A CONTRIBUTION TO THE BIOLOGY OF
THE ACANTHURIDAE (SURGEON FISHES)

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF THE
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INTRODUCTION

The surgeon fishes (family Acanthuridae), which are distinctive chiefly in their possession of a defensive apparatus at the base of the tail in the form of a knife-like spine or spines, are one of the dominant groups of tropical inshore marine fishes. Over much of their vast range, including Hawaii where they are especially prominent on the reefs, they are important components of subsistence fisheries. Nevertheless, little is known of their biology. There are only scattered references to the herbivorous food habits of the group and general remarks on the habitat of certain species. It is perhaps more surprising that the classification is greatly in need of revision.

The confused status of the taxonomy first became apparent to the writer from an investigation of the surgeon fishes of the Hawaiian Islands. Because Hawaiian forms should not be considered without reference to other tropical regions, an attempt to clarify the systematics of the Hawaiian species led to an analysis of all the genera and revisions of the species of four of them on a world-wide basis. These four, Acanthurus, Paracanthurus, Zebrasoma, and Ctenochaetus, have a single folding spine at the base of the caudal fin. The systematic work constitutes Section I of the thesis. It is based on the collections in the following institutions: United States National Museum, Museum of Comparative Zoology at Harvard College, Academy of Natural Sciences of Philadelphia, Stanford Natural History Museum, California Academy of Sciences, Bernice P. Bishop Museum, University of Hawaii, University of Miami, University of California at Los Angeles, and the Pacific Oceanic Fishery Investigations, Honolulu.

The biology of one of the species, the Hawaiian manini (Acanthurus
triostegus sandvicensis Streets) comprises Section II. It was felt that a greater contribution could be made to the biology of the family as a whole by studying one species thoroughly than by dealing more superficially with several or all of the Hawaiian forms. The manini was chosen for several reasons. It is the most abundant and most important commercial species of surgeon fish in the Hawaiian Islands. The young reside in tidepools, and are therefore more accessible for observation and experimentation than the young of other local surgeon fishes which are usually found in deeper water. The species has the widest distribution of all of the surgeon fishes — Africa to the Gulf of California. Interest in its biology may therefore be greater than that of a localized species.

Acknowledgements

I acknowledge with gratitude the guidance of my doctoral committee and other faculty of the University of Hawaii. Special thanks are due Leonard P. Schultz, Ernest A. Lachner, Robert H. Kanazawa, and Frederick M. Bayer of the United States National Museum who have assisted me materially in my systematic work.

H. W. Manter and Leland S. Olsen of the University of Nebraska, Paul Illg of the University of Washington, Cadet Hand of the University of California, and J. Percy Moore of the University of Pennsylvania have assisted in the identification of parasites of the manini.

Personnel of the Territorial Division of Fish and Game have been most cooperative in providing contact with trap fishermen and in the carrying out of a tagging program on the manini.

Finally I would like to express thanks to my wife, Helen Au Randall, who has helped in much of the laboratory work and the preparation of figures.
SECTION I
SYSTEMATICS

There has been no review of the surgeon fishes since the long out-dated work of Günther in 1861. As Ahl (1923: 36) and others have pointed out, the genera of few families of marine fishes have been as badly jumbled as those of the Acanthuridae, and the need for a careful revision therefore exists at the generic as well as at the specific level. As may be seen in the key below, the genera are easily distinguished; most of the inconsistency with respect to use of names has been purely nomenclatorial.

Most of the species of surgeon fishes are wide-ranging and have been described many times under different names. A total of 117 Recent specific names, discounting misspellings, have been applied to the 32 species, as here recognized, of the one genus Acanthurus.

In the preparation of the synonymy for each species, mere listings or names with insufficient descriptive data have been omitted generally unless I have seen the specimens reported. References in the synonymy are given with no locality when an author did not cite the locality or when he based his record on the work of a previous author. Misidentifications are indicated by a period immediately following the specific name.

References in the generic synonymy include abbreviated titles and volume numbers. A shorter style is used for the synonymy to the species to avoid repetition that results when many species are listed in the same work; the reader is referred to the bibliography for complete references.
Each ray of the dorsal and anal fins with a distinct base was counted regardless of how close adjacent rays might be. In cases where two rays branch from a common base, they were counted as one. At times dissection was necessary to determine whether the last two rays originate from a single basal element. Pectoral fin ray counts include the two uppermost unbranched rays, the first of which is a short bony spicule.

The gill rakers are small and occur in two distinct series, one on each side of the gill arch. Counts of both series are of diagnostic importance in the Acanthuridae. The usual gill raker counts are here designated anterior; those on the postero-medial side of the arch are called posterior. Gill raker counts were made on the first arch and include all rudiments. The raker counts were made on five specimens unless otherwise stated.

The scales are small and do no occur in regular rows. Successive trials at counting scales on the same specimen rarely resulted in the same count. The only scale counts which are recorded are those for the six species which are being described as new by the author (in press).

The standard length is measured from the tip of the snout to the base of the caudal fin (end of hypural plate). All references to length of specimens are standard length. Head length is taken from the tip of the snout horizontally to a vertical at the most posterior end of the opercular membrane. Body depth is the distance from the natural groove at the base of the second anal spine vertically to a similar groove at the base of the dorsal fin. Caudal concavity is the distance between vertical lines passing through the tips of the shortest middle caudal
rays and the longest ray of the dorsal lobe of the caudal fin; this measurement is not made from a compressed or stretched caudal fin, but one in the normal resting position as shown in the figures of the various species.

KEY TO THE GENERA OF ACANTHURIDAE

1a. 1 to 6 immovable keel or thorn-like spines or laminae on each side of caudal peduncle; least depth of caudal peduncle contained 3.5 to 6 times in length of head; dorsal and anal spines stout..........2

1b. A single folding spine on each side of caudal peduncle; least depth of caudal peduncle contained 2.1 to 3.5 times in length of head; dorsal and anal spines slender (except Paracanthurus).........3

2a. 1 to 2 pairs of caudal spines or laminae; pelvic fin rays I, 3; anal spines II; dorsal spines IV to VII; teeth small, conical with tips slightly compressed, smooth or with very small denticulations. (Indo-West-Pacific)........................................Naso (p. 10)

2b. 3 to 6 pairs of caudal spines or laminae; pelvic fin rays I, 5; anal spines III; dorsal spines VIII or IX; teeth moderately large, flattened, close-set, with large denticulations. (Japan, Australia, tropical eastern Pacific, Galapagos Islands).........

.........................................................Prionurus (p. 12)

3a. Pelvic fin rays I, 5; scales on head not modified to tuberculated plates.........................................................4

3b. Pelvic fin rays I, 3; scales on head modified to tuberculated plates. (Indo-West-Pacific)....................Paracanthurus (p. 14)
4a. Dorsal spines VI to IX (usually VIII or IX); the length of longest dorsal ray contained 3.5 to 6 times in standard length; scales not elevated and ctenii not long; least depth of caudal peduncle 2.1 to 3.2 in length of head; caudal peduncle spine in a sharply-defined groove...............................5

4b. Dorsal spines IV or V; length of longest dorsal ray contained 2.2 to 3.8 times in standard length; scales elevated and with long ctenii; least depth of caudal peduncle 3 to 3.5 in length of head; caudal peduncle spine in a shallow depression. (Indo-West-Pacific)..........................Zebrasoma (p. 17)

5a. Teeth fixed, not attenuate with expanded incurved tips, denticulated on both lateral and medial margins, and not over 26 in upper jaw; dorsal spines IX (except one species with VI or VII and two with VIII). (Circumtropical).................Acanthurus (p. 49)

5b. Teeth movable, attenuate with expanded incurved tips which bear only lateral denticulations, and from 30 to 60 in upper jaw (of specimens over 75 mm. in standard length); dorsal spines VIII. (Indo-Pacific)..........................Ctenochaetus (p. 213)

The relationship of the existing genera of surgeon fishes is not easily fitted into a conventional family tree pattern. Aoyagi (1943: 196) has constructed such a tree for the Acanthuridae on the basis of dentition alone. For this one character his conclusions are well drawn. *Naso*, with its conical teeth, is listed as most primitive. *N. lituratus* (Bloch and Schneider) and *N. unicornis* (Forskal) exemplify those species of this genus which have teeth lacking denticulations. Others, like *N. hexacanthus* (Bleeker), have tiny denticulations
and are higher in the evolutionary sequence. *Prionurus, Paracanthurus, Zebrasoma,* and *Acanthurus* are progressively more specialized, though these four genera are basically similar. The teeth have become close-set, flattened, and strongly denticulate. *Ctenochaetus,* which has comb-like teeth, is portrayed as being derived from *Acanthurus.*

This picture is strengthened by a consideration of food habits of the genera. The acanthurids, in general, are herbivorous. *Naso* tends to feed on leafy algae such as *Sargassum;* its teeth are not efficient for feeding on slick, filamentous algae. The flattened, denticulated teeth of the next four genera might represent a specialization for feeding on fine algae. *Ctenochaetus* with its numerous, long, protruding teeth, feeds effectively on loose algal filaments and other detrital material on the bottom (see further discussion under genus *Ctenochaetus*).

When, however, characters other than dentition are considered, the interrelationships of the genera are not so simple. *Naso* and *Prionurus,* both with fixed caudal spines, have different numbers of pelvic rays. *Paracanthurus,* which has a movable caudal spine and is separated from *Naso* by *Prionurus* in the phyletic line of Aoyagi, has a pelvic formula of I, 3 like *Naso.* It appears that the reduction in pelvic fin rays from I, 5 to I, 3 must have occurred independently in *Naso* and *Paracanthurus* or that the I, 5 condition was secondarily regained in *Prionurus.* The dorsal spines in *Naso* are IV to VII. In *Prionurus* and *Paracanthurus* they are VIII or IX. In *Zebrasoma* they drop to IV or V, and in *Acanthurus* and *Ctenochaetus* they increase again to VIII or IX. The scales present an even more perplexing problem. The supposedly advanced genera, *Acanthurus* and *Ctenochaetus,*
have ctenoid scales which are less specialized than the unusual raised and often spinulous scales of the other genera. It is difficult to place Acanthurus in a more primitive position than Naso, however, for it does not seem that a folding caudal spine and denticulate teeth could precede a fixed spine and smooth teeth. Perhaps the linear pattern of evolution postulated by Aoyagi would be less likely than one which supposes that all the Recent genera (except Ctenochasatus, which does appear to be derived from Acanthurus) arose from common stock at essentially the same period of geologic time.

It should be apparent from the above that the division of the Acanthuridae into two or more families or subfamilies is not justified, nevertheless, Smith (1955) split off the genera with fixed caudal spines as a separate family, Nasidae.

Eastman (1904a) has commented on the sudden appearance in the Eocene of a host of modern teleost types, many of which were as highly specialized then as they are today. The fossil record of the Acanthuridae indicates that both Naso and Acanthurus date back to the Eocene (Agassiz, 1838; Woodward, 1901; Eastman, 1917), thus these are among the specialized genera making the apparent sudden appearance in the early Tertiary.

Hussakof (1907) recorded a fossil Zebrasoma (as Z. deani) from the West Indies. The specimen, which was well preserved, was considered possibly of Eocene age. In my opinion this fish is not a Zebrasoma. It lacks the great depth of body and elevated fins of this genus. Also there is a very narrow caudal peduncle and a crescentic (high and narrow) caudal fin, and no caudal peduncle spines were located. Of existing genera, it seems closest to Naso. This specimen, which
was deposited in the American Museum, should be re-examined and its position within the Acanthuridae re-evaluated.

Two extinct genera, Aulorhamphus de Zigno (Eocene) and Apostasella Whitley (new name for Apostasis Gorjanović-Kramberger) (Oligocene-Miocene) have been included in the Acanthuridae although no caudal peduncle spines have been found for these forms. Ogilby (1916: 173) views "with grave suspicion" the inclusion of these genera in the surgeon fish family. I concur in this doubt.

The fossil Acanthurus gaudryi de Zigno and A. gazolae Massalongo were considered by Woodward (1901) and Eastman (1904a) as not belonging to the genus Acanthurus. Woodward believed they might be better placed in the Chaetodontidae. Eastman thought them types of distinct genera, but preferred to include them in Pygaerus Agassiz, the limits of which were widely extended by Agassiz. In Jordan's opinion (Eastman, 1904b), Pygaerus is a generalized type ancestral to the Chaetodontidae, Acanthuridae, and Teuthidae (Siganidae). Berg (1947: 482) thought the VIII or IX anal spines of some Pygaerus allies it more closely with the latter than with the other two families.

It is evident that more study of the fossil Acanthuridae and related families is needed, with special effort to integrate knowledge of fossil with that of present forms and to reconstruct the evolutionary picture in more precise terms.

Genus NASO Lacépède

Naso Lacépède, 1801. Hist. nat. poisss. Vol. 3, p. 105. (Type species by subsequent designation (Valenciennes, 1837, pl. 72, fig. 1),

Naso fronticornis Lacépède = Chaetodon unicornis Forskal.)

Nasonus Rafinesque, 1815. Anal. natur. p. 88. (Substitute name for Naso.) [Reference after Gill, 1885.]

Priedon Quoy and Gaimard, Voyage autour du monde...Uranie...Zool. p. 377. (Type species, Priedon annulatus Quoy and Gaimard.)


Priedontichthys Bonaparte, 1833. Saggio. distrib. metod. anim. vert. p. 34. (Type species, Priedon annularis Cuvier and Valenciennes = Priedon annulatus Quoy and Gaimard.) [Reference after Gill, 1885.]


Callicanthus Swainson, 1839. Nat. hist....fishes...Vol. 2, p. 256. (Type species, Aspisurus elegans Rüppell = Acanthurus lituratus Bloch and Schneider.)


Cyphomycter Fowler and Bean, 1929. U. S. Natl. Mus., Bul. 100, vol. 8, p. 264. (Type species, Naso tuberosus Lacépède.) (Proposed as a subgenus; raised to generic rank by Smith, 1951: 1126.)

Prionolepis Smith, 1931. Albany Mus., Rec. 4: 125. (Type species, Prionolepis hewitti Smith = Chaetodon unicornis Forskal.)

The genus *Naso* has been split by some authors into two or more genera. A frequent basis for this division has been the presence or absence of a horn on the forehead in adults. I do not believe that this is a valid means of separation in view of the late appearance of this character, the difficulty at times in assessing what is a horn and what a mere bony prominence, and the demonstration by Smith (1951: 1126) that the horn occurs only on the male in *Naso rigoleto* Smith.

The use of the name *Axinurus* Cuvier and Valenciennes by Fowler and Bean as a subgenus for *Naso thynnoides* (Cuvier and Valenciennes), which has a single buckler on each side of the caudal peduncle, seems more reasonable than applying this name as a genus as has Smith (1951: 1126).

Guoy and Caimard (1824: 375) erroneously used the generic name *Aspisurus* Lacépède (= *Acanthurus* Forskal) for a species of *Naso*. Lesson (1830: 151) did the same with *Prionurus* Lacépède. Shaw (1803) applied the name *Acanthurus* to all of the species of surgeon fishes (which included *Naso*) in his *General Zoology*. Jordan and Fowler (1902: 558) used *Acanthurus* for species of *Naso* which have an elongate horn on the forehead in the adult (see section under *Acanthurus* for discussion of this).

*Keris* and *Prionolepis* were proposed for the late postlarval stage of *Naso*.

The species of *Naso* are not here considered.

Genus *PRIONURUS* Lacépède

Xesurus Jordan and Evermann, 1896. Check-list fishes N. and Middle America. p. 421. (Type species, Prionurus punctatus Gill.)

Acanthocaulus Waite, 1900. Australian Mus., Rec. 3: 206. (Substitute name for Prionurus.)

Burobulla Whitley, 1931. Australian Zoologist 6: 321. (Type species, Xesurus maculatus Ogilby.)


Xesurus is distinguished from Prionurus by having three to four instead of six keeled laminae on each side of the caudal peduncle. I do not believe that the number of caudal laminae is of generic significance (a specimen of Prionurus microlepidotus Lacépède from Port Jackson, Australia, United States National Museum No. 47964, has five keeled laminae on one side of the caudal peduncle and six on the other), and in view of the lack of other differences, I place Xesurus in the synonymy of Prionurus. There is less basis for the recognition of Xesurus than there is for the division of Naso into two or more genera.

As pointed out by Gill (1904: 121) Waite was in error in proposing Acanthocaulus as a substitute for Prionurus. He did so in the belief that Prionurus was established by Lacépède in 1830 instead of 1804. In 1829 Prionurus was proposed by Ehrenberg in the Arachnida.

The type species for Burobulla Whitley and Triacanthurodes Fowler clearly belong in the genus Prionurus.

The species of Prionurus are not here considered.
Genus PARACANTHURUS Bleeker

Paracanthurus Bleeker, 1863. Ned. Tijdschr. Dierk. 1: 252. (Type species by monotypy, Acanthurus hepatus (Linnaeus) Bloch and Schneider = Teuthis hepatus Linnaeus, as restricted by Cuvier and Valenciennes.)

Colocopus Gill, 1885. U. S. Natl. Mus., Proc. 7: 277, 279. (Type species, Colocopus laevoidurus Gill = Teuthis hepatus Linnaeus, as restricted by Cuvier and Valenciennes.)

 Günther (1873: 115) and subsequent authors continued to use Acanthurus for the genus Paracanthurus after its proposal by Bleeker. The name Paracanthurus was unnoticed until Fowler (1926: 139) pointed out that it preceded Colocopus Gill.

The characteristics of the genus are those of the single known species.

Paracanthurus hepatus (Linnaeus)

Figs. 1 G, 2; Pl. I


Acanthurus hepatus Bloch and Schneider (in part) (1802: 11); Cuvier and Valenciennes (1835: 183, pl. 288) (Mauritius and New Guinea); Bleeker (1854b: 325) (Flores, East Indies); Günther (1861: 341) (Ambon, East Indies); Günther (1873: 115, pl. 75) (Gilbert Islands); Day (1876: 206) (seas of India).

Acanthurus theuthis Lacépède (1802: 547, 549).

Acanthurus Theuthis Shaw (1802: 377).
Acanthurus triangulus Cuvier and Valenciennes (1835: 189) (after Vlaming); Günther (1861: 341).

Paracanthurus hepatus Bleeker (1863b: 252) (Ceram, East Indies); de Beaufort (1951: 131, fig. 25) (Pulu Weh and Banda, East Indies).

Colocopus lambdurus Gill (1885: 279); Jordan and Seale (1906: 355).

Acanthurus teuthis Weber (1913: 318) (Banda, East Indies).

Paracanthurus lambdurus Fowler (1926: 140); Herre (1927: 435, pl. 13, fig. 3) (Philippine Islands); Herre (1934: 63).

Paracanthurus teuthis Fowler (1928: 273); Fowler and Bean (1929: 205, fig. 10) (Philippine Islands and East Indies); Fowler (1931: 344) (Palau Islands); Aoyagi (1943: 202, pl. 8, fig. 1, pl. 4, fig. 8) (Riu Kiu Islands); Smith (1949: 239, pl. 33, no. 607) (Mozambique).

The following is based on the one cataloged adult specimen in the United States National Museum (No. 146636, 204 mm., Philippine Islands): body compressed, elliptical, the depth contained 2.3 in standard length; head length contained 3.75 in standard length; a broad groove on each side of caudal peduncle with a single movable spine, sharp anteriorly, broadly joined to body posteriorly; length of caudal spine 4 in head length; least depth of caudal peduncle 2.4 in head length; mouth very small, terminal; jaws equal; teeth small, close-set, denticulated, 14 in upper jaw and 17 in lower jaw (a 140 mm. specimen from the Gilbert Islands and now in the Bishop Museum, Honolulu, had 12 upper and 14 lower teeth); all spines of fins stout; dorsal and anal fins not elevated, longest dorsal ray 8.2 in standard length; dorsal fin rays IX (the first very short), 19 or 20; anal fin rays III (the first very short), 18 or 19 (based on four specimens from the Philippines, one from the Gilbert Islands, and two from
Mauritius); pectoral fin rays 16; pelvic fin rays 1, 3 (the first soft ray closely applied to the spine); length of pectoral fin 4.3 in standard length; length of pelvic fin 7.5 in standard length; caudal fin with 16 principal rays, truncate with upper and lower lobes slightly projecting; length of caudal fin 5.6 in standard length; eye small, 6 in head length; interorbital highly arched, 3.4 in head length; gill openings well-restricted to sides; gill membranes confluent and very broadly attached to isthmus; scales of body thick, each with many short ctenii on upper surface (ctenii on scales in a small area just anterior to caudal spines about three times as long as elsewhere on body); scales on head, especially anteriorly, enlarged to tuberculated plates; 22 vertebrae; stomach oval with moderately thick walls.

Color (in alcohol) light grayish brown (blue in life) with a broad black area on back, enclosing an oval light gray-brown region at the tip of the pectoral, and extending forward dorsally to eye; a long yellowish triangle (bright yellow in life) with apex anterior to caudal spine and base formed by truncate posterior margin of caudal fin; upper and lower lobes of caudal fin black, this color confluent with the black area of the back; pectoral fin dark gray on first two principal rays and basal two-thirds of remaining rays; dorsal and anal fins with basal half yellowish gray and distal half dark gray; pelvics yellowish gray.

Fowler and Bean (1929: 206, fig. 10) show variation of color markings of this species with age.

Smaller than any of the specimens figured by Fowler and Bean is one, 30 mm. in standard length, collected in shallow water at Biak,
Schouten Islands, in April, 1945, by Frederick W. Bayer. His unpublished painting is reproduced as Fig. 2. The specimen had a bright blue body, yellow tail, and black markings as shown.

Acanthurus triangulus Cuvier and Valenciennes was described from an old drawing by Vlaming. It appears to be Paracanthurus hepatus with the black and yellow colors reversed.

P. hepatus is known from East Africa to the Philippines and the Riu Kiu Islands. It does not appear to range throughout the tropical Pacific, the only record from this vast area being that of Günther (1873) from the Gilbert Islands.

Three different species of surgeon fishes of five prelinnaean authors were cited by Linnaeus (1766: 507) under the specific name hepatus. Cuvier and Valenciennes (1835: 183) were the first to realize this confusion and used the name for the East Indian species of Seba (1734: 104, pl. 33, fig. 3) which is easily recognized as Paracanthurus (see de Beaufort, 1951: 133, for further discussion). The Atlantic species of Acanthurus usually called hepatus must therefore be given another specific designation. Acanthurus chirurgus (Bloch) is the first available name.

Genus ZEBRASOMA Swainson

Harpurus Swainson, 1839. Nat. hist....fishes...Vol. 2, p. 256. (Not Harpurus of Forster.)

Zebrosisoma Swainson, Nat. hist....fishes...Vol. 2, p. 256. (Type species by monotypy, Acanthurus velifer Bloch.)

Scopus Kner, 1865-67. Reise...fregatte Novara...Fische. p. 212. (Type species, Acanthurus scopas Cuvier and Valenciennes.) (Scopus of
Laepichthys Ogilby, 1916. Queensland Mus., Mem. 5: 173. (Type species, Acanthurus rostratus Günther.)

Bleeker (1851) and other authors after him persisted in using the generic name Acanthurus for species of Zebrasoma, probably without the realization that the latter had been proposed.

Ogilby established the genus Laepichthys for the species Acanthurus rostratus Günther on the basis of the unusually long snout and thick dorsal spines as shown in a painting by Garrett. Examination of 13 specimens, among them two collected by Garrett from the Society Islands and probably the ones from which the painting was made, revealed considerable variation in snout length. Some specimens had shorter snouts than the average snout length of Zebrasoma flavescens (Bennett) or Z. acopas (Cuvier). None had thick dorsal spines. No other differences even approaching generic level could be found between rostratus and species of Zebrasoma; thus Laepichthys is not well founded.

Jordan and Jordan (1922: 66) used the name Scopas as a subgenus for Z. flavescens to emphasize its distinctness from Zebrasoma (Zebrasoma) veliferum (Bloch). Z. gemmata (Cuvier and Valenciennes) tends to invalidate this subgeneric concept, for it has a tooth structure and fin ray counts approaching that of veliferum, yet it lacks the extremely elevated dorsal fin of this species and has a body form more like other Zebrasoma.

Von Bonde (1934: 449, fig. 3) described a new species of acanthurid, Hepatus eoccinatus, from Zanzibar. His description and photograph leave little doubt that his specimens are Zebrasoma veliferum, although he gave the dorsal spine count as VII instead of the usual IV.
Fig. 1. Camera lucida drawings of upper and lower teeth of Zebrasoma and Paracanthurus. Teeth were taken from right side of jaws near center and drawn in inner or lingual view. A. Z. veliferum, 171 mm. specimen, Gilbert Islands. B. Z. gaimardum, 121 mm. specimen, Mauritius. C. Z. xanthurum, 181 mm. specimen, Red Sea. F. Z. rostratum, 140 mm. specimen, Tuamotu Archipelago. D. Z. flavescens, 100 mm. specimen, Johnston Island. E. Z. scopas, 108 mm. specimen, Philippine Islands. G. P. hepatus, 155 mm. specimen, Philippine Islands.

Fig. 2. Paracanthurus hepatus (Linnaeus), 30 mm., Schouten Islands, East Indies (from a painting by Frederick M. Bayer).
Plate I

Young of Zebrasoma veliferum (left) and Zebrasoma scopas (right), Gilbert Islands (from a Kodachrome by the author).

Paracanthurus hepatus, 204 mm., Philippine Islands (from an unpublished painting of the Albatross Philippine Expedition).
Zebrasoma is characterized as follows: body compressed, ovate, depth contained 1.4 to 2.1 times in standard length (this and other proportional measurements based on specimens over 50 mm. in standard length); head length 2.9 to 3.7 in standard length; snout produced; caudal peduncle with a single folding spine on each side, fitting into a shallow depression; length of caudal spine 3 to 6 in head length; least depth of caudal peduncle 2.7 to 3.6 in head length; mouth small, terminal; jaws equal; teeth close-set, compressed, denticulate, 10 to 20 in upper jaw, 12 to 22 in lower jaw; dorsal and anal fins elevated; dorsal fin with IV to V slender spines and 23 to 33 rays; anal fin with III spines and 19 to 26 rays; pectoral fin 2.7 to 3.3 in standard length; pectoral fin rays 14 to 17, the uppermost a short bony spicule, the next long and unbranched; pelvic fin with 1 spine and 5 rays, its length contained 3.5 to 4.5 in standard length; caudal fin truncate, with 16 principal rays; eye diameter (in specimens of 120 to 150 mm. in standard length) 3.5 to 4.5 in head length (except long-snouted specimens of Z. rostratum); interorbital slightly rounded, 2.9 to 3.4 in head length (also with the exception of Z. rostratum); gill openings restricted to sides; gill membranes attached to isthmus; anterior gill rakers 8 to 12; posterior gill rakers 9 to 13; scales very small, elevated, and with stout ctenii; 22 vertebrae; stomach elongate and thin-walled.

Zebrasoma is generally considered as an Indo-West-Pacific genus (two species are confined to the Indian Ocean, two to the Pacific, and two are common to both oceans). Guichenot (1853: 122), however, recorded it (as Acanthurus scopas Cuvier and Valenciennes) from Cuba. He mentioned the very prominent snout, the great body depth, the small
rough scales, and the patch of dense setae caudally on the body. The color was noted as gray-violet with brown spots; there were lines of white marks on the side and a white band in the humeral region. His choice of words in the brief description was very similar to that of Cuvier and Valenciennes (1835: 245). No meristic data were given, but there is little question that this author was describing a Zebrasoma. Günther (1861a: 343) considered Guichenot's citing of scopas from Cuba as a "most remarkable fact". L. Bertin kindly checked for the specimen in the Paris Museum for me but could find no record of it. It seems possible that Guichenot's record is an error. To my knowledge there has been no further mention of Zebrasoma from the Atlantic.

KEY TO THE SPECIES OF ZEBRASOMA

1a. Dorsal rays IV, 28 to 33; anal soft rays 22 to 26; longest dorsal ray 2.1 to 2.5 in standard length (in specimens over 50 mm. in length); body with alternate pale and dark vertical bands.

Zebrasoma veliferum

1b. Dorsal fin rays IV or V, 23 to 28; anal soft rays 19 to 24; longest dorsal ray 2.8 to 3.7 in standard length (in specimens over 50 mm. in length); body without alternate pale and dark vertical bands.

2a. Dorsal fin rays V (rarely IV), 23 to 26; anal soft rays 19 to 22; denticulations on lateral edge of upper teeth decidedly smaller than medial denticulations (Fig. 1 C - F); body and dorsal and anal fins without spots (except longitudinal lines on scopas broken into fine spots anteriorly on the body).
2b. Dorsal fin rays (based on 2 specimens) IV, 28; anal soft rays 24; denticulations on both edges of teeth of equal size (Fig. 1 B); body and dorsal and anal fins with numerous white (said to be blue in life) spots..................Zebrasoma gemmatum

3a. Caudal fin abruptly pale (yellow in life) and in sharp contrast to dark body color; sheath of caudal spine black; profile of head from eye to upper lip only slightly concave..................

.................................Zebrasoma xanthurum

3b. Caudal fin same color as body; sheath of caudal spine white; profile of head from eye to upper lip markedly concave (as snout is strongly produced)............................4

4a. Body and fins not uniform black; lower teeth with 7 denticulations, the centermost only slightly larger than adjacent ones (Fig. 1 D and E)..................................................5

4b. Body and fins uniform black; lower teeth with 5 denticulations, the centermost about twice as large as adjacent ones (Fig. 1 F).....

..................................................Zebrasoma rostratum

5a. Body pale (yellow in life); dorsal soft rays 24 to 26 (usually 25); anal soft rays 19 to 22 (usually 20 or 21)..................

..................................................Zebrasoma flavescens

5b. Body brown with numerous pale lengthwise lines; dorsal soft rays 23 to 25 (usually 24); anal soft rays 19 to 21 (usually 19 or 20)..........................Zebrasoma scopas
Table 1  Fin Ray Counts of Species of Zebrasoma

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<thead>
<tr>
<th>Species and locality</th>
<th>Dorsal spines</th>
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<th>Anal soft rays</th>
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Table 1 (Continued) Fin Ray Counts of Species of Zebrasoma

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<td>1 2</td>
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Zebrasoma veliferum (Bloch)

Figs. 1 A, 3, 4; Pl. I

Acanthurus velifer Bloch (1797: 106, pl. 427, fig. 1) (seas of East Indies); Lacépède (1802: 547); Rüppell (1828: 58, pl. 15, fig. 2) (Red Sea); Cuvier (1829: 224); Cuvier and Valenciennes (1835: 251) (Mauritius, East Indies, Red Sea); Günther (1861a: 344) (Fiji Islands); Playfair in Playfair and Günther (1866: 57) (Zanzibar); Klunzinger (1871: 505) (Red Sea); Day (1876: 207) (seas of India); Sauvage (1891: 344) (Madagascar).

Acanthurus velifer Bloch and Schneider (1801: xxxviii, 214).

Acanthurus (Harpurus) velifer Klunzinger (1884: 85).

Acanthurus Desjardini Bennett (1835b: 207) (Mauritius).

Acanthurus desjardini Günther (1861a: 344) (Mauritius); Playfair in Playfair and Günther (1866: 57) (Zanzibar).

Acanthurus RupPELLii Bennett (1835b: 207) (Red Sea); Bleeker (1855: 451) (Kokos Island, Sumatra).

Acanthurus rupPELLii Günther (1861a: 345) (Red Sea).

Acanthurus Blochii Bennett (1835b: 207) (India).

Zebrasoma velifer Swainson (1839: 256); Herre (1934: 63) (Philippine Islands).

Acanthurus suillus Cuvier (1829: 224) (after Renard, 1718, vol. I, pl. 14, fig. 82); Cuvier and Valenciennes (1835: 254) (Mauritius); Günther (1861a: 345).


Acanthurus hypselopterus Bleeker (1854b: 327) (Larantuka, East Indies); Günther (1861a: 344); Günther (1873: 117) (Samoa, Palau Islands and
Acanthurus maristarum Thiollière in Montrouzier (1856: 458) (Island of Woodlark).

Acanthus (Harpurus) hypselopterus Steindachner (1901: 494, pl. 4, fig. 1) (Honolulu).

Acanthurus kipas Bleeker (1854b: 327) (East Indies).

Harpurus hypselopterus Bleeker (1863b: 252) (Flores, East Indies).


Harpurus Desjardini Bleeker and Pollen (1874: 96) (Mauritius).

Acanthus virgatus Vaillant and Sauvage (1875: 283) (Hawaiian Islands).

Acanthus fasciatus Bliss (1883: 53) (Mauritius).

Zebrasoma hypselopterus Jenkins (1903: 479) (Honolulu); Ogilby (1916a: 174, pl. 23) (Queensland, Australia).

Zebrasoma veliferum Jordan and Evermann (1905: 396, fig. 173) (Honolulu); Jordan and Seale (1906: 356) (Samoa); Kendall and Radcliffe (1912: 143) (Manga Reva); Jordan and Jordan (1922: 66) (Honolulu); Herre (1927: 443, pl. 11, labelled Zebrasoma veliferum) (Philippine Islands); Fowler (1928: 275, pl. 32, fig. B); Fowler and Bean (1929: 255) (Philippine Islands and East Indies); Schmidt (1930b: 104) (Riu Kiu Islands); Fowler (1931: 346) (Honolulu); Herre (1936: 249) (Solomon Islands); Hiyama (1943: 95, pl. 21, fig. 58); Aoyagi (1943: 205, pl. 4, fig. 6, teeth only) (Riu Kiu Islands); Schultz (1943: 166) (Phoenix Islands and Samoa Islands); de Beaufort (1951: 167, fig. 28) (New Guinea and Ambon, East Indies); Schultz and Woods (1953: 640) (Marshall Islands); Harry (1953: 152) (Raroia, Tuamotu Archipelago).

Zebrasoma veliferum novae caledoniae Borodin (1932: 88) (New Caledonia).
Hepatus coscinatus von Bonde (1934: 449, fig. 3) (Zanzibar).


Dorsal rays IV, 28 to 33 (in Oceania usually 31 or 32); anal rays III, 22 to 26 (in Oceania usually 24 or 25); pectoral rays 15 to 17 (usually 16); anterior gill rakers 8 to 11 and posterior gill rakers 9 or 10 (12 specimens from nine localities over the range of the species); the number of teeth increase slowly with age: a 25 mm. specimen from the Gilbert Islands had 10 upper and 12 lower teeth; 51, 80, and 94 mm. specimens had 12 upper and 14 lower teeth; 128, 154, and 168 mm. specimens had 14 upper and 16 lower teeth; 233 and 245 mm. specimens had 16 upper and 18 lower teeth.

Dorsal fin very elevated, longest soft dorsal ray 2.1 to 2.5 in standard length; fourth dorsal spine 2.5 to 2.8 in standard length; body depth 1.8 to 2 in standard length (1.4 in 25 mm. specimen); no patch of stiff bristles on side of body anterior to caudal spine. The posterior end of the caudal spine is not as broadly joined to the body in veliferum as other species of Zebrasoma.

Color (in alcohol) brown with alternate, near-vertical, dark and light (yellowish in life) bands; the first dark band passes through the eye and angles backward to the origin of the pelvic fins; the first pale band runs from the nape across the opercle just behind the eye to the pelvic region; the remaining four or five pale bands on the body are about one-third to one-fourth as broad as the intermediate brown areas, and each is bisected by a narrow dark line; within the intermediate brown areas alternate lines of dark and light are perceptible, the dark lines tending to break into spots antero-ventrally on the body; head and chest with small pale spots; dorsal and anal fins
Fig. 3. *Zebrasoma veliferum* (Bloch), Gilbert Islands
(reproduced from a Kodachrome by the author).
Fig. 4. Postlarval Zebrasoma veliferum, 18 mm., Hawaiian Islands. Drawn with the aid of a camera lucida by H. Randall.
dark with curved pale lines which may be broken into spots; caudal fin
dark with faint pale spots; caudal spine in a blackish area.

The low dorsal and anal fin ray counts (Table 1) of the Red Sea,
Zanzibar, and Mauritius specimens and slightly different color (the
very narrow vertical pale lines on the body are more conspicuous) sug-
gest that the form in the Indian Ocean and Red Sea might be regarded
as a different subspecies from that in the East Indies and Oceania.
Many more specimens from various parts of the Indian Ocean are needed
to establish the nature of subspecific differentiation in this species.

The 18 mm. postlarval specimen of *Z. veliferum* (Fig. 4) was col-
lected by Joseph E. King of the Pacific Oceanic Fishery Investigations
on Dec. 26, 1951 offshore from Kaneohe, Oahu. It was taken in an
oblique haul from the surface to about 200 meters with a 6 foot trawl.

The juvenile specimen (Pl. 1) was taken with rotenone by the
author from a channel of 3 to 5 foot depth at Onotoa Atoll, Gilbert
Islands. The area was sandy with occasional heads of *Heliopora*.

The largest specimen seen by me was 275 mm. in standard length.
De Beaufort (1951: 169) recorded total length to 395 mm., which would
be about 315 mm. in standard length.

Although widespread in the tropical Indian and West Pacific Oceans,
this species is not as abundant as many of the other surgeon fishes.
Schults and Woods (1953: 641) state that a large school was observed
entering shallow water in the Marshall Islands; the individuals of the
school were swimming at times with their dorsal fins out of water like
a sail. I have occasionally observed *Z. veliferum* underwater in the
Hawaiian Islands and in the Gilbert Islands, but only as solitary in-
dividuals. I have never seen the dorsal fin elevated.
**Zebrasoma gemmata** (Cuvier and Valenciennes)

Figs. 1 B, 5

Acanthurus gemmatus Cuvier and Valenciennes (1835: 255) (Mauritius);

Gunther (1861a: 343); Sauvage (1891: 343) (Madagascar?).

Harpurus gemmatus Bleeker and Pollen (1874: 96) (Mauritius).

Zebrasoma gemmata Fowler and Bean (1929: 258).

Dorsal rays IV, 28; anal rays III, 24; pectoral rays 16 or 17;

anterior gill rakers 12 and posterior gill rakers 11; 121 mm. specimen with 15 upper and 17 lower teeth; 179 mm. specimen with 18 upper and 20 lower teeth.

Longest soft dorsal ray 3 to 3.1 in standard length; fourth dorsal spine 4.5 to 5.9 in standard length; body depth 1.7 to 1.9 in standard length; no patch of setae on side of body anterior to caudal spine. All counts and measurements are based on two specimens.

Color (in alcohol) brown with numerous white spots on head, body, dorsal and anal fins, base of pectoral fin, and very faintly on caudal fin (these spots tend to be round on fins, head, and dorsal part of body, but elongate elsewhere on the body); caudal fin pale.

Cuvier and Valenciennes (1835: 256) stated that the caudal fin was yellow. Sauvage (1891: 344) (after Liénard) described the spots on this fish as blue.

*Z. gemmata* is known only from the island of Mauritius and possibly Madagascar.
Fig. 5. *Zebrasoma gemmatum* (Cuvier and Valenciennes), 121 mm., Mauritius.
Zebrasoma xanthurum (Blyth)

Figs. 1 C, 6

Acanthurus xanthurus Blyth in Kelaart (1852: appendix p. 50) (Ceylon); Günther (1861a: 343); Playfair in Playfair and Günther (1866: 57, pl. 8, fig. 4) (Aden); Klunzinger (1871: 504) (Red Sea); Day (1876: 207).

Acanthurus (Harpurus) xanthurus Klunzinger (1884: 85).

Zebrasoma xanthurum Fowler and Bean (1929: 262).

Dorsal rays V, 24 or 25; anal rays III, 19 or 20; pectoral rays 15; gill rakers (from one specimen): anterior 11, posterior 13; upper teeth 18 to 20; lower teeth 22.

Longest soft dorsal ray 3.4 to 3.7 in standard length; fifth dorsal spine 3.9 to 4.1 in standard length; body depth 1.7 to 1.85 in standard length; an oval, velvety patch on side of body anterior to caudal spine. All measurement and meristic data except gill raker counts based on seven specimens, 120 to 181 mm., from the Red Sea.

Color (in alcohol) dark gray to black with small spots on head, nape, and chest (these spots pale on two of the specimens and dark on the others); entire caudal fin abruptly pale yellowish just posterior to caudal spine; dorsal, anal, and pelvic fins dark gray; pectoral fin with basal two-thirds dark gray, outer one-third pale.

Blyth (in Kelaart, 1882: appendix p. 50) described the color in life from a 7.5 inch specimen as "...wholly black with bright golden-yellow tail, and a tinge of the same upon the pectorals."

This species is difficult to separate from Z. scopas and Z. flavescens on any basis other than color. The snout is slightly
Fig. 6. *Zebrasoma xanthurum* (Blyth), (after Playfair, 1866).
less produced in *Z. xanthurum* and, for a comparable size, the velvet like area on the side much less developed. It seems likely that *Z. xanthurum* attains a larger size. Four of the seven specimens from the Red Sea range from 145 to 181 mm. in standard length. The largest *Z. scopas* I have seen is 149 mm. in standard length (from the Society Islands). Of over 100 adult specimens in the United States National Museum from the Philippines and East Indies, the largest is 145 mm. and only nine exceed 115 mm. The largest of many *Z. flavescens* examined by me is a Hawaiian specimen 149 mm. in length.

*Zebrasoma xanthurum* is thus far reported only from Ceylon, the Gulf of Aden, and the Red Sea.

*Zebrasoma rostratum* (Günther)

Figs. 1 F, 7

*Acanthurus rostratus* Günther (1873: 117, pl. 66, fig. B) (Society Islands).

*Zebrasoma rostratum* Fowler (1928: 275); Harry (1953: 152) (Raroia, Tuamotu Archipelago).

*Zebrasoma (Laephichthys) rostratum* Fowler and Bean (1929: 262).

*Laephichthys rostratus* Fowler (1938: 127) (Apataki, Tuamotu Archipelago); Fowler (1952: 25, fig.).

Dorsal rays V (rarely IV), 23 to 25; anal rays III, 19 or 20; pectoral rays 15; anterior gill rakers 10 and posterior gill rakers 9 or 10 (from 2 specimens, Society Islands); 84 and 121 mm. specimens had 16 upper and lower teeth; a 166 mm. specimen had 16 upper and 18 lower teeth, and a 170 mm. specimen 18 upper and lower teeth.

Longest soft dorsal ray 3. to 3.7 in standard length; fifth dorsal
Fig. 7. *Zebrasoma rostratum* (Günther), (after Günther, 1873).
spine 3.7 to 4 in standard length; body depth about 2 in standard length; patch of setae in front of the caudal spine may or may not be present (two of seven specimens which could be sexed had well-developed setae and were males; the others lacked this bristle area and were females; thus it is possible that this is a sexual character in this species).

The long snout was believed to be the most characteristic feature; however, examination of a series of 10 specimens in the Stanford Natural History Museum, collected by R. R. Harry from Raroia Atoll in the Tuamotus, revealed considerable variability in snout length. The ratio of snout length (measured from tip of upper teeth to nearest edge of eye) to standard length (tip of snout to base of caudal fin) ranged from about 3 to 5. This variability is not associated with growth nor does it appear to be related to sex.

I did not observe the dorsal spines to be noticeably stouter than those of other species of Zebrasoma, although Garrett's drawing (in Günther, 1873, reproduced herein as Fig. 7) shows them to be.

Color (in alcohol) entirely black except membranes of pectoral fin which are clear, the caudal spine which is hyaline with a white sheath, and in some specimens a faint pale longitudinal band in the posterior half of the dorsal and anal fins. Harry (1953: 152) gives the life color as solid black with white caudal spine.

Günther described Acanthurus rostratus from Garrett's notes and his painting of a 7.5 inch specimen. It has been presumed that the specimen is not in existence; however, I found two, both 7.5 inches in total length, at the Museum of Comparative Zoology which were collected by Garrett. It seems likely that one of these was the
basis for the figure and therefore should be considered as the type.

Fowler (1938: 128) thought that the velvet-like patch in front of the caudal spine was removed by the publishers of "Fische der Sudsee" from the painting. In this he is probably in error, for both of the Garrett specimens are females and lack this setous area.

*Zebrasoma rostratum* is known only from the Society Islands and two islands in the Tuamotus. Harry collected his specimens from lagoon shore reefs at Raroia and observed the species also on lagoon coral heads.

*Zebrasoma flavescens* (Bennett)

*Figs. 1 D, 8*

_Acanthurus flavescens_ Bennett (1828: 41) (Oahu); Cünther (1873: 116, pl. 76, fig. B) (Hawaiian Islands); Steindachner (1901: 493) (Honolulu).

_Zebrasoma agama_ Seale (1901: 110) (Cuam).

_Zebrasoma flavescens_ Bryan and Herre (1903: 134) (Marcus Island);

Jordan and Evermann (1905: 397, pl. 59) (Oahu); Jordan and Seale (1906: 355); Jordan and Jordan (1922: 66) (Hawaii); Fowler and Ball (1925: 19) (Johnston Island); Fowler (1928: 274, pl. 32, fig. A) (Hawaiian Islands, Johnston Island, Marcus Island); Aoyagi (in part) (1943: 203) (Riu Kiu Islands); Schultz and Woods in Schultz et al (in part) (1953: 641) (Bikini Atoll, Marshall Islands).

_Scopas flavescens_ Jenkine (1903: 480) (Honolulu and Puako Bay, Hawaii).

Dorsal rays V (rarely IV), 23 to 26 (usually 24 or 25); anal rays III, 19 to 22 (usually 20 or 21); pectoral rays 14 to 16 (usually 15); anterior gill rakers 8 to 12 and posterior gill rakers 11 or 12 (based
Fig. 8. *Zebrasoma flavescens* (Bennett), Hawaiian Islands (reproduced from a Kodachrome by the author).
on a total of 12 specimens from the Hawaiian Islands, Johnston Island, Wake Island, Bikini Atoll, Marcus Island, and Guam); a 25 mm. transforming specimen from Saipan had 12 upper and 14 lower teeth; a 77 mm. specimen collected by Schultz, Hiatt, and Brock at Bikini (U. S. N. M. No. 140586) had 15 upper teeth and 18 lower teeth; a 149 mm. specimen from Hawaii had 18 upper and 22 lower teeth.

The following proportional measurements were made on 15 specimens from 75 to 149 mm. in standard length: length of longest dorsal ray 2.8 to 3.8 in standard length; length of fifth dorsal spine 2.95 to 4.0 in standard length; body depth 1.4 to 1.75 (2.4 in 26 mm. juvenile specimen); a well-developed dense patch of setae posteriorly on the side of the body, progressively more prominent in larger specimens.

Color (in alcohol) uniform pale yellowish, in life bright chrome yellow. Upper edge of pectoral fin with a very narrow dark margin; sheath of caudal spine white. Preserved specimens often show a long, faint whitish band running backward and slightly downward from just behind the upper end of the gill opening.

Two of three yellow specimens of Z. flavescens (U. S. N. M. No. 140567) collected by L. F. Schultz from Johnston Island are a light dusky color over the back and head and there is a slight concentration of brownish pigment anteriorly in the dorsal fin. The yellow Bikini specimen shows this same diffuse marking in the fin. Still, this is but a slight departure from the usual pure yellow color.

This brightly-colored species is abundant in the Hawaiian Islands. Brock (1954: 302) calls attention to the interesting fact that it is much more common on leeward sides of islands than windward. His Figure 1 shows the relative abundance of this fish (as Zebrasoma) in nine
different localities around the islands of Hawaii and Oahu.

Jordan and Evermann (1905: 398) believed Acanthurus virgatus Vaillant and Sauvage to be the young of Z. flavescens and placed it in the synonymy of the latter. A. virgatus had vertical dark bars on the body and was probably a juvenile Zebrasoma veliferum. Juvenile Z. flavescens display no dark markings of any kind. A 21.5 mm. transforming specimen taken at a depth of 40 feet off Waikiki, Oahu, on June 3, 1952 was bright yellow in color like adults.

Except for one sight record in the Tuamotus (Harry, 1953), Z. flavescens appears to be confined to the northern part of the tropical Pacific. I have seen specimens only from the Hawaiian Islands, Johnston Island, Wake Island, Marcus Island, northern Marshall Islands, and the Marianas (including the type of Z. agaña Saale from Guam, kindly loaned by E. N. Bryan of the Bishop Museum, and two small bright yellow specimens collected by Eugenie Clark at Saipan). See section on _Z. scopas_ for further discussion of _Z. flavescens._

**Zebrasoma scopas (Cuvier)**

Fig. 1 E; Pl. I

_Acanthurus scopas_ Cuvier (1829: 224) (after Renard, 1718, Vol. 1, pl. 40, fig. 210) (Neira, Province of Banda); Cuvier and Valenciennes (1835: 245, pl. 290) (New Guinea); Bleeker (1851: 343) (Solor, East Indies); Thiollière in Montrouzier (1856: 459) (Island of Woodlark).

_Acanthurus rhomboeus_ von Kittlitz (1834: 194, pl. 13, fig. 6) (Ulea Island = Woleai Atoll, Caroline Islands); Günther (1861a: 342) (Aneityum, New Hebrides and Ceram, East Indies); Playfair in Playfair and Günther (1866: 57) (Zanzibar).
Acanthurus altivelis Cuvier and Valenciennes (1835: 249) (Indian Ocean and Mauritius).

Harpurus scopas Swainson (1839: 256).

Acanthurus goramensis Bleeker (1858b: 208) (Goram, East Indies); Günther (1861a: 343); Jatzow and Lenz (1898: 514, pl. 36, fig. 11) (Zanzibar).

Harpurus rhomboeus Bleeker (1863b: 271) (Timor, East Indies).

Acanthurus flavescens Günther (1873: 116, pl. 76, fig. A) (Tahiti); Sauvage (1891: 342) (Madagascar).

Zebrasoma rhombens Jordan and Seale (1906: 355) (Samoa): Jordan and Seale (1907: 34) (Panay, Philippine Islands); Jordan and Richardson (1908: 270) (Cagayanillo, Philippine Islands); Fowler (1928: 275) (Indo-Pacific, but not Hawaiian Islands, Johnston Island, or Marcus Island).

Zebrasoma flavescens Jordan and Fowler (1902: 555) (Okinawa); Herre (1927: 441) (Philippine Islands); Fowler and Bean (1929: 258) (Philippine Islands and East Indies); Schmidt (1930b: 103) (Riu Kiu Islands); Giltay (1933: 86) (East Indies); Herre (1934: 63) (Philippine Islands); Herre (1936: 248) (Society Islands, New Hebrides, Solomon Islands); Poll (1942: 11, fig. 3) (Tahiti); Aoyagi (in part) (1943: 203, pl. 8, fig. 3) (Riu Kiu Islands); Schultz (1943: 167) (Samoa Islands); de Beaufort (1951: 170) (Java); Schultz and Woods in Schultz et al (in part) (1953: 641, pl. 66, fig. B) (Marshall Islands); Harry (1953: 152) (Maroa, Tuamotu Archipelago).

Zebrasoma rostratum Jordan and Seale (1906: 356) (Samoa).

Zebrasoma supra-alba Fowler (1946: 193, fig. 70) (Riu Kiu Islands).
Dorsal rays V (rarely IV), 23 to 25 (usually 24); anal rays III, 19 to 21 (usually 19 or 20); pectoral rays 14 to 16 (usually 15); anterior gill rakers 9 to 12 and posterior gill rakers 10 to 13 (based on a total of 12 specimens from the Marshall Islands, Samoa, Society Islands, Philippine Islands, and East Indies); a 30 mm. specimen from the Gilbert Islands had 12 upper and 14 lower teeth; a 74 mm. specimen from the Philippines had 14 upper and 16 lower teeth; a 145 mm. specimen from the Philippines had 18 upper and 22 lower teeth.

The following proportional measurements were made on 15 specimens from 52 to 145 mm. in standard length: length of longest dorsal ray 2.7 to 3.6 in standard length; length of fifth dorsal spine 2.9 to 3.9 in standard length; body depth 1.5 to 1.7 in standard length (2.2 in a 30 mm. juvenile); oval-shaped brush-like patch of setae on sides, very prominent in larger specimens where it extends nearly half way to the base of the pectoral fin from the caudal spine (this velvet-like region first becomes apparent in specimens of 65 to 70 mm. in standard length).

Color (in alcohol) brown with numerous, thin, whitish, irregular, horizontal lines on the body which are broken into discrete spots anteriorly and on head; on small specimens (about 45 to 65 mm. in standard length) the lines are entirely broken up on the body. Specimens smaller than 45 mm. have narrow vertical pale lines on the body between which spots are aligned vertically. In most specimens, regardless of length, a whitish band of about the diameter of a pupil of eye in width extends posteriorly from a point just behind the upper edge of the gill opening over half the distance to the caudal spine. Sheath of caudal spine white; median fins brown; pectoral fin
membranes hyaline, rays light brownish; upper edge of unbranched pectoral ray with a narrow black line.

Color (in life) dark brown, yellowish brown anteriorly, with numerous, narrow, wavy, light blue longitudinal lines on the body, breaking up to small blue dots on nape, chest, and head (no linear pattern being evident on the latter); all fins except pectorals dark brown; pectorals clear with dusky orange rays and a narrow black upper margin. This color note was obtained from an 88 mm. specimen collected by me from a recess in a stand of dead staghorn coral in the lagoon of Onotoa Atoll, Gilbert Islands.

Although colors of olive or dark green and black have been given for the species, the majority of the records of the basic life color are brown. The other colors may represent variability which is possible in individual specimens. Other acanthurids are known for the ability to alter their hues (Townsend, 1929). Ctenochaetus striatus (Quoy and Gaimard), also a brown, blue-lined species, may appear almost black or distinctly olivaceous when alive.

Plate I of fresh specimens from Onotoa Atoll provides comparison of the young of Z. scopas and Z. veliferum.

Schultz and Woods (1953: 642) reported that this species was found in or close to deep water in the Marshall Islands. I observed adults in about 8 feet of water in the Onotoa lagoon and on the lee reef of Butaritari Atoll in the Gilbert Islands; however, they were infrequently seen.

The largest specimen in the museum material which I have examined measured 149 mm. in standard length.

Günther (1873: 117) united Acanthurus rhombeus ( = Z. scopas) with
flavescens, regarding the yellow form in Hawaii as probably a case of albinism. Jordan and Seale (1906: 355) (1907: 34) stated that the two are probably the same species, though they retained both names. Herre (1927: 443), Fowler and Bean (1929: 260), Aoyagi (1943: 204), Schultz and Woods (1953: 152), and others have asserted their belief that these are color forms of a single species.

Jordan and Fowler (1902: 556) wrote, "Probably the typical flavescens is found in deep water, the variety rhombeum living near shore." Certainly this does not seem to be true, for neither form appears restricted to any particular depth of the reef. I have observed Z. flavescens in Hawaii in from about 3 to 90 feet of water.

Z. scopas (as here defined) is known from Zanzibar to southern and western Oceania. In spite of extensive collecting and underwater observation in the Hawaiian Islands, Johnston Island, and Wake Island by W. A. Gosline, V. E. Brock, myself, and others, no specimens of Z. scopas (the so called brown phase of Z. flavescens) have been seen, although the bright yellow Z. flavescens is abundant. The few museum specimens from Marcus Island and Guam are pale, presumably yellow in life, and hence Z. flavescens.

I have examined 167 specimens from the Philippines, East Indies, Gilbert Islands, Samoa Islands, Society Islands, and Mauritius and all were brown. Jordan and Seale (1906: 356) had 50 specimens from Samoa and saw none yellow in color. Fowler (1928: 274) recorded Z. flavescens from the Hawaiian Islands, Johnston Island, Samoa, Marcus Island, and Raiatea and described the species from preserved specimens as fuscous-black with fine grayish lines. Of his specimens only those from Samoa and Raiatea were of this color; the rest were pale
yellowish.

Only from Bikini Atoll in the northern Marshall Islands have I seen both yellow and brown specimens from the same area. Of 14 specimens only one was yellow. Aoyagi (1943: 204) reported both yellow and brown and intermediate forms from the Riu Kiu Islands, however, he mentioned that there was some geographical separation. R. R. Harry (1953: 152) stated that he observed one yellow specimen underwater at Rarotia Atoll in the Tuamotus but took only the dark form. Upon discussing his sight record with Harry, I learned that he was unaware of the solid bright yellow color of the young of Acanthurus olivaceus Bloch and Schneider. He then stated that he could not be certain that the specimen he saw was Z. flavescens and not A. olivaceus.

My efforts to distinguish the yellow Z. flavescens and the brown Z. scopas on other grounds than color met with the usual failure except for fin ray counts (Table 1) which provide a partial separation, the counts of Z. flavescens being higher. One might say that this meristic difference is due to the colder water of the northern part of Oceania to which the yellow "phase" seems to be restricted; however, the water of the Mariana Islands is as warm as the warmest areas of the Pacific (more specimens are needed from this region however, to be certain that the fin ray counts are really higher), and the fin ray counts of Z. scopas from the Society Islands, which are about as far south as the Hawaiian Islands are north and have sea surface temperatures which are almost as cool as Hawaii (Hydrographic Office, 1944) show no increase (Table 1). Also Z. valiferum does not exhibit any obvious increase in ray counts in the Hawaiian Islands.

In view of the available data, I do not believe that Z. flavescens
and *Z. scopas* can be considered as color varieties of one polymorphic species. If they were color varieties, at least an occasional brown specimen should have turned up in areas like the Hawaiian Islands, or yellow ones from the southern or western tropical Pacific or Indian Oceans. More important, one would not expect the fin ray counts of both phases to be different. Two other possibilities exist: the brown and yellow forms are full species or they are subspecies. My data are not yet sufficient to decide with assurance which is the case. At the present time I favor considering the two as species, although I may be placing too much emphasis on the single yellow specimen from Bikini with higher fin ray counts than brown specimens from the same atoll. This one yellow specimen might have been carried there as a larva from a *Z. flavescens* area such as Wake Island. If this were true, the case for subspecies would be strengthened.

The claim made by Aoyagi that yellow, brown, and intermediate forms occur in the Riu Kiu is difficult to assess and should be checked. The intermediate forms were described as yellowish brown with minute spots. This is normal coloration for subadult and juvenile *Z. scopas*; thus this author might not have observed true intermediate forms at all. If the "geographical separation" which he mentioned is north-south within this island chain and true intermediate forms were found in a region of contact of the yellow and brown, the best explanation would be in terms of subspecies.

I examined the type of *Zebrasoma supra-alba* Fowler from the Riu Kiu Islands at the Academy of Natural Sciences of Philadelphia. The unique feature of the anterior part of the dorsal fin being white appears to be caused by damage to the specimen. The fin membranes of
the first four spines are completely torn off. A white area does
appear posterior to the fourth spine to about the middle of the fin,
but this seems to be due to a stripping off of the pigmented epidermis.
The fin ray counts of this specimen are given in Table 1 for the Riu
Kiu Islands under the heading scopas.

Genus ACANTHURUS Forskal

Hepatus Gronow, 1763. Zoophyllum...p. 113. (Nonbinominal.)
Teuthis Linnaeus, 1766. Syst. nat. Ed. 12, vol. 1, p. 507. (Linnaeus
included in Teuthis several acanthurids under the one name hepatus
and a siganid. In Opinion 93 of the International Commission on
Zoological Nomenclature the siganid, T. javus, was fixed as type.)
Acanthurus Forskal, 1775. Descr. animalium. p. 59. (Type species by
subsequent designation (Jordan 1917: 33), Chaetodon sohal Forskal.)
Harpurus Forster, 1778. Enchiridion hist. nat....p.84. (Type species,
Harpurus fasciatus Forster = Chaetodon triostegus Linnaeus.) (Re-
ference after Jordan, 1917.)
Rhombotides Walbaum, 1792 (ex Klein, 1775, nonbinominal.). Petri Artedi
...ichthyologiae pars iii, p. 582.
Aspisurus Lacépède, 1802. Hist. nat. poiss. Vol. 4, p. 556. (Type
species, Chaetodon sohal Forskal.)
Ctenodon Swainson, 1839. Nat. hist....fishes...Vol. 2, p. 255. (Pre-
occupied by Ctenodon Wagler, 1830.)
Acronurus Cronow, 1854. Cat. fish collected...p. 190. (Type species,
Acanthurus argenteus Quoy and Gaimard.)
Harpurina Fowler and Bean, 1929. U. S. Natl. Mus., Bul. 100, vol. 8, p. 253. (Type species, Hepatus nubilus Fowler and Bean.) (Proposed as a subgenus; raised to generic rank by de Beaufort, 1951: 165.)

Forskal (1775: 59) proposed Acanthurus as a subgeneric category of Chaetodon, and in it he included unicornis, sohal, nigrofuscus, and gahhm (the latter was considered by him as a variant of nigrofuscus). None of these was designated by him as the type species. Lacépède (1801: 105) established the genus Naso and listed unicornis as a synonym of his Naso fronticornis (even though unicornis is an earlier name). Also (1802: 556) he removed sohal (erroneously as sohar) from Acanthurus and erected the genus Aspisurus for this one species. Aspisurus has properly been placed back in Acanthurus; unicornis remains in Naso. Valenciennes (1837, pl. 71, fig. 2) figured Acanthus xanthopterus Cuvier and Valenciennes as the type species of Acanthurus. Gill (1855: 278) listed "Teuthis hepatus Linnaeus = Acanthus chirurgus Bloch" as the type. Neither of these type designations is valid, for these species were not among those included by Forskal in Acanthurus.

Jordan and Fowler (1902: 558) used the genus Acanthus for species of Naso which have the frontal horn, under the belief that unicornis should be considered as the type of Acanthurus since it was the first species listed by Forskal in his subgeneric category Acanthurus. I quote Jordan and Fowler: "The first species named by Forskal, unicornis being taken as its type, Acanthurus becomes equivalent to Monoceros."

Later Jordan (1917: 33) selected Chaetodon sohal Forskal as the type species of Acanthurus, and both Jordan and Fowler reverted to the usual use of Naso. Should Jordan and Fowler's statement on unicornis be construed as a valid type designation, I would recommend application to
the International Commission on Zoological Nomenclature to preserve the common usage of *Acanthurus* and *Naso*.

According to Opinion 21 of the International Commission on Zoological Nomenclature, the genera of Klein (1744) do not gain nomenclatorial status by reason of being quoted by Walbaum (1792); thus *Rhombotides* is not valid. Bleeker often used this name instead of *Acanthurus*.

The genus *Harpurina* Fowler and Bean, in which de Beaufort (1951: 165) placed the single species *nubilus* Fowler and Bean, is characterized primarily by small teeth and VI or VII dorsal spines. *Acanthurus thompsoni* (Fowler) and *A. bleekeri* Günther have the same type of denticion (and other similarities), but the usual IX dorsal spines. They serve to connect *nubilus* with more typical species of *Acanthurus*; thus I do not believe that *Harpurina* is a valid genus.

Fowler (1944a: 109) established the subgenus *Rhombotethys* for the species *Acanthurus coeruleus* Bloch and Schneider on the basis of its deep body, long pectoral fins, and small caudal spine. If only the Atlantic species of *Acanthurus* were classified, such a subgenus might be a useful criterion, but it breaks down when the Indo-Pacific forms are considered, for some, like *Acanthurus guttatus* Bloch and Schneider and *A. nubilus* have a body depth as great or greater and pectoral fins as long as *A. coeruleus*, and *A. triostegus* (Linnaeus) has a smaller caudal spine. None of these species could be grouped with *coeruleus* to form a natural subgeneric category apart from other species of *Acanthurus*. Better subgenera could be formed by grouping *A. achilles* Shaw, *A. glaucopareius* Cuvier, and *A. leucomosternon* Bennett or *A. nubilus*, *A. bleekeri* Günther, and *A. thompsoni* (Fowler); however, I do not believe that even these are advisable.
The late postlarval Acanthurus is quite different from the juvenile. It is more disc-like, transparent in life with silvery abdomen, and naked with vertical striae or folds on the body. It is not difficult to understand why Gronow erected Acronurus for this stage and how this genus persisted so long in the literature. Although now well known to be larval, acronurus remains as a common name for the late postlarval stage of Acanthurus. Some authors apply the designation to all postlarval acanthurids.

