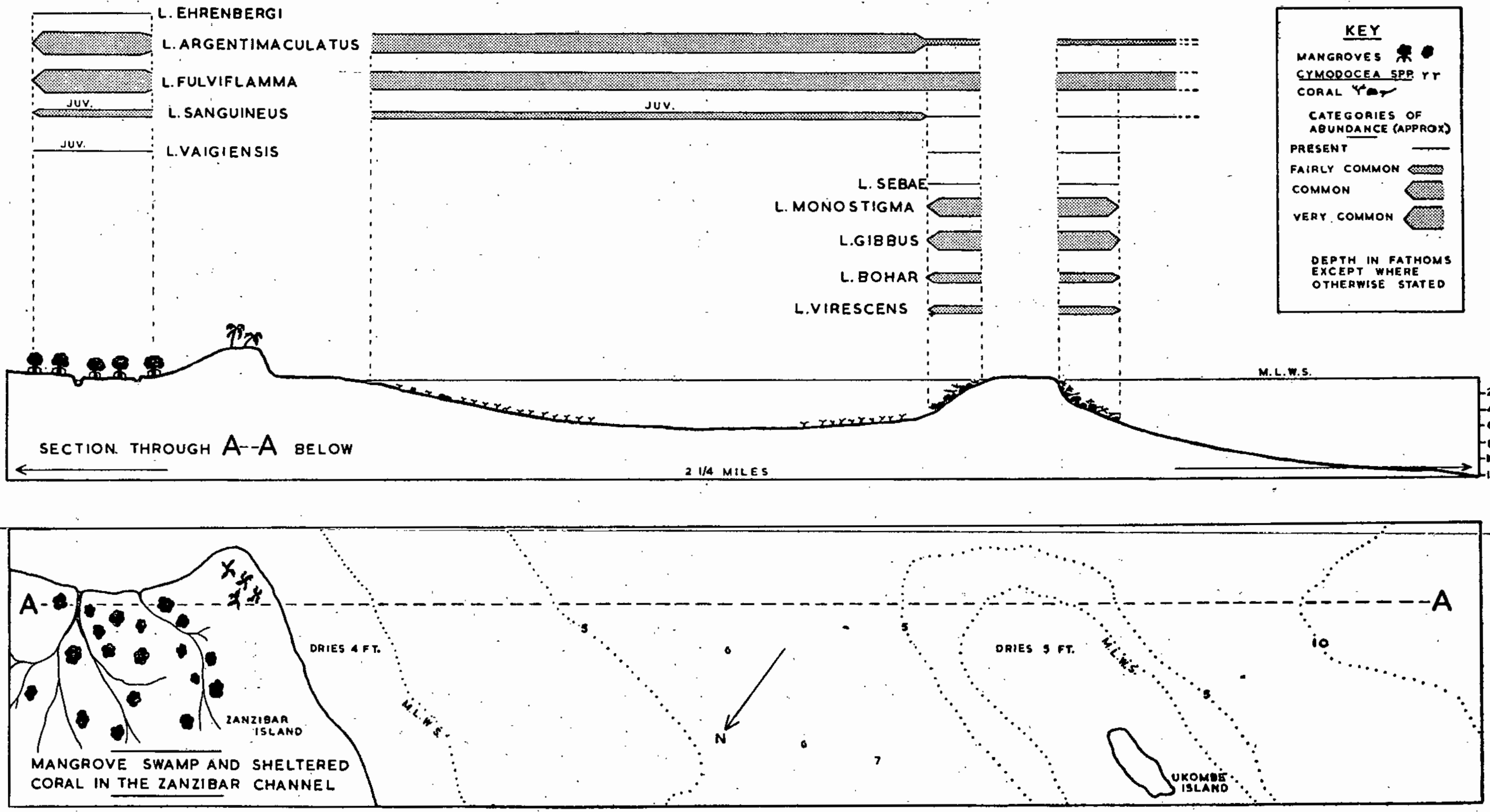

FIG. 4

Distribution of Lutjanids and an indication of relative abundance in mangroves and a coral area not exposed to violent wave action. This example has been taken from the Zanzibar Channel at Ukombe Island Reef. (Based on British Admiralty Chart 665.)

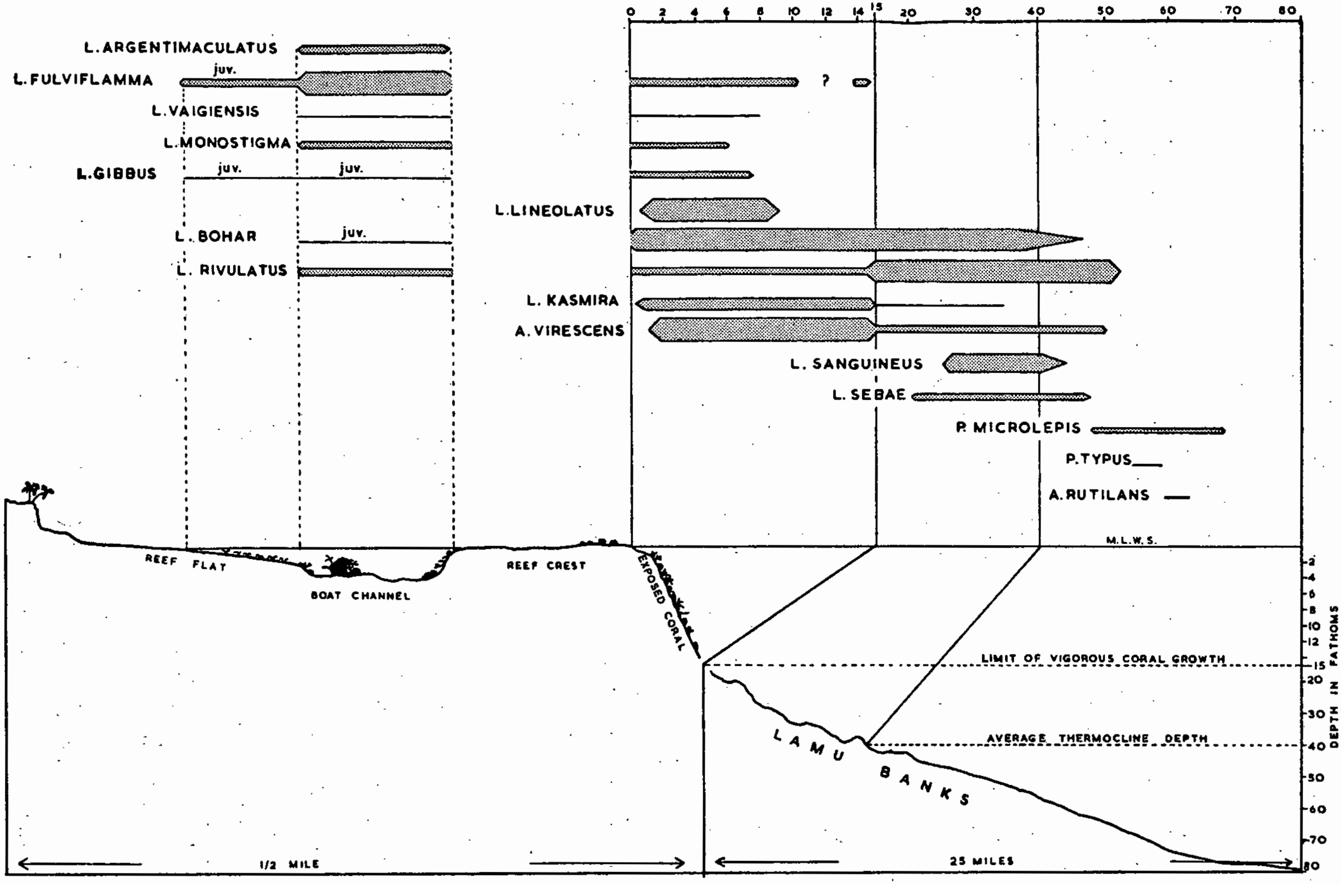

FIG. 5

Distribution of Lutjanids and an indication of relative abundance on a coral reef exposed to the open Indian Ocean, with its sheltered reef flat and boat channel, and the deep-water banks at Lamu. The profile is diagrammatic and based on no single area. An outer reef flat between the reef crest and the boat channel is not included here, as its fish fauna is similar to that of the inner flat. Key as in fig. 4.

Ripe females were found in March, August, October and December, suggesting an extended breeding season mainly in the north-east monsoon period.

Lutjanus gibbus (Forskal)

Lutjanus gibbus is a small species, seldom reaching more than 4 lb. in weight, occasionally seen in local fish markets, but seldom in large numbers.

One hundred and twenty-one specimens were taken by handlining and trammel-nets, always on the bottom and never in mid-water with *L. bohar* and *A. virescens*. The size range of fish taken was from 170 to 355 mm. This species was usually taken at night. It was only found in shallow water of from 3 to 8 fathoms.

Underwater observations showed that this species keeps a few inches above the coral, often sheltering in the branches of 'stag coral' (*Acropora formosa* [Dana]), and in the leaves of 'platform coral' (*Acropora hyacinthus* [Dana]). It was seldom seen singly but usually in dense, closely knit shoals, typically roving over the bottom in a single layer, closely following the bottom contours. Numbers ranging from one to fifty fish and over were seen, but usually shoals were from ten to twenty-five. The species is common on exposed and sheltered coral reefs with rich coral growth, and was seen at Tutia, Vulture, and Cumulus banks in the Mafia area, and on the fringing reef outer slope at Zanzibar. It was also taken on Latham bank and at Lamu. Adults were never seen in the fringing reef channels. Juveniles of about 50 mm. long were seen on the reef flat, and are occasionally taken in beach seine hauls on Zanzibar Island.

Feeding

Foods eaten were mainly crustaceans, including crabs and Penaeid prawns. Small coral fishes were also occasionally taken. Coral and sand were sometimes present in small quantities.

Maturity and Spawning

The smallest mature females with gonads approaching spawning condition (Stage IV) were found at 223, 235, 240 and 245 mm. standard length. The smallest mature males were 240 and 280 mm. Ripe fishes (either sex) were found in March, November, September and December, i.e. the north-east monsoon period.

Lutjanus sanguineus (Cuvier and Valenciennes)

One hundred and two specimens were taken by handline and basket-trap, ranging from 170–650 mm. (13 lb.). Juveniles were taken in basket-traps in the Zanzibar channel and in the Mafia area, in 6 to 7 fathoms on coral and

Cymodocea bottoms, and were also found in the Chukwani fish-ponds (Zanzibar Island), a mangrove area. Adults were not taken by basket-trap, or by handlining in daylight over coral reefs. On one bank in the Mafia area (Snapper Knoll, Niororo Island) adults were taken on four occasions by handlining at night. Adults and juveniles were also taken by trammel-nets overnight in shallow water in Lamu Harbour. Adults of *L. sanguineus* were common in 25–47 fathoms off Lamu, and were one of the dominant species in these deep-water catches (mentioned on p. 555).

At certain times of year (January, February and March) this species occasionally floods local markets (Zanzibar Island), being taken off the southern tip of Zanzibar Island in 40 fathoms. Off Shimoni (Kenya) it is also taken in quantity at certain times of the north-east monsoon (November to April).

L. sanguineus was never observed underwater.

When it is caught it is seldom taken singly, but usually a number within a few minutes suggesting a shoaling habit.

FEEDING

Fishes were the commonest food (including *Syngnathus biaculeatus*, Monacanthids and Apogonids) but Penaeid prawns, crabs, stomatopods, cephalopods and plankton (salps, doliolids, pteropods and medusae) were also found. No change in diet with size was found.

MATURITY AND SPAWNING

The smallest males and females with ripe gonads were 480 mm. and 505 mm. respectively. Stage IV females were found in March, August, September and November and Stage V females in April and August. Stage III males were found in March, April, August and November.

Lutjanus kasmira (Forskal)

Seventy-seven specimens were caught by trammel-net, underwater spearing, and handline, ranging from 125–205 mm. *L. kasmira* is a small species seldom reaching $\frac{3}{4}$ lb. in weight, and is not caught unless very fine lines and hooks are used.

Underwater it is seen to be abundant, often in dense shoals of 25 fish and more, never singly, and usually about actively growing coral in exposed areas. It has been seen off Ras Nungwe (Zanzibar), Tutia Reef, and outside the fringing reef on the Zanzibar east coast, in 2–5 fathoms. One specimen taken in deep water (35 fathoms) off Malindi (Kenya) differs slightly in coloration, scaling, and the number of dorsal spines from the shallow water specimens, and is probably a deep water race. This specimen has been described in a previous communication (Talbot, 1957). The species is not found in sheltered mangrove areas, and has not been seen about the Zanzibar channel reefs. It is occasionally seen in local markets.

FEEDING

Crustaceans were the predominant food and included crabs and amphipods. Squid, fish remains and algae were also found.

MATURITY AND SPAWNING

Females were mature at the smallest sizes taken, i.e. 125 mm. Males were first seen with sperm at 155 mm., and first recorded as ripe at 165 mm.

Ripe fishes were found in March and November suggesting breeding in the warm water north-east monsoon period.

Lutjanus sebae (Cuvier)

Twenty-seven specimens were taken by handlines (adults), basket-traps and spear-guns (immature fish), ranging from 128 to 665 mm.

The juveniles of this species occur in shallow water (5–10 fathoms) and fish up to 360 mm. (3½ lb.) have been taken on banks in the Mafia archipelago (Snapper Knoll near Niororo Island and Sefo Reef). Larger specimens have been found to be fairly common in deeper water of 20–48 fathoms and were taken off Tutia Reef and on the Lanu Banks. Occasional specimens of up to 60 lb. have been seen at Ras Kizimkazi (Zanzibar Island) taken on handlines in 40 fathoms by local fishermen. *L. sebae* occurs regularly in small quantities in Zanzibar markets. It was never seen underwater by the author but has been seen in 5 fathoms on Sefo Reef by Dr. J. F. C. Morgans (personal communication).

FEEDING

Stomachs contained fish, stomatopods, crab and cephalopod remains.

MATURITY AND SPAWNING

Females with developed gonads (Stages IV and V) were only found above 490 mm. standard length. Insufficient data were obtained to estimate size at which males mature. Breeding is in the north-east monsoon period, ripe fish having been found from November to March.

