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DEVELOPMENT AND DISTRIBUTION OF THE SHORT BIGEYE *PSEUDOPRIACANTHUS ALTUS* (GILL) IN THE WESTERN NORTH ATLANTIC

BY DAVID K. CALDWELL

FISHERY BULLETIN 203

From Fishery Bulletin of the Fish and Wildlife Service

VOLUME 62

PUBLISHED BY UNITED STATES FISH AND WILDLIFE SERVICE • WASHINGTON • 1962

PRINTED BY UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.
Price 35 cents

Library of Congress catalog card for the series, Fishery Bulletin of the Fish and Wildlife Service:

U.S. *Fish and Wildlife Service.*
Fishery bulletin. v. 1–
Washington, U.S. Govt. Print. Off., 1881–19

v. in illus., maps (part fold.) 23–28 cm.

Some vols. issued in the congressional series as Senate or House documents.
Bulletins composing v. 47– also numbered 1–
Title varies: v. 1–49, Bulletin.
Vols. 1–49 issued by Bureau of Fisheries (called Fish Commission, v. 1–23)

1. Fisheries—U.S. 2. Fish-culture—U.S. I. Title.

SH11.A25 639.206173 9—35239*

Library of Congress [59r55b1]

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ABSTRACT

The short bigeye, *Pseudopriacanthus altus* (Gill), is a marine fish restricted to the western North Atlantic, ranging, primarily on hard bottom, from Southport, Me., south to the Virgin Islands and in the Gulf of Mexico and Bermuda waters. Caribbean and Bahamian records are scarce, and the species may range more widely in these areas than present findings indicate. The late-summer spawned larvae are pelagic, occurring in the Gulf Stream. The prejuveniles are pelagic initially, but they migrate to live at or near the bottom in sandy or rocky habitats where the adults are found. The larvae and prejuveniles undergo a transformation in color and color pattern as they change habitat. While changes in chromatophore arrangement are well-known for larvae, apparently the change in pigmentation to the final chromatophoral arrangement occurring in large prejuvenile *P. altus* is little known and rarely reported in fishes.

Meristic and proportional characters and their development from larvae through adults are discussed. The development of other morphological features, as well as color pattern, also is discussed in detail.

DEVELOPMENT AND DISTRIBUTION OF THE SHORT BIGEYE *PSEUDOPRIACANTHUS ALTUS* (GILL), IN THE WESTERN NORTH ATLANTIC

By DAVID K. CALDWELL, *Fishery Research Biologist*

BUREAU OF COMMERCIAL FISHERIES

The initial phase of a biological inventory of the marine waters between the Florida Straits and Cape Hatteras, N.C., included the collection of both plankton and dip-net samples of larger pelagic organisms during the biological, chemical, and oceanographic operations of the U.S. Fish and Wildlife Service research vessel *Theodore N. Gill*. Nine cruises were conducted to a prearranged network of stations (Anderson, Gehringer, and Cohen, 1956) from January 1953 to December 1954. Part of the second phase of this inventory is the identification of larval and prejuvenile fishes collected at sea. Series of these small fishes provide excellent opportunities for studying phases of the early life histories.

Understanding life histories of fishes, even though all species may not be of direct commercial value, is necessary for an understanding of the interrelationships of different forms and for an intelligent analysis of the biological potential of an area. Such is particularly true when the species under study demonstrates ecological principles which might later be applied to the management of commercial, sport, or forage fishes. *Pseudopriacanthus altus* (Gill), the short bigeye, of the family Priacanthidae, is an example of such a species. A discussion of the distribution and development of this species contributes to a general knowledge of the biology of the fishes of an area which is undergoing extensive study to determine its biological potential and productivity.

This paper, based on collections of the *Theodore N. Gill* and material from other sources, provides a description of the very early development of the short bigeye and carries this development through to the adult stage. The ecological requirements are discussed, along with life history and systematic notes, and geographical distribution. The study provides meristic, morphological, and morphometric characters that form a basis for comparisons with other members of the genus from other geographical areas. Materials are provided which more clearly define generic relationships and solidify family characteristics.

It is appropriate that the operations of the vessel named for the author of this species should, nearly a century later, contribute so materially, in the form of data and specimens, to an understanding of the early life history of the species.

Various staff members of the Bureau of Commercial Fisheries Biological Laboratory at Brunswick, Ga., assisted in gathering and processing data used in this paper. W. I. Follett and Mrs. Lillian Dempster made many constructive suggestions regarding the manuscript; elsewhere in the text, where appropriate, I have mentioned others who were most helpful during the course of the work. In addition, W. B. Gray, of the Miami Seaquarium, provided useful comments on living specimens.

NOMENCLATURE

Pending conclusions from a worldwide revision of this group being prepared by W. I. Follett, of the California Academy of Sciences, and myself, I use the generic name *Pseudopriacanthus* Bleeker instead of *Pristigenys* Agassiz, that is sometimes used. *Pristigenys* was first applied to a fossil fish, and if that form should prove synonymous with the living one, it will have nomenclatorial priority for the species *altus* (and other species of the Pacific). Myers (1958: p. 40) briefly discussed this problem recently, calling attention to an earlier paper (White, 1936: p. 49) on the same subject. Myers (p. 41) pointed out that

NOTE.—Presently Curator of Marine Zoology, Los Angeles County Museum, Los Angeles, California; also Research Associate, Florida State Museum, and Collaborator in Ichthyology, Institute of Jamaica.