The type species of Acronurus by subsequent designation is Acanthurus argenteus Quoy and Gaimard. As indicated by Randall (in press), this species may be the young of Ctenochaetus striatus (Quoy and Gaimard). If this could be conclusively demonstrated, the generic name Ctenochaetus would have to be replaced by Acronurus. Under such circumstances, it would be advisable to apply to the International Commission on Zoological Nomenclature to conserve the name Ctenochaetus. Nearly all use of Acronurus has been for the young of Acanthurus.

Swainson (1839) listed Teuthys as a surgeon fish genus (an emendation or erroneous spelling for Teuthis Linnaeus) for the single species Acanthurus argenteus Quoy and Gaimard. His brief description obviously applies to an acronurus. Linnaeus, however, did not include any acronurus forms in Teuthis.

Seale placed in Zebrasoma (probably a typographical error for Zebrasoma), his new species agane (= flavescens) and a species of Acanthurus (A. guttatus). He apparently mistook A. guttatus for a Zebrasoma because of its high body.

Acanthurus is characterized as follows: body compressed, elliptical, the depth contained 1.55 to 2.5 in standard length; head length
3 to 4.3 in standard length; caudal peduncle with a single sharp folding spine on each side, fitting into a definite socket; length of caudal spine 1.9 to 1.5 in head length; least depth of caudal peduncle 1.9 to 3.1 in head length; mouth small, terminal, and only slightly protractile; jaws equal; teeth close-set, compressed, denticulate, 8 to 24 in upper jaw and 10 to 24 in lower jaw; dorsal fin with VI to IX (usually IX) spines and 22 to 33 rays; anal fin with III spines and 19 to 29 rays; pectoral fin rays 15 to 17; pelvic fin with 1 spine and 5 rays; caudal fin with 16 principal rays; caudal fin varying in shape from nearly truncate to very lunate; dorsal and anal fins continuous and unnotched; longest dorsal ray 3.5 to 6 in standard length; length of pectoral fin 2.7 to 3.8 in standard length; length of pelvic fin 3.2 to 5.5 in standard length; origin of pelvic fin at or slightly posterior to a vertical through middle of base of pectoral fin; diameter of eye in adults 2.8 to 5.7 in head length; interorbital space 2.5 to 3.6 in head length; snout length 3.9 to 8.2 in standard length; gill openings restricted to sides; gill membranes attached to isthmus; anterior gill rakers 13 to 29; posterior gill rakers 13 to 32; scales ctenoid, very small, and not in regular rows; head scaled, though not conspicuously; lateral line complete; 22 or 23 vertebrae; stomach varies from round and heavy walled to elongate and thin walled.

Agassiz (1833-43: vol. 4, p. 207, pl. J) discussed the osteology of Acanthurus. Günther (1861: 327) described the osteology of Acanthurus triostegus, and Gregory (1933: fig. 156) figured the skull of this species. Souche (1935) made an anatomical study of the musculature of the caudal spine of Acanthurus chirurgus. Willem (1944) studied the respiratory system of Acanthurus triostegus along with
that of other species.

Plate 5, Figures 3, 4, and 5 of Lütken (1880) represent the post-acronurus, acronurus, and postlarval forms, respectively, of Acanthurus coerulescens. His Figure 5 was drawn from a 5.7 mm. specimen. Weber (1913: fig. 70) figured a 7 mm. postlarval stage of an unidentified species of Acanthurus.

The gender of the name Acanthurus is uncertain. The probable derivation of this generic name is from the Greek acantha (thorn, fem.) and the Greek oura (tail, fem.). If properly latinized, it would have been Acanthura. Forskal, who never used it in combination with a specific name, probably intended that it be masculine. Subsequent authors, including those who wrote primarily in Latin, have consistently treated the genus as masculine, a practice followed in the present paper.

The original descriptions of a few species of Acanthurus for which there are no known types are so fragmentary (or in cases probably erroneous) that it would be pure guess work to allocate the names to known forms. In this category are the following: Acanthurus Militaris Shaw, Acanthurus Umbraetus Shaw, Acanthurus Melasgris Shaw, Acanthurus fuliginosus Lesson, Acanthurus fraterculus Cuvier and Valenciennes, and Acanthurus lineolatus Cuvier and Valenciennes.

The only species of Acanthurus described by Shaw (1803) which has been recognized is A. achilles. I have never seen other Shaw names used, and the descriptions are much too brief to permit identification. A. C. Wheeler of the British Museum answered my query about types by writing, "I have searched everywhere for Shaw's types, and I am quite certain that they are now not in existence, be they in spirit, stuffed, or skins".
Acanthurus fuliginosus was figured by Lesson (1830: pl. 27, fig. 2) as a uniformly brown fish with a broad bright blue line under the chin. In life there were fine, transverse, reddish lines on the body. I know of no species with such coloration. Certainly the use of the name by Fowler, Schultz, and others for Acanthurus xanthonopterus Cuvier and Valenciennes is not proper, as has been pointed out by de Beaufort (1951: 159).

Acanthurus fraterculus Cuvier and Valenciennes was described from a figure by Renard as brown with three oblique blue and red bands on each side of the head, a blue spot below the middle of the dorsal fin, and green fins except the spinous dorsal which is blue and yellow. Although Günther (1861: 341) listed this species, he added that it had not been recognized.

Chaetodon elongatus Lacépède (1803: 454) is a special problem. It is a species of Acanthurus, and the type (No. A. 2506) is in the Paris Museum. L. Bertin (personal communication) writes that it is 90 mm. in standard length, has 16 upper teeth, and a caudal concavity of 4 mm. He adds that the specimen is dry, in very poor condition, and with no color markings perceptible. Günther (1861) listed A. elongatus as a questioned synonym of Acanthurus nigrofuscus (Forskal); the most frequent use of the name elongatus has been for A. nigrofuscus; however A. elongatus could not be this species. A 90 mm. specimen of A. nigrofuscus would have, at most, 12 upper teeth and would have a caudal concavity of about 16 mm. Acanthurus elongatus is probably a subadult of one of the larger species of Acanthurus such as A. dussumieri Cuvier and Valenciennes, A. xanthonopterus Cuvier and Valenciennes, or A. mata (Cuvier). It is difficult to identify
even fresh specimens of 90 mm. length of species in this complex. Because of the apparent juvenile nature and poor state of preservation of the type specimen, coupled with the inadequate original description, elongatus should be considered a nomen inqueredum.

Acanthurus rachliflfi Schultz (1943: 157, 163, fig. 13) is probably a hybrid of Acanthurus achilles Shaw and Acanthurus glaucopareius Cuvier (see page 208).

Sauvage (1891: 519) listed lunulatus Liénard among the species of Acanthurus from Madagascar. I am unable to find the work of Liénard in which this species was described. This author was at times non-bi-nominal.

Acanthurus doreensis Cuvier and Valenciennes is here treated as a doubtful species.

Some species of Acanthurus have been described from the late post-larval or acronurus stage, and many of these were originally placed in the genus Acronurus Gronow. The larval nature of Acronurus has been known at least since Gönther (1873); nevertheless as recently as 1944 Fowler described a new species in the genus. It has not been possible in most cases for me to determine the correct adult name for species described from acronurus or early juvenile stages. The following such species I cannot with assurance place in synonymy: Acronurus orbicularis Quoy and Gaimard, Acronurus fuscus Gronow, Acronurus anginosus Bleeker, Acronurus brevispinis Gönther, Acronurus argenteus Gönther (not of Quoy and Gaimard), Acronurus melanurus Day, Acronurus carneus Poey, Acronurus lineolatus Klunzinger, Acronurus machaeropeterus Fowler, Acanthurus melanurus Cuvier and Valenciennes, Acanthurus melas Cuvier and Valenciennes, Hepatus leucopareius Fowler (from Guam), Teuthis
alongatus Kendall and Goldsborough, Hepatus elegans Kamohara (not of Garman), and Teuthis spinifrons Whitley.

I have been more successful in identifying to species actual museum specimens of acronurus forms and early juveniles. Some of these are shown in Figure 9. The adults of all of the species of Acanthurus are herein figured.

I have seen specimens of all of the known species of Acanthurus except A. polyzona (Bleeker), A. leucocheilus Herre, and A. mindorensis Herre. A. W. Herre has informed me that the types of the latter two were destroyed at Manila. To my knowledge there are no other specimens in existence. The specimens which Herre (1934: 62) identified as A. leucocheilos [error for leucocheilus] are Acanthurus pyroferus.

Like most fishes, there are some obvious differences with age in species of Acanthurus. With increasing age, the eye becomes relatively smaller, the caudal fin generally more lunate, and in many species the body is more elongate; the teeth increase in number and at least in some species (see Table 17 under A. gahma) the number of denticulations on the teeth decrease (for this reason the lengths are given for specimens from which teeth are taken for the tooth drawings of Figure 10). Most striking in many species are the color changes with age. Examples are as follows: the young of A. coeruleus Bloch and Schneider and A. olivaceus Bloch and Schneider are solid yellow in color; the distinctive mark found on the shoulder region of many of the species of Acanthurus are not present in juveniles; the semicircular black shoulder mark of A. tennanti Günther changes in older individuals to two elongate black bands; A. achilles does not develop its bright orange spot on the caudal peduncle until it has attained a size of about 65 to 70 mm.
Two keys are given, one to the Indo-Pacific species and one to the Atlantic species, not because there are any marked differences between the species of these two major regions, but as a convenience to the reader. The species are keyed out, insofar as possible, in natural groups (as based on superficial characters). These species groups are not sufficiently demarked from one another, in my opinion, to be regarded as subgenera. They are as follows:

1. A. triostegus (Linnaeus) and A. polyzona (Bleeker).

2. A. nubilus (Fowler and Bean), A. bleekeri Günther, and A. thompsoni (Fowler).

3. A. nigrofuscus (Forskal), A. nigroris Cuvier and Valenciennes, A. leucopareius (Jenkins), A. guttatus Bloch and Schneider, and possibly A. coeruleus Bloch and Schneider.

4. A. lineatus (Linnaeus) and A. sohal (Forskal).

5. A. achilles Shaw, A. glaucopareius Cuvier, and A. leucosternon Bennett.

6. A. pyroferus Kittlitz.

7. The remaining three Atlantic species and the last 11 Indo-Pacific species (A. leucochelis and A. mindorensis not considered).

A. pyroferus is placed by itself because of its intermediacy between Groups 5 and 7; this is discussed in detail under A. pyroferus.

Group 7 constitutes a superspecific assemblage which has as its most characteristic feature a large, round, thick-walled stomach. Such a gizzard-like stomach is not found in any other Acanthurus except A. pyroferus. These species are commonly found in bay or lagoon environments, and the gut contents generally contain a large percentage of
hard, coarse, sedimentary material. The teeth tend to be elongate with numerous denticulations. Eight of the Indo-Pacific species develop with age a distinctive color mark in the shoulder region just above the gill opening. In most of the species the caudal spine is accentuated by being surrounded with color (often black or dark brown). They are not exclusive in this feature, however, for Acanthurus achilles, Acanthurus sohal, and certain species of Naso have their caudal spines contained within areas of bright color. Presumably this color serves as warning coloration, a means of calling attention to the sharp caudal spines. There is a tendency in this group toward large size, this being most apparent in A. xanthopterus, A. dussumieri, and A. mata.

It is only in this last group of species that I have observed sexual dimorphism in Acanthurus. Large adult males develop a definite convexity in the profile of the head above the mouth. Although there is a tendency for the profile to become more convex regardless of sex, it is much more evident in males than in females of the same size.

The distribution of the species of Acanthurus as indicated in the keys and Table 2 is based on localities of museum specimens seen by me and records from the literature about which there is little or no question. Further collecting may result in the extension of the range of some of the species.

Like most widely-distributed genera of tropical marine fishes, the greatest number of species of Acanthurus occurs in the Indo-Malayan region. Twenty-three are recorded from the East Indies and Philippines, six of which are endemic to the area. This is a higher degree of endemism than that of any other region.

Only two species of Acanthurus, A. achilles and A. leucopareius
Table 2 Distribution of the Species of *Acanthurus*

<table>
<thead>
<tr>
<th>Major tropical and subtropical regions</th>
<th>No. of species known to occur in region</th>
<th>No. of species confined to region</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indo-Pacific (28 species)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indian Ocean</td>
<td>13*</td>
<td>3#</td>
</tr>
<tr>
<td>Common to Indian Ocean and Indo-Malaya</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Indo-Malayan region</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>Common to Indo-Malaya and Oceania</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Oceania**</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>Common to Indian Ocean and Oceania</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Eastern Pacific</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td><strong>Atlantic (4 species###)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Atlantic</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>West Africa</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

* *Acanthurus glaucopareius* is recorded from Christmas Island and Cocos-Keeling Islands in the Indian Ocean. Since these are near the East Indies and the species is unknown from the rest of the Indian Ocean, it is not included in this figure.

# Includes *Acanthurus sohal*, a species known only from the Red Sea.

// East Indies, northern Australia, Malaya, and Philippine Islands.

** Oceanic islands of the tropical western, southern, and central Pacific Ocean.

### The Indo-Pacific *Acanthurus triostegus* is not included in this figure, although there is one record of this species from West Africa.
appear to be confined to oceanic islands of the Pacific. The latter is known by authentic records only from the Hawaiian Islands, Marcus Island, and Easter Island, areas widely separated and peripheral in Oceania, suggesting that A. leucoparsius may be a relict species.

Acanthurus lineatus, though widely distributed, is not reported from the Red Sea. The species which most resembles A. lineatus is A. sohal. The latter appears to be restricted to the Red Sea. A. achilles and the similar A. leucosternon are not recorded from the same area; A. achilles, as mentioned, seems to be characteristic of Oceania whereas A. leucosternon is an Indian Ocean and East Indian species. The Indian Ocean species A. tenenti is very closely related to A. olivaceus. The latter, however, does not seem to occur in the Indian Ocean, but ranges from the East Indies into the tropical Pacific. Although further collecting may result in the two species of these three pairs being found together, it may be worth noting at this time that they may be species which will not co-exist due to similarities in ecological tolerances (Gause, 1934). I suspect that this may be the explanation because of the apparent ease with which species of Acanthurus achieve wide distribution (probably because of long planktonic larval life). Since A. olivaceus, for example, ranges from the East Indies throughout Oceania, it would be expected to occur also in the Indian Ocean in view of existing current patterns.

One of the Atlantic species, Acanthurus chirurgus (Bloch) is very similar to the Indo-Pacific A. xanthopterus which occurs on the Pacific coast of Mexico and Central America, where it has usually been known by the name Acanthurus crestonis (Jordan and Starks). Although not included among the geminate species (listed by Jordan 1908: 76) which
occur on either side of the isthmus of Panama, these two could, in my opinion, qualify as another example.

The three Atlantic species which are common in the West Indies and Florida are occasionally taken as far north as New York and Massachusetts. It is believed that these species are not resident in such northern localities but represent individuals carried northward as larvae by the Gulf Stream.

The acronurus of Acanthurus triostegus is taken farther south on the southeast coast of Africa than are adults (Smith, 1949: 240 and by personal communication). The strong southerly current in this region is probably responsible. The same thing appears to be true of several species of surgeon fishes on the east coast of Australia (Whitley, 1953).

KEY TO THE SPECIES OF ACANTHURUS OF THE INDIAN AND PACIFIC OCEANS

1a. Body light in color with vertical black bars; caudal fin truncate or slightly emarginate, caudal concavity contained more than 15 times in standard length; caudal spine very small....................2

1b. Body not light in color with vertical black bars; caudal fin, at least in adults, emarginate to lunate, caudal concavity contained less than 15 times in standard length (except guttatus); caudal spine usually not small..................................................3

2a. 6 vertical black bars (one on head passing through eye; 4 on side of body; one on caudal peduncle); bars on side of about uniform width; anal soft rays 19 to 22; dorsal soft rays 22 to 24 (excluding fin ray counts of Hawaiian subspecies). (Indo-Pacific)........

.......................................................................................................................... triostegus (p. 79)
2b. 12 vertical black bars (4 on head, the longest passing through eye; 6 on side of body; 2 on caudal peduncle); bars on side about five times as broad dorsally as ventrally; anal soft rays 21 to 23; dorsal soft rays 23 to 25. (Réunion Island, Indian Ocean) (after Bleeker). \textit{polysoma} (p. 93)

3a. Snout short, its length contained 6.6 to 8.2 times in standard length; mouth small and teeth small and numerous, 22 or more in lower jaw of adults.

3b. Snout not short, its length contained 3.9 to 5.3 times in standard length; mouth usually not small (if small, not more than 12 teeth in lower jaw) and teeth not small and numerous, 22 or less (rarely 22) in lower jaw of adults.

4a. Dorsal spines VI or VII; body depth 1.8 in standard length; anterior gill rakers 21; posterior gill rakers 24 (based on 1 specimen). (Philippine Islands and East Indies). \textit{nubilus} (p. 95)

4b. Dorsal spines IX; body depth 2.1 to 2.5 in standard length; anterior gill rakers 13 to 17; posterior gill rakers 13 to 15.

5a. Lengthwise blue lines on side of head and body (may be faded in preserved specimens); snout 6.6 to 7.1 in standard length; least depth of caudal peduncle 2.7 to 3 in head length; no dark brown spot just below axil of pectoral fin; maximum length about 300 mm. in standard length. (Indo-West-Pacific, except Hawaii). \textit{bleekeri} (p. 96)

5b. No lengthwise blue lines on side of head and body; snout 7.9
to 8.2 in standard length; least depth of caudal peduncle 2.2 to 2.5 in head length; a dark brown spot just below axil of pectoral fin; maximum standard length about 150 mm. (East Indies, Philippine Islands, and Oceania)...........thompsoni (p. 100)

6a. Mouth low in origin on head and produced; a deep brown ring at base of caudal fin; all fins black. (Philippine Islands) (after Herre)..........................mindorensis (p. 103)

6b. Mouth not low in origin on head and usually not produced; no deep brown ring at base of caudal fin; all fins not black........7

7a. Posterior half of body and dorsal and anal fins with numerous white spots on a brown background; body with 3 vertical whitish bars, the first running from occiput to opercle, the second from base of third and fourth dorsal spines to region of anus, and the third from base of first few dorsal soft rays to base of first few anal soft rays; body very deep, greatest depth 1.5 to 1.6 in standard length. (Indo-West-Pacific).........guttatus (p. 105)

7b. Posterior half of body without numerous white spots; body without 3 vertical whitish bars; body not very deep, greatest depth 1.7 to 2.5 in standard length.........................8

8a. A black spot at base of last few rays of both the dorsal and anal fins (spot in axil of anal fin in leucopareius very small).................................................................9

8b. No black spot at base of last few rays of dorsal and anal fins.................................................................11

9a. A whitish band, broadly bordered by dark brown bands, running
from origin of dorsal fin across operculum just behind eye (faded in some specimens); caudal fin with no white posterior margin; caudal fin emarginate, caudal concavity 10.5 to 12 in standard length of adults; body depth 1.7 to 1.8 in standard length; anterior gill rakers 15 to 13. (Hawaiian Islands, Marcus Island, and Easter Island).....leucoparcius (p. 108)

9b. No whitish band running from origin of dorsal fin across operculum; caudal fin with a white posterior margin; caudal fin moderately concave to lunate, caudal concavity 4.5 to 10 in standard length; body depth 1.8 to 2.3 in standard length; anterior gill rakers 20 to 29.........................................10

10a. Caudal fin moderately concave, caudal concavity 5.9 to 10.5 in standard length; black spot at axil of soft dorsal fin not large, its greatest width contained more than 2 times in diameter of pupil of eye; white posterior margin of caudal fin narrow, its width rarely less than 4 in pupil; no definite black margin around groove of caudal spine; body depth 1.3 to 2 in standard length; ends of median upper teeth rounded (Fig. 10 g); maximum standard length about 200 mm.; no orange spots on head in life. (East Indies, Philippine Islands, and Oceania).............................nigroris (p. 113)

10b. Caudal fin lunate, caudal concavity 4.5 to 6 in standard length; black spot at axil of soft dorsal fin large, its greatest width contained less than 2 times in diameter of pupil of eye; white posterior margin of caudal fin not narrow, its greatest width about 2 in pupil (in specimens from Oceania); a definite black margin around groove of
caudal spine; body depth 2 to 2.3 in standard length; ends of median upper teeth tend to be pointed (Fig. 10 h); maximum standard length about 150 mm. (rarely over 120 mm.); orange spots on head in life (which usually fade in preservative). (Indo-West-Pacific).......................... nigrofuscus (p. 119)

11a. Upper 3/4 of body with conspicuous lengthwise black bands and in sharp contrast to uniform light grayish brown of lower 1/4; caudal spine very long (1.9 to 2 in head length) and without a definite sheath; posterior, gill rakers 13 to 15; anterior gill rakers 14 to 17.........................12

11b. Body without conspicuous lengthwise black bands; caudal spine not very long (2.1 to 8 in head length) and with a definite sheath; posterior gill rakers 17 to 32; anterior gill rakers 16 to 29...............................................................13

12a. Dorsal rays IX, 27 to 29; about 7 black lengthwise bands on body below lateral line (anteriorly), each bisected with a blue line and alternating with whitish (yellow in life) lines; median and pelvic fins not black. (Indo-West-Pacific, but not Hawaii).......................... lineatus (p. 127)

12b. Dorsal rays VIII, 30 to 31; about 15 black lengthwise bands on body below lateral line (anteriorly), none bisected with blue lines and not alternating with whitish lines (the narrow intermediate lines of same color as ventral part of body); median and pelvic fins black. (Red Sea)........... sohal (p. 130)

13a. Lips reddish in life and surrounded (or nearly surrounded) by a pearly white line with a black band behind it; a bluish
white band of about a half an eye diameter in thickness crossing chest slightly anterior to a vertical through center of eye; outer part of soft dorsal fin in life with 3 and anal fin with 2 narrow red lines alternating with bluish lines; pelvic fins brick red with black outer margin. (Philippine Islands) (after Herre).............leucocheilus (p. 133)

13b. Lips not reddish in life and never completely surrounded by a pearly white line with a black band behind it; no bluish white band of about a half an eye diameter in width crossing chest; no red lines in outer part of soft dorsal and anal fins; pelvic fins not brick red with black outer margin........14

14a. Dorsal spines VIII; caudal fin black except for a broad pale (yellow in life) band of near-uniform width on entire posterior margin (hence most of prolonged outer lobes of caudal fin pale); a white line under chin extending slightly above rictus; upper end of gill opening and edge of operculum broadly black; a diffuse orange area in life behind gill opening extending to axil of pectoral fin. (Indian Ocean, East Indies, Philippine Islands, and Western Oceania).............

..................................................pyroferus (p. 135)

14b. Dorsal spine IX; caudal fin not black with a broad pale posterior margin of uniform width; upper end of gill opening and edge of operculum not broadly black; no diffuse orange area in life behind gill opening extending to axil of pectoral fin.....15

15a. Mouth very small, its width from rictus to rictus contained 4.5 to 6 times in length of head; maximum number of upper or lower teeth 12; a white line under chin; depth of body 1.7 to
1.9 in standard length; dorsal soft rays 28 to 33; anal soft rays 26 to 29.

15b. Mouth not very small, its width from rictus to rictus contained 3.2 to 4.8 times in length of head; maximum number of upper or lower teeth 22 (specimens over 50 mm. in standard length with at least 14 teeth in either jaw); no white line under chin; depth of body 1.9 to 2.5 in standard length; dorsal soft rays 23 to 28; anal soft rays 22 to 26.

16a. Isthmus and chest with a chalky white band (as broad as depth of caudal peduncle) extending to base of pectoral fin; body bluish gray in preservative, head dark brown. (East Indies and Indian Ocean). leucosternon (p. 140)

16b. Isthmus and chest without a broad white band; body and head dark brown to black.

17a. No large elliptical pale yellowish area posteriorly on body; an oval white spot under eye; no white mark on opercular membrane; white line on chin extending above rictus; pale area at base of dorsal and anal fins very broad posteriorly; caudal fin emarginate, caudal concavity 10 to 14.5 in standard length; dorsal soft rays 28 to 31 (usually 29 or 30); anal soft rays 26 to 28 (usually 26 or 27). (East Indies, Philippine Islands, Oceania, and islands of tropical eastern Pacific). glaucopareius (p. 142)

17b. A large elliptical pale yellowish area (bright orange in life) posteriorly on body, enclosing in its hind part the caudal spines (this area absent in specimens less than about
65 to 70 mm. in standard length); no oval white spot under eye; an elongate pure white mark on opercular membrane; white line on chin not extending above rictus; pale area at base of dorsal and anal fins narrow and of almost uniform width; caudal fin lunate, caudal concavity 5.5 to 8.5 in standard length; dorsal soft rays 29 to 33 (usually 30 to 32); anal soft rays 26 to 29 (usually 27 to 29). (Oceania)..................achilles (p. 147)

18a. A prominent dark mark on shoulder (absent in young)...................19
18b. No dark mark on shoulder..................................................25

19a. Shoulder mark semicircular (open end forward at level of eye), a very elongate horizontal ellipse, or two elongate bands (one above the other); a large crescent-shaped white region posteriorly in caudal fin, its greatest width more than half the diameter of eye; base of caudal fin not pale; anal soft rays 22 to 24; dorsal soft rays 23 to 25; no fine longitudinal lines on body.................................................................20

19b. Shoulder mark a spot, horizontal solid bar, or open triangle or semicircle (open part forward and below level of eye); no large crescent-shaped white region posteriorly in caudal fin (a white posterior margin, if present, of a maximum width of less than 1/3 eye diameter); base of caudal fin pale; anal soft rays 23 to 26; dorsal soft rays 24 to 28; fine longitudinal lines may or may not be present on body..........21

20a. Shoulder mark elongate with pale yellowish (bright orange in life) center; no dark area around caudal spine; white crescent in caudal fin with a narrow black posterior margin; brown
portion of caudal fin with dark brown spots; color of young in life solid yellow (pale in preservative). (East Indies, Philippine Islands, and Oceania).................*olivaceus* (p. 151)

20b. Shoulder mark semicircular with no pale center or (at a size of 100 to 110 mm. or more in standard length) 2 elongate black bands; a black, light bluish-bordered area around caudal spine (this area becoming relatively larger in larger specimens); white crescent in caudal fin without a black posterior margin; caudal fin without brown spots; color of young unknown to me. (Ceylon and Mauritius)..........*tennenti* (p. 156)

21a. Shoulder mark triangular or semicircular with uppermost part just above dorsal end of gill opening and lower part near axil of pectoral fin; posterior gill rakers 29 to 32. (East Indies and Philippine Islands).................*fowleri* (p. 158)

21b. Shoulder mark a spot or solid bar; posterior gill rakers 17 to 28.................................................................22

22a. Shoulder mark a round black spot (just behind eye), at times with a narrow light bluish border; a blue line at base of dorsal fin in life, usually persisting as a bluish white line on preserved specimens; depth of body 1.9 to 2 in standard length. (east coast of Africa, East Indies, Philippine Islands, and Riu Kiu Islands).................*bariense* (p. 160)

22b. Shoulder mark a black or dark brown bar; no blue line at base of dorsal fin in life; depth of body 2 to 2.2 in standard length.........................................................23

23a. Caudal fin with a distinct white posterior margin, broader
centrally, about 1/4 eye diameter in maximum width; a long, pointed, black streak extending anteriorly from caudal spine (first appearing at a size of about 100 mm. and becoming progressively longer in larger specimens until it extends over half distance from caudal spine to base of pectoral fin); length of black shoulder bar (in specimen over 100 mm. in standard length) about 4.5 to 7 in standard length; numerous pale lengthwise lines not present on body; anal soft rays 24 to 26; dorsal soft rays 25 to 28. (Indo-West-Pacific)

23b. Caudal fin without a distinct white posterior margin; no long, pointed, black streak extending anteriorly from caudal spine; length of dark shoulder bar about 9 to 13 in standard length; numerous pale lengthwise lines present on body (faint on some specimens); anal soft rays 23 to 24; dorsal soft rays 24 to 26.

24. Head and nape with numerous prominent pale spots; upper distal part of pectoral fin with a large pale yellowish spot; shoulder mark in back of gill opening black (indistinct above and anterior to gill opening), horizontal, and usually somewhat pointed at end; dorsal fin with about 9 narrow longitudinal bands from base to margin; posterior gill rakers 21 to 24. (East Indies, Philippine Islands, and Gilbert Islands)

24b. Head and nape without pale spots; upper distal part of pectoral fin without a large pale spot; shoulder mark dark brown (indistinct and narrow above gill opening), tilting sharply
downward as it passes posteriorly, and rounded at end; dorsal fin without lengthwise bands or with only one or two posteriorly near outer border; posterior gill rakers 25 to 28. 

(Philippine Islands and East Indies)...........auranticavus (p. 168)

25a. Head with small pale (rust color in life) spots; black around caudal spine groove of adults extending ahead of front end of spine (to a distance almost as long as spine in a 245 mm. specimen); caudal fin with a very narrow white posterior margin (broader in young); body depth of adults (over 200 mm. in standard length) 2.2 to 2.5 in standard length. (northern Australia)............................grammoptilus (p. 171)

25b. Head without small pale spots; dark brown or black around groove of caudal spine not extending much beyond front end of spine; caudal fin without a narrow white posterior margin (except in young which may have a very narrow pale margin); body depth of adults 1.9 to 2.1 in standard length........26

26a. Caudal fin marked with numerous blackish spots; sheath of caudal spine whitish and in sharp contrast to black surrounding caudal spine groove; a pale (yellow in life) band crossing or nearly crossing interorbital space from eye to eye; body with numerous, fine, slightly wavy, pale bluish, lengthwise lines which usually persist in preservative; dorsal fin of adults without alternating dark and light bands or with only a few faint narrow ones in outer portion of fin; eye large, its greatest diameter contained in head length about 3.2 to 4.7 times over the range in standard length of
120 to 300 mm.; anal soft rays 24 to 26. (Indo-West-Pacific)........

............................................................dussumieri (p. 175)

26b. Caudal fin not marked with blackish spots; sheath of caudal spine brownish; no pale band crossing interorbital space (a pale yellowish area may extend anteriorly from eye but as a definite band); body without numerous slightly wavy, fine, pale bluish, lengthwise lines (lines, if present, indistinct and broken or coarse and very wavy and rarely evident in preserved specimens); dorsal and anal fins with lengthwise dark brown (blue in life) bands alternating with light brown (yellow in life) bands from base to margin (may fade in preservative, especially in mat); eye not large, its greatest diameter contained about 3.9 to 5.4 times in head length over the range in standard length of 120 to 300 mm.; anal soft rays 23 to 25..........................27

27a. Outer 1/3 of pectoral fin pale (yellowish in life) and contrasting with darker basal 2/3 of fin (in specimens over about 120 mm. in standard length); dorsal fin with about 4 broad lengthwise bands; caudal fin very lunate, caudal concavity about 4.5 to 7 in standard length; caudal spine usually small, about 4.5 to 5.5 in length of head; dark margin around socket of caudal spine usually narrow and indistinct; white band at base of caudal fin usually not distinct; anterior gill rakers 16 to 22; posterior gill rakers 17 to 22. (Indo-Pacific).........................

.................................xanthopterus (p. 179)  

27b. Pectoral fin uniform brown; dorsal fin (at least in Hawaiian specimens) with about 8 narrow lengthwise bands; caudal fin
not very lunate, caudal concavity about 6 to 10 in standard length; caudal spine usually not small, about 3 to 4.2 in length of head; a definite dark brown or black margin around socket of caudal spine forming an area about twice as high as maximum width of spine; white band at base of caudal fin usually distinct; anterior gill rakers 21 to 25; posterior gill rakers 23 to 25. (Indo-West-Pacific).ata (p. 188)

KEY TO THE ATLANTIC SPECIES OF ACANTHURUS

1a. Body very pale with 6 vertical black bars, the first passing through eye, the last dorsally on caudal peduncle; anal soft rays 19 to 21; dorsal soft rays 22 to 24. (Indo-Pacific, one record from West Africa).tricostegus (p. 79)

1b. Body not very pale with 6 vertical black bars; anal soft rays 22 to 26; dorsal soft rays 24 to 28.

2a. A very large pale (yellow or orange in life) spot on caudal peduncle with caudal spine in center. (West Africa).monroviae (p. 193)

2b. No large pale spot on caudal peduncle.

3a. Anal soft rays 24 to 26; dorsal soft rays 26 to 28 (usually 27); body depth about 1.7 in standard length; no narrow dark area around caudal spine; sheath of caudal spine pale; body purplish in life with conspicuous lengthwise lines (in young bright yellow without lines); anterior gill rakers 13 to 14. coeruleus (p. 195)
3b. Anal soft rays 21 to 23; dorsal soft rays 23 to 26 (rarely 26); body depth about 2 in standard length; a narrow dark area (blue in life) around caudal spine; sheath of caudal spine dusky; body light to dark brown in life with or without faint narrow lengthwise lines; anterior gill rakers 16 to 19..........................4

4a. 8 to 12 dark brown vertical bars on side of body; caudal fin emarginate (nearly truncate in young), caudal concavity contained about 14 to 18 times in standard length; caudal fin without a definite white posterior margin; outer 1/3 of pectoral fin pale in adults; no fine lengthwise lines on body; posterior gill rakers 15 to 18..........chirurgus (p. 199)

4b. No dark brown vertical bars on side of body; caudal fin lunate, caudal concavity contained about 5 to 12 times in standard length; caudal fin with a whitish posterior margin, broadest centrally (about 1/4 to 1/3 pupil diameter in width in adults, greater in young); outer 1/3 of pectoral fin not distinctly paler than rest of fin; fine lengthwise lines on body (which usually fade in preservative); posterior gill rakers 22 to 24..............bahianus (p. 203)
Fig. 10. Camera lucida drawings of upper (left) and lower (right) teeth of various species of Acanthurus. Teeth were taken from right side of jaws near center and drawn in inner or lingual view. 

a. *triostegus*, 140 mm. specimen, Marshall Islands.  
  b. *nubilus*, 156 mm. specimen, East Indies.  
  c. *bleekeri*, 223 mm. specimen, Philippine Islands.  
  d. *thompsoni*, 133 mm. specimen, Gilbert Islands.  
  e. *guttatus*, 165 mm. specimen, Gilbert Islands.  
  f. *leucopareius*, 155 mm. specimen, Hawaiian Islands.  
  g. *nigroris*, 31 mm. specimen, Marshall Islands.  
  h. *nigrofuscus*, 51 mm. specimen, Marshall Islands.  
  i. *lineatus*, 150 mm. specimen, Gilbert Islands.  
  j. *sohal*, 203 mm. specimen, Red Sea.  
  k. *pyroferus*, 143 mm. specimen, Philippine Islands.  
  l. *lecosternon*, 173 mm. specimen, Mauritius.  
  m. *glaucopareius*, 143 mm. specimen, Marshall Islands.  
  n. *achilles*, 137 mm. specimen, Phoenix Islands.  
  o. *olivaceus*, 190 mm. specimen, Marshall Islands.  
  p. *tennentii*, 115 mm. specimen, locality unknown.  
  q. *fowleri*, 198 mm. specimen, Philippine Islands.  
  r. *bariens*, 169 mm. specimen, Philippine Islands.  
  s. *gahhm*, 179 mm. specimen, Phoenix Islands.  
  t. *maculiceps*, 134 mm. specimen, Gilbert Islands.  
  u. *auranticavus*, 205 mm. specimen, Philippine Islands.  
  v. *grammoptilus*, 204 mm. specimen, Philippine Islands.  
  w. *dussumieri*, 210 mm. specimen, Hawaiian Islands.  
  x. *xanthopterus*, 200 mm. specimen, Gilbert Islands.  
  y. *mata*, 228 mm. specimen, Wake Island.  
  z. *monroviae*, 192 mm. specimen, Liberia.  
  aa. *coeruleus*, 127 mm. specimen, Haiti.  
  bb. *chirurgus*, 178 mm. specimen, Cuba.  
  cc. *bahianus*, 168 mm. specimen, Cuba.
Fig. 10. (For legend see previous page.)
Acanthurus triostegus (Linnaeus)
Figs. 9 a, 10 a, 11

Chaetodon triostegus Linnaeus (1758: 274) (Indies).
Harpurus fasciatus Forster (1788) (reference after Jordan 1917).

Acanthurus Triostegus Bloch and Schneider (1801: xxviii, 215)
(Indian and Pacific Oceans).

Acanthurus zebra Lacépède (1802: 546) (Pacific Ocean and East Indies).
Chaetodon couga Lacépède (1802: 726, 727, pl. 6, middle fig.).

Teuthis australis Gray (1827: 435) (Australia).


Acanthurus triostegus Cuvier and Valenciennes (1835: 197) (Mauritius, Seychelles, Marianas, New Zealand, Cualan, Society Islands, and Hawaiian Islands); Bleeker (1850a: 13) (Batavia, Java); Günther (1861: 327) (East Indies, New Hebrides, Mauritius, New Zealand, west coast of Australia, and Hawaiian Islands); Playfair in Playfair and Günther (1866: 56) (Zanzibar); Günther (1873: 108) (Indian Ocean and Polynesia); Day (1876: 204, pl. 48, fig. 2) (seas of India); Macleay (1831: 527) (west coast of Australia); Steindachner (1882: 54) (Congo Coast, West Africa); Hilgendorf (1883: 43); Day (1889: 139, fig. 54); Waite (1894: 217) (Maroubra, New South Wales); Waite (1897: 187) (Funafuti, Ellice Islands); Weber (1913: 316) (East Indies); Herre (1927: 407, pl. 1, fig. 1) (Philippine Islands and Guam); Herre (1936: 240) (Cocos Island off Costa Rica, Marquesas Islands, Tuamotu Archipelago, Tahiti, Fiji Islands, and New Hebrides); Brock (1943: 130) (Tres Marias Islands, Mexico); Schultz (1943: 162) (Phoenix and Samoa Islands); Smith (1949: 240, pl. 33, no. 608) (east coast of Africa south to Zululand); de Beaufort (1951: 144)
Acanthurus triostegus Swainson (1839: 255) (error for triostegus).

Acanthurus Subarmatus Bennett, F. D. (1840: 273, fig.) (Society Islands).

Acanthurus pantazona Bleeker (1850a: 4, 13) (Batavia, Java); Bleeker (1850b: 107) (Batavia, Java); Günther (1861: 329).

Rhombotides triostegus Bleeker (1863b: 235) (Ternate, East Indies).

Rhombotides pentazona Bleeker (1865: 238) (Ambon, East Indies).

Acanthurus triostegus var. sandvicensis Streets (1877: 67) (Honolulu).


Teuthis triostegus Jordan and Evermann (1898: 1690) (Clarion and Socorro Islands, western Mexico); Seale (1901: 108) (Guam); Jordan and Evermann (1902: 357) (Kotósho Island, Formosa); Jordan and Fowler (1902: 552) (Okinawa); Kendall and Goldsborough (1911: 309) (Tuamotu Archipelago and Marshall Islands); Kendall and Radcliffe (1912: 144) (Manga Reva); Barnard (1927: 778, pl. 31, fig. 5) (Natal coast, Africa); Marshall, T. C. (1941: 62) (Moreton Bay and Townsville, Queensland); Fowler (1944b: 172) (New Hebrides); Fowler (1945: 66) (Saipan).

Teuthis elegans Garman (1899: 70, pl. L, fig. 2) (Cocos Island off Costa Rica).

Teuthis sandvicensis Jenkins (1903: 479) (Hawaiian Islands); Snyder (1904: 533) (Hawaiian Islands); Fowler (1941: 257) (Cahu); Fowler (1949: 104).

Hepatus sandvicensis Jordan and Evermann (1905: 394, fig. 172) (Hawaiian Islands); Jordan and Seale (1906: 354) (Hawaii).
Hepatus triostegus Snodgrass and Heller (1905: 403) (Revillagigedo Islands and Cocos Island); Jordan and Seale (1906: 354) (Samoa); Steindachner (1906: 1392) (Samoa Islands); Ogilby (1916b: 184) (coast of Queensland); Fowler and Silvester (1922: 124) (Samoa); Fowler and Ball (1925: 19) (Laysan, Lisiansky, French Frigate Shoals, and Necker Island in the Hawaiian Archipelago, Johnston Island, and Wake Island); Fowler (1928: 264, pl. 31, fig. A) (Indo-Pacific); Fowler and Bean (1929: 249) (Indo-Pacific); Fowler (1932: 10) (Marquesas Islands); Seale (1935: 364) (Solomon Islands); Fowler (1938: 173, 184) (Bora Bora and Tongareva); Pietschmann (1938: 26, pl. 4) (Molokai and Pearl and Hermes Reef, Hawaiian Archipelago); Schmidt and Schultz (1940: 8) (Clipperton Island); Hiyama (1943: 95, pl. 20, fig. 57) (Marshall Islands); Aoyagi (1943: 216, pl. 6, fig. 16, teeth only) (Riu Kiu Islands); Kamohara (1954: 52) (Tokara Islands, southern Japan).

Acanthus sandvicensis Jordan and Jordan (1922: 66) (Hawaiian Islands); Schultz and Woods (1948: 248, fig. 1,A) (Hawaiian Islands and Johnston Island).

Teuthia troughtoni Whitley (1928a: 233, pl. 16, fig. 1) (Vanikoro, Santa Cruz Islands); Whitley and Colefax (1938: 294, fig. 3) (Nauru Island and Ocean Island); Fowler (1946: 197) (Riu Kiu Islands).

Acanthus triostegus Borodin (1932: 87) (Samoa, Bora Bora, and Raiatea) (error for triostegus).

Acanthus triostegus triostegus Schultz and Woods (1948: 249, fig. 1,B) (Indo-Pacific); Schultz and Woods in Schultz et al (1953: 624, fig. 90,b,d,e, pl. 63,A,B,C, pl. 64,A,B,C) (Marshall and Mariana Islands).

Acanthus triostegus marquesensis Schultz and Woods (1948: 250, fig. 1,C,F) (Marquesas Islands).
Dorsal rays IX, 22 to 24 (except in the Hawaiian Islands where the soft rays range to 26); anal rays III, 19 to 22; pectoral rays 14 to 16; anterior gill rakers of eight specimens from the Marshall Islands 19 to 22; posterior gill rakers 20 to 24; anterior gill rakers of eight specimens from the Hawaiian Islands 18 to 22; posterior gill rakers 19 to 22; a 54 mm. specimen has 12 upper and 14 lower teeth; a 134 mm. specimen has 14 upper and 16 lower teeth; a 158 mm. specimen has 16 upper and 18 lower teeth.

Very rarely specimens were found with VIII dorsal spines, but these could be recognized as abnormalities. The specimen reported with VIII dorsal spines from Tahiti by Schultz and Woods (1948: 250), for example, has a broad gap between its seventh and eighth spines.

Color (in life) light olivaceous gray, shading to white ventrally, with six narrow vertical black bars on head and body, the first running through eye, the second from origin of dorsal fin to base of pectoral fin, and the last dorsally on caudal peduncle; fins olivaceous gray except for margins of anal and pelvic fins which are white. Often there is a sharp demarcation between the gray color of about the upper five-sixths of the body and the pure white lower sixth, and there may be a narrow irregular dark line dividing these two colors. Schultz and Woods (1948: 248) attribute this line and the abrupt transition to white to breeding coloration. I am unable to confirm this finding, for I have observed numerous specimens with the gonads only slightly developed which exhibit this color pattern.

It was noted that specimens of _A. triostegus_ from coral atolls or low-lying coral islands had narrower vertical bars on the side of the body than specimens from high islands. In 20 specimens 110 mm. or more
Table 3 Variation in Fin Ray Counts of Specimens of Acanthurus triostegus from Different Localities.

<table>
<thead>
<tr>
<th>Localities</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>22 23 24 25 26</td>
<td>19 20 21 22</td>
</tr>
<tr>
<td>Natal, S. Africa</td>
<td>2 6 1</td>
<td>6 3</td>
</tr>
<tr>
<td>Mauritius</td>
<td>7 9 2</td>
<td>2 11 5</td>
</tr>
<tr>
<td>S. India</td>
<td>1 1</td>
<td>2</td>
</tr>
<tr>
<td>Siam</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Maroubra Bay, New South Wales</td>
<td>1 1</td>
<td>1 2</td>
</tr>
<tr>
<td>East Indies and Philippines</td>
<td>4 6</td>
<td>1 8 1</td>
</tr>
<tr>
<td>Okinawa</td>
<td>1 6 2</td>
<td>4 5</td>
</tr>
<tr>
<td>Ningpo, China (29.5°N)</td>
<td>3 9</td>
<td>7 5</td>
</tr>
<tr>
<td>S. Japan (30.4°N)</td>
<td>3</td>
<td>2 1</td>
</tr>
<tr>
<td>Palau Islands</td>
<td>2 7 6</td>
<td>10 5</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>1 1</td>
<td>2</td>
</tr>
<tr>
<td>Fiji Islands</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Samoa Islands</td>
<td>3 16 6</td>
<td>1 16 8</td>
</tr>
<tr>
<td>Gilbert Islands</td>
<td>9 22 2</td>
<td>3 19 11</td>
</tr>
<tr>
<td>Marshall Islands</td>
<td>10 31 4</td>
<td>5 28 12</td>
</tr>
<tr>
<td>Wake Island</td>
<td>3 14 2</td>
<td>12 7</td>
</tr>
<tr>
<td>Marcus Island</td>
<td>3 1</td>
<td>4</td>
</tr>
<tr>
<td>Mariana Islands</td>
<td>2 19 4</td>
<td>2 18 5</td>
</tr>
<tr>
<td>Cook Islands</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tubuai Islands</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tahiti</td>
<td>1 12 8</td>
<td>1 10 10</td>
</tr>
<tr>
<td>Tuamotu Archipelago</td>
<td>1 9 1</td>
<td>7 4</td>
</tr>
<tr>
<td>Mangareva</td>
<td>1 2 2</td>
<td>2 1 2</td>
</tr>
<tr>
<td>Marquesas Islands</td>
<td>1 8 5</td>
<td>6 8</td>
</tr>
<tr>
<td>Phoenix Islands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hull and Canton</td>
<td>6 35 11</td>
<td>1 38 13</td>
</tr>
<tr>
<td>Enderbury</td>
<td>1 7 7</td>
<td>3 10 2</td>
</tr>
<tr>
<td>Baker Island</td>
<td>1 2</td>
<td>1 1</td>
</tr>
<tr>
<td>Line Islands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palmyra</td>
<td>6 28 7</td>
<td>4 28 9</td>
</tr>
<tr>
<td>Fanning</td>
<td>4 1</td>
<td>3 2</td>
</tr>
<tr>
<td>Washington and Christmas</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Galapagos Islands</td>
<td>1 3</td>
<td>2 2</td>
</tr>
<tr>
<td>Cocos Island (Costa Rica)</td>
<td>2 6 1</td>
<td>2 5 2</td>
</tr>
<tr>
<td>Clipperton Island</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Clarion Island</td>
<td>3 6 5</td>
<td>2 4 8</td>
</tr>
<tr>
<td>Gulf of California</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hawaiian Archipelago</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kauai to Hawaii</td>
<td>1 36 59 5 1</td>
<td>15 72 15</td>
</tr>
<tr>
<td>Midway to French Frigate Shoal</td>
<td>1 17 17</td>
<td>7 27 3</td>
</tr>
<tr>
<td>Johnston Island</td>
<td>5 15 3</td>
<td>1 18 4</td>
</tr>
</tbody>
</table>
Fig. 11. *Acanthurus triostegus sandvicensis* (after Jordan and Evermann, 1905).
in standard length from low islands (10 of which were collected from Midway, Laysan, French Frigate Shoal, and Johnston Island) the width of the central bar of the body (as measured midlaterally) is contained 3.3 to 8.2 times in the greatest diameter of the eye; the mean is 5.27. The width of the bar into the eye in 20 specimens of comparable size from high islands (including the Hawaiian Islands) is 1.7 to 3.9 with a mean of 2.65. Seven specimens from a tidal pond on the island of Hawaii were strongly melanistic, and the bar width was contained in the eye diameter 1.25 to 1.8 times with a mean of 1.43. The water in this pond was clear, and the bottom was black basalt with no coral and little algae. Around coral islands the bottom is notable for being light in color. The littoral area of volcanic islands is considerably darker, in general, due to the dark brown to black color of basalt. The above mentioned tidal pond on Hawaii is unusually dark. It is therefore believed that the width of the black bars of *A. triostegus* is correlated with the degree of darkness of the substrate. This is in agreement with the well-known phenomenon of increased production of melanophores from a dark background (Breder and Rasquin, 1952: 19).

Schultz and Woods (1953: pl. 64, A, B, C) have photographs of the postacronurus and juvenile stages of *A. triostegus*.

Streets (1877: 67) first called attention to the differences in color between *A. triostegus* in the Hawaiian Islands and elsewhere in its range; he designated the Hawaiian form as variety *sandvicensis*. It has an elongate black streak at the base of the pectoral fin, a vertical black bar dorsally on the caudal peduncle which reaches almost to the mid-lateral line but usually has no black spot on the peduncle below this bar; there is no definite black line mid-dorsally on the
head. From the rest of its range specimens have a single black spot, two black spots, or a short bar at the pectoral base; the vertical black bar on the caudal peduncle is usually more restricted to the dorsal part and there is a black spot or short bar ventrally on the peduncle; a median black line is usually evident on the head.

Schultze and Woods (1948: fig. 1) diagrammed the different color marks at the base of the pectoral fin of *A. triostegus* and tabulated the dorsal, anal, and pectoral fin ray counts of samples from a number of localities. They demonstrated the higher fin ray counts of the species in Hawaii; however they pointed out the possibility that cooler water in the Hawaiian Islands may be the cause of these higher counts. Nevertheless, these authors (and others) regarded the Hawaiian form as a full species, *Acanthurus sandvicensis*. In view of the marked geographical separation of the Hawaiian chain from other major island groups, at least slight differences are to be expected in Hawaiian populations of reef fishes. Since there is no possibility of readily testing whether Hawaiian stocks will freely interbreed with those of other areas, the task of making inferences of degree of interfertility from the observed morphological differences must be made. In my opinion the differences of *A. triostegus* in the Hawaiian Islands are not of sufficient magnitude to warrant their recognition as a basis of a species. Because of the frequent use of the name *sandvicensis*, however, I prefer to retain this as a subspecific designation for the species in Hawaii.

I have made dorsal and anal fin ray counts of *A. triostegus* from various localities (Table 3) in order to note variation from area to area and in the hope of shedding light on the question of whether water temperature has any effect on the number of fin rays. Unfortunately
the number of specimens are too few in some important localities to be
certain whether the apparent differences are real or due to chance.
Other difficulties bear mentioning. Cooler temperatures, when correlated
with high fin ray counts, might seem to be the cause of the high counts;
however these might be a manifestation of the differentiation of popula-
tions in different areas. Unless counts are made from small juveniles
from such regions, the temperature at which the number of fin rays was
fixes during development could not be estimated with any degree of as-
surance. Even more disturbing is the problem of fin ray counts made
from specimens from colder areas in the path of currents from warm
regions. If the counts were made from individuals of a resident popu-
lation, they would reflect possible temperature effects of the area.
If, however, the counts were made from fish carried as larvae from a
warmer area, such an interpretation would be erroneous. The duration
of the planktonic larval life of *A. triostegus* in the Hawaiian Islands
has been estimated as two and one-half months (see discussion on spawn-
ing in Section II). Larvae of *A. triostegus* could float from the
Philippines to Japan in about half this time (computed from current
velocities given by Sverdrup, Johnson, and Fleming, 1946: 720). There-
fore, the fin ray counts of specimens from S. Africa, New South Wales,
Okinawa, and S. Japan are here not considered with respect to tempera-
ture effects on the number of fin rays.

Disregarding those areas in Table 3 in which a single specimen
was available for fin ray counts, there remain eleven regions where
average monthly sea surface temperatures (based on Hydrographic Office
Publ. No. 225) may dip to 78° F. or lower, at least one month of the
year. These are Mauritius, Ningpo, China (the southerly current along
the coast of China permits consideration of this locality but not
Okinawa or S. Japan which are directly in the path of the Kuroshio),
Marcus Island, Tahiti, Tuamotu Archipelago, Mangareva, possibly the
Marquesas Islands, Galapagos Islands, Clarion Island, Hawaiian Archi-
pelago, and Johnston Island. In seven of these regions (Mauritius,
Marcus, and the Tuamotus excepted) the counts tend to be high; the num-
ber of specimens in the samples with 21 or more anal rays exceeds or is
equal to the number with 20 rays. Four of these seven regions, Ningpo,
Mangareva, Galapagos, and Clarion have a month in which the average sea
surface temperature is 72° or less. With the exception of Galapagos,
these are all areas in which the samples display a definite increase
in fin ray counts. Although more counts are needed from these and
other colder areas and more precise information on temperature, the
data suggest that cool water is correlated with high dorsal and anal
fin ray counts of *A. triostegus*.

The fin ray counts of specimens of *A. triostegus* from the principal
Hawaiian Islands (Kauai to Hawaii) seem higher than might be expected
from the annual range of average monthly sea surface temperatures
(normally about 75° to 82° F. as based on U. S. Coast and Geodetic
Survey Publ. TW-2). The dorsal rays, for example, are apparently
higher than those from specimens in any other region given in Table 3
except possibly Ningpo, China. Moreover, the counts of the dorsal and
anal rays of specimens from Midway to French Frigate Shoal are not
higher than the Hawaiian Islands proper in spite of lower temperatures
in the Leeward group (about 70° to 80° F.). This suggests that the
greater number of fin rays in the Hawaiian Archipelago may be due to
genetic factors; the usual temperature variation within this chain of
islands may not influence the number of rays. This is consistent with the color differences of the species in the Hawaiian Islands as given above. These color differences are probably genetically governed, for no specimens from colder areas other than the Hawaiian chain were seen with typical _sandvicen시스_ markings.

Fowler (1927b: 20) noted that there was a dark streak at the base of the pectoral of specimens from Fanning Island in the Line Islands. I examined two of his specimens at the Bishop Museum. One of these, 109 mm. in standard length, has a definite 10 mm. streak in which the eye diameter is contained 1.2 times. This is only about half the length of the usual _sandvicen시스_ streak, however.

Other slightly streaked specimens were found among the collections from the Line Islands and the Phoenix Islands (and to a lesser extent in some juveniles from Tahiti). The most pronounced streaks, 1.25 to 1.5 eye diameters in length, were seen on five specimens, 41 to 61 mm. in standard length, from Enderbury Atoll. These specimens were from the sample from which the high fin ray counts recorded in Table 3 were made. These counts are the highest of all the samples from warm water regions in the table. The streaked specimens did not exhibit higher numbers of dorsal or anal rays than those with typical _triostegus_ coloration. The same applies to other specimens with short streaks (or elongate spots) from the Phoenix and Line Islands.

The tendency to streaking at the base of the pectoral in island groups to the south of Hawaii might somehow be due to interbreeding effects from larvae carried to these areas from the Hawaiian Islands or Johnston Island. Admittedly this is difficult to explain in terms of existing current patterns because of the strong westerly component.
of the equatorial currents. Transport back to the east in the counter-equatorial does not appear to provide the answer, for it would seem that larvae would be carried at least to the Marshall Islands before the counterequatorial could possibly be reached; thus one would expect to find any effects of interbreeding to be most pronounced in the Marshall Islands. This, however, is not the case.

The size of the transforming acronurus larva of *A. triostegus*, again suggests genetic influence of Hawaiian populations in islands to the south. The acronurus or late postlarval form of *A. triostegus* enters tide pools to transform to the juvenile stage. Due to the accessibility of tide pools for collecting and the abundance of the species, the transforming stage often appears in museum collections. Fifty-six such specimens from the East Indies, Palaus, Marianas, and Gilbert Islands, all very warm regions of the Pacific, range in standard length from 19 to 25 mm. and have a mean length of 21.7 mm. The 42 available specimens of the transforming acronurus stage were measured from the following cooler regions of the Pacific: Ningpo, Marcus Island, Tahiti, Tuamotu Archipelago, Mangareva, Marquesas, and Clarion Island. The standard length of these range from 22.5 to 26.5 mm. with a mean of 24.8. The larger average size of the acronuri developing in cooler water is probably a temperature effect. Seventy-seven transforming specimens from the Hawaiian Islands vary from 23 to 29.5 mm. in standard length, with a mean length of 25.9 mm. This is higher than one might expect if the average postlarval size were wholly dependent on temperature. Twenty-two specimens from the Phoenix Islands vary from 23 to 27 mm. and have a mean standard length of 24.9. Only two specimens were found in collections from the Line Islands; these measured
23.5 and 24 mm. in standard length. The large size in the Phoenix Islands (and possibly also in the Line Islands) is not consistent with the sea surface temperatures of these groups (in excess of 80° F. throughout the year). These islands are no more geographically isolated than most of the other islands of the Pacific where the sea surface temperatures are warm, so there is no reason to suspect any marked population differentiation.

The largest specimen of adult _Acanthurus triostegus_ examined by me was one of a series of 17 caught by personnel of the Pacific Oceanic Fishery Investigations with a beach seine at Midway Island. It measured 213 mm. in standard length. Twelve others in the sample ranged from 174 to 206 mm. in standard length. Of over 2,000 adult specimens caught in traps off Oahu, the longest was 175 mm. in standard length. The colder water at Midway may be the principal basis for the larger size at this locality. In a small collection from Clarion and Socorro in the Revillagigedo Islands (Mexico) there are two large specimens measuring 187 and 188 mm. in standard length. The water around these islands is also cool. Of 905 specimens reported by Schultz and Woods (1953: 624) from the Marshall Islands and Marianas, the largest was 152 mm. The species appears to be small in other warm areas of the Pacific except the Line Islands and the Phoenix Islands where specimens as large as 189 mm. in standard length have been taken.

The range of _Acanthurus triostegus_, as is apparent from the above discussion, is very extensive. This species is in continuous distribution from East Africa to the tropical Pacific; it is one of the three species of the genus _Acanthurus_ to have crossed the eastern Pacific barrier. It is recorded from the Galapagos Islands, Cocos Island off
Costa Rica, and Clipperton Island, the Revillagigedo Islands, and Tres Marias Islands off the coast of Mexico. Vernon E. Brock has informed me that the species is rare at islands off the coast of Mexico. Boyd W. Walker kindly loaned a 94 mm. specimen collected by M. A. Newman and J. E. Fitch from Frailes Bay, Gulf of California. This is the first record from the coast of North America.

There is one record of *A. triostegus* from the Atlantic Ocean, that of Steindachner (1882: 54) from the Congo coast of Africa. Further records are needed to substantiate this.

Schultz and Woods (1948: 250) observed a much higher incidence of specimens of *A. triostegus* with two spots at the base of the pectoral fin than with a single spot or bar in the Marquesas Islands; these authors proposed the subspecific name *marquesensis* for the species in this group of islands.

It is interesting to note that neither this nor the Hawaiian subspecies has reached the coast and continental islands of America. Instead, the eastern Pacific form is *A. triostegus triostegus* which is found in the Line Islands and elsewhere in Oceania (except Hawaii and the Marquesas). This supports the contention of Herre (1940) that the counterequatorial current would seem to be the only possible mode of transport of Indo-West-Pacific fishes to the American coast. Jordan and Seale (1906: 354), Herre (1927: 409), and de Beaufort (1951: 147) are probably all in error in stating that the *sandvicensis* form of the species occurs at islands offshore from Mexico. All of the specimens which I have seen from such islands have a single black spot at the pectoral base, or occasionally two spots, or a short bar.

De Beaufort (1951: 147) stated that the typical form of *Acanthurus*
triostegus occurs together with the subspecies sandvicensis in the Hawaiian Islands. The basis for his statement is probably the information from Fowler (1928: 265) to the effect that the brown band in some specimens of the sandvicensis form does not continue below the pectoral base. I have never seen a specimen of A. triostegus from the Hawaiian Islands on which the brown streak does not continue below the base of the pectoral fin. Considerable variability may be observed in this marking, however, and it is conceivable that very rarely a specimen might be found with only a short bar at the pectoral base. Often the streak is interrupted such that a short bar at the pectoral base is separated from the larger part of the streak below. The streak may even be broken into three separate segments.

_Acanthus polyzona_ (Bleeker)

_Fig. 12_

Rhombotides polyzona Bleeker (1868a: 277) (Réunion); Bleeker in Bleeker and Pollen (1874: 44, pl. 12, fig. 2).

_Acanthus triostegus_ var. _polyzona_ Peters (1876: 439).

_Acanthus polyzona_ Sauvage (1891: 519).

Dorsal rays IX, 23 to 25; anal rays III, 21 to 23; pectoral rays 16; eight or nine teeth on each side of upper jaw and nine or ten on each side of lower jaw.

Bleeker described the color in life as olivaceous on the back and olivaceous-silvery ventrally, with vertical black bars as follows: the first rostro-frontal on head (not very evident in figure), the second maxillo-ocular, the third oculo-interopercular, the fourth opercular, the next six on the body proper, and the last two on the
Fig. 12. *Acanthurus polyzona* (after Bleeker and Pollen, 1874).

Fig. 13. *Acanthurus nubilus* (after Fowler and Bean, 1929).
This species seems to be closely allied to A. triostegus, sharing with it the slightly emarginate caudal fin, low number of dorsal and anal fin rays, small caudal peduncle spine (as based on the figure in Bleeker and Pollen) and barred color pattern. Unlike the bars of A. triostegus, those of A. polyzona are more numerous and much broader dorsally than ventrally.

Acanthurus polyzona is apparently known only from the island of Réunion in the Indian Ocean. I have seen no specimens of this species.

Acanthurus nubilus (Fowler and Bean)

Figs. 10 b, 13

Hepatus (Harpurina) nubilus Fowler and Bean (1929: 253, fig. 15)
(Dodepo Island, Celebes).

Harpurina nubilus de Beaufort (1951: 166, fig. 27).

Dorsal rays VI, 27; anal rays III, 24; pectoral rays 16; anterior gill rakers 21; posterior gill rakers 24; 24 upper teeth; 28 lower teeth. These counts are based on the holotype, 153 mm. in standard length.

Other specimens of this species reported on by Fowler and Bean were not located. These authors recorded the number of dorsal spines as VI or VII.

Mouth small, its width as measured from rictus to rictus contained 3.8 times in head length; snout short, snout length 6.8 in standard length; depth of body 1.8 in standard length; head length 4.1 in standard length; least depth of caudal peduncle 1.8 in head length; diameter of eye 3 in head length; caudal concavity 6.7 in standard length.

Color given by Fowler and Bean, for specimens other than the type, is as follows: "Nearly black, shading to brown under scales, probably
dark seal brown with slaty streaks in life, of which usually 2 to each scale row. On side of head and breast brown in form of hexagonal spots in pale ground color, spots size of number 6 shot. No black shoulder blotch or black spots in axils of verticals. Fins nearly black. Dorsal with oblique bars extending upward and backward, best seen in reflected light. Oblique bars very indistinct on anal. Caudal without markings. Pectoral membranes hyaline."

Color (in alcohol) of holotype uniformly brown except membranes of pectoral fin which are hyaline.

This species is known only from Buka Buka Island in the Gulf of Tomini, Celebes, and Dodepo Island, Celebes.

*A. nubilus* is related to *A. thompsoni* and *A. bleekeri*. These three species of *Acanthurus* are distinctive in having small mouths, small teeth, and a moderately large eye which is set more toward the center of the head than other species in the genus.

Were it not for *A. thompsoni* and *A. bleekeri*, *A. nubilus* would probably best be placed by itself in the genus Harpurina because of the above characteristics and its VI or VII dorsal spines. The former species possess the usual IX dorsal spines and serve to connect *A. nubilus* with more typical *Acanthurus*.

*Acanthurus bleekeri* Göntner

Figs. 10 c, 14

*Acanthurus mata*. Bleeker (non Cuvier and Valenciennes) (1854c: 432)

(Java); Aoyagi (1943: 206, pl. 4, fig. 9, teeth only).

*Acanthurus bleekeri* Göntner (1861: 335) (after Bleeker); Herre (1927: 423, pl. 14, fig. 2) (Philippine Islands); de Beaufort (1951: 162) (East Indies); Schultz and Woods in Schultz et al (1953: 636)
(Rongelap Atoll, Marshall Islands).


_Acanthurus Bleekeri_ Klunzinger (1871: 509) (Red Sea).

_Acanthurus curolinus_ Day (1876: 204, pl. 48, fig. 3) (Coromandel coast of India); Day (1889: 139).