Lutjanus monostigma (Cuvier)

Eighteen specimens were taken, 15 by underwater fishing and 3 by handlining in 1–4 fathoms. Size range was from 275 to 420 mm. This species is very rare in the local markets. Underwater observation, however, showed it to be common in areas where large coral growths form deep shelter, and it seems completely limited to this type of habitat. It was common about Tutia Reef, Latham Island, in the Zanzibar Channel, and was seen occasionally inside the fringing reef on the Zanzibar east coast. It was never seen in shoals although two or three were often seen under one coral shelter. Individuals often remained under one coral for the whole period of observation (up to two hours).

FEEDING

Fish remains (including one Mullid and one Labrid) were present in most stomachs, and Penaeid prawn remains were also found.

MATURITY AND SPAWNING

Ripe or nearly ripe females (Stages IV–V) of 395 mm., 390 mm., 420 mm., and 400 mm. were taken. No ripe males were caught. From the meagre data the fish appear to mature at over 350 mm. (2 lb.).

Ripe females were found in November and February.

Lutjanus argentimaculatus (Forskal)

Thirteen specimens of 300 to 630 mm. (15½ lb.) were taken from sheltered reef areas in up to 7 fathoms by handlining or set nets at night. This species is abundant in East African coastal waters, and is an important market species. It does not occur on exposed coral reefs, however, and is therefore not well represented in the E.A.M.F.R.O. catches. It is very common in shallow mangrove areas and estuaries, and common in sheltered waters such as the Zanzibar channel. It was commonly seen during underwater observation inside the fringing reef off the Zanzibar east coast, in the semi-estuarine waters of Chwaka creek (Zanzibar) and about large, and often dead, coral growths in the Zanzibar channel. It may occur singly or in shoals of up to 20 fish. Juveniles are fairly common in sheltered mangrove areas.

L. argentimaculatus was never seen during underwater observation on exposed coral reefs.

MATURITY AND SPAWNING

Males were found with testes containing sperm at 330 mm., 410 mm. and 460 mm., and one ripe male of 515 mm. was taken in November 1958. One female was considered mature at 460 mm., and one ripe female of 630 mm. was taken in November 1957.

Lutjanus ehrenbergi (Peters)

Six specimens were taken from mangrove pools on Zanzibar Island (Chukwani fish-ponds) from 44 to 98 mm. standard length. Two of the specimens were fully mature females of 75 mm. These are the smallest mature *Lutjanids* found during the survey. *L. fulviflamma*, also maturing at a relatively small size, was first found mature at 150 mm. *L. ehrenbergi* was never seen during underwater observation.

Lutjanus lineolatus (Ruppell)

Five individuals of this small species were taken (standard lengths 120–175 mm.) but no biological data were obtained from them. Underwater observation showed this species to be often present in large shoals (30 to over 100 fishes) on exposed coral reefs, often in conjunction with *L. kasmira*. It is also fairly common in East African markets, and its rarity in E.A.M.F.R.O. catches are due to catching methods.

Lutjanus vaigiensis (Quoy and Gaimard)

Six specimens were taken by underwater spearing and handlines from 200 to 250 mm.

This small species has very occasionally been seen in local markets, and underwater observations shows that it is present, although not common, on shallow coral reefs (Ras Nungwe, Tutia Reef, inside the Zanzibar fringing reef), usually singly, but occasionally in pairs. It is always in or near coral shelter. It is often present in the same areas as *L. monostigma*. Shoaling in this species has never been seen. Juveniles have been taken in a mangrove area (Chukwani fish ponds, Zanzibar Island). Fully mature males were found at 190 and 205 mm.

Pristipomoides microlepis (Bleeker)

Twelve specimens were obtained by deep lining (47–67 fathoms) ranging from 260 to 645 mm. (14 lb.).

This species has been taken off Malindi, Pemba, and Tutia Reef. Smith (1954) records it as a major component of the Shimoni (Kenya) deep-water fishery. The species lives in the cold sub-surface water below the thermocline, and has not been taken in shallow water.

Pristipomoides typus (Bleeker)

One specimen of 525 mm. (8½ lb.) was taken off Tutia Reef in deep water (about 55 fathoms). Smith (1954) records it as occurring in the deep-water Shimoni fishery.

Aphareus rutilans Cuvier

One specimen, a mature female of 785 mm., was taken at 60 fathoms off Lamu. Water temperature at that depth was 19°C. from a bathythermograph reading.

Lutjanus duodecimlineatus (Valenciennes)

One specimen was purchased in the Zanzibar fish market (150 mm.).

CONCLUSION

Few *Lutjanids* are restricted to the East African coast. Of the seventeen species recorded here, all except two (*L. ehrenbergi* and *L. duodecimlineatus*) reach the Australo-Pacific region. In the reverse direction distribution of this family is not so uniform, however. Many Lutjanids found in the Parific Ocean and the Eastern Indian Ocean are not found in the Western Indian Ocean. For example, in the genus *Lutjanus* 32 species occur in the Hawaiian Islands (Herre, 1953), excluding the freshwater *L. maxweberi* and the doubtful *L. philippinus*. Of these only 13 are found in East Africa. This suggests a centre of origin, or at least strong adaptive radiation in the Australo-Pacific region. At present there is clearly difficulty of dispersal in an east-west direction for many species, but whether this is due to paucity of suitable environments in the north and western Indian Ocean, or to some physical barrier to migration is not obvious. Temperature, which limits the southerly distribution of this typically warm-water family down the coast of Africa, does not operate as a barrier to its spread along the Indian and Iran coasts. Lutjanid distribution bears out Ekman's statement that 'the rich Indo-Malayan fauna is distributed over a large part of the Indian Ocean, but the number of species constantly decreases as we proceed in a westerly direction'.

Down the African coast some species disappear at Delagoa Bay (26°S.), with the last coral reefs, and then there is a steady decrease in species to East London (33°S.), no members of the genus *Lutjanus*, and only the genera *Aprion* and *Etelis* (Indo-Pacific, not recorded during this survey) reaching farther south, to Knysna (34° 5′S.). (Note: Two specimens of *L. sanguineus* have been taken in Algoa Bay, and one at Plettenberg Bay, 34°S., during 1958–9.) The distribution of this family is paralleled by that of the reef-building corals. Although no coral reef growths have been found south of Delagoa Bay, reef-building genera are found to just north of East London (Stephenson, 1947). Coastal temperatures drop rapidly between Port St. Johns (31° 40′S.) and East London (33°S.) due to an outward turning of the Agulhas current. The latter port coincides with the 20°C. isotherm in winter (Sverdrup *et al.*, 1942).

Vertical distribution is very limited in most of the family (see fig. 4). Of the seventeen species taken eight species were never caught deeper than 14 fathoms. Of these most were common about coral reefs, and their deepest limits coincided with the limit of vigorous coral growth, which was usually between 10 and 15 fathoms. It is possible that the same factors might be the cause of both the limit of distribution of the fishes and the end of reef growth, but more likely that the fishes are limited to the coral habitat.

The thermocline, varying from 25–50 fathoms, is deeper than the foot of the actively growing coral area, and at 10–15 fathoms water conditions differ little from the surface. Temperatures at this depth were not found below 24°C. by Newell (1957) and in summer are very much above this, so temperature does not seem to be a barrier in this connection. Suggested reasons for the downward limit of coral growth will be discussed in a later paper; here it will be sufficient to state that for *L. vaigiensis*, *L. monostigma*, *L. lineolatus*, *L. gibbus*, *L. fulviflamma* and the shallow-water form of *L. kasmira* (referred to on p. 565), the foot of the living coral reef (excluding tallus slopes) is the downward limit. Although some physical environmental factor or combination of factors may be the cause of this, the abrupt ending coincident with that of the coral suggests that in a downward direction the fish distribution is determined by the latter. *L. fulviflamma* was not restricted to coral areas but was also abundant in sheltered areas such as mangrove swamp channels and *Cymodocea* beds. *L. argentimaculatus*, also limited to shallow water, was found in more sheltered habitats only, including mangrove areas, the boat channel of fringing reefs, and sheltered coral. *L. ehrenbergi* was taken only in a mangrove swamp.

L. bohar and *L. rivulatus* were for a long period (1951–5) considered to have only a shallow-water distribution, never being taken below about 14 fathoms. In 1956, however, when the deep-water (25–65 fathoms) banks off Lamu, Kenya, were fished it was discovered that these two species were often abundant at much greater depths, reaching 46 and 51 fathoms respectively. In these areas the shelf is unusually wide for the East African coast (considered by Morgans, 1959, to be due to the deposition from an old river delta), and rich feeding-grounds are present. It seems clear that this favourable habitat is the reason for the presence of *L. bohar* and *L. rivulatus* in deeper water.

On these banks the bottom temperature may vary from 22°C. to 29°C. Newell also gives one reading of 18°C. at 50 fathoms. (Newell 1959, Morgans in unpublished E.A.M.F.R.O. reports.) From the foods taken by these members of the genus *Lutjanus* it appears that they are all bottom feeders, and it is probable that temperature becomes an important factor in the distribution of these members of this genus to the colder deeper portions of these banks, if we may judge by their distribution down Africa, referred to above. It is quite clear from the great deal of fishing that has now been done in this area that the genus *Lutjanus* is only found in water of the East African coastal current, and not below the thermocline. No members of this genus have been taken in water below 23°C. where a bathythermograph has been used in conjunction with fishing. In addition to *L. bohar* and *L. rivulatus* this also applies to *L. sebae* and *L. sanguineus* whose adults were common on these banks. In the former only juveniles and young fishes up to 360 mm. were taken in shallow water, and adults in water of 30–49 fathoms. Adults of the latter extended from the shallow water of Lamu Harbour (a mangrove area of 4 fathoms) to 47 fathoms, and were more abundant in deep water. Juveniles of these species were only taken in sheltered water.

In contrast to the genus *Lutjanus* the two species of the genus *Pristipomoides* and *Aphareus rutilans* were taken in 47–67 fathoms and 60 fathoms respectively and never in shallower water. Also found on the Lamu Banks, these species are usually present below the thermocline. *A. furcatus*, not taken during this survey but recorded by Smith (1954) in East Africa, seems to be a shallow-water species, being referred to by Randall (1955) as fairly commonly seen underwater in shallow coral-rich areas of the Gilbert Islands, and taken on the surface on lures by Schultz (1953) on Bikini Atoll. Smith's record is of one specimen from 20 fathoms off Pemba Island.

The genus *Aprion* has a pelagic habit and a depth range to about 50 fathoms, but is more abundant in shallow water over the reefs.

Clear differences were found between the catches of Lutjanids from coral areas facing the open Indian Ocean and exposed to violent wave action, and those of sheltered coral islands in the 15-mile channel between the African mainland and Zanzibar Island or from the inner Mafia Archipelago (see fig. 1). *L. argentimaculatus* was taken both in the boat channel and also from sheltered coral reefs, but never on the outer exposed reef slope. *L. kasmira*, common on the outer slope, was never taken in sheltered water. Numbers of species common to both types of coral area also differed. *L. bohar* was one of the dominant species of the outer slope, but although present in the more sheltered water it was very much less common. Conversely *L. gibbus* was common and sometimes abundant in sheltered areas, but on the outer slope it was poorly represented in the catches.

The reasons for the patterns of distribution described in the above paragraphs are obviously complex, and not within the scope of this work, but many of the problems here raised could be approached experimentally. Temperature, salinity, light, O_2 concentration and turbidity preferences of the juveniles and adults of different species could be tested with carefully designed aquarium equipment, especially for the smaller species, and would undoubtedly give valuable clues to the reasons for their distribution.

On a typical East African reef the Lutjanids are a major component of the fish fauna. They and the *Serranidae* form in general the bulk of the non-pelagic predators, in contrast to the *Carangidae*, *Scomberomoridae* and *Sphyraenidae*. They differ from the *Serranidae* in that while members of this family are usually often solitary and many are more or less stationary for long periods most Lutjanids tend to school and move actively over the coral. The commonest line-caught fish over exposed coral was the large, mainly fish-eating, *L. bohar*, with *A. virescens* common in mid-water and at the surface in the same areas. The commonest smaller species, *L. fulviflamma*, *L. kasmira* and *L. lineolatus*, are often present in shoals numbering 50 and more. These species swim close to the coral and are predominantly crustacean feeders. On sandy bottoms and *Cymodocea* beds their place is taken by the *Lethrinidae*.

In the deeper Lamu Banks off the Kenya coast this family forms the bulk of the predators, if we may judge by the quantities of line-caught fish. Lutjanids, mainly *L. bohar*, *L. rivulatus*, and *L. sanguineus* formed 54% of the fishes taken, the *Serranidae* 26% and the *Lethrinidae* 15%, with 5% of sharks and other species (Williams, 1958).

No sharply marked breeding seasons were found in any of the species studied, although sometimes a single sample would contain many ripe fishes of both sexes. In general all species seemed to breed over a large part of the year, but mostly in the warm north-east monsoon period.

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SUMMARY

Seventeen species of the family Lutjanidae from the East African coast are discussed, and notes on their distribution, feeding, spawning seasons and shoaling habits are presented.

Eight species of the genus *Lutjanus* were found only in shallow water, and were never found below the limit of active coral reef growth (approximately 15 fathoms). The major thermocline at from 25–50 fathoms is suggested to be a barrier to deeper distribution of the five species (four of the genus *Lutjanus* and *Aprion virescens*) found from shallow water to below the living coral reefs. Three species (two of the genus *Pristipomoides* and *Aphareus rutilans*) were found only in deeper water, and never above the major thermocline.

No evidence of migrations was found.

Sheltered coral, and coral exposed to violent wave action were found to differ in the presence or absence of some species of the family, and also in the numbers of species common to both habitats.

All the species studied were euryphagous predators. Details of feeding are given.

No sharply defined breeding seasons were found, but the extended periods in which breeding took place were mostly in the warm months, November to April.

Regular growth rings were found on the scales of *Lutjanus bohar*. Checks were formed at different times of year in different fishes. It is suggested that these are related to spawning. Growth increments of from 70 mm. (3rd–4th year) to 35 mm. (10th – 11th year) were estimated.

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PART 4

SUPPORTING PAPERS.

Nahrungsverdauung bei *Pseudactinia flagellifera.*
B. J. KRIJGSMAN and F. H. TALBOT

Experiments on digestion in sea-anemones.
B. J. KRIJGSMAN and F. H. TALBOT

Notes on the biology of the white stumpnose, *Rhabdosargus globiceps* (Cuvier), and on the fish fauna of the Klein River estuary.
F. H. TALBOT

A preliminary note on the breeding and growth of *Tilapia* in marine fish ponds on Zanzibar Island.
F. H. TALBOT and B. S. NEWELL

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Nahrungsverdauung bei Pseudactinia flagellifera.