Approved for publication, June 2, 1961. Fishery Bulletin 203.

the etymological root of *Pristigenys* is feminine in gender, and if that generic name is accepted the Atlantic short bigeye should be *Pristigenys alta* (Gill).

METHODS

COUNTS

Counts of meristic characters were made under magnification. Aberrant counts were omitted if the apparent result of injury or were verified if the specimen appeared normal otherwise.

MEASUREMENTS

Measurements were made in straight lines between points, never over the curve of the part, and were recorded to the nearest 0.1 mm. Measurements on fish less than about 10 mm. were made with a micrometer eyepiece and a stereomicroscope; those on fish of about 10 to 25 mm. were made with the micrometer eyepiece or a pair of fine-pointed dial calipers (calibrated to tenths of a millimeter) under magnification; and those on larger fish were made with the calipers. Body parts showing injury or damage were not measured.

CONSTRUCTION OF GRAPHS

Arithmetical plots of empirical data were used in graphs of selected body parts in relation to standard length. In addition, eye diameter into standard length was plotted in relation to standard length. Trend lines were not drawn, except in the character of eye diameter, but were determined by visual examination of the plots. The term "inflection," in the discussion of body proportions in relation to size, follows Martin (1949) and denotes a change in slope of the line.

FISH ILLUSTRATIONS

Larvae were illustrated by elaborating detail on ink drawings made at the Brunswick laboratory by Mrs. Fanny Lee Phillips about 1955. The same specimens were used by each of us.

THEODORE N. GILL COLLECTIONS

The larvae and several of the prejuveniles were from collections from *Gill* cruises, and the network of collecting stations is described by Anderson, Gehringer, and Cohen (1956). The abbreviation "Reg." (regular station) in association with the depository prefix BLBG applies to *Gill* cruises and specimens listed in table 1.

DEFINITIONS

MEASUREMENTS

Standard length.—Distance from tip of snout (all measurements involving the snout were at the lateral projection not at the midline) to posterior end of hypural plate (base of midcaudal rays), or tip of urostyle in larvae. Unless otherwise noted, all lengths of specimens referred to are in standard length.

Depth A.—Distance from anterior edge of insertion of pelvic spine to midpoint of base of third dorsal spine.

Depth B.—Distance from midpoint of base of third anal spine to midpoint of base of last dorsal spine.

Head length.—Distance from tip of snout to posterior edge of fleshy part of operculum.

Snout length.—Distance between inner edge of anterior circumorbitals at middle of nostrils and tip of snout.

Postorbital length.—Least distance between inner margins of posterior circumorbitals and posterior edge of fleshy part of operculum.

Eye diameter.—Horizontal diameter from inner margin of anterior circumorbitals at lower level of nostrils to inner margin of posterior circumorbitals.

Interorbital width.—Least distance across top of head between inner margins of dorsal circumorbitals of each eye.

Least depth of caudal peduncle.—Distance on a vertical with midline axis of body.

Dorsal-fin base and anal-fin base.—Distance from anterior edge of base of first spine of fin to posterior edge of base of last segmented ray of fin.

Pectoral-fin length.—Distance from inner dorsal edge of base of most-dorsal element to tip of longest ray with fin laid flat against the body.

Pelvic-spine length, second pelvic soft-ray length, third dorsal soft-ray length, and third anal soft-ray length.—Distance in an erected position on a chord from midpoint of their bases to their tips.

Snout to dorsal-fin origin and snout to anal-fin origin.—Distance from tip of snout to anterior edge of base of first spine in each fin.

Snout to dorsal-fin termination.—Distance from tip of snout to posterior edge of base of last soft-ray of fin.

Snout to pectoral-fin origin.—Distance from tip of snout to inner dorsal edge of base of most-dorsal element of fin.

Pectoral-fin origin to midcaudal base.—Distance from inner dorsal edge of base of most-dorsal element of pectoral fin to base of midcaudal rays.

Dorsal-fin and anal-fin origin to midcaudal base.—Distance from anterior edge of base of first spine of fin to base of midcaudal rays.

Dorsal-fin and anal-fin termination to midcaudal base.—Distance from posterior edge of base of last soft-ray of fin to base of midcaudal rays.

COUNTS

Dorsal and anal spines.—There are ten dorsal and three anal spines, all clearly visible and separate. Numbers are recorded in Roman numerals.

Dorsal and anal soft-rays.—Normally there are 11 dorsal and 10 anal soft-rays. The last soft-ray of each fin, split to the base, was counted as one. As the base of the penultimate soft-ray is often very close to the base of the last split ray, its ray should not be considered the anteriormost branch of a doubly split soft-ray. Numbers are recorded in Arabic numerals.