_Acanthurus (Rhombotides) Bleekeri_ Klunzinger (1884: 85) (Red Sea).

_Harpurus gnophodes_ Fowler (1904: 544, pl. 22, upper fig.) (Padang, Sumatra).

_Teuthis mata._ Kendall and Goldsborough (1911: 310) (Tuamotu Archipelago).


_Hepatus weberi_ Aih (1923: 317) (new name for _Acanthurus Güntheri_ Weber).

_Hepatus bleekeri_ Fowler (1928: 270) (Sumatra and Pakarava, Tuamotu Archipelago); Fowler and Bean (1929: 220) (Philippine Islands and East Indies); Hiyama (1943: 94, pl. 19, fig. 54).

_Teuthis bleekeri_ Fowler (1949: 102).

_Acanthurus weberi_ de Beaufort (1951: 163) (East Indies).

Dorsal rays IX, 24 to 26; anal rays III, 23 or 24; pectoral rays 16 or 17 (usually 17); anterior gill rakers 13 to 15 and posterior gill rakers 13 to 15 (gill raker counts from Philippine specimens); a 71 mm. specimen has 14 upper and 16 lower teeth; a 146 mm. specimen has 18 upper and 22 lower teeth; a 200 mm. specimen has 22 upper and 24 lower teeth; a 283 mm. specimen has 24 upper and 26 lower teeth.

Mouth small, its width from rictus to rictus contained 4.7 to 5 in head length; snout short, its length 6.6 to 6.9 in standard length; relative body depth decreasing with size from 2.1 in standard length in 118 mm. specimen to 2.5 in 283 mm. specimen; forehead sloping, the angle between a vertical at the mouth and the anterior profile of the
head about $45^\circ$; length of head 3.6 to 3.7 in standard length; diameter of eye 3.2 to 4.5 in head length in specimens over a range in standard length of 118 to 283 mm.; caudal concavity about 6.5 to 8 in standard length (9 in a 71 mm. specimen); least depth of caudal peduncle 10 to 12 in standard length. This species has a narrower caudal peduncle than all other species of *Acanthurus* (in which the least depth is contained 7.7 to 9.5 times in the standard length). The stomach is large, U-shaped, with about nine rows of very large, thorn-like papillae on the inner surface.

Table 4 Variation in Fin Ray Counts of Specimens of *Acanthurus bleekeri* from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 25 26</td>
<td>23 24</td>
</tr>
<tr>
<td>Delagoa Bay, S. Africa</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>East Indies</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Philippine Islands</td>
<td>2 5 4</td>
<td>2 9</td>
</tr>
<tr>
<td>Tuamotu Archipelago</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Marshall Islands</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Color (in alcohol) brown with fairly straight lengthwise pale bluish gray lines on the side of the body (28 in a specimen 200 mm. in standard length, each line about one third as broad as the brown inter-spaces); head with similar, though slightly more irregular, lines (eight between eye and lower limb of preopercle in the 200 mm. specimen); opercular membranes dark brown; sheath of caudal spine blackish brown and edge of socket dark brown; all fins brown, the dorsal with a dark
Fig. 14. *Acanthurus bleekeri* (after Hiyama, 1943).

Fig. 15. *Acanthurus thompsoni* (reproduced from a Kodachrome transparency by the author), Gilbert Islands.
brown line at the base which becomes broader posteriorly, and the dorsal and the anal with faint longitudinal banding.

Life colors from Hiyama's plate (herein reproduced in black and white as Fig. 14) dark brown with lengthwise blue lines on head and body, a yellow area behind eye, and two yellow bands extending anterior from eye, one from the upper edge and one from the lower.

J. L. B. Smith kindly loaned a specimen identified in his *The sea fishes of southern Africa* (1949: 240, pl. 33, no. 609) as *Acanthurus lineolatus*. The specimen is 71 mm. in standard length and was collected in Delagoa Bay. The species figured by Smith appears to be *A. mata*, however, the specimen turned out to be *A. bleekeri*, hitherto unrecorded from southern Africa. It has been returned to Dr. Smith.

*Acanthurus bleekeri* is an Indo-West-Pacific species. It is not recorded from the Hawaiian Islands and is not commonly taken from the rest of the tropical Pacific.

*Acanthurus thompsoni* (Fowler)

Figs. 10 d, 15

*Hepatus thompsoni* Fowler (1923: 386) (Honolulu); Fowler and Ball (1925: 19) (Wake Island); Fowler (1928: 268, fig. 49); Fowler (1938: 231) (Honolulu).

*Acanthurus philippinensis* Herre (1927: 434, pl. 5, fig. 1) (Calapan, Mindoro, Philippine Islands); Schultz and Woods in Schultz et al (1953: 637) (Rongelap, Marshall Islands); de Beaufort (1951: 161).

*Hepatus philippinensis* Fowler and Bean (1929: 215, fig. 11) (Philippine Islands and East Indies); Kamohara (1952: 8) (Okinoshima, Province of Tosa, Japan).

*Teuthis thompsoni* Fowler (1949: 102).
Dorsal rays IX, 23 to 26; anal rays III, 23 to 26; pectoral rays 17; anterior gill rakers of two Philippine and one Marshall Islands specimens 15 to 16; posterior gill rakers 14 to 15; anterior gill rakers of one Hawaiian Islands specimen 18; posterior gill rakers 16; a 93 mm. specimen has 20 upper and 24 lower teeth; a 138 mm. specimen has 21 lower and 24 upper teeth.

Table 5 Variation in Fin Ray Counts of Specimens of Acanthurus thompsoni from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23 24 25 26</td>
<td>23 24 25 26</td>
</tr>
<tr>
<td>East Indies</td>
<td>1 1</td>
<td>1 1</td>
</tr>
<tr>
<td>Philippine Islands</td>
<td>2 2 1</td>
<td>1 3 1</td>
</tr>
<tr>
<td>Marshall Islands</td>
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<td>1</td>
</tr>
<tr>
<td>Gilbert Islands</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Society Islands</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hawaiian Islands</td>
<td>1 2</td>
<td>2 1</td>
</tr>
</tbody>
</table>

Mouth small, its width from rictus to rictus contained about 4 times in head length; snout very short, its length 7.9 to 8.2 in standard length; body depth about 2.3 in standard length; head length 3.7 to 4.3 in standard length; diameter of eye 3.2 to 3.5 in head length in specimens over 90 mm.; least depth of caudal peduncle 2.2 to 2.5 in head length; caudal concavity about 5 in standard length.

Color (in alcohol) brown with pale yellowish brown caudal fin (except specimens from the Hawaiian Islands in which the caudal fin is as dark as the body); a small dark brown spot just below and adjacent
to axil of pectoral fin (this spot not as prominent as Fowler figured it and is difficult to see in dark specimens); about six dark bands may be visible running lengthwise in posterior part of soft dorsal fin and about five in the anal fin, although in many specimens these have faded.

Herre (1927: 434) stated that the pale caudal fin of his Philippine specimens was evidently yellow in life; however, the single specimen which I collected in the Gilbert Islands had a snow white caudal fin (which became dusky white immediately following death).

A 134 mm. specimen speared by me at a depth of 90 feet in Kealakekua Bay, Hawaii was olive drab with brown fins; the dorsal and anal fins had a narrow blue-black margin, and there were two to three narrow longitudinal yellow-brown lines in the outer part of these fins; the pelvic fins showed brownish yellow patches distally; the head had a reticulation of purplish yellow and brownish yellow lines. A 49 mm. juvenile specimen (U.S.N.M. No. 167250) was taken in the same locality and at the same depth. It was apparent from the scale structure and the dentition that it had only recently transformed from the acronurus stage. It was purplish blue with black longitudinal lines on the side of the body; the pectoral was yellowish with a black line at the top; there was a small black spot at the axil of the dorsal fin; however none was visible at the lower part of the axil of the pectoral fin.

I examined the holotype (Bishop Mus. No. 3394) and compared it with the specimen from the Gilbert Islands. Apart from the color of the caudal fin, no differences could be observed.

The largest specimen seen by me is the holotype. It is 155 mm. in standard length.

Schultze and Woods (1953: 637) stated that the species was observed
swimming in a large school in the Rongelap lagoon about coral heads at depths of more than 10 feet. I saw only two solitary individuals at Onotoa Atoll in the Gilbert Islands; these occurred at a depth of from 40 to 50 feet on the coralliferous terrace of the outer reef. The adult which was collected in Hawaii was one of a group of about eight or ten individuals that tended to stay in the same general region of the reef. They were seen several times swimming slowly, about 10 to 20 feet off the coral-covered bottom. Upon my approach they swam almost straight down. Underwater some appeared dark gray, almost black, and others were light blue.

Acanthurus thompsoni occurs in the East Indies, Philippines, Japan, and Oceania. In general, it is not a common species.

Acanthurus mindorensis Herre

Fig. 16

Acanthurus mindorensis Herre (1927: 433, pl. 4, fig. 2) (Calapan, Mindoro, Philippine Islands).

Hepatus mindorensis Fowler and Bean (1929: 213).

The following is from Herre's description: dorsal rays IX, 26; anal rays III, 23; origin of mouth low on head; jaws protuberant; length of snout 1.25 in length of head (taken from figure); length of head 3.4 in total length; depth at origin of pelves 2.3 in length; eye 4.16 in head length; interorbital gently rounded, 2.94 in head and nearly thrice eye (one of the last two proportional measurements, probably the latter, is an error); caudal spine slender, its length equal to diameter of eye; depth of caudal peduncle 2.77 in head; caudal fin moderately concave, caudal concavity 11 in standard length (from figure); pectoral fin 1.16
Fig. 16. *Acanthurus mindorensis* (after Herre, 1927).

Fig. 17. *Acanthurus guttatus* (reproduced from a Kodachrome transparency by the author), Gilbert Islands.
in head; pelvic fin 0.1 as long as head. The type, a 170 mm. specimen, had eight broad denticulate teeth on each side of the upper jaw and eight or nine on each side of the lower jaw. The denticulations on the lower teeth were more confined to the ends of these teeth than were those on the upper teeth. The color (in alcohol) was black, sides of head and breast blackish brown; a deep brown ring at base of caudal; all fins black.

Herre has informed me that the type of this species was destroyed in Manila during World War II. To my knowledge there are no other specimens in existence.

There are two important differences between Herre's description and his figure, and at the present time there is no way to reconcile these. He described the species as having IX dorsal spines, the first one longer than in most species and not concealed. The figure shows X dorsal spines, the first smaller than that as seen on most of his figures of other species of Acanthurus. The deep brown ring at the base of the caudal fin is not apparent in the figure. Instead the base of the caudal fin has a pale band.

The most distinctive feature of this species is the peculiar shape of the head.

_Acanthurus guttatus_ Bloch and Schneider

_Figs. 9 j, 10 e, 17_

_Acanthurus Guttatus_ Bloch and Schneider (1801: xxxviii, 215) (Tahiti).
_Acanthurus guttatus_ Cuvier and Valenciennes (1835: 195) (Tonga Islands and Mauritius); Günther (1861: 329) (Tahiti, New Hebrides, and Mauritius); Günther (1873: 109, pl. 69, fig. A) (Indo-Pacific);
Waite (1897: 183) (Funafuti, Ellice Islands); Jordan and Jordan
(1922: 66) (Hawaiian Islands); Schultz (1943: 163) (Phoenix and Samoa Islands); de Beaufort (1951: 142) (Sumatra); Schultz and Woods in Schultz et al (1953: 631, pl. 66, fig. 4) (Marshall and Mariana Islands); Harry (1953: 146) (Raroia, Tuamotu Archipelago).

Harpurus guttatus Forster (1844: 218) (Tahiti).

Rhombotides guttatus Bleeker in Bleeker and Pollen (1874: 96) (Réunion and Mauritius).

Zabrasoma guttatus Seale (1901: 110) (Guam).

Teuthis guttatus Jenkins (1903: 479) (Honolulu); Kendall and Goldsborough (1911: 310) (Gilbert Islands and Tuamotu Archipelago); Fowler (1949: 103) (Baker Island).

Hepatus guttatus Jordan and Evermann (1905: 392, fig. 70) (Honolulu); Jordan and Seale (1906: 354) (Samoa); Fowler and Bean (1929: 248) (Philippine Islands, Samoa, Gilbert Islands, and Mauritius); Fowler (1938: 184) (Tongareva).

Teuthis fuliginosus. Whitley and Colefax (1938: 294, pl. 14, fig. 4) (Nauru Island).

Dorsal rays IX, 27 to 30; anal rays III, 23 to 26; pectoral rays 15 to 17; anterior gill rakers 21 to 24; posterior gill rakers 19 to 23 (gill raker counts based on specimen from Samoa); a 43 mm. specimen has eight upper and eight lower teeth; an 85 mm. specimen has ten upper and ten lower teeth; a 152 mm. specimen has 12 upper and 12 lower teeth; a 187 mm. specimen has 12 upper and 14 lower teeth.

Body depth great, 1.5 to 1.6 in standard length; caudal fin slightly emarginate, caudal concavity contained about 14 to 17 times in standard length. Length of pectoral fin about 2.7 in standard length.
Table 6 Variation in Fin Ray Counts of Specimens of

*Acanthurus guttatus* from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27 28 29 30</td>
<td>23 24 25 26</td>
</tr>
<tr>
<td>Mauritius</td>
<td>1 1</td>
<td>1 1</td>
</tr>
<tr>
<td>Mariana Islands</td>
<td>2 1 1</td>
<td>2 1 1</td>
</tr>
<tr>
<td>Wake Island</td>
<td>2 7 2</td>
<td>7 4</td>
</tr>
<tr>
<td>Marshall Islands</td>
<td>4 11 4</td>
<td>3 8 3</td>
</tr>
<tr>
<td>Gilbert Islands</td>
<td>2 2</td>
<td>2 2</td>
</tr>
<tr>
<td>Samoa Islands</td>
<td>1 7 4 1</td>
<td>2 7 3 1</td>
</tr>
<tr>
<td>Phoenix Islands</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Society Islands</td>
<td>2 3 2</td>
<td>1 2 4</td>
</tr>
<tr>
<td>Tuamotu Archipelago</td>
<td>1 1</td>
<td>1 1</td>
</tr>
<tr>
<td>Line Islands</td>
<td>1 1</td>
<td>2</td>
</tr>
<tr>
<td>Hawaiian Islands</td>
<td>1 3 1</td>
<td>1 2 2</td>
</tr>
</tbody>
</table>

Color (in alcohol) brown with many small round or elliptical white spots (usually bordered with dark brown) on posterior half of body and dorsal and anal fins, and three vertical white bars, the first on head just behind eye, the second running from base of fourth dorsal spine to anus, and the third (about one-third as broad) from base of fifth or sixth dorsal soft rays to the second or third anal soft rays; pectoral dusky yellow; pelvics light brown; caudal fin with basal half light brown, outer portion brown.

In life the pelvic fins are bright yellow.

*Acanthurus guttatus* is characteristic of turbulent water in shallow
reef areas. In atolls it is commonly found schooling in surge channels. The postacronurus may appear in tide pools. Three such specimens (Fig. 9 j) vary in standard length from 33 to 36 mm.

The largest adult specimen seen by me was 228 mm in standard length from the Hawaiian Islands.

De Beaufort (1951: 137) is probably in error in considering Teuthis fuliginosus Whitley and Colefax a synonym of Acanthurus fuscus Stein-dachner (the latter being a synonym of Acanthurus pyroferus Kittlitz). The specimen in Whitley and Colefax's photograph appears to be A. guttatus with the white spots barely visible.

Acanthurus guttatus would seem to stand apart from all other species of the genus primarily because of its deep body, nearly truncate caudal fin, and color pattern. A. leucoparaleus, however, appears to link this species with A. nigrofuscus and A. nigroris, for it is intermediate in body depth, caudal concavity, structure of the teeth, dorsal and anal fin ray counts, size, and color.

Acanthurus leucoparaleus (Jenkins)

Figs. 10 f, 18

Teuthis leucoparaleus Jenkins (1903: 476, fig. 23) (Honolulu).

Teuthis umbra Jenkins (1903: 477) (Honolulu); Kendall and Radcliffe (1912: 144) (Cook Bay, Easter Island).

Teuthis bishopi Bryan and Herre (1903: 134) (Marcus Island).

Hepatus leucoparaleus Jordan and Evermann (1905: 386, fig. 167) (Hawaiian Islands); Jordan and Seale (1906: 352); Fowler (1928: 266, pl. 30, fig. B) (Hawaiian Islands, Easter Island, and Marcus Island); Fowler and Bean (in part) (1929: 214) (Hawaiian Islands and Easter Island).
Hepatus umbra Jordan and Evermann (1905: 387, pl. 47) (Honolulu);

Jordan and Seale (1906: 353).

Acanthurus leucopareius Jordan and Jordan (1922: 65) (Honolulu).

Acanthurus umbra Jordan and Jordan (in part) (1922: 65) (Hawaiian Islands).

Dorsal rays IX, 25 to 27; anal rays III, 23 to 25; pectoral rays 16; anterior gill rakers 15 to 18; posterior gill rakers 18 to 21 (raker counts from Hawaiian specimens); a 38 mm. specimen has 8 upper and 10 lower teeth; a 70 mm. specimen has 10 upper and 12 lower teeth; a 109 mm. specimen has 12 upper and 14 lower teeth; a 145 mm. specimen has 14 upper and 16 lower teeth; a 197 mm. specimen has 16 upper and 20 lower teeth.

Table 7  Variation in Fin Ray Counts of Specimens of

Acanthurus leucopareius from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25   26  27</td>
<td>23   24  25</td>
</tr>
<tr>
<td>Hawaiian Islands</td>
<td>6 15  2</td>
<td>3 16  4</td>
</tr>
<tr>
<td>Easter Island</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Marcus Island</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Body depth 1.7 to 1.85 in standard length; caudal concavity 10 to 11 in standard length; length of pectoral fin 2.8 to 3.2 in standard length.

Color (in alcohol) brown with a dusky white band extending from origin of dorsal fin to posterior portion of opercle; posterior and adjacent to this white band a prominent dark brown band; anterior and
adjacent to white band an obscure dark brown band which passes through eye; a small black spot at axil of dorsal fin (relatively large in Easter Island specimen); base of caudal fin with a distinct white band; all fins brown except pectorals which are pale with a narrow black upper margin; a faint longitudinal banding may be visible in dorsal and anal fins.

In some specimens the dark and light bands on the head are difficult to see. This is true of some freshly preserved specimens; therefore the lack of bands cannot be attributed solely to fading.

In life the white band on the head and the one at the base of the caudal fin are vivid. Faint irregular bluish lines may be seen on the body. In a 70 mm. specimen the bluish lines are fewer in number and more evident than in large specimens. On the upper one-third of the body they consist of oblique rows of discrete spots.

Transformation from the acronurus to the juvenile stage occurs at a size of about 33 to 34 mm. in standard length. The dark and light bands on the head are just making their appearance on a 40 mm. specimen.

I examined the type of Teuthis bishopi Bryan and Herre at the Bishop Museum (a 206 mm. specimen from Marcus Island) and the type of Teuthis umbra Jenkins at the United States National Museum; both are specimens of Acanthurus leucopareius. As the bands on the head of the type of umbra are very faint it is understandable how Jenkins could have overlooked them and considered the specimen as representing a new species.

Since Jenkins, a number of authors have applied the name umbra to various species of Acanthurus. Of the specimens considered as Acanthurus umbra by Jordan and Jordan (1922), for example, some were A. mata, one was A. xanthopterus, and one was A. leucopareius. A. mata received the designation of umbra more than other species probably because of its
marked pale band at the base of the caudal fin and lack of other obvious color markings.

Fowler (1928: 266) listed two "Albatross" specimens from Puako Bay, Hawaii (U.S.N.M. No. 55582) as *Hepatus leucopareius*. One of these, however, is either *Acanthurus xanthopterus* or *A. mata*. The two which he recorded as *leucopareius* from Apia, Samoa (U.S.N.M. No. 52456) are *Acanthurus nigroris*, as is the one from the Tubuai Islands (Bishop Mus. No. 750). The 105 mm. specimen from Suva, Fiji (Bishop Mus. No. 4339), which was identified as *Hepatus leucopareius*, is *Acanthurus mata*. Also misidentified by Fowler as *leucopareius* are two subadults from the New Hebrides (Bishop Mus. No. 1028). Two specimens from Guam (Bishop Mus. No. 4261) which Fowler (1925: 12) reported as *Hepatus leucopareius* are 26 mm. acronuri which are definitely not this species.

Fowler (1930: 612) recorded *Hepatus leucopareius* from Hong Kong. I was unable to locate his specimen at the Academy of Natural Sciences of Philadelphia. Also I have not examined his specimens of *leucopareius* from the Philippines. His reference to their poor condition (1927a: 237) suggests that this may be a tenuous identification. A. W. Herre has written me that he has never seen *Acanthurus leucopareius* in the Philippines. The presence of the species in his checklist (1953: 336) is probably based on Fowler.

The only definite records of this species are from the Hawaiian Islands, Marcus Island, and Easter Island, all remote and widely separated areas of Oceania. If these three regions represent the total distribution, *A. leucopareius* would seem to be a relict species. It is easier to suppose that it was once in continuous distribution throughout Oceania but survives now only in these three outposts than to assume
Fig. 18. *Acanthurus leucoparaicus* (after Jordan and Evermann, 1905).

Fig. 19. *Acanthurus nigricus* (after Jordan and Evermann, 1905; retouched).
that it is endemic to one of these islands and spread to the others without becoming established in intervening areas.

This species is one of the most common of the genus in the Hawaiian Islands. It is most often seen in relatively shallow reef areas subject to some turbulence from wave action. It has been observed in schools.

_Acanthurus nigroris_ Cuvier and Valenciennes

_Figs. 9 i, 10 g, 19_

_Acanthurus nigroris_ Cuvier and Valenciennes (1835: 208) (Hawaii); Weber (1913: 317) (East Indies).

_Acanthurus lineolatus_ Bleeker (1854: 101) (Banda Islands, East Indies);

 Günther (1873: 112, pl. 73, fig. A) (Society Islands); Steindachner (1901: 493) (Honolulu); de Beaufort (in part?) (1951: 160) (East Indies).

_Acanthurus bipunctatus_ Günther (1861: 331) (China).


_Rhombotides lineolatus_ Bleeker (1865: 288) (Ambon, East Indies).

_Teuthis atrimentatus_ Jordan and Evermann (1903: 198) (Honolulu); Jenkins (1903: 478) (Hawaiian Islands).

_Teuthis striatus_ Bryan and Herre (1903: 133) (Marcus Island).

_Hepatus atrimentatus_ Jordan and Evermann (1905: 393, fig. 171) (Hawaiian Islands); Jordan and Seale (1906: 352) (Samoa).

_Acanthurus atrimentatus_ Jordan and Jordan (1922: 65) (Hawaiian Islands);

 Herre (1927: 422, pl. 3, fig. 1) (Philippine Islands).

_Hepatus elongatus_ Fowler (in part) (1928: 267) (Oceania).

_Hepatus lineolatus_ Fowler (in part) (1928: 270) (Oceania); Fowler and
Bean (in part) (1929: 228) (Philippine Islands and Hawaiian Islands); Fowler (1931: 345) (Honolulu); Fowler (1938: 232) (Honolulu).

Hepatus fuliginosus. Fowler and Bean (in part) (1929: 211) (Honolulu).


Teuthis lineolatus. Fowler (1941: 257, fig. 9) (Honolulu); Fowler (1949: 103) (Howland Island).


Dorsal rays IX, 23 to 27; anal rays III, 22 to 25 (one specimen from the Hawaiian Islands has IV anal spines); pectoral rays 15 or 16; a 61 mm. specimen has 10 upper and 12 lower teeth; a 96 mm. specimen has 12 upper and 14 lower teeth; a 159 mm. specimen has 12 upper and 14 lower teeth. See Table 10 for gill raker counts.

Caudal concavity 5.8 to 10.5 in standard length (5.8 to 7.5 in specimens from the Hawaiian Islands and Johnston Island and 6.7 to 10.5 from elsewhere in the Pacific); body depth 1.8 to 2 in standard length; ends of central upper teeth rounded (Fig. 10 g).

The largest specimen seen by me measures 204 mm. in standard length. It was collected at French Frigate Shoal.

Color (in alcohol) of Hawaiian specimens brown with irregular, lengthwise, bluish gray or dark brown lines (about one fourth as broad as intervening brown areas) on body; about six or seven slightly irregular, narrow, dark bluish gray or dark brown lines on head running parallel to profile of snout (in some preserved specimens these lines and those on the body are very faint or imperceptible); a small black spot about the size of the pupil at the axil of both the dorsal and the anal
fins; dorsal fin with about five or six lengthwise dark brown bands; anal fin with four or five similar bands; a light grayish brown band often present at base of caudal fin; posterior margin of caudal fin very narrowly pale; pectoral fin pale with narrow dark upper margin; pelvic fins brown; no narrow black margin around socket of caudal spine.

In life the bluish gray or dark brown lines on the body and head are light blue; the dark bands in the dorsal and anal fins are bluish and the intervening bands light yellowish brown; pectoral fin rays dull yellow, membranes clear; iris yellow.

Wake Island specimen, even large adults, have rows of small round blue spots on the body instead of entire or slightly broken blue lines. Specimens from elsewhere in Oceania appear to be colored much like Hawaiian examples, as indicated in the color plate in Günther (1873) of a specimen from the Society Islands (identified as Acanthurus lineolatus).

The number of blue lines on the body are fewer in smaller specimens. A 51 mm. juvenile from the Hawaiian Islands, for example, has only 11 lines on the body.

In this species and Acanthurus nigrofuscus the black spot in the axil of the dorsal fin makes its appearance before the spot in the axil of the anal fin. The dorsal spot first shows before these species complete the transformation from the acronurus to the juvenile state (which occurs at a standard length of from about 34 to 39 mm. in A. nigrofusca). The anal spot first appears on specimens of nigrofusca about 42 to 50 mm. in standard length.
Table 8 Variation in Fin Ray Counts of Specimens of
Acanthurus nigroris from Different Localities

<table>
<thead>
<tr>
<th>Localities</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
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<td>22 23 24 25</td>
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<td>Laysan and French Frigate Shoal</td>
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<tr>
<td>Johnston Island</td>
<td>3 8 9</td>
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</table>

A. nigrofuscus seems to be closely related to A. nigroris, and these two species have often been confused. As indicated in the key, they may be separated by caudal concavity, body depth, maximum size, shape of upper teeth, size of the spot in the axil of the dorsal fin, width of the pale posterior margin of the caudal fin, presence or absence of spots on the head, and presence or absence of a dark margin around the groove of the caudal spine. In addition, the posterior tips of the dorsal and anal fins of A. nigrofuscus are more pointed when these fins are elevated than are the fins of A. nigroris. The base of the caudal fin of A. nigrofuscus is rarely paler than the rest of the fin or the body. The bands in the dorsal and anal fins of A.
nigrofuscus are poorly defined and rarely persist in preserved specimens. The lips of A. nigrofuscus tend to be blackish while those of A. nigroris are usually only slightly darker than the rest of the head.

Small juveniles of these two species are difficult to distinguish, but the greater concavity of the caudal fin and larger black spot at the base of the last few dorsal and anal rays of A. nigrofuscus still permit separation. I am unable, however, to distinguish with assurance the acronurus or postacronurus larval forms of these species. The immediate postacronurus of Fig. 91 from Wake Island is identified largely because of the prevalence of A. nigroris at this island and the apparent absence of A. nigrofuscus (as based on collections and observations of W. A. Gosline and the author).

The Phoenix Islands, Swain's Island, and Johnston Island are other areas in the Pacific from which A. nigroris has been taken and A. nigrofuscus is as yet unknown. Forty-seven specimens of A. nigroris were collected by L. P. Schultz from the Phoenix Islands and Swain's Island. These are not as well differentiated from A. nigrofuscus as specimens from other regions such as the Marshall Islands. The caudal fin is slightly more lunate, and the white posterior edge is broader; the black spot at the rear base of the dorsal and of the anal fin is a little larger. Forty-eight specimens of A. nigroris were collected by Gosline, Brock, Yamaguchi, et al from Johnston Island. Also there are several specimens of this species from Johnston in the United States National Museum and the Bishop Museum. When A. nigroris and A. nigrofuscus occur together, the latter is usually more prevalent. For example, the 82 specimens of these two species collected by Schultz at Rose Island in the Samoa Islands include only eight A. nigroris.
The populations of *A. nigroris* from Johnston Island and the Hawaiian Islands differ significantly from those of other regions of the Pacific in having higher fin ray counts (Table 8), higher gill raker counts (Table 10), and more concave caudal fins. There appear to be slight meristic differences between the species in Johnston Island and the Hawaiian Islands.

The type of *Acanthurus nigroris* Cuvier and Valenciennes is in the Paris Museum. The type locality is Hawaii. According to L. Bertin (personal communication), the specimen is 130 mm. in standard length and has 12 upper and 12 lower teeth (Cuvier and Valenciennes recorded 12 upper and 14 lower teeth). Of the known species of Hawaiian acanthurids, this information alone narrows the possibility to three, *A. nigroris* as here defined, *A. nigrofuscus*, and *A. leucoparaleus*. Apparently no color markings are now evident on the specimen, but information on the shape of the caudal fin and ends of the dorsal and anal fins clearly eliminates *A. nigrofuscus*. Failure of Cuvier and Valenciennes to mention the vertical white and dark brown bands on the head, so characteristic of *A. leucoparaleus*, strongly favors the present use of the name *nigroris*.

Jordan and Evermann (1903) were the first to realize that the use of the name *lineolatus* for this species was an error. They proposed the name *atramentatus*. I examined their type of *Teuthis atramentatus* (*= Acanthurus nigroris*) in the United States National Museum.

Through correspondence with A. C. Wheeler of the British Museum, I was able to learn that one of the types of *Acanthurus bipunctatus* Günther is *A. nigroris* and the other is *A. nigrofuscus*. Günther also included specimens of both of these species as types of *Acanthurus nigros*. 
For purposes of synonymy I designate as the lectotype of Acanthurus bipunctatus Günther the 126 mm. specimen (British Mus. No. 1848.3.13.215) from China. I designate as lectotype of Acanthurus nigros Günther the 160 mm. specimen (British Mus. No. 1861.5.31.29) from the New Hebrides. Thus both of these names become synonyms of Acanthurus nigrofris Cuvier and Valenciennes as the species is here interpreted.

A. nigrofris appears to range throughout Oceania. The species probably occurs in China, the Philippines, and the East Indies as well. I have seen no specimens from the Indo-Malayan region. Herre's (1927: 422) description of Acanthurus atramentatus (Jordan and Evermann) from the Philippines seems to apply to A. nigrofris; however his figure (pl. 3, fig. 1) is suggestive of A. nigrofuscus. Bleeker's (1854a: 101) description of Acanthurus lineolatus (not of Cuvier and Valenciennes) from the Banda Islands, East Indies, and that of de Beaufort (1951: 160) check with A. nigrofris. De Beaufort's reference to a lunate caudal fin and certain variability in color pattern suggests, however, that he also had some specimens of A. nigrofuscus.

Acanthurus nigrofuscus (Forskal)

Fig. 10 h; Pl. II

Chaetodon nigro-fuscus Forskal (1775: xiii, 64) (Red Sea).

Chaetodon nigrofuscus Linnaeus and Gmelin (1788: 1268).

Acanthurus rubropunctatus Rüppell (1828: 59, pl. 15, fig. 1) (Red Sea);

Günther (1861: 333); Klunzinger (1871: 508) (Red Sea).

Acanthurus matoides Cuvier and Valenciennes (1835: 204) (Oualan).

?Acanthurus lineolatus Cuvier and Valenciennes (1835: 207) (East Indies).

Acanthurus nigro-fuscus Cuvier and Valenciennes (1835: 214) (Réunion and Red Sea).
Acanthurus rubro-punctatus Cuvier and Valenciennes (1835: 222).
Ctenodon rubropunctatus Swainson (1839: 256).
Acanthurus mata. Day (1876: 205, pl. 48, fig. 1) (seas of India).
Acanthurus (Rhombotides) nigrofuscus Klunzinger (1884: 84) (Red Sea).
Acanthurus bipunctatus. Steindachner (1901: 494) (Honolulu).
Teuthis bipunctatus. Jordan and Evermann (1902: 358) (Koto sho Island, Formosa); Jordan and Fowler (1902: 554) (Riu Kiu Islands and Formosa); Jenkins (1903: 479) (Honolulu).
Hepatus elongatus. Jordan and Evermann (1905: 389) (Hawaiian Islands); Jordan and Seale (1906: 352) (Samoa); Fowler (in part) (1928: 267) (Oceania); Fowler and Bean (in part) (1929: 213) (Hawaiian Islands); Fowler (1938: 230) (Honolulu); Aoyagi (1943: 208, pl. 6, fig. 18) (Riu Kiu Islands); Kamohara (1954: 52, fig. 13) (Tokara Islands, southern Japan).
Acanthurus elongatus. Jordan and Jordan (1922: 65) (Hawaiian Islands);
Herre (1936: 246) (Tuamotu Archipelago and New Hebrides); Schultz (in part) (1943: 165) (Samoa Islands); Schultz and Woods in Schultz et al. (1953: 634, pl. 62, fig. D) (Marshall and Mariana Islands);
Acanthurus marginatus. Herre (1927: 427, pl. 3, fig. 2) (Philippine Islands).
Acanthurus nigrooris. Herre (1927: 428, pl. 4, fig. 1) (Philippine Islands and Guam); Schmidt (1930a: 103) (Riu Kiu Islands).
Hepatus fuliginosus. Fowler (in part) (1928: 266) (Oceania).
Hepatus lineolatus. Fowler (in part) (1928: 270) (Oceania); Fowler and
Bean (in part) (1929: 228) (Philippine Islands, Mauritius, Samoa, and Hawaiian Islands); Pietschmann (1938: 26, pl. 2, fig. C) (Molokai, Hawaiian Islands).


Hepatus lucillae Fowler (1938: 231, fig. 23) (Honolulu).
Teuthis lucillae Fowler (1941: 257) (Honolulu); Fowler (1949: 103).

Dorsal rays IX, 24 to 27; anal rays III, 22 to 24; pectoral rays 16 or 17; a 55 mm. specimen has 10 upper and 12 lower teeth; a 79 mm. specimen has 12 upper and 14 lower teeth; a 120 mm. specimen has 12 upper and 14 lower teeth; a 148 mm. specimen has 14 upper and 16 lower teeth. See Table 10 for gill raker counts.

Caudal fin lunate, caudal concavity 4.5 to 6 in standard length; body depth 2 to 2.3 in standard length; ends of upper teeth tend to be pointed (Fig. 10 h).

Color (in alcohol) brown, with or without fine bluish gray longitudinal lines on body; a prominent black spot, greater in width than half the diameter of eye, in axil of dorsal fin; a slightly smaller black spot in axil of anal fin; head and chest in life with numerous small bright orange spots which may or may not persist as pale spots in preservative; caudal fin with a distinct dull white posterior border, about one-half pupil diameter in width at the center and becoming narrow out on lobes (in East Indian and Indian Ocean specimens this border is narrower); an indistinct blackish brown area submarginal to white border of caudal fin; a narrow black margin around socket of caudal spine; lips blackish brown; dorsal and anal fins with faint longitudinal banding in life which is rarely evident on preserved specimens; margin of dorsal and anal fins narrowly dark (blue in life on anal fin); pectoral fin pale.
with upper edge narrowly black; pelvic fins brown.

Table 9 Variation in Fin Ray Counts of Specimens of

*Acanthurus nigrofuscus* from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
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</tr>
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<td>Samoa Islands</td>
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</tr>
<tr>
<td>Hawaiian Islands</td>
<td>6 16 4 1</td>
<td>1 9 16</td>
</tr>
</tbody>
</table>

*Acanthurus nigrofuscus* appears to reach a larger size in the Hawaiian Islands than in the Marshall, Mariana, and Samoa Islands (island groups from which large collections of this species are available). In Hawaii the species attains a size of at least 152 mm. in standard length. Few specimens from the Marshall, Marianas, or Samoa exceed 100 mm. in standard length. A 143 mm. one was found among specimens in a collection from Mauritius.

Although the acronurus is difficult to separate from that of *A. nigroris*, late transforming specimens of *A. nigrofuscus* have been
identified from the Hawaiian Islands and the Marshall Islands. The size at transformation in both areas is about 43 mm. A 34 mm. post-acronurus from the East Indies is identified as this species.

I know of no type material of \textit{Acanthurus nigrofuscus} (Forskal). The species was described as having a brown-black body and a caudal fin with a whitish posterior edge and lobes which are falcate and half as long as the entire fin. Although the description of \textit{A. nigrofuscus} is brief, it fits the species as here defined better than any other known species of the genus. This is especially true when only the species of \textit{Acanthurus} is the Red Sea and their relative abundance are considered. With the possible exception of \textit{Acanthurus sohal} (Forskal) and \textit{Acanthurus gahna} (Forskal), \textit{Acanthurus nigrofuscus} appears to be the most common species of the genus in the Red Sea. Although Forskal did not state that a black spot was present at the axil of the dorsal and anal fins, these spots could have been overlooked. Specimens of \textit{A. nigrofuscus} in the United States National Museum recently collected from the Red Sea are sufficiently melanistic so that these spots cannot be perceived easily without holding the fish in front of a bright light.

The failure to note these spots by some authors and their observance by others has contributed to the nomenclatorial confusion of this species. More confusing is the evanescent quality of the orange spots on the head. A number of synonyms of \textit{A. nigrofuscus} owe their origin to descriptions from fresh specimens on which the spots are the most conspicuous color feature. Preserved specimens, with these spots faint or absent, have often been listed under different names. Rüppell (1828: 59, pl. 15, fig. 1) described and figured \textit{Acanthurus rubropunctatus} from the Red Sea. He emphasized the small red spots on the head, but did not mention black
spots in the axils of the dorsal and anal fins. W. Klausewitz (personal communication) has provided additional information on the types in the Senckenberg Museum at Frankfurt. These have a black spot at the base of the last few dorsal rays and another at the base of the last few anal rays.

I have examined the holotype and paratypes of *Hepatus lucillae* Fowler at the Academy of Natural Sciences of Philadelphia. The specimens are *Acanthurus nigrofuscus*. They were considered distinctive by Fowler largely because of the bright golden spots on the head.

Herre, in his review of Philippine surgeon fishes (1927), listed this species under two names, *Acanthurus marginatus* Cuvier and Valenciennes (with whitish spots on the head) and *Acanthurus nigrofuscus* Cuvier and Valenciennes. The former is a new name for *Acanthurus guttatus* Kittlitz. I was unable to locate Kittlitz' type; it was described as a brown fish with numerous blue spots on the head and body and is either the true *Acanthurus nigrofuscus* or a *Ctenochaetus* (see discussion under *Ctenochaetus cyanoguttatus*). In 1936 Herre used two different names for *A. nigrofuscus*; these were *Acanthurus flavoguttatus* Kittlitz [probably = *Ctenochaetus striatus* (Quoy and Gaimard)] and *Acanthurus elongatus* (Lacépède).

The name *elongatus* has been applied to the species *Acanthurus nigrofuscus* by other authors as well. Not only is *Chaetodon elongatus* Lacépède a later name than *Chaetodon nigrofuscus* Forskal, but it was used by Lacépède for another species, probably one in the *A. xanthonterus* – *A. mata* – *A. dussumieri* complex.

L. Bertin has supplied me with sufficient information on the type of *Acanthurus aspidides* Cuvier and Valenciennes to enable me to place this name in the synonymy of *Acanthurus nigrofuscus*. The type of *A.*
Table 10 Variation in Gill Raker Counts of Specimens of *Acanthurus nigroris* and *Acanthurus nigrofuscus* from Different Localities

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Acanthurus nigrofuscus, Hawaiian Islands

Acanthurus lineatus, Gilbert Islands
matoides is 120 mm. in standard length, has 12 upper and 12 lower teeth, and a caudal concavity of 23 mm. This name has been most commonly used for the species Acanthurus xanthopterus Cuvier and Valenciennes.

Bertin could find no type of Acanthurus lineolatus Cuvier and Valenciennes in the Paris Museum. The original description is too brief to permit certain identification. Mention of the shape of the caudal fin and of fine longitudinal blue lines on the body suggests that these authors had specimens of Acanthurus nigrofuscus.

Acanthurus lineatus (Linnaeus)

Figs. 9 e, 10 i; Pl. II

Chaetodon lineatus Linnaeus (1758: 274) (Indies).

Acanthurus Lineatus Bloch and Schneider (1801: xxxviii, 214) (East Indies).

Acanthurus lineatus Lacépède (1802: 547, 550); Cuvier and Valenciennes (1835: 223) (East Indies); Bleeker (1853a: 263) (Sumatra); Günther (1861: 333) (East Indies and Philippine Islands); Kner (1865-67: 210) (Tahiti); Günther (1873: 111, pl. 70) (East Indies, Polynesia south of equator, and Indian Ocean); Day (1876: 203) (seas of India); Day (1889: 138); Weber (1913: 317) (East Indies); Herre (1927: 420, pl. 14, fig. 1) (Philippine Islands and Guam); Herre (1936: 242) (Bora Bora and New Hebrides); Schultz (1943: 165) (Phoenix and Samoa Islands); Smith (1949: 240, pl. 33, no. 610) (east coast of Africa south to Delagoa Bay); de Beaufort (1951: 147) (East Indies); Schultz and Woods in Schultz et al (1953: 630) (Marshall and Mariana Islands); Harry (1953: 149) (Rapaia, Tuamotu Archipelago).

Acanthurus vittatus Bennett, J. W. (1828: pl. 2) (Ceylon).

Ctenodon lineatus Swainson (1839: 256).

Harpurus lineatus Forster (1844: 216).

Teuthis lineatus Seale (1901: 108) (Guam); Schmidt (1930a: 555) (Riu Kiu Islands); Fowler (1946: 198) (Riu Kiu Islands); Fowler (1949: 102) (Jarvis Island and Howland Island).

Hepatus lineatus Jordan and Seale (1906: 351) (Samoa); Evermann and Seale (1923: 78) (Guadalcanal, Solomon Islands); Fowler (1928: 269) (Oceania); Fowler and Bean (1929: 218, fig. 12) (Philippine Islands and East Indies); Fowler (1938: 147, 202) (Tahiti and Christmas Island); Aoyagi (1943: 215, pl. 6, fig. 17) (Riu Kiu Islands).

Dorsal rays IX, 27 to 30; anal rays III, 25 to 28; pectoral rays 16; anterior gill rakers 14 to 16; posterior gill rakers 13 to 15 (raker counts from Samoan specimens); a 107 mm. specimen has 12 upper and 14 lower teeth; a 180 mm. specimen has 14 upper and 15 lower teeth.

Caudal fin strongly lunate, caudal concavity contained 3.3 to 4.5 times in standard length; caudal spine long (its length about 1.9 to 2 in head length), slender, and sharp on both edges; body depth 2.1 to 3 in standard length (in specimens over 100 mm. in standard length).

Color in alcohol: lower one-fourth of body light grayish brown; upper three-fourths with alternate pale yellowish white and broad black near-longitudinal lines, each of the latter bisected with a pale bluish gray line; head with a varying pattern of curved lines similar to those on body (but with black lines narrower); dorsal fin with numerous alternating narrow dark brown and bluish gray lines; anal fin dusky yellow; both dorsal and anal fins with a narrow black margin (extreme edge pale); caudal fin dark brown with vertical dark and light lines at base and a large crescentic area in mid-posterior portion; pectoral fin pale with dusky rays; pelvic fins light yellowish brown,
the outer margin black.

Fowler and Bean (1929: fig. 12) demonstrated the variability in color pattern which may be seen in Philippine specimens of this species.

The two sides of the same fish may show different patterns of lines.

In addition to the blue, yellow, and black color as seen in adults, four juvenile specimens (37 to 40 mm. in standard length) from the Gilbert Islands displayed bright red color on the dorsal and anal fins (especially posteriorly) and on the caudal fin and pelvic fins.

Table II Variation in Fin Ray Counts of Specimens of  
Acanthurus lineatus from Different Localities

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Four specimens examined from the Marianas, Palaua, and East Indies are in the stage of transformation from the acronurus to the juvenile
state at a size of from 27 to 32.5 mm. in standard length.

Museum specimens of transforming A. nigrofus have been found misidentified as A. lineatus. Although both have a linear color pattern in the late acronurus (Fig. 9 e and i), they may be distinguished readily.

Acanthurus lineatus is distributed from East Africa to the central Pacific. It appears to be absent from the Red Sea. It is not known from the Hawaiian Islands, Johnston Island, Wake Island, or Marcus Island (Fowler, 1928: 269, was in error in considering Tautethis striatus Bryan and Herre to be A. lineatus; the specimens are A. nigrofus). The extensive collections of fishes from the northern Marshall Islands, which are being reported on by Schultz et al. (1953), include only two specimens of this species. In the Gilbert Islands, however, I found A. lineatus to be very common, especially in the surge channel habitat. Vernon E. Brock has informed me that the species is common at Palmyra in the Line Islands.

The colorful A. lineatus and A. sohal are well demarked from other species of Acanthurus. They are distinctive in the possession of dark lengthwise bands on the body, strongly lunate caudal fins, and highly developed caudal spines. In addition to being very long and sharp, the spines of these two species are peculiar in being nearly free of sheath.

Acanthurus sohal (Forskal)

Figs. 9 g, 10 j, 20

Chaetodon sohal Forskal (1775: xiii, 63) (Red Sea).

Chaetodon Sohar Linnæus and Gmelin (1788: 1268) (coasts of Arabia).

Acanthurus Sohal Bloch and Schneider (1801: xxxviii, 215) (coasts of Arabia); Cuvier and Valenciennes (1835: 227) (Red Sea).
Acanthurus carinatus Bloch and Schneider (1802: 216) (Arabian Sea).

Aspisurus sohar Lacepède (1802: 556) (sea of Arabia).

Cheetodon sohab Cuvier (1817: 331) (after Linnaeus and Gmelin).

Acanthurus sohab Rüppell (1828: 56, pl. 16, fig. 1) (Red Sea); Günther (1861: 334) (Red Sea); Klunzinger (1871: 507) (Red Sea).

Ctenodon Rüppelli Swainson (1839: 256, fig. 74).

Acanthurus (Rhombotides) sohab Klunzinger (1884: 83) (Red Sea).

Dorsal rays VIII, 30 or 31; anal rays III, 26 or 29 (usually 29); pectoral rays 17 (fin ray counts from six specimens from the Red Sea); anterior gill rakers 15 to 17; posterior gill rakers 14 or 15 (raker counts from three Red Sea specimens); an 87 mm. specimen has 12 upper and 14 lower teeth; a 130 mm. specimen has 12 upper and 16 lower teeth; a 206 mm. specimen has 14 upper and 16 lower teeth; a 270 mm. specimen has 16 upper and 18 lower teeth.

Caudal fin strongly lunate, caudal concavity contained about 3 to 4 times in standard length (in specimens over 150 mm. in standard length; an 87 mm. specimen has a caudal concavity which is contained 5 times in its standard length); caudal spine long in adults (1.9 to 2 in head length), slender, very sharp, and without a thick sheath; body depth 2 to 2.2 in standard length; diameter of eye varies from 3 in head length of 87 mm. specimen to 5 in head length of 270 mm. specimen.

Color (in alcohol) light brown with about 15 longitudinal dark brown bands (each about two to three times as broad as intervening light brown bands) on side of body above level of lower part of pectoral fin; on the back a second less conspicuous and more oblique
Fig. 20. *Acanthurus sohal* (after Rüppell, 1828).

Fig. 21. *Acanthurus leucocelis* (after Herre, 1927).
A series of bands which become relatively narrower with age; longitudinal dark lines on head dorsal to lower margin of eye; dorsal, anal, and pelvic fins brownish black (smaller specimens with lengthwise bands in dorsal fin); caudal fin black, shading to dark brown in center, with a narrow pale margin (broader in smaller specimens); pectoral fin dark brown, slightly paler in upper middle portion, with narrow pale posterior margin; caudal spine and margin of socket cream.

Color of a fresh specimen as shown in a photograph (Cousteau, 1952: 461): body below pectoral fin light tan, above with alternating dark brown and pale bluish bands; caudal spine bright orange; dorsal and anal fins black with a narrow blue line at the base which becomes broader posteriorly; anal fin with a narrow blue margin; caudal fin dark brown, shading to black peripherally except narrow margin which is blue; pectoral fin light brown on upper half, dusky blue on lower half, with a black margin all around fin; pelvic fins black with narrow blue margin.

Although this species reaches a large size (at least 270 mm. in standard length), it has a small acronurus. The transforming specimen shown in Figure 9 g is 21 mm. in standard length.

Acanthurus sohal appears to be confined to the Red Sea.

Fowler and Bean (1929: 216) erroneously applied the name sohal to the species Acanthurus tennenti Günther.

Acanthurus leucocheilus Herre

Fig. 21

Acanthurus leucocheilus Herre (1927: 419, pl. 12, fig. 3) (Philippine Islands); de Beaufort (1951: 140).
The following is based on Herre’s description of three specimens, 175 to 200 mm. long, from Bantayan Island, and a 196 mm. specimen from Cebu: dorsal rays IX, 24 or 25; anal rays III, 23; 9 or 10 teeth with broad lobate tips on each side of upper jaw and 10 or 11 on each side of lower jaw; depth of body 2 to 2.4 in length; head 3.3 to 3.7 in length; snout 1.3 to 1.44 in head; eye 3.6 to 3.9 in head; eye 1.07 to 1.28 in interorbital; caudal deeply lunate with long pointed tips (caudal concavity in figure about 3.5 in standard length); length of pectoral approximately equal to length of head; first ventral ray elongate, 1.1 to 1.25 in head. Color (in alcohol) blackish brown; snout just above and behind lips black; a bluish white band encircling mouth (though it may be only partially developed on upper lip); a similar but wider white band across chest; a broad bluish white band around base of caudal; pectoral black with a white bar on posterior third; dorsal, anal, and pelvic fins black or brownish black; caudal fin black, sometimes with a bluish white lunate band near posterior margin; caudal spine white, its groove with a narrow black margin. A fresh specimen, 186 mm. in length, from Agutaya, one of the Cuyo Islands, was blackish brown above, deep brown elsewhere except cheeks and snout which were reddish brown; lips reddish with a bluish band around mouth; the chest band was bluish white; soft dorsal fin with three and anal fin with two dark red lines near margin alternating with bluish; narrow margin of these fins sky blue, posteriorly brick red; caudal fin very dark brown with a wide bluish white band around base and a submarginal blue band posteriorly; pectoral blackish brown with a bright yellow bar on posterior third, the margin with rays dusky, membranes clear; pelvics black basally and along outer margin, the rest brick red.
The types of this species were destroyed in Manila during World War II, and to my knowledge, no other specimens are in existence. Herre (1934: 62) recorded the species (as *Acanthurus leucocheilus*) from a specimen (Stanford Mus. No. 264.01) from the Philippines. I examined it and found that it is *Acanthurus pyroferus*.

Fowler and Bean (1929: 225) erroneously placed *Acanthurus leucocheilus* Herre in the synonymy of *Hepatus grammoptilus* (Richardson). The specimens which these authors identified as *grammoptilus* are *Acanthus xanthopterus* and *Acanthus duessumeri*. *A. leucocheilus*, as originally described, is probably a valid species.

*Acanthus pyroferus* Kittlitz

Figs. 10 k, 22

*Acanthus pyroferus* Kittlitz (1834: 191, pl. 12, fig. 2) (Ulea Island = Woleai Atoll, Caroline Islands); Günther (1861: 337); Günther (1873: 113).

*Acanthus armiger* Cuvier and Valenciennes (1834: 234).

*Acanthus celebicus* Bleeker (1852: 761) (Macassar, Celebes); Kner (1865-67: 211) (Madras); Günther (1861: 339); Günther (1873: 115, pl. 73, fig. B) (Solomon Islands and Tahiti); Day (1889: 142) (Malay Archipelago); Herre (1927: 417, pl. 13, fig. 1) (Mindoro, Philippine Islands); de Beaufort (1951: 141) (Java and Adonare).

*Acanthus fusces* Steindachner (1861: 176, pl. 5) (Ambon, East Indies); Günther (1861: 339); de Beaufort (1851: 137).

*Phrombotides celebicus* Bleeker (1863b: 235) (Ternate, East Indies).

*Acanthus Celebicus* Day (1876: 206) (Malay Archipelago).

*Acanthus tristis* Tickell in Day (1888: 738) (Arrakan, Burma); Myers (1951: 26).
**Hepatus pyriferus** Jordan and Seale (1906: 350) (error for *pyroferus*).

**Hepatus celebensis** Jordan and Seale (1906: 352); Jordan and Seale (1907: 34) (Philippine Islands).

**Hepatus pyroferus** Fowler (1928: 272).

**Hepatus leucosternon**. Fowler (1928: 272); Fowler and Bean (in part)

(1929: 243, fig. 14) (Riu Kiu Islands, Philippine Islands, and East Indies); Koyagi (1943: 207, text fig. 52, pl. 5, fig. 13) (Riu Kiu Islands).

**Acanthurus leucocheilos**. Herre (1934: 62) (Linapacan, Philippine Islands).

**Acanthurus leucosternon**. Schultz and Woods in Schultz et al (1953: 626, pl. 61, fig. 8) (Bikini Atoll, Marshall Islands).

Dorsal rays VIII, 27 or 28; anal rays III, 24 to 26; pectoral rays 16; anterior gill rakers 23 to 26; posterior gill rakers 25 to 27 (raker counts from four specimens from the Marshall Islands); a 109 mm. specimen has 14 upper and 16 lower teeth; a 145 mm. specimen has 16 upper and 18 lower teeth; a 159 mm. specimen has 16 upper and 21 lower teeth.

Table 12 Variation in Fin Ray Counts of Specimens of **Acanthurus pyroferus** from Different Localities

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<td></td>
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<td>Marshall Islands</td>
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</table>

Snout somewhat produced; snout length 4.6 to 4.7 in standard length; caudal fin lunate, caudal concavity 4 to 5 in standard length; longest
dorsal ray about 4.5 in standard length.

Color from a 35 mm Kodachrome transparency (given to me by Leonard P. Schultz) of a Marshall Islands specimen (reproduced in black and white herein as Figure 22): purplish black with an orange area, higher than wide, at edge of gill opening just above base of pectoral fin; a diffuse patch of orange anterior to base of pectoral and a trace of orange just behind eye; a broad black band beginning at upper end of gill opening and extending on to margin of gill cover down to isthmus (this band is more apparent in preserved specimens, as is a black band at the base of the dorsal fin, one at the base of the anal fin, blackish lips, and a narrow black margin around caudal spine socket); a white line under chin extending slightly above rictus; median fins black except for a broad posterior band on back edge of caudal fin which is pale yellow; pectoral fin blackish, especially basally on rays, with a large pale yellow spot in lower central part of fin.

Kittlitz (1834) stated that the species is common at Ulea (Caroline Islands), and the young are dirty yellow in color. I have seen no juvenile specimens of this species. It is possible that Kittlitz might have confused the young of Acanthurus olivaceus, which are yellow, with Acanthurus pyroferus.

_Acanthurus pyroferus_ occurs in the East Indies and Philippines and into the Indian Ocean at least as far as India. It ranges out into the tropical central Pacific; however it is recorded from only a few of the major island groups. De Beaufort (1951: 142) lists the species (as _A. celebicus_) from Hawaii. In this I believe he is in error.
I know of no type specimen of *Acanthurus pyroferus* Kittlitz. Although no one has identified a specimen of *Acanthurus* as *pyroferus* since Kittlitz (1834), and de Beaufort (1951: 138) regarded it as a problematic species, there is little doubt that it is the same as *Acanthurus celebicus* Bleeker. Kittlitz' figure shows the vertically aligned orange area, which is edged in black, just above the pectoral fin and the prominent, uniformly broad, yellow, posterior margin on the caudal fin. The dorsal and anal fins are relatively elevated, and the snout is produced (although this feature seems to be exaggerated). The dorsal and anal fin ray counts (D VII, 29; A III, 25) check closely (as in most species of *Acanthurus*, the first dorsal spine is very short and covered with skin; it could have been overlooked by Kittlitz, or he may have counted the eighth spine as a soft ray). The narrow ring of white under the chin is not present on the figure, nor is it mentioned in the description. Probably it was missed. There are greater omissions than this from some of the figures and descriptions of better known species of acanthurids from the same paper.

Herre (1927: 418) observed two living specimens from the Philippines and reported that the amount and intensity of red color behind the head and about the pectoral base vary considerably according to light conditions and the state of excitement of the fish.

*Acanthurus tristis* Tickell (Day) was described as having a caudal fin "nearly white externally" and an irregular black band from the upper edge of the orbit across the top of the opercle to the base of the pectoral fin. Although I have not seen a specimen of *Acanthurus pyroferus* with the black band extending to the eye, Herre's plate (1927: pl. 13, fig. 1) shows this pattern, and I consider it as probably within the
Fig. 22. *Acanthurus pyroferus* (after Schultz and Woods, 1953; retouched).

Fig. 23. *Acanthurus leucosternon* (after de Beaufort, 1951).
range of variability of the species.

Acanthurus pyroferus appears to link the group of three species, Acanthurus leucosternon, Acanthurus glaucoparaius, and Acanthurus achilles with the last 11 Indo-West-Pacific species as discussed in this paper (species such as A. olivaceus, which have a distinctive color mark on the shoulder region, and large species such as A. xanthopterus) and the Atlantic species except A. coerulesc. A. pyroferus is intermediate in dorsal and anal fin ray counts, tooth structure, and tooth counts. It has a produced snout and white line on the chin in common with the former group and the large, round, gizzard-like stomach of the latter.

Acanthurus leucosternon Bennett

Figs. 10 1, 23

Acanthurus leucosternon Bennett, E. T. (1832: 183) (Ceylon); Bleeker (1853b: 48); Bleeker (1856-57: 237) (Batoe Islands, Sumatra); Günther (1861: 340) (Ceylon); Playfair in Playfair and Günther (1866: 56) (Zanzibar); Day (1876: 203); de Beaufort (1951: 139, fig. 26) (Pulu Weh and coast of Deli, Sumatra).

Acanthurus Delisiani Cuvier and Valenciennes (1835: 193), (Mauritius).

Acanthurus Delisianus Valenciennes in Cuvier (1837: pl. 45); Guérin (1844: pl. 35, fig. 2).

Rhombotides leucosternon Bleeker in Bleeker and Pollen (1874: 97).


Dorsal rays IX, 30; anal rays III, 27; pectoral rays 16; 11 upper teeth and 12 lower teeth. All counts based on one 173 mm. specimen from Mauritius in the Museum of Comparative Zoology at Harvard College.
This specimen, the only one which I have examined, was used for the proportional measurements and color description below.

Body depth 1.7 in standard length; caudal concavity 13 in standard length; longest dorsal ray 5.4 in standard length; caudal spine 3 in head length.

Color in alcohol: body bluish gray; head dark brown; chin with a chalky white line at edge of lip which extends a distance equivalent to half the diameter of an eye above the rictus and narrows to a point apically; a broad chalky white band on chest, as wide as depth of caudal peduncle, extending to base of pectoral fin; caudal fin with a white posterior marginal band (equal in width to one-third the diameter of the pupil of the eye), a blackish submarginal band (an eye diameter in width centrally, but narrowing toward lobes where it meets blackish upper and lower edges of caudal fin), and a narrow blackish band across base which connects the dark upper and lower margins of caudal lobes; dorsal fin pale yellow with a narrow white marginal line on upper edge and a black submarginal line; anal fin pale yellow with narrow white outer margin and white line at base; pectoral fin pale yellow; pelvic fins purplish gray with a white margin; region around caudal spine slightly paler than body.

Acanthurus leucosternon resembles Acanthurus achilles and Acanthurus glaucopareius in morphology and color. It ranges from East Africa to the East Indies, and does not appear to be a common species.

Fowler (1928), Fowler and Bean (1929), Aoyagi (1943) and Schulte and Woods (1953) were all in error in their use of the name leucosternon for the species Acanthus pyroferus.
Acanthurus glaucopareius Cuvier

Figs. 9 1, 10 m; Pl. III

Acanthurus glauco-pareius Cuvier (1829: 224) (after Seba) (Günther, 1861, gives the type locality as Tahiti).

Acanthurus ali-alà Lesson (1830: 150) (Oualan).

Acanthurus glaucopareius Kittlitz (1834: 192, pl. 13, fig. 3) (Ulea Island = Woleai Atoll, Caroline Islands); Cuvier and Valenciennes (1835: 190) (Tahiti); Bleeker (1856: 47) (Ambon, East Indies); Günther (1861: 339) (Ambon, East Indies and Tahiti); Günther (1873: 114, pl. 71, fig. A) (Polynesian and East Indies); Schultz (1943: 161) (Phoenix and Samoa Islands); Marshall, N. B. (1950: 194) (Cocos-Keeling Islands); Palmer (1950: 202) (Christmas Island, Indian Ocean); de Beaufort (1951: 138) (Ambon, Misol, and New Guinea).

Rhombotides glaucopareius Bleeker (1865: 238) (Ambon, East Indies).

Teuthis ali-alà Jordan and Evermann (1898: 1693) (Clarion and Socorro Islands, western Mexico); Jordan and McGregor (1899: 280) (Clarion and Socorro Islands); Seale (1901: 109) (Guam).

Hepatus ali-alà Snodgrass and Heller (1905: 403) (Cocos Island and Clipperton Island); Jordan and Seale (1906: 350) (Samoa); Aoyagi (1943: 209, pl. 8, fig. 2, pl. 6, fig. 19) (Okinawa).

Acanthurus ali-alà Herre (1927: 416, pl. 2, fig. 2) (Philippine Islands); Herre (1936: 241) (Cocos Island off Costa Rica, Marquesas Islands, Tuamotu Archipelago, and Society Islands); Schultz and Woods in Schultz et al (1953: 627, pl. 65, fig. A) (Marshall Islands).

Hepatus glaucopareius Fowler (1928: 272) (Oceania); Fowler and Bean (1929: 246) (Philippine Islands, Guam, Samoa, and Honolulu).

Hepatus ali-alà japonicus Schmidt (1930b: 102, pl. 6, fig. 3) (Riu Kiu
Islands).


*Teuthis japonicus* Fowler (1946: 197).

*Teuthis glauco-pareius* Fowler (1949: 103) (Jarvis Island).

*Acanthurus sp.* one Harry (1953: 149) (Maroa, Tuamotu Archipelago).

Dorsal rays IX, 28 to 31; anal rays III, 26 to 28; pectoral rays 16; anterior gill rakers 17 to 19; posterior gill rakers 18 to 20 (raker counts from specimens from the Phoenix Islands); 80 mm., 108 mm., and 133 mm. specimens have 10 upper and 10 lower teeth; 153 mm. and 171 mm. specimens have 10 upper and 12 lower teeth.

Depth of body 1.7 to 1.85 in standard length; caudal concavity 10 to 14.5 in standard length; width of mouth from rictus to rictus 4.5 to 5.3 in head length; length of snout 4 to 4.3 in standard length.

Color (in alcohol) dark purplish brown; a whitish elliptical area below and adjacent to eye; a pale line under chin extending and narrowing about one-half eye diameter in distance above rictus; no pale area around caudal spine and no white mark on opercle; caudal fin abruptly yellowish white with a pale yellow band (the posterior edge of which is bordered with a narrow dark line), about one-fourth to one-third the diameter of the eye in width, in outer part of fin paralleling posterior margin; dorsal and anal fins colored like body except basally where there is a prominent pale yellowish white (yellow in life) band which broadens posteriorly in fin to about three-fourths the length of the last few rays; dorsal and anal fins with a narrow white margin and a black submarginal line; rays of pectoral fin dusky, membranes clear; pelvic fins dark with narrow pale outer margin.
Table 13 Variation in Fin Ray Counts of Specimens of
Acanthurus glaucopareius from Different Localities

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</tbody>
</table>

Marshall (1950: 194) and Palmer (1950: 202) recorded a color form of this species which co-exists with the normal one at Cocos-Keeling Islands and Christmas Island, respectively, in the Indian Ocean. The salient feature of this form is the lack of the usual sharp dividing line in color at the caudal flexure. There is a gradual blending of dark body color and pale caudal color over the proximal one-third of the fin. Also the dorsal and anal fins are paler.