Die Verdauung der Coelenteraten erschien früheren Autoren problematisch, da die Vermutung nahelag, der Inhalt der Gastralhöhle müsse jedesmal, wenn neue Nahrung aufgenommen wird, durch mit eindringendes Seewasser verdünnt werden. Sieht man von Formen wie *Rhizostoma* (Wurzelqualle) ab, die einen Pump-Filter-Mechanismus haben und insofern besondere Verhältnisse auch hinsichtlich der Größe ihre Nahrungsobjekte darbieten, so wird die gedachte Schwierigkeit, mindestens zum größten Teil, durch zwei Eigentümlichkeiten beseitigt: Zunächst schlucken die Coelenteraten nicht eigentlich, sondern sie kriechen über ihre relativ großen Beutestücke gewissermaßen hinüber und halten dabei ihre Körperwand allerseits in so engem Kontakt mit dem Nahrungskörper, daß nur wenig Seewasser mit eindringen kann. Sodann wird die Beute durch eine extrazelluläre Vorverdauung im Gastralraum so weit chemisch zerkleinert, daß die noch nicht gelösten Partikel klein genug für eine Verarbeitung durch Phagozytose und nachfolgende, von einer etwaigen Verdünnung des Magensafts unabhängige, intrazelluläre Verdauung sind. Genaueres über die bei der intrazellulären Verdauung wirksamen Enzyme ist nicht bekannt, im Magensaft verschiedener Arten wurden von Beutler[1]), Hyman[2]) und Yonge[3]) Proteasen und eine Lipase nachgewiesen. Unsere Kenntnisse über die Verdauungsenzyme sind demnach noch recht unvollständig.

Wir haben deshalb die extrazelluläre und auch die intrazelluläre Verdauung von *Pseudactinia* untersucht. Magensaft wurde erhalten durch Verfüttern von Badeschwammstückchen, die nach der Methode von Beutler und Hyman mit Fleischbrühe getränkt waren. Die Anwesenheit von Proteinase wurde untersucht mit der Gelatineverflüssigungsmethode nach Fermi und der Kaseinpräzipitationsmethode nach Michaelis. Es stellte sich heraus, daß eine kräftig wirkende Proteinase im Magensaft vorhanden war, mit einem Optimum im Bereich von p_H 7,3 bis 8,0. Mit der stalagmometrischen Methode wurde eine Esterase gefunden, welche Tributyrin optimal bei p_H etwas über 7,0 spaltet; Milchfett dagegen wurde kaum angegriffen. Die übliche Jodmethode ergab die Existenz einer sehr schwachen Amylase, welche nur merkliche Aktivität entfaltete bei p_H 6,3 bis 7,6. Außerdem zeigte der Magensaft eine bedeutende Labwirkung auf Milch. Disaccharasen wurden, trotz Anwendung quantitativer Methoden (Hagedorn-Jensen-Titration), nicht gefunden.

In Extrakten von Gastralfilamenten (hergestellt durch Verreiben mit Phosphatpuffer) wurde eine sehr starke Proteinase festgestellt, deren Optimum etwas höher lag (p_H 8,2 bis 8,5) als das Optimum der extrazellulären Proteinase. Es ist jedoch kein Grund vorhanden, die Existenz zweier verschiedener Proteinasen anzunehmen, da verschiedene Stoffe, aus dem Gewebe mitextrahiert, kleine Verschiebungen des Optimums hervorrufen könnten. Ferner wurde eine auf Tributyrin kräftig wirkende Lipase, sowie eine mäßig starke Amylase festgestellt. Auch diese Enzyme sind offenbar identisch mit der extrazellulären Lipase und Amylase. Die Labwirkung der Gewebsextrakte war sehr stark. Disaccharasen fehlten wie im Magensaft.

Unseren Resultaten, welche an anderer Stelle ausführlich publiziert werden, kann man entnehmen, daß die extrazelluläre Proteinase die Hauptrolle spielt bei der Vorverdauung der Nahrung. Dieses Enzym ist sehr wahrscheinlich adsorbiert an dem Schleim, der vom Epithel sezerniert wird als Reaktion auf Eintreten von Nahrung in die Magenhöhle. Die Möglichkeit besteht, daß dieser Schleim durch die Labwirkung des Magensaftes koaguliert wird und so eine gelatinöse Hülle um die Beute bildet. Auf diese Weise könnte Verdünnung und somit Verlust von Enzymen und Nahrungsprodukten durch eintretendes Seewasser zuvorgekommen werden. Nach der extrazellulären Vorverdauung können die aufgedeckten intrazellulären Enzyme die Verdauung vollenden.

Es ist nicht klar, warum wir weder im Magensaft noch im Gewebsextrakt Disaccharasen fanden. Während sie zur Vorverdauung im Magen nicht notwendig erscheinen, könnte man doch ihre Existenz im Extrakt erwarten, da jene Enzyme im ganzen Tierreich bei der Verdauung von Kohlenhydraten eine Rolle spielen. Auch andere Fragen warten noch auf ihre Lösung. Erstens wissen wir noch nicht, ob die Verdauungsprozesse bei allen Coelenteraten sich ähnlich sind, da bis jetzt nur wenig Arten untersucht wurden. Weiter liegen noch keine quantitativ biochemischen Untersuchungen mit gereinigten Verdauungsenzymen vor, welche deren Spezifität in Beziehung zu Verdauungsenzymen anderer Tiergruppen aufklären könnten. Es erscheint sehr wünschenswert, daß diese Probleme weitere Bearbeitung finden.

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B. J. Krijgsman und F. H. Talbot.

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[1] Beutler: Z. vergl. Physiol. **1**, 1 (1924); **3**, 737 (1926); **6**, 473 (1927).

[2] Hyman: Biol. Bull. **79**, 282 (1940).

[3] Yonge: Sci. Rep. G. Barrier Reef Exp. Brit. Mus. **1**, 59 (1930).

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EXPERIMENTS ON DIGESTION IN SEA-ANEMONES.

BY

B. J. Krijgsman and F. H. Talbot
(*University of Cape Town*)

(1 figure)

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EXPERIMENTS ON DIGESTION IN SEA-ANEMONES

BY

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(1 figure)

Introduction

Digestive processes in Coelenterates have early attracted the attention of physiologists. In most medusae as well as in sessile forms the gastric cavity is not a physiologically closed system, since its sac-like shape and wide entrance must give rise to considerable contamination of the contents with water every time the mouth opens. In some forms we even find a continuous circulation of water through the gastric cavity. Consequently special steps have to be taken by the animals to restrict dilution of digestive enzymes and loss of digested food. Coelenterates have solved this problem with the aid of phagocytosis. In those forms which take in particulate matter (i. e. plankton- and detritus feeders) phagocytosis does not introduce special difficulties. The epithelium of the gastric filaments ingests the small food particles and digestion is carried out intracellularly.

However, many Coelenterates, e. g. sea-anemones, ingest food ranging from small *Crustacea* to fishes as large as the predator itself. As phagocytosis of such large material is impossible, there must occur some preliminary disintegration in the gastric cavity. PARKER (cited by JORDAN, **18**) was the first to suggest the occurrence of preliminary digestion in the gastric cavity, by which the food might be broken down to particles small enough to be phagocytised. Subsequent intracellular breakdown could then complete the digestive processes. This suggestion directed the experimental work into two directions : 1) Investigation of enzymes in the gastric cavity which may carry out preliminary digestion, and 2) investigation of intracellular enzymes which complete digestion.

As far as the *extracellular enzymes* are concerned, early investigations exhibit many contradictions. Some authors found a digestion of animal tissue which was in contact with the gastric filaments (MULLER, **26**; GREENWOOD, **13**; BIGELOW, **6**; CHAPEAUX, **9**; SCHÄPPI, **30**; DOWNING, **11**; HADŽI, **14**). Others claimed that this contact was essential, since they did not find digestion if the food did not touch the filaments (meat in a feather shaft in the gastric cavity, LEWES cited by BIEDERMAN, **5**, KRUKENBERG, **19**). This was the reason why the term « contact digestion » was introduced. But even this contact digestion was denied by MESNIL (**23**), who did not discover any sign of digestion in the gastric cavity of sea-anemones. This, however, is in contradiction to other results, and it is easy to prove that a piece of fish or mussel is readily digested in the gastric cavity. That there is contact digestion is certain. therefore, but in addition it has been shown by WILLEM (**32**) that animals covered with a shell (*Crustacea*) were readily digested in spite of lack of contact between digestible material and gastric filaments. Furthermore, WILLEM showed that this disintegration was no autolysis, since dead *Crustacea* in seawater do not autolyse so rapidly. His opinion was supported by the results of CHAPEAUX, who found a slight digestive action of gastric juice of *Actinia* on fibrin *in vitro*. The final proof that digestive processes in Coelenterates are not confined to contact digestion was brought by JORDAN (**17**), who observed a disintegration of fibrin enclosed in a sac of filterpaper in the stomach of *Anemonia sulcata*, and by ABDERHALDEN and HEISE (**1**), who found a digestion of polypeptids. Then, for many years, scientists seem to have lost interest in this problem, for only in 1924 does BODANSKY (**7**) take up the question again. He finds very little digestive action exerted by filtered gastric juice of *Metridium*. More promising are the results of BEUTLER (**2**, **3**, **4**), who collected gastric juice from *Hydra* polyps by feeding them with small pieces of sponge. The fluid absorbed by the sponge readily digested fibrin and gelatin at a pH of 8.2. YONGE (**35**) found a proteinase in the gastric juice of the medusa *Aequora sulcata*. As far as other extracellular enzymes are concerned results are poor. CHAPEAUX, BODANSKY, BEUTLER, YONGE and HYMAN (**16**) failed to detect an amylase in the gastric cavity. BEUTLER and YONGE could not discover extracellular digestion of fat or lower esters. Only HYMAN reports a digestion of milk fat.

The picture of *intracellular enzymes* is more definite. A proteinase can be readily demonstrated in extracts of gastric filaments. According to FREDERICQ (**12**), CHAPEAUX and MESNIL, extracts of *Anemonia* and *Adamsia* break down fibrin, boiled egg-white, gelatin and casein at a pH ranging from slightly alkaline to·about 4.4. Since digestion was quickest at about pH 7, they postulated the presence of a « trypsin-like » proteinase. BODANSKY and ROSE (**8**) found, in extracts of filaments of *Stomolophus meleagris* and *Physalia arethusa*, a proteinase with two optima when acting on gelatin, but with a poor action on albumin, fibrin and casein. BODANSKY (**7**) also found a trypsin-like proteinase in filaments of Metridium. YONGE, in extracts of *Madreporia*, found a proteinase and a dipeptidase ; the pH-optimum of the proteinase varied for different genera (8-8.75 or 6.9-7.9). SAVIANO (**29**) discovered a trypsin-like proteinase in the endoderm of *Anemonia sulcata.* The results concerning carbohydrases are contradictory. FREDERICQ, CHAPEAUX and MESNIL found no amylase and no sucrase, BEUTLER failed to observe intracellular digestion of starch in *Hydra.* YONGE detected an amylase in some forms ; this enzyme, however, was apparently contained in zooxanthellæ, since he did not find it in zooxanthellæ-free *Madreporia.* SAVIANO did not find amylase in extracts of *Anemonia.* BODANSKY and ROSE, and BODANSKY report the existence of an amylase and a weak maltase in extracts of *Stomolophus*, *Physalia* and *Metridium*, but they did not mention the possible occurrence of zooxanthellæ. As far as lipolytic enzymes are concerned, FREDERICQ, CHAPEAUX and MESNIL report a slight action of extracts on almond milk and a reasonable action on monobutyrin ; CHAPEAUX also observed intracellular digestion of olive oil. BODANSKY and ROSE found a slow action on ethyl-butyrate, amylacetate and milkfat ; YONGE also found a lipase. SAVIANO found a strong action of extracts on tributyrin, but no breakdown of higher esters. BEUTLER did not discover any lipolytic action. A rennitic action was reported by MESNIL, BODANSKY and ROSE, and by BODANSKY. As no comparison was made with standard preparations of proteinases, it is not certain whether this clotting action was produced by a specific rennin or merely by the action of the proteinase present.

As a whole, the position is far from established and worth further attention. A factor which may have contributed to confusing results is that different authors worked with different species. Apart from that, most authors do not discuss the question of zooxanthellæ, thus is not always clear whether the reported enzymes originate from the Coelenterates themselves or from their symbionts..

Methods

After some preliminary experiments with *Bunodactis reynaudi* we used only the large sea-anemone *Pseudactinia flagellifera*, which is abundant along the coast of the Cape Peninsula. This species lives in the tidal zone, ingests a variety of animal food and does not possess zooxanthellæ. The gastric cavity often contains gastropods, Crabs, sea urchins and the like in a more or less advanced state of digestion. It is interesting to note that *Pseudactinia* never contains mussels. *Bunodactis*, on the other hand, often swallows pelecypods which it is able to crack in the gastric cavity.

In order to collect gastric juice we used the method of BEUTLER. Small pieces of sponge, soaked in diluted meat extract (Bovril) and attached to a thread, were fed to the animals and ingested readily. The use of meat extract favours ingestion and may be a stimulus for the secretion of enzymes. In the first experiments the sea-anemones were removed from the rocks, put in aerated seawater and fed in the laboratory. It was found, however, more satisfactory to feed them in their natural rock pools at low tide; this method was used in all further experiments. The sponges were left in the animals for about 90 mins., the anemones were then removed from the rocks and the sponges pulled out above water. The sponges were always found to be soaked with a mass of stiff mucus. HOLLARD (**15**) was the first author to report that the walls of the gastric cavity secrete abundant mucus. We believe that the mucus is secreted as a result of the sham feeding. In normal conditions this secretion is probably evoked by soluble organic compounds of the food, in empty animals it is absent. The sponges were squeezed out, the fluid obtained filtered to make sure that no tissue fragments were present, and diluted with boiled seawater. Control experiments showed that the meat extract did not exert any enzymatic action. In order to obtain extracts of gastric filaments, the filaments of fresh specimens were separated from the gonads with forceps, ground with chemically pure sand and diluted with boiled seawater.