Pectoral fin.—All rays in both fins were counted, including rudiments. All are segmented, at least in large adults (the most-dorsal segments at a large size), and all but the most-dorsal and the two most-ventral become branched. Numbers are recorded in Arabic numerals.

Pelvic fin.—It has a single spine, similar in structure to spines of the vertical fins, and five soft-rays (one of my specimens had four soft-rays in one fin).

Caudal fin.—The caudal fin has 16 principal rays equally distributed between the two lobes, as is characteristic in the family Priacanthidae. All are segmented, and the innermost 14 are branched. There is also a small number of segmented secondary rays.

Gill rakers.—Counts were made on the first arch, usually on the right side. Rudimentary gill rakers, often one or two occurring at the origin of either limb, were included. A gill raker located at the junction (angle) of the upper and lower limbs was included in the count for the lower limb.

Pored lateral-line scales.—Only scales with a complete tube were counted, usually on the left side of the specimen, from the upper angle of the opercular opening back to and including the scale covering the base of the midcaudal rays. The several additional pored scales extending onto the caudal rays were not counted. Sometimes the tube system extended onto an adjacent scale slightly above or below the main scale, but this incompletely pored scale was not counted. Judgement as to completeness of a tube may distort the scale count by one or two scales. Counts were considered the more accurate on larger specimens.

Vertical scale rows.—The number of anteriorly oblique vertical scale rows was counted along the midline of the body, usually on the left side, beginning at a point just below the anterior terminus of the lateral line (counting from and including the first complete scale on the cleithrum) and continuing posteriorly to the base of the caudal fin. Like the pored-scale row, several vertical rows of scales continue onto the fin, and the last row counted was the one which, when visually extended anterodorsally, included the last pored scale counted (the scale covering the base of the midcaudal rays). Counts of the number of rows on a fish may vary one or two rows due to the sometimes irregular arrangement of the rows, and counts made on larger fish were considered the more reliable.

Scales above and below lateral line.—Scales above the lateral line were counted in an anteriorly directed oblique line to the origin of the dorsal fin, and those below in a posteriorly directed oblique line to the origin of the anal fin. Scales are subject to crowding in the region adjacent to the fins and the counts could not always be made accurately, except on the largest fish. Pored lateral-line scales were not included in a count.

PIGMENTATION

Descriptions of pigmentation represented in the drawings and photographs were made from microscopic observations of preserved individuals. Chromatophores may have faded from some of the smaller specimens, and descriptions of these fish may be incomplete.

DEVELOPMENTAL STAGES

Larval.—Defined as the stage of development beginning with hatching and ending with formation of the adult complement of all fin rays, or in *P. altus* when about 7–8 mm. A ray was considered to be completely formed when it became partially ossified (determined by its staining red when treated with alizarin). Larvae of this species are pelagic on the open sea.

Prejuvenile.—Defined as beginning with end of the larval stage and continuing until the individual leaves its pelagic habitat, descends to the bottom, and completes a transformation in physical appearance to that of the juvenile and adult. Early prejuveniles have immaculate soft dorsal and anal fins; later ones have the soft parts of the vertical fins spotted, with or without a black edge. The maximum size for prejuveniles in nature apparently is about 65 mm.

Juvenile.—Defined as commencing when transformation to the adult physical appearance is complete (in the bottom habitat) and terminating with attainment of sexual maturity. In both juveniles and adults the soft parts of the vertical fins are immaculate except for a black edge. The size at which the juvenile-adult transition stage is reached was not determined.

Adult.—Defined as starting with the onset of sexual maturity.

STUDY MATERIAL

The larvae of *P. altus* used in this study were collected during plankton surveys conducted from the M/V *Theodore N. Gill* in the waters off the Atlantic coast of the southeastern United States by the U.S. Fish and Wildlife Service South Atlantic Fishery Investigations (now Bureau of Commercial Fisheries Biological Laboratory, Brunswick, Georgia). Several prejuvenile and numerous adult specimens are also deposited at this laboratory as a result of exploratory-fishing operations conducted by other Bureau vessels (primarily M/V *Oregon*, *Silver Bay*, and *Combat*) and my own collections. All of the material at this laboratory is referred to in this paper by the letters BLBG (no catalog numbers) and accompanying pertinent data.

This study material was greatly supplemented, especially in the middle sizes, by specimens from various institutions. I am most grateful to the persons named here for permitting me to examine materials in their charge or, in two instances, for examining specimens for me. These persons and their institutions, collections, or the place in which they examined specimens include—

United States National Museum (USNM), through Leonard P. Schultz; Chicago Natural History Museum (CNHM), through Loren P. Woods; Academy of Natural Sciences of Philadelphia (ANSP), through James E. Böhlke; Woods Hole Oceanographic Institution (WHOI), through Richard H. Backus; University of Florida Collections (UF), through John C. Briggs, John D. Kilby, and Daniel M. Cohen; Bingham Oceanographic Collection (BOC), through James E. Morrow; Tulane University (TU), through Royal D. Suttkus; University of Georgia (UG), through Donald C. Scott; Charleston