Schmidt (1930b: 102, pl. 6, fig. 3) described a subspecies, Acanthurus
glaucopareius japonicus, from the Riu Kiu Islands which Fowler (1946: 197) elevated to species rank. Aoyagi (1943: 210), however, observed this form occurring with the typical Acanthurus glaucopareius in the Riu Kiu and found intermediates between the two. I examined a 90 mm. specimen of the japonicus form at the Academy of Natural Sciences of Philadelphia. It differs from the normal glaucopareius chiefly in having a broad pale band running from the eye to the posterior half of the upper lip and a large pale spot at the base of the pectoral fin. There are no obvious meristic differences; the counts of this specimen are: D IX, 28; A III, 26; P 16; 10 upper teeth; 10 lower teeth.

Acanthurus glaucopareius, Acanthurus achilles, and Acanthurus leucosternon stand apart from other species of the genus principally in having a produced snout, a small mouth with few, relatively large teeth of distinctive structure, a high body, dark purplish color, and a white line on the chin. Also, at least in A. achilles and A. glaucopareius, the size at transformation from the acronurus to the juvenile stage is very large, about 55 to 60 mm. in standard length. These differences would probably warrant recognition of this group as a subgenus were it not for Acanthurus pyroferus which links these three to other species of Acanthurus.

The largest specimen of A. glaucopareius examined by me measures 171 mm. in standard length. It was collected from Enderbury Atoll in the Phoenix Islands.

Acanthurus glaucopareius appears to be absent from the Indian Ocean except for Christmas and Cocos-Keeling Islands. It occurs in the East Indies and Philippine Islands and is recorded from most of the island groups of the tropical Pacific. It is one of the three
Plate III

Acanthurus glaucopareius, Gilbert Islands

Acanthurus achilles, Hawaiian Islands
species of *Acanthurus* to have crossed the eastern Pacific barrier; it seems to be common in the waters of the Galapagos Islands, Cocos Island, and the Revillagigedo Islands (Mexico). It is usually abundant where it is found; however it is probably the rarest of the species of surgeon fishes in the Hawaiian Islands.

In atolls of the Gilbert Islands, *A. glaucopareius* was most commonly seen on the coralliferous terrace of the outer reef, especially near the entrances to surge channels; however, it was often observed in coral-rich areas of more sheltered waters.

Many authors have used the name *Acanthurus alisala* Lesson (1830) for this species. It is true that the name *glaucopareius* does not appear on page 212 of Bloch and Schneider (1801) even though a description which fits this species can be found on this page in a separate section under the heading *Acanthurus nigriance*. Cuvier's listing (1829: 224) of *Acanthurus glaucopareius* and reference to the work of the pre-Linnaean author Seba (1758) who figured the species, however, clearly predates Lesson.

*Acanthurus achilles* Shaw

Figs. 9 k, 10 n; Pl. III

*Acanthurus Achilles* Shaw (1803: 383) (no locality); Cuvier and Valenciennes (1835: 218).

*Acanthurus achilles* Günther (1861: 340) (China); Günther (1873: 115, pl. 71, fig. B) (Polynesia); Waite (1897: 188) (Funafuti, Ellice Islands); Steindachner (1901: 493) (Honolulu); Jordan and Jordan (1922: 65) (Hawaiian Islands); Herre (1927: 414, pl. 2, fig. 1) (Guam); Schultz (1943: 162) (Phoenix and Samoa Islands); Schultz and Woods in Schultz *et al* (1953: 629, pl. 65, fig. B) (Marshall
Islands); Harry (1953: 147) (Raroia, Tuamotu Archipelago).

*Acanthurus aterrimus* Günther (1873: 114, pl. 77, fig. B) (Samoa).

*Acanthurus formosus* Castelnau (1873: 104) (Torres Straights); Macleay (1881: 528).

*Teuthis achailes* Fowler (1899: 494) (Caroline Islands); Jenkins (1903: 475) (Hawaiian Islands).

*Hepatus achailes* Jordan and Evermann (1905: 384, pl. 58) (Honolulu); Jordan and Seale (1906: 350) (Samoa); Fowler (1928: 273) (Oceania); Fowler and Bean (1929: 247) (Fanning Island, Samoa, and Hawaiian Islands); Fowler (1938: 104, 184) (Takaroa, Tuamotu Archipelago and Tongareva).

*Hepatus aterrimus* Jordan and Seale (1906: 351); Fowler (1928: 268) (Society Islands); Fowler and Bean (1929: 243).

*Teuthis aterrimus* Fowler (1929: 103).

Dorsal rays IX, 29 to 33; anal rays III, 26 to 29; pectoral rays 16; anterior gill rakers 16 to 20; posterior gill rakers 18 to 20 (raker counts from specimens from the Phoenix Islands); 84 mm., 140 mm., and 155 mm. specimens have 8 upper and 10 lower teeth; a 185 mm. specimen has 10 upper and 12 lower teeth.

Depth of body 1.75 to 1.9 in standard length; caudal concavity 5.5 to 8 in standard length; width of mouth from rictus to rictus 4.5 to 6 in head length; length of snout 3.9 to 4 in standard length.

Color (in alcohol) blackish brown with a large oval pale yellow (orange in life) area extending forward from rear of caudal spine; broad median portion of opercular membrane snow white; pale line on chin ending at rictus; basal one-third of caudal fin dark like body; next one-third of fin light orangish brown, bordered posteriorly with
a prominent black band which follows the contour of the hind edge of the fin; outer one-fourth to one-third of caudal fin white; dorsal and anal fins colored like body except for a pale line at the base which is only slightly broader posteriorly than anteriorly and a narrow white margin; pectoral rays black, membranes pale; pelvics dark brown with outer margins white.

The large elliptical orange spot on the posterior part of the body of *A. achilles* does not appear until a standard length of about 65 to 70 mm. is attained. Günther (1873) described a juvenile *A. achilles* which had not yet developed its orange spot as a new species, *A. aterrimus*. Schultz (1943: 162) corrected this error.

Table 14. Variation in Fin Ray Counts of Specimens of *Acanthurus achilles* from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>29 30 31 32 33</td>
<td>26 27 28 29</td>
</tr>
<tr>
<td>Marshall Islands</td>
<td>2 10 12 7</td>
<td>1 7 14 9</td>
</tr>
<tr>
<td>Gilbert Islands</td>
<td>4</td>
<td>1 3</td>
</tr>
<tr>
<td>Samoa Islands</td>
<td>6 10 16</td>
<td>4 13 15</td>
</tr>
<tr>
<td>Phoenix Islands</td>
<td>1 3 5 2</td>
<td>3 6 2</td>
</tr>
<tr>
<td>Line Islands</td>
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<td>Walden Island</td>
<td>1 1 1</td>
<td>3</td>
</tr>
<tr>
<td>Wake Island</td>
<td>3 3 1</td>
<td>2 4 1</td>
</tr>
<tr>
<td>Hawaiian Islands</td>
<td>1 4 8 4 2</td>
<td>1 4 8 6</td>
</tr>
<tr>
<td>Johnston Island</td>
<td>8 2</td>
<td>6 4</td>
</tr>
</tbody>
</table>
The acronurus of _A. achilles_ (Fig. 9 k) reaches a large size, about 60 mm. in standard length. It is spotted with black, a characteristic which one usually associates with the acronuri of _Naso_.

_Acronurus formosus_ Castelnau may be the acronurus of _A. achilles_. It was described as having four rows of black spots and the dorsal and anal fin ray counts were high as in _achilles_. Whitley (1940: 425) selected the largest of Castelnau's specimens (62 mm. in standard length) as lectotype and figured it (fig. 42), but did not show any spots. Whitley's counts are also high (D VIII, 31?; A III, 32?). The specimen was collected from the Torres Strait which separates New Guinea from Australia. _Acanthurus achilles_ is not recorded from the East Indies, which suggests that the specimen may be the acronurus of _A. leucosternon_ which I have not seen.

_Acanthurus achilles_ is common throughout Oceania. It is not known from the Indian Ocean. With the possible exception of the specimen of _Acronurus formosus_, it appears to be absent from the East Indies. The only record of _A. achilles_ from the Philippine Islands is the listing of the name with a question mark by Elera (1895: 532). As he did not include _A. glaucopareius_ among the surgeon fishes in his catalog, it seems possible that he might have confused these two species. Herre (1927) included _A. achilles_ in his work on Philippine surgeon fishes only because he believed the species should occur there. Fowler and Bean (1929) did not find any specimens among the extensive "Albatross" collections of fishes from the Philippines and East Indies; these authors recorded the species from the Philippines on the strength of Elera's dubious record. Here (1953: 532) erred in listing _achilles_ in his checklist of fishes of the Philippines on the basis of his 1927 work. _A._
Achilles is not known from the Riu Kiu Islands or Japan. Günther (1861: 340), however, listed it from China; this record is inconsistent with the known distribution and should be checked.

Acanthurus achilles is most often found in inshore regions of moderately rough water. At atolls in the Gilbert Islands the species was frequently observed in surge channels of the windward reef.

The largest specimen seen by me is 195 mm. in standard length; it was collected at Walden Island.

For further remarks on A. achilles see discussion under A. glaucopareius.

Acanthurus olivaceus Bloch and Schneider

Figs. 9 f, 10 o, 24


Acanthurus epaurei Lesson (1830: 147, pl. 27, fig. 1) (Tahiti).

Acanthurus olivaceus Kittlitz (1834: 189, pl. 12, fig. 1) (Caroline Islands); Günther (1861: 336) (Tahiti and Fiji Islands); Günther (1873: 113) (East Indies and South Seas); Steindachner (1901: 493) (Honolulu); Jordan and Jordan (1922: 65) (Hawaiian Islands); Herre (1927: 413, pl. 12, fig. 1) (Philippine Islands); Schultz (1943: 166) (Samoa Islands); de Beaufort (1951: 154) (East Indies); Schultz and Woods in Schultz et al (1953: 632, pl. 67) (Marshall Islands).

Acanthurus humeralis Cuvier and Valenciennes (1835: 231) (Caroline Islands and Tahiti); Eydoux and Souleyet (1841: 169, pl. 2, fig. 3) (Hawaiian Islands); Bleeker (1852: 762) (Macassar, Celebes).

Ctenodon erythromelas Swainson (1839: 256) (error or emendation for
Acanthurus sparei Lesson.

Harpurus paroticus Forster (1844: 183).

Acanthurus chrysosoma Bleeker (1857: 67) (Kajeli); Günther (1861: 332); de Beaufort (1951: 165) (East Indies).

Rhombotides xanthosoma Bleeker (1865: 288) (error for chrysosoma?).

Rhombotides olivaceus Bleeker (1865: 288) (Ambon, East Indies).

Teuthis olivaceus Seale (1901: 107) (Guam); Jordan and Evermann (1902: 358, fig. 23) (Formosa); Jenkins (1903: 476) (Hawaiian Islands).

Hepatus olivaceus Jordan and Evermann (1905: 385, fig. 166); Jordan and Seale (1906: 350) (Samoa); Jordan and Richardson (1908: 270) (Cagayancillo, Philippine Islands); McCulloch (1922: 243) (Capricorn Islands, Queensland); Fowler (1928: 271) (Oceania); Fowler and Bean (1929: 231) (Philippine Islands, Okinawa, Samoa, and Hawaiian Islands); Schmidt (1930a: 556) (Riu Kiu Islands); Fowler (1931: 345) (Honolulu); Fowler (1938: 232) (Honolulu); Aoyagi (1943: 211, pl. 5, fig. 15, teeth only) (Riu Kiu Islands); Hiyama (1943: 94, pl. 20, fig. 55).

Hepatus chrysosoma Fowler (1928: 269); Fowler and Bean (1929: 214).

Dorsal rays IX, 23 to 25; anal rays III, 22 to 24; pectoral rays 16 or 17 (usually 17); anterior gill rakers 24 to 28; posterior gill rakers 23 to 27 (raker counts from Hawaiian specimens); a 44 mm. specimen has 14 upper and 14 lower teeth; a 123 mm. specimen has 14 upper and 16 lower teeth; a 138 mm. specimen has 16 upper and 18 lower teeth; a 208 mm. specimen has 18 upper and 20 lower teeth; a 225 mm. specimen has 20 upper and 21 lower teeth.

Caudal fin of adults strongly lunate, caudal concavity (in specimens greater than 180 mm. in standard length) contained 4 to 5 times
in standard length; in specimens about 100 mm. in standard length, the
caudal concavity is contained about 9 times in the standard length;
-snout length 4.5 to 4.9 in standard length; longest soft dorsal ray 5.5
to 6 in standard length; eye of 104 mm. specimen 3.3 in head length;
eye of 208 mm. specimen 4.5 in head length; caudal spine of 104 mm.
specimen 3.5 in head length; caudal spine of 208 mm. specimen 2.5 in
head length.

Large adult males (about 170 mm. or greater in standard length)
develop a definite convexity in the profile of the snout which may
permit determination of the sex of specimens without resorting to
examination of the gonads. This sexual dimorphism of large adults
is evident to a greater or less degree in the remaining Indo-West-
Pacific species considered in this work and possibly also the Atlantic
species except A. coeruleus. In most of the species the profile of
the head of the female also becomes more convex with age. Males the
same size, however, show distinctly greater convexity than females.
All of these species have a large, round, very thick-walled stomach.

Color in life from a 35 mm. Kodachrome transparency taken by
the author of a 132 mm. specimen speared at Arno Atoll, Marshall
Islands: dark grayish brown with a bright orange horizontal band,
broadly bordered with purplish black, extending posteriorly from upper
end of gill opening a distance greater than the length of the head;
a dull orange line at base of dorsal fin; a similar, but fainter, line
at base of anal fin; a large crescentic white area in centro-posterior
part of caudal fin; rest of caudal fin, especially the lobes, spotted
with dark brown; other fins colored like body except outer portion of
pectoral which is pale; a faint longitudinal banding may be seen in soft
portion of dorsal fin. Many adult specimens have been observed on which
the color of the body posterior to a vertical at about the level of the
fifth dorsal soft ray is much darker than that in front of this demarca-
tion.

Table 15 Variation in Fin Ray Counts of Specimens of

Acanthurus olivaceus from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
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<td>23</td>
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<td>3</td>
</tr>
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<td>Society Islands</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hawaiian Islands</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Johnston Island</td>
<td>1</td>
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</table>

F. W. Strasburg (45) has pointed out that the young of Acanthurus
olivaceus are yellow. From a transformation size of about 29 mm. in
standard length to a length of about 55 mm. the body color is bright
yellow. The margins (except posterior) of the median fins and lateral
outer edge of the pelvic fins are narrowly black. At a size of about
45 mm. in standard length the mark on the shoulder region first makes
Fig. 24. *Acanthurus olivaceus* (after Schultz and Woods, 1953; retouched).

Fig. 25. *Acanthurus tennentii*. Drawing by author. Locality unknown.
its appearance as a small dusky area. Specimens larger than about 55 mm. in standard length show a progressive accumulation of brown pigment until, at a standard length of about 85 mm., the brown color predominates. The shoulder bar first acquires a pale orange center at a standard length of about 55 mm.

*Acanthurus chrysosoma* Bleeker is probably the young of *Acanthurus olivaceus*. Bleeker's type specimens were 43 to 51 mm. in length. The color when fresh was orange-yellow with brownish edges on the dorsal, anal, and caudal fins.

*A. olivaceus* occurs from the East Indies to Oceania. Records from the Indian Ocean, such as from Mauritius, all appear to be the closely related *A. tennenti*.

*A. olivaceus* is usually found in fairly deep water, about 30 feet or more in depth. It is most commonly seen where much of the bottom is sandy.

*Acanthurus tennenti* Günther

Figs. 10 p, 25

*Acanthurus tennenti* Günther (1861: 337) (Ceylon); Day (1889: 140).

*Acanthurus Tennenti* Day (1876: 204).

*Acanthurus plagiatus* Peters (1876: 439) (Mauritius).

*Acanthurus olivaceus*. Sauvage (1891: 343) (Mauritius).

*Nepatus sohal*. Fowler and Bean (1929: 216) (locality unknown).

Dorsal rays IX, 23 or 24; anal rays III, 22 or 23; pectoral rays 16 (fin ray counts from 7 specimens from Mauritius and Ceylon); anterior gill rakers 25, posterior gill rakers 25 (based on one specimen); a 105 mm. specimen has 15 upper and 16 lower teeth; a 214 mm. specimen
has 20 upper and 22 lower teeth.

Caudal fin lunate, caudal concavity varying from 10 in standard length of a 105 mm. specimen to 5 in standard length of a 214 mm. specimen.

Color (in alcohol) brown with a horseshoe-shaped black mark (open end pointing anteriorly) just behind upper edge of gill opening, at level of eye (in specimens of about 120 mm. or more in standard length this mark is broken posteriorly, forming two longitudinal curved bands; in very large specimens these bands are straighter, more elongate, and attenuate posteriorly); caudal spine enclosed in a prominent black area which, in turn, is surrounded by a bluish white region. This dark area becomes progressively larger with age and its bluish white margin relatively narrower (in a 214 mm. specimen the black area was oval in shape, slightly more pointed anteriorly, 37 mm. in length and 16 mm. high; the bluish white margin was a little greater than 1 mm. in width); caudal fin with a broad crescentic white area posteriorly; large specimens with pale margins on the very elongate upper and lower caudal lobes; dorsal and anal fins brown with no trace of banding; pectoral fin brown with a broad pale posterior margin (more distinct in large specimens); pelvic fins brown.

Fowler and Bean (1929: 216) misidentified a 116 mm. specimen of this species (U.S.N.M. No. 21294) as Hematus sohal. It is this specimen which I have drawn as Figure 25. No field data or locality are available.

A. C. Wheeler kindly sent an X ray, a drawing, and other data on the type specimen in the British Museum. The specimen is 103 mm. in standard length and is conspecific with the Fowler and Bean specimen.
Peters (1876: 439) described Acanthurus plagiatus as having two elongate triangular black marks on the shoulder, a black area with blue margin around the caudal spine, and a lunate caudal fin with a broad yellow posterior margin and a narrow yellow edge on the upper and lower caudal lobes. Had I not seen the five specimens in the Museum of Comparative Zoology at Harvard College which connect the large plagiatus form to A. tennenti of a little over 100 mm. in standard length, I would have probably considered Peter's species as valid.

Acanthus tennenti is very closely related to Acanthurus olivaceus, and, with the possible exception of pectoral fin ray counts (more specimens needed), I can separate the two only by color. To my knowledge they are not known from the same area, A. tennenti occurring in the Indian Ocean and A. olivaceus in the East Indies and Oceania. Sauvage (1891: 343) (after liénard) recorded A. olivaceus from Mauritius; however, he described it as having two oblong black marks on the supra-scapular region, thus indicating that he had a large specimen of A. tennenti. It is possible that the distinction between A. olivaceus and A. tennenti is subspecific; however, the color differences as noted in the key are greater than those seen on other similar pairs of acanthurids (such as Acanthus xanthopterus and Acanthus mata) which may be observed together.

Acanthus fwlieri de Beaufort

Fig: 10 q; Pl. IV


Hepatus pyroferus. Fowler and Bean (non Kittlitz) (1929: 232) (Philippine Islands and East Indies).
Acanthurus fowleri de Beaufort (1951: 149) (after Fowler and Bean).

Dorsal rays IX, 27; anal rays III, 25 or 26; pectoral rays 15 or 16; anterior gill rakers 23 to 25; posterior gill rakers 29 to 32. All counts based on five specimens from the Philippine Islands. A 165 mm. specimen has 17 upper and 18 lower teeth; a 270 mm. specimen has 18 upper and 20 lower teeth.

A 165 mm. specimen has a body depth which is contained 1.9 times in standard length, a snout length which is 4.4 in standard length, a caudal concavity which is 4.9 in standard length, an eye diameter which is 4.7 in head length, and a caudal spine length which is 3.7 in head length. A 270 mm. specimen has a body depth which is contained 2.3 times in standard length, a snout length which is 4.65 in standard length; a caudal concavity which is 4.4 in standard length, an eye diameter which is 5.7 in head length, and a caudal spine length which is 2.3 in head length.

Color (in alcohol) brown with numerous fine longitudinal pale lines on body which are about equal in width to the dark interspaces; a black triangular or horseshoe-shaped mark on shoulder region, the upper end of which is just above upper end of gill opening and the lower end approaches the upper part of the axil of the pectoral fin (the width of the band forming this mark is about one-half the diameter of the pupil of the eye); sheath of caudal spine and a broad margin around socket of spine black; base of caudal fin abruptly pale; upper and lower lobes of caudal slightly lighter than dark brown center of fin; pectoral fins brown with a large pale yellow spot in outer upper part; dorsal, anal, and pelvic fins brown.

Fowler and Bean (1929) were in error in calling this species Hepatus
pyroferus (Kittlitz). De Beaufort (1951) realized this and proposed the name *Acanthurus fowleri*. Fowler and Bean give two detailed color descriptions for the species (1929: 233).

Herre (1927: 411) included in *Acanthurus bariene* a 240 mm. specimen from Bantayan Island which had a violet-black line encircling an area on the shoulder more than twice the size of the eye, the caudal fin with a bluish white ring at the base and the central part black, and the caudal spine in a black spot. Probably he was describing a specimen of *A. fowleri*.

*Acanthurus fowleri* is unknown outside the Philippine-East Indian region.

*Acanthurus bariene* Lesson

Fig. 10 r; Pl. IV

*aicanthurus bariene* Lesson (1830: 150) (Waigiu Island = Waigao Island, New Guinea).

*Acanthurus nummifer* Cuvier and Valenciennes (1835: 234); Günther (1861: 338).

*Acanthurus kingii* Bennett, E. T. (1835g: 119) (Port Praya).

*Rhombotides nummifer* Bleeker (1868: 297).

*Hepatus bariene* Jordan and Seale (1906: 352); Fowler and Bean (in part) (1929: 222) (Philippine Islands); Aoyagi (1943: 212, pl. 5, fig. 11, teeth only) (Okinawa).

*Acanthurus bariene* Herre (in part) (1927: 409, pl. 1, fig. 2) (Philippine Islands); Smith (in part) (1949: 240) (Mozambique); de Beaufort (1951: 153).

Dorsal rays IX, 26 to 28; anal rays III, 25 to 26; pectoral rays
17 (fin ray counts based on six specimens from the Philippines); anterior gill rakers 19 to 23; posterior gill rakers 22 to 24 (raker counts from Philippine specimens); a 167 mm. specimen has 18 upper and 20 lower teeth; a 290 mm. specimen has 21 upper and 22 lower teeth.

Depth of body 1.9 to 2 in standard length; caudal concavity varying from 6.7 in standard length of 167 mm. specimen to 3.7 in standard length of 290 mm. specimen; longest dorsal ray varying from 4.9 in standard length of 167 mm. specimen to 5.3 in standard length of 290 mm. specimen.

Color (in alcohol) brown with numerous fine bluish gray longitudinal lines faintly visible on side of body; a round black spot, with a diameter about two-thirds that of eye, just above upper end of gill opening at level of eye (in some specimens this spot has a narrow pale blue margin); a dark brown area, about twice as high as maximum width of caudal spine, surrounding caudal spine; base of caudal fin abruptly pale, this pale region shading out a short distance on caudal lobes; central and posterior part of caudal fin brown; dorsal fin brownish yellow with narrow blue marginal and black submarginal lines, traces of dark longitudinal lines in outer part of fin, and a dark brown line at the base with a bluish gray line adjacent and distal to it; paired fins brown; opercular membrane dark brown.

H. W. Fowler and others have erred in applying the name *bariens* to the species *Acanthurus dussumieri* Cuvier and Valenciennes.

*Acanthurus bariens* appears to range from East Africa to the Riu Kiu Islands.
Acanthurus gahna (Forskal)

Fig. 10 s; Pl. IV

Chaetodon nigro-fuscus var. Gahna Forskal (1775: xiii, 64) (Red Sea).

Chaetodon Gahna Linnaeus and Gmelin (1788: 1268).

Acanthurus gahna Cuvier and Valenciennes (1835: 219) (Red Sea and Mauritius); Günther (1861: 338); Klunzinger (1871: 506) (Red Sea); Günther (1873: 113, pl. 74) (Red Sea to the South Seas); Weber (1913: 318) (Saleyar, East Indies); Herre (1927: 411, pl. 12, fig. 2) (Philippine Islands); Herre (1936: 241) (Bora Bora and New Hebrides).

Acanthurus gahna Bleeker (1858: 8) (Macassar, Celebes); de Beaufort (1951: 150) (East Indies).

?Acanthurus gahnoides Quichonot (1862: c. 8) (Réunion).

Rhombotides gahna Bleeker (1865: 238) (Ambon, East Indies).

Acanthurus (Rhombotides) gahna Klunzinger (in part) (1884: 84) (Red Sea).

Hepatus nigricans. Jordan and Seale (1906: 351) (Samoa); Fowler (1923: 386) (Honolulu?); Fowler (1928: 272) (Oceania); Fowler and Bean (in part) (1929: 233) (Philippine Islands, East Indies, and Fiji).

Acanthurus gahna nigricauda Duncker and Mohr (1929: 75) (South Seas).

Acanthurus nigricans. Schultz (1943: 166) (Phoenix and Samoa Islands); Smith (1949: 240, pl. 36, no. 612) (east coast of Africa south to Durban); Schultz and Woods in Schultz et al (1953: 633, pl. 68) (Marshall and Mariana Islands); Harry (1953: 148) (Karofa, Tuamotu Archipelago).

Hepatus nigrofuscus. Hiyama (1943: 94, pl. 20, fig. 56).

Dorsal rays IX, 25 to 28; anal rays III, 23 to 26; pectoral rays 17; anterior gill rakers 20 or 21; posterior gill rakers 20 to 26 (raker counts from Philippine specimens); a 25 mm. specimen has 14 upper and
14 lower teeth; a 46 mm. specimen has 15 upper and 16 lower teeth; a 74 mm. specimen has 16 upper and 16 lower teeth; a 135 mm. specimen has 16 upper and 18 lower teeth; a 170 mm. specimen has 17 upper and 19 lower teeth; a 195 mm. specimen has 18 upper and 20 lower teeth; a 226 mm. specimen has 19 upper and 22 lower teeth. The number of denticulations on the teeth decrease with age (see Table 17).

Table 16 Variation in Fin Ray Counts of Specimens of
Acanthurus gahhm from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 26 27 28</td>
<td>23 24 25 26</td>
</tr>
<tr>
<td>Mauritius</td>
<td>1 1</td>
<td>1 1</td>
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<tr>
<td>New Guinea</td>
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<tr>
<td>Philippine Islands</td>
<td>1 4 3</td>
<td>1 4 3</td>
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<tr>
<td>Okinawa</td>
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<td>1</td>
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<tr>
<td>Palau Islands</td>
<td>3 4 1</td>
<td>1 4 3</td>
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<tr>
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<td>Mariana Islands</td>
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<td>1 2 1</td>
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<td>4 3</td>
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<td>4 7 1</td>
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<td>Samoa Islands</td>
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<td>Phoenix Islands</td>
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<tr>
<td>Society Islands</td>
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</tr>
</tbody>
</table>
Table 17  The Change in the Number of Denticulations on the Teeth of Specimens of \textit{Acanthurus gahhm} of increasing Standard Length.

<table>
<thead>
<tr>
<th>Standard length (mm.)</th>
<th>Number on upper teeth</th>
<th>Number on lower teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>35</td>
<td>15 - 16</td>
<td>11</td>
</tr>
<tr>
<td>42</td>
<td>15 - 16</td>
<td>11 - 12</td>
</tr>
<tr>
<td>48</td>
<td>14 - 15</td>
<td>10 - 11</td>
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<tr>
<td>57</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>75</td>
<td>12 - 13</td>
<td>9</td>
</tr>
<tr>
<td>115</td>
<td>10 - 11</td>
<td>8</td>
</tr>
<tr>
<td>135</td>
<td>9 - 10</td>
<td>8</td>
</tr>
<tr>
<td>168</td>
<td>9</td>
<td>7 - 8</td>
</tr>
<tr>
<td>191</td>
<td>7 - 8</td>
<td>7 - 8</td>
</tr>
</tbody>
</table>

Caudal fin progressively more lunate with age, caudal concavity 6.5 in standard length of 76 mm. specimen and 3.6 in standard length of 237 mm. specimen; depth of body varying from 1.9 in standard length of 76 mm. specimen to 2.2 in 237 mm. specimen; snout length 4.3 to 4.5 in standard length; caudal spine 7.5 in head length of 76 mm. specimen, 4.5 in head length of 237 mm. specimen.

Color (in alcohol) brown, without lines on the body or spots on the head; a horizontal black band (usually rounded posteriorly) running backward from upper edge of gill opening (this band first appears in specimens about 55 to 60 mm. in standard length; on a 96 mm. specimen the length of the band is contained 7.6 times in the standard length;
on a 237 mm. one the band is 5.5 in the standard length); a long lanceolate black line extending anteriorly from caudal spine (this line does not appear until a standard length of about 100 mm. is attained; it becomes relatively longer in larger specimens and may reach half way from the caudal spine to the base of the pectoral fin on large specimens); caudal fin brown with prominent pale posterior margin (caudal fin of young entirely pale) which is broader in middle portion of fin, but narrows and disappears on caudal lobes (greatest width of posterior caudal margin of 96 mm. specimen contained 3.5 times in diameter of eye; greatest width of margin in 237 mm. specimen 4 in eye); base of caudal fin usually abruptly pale; outer one-third of pectoral fin pale (the inner half of this pale portion yellow in life); remaining fins brown.

Hiyama (1943: pl. 20, fig. 26) has figured the species [erroneously labelled Hepatus nigrofuscus (Forskal)] in the usual brown color form. Herre (1927: pl. 12, fig. 2) and Smith (1949: pl. 36, no. 612) have portrayed a bluish form with yellow dorsal and anal fins. Herre noted and figured an elongate dark blue spot on the nape anterior to the origin of the dorsal fin. He observed a living specimen in an aquarium which varied in color at different times from grayish blue to brownish gray. A specimen in the blue color phase with yellow fins was collected at Wake Island by W. A. Gosline and myself. It was not as light a blue as figured by Herre and by Smith but was dark purplish gray in color. An elongate purple mark was clearly visible just in front of the origin of the dorsal fin.

Forskal (1775: 64) listed gahhm as a variety of Chaetodon nigrofuscus. His description is incomplete, but it applies to the species as here
interpreted better than any other known Red Sea species of the genus. The color of the fish was given as black with the base of the caudal fin violet and the hind margin of the pectoral fin yellow.

Many recent authors have used the specific name nigricans for Acanthurus gahhm. Chaetodon nigricans Linnaeus, however, appears to be a species of Naso. The species described by Hasselquist (1757: 332), to which Linnaeus refers in his listing of Chaetodon nigricans, is definitely a Naso.

Acanthurus gahhm ranges from East Africa to Oceania. It is known from most of the island groups in Oceania. There is only one record from the Hawaiian Islands, that of Fowler (1923: 386) who used the name Hepatus nigricans for the species. He included no descriptive information with the record, and I have been unable to locate his specimen(s). One adult specimen of Acanthurus olivaceus from Johnston Island in the Bishop Museum was identified as Hepatus nigricans by Fowler. It is possible that the single Hawaiian record is a misidentification.

At Onotoa Atoll in the Gilbert Islands, adult Acanthurus gahhm were commonly seen around isolated coral heads in sandy regions of the lagoon, and the young were abundant in lagoon tide pools. No juvenile or adult individuals were observed in outer reef areas.

**Acanthurus maculiceps** (Ahl)

Fig. 10 t; Pl. IV

*Hepatus maculiceps* Ahl (1923: 36) (Talassia, New Britain); Fowler (1928: 269); Fowler and Bean (1929: 240, fig. 13) (Philippine Islands and East Indies); Aoyagi (1943: 212, text fig. 53, pl. 4, fig. 10) (Okinawa).

*Hepatus nigricans*. Fowler and Bean (in part) (1929: 233) (Cebes).
Acanthurus maculiceps de Beaufort (1951: 152).

Dorsal rays IX, 24 to 26, anal rays III, 23 or 24; pectoral rays 16; anterior gill rakers 19 to 23; posterior gill rakers 21 to 24 (raker counts from Philippine specimens); a 182 mm. specimen has 17 upper and 20 lower teeth; a 222 mm. specimen has 18 upper and 20 lower teeth.

**Table 18 Variation in Fin Ray Counts of Specimens of Acanthurus maculiceps from Different Localities**

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 25 26</td>
<td>22 23 24</td>
</tr>
<tr>
<td>East Indies</td>
<td>2 1</td>
<td>2 1</td>
</tr>
<tr>
<td>Philippine Islands</td>
<td>1 6 3</td>
<td>2 5 3</td>
</tr>
<tr>
<td>Gilbert Islands</td>
<td>1 1</td>
<td>2</td>
</tr>
</tbody>
</table>

Body depth 2 to 2.1 in standard length; caudal concavity varying from 5.7 in standard length of 182 mm. specimen to 3.5 in standard length of 228 mm. specimen; longest dorsal ray 5.4 to 5.5 in standard length; caudal spine 3.1 to 3.2 in head length.

Color (in alcohol) brown with numerous longitudinal paler brown lines on body (difficult to see on some specimens); a black bar, slightly greater than eye diameter in length, extending backward from upper edge of gill opening and often ending in a slight point; a second dark mark, less intense than the first and about the size of the pupil of the eye, just behind eye and often connected narrowly with the black bar; head with numerous pale spots (in average diameter slightly less than half the diameter of the pupil); all fins brown except for a vertical light
gray band at base of caudal fin and pale yellow on outer third of upper.
six branched pectoral rays; nine dark brown longitudinal bands usually
visible in dorsal fin; a very dark brown line, which is wider posteriorly,
at base of dorsal fin; region around caudal spine dark brown.

The specimen shown in color in Plate IV was collected from Binang
Unang Island, Celebes, by the "Albatross" Expedition. It was misiden-
tified as *Hepatus nigricans* by Fowler and Bean (1929: 236).

*Acanthurus maculiceps* is known at the present time only from the
East Indies, Philippines, Riu Kiu Islands, and the Gilbert Islands.

A 193 mm. specimen collected by the author on Onotoa Atoll in the
Gilbert Islands was speared at a depth of about 20 feet on the coral-
liferous terrace of the outer reef.

*Acanthurus auranticavus* Randall

Figs. 10 u, 26

*Hepatus nigrofuscus*. Fowler and Bean (in part) (non Forskal) (1929: 237)
(Philippine Islands and East Indies).

*Acanthurus auranticavus* Randall (in press, a) (Philippine Islands and
East Indies).

Dorsal rays IX, 25 or 26; anal rays III, 23 or 24 (usually 24);
pectoral rays 16 or 17; anterior gill rakers 20 to 23; posterior gill
rakers 24 to 28; scales from gill opening to posterior end of caudal
spine 195 to 233; number of upper 18 or 19; number of lower teeth 18
to 20.

Depth of body 2 to 2.15 in standard length; length of snout 4.6
to 5 in standard length; longest dorsal ray 5.2 to 6.5 in standard length;
caudal concavity 4.2 to 6.8 in standard length; diameter of eye 3.5 to
4.5 in head length; length of caudal spine 2.2 to 4.5 in head length. All counts and proportional measurements from the holotype and five paratypes, 144 to 217 mm. in standard length.

Color in life of specimens including the holotype (identified by "Albatross" field number) from Fowler and Bean (1929: 236): "Dark brown, sometimes with slate; on fading side shows narrow brown lines with blue-white interspaces as in Ctenochaetus strigosus. Breast from pectoral base downward washed orange brown. Caudal spine with bright orange socket. Orange blotch before and behind pupil. Dull obscure orange stripe from eye through nostrils across frontal region. No shoulder blotch. Dorsal slate-gray or almost black basally, and in alcohol few narrow bars appear on hind terminal portion. Anal like dorsal, without dark base and edge narrowly bright blue. Caudal slate, without white tip but white band across base. Pectoral slate, tips somewhat olive yellow. Ventral slate, with slight yellowish dash at tips of last rays."

Color in life of paratype from Buang Bay, Talajit Island from Fowler and Bean (1929: 240): "Body very finely striped with purplish blue and olive. Front and side of head brown becoming blackish on vertical flap. Very short dark blotch behind upper angle of gill opening. Breast mostly dusky, also with orange shades. Fins dull violaceous, dorsal edge somewhat purplish with submarginal translucent bar; anal margin bright purple. White band across caudal base. Caudal spine with orange socket. Paired fins olive or black, without marks or color variation."

Color (in alcohol) brown with about 55 slightly wavy bluish gray longitudinal lines on body (faded in some specimens) which tend to
Fig. 26. *Acanthurus auranticavus*. Drawing by Aime M. Awl, United States National Museum.

Fig. 27. *Acanthurus grammoptilus*. Photograph of preserved specimen by Frederick M. Bayer, United States National Museum.
converge posteriorly on caudal spine; a dark brown bar (1.3 eye diameters in length, in the holotype) on shoulder region which is restricted in width as it passes upper end of gill opening; shoulder bar tilted downward so that a line bisecting it passes from the center of the eye to the base of the 18th anal ray; caudal fin yellowish brown with a chalky white bar at base; dorsal fin yellowish brown with a dark brown band at base (broader posteriorly) and an indistinct narrow dark outer margin; anal fin grayish brown with a faint bluish white band at base and an indistinct narrow dark outer margin; pectoral fins yellowish brown; pelvic fins grayish brown; socket of caudal spine and a margin around the socket as wide as half the width of the spine orange-brown.

The shoulder blotch in this species is not black as in Acanthurus gahna and Acanthurus maculiceps but dark brown or orange brown. On some specimens it can be perceived only with difficulty.

Acanthurus auranticavus appears to be most closely related to Acanthurus maculiceps from which it differs primarily in shape and color of the shoulder blotch and lack of pale spots on the head; there is no large pale area on the pectoral fin, nor are there prominent bands in the dorsal and anal fins. Also the posterior gill rakers are more numerous in A. auranticavus.

The species is named auranticavus in reference to the orange socket of the caudal spine.

I have seen specimens only from the Philippine Islands and the East Indies.

Acanthurus grammoptilus Richardson

Figs. 10 v, 27

Acanthurus grammoptilus Richardson (1843: 176) (Port Essington, N.)
Australia); Bleeker (1855: 11) (van Diemensland, N. Australia); Gönther (1861: 335); Macleay (1878: 354) (Port Darwin, N. Australia); Macleay (1881: 528).

**Hepatus nigrofuscus.** Fowler and Bean (in part) (1929: 237) (Mansalay, Mindoro, Philippine Islands).

Dorsal rays VIII or IX (one specimen with VIII, four with IX), 25 or 26; anal rays III, 23 or 24; pectoral rays 16 or 17; anterior gill rakers 16 to 18; posterior gill rakers 21 to 23; a 93 mm. specimen has 14 upper and 18 lower teeth; a 205 mm. specimen has 18 upper and 20 lower teeth; a 245 mm. specimen has 18 upper and 20 lower teeth. All counts based on five specimens from Arnhem Land, northern Australia.

Body depth varying from 1.9 in standard length of a 93 mm. specimen to 2.5 in a 245 mm. specimen; caudal concavity 6.3 to 7.7 in standard length; head length 3.4 to 3.7 in standard length; pectoral fin 3.3 to 3.4 in standard length; pelvic fin 3.6 to 4.3 in standard length; length of snout 4.4 to 4.5 in standard length; length of longest dorsal ray 5 to 5.5 in standard length; interorbital space 3.1 to 3.2 in head length; diameter of eye 3.5 in head length of 93 mm. specimen, 5.2 in head length of 245 mm. specimen.

Color (in alcohol) of 245 mm. Arnhem Land specimen brown with narrow light brown longitudinal undulating lines faintly visible on the sides; caudal spine surrounded by a very dark brown area which extends anterior to the spine a distance greater than one eye diameter; base of caudal fin white; rest of fin brown except posterior margin which is narrowly pale; pectoral fin with outer one-third pale, basal two-thirds brown; a light brown area behind eye, outlined by a narrow dark line; five acuminate light brown bands projecting forward from eye
and separated by dark brown lines; remainder of head brown with pale brown spots; dorsal and anal fins brown with a narrow dark brown border and traces of narrow dark brown bands in distal part of soft portion of these fins; five narrow dark brown longitudinal bands barely visible in spinous part of dorsal fin; a dark brown band at base of dorsal fin; pelvic fins brown; opercular membrane dark brown. At the upper end of the gill opening there is a faint dark brown elongate blotch which extends posteriorly a distance almost equivalent to an eye diameter.

The 93 mm. Arnhem Land specimen differed from the above in having fewer lines on the body, a wider pale posterior border to the caudal fin (about one-third pupil diameter in width), a narrower dark margin around the caudal spine which does not extend anterior to spine, more prominent bands in the dorsal and anal fins, and no dark brown band at the base of the dorsal fin. The color of this specimen in life (from field notes of R. R. Miller who collected the Arnhem Land specimens in 1942) was brown with a white band across the base of the caudal fin and a white posterior margin to the fin. Rust-colored spots, blotches, and wavy lines were present on the head and nape; the pectoral fin was yellowish, and there was a narrow blue margin on the anal fin.

A. C. Wheeler has kindly provided information on two of Richardson's specimens (actually half skins) of A. grammoptilus, the larger of which (labelled Coral Bay, Port Essington, Nov. 1840, No. 13 and bearing British Museum No. 1843.6.15.38) is 191 mm. in standard length and evidently formed the basis for Richardson's description. Günther (1861: 335) listed these skins as types. I designate the larger as lectotype.

Richardson's description plus data from Wheeler to the effect that
the larger specimen has a depth of 86 mm., 18 or 19 teeth in the jaws, inconspicuous dark streaks in the dorsal and anal fins, a dark area around the caudal peduncle spine, faint longitudinal lines on the body, no black spot at axil of dorsal or anal fins (Günther was in error in reporting these), and a pectoral fin which is darker basally leave no doubt that the species is valid and that the Arnhem Land specimens which I examined are the same.

A 204 mm. specimen in the United States National Museum from Mindoro, Philippine Islands (misidentified as *Hepatus nigrofuscus* by Fowler and Bean, 1929) appears to be *Acanthurus grammoptilus*. A color note given by Fowler and Bean (1929: 239, “Albatross” No. 6167) is as follows: “No trace of black shoulder mark. More or less orange below caudal spine. Dorsal and anal edged blue. Caudal with very narrow pale edge behind. Pectoral edge yellow.” In spite of word to the contrary, there is a faint dark brown shoulder mark. It extends posteriorly from the upper edge of the gill opening a distance equivalent to about one and one-half eye diameters. The mark is not black and could have been overlooked in the field. Surrounding the caudal spine and projecting anterior to it is a reddish brown area. This area is rounded anteriorly like the comparable dark brown region in front of the caudal spine of the large Arnhem Land specimen. The outer one-fourth of the pectoral fin is pale. There is a dark brown band at the base of the dorsal fin and a narrow dark brown margin. The margin of the anal fin is dark blue.

Counts of this specimen are: D IX, 26; A III, 24; P 17; anterior gill rakers 22; posterior gill rakers 24; 17 upper teeth; 20 lower teeth (the end ones tiny).

An Arnhem Land specimen of the same length as the Philippine one
provided a basis for comparison of proportional measurements (although the Philippine specimen is a male with the typical highly convex forehead and the Arnhem Land one a female). The Philippine fish has a shorter body (depth 2.2 in standard length, instead of 2.4), a shorter head (3.9 in standard length instead of 3.4), a shorter snout, a longer caudal spine, and a smaller eye. With so few specimens available and the differing sex of the two in question, it is difficult to assess these differences. Even if it could be demonstrated that the measurements of the Philippine specimen are not within the range of variability of Australian *A. grammoptilus*, the problem of deciding whether the differences are subspecific and reflect the geographic separation of the Philippines from Australia would still remain unsolved. In view of the similarity in color pattern, I prefer to regard the Philippine and Arnhem Land specimens as conspecific.

McCulloch (1918) erroneously used the name *grammoptilus* for the species *Acanthurus dussumieri*. Fowler and Bean (1929) applied the name to specimens of *A. dussumieri* and *A. xanthurus*.

*Acanthurus dorensis* Cuvier and Valenciennes may be a specimen of *A. grammoptilus* with abnormal fin ray counts (see discussion under the heading, Doubtful Species).

*Acanthurus dussumieri* Cuvier and Valenciennes

Figs. 9 h, 10 w; Pl. IV

*Acanthurus Dussumieri* Cuvier and Valenciennes (1835: 201) (*Mauritius*).
*Acanthurus undulatus* Cuvier and Valenciennes (1835: 205) (*Indian Ocean*);
Günther (1861: 335).
*Acanthurus Lamarrii* Cuvier and Valenciennes (1835: 236) (*Mauritius*).
*Acanthurus dussumieri* Günther (1861: 335); Günther (1873: 112, pl. 14,
fig. 3) (Hawaiian Islands); Sauvage (1891: 337) (Madagascar);
Steindachner (1901: 493) (Honolulu); Jordan and Jordan (1922: 65)
(Hawaiian Islands); Herre (1927: 425, pl. 14, fig. 3) (Philippine
Islands); de Beaufort (1951: 155).
Acanthurus matoides Var. b. Playfair in Playfair and Gönther (1866:
56) (Zanzibar).
Rhombotides dujsumieri Bleeker in Bleeker and Polyen (1874: 96)
(Mauritius).
Rhombotides Lamarck Bleeker in Bleeker and Polyen (1874: 96) (Mauritius).
Teuthis dujsumieri Jordan and Evermann (1902: 357) (Formosa); Jenkins
(1903: 477) (Honolulu).
Hepatus dujsumieri Jordan and Evermann (1905: 390, fig. 167) (Hawaiian
Islands); Jordan and Seale (1906: 351); Aoyagi (1943: 214, text fig.
54, pl. 5, fig. 14) (Riu Kiu Islands).
Teuthis grammoptilus. McCulloch (1918: 92, pl. 28) (Clarence River and
Masthead Island, New South Wales).
Hepatus bariene. Fowler (1928: 270, pl. 31, fig. C) (Hawaiian Islands);
Fowler and Bean (in part) (1929: 222) (Philippine Islands).
Hepatus grammoptilus. Fowler and Bean (in part) (1929: 225) (Philippine
Islands and East Indies).
Acanthurus bariene. Smith (in part) (1949: 240, pl. 33, no. 613) (east
coast of Africa south to Delagoa Bay).

Dorsal rays IX (one specimen found with VIII), 25 to 27; anal rays
III, 24 to 26; pectoral rays 16 or 17 (usually 17); anterior gill rakers
22 to 26; posterior gill rakers 23 to 27 (see Table 21); a 48 mm. speci-
men has 14 upper and 14 lower teeth; a 61 mm. specimen has 16 upper and
18 lower teeth; a 94 mm. specimen has 17 upper and 18 lower teeth; a 132
mm. specimen has 19 upper and 20 lower teeth; a 325 mm. specimen has 20 upper and 22 lower teeth.

Table 19 Variation in Fin Ray Counts of Specimens of Acanthurus dussumieri from Different Localities

<table>
<thead>
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<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
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<td>24  25  26</td>
</tr>
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<td>3</td>
</tr>
<tr>
<td>Philippine Islands</td>
<td>2  8  2</td>
<td>1  10  1</td>
</tr>
<tr>
<td>Formosa</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Okinawa</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hawaiian Islands</td>
<td>4 10 3</td>
<td>2 10 5</td>
</tr>
</tbody>
</table>

Depth of body (in specimens 110 to 214 mm. in standard length) about 1.9 in standard length (nearly 2.1 in specimens greater than 300 mm. in standard length); caudal concavity varies from 14 in standard length in a 110 mm. specimen to about 7 to 9 in specimens 167 to 214 mm. in standard length to about 5 or less in specimens over 300 mm. in standard length; length of snout 4.2 to 4.6 in standard length; length of caudal spine 3. to 5 in head length (relatively longer in larger specimens); diameter of eye 3.4 in head length of 110 mm. specimen, 4 in head length of 214 mm. specimen, and 4.7 in 300 mm. specimen.

Color (in alcohol) light brown with numerous, narrow, longitudinal, slightly wavy, purplish or bluish gray lines on body; similar but broader and more irregular lines on head (these and the body lines may fade in preserved specimens); a pale brown (yellow in life) band about as wide as the pupil diameter extending antero-dorsally from eye and often meeting
a comparable band from other side midway in interorbital space; pos-
terior edge of eye margined with a pale brown (yellow in life) area;
caudal spine largely covered by a cream sheath; socket of caudal spine
surrounded by a black area about three times as high as maximum width
of caudal spine; caudal fin light brown basally and on lobes, darker
in major median portion (deep blue in life) with numerous small brownish
black spots; dorsal and anal fins of adults light yellowish brown (yellow
in life) with traces of about two or three longitudinal dark lines
postero-distally (absent in large adults); a pale bluish gray line at
base of dorsal and anal fins; pectoral fins light yellowish brown; pel-
ic fins brown; opercular membrane black.

_Acanthurus dussumieri_ has at times been confused with _A. xanthopterus_
and _A. mata_. Adults of _A. dussumieri_ may be readily recognized by the
black spots on the caudal fin, the white caudal spine sheath and black
area around the caudal spine, lack of a distinct series of longitudinal
dark bands from base to margin of dorsal and anal fins, and the presence
of purplish longitudinal lines on the body. In small specimens, however,
there are longitudinal dark bands from base to margin of the dorsal and
anal fins (eight in the soft dorsal of a 110 mm. specimen), the spots
on the tail are less distinct or absent, and the sheath of the caudal
spine is not as contrastingly pale. The lines on the body are broader
and hence fewer in number; in fresh specimens the linear pattern on the
body remains as the best color character for separating _A. dussumieri_ from
the other two species, but, as mentioned, the lines may fade on preserved
specimens. The larger eye and higher gill _raker_ counts of _A. dussumieri_
are then very helpful in distinguishing this species.

I have seen specimens of _A. dussumieri_ or know of definite records
of this species from the east coast of Africa, islands in the Indian Ocean, Australia, East Indies, Formosa, Philippine Islands, Riu Kiu Islands and probably also southern Japan, and the Hawaiian Islands. The latter group of islands represents the sole locality for the species in Oceania. If this were ultimately found to be the true range of the species, it would be supporting evidence that pioneer fishes of the Hawaiian Archipelago arrived via the extension of the Kuroshio Current and the North Pacific Current from islands to the west of Hawaii, rather than from reefs and small islands south of Hawaii by way of a branch of the north equatorial current as postulated by Herre (1940). I do not advocate, however, that such an indication from one or even several species should form the basis for the assumption that the entire Hawaiian fish fauna had such a mode of origin.

Jordan and Seale (1906: 351) stated that *Hepterus dussumieri* is the commonest species of the genus about the Hawaiian Islands. In the same work these authors listed *Hepterus sandvicensis* (= *Acanthurus triostegus sandvicensis*) as the most abundant species of the genus about Hawaii. I concur in their latter statement. Although *Acanthurus dussumieri* is a very common species in the Hawaiian Islands, it is probably exceeded in abundance by *Acanthurus nigrofuscus* and perhaps other species as well as *Acanthurus triostegus*. It occurs both in bays and in exposed reef areas.

*A. dussumieri* is one of the three largest species of *Acanthurus*; it reaches a standard length of at least 400 mm.

*Acanthurus xantheropterus* Cuvier and Valenciennes

*Fig. 10 x; Pl. IV*

*Acanthurus xantheropterus* Cuvier and Valenciennes (1835: 215) (Seychelles);
Valenciennes (1837: pl. 71, fig. 2); Cantor (1849: 1191, pl. 4)
(Pinang, Malaya).

_Acanthurus matoides._ Bleeker (1850a: 12) (Batavia, Java); Günther
(1861: 330) (East Indies and Fiji Islands); Day (1865: 126) (seas of India);
Playfair in Playfair and Günther (1866: 56) (Zanzibar) (as Variety a);
Kunzinger (1871: 508) (Red Sea); Day (1876: 205) (seas of India);
Day (1889: 141); Jordan and Snyder (1907: 217) (Hawaiian Islands);
Jordan and Jordan (1922: 65) (Honolulu); Vinciguerra (1926: 567) (Sarawak, Borneo);
Herre (1927: 430, pl. 16, fig. 3) (Honolulu and Philippine Islands);
Herre (1936: 243) (Tahiti and Solomon Islands); de Beaufort (1951: 156) (East Indies).

_Rhombotides matoides_ Bleeker (1863b: 235) (Ternate, East Indies).

? _Acanthurus matoides_ Kner (1865-67) (India).

_Acanthus blochii._ Günther (1873: 109, pl. 69, fig. B) (Indo-Pacific);
Waite (1897: 188) (Funafuti, Ellice Islands).

_Teuthis crestonia_ Jordan and Starks in Jordan (1895: 435, pl. 47)
(Mazatlán, Mexico); Jordan and Evermann (1898: 1692); Jordan and
Evermann (1900: pl. 256, no. 628); Gilbert and Starks (1904: 151)
(Panama Bay).

_Teuthis mata._ Seale (1901: 107) (Guam).

_Teuthis argenteus._ Jordan and Fowler (1902: 553) (Okinawa and Japan).
_Teuthis gûntheri_ Jenkins (1903: 477, fig. 29) (Honolulu).
_Teuthis xanthopterus_ Jenkins (1903: 477) (Hawaiian Islands).

_Hepatus matoides._ Jordan and Evermann (1905: 387) (Honolulu); Jordan
and Seale (1906: 352) (Samoa); Jordan and Seale (1907: 34) (Philippine Islands).

_Hepatus guntheri_ Jordan and Evermann (1905: 388, fig. 168).
Hepatus aquilinus. Jordan and Seale (1906: 353, fig. 66) (Apia, Samoa).
Teuthis guentheri. Bamber (1915: 482) (Red Sea).
Hepatus crestonis. Snodgrass and Heller (1905: 403) (Cocos Island off Costa Rica); Fowler (1916: 411) (Panama Bay).
Hepatus fuliginosus. Fowler (1927: 17) (Fanning Island, Line Islands); Fowler (in part) (1928: 266, pl. 31, fig. B) (Oceania); Fowler and Bean (in part) (1929: 211) (Hawaiian Islands); Fowler (1934: 480) (Durban, Natal); Fowler (1938: 102, 202, 211, 230) (Takaroa in the Tuamotu Archipelago, Christmas and Fanning Islands, and Honolulu).
Acanthurus crestonis. Week and Hildebrand (1928: 782) (west coast of Panama).
Hepatus elongatus. Fowler and Bean (in part) (1929: 213) (Hawaiian Islands and Samoa).
Hepatus bariene. Fowler and Bean (in part) (1929: 222) (Hawaiian Islands).
Acanthurus fuliginosus. Schultz (1943: 166) (Phoenix and Samoa Islands); Smith (1949: 240, pl. 33, no. 611) (east coast of Africa south to Durban); Schultz and Woods in Schultz et al (1953: 637) (Guam).
Teuthis fuliginosus. Fowler (1949: 102).

Dorsal rays IX (two specimens were found with VIII), 25 to 27; anal rays III, 23 to 25; pectoral rays 16 or 17 (usually 17); anterior
gill rakers 16 to 24; posterior gill rakers 17 to 22 (see Table 21); a 37 mm. specimen has 12 upper and 14 lower teeth; a 59 mm. specimen has 13 upper and 15 lower teeth; a 97 mm. specimen has 15 upper and 16 lower teeth; a 126 mm. specimen has 17 upper and 18 lower teeth; a 196 mm. specimen has 18 upper and 20 lower teeth; a 320 mm. specimen has 18 upper and 21 lower teeth.

Table 20 Variation in Fin Ray Counts of Specimens of Acanthurus xanthopterus from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 26 27</td>
<td>23 24 25</td>
</tr>
<tr>
<td>Durban, S. Africa</td>
<td>3 2</td>
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<td>Red Sea</td>
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<td>1</td>
</tr>
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<td>East Indies</td>
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<td>Philippine Islands</td>
<td>1 4 2</td>
<td>1 3 3</td>
</tr>
<tr>
<td>Solomon Islands</td>
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<td>2</td>
</tr>
<tr>
<td>Mariana Islands</td>
<td>1 5 1</td>
<td>7</td>
</tr>
<tr>
<td>Gilbert Islands</td>
<td>1 1</td>
<td>1 1</td>
</tr>
<tr>
<td>Phoenix and Samoa Islands</td>
<td>5 2</td>
<td>5 2</td>
</tr>
<tr>
<td>Line Islands</td>
<td>3</td>
<td>1 2</td>
</tr>
<tr>
<td>Jarvis Island</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hawaiian Islands</td>
<td>2 3 2</td>
<td>6 1</td>
</tr>
<tr>
<td>Galapagos Islands</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>W. Mexico and W. Panama</td>
<td>2 5 1</td>
<td>4 4</td>
</tr>
</tbody>
</table>
Body depth varies from 1.95 in standard length of a 127 mm. specimen to 2.25 in a 423 mm. specimen; caudal concavity 7 in standard length of a 127 mm. specimen, 5 in standard length of a 196 mm. specimen, and 4.6 in a 320 mm. specimen; length of snout 4.8 in standard length of 127 mm. specimen, 4.95 in 196 mm. specimen, and 5.3 in 423 mm. specimen; diameter of eye 3.9 in head length of 127 mm. specimen, 4.1 in 173 mm. specimen, 4.4 in 196 mm. specimen, 4.7 in 310 mm. specimen, and 5.6 in 415 mm. specimen; length of caudal spine 5.5 in head length of 127 mm. specimen, 5 in 173 and 196 mm. specimens, 4.4 in a 310 mm. specimen; longest dorsal ray 4.4 in standard length of 127 mm. specimen, 5 in standard length of 196 mm. specimen, and 5.7 in standard length of a 320 mm. specimen.

A 196 mm. specimen of *A. xanthopterus* was speared by the author in the lagoon at Tarawa Atoll, Gilbert Islands, at a depth of 39 feet and provided the following description of the life colors: while the fish was still alive, the body color changed back and forth from uniform purplish gray to a color phase in which extremely irregular dark gray lines (about two scales in width) alternated with light blue-gray lines of about the same width; extreme posterior part of caudal peduncle and base of caudal fin dull white; remainder of caudal fin purplish gray; dorsal and anal fins yellowish gray basally, shading to dull yellow distally, with four longitudinal broad blue bands; a narrow bluish gray band at base of dorsal and anal fins; outer margin of dorsal and anal fins narrowly black; basal two-thirds of pectoral fin dusky, outer one-third yellow except extreme distal part which is hyaline; pelvic rays purplish gray, membranes dusky yellow; lower two-thirds of eye margined with diffuse yellow; a region of dull yellow extending directly
anterior from eye a distance equivalent to about one eye diameter; a lesser posterior extension of dull yellow from lower corner of eye.

Preserved specimens are usually a uniform grayish brown; only occasional specimens retain the tortuous line pattern on the body. The bands in the dorsal and anal fins may fade.

The most important color characters of *A. xanthopterus* , for separating the species from *A. mata* and *A. dussumieri*, are the number of longitudinal bands in the dorsal and anal fins, the lack of narrow, nearly straight, longitudinal lines or rows of spots on the body, the lack of a black region around the caudal spine (although the region around the spine may be slightly darker than the color of the body), and (in adults) the abrupt pale color of the outer one-third of the pectoral fin. There are no small black spots on the caudal fin, no whitish caudal spine sheath, and no definite pale band which crosses or nearly crosses the interorbital space, all characteristic color markings of *A. dussumieri*.

Apart from color, *A. xanthopterus* is most distinctive in its possession of a small caudal spine, small eye (not useful in separation from *A. mata*), and low gill raker counts (see Table 21).

In Fowler and Bean (1929: 227) there is a color description of specimens bearing "Albatross" numbers 8509 and 8510 which these authors identified as *Hepatus grammoptilus*. These specimens and probably others are *Acanthurus xanthopterus*. The description of the color of specimens with the numbers 7803, 7804, and 7806, however, apply to *Acanthurus dussumieri*.

The specific names most commonly used for *A. xanthopterus* are *matoides* and *fuliginosus*. *Acanthurus matoides* Cuvier and Valenciennes
is a synonym of *Acanthurus nigrofuscus*. *Acanthurus fuliginosus* Lesson was described as a uniform brown fish with a blue line on the chin. It is very unlikely that this species is the same as *A. xanthopterus* (see page 55).

Günther (1873: 109, pl. 69, fig. B) misidentified *A. xanthopterus* as *Acanthurus blochii*. *Acanthurus blochii* Cuvier and Valenciennes is probably a synonym of *Acanthurus mata* (Cuvier).

Fowler and Bean (1929: 214) placed *Hepatus aquilinus* Jordan and Seale in the synonymy of *Hepatus elongatus*. I examined the type of *H. aquilinus*, and it is a moderately large specimen of *Acanthurus xanthopterus*.

I am unable to distinguish *Acanthurus crestonis* (Jordan and Starks) of the western coast of Mexico and Central America from *Acanthurus xanthopterus*; thus I have placed the former in the synonymy of the latter.

The type of *Acanthurus xanthopterus*, a 162 mm. specimen, is in the Paris Museum (No. 162).

*A. xanthopterus* is probably the largest species of *Acanthurus*. It may exceed 500 mm. in standard length. It occurs commonly in bays and lagoons, but may also be taken in outer reef areas. At least in the adult stage it appears to be more characteristic of deeper water than most surgeon fishes. Trap fishermen in the Hawaiian Islands refer to the species as deep water pualu; they call *A. mata* merely pualu.

*A. xanthopterus* is a wide-ranging species. It is known from East Africa to West Mexico.
Table 21 Variation in Gill Raker Counts of Specimens of *Acanthurus dussumieri*, *Acanthurus xanthopterus*, and *Acanthurus mata* from Different Localities.

<table>
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<tr>
<th>Species and locality</th>
<th>Anterior gill rakers</th>
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<tbody>
<tr>
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<td><em>Acanthurus dussumieri</em></td>
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<td>Mauritius</td>
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<td>Philippine Islands</td>
<td>1 2 1 1</td>
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<tr>
<td>Hawaiian Islands</td>
<td>3 3 1</td>
</tr>
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<td><em>Acanthurus xanthopterus</em></td>
<td></td>
</tr>
<tr>
<td>Durban, S. Africa</td>
<td>1 1</td>
</tr>
<tr>
<td>Red Sea</td>
<td>1</td>
</tr>
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<td>Mauritius</td>
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<td>Gilbert Islands</td>
<td>1 1</td>
</tr>
<tr>
<td>Phoenix and Samoa Islands</td>
<td>1 3</td>
</tr>
<tr>
<td>Line Islands</td>
<td>2 1</td>
</tr>
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<td>Hawaiian Islands</td>
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<td>W. Mexico and W. Panama</td>
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<td>Species and locality</td>
<td>Posterior gill rakers</td>
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<td><strong>Acanthurus xanthopterus</strong></td>
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<td><strong>Acanthurus mata</strong></td>
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<td>Marshall Islands</td>
<td>1</td>
</tr>
<tr>
<td>Wake Island</td>
<td>1</td>
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<tr>
<td>Tuamotu Archipelago</td>
<td></td>
</tr>
<tr>
<td>Hawaiian Islands</td>
<td></td>
</tr>
</tbody>
</table>
Acanthurus mata (Cuvier)

Figs. 9 d, 10 y; Pl. IV


Chaetodon mata Cuvier (1829: 224) (after Russell, error for mata).


Acanthus rasi Cuvier and Valenciennes (1835: 203) (Pondichéry, India).


Acanthus nigro-fuscus. Günther (1861: 331) (Ceylon and Ambon, East Indies).

Acanthus blochii Streets (1877: 68) (Harbor of Honolulu).

Acanthus umbra. Jordan and Jordan (in part) (1922: 65) (Hawaiian Islands); Schultz (1943: 165) (Tutuila Island, Samoa Islands).

?Hepatus mata Fowler (1928: 267) (Society Islands).

Hepatus bariene. Fowler and Bean (in part) (1929: 222) (Philippine Islands).


Acanthus sp. two Harry (1953: 150) (Raroia, Tuamotu Archipelago).

Acanthus lineolatus. Smith (in part) (1949: 240, pl. 33, no. 609) (east coast of Africa south to Durban).