Some of the experiments were carried out at room temperature. In other cases, especially in the more accurate experiments, the digestive sets were kept in a thermostat. Phosphate buffer was used to obtain the desired pH, which was checked electrometrically.

Experimental

EXTRACELLULAR ENZYMES

Acidity of gastric cavity

The pH of the gastric juice, measured electrometically, varied between 6.7 and 7.8. This is in agreement with the results of other authors, who reported 7.0-7.8 In some cases, in which we collected juice from animals while digestion was in progress, the pH of the gastric juice (7.2-7.3) was distinctly different from the pH of the water of the pools in which the animals lived (8.0).

Proteinase

Preliminary experiments with congo red fibrin as substratum, at varying pH, did not show liberation of dye within 24 hrs. Even with the highest possible concentration of gastric juice we failed to observe any digestion. Thus we continued our experiments with other substrates. Casein was used with the precipitation method of MICHAELIS (**24**), by which the amount of undigested casein is measured as a precipitate, produced by diluted acetic acid. For each experiment we used 6 ml. of gastric juice of varying concentration, mixed with 4 ml. of 0.1 % alkaline casein solution; the pH of the mixture was 8.5. At suitable intervals a sample of 1 ml. was mixed with 4 drops acetic acid and the precipitate estimated. Four gradations of the precipitate could be discriminated, labelled « strong », « moderate », « faint » and « absent ». The experiments carried out with this method gave uniform results. An example of an experiment is given in Table I (temp. 30° C). The percentage at the top of each column refers to the concentration of the gastric juice in the digestive mixture.

TABLE I

Time in hrs.	10 %	20 %	40 %	60 %	Control with boiled enzyme
0	strong	strong	strong	strong	strong
½	strong	strong	strong	strong	strong
1½	strong	strong	moderate	moderate	strong
2	strong	moderate	faint	faint	strong
3	moderate	moderate	absent	absent	strong
5	moderate	faint	absent	absent	strong
7	faint	absent	absent	absent	strong

The experiments with casein clearly prove the presence of an extracellular proteinase with considerable activity at pH 8.5.

In order to study the relation of proteolytic activity to pH we used two methods. First of all the gelatin liquefaction method of PALITZSCH and WALBUM (**27**). In this method a gelatin solution is mixed with the enzyme solution to be tested and the progress of liquefaction is observed. Many experiments were done in the pH-region 4.8-9.8. Within 3 hrs. no digestion ever occurred at a pH lower than 5.6; between pH 5.6 and about 8 digestion took place, increasing with pH, above pH 8 there was a rapid decrease and above pH about 8.5 no digestion was shown.

The gelatin liquefaction method still has a somewhat qualitative character. We therefore carried out a number of quantitative experiments in the pH-range 5-9 with the alcohol titration method of WALDSCHMIDT-LEITZ (**31**). 2 ml. of enzyme solution was mixed with 3 ml. phosphate buffer and 2 ml. of 5 % gelatin solution. The digestive sets were kept at 30° C. Titration of 3 ml. samples with 0.1n KOH in 90 % alcohol after 3 hrs. This set of experiments was repeated six times with consistent results. A typical example is given in figure 1.

From our experiments it can be concluded that the gastric juice contains a proteinase which acts on casein and gelatin, with an optimum for gelatin at a pH round 8. These results are in agreement with those of BEUTLER, who found proteolytic activity of gastric

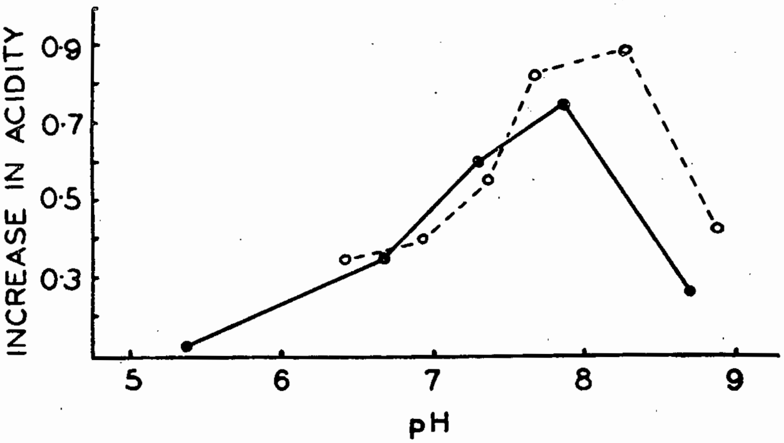

FIG. 1. — Proteolytic action of gastric juice of Pseudactinia (full line), after 3 hrs. digestion, and of extract of filaments (broken line), after 2 hrs. digestion, both on gelatin. Increase in acidity (ml. 0.1n KOH used for titration) plotted against pH.

juice at pH 8.2, and of YONGE, who observed protein digestion at pH 7.1.

Clotting action

The gastric juice of *Pseudactinia* showed a definite coagulating action on milk. 50 ml. boiled milk were mixed with 5 ml. 1 % $CaCl_2$, 2 ml. of this mixture was added to 1 ml. gastric juice and several samples of this preparation kept at 18° C. Within 3 hrs. a complete coagulation occurred, whereas controls with boiled enzyme showed no change. It is known that all enzymes which can hydrolyse casein can cause milk to clot. We had no standard preparations of proteinases available for comparison, so it is impossible to tell whether the clotting observed is due to action of a specific « rennin » or to the proteinase described above. No other authors have mentioned a rennitic action of gastric juice of Coelenterates.

Amylase

For the detection of amylase we used the well-known iodine method of MICHAELIS (**29**). 4 ml. gastric juice was mixed with 0.7 ml. 1 % starch solution, 2 ml. phosphate buffer and a few drops of toluene. At suitable intervals samples were mixed with a given small quantity of iodine solution. Even with the strongest possible concentration of gastric juice only a very weak amylolytic action was shown in 8-18 hrs., in the pH-region 6.3-7.6. This action was so weak that it was impossible to investigate the pH-optimum more closely. Former authors did not detect amylase in the gastric juice of Coelenterates.

Maltase

In order to check the presence of a maltase, experiments were made with maltose as substrate, at varied pH. Tests with FEHLING solution failed to show any increase in reducing power of digestive mixtures. Attempts to discover increase in reducing power with methylene blue as an indicator (method of LANE and ENYON, cited by COLE, **10**) also failed. More accurate experiments over a wide range of pH with the polarimetric estimation of WILLSTÄTTER et al. (**33**) and with the HAGEDORN-JENSEN titration still brought no results. Even with very concentrated extracts no maltase was found. Thus we must conclude that the gastric juice of *Pseudactinia* does not contain this enzyme in noticeable quantity.

Lipase

Preliminary experiments with milk, mixed with gastric juice and phenolphthalein as indicator, failed to show the production of fatty acids. Experiments were then carried out with olive oil as substrate according to the titration method of WILLSTATTER and WALDSCHMIDT-LEITZ (**34**). 4 ml. of enzyme solution were mixed with 2 ml. phosphate buffer and 1 ml. olive oil. The experiments were carried out at a pH range of 5.3-8.7, at 30° C. No digestion occurred within 24 hrs., the variation in KOH-consumption never exceeded the limits of error.

Since our experiments with higher esters proved to be negative, we have tried to show a breakdown of lower esters (tributyrin) by the gastric juice. These experiments were carried out with the method of RONA and MICHAELIS (**28**) with a KRIJGSMAN stalagmometer (KRIJGSMAN, **20**, **21**). A saturated, fresh solution of pure tributyrin in water was used, 9 ml. of which was added to 1 ml. gastric juice and 1 ml. phosphate buffer. Tributyrin in watery solution lowers the surface tension considerably, consequently the number of drops to a given volume is much greater than to the same volume of pure water. The breakdown of the ester causes a rise in surface tension. Consequently the breakdown can be followed quantitatively with a stalagmometer, progressive decrease of the number of drops indicating progressive breakdown. A lipolytic action was shown in all experiments. An example is given in Table II. Temperature 27° C.

TABLE II

Time in hrs.	Number of drops given by 6 ml.				
	pH 7.6	pH 7.05	pH 6.3	pH 3.5	Control with boiled enzyme
0	95	96	96	96	96
2	83	92	93	96	95
4	87	90	92	95	95
8	71	79	89	96	96

Our results clearly show the existence, in the gastric juice, of a lipolytic enzyme, which does not act on milk-fat or olive oil, but digests tributyrin fairly well at pH 7.6-7.0. No digestion occurs at pH 4. HYMAN is the only author who has found a lipolytic action by the gastric juice of Coelenterates.

INTRACELLULAR ENZYMES

Proteinase

Extracts of gastric filaments showed very little action on congo red fibrin. In other experiments, carried out with the casein precipitation method and the gelatin liquefaction method, we found a strong proteolytic action. With gelatin a number of experiments were performed at different pH, using the titration method of WILLSTÄTTER and WALDSCHMIDT-LEITZ. 2 ml. of extract were mixed with 3 ml. phosphate buffer and 3 ml. gelatin solution. Titration of 3 ml. samples after 2 hrs., temp. 30° C. Optimal digestion was found to occur round pH 8, some action still occurring at pH 6.4 and pH 8.9. A typical example of these experiments is reproduced in figure 1 (broken line). Our results are in agreement with the statements of those former authors, who found proteinase in extracts of filaments.

Clotting action

The clotting action of extracts on milk, estimated in the same way as for gastric juice, was very strong. Coagulation occurred within 10 mins. at 18° C. Extracts of other Coelenterates also show a rennitic action (BODANSKY and ROSE, BODANSKY).

Amylase

The starch-iodine method was used, as for extracellular amylase. The extracts showed an amylolytic action, which was somewhat stronger than that of gastric juice, but still so weak that it was difficult to obtain quantitative data on its action. At 28° C and after about 2½ hrs. the first indication of digestion appeared, in the pH-region 5.2-7.0, shown by a faint paling of the blue colour as compared with the control. Within 7½ hrs. the paling became quite definite in this pH-range, but no reaction was seen at a pH lower than 5.2. Attempts to strengthen the amylase action by using more concentrated extracts failed. Amylase has been found in extracts of other Coelenterates by BODANSKY and ROSE, and BODANSKY, who do not state whether their subjects contain zooxanthellæ, and also by YONGE, who attributes the presence of the enzyme to zooxanthellæ.

Maltase

Attempts to detect the presence of a maltase in extracts, with maltose as a substrate, at a wide range of pH, all faited. Increase in reducing power could not be demonstrated with the methods described for gastric juice, so we must conclude that the extracts did not contain an active maltase.

Lipase

Extracts of gastric filaments showed very little or no action on milk-fat. A very weak action on olive oil (titration method as for gastric juice) was observed. Breakdown of tributyrin, on the other hand, was very rapid in all experiments. An example (8 ml. tributyrin solution, mixed with 2 ml. buffer and 3 drops of extract, at 28° C) is given in Table III.

TABLE III

Time in mins.	Number of drops given by 6 ml.					
	pH 7.7	pH 6.7	pH 5.5	pH 5.0	pH 2.3	Control with boiled enzyme
0	95	94	94	92	93	94
30	88	88	89	89	93	94
45	79	84	84	86	94	95
60	75	79	80	82	94	94
70	72	77	79	81	93	95

From our results it is clear that a lipolytic enzyme is present in the filaments, acting on tributyrin, with a strong action at pH 7.7-6.7, and showing no action at a pH lower than about 5. Our results are in accordance with most former authors, who, however, do not give pH-ranges.

Discussion

Our results prove that the gastric juice of *Pseudactinia flagellifera* contains digestive enzymes (compare KRIJGSMAN and TALBOT, **22**). The proteinase found, although not acting noticeably on fibrin, shows considerable action on casein and on gelatin. The optimal action on gelatin occurs round pH 8. Under natural conditions the proteinase apparently acts in its optimal pH-region, since the gastric juice has a pH of 6.7-7.8. Very probably this proteinase is of the trypsin type; definite proof of its nature should be revealed by experiments with purified enzyme and activators. The proteolytic action of the gastric juice appears to be sufficient to cause disintegration of the tissues of the prey for subsequent phagocytosis.

The lipase of the gastric juice breaks down tributyrin at a noticeable speed in a neutral or slightly alkaline medium, but does not act on higher esters. The biological significance of this action on lower esters is not clear, for one cannot understand how such action could contribute to the preliminary disintegration of the food.

The amylolytic action of the gastric juice is extremely weak, this amylase apparently plays no part in extracellular digestion.

For the final intracellular digestion a strong proteinase is available, which shows an optimal activity at the same pH-range as the extracellular proteolytic action. Probably, therefore, extra- and intracellular proteinase are identical, and of the trypsin type. It is not a tissue proteinase of the kathepsin type, since kathepsins show lower pH-optima. The intracellular lipase acts strongly on tributyrin in the same pH-region as the extracellular one. Apparently both lipases are identical. Its action on milk-fat and olive oil is very poor, which is in agreement with the results of most former authors. The question arises, therefore, whether this poor action on higher esters means that Coelenterates are unable to utilise a considerable part of their food. This seems unlikely. Do they possess, then, specific lipases which act better on invertebrate than on vertebrate or vegetable fat? Although the known differences in composition between these fats do not seem to justify the assumption that Coelenterates possess specific lipases, it may be worthwhile to investigate the action of Coelenterate lipase on the fats of their normal food.

The intracellular amylase causes a slow digestion of starch. It possibly acts better on glycogen, which is the principal polysaccharide contained in the food of *Pseudactinia*. It is somewhat surprising that neither we nor former authors (except BODANSKY) have found an intracellular maltase. This enzyme is present throughout the animal kingdom as a necessary agent for the breakdown of maltose which results from the decomposition of polysaccharides. It does not seem probable, therefore, that it would be lacking in the endoderm of Coelenterates. Possibly it is bound in such a way in the cells that ordinary extraction methods fail.

It is not clear whether the strong clotting action of gastric juice and extracts has a biological significance. It may be suggested that by this action the excreted mucus is coagulated, so that it forms a solid layer coating the prey. It seems very unlikely, anyhow, that the mucus is secreted in the solid condition in which we find it in the gastric cavity. As far as we know, mucus is, throughout the animal kingdom, secreted in a fluid state.

As far as can be concluded from our experiments the digestive mechanism in *Pseudactinia* takes the following course : A prey is ingested, a process which is certainly accompanied by the swallowing of seawater. After ingestion the mouth closes, there being no continuous communication with the surrounding water. Continuous communication may occur in plankton feeders, in which a permanent stream of food particles enters the gastric cavity. In *Pseudactinia*, however, this is not the case as indicated by the difference between the pH of the gastric juice and the surrounding water. Nevertheless, *Pseudactinia* certainly does not keep its mouth closed as long as the gastric cavity contains food, frequently taking in new prey while digestion of previously swallowed food is till going on. Consequently a certain contamination with seawater must occur. Therefore mucus, secreted as a reaction to the ingested food, covers the prey and is possibly solidified by rennitic action. This mucus, which contains a fairly strong concentration of proteinase, impregnates the food, and by the protection of this stiff jelly digestion may go on without being disturbed by seawater. The particulate products of the extracellular digestion are phagocytised by the endoderm cells, and digestion is completed intracellularly. In those cases in which the prey is covered by a chitinous cuticle, the enzymes may diffuse from the surrounding jelly through the permeable regions of the cuticle. Possibly a chitinase assists the disintegration of food with a chitinous skeleton. No experimental data on chitinase are, however, available.

Summary

1) The digestive mechanism of *Pseudactinia flagellifera* was investigated.

2) The gastric juice has a pH between 6.7 and 7.8, which is not always the same as the surrounding water.

3) The gastric juice contains a proteinase (optimum for gelatin round pH 8), a lipase acting on tributyrin at about pH 6-8 and a very weak amylase. No maltase was found.

4) Extracts of filaments show a strong proteolytic action (optimum for gelatin round pH 8), a lipase strongly acting on lower esters but very poorly on olive oil and milk fat, and a weak amylase. No maltase was found.

5) Gastric juice and extracts of gastric filaments show a definite clotting action on milk.

6) The biological significance of the results obtained is discussed.

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NOTES ON THE BIOLOGY OF THE WHITE STUMPNOSE, *RHABDOSARGUS GLOBICEPS* (CUVIER), AND ON THE FISH FAUNA OF THE KLEIN RIVER ESTUARY

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East African Marine Fisheries Research Organization, Zanzibar

(With three text-figures)

(Read November 17, 1954)

The fish fauna of the Klein River estuary is discussed in relation to food, shelter, and hydrographic conditions.

The biology of the white stumpnose is described on the basis of an examination of 1,905 specimens from estuarine and sea samples.

The growth rate of the white stumpnose as determined by length-frequency data and by otolith examination is suggested to be about 60 mm. per year.

Only juvenile white stumpnose are present in estuaries, entering annually, and remaining until they reach a length of about 140 mm., then leaving for the open sea and not returning.

Females are considered to mature at between 220 mm. and 240 mm. in length. Males were first found with well-developed gonads at 275 mm. Males and females were first found breeding in their third year.

INTRODUCTION

The white stumpnose, *Rhabdosargus globiceps* (Cuvier), is a common South African inshore fish. It ranges from Walvis Bay to Durban, and is of angling and commercial importance on the Cape south and west coasts. Adult fishes, often in large shoals, are found along the coastline and down to forty fathoms (Barnard, 1927), being caught by shore seiners, line boats, and trawlers. Juveniles, up to about 15 cm. in length, frequent estuaries, where they may be netted and sun-dried to form 'Bokkems', a term covering other small estuarine fishes such as juvenile white steenbras (*Lithognathus lithognathus*) and mullet or haarders (*Liza ramada*).

Little is known about the general biology of the species, or its movements, as is unfortunately the case with most South African fishes. This work was, therefore, undertaken as a preliminary study of factors such as rate of growth, size at sexual maturity, migrations and others.

The *R. globiceps* population of the Klein River estuary near Hermanus and the Milnerton estuary near Cape Town were studied, and samples of marine fish were bought from Kalk Bay line boats. The fish populations of the two estuaries were found to be nearly identical and it was therefore considered necessary to describe only the Klein River estuary fully and merely to refer to the Milnerton estuary where it showed differences or provided additional information. To give a clear picture of the biotope of *R. globiceps* the fish fauna of the Klein River estuary is fully described. Scott, Harrison, and Macnae (1952) made a qualitative survey of the bottom fauna of this estuary.

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METHOD

Samples were obtained by regular nettings made over a period of eighteen months at Milnerton estuary and the Klein River estuary. Samples of *R. globiceps* were also bought from Kalk Bay line boats. This sampling was irregular because catches at times contained no *R. globiceps*, and because boats leave this harbour during the period that the snoek, *Thyrsites atun* Euphrasen, is abundant around the Peninsula. Two collecting expeditions by the ecological survey team of the Zoology Department, University of Cape Town, to the Breede River estuary, in which I was able to participate, yielded a summer and a winter sample of *R. globiceps*. Odd records were also obtained from trawlers and shore anglers. (Table I.)

TABLE I

Place and dates	*Gear*	*Number of fish measured*	*Number of fish opened*	*Size range*
Klein River estuary .. May '50–July '51	Large seine	1,166	371	52–154 mm.
Klein River estuary .. Jan., Feb., March., April 1951	Drag net	12	12	27–105 mm.
Milnerton estuary .. April '50–June '51	Small seine	631	238	28–98 mm.
Breede River estuary.. July 1951	All nets	44	44	35–124 mm.
Kalk Bay .. .. Jan.–July '51	Hand lines	41	41	128–300 mm.
Cape Infanta .. .. July '50, July '51	Trawl at 30 fathoms	5	5	128–260 mm.
Miller's Point .. May 1951	Angling	6	6	200–300 mm.
Buffels River mouth .. July 1951	Angling	–	6	300–350 mm. (approx.)
	TOTALS:	1,905	723	27–350 mm.

Nets of three types were used for samplings:

(i) *The Large Seine*. This is a net of English design (the Saltash Tuck Seine), weighted to sink when pulled so that it rides the bottom, and does not float as do the seine nets of commercial fishermen used for shore and estuary fishing in South Africa. It is 152 ft. in length, with a purse of 19 ft., is 5 ft. deep in the wings and

7 ft. deep at the purse. The mesh of the wings is 1½ in. bar, and that of the purse ¾ in. bar. The net has 250 ft. ropes at each end, and is shot from a boat.

Fish below 70–80 mm. escape through the meshes of the large seine, so that length-frequency curves are skewed from this size and below. With capture by net only, there is a possibility that the larger and faster fish may more easily escape this gear, resulting in skewing of the length-frequency curves of the larger sizes. Estuarine *R. globiceps* do not reach a large size, however, and it is unlikely that this type of error is affecting the large seine captures.

(ii) *The Small Seine.* This is a much smaller net than the above, being 40 ft. in length, 4 ft. deep in the wings, and 6½ ft. deep at the bunt. Unlike the large seine it has no long purse, but has a slight belly of about 6 ft. The mesh is ½ in. bar. The small seine is pulled by two persons without ropes, and is therefore limited to water that is shallow enough for wading (about 4½ ft.). The small seine was used at Milnerton estuary, as the large seine dug into the soft muddy bottom. This net has considerable netting error. Small fish of about 30 mm. and below are able to escape through the meshes, and larger fish of about 120 mm. approx. have often been seen to swim out of the net due to the slow pulling.

(iii) *The Drag Net.* This is a small conical net pulled by two people. Ropes 10 ft. long are attached to each end of the mouth which is 6 ft. 9 in. wide. The depth of the net is 15 in., its length 10 ft., and mesh ½ in. bar. The net has retaining flaps half-way down its length, helping to retain fish already caught. The head rope of the net is corked, with the foot rope attached to a length of chain. The net is basically a trawl (originally intended to be kept open with a beam) that has been put to a different use. It was found to be ideal for dragging through weed beds of *Zostera capensis* and *Ruppia maritima* as the chain prevented the foot of the net rolling up. Because this net has a narrow mouth, and because the operators dragging it pass near the region to be netted, the drag net can be considered to give a representative sample of fish from 30 to 60 mm. only. It is of little use for length-frequency data but was useful for showing the presence or absence of smaller fish than those caught with the large seine in areas where the small seine was useless because of weed beds.

Due to the selectivity of all the above nets, all length-frequency distribution below 80 mm. is inaccurate (fig. 2).

Preservation of the fish was done immediately after netting. An incision was made in the abdominal wall and the fish put into 20 per cent formaldehyde. This stopped digestion immediately, and gut and gonads were preserved in good condition.

Gut contents of the whole alimentary canal were washed out and the different types of food organisms and the numbers of each type present were noted.

Maturity. Gonads were weighed. In males the presence or absence of milt was noted, and in females the colour of the ovary, the transparency of the ova, and maximum ovum diameter were recorded.

Age determination was made by counting otolith growth rings. The concave dorso-lateral surfaces of the otoliths were flattened by grinding down on a ground-glass screen using powdered glass as an abrasive. Growth rings showed clearly when the otoliths were examined by reflected light.

Sample errors. The samples from which the length-frequency curves were built are considered adequate, as successive monthly samples show very similar curves.

The monthly food comparisons were made on samples of thirty fish. Some idea of the error due to sampling alone was afforded by the occurrence of an Acanthocephalan parasite in successive monthly samples of fish. The following are the percentages of fish that contained these parasites in monthly samples:

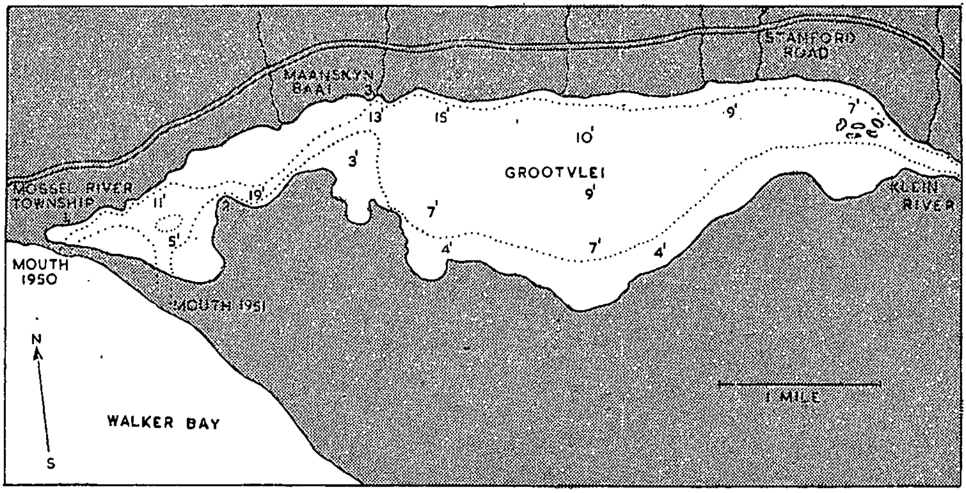

FIG. 1. The Klein River Estuary. Dotted line indicates extent of lagoon at lowest water level.

1950		1951				
November	*December*	*January*	*February*	*March*	*April*	*May*
20%	16%	45%	16%	40%	34%	14%

The parasite was firmly attached to the inside of the rectum, usually about one to four being present in infected fish. The adult parasite is non-motile. It can be assumed that the percentage of infected fish in the lagoon, at least from February to May 1951 when the lagoon was closed to the sea, was fairly constant. Infected fish were in excellent condition, so the number of parasitized fish was not being reduced through deaths. An increase or decrease in percentage infection would be expected to be fairly gradual, yet the percentages given above are extremely erratic. If the assumption is correct that the total percentage of parasitized fish in the lagoon is roughly constant, these fluctuations must be due to numerical sampling error. This can be utilized in evaluating the monthly occurrence of food items. If a food item is present in samples over a period of months in 20 per cent of the total population, percentages in monthly samples of thirty fish would be expected to show fluctuations similar to those of the parasites given above. These variations would reflect no change in the feeding habits of the population. Only very marked changes in the monthly percentages of food items can therefore be considered as indicative of food changes in the fish population.

Identification and terminology of the fishes is based on Smith (1949).

Lengths of fishes are standard lengths (i.e. excluding the caudal fin).

THE KLEIN RIVER ESTUARY

DESCRIPTION

As a detailed description of this estuary and its bottom fauna has been made by Scott, Harrison, and Macnae (1952), only a short account will be given here.

The Klein River and a number of smaller streams flow into a wide lagoon, separated from the sea along its eastern edge by a range of low sand-dunes. At the southern edge of the lagoon these dunes flatten out to form a low, sandy strip where the mouth of the estuary is situated.

The lagoon is six miles long and at most half a mile wide, with an average depth of 8 ft. in summer and a few feet deeper in winter when the level is raised by flood water. Depths of up to 19 feet have been recorded in the channel (fig. 1).

In the summer little water enters the lagoon, a sand-bank is built up at the mouth by wave action and the lagoon becomes land-locked. Evaporation causes a slight drop in level during the summer months and then the winter rains swell the lagoon until the increase in area of the lake interferes with farming at its margin. When this happens local farmers dig a channel through the sand-bank. By the time the dammed-up water has poured out, a wide mouth is formed and the lagoon becomes tidal for most of its length. The mouth then closes gradually, usually taking about five months.

There are thus fairly regular periods every year during which the mouth is alternately open and closed, which has profound effects on the lagoon fauna. During 1950 and 1951 when this study was in progress the state of the mouth was as follows:

1950	Mouth closed	.. February-September	Open	.. Oct.-Jan. (1951)
1951	Mouth closed	.. February-June	Open	.. July onwards

This more or less regular opening and closing of an estuary is a common occurrence along both the Cape and Natal coasts.

Both the flora and the fauna of the lagoon are rich. Beds of *Zostera capensis*, *Ruppia maritima*, and filamentous algae shelter and feed abundant life. Animals such as the small gasteropod, *Assiminea* sp., the bivalve, *Modiola capensis*, the amphipods, *Corophium triaenonyx* and *Melita zeylanica* and Chironomid insect larvae abound in the weed beds. Mudprawn *Callianassa kraussi* is found in muddy sand in the shallows near the mouth and along the margins of the lagoon; in the firmer sand of the mouth region the razor shell *Solen capensis* is abundant.

The lagoon has therefore the main elements for the support of a very rich fish fauna, providing cover from predators, and plant and animal foods in plenty.

Two stations were chosen for regular nettings of the lagoon: the region of the mouth (between 1 and 2) and Maanskynbaai (3) (fig. 1). The first lay in the channel; the second at the edge of the open lagoon.