Dorsal rays IX, 25 to 27; anal rays III, 24 or 25; pectoral rays 17; anterior gill rakers 20 to 25; posterior gill rakers 23 to 26 (see Table 21); a 47 mm. specimen has 14 upper and 14 lower teeth; an 84 mm. specimen has 16 upper and 16 lower teeth; a 101 mm. specimen has 16 upper and 18 lower teeth; a 153 mm. specimen has 18 upper and 19
lower teeth; a 203 mm. specimen has 18 upper and 20 lower teeth; a
247 mm. specimen has 20 upper and 20 lower teeth.

Table 22 Variation in Fin Ray Counts of Specimens of
Acanthurus mata from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25   26  27</td>
<td>23  24  25</td>
</tr>
<tr>
<td>Durban, S. Africa</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mariana Islands</td>
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<td>Marshall Islands</td>
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<td>2</td>
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<tr>
<td>Wake Island</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tuamotu Archipelago</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hawaiian Islands</td>
<td>4 9 2</td>
<td>1 12 2</td>
</tr>
</tbody>
</table>

Depth of body 1.9 to 2.1 in standard length; caudal concavity
varies from 10 in standard length of a 151 mm. specimen to 8.2 in a
191 mm. specimen, and to 6.2 in a 292 mm. specimen; length of snout
4.3 to 4.5 in standard length; eye diameter 3.1 in head length of 47
mm. specimen, 4.2 in head length of 151 mm. specimen, and 5 in head
length of 292 mm. specimen; length of caudal spine 3 to 4.4 in head
length.

Color (in alcohol) brown (the rows of small faint spots on the
sides are usually lost in preservative); base of caudal fin abruptly
pale; remainder of fin brown (dark blue in life with about 6 indistinct,
vertical, slightly wavy, dark lines); dorsal fin with eight or nine
narrow longitudinal dark bands, and anal fin with five or six similar
bands (the bands in the fins are often not visible in preserved specimens);
Pectoral fins entirely brown; pelvic fins brown; dark brown to black
region around caudal spine about twice as high as maximum width of spine;
the most prominent marking on the head in life is an elongate yellow
spot (about half the size of the eye) which extends posteriorly and
slightly upward from lowermost edge of eye; this is usually lost in
preservative.

A. mata is distinct from A. xanthopterus in having eight or nine
instead of four or five longitudinal dark bands in the soft portion of
the dorsal fin, a uniform brown pectoral fin (the outer one-third of the
pectoral fin of A. xanthopterus is pale), a more definite dark area
around the caudal spine, a larger caudal spine, and higher gill raker
counts.

Adult A. mata may be distinguished from adult A. dussuriari by
lacking black caudal spots, white caudal spine sheath, and a pale trans-
verse band on the interorbital, and having numerous longitudinal bands
in the dorsal and anal fins. Fresh specimens of subadult mata may be
best distinguished from A. dussuriari of about the same size (which may
have eight or nine bands in the dorsal fin and five or six in the anal
like mata) by the linear pattern of the body. Lines of small pale spots
occur on A. mata; the lines on the body of A. dussuriari are unbroken.
On preserved specimens the body color of either species may be uniform
brown; the larger size of the eye of dussuriari is then the best means
of separation.

When viewed underwater, A. mata appears almost black except for the
base of the caudal fin which is usually white. The degree of whiteness
of the caudal band is variable. The band is generally dull white or gray
on captive fish. This appears to be true of all of the species of Acanthurus which have a white or light gray caudal base.

The blue and yellow colors of specimens of A. mata collected from bays were noticeably duller than these colors on specimens from clear outer reef areas.

There is no type specimen of Acanthurus mata. The name and description originated with the prelinnaean author Russell whose work I have not seen. Cuvier (1829: 224) cited Russell when he listed Chaetodon mata among the surgeon fishes in his Règne Animal. This appears to be an error for mata, for all subsequent authors, some of whom have referred to Russell, have spelled the name mata. Cuvier and Valenciennes (1835: 202) gave a brief description based on Russell. Their reference to the similarity to Acanthurus dussumieri, the dark body color with blue on the head and elsewhere, and a size up to 18 inches constitutes the principal basis for my calling the species, as here defined, Acanthurus mata.

Schultz and Woods (1953: 640) correctly assigned the name Acanthurus mata to two large specimens (280 and 310 mm.) from the northern Marshall Islands. These authors proposed that the name mata be restricted to Plate 48, Figure 1 of Day (1876); however, this figure appears to be Acanthurus nigrofuscus (Forskal).

I have been unable to identify or can only tentatively identify many of the records in the literature which may be A. mata because of insufficient descriptive information. To my knowledge, the species has never been figured. Most of the unquestioned names in my synonymy for the species are based on the examination of the specimens. Acanthurus blochi of Streets (1877: 68), for example, are small specimens of A. mata.
Plate IV

Acanthurus fowleri  Acanthurus bariene
Acanthurus maculiceps  Acanthurus gahhm
From unpublished paintings of the Philippine Albatross Expedition, 1909.

Acanthurus xanthopterus, 174 mm.
Hawaiian Islands

Acanthurus dussumieri, 255 mm.
Hawaiian Islands

Acanthurus mata, 269 mm.
Hawaiian Islands

Acanthurus chirurgus
Florida (pale phase)
Fowler and Bean (1929: 246) were in error in considering these as *Acanthus glaucopareius*.

Although the color seems a little different, the species from Africa identified as *Acanthus lineolatus* by Smith (1949: 240, pl. 33, fig. 609) is probably *A. mata*. A 71 mm. specimen kindly loaned by Smith proved to be *Acanthus bleekeri*, however.

*Acanthus monroviae* Steindachner

Figs. 10 z, 28

*Acanthus phlebotomus* Troschel (*non* Cuvier and Valenciennes) (1866: 227) (Cape Verde Islands).

*Acanthus Monroviae* Steindachner (1876: 160) (Monrovia, Liberia).

*Acanthus chirurgus* Peters (1876: 246) (Victoria, Cameroon, West Africa).

*Acanthus monroviae* Steindachner (1895: 18) (mouth of Messurado River and Cape Mount, Liberia); Metzelaar (1919: 256) (Senegal Coast, West Africa).

*Teuthis monroviae* Gill (1896: 188) (error for *monroviae*).

Dorsal rays IX, 25 to 27; anal rays III, 24 to 26; pectoral rays 17; anterior gill rakers 16 or 17; posterior gill rakers 16; an 88 mm. specimen has 12 upper and 14 lower teeth; a 192 mm. specimen has 13 upper and 13 lower teeth. These counts and the measurements given below were obtained from two specimens from Liberia which are in the United States National Museum.

Depth of body 2.0 (in 192 mm. specimen) to 2.2 (in 88 mm. specimen) in standard length; caudal concavity 7.6 (in 192 mm. specimen) to 10.4 (in 88 mm. specimen) in standard length; diameter of eye 3.5 (in 88 mm. specimen)
Fig. 28. *Acanthurus monroviae*. Drawing by L. B. Isham, United States National Museum.

Fig. 29. *Acanthurus coeruleus* (after Jordan and Marsh, 1902).
specimen) to 4.0 (in 192 mm. specimen) in head length; length of snout 4.9 to 5.2 in standard length; length of longest dorsal ray 4.9 to 5.1 in standard length; length of pectoral fin 3.4 (in 88 mm. specimen) to 3.6 (in 192 mm. specimen) in standard length; length of caudal spine 4.5 to 5.7 in head length.

Color (in alcohol) of 88 mm. specimen brown with a white area (in height slightly less than diameter of eye) around caudal spine; about 15 narrow, dark, undulating lines on side of body; opercular membrane very dark brown; area around edge of upper limb of preopercle very dark brown; median fins very dark brown except extreme margin of central part of caudal fin which is pale; pectoral fin rays dusky except for outer part of lower II rays which are pale; pectoral membranes pale; pelvic fins very dark brown. The 192 mm. specimen differs in color in having more numerous and less conspicuous lines on the body, a relatively larger pale area around the caudal spine (in height almost onethird the head length), black median fins except base of dorsal and anal which are brown, and the margin of the preopercle only slightly darker than the rest of the head.

The pale spot around the caudal spine was described as yellow in life. Peters (1876) mentioned a blue border around this yellow area. Both Peters and Steindachner described the lines on the body as blue.

Fowler (1936: 912) erroneously synonymized this species with Hepatus hepatus ( = Acanthurus chirurgus).

Acanthurus monroviae is known only from West Africa.

Acanthurus coeruleus Bloch and Schneider

Figs. 10 aa, 29

Acanthurus Coeruleus Bloch and Schneider (1801: xxxviii, 214) (Carolina
and Havana).

**Acanthurus Broussonnetii** Desmarest (1823: 26, pl. 3, fig. 1) (Cuba).

**Acanthurus caeruleus** Cuvier and Valenciennes (1835: 175) (Martinique, Puerto Rico, and Santo Domingo); Castelnau (1855: 25) (Bahia, Brazil); Günther (1861: 336) (West Indies, Caribbean Sea, and Bahia); Poey (1868: 355) (Cuba); Beebe and Tee-Van (1928: 184) (Port-au-Prince Bay, Haiti); Breder (1929: 221); Beebe and Tee-Van (1933: 179) (Bermuda); Longley and Hildebrand (1941: 155) (Tortugas, Florida).

**Acanthurus coeruleus** Storer (1846: 112); Lütken (1880: 609, pl. 5, fig. 3) (Antilles); Jordan and Gilbert (1882: 617); Meek and Hildebrand (1928: 782) (Atlantic coast of Panama).

**Acanthurus violaceus** Castelnau (1855: 25).

**Acanthurus brevis** Poey (1860: 207) (Cuba); Poey (1868: 355).

**Acronurus caeruleatus** Poey (1875: 69, pl. 3, figs. 15 to 17 of developing scales) (Cuba).

**Acanthurus nigricans** Goode (1876: 41) (Bermuda).

**Teuthis coeruleus** Meek and Hoffman (1884: 228); Evermann and Marsh (1902: 253, pl. 38) (Puerto Rico).

**Teuthis helioides** Barbour (1905: 127, pl. 3) (Bermuda).

**Hepatus caeruleus** Fowler (1916: 405) (Colon, Panama).

**Hepatus pawnee** Breder (1927: 73, fig. 32) (Clove Reef, British Honduras).

**Teuthis caeruleus** Nichols and Breder (1927: 134) (New York).

**Acanthurus helioides** Beebe and Tee-Van (1933: 179) (error for helioides) (Bermuda).

**Teuthis (Rhomboteuthis) coeruleus** Fowler (1944a: 109, pl. 13, upper left fig.) (Courtown Keys, Caribbean Sea).

**Acanthurus hepatus.** Carvalho (1952: 115, fig.) (Trinidad).
Dorsal rays IX, 26 to 28; anal rays III, 24 to 26; pectoral rays 16 or 17; anterior gill rakers 13 or 14; posterior gill rakers 13 (raker counts from specimens from Bermuda to Brazil); a 38 mm. specimen has 8 upper and 10 lower teeth; an 82 mm. specimen has 10 upper and 12 lower teeth; 90 and 115 mm. specimens have 12 upper and 14 lower teeth; a 235 mm. specimen has 14 upper and 16 lower teeth.

Table 23 Variation in Fin Ray Counts of Specimens of
Acanthurus coeruleus from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26 27 28</td>
<td>24 25 26</td>
</tr>
<tr>
<td>Bermuda</td>
<td>2 1</td>
<td>2 1</td>
</tr>
<tr>
<td>Florida</td>
<td>1 2</td>
<td>1 2</td>
</tr>
<tr>
<td>West Indies</td>
<td>3 11 2</td>
<td>2 11 3</td>
</tr>
<tr>
<td>Brazil</td>
<td>1 1</td>
<td>1 1</td>
</tr>
</tbody>
</table>

Depth of body 1.7 in standard length; caudal concavity varies from 11.7 in standard length in an 82 mm. specimen to 7.7 in a 115 mm. specimen, to 5.3 in a 178 mm. specimen, and 5.1 in a 235 mm. specimen; caudal spine 6.5 in head length of an 82 mm. specimen, 3.7 in 235 mm. specimen; length of pectoral fin 2.8 to 2.95 in standard length; diameter of eye 3 in head length of an 82 mm. specimen and 4.5 in head length of a 235 mm. specimen.

Color (in alcohol) grayish brown with alternating dark and light, slightly irregular, longitudinal lines on body (the light lines are about three times as broad as the dark); lines on dorsal part of body
angle upward to dorsal fin; caudal fin grayish brown with a very narrow pale posterior margin and a dark submarginal band about four times as broad as the pale margin; dorsal fin with about seven dark longitudinal bands in the spinous portion and nine in the soft portion; anal fin with about five longitudinal dark bands; margins of dorsal and anal fins dark brown; pectoral fins pale; pelvic fins dark brown; no dark area around caudal spine; sheath of caudal spine pale.

A 125 mm. specimen speared by the writer at Nassau, Bahamas, provided the following color note: body purplish gray with 26 irregular dark gray longitudinal lines; dorsal and anal fins bright blue with orange-brown longitudinal bands; caudal fin blue, shading to yellowish gray in center; pectoral fins clear yellow; pelvic fins blue; sheath of caudal spine white. Some specimens observed underwater had three vertical pale bars on the body.

Townsend (1929: 19, pl. 21) described and figured three color phases of this species from aquarium observations, a blue, a blue with three or four pale vertical bars, and a creamy white with blue margins on the fins. The latter phase was seldom seen until evening when the fish settled toward a white sand bottom. Longley (1941: 155) observed that the species was very light over a pale sandy bottom.

Longley also observed that the young are clear yellow, and he correctly referred *Teuthis helioides* Barbour to the synonymy of *Acanthurus coeruleus*. He stated that specimens up to 100 or 125 mm. in length may be yellow. His length measure is probably total length. The longest yellow specimen which I have seen is the type of *Teuthis helioides* in the Museum of Comparative Zoology (No. 29053). It is 77 mm. in standard length. The size at which the blue-gray color replaces the yellow is
variable. I speared a 31 mm. specimen at Nassau which was blue except for the middle of the caudal fin which was yellow.

The largest specimen of *A. coeruleus* seen by me is a 235 mm. one from Bermuda. Another from Bimini is 234 mm. in standard length.

Lütken (1880: pl. 5, figs. 3, 4, and 5) figured the postacronurus, acronurus, and a 5.7 mm. postlarval specimen of *Acanthurus coeruleus*. The postacronurus has three vertical pale bands on the body.

*Hepatus pavo* Bréder (1927: 73, fig. 32) is apparently the acronurus of *A. coeruleus*, judging from the deep body and the fin ray counts D IX, 27 and A III, 25. It was taken at a night light at Glover Reef, British Honduras.

Fowler (1944a: 109) proposed the subgenus *Rhomboteuthis* for *Acanthurus coeruleus*. As previously discussed (see page 51), this does not seem justified.

Longley (1941: 155) pointed out that *Acanthurus coeruleus* is seen more often well above the bottom than the other two surgeon fishes commonly seen in Florida waters, *A. chirurgus* and *A. bahianus*. He stated that the food of *A. coeruleus* is wholly algal like that of *A. chirurgus* and *A. bahianus* but contains less sand and bottom debris than that of the latter two species. This is consistent with the structure of the stomach of these three species. *A. coeruleus* has a thin-walled stomach, whereas the other two species have heavy-walled, gizzard-like stomachs.

*Acanthurus chirurgus* (Bloch)

Figs. 9 b, 10 bb; Pl. IV

*Chaetodon chirurgus* Bloch (1787: 204, pl. 208) (Martinique).

*Acanthurus Chirurgus* Bloch and Schneider (1801: xxxviii, 214) (Carib-
bean Sea).

**Acanthurus Hepatus.** Bloch and Schneider (in part) (1801: 211) (America and Bahama Islands).

**Acanthurus chirurgus** Lacepède (1802: 546); Cuvier and Valenciennes (1835: 168) (Martinique, Puerto Rico, Cuba, and Brazil); Storer (1846: 112); Günther (in part) (1861: 329) (Caribbean Sea, West Indies, Venezuela, and Brazil); Günther (1869: 238) (St. Helena); Goode (1876: 42) (Bermuda); Jordan and Gilbert (1882: 617); Metzelaar (1919: 256) (both sides of Atlantic).

**Acanthurus phlebotomus** Cuvier and Valenciennes (1835: 176, pl. 287) (Martinique, Brazil, Havana, and New York); Storer (1846: 111); Poey (1868: 355) (Cuba).

**Acanthus chirurgicus** Castelnau (1855: 24) (Bahia, Brazil).

**Acanthus nigricans.** Jordan and Gilbert (1882: 941).

**Teuthis hepatus.** Meek and Hoffman (1884: 229); Jordan and Evermann (1898: 1691); Evermann and Marsh (1902: 254) (Puerto Rico); Nichols and Breder (1927: 134) (New York); Gudger (1929: 196) (Tortugas, Florida); Fowler (1944a: 110, pl. 13, right hand figs.) (Courtown Keys, Caribbean Sea).

**Hepatus hepatus.** Fowler (1916: 403) (Colon, Panama); Fowler (1936: 912, fig. 385) (West Africa).

**Acanthurus hepatus.** Meek and Hildebrand (1928: 734) (Atlantic coast of Panama); Beebe and Tee-Van (1928: 185) (Port-au-Prince Bay, Haiti); Breder (1929: 221); Beebe and Tee-Van (1933: 181, col. pl. 4, incorrectly labelled **Acanthurus caeruleus** (Bermuda); Longley and Hildebrand (1941: 156) (Tortugas, Florida).

Dorsal rays IX, 24 or 25; anal rays III, 22 or 23; pectoral rays
16 or 17; anterior gill rakers 16 to 19; posterior gill rakers 15 to 16.
(raker counts from West Indian specimens); 32 mm. and 54 mm. specimens have 10 upper and 12 lower teeth; a 140 mm. specimen has 16 upper and 18 lower teeth; a 184 mm. specimen has 18 upper and 20 lower teeth.

Table 24. Variation in Fin Ray Counts of Specimens of
Acanthurus chirurgus from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24  25</td>
<td>22  23</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>1    1</td>
<td>1    1</td>
</tr>
<tr>
<td>Bermuda</td>
<td>1    1</td>
<td>1    1</td>
</tr>
<tr>
<td>Florida</td>
<td>2    2</td>
<td>2    2</td>
</tr>
<tr>
<td>West Indies</td>
<td>9    22</td>
<td>10  21</td>
</tr>
<tr>
<td>Brazil</td>
<td>1    1</td>
<td>1    1</td>
</tr>
</tbody>
</table>

Depth of body about 2 in standard length; caudal fin emarginate
(nearly truncate in young), caudal concavity about 14 to 18 in standard
length; length of caudal spine 5 in head length of a 54 mm. specimen,
3.5 in a 165 mm. specimen; length of pectoral fin 3 in standard length;
diameter of eye 2.9 in standard length of a 54 mm. specimen, 3.8 in a
184 mm. specimen.

Color (in alcohol) brown, usually with 10 to 12 long vertical dark
brown bars visible on side of body; caudal spine enclosed in a very
dark brown area, the height of which is about three times the maximum
width of the spine; no definite white posterior margin to caudal fin
(extreme tips of caudal rays pale, resulting in a very narrow, irregular,
white margin); dorsal fin with nine diagonal dark bands in spinous portion (two to seven on each interspinous membrane) and nine or ten in soft portion (these mostly longitudinal); anal fin with four similar bands (the bands in the fins often fade completely in preservative); margins of dorsal and anal fins narrowly dark brown; outer one-third of pectoral fin pale in adult specimens; membranes of pelvic fins very dark brown; opercular membrane black.

The color photograph of *A. chirurgus* from which Plate IV was reproduced was taken of a specimen collected by the author in a sandy region at Soldier Key, Florida. It is in a pale color phase. Over a dark substrate the species is usually brown as shown in the two lower figures of Plate 22 in Townsend (1929). Longley (1941: 156) described the color phases of this species in detail.

The largest specimen seen by me measured 228 mm. It was taken at Panama.

*A. chirurgus* is probably the most wide-ranging species of *Acanthurus* in the Atlantic, apparently occurring on the coast of West Africa as well as the entire tropical and subtropical regions of the West Atlantic. Its extension into cooler waters of the northeast United States (such as Massachusetts) is probably a result of transport of the larvae by the Gulf Stream from more southern regions where resident populations are established. The specimens which I have seen from such northern localities have all been juveniles or subadults. The same applies to specimens of *A. coeruleus* and *A. bahianus*. Breder (1929: 222) stated that *A. chirurgus* is the most common species of the family on the Atlantic coast of the United States.

Townsend (1929: 19) reported that this fish lives well in captivity.
Although largely herbivorous, specimens were kept as long as five years in the New York Aquarium on a fish and clam diet varied occasionally with seaweed.

Longley (1941: 156) pointed out, and I have verified his observation, that *Acanthurus chirurgus* often swims in small schools with *A. bahianus*.

After first doubting Longley's placing of *Hepatus pawnee* in the synonymy of *Acanthurus hepatus* (= *Acanthurus chirurgus*), Breder (1949a: 296) decided he was correct. I believe, however, that *H. pawnee* as figured by Breder (1927: fig. 32) is the acronurus of *Acanthurus coeruleus*. If the fin ray counts D IX, 27; A III, 25 are correct, no other conclusion could be drawn (see Tables 23 to 25).

Many recent authors have applied the name *Acanthurus hepatus* to the species *Acanthurus chirurgus*. Three different species of surgeon fishes of five prelinnaean authors were cited by Linnaeus (1766: 507) under the name *hepatus*. Cuvier and Valenciennes were the first to restrict the name. They used it for the East Indian species of Seba (1734: 104, pl. 33, fig. 3) which is now recognized as the single species in the genus *Paracanthus*.

*Acanthurus bahianus* Castelnau

Figs. 9 c, 10 cc, 30

*Acanthus bahianus* Castelnau (1855: 24, pl. 11, fig. 1) (Bahia, Brazil); Meek and Hildebrand (1928: 783) (Atlantic coast of Panama); Beebe and Tee-Van (1928: 184) (Port-au-Prince Bay, Haiti); Breder (1929: 222); Beebe and Tee-Van (1933: 180) (Bermuda); Longley and Hildebrand (1941: 156) (Tortugas, Florida).

*Acanthus tractus* Poey (1860: 208) (Cuba); Poey (1868: 356); Jordan and Gilbert (1882: 941).
Acanthurus chirurgus. Günther (in part) (1861: 329) (Caribbean Sea and Brazil).

Acronurus nigriculus Poey (1875: 69, pl. 3, figs. 18 and 19 of scales and caudal fin) (Cuba).

Teuthia tractus Meek and Hoffman (1884: 229).

Teuthia bahianus Jordan and Evermann (1898: 1693) (Key West, Florida and Bahia, Brazil); Jordan and Evermann (1900: pl. 256, no. 629); Evermann and Marsh (1902: 254, fig. 70) (Puerto Rico); Nichols and Breder (1927: 135) (Woods Hole); Gudger (1929: 197) (Tortugas, Florida); Fowler (1944: 110, pl. 13, lower left fig.) (Courtown Keys, Caribbean Sea).

Hepatus bahianus Fowler (1916: 405) (Colon, Panama).


Dorsal rays IX, 23 to 26; anal rays III, 21 to 23; pectoral rays 15 to 17 (usually 16); anterior gill rakers 20 to 22; posterior gill rakers 17 to 19 (raker counts from West Indian specimens); a 55 mm. specimen has 12 upper and 12 lower teeth; an 85 mm. specimen has 12 upper and 14 lower teeth; a 100 mm. specimen has 14 upper and 16 lower teeth; a 170 mm. specimen has 14 upper and 16 lower teeth.

Depth of body about 2 in standard length; caudal concavity varies from 13.5 in a 68 mm. specimen to 8.3 in a 124 mm. specimen to 4.6 in a 170 mm. specimen; length of caudal spine 3.5 in head length of a 105 mm. specimen, 2.8 in a 155 mm. specimen; length of pectoral fin 3 in standard length of a 105 mm. specimen, 3.5 in standard length of a 155 mm. specimen; diameter of eye 3 in head length of a 105 mm. specimen, 3.5 in 155 mm. specimen.
Table 25 Variation in Fin Ray Counts of Specimens of

*Acanthurus bahianus* from Different Localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23 24 25 26</td>
<td>21 22 23</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bermuda</td>
<td>2 2</td>
<td>2</td>
</tr>
<tr>
<td>Florida</td>
<td>2 1</td>
<td>1 2</td>
</tr>
<tr>
<td>West Indies</td>
<td>2 19 8 1</td>
<td>2 21 7</td>
</tr>
<tr>
<td>Brazil</td>
<td>3 1</td>
<td>3 1</td>
</tr>
</tbody>
</table>

Color (in alcohol) brown, with or without narrow, faint, longitudinal lines on body; caudal fin with a definite white posterior margin which is broader in median part of fin (in maximum width about one-third the diameter of the pupil in adults, proportionally wider in young); base of caudal fin usually paler than rest of body; 9 to 11 narrow longitudinal dark lines usually visible in dorsal fin; anal fin with about four similar bands, but these usually fade in preservative; margins of dorsal and anal fins narrowly dark brown; pectoral fins light brown; membranes of pelvic fins dark brown; margin of caudal spine socket narrowly black; sheath of caudal spine dark brown; opercular membrane black.

Color in life of a 121 mm. specimen collected by the author at Bache Shoal, Florida: body light yellowish brown with faint pale greenish gray longitudinal lines (ventrally the body is dull brassy yellow and the lines are light grayish blue); throat pale grayish blue; caudal fin olive-yellow, the posterior margin bluish white; margin of dorsal and anal fins bright blue; dorsal fin with alternating lengthwise bands of
dull orange and light bluish green; anal fin with alternating grayish blue and dark gray bands; pectoral rays dusky orange, membranes hyaline; pelvic rays pale blue, membranes black; a narrow violet area surrounding caudal spine; upper one-fourth of opercular membrane purple, lower three-fourths black; a purplish gray area adjacent to posterior edge of eye, this region crossed by six to seven narrow yellow lines which radiate from eye; a few small yellow spots below eye; a short blue line anterior to eye.

Longley (1941: 157) stated that this species is golden brown on the open reef and matches very well the dominant color of the algae on which it may be seen cropping all day long. Like *A. chirurgus*, it readily displays a very pale color phase.

I examined the type specimen of *Acanthurus tractus* Poey at the Museum of Comparative Zoology. Without doubt it is *A. bahianus*.

The largest specimen seen by me measures 170 mm. in standard length. It was collected at Cuba.

*Acanthurus bahianus* appears to be confined to the western Atlantic. It is known from Brazil to Massachusetts.
Doubtful Species

Acanthurus doreensis Cuvier and Valenciennes

Acanthurus doreensis Cuvier and Valenciennes (1835: 220) (Dorey Harbor, New Guinea); Bleeker (1850: 5); Günther (1861: 332); Macleay (1883: 354).

Rhombotides doreensis Bleeker (1878: 51).

Hepatus doreensis Fowler (1928: 268); Jordan and Seale (1906: 351).

To my knowledge the species is known only from the type (No. A 7099) in the Paris Museum. It was described by Valenciennes as brown with the posterior part of the pectoral yellowish and the terminal border of the caudal fin with a white margin. The length was given as 8 inches. The fin ray counts D IX, 28 and A III, 20 are most distinctive, and on the basis of these Bleeker, Günther, Macleay, and Fowler all regarded the species as valid. Jordan and Seale, however, suggested that it might be the young of Hepatus nigricans (= Acanthurus gahhm) or H. elongatus (= A. nigrofuscus), and that the anal rays of the specimen were mis-counted. These authors are probably in error in considering it a juvenile, for an eight inch specimen of any known species of Acanthurus would be an adult or near-adult.

L. Bertin of the Paris Museum has kindly supplied the following information on the type. It is 166 mm. in standard length, has a caudal concavity of 20 mm., and 16 upper and 18 lower teeth. No black bar can be perceived on the shoulder region of the specimen. There are 28 dorsal soft rays and 20 anal soft rays. "Aucun doute à cet égard."

Of the known species of Acanthurus, A. doreensis is closest to A. grammoptilus Richardson. The number of teeth in the jaws, shape of
the caudal fin, yellowish outer part of the pectoral fin, white posterior margin of the caudal fin, and lack of a definite mark on the shoulder region are characteristic of the latter species. The usual soft fin ray counts of D 26 and A 24 of *A. grammoptilus* do not seem to offer any possibility, however, even in the extreme range of normal variability, of ever being D 28 and A 20. In fact, the latter combination of counts can be found in no species of *Acanthurus*. It would seem, therefore, that *A. doreensis* is either an abnormal specimen of *A. grammoptilus* or is a good species. Decision on the matter should await the collection of further specimens.

**POSSIBLE HYBRID**

*Acanthurus rackliffei* Schultz (1943: 157, 163, fig. 13) appears to be a hybrid between *Acanthurus glaucopareius* and *Acanthurus achilles*. It is known from three specimens, each collected in a different locality (a pool on the reef, the outer edge of the reef, and the channel connecting the ocean to the lagoon) at Hull Island, an atoll in the Phoenix Islands.

The published records of marine fish hybrids are very few in number in contrast to naturally-occurring hybrids of freshwater fishes. In an unpublished review of hybridization in New World fishes (1954), Robert Rush Miller advises me that only six marine hybrids have been reported whereas 129 freshwater crosses are known. The overwhelming majority of freshwater hybrids is reflected not only from our greater knowledge of American freshwater fishes and greater opportunity for sampling populations from freshwater habitats but probably also from an actual lower percentage of hybrids in the sea. Undoubtedly conditions
are more favorable, in general, to hybridization of fishes in the fresh-water environment than in the marine. In view of the paucity of records of hybrid marine fishes, even suspected cases are worth documenting.

I know of no reference to hybrid surgeon fishes. The marine hybrid closest from a phylogenetic standpoint is an example in the Chaetodontidae from Tortugas, Florida cited by Longley in Longley and Hildebrand (1941: 154). He concluded that *Holocanthus townsendi* (Nichols and Howbray) was probably a cross between *H. ciliaris* and *H. isabelita*.

The similarity of *Acanthurus glaucopareius* and *Acanthurus achilles* has been pointed out (p. 145). In addition these two surgeon fishes have similar habitats and food habits. In the outer part of surge channels at Onotoa Atoll in the Gilbert Islands the two species were frequently observed swimming side by side. R. R. Harry (1953: 150) stated that *A. glaucopareius* (his *Acanthurus sp. one*) was often in association with *Acanthurus achilles* at Raroia Atoll, Tuamotu Archipelago. The stomach contents of 10 specimens of *achilles* and 12 of *glaucopareius* were examined and found to be essentially the same in both species. Most of the algae was fine and filamentous, and very little sedimentary material was present. No single alga predominated, although there were more reds in general, such as *Alsidium sp.* *Gelidium sp.* and *Lophosiphonia sp.* than greens, browns, or bluegreens. More *Caulerpa serrulata*, a green alga common on the outer part of the reef flat, was found in *achilles* stomachs, probably reflecting the greater tendency of this species to enter shallow water.

Nothing is known of the breeding habits of either species. The gonads of 36 adult specimens of *achilles* and 27 of *glaucopareius*, collected from May to September in the Phoenix, Gilbert, and Marshall Is-
lands, were found to be in all stages of development and no trend could be perceived over this period. Occasional specimens of both species, collected at the same time, had comparably-developed gonads. It is believed that there is no definite spawning season for these fishes in these regions. This might be expected from the slight annual variation in water temperature.

Table 26 summarizes the differences in color and morphology between A. achilles, A. glaucopareius, and the postulated hybrid, A. rackliffei. It will be noted that the hybrid either shares color characters of achilles or glaucopareius or is intermediate. Figure 31 shows the posterior parts of specimens of about equal size of all three forms from Hull Island. The illustration of the hybrid is drawn from the paratype of A. rackliffei in the Museum of Comparative Zoology. The holotype and a small paratype are in the United States National Museum. There appears to be a progressive development of the pale area around the caudal spine in the three specimens. It is absent in the 68 mm. paratype, narrowly developed in the 150 mm. holotype, and obvious in the 161 mm. paratype as figured. The similar enlargement of the pale area around the caudal spine with age of Acanthurus achilles takes place over a much shorter range in standard length and is first visible at a smaller size.

The dorsal and anal fin ray counts of the three specimens of A. rackliffei are as follows: D IX, 29 to 31; A III, 27 or 28. These counts are about as intermediate between those of A. achilles and A. glaucopareius as they could be (see Tables 13 and 14); however many more specimens of rackliffei are needed to establish this intermediacy.

Gill raker counts are not useful in effecting a separation of
**Acanthurus achilles** and **A. glaucopareius**, for they vary in both species from 16 to 20. The holotype of *rakliffei* has 18 anterior and 19 posterior rakers.

**Table 26** Comparison of color and morphology of

*Acanthurus achilles*, *Acanthurus glaucopareius*, and hybrid.

<table>
<thead>
<tr>
<th>Feature</th>
<th>achilles</th>
<th>achilles X glaucopareius</th>
<th>glaucopareius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape of caudal fin</td>
<td>Strongly lunate</td>
<td>Moderately lunate</td>
<td>Emarginate</td>
</tr>
<tr>
<td>Dark submarginal line in caudal fin</td>
<td>Present and prominent</td>
<td>Present</td>
<td>Faint and narrow</td>
</tr>
<tr>
<td>Demarcation of dark body color and pale color of caudal fin</td>
<td>Located at base of caudal fin</td>
<td>Located 1/5 caudal length distal to base of caudal fin</td>
<td>Located 2/5 caudal length distal to base of caudal fin</td>
</tr>
<tr>
<td>Pale area around and in front of caudal spine of adults</td>
<td>Large</td>
<td>Small</td>
<td>Absent</td>
</tr>
<tr>
<td>Pale area at base of posterior dorsal and anal fin rays</td>
<td>Narrow, about 1/4 length of last few rays</td>
<td>Moderately broad, about 1/2 length of last few rays</td>
<td>Broad, about 7/8 length of last few rays</td>
</tr>
<tr>
<td>Color and width of middle part of opercular membrane</td>
<td>White and broad</td>
<td>Dark and narrow</td>
<td>Dark and narrow</td>
</tr>
<tr>
<td>Pale spot under eye</td>
<td>Absent</td>
<td>Faint, maximum height 1/2 eye diameter</td>
<td>Large and conspicuous, maximum height 2/3 eye diameter</td>
</tr>
<tr>
<td>Pale mark on chin</td>
<td>Ends at rictus</td>
<td>Ends at rictus</td>
<td>Extends above rictus</td>
</tr>
</tbody>
</table>
Fig. 31. Posterior regions of body of A. Acanthurus achilles, B. A. achilles X A. glaucopareius, C. Acanthurus glaucopareius.
Genus CTENOCHAETUS Gill


Ctenochaetus Gill, 1885. U. S. Natl. Mus., Proc. 7: 279. (Type species by original designation, Acanthurus strigosus Bennett.)

Ctenodon was first proposed by Wagler (1830) for a reptile. Swainson (1839) used the same generic name for five species of Acanthurus and one Ctenochaetus. Klunzinger applied the name as a subgenus for the species Acanthurus ctenodon Cuvier and Valenciennes (= Acanthurus striatus Quoy and Gaimard) and Acanthurus strigosus Bennett. Fowler (1904: 545) elevated Klunzinger's subgenus to a genus.

The use by Day (1889: 143) (and subsequent authors) of Acanthurus for Ctenochaetus (and Teuthis for Ctenochaetus by Barnard, 1927: 780) appears to be due to ignorance of Gill's name Ctenochaetus for this well-differentiated genus.

As is indicated in the discussion of Acronurus in the section on Acanthurus, there is a possible question as to the validity of the name Ctenochaetus.

Ctenochaetus is characterized as follows: body compressed, elliptical, the depth contained 1.7 to 2.1 remained length; head length 3 to 3.8 in standard length; caudal peduncle armed on each side by a single, sharp, folding spine; length of caudal peduncle spine 2.3 to 4.3 in head length; least depth of caudal peduncle 1.9 to 2.7 in head length; mouth small, terminal, and only slightly protrtactile; jaws equal; teeth numerous, in a single series in each jaw, movable, elongate, with tips expanded, incurved, and denticulate on the lateral margin;
eye diameter contained about 3 to 5 times in head length; interorbital
space 2.6 to 3.3 in length of head; gill openings restricted to the
sides; gill membranes confluent and attached to the isthmus; scales
ctenoid, very small, and not in regular rows; head scaled, though not
conspicuously; lateral line complete; dorsal fin single, continuous,
unnotched, with 8 spines, the first small and easily overlooked; dorsal
soft rays 24 to 31; anal fin with 3 spines, the first very short, and
21 to 28 soft rays; the first 2 to 6 dorsal and anal soft rays unbranched;
pectoral fins long, their length contained 2.7 to 3.2 in standard length;
pectoral rays 15 to 17; pelvic fins 1, 5, relatively long and pointed,
and only slightly posterior in their insertion to the base of the pecto-
ral fins; caudal fin with 16 principal rays and varying in shape from
lunate to nearly truncate; 22 vertebrae; stomach subspherical to oval
with very thick walls.

Quoy and Gaimard (1824) described and figured the first species of
this genus as Acanthurus striatus. They remarked on its unusual denti-
tion. E. T. Bennett (1828) named another, Acanthurus strigosus, from
Hawaii, and he accurately described the teeth. Although Günther (1861)
separated two of the species, strigosus and ctenodon Cuvier and Valen-
ciennes, in a key on the basis of dentition, he left them in Acanthurus.
Gill (1884) established the genus Ctenochaetus, designating A. strigosus
Bennett as the type species. He was apparently unaware of A. striatus
Quoy and Gaimard.

Ctenochaetus is an Indo-Pacific genus. Its distribution is unusual
in that three of the seven species are known only from islands in the
central and eastern Pacific. Two others appear to be endemic to the
Indo-Malayan region. The remaining two, C. striatus and C. strigosus
occur in both the Indian and Pacific Oceans.

On page 62 in the discussion of the distribution of the genus Acanththurus mention was made of pairs of similar species that have not yet been reported from the same area. The possibility that two species of Ctenochaetus may be mutually exclusive also bears checking. C. magnus Randall is known thus far from only three localities, Jarvis Island, Malden Island, and Cocos Island (off Costa Rica). The usually abundant C. striatus (Quoy and Gaimard) has not been collected from any of these islands, although it would not be expected at Cocos since this species does not appear to be among the few surgeon fishes to have crossed the Eastern Pacific Barrier (see Ekman, 1953).

Ctenochaetus striatus and certain other species of this genus are similar in general body shape and color pattern to Acanththurus nigrofibrosus Cuvier and Valenciennes (= Heterurus atramentatus Jordan and Evermann 1905, and Acanththurus lineolatus Günther 1873). The similarity may be seen even in the transforming acronurus stages of these fishes by comparing Fig. A (C. striatus) and Fig. C (A. nigrofibrosus) in Plate 62 of Schultz and Woods (1953). Other Acanththurus species such as lineatus and solitarius may be striped in the postacronurus form, but the stripes do not descend as they pass posteriorly on the body. Inconsistent with the apparent close relationship of Ctenochaetus to A. nigrofibrosus is the finding that the round, heavy-walled stomach of the former does not resemble the elongate, thin-walled stomach of A. nigrofibrosus but rather that of such acanthurids as A. olivaceus and A. gahhm.

Although no existing Acanththurus species may be considered the direct progenitor of the genus Ctenochaetus, it seems reasonable to conclude (as has Aoyagi, 1943) that Ctenochaetus was derived from Acanththurus-like
stock. This view is supported by the fact that postlarval Ctenochaetus have teeth much like those of postlarval Acanthurus, and these transform into the typical adult Ctenochaetus dentition (see Fig. 34 and discussion under striatus).

The food habits and method of feeding of Ctenochaetus strigosus were investigated. The stomach contents of seven adult specimens from different localities in the Hawaiian Islands were analyzed. All but one fish contained a very large amount (up to 90 per cent) of fine inorganic sediment; the remaining detrital material was mostly algal, consisting of diatoms and small fragments of many kinds of red, green, and blue-green algae. About 1 to 2 per cent was soft, unidentifiable organic matter. There were occasional tiny molluscs and crustaceans, sponge spicules, holothurian plates, pedicellaria fragments, etc. The stomach of one specimen was filled primarily with a fine red alga (Ceramium sp.), though there was still a large amount of sediment. When a thallus of fine filamentous red algae (Polysiphonia sp.) was placed in an aquarium containing two adult specimens of strigosus, the fish tried to feed upon it. Their slender movable teeth, not able to effectively bite off pieces, soon became tangled in the algae, resulting in very little being ingested. When fine particles of the alga were put in the tank and allowed to settle, the fish fed in the following manner: the body was elevated to a near-vertical position about 15 mm. above the bottom, there was a pause, then the fish pecked at a small area, the teeth and lips scraping over the surface. Such an area was not only cleaned of particulate algae but also of very fine sediment that had collected there, suggesting that a suction mechanism is involved as well as a scraping one. There was definitely no lateral plowing or sieving action by the
teeth as their comb-like structure might suggest. Sand on the bottom was generally avoided, but if picked up, most was usually forcefully ejected.

KEY TO THE SPECIES OF CTENOCHAETUS

1a. No prominent blackish spot at base of last 3 to 7 rays of both the dorsal and anal fins. (Juvenile and young adult striatus have a small black spot basally at rear of dorsal fin only).......2

1b. A prominent blackish spot at base of last 3 to 7 rays of both the dorsal and anal fin, these spots extending narrowly on adjacent regions of caudal peduncle........................................6

2a. Teeth of the upper jaw with 4 to 7 denticulations (including tip) on lateral edge of their distal expanded ends......................3

2b. Teeth of upper jaw with 3 denticulations (including tip) on lateral edge of their distal expanded ends......................5

3a. Teeth of the upper jaw with 5 to 7 denticulations on lateral edge of their distal expanded ends; body with numerous pale longitudinal stripes (often faint or not visible in preserved specimens); spots, if present, occur only on head or anterior part of body; interradial membranes of pectoral fin hyaline; length of longest dorsal ray contained 3.6 to 4.4 times in standard length............4

3b. Teeth of upper jaw with 4 denticulations on lateral edge of their distal expanded ends; body without stripes, when alive speckled with numerous bright blue spots which may or may not persist as pale spots in preserved specimens; interradial membranes of pectoral fin dark brown; length of longest dorsal ray contained about
5.2 times in standard length

cyanoguttatus

4a. Teeth of upper jaw with 6 denticulations (rarely 5 or 7); teeth of lower jaw with 4 denticulations (including tip); caudal fin lunate, caudal concavity contained 3.7 to 6 times in standard length; body depth contained 1.9 to 2.3 in standard length; dorsal fin rays VIII, 27 to 31 (usually 28 to 30); anal fin rays III, 24 to 28 (usually 25 to 27)

striatus

4b. Teeth of upper jaw with 5 denticulations; teeth of lower jaw with 3 denticulations (including tip); caudal fin moderately concave, caudal concavity contained 5.7 to 10 times in standard length; body depth contained 1.7 to 2.0 in standard length; dorsal fin rays VIII, 25 to 28 (usually 26 or 27); anal fin rays III, 21 to 25 (usually 23 or 24)

strigosus

5a. Ratio of number of teeth in lower jaw to number in upper jaw about 2:1; caudal fin slightly emarginate, caudal concavity contained 18 to 40 times in standard length; longest dorsal ray contained 4 to 5 times in standard length; inner surfaces of lips plicate, margins crenulate; distance from base of upper lip to distal end of upper teeth contained 3.1 to 3.7 times in head length; length of snout contained 3.6 to 3.9 in standard length

hawaiensis

5b. Ratio of number of teeth in lower jaw to number in upper jaw about 1.2:1; caudal fin lunate, caudal concavity contained 6 to 7 times in standard length; longest dorsal ray contained 5.5 to 6 times in standard length; inner surfaces and margins of lips smooth; distance from base of upper lip to distal end
of upper teeth contained 4.5 to 5.3 times in head length; length of snout contained 4.1 to 4.3 in standard length........magnus

6a. Membranes of caudal fin and posterior parts of dorsal and anal fins pale; margins of lips papillate; enlarged distal curved portions of each tooth of upper jaw with lower half smooth and blade-like and upper half with 3 (rarely 2) lateral denticulations..............................tominiensis

6b. Membranes of caudal, dorsal, and anal fins dark brown; margins of lips smooth; enlarged distal curved portion of each tooth of upper jaw divided into 6 approximately equal lateral denticulations.................................binotatus

Table 27 Counts of Pectoral Fin Rays for the Species of Osteochaetus

<table>
<thead>
<tr>
<th>Species and locality</th>
<th>Pectoral fin rays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td>striatus</td>
<td></td>
</tr>
<tr>
<td>Marshall, Marianas, and Samoa Is.</td>
<td></td>
</tr>
<tr>
<td>Philippine Is. and East Indies</td>
<td></td>
</tr>
<tr>
<td>Egypt, Red Sea</td>
<td></td>
</tr>
<tr>
<td>Mauritius</td>
<td></td>
</tr>
<tr>
<td>strigosus</td>
<td></td>
</tr>
<tr>
<td>Hawaiian Is.</td>
<td>1 22</td>
</tr>
<tr>
<td>Philippine Is.</td>
<td>13</td>
</tr>
<tr>
<td>Mauritius</td>
<td>1</td>
</tr>
<tr>
<td>cyanoguttatus</td>
<td></td>
</tr>
<tr>
<td>Gilbert, Phoenix, and Cocos Is.</td>
<td>1 3</td>
</tr>
<tr>
<td>hawaiiensis</td>
<td></td>
</tr>
<tr>
<td>Hawaii</td>
<td>4</td>
</tr>
<tr>
<td>magnus</td>
<td></td>
</tr>
<tr>
<td>Malden, Jarvis, and Cocos Is.</td>
<td>1 3</td>
</tr>
<tr>
<td>tominiensis</td>
<td></td>
</tr>
<tr>
<td>Celebes</td>
<td>2 4</td>
</tr>
<tr>
<td>binotatus</td>
<td></td>
</tr>
<tr>
<td>Philippine and Molucca Is.</td>
<td>3 27</td>
</tr>
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</table>
Table 28  Counts of the Soft Rays of the Dorsal and Anal Fins for Species of *Ctenochaetus*.

<table>
<thead>
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<th>Species and locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td><em>striatus</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wake I.</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Marshall Is.</td>
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<td>14</td>
</tr>
<tr>
<td>Gilbert Is.</td>
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<td>9</td>
</tr>
<tr>
<td>Line Is.</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Phoenix Is.</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Samoa Is.</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Tuamotu Arch.</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Society Is.</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Austral Is.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solomon Is.</td>
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<td>2</td>
</tr>
<tr>
<td>New Hebrides</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Palau Is.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Mariana Is.</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Philippine Is.</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Formosa</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>East Indies</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Egypt, Red Sea</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Mauritius</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Madagascar</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>strigosus</em></td>
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<td></td>
</tr>
<tr>
<td>Hawaiian Is.</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>Johnston I.</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Tuamotu Arch.</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Philippine Is. &amp; East Indies</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
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Table 28 (Continued) Counts of the Soft Rays of the Dorsal and Anal Fins for Species of Ctenochaetus.

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<th>Species and locality</th>
<th>Dorsal soft rays</th>
<th>Anal soft rays</th>
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<td></td>
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<td>21 22 23 24 25 26 27 28</td>
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<td></td>
</tr>
<tr>
<td>Gilbert Is.</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Phoenix Is.</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cocos I.</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>hawaiiensis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hawaii</td>
<td>1 3</td>
<td>3 1</td>
</tr>
<tr>
<td><strong>magnus</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malden &amp; Jarvis I.</td>
<td>3</td>
<td>2 1</td>
</tr>
<tr>
<td>Cocos I.</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>tosiminiensis</strong></td>
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<td></td>
</tr>
<tr>
<td>Celebes</td>
<td>1 5</td>
<td>4 2</td>
</tr>
<tr>
<td><strong>binotatus</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philippine Is. &amp; Molucca Is.</td>
<td>2 4 16 8</td>
<td>1 9 17 3</td>
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Table 29 Counts of Gill Rakers from the First Gill Arch for the Species of Ctenochaetus.

<table>
<thead>
<tr>
<th>Species and locality</th>
<th>Anterior series of gill rakers</th>
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<tbody>
<tr>
<td></td>
<td>20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42</td>
</tr>
<tr>
<td><strong>striatus</strong></td>
<td></td>
</tr>
<tr>
<td>Marshall, Mariana, and Samos Is.</td>
<td>1 1 3 5 4 4 3 1</td>
</tr>
<tr>
<td>Philippine Is. and East Indies</td>
<td>3 5 6 3 1</td>
</tr>
<tr>
<td>Egypt, Red Sea</td>
<td>1 2 1</td>
</tr>
<tr>
<td>Mauritius</td>
<td>2 3 1 1</td>
</tr>
<tr>
<td><strong>strigosus</strong></td>
<td></td>
</tr>
<tr>
<td>Hawaiian Is.</td>
<td>1 2 2 2 2 2 2 2</td>
</tr>
<tr>
<td>Philippine Is.</td>
<td>2 1 1 1 1</td>
</tr>
<tr>
<td><strong>cyanoguttatus</strong></td>
<td></td>
</tr>
<tr>
<td>Gilbert and Phoenix Is.</td>
<td>1 1 1</td>
</tr>
<tr>
<td><strong>hawaiiensis</strong></td>
<td>2 2</td>
</tr>
<tr>
<td><strong>magnus</strong></td>
<td></td>
</tr>
<tr>
<td>Malden, Jarvis, and Cocos I.</td>
<td>3 1</td>
</tr>
<tr>
<td><strong>tominiensis</strong></td>
<td>1 3</td>
</tr>
<tr>
<td>Celebes</td>
<td></td>
</tr>
<tr>
<td><strong>binotatus</strong></td>
<td>1 2 1 2 2 2 2 1</td>
</tr>
<tr>
<td>Philippine Is.</td>
<td></td>
</tr>
</tbody>
</table>
Table 29 (Continued) Counts of Gill Rakers from the First Gill Arch for the Species of Ctenochaetus.

<table>
<thead>
<tr>
<th>Species and locality</th>
<th>Posterior series of gill rakers</th>
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<tr>
<td>strigatus</td>
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<tr>
<td>Marshall, Mariana,</td>
<td>1 1 2 3 4 4 4 2 1</td>
</tr>
<tr>
<td>and Samoa Is.</td>
<td></td>
</tr>
<tr>
<td>Philippine Is. and</td>
<td></td>
</tr>
<tr>
<td>East Indies</td>
<td>1 1 1 2 3 2 4 3 1</td>
</tr>
<tr>
<td>Egypt, Red Sea</td>
<td>1 2 1</td>
</tr>
<tr>
<td>Mauritius</td>
<td>1 2 1 2 1</td>
</tr>
<tr>
<td>strigosus</td>
<td></td>
</tr>
<tr>
<td>Hawaiian Is.</td>
<td>1 4 4 2</td>
</tr>
<tr>
<td>Philippine Is.</td>
<td>1 3 1 1</td>
</tr>
<tr>
<td>cyanoguttatus</td>
<td></td>
</tr>
<tr>
<td>Gilbert and Phoenix Is.</td>
<td>1 1 1</td>
</tr>
<tr>
<td>hawaiiensis</td>
<td></td>
</tr>
<tr>
<td>Hawaii</td>
<td>1 2 1</td>
</tr>
<tr>
<td>magnus</td>
<td></td>
</tr>
<tr>
<td>Malden, Jarvis,</td>
<td>1 3</td>
</tr>
<tr>
<td>and Cocos Is.</td>
<td></td>
</tr>
<tr>
<td>tominiensis</td>
<td></td>
</tr>
<tr>
<td>Celebes</td>
<td>4</td>
</tr>
<tr>
<td>binotatus</td>
<td></td>
</tr>
<tr>
<td>Philippine Is.</td>
<td>1 4 1 3 2</td>
</tr>
</tbody>
</table>
Fig. 32. Camera lucida drawings of the teeth of Ctenochaetus. A. striatus, 141 mm. specimen, Marshall Islands. B. strigosus, 119 mm. specimen, Hawaiian Islands. C. cyanoguttatus, type. D. hawaiiensis, type. E. magnus, type. F. tominiensis, type. G. binotatus, type. 1. lateral view of upper tooth. 2. inner view of end of upper tooth. 3. lateral view of lower tooth. 4. inner view of end of lower tooth. All of the teeth were taken from the left side of the jaw near the center of the mouth.

Fig. 33. A. Upper tooth of 27 mm. acronurus larva of Ctenochaetus strigosus. B to D. Upper teeth from 31 mm. postacronurus stage of Ctenochaetus striatus. Dotted lines indicate margins of pulp cavity.
Fig. 34 Tooth Counts of *Ctenochaetus*
Ctenochaetus cyanoguttatus Randall

Fig. 32 C

?Acanthurus guttatus Kittlitz (1834: 193, pl. 13, fig. 4) (not of Bloch and Schneider) (Iunganor Island).

?Acanthurus marginatus Cuvier and Valenciennes (1935: 221) (new name for Acanthurus guttatus Kittlitz); Günther (1861: 333) (Iunganor Island).

?Acanthurus ctenodon Var. b Playfair (1866: 57) (Zanzibar).


Ctenochaetus sp. Hiyama (1943: 92, pl. 19, fig. 53) (Marshall Islands).

Ctenochaetus cyanoguttatus Randall (in press, a) (Gilbert Islands, Phoenix Islands, and Cocos Island, Costa Rica).

Dorsal rays VIII, 27 or 28; anal rays III, 25; pectoral rays 16 or 17; anterior gill rakers 26 to 29; posterior gill rakers 34 to 37; scales from gill opening to posterior end of caudal spine 94 to 104; a 170 mm. specimen has 44 upper and 60 lower teeth.

Depth of body 1.85 to 1.95, length of snout 4.3 to 4.8, length of pelvic fin 2.9, length of longest dorsal ray 4.6 to 5.1, caudal concavity 5.8 to 6.2, all in standard length.

Inner surfaces of lips and margin of upper lip smooth; margin of lower lip, especially posteriorly, papillate. Upper teeth with 4 (rarely 3) denticulations (the one at the tip being longest); lower teeth with 3 denticulations (counting tip).

Color (in alcohol) dark brown with numerous small pale spots on the body and pectoral fin (these spots are faint and difficult to see even in freshly preserved fish); all fins brown; dorsal and anal fins
with about 9 or 10 longitudinal dark brown lines (fewer anteriorly in these fins).

Color in life dark brown with head, body, and pectoral fins profusely covered with small bright blue spots, hence the name, cyanoguttatus.

This species was observed by me in its natural habitat on two occasions at Onotoa, Gilbert Islands. It was seen in small rapidly-moving schools in moderately rough water in broad shallow surge channels on the lee side of the atoll. It was a mode of life similar to that of Acanthurus guttatus, the latter species schooling in the rougher water of sharply-defined surge channels on the windward side of the atoll. The spotting of the body of both these species might be a form of protective coloration. The surf zone where they live is characterized by masses of swirling air bubbles.

Acanthurus guttatus Kitlitz was a brown fish with blue spots and 8 dorsal spines. Cuvier and Valenciennes, realizing that this could not be the A. guttatus of Bloch and Schneider, gave the species the name marginatus. It is possible that this species was Ctenochastus cyanoguttatus. But no mention was made of the important item of dentition, although the teeth in Kitlitz' figure are drawn fairly long. The count of dorsal spines cannot be considered too diagnostic, for species of Acanthurus have been recorded with 8 instead of 9 dorsal spines because of the inconspicuous nature of the first spine. Even the blue spots are not unique, for adult Acanthurus nigroris Cuvier and Valenciennes at Wake Island had the usual blue lines broken up into spots, which gave this species an appearance much like C. cyanoguttatus. In view of this, and the fact that the Kitlitz specimen has not been located, describing the species as new seems in order. The Kitlitz specimen is not in the
Sanckenberg Museum. Günther (1861: 337) states that the type of Acanthurus pyroferus described by Kittlitz from the same publication was in the old St. Petersburg Museum. The specimen of A. marginatus may be there; I have been unable to complete correspondence on the matter.

The Cocos Island specimen of Snodgrass and Heller (1904) is referable to this species, although there is no record of the color in life and the spots which were probably present have now faded. G. S. Myers, who kindly loaned the specimen (SU 12280) to me, states that only one other of the four specimens collected from Cocos is now located at the Natural History Museum, Stanford University.

Ctenochaetus striatus (Quoy and Gaimard)

Figs. 32 A, 33 B-D, 35

Acanthurus argenteus Quoy and Gaimard (1824: 372, pl. 63, fig. 2) (Guam); Cuvier and Valenciennes (1835: 239).

Acanthurus striatus Quoy and Gaimard (1824: 373, pl. 63, fig. 3) (type locality, Guam); Cuvier and Valenciennes (1835: 229) (not Hawaiian Islands); Günther (1861: 334) (Borneo).

Acanthurus ostenodon Cuvier (1829: 224); Cuvier and Valenciennes (1835: 241, pl. 289) (Caroline Islands and New Guinea); Günther (1861: 342) (Ceylon and East Indies); Bleeker (1863a: 156) (Halmahera); Playfair (1866: 57) (Zanzibar) (as variety a); Day (1870: 688) (Andaman Islands).

?Acanthurus flavoguttatus Kittlitz (1834: 193, pl. 13, fig. 5) (not of Herre, 1936, or Fowler, 1944) (Caroline Islands).

?Acanthurus Ktlitzii Cuvier and Valenciennes (1835: 222).

Acanthurus strigosus Cuvier and Valenciennes (1835: 243) (not of Bennett) (New Guinea); Bleeker (1853a: 264) (New Guinea, not Hawaiian Islands); Bleeker (1854a: 102) (East Indies); Günther (1861: 342) (New Guinea,
not Hawaiian Islands); Kner (1865-67: 211) (Tahiti); Günther (1873: 116, pl. 79, figs. B and C) (Indo-Pacific); Day (1876: 207, pl. 47, fig. 2) (Andaman Islands); Day (1889: 143) (India); Hardenburg (1933: 155, fig. 1).

Ctenodon Cuvierii Swainson (1839: 256).

Acronurus argenteus Günther (in part) (1861: 346) (Mariana Islands).

Acanthurus (Ctenodon) stenodon Klunzinger (1871: 509) (Red Sea).

Acanthurus (Ctenodon) strigosus Klunzinger (1884: 85) (Red Sea); Weber (1913: 319) (Indo-Australian Archipelago).

Ctenocharastus strigosus Seale (1901: 109) (Guam); Fowler and Ball (in part) (1925: 19) (Wake Island, not Hawaiian Islands or Johnston Island); Herre (1927: 438, pl. 15, figs. 2 and 3) (Philippine Islands); Fowler (in part) (1928: 247) (Oceania, not Hawaiian Islands); Fowler and Bean (in part) (1929: 200) (Philippine Islands and East Indies); Herre (1936: 247) (Polynesia and East Indies); Fowler (1938: 76, 147, 173, 185, 202, 215) (Marquesas Islands, Society Islands, and Christmas Island in the Line Islands); Poll (1942: 11) (Society Islands); Aoyagi (1943: 218, pl. 6, fig. 20, teeth only) (Riu Kiu Islands); Schultz (in part) (1943: 161) (Phoenix and Samoa Islands); Hiyama (1943: 83, pl. 19, fig. 52) (Marshall Islands); Smith (1949: 240, pl. 33, fig. 614) (Natal); de Beaufort (1951: 128, fig. 24) (Indo-Pacific, not Hawaiian Islands); Harry (1953: 150) (Raroia, Tuamotu Archipelago).

Ctenodon stenodon Fowler (1904: 545) (Sumatra).

Ctenocharastus striatus Jordan and Seale (in part) (1906: 355) (Oceania, not Hawaiian Islands); Seale (1906: 67) (Society Islands, Cook Islands, New Hebrides, Austral Islands, and Solomon Islands); Evermann and Seale (1907: 97) (Zamboanga, Philippine Islands); Kendall and Rad-
Teuthis striatus Barnard (1927: 780) (Natal).

Ctenochaetus ctenodon Whitley (1928b: 12) (Santa Cruz Islands); Whitley and Colefax (1938: 294) (Nauru).

Dorsal rays VIII, 27 to 31; anal rays III, 24 to 28; pectoral rays 16 or 17; anterior gill rakers 27 to 36; posterior gill rakers 29 to 42; scales from gill opening to posterior end of caudal peduncle spine 104 to 122.

Body depth 1.9 to 2.3, snout 4.2 to 4.8, pelvic fin 3.3 to 3.7, longest dorsal ray 3.6 to 4.4, caudal concavity 3.7 to 6, all in standard length.

Margins and inner surfaces of lips smooth. Upper teeth with lateral edge of distal expanded end with 6 (rarely 5 or 7) denticulations. Lower teeth with 4 lateral denticulations at end (a small fifth one is sometimes evident).

Color (in alcohol) dark brown with numerous pale lengthwise slightly irregular lines on body (which are often faded and difficult to see); median fins brown; traces of about 5 lengthwise bands may at times be seen in the soft dorsal and anal fins; pectoral fin with rays light brownish (except uppermost principal ray which is edged in dark brown) and membranes hyaline; pelvic fins brown; young specimens may show a small black spot at the base of the last few dorsal rays. Color of
juveniles dark brown with 8 to 12 pale longitudinal stripes on the body about 1/3 as broad as intermediate brown areas, which angle slightly downward as they pass posteriorly. At a standard length from 50 to 65 mm. the number of pale lines is suddenly doubled by the appearance of thin whitish lines in the center of the brown intermediate areas; these narrow lines become as broad as the pale lines of the first set, and more lines are added above and below, especially above, until the adult number of about 30 to 40 is attained. The ones added above the original set tend to angle upwards.

Color (in life) dark olive brown with blue longitudinal lines on the body and small orange spots on the head and nuchal regions; soft dorsal and anal fins with about 5 lengthwise dark bluish lines; pectoral fin yellowish.

Juvenile specimens from the Gilbert Islands of about 40 mm. length were observed with the first set of pale lines red in color, narrow light bluish lines in the intermediate brown areas, and red tips to the lobes of the caudal fin. It is this color pattern that Herre (1927) probably tried to show in his Figure 2 of plate 13 and which led him into the mistaken and persistent contention that this juvenile form was a different species. The error is an easy one to make in view of the variability in length at which adult coloration and configuration is assumed.

One specimen in the acronurus stage (transparent with silvery abdomen) was secured by night lighting at anchorage at Sydney Island in the Phoenix Islands by personnel of the Pacific Oceanic Fishery Investigations. This specimen, (U.S.N.M. No. 163616), 32 mm. in standard length, is shown in Fig. 35 (right hand series top specimen). It is interesting to note that
there is already a change-over taking place from larval dentition to adult-type dentition even though there is no evidence of any other bodily transformation to adult form. This change in dentition may be seen in only a slightly more advanced state in the transforming specimen of Fig. 35 (right hand series middle specimen), from which the three teeth in Fig. 33 B to D were drawn. The teeth were all taken from the upper jaw of this specimen and show early stages in the transformation of tooth form. The inward bending of the expanded tips, already apparent in C, can only be seen in a side view of the teeth. The tooth drawn in A of Fig. 33 was taken from the strigosus acronurus of Fig. 35 (left hand series top specimen). All of its teeth are essentially alike; there are about 18 in each jaw. Probably this specimen is in an earlier stage of development than the striatus acronurus of Fig. 35 (right hand series top specimen). It is suspected that the teeth of striatus younger than the latter will bear 3 denticulations like the strigosus acronurus. The striatus acronurus has about 18 upper teeth and 16 lower teeth with more apparent just beneath the gums at the ends of the jaws. The lateral teeth are more adult-like in form than more medially-located teeth. The most striking thing about the dentition was the finding, upon dissection, of good-sized adult-type teeth imbedded in the soft tissue within the bones of the jaws. Five were found from one side of the upper jaw just above the upper teeth and six from one side of the lower jaw just below the lower teeth. Only the most medial of these imbedded teeth showed a departure from the Ctenochaetus pattern, for not all of the denticulations of this tooth were restricted to the lateral side. Subsequent dissection of the premaxillary and dentary bones of juvenile and adult specimens of C. striatus and other Ctenochaetus of all sizes showed these teeth to be
present, in greater number and larger size in larger specimens, and it is believed that they function as replacement teeth. Specimens of species of Acanthurus, including acronurus and postacronurus forms, were examined, and adult-type teeth characteristic of this genus were also found imbedded in the bones of the jaws.

*C. striatus* is an exceedingly abundant and widespread species, probably occurring in the entire tropical Indo-Pacific region except the Hawaiian Islands. Jordan, Tanaka, and Snyder (1913) record what is probably this species from Japan. J. L. B. Smith in a letter states that it appears to be the most abundant acanthurid on the reefs of tropical east Africa. At Onotoa Atoll in the Gilbert Islands, after two months of collecting, I found it was the dominant fish on a weight basis among all the reef fishes taken. It was very common on the bench reef slope (Cloud, 1952) of the windward reef of the atoll and about coral heads in the lagoon.

In the Red Sea *striatus* seems to have a lower gill raker count (Table 29) and also a greater percentage of specimens with 17 pectoral rays than 16 (Table 27). More material is needed from the Indian Ocean and Arabian Sea, to clarify these and other differences.

Better established in the demarcation on the basis of dorsal and anal fin ray counts (Table 28) between populations in the Philippines and East Indies and the rest of Oceania. Also from the examination of fin ray counts, southeast Oceania (i.e., Society Islands and Tuamotus) may represent a differentiated population.

The largest specimen seen by me was 195 mm. in standard length. It was taken in the Philippines.

*Acanthurus argenteus* Quoy and Gaimard is probably a transforming *Ctenochaetus striatus*. These authors suspected that it was the young
of some species they had not collected, but the nature of the striped color pattern and the high fin ray counts leave little doubt that it is the same as striatus. I retain the name striatus because it has been commonly used, whereas argenteus has been recognized as a name applying to an immediate postacronurus form (the name referring to the silvery coloration of the abdomen) and has never been applied to any adult surgeon fish.

The consideration of Acanthurus flavoguttatus Kittlitz (A. Ketlitzii Cuvier and Valenciennes) as a synonym of G. striatus is based on the Kittlitz figure which is greenish with yellow spots on the head and yellow lines on the body. Lack of reference to dentition and the peculiar fin ray counts account for the uncertainty in my decision. The type of flavoguttatus was not located.

Acanthus ctenodon Cuvier and Valenciennes was referred to synonymy by Kner (1865) and by Günther (1873).

Much confusion has resulted from the frequent use of the name strigosus for the species striatus. This seems to stem from Günther (1873) who considered striatus the young of strigosus and in the overlooking by Gill (1884) of the Quoy and Gaimard species altogether in his erecting of the genus Ctenochaetus. Jordan and Evermann (1905) perpetuated the error by copying Günther's plate of striatus and using it to represent the common Hawaiian species which, in reality, is strigosus. Fowler (1928) did not help by referring striatus to the synonymy of Acanthurus lineatus.

Herre's (1927) separation of strigosus and striatus was based on specimens not exceeding 60 mm. in length and is erroneous.
Fig. 35. Acronurus, postacronurus, and juvenile stages of Ctenochaetus. Left hand series, C. strigosus; right hand series, C. striatus. Natural size.
Ctenochaetus strigosus (Bennett)

Figs. 32 B, 33 A, 35, 36

Acanthurus strigosus Bennett (1828: 41) (type locality, Hawaiian Islands);
Cuvier and Valenciennes (in part?) (1835: 243) (Hawaiian Islands,
probably not New Guinea); Günther (in part?) (1861: 342) (Hawaiian
Islands, probably not New Guinea).

Acanthurus (Etonodon) strigosus Steindachner (1901: 495) (Honolulu).

Ctenochaetus strigosus Jenkins (1903: 480) (Honolulu); Snyder (1904:
534) (Honolulu); Fowler and Ball (in part) (1925: 19) (Laysan, French
Frigate Shoal, and Johnston Island, but not Wake Island); Fowler
(in part) (1928: 274) (only Hawaiian Islands); Fowler and Bean (in
part) (1929: 200) (Philippine Islands and East Indies); Fowler (1931:
344) (Honolulu); Fowler (1938: 233) (Honolulu); Fowler (1941: 257)
(Honolulu); Whitley (1954: 23) (Great Barrier Reef, Australia).

Ctenochaetus striatus Jordan and Evermann (1905: 398, fig. 174 after
Günther, not strigosus) (Hawaiian Islands); Jordan and Jordan (1922;
66) (Hawaiian Islands).

Ctenochaetus flavicauda Fowler (1938: 104, pl. 10, fig. 24) (Takaroa,
Tuamotu Archipelago); Fowler (1949: 104) (Takaroa, Tuamotu Archi-
pelago).

Ctenochaetus sp. Harry (1953: 151) (Raroia, Tuamotu Archipelago).

Dorsal rays VIII, 25 to 28; anal rays III, 21 to 25; pectoral rays
16 (rarely 15); anterior gill rakers 27 to 34; posterior gill rakers 28
to 33; scales from gill opening to posterior end of caudal peduncle
spine 85 to 96.

Body depth 1.7 to 2, snout 4.3 to 4.8, pelvic fin 3.1 to 3.4,
longest dorsal ray 3.8 to 4.2, caudal concavity 6 to 10, all in standard
Fig. 36. Ctenochaetus strigosus (Bennett). 95 mm. specimen from the Hawaiian Islands drawn by Miss Marian Adachi.
length.

Margins and inner surfaces of lips smooth; upper teeth with 5 denticulations (occasional teeth from Philippine specimens will show tiny 6th denticulation); lower teeth with 3 denticulations (including tip).

Color (in alcohol) brown with about 35 narrow pale bluish longitudinal lines (about 1/4 as broad as the alternate brown bands) on the body which angle upward on the basal part of the dorsal fin and downward on the basal part of the anal; small pale spots on the head (and anteriorly on the body in Philippine specimens); a pale ring, broader posteriorly, around the eye in Hawaiian and Tuamotu specimens, restricted to the posterior edge of the eye in Johnston Island material, and absent in Philippine specimens; median fins brown (except caudal fin of Tuamotu specimens which is abruptly pale, white in life); pectoral fin pale except edge of uppermost principal ray which is almost black; pelvic fins brown.

Color (in life) from a 35 mm. Kodachrome transparency of a Hawaiian specimen: brown with narrow pale blue longitudinal lines on the body and basally on dorsal and anal fins; purplish region on chin; blue spots on head; yellow ring around eyes; caudal fin brown; pectoral fin rays brownish, membranes orange-yellow; pelvic fins brown.

Hawaiian specimens in life show considerable variation in ground color. Some, especially in a light-colored environment (as areas of high coral cover), become a light tan in color. Others may be dark brown. The ground color of the species at Raroia, Tuamotus, was observed by Harry (1953) to be black.

Along with the color differences noted above, and meristic data, differences in the shape of the caudal fin may be seen among the speci-
mene from the Philippines and East Indies, Hawaiian Islands, Johnston Island, Tuamotus, and Mauritius which might form the basis for the re-
cognition of subspecies when more material is available and the range
of the species more completely known. The single specimen from Mauritius
has the least concave caudal fin, the caudal concavity being contained
in the standard length about 20 times. The caudal concavity of specimens
from the Philippines and the Hawaiian Islands is 7 to 10. Johnston Island
specimens have a caudal concavity which ranges from 5.7 to 9 in the stand-
ard length; Tuamotu specimens have the most lunate caudal fins, the caudal
concavity contained about 5.7 times in the standard length.

Harry (1953) reported acute pain and swelling in the hand and arm
when cut on the hand by the caudal spine of this species in Raroia; the
pain did not subside until the second day and persisted for a week. He
added that the only other surgeon fish he encountered producing such
effects was C. striatus (recorded as strigosus), though pain from this
species lasted only 3 to 4 hours and was not so intense. I tested the
poisonous qualities of the caudal spine of Hawaiian strigosus by gingerly
inserting the tip of the spine into my palm; a stinging sensation was
soon experienced, and the experiment was carried no further.

This species is extremely abundant in the Hawaiian Islands where
it is known by the local name kole. Elsewhere, except perhaps Johnston
Island, it is not at all common. Only 13 specimens from the Philippines,
Moluccas, and Celebes were found at the U. S. National Museum among the
vast collections made by the "Albatross" Philippine Expedition (1907-
1910); only four are known from the Tuamotus, and one from Mauritius.
The single specimen from the Great Barrier Reef was identified by Whitley
with the aid of a manuscript key such as appears in this paper and was
recorded from Australia by him (1954).

Although more collecting in the Indo-Pacific region may reveal new localities for *strigosus*, it is believed that it is not in continuous distribution throughout its range. The differentiation which has taken place in five of its known localities supports this contention. The great abundance of this species in Hawaii stands in sharp contrast to its apparent absence from much of the Indo-Pacific and its scarcity in the few areas where it does occur. This may be associated with the absence of *striatus* from the Hawaiian Islands.

The acronurus specimen (Fig. 35, left hand series top specimen), U.S.N.M. 118040 and 27 mm. in standard length, was taken at night from the steamer "Albatross" at the surface at Diamond Head Light, Oahu, Hawaiian Islands, on May 6, 1902. The transforming specimen of Fig. 35 (left hand series middle specimen) (University of Hawaii No. 1877) was collected by W. A. Gosline on the reef at Diamond Head, Oahu, May 16, 1950. It is 28 mm. in standard length. The recently transformed juvenile (Fig. 35, left hand series bottom specimen), U.S.N.M. 167199, was taken by the author at a depth of 40 feet, Waikiki, Oahu, on June 4, 1952. As no small juveniles have been seen in tide pools or very shallow water, it is suspected that the acronurus transforms to the juvenile stage at a moderate depth on the reef. Postacronurus and juvenile *striatus*, on the other hand, occur in immense numbers in tide pools and protected shallow-water areas.

The largest specimen of *strigosus* seen by me, 139 mm. in standard length, was collected by the "Albatross" Philippine Expedition at Luzon.
Ctenochaetus hawaiiensis Randall

Figs. 32 D, 37

*Ctenochaetus hawaiiensis* Brock (1954: 307) (*nomen nudum*; name used by Brock from a personal communication before species published.)

*Ctenochaetus hawaiiensis* Randall (in press, a) (Hawaii).

Dorsal rays VIII, 27 or 28; anal rays III, 25 or 26; pectoral rays 16; anterior gill rakers 23 to 25; posterior gill rakers 25 to 28; scales from gill opening to posterior end of caudal spine 115 to 139; a 197 mm. specimen has 26 upper and 56 lower teeth.

Depth of body 1.8 to 1.85, length of about 3.65 to 3.9, length of pelvic fin 3.6 to 3.8, length of longest dorsal ray 4.1 to 4.2, caudal concavity 15 to 40, all in standard length.

Margins of lips finely crenulate; distal one-fourth of inner surfaces of lips plicate, the ridges running perpendicular to the margin. Upper and lower teeth with 3 denticulations (including tips); lower teeth about twice as numerous as upper teeth.

Color (in alcohol) very dark brown with many narrow pale longitudinal lines faintly visible on head and body; (these lines tend to be less irregular than those on other species, the lines on the head are somewhat diagonal); all fins dark brown.

Color (in life) dark olive brown (appearing almost black underwater) with fine yellowish gray lengthwise lines on the head and body.

This species is thus far known only from the island of Hawaii in the Hawaiian Islands, where it is common; it is named for this locality. Fishermen have told me that it is seen rarely at the island of Maui. It certainly does not seem to be present in the waters around the island.
Fig. 37. *Ctenochaetus hawaiensis* Randall. Drawing of holotype by Miss Marian Adachi.
of Oahu, which are well collected.

I have observed C. hawaiensis underwater on only four occasions, three times as a solitary fish and once as a group of three fish. Vernon E. Brock, Division of Fish and Game, Territory of Hawaii, has told me that he has observed the species in schools.

A smaller specimen, yellowish brown in color, (estimated 100 mm. in standard length), and possibly hawaiensis was sighted by me at a depth of 70 feet in Kealakekua Bay, Hawaii, but was not taken.

Ctenochaetus magnus Randall

Fig. 32 E

Ctenochaetus strigosus Fowler (in part) (1927b: 20) (Jarvis Island).

Dorsal rays VIII, 26 to 28; anal rays III, 24 or 25; pectoral rays 16 or 17; anterior gill rakers 28 or 29; posterior gill rakers 35 or 36; scales from gill opening to posterior end of caudal spine 149 to 164; a 225 mm. specimen has 59 upper and 68 lower teeth.

Depth of body 2 to 2.15, length of snout 4.2 to 4.8, length of pelvic fin 2.85 to 3.15, length of longest dorsal ray 5.5 to 5.9, caudal concavity 5.6 to 7.5, all in standard length.

Margins and inner surfaces of lips smooth. Upper and lower teeth with 3 denticulations (including tips).

In alcohol the color of this species is uniformly dark brown. The only record of color in life which I have is that given by Fowler (1927) for the Jarvis Island specimen. He states that the body including the pectorals was covered all over with fine blue-gray dots.
Thus far Ctenochaetus striatus (and C. strigosus as well) is not known from Malden, Jarvis, and Cocos Islands, in spite of its common occurrence elsewhere in the tropical Pacific. These three islands are the sole known localities for C. magnus.

Assuming that Ctenochaetus is Indo-Pacific in origin, which seems reasonable in view of the distribution of the species of this genus and the Acanthuridae in general, one must explain how magnus (and cyanoguttatus) crossed the East Pacific barrier (Ekman, 1953). Malden Island and especially Jarvis Island are near the counter-equatorial current which could conceivably carry fish larvae the great distance to Cocos Island (possibly via the Galapagos Islands). Herre (1940) discusses this mode of transport.

This species is named magnus in reference to its large size. All of the known specimens exceed 200 mm. in standard length.

Ctenochaetus tominiensis Randall

Fig. 32 F

Ctenochaetus strigosus Fowler and Bean (in part) (1929: 200) (Gulf of Tomini, Celebes).

Ctenochaetus tominiensis Randall (in press, a) (Gulf of Tomini, Celebes).

Dorsal rays VIII, 24 or 25; anal rays III, 22 or 23; pectoral rays 15 or 16; anterior gill rakers 20 or 21; posterior gill rakers 20; scales from gill opening to posterior end of caudal spine 83 to 91; a 98 mm. specimen has 33 upper and 32 lower teeth.

Depth of body 1.8 to 2.05, length of snout 4.4 to 4.65, length of pelvic fin 3.3 to 3.6, length of longest dorsal ray 3.5 to 4.4, caudal concavity 4.3 to 6.6, all in standard length.
Margins of lips papillate or crenulate, inner surfaces smooth.
Upper teeth with distal half of the expanded ends smooth and blade-like and basal half divided into 3 (rarely 2) lateral denticulations; lower teeth with 3 (occasionally 4) denticulations (including tips).

Color (in alcohol) brown with a jet black spot at the base of the last few dorsal and anal fin rays, these spots extending slightly on to the caudal peduncle; caudal fin pale yellowish, gradually becoming brown basally, outer portions of the soft dorsal and anal fins pale yellow, especially posteriorly, basally brown like body; outer portion of the brown part of these fins with about 3 to 5 narrow pale horizontal bands (difficult to see on some specimens) which become confluent with the pale distal region of the fins as they pass posteriorly; pectoral fins with rays brownish, membranes pale; pelvic fins brown, a little darker terminally.

The following color note from fresh specimens was taken from Fowler and Bean (1929); it was associated with this species by means of "Albatross" field numbers. "Brownish, dark in life, spotting of side of head indistinct, lower part slightly paler. Dorsal olive, with 5 or 6 bars, beginning as darker olive and on soft fin become cadmium or orange, fuse on fin posteriorly and terminally to form entire color; extreme fin edged narrowly black above; black blotch at axil. Anal like dorsal. Caudal fades whitish. Ventral blackish terminally, membranes hyaline and scattered small, orange, basal spots, rays probably black in life."

Named tominiensis for the Gulf of Tomini, Celebes.
Ctenochaetus binotatus Randall

"Fig. 32 G"

Ctenochaetus strigosus Fowler and Bean (in part) (1929: 200) (Philippine Islands and East Indies).

Ctenochaetus binotatus Randall (in press, a) (Philippine Islands and East Indies).

Dorsal rays VIII, 24 to 27; anal rays III, 22 to 25; pectoral rays 15 or 16; anterior gill rakers 23 to 29; posterior gill rakers 22 to 27; scales from gill opening to posterior end of caudal spine 93 to 102; a 111 mm. specimen has 39 upper and 42 lower teeth.

Depth of body 1.85 to 2.05, length of snout 4.75 to 5.48, length of pelvic fin 3.4 to 3.8, length of longest dorsal ray 3.6 to 4.6, caudal concavity 4.2 to 6.2, all in standard length.

Margins and inner surfaces of lips smooth. Upper teeth with expanded distal part divided into 6 approximately equal lateral denticulations; lower teeth with 3 denticulations (counting tip).

Color (in alcohol) brown with pale lengthwise lines on the body, (much as in strigosus except these lines are about twice as broad as the alternate darker brown lines); a prominent black spot at the base of the last few dorsal and anal fin rays, these spots extending narrowly on to the caudal peduncle; median fins brown; pectoral rays light brownish, the membranes hyaline; margin of uppermost principal pectoral ray dark brown; pelvic fins yellowish, lateral edges and ends of rays brownish.

There is no positive record of the color in life. Fowler and Bean (1929) give a color note for three specimens, one of which was identified
as the type of binotatus by virtue of the "Albatross" field number; however, one of the remaining specimens (the other was not located) proved to be C. striatus. The color description is as follows: "Fine stripes of light bluish on the shoulder at and below the pectoral base and body posteriorly greenish. On dorsal 5 or 6 densely greenish stripes, similarly on anal. First pectoral ray very dark, center of fin yellow. Ventra like body. Some examples with fine lines on body very deep violet." Both the type of binotatus and the one specimen of striatus faintly show in the preserved state the narrow lengthwise lines posteriorly on the body as well as the shoulder and pectoral region. It seems odd that the posterior markings would not be apparent in life.

Named binotatus for the two black marks, one at the axil of the soft dorsal fin and the other at the axil of the anal fin.

A recently-transformed 35 mm. specimen of Ctenochaetus (U.S.N.M. No. 167177), collected in the lagoon at Onotoa Atoll, Gilbert Islands, by the author was noted to have a brilliant yellow caudal peduncle and caudal fin and stood out in sharp contrast to the young of C. striatus picked up at the same time. Examination of the preserved specimen some months later revealed the last few rays of the soft dorsal and anal fins to be colorless and a small black spot to be present in each fin at the base of these rays; small dark brown spots were observed on the head and anteriorly on the body. Meristic data are as follows: D VIII, 27; A III, 25; pectoral rays 15; anterior gill rakers 27; posterior gill rakers 27, upper teeth 22, lower teeth 22. The upper teeth bear 6 or 7 denticulations (usually 7) and the lower teeth 3 or 4 (mostly 4). Of the known species of Ctenochaetus, this specimen would best receive the label of binotatus, however there are some obvious differences such as coloration
and structure of the teeth. Since no specimens of \textit{binotatus} below 79 mm. in standard length are available for comparison and none of any size from the Gilbert Islands (if the species occurs there), the differences observed may be due to the juvenile nature of the specimen of the geographical separation of the Gilbert Islands from the Philippines and East Indies. It is certain that the specimen is not \textit{Ctenochaetus flavigauda} Fowler, for the latter is a variant of \textit{C. strigosus}, and probably had a white tail in life instead of a yellow one.
SECTION II

THE BIOLOGY OF THE MANINI, ACANTHURUS TRIOSTEGUS SANDVICENSIS

HABITAT

The manini is one of the most abundant of Hawaiian reef fishes. The species appears to be common elsewhere in the Indo-Pacific region, judging from its prevalence in museum collections. This is also indicated by statements such as the following by Jordan and Seale (1906: 354): "This species is the most abundant of the genus about Samoa, swarming everywhere on the reefs."

In the Hawaiian Islands the manini occurs in many different habitats. It is found in bays and harbors as well as exposed reef areas. It is abundant in tide pools and shallow water, yet is known at depths of at least 100 feet. Although not often seen where water is turbid or brackish, it nevertheless has been taken from such regions.

Like most species of reef fishes, the manini avoids extensive stretches of sand or mud bottom. Its absence from such areas is probably due to the lack of food. The lack of cover may also be a factor, for, the manini is rarely seen far from some hole or crevice in the reef where it can hide.

The manini in the Gilbert Islands and Marshall Islands appears to be more restricted in habitat, possibly because of the sharper definition of the ecological zones of these atolls. It occurs in these islands both in the lagoon and outer reef areas; however it seems to be confined to shallow water. On the outer reef the fish were seen only on the reef flat, the young in great abundance in the shallower sections and the adults on the seaward portions. The species was only rarely observed in
the turbulent surge channel zone and was never seen on the coralliferous terrace (bench area of living coral offshore from the reef flat).

As in the Gilberts and Marshalls, the presence of heavy coralline areas in the Hawaiian Islands seems to limit the manini. This is apparent from the underwater transect work of Brock (1954). Areas like the northern part of Kealakekua Bay, Hawaii, where the coral growth is extremely rich for the Hawaiian region, are almost devoid of manini. Since this species is herbivorous, its diminution in coral areas may be associated with the small amount of substratum available for the growth of algae. Surprisingly, other surgeon fishes such as Acanthurus leucopareius, Acanthurus achilles, and Zebrasoma flavescens, usually less abundant than manini, were fairly common in this part of the bay, but these species are more inclined to crop close to the substratum than the manini, judging from the greater amount of inorganic debris in their stomach contents, and may therefore be superior competitors under such conditions. The constant feeding by these and other herbivorous or omnivorous forms such as pomacentrid fishes and echinoids on small areas which were covered with a short stubble of algae was observed. This suggested that the short length of the thalli of the many species of algae that comprise the algal mat was due to overgrazing. In order to test this hypothesis, small enclosures of 1 inch mesh wire were attached to coral-free sections of the bottom in the bay to prevent feeding on the algae by the larger grazing animals. When first observed one month later, the algal growth was distinctly greater inside than outside the enclosures.

The eggs and larvae of the manini are pelagic. This has been ascertained by a study of development following artificial fertilization of the eggs, by the capture of larvae in plankton nets, and by the
taking of the late postlarval or acronurus stage at night lights off-shore.

A total of eleven acanthurid larvae (at least three of which are manini), 4.2 to 8.7 mm. in total length, were found in the plankton collections from Hawaiian waters of Cruises 4 (May, 1950) and 6 (August, 1950) of the "Hugh M. Smith", a research vessel of the Pacific Oceanic Fishery Investigations. These fish were taken at eight stations ranging from about 20 to 140 miles from the nearest island (for more exact locations, see King and Hida, 1954: fig. 1, stations 1A, 10, 13, 15, 17, and 23 of Cruise 4 and stations 7 and 14 of Cruise 6). They were captured in horizontal tows made with fine meshed plankton nets (1 meter) which sampled three different levels simultaneously. For both cruises combined, a total of 58 hauls were made at the surface, 24 at a depth of 50 meters, and 112 at depths from 100 to 300 meters. Six of the larvae were taken at the surface, five at 50 meters, and none at greater depths. The failure to find more larvae in these collections is probably due to the distance from land of most of the stations. Only six of the 29 stations of each cruise were within 25 miles of any of the Hawaiian Islands and only one within 10 miles. The absence of larval Acanthurus longer than 8.7 mm. in the collections is probably due to the ability of larger larvae to elude the plankton net. The lack of specimens shorter than 4.2 mm. may be the result of a paucity of small larvae so far off-shore.

That acanthurid larvae, in general, are more abundant close to land has been shown by Reintjes and King (1953). These authors found a total of 1,067 acanthurid larvae in the stomachs of 184 of 1,097 yellowfin tuna (Neothunnus macropterus) sampled from the region of the Line Islands
and Phoenix Islands. They stated that the acanthurids were common in the stomachs of near-shore yellowfin, along with balistids and carangids. Representatives of the Bramidae, Exocoetidae, and Gempylidae predominated in the stomachs of offshore yellowfin.

Mr. King kindly allowed me to examine the stomach content work sheets in order to compare the occurrence of larval acanthurids in the stomachs of tuna caught at the surface by pole-and-line fishing and by trolling with those caught at depths of 100 to 500 feet by long-lining. The comparison revealed more acanthurid larvae in the stomachs of surface-caught fish.

The acronurus larval form of the manini, averaging about 26 mm. in standard length in the Hawaiian Islands, leaves the pelagic realm and enters very shallow water, often tide pools, to transform to the juvenile stage. Although juveniles tend to remain in shallow water, there is a progressive movement with increasing size to somewhat deeper water to seaward. Adults are not entirely absent from tide pools, however. Several were seen in deep pools cut off from the open sea at low tide on Moku Manu Island and Manana Island (Rabbit Island). Also, at night on Oahu, manini as large as 70 mm. were occasionally found in high tide pools.

**TOLERANCE TO TEMPERATURE AND SALINITY**

In order to determine if the manini is capable of surviving the extremes of temperatures and salinity which it encounters on Oahu, a survey of these factors in tide pools and brackish areas known to be penetrated by the species was undertaken and compared with the tolerance of the species to these factors as determined by laboratory experiments on both juveniles and adults.
Environmental extremes of temperature and salinity

The survey of environmental temperature and salinity was not made on any regular schedule. Only when conditions occurred which suggested that high and low values of temperature and salinity might be found were measurements of these factors made. Temperatures were taken at mid-depth of the tide pools tested. Water samples of which chlorinity was determined (as a measure of salinity) were obtained after stirring the pools. The Mohr method was used to determine chlorinity, and the results are expressed as grams of chlorine per kilogram of sea water, i.e. in parts per thousand (‰).

The maximum temperature recorded was 35.1°C. It was taken in a tide pool with basalt bottom at Makapuu Point on August 31, 1953, at 2:00 P.M. A reverse stratification of temperature was present in the pool (i.e. the water at the bottom was warmer than at the surface). A plus 0.2 low tide had occurred at 1:50 P.M. (time of low tide being taken as the midpoint between the time of Hanauma Bay and Waimanalo low tides). The maximum air temperature at Makapuu Point for August 31 was 79°F (= 26.2°C). Other fishes observed in the tide pool along with manini included aholehole (Kuhlia sandvicensis) and kupipi (Abudes duf sordidus).

The minimum temperature found was 16.2°C. It was taken in a small tide pool at Diamond Head on March 5, 1954, at 11:15 P.M. A minus 0.2 low tide had occurred at Honolulu at 10:42 P.M. The minimum air temperature during the night was 60°F (= 15.5°C). A strong northerly wind was blowing. The wind velocity for the hour prior to the temperature reading was as high as 33 knots.

The extremes of environmental temperature recorded by Tester and Takata (1953: 48) for the aholehole on Oahu are 20.1°C and 32.1°C.
Like the manini the aholehole is a tide-pool resident. Although found in the highest pools of the intertidal zone, it is less inclined than the manini to enter small pools. A more notable difference of these species is the ability of the aholehole to live in streams where the chlorinity is very slight or nil.

The lowest chlorinity recorded by me from pools where manini were observed was 2.65 0/00. It was found in a high tide pool at Diamond Head during a heavy rain at 9:00 A.M. on March 1, 1954. A plus 0.1 low tide occurred at 9:02 A.M. A rivulet of rain water was observed entering the pool.

Another low chlorinity (3.62 0/00) was obtained in a sample taken from the shore of the Ala Wai Canal at the Ala Moana Bridge on February 23, 1954, following a heavy rain. Although manini could not be seen at the time because of the turbidity of the water, they were observed in the area prior to the rain and after the water had cleared.

The highest chlorinity was 21.30 0/00. The water sample was taken from the pool at Makapuu Point in which the 35.1° C. temperature was recorded.

Experiments on temperature tolerance

The experiments on temperature tolerance were performed on manini which were maintained in aquaria at a near-constant temperature of 24° C. for at least 24 hours. The fish were placed singly in a gallon jar of sea water at the temperature of the aquarium from which they were taken. The jar was then placed in a water-filled copper compartment containing either a heating unit or a refrigerating unit, strongly aerated, and gradually brought to the test temperature in 1 hour plus or minus 10
minutes. The fish were kept at this temperature for one hour. If
death ensued before the end of this hour, the time was recorded. The
duration of the test period was chosen as a rough approximation of the
temporal conditions of exposure to temperature extremes experienced by
manini in high tide pools.

At about 5° C. before the maximum or minimum temperatures were
reached, the fish began to increase their rate of swimming, dart around
the jar, and break the surface with their snouts. As the lethal tem-
perature was approached more closely, the equilibrium of the fish was
affected. They swam on one side, upside down, or in small circles.
The last major activity was usually a rapid, spasmodic, swimming move-
ment, often in a short spiral.

The results, except those of tests of both juveniles and adults
run at temperatures of 36.5° or less and 13° or greater (which caused
no deaths), are shown in Table 30.

<table>
<thead>
<tr>
<th>Standard length (mm.)</th>
<th>Test temperature (° C.)</th>
<th>Minutes test temperature endured</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>37.0</td>
<td>45</td>
</tr>
<tr>
<td>97</td>
<td>37.0</td>
<td>60</td>
</tr>
<tr>
<td>137</td>
<td>37.5</td>
<td>25</td>
</tr>
<tr>
<td>96</td>
<td>37.6</td>
<td>10</td>
</tr>
<tr>
<td>86</td>
<td>38.0</td>
<td>4</td>
</tr>
<tr>
<td>97</td>
<td>38.0</td>
<td>15</td>
</tr>
<tr>
<td>101</td>
<td>38.2</td>
<td>6</td>
</tr>
<tr>
<td>103</td>
<td>38.3</td>
<td>20</td>
</tr>
</tbody>
</table>
Although the data are not adequate to determine individual variation in the region of the temperature extremes, it seems evident that a range of about 13 to 36°C is withstood by this species in the Hawaiian
Islands, disregarding the possible extension of this range by acclimatzation. This is probably in excess of the extremes of temperature encountered by the manini in Hawaii.

Although the range of temperature which manini can withstand appears to be extra-limital to the extremes normally encountered by the species in the Hawaiian Islands, information generously supplied by Dr. Strasburg in a letter indicates that juvenile manini in the southern Marshall Islands are upon occasions killed in tide pools by excessive variation in temperature. On August 17, 1950 a high tide pool, about 30 square feet in surface area and 1 foot deep, on the ocean side of Arno Atoll was observed at low tide to contain two small Acanthurus triostegus triostegus and one small Istiblennius edentulus. Several hours later the two manini were dead. The blenny was still living. The temperature of the pool at mid-depth was 41° C.

Experiments on salinity tolerance

Salinity tolerance experiments on manini were carried out in a 30 gallon aquarium. All fish were retained in aquaria at least 24 hours before use in experiments. The fish were not exposed to the test salinity suddenly. Instead the salinity was gradually changed over a period of 2 hours either by the removal of aquarium water and replacement with tap water (previously allowed to stand for at least 12 hours) or the addition of salt from evaporated sea water. Fish were held at the test salinity for a maximum of 24 hours. The long period of exposure to salinity extremes was chosen because manini entering brackish areas are probably subjected to water of low salt content for at least 24 hours.

The results are given in Table 31. Omitted are trials run at
chlorinity values greater than 1.4 0/00, none of which caused any deaths. No trials were run at chlorinities greater than 38.25 0/00.

Table 31 Salinity Tolerance of Acanthurus triostegus sandvicensis

<table>
<thead>
<tr>
<th>Number of fish</th>
<th>Standard length (mm.)</th>
<th>Chlorinity (0/00)</th>
<th>No. surviving 24 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>26 - 29</td>
<td>1.4</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>26 - 29</td>
<td>0.7</td>
<td>0‡</td>
</tr>
<tr>
<td>3</td>
<td>27 - 29</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>92</td>
<td>1.4</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>89</td>
<td>0.7</td>
<td>0‡</td>
</tr>
<tr>
<td>2</td>
<td>86 - 90</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>27 - 29</td>
<td>34.8</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>26 - 28</td>
<td>35.7</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>28 - 29</td>
<td>37.4</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>26 - 29</td>
<td>38.25</td>
<td>0‡</td>
</tr>
<tr>
<td>1</td>
<td>83</td>
<td>38.25</td>
<td>0**</td>
</tr>
</tbody>
</table>

* All specimens dead in 5 hours.
† Specimen died after 8 hours.
‡ All specimens dead in 5 hours.
** Specimen died after 17.5 hours.

Although more data are needed to determine with accuracy the minimum salinity which manini can withstand, it seems evident that manini in tide pools can tolerate a greater range in salinity than they normally experience. Since they cannot live in water of extremely low salinity, they probably do not enter fresh water habitats.
PREDATORS

Predation of the manini is probably most acute during the early stages of the life history; however, I have no information on the identity of the many pelagic animals that must feed on the eggs and small larvae. The large number of late larval stages of acanthurids found in the stomachs of adult yellowfin tuna has been discussed.

Only a few instances of predation on juvenile manini have been encountered incidentally and are presented here briefly. Juvenile manini have been found in the stomachs of moray eels (Muraenidae). A small lizard fish (Synodontidae) was observed to catch a juvenile manini in its jaws in shallow water in Kaneohe Bay, Oahu. The manini was too large to be swallowed, and it eventually escaped. A 50 mm. specimen of Antennarius was placed in an aquarium with six juvenile manini. A half an hour later he had eaten a 31 mm. manini.

It is believed that predation (man excluded) on the juvenile stage of the manini in the Hawaiian Islands is much more pronounced than on the adult stage. In addition to the fishes mentioned above, holocentrids, carangids (especially Caranx spp.), scorpaenids, cirrhitids, and sphyraenids, and possibly also certain of the larger nocturnal crabs, probably feed on small manini. Once a manini reaches adult size, it probably enjoys freedom from predation by most of these fishes (although not from man). The Hawaiian marine fauna is peculiar in the paucity of moderately large shallow water carnivorous fishes such as serranids and lutjanids which are well adapted for feeding on reef fishes. The larger predaceous fishes which are present, such as adult Caranx, adult Sphyraena, and sharks, are not prone to enter small holes or crevices in the reef in pursuit of reef fishes. Also these predators are not numerous at the
present time, probably because of fishing pressure.

PARASITES

Seventeen parasites were detected on and within the manini. They are discussed below in systematic order.

Hydrozoa

Seven specimens of transforming manini have been found parasitized by *Hydrichtys* (Figs. 38 and 39). This unusual hydroid was located in no special place on the fish, occurring on head, body, and fins. It was never seen on juveniles or adults.

Colonies of this hydroid have been sent to Dr. Cadet Hand, who is studying the genus, for identification. As yet he has been unable to identify the species with certainty.

Hyman (1940: fig. 136, B, pp. 447-448) has presented a labelled drawing of a colony and a brief discussion of the mode of feeding of *Hydrichtys*.

Trematoda

Three specimens of a monogenetic fluke were discovered on the epidermis of two adult manini. The flukes are small (less than 2 mm. in length), perfectly transparent in life, and were hidden in the slime of the fish. They are difficult to find and are probably more common than the paucity of specimens would indicate. Figure 40 is a photograph of a stained specimen. It was identified as a species of *Benedenia* Diesing. This genus is characterized chiefly by two adjacent suckers on the prohaptor and a prominent opishaptor which is armed with a pair of stout hooks. A detailed, labelled drawing of the genus may be found in Hyman (1951: fig. 92, D). Jahn and Kuhn (1932) have worked out the life cycle of *Benedenia mellani*. 
Fig. 38 Colony of Hydrichthys sp. on the dorsal fin of Acanthurus triostegus sandvicensis in its first day of transformation from the acronurus to the juvenile state.

Fig. 39 Colony of Hydrichthys sp. on the postorbital part of the head of Acanthurus triostegus sandvicensis in its second day of transformation from the acronurus to the juvenile state.
The most common fluke of the manini is an unidentified species of the gyrodyctylic genus *Ancyrocephalus* Creplin. The most diagnostic feature of the genus is the structure of the opisthaptor. It is fairly distinct from the main part of the body, bears two pairs of hooks, two cuticular supporting bars, and marginal hooklets (Dawes, 1946: 114). Figure 41 is a drawing of a living specimen, 631 micra in length, which was obtained from the gills of a 132 mm. manini. This tiny fluke was found on the gills of most of the manini which were examined. In some of the manini the infestations were heavy, an average of about one fluke per gill filament being present. This fluke is extremely active and highly extensible. It was observed to change its position on a gill filament frequently by attaching with the anterior end and looping the posterior end over to another location where the hooks were dug into place. Siwak (1931) has worked out the life cycle of a species of *Ancyrocephalus*.

Two digenetic trematodes were found in the digestive tract of the manini. Specimens were sent to Dr. Harold W. Manter for identification. He stated in a letter that they are *Hapladena varia* Linton and *Haplo-splanchnus obtusus* (Linton), previously known only from the surgeon fishes *Acanthurus hepatus* (= *chirurgus*) and *Acanthurus coeruleus* at Tortugas, Florida. Manter (1955: 76) included a discussion of this distribution in a recent paper reviewing the zoogeography of trematodes of marine fishes.

*Hapladena varia* (Fig. 42) was only occasionally found in the intestine of the manini. A total of 22 specimens were taken from 200 manini whose digestive tracts were examined for parasites. The manini harbouring the fluke ranged from 43 to 136 mm. in standard length. The intesti-
Fig. 40 *Benedenia* sp. from the epidermis of *Acanthurus triostegus sandvicensis*. Length of specimen, 1.9 mm.

Fig. 41 *Ancyrocephalus* sp. from the gills of *Acanthurus triostegus sandvicensis*. 
Fig. 42 *Hapladena varia* Linton, a fluke from the duodenum of *Acanthurus triostegus sandvicensis*. Length of specimen, 2.9 mm.

Fig. 43 Unidentified leech from the gills of *Acanthurus triostegus sandvicensis*. Length of specimen, 2.4 mm.
time of most of the manini examined was filled with algae. Undoubtedly many of the flukes were overlooked, for they are small (usually less than 3 mm. in length when relaxed). Linton (1910: 65, fig. 156) described the species in detail; he included a labelled drawing.

_Haplosplanchus obtusus_, described in the same work by Linton, was found only in juvenile manini, although it may have been overlooked in adults. It is smaller than _Hapladana varia_, usually less than 1.3 mm., and not as slender. The length of the fluke is about 2.5 times the width. Some of the juvenile manini contain a large number of these flukes. 71 were counted in one 49 mm. specimen. Most of the flukes were in the duodenum; a few extended as far back as about the half way point of the intestine. A few were found in the pyloric caeca, but none were ever seen in the stomach. _H. obtusus_ was observed in life through the translucent intestine of the small fish. It is an active parasite, often moving from one part of the intestine to the next.

**Nematoda**

Four different nematodes were found in the manini. Specimens of all of these were sent to Dr. Leland S. Olsen for identification. Two could not be identified. One of these was a very attenuate immature male from suprpharyngeal tissue of the fish. The other was represented only by larval specimens; these were taken from the pyloric caeca. A third worm, which was occasionally found encysted in the mesenteries, was considered to be the immature female of an unidentified species of _Contracaecum_ Railliet and Henry.

The fourth nematode, _Spirocamallanus monotaxis_, had been previously described by Olsen (1952: 196-197, figs. 79 to 84, see Fig. 45 in this thesis). The most distinctive feature of the genus is the structure of
the buccal capsule. It is not separated into paired lateral valves, and the inner wall bears prominent spiral thickenings. Prior to the finding of this nematode from the intestine of the manini, it was known only from *Monotaxis grandoculis*. In view of the differences between the manini and the latter fish (it is a lutjanoid and a mollusk feeder), it seems likely that *S. monotaxis* will be found in other marine fishes.

Of 200 manini (mostly adults obtained from fishermen who set traps from Kewalo Basin to Koko Head, Oahu) examined throughout the year for internal parasites, 76 were found which harbored *S. monotaxis* in the intestine or pyloric caeca. The average number of worms found in these 76 fish was 5. The largest number of worms found was 35. No obvious variation of the degree of infestation of this nematode in the manini was observed during the year.

This species of nematode, red in life, was first noticed when it was seen to wriggle part way out of the anus of a manini which had recently died. The female (Fig. 44) reaches a length of about 45 mm., and the male about half this size.

*S. monotaxis* is viviparous, and the large uterus of mature females is filled with developing eggs and larval worms (Fig. 45). When released, the larval nematodes settle to the bottom with the feces. Under a binocular dissecting microscope it was noted that they rhythmically coiled and uncoiled. 71 such movements per minute were counted for one worm and 76 for another (temperature, 26°C). Some diatomaceous detrital material was added to the watch glass containing the larvae, and the water was changed daily. Some of the worms lived as long as 14 days, but they did not increase in size. Since the species of Camallanidae whose life cycle is known require an arthropod intermediate host (often
Fig. 44. Adult female *Spirocamallanus monotaxis* Olsen from the intestine of *Acanthurus triostegus sandvicensis*.

Fig. 45. Morphological detail of *Spirocamallanus monotaxis* (after Olsen, 1952).
a copepod), it seems likely that this species also needs such a host to complete its life cycle. This is supported by the finding that manini could not be directly infected with the larval nematodes. Six juveniles, ranging from 38 to 49 mm., were fed a large number of larvae by mixing the latter with algae. The fish were killed over a period of 3 to 50 days following the attempted infection and examined for nematodes in various parts of the viscera; none were found. The process was repeated for an 89 mm. manini. It was dissected a week later, but there was no sign of the worms.

Hirudinea

Two different leeches were found on the manini. Both have been sent to Dr. J. Percy Moore for identification. He reports that they are species in family Pisicolidae (possible genus Cystobranchus) and cannot be identified by external characters. One is represented by a single 2.4 mm. specimen (stained and photographed herein as Fig. 43) which was taken from the gills of an adult manini. Dr. Moore states that it is immature and probably cannot be identified. Mature specimens were obtained of the other leech, but these will have to be sectioned to learn their identity. Six specimens of the latter were collected from the body surface of three juvenile manini, 26 to 31 mm. in standard length, taken in the Ala Moana Yacht Basin on April 17, 1955. These leeches varied from 2.9 to 7.5 mm. in length, were dark brown in life, and easily detected on the host. None were found on the numerous manini collected from the same region in previous years. They were capable of moving over the body of the fish with great agility; however they usually remained in one place for a considerable length of time. One attached to the eye of a small manini for nearly an entire day. Another remained
on the dorsal fin of a second fish for a period of four days.

**Crustacea**

Six species of parasitic copepods have been taken from the body surface and pharyngeal cavity of the manini. In the identification of these copepods I have been assisted by Dr. Paul Illg.

Figure 46 is a subadult cyclopoid copepod which was taken from the body surface of an adult manini. Only one specimen was found; therefore this may be a case of accidental parasitism. Dr. Illg believes that it is a species of *Taeniacanthus* Sumpf.

The remaining copepods are all calagoids. Figure 47 represents an undescribed species of the genus *Dentigryps* Wilson. Only three specimens were found, all females from the epidermis of adult manini. This genus is unique in having the free thoracic segment fused with the genital segment; there is a smooth conical process on each latero-posterior corner of the thoraco-genital segment; the caudal rami are very small. Only one species is described in the genus. It occurs in the mouth of a grouper in Bermuda.

The most common parasitic copepod of the manini is a species of the caligid genus *Lepeophtheirus* Nordmann. It probably is undescribed. Figure 48 shows the subadult female, subadult male, and adult female of the species. The genus is distinctive in the sum total of the following characters: one free thoracic segment bearing the fourth pair of legs, fourth legs with four segments, frontal plate without lunules, caudal rami present on normally developed abdomen, maxillae tiny and bifurcate, maxillary palp and furca present. The known species of the genus closest in morphology to the present species is *L. dissimulatus* Wilson. It was collected from groupers in Bermuda and the Galapagos Islands. The present
Fig. 46 Taeniacanthus sp.  
Taken from the body surface of  
Acanthurus triostegus sandvicensis.

Fig. 47 Dentigryps sp.  A female  
collected from the body surface of  
Acanthurus triostegus sandvicensis.
Fig. 48 Lepeophtheirus sp. Taken from the body surface of Acanthurus triostegus sandvicensis.
species differs from this in its smaller size, lack of two pairs of papillae on the posterior part of the genital segment in the female, shorter caudal rami, and coloration. *L. dissimulatus* is dark yellow in life without pigment spots. The species from the manini is transparent in life with about 40 yellow-brown chromatophores on the surface and fewer bright blue spots which seem to be deeper in the body; there are occasional black spots, especially posteriorly; the eyes are reddish brown and separated by a region of white shaped like an inverted "Y".

Of 164 manini examined for external parasites throughout the year, 112 were found with one or more of these copepods. The largest number found on a single fish was 20. The average number on the infested fish was 3.9. Because of their small, dorso-ventrally flattened bodies and transparency, they are hard to locate on the host. They are capable of skittering rapidly over the epidermis, and if detached from the fish they are able to swim freely in the water.

An interesting association, probably a result of parasitic copepods such as this species of *Lepeophtheirus*, was observed between the manini (and other reef fishes) and a small colorful undescribed fish of the labrid genus *Labroides*. In the clear water off Manana Island (Rabbit Island) two adult manini were seen being pecked over the head and body by this wrasse. The manini remained motionless in the water except for slight undulation of the fins. Since the stomach contents of several of the labrids consisted primarily of calagoid copepods, it is believed that they were removing these parasites from the manini. On another occasion a manini was observed to swim directly to the "domain" of two of these labrids. As the manini was approached by one of the labrids, the surgeon fish was speared and brought ashore. At least two *Lepeophtheirus* sp. were
present on its body.

Another unknown species of *Lepaeophtheirus* from the manini is shown in Figure 49. Considerably larger than the previous one, it was seen on the host more readily. Only one specimen was collected; hence this also may be a case of accidental parasitism.

Figure 50 is an undescribed species of the lernaeid genus *Paniculus* Nordmann. This unusual genus is characterized in the female by a fusion of the head with the first segment, a lack of horns or processes on the head, narrowed second and third segments, fourth segment widened, fifth and genital segments and abdomen fused into a long cylindrical trunk, and the appendages variously reduced or absent. The male is unknown. Ten species have been described. The present species is different from these ten by the greater length of its caudal rami. Only nine specimens were found, all securely attached to fins, with the elongate body in alignment with the fin rays. Because of this and the small size of the parasite, many specimens were probably overlooked.

Figure 51 represents an undescribed genus of copepod of the family Pandaridae. This genus appears to be closely related to *Pandarus* and *Perissopus*. It differs from *Pandarus* in lacking secondary posterior lobes on the carapace, having a one-segmented abdomen, and possessing a fourth pair of swimming legs, the rami of which are indistinctly segmented. It differs from *Perissopus* in the shape of the genital segment, in having shorter latero-posterior lobes on the carapace, and lacking large hemispherical knobs on the ventral surface of the carapace on either side opposite the second maxillipeds. It is distinct from both these genera in lacking leg rudiments on the genital segment, in having no lateral lobes on the second thoracic segment (the first free segment),
Fig. 49  Lepeophtheirus sp.
Female from the body surface of
Acanthurus triostegus sandvicensis.

Fig. 50  Peniculus sp.
Female from the pelvic fin of
Acanthurus triostegus sandvicensis.
Fig. 51 Undescribed genus and species of parasitic copepod of the family Pandaridae. A male removed from a cyst in the dorsal fin of *Acanthurus triostegus sandvicensis*. 
and in having two eyes instead of three. The genus differs from all pandarids in having a genital segment which is not distinctly larger than any preceding segments. Furthermore, it will be the first species known from a host other than a shark or ray, and the only one which encysts in the host's tissue. All of the copepods of this species were found within small sacs in the fin membranes of the manini. What appears to be the same species was seen encysted in the fins of Chaetodon fremblii and Zanclus cornutus. 49 of 164 manini examined during an entire year for external parasites had this copepod in its fins. The greatest number on any one fish was 6; the average number per infested fish was 1.8. Many cysts were found which had been vacated by the parasite. Whether occupied or not, each cyst had a small aperture at one end. All of the specimens dissected from the cysts were males or subadult males.

The life history of pandarids appears to be highly complex, and a complete series of stadia has never been satisfactorily compiled for any species as yet. One problem is a marked sexual dimorphism. Another is an apparent alternation of free swimming and parasitic stages.

DISEASES

The only data on disease were obtained from a series of unsuccessful attempts to maintain manini in an aquarium. Four adult fish were placed in a 23 gallon stainless steel aquarium which had previously been successfully used to keep adult and juvenile manini for periods of several weeks. The water was aerated and filtered. Two days later two of the fish died, and on the following day the remaining fish were dead. Several hours before their death the manini swam in a disoriented manner. The fins were badly eroded — the caudal fin of one was completely
eaten away. Scattered large sores were present on the head and body which was excessively slimy. The fish were examined for parasites and found to have no more than the average complement.

The tank was cleaned (but not sterilized) and two more adult fish added. They died in a similar fashion in 48 hours. The tank was again cleaned and a 57 mm juvenile manini placed in it. This fish died just 48 hours later.

In spite of the filtration, the tank became cloudy on the second day. A milliliter of the water was taken, successive dilutions made, and the higher dilutions cultured with a sea water-agar mixture (sterile aged sea water, agar, and a small amount of peptone and ferric phosphate). The number of resulting colonies were counted; the bacterial count of the original milliliter of aquarium water was computed at 212,000,000. Before the fish were placed in the aquarium the number of bacteria were probably less than 1,000,000 per ml.

Several smears were taken from eroded areas of dying manini. The dominant organism was a short, plump, gram-negative rod. It is not known whether this is the etiological agent of the disease or merely a secondary bacterium.

Oppenheimer (1953) reported on the sudden death of 14 California yellowtail (Seriola dorsalis) in a marine aquarium. At the time of the death of the fish the water was cloudy and contained approximately 10,000,000 bacteria per cubic centimeter. The skin of the fish was covered with a heavy mucous coat.

FOOD HABITS

Food of larval manini

Although few specimens of larval manini were available for an
analysis of food habits, it appears from these that the manini in the pelagic habitat of a size of at least 6.6 mm. in total length feeds on zooplankton. The digestive tracts of three manini, 6.6 to 7.0 mm. in total length (see section on development), were removed and opened under a binocular dissecting microscope. Two of these fish were taken in a plankton net towed between 5:46 and 6:48 A.M. One was empty and the stomach of the other contained two appendicularians and a larval polychaete. The third fish was captured between 3:20 and 4:25 A.M. and was empty.

The digestive tracts of 57 manini in the acronurus stage (see section on transformation), which were obtained at night light stations in the Hawaiian Islands, Line Islands, and Phoenix Islands, were examined in the same way. 45 were completely empty. Four contained one to seven tiny fish scales; one of these also contained a shrimp chela. A few crustacean appendages (mostly from shrimp) were found in three other fish, one of which had also eaten a barnacle metanauplius. The intestines of two fish had a small amount of unidentified chitinous remains. The crustacean appendages, metanauplius, and fish scales were not free in the gut lumen but were caught between longitudinal folds of the gut. It is evident that the acronuri do not feed at night.

Four Acanthurus acronuri were obtained from the stomachs of skipjack (Katsuwonus pelamys) caught during the day in Hawaiian waters. Because of their being partially digested, I am not able to identify any of these acronuri to species; two, however, are too large to be manini. The stomachs and intestines of all four of these fish were filled with food. Planktonic shrimps and shrimp larvae were the principal food items. Also found were copepods, polychaetes, and the remains of larval fish.
Food of transforming manini

In an aquarium manini in their first day of transformation from the acronurus to the juvenile stage were not observed to feed. The digestive tracts of thirty specimens collected in tide pools during the morning of their first day of transformation and preserved immediately were devoid of food material. Of 24 similar specimens collected in the afternoon, 19 were empty, but five had eaten small amounts of fine filamentous algae and leptopel (Fox, Isaacs, and Corcoran, 1951). Second day transforming manini were seen to feed on algae in an aquarium, though not frequently, and preserved specimens of the same transformation age all contained small amounts of algae and leptopel. During the remaining two or three days of transformation feeding is progressively heavier.

Food of juvenile and adult manini

The gut contents of juvenile and adult manini consist almost entirely of relatively fine filamentous algae. The teeth of the manini are close-set and denticulate on the margins (Fig. 10 a) like other species of Acanthurus. They are therefore well adapted for feeding on filaments of algae. Experiments on feeding in aquaria showed that the absence of coarser algae in the gut contents is due to limitation in the size and strength of the jaws and teeth. Only the smaller branches of coarser algae, like species of Hypnea, were eaten. Small juvenile manini only ate the fine end branches whereas larger fish ate progressively larger branches.

Inorganic sediment was rarely found in the stomach or intestines of manini. When branches of a delicate species of the red alga Poly-siphonia were mixed with fine sand and offered to aquarium manini, the
fish were most adept at picking out the filaments which projected above the sand. The stomach of the manini is thin-walled, similar to that figured and described by Breder and Clark (1947: 295, fig. 1) for *Acanthurus coeruleus*. It contrasts sharply with the thick-walled, gizzard-like stomachs of many of the other species of *Acanthurus* (see p. 59). Unlike the manini, the latter species normally ingest large amounts of inorganic sediment with the algae upon which they feed.

In addition to avoiding the ingestion of inorganic debris, juvenile and adult manini do not feed on animal material. Even when hungry, they declined to eat any of several kinds of animal food which were offered.

In an aquarium the fish were very skillful in shunning small crustaceans and small masses of tunicate or sponge which were in close proximity to the algae on which they were feeding. Occasional small animals are found in the gut contents, however. These are probably taken in accidently. In shallow water at Coconut Island an adult manini was observed feeding on algae close to an egg mass of the damsel fish, *Abudefduf abdominalis* (the guarding fish had been frightened away). When the manini reached the edge of the egg mass, it ceased to feed, swam over the mass, and began feeding on algae on the other side. Other fish, such as labrids and chaetodonts, feed greedily on the eggs when afforded the opportunity to do so by the absence of the guarding parent.

A study of the kinds of filamentous algae eaten by manini was undertaken. It was soon apparent that a great many different species of algae are eaten, and it is believed that at least a few filaments of virtually every filamentous alga in the Hawaiian area can ultimately be found in the gut of the manini if enough specimens are examined. Any partial listing of these algae would be meaningless or even misleading; therefore
a new approach was pursued. A simple piece of apparatus was devised to
test the preference by manini for various kinds of common filamentous
algae. Ten tongue depressors were attached 2 cm. apart to a piece of
wood. The free end of each depressor was notched and wrapped with a
short piece of pliable galvanized steel wire. Different kinds of algae
were fastened to the depressors by wrapping the wire ends around them.
All ten depressors with the assortment of algae attached were lowered
simultaneously into the center of an aquarium in which juvenile manini,
26 to 30 mm. in standard length, were kept. When experiments were re­
peated, the position of the algae was always changed. If an alga was
not eaten during the course of the experiment, it was left in the aquar­
ium as long as it appeared edible, to see if it would ultimately be de­
voured. The results are given in Table 32.

Table 32 Preference Feeding Experiments on Juvenile
Acanthurus triostegus sandvicensis

<table>
<thead>
<tr>
<th>Preferred</th>
<th>Completely eaten</th>
<th>Sparingly eaten</th>
<th>Never eaten</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polysiphonia sp.</td>
<td>Hypnea sp.</td>
<td>Ectocarpus</td>
<td>Lyngbya majusculis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>indicus</td>
<td>Lyngbya sp.</td>
</tr>
<tr>
<td>Enteromorpha sp.</td>
<td>Hypnea sp.</td>
<td>Sphacelaria sp.</td>
<td>Hormothamnion</td>
</tr>
<tr>
<td></td>
<td>Lophosiphonia sp.</td>
<td>Liagora sp.</td>
<td>enteromorphoides</td>
</tr>
<tr>
<td></td>
<td>Ceramium sp.</td>
<td>Jania sp.</td>
<td>Hydrocoleum</td>
</tr>
<tr>
<td></td>
<td>Centrocercas sp.</td>
<td>Rosenvingia sp.</td>
<td>cantharidium</td>
</tr>
<tr>
<td></td>
<td>Gracilaria sp.</td>
<td>Trichogloia sp.</td>
<td>Calothrix</td>
</tr>
<tr>
<td></td>
<td>Rhizoclonium sp.</td>
<td>Fixed diatoms</td>
<td>confervicola</td>
</tr>
<tr>
<td></td>
<td>Dasysa sp.</td>
<td>(many species)</td>
<td>Ectocarpus</td>
</tr>
<tr>
<td></td>
<td>Enteromorpha sp.</td>
<td></td>
<td>breviarticulatus</td>
</tr>
<tr>
<td></td>
<td>Cladophora sp.</td>
<td></td>
<td>Asparagopsis</td>
</tr>
<tr>
<td></td>
<td>Grateloupia sp.</td>
<td></td>
<td>taxiformis</td>
</tr>
<tr>
<td></td>
<td>Herposiphonia sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Microdictyon</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>setchellianum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Many of the above algae were offered in a comparable manner to two adult manini, 123 and 128 mm. in standard length, with similar results.

Some species of algae not listed in the table were offered but not eaten; these, however, were probably too coarse for the juveniles. Included were two species of Laurencia, a species of Gelidium, a Gracilaria, and a species of Dictyota. A thallus of one of the species of Laurencia was placed in the aquarium with the adult manini. The small branches were eaten, leaving the major branches denuded.

Of the seven kinds of algae fine enough to be eaten, but ignored in the preference experiments, one is a red (Asparagopsis taxiformis, well known for its high iodine content), one is a brown (Ectocarpus breviiarticulatus), and the rest are blue-greens. These were the only blue-greens tested.

Blue-green algae, some of which are the same species as those in the preference experiments, have been found in the stomachs and intestines of manini. This seems inconsistent with the results of the experiments. It was noted, however, that the blue-greens were never the exclusive food material, but were always mixed with large amounts of other algae, usually reds or greens.

In May, 1952, in water 10 to 20 feet deep in Hanauma Bay, Oahu, the bottom was examined for the kinds of fine algae which reached a height of about 5 cm. or more. Three species this size were common: Lyngbya majuscula, Asparagopsis taxiformis, and Plocamium sandvicense (a red alga). Since surgeon fishes are abundant in the bay and at least two of the three algae are distasteful to one surgeon fish, the success of these algae might be associated with distasteful qualities.

Kluegel (Master's thesis, University of Hawaii, 1921) made the
following statement concerning herbivorous fishes: "No fishes are strictly herbivorous. Although some fish apparently feed only on algae, yet a careful examination shows the presence of crustacean setae, the soft parts of which are more easily digested than the tougher seaweed." Among the fishes examined by her were two specimens of manini. She found algae and crustacean setae in the stomachs. Contrary to Klugeal is the work of Allee and Frank (1948) who showed that goldfish could be sustained with Chlorella alone.

Although there was little question from my observations, crustacean setae notwithstanding, that the manini requires no animal food, an experiment was designed to demonstrate that this species can subsist and grow on algae alone. Since Lefèvre (1940) has shown that different kinds of algae resist digestion by gastro-intestinal juices of fishes in various degrees, it was decided to feed two lots of fish with different algae. A 23 gallon aquarium was divided into two compartments with a piece of plexiglass. Six manini, 26 to 31 mm. in standard length, were placed on each side and provided with cover in the form of several rocks grouped in the center of each compartment. The fish on one side were fed with a Polysiphonia and those on the other with an Enteromorpha (these were the algae upon which manini fed most vigorously in the preference experiments).

These algae are among the first macroscopic organisms to appear on the bottom of boats in harbor areas on Oahu. They are fast growing (especially the Enteromorpha which increased its length an average of 27 mm. per day on the eastern side of a boat during a period of five sunny days in April). If collected when the thalli first develop, they are almost devoid of animal life. 1.75 grams of a fresh mass of the Enteromorpha contained one ciliate, one nematode, one copepod, and a few epiphytic
pennate diatoms and blue-green algal cells. Nevertheless the algae were thoroughly washed and picked over for animals before being fed to the fish. Fresh algae were added to the aquarium every day, and the previous day's algae removed. At the end of two weeks the fish were measured. Those fed on *Polysiphonia* grew an average of 2.9 mm.; those fed on *Enteromorpha* grew an average of 3.1 mm. During the two week interval the temperature in the aquarium was cool, varying from 23.0 to 23.8° C.; thus the amount of growth is even more significant.

The preference experiments indicated that neither of these algae was eaten more readily than the other. *Manini* often alternated between feeding on the two. After two weeks of feeding on one of these, both kinds were added at the same time. It was immediately apparent that the fish had been conditioned to the alga on which they had been feeding. The "new" alga was untouched initially and only occasionally sampled an hour later. The preference was no longer obvious by the end of the day, however.

*Manini* feed almost constantly during the day, both in an aquarium and their natural habitat. They do not feed at night (see section on behavior).

The volume of algae consumed is large. Four juvenile *manini*, 28.5 to 45 mm. in standard length and weighing a total of 8.3 grams, were fed a known mass of *Enteromorpha* in an aquarium early in the morning. The alga was weighed after firm squeezing followed by blotting on paper towels. At the end of the day the remaining fresh algal material was weighed in the same manner. Fresh algae can be distinguished from fecal algae by the brownish or blackish green color of the latter (instead of grass green) and the tendency of the latter to remain in pellets. 10.8
grams of this alga was eaten one day and 8.8 grams the next. The same procedure was utilized for two adult fish, 123 and 128 mm. in standard length and 83.2 and 94.5 grams in weight respectively. These two fish ate 27.4 grams of Enteromorpha on one day. The second day 16.3 grams of Polysiphonia was consumed. After being unfed during the morning of the third day, they ate 25.2 grams of Enteromorpha during the remaining six hours of the day. Although these two adult manini in the above experiment were well adapted to aquarium life (they were reared to this size as captive fish in a pond of the Hawaii Marine Laboratory at Coconut Island and were maintained in the aquarium 12 days before the experiments), it was observed that they did not feed as frequently as adult manini in the natural environment (whereas the juveniles did). The feeding by the adults was readily interrupted by the approach of an observer. Usually only one fish fed at a time, and since the larger one dominated the smaller and held it in a corner of the aquarium for much of the day, the former consumed the major part of the algae. Yet both fish disdained to feed at all when placed in separate aquaria.

Stimulus to feeding

Wunder (1927) carried out an extensive study on the sense organs of marine teleost fishes in relation to feeding. Normal fishes were compared with the same fishes after various sense organs were extirpated. He found close agreement between the importance of each sense and the development of the corresponding organ. The relative importance in feeding of the different sense organs varied widely. In some species the eyes were of little significance.

The following simple experiments and observations were conducted in order to ascertain what sensory mechanism or mechanisms are utilized
by the herbivorous manini in finding food.

The juice from several grams of Enteromorpha was squeezed into the aquarium in which two adult manini had been starved for a day. This was unfiltered and colored the water green when first dropped into the aquarium. No response was observed in the fish, even when some of the green color was seen to diffuse in the immediate vicinity of the nose and mouth of the fish. A similar experiment was performed on several juvenile manini with Polysiphonia, again with no visible response. By contrast, when an extract of Polysiphonia was dropped into an aquarium containing an adult Abudeful abdominalis, this fish swam to the surface where the extract clouded the water red and snapped its jaws erratically in this region. When the colorless filtered extract from shrimp flesh was added, this species of damsel fish became active and darted around the surface. A small piece of paper which was placed in the tank at this time was repeatedly ingested and rejected.

Some Enteromorpha and Polysiphonia was boiled to the extent that the algae began to disintegrate and lose most of their color. This was placed in the aquarium with fresh algae of the same kinds. Although juvenile manini fed initially on the fresh algae, the boiled algae was ultimately completely eaten.

Some maroon rayon fiber similar in texture and color to Polysiphonia was placed in an aquarium with juvenile manini. It was taken into the mouth temporarily by several of the fish. When the rayon was soaked in extract of the Polysiphonia, it was not taken in with greater frequency.

When recently voided fecal Enteromorpha was placed at the surface of the aquarium in the same manner that fresh algae was offered, most of the manini approached it, hesitated, and swam away. One juvenile drew
a small amount into its mouth but hastily ejected it. When defecated filaments were added together with fresh filaments of Enteromorpha, only the fresh algae were eaten. In the absence of fresh algae, fecal algae which have remained in the aquarium for several hours may be ingested. The results of offering the blue-green algae listed in Table 32 were similar to that just described for recently voided fecal algae. The blue-greens were approached, but rarely taken into the mouth.

The nasal organs of a 26 mm. manini were cauterized with a hot wire. Five minutes after this, the fish was offered some Polysiphonia. It fed on this with the same "enthusiasm" as previously.