Fish Fauna of the Lagoon

Table II is a list of fish species netted in the estuary during 1950 and 1951. Division into three groups gives an idea of relative abundance: A—abundant, C—Common, R—rare. At least twenty of the twenty-five species found were marine fishes tolerant of estuarine conditions.

Of the other five species *Gilchristella aestuarius*, *Atherina breviceps* and *Psammogobius knysnaensis* are chiefly estuarine. In the western Cape the remaining two, *Rhabdosargus tricuspidens* and *Syngnathus acus*, are also known mainly from estuaries. An unexpected omission from the list is *Mugil cephalus*, a mullet common in estuaries both east and west of the Klein River. It is possible that the fish was present in the lagoon and not netted, for it is known for its habit of swimming upwards when disturbed, at times leaping clear of the water over the top of a floating net. The large seine, sweeping the bottom of the lagoon, would probably have allowed them to escape.

Table II

Species according to families	*Standard length range*	*A.*	*C.*	*R.*
Rhinobatidae				
Rhinobatos annulatus (M. &. H.)	740 mm.			x
Stolephoridae				
Gilchristella aestuarius (G. & T.)	38–50 mm.		x	
Tachysuridae				
Tachysurus feliceps (Valenciennes)	60–250 mm.		x	
Soleidae				
Heteromycteris capensis Kaup.	20–70 mm.		x	
Solea bleekeri Boulenger	90–110 mm.		x	
Syngnathidae				
Syngnathus acus Linn.	61–155 mm.		x	
Carangidae				
Hypacanthus amia (Linn.)	225–530 mm.		x	
Pomatomidae				
Pomatomus saltator (Linn.)	205–300 mm.		x	
Sciaenidae				
Atractoscion aequidens (Cuv.)	200 mm.			x
Pomadasyidae				
Pomadasys olivaceum Day	95–156 mm.			x
Sparidae				
Rhabdosargus globiceps (Cuv.)	27–158 mm.	x		
Rhabdosargus tricuspidens Smith	112–260 mm.		x	
Diplodus sargus Linn.	70–105 mm.			x
Diplodus trifasciatus (Rafinesque)	70–100 mm.			x
Lithognathus lithognathus (Cuvier)	90–330 mm.	x		
Lithognathus mormyrus (Linn.)	75–170 mm.			x
Sarpa salpa (Linnaeus)	105–120 mm.		x	
Spondyliosoma emarginatum (Cuv.)	85 mm.			x

TABLE II (*contd.*)

Species according to families	*Standard length range*	*A.*	*C.*	*R.*
MUGILIDAE				
Liza ramada (Risso)	50–260 mm.	x		
ATHERINIDAE				
Atherina breviceps Cuv.	15–60 mm.		x	
GOBIIDAE				
Psammogobius knysnaensis Smith	27–50 mm.		x	
Gobius nudiceps Cuv.	50–115 mm.		x	
CLINIDAE				
Clinus superciliosus (Linn.)	62–110 mm.		x	
TRIGLIDAE				
Trigla capensis Cuv.	140–200 mm.			x
LAGOCEPHALIDAE				
Amblyrhynchos honkenii (Bloch)	120–145 mm.		x	

Fish netted in the Klein River estuary during 1950 and 1951

(i) *Migration*

Many coastal fishes are known to migrate and it seems probable on *a priori* grounds that migration to and from Cape estuaries should take place, as there are considerable changes in temperature, salinity and turbidity between summer and winter in most estuaries.

At the Klein River estuary, however, whatever migrations might take place are prevented in most years by the closure of the mouth during the whole of the winter, and fish that have entered during the summer months are forced to remain in an environment of low salinity, low temperature, and high turbidity.

In 1951 the mouth of the estuary was cut earlier than usual, and was open during the latter half of the winter. Due to exceptionally heavy rains the lagoon was very muddy, and cold water poured out through the mouth. Scott, Harrison, and Macnae (op. cit.) state that under conditions of this type, temperatures in the estuary may go down to 12° C. and salinities down to 20 parts per thousand. During this period white stumpnose, *R. globiceps*, elf, *Pomatomus saltator*, and leerfish, *Hypacanthus amia*, were absent from nettings.

It seems therefore that fish trapped in the lagoon are able to withstand the average winter conditions, but that a number of species would migrate away from the lagoon if this were possible.

(ii) *General Note on Feeding*

Few fishes feed directly on the vegetable matter in the lagoon. Perhaps the only complete herbivore is the mullet, *Liza ramada*, whose diet consists chiefly of diatoms and unicellular algae, the cell walls of which are crushed by its exceptionally muscular stomach filled with sand grains.

Rhabdosargus globiceps, *R. tricuspidens*, *Sarpa salpa*, *Diplodus sargus* and *D. trifasciatus* were found to be omnivorous, cropping plants such as *Zostera capensis*, *Ruppia maritima*, and filamentous algae (mainly *Enteromorpha* sp.), and also feeding on the small crustaceans, polychaetes, and molluscs of the weed beds and bottom.

Lithognathus lithognathus, the white steenbras, although taking vegetable matter occasionally, is mainly carnivorous, feeding on the animals sheltering in the weeds, and using its elongated snout to suck or blow *Callianassa kraussi* and *Solen capensis* out of the sand.

The small sole, *Heteromycteris capensis*, and the small goby, *Psammogobius knysnaensis*, are common on the sandy shallows near the mouth of the lagoon. *P. knysnaensis* had fed on ostracods, amphipods and sphaeromid isopods, and the few *Heteromycteris capensis* examined had eaten ostracods and foraminifera. *Solea bleekeri*, the larger sole present in the lagoon and not restricted to the mouth region, had a more varied diet including isopods, amphipods, *Assiminea* sp., and occasional small crabs and small fish.

The whitebaits, *Atherina breviceps* and *Gilchristella aestuarius*, swim in shoals, feeding on planktonic copepods and amphipods.

Two large fish predators were present in the lagoon, the leerfish or garrick, *Hypacanthus amia*, and the elf or shad, *Pomatomus saltator*. These two species were only occasionally netted, but being exceptionally speedy fish, and probably swimming near the surface, they may be present in greater numbers than shown by the large seine nettings.

Three species of cormorant were present in the lagoon, all fish predators. These were *Phalacrocorax neglectus* (the white-breasted cormorant), *P. capensis* (the Cape cormorant or trek-duiker), and *P. africanus* (the reed cormorant). *Anhinga rufa* (the darter), another fish-eater, was also occasionally seen. Predation of the fish population due to these birds cannot be heavy, for an average daily count of all species was about twelve to fifteen birds.

Biology

Age Determination and Rate of Growth

Many workers have found that bands or rings are present on the calcareous otoliths, and also on the scales and other bony parts of many fish, which may be annual in nature and are formed by varying rates of growth causing material of different transparencies to be laid down. The scales, otoliths, and supra-occipital crests of *Rhabdosargus globiceps* were examined to see whether any such markings could be found.

Although banding was occasionally present on scales and supra-occipital crests, otoliths gave much more consistent results, and eventually only this method of age determination was used.

Otoliths of all fish had opaque centres. Clear banding was normal in estuarine *R. globiceps*, which were one or two years old. Fish from the sea samples were older, and rings toward the periphery of the otoliths were crowded together, and sometimes unreadable.

In previous work done on age-reading using otoliths, some investigators have simply assumed the annual nature of the rings (Roux, 1947, on the Cape Stockfish). In all cases where the validity of this has been tested (Menon, 1950, on the Poor

Cod; Hickling, 1931, on the Hake; Jones and Hynes, 1950, on the Stickleback, among others) it has been found to hold. The commonest method of testing is to find out from periodic samples the seasons during which each type of band is laid down at the periphery.

Hickling (1931) found that in the hake the light and dark bands were due to alternating layers of thick and thin organic lamellae embedded between radially arranged inorganic crystalline material. The cause of the change in the thickness of these lamellae is not known. Most workers have found that the transparent band is formed in winter, and the opaque in summer. This is not an invariable rule and may alter with the species of fish studied.

(i) *Time of Formation of Opaque and Transparent Bands in the Otoliths of R. globiceps*

In small specimens of *R. globiceps* it is easy to see whether an opaque or transparent band of otolith material is being laid down at the periphery. In larger fishes the bands become very narrow at the periphery and it is more difficult to see which type of band is forming. The thinning of the otolith at its edge interferes by making an opaque zone look lighter. Thus the larger size groups taken by line fishing gave no clue to the time of year the bands were produced.

Sea fishes entering the Klein River estuary in October 1951 had thin opaque bands at the periphery, suggesting that opaque material would continue to be deposited during the summer. Fish, caught at the same time, that had been in the estuary during the winter showed wide transparent bands, with no trace of opaque material. Estuarine conditions must therefore be able to effect a change in the normal banding. The new estuarine population, as soon as the mouth closed in January, also started forming transparent material.

It is probable therefore that in marine *R. globiceps* an opaque band is formed in summer and a transparent band in winter. *R. globiceps* trapped in the lagoon, however, lay down transparent material during the greater part, or possibly the whole, of the year.

In the following discussion it is assumed that the ringing is annual, and that the transparent bands are always counted. In spite of the interference of the normal banding by estuarine conditions, fish trapped and laying down transparent material from February to October would still have the total number of bands unaltered.

(ii) *Age Groups*

If the modes in length-frequency distribution (fig. 2) represent year groups, it would be expected that the fish in one mode would have the same number of otolith bands. This was found to be so. Fish of mode A taken in May, August, and September all had two transparent otolith rings. Fish of the smaller mode B entering the lagoon in October had one transparent otolith band.

TABLE III

Length in mm.	1 *ring*	2 *rings*	3 *rings*	4 *rings*
60	x			
70				
80	x			
90	x	x		
100	x	x		
110	x	x		
120		x		
130		x		
140		x		
150		x		
160				
170				
180		X		
190		X	X	
200		X	X	
210			X	X
220			X	
230				
240			X	
250			X	X
260				X
270				
280				X
290			X	X
300			X	
310				
320				X
Number of fish examined	17	21	10	7

The number of transparent otolith rings in *R. globiceps* of different sizes from the Klein River estuary (x) and from Kalk Bay line boats (X).

A second transparent band started to form on the otoliths of these fishes in January. Mode C fishes had one transparent band. Otoliths of mode X fish were not examined.

Mode B in October 1950 and mode C in March 1951 consist of one-year fish. Mode A in May, August, and September 1950 and mode B in April 1951 are composed of two-year fish. Mode x is considered as a small element in the lagoon fauna of fish under one year.

(iii) *Rate of Growth*

This can be assessed in a number of different ways from the data available. Modes A and B are different year groups of *R. globiceps*, mode A consisting of two-year fish and mode B in October 1950 consisting of one-year fish. The difference between these two modes is about 60 mm., representing one year's growth.

From the movement of a single mode in successive months increase in average size of fish is between 5 and 10 mm. per month, i.e. between 60 and 120 mm. per year.

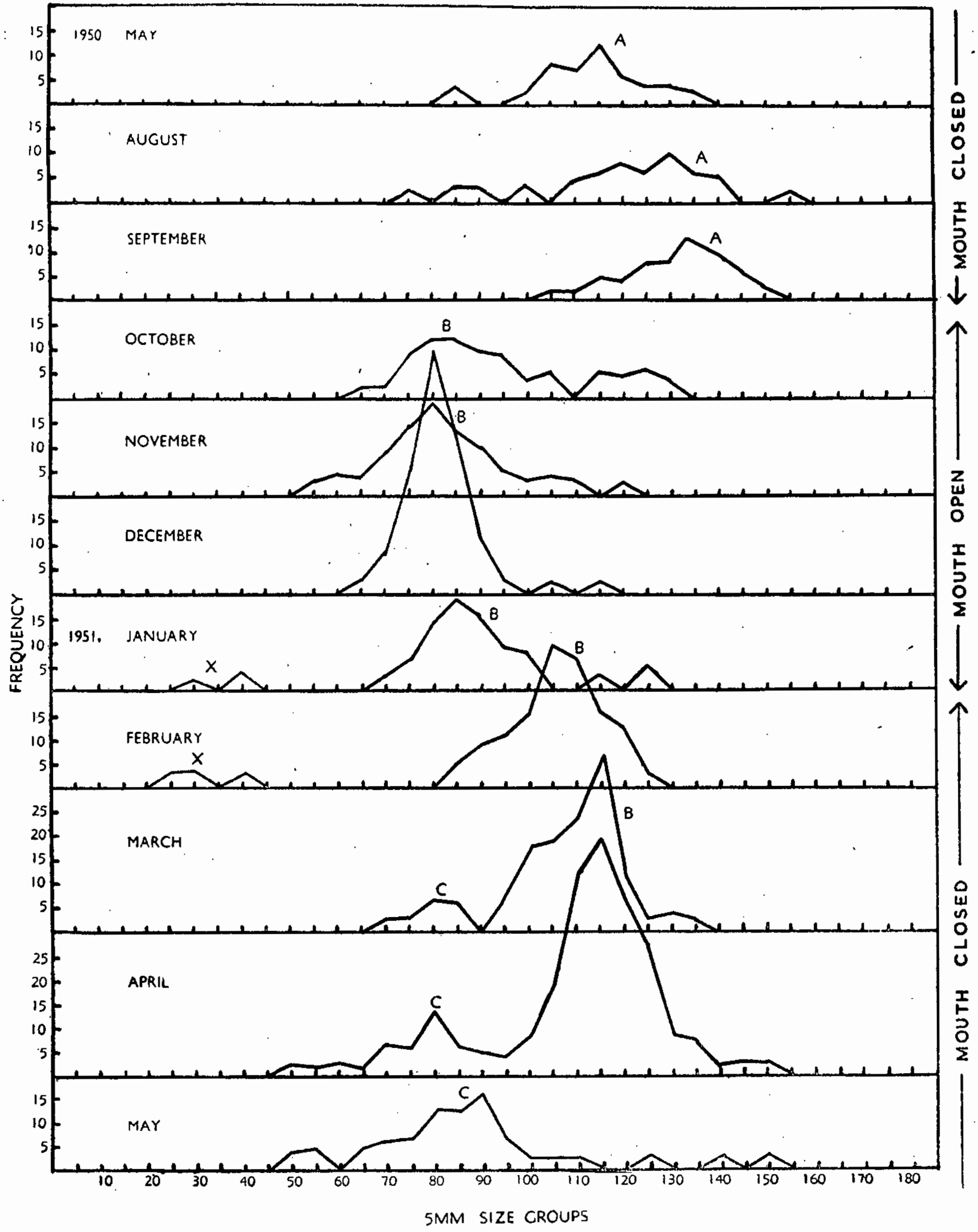

FIG. 2. Length-frequency distribution of *Rhabdosargus globiceps* in the Klein River estuary.