Another juvenile fish was blinded by wiping a crystal of potassium hydroxide over the eye (other fish were blinded with silver nitrate crystals but these invariably died within 36 hours). After contact with the potassium hydroxide, the surface of the eye became opaque white; this fish survived more than three days. It moved slowly about the bottom, occasionally swimming by chance into a mass of Polysiphonia. It never swam directly to the algae. When the algae touched the mouth it was often eaten. By the third day when the aimless movements carried the fish into a mass of algae, it fed voraciously.

It is concluded from the above that vision alone is needed to locate algal food, and the nasal sense functions in feeding only to avoid unsavory material. Chemoreceptor organs in the mouth and possibly tactile organs as well also seem to be associated with the acceptance of algae and the rejection of material which is not utilized as food. The selection to feed more of one alga rather than another develops after the algae have been sampled; this is probably also due to the experiences of taste and touch.
DIGESTION

In the work on nutrition of marine animals much effort has been expended on the analysis of mode of feeding and stomach contents, whereas little has been applied to the important aspect of the digestion of these animals. Yonge (1931) pointed out that information as to what an animal may collect and pass into its alimentary system may or may not indicate the true food of the animal. Thus, a study of digestion should logically accompany an investigation of food habits.

Morphology of the digestive tract

The similarity of the stomach of the manini to that of Acanthurus coeruleus as described by Breder and Clark (1947) has been mentioned. The manini stomach is elongate, and divisible into cardiac and pyloric portions. The cardiac part has prominent, longitudinal, irregularly scalloped folds on the inner surface; the pyloric part is smooth. A cross-section of the pyloric part showed the muscle tunic to be about the same width as the mucosa. There are few multicellular glands. The total width of the stomach wall is less than 0.1 mm. thick except posteriorly near the pylorus where it is slightly thicker than 1 mm.

Just posterior to the pylorus are five pyloric caeca. Several authors (including Yonge, 1931) have claimed that the pyloric caeca have taken over the role of the pancreas in certain teleosts, the latter organ supposedly being absent in these fishes. Dawes (1929) found that the pyloric caeca of the plaice (Pleuronectes platessa) had the same structure as the intestine with which it was in free communication, and Rahimullah (1945) came to the same conclusion after examination of 119 species in 50 different families of fishes. The structure of the pyloric caeca of the manini is consistent with the findings of Dawes and Rahi-
The bile duct opens into the base of one of the pyloric caeca.

The pancreas of the manini proved to be difficult to find. It was finally located in the form of two to four (usually three) tiny, round, buff glands lying in the mesentery alongside the bile duct near its junction with the liver.

The intestine of the manini is long, in keeping with the well founded biological principle that herbivorous animals have lengthy intestines. The length of the alimentary tract of large adult manini is nearly six times the standard length of the fish. Most of this length is attributable to the intestine which is complexly folded within the body cavity. The length of the alimentary tract of small juvenile manini is only slightly greater than three times the standard length of the fish. The increase of the alimentary tract relative to standard length is shown in the graph of Figure 52. With increasing size the volume of a body requiring nutrient increases faster than the intestinal surface if the rate of growth of the two is equal. A disproportionate elongation of the intestine is necessary to keep the area of absorptive surface adequate to the needs of the body. Hiatt (1947: 254, 257) noted a striking increase in the relative growth of the intestine of the herbivorous milkfish (*Chanos chanos*) between 90 and 115 millimeters standard length. The ratio of intestinal length to standard length increased from 3.5:1 to 7.2:1. He noted a correlation between the increase in length of intestine and the substantial rise in the amount of larger algal types in the stomach contents and the reduced number of smaller food items like diatoms and blue-green algae. No sudden change-over in the size of algal food which is eaten by the manini occurs at any size range once transformation has taken place, and the curve of alimentary tract length plotted against standard
Fig. 52 Change in length of the alimentary tract of *Acanthurus triostegus sandvicensis* with increase in standard length. The group of points at A represents the length of the tract of 10 specimens (24 to 27.5 mm.) in the acronurus larval stage which were taken at a night light offshore. The points at B represent 10 specimens (24 to 28 mm.) collected in tidepools which have just completed their transformation to the juvenile stage.
length is without sharp inflection. The great increase of the gut length which occurs when manini transform from the acronurus to the juvenile state is discussed in the section on transformation.

The inner surface of the intestine is covered with small villi. The wall of the intestine is thin, its average thickness, not including any villi, is about 0.05 mm. The mucosa is about three to four times as broad as the muscle tunic.

**Time for algae to pass through gut**

In order to find out the time which is required for algae to pass through the entire alimentary canal of the manini, two adults, 123 and 128 mm. in standard length, were fed only the red alga, Polysiphonia, for a period of two weeks. The tank was cleaned and the diet switched to the green alga, Enteromorpha. Two hours and twenty-five minutes later the fish were observed defecating the green alga. They had already deposited some on the bottom of the aquarium, so the following day the experiment was repeated by switching back to the red alga. In two hours and four minutes the first of the red alga was voided. In view of the great length of the digestive tract, this short interval of time seems extraordinary. However, when considered in the light of the nearly constant diurnal feeding and the volume of algae consumed, it becomes more understandable.

The same procedure was repeated for small juvenile manini, ranging from 26 to 30 mm. in standard length. The Polysiphonia passed through their alimentary tracts in one hour and forty-five minutes.

At night, when feeding ceases and the fish enter a state of torpor, the gut is not completely emptied in two hours or so. One 39 mm. manini, for example, which was caught at 1:15 A.M. still had a small amount of
algae in the stomach and in the last 26 mm. of the intestine. The total length of the alimentary tract of this specimen was 177 mm.

**Digestive enzymes**

No reference was found in the literature to any assay of the digestive enzymes of a strictly herbivorous fish. From work on herbivorous animals other than fishes the generalization can be made that proteinase is less active in herbivorous forms than in carnivores and amylase more active. There are indications that this is true for fishes at least for amylase. Kenyon (1925) compared starch digestion in the carp (*Cyprinus carpio*) which, though omnivorous, eats large amounts of algae, and the carnivorous pike (*Esox lucius*). He wrote, "...the carp, which is largely a vegetarian, possesses amylase in tremendous amounts in the hepatopancreas and to a less extent throughout the intestinal mucosa. The pickerel, on the contrary,...possesses only a negligible quantity of amylase, having little in the pancreas, esophagus, intestine, and practically none in the stomach." Vonk (1927) wrote that the carp has more than 1000 times the amount of amylase in the pancreas than that of the carnivorous pike or shark. Schlottke (1939) found amylase in large quantities in the carp, whereas the predaceous rainbow trout (*Trutta iridea*) and perch (*Perca fluviatilis*) evidently produced almost no amylase. Data comparing the activity of proteinase and lipase of omnivorous and carnivorous fishes are meager and conflicting.

In view of the importance of the hydrogen ion concentration to enzyme activity, the pH of the contents of various parts of the digestive system of the manini was determined. The measurements of pH were made with a Beckman pH meter on six adult fish which averaged 120 mm. in
standard length. The results, expressed in the ranges of pH found, are given in Table 33.

Table 33 pH of Organs of the Digestive System of Acanthurus triostegus sandvicensis

<table>
<thead>
<tr>
<th>Organ</th>
<th>Range of pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>6.3 - 7.7</td>
</tr>
<tr>
<td>Duodenum</td>
<td>7.7 - 9.1</td>
</tr>
<tr>
<td>Intestine</td>
<td>8.0 - 9.1</td>
</tr>
<tr>
<td>Gall bladder</td>
<td>6.2 - 6.4</td>
</tr>
</tbody>
</table>

The variation in pH in the stomach, duodenum, and intestine appeared to be correlated with the degree of fullness of the organs. The low pH values were found in the organs when they were filled with algae. Hydrochloric acid secretion in a stomach in which food is present is a possible explanation for the greater acidity at this time. Babkin and Bowie (1928) found a variation in pH of the duodenum of the killifish (Fundulus heteroclitus) similar to that shown above for the manini. These authors also noted that low values of pH were obtained when the duodenum contained food. They attributed this to the discharge of bile to the organ when filled with food.

Extracts for the enzyme study were consistently prepared from the stomach (both cardiac and pyloric portions combined), pancreas, pyloric caeca, duodenum, and intestine of adult manini which were killed immediately before the removal of these organs. Because of the excessive thinness of the gut wall, it was very difficult to separate the mucosa from the muscle layers; therefore extracts were made of entire organs.
or linear parts of organs. All portions of the digestive tube to be extracted were first washed with sea water to remove all traces of food material. Tissues were ground in mortar and pestle with calcareous sand. This sand had previously been cleaned by repeated washings with water, boiling with 3 per cent potassium hydroxide and then for a short while with 2 per cent hydrochloric acid. In view of MacKay's (1929) reporting that 30 per cent alcohol yielded the most active amylase from the eel pout (Zoarces anguillarlis), this agent was also used for extracting amylase in the present study. Lipase extracts were made in 40 per cent glycerol and protease extracts in 50 per cent glycerol. Extraction was carried out in a refrigerator for a period of 24 hours.

Digestion by amylase and lipase proved to be rapid at room temperature (26 - 27°C); thus no incubation was necessary in experiments with these enzymes. Digest tubes with protease were incubated at 36°C.

Buffer solutions used in the digestion experiments were based on the mixtures of Clark and Lubs (Hawk and Bergeim, 1942: 24).

Bacterial action was prevented by the addition of several drops of toluol to the extract and digest test tubes.

The substrate for amylase experiments was 1 per cent starch solution. To each test tube containing 1 ml. of extract of the digestive organs 5 ml. of starch solution, 1 ml. of buffer of pH 6.8, and toluol were added. For each tissue there was a control tube identical with the experimental digest tube except for the previous boiling of the extract to inactivate all enzymes.

The progress of digestion was followed by removing small amounts of fluid from the digest tubes and testing with Lugol's solution. The changes in the solution from deep blue-black through purple, red, yellow, and
finally colorless indicated a breakdown of the starch at least to aehroo-
dextrine. Ultimately all of the tubes were colorless, thus disclosing
starch digestion by the pancreas, pyloric caeca, duodenum, intestine, and
stomach. The experiment was repeated three times with sections of the
digestive tract vigorously washed to minimize the possibility of enzyme
from another source being adsorbed on the epithelial surface of the organ
being tested. Again, there was a definite amylase present in each organ.

The positive results seem unusual in view of the fact that most
vertebrates (except for mammals which secrete ptyalin in their saliva)
break down starch initially with pancreatic amylase and complete the
process with intestinal maltase. These results on the manini seem less
dubious, however, in the light of the finding by Kenyon of amylase
throughout the whole gut of the carp (although it was considered to lack
a true stomach) and by the detection of stomach and duodenal amylase
in Zoarcus by MacKay. Also Babkin and Bowie found amylase in the intes-
tine of the killifish. They were certain it was not adsorbed pancreatic
amylase, for they were unable to observe any proteolytic action in the
same extract.

In view of the variable amount of glandular tissue in the organs
tested, no precise comparison was possible of the relative strength of
amylase of these organs; nevertheless attempts were made to obtain ex-
tracts from equal amounts of glandular tissue of the organs and compari-
sions made in terms of the time required for digestion to the colorless
state. Additional toluol was added to tubes requiring long digestion
time. Two trials were conducted and the results indicate that pancreatic
amylase is nearly twenty times more powerful per unit of tissue than the
amylase from other organs. That from the stomach was weakest.
The pH optimum of the amylase was determined by simultaneously boiling for 15 minutes a series of test tubes buffered to different pH values in which digestion had been allowed to proceed almost to completion, and then testing with Lugol's solution. The red color of erythrodextrine was apparent in solution from tubes at pH 5.6 and 6.0. Five tubes from pH 6.0 to 7.0 were straw colored, those at 6.6 and 6.8 being slightly paler than the others. Solution from the tubes from pH 6.0 to 7.0 was further tested by an iodometric method of detecting reducing sugar based on the micro method of Linderström-Lang (Linderström-Lang and Holter, 1933). The tubes at pH 6.6 and 6.8 were found to contain equal amounts of sugar and larger amounts than other tubes; however, as indicated by the color test, the distinction between the amounts present in all of these tubes was not great. Final titration values with 0.05 normal sodium thiosulfate ranged only from 1.41 to 1.57 ml. It may be stated that the optimum pH appears to be 6.7, but it is as important to add that this optimum is not sharply defined.

The method of Michaelis and Rona (v. Weal, 1937: 245) was used in lipase experiments. Solutions of the substrate, tri-n-butyryl, were prepared by adding eight drops to 400 ml. of distilled water, shaking manually for one hour, and filtering. When the tri-n-butyryl solution is exposed to the action of lipase and digested, the viscosity of the solution is lessened. This alteration in viscosity was detected by use of a stalgmometer of 7.3 ml. capacity. The average number of drops of undigested tri-n-butyryl solution which was liberated from the instrument was 86. When distilled water was used, 62.5 drops fell. The percentage of digestion was computed from a knowledge of the number of drops which fell from the instrument when a series of dilutions between saturated
tri-n-butyrl and distilled water were used.

Each digest tube testing lipase action of one of the digestive organs was prepared by adding 25 ml. of the saturated tri-n-butyrl solution, 2 ml. of buffer, and toluol to 2 ml. of the extract of the organ. Controls consisted of similar test tubes with boiled extracts.

Digestion was found to occur rapidly in all the organs tested. Again, no precise comparison of the strength of enzyme from the different sections of the alimentary tract on a quantitative basis was possible, but the relative time needed for digestion by approximately equal tissue extract concentrations from the different organs permits a qualitative expression of enzyme strength. It was evident that the pancreas produced the most lipase and the stomach the least, although the difference was not as marked as with amylase. The pyloric caeca showed the greatest lipase activity of the remaining organs. Difference between the duodenum and the rest of the intestine was not discernible.

The pH optimum was determined for pyloric caeca lipase. Digestion was allowed to proceed simultaneously in 15 test tubes of different pH values for 2½ hours, and was then terminated by placing all of the tubes in boiling water for 15 minutes. They were allowed to cool to room temperature before being tested with the stalagmometer. The results are given in Table 34.

Table 34  pH Optimum of Lipase of the Pyloric Caeca of Acanthurus triostegus sandvicensis

<table>
<thead>
<tr>
<th>pH</th>
<th>Number of drops</th>
<th>Digestion (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>84.5</td>
<td>15.0</td>
</tr>
<tr>
<td>4.0</td>
<td>79.0</td>
<td>63.0</td>
</tr>
</tbody>
</table>
Table 34 (Continued) pH Optimum of Lipase of the Pyloric Caeca of Acantharus triostegus sandvicensis

<table>
<thead>
<tr>
<th>pH</th>
<th>Number of drops</th>
<th>Digestion (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>73.5</td>
<td>79.0</td>
</tr>
<tr>
<td>6.0</td>
<td>69.0</td>
<td>89.1</td>
</tr>
<tr>
<td>6.2</td>
<td>68.0</td>
<td>90.9</td>
</tr>
<tr>
<td>6.4</td>
<td>67.5</td>
<td>91.8</td>
</tr>
<tr>
<td>6.6</td>
<td>66.7</td>
<td>93.3</td>
</tr>
<tr>
<td>6.8</td>
<td>66.0</td>
<td>94.5</td>
</tr>
<tr>
<td>7.0</td>
<td>65.5</td>
<td>95.2</td>
</tr>
<tr>
<td>7.2</td>
<td>65.2</td>
<td>95.7</td>
</tr>
<tr>
<td>7.4</td>
<td>65.6</td>
<td>95.1</td>
</tr>
<tr>
<td>7.7</td>
<td>65.7</td>
<td>94.8</td>
</tr>
<tr>
<td>8.0</td>
<td>65.8</td>
<td>94.7</td>
</tr>
<tr>
<td>9.0</td>
<td>67.0</td>
<td>92.7</td>
</tr>
<tr>
<td>10.0</td>
<td>68.5</td>
<td>90.0</td>
</tr>
</tbody>
</table>

Three additional experiments (using new extract) were performed over a more restricted pH range. In each of these experiments the pH of 7.2 gave the lowest number of drops; thus this pH appears to be the optimum for the enzyme.

Detection of protein digestion was based on the formaldehyde titration of Sörensen (Jordan, 1927). The principle underlying this method is the quantitative neutralization by alkali of the acid radicals exposed when the long protein molecules are split. The basic NH₂ groups, likewise exposed, are first inactivated with formaldehyde.

The substrate was a 3 per cent colloidal solution of gelatin. 5 ml.
of this solution were placed in a digest tube, and 1 ml. of extract, 2 ml. of buffer, and toluol added. Immediately after mixing, 2 ml. of the mixture were removed from each tube and 3 ml. of one-third strength saturated formaldehyde solution (previously neutralized with 0.1 normal sodium hydroxide) added. Titration of one portion with 0.1 normal sodium hydroxide followed, with phenolphthalein as indicator. This initial titration served as a control and was compared with the result from identical treatment after a period of digestion. It was necessary to have a control for each buffer used, as different amounts of acid were present in the various buffer solutions.

In initial experiments protease was found in the pancreas, pyloric caeca, duodenum, and intestine, but not in the stomach. In none of the organs was the proteolytic activity strong as may be seen from the following summarizations of two of the experiments.

The pancreatic glands from six manini averaging 131 mm. in standard length were removed, extracted in 50 per cent glycerol, centrifuged, and the supernatant diluted to 12 ml. with distilled water. Enough acid was produced by 1 ml. of this solution (thus one half the extractable pancreatic enzyme from a single fish) after three hours of digestion at a pH of 8.4 to require 0.35 ml. of 0.015 normal sodium hydroxide more than the control for neutralization.

The entire intestine, less the duodenum, from an 86 mm. specimen was extracted in 50 per cent glycerol and diluted to 12 ml. Acid produced by 1 ml. of this mixture after three hours of digestion at pH 8.8 required 0.2 ml. of the sodium hydroxide solution more than the control for neutralization.

Because of the acidic reaction in the stomach of the manini and the
knowledge that protease in this organ can vary widely from individual to individual depending on the state of hunger of the animal (Schlottke, 1939), further effort was expended to localize this enzyme in the stomach. In the first of the repeat experiments, conducted at pH values of 4.0, 6.0, and 8.0, negative results were obtained. A second trial at pH values of 2.0, 3.0, 4.0, and 5.0 was also negative. A third trial, conducted with fresh extract of high concentration (prepared from trituration in 5 ml. of 50 per cent glycerol of three stomachs, two of which contained considerable algae, from manini averaging 115 mm. in standard length) finally gave positive results. 1 ml. of this concentrated extract (thus containing extractable enzyme from three-fifths of a stomach) at pH 6.0 yielded acid equivalent to 0.2 ml. of 0.015 normal sodium hydroxide after four hours of incubation.

A pH optimum of about 8.4 for the pancreatic protease of the manini is indicated from the titrations listed in Table 35. Extracts used for the pH optimum determination were made from the pancreatic tissue of seven adult manini. The digestion time was three hours. The number of milliliters of 0.015 normal sodium hydroxide solution shown in the table represent the average of two series of titrations.

Table 35  pH Optimum of Protease of the Pancreas of Acanthurus triostegus sandvicensis

<table>
<thead>
<tr>
<th>pH</th>
<th>0.015 N NaOH (ml.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>0.07</td>
</tr>
<tr>
<td>6.0</td>
<td>0.13</td>
</tr>
<tr>
<td>7.0</td>
<td>0.18</td>
</tr>
<tr>
<td>7.6</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Table 35 (Continued) pH Optimum of Protease of the Pancreas of Acanthurus triostegus sandvicensis

<table>
<thead>
<tr>
<th>pH</th>
<th>0.015 M NaOH (ml.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.9</td>
<td>0.31</td>
</tr>
<tr>
<td>8.1</td>
<td>0.34</td>
</tr>
<tr>
<td>8.4</td>
<td>0.35</td>
</tr>
<tr>
<td>8.8</td>
<td>0.30</td>
</tr>
<tr>
<td>9.2</td>
<td>0.25</td>
</tr>
<tr>
<td>9.6</td>
<td>0.17</td>
</tr>
<tr>
<td>11.5</td>
<td>0.09</td>
</tr>
</tbody>
</table>

It is concluded that the results of the enzyme study of the manini are consistent with the generalization made on page 292 concerning the digestive enzymes of herbivorous animals. The predominant enzyme is amylase. As in the carp, it is found throughout the digestive tract. Lipase activity is prominent and is also widespread in the system. Proteolytic enzymes are weak, especially that in the stomach.

REPRODUCTION

Sex ratio

No differentiation of the sexes in external morphology or color could be detected; therefore gonad examination was necessary for sex determination. The gonads lie in the ventro-posterior part of the body cavity. Except for immature fish (here not considered), no difficulty was experienced in distinguishing an ovary from a testis macroscopically. The ovaries are pinkish cream, smooth, slightly compressed laterally, and closely applied to one another in the mid-line... The testes are
white, strongly compressed, irregularly lobular, and in contact only ventrally.

It was apparent from sampling the catch of trap fishermen throughout the year that approximately twice as many male manini as females were taken. In the month of May, 1953, 291 trap-caught adult fish were sexed; 68 per cent of these were males. The traps in which the fish are caught are unbaited. A typical trap consists of a rectangular framework (about 2 feet by 5 feet by 6 feet) of steel rod covered with chicken wire. A cone of chicken wire with a narrow slit-like opening extends inward from one end to about the center. Some trap fishermen prefer to leave one or two butterfly fish or other fishes of little economic value in the trap in the belief that other fishes will be more prone to enter. If male manini are more gregarious or less cautious or more migratory than females, they would be caught in traps with greater frequency than females; therefore sex ratios ascertained from trapped fish should be viewed with caution.

The sex of 221 adult manini from islands in the tropical Pacific in the collections of the U.S. National Museum, the Bernice P. Bishop Museum, and the University of Hawaii was determined. The majority of these specimens was taken with rotenone, seine, and throw-net — much less selective methods of collecting fishes than traps. 134 (60.7%) of the 221 fish are females. A chi square value of 10 results from testing whether 134 females could be obtained from 221 fish randomly sampled from a population in which the true sex ratio is 50-50. This high chi square has a probability greater than 0.01 that a sample more extreme than the above could be drawn by chance from a half male, half female population; thus the hypothesis of a 50-50 sex ratio is rejected.

Species of fishes which are represented in nature by more adult
females than adult males are not unknown. Craige (1927) determined the sex ratios of Canadian marine teleost fishes. Although he found that most were 50-50, some showed a preponderance of females. Tester (1937: 131) demonstrated that the percentage of males of the Pacific herring changed from 56.5 per cent at age 2 to 44.2 per cent at age 5.

It is possible, however, that the apparent predominance of female manini is spurious. Most of the 221 specimens were taken in inshore areas. The traps from which 196 males of 291 manini were taken were set in from 30 to 90 feet of water. Perhaps females are more abundant in shallower water and the males predominant over deeper parts of the reef.

The museum collections of manini offer some evidence for differential schooling by sexes. One sample of seven manini from the outer reef at Eniwetok Atoll, Marshall Islands is entirely male; another of 12 fish from the lagoon of Kwajalein Atoll in the Marshalls is wholly female.

**Spawning cycle**

The manini in the Hawaiian Islands has a distinct spawning season. This has been ascertained by the examination of the gonads of adult fish and collections of young throughout the year. In more equatorial areas, on the contrary, the spawning of this surgeon fish appears to be year-around. There is also evidence both in Hawaii and the Gilbert Islands that the pattern of the incoming young correlates with the lunar cycle. This is attributed to a lunar effect on spawning by adults.

From October 31, 1952 to October 27, 1953 a total of 133 female and 145 male manini 100 mm. or more in standard length were purchased in 41 samples from a fisherman for the purpose of examination of the gonads. The fish were caught in traps set in depths from 30 to 90 feet from
Kewalo Basin to Koko Head, Oahu. The length of the gonad on each side of the body cavity of each specimen was measured and the average length recorded. This average measurement was divided by the standard length and the quotient multiplied by 100. The range and mean of the resulting percentages are presented in the following table.

Table 36 Gonad Length as a Percentage of Standard Length by Month, 1952-53

<table>
<thead>
<tr>
<th>Month</th>
<th>Number of females</th>
<th>Gonad length/standard length x 100</th>
<th>Number of males</th>
<th>Gonad length/standard length x 100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
<td></td>
<td>Range</td>
</tr>
<tr>
<td>Oct.</td>
<td>15</td>
<td>7.1-18.2</td>
<td>9.4</td>
<td>14</td>
</tr>
<tr>
<td>Nov.</td>
<td>1</td>
<td>7.7</td>
<td>8</td>
<td>8.3-22.8</td>
</tr>
<tr>
<td>Dec.</td>
<td>4</td>
<td>12.3-25.0</td>
<td>14.3</td>
<td>10.0-22.1</td>
</tr>
<tr>
<td>Jan.</td>
<td>9</td>
<td>8.6-25.6</td>
<td>13.5</td>
<td>8.4-25.0</td>
</tr>
<tr>
<td>Feb.</td>
<td>15</td>
<td>14.1-25.6</td>
<td>18.2</td>
<td>20.4-34.5</td>
</tr>
<tr>
<td>Mar.</td>
<td>19</td>
<td>13.5-32.2</td>
<td>19.3</td>
<td>12.8-35.7</td>
</tr>
<tr>
<td>Apr.</td>
<td>17</td>
<td>10.4-26.4</td>
<td>17.3</td>
<td>22.8-38.5</td>
</tr>
<tr>
<td>May</td>
<td>6</td>
<td>9.8-23.3</td>
<td>16.2</td>
<td>18.2-31.2</td>
</tr>
<tr>
<td>June</td>
<td>6</td>
<td>7.0-34.5</td>
<td>11.8</td>
<td>19.3-23.9</td>
</tr>
<tr>
<td>July</td>
<td>10</td>
<td>7.5-17.6</td>
<td>9.6</td>
<td>8.1-26.3</td>
</tr>
<tr>
<td>Aug.</td>
<td>9</td>
<td>5.5-11.9</td>
<td>7.2</td>
<td>6.5-23.8</td>
</tr>
<tr>
<td>Sept.</td>
<td>22</td>
<td>5.0-14.5</td>
<td>8.4</td>
<td>7.6-17.3</td>
</tr>
</tbody>
</table>

Although the monthly samples are small, it is nevertheless apparent that the gonads of both sexes undergo a significant change in relative length during the year. They are largest in late winter and spring and smallest in late summer and early fall. The change which takes place in
the ovary in late July and August is more complex than would be indicated from a mere shortening. The ovary (presumably following the last spawning) is red and flattened with a large lumen. Residual eggs are gradually absorbed (eggs being absorbed are apparent as amorphous masses of variable size), and the entire organ regresses to small size and a hyaline gray color. There is variation in the time when this occurs in individual fish, hence the ultimate small size is not apparent when the values of a number of fish are averaged by month. The ovary of a 145 mm. female taken on August 7, for example, was only 6 mm. in length.

The gonad measurement data are more significant in indicating a definite spawning season of the manini when coupled with the results of sampling the young throughout the year. The larva of the manini is pelagic until an average standard length of 25.8 mm. is attained. At this size it is termed the acronurus. This late postlarva enters tide pools or other inshore areas to transform to the juvenile stage. A year-around assay of transforming and small juvenile specimens was made. It was observed that these early stages were absent from inshore areas during the fall and early winter months of 1952–53. Extensive observation and collecting were undertaken during the winter and early fall to ascertain the time of the first and last influx of acronuri of the season. The first transforming young were sighted on February 14; the last of the season straggled in on October 6. In the year 1954 the first young were discovered on February 9. During my absence from the territory, my wife and Philip Helfrich made an effort to determine the date of the last influx of young in 1954. In October only a single small juvenile was collected. It was taken on the ninth of the month and measures 27.5 mm. in standard length. It is completely transformed; therefore it had been
in the tide-pool zone for about 5 to 8 days (see sections on transformation and growth). The first transforming young of the 1955 season were observed on January 27.

The time between the finding of the first ripe female of the season and the date of first incoming young and the time between the last ripe female and the last incoming young constitute estimates of the duration of larval life. The last ripe female of the 1952-53 season which was detected in the sampling program (see Table 37) was July 21. The first ripe female of the 1953-54 season was found on December 1. The last ripe females of this season were observed in the July 16 sample. The three estimates of the duration of larval life from the above data are 71 days, 78 days, and 83 days. Admittedly such estimates are subject to considerable error. Their average, 77 days, approximates two and one-half months.

In order to obtain quantitative data on the recruitment of young to inshore areas of Oahu, a single large tide pool at Diamond Head (Fig. 53) was chosen for repeated collections of manini. This pool is nearly isolated at low tide. An overhanging ledge on the left (east) side of the pool provides excellent cover for the small fish. Pools as large as this but lacking such cover contain fewer manini. Each week at low tide the narrow outlet to the sea was occluded with a net, and all the manini in the pool were poisoned with rotenone. A total of 157 manini less than 30 mm. in standard length were taken from the pool during the season (Fig. 54). 19 specimens 30 mm. or longer were collected; these are presumed to have been in the tide-pool zone for more than one week (see section on growth) and hence are probably migrants from adjacent pools. They are not included in the graph of Figure 54. The poison stations on August 13 and
Fig. 53 Diamond Head tide pool at low tide from which the collections of *Acanthurus triostegus sandvicensis* of Figure 54 were made.
Fig. 54 Weekly collections of *Acanthus triostegus sandvicensis* made in 1953 from a single tidepool at Diamond Head, Oahu. Only specimens 30 mm. or less are recorded. Times of new moon indicated by black circles.
August 21 were interrupted by unexpected large waves, and no fish were collected. However, on these two dates manini were counted in the pool before rotenone was added and these numbers are indicated by the dotted line on the graph. Probably there were at least twice as many small manini in the pool as are recorded, for most of the fish take cover rapidly when an observer approaches and are hidden before they can be counted. The 36 fish sample taken at the September 12 station, on the other hand, may be higher relative to the overall number of tide-pool young at this time than it should be. Observation of other pools at Diamond Head and along the shore of the Ala Moana Yacht Basin prior to, during, and after the 12th of September failed to disclose any striking influx of young. Nevertheless, the number of incoming young in September, in general, is high and this month should be included with the period May to August as indicating large tide-pool recruitment on Oahu.

Although this sampling from a single pool is not sufficiently great to be correlated closely with the similarly inadequate samples of adult gonads, the May to September recruitment appears to correspond roughly to the greater degree of gonad development from February to June.

The seasonal spawning in the Hawaiian Islands is correlated with temperature change. The initial enlargement of the gonads coincides with the time of decreasing sea surface temperature in the fall. The marked increase in tide-pool recruitment in May probably corresponds to increased spawning in February-March, the time of coldest water temperature in Hawaii.

In more equatorial waters the manini appears to spawn throughout the year. The 221 adult manini used for the sex ratio determination were collected mostly from the Mariana Islands, Marshall Islands, Gilbert Is-
lands, Line Islands, and Phoenix Islands — all island groups in which the sea surface temperature exceeds 80° F. (26.7° C.) the year-around and where the annual variation in temperature of the sea is slight (based on Hydrographic Office Publ. No. 225). Examination of these fish revealed ripe gonads in every month of the year. Transforming or early juvenile manini were found in museum collections from these areas every month of the year.

The most plausible cause for the seasonal spawning of the manini in Hawaii is the greater annual variation in temperature of the sea than areas of lower latitude in the central Pacific. The mean monthly sea surface temperatures around Oahu (1941 to 1947) varied from about 75 to 81° F. (Liepper and Anderson, 1950). Although a 6° F. (3.3° C.) change in a year seems insufficient a priori to cause the complete cessation of spawning, temperature is the most likely factor. J. H. Orton (1919: 360) studied the influence of temperature on reproduction of marine animals. He stated, "A review of all the information collected bearing on the influence of temperature change on breeding leads one to the conclusion that a temperature stimulus of some kind is the normal impulse of inducing sexual activity in marine animals..."

If temperature is the cause of interrupted spawning in Hawaii, then manini in a region of the South Pacific Ocean such as the southern Tuamotus with a comparable annual variation in water temperature should spawn seasonally and six months out of phase from Hawaiian manini. Although I have no data from a southern area equivalent in temperature to Hawaii, collections and information supplied to me by Robert Houts and Paul Blackford (December, 1953 to May, 1954) from the Society Islands (where temperatures range from about 77.5 to 81° F. = 25.2 to 27.2° C.)
strongly suggest that spawning by the manini in this region, although probably not completely interrupted, varies with season differently than spawning in Hawaii. I shall quote from a letter by Mr. Houtz dated May 6, 1954. "Up until about mid-January there were plenty of the 20-30 mm manini. They were practically non-existent during February. During March I...could find those 40-50 mm ones...and saw only 2 of the smaller ones. ...I spotted 2 small manini in 2 separate pools on April 28th at Opua. ...we managed to snare a 23 mm one." A collection of 140 transforming and juvenile manini, 22 to 36 mm in standard length, were taken in Tahiti on December 30, 1953 by Mr. Houtz and Mr. Blackford and shipped to me; therefore I am entirely convinced that the species on which these two helpful gentlemen have reported is truly Acanthurus triostegus. Only two transforming specimens of manini were found among museum collections from Tahiti. One bears the date June 15, and the other was collected in February.

A cyclic fluctuation in the abundance of incoming young within the season in the Hawaiian Islands is apparent from Figure 54. The peaks of these fluctuations are approximately correlated with the time of new moon. This correlation is also evident from the extensive collections made from various tide pools plotted in Figure 55. The large mode of May 10 centered on a standard length of 26 mm. contains 54 transforming fish. The time of new moon was May 13. The large mode of April 17 is centered on a standard length of 27 mm. and contains 10 transforming manini. New moon in April occurred on the 13th day of the month.

Tester and Takata (1953: 36, Fig. 14) have demonstrated a similar lunar periodicity in the influx of young aholehole (Kuhlia sandvicensis) to tide pools on Oahu.
Fig. 53 Tidepool Collections of Acanthus triostegus sandvicensis
Oahu, Ala Moana Yacht Basin to Makapuu Point, 1953.
Vertical distance between horizontal lines proportional to
number of days between samples. One specimen is indicated
by .5 mm. line length on vertical scale.
If the periodicity in the influx of manini acronuri is a function of some lunar effect on the young and not on the spawning adults, then the peak fluctuations of incoming acronuri in areas of different temperature, and hence different rates of development (see development section), should still correlate with the time of new moon. A sample of 108 small manini collected with rotenone by the author from tide pools at Onotoa Atoll, Gilbert Islands, on August 21, 1951 (Fig. 56) demonstrates that this is not the case. Onotoa is located in the central Pacific (1° 47' S., 175° 32' E.); the monthly mean sea surface temperature varies only slightly from 82.5° F. (28.6° C.) throughout the year (Hydrographic Office Publ. No. 225). The mean monthly sea surface temperature at Oahu from January to April is 75 to 76.5° F. (23.9 to 24.5° C.). Full moon occurred on August 16 (new moon on August 2). The large mode of Figure 56 centered on about 23 mm. standard length includes only nine transforming specimens which average 23.5 mm. in standard length. Thus the peak influx of the fish comprising this mode is estimated at 4 to 5 days previous to August 21. This large Onotoa sample, therefore, is about 11 days out of phase with the lunar cycle of incoming young in Hawaii.

In order to obtain direct evidence of lunar spawning by adult manini and to more sharply delimit the spawning season (see p. 306), the entire catch of two trap fishermen was examined for ripe fish on 62 days from June 19, 1953 to September 3, 1954. The catch was usually brought to port alive. The fishermen would not permit the opening of the body cavity without purchasing the fish, but they allowed pressure to be applied to the abdomen of each manini.

When running ripe males (the sperm of which were motile) were discovered in samples taken throughout the year, it was realized that the
Fig. 56 Collection of Acanthurus triostegus triostegus from tidepools of the outer reef flat, Onotoa Atoll, Gilbert Islands, August 21, 1951. Sample size 108. Nine specimens 21 to 25 mm. in standard length are transforming from the acronurus larval form to the juvenile stage; the rest are juveniles. Time of full moon, Aug. 16.
limits of the spawning season could not be defined by the development of the male gonad. As would be expected from Table 36, however, there were more ripe males during the spawning season than outside of it. Of 745 adult manini (an estimated two-thirds of which were males) examined from September to November, 11.8 per cent were running ripe males; 23 per cent of 2061 adult manini (an estimated two-thirds of which were males) examined from February to June were running ripe males. No variation in degree of ripeness was apparent within the period of a single month. It should be emphasized, however, that no sharp dividing line exists between the condition of a running ripe male and one that is not quite running ripe, and these data tend to be subjective in this regard.

Ripe females are more easily distinguished. Fertilizable eggs of female manini are large (about 0.7 mm. in diameter), perfectly transparent, and are released when the abdomen is only slightly squeezed. The data on ripe females in terms of the lunar month are summarized in Table 37. As may be seen in this table, the number of fish examined on the different days ranged from 9 to 252. This variability is entirely due to catch variation. Also, there is no regular sequence in time when the catches were examined. Scheduled sampling was not possible largely because of the great dependence of trap fishing on hydrographic conditions. In addition to being impeded by rough seas, trap fishermen are restricted by turbid water (traps are not found by surface markers but by observing through a glass-bottomed box at the surface). Although the fishermen ordinarily tend their traps twice a week, they may be held in port several weeks by dirty water. A successful sampling day was also contingent on being at Kewalo Basin when the catches were unloaded. Frequently the fishermen came in unexpectedly early, and their fish were taken to the
market before I arrived. Market fish were not sampled because the date when fish are caught is usually not available and examination of dead fish is not comparable with that of living - especially if the contents of the body cavity have begun to decompose.

Table 37 Results of Sampling for Ripe Female Manini during the Spawning Season

<table>
<thead>
<tr>
<th>Date</th>
<th>Days to nearest full moon</th>
<th>Number of fish examined</th>
<th>Number of ripe females</th>
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Table 37 (Continued) Results of Sampling for Ripe Female Manini during the Spawning Season

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<th>Number of fish examined</th>
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A total of 43 running ripe females were found. 39 of these were taken from 12 days before to 2 days after the full moon and only 4 from the remaining half of the lunar month. A total of 2552 adult manini were examined in the former period, however, and only 1311 in the latter; therefore a correction is necessary for this discrepancy in sample size. A corrected figure of 7.8 ripe females instead of 4 is the proper number to compare with 39. Nevertheless, it still remains obvious that a significantly greater number of ripe females, and hence probably greater spawning, occurs before and shortly after full moon than before and shortly after new moon. Since at least a few acornuri of all sizes (see section on transformation) enter tide pools at all times during the month and not totally in a portion thereof, some spawning might be expected throughout the month.

It is not known whether spawning by the same fish takes place every month. There is evidence, however, that individual fish spawn more than once a season. The long season in itself suggests repeated spawning. If large ripe females were found at the start and progressively smaller ones throughout the rest of the season, a long spawning season might be indicated with each individual spawning only once, but no obvious trend in size of the 43 ripe females was apparent. The first ripe female of the season which was found (December 1) measured 138 mm. in standard length. The last (July 21) was also large, 140 mm. The shortest found were 106 mm. on March 13 and 101 mm. on July 14. More convincing is the failure to see any completely spent ovaries in fish during the spawning season and the observation of spent and regressing ovaries in all of the females at the end of the season. The strongest evidence concerns the finding in ripe females of a second mode of egg size about half the size
of the ripe egg mode, coupled with the knowledge that this mode is not retained in the ovary through the summer months. Surprisingly, this mode of intermediate-sized eggs appears to be a persistent unit within the ovary of all mature female manini during and 1 to 2 months before the spawning season, suggesting that it constitutes a static mass of eggs from which modes of ripe eggs may develop periodically. This mass may be built up constantly or at short intervals from the huge reserve of minute primordial eggs which is present in the ovary of every adult female regardless of the time of year (and is here not considered as a mode of egg size). A detailed discussion of the egg diameter study leading to these conclusion is given below.

The procedure for the determination of egg diameters was as follows: tiny sections were snipped from various parts of an ovary (which was previously preserved in 8 per cent formaldehyde solution) and placed in water in a Syracuse watch glass. The eggs were teased from the ovarian tissue with dissecting needles. The egg diameters were then measured with an ocular micrometer at a magnification of 24. Many of the eggs were oblong, probably because of unequal pressure of adjacent eggs at the time of preservation. Instead of measuring the greatest or least diameter, the eggs were randomly moved into position (by moving the watch glass) on the micrometer image. This method reduces the possibility of bias but has the disadvantage of increasing the spread of modal groups on graphs of egg diameter measurements.

Graphs of the egg diameters of ovaries from nine adult female manini are shown in Figure 57. These graphs are not presented to show any definite sequence. Graph C, of a 15 mm. ovary from a female taken on January 2, for example, is included to portray the egg diameter pattern
Fig. 57 Egg diameters of *Acanthurus triostegus sandvicensis* plotted as units of an ocular micrometer. Scale: 1 unit = .035 mm. Except for A where the number of eggs of 1 and 2 micrometer units were estimated at 1575 and 627, respectively, no eggs less than 3 micrometer units were measured.
Fig. 57 Egg diameters of *Acanthurus triostegus sandvicensis*

Scale: 1 unit = .035 mm.
Fig. 57 Egg diameters of *Acanthurus triostegus sandvicensis*
Scale: 1 unit = .035 mm.
of an immature but maturing ovary. Although examined microscopically, no graphs were made of egg diameters of ovaries from adult fish taken in August, since the fish have only primordial eggs about 1 to 3 micrometer units (.035 to .105 mm.) in diameter except for those in which larger eggs are being resorbed. The relative size of the group of primordial eggs was estimated only for the ovary graphically illustrated in A.

Except for the immature gonad of C, all of the ovaries display a mode of egg size centered on about 10 to 11 micrometer units in diameter. This prompted the examination of samples of eggs from 54 ovaries taken from female fish throughout the year (more, however, from mature females during the spawning season). Sufficient eggs from each ovary were measured to determine the presence of obvious modal groups. A definite mode at from 9 to 12 micrometer units in egg diameter occurred in 46 of the ovaries, 15 to 35 mm. in length, from fish caught from September 15 to July 21. The median of this mode of 38 of these fish appears to lie between 10 and 12 micrometer units. In the ovaries of the remaining eight fish, the median lies between about 9 and 10 units. One of the latter eight fish is the only running ripe female of the 54 examined. The eight fish lacking an intermediate-sized mode all had small gonads.

Data on these is as follows: a 124 mm. fish caught on September 15 has a 9 mm. ovary with no eggs as large as 3 units in diameter; a 142 mm. fish caught on September 18 has an 18 mm. ovary with a group of primordial eggs just starting to enlarge, the largest being 5 micrometer units in diameter; a 110 mm. fish caught on October 31 has a 12 mm. ovary which contains only small primordial eggs; this is also true of a second fish caught on October 31, 113 mm. in standard length, with a 6 mm.
ovary, a 112 mm. fish caught on January 2 with a 10 mm. ovary, and a
120 mm. fish caught on July 21 with a 9 mm. ovary; a 120 mm. fish caught
on February 13, with a 17 mm. ovary, has only small eggs up to 7 micro-
meter units in diameter (graphically, the plotting of a large number of
egg diameters of this fish would probably be similar to Fig. 57 C); a
106 mm. fish caught on June 16 is also similar except no eggs larger
than 6 units were seen. No specimens were found among the 54 females
with a group of eggs which have an average diameter greater than 12 units
but less than the 20 to 21 unit average size of ripe eggs. Also when
checking for ripe females among the 4,951 adult manini which were exam-
ined, the eggs pressed from the body cavity of few, if any, of these
were of a size between that of the usual mode and the ripe egg mode.
It is expected that such a size would be extruded with moderate pressure
on the abdomen of the fish, since eggs of about 10 micrometer units
(0.35 mm.) are frequently forced out. Eggs as large or nearly as large
as completely ripe eggs, but in which small opaque white regions were
visible, were seen almost as often as the ripe, perfectly transparent
eggs. These are not fertilizable, and females containing them were not
considered among the ripe fish previously discussed. The failure to find
a mode of eggs intermediate in size between about 10 and 20 micrometer
units suggests that eggs maturing from the former modal group (the eggs
of which are opaque) do so rapidly. Perhaps the enlargement is essen-
tially a process of hydration.

In view of the finding of only 43 female manini with fertilizable
eggs during the season, it is further believed that ripe eggs are not
retained very long in the ovary. Although a change in behavior of ripe
females might influence the frequency with which they enter traps, the
possible cessation of feeding, at least, would not seem to affect the rate of entry, for the traps are unbaited.

If it is assumed that ripe eggs are held within a female no longer than 1 day on the average, and 43 is the number present in truly random samples of the population comparable to the ones taken, then the small number of ripe females actually constitutes an indication that every female spawns once each lunar month. Since the lunar month is 29.53 days, only about one-thirtieth of the females sampled from the population during the spawning season would be ripe. 3,863 adult manini were examined during the season, an estimated one-third of which, or 1,288, were females. One-thirtieth of 1,288 is 43, precisely the number of ripe females which were found. However, other assumptions could lead to other interpretations.

Size and age at maturity

The smallest running ripe female seen by me was 101 mm. in standard length. The smallest running ripe male was 97 mm. in standard length. These are probably near the minimum lengths for manini around Oahu.

Ten manini were reared in a large concrete tank of the Hawaii Marine Laboratory at Coconut Island from a size of 25 to 27 mm. in standard length beginning on March 17, 1953 (see detailed discussion in section on growth). Two fish of this group, an 89.5 mm. male and a 99 mm. female were killed for gonad study on July 24, 1953. The female had an immature gonad, clear gray in color, and only 5 mm. in length. The ova were minute, only 0.015 to 0.03 mm. in diameter. The male was detected because it was possible to strip a small amount of milt from it, although considerable pressure on the abdomen was necessary. The sperm, however, were not motile. Its testis is slender and 6 mm. long. Subsequent study
of the gonads of the remaining eight captive manini was not made because of arrested growth of the fish following inadvertent destruction of the algal food supply when seining the tank.

There appears to be considerable variability in the size at maturity. This variability is apparent when the 101 mm ripe female manini is contrasted with the 127 mm immature specimen whose egg diameters are graphically illustrated in Figure 57 C.

It is doubtful that any female manini spawn during the season in which they first arrived as acronuris in tide pools. Even if the 99 mm female, which was killed on July 24 following its growth in captivity from a small juvenile on March 17, had been among the first few arrivals to shallow water of the season (middle February), another month of growth and gonad development would hardly seem sufficient to bring a tiny immature ovary such as that seen in this specimen on July 24 to full maturity before the season ended. It also seems unlikely that males will spawn within their first season following recruitment to tide pools.

It seems probable, from a knowledge of growth (see growth section) and the approximate size at maturity, that some manini will spawn in the season following their first sojourn as juveniles in inshore waters. This would be very likely for the first young of the season, but I do not believe that the last young of the season would have sufficient time to develop to sexual maturity before the following spawning season ended. Such a situation would probably increase the variation in the size of the fish at maturity.

**Fecundity**

Fecundity is defined as the total number of ripe eggs produced by a female in one year. It is impossible to ascertain this for fish like
the manini which may spawn more than once a year, when the number of spawning per year is unknown. Therefore only the number of eggs released at one spawning can be determined. This was attempted for only a single female manini.

The fish chosen for the egg count was the 123 mm June 21 specimen, the egg diameters of which are plotted in Figure 57 J. This fish had a very large ovary (42 mm. in length) which contained a high percentage of large eggs. These eggs were not completely transparent and none appeared to have been expelled by the fish. This ovary was strongly agitated by vigorously shaking the vial in which it had been preserved with a minimum of fluid. The agitation released most of the near-ripe eggs from ovarian tissue and placed them in uniform suspension. The contents of the vial were then placed in a graduated cylinder, allowed to settle, and the small amount of excess fluid poured off. A sample of the ovarian mass was drawn off. After its removal, the volume was computed as 26 percent of the total. All of the large eggs in this sample were counted in successive lots placed in a Petri dish under a binocular dissecting microscope. The sample contained 10,814 large eggs. The total number of large eggs in the ovary is therefore estimated at about 40,000.

DEVELOPMENT

Fertilization of the eggs of the manini was effected artificially using live fish obtained from trap fishermen. As previously discussed, ripe female fish are detected by the release of perfectly transparent eggs following gentle pressure on the abdomen. The milt of running ripe male manini oozes even more readily from the fish than the eggs of ripe females; however, it was found that eggs could be fertilized with sperm from males in which definite squeezing was necessary to bring forth the
milt. Eggs were fertilized by stripping ripe males and females concurrently into sea water with genital apertures in close proximity and by stripping them separately into different containers and subsequently mixing the contents.

The fertilized eggs are spherical, 0.66 to 0.70 mm. in diameter, and contain a single oil globule which is 0.165 mm. in diameter. If suspended in sea water the eggs slowly rise to the surface. They exhibit no stickiness and do not adhere to objects or one another, although they often lie in single-layered groups at the surface.

Unfertilized (but fertile) eggs are also less dense than sea water. No difference in diameter of unfertilized and fertilized eggs could be detected; no elevation of a fertilization membrane was apparent when fertilization took place.

Developing eggs were placed in large finger bowls, an aerated battery jar, and an aerated 20 gallon aquarium. In all of these containers heavy mortality of the larvae ensued because of settling to the bottom (probably through contact with numerous bacteria there and not to any physical injury). Efforts were made to keep the larvae in suspension by placing a fine mesh false bottom in a battery jar and locating a bubbling aerator stone beneath a hole at one side and by installing a paddle which was slowly turned by an electric motor. Although these methods reduced the amount of settling, mortality was still high and only a few larvae survived to an age of five days or more when oriented swimming began.

Attempts to rear pelagic larvae of marine fishes under laboratory conditions have been notoriously unsuccessful. Garstang (1900) reported on the three known successes in the experimental rearing of larvae of marine fishes and discussed the method he employed to raise the fry of
**Blennius ocellaris**, a species with demersal eggs. Notable among the few achievements in rearing the young of fishes in recent years is that of Morris (1951) who carried out a detailed study of the development of *Clinocottus recalvus*, also a species with demersal eggs. His method was not discussed.

In view of the usual difficulties of rearing larvae in rigid containers, a new approach was tried for the manini. A fine mesh bag, 1.2 meters on a side, with cork along the top was floated in the Ala Moana Yacht Basin. Fertilized eggs were placed within and allowed to develop. Approximately the same mortality resulted, however.

Once the manini larvae were capable of oriented swimming, they were maintained as easily in unaerated finger bowls as any other way. At this time the critical factor became the supply of food.

The principal stages in early development from 0 hours to 5 days, 22 hours are shown in Figures 58 to 63. The drawings of eggs before hatching were made shortly after placing the eggs in 10 per cent acetic acid, a treatment which makes the blastodisc opaque white and the cleavage pattern more visible. The ages given are based on an average development temperature of 24° C. During development the temperature was 24° C. plus or minus about 1° C.

Although temperature control was not sufficiently precise to permit an assay of the change of rate of development with changing temperature, it was obvious from the rearing of one batch of eggs at 26° C., plus or minus 1° C., that temperature has a marked effect on the rate. The stage attained at 28 hours and 40 minutes at 24° C. was reached in about 22 hours and 30 minutes at 26° C. The 42 hour stage at 24° C. was reached in about 32 hours at 26° C.
No attempt was made to determine the temperature limits within which normal development of the manini is possible. Due to proximity of a light bulb, the temperature of one finger bowl in which 37 hour larvae were developing was inadvertently raised in a short time to 29.3° C. None of the larvae died.

The blastodisc of the fertilized egg is 0.4 mm. long. One hour after fertilization the first cleavage becomes apparent. At the end of the second hour eight cells are present, and after four hours about 55 cells can be counted in the blastodisc.

At the age of six hours gastrulation is under way. Epiboly is evident from the thin layer with a wavy edge which is extending downward over the yolk. The cells are very small and numerous and are not shown in the drawing of this and subsequent stages.

At 14 hours the primitive streak is apparent and the cephalic region of the embryo well developed. By about 18 hours epiboly is complete, and the yolk plug is visible as a small clear area near the oil globule.

By 15 hours and 30 minutes the body of the embryo is beginning to take form and elongate over the yolk. At 18 hours and 20 minutes nine somites can be counted and the optic vesicles are prominent. At 21 hours and 45 minutes 12 somites are present. At 25 hours 19 or 20 somites are visible; the lens of the eye is just starting to form; the auditory vesicle is present and the statoliths are just forming; 24 tiny melanophores can be seen in lateral view on the body; twitching movements are common; the heart contains blood although it has not yet started to beat.

Hatching occurs at the age of about 26 hours. At 27 hours the larva is 1.7 mm. in length and has 22 somites; the heart is still quiescent. At 31 hours the heart was observed to beat; occasional short random
Fig. 58 Developmental stages of *Acanthurus triostegus sandvicensis* (X 55)
Fig. 59 Developmental stages of *Acanthurus triostegus sandvicensis* (X 55)
Fig. 60 Developmental stages of *Acanthurus triostegus sandvicensis* (X 55)
swimming movements occur by rapid vibration of the posterior half of the body.

At the age of 42 hours the amount of yolk is reduced to about half of what is present in the 31 hour larva. As the yolk is used up, the larvae show a progressive tendency to sink. 39 hour larvae still float head down at the surface, but 42.5 hour fish have begun to settle. The rate of settling of one larva at this age was measured at 1.2 cm. per minute. The average rate of three 44.5 hour larvae was 1.67 cm. per minute, and the average rate of four 47 hour larvae was 1.88 cm. per minute. One 71 hour larva sank at the rate of 3.2 cm. per minute.

At 42.5 hours some larvae were already settling out at the bottom of the aquarium. Most, however, succeeded in combatting their sinking by swimming movements. I observed 300 such movements in an aquarium which contained several hundred larvae. Of these movements, 227 resulted in the larvae being in a higher position in the tank, the rest were sideways or downward. Movements which consisted only of a twitch were not counted. The ability to overcome settling is more efficient than 227 movements with an upward component out of 300 would indicate. Since the head is directed downward, swimming is initiated in this direction. In most cases the fish soon turn sharply and swim upward. If the interval of movement is short, there may be insufficient time to end up higher than the starting position, but usually the fish is not significantly lower. The interval between movements is highly variable, but it averages about one minute. The distance traveled by the larvae per movement is usually less than 40 mm. One, however, stopped 110 mm. above its starting position.

In addition to geotaxic responses, swimming movements were made to
avoid contact with an approaching object. This was first observed in 42 hour larvae; however, it may be operative several hours earlier. I do not know by what sensory means an approaching object is perceived at this early age, but I doubt if it is visual, for the eyes do not seem sufficiently well developed to be functional. Also an approaching glass rod is detected as easily as an opaque object. Before such an object touches a larva, and sometimes when it is as far as 2 or 3 cm. away, a fleeing movement is initiated. A second stimulus soon after the flight reaction will usually result in a second swimming movement. Curiously, contact with the bottom due to slow settling usually will not result in a swimming movement. Such movements occur at about the same rate when the fish are on the bottom. They may enable a larva to become suspended again, but usually only for a short time.

Areas of white pigment are beginning to form on the ventral part of the seventh and fifteenth somites of the 42 hour larva. These are large and conspicuous in the 54 hour larva, and lesser white areas may be seen on the ventral part of the body anterior to the seventh somite and on the head. At this stage the intestine has just formed and the yolk mass is small. The melanophores over the yolk are large and dendritic.

Figure 61 is a microphotograph of the lateral aspect of a living 75 hour larva with the light transmitted through the specimen. The larva was 2.2 mm. long. The dorsal fin fold is a prominent feature at this stage (it was first noticed in the 66 hour larva), and the pectoral fins are developing. Dark pigment around the eye is evident.

Figure 62 is a microphotograph of a living 4 day, 1 hour larva in dorsal view. At this age the rate of sinking was observed to have diminished. One larva sank 2.5 cm. per minute and another less than 1 cm per
Fig. 61 Microphotograph of a 75 hour larva of Acanthurus triostegus sandvicensis in side view. Length 2.2 mm.

Fig. 62 Microphotograph of a 4 day, 1 hour larva of Acanthurus triostegus sandvicensis in top view. Length 2.5 mm.
minute. The 4 day, 12 hour larva remained suspended head down in the water, thus indicating that the air bladder had formed.

The 4 day, 5 hour larva of Figure 63 is 2.5 mm. long. The jaws of this stage were observed to move.

Although still tending to float head downward, the 5 day larva is capable of normal oriented swimming. The pectoral fins can be fluttered rapidly. The eyes move, and the jaws are functional. The yolk is completely gone and the oil globule half resorbed. By 5 days, 12 hours, the three individuals which survived to this age appeared to be feeding by short darting movements. Material from a culture of marine ciliates was added to the finger bowl in which these three larva were kept. One died after 5 days, 17 hours of development. Food was present in the intestine of this specimen. The last larva survived to the age of 6 days, 12 hours. It had grown very little during the previous 24 hours, presumably because of insufficient or inadequate food. The other member of this trio was dying at the age of 5 days, 22 hours. It was removed from the finger bowl for the lower drawing of Figure 63. As may be seen in this drawing, no trace of the oil globule remains, the intestine is convoluted, the liver is prominent, and the gall bladder is visible. The two large white areas on the body have disappeared. The total length is nearly 2.7 mm.

Three of the 11 acanthurid larvae from the plankton collections of the Pacific Oceanic Fishery Investigations (see p. 251) were identified as manini by dorsal and anal fin ray counts. They are 6.6 to 7.0 mm. in total length. Figure 64 is a drawing of the 6.6 mm. specimen (standard length 5.3 mm.). The teeth are not visible without opening the jaws. They are simple canines; the total length of the anterior upper teeth is contained 3.7 times in the diameter of the pupil of the eye.
Fig. 63 Developmental stages of *Acanthurus triostegus sandvicensis* (X 55)
Fig. 64 Postlarval Acanthurus triostegus sandvicensis. Taken in a 1 meter plankton net at a depth of 50 meters at 22° 38' N., 157° 11' W., by personnel of the Pacific Oceanic Fishery Investigations.
Specimens smaller than this one could not be identified by ray
counts, for the soft rays are not fully formed. A 4.2 mm. specimen
could not be positively identified at this time to genus, for only the
first three dorsal spines are sufficiently developed to distinguish them
from soft rays; however this specimen lies intermediate in structure to
the 5 day, 22 hour larva and the 6.6 mm. larva (though is closer to the
latter). Its body depth is contained 1.8 times in the total length, and
the relative length of the second dorsal, second anal, and pelvic spines
is about two-thirds as great as that of the 6.6 mm. larva. The caudal
fin is about half formed - the urostyle extending to the posterior part
of the incipient fin.

A 4.3 mm. specimen was the only acanthurid found in the larval fish
collections of the Pacific Oceanic Fishery Investigations which were
taken with a 6 foot modified Isaacs-Kidd trawl (except for the 18 mm.
Zebrasoma veliferum shown in Fig. 4). It was captured near the surface
off Kahuku, Oahu. Although a little longer than the specimen just men-
tioned, it is in a slightly earlier stage of development and may there-
fore be a different species. If a large series of specimens were avail-
able instead of just a few, it might be possible to identify the various
stages of the manini to the size where fin ray counts alone can provide
definite identification.

No postlarval specimens of Acanthurus greater than 7.3 mm. in length
but smaller than the acronurus form were found in any of the P.O.F.I.
collections or museum collections. Possibly specimens larger than about
3 mm. in length succeed in eluding a meter plankton net. The presence
of the 18 mm. Zebrasoma veliferum in the collections from the 6 foot
trawl suggests that this would be the best means of catching larger lar-
val acanthurids. The failure to take more acanthurids in the trawl is probably a result of the great distance from land of most of the trawl tows.

An attempt was made to catch large larval acanthurids in a coarse-mesh meter net (stretch mesh measurement 6 mm.) towed in local waters in June, 1953 by my own vessel, a 37 foot auxiliary ketch. The net could not be pulled faster than 4 knots, and few postlarval fishes were taken; none were surgeon fishes.

Apart from the postlarval stages of Acanthurus coeruleus identified by Lütken and an unidentified 7 mm. postlarval Acanthus and a postlarval Naso figured by Weber (as noted in Section I), no records of the early stages of acanthurids were found in the literature. Spartà (1928), however, reported on a long, ribbon-like, transparent, pelagic egg mass of an unknown teleost fish from the Mediterranean Sea. The early developmental stages which he succeeded in rearing from this egg mass are remarkably similar to those of the manini. Spartà concluded that the eggs were from a species as yet unrecorded from the Mediterranean. To my knowledge, no recent surgeon fishes are known from this sea.

**TRANSFORMATION**

The late postlarval form of the genus Acanthus (and Ctenochaetus) is characteristic in morphology, yet identifiable to family Acanthuridae by the presence of the caudal spine and a diagnostic number of fin rays. Originally this stage was placed in a genus by itself, Acronurus (see p. 52). The name acronurus has persisted as a common name for this stage, reminiscent of the leptocephalus of eels.

Acronuri are often represented in museum collections. As previously discussed, it is the acronurus which leaves the pelagic habitat and enters
littoral waters where it is easily collected. Also, acronuri are commonly
taken at night light stations. I have examined 62 manini acronuri and
many of other species collected at night lights and by night light traps
offshore in the vicinity of the Hawaiian Islands, Line Islands, and Phoe-
nix Islands. I have found no specimens in night light collections smaller
than the acronurus stage. It is inferred, therefore, that a positive
phototaxis develops in the acronurus. The lack of food material in the
gut of night light specimens (see p. 278) indicates that the presence of
numerous small planktonic animals around a light at night is not the attract-
ant. Once transformation to the juvenile stage has begun, the positive
phototaxis disappears.

Figure 65 is a photograph of a live specimen of the manini acronurus
taken shortly after its arrival in a tide pool. The characteristic trans-
parent scaleless body with silvery abdomen and head (except snout and
nape), disk-like form, and vertical striae on the body are apparent. The
vertical bars are just beginning to form.

The acronurus comes into inshore regions only at night. New arrivals
to inshore areas have been collected all through the night, some as early
as 9 P.M. and others just before dawn. Most of the night collecting was
done at low tide. It is not known whether the influx of acronuri is
greater at one phase of the tide than another.

On two occasions before midnight at low tide in ankle deep water
along the shore of the Ala Moana Yacht Basin near the entrance to the
Ala Wai Canal, manini acronuri were observed just coming into the area
from deeper water. They did not passively float into the shallow zone
but swam in rapidly. One crossed several times through the beam of my
head lamp before it was caught. If it is assumed that these fish were
Fig. 65 The acronurus of *Acanthurus triostegus sandvicensis*. Captured at dawn in a tide pool at Diamond Head, Oahu. Photographed alive.

Fig. 66 Transformation of *Acanthurus triostegus sandvicensis* from the acronurus to the juvenile stage. Upper left, first day; upper right, second day; lower left, third day; lower right, fourth or fifth day.
in deep water beyond the breaker zone before nightfall, then they must have actively swum into the harbor area and not been carried in by any tidal currents. Prior to low tide, tidal currents would be flowing out of the yacht basin and not into it.

An attempt was made to see if there was any definite relationship between the force and direction of the wind during the night (this information was obtained from the Weather Bureau in Honolulu) and the number of manini acronuri which were caught in tide pools at Diamond Head on 16 different days from March 13 to June 14, 1953. No correlation was found.

As was pointed out in the section on spawning, there is a regular fluctuation in the influx of manini acronuri to inshore regions which is correlated with the lunar cycle (Figs. 54 and 55). The lunar phenomenon seems to be associated with spawning rather than directly with the incoming young.

Breder (1949a: 296) reported observing transforming specimens of the West Indian surgeon fish Acanthurus hepatus (= A. chirurgus) at sizes from 23 to 29 mm. Juveniles from 10 to 20 mm. in length were found in tide pools at Bimini. He inferred that late postlarval surgeon fish reach a certain size in the plankton at which transformation is possible but continue to grow. Their size at transformation is dependent on the size of the acronurus which happens to be carried into shallow water by the "vagaries of current". I suspect that Breder is confusing two species of Acanthurus (see p. 199) and that the variation of transformation size of A. chirurgus from at least 10 to 29 mm. is erroneous, although some variation is probably present. Breder's explanation of the cause of variability may be correct, although, as pointed out above, more than vagaries
of current may be involved with the means by which acronuri reach shallow water.

Manini in the Hawaiian Islands have been found transforming to the juvenile stage at standard lengths of from 22 to 29.5 mm. This would seem, a priori, to be more variation in length than would be expected from mere growth variation alone in the pelagic habitat. A small amount of this variability in Hawaii is due to the change in temperature at which development occurs during the season (see below), but considerable variation can be seen in the transformation size of acronuri taken within the period of a single month, and therefore cannot be attributed to temperature differences.

The fluctuation in abundance of incoming young manini has provided an opportunity to test Breder's hypothesis. If the variation in size at transformation were entirely due to normal variation in growth, then no difference should be apparent in the size of manini which are transforming during the time of the month when a big influx is occurring and the period when the recruitment to inshore areas is minimal. If, however, more extremes in size were found when the recruitment is at a minimum, it could be assumed that growth of the manini occurs in the plankton after transformation is possible and that members of a modal group which arrive inshore and transform earlier or later than the majority of the group will be smaller and larger, respectively.

The standard length of 175 manini in their first day of transformation from the acronurus to the juvenile stage was measured to the nearest 0.5 mm. These fish were collected in shallow waters on Oahu from April 11 to October 4, 1953. In Figure 67 the lengths of the 116 fish which were collected within the period 5 days before to 5 days after peak tide pool
Fig. 67 Size of *Acanthurus triostegus sandvicensis* during the first day of transformation from the late postlarval to the juvenile stage. The solid line represents the percent of fish at the designated standard lengths of samples from 5 days before to 5 days after peak tidepool recruitment (3 days before new moon). The dotted line represents percent of fish from samples taken during the rest of the lunar month. The solid line is based on a total of 116 fish and the dotted line on 59 fish. Samples include all of the first day transforming fish which were collected from April 11 to October 4, 1953.
recruitment (taken as 3 days before the time of new moon; see p. 311 and Fig. 55) are compared to the lengths of the remaining manini caught outside this period. Clearly, a higher percentage of extremes in length at transformation occur during the part of the month when the number of acornuri entering shallow water to transform is low.

If spawning of the manini occurred only during a definite small segment of the month, the dotted curve of Figure 67 would probably be bimodal, one of the modes centered on a low and the other on a high standard length. Since, however, spawning appears to occur throughout the month and merely more prominently in one part than another, most of the young resulting from fertilization at a time of low spawning intensity will come into shoal areas at a more nearly average size during the interval between periods of high tide pool recruitment and obscure the postulated bimodal effect. The extremes in size of this small group would enter the tide pool zone at the time of peak recruitment; thus, if the samples were large enough, both curves would extend to the same limits.

The maintenance of populations of manini around small islands such as Johnston Island, the shores of which are constantly swept by a strong current in one direction, would seem to demand some means on the part of the developing pelagic larvae of remaining close to land. The presence of small eddy systems around the island might afford the explanation providing the larvae can stay within such systems. The apparent differentiation of the manini at Johnston Island (see Table 3) and also of Ctenochaetus strigosus (see discussion under this species) would seem to rule out the possibility that the Johnston Island populations are derived primarily from fishes which spawn in the Hawaiian Islands proper.

While examining museum specimens of transforming manini from many
localities, I noticed a definite variation in size with locality. The standard lengths of all the early transforming specimens available to me were measured. These lengths (except those of Hawaiian Islands specimens—see Fig. 68 for these data) are given in Table 38 with localities and with collection dates when known.

It is readily apparent that a correlation exists between the size of manini at transformation and the temperature of the water of the locality. The warmest region listed in the table is the East Indies where the mean monthly sea surface temperature may reach 85°F. (29.4° C.) (Hydrographic Office Publ. No. 225). Here we find the smallest size at transformation, 20 to 21 mm. Small standard lengths, averaging less than 23.5 mm., are found in other warm areas such as the Palau Islands, Marian Islands, Gilbert Islands, and Marshall Islands (all regions where the mean monthly sea surface temperature exceeds 81°F. (27.3°C.) during the entire year) and southern India in January and Okinawa in September. Transforming specimens from regions where the temperature is 80°F. (26.6°C.) or less throughout the year or during the month of the date of collection are large, 24 mm. or greater in standard length. These areas include Durban (S. Africa), New South Wales, Ningpo (China), Hawaiian Islands, Mangareva, the Marquesas Islands (in August), and probably Tahiti in December and Clarion Island. The large transformation size of the specimens from the Phoenix Islands, where the sea surface temperature exceeds 82°F. (27.3°C.) all year, is an obvious exception to the above (see further discussion on pp. 89 to 91).

In order to preclude the possibility that the different transformation sizes of the different areas are entirely due to genetic factors (reflecting possible races of the manini in the different areas) a com-
Table 38 Size of *Acanthurus triostegus* at Transformation from the Postlarval to the Juvenile State

<table>
<thead>
<tr>
<th>Locality</th>
<th>Date</th>
<th>No. specimens</th>
<th>Standard length (mm.) range</th>
<th>mean</th>
</tr>
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<tbody>
<tr>
<td>Durban, S. Africa</td>
<td>May 8</td>
<td>2</td>
<td>23-25</td>
<td>24</td>
</tr>
<tr>
<td>S. India</td>
<td>Jan 19</td>
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<td>22.5</td>
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</tr>
<tr>
<td>East Indies</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Sumatra</td>
<td>Dec. 19-25</td>
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<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Moluccas</td>
<td>---</td>
<td>10</td>
<td>19-21</td>
<td>20.2</td>
</tr>
<tr>
<td>New South Wales</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palau Islands</td>
<td>Aug 3-6</td>
<td>7</td>
<td>21-23</td>
<td>22.1</td>
</tr>
<tr>
<td>Philippine Islands</td>
<td>June</td>
<td>1</td>
<td>23.5</td>
<td>23.5</td>
</tr>
<tr>
<td>Okinawa</td>
<td>Sept 6-8</td>
<td>2</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>S. Japan (30.4° N)</td>
<td>---</td>
<td>2</td>
<td>21-23</td>
<td>22</td>
</tr>
<tr>
<td>Rongpo, China (29.5° N)</td>
<td>---</td>
<td>5</td>
<td>24-26</td>
<td>24.9</td>
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<tr>
<td>Mariana Islands</td>
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<td></td>
<td></td>
<td></td>
</tr>
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<td>June 28</td>
<td>3</td>
<td>22-24</td>
<td>22.7</td>
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<td>July 24</td>
<td>7</td>
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<td>21.8</td>
</tr>
<tr>
<td></td>
<td>Nov 25</td>
<td>2</td>
<td>21.5-23</td>
<td>21.25</td>
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<tr>
<td>Saipan</td>
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<td>22</td>
</tr>
<tr>
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<td>Nov 11-13</td>
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<td>Apr 1</td>
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<tr>
<td></td>
<td>Aug 17-18</td>
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<tr>
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<tr>
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<td>Aug 21</td>
<td>9</td>
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<tr>
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<td></td>
<td></td>
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<td>Swains</td>
<td>May 3-9</td>
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<tr>
<td>Phoenix Islands</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canton</td>
<td>Apr 15-28</td>
<td>3</td>
<td>25-26.5</td>
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</tr>
<tr>
<td></td>
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<td>25-27</td>
<td>25.8</td>
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<tr>
<td>Enderbury</td>
<td>May 15-19</td>
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<td>25-27</td>
<td>25.3</td>
</tr>
<tr>
<td>Hull</td>
<td>July 7-17</td>
<td>9</td>
<td>23-25.5</td>
<td>24.1</td>
</tr>
<tr>
<td>Howland Island</td>
<td>Sept 24</td>
<td>8</td>
<td>23.5-26</td>
<td>24.3</td>
</tr>
<tr>
<td>Line Islands</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palmyra</td>
<td>Jan 18</td>
<td>1</td>
<td>23.5</td>
<td>23.5</td>
</tr>
<tr>
<td>Fanning</td>
<td>August</td>
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<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Wake Island</td>
<td>June 9</td>
<td>2</td>
<td>23.5-24</td>
<td>23.75</td>
</tr>
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<td>Marcus Island</td>
<td>August</td>
<td>4</td>
<td>25-26.5</td>
<td>25.6</td>
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<td>Marquesas Islands</td>
<td>Feb 3</td>
<td>1</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>2</td>
<td>26-26.5</td>
<td>26.25</td>
</tr>
<tr>
<td>Makatea, Tuamotus</td>
<td>Feb 13</td>
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<td>23.5-25</td>
<td>24.3</td>
</tr>
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<td>Mangareva</td>
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</tr>
<tr>
<td>Tahiti</td>
<td>February</td>
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<td>26.5</td>
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<tr>
<td></td>
<td>June 15</td>
<td>1</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Dec 30</td>
<td>17</td>
<td>22.5-26.5</td>
<td>24.5</td>
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<tr>
<td>Clarion Island (Mexico)</td>
<td>---</td>
<td>1</td>
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parison was made of the size at transformation of specimens obtained at Oahu in an early cold and a late warm part of the season. 39 first day transforming manini were obtained in collections from April 11 to May 8, 1953. The standard lengths of these specimens are plotted as the solid line of Figure 68. The dotted line enclosing the stippled portion of the graph represents the lengths of 38 first day transforming manini taken from July 7 to October 4, 1953. The average sea surface temperature at Oahu from February to May is 75.7° F. (24.2° C.); the average from May to October is 79.1° F. (26.2° C.) (based on average temperatures from 1941 to 1947 presented by Leipper and Anderson, 1950). The mean length of the April-May group is 26.256 mm.; the mean length of the July-October group is 25.447 mm. Although the difference in length appears highly significant, a t-test was made by the group comparison method (Snedecor, 1948: 30). The resulting t value of 3.11 gives a probability of nearly 0.001 of obtaining a value greater than this; thus it is extremely unlikely that samples as diverse as the above could be drawn by chance from a population in which the transformation length was the same throughout the season. It is therefore concluded that a relationship as indicated above exists between the size of transformation of the manini and the temperature of the water.

Breder (1949a: 296) stated that the complete transformation of Acanthurus chirurgus occurred in a period of about 48 hours. He did not, however, define the morphological state that constitutes complete transformation. In the manini, adult coloration is nearly acquired after about 48 hours, but other major changes are less than half completed after this length of time. Admittedly it is difficult to define a precise stage at which larval characteristics have completely disappeared and miniature
Fig. 68 Size of *Acanthurus triostegus sandvicensis* from Oahu during the first day of transformation from the acronurus to the juvenile stage. The solid line represents all of the specimens collected from April 11 to May 8, 1953; the dotted line indicates those collected from July 7 to October 4, 1953.
adult structure is assumed. Probably the most convenient criterion is the stage at which the scales have completely formed. They develop as posterior outgrowths from the upper part of the narrow, vertical, fleshy ridges. Drawings of developing scales have been made by Poey (1875: pl. 3) for the West Indian species, *Acronurus caeruleatus* (= *Acanthurus coeruleus*) and *Acronurus nigriculus* (= *Acanthurus bahianus*). The first evidence of the formation of the scales on the posterior half of the body is the appearance of scattered thorn-like spines which project upward as well as posteriorly from the ridges (these do not occur on the anterior half of the body). Actually, these spines are present on manini acronuri caught offshore at a night light, but they can be seen only with the aid of a microscope. These tiny spines enlarge and become visible (when wet) with the naked eye on the majority of specimens taken in their first day of transformation as early as 6:30 and 7:30 A.M. Each such spine on later stages was found to be a central stout ctenium of a single developing scale. The majority of the scales, however, do not develop these. As scale development proceeds, the large ctenii flatten, become overlaid with epidermis, and can no longer be perceived macroscopically. When this occurs, scale development is essentially complete as are other major changes of the transformation process. Scale development normally requires 4 to 5 days. In an aquarium the whole process is delayed and about 6 days are necessary.

Figure 66 shows transforming manini on the first day, second day, third day, and fourth to fifth day. The second day and third day stages were identified with assurance by comparison with specimens recovered in tide pools following fin clipping on the first day of transformation. No older marked specimens were recovered at the stage when scale structure
is just complete, and the time this required had to be inferred from the percentage of specimens in the different stages collected in the weekly poison stations of the Diamond Head tide pool of Figure 54.

The vertical dark bars which are so characteristic of the manini are absent from the majority of night light specimens. They are faintly visible on a few such specimens, however. Manini caught in tide pools during the same night when they came in usually possess traces of the dark bars, but some, presumably very recent arrivals, are totally lacking these markings. One of the two previously mentioned specimens which were observed just entering shallow water from deeper areas of the Ala Moana Yacht Basin had traces of the bars and the other lacked them. The bars are not dark on any of the specimens collected at night. During daylight of the first day of transformation the bars become intensely dark brown. This suggests that sunlight might accelerate or perhaps even be necessary for the darkening. In a review on the biochemistry of the production of melanin, Lerner and Fitzpatrick (1950: 119) pointed out that ultra violet irradiation appears to be concerned with melanin formation in at least four different ways, all of which tend to increase pigmentation.

An experiment was designed to see whether any changes occurred in the transformation process when light is excluded. Two transparent specimens which displayed no evidence of dark vertical bars on the body were taken at midnight. These were placed in a battery jar containing 2½ gallons of aerated fresh sea water. The jar was covered with a box which, in turn, was covered with a heavy black cloth. Three other transparent specimens taken at the same time were placed in a small uncovered aquarium. These had faint bars on the body when they were collected. The battery jar was uncovered 12 hours later. The transformation of the two specimens
had barely started. The stage which was reached was about comparable to transforming fish taken shortly after dawn. The bars on the side were barely discernible and the stenii of the developing scales on the posterior half of the body were just visible. One of the fish was on its side, dying. It was removed, and the jar was again darkened. Eight hours later the second specimen was found nearly dead. The bars were possibly a little darker; the transparency of the body was largely replaced by opaque white, an abnormal color alteration. The three aquarium specimens completed their transformation. The results suggest that light is essential to normal transformation. To be conclusive, however, the experiment should be repeated several times with control conditions more similar to the experimental. If light were conclusively demonstrated to be essential to the metamorphosis of the manini, the mechanism by which it exerts its effect would still not be known. It might act directly on the tissues, or by way of the visual sense, or both.

During the first day the transparency of the body is gradually lost. By the end of the day the dark brown bars on one side of the body cannot be seen through the body from the other side as they may be on specimens such as the one in Figure 65. The bright silvery color on the abdomen and head is slightly dulled by the end of the day due to the development of melanophores external to the silver layer. The iridocytes causing the silvery sheen on the abdomen are present in the peritoneum. On the gill cover they occur in a layer on the underside of the opercular bones. They are found on the surface of the cleithrum at the edge of the gill opening. No silver color is present dorsal to the eye. Instead there is a broad black band which covers the brain. This is found beneath the dorsal bones of the head. By the third day both the silvery color and the black band
on the head are nearly imperceptible. They are, like the rest of the
body except the region of the dark bars, white with numerous, close-set,
tiny flecks of dark brown. The olivaceous cast of the body as seen on
juvenile and adult manini is not conspicuous until about the fourth or
fifth day of transformation, probably because of slow development of
yellow chromatophores.

As may be seen in Figure 65 the second dorsal and second anal spines
of the acronurus stage are longer and stouter than the other spines
of these fins. If stuck by either of these spines or by the pelvic
spines, a stinging sensation about comparable in intensity to a bee sting
is felt. It is believed that these same spines, very elongate in the 6.6
mm. manini, are similarly poisonous in earlier stages. The poisonous
nature of the spines appears to be a larval adaptation, for it is lost
by the third day of transformation. A diminution in the relative length
of the second dorsal and second anal spines may be seen in the series of
transforming specimens of Figure 66. The relative change in length of
these spines continues until, in late juveniles and adults, the third
dorsal and third anal spines are much longer than the second dorsal and
second anal spines, respectively. The latter, however, remain thicker.
All of the acronurus spines are T-shaped in cross-section; all are solid.
The nature of the poison apparatus is unknown. The T-shape of the spines
persists into the juvenile stage.

One of the most striking changes during transformation is the al-
teration of the configuration of the head. Primarily this consists of
an increase in the length of the snout, resulting in the mouth being in
a more ventral position. This prolongation may be seen in Figures 65 and
66. The diameter of the eye (which does not change during transformation)
of the transparent specimen of Figure 65 is slightly longer than the length of the snout; in the just transformed manini the eye diameter is contained about 1.5 times in the length of the snout. The osteological changes which accompany the changes in the proportions of the head were not investigated.

A slight increase in standard length occurs during transformation. After five days in an aquarium, three transforming specimens, 24.1 to 25.0 mm. in standard length, increased 1.2 to 1.5 mm. in standard length. Most of the increase is attributable to the prolongation of the snout. A remarkable lengthening of the digestive tract takes place during transformation (Fig. 52). In a period of four to five days the total length of the alimentary tract of the manini increases about three-fold. This lengthening is correlated with a change in food habits from feeding on zooplankton to feeding on algae (see pp. 278-279).

The teeth of the manini acronurus of transformation sizes are very different from the simple conical teeth of the postlarval manini 6.6 to 7.8 mm. in total length. They are close-set and flattened with denticulations on the edges similar to adult teeth. There are about 14 of these teeth, each with six or seven denticulations, in the upper jaw with a broad gap between teeth at the symphysis of the jaw. There are 14 such teeth in the lower jaw with five denticulations. During transformation eight large adult-type teeth (with about 12 denticulations), which are preformed within the premaxillary bone above the series of larval teeth, grow down over the larval teeth which appear to be shed. The more medial of these large teeth are the largest and the first to appear in transformation. In the lower jaw the same process occurs. Six large adult-type teeth with seven denticulations grow over the larval teeth. Larval teeth
lateral to these large ones may persist beyond the period of transformation.

The sequence of tooth replacement is not without variation from specimen to specimen. At the stage when the scales are just completely formed on the body some specimens have fewer than eight upper and six lower teeth in position. Some specimens taken at night lights in deep water appear to be getting their adult teeth prematurely. One specimen obtained at a night light trap at anchorage at Christmas Island already has six large upper and two large lower teeth.

GROWTH

No information could be found in the literature on growth of any species of surgeon fish. The closest family, phylogenetically, to the Acanthuridae in which growth data are available for comparative purposes is the Teuthididae (Siganidae of most authors). Like the acanthurids, the teuthidids are herbivorous (Suyehiro, 1942, and Al-Mussaini, 1947). Whitehouse (1923: 68-70, 83-85) reported that juvenile *Teuthis jave* grew from a length of 25 mm. in April to 75 mm. in September in Silavattural Lagoon, Tuticorin, India. Ommanney (1949: 48-49) stated that *Siganus corallinus* (= *Teuthis corallinus*) reached a length of 180 to 220 mm. after two years growth, and about 250 mm. at the end of the third year, in Mauritius.

Information on growth of the manini was obtained by the rearing of fish in a tank at Coconut Island, analysis of the progression of modes among the juveniles of Figure 55, recovery of young fish marked by fin clipping, and the recovery of tagged adults. The data are discussed separately under these headings below.

The standard length measurement for all of the work on growth of
the manini is the length from the tip of the snout to the middle of the dorsal black bar posteriorly on the caudal peduncle. It was found that this measurement could be made with greater accuracy on living fish than the usual standard length to the base of the caudal fin (i.e. posterior end of hypural plate). The original measurements are herein retained for all tables, graphs, and discussion (and designated simply "standard length"), rather than converting to true standard length. Should the latter measurement be desired, it may be obtained by increasing the length to the peduncular bar by 3.5 per cent.

Growth of captive fish

Ten manini, 25 to 27 mm. in standard length (mean length 26.4 mm.), were placed in a concrete tank of the Hawaii Marine Laboratory at Coconut Island on March 17, 1953. The tank measures 34.7 feet by 10.8 feet and is an average 3.9 feet in depth. A constant supply of sea water is pumped into the tank. When the fish were introduced, no other fishes were present and the walls were covered with an exceedingly luxuriant growth of many species of algae. The top of the caudal fin of the ten juveniles was removed to permanently mark them (see below) as a safeguard against the possible addition of more manini to the tank by other persons.

The growth of these fishes is recorded in Figure 69. The three fish captured on May 13 (mean length 66.0 mm.) had grown an average of 20 mm. per month since March 17. On August 6 all of the manini were caught (two had disappeared and three were killed for gonad study). They averaged 90.9 mm. in standard length. By September 27 they had grown to an average standard length of 94.3 mm.; thus the average rate of growth from August 6 to September 27 had diminished to 1.8 mm. per month.

The manini were caught by seining the tank after partially draining
Fig. 69 Growth of *Acanthurus triostegus sandvicensis*. Based on 10 marked juvenile specimens, 25 to 27 mm in length, released in a concrete tank (34.7' long, 10.8' wide, 3.9' deep) at Coconut Island, Kamehame Bay, Oahu, March 17, 1953. Dotted line indicates approximate rate of growth from the plotted measurements.

Fig. 70 Early Growth of Juvenile *Acanthurus triostegus sandvicensis*. Based on recovery of marked fish.
it. The efforts to catch them on September 27 failed several times, and much of the algae was detached from the walls of the tank before all of the fish were netted. Following this the amount of algae on the walls remained slight and apparently insufficient to support the growth of the fish. The five remaining manini were measured again on November 19. They were thin, and instead of growing, they lost an average of 1.3 mm. in standard length. It is presumed that length was lost because of reduction in the amount of intervertebral tissue. Manini this size shrink nearly 3 mm. in standard length when preserved in 10 per cent formaldehyde solution.

Growth measurement from progression of modes

The collections of juvenile manini from Kewalo Basin to Makapuu Point, Oahu, plotted in histogram form in Figure 55 permit an estimate of the early growth rate by analysis of the progression in standard length of prominent modal groups from week to week. By this method the growth rate of juvenile manini from about 26 to 45 mm. in length is computed at about 12 mm. per month. Particular reference was made to the mode which first fully appears on April 17.

Growth of marked juveniles

Before undertaking the marking of juvenile manini in the field by fin clipping, experiments were performed in aquaria to test the possibility of fin regeneration. One pelvic fin and the posterior part of the soft portion of the dorsal fin were cut from three juvenile manini averaging 27.5 mm. in standard length. Although the fins were severed at the juncture with the body, they regenerated rapidly and were nearly completely formed in a month. In a second experiment the top few rays of the caudal
fin were removed, as well as the upper corner of the hypural plate to insure the removal of all fin elements. This cutting resulted in the permanent deformation of the caudal fin of the fish.

Ten manini, 28.5 to 30 mm. in standard length (mean 29.25) were caught at the Ala Wai Canal near its entrance to the Ala Moana Yacht Basin on April 24, 1953. The top of the caudal fin of these fish was removed and they were released in the same area. Three of these marked fish were recovered, one on May 2 which measured 32.5 mm. in standard length and two on May 15 which were 34.8 and 37.0 mm. long (Fig. 70). The average growth rate is 9.6 mm. per month.

96 juvenile manini, 25 to 28 mm. in standard length (mean 26.6 mm.), were caught, marked, and released in a Diamond Head tide pool on May 10, 1953. A total of 11 were recovered from this pool on three different dates (Fig. 70). The average growth rate of these fish was 12.9 mm. per month. The four manini of this group which were recovered on June 23 ranged from 42.5 mm. to 48 mm. in standard length and averaged 45.1 mm. When first caught with the 92 others on May 10, these fish were a part of the prominent mode which may be seen centered on about 26.5 mm. standard length on the graph for this date in Figure 55. This same mode is still apparent in the sample of 147 fish which were collected at Diamond Head on June 23 in an effort to recover marked fish. At this time the mode is composed of 27 fish, 40 to 49 mm. in standard length with a mean of 43.3. Since the four marked manini taken at this date are distributed well within the mode and of larger average size than its mean value, it is concluded that the fin clipping did not retard the growth.

The difference in growth rate between the Diamond Head marked manini and the Ala Wai marked fish may be associated with the difference in algal
flora of the two areas. Algal growth in the latter area is sparse; it consists primarily of diatoms. The extraordinary growth rate of the captive manini in the Coconut Island tank is probably also associated with the algal food supply. Here, as mentioned, the stand of algae was exceptional—much greater than I have ever observed in normal reef or bay areas around Oahu. Invertebrates, including herbivorous types such as echinoids, gastropods, and decapod crustaceans, were present in the tank. It is assumed that the large supply of algae was primarily due to the lack of herbivorous fishes. When introduced to this unusual environment, the ten juvenile manini were given an unprecedented opportunity for rapid growth.

In view of the more normal environment of the Diamond Head tide-pool region and the similarity in growth rate of marked fish from this region to the rate computed from the progression of modes, this rate (i.e. 12 to 13 mm. per month) is considered as the probable rate of growth in spring of early juveniles of the bulk of the Oahu manini population.

The growth of juveniles in the winter was observed to come to a standstill. This was first noticed from shallow water collections and observations made during the fall and winter months of 1952-53. Up to November manini less than 40 mm. could usually be found in the collections or seen in the water. In late November, December, and January no specimens less than 40 mm. were found, but the 40 mm. size persisted. This suggested that the last incoming juveniles of the season, which enter tide pools in early October, grow to a standard length of about 40 mm. by November and then stop growing. During the next two winters the same phenomenon was noted.

In order to demonstrate this cessation of growth and to ascertain
the time when growth is resumed, 22 juvenile manini, 40 to 72 mm. long, were caught with a dip net, marked by fin clipping, and released on the nights of January 5 and 6, 1954 at the entrance of the Ala Wai Canal to the Ala Moana Yacht Basin, Oahu. Fish were taken at both the northwest (Waikiki Yacht Club) and southeast shores of the canal entrance. Within these two areas, three major categories of fin clipping were established: the top of the caudal fin was removed, the bottom of the fin, and both the top and the bottom. Manini of variable size were chosen for each category, and another fin was cut on each specimen. Also any distinctive color marks (usually at the base of the pectoral fin) were noted.

Subsequent efforts to recover the fish were limited by conditions of wind, tide, and turbidity of the water. Although more subject to the effects of turbidity than exposed shores, the Ala Wai area was preferred, for fish are more restricted to the shore area because of the mud bottom away from the bank of the canal. Fish of this size range in a region such as Diamond Head move well out on the reef where the broader area, deeper water, and action of surf would make them difficult to capture and recapture. Although, as mentioned, some of the manini this size come into tide pools at night, their numbers are not sufficient for such a marking program.

Since fish were measured alive with a light at night, difficulty was experienced in obtaining precise length determinations. Although the lengths were recorded to 0.5 mm., it should be added that variations as great as 1 mm. from the original measurement were noted in unbiased tests of accuracy.

Eleven of the 22 marked fish were recovered - all from the area of release. Two of these were recaptured a second time. Of the nine fish taken before February 1, few, if any, showed significant growth. The four
recovered on February 21 and 27 displayed definite increments of growth, indicating a resumption of growth during this month in the area tested and for the year 1954.

Table 39 Recovery Size of Juvenile Acanthurus triostegus sandvicensis Marked on January 5-6, 1954.

<table>
<thead>
<tr>
<th>Standard length when marked (mm)</th>
<th>Jan. 20</th>
<th>Jan. 26</th>
<th>Feb. 1</th>
<th>Feb. 21</th>
<th>Feb. 27</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.0</td>
<td>41.0</td>
<td></td>
<td></td>
<td></td>
<td>54.5</td>
</tr>
<tr>
<td>46.5</td>
<td>47.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>49.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51.5</td>
<td></td>
<td></td>
<td></td>
<td>57.0</td>
<td></td>
</tr>
<tr>
<td>55.0</td>
<td>55.5</td>
<td></td>
<td></td>
<td>60.0</td>
<td></td>
</tr>
<tr>
<td>55.5</td>
<td>55.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56.0</td>
<td></td>
<td></td>
<td>56.5</td>
<td>64.0</td>
<td></td>
</tr>
<tr>
<td>64.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>64.0</td>
</tr>
<tr>
<td>66.5</td>
<td></td>
<td></td>
<td>66.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70.5</td>
<td>70.5</td>
<td></td>
<td></td>
<td></td>
<td>79.0</td>
</tr>
<tr>
<td>72.0</td>
<td>72.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

One other marked fish caught in February and two in early March had regenerated the fin other than the caudal fin which had been cut and could not be distinguished from at least one other fish of their respective caudal fin categories.

Although there is some indication of a relationship between increasing water temperature and the onset of growth of these young, the temperature data are inadequate to establish any definite correlation. Temperature were taken in the canal at night between 9:30 and 12:00 P.M. about
3 inches beneath the surface.

Table 4.0 Temperature at the Mouth of the Ala Wai Canal

<table>
<thead>
<tr>
<th>Date</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 5</td>
<td>22.8</td>
</tr>
<tr>
<td>Jan. 20</td>
<td>23.2</td>
</tr>
<tr>
<td>Feb. 1</td>
<td>23.1</td>
</tr>
<tr>
<td>Feb. 27</td>
<td>25.3</td>
</tr>
<tr>
<td>Mar. 2</td>
<td>24.7</td>
</tr>
<tr>
<td>Mar. 21</td>
<td>24.9</td>
</tr>
</tbody>
</table>

It should be emphasized that the temperature at the mouth of the Ala Wai Canal probably varies much more in a day or from day to day than the sea surface temperature off Oahu. It is not a large body of water and is therefore more subject to change due to variation in insolation and atmospheric temperature. Probably more important are the changes produced due to variation in the run off of water from Palolo and Moana Valleys which drains to the canal and to the ever-variable tide which affects this estuarine region. In order to provide adequate data for the determination of a correlation, repeated temperatures should be taken at regular intervals each day for every day of the period of the fin clipping program, and an analysis of growth made in terms of average daily water temperatures.

Growth of tagged adults

The first tag used on the manini was of the Atkins type (Rounsefell and Kask, 1945: 330, fig. 1). It consisted of a single rectangular piece
of white cellulose acetate, 5 by 28 mm. in size, and was attached through the back of two small adult manini beneath the posterior part of the dorsal fin with 4 pound test monofilament nylon. The fish were held in a tank of the Hawaii Marine Laboratory at Coconut Island. Within three weeks the tags were no longer present on the fish. They were recovered from the bottom of the tank with the loops of nylon intact, thus indicating that the nylon had pulled through the flesh.

The same type of tag was then threaded through the upper part of the hypural plate of the two fish. As they swam, the tag of each oscillated slightly as it was drawn along in a position just above the caudal fin. Three months later both tags were in place, and the method looked promising; therefore, over 50 tags were made, numbered, and labelled further as follows: Reward for Fish, University of Hawaii; Phone 90551, ext. 273. On March 3, 1953, 50 adult manini were affixed with these tags while operating from the fishing vessel "Friendly Isle", owned by Mr. Samuel Kaolulo. Two fish were recovered five days later, both in the vicinity of the point of release. No other recoveries were reported. The two Coconut Island manini lost their tags before six months elapsed, and further plans for tagging by this method were abandoned. Disappointing results with Atkins tags were later reported by Fraser (1955) for the smallmouth bass.

Petersen disk tags, hand-made from cellulose nitrate, were then tried. Since stainless steel seemed most promising among the metals commonly used to attach these tags (Calhoun, Fry, and Hughes, 1951, and subsequently Skinner and Calhoun, 1954, and Forrester and Ketchen, 1955), this material was chosen for initial trials. Considerable difficulty was experienced, however, in bending the free ends of the wire on a struggling
fish, a disadvantage clearly pointed out by Calhoun, et al. Attention was then shifted to nonmetallic substances, of which nylon seemed the most propitious. It is superior to metal in its pliability, nontoxicity, and in not being subject to electrolytic action or fatigue; however, there are important disadvantages to the use of this synthetic for tagging when knots must be tied: knots of nylon are prone to slip; thickness of nylon must be sacrificed to obtain tight knots; a considerable length of nylon is needed for each tying, much of which must be discarded; knot tying is very time consuming in an operation that demands dispatch. An attempt was then made to devise a means of using nylon without resorting to tying knots. The idea came to mind to melt each free end of the nylon into a little knob (Fig. 71). It was found that a flame was necessary to obtain sufficient heat to melt the nylon. The most convenient flame-producing device of several tried was the Ronson windlite cigarette lighter.

On August 6, 1953 three captive adult manini were tagged with the disks (as shown in Fig. 72) by 60 pound test monofilament nylon (diameter, 1 mm.) and one with stainless steel wire. The procedure for the nylon-attached fish was as follows: one end of the nylon was melted into a ball and the first disk threaded in place. A dissecting needle was run through the back of the fish and drawn back and forth several times. The remaining free end of the nylon, which was cut on an angle to form a point, was inserted through the hole, and the second disk put in place. The flame was then used to cut off any excess length of nylon and melt the end into a knob. The second disk served as a natural shield against burning the epidermis during the melting process. Approximately 3 mm. space was left on each side of small adults between each knob and adjacent disk to allow for growth.
Fig. 71 Petersen disk tag used in tagging *Acanthurus triostegus sandvicensis* on Oahu. The ends of the monofilament nylon connecting the two disks have been melted into knobs. The heating caused a blackening of the one knob which is visible.

**REWARD!**

![Fish diagram](image)

**IF A MANINI IS CAUGHT WHICH IS TAGGED AS SHOWN IN THE ABOVE DRAWING, PLEASE CONTACT FISH & GAME WARDEN OR BRING THE FISH TO THE DIVISION OF FISH & GAME (PHONE 9207). ONE DOLLAR ($1.00) REWARD WILL BE GIVEN.**

Fig. 72 Poster used to publicize manini tagging program.
Seven weeks after tagging, all four fish, along with six untagged fish (all of the fish in the tank) which were measured at the time the four fish were tagged, were caught and remeasured. The six untagged fish, which had a mean standard length of 86.3 mm., had grown an average of 6.6 mm. The three tagged with nylon (mean standard length 84.4 mm.) grew an average of 7.7 mm. The 92 mm. fish whose disks were attached with stainless steel wire added the smallest increment of growth, 2.5 mm. Although there are insufficient data for definite conclusions, it seems apparent that manini tagged with Petersen disk tags fastened with monofilament nylon are capable of normal growth.

One of the fish which survived 11 months until July when the tank was needed for other purposes still retained its disks fastened with nylon. It was noted that the flesh around the hole pierced by the nylon strand was almost in contact with the nylon. There was no evidence of deterioration of the nylon.

Since the experimental tagging demonstrated no obvious fault in this method, field tagging was begun. 45 manini were tagged by the writer with hand-made tags. Because of the great amount of time needed to make the tags and obtain live adult manini for tagging, and the expense of paying rewards, assistance was requested of the Territorial Division of Fish and Game. This was granted. Manufactured disk tags of laminated cellulose acetate (although cellulose nitrate is more durable (see Calhoun, Fry, and Hughes, 1951) the acetate is preferred by manufacturers because of the fire hazard of the former) as shown in Figure 71 were purchased from the Howitt Plastics Company, Molalla, Oregon.

Under the direction of Mr. Vernon E. Brock and Mr. Yoshio Yamaguchi, Mr. Carl M. Nemoto tagged a total of 1152 manini, 70 to 152 mm. in stand-
and length, from July 6 to November 23, 1954. The tagging was carried out from Mr. Kaolulo's vessel between Kewalo Basin and Koko Head, Oahu. The manini were caught in traps, tagged, measured, and released at the place of capture, which was recorded.

Due to the difficulty of using a flame when tagging from a vessel exposed to the strong winds of the Kaiwi Channel (Molokai Channel), Mr. Nemoto tagged many of the fish by crimping brass leader sleeve on one end of the nylon (the other end was melted into a knob prior to the departure of the vessel). This method was devised by Mr. Kenji Ego of the Division of Fish and Game and had been used with success by Mr. Yamaguchi.

In order to publicize the tagging, a poster (shown reduced to about one-third size in Fig. 72) was distributed by game wardens. Also an article appeared in a local newspaper.

Up to April 27, 1955 there have been a total of 273 recoveries of manini tagged with disk tags. One dollar reward for each recovery has been paid by the Division of Fish and Game. 166 of the recovered fish have been returned alive, providing the opportunity for re-release. 23 of these have been caught again, and three have been taken a third time (these recoveries are included in the 273 mentioned above).

The following table shows the lapse of time by two week periods between the release and recovery of tagged manini.

<table>
<thead>
<tr>
<th>Table 41 Recovery Time of Tagged Acanthurus triostegus sandvicensis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two week intervals following release of fish</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>
Table 41 (Continued) Recovery Time of Tagged
*Acanthurus triostegus sandvicensis*

<table>
<thead>
<tr>
<th>Two week intervals following release of fish</th>
<th>Number of fish recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
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</tr>
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<td>15</td>
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</tr>
<tr>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
</tr>
</tbody>
</table>

The fish with the longest recovery time was tagged on July 23, 1954 and recovered on March 25, 1955. The disk was held on one side by crimped brass and on the other by a nylon knob.

The explanation of the large number of manini recovered in the first few weeks following release and the sharp drop off in returns thereafter probably involves a number of factors, the most obvious of which is the catching and hence elimination of tagged fish. Others are natural mortality, loss of tags, and movement from the immediate area of release.
In addition to usual mortality, additional mortality might be expected of manini tagged following capture in traps.

It is known that at least some loss of tags has occurred, for manini with the tagging wound but without tags have been noticed by fishermen. Since no fish have been seen with a tag in the process of migrating up through the back and dorsal fin, it is assumed that such losses occurred due to the dropping off of a disk because of the knob being too small or the brass inadequately crimped. Analysis of the returned tags indicated that the knobs were too small in many cases. When the diameter of the hole in the disk is 1 mm., the knob should measure at least 2 mm.

Movement from the trap area could account for a diminution in recoveries of tagged fish; however, evidence is strong against at least extensive migration by this species (see section on migration).

The marked drop in number of recoveries still seems too high to be accounted by any or all of the above reasons. One other possibility exists which is supported by the extraordinary high percentage of returns. A tagged manini may show a greater predilection to re-enter a trap than untagged manini to enter a first time. This phenomenon has been conclusively demonstrated by Lawrence (1952) for bluegill sunfish in Iowa farm ponds. If such a tendency exists, it might be expected to be greatest in the fish soon after release and gradually abate with time. One manini was caught, tagged, released near the next trap, and caught again in this trap minutes later.

The data on growth from recovery of tagged manini have been complicated by several factors. The first 154 manini tagged by Mr. Nemoto were measured to the center of the black bar dorsally on the caudal peduncle. In order to be consistent with the usual Division of Fish and Game methods,
the length measurement was changed to fork length for the next 855 fish. When the difficulty of measuring the end of a frayed or eroding caudal fin became apparent to Mr. Nemoto, he elected to make both kinds of length measurement for the rest of the fish. Some tagged fish have been recovered which were originally measured by the first method and the second time by fork length. In order to ascertain the growth increment, the original length of these fish was converted to fork length by use of a graph with fork length on one axis and standard length measured to the peduncular mark on the other. This graph was prepared from 93 manini randomly chosen from among the fish measured by the two methods by Mr. Nemoto.

The 166 tagged fish which were returned alive were measured alive a second time by Mr. Nemoto and released. The remaining tagged manini were measured after they had died, and usually not when fresh but following partial drying and/or freezing. Seventeen of the latter group were recovered within the first two weeks following tagging. These fish were all from 1 to 7 mm. shorter than when first measured. The average shrinkage was 3.53 mm. The average standard length of these specimens measured to the peduncular mark is 109.8 mm. The average shrinkage per millimeter of length is therefore 0.0321 mm. A correction was made for each fish which was measured dead by multiplying its recovery length by this factor and adding the product to the length.

A total of 70 tagged manini were measured alive a second time following recovery within two weeks of tagging. Surprisingly, 46 of these were from 1 to 5 mm. shorter than when first measured; ten were the same size; 14 were from 1 to 3 mm. larger. The average "growth" was -1.06 mm. A t test applied to this data to ascertain the probability of obtaining
such a distribution from a population in which no change in length occurred and the variation in recovery length was purely due to chance errors of measurement resulted in a t value of 5.1. With 69 degrees of freedom this gives a probability of getting a higher t value of less than 0.001; thus the null hypothesis is rejected. Since the same person measured the fish both times, the reason for the significantly shorter length is not apt to be any bias in measurement. I believe that the shorter length is due to shrinkage from starvation in the traps. Manini which are caught in traps may have been held in the traps for a week or more. Although a week might not constitute starvation to a carnivorous fish which feeds only occasionally, it does to the herbivorous manini, which, as mentioned, feeds almost continuously during the day.

In order to test the hypothesis that actual shrinkage occurs during starvation, 17 trap-caught adult manini (none of which showed evidence of long sojourn in traps), were tagged, measured, placed in two large aquaria, and allowed to starve. 11 days later the five fish which survived were remeasured. Their initial standard length were 112-131 mm. A definite shrinkage of from 1 to 5 mm. (mean 3.4 mm.) had taken place. The measurements were made by Mr. Hamoto.

The average length of the 70 fish was 107.5 mm. The average shrinkage per millimeter of length is 0.00986 mm. A correction was applied with this factor to obtain the growth increment of all manini measured alive.

The difficulty with the postulation of shrinkage and the application of a correction is the necessity of presuming that greater shrinkage occurs in a manini the second time it is caught than the first time. This is readily understandable with fish such as the 70 mentioned above which
spend another period of confinement in traps within two weeks of their first, but the growth estimates are based on fish captured after being tagged a month or more. Two explanations are offered. Manini which were in bad condition from a long stay in a trap (frayed and eroded fins, lean body, and epidermis worn off snout from butting against the chicken wire of the trap) were generally not tagged, especially when more fish came up in a trap than could be tagged and released in the same area before the boat reached the next area. A recovered tagged fish, however, was always released as long as it was alive. 119 of the 166 tagged manini released alive after recovery were retained at least a day and usually several days in the wells of the trap vessels in Kewalo Basin before Mr. Nemoto was able to come down to release them; thus these fish were subjected to further starvation. Probably proportionately greater shortening occurs with each additional day of starvation. The best argument for applying the correction is the negative winter growth which would result if the correction were not applied (see Table 42 and Fig. 74). The average growth per month of the 26 fish recovered after a month or more in the water following tagging on November 19 and 23, 1954 is -0.108 mm. This does not differ significantly from 0 growth. Without the correction, it would be necessary to postulate that manini shorten in length during winter months.

The large amount of variation (-5 to +3 mm.) in the series of differences between the measurements made on the 70 fish when tagged and when recovered within two weeks was unexpected. When it is realized that four different sources contribute to this variability, it is more comprehensible. There is the error in the first measurement of a struggling fish. The second measurement of this same fish constitutes an
independent source of error. The shrinkage due to starvation is a third. Some manini which are caught have not been in a trap more than a few hours and will not have shortened at all; others held prisoner for a week or more may have shrunk as much as 2 mm. Some manini initially caught after a very short stay in a trap, tagged with a minimum of injury, and recovered a full two weeks later after another brief period in a trap might have grown about a millimeter; thus growth itself probably forms a fourth source. An important fifth source of error in the measurement of the dead tagged fish is the variation in shrinkage after death. Still another cause of variation in growth increment data is due to the necessity for conversion from one method of length measurement to another. All of this variability has necessitated a statistical approach to the analysis of the data, and for this purpose the large number of recoveries has been most welcome.

In Table 42 below the data are recorded for the 68 tagged manini which were recovered after spending a month or more in the water following being tagged from July 6, 1954 to September 28, 1954. Columns 3 and 5 of Table 42 are plotted in Figure 73. The dotted line represents the regression of millimeters of growth per month on standard length. The regression coefficient "b" (slope of the regression line) is -0.0292. The t value testing whether this regression differs significantly from zero is computed as 2.085. With 66 degrees of freedom, the probability of getting a larger value of t is 0.04; thus the null hypothesis is rejected.

The comparison of the regression line with the upper part of the growth curve of Figure 69 is favorable. The average growth rate of the captive fish from August 6 to September 27 was given as 1.8 mm. per month.
The average rate for the size range of these captive fish (90.0 to 94.3 mm.) from the regression line is 1.74 mm. per month.

Table 4.2 Growth of Acanthurus triostegus sandvicensis Recovered After One Month or More Following Tagging from July 6 to September 28, 1954.

<table>
<thead>
<tr>
<th>Date released</th>
<th>Date of recovery</th>
<th>Standard length</th>
<th>mm. of Growth*</th>
<th>mm. of growth per month</th>
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</thead>
<tbody>
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<td>Aug. 6</td>
<td>104</td>
<td>1.3</td>
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</tr>
<tr>
<td>July 6</td>
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<td>106</td>
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<td>0.1</td>
</tr>
<tr>
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<td>Nov. 16</td>
<td>112</td>
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<td>0.3</td>
</tr>
<tr>
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<td>Aug. 6</td>
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<td>-0.6</td>
</tr>
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<td>Aug. 17</td>
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<td>7.1</td>
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Table 42 (Continued) Growth of Acanthus triostegus sandvicensis Recovered After One Month or More Following Tagging from July 6 to September 28, 1954.

<table>
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<tr>
<th>Date released</th>
<th>Date of recovery</th>
<th>Standard length</th>
<th>mm. of Growth*</th>
<th>mm. of growth per month</th>
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<td>-0.5</td>
</tr>
</tbody>
</table>

* - includes correction for shrinkage.

In order to confirm further the finding of cessation of growth in winter, 155 manini were tagged on November 19 and November 23, 1954 by Mr. Nemoto. 25 of these fish have been recovered from December 23, 1954 to February 18, 1955 (see Table 43 and Fig. 74). It is concluded that no growth has taken place.
Fig. 73 Growth of *Acanthurus triostegus sandvicensis* during the period July 6 to November 19, 1954. The points represent growth increment of tagged fish recovered after at least one month in the water. Circles indicate the superposition of one point on another. The dotted line represents the regression of growth on standard length. Complete data are presented in Table 42.

Fig. 74 Growth of *Acanthurus triostegus sandvicensis* during the period November 19, 1954 to February 18, 1955, as based on the recovery of tagged fish which were in the water one month or more. The horizontal line was added at the zero mark to facilitate the comparison of the distribution of points with Fig. 73 Complete data are presented in Table 43.
Table 43 Growth of Acanthurus triostegus sandvicensis Recovered After One Month or More Following Tagging from November 19 to 23, 1954.

<table>
<thead>
<tr>
<th>Date released</th>
<th>Date of recovery</th>
<th>Standard length</th>
<th>mm. of Growth*</th>
<th>mm. of growth per month</th>
</tr>
</thead>
<tbody>
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</table>

* - includes correction for shrinkage.

No data are available for the growth of adult manini in spring.

**AGE**

In view of the lack of winter growth of the manini and the finding by Chevey (1935) of marks on the scales of marine fishes in Indo-China which he attributed to temperature effect on growth, it was hoped that annuli might be detected on the scales of the manini; however, none could be seen. Even the circuli of the tiny scales of this species are not very
distinct. Cross-sections of vertebrae and otoliths were also examined, but with negative results. It was necessary to grind otoliths to about 1 millimeter thickness and view them with subdued light under a compound microscope before any concentric rings could be seen. These were numerous and variable, and none were more sharply defined or grouped closer together than others.

The next approach to obtaining the age of manini was the preparation of the length frequency curve of Figure 75. As the recruitment of the manini is seasonal, it seemed possible that year classes might stand out as modes on such a graph. At least for this curve, however, no definite modes are visible. Probably the long period of recruitment (February to October), coupled with the lack of growth over winter, precludes the formation of distinct modal groups in standard length. Also the variable growth of juveniles reared under identical conditions (see Figs. 69 and 70) indicates a comparable or more extensive variability in the normal environment which would tend to spread out any concentration of fish of equal size.

Age determinations of the manini would therefore seem possible only by the rearing of fish, recovery of tagged fish (tagged at a size which is small enough to predict the age from growth rate with reasonable accuracy), or gross estimates from growth rate and knowledge of the maximum size.

Although the age attained by the manini is unknown, the following information on the age of two surgeon fishes supplied by Mr. Spencer Tinker, director of the Honolulu Aquarium, indicates that at least some acanthurids are long-lived. Two specimens of Naso unicornis which were present in the aquarium when an assistant arrived in 1935, are still
Fig. 75 Length Frequency Distribution of *Acanthurus triostegus sandvicensis*. Based on 426 specimens caught in traps from Kewalo Basin to Koko Head, Oahu, from April 2 to April 9, 1954.
alive today. In 1940 several specimens of Acanthurus xanthopterus approximately 5 to 6 inches in length were placed in the aquarium. Two of these survived until 1951 in a small tank together; they had reached a size of about 20 inches. At this time one slashed the other with its caudal spine and the latter ultimately died. The remaining fish is still alive.

BEHAVIOR

Migration

Small juvenile manini tend to remain in the tide pool or shallow water area to which they first come from the pelagic state. Some evidence for this has already been presented. Of 176 juveniles taken in the weekly collections during a season from the tide pool of Figure 53, only 19 were 30 mm. or more in standard length and hence definite migrants to the pool from other areas. Since all of the fish in this pool were killed with rotenone each week, a much greater movement to such a large unoccupied area would be expected from the smaller adjacent pools if the species did not exhibit a tendency to remain in one location. When the adjacent pools were sampled for manini, they invariably contained many more specimens 30 mm. or larger, than less than 30 mm. It should be emphasized that these pools are isolated from one another for only about an hour or less during the infrequent low tides less than 0.0 feet. Even in areas like the shore of the Ala Wai Canal and the Ala Moana Yacht Basin where adjacent areas are freely available at all times and essentially identical in cover and food supply, appreciable movement does not take place. This is attested by the success in recovery of marked fish at the mouth of the Ala Wai Canal (Fig. 70 and Table 39). Failure to take more of these fish was not due to their movement out of the area.
but to my inability to catch them. Less than one-fourth of the manini sighted were caught, and probably many others were hidden from view under large rocks, etc. None of the fish were taken farther than 20 feet from the point of release, although the shore was searched as much as 100 feet away.

On March 7, 1953, a juvenile manini, estimated 36 mm. in standard length, was seen next to the sea wall of the Ala Moana Yacht Basin beside a pier. It was probably among the first manini of the season to come into the area, and was the only individual this size visible for over 100 feet of sea wall on either side of the pier. On the nine different days up to March 28 when attempts were made to find this fish, it was seen. Its greatest movement from the place where first observed was only 12 feet. On March 28 it was caught (measured as 41 mm.), and the posterior part of the soft portion of the dorsal fin removed in order to identify it with greater certainty in further observations. It was found on ten different days up to May 2, but never more than 12 feet to either side of the pier. On April 24 the dorsal fin had almost completely regenerated and by May 2 the fin appeared normal.

As juvenile manini grow, they migrate seaward from the tide-pool zone (in the harbor area, as mentioned, the larger fish remain in shallow water because of the lack of cover and algae on the mud bottom away from shore). This movement is demonstrated in the graphs of Figure 55. The relative size of any one modal group is progressively smaller in subsequent collections. The one seeming exception is the large collection of May 29. This, however, was made from a very large pool at Diamond Head which averages about 4 feet in depth. A higher percentage of larger manini were expected from this collection than previous collections which
were all made in pools less than 2 feet deep.

Information on movements of adult manini was obtained from the recovery of tagged fish. Unfortunately, exact locality data for the areas of release and recovery are not available. Since Mr. Nemoto was operating from a commercial vessel solely by virtue of the kindness of Mr. Kaolulo, he was not at liberty to delay the fishing to take bearings or soundings. The tagging of the fish and their return to the place of capture as soon as possible is of paramount importance and rarely leaves time for precise consideration of locality. In most cases knowledge of the exact location of the area of release would be meaningless, for recovery records are usually very general. As a result, nothing is known of local movements of adults and only migrations from one major area to the next, or the lack of such migrations can be presented.

Mr. Kaolulo's traps are arranged in groups, most of which are well separated. Mr. Nemoto designated these areas as offshore from the following: Yacht Basin, Royal Hawaiian Hotel, Natatorium, Diamond Head, Diamond Head Lighthouse, Black Point, Kahala, KULA antenna, Wailupe, Aina Haina, Kuliouou, Miu Peninsula, Portlock, and Koko Head.

231 of the 273 recoveries of tagged manini have been made by Mr. Kaolulo. 126 tagged fish, most of which were early recoveries by Mr. Kaolulo, have been returned to the Division of Fish and Game with no record of where they were caught. This difficulty arose because of his resorting to memory alone to recall the area where tagged fish were taken. When he caught several fish he would usually admit that he could not be sure where any of them were caught. He was finally persuaded to keep record of locality by tag number. His designations of the localities agreed closely with Mr. Nemoto's. Locality records from other fishermen
were rarely specific, and the general term given for a region seemed
to conflict at times with the Nemoto terminology. A recovery from Black
Point might be called Kahala, and Miu Peninsula either Koko Head or
Kuliouou. In analyzing tag returns, no apparent movement from one area
to another was considered as a migration when there was reason to sus-
pect confusion in area designation. Also not considered as having mi-
 grated were those fish caught at the adjacent area to the initial area
of capture in the direction of the course of the vessel, for fish were
often released when the vessel was under way to the region of the next
group of traps.

125 tagged manini were recovered which have exhibited no definite
migration. Ignoring Kewalo-released fish for the moment, this leaves
only 11 records indicating that some migration might have occurred.
Five of these were fishes which were displaced from their home area by
movement of the vessel to the next area and which apparently returned
to the home area. One was caught at Wailupe, released at Black Point,
and caught again at Wailupe. The same fish was not released the second
time until the Kuliouou area was entered. It was caught a third time
back at Wailupe. Another Wailupe manini was released opposite the KULA
antenna and was recovered at Wailupe. Two fish were caught at Black
Point, released farther offshore at Kahala, and caught again at Black
Point. The remaining six records are as follows: one fish supposedly
migrated from Kuliouou to Wailupe; another went from the KULA antenna
to Miu Valley; two apparently went from Kuliouou to Wailupe, and the last
two swam from Black Point to Kuliouou. The possibility of error must
be kept foremost in mind for all of these apparent migrations. The two
manini which moved from Black Point to Kuliouou were both caught by Mr.
Kaolulo on the same day, which seems unusual.

In view of the manner in which the locality data have been reported, it is surprising that more alleged migrations have not taken place. It is therefore concluded that extensive migrations of this surgeon fish probably do not normally occur.

119 of the 166 tagged manini which were released a second time were set free in Kewalo Basin. 11 of these have been recovered. One was taken between Piers 7 and 8 in Honolulu Harbor. The rest were all captured either at Kewalo or in the Diamond Head direction. One was taken from a tuna boat in the basin, and two off the Kewalo breakwater. One locality reads Ala Moana and another Ala Wai. One manini was caught by Mr. Kaolulo with no record of locality. Since his nearest trap is off the Yacht Basin, this fish must have migrated at least this far. One manini released at Kewalo was caught at a depth of 30 feet by Mr. George Ikeda directly off the Royal Hawaiian Hotel. The most interesting recoveries of Kewalo-released fish are two from Kuliouou which were originally captured at Kuliouou and one at Wailupe which was first caught off Wailupe. Although, again, the possibility of error must be kept in mind, it seems unlikely that the only three examples of extensive migration—all of which occurred among the 11 fish recovered following release at Kewalo Basin—could be mistakes. One of the Kuliouou returns seems fairly definite. This manini was recorded from this area by tag number by Mr. Kaolulo. When questioned of any chance of error, he insisted there could be no mistake. An interval of 3½ months elapsed between its release in Kewalo and its final capture. The other Kuliouou fish was obtained from the Young Market in Honolulu. The interval between the release and capture of this fish was 16 days. The Wailupe fish was
recovered by Mr. Kaolulol one month after release in Kewalo Basin. The locality was reported verbally. The intriguing interpretation of these three long records of migration is that at least some manini removed from their home area continued to wander on the reef until they returned. Three records are too few on which to base such a conclusion; therefore more data are being sought at the present time by purposely displacing manini considerable distances from the original area of capture.

Aggregations

Adult manini are often observed in large feeding aggregations which slowly move over the bottom. These aggregations may be dense and cover areas more than 50 feet in diameter. What appears to be the same school was repeatedly seen in the same general location at the northwestern end of Manana Island. This group of fish was observed in the area in fall as well as during the breeding season. The behavior of individual manini of the school did not differ from that of solitary adults.

Juvenile manini are gregarious and are often seen swimming in groups. One group of 11 individuals, all less than about 36 mm. in standard length, were observed for a period of half an hour at the shore of the Ala Moana Yacht Basin. No fish became separated by more than 12 inches from the rest of the group.

Reaction to danger

Juvenile manini along the shore of a part of the Ala Wai Canal infrequently visited by man perceive the approach of a person walking along the bank from an average distance of about 20 feet. This distance is contingent on the position of the sun and the depth and turbidity of the water. The usual reaction is a swift darting to some immediate hiding
place. If an observer remains immobile, the fish come out of hiding in from about 15 to 25 seconds and resume feeding shortly thereafter. Manini of the same size next to the sea wall of the Ala Moana Yacht Basin, where people pass almost continuously, do not interrupt their feeding at the approach of a person unless some unusual sharp movement is made, at which time they may hide.

The manini in a large tide pool at Diamond Head were observed to have two hiding places, each beneath a ledge at the side of the pool. One of these was preferred, and most of the fish swam to it when the pool was approached. When rotenone was spread in the region of this retreat, all of the fish swam rapidly in a direct line to the second ledge, in spite of the turbidity of the water (from the rotenone), and even though they had to move in the direction of the observer and pass over a very shallow part of the pool. The part of the pool away from the observer was broader, deeper, free of rotenone at the time, but without good cover. It was evident that the fish were well aware of the location of the best places to seek refuge.

An experiment was designed to determine the time required by juvenile manini to recognize and accept a new site of cover. A small opaque plastic bowl was inverted and placed with one edge elevated from the bottom of a 23 gallon aquarium in which 12 manini, 26 to 39 mm. in standard length, had been kept without a place of shelter for three days. Initially this bowl was avoided by all the fish. 15 minutes elapsed before any fish swam near it. One hour after the bowl had been added to the tank, the fish were frightened by rapid arm movements all around the aquarium; however no manini sought refuge in the new shelter. Upon being similarly frightened three hours later, two of the smallest fish
went into the bowl. Three hours after this, all of the manini swam to
the bowl for cover.

Adult manini are less inclined to seek shelter. Their reaction to
an approaching swimmer usually takes the form of retreat. When cover
is sought, the hole into which the fish swim usually has two or more
entrances. As has been pointed out by Breder (1949b: 97) a reaction to
attack which alternates between flight and hiding is common among fishes.

Fighting

Juvenile manini may often be seen fighting among themselves in the
natural environment. Also, several days after being placed in an
aquarium, this behavior becomes noticeable. It increases with time to
the extent that it interferes with feeding. After two weeks in an aqua-
rium, fully half the diurnal time of 12 juveniles was spent at this ac-
tivity. The fighting is not associated with territoriality, but takes
place among all the fish and in all parts of the tank. Three of the
larger fish were consistently the aggressors and the smaller fish usu-
ally bore the brunt of their attack, but no definite peck order was
established. When only two fish are present, however, the larger in-
varily dominates the smaller and forces it to remain in a corner of
the aquarium for much of the day.

A distinct color change, which results in an almost complete rever-
sal of the usual color pattern, accompanies the fighting. The broad
pale interspaces between the vertical black bars become very dark, and
the upper seven-eighths of the bars change to yellowish white except for
a fine dark line in the center of each. On the lower eighth of the body
the black bars are faintly visible in their normal width. The more
aggressive fish are darker than the less aggressive ones.
The fighting usually involves little actual contact between fish. Most of the time a fish under attack hastily withdraws, a response which generally satisfies the attacker for the moment. When there is no immediate retreat the two fish circle around at close quarters and make pugnacious movements, mostly with the posterior part of the body. When a new manini was placed in the tank, it was attacked with ferocity by all of the other manini, but rarely more than one at a time. The hapless fish was pecked over the head and body, strongly bumped, and lashed at with the caudal spines of the others as it scurried from one part of the tank to the next. A manini twice the size of any in the tank was given the same treatment. After about a half hour of incessant attack, this oppressed fish was observed to lie on its side on the bottom and submit completely to the relentless abuse. It was caught and examined shortly thereafter. Only a few small scratches on the fins and two small cuts on the body could be seen. The manini has a much smaller caudal spine than other species of Acanthurus and is not capable of inflicting much damage with it. Also the jaws are not strong enough to injure other fishes of equal size.

Manini were never observed to fight with other species of fishes. They appear to display a dominant behavior pattern to at least some, however. Six small pomacentrids (Abudefduf abdominalis) ranging from an estimated 18 to 38 mm. in standard length were observed to intermingle with four juvenile manini about 28 to 36 mm. in standard length at the shore of the Ala Moana Yacht Basin. Although the pomacentrids swam about close to one another, they usually avoided coming within a body length of any manini. When one did and this was observed by a manini, the latter responded by a slow sideward movement of the body toward the
intruding fish. The posterior half of the manini's body was curved toward the pomacentrid and vibrated slightly. The pomacentrid invariably retreated a short distance.

Breder (1948: 293) observed similar behavior in an aquarium with Acanthurus chirurgus. He noted that a peck order was established among certain fishes in an aquarium. This involved four pomacentrids and one gerrid. A small specimen of Acanthurus chirurgus was added which was about equal in size to the largest pomacentrid. Although the surgeon fish was not bothered much by the other fish at first, it seemed to be low or lowest on the peck order. It was never noted to pursue the others, but was occasionally pecked at by the others. Fourteen days later the peck order was modified and the acanthurid was definitely number one. There was little fighting but all kept clear of the surgeon fish which "showed" its peduncular spine to the more timorous.

I have never observed fighting among adult manini. Larger individuals may display dominance over smaller ones, however.

Behavior at night

At night, both in the natural habitat and in the aquarium, manini rest quietly on the bottom, usually with the pelvic fins and anal fin touching the substratum, in what appears to be a state of torpor or sleep. In general the body color is darker than during the day. Large dark blotches which may be seen faintly during the day between the vertical dark bars are more conspicuous at night. This resting phase is not without movement, for the pectoral fins are almost in constant slow motion and there are vertical undulations of the median fins. When a light was flashed on a darkened aquarium at night, short movements over the bottom were occasionally found to be in progress. These are directed
backward more often than forward.

Usually the manini in an aquarium or a tide pool at night are well dispersed. In the normal environment most of the fish choose a sheltered although not a confining location. Many, however, may be seen in very exposed locations. Breder (1948: 294) observed that Acanthurus chirurgus rested on the bottom of an aquarium at night in the proximity of some shells, but in no case did it enter or hide in the shells.

If light is turned on a sleeping manini at night, and no sharp movements are made, the fish can be lightly touched or even picked up without its making any effort to escape. If a sharp movement is made in the water of the aquarium, or if the fish is roughly handled, it will dart away for a considerable distance over the bottom. This behavior was put to good use for the collection of this species alive. Using a head lamp at night to locate a sleeping fish, a dip net was cautiously placed in front of the quarry. A long stick was used to prod the posterior end of the fish which often responded by swimming into the net.

The following observations on sleep were made on ten juveniles, 27 to 40 mm. in standard length, which had been maintained in an aquarium for 12 days:

With the onset of darkness the fish settled to the bottom of the tank, although they continued to move about and occasionally these movements would take them above the bottom. 25 minutes after total darkness was required before they entered the state of suspended animation completely. This state was ascertained by lightly stroking the fish with a glass rod. When they ceased to flee from such contact, it was assumed that they were asleep. Since the period of attaining sleep was prolonged
by the interruptions, a series of observations on successive nights was necessary to determine the normal period.

The stimulus to sleep was shown to be the onset of darkness and not merely the passage of a definite number of hours of diurnal existence, for the manini remained active for many hours when a light was kept burning above the tank after darkness set in. In one experiment the fish were kept awake for a period of 24 hours. They remained active during the time; however they ceased to feed toward the end of this period and displayed "restless" swimming.

When the fish were kept in total darkness for 24 hours, they remained relatively quiet on the bottom during the entire period. At the end of this period, however, it was noticed that they perceived the immersion of a hand into the tank regardless of how slowly it was inserted.

After being allowed to enter normal sleep for three hours, lights were turned on to see how long the state of torpor would persist. In 13 to 14 minutes the first three fish awakened and began to swim around the aquarium. These were the largest of the ten manini. The remaining fish awakened according to size. The two smallest required 25 and 28 minutes, respectively, to wake up. All of the fish displayed very restless swimming, moving constantly back and forth and from side to side in the aquarium. When the lights were turned off, they required 39 minutes to re-enter the state of torpor. No distinction could be detected in the time needed for the different sized fish to go back to sleep.
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