Table III also gives an estimate of growth. From the table it can be seen that sea fish have reached a length of about 260 mm. in their fourth year, averaging a growth of about 60 mm. per year.

The three calculations are therefore in fair agreement. The only growth rate that has been calculated for Cape fish to my knowledge is that of the stockfish (*Merluccius capensis*), a member of the Gadidae. Roux (1947) found it to be from 90 to 110 mm. per year.

The Population in the Klein River Estuary

As has been shown, juvenile *R. globiceps* are among the commonest fishes in the Klein River estuary. The population of *R. globiceps* during the time of study consisted of immature fish up to 15 cm. in length. If normal growth is taking place larger fish than this must be migrating out of the lagoon, with smaller fish entering and continually replacing the stock.

From the beginning of sampling in May 1950 until September of the same year the population consisted mainly of a single year group of two-year-old fishes (mode A, fig. 2). On the opening of the lagoon in October this mode immediately began to diminish in size, the fish migrating out to sea, until by December this group was hardly represented.

Simultaneously a new mode appeared in the length-frequency data (mode B, fig. 2), consisting of one-year-old fish which replaced the older population during these three months.

The younger fish are therefore attracted to the rich estuary, but at a slightly larger size they migrate out to sea. This change in choice of environment is probably related to the physiological changes in the fish connected with development to maturity. Spawning takes place at about 240 mm., but marked increase in gonad weight is already seen at 200 mm.

The drag nettings occasionally caught much smaller fish of about 30 mm., well below the netting range of the large seines (mode X, fig. 2). Mode C, first seen in the large seine nettings of March 1951, is considered to be formed of the larger members of this O-year group, just beginning to fall within the large seine nettings. The fact that mode C does not show growth movement to the right in successive months shows that the majority of the fish are still below the mesh size.

In May 1951 mode B was not represented. At this time the lagoon was filled with fresh water from heavy rains. Turbidity in the lagoon was high. Mode B fish were out of range of the nettings, so must have been in the deeper, more inaccessible parts of the lagoon. It is suggested that the inflowing fresh water overlay the denser more saline water, which would be least diluted in the deepest portions of the lagoon. That the larger fish of mode B and not the smaller fish of mode C should seek these deep areas is consistent with the difference in choice between larger and smaller fish on the opening of the lagoon in October 1950.

This preference of two-year fish for the open sea, ensuring that an estuarine population consists always of immature fish, seems to be a general rule for *R. globiceps*, and also for a number of estuarine fishes. This has also been found to hold by Hartley (1940) in England and by Irvine (1947) on the Gold Coast.

FEEDING OF R. GLOBICEPS

(i) *Estuarine Fish*

Table IV lists all the food organisms found in *Rhabdosargus globiceps* netted in the Klein River estuary. A wide variety of both hard and soft foods was found. As well as small animals, vegetable matter in the form of algae, blades of *Zostera capensis* and *Ruppia maritima* and seeds are eaten.

TABLE IV

PROTOZOA
- *Foraminifera.*

POLYCHAETA
- Spionid. ?*Prionospia* larva.
- *Lumbriconereis* sp.
- *Glycera* sp.
- *Pectinaria* sp.

MOLLUSCA
- *Haminea alfredensis* Bartsch.
- *Modiola capensis* Krauss.
- *Solen capensis* Fischer.
- *Assiminea* sp.

INSECTA
- Chironomid larvae.
- Syrphid larvae.
- Syrphid pupae.

CRUSTACEA
- Ostracods.
- Copepods.
- *Melita zeylanica* Stebb.
- *Parorchestia rectipalma* Brnd.
- *Corophium triaenonyx* Stebb.
- *Exosphaeroma hylecoetes* Brnd.
- *Tanais philetaerus* Stebb.
- *Callianassa kraussi* Stebb.
- *Hymenosoma orbiculare* Desm.

PISCES
- *Psammogobius knysnaensis* Smith.
- Fish scales.

ALGAE
- *Enteromorpha* sp.
- *Ulva* sp.

ANGIOSPERMAE
- Grass seeds.
- Potamogetonaceae seeds.
- *Ruppia maritima* Linnaeus.
- *Zostera capensis.*

Food organisms found in *R. globiceps* from the Klein River estuary.

The commonest food item occurring in estuarine *R. globiceps* is filamentous algae (*Enteromorpha* sp.) (fig. 3). It is possible, however, that fish do not derive as much food value from vegetable as from animal matter, and it has also been suggested that they may often eat algae for the animals that shelter in them. The latter is not the case with *R. globiceps*, for many fish of a sample may have the stomach and intestine packed with algae, although no animal remains are present. In some months, noticeably October and November 1950, filamentous algae formed by far the bulk of the food.

The remainder of the common food organisms are animals that shelter in the weed beds, such as the amphipods *Melita zeylanica* and *Corophium triaenonyx*, the isopod *Exosphaeroma hylecoetes* and the small gastropod *Assiminea* sp., and bottom animals, such as the bivalve *Modiola capensis*. Cropped pieces of *Ruppia* were often found, sometimes packing the alimentary tract. Grass seeds and a potamogetonaceous seed were occasionally present, the latter sometimes having begun to germinate. No whole specimens of *Solen capensis* were ever found, although this bivalve is abundant on the estuary bottom in some areas. Unlike *Lithognathus lithognathus*, *R. globiceps* seems unable to dig the whole animal out of the sand. However, the siphons of *Solen capensis* were often present, suggesting that the fish had apparently bitten off the siphons without destroying the animal in the sand below.

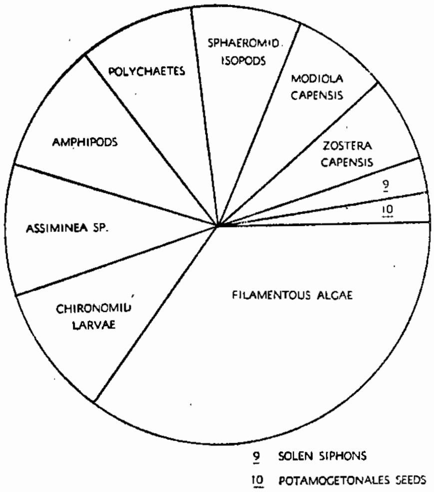

FIG. 3. Relative proportions of the ten main food organisms of *R. globiceps* in the Klein River estuary.

Steven (1930) and other authors have found that most species of fish will take the commonest foods available to them in their particular habitats. This general rule also holds for *R. globiceps*, because its diet is composed of organisms which Scott, Harrison, and Macnae (1952) found to be commonest in the estuary.

Although the rule applies to the fish sample as a whole, there is evidence of choice of particular types of food by individuals. In a sample of fish one individual may be found to have fed only on seeds, another only on chironomid larvae, another only on *Assiminea* sp., and a fourth may have only algae in its gut. This occurs where a whole sample has been netted over one weed bed, and therefore cannot be due to fish feeding on different organisms in different areas. Lebour (1919) carried out experiments on the feeding habits of small fish and found that they would often eliminate one species of plankton food before feeding on another. Dannevig (from Lebour, 1918) found that young plaice will only eat one food at a time, but that different individuals will be selecting different species of food at the same time. This is what occurs in *R. globiceps*. It seems possible that after snapping up the first likely food it finds, a hungry fish may ignore other types of food present, and continue to take this first type because it is satisfying the hunger. This has not, however, been checked by aquarium experiments.

Some change in choice of food organisms takes place with increasing size of fish. This is shown in Table V.

It is known that the larval fish feed on plankton (Gilchrist, 1904), and later become bottom feeders. The smallest fishes found in the Klein River estuary are just at this transition period. At a length of just over 20 mm. they have a diet consisting chiefly of planktonic copepods and amphipods, and also take sphaeromids, ostracods, and algae.

As the fish increase in size other animals become available to them as food, and the larger fishes have a more varied diet. Increase of mouth size, strength of jaw, size of teeth, and speed of movement must effect this. Large polychaetes such as *Lumbriconereis* sp. and chironomid larvae are eaten by fish of 40 mm. and larger. The first hard foods (the gastropod *Assiminea* sp. and the bivalve *Modiola capensis*) are taken by fish over 70 mm. Above this size larger animals such as *Haminea alfredensis* and *Hymenosoma orbiculare* are included in the diet, and the first pieces of *Solen* siphon are taken. Hard molluscs become increasingly important as foods of the larger fish over 100 mm., and *Callianassa kraussi* is also eaten.

TABLE V

	20–39 %	40–69 %	70–99 %	100–129 %	130–159 mm. %
Copepods	83		2	1	
Amphipods	83	38	23	25	34
Ostracods	17	8	3	3	5
Fil. Algae	17	46	70	74	67
Sphaeromids . . .	17	23	15	16	20
Chironomids . . .		38	22	16	26
Lumbriconereis . . .		31	8	4	2
Zostera, Ruppia . . .		8	13	16	18
Glycera sp.			1	1	
Haminea			1	4	
Solen siphons			6	6	
Modiola			5	16	48
Assiminea			7	29	56
Grass seeds			1	5	13
Potamogetonales seeds .			1	7	10
Hymenosoma			1	6	5
Callianassa				1	2
NO. OF FISH . . .	6	13	140	140	61

Change of food organisms with size of *R. globiceps* from the Klein River estuary. The number of times an organism is found in each size group is represented as a percentage of the total number of fish in that group. Fish in 20 mm. groups.

Three fairly distinct stages are seen. The very small fish (20-40 mm.) feed mainly on planktonic organisms, although a small proportion of bottom forms are are also taken. Medium-sized lagoon fish, up to 100 mm., feed on a wide range of small animals, but only a very small proportion of these have hard shells. Above 100 mm. hard molluscs become one of the most important food organisms in the diet. Throughout all sizes filamentous algae and amphipods are important foods.

Little change of food with season was found. When the mouth of the lagoon opened in October some difference was seen, but here smaller one-year fishes were replacing the two-year fish, and size may have affected the comparison. The young fish entering the lagoon feed mainly on filamentous algae, *Zostera* and *Ruppia*, *Modiola capensis* and *Corophium triaenonyx*, and the quantities of *Assiminea* sp., the isopod *Exosphaeroma hylecoetes*, polychaetes and chironomid larvae show a sudden reduction from the September sample. Scott, Harrison, and Macnae (1952) found almost no change in the bottom fauna when the mouth opened, and suggest that there is little difference in the abundance of the common animals. The change in food is then not due to a change in the food organisms present in the lagoon.

It is unlikely that the small size of the group entering the lagoon accounts for the change in diet, because most of the food organisms showing a reduction are animals which are normally taken by very small fish, as can be seen from Table V.

The average size of fish remains the same in the samples of the next three months, but the four food species which showed a reduction are again taken by the fish in increasing numbers during these three months.

It seems, therefore, that although a number of food species are available to the one-year fish, they select certain foods on entering the lagoon, and only gradually are other foods taken. This 'lag' in the use of available food may be due to the feeding habits before the fishes enter the lagoon. Accustomed to feeding on other types of food outside the estuary, the fish would have to learn new feeding habits before some of the new food species could be taken. Lebour (1918, 1919a, 1919b, 1920), Scott (1922 from Hartley, 1940), and others have shown that some fish do learn definite feeding habits, and it is reasonable to suppose that it must take some time to change these.

Feeding of *R. globiceps* in the Milnerton and Breede River estuaries showed patterns similar to those in the Klein River estuary.

(ii) *Sea Fish*

Fifty-eight specimens of *R. globiceps* were obtained from the sea. Unlike estuarine fish, where the percentage of fish with no food in the alimentary canal was negligible, nineteen out of fifty-eight fish had both stomach and intestine empty, or contained only bait. The only record of the feeding of marine *R. globiceps* is that of Biden (1930), who mentions that black mussels (*Mytilus perna*, *Mytilus meridionalis*) and polychaete worms are important foods.

Table VI lists the food organisms found in *R. globiceps* from sea samples. Amphipods were by far the commonest food, being found in abundance in Kalk Bay and west coast fish. Bivalves were also important. Six fish caught by Mr. Len Reed when angling at Miller's Point were packed with *Mytilus perna*, and many fish caught by other anglers at the same time also contained mussels.

TABLE VI

Place and date	*Size*	*Foods*	*No. of fish*
Kalk Bay Line Boats Summer and autumn 1951	128–300 mm.	Amphipods, Barnacle shells Bivalve remains Sand Ostracods Crab remains *Chorisochismus dentex*	41
Cape Infanta Trawled 36 fathoms. July 1950	260 mm.	Crab remains Bivalves Polychaete worms	3
Cape Infanta Trawled 35 fathoms. July 1951	128–203 mm.	Crushed echinoid Amphipods Crab leg	2

TABLE VI (*contd.*)

Place and date	*Size*	*Foods*	*No. of fish*
Miller's Point, Cape Peninsula Angling by Mr. Reed. May 1951		*Mytilus perna*	6
Buffels River mouth, West Coast Angling by Mr. Guy Currie, July 1951	300–350 mm.	Amphipods, including *Hyale saldanha* Chilton *Paridotea* sp. *Ascidians* *Ulva* sp. Sponge	6
			58

Food organisms found in *R. globiceps* from the shore to 36 fathoms.

Small white bivalve fragments (sp. indet.) were also found in Kalk Bay fish, and a small brown bivalve (sp. indet.) was present in a sample of three fish from Cape Infanta. Crab remains were found in a few stomachs, and the other organisms listed in Table VI were present in one or two fish.

No change of food with size or with season could be ascertained from the data.

In conclusion it can be stated that: (*a*) amphipods and bivalves are important foods; (*b*) ostracods, isopods, crabs, echinoids, barnacles and fish are also taken; and (*c*) vegetable matter is seldom eaten. The fish are solely bottom feeders, as all the organisms found, including the amphipods and fish, were bottom forms. The powerful incisors and molars enable adult fish to remove and crush barnacles and bivalves from rock surfaces.

SPAWNING AND SEXUAL MATURITY

R. globiceps lays eggs which float and on hatching give rise to pelagic larvae (Gilchrist, 1904). Spawning probably takes place close inshore, for fertilized eggs have been pumped into the old St. James aquarium through the water inlet (Biden, 1930). Little is known about the spawning season but Gilchrist states that an abundance of ripe males and females can be obtained from trawlers in November and December, and he performed successful fertilization experiments with the eggs and sperm of these fish. Biden mentions that very enlarged yellow ovaries can be obtained throughout the year from fish caught by the Kalk Bay line boats.

In December 1950 it was decided not to restrict the records of *R. globiceps* to estuarine fish, and from this date until August 1951 the gonads of fish bought from Kalk Bay line boats were examined. Although gonads that were enlarged and yellow were found in December, January and February, the only fish that had fully ripe eggs (large, round, perfectly transparent, and with a central oil globule) were taken in August. From the few facts that are available, it would seem that there is an extended breeding season from August to about February. It is possible that the fish may breed throughout the year, but Biden's observations are not definite enough to establish this.

TABLE VII

Size groups	*Average egg diameters*
60–79	0·04
80–99	0·04
100–119	0·06
120–139	0·08
140–159	0·09
160–179	—
180–199	0·08
200–219	0·07
220–239	0·60
240–259	0·68
260–279	0·60
280–299	0·10
300–319	—
320–339	0·50

Average diameter of ova of *R. globiceps* from the Klein River estuary and Kalk Bay, for different size groups. All measurements in millimetres.

The eggs seem to go through three stages during their formation. They are at first transparent, closely packed, and of different shapes dependent on how they have been pressed by their neighbours. Later they become granular, yellow, and more rounded. Finally the egg ready for shedding has again become transparent and is rounded and soft, with one distinct oil globule in the centre.

Gilchrist measured the eggs of one female, and found the variation of fifty eggs measured to be from 0·85 mm. to 0·89 mm. Ovaries from two females taken in August 1950 contained eggs that corresponded to Gilchrist's descriptions, but the average diameter was 1·05 mm.

Table VII gives the egg diameters of different size groups of *R. globiceps* taken from marine and estuarine fish.

Females under 60 mm. had ovaries that were fine threads, and the egg diameter averaged about 0·04 mm. At about 220 mm. the egg diameter suddenly increases about ninefold.

Gonad weights showed a sudden increase in weight at almost the same fish length. Fish of up to 180 mm. had a maximum gonad weight of 1·7 gms. At 200 mm. ovary weights were up to 8·0 gms., or about five times the weight. At 240 mm. some fish had tremendously enlarged ovaries, up to 41 gms. Females can therefore be considered to mature at 220-40 mm. in length.

The condition of maturity of the male is more difficult to determine, but the first males to be described as 'faintly milky' were 275 mm.

The ratio of males to females is difficult to determine among juvenile fish in the estuaries, for there is little visible difference between females with extremely undeveloped ovaries and immature males. However there are definitely more females. The ratio among the sea fish from Kalk Bay samples was 2:1 females to males. Biden (op. cit.) mentions that ratios of 10:1 and 20:1 females to males are common in large shoals of *R. globiceps.*

In conclusion it can be said that *R. globiceps* mature at the beginning of their third year, at a length of just over 200 mm., with males maturing at a slightly larger size than females.

PARASITISM IN R. GLOBICEPS

A trematode, some small nematode parasites, and an acanthocephalan were found in the alimentary tracts of estuarine *R. globiceps*.

The trematode (unidentified) was a small parasite about 5 mm. long present in the intestine of *R. globiceps* that entered the Klein River estuary and Milnerton estuary in the spring of 1950. Percentage infection was at first high in fish from both estuaries, but rapidly decreased over a period of three months, after which it was rarely found. No parasitized fish seemed in poor condition.

The acanthocephalan parasite, with a body about 5 mm. long and a proboscis of about 2 mm., was attached to the rectum just inside the anus. Usually two or three per fish were present, but as many as twelve were found. About 20 per cent of Klein River estuary fish were infected, and none found were in poor condition.

No parasites were found in sea fish.

CONCLUSION

It is well known that estuarine faunas are derived mainly from marine forms, but include a few purely estuarine species, and a few fresh-water forms in the upper reaches of the estuary (Day, 1951). This has been shown specifically for fish faunas by Hardenberg (1931), Hartley (1940), and Irvine (1947), and was found to be the case in this survey. Day has divided estuarine faunas into five components; (*a*) the fresh-water component, restricted to waters of low salinity; (*b*) the stenohaline marine component at the mouth of the estuary; (*c*) the euryhaline marine component, being marine forms able to tolerate the estuarine conditions; (*d*) the estuarine component, comprising the few species restricted to estuaries, and (*e*) the migratory component whose members spend only part of their lives in estuaries.

It is interesting to note that at least 80 per cent of the fish fauna of the Klein River estuary must be considered as falling under component (*e*), migratory animals not spending their whole lives in the estuary. The fish of this component must be further divided into two categories, those fishes present in the estuary only as juveniles, such as *Rhabdosargus globiceps*, *Lithognathus lithognathus* and *Pomatomus saltator*, and those fishes present both as juveniles and adults, but which leave the estuary for the purposes of spawning.

Clinus superciliosus, *Gobius nudiceps* and *Syngnathus acus* seem to represent the euryhaline marine component, being marine fishes extending into the estuary and able both to live and to breed there.

The truly estuarine component (*d*) is represented by *Psammogobius knysnaensis* and *Gilchristella aestuarius*, although the latter is also known from fresh water (Barnard, 1947).

No fresh-water component was found in this survey, but Scott, Harrison, and Macnae (personal communication) found a small silurid in the upper reaches of the estuary.

No stenohaline marine forms were found at the entrance of the estuary, or moving in and out with the tide, although nettings were made a hundred yards from the mouth.

It has been suggested that the Klein River estuary might be suitable for fish farming. It is quite possible that fertilization of the lagoon might produce more abundant growth of both animals and plants, and the growth rate of the fish fauna might be increased. Annual replenishment of fish stocks by young *R. globiceps* and possibly other species would obviate restocking by more laborious methods.

It has been stressed by MacGinitie and MacGinitie (1949) that the basic foodstuff supporting estuarine faunas is detritus; both that derived from the green matter in the estuary and that brought down by the river system. In the Klein River estuary, *R. globiceps* and mullet *Liza ramada* form a considerable proportion of the fish fauna, and both these fishes are supported in the main by the green matter of the estuary, before it has been broken down to detritus. The latter feeds almost exclusively on attached diatoms, and the former has filamentous algae as one of its main foods, and the two food organisms next in importance (*Assiminea* sp. and chironomid larvae), are eaters of green matter, not detritus. The bulk of the estuarine fauna is undoubtedly directly or indirectly supported by detritus or the bacteria living on detritus, but in a weedy estuary of this type much of the fish population is more directly dependent on living plant matter.

In spite of the prevalent opinion of South African anglers and commercial fishermen, few fish seem to breed in estuaries. Protection of estuarine fish stocks is possibly useful, not to protect breeding-grounds, but to protect nurseries of young marine fish. What proportion of young *R. globiceps* enter estuaries out of the whole young population of the species cannot be assessed from the present meagre knowledge of marine *R. globiceps*.

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A PRELIMINARY NOTE ON THE BREEDING AND GROWTH OF TILAPIA IN MARINE FISH PONDS ON ZANZIBAR ISLAND

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The following notes describe an initial experiment in the stocking of marine fish ponds operated by the Organization with a species of wild *Tilapia* found in the estuarine reaches of the Mzinga Mzinga stream, at the north-western end of Zanzibar Island. This species had been collected twice previously from Zanzibar. It is closely allied to *Tilapia mossambica* (Peters) and to *Tilapia pangani* Lowe, being fairly similar to the latter but differing from it in the lateral line scale count. It is possibly a distinct species, and Dr. Trewavas of the British Museum is working on its systematic position.

The species is hardy, as is shown by its tolerance of widely varying environments. For instance, *Tilapia* fry were netted in the Mzinga Mzinga stream where the water was almost completely fresh, and where in places the oxygen content was very low—only about one quarter saturation. When transferred to the fish ponds, they successfully adapted themselves to water slightly saltier that the outside sea, and supersaturated with oxygen. The temperature difference between the two environments was about 12° C. (21° F.), and, whilst the fish pond water (like the open sea) is always alkaline, the stream water was slightly acid.

Two series of water samples were collected from the Mzinga Mzinga stream: the first series just before low water springs in February, 1956, and the second at about half-tide a month later a few hundred yards downstream from the earlier location. In each case the flow was seaward. Sampling at the pond was carried out in March, one day before the periodic "topping-up" that is effected twice a month at each high water spring tide. Salinity and temperature are here affected by rain, drainage from the surrounding land, evaporation and the prevailing meteorological conditions. At the time of sampling there had been no rain for two weeks and the sky was clear. As the atmospheric temperature in March is at its maximum for the year, the conditions of sampling probably represent the highest extremes of temperature and salinity to which *Tilapia* have so far been subjected.

The analyses of the stream and pond samples are given in the Appendix, Tables I, II, III and IV. Where a range of values is given (e.g. for oxygen in the Mzinga Mzinga stream) these are the limits of all samples, the bottles having been filled at random in various parts of the stream. So far no *Tilapia* have been caught at high tide; but this is more likely to be due to the physical difficulties of netting in deeper water than to the absence of the fishes.

THE EXPERIMENTAL POND

The fish ponds at Chukwani, some four miles from Zanzibar Town, are designed on the simple mud-walled system of the East, but with cement gateways, grooved to fit heavy wooden doors. Every spring tide the ponds are topped-up by placing a wire-netting sieve over the cement entrance on the flooding tide, and opening the doors until high tide.

The pond used for *Tilapia* is half an acre in extent, and normally 30 to 20 inches deep over most of the area at average filling, but with a deeper pool just inside the sill, and a deep ditch 18ft. by 60 ft., these providing cooler water and shade when the water level is low. The pool varies from 10 inches when all doors are removed to 40 inches in depth at average filling, and the ditch from 25 inches when all doors are removed to 55 inches at average filling. The water in the pond will be subject to considerable variation in properties, since, during the period of each two weeks prior to topping-up, its salinity, temperature and oxygen content will vary with meteorological conditions, especially over the course of the year as the seasons change. These changes can be expected to affect the flora and micro-fauna of the pond, which will themselves in turn affect such important factors as oxygen and nutrient salt content and pH. Furthermore, at each topping-up the pond suffers an influx of sea-water (itself varying in properties with the seasons) which has passed over a mangrove tidal flat. These conditions severely limit the number of species able to live and grow in the ponds. Of those species stirring is necessary to disperse it. After stirring, the emulsion descends and the fish can be seen to react to this descending "barrier", immediately diving to the bottom as they encounter it. It is the normal behaviour of *Tilapia* to dive to the bottom of the pond when disturbed, and in this way many of them may escape the poison. Further tests will be carried out in the laboratory when supplies of fish are avaialble from the pond, to establish the minimal concentration of rotenone necessary for lethal effect on various species of fish. It would seem that it may be possible to "clean" the pond of all species of fish other than *Tilapia* by judicious use of the rotenone poison.

The rotenone used was in the form of "Staff Allens" Rotenex resin, containing 25 per cent rotenone. This is dissolved in warm xylene and one volume of this solution is added to an equal volume of emulsifying agent. The latter consists of a 50:50 mixture of solutions of "Manoxol O.T." (Hardman & Holden Ltd., Manchester) and "Ethylan C.P." (Lankro Chemicals Ltd., Manchester). These materials were obtained through the courtesy of the Zanzibar Government Entomologist, Dr. F. L. Vanderplank.

For help with identifications our thanks are due to Dr. Ethelwyn Trewavas (*Tilapia*), Dr. Isabella Gordon (Crustacea), Miss D. Ballantine (Algæ), Mr. F. Williams (Carangidæ and Sphyrænidæ) and Mr. J. F. C. Morgans (Serranidae).

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APPENDIX

TABLE I

Water samples collected from the Mzinga Mzinga stream at 10.30 hrs. on 13th February, 1956 (low water springs 11.11 hrs.). A slow but steady flow seawards was observed. Sandy bed with no black mud or deposit visible. Greatest depth of water about 1½ ft. High banks densely vegetated, hindering wind access. Water cloudy:—

Temperature—26·2° C.

pH—6·7/6·8.

Oxygen { 1·6 to 2·65 mils/litre.
  27% to 45% saturation at 26·2° C.

Alkalinity { Bound CO_2 1·12 millimols/litre.
  Total CO_2 2·15 millimols/litre.

Total solids { Organic matter 0·237 grams/litre.
  Mineral residue 0·867 grams/litre.
  Silver nitrate titre 0·8 to 1·0 p.p. mille.

Calcium { Total—60 milligrams/litre.
  Dissolved—40 milligrams/litre.

Phosphate—Negligible (less than 2 micro-gram atoms P/litre).

Ammonia—Negligible (less than ·04 p.p.m.).

TABLE II

Water samples collected from the Mzinga Mzinga stream at 09.00 hrs. on 16th March, 1956 (high water springs 06.10 hrs.). The site visited was a ford a few hundred yards downstream from that used in February. A strong current seawards was observed, and shoals of small mullet and a few large prawns were seen. Greatest depth of water, 3 ft.

Temperature—28·1° C.

Oxygen { 2·6 to 2·8 mils/litre.
  49% to 53% saturation at 28·1° C. and chlorinity 8·5 p.p.mille.

pH—7·5/7·9.

Salinity—15·5 p.p.mille (Silver nitrate titre).

TABLE III

Water samples were collected from Chukwani main pond on 12th March, 1956, the bottles being filled from the sump adjacent to the gates one day before the periodic topping-up.

Temperature { Sump—37° C.
  Periphery 38° C.

pH { Surface—8·4 (*in situ*; all corrections applied
  Bottom—8·4 for salinity and temperature.)

Oxygen { Surface 4·7 mils/litre (117·5% saturation).
  Bottom 3·3 mils/litre (82·5% saturation).

Salinity—35·10 p.p.mille (Silver nitrate titre).

Phosphate—0·25 micro-gram atoms P/litre.

TABLE IV

Figures for surface water in the open sea off Zanzibar at this time of the year are as follows:—

Temperature—29·35° C.

pH—8·49.

Oxygen—4·4 mils/litre (97% saturation).

Salinity—34·8 p.p.mille.

Phosphate—0·5 micro-gram atoms P/litre.

Methods of analysis will be described in a subsequent publication, together with results of a histological examination of *Tilapia* kidneys and further biometric data on this fish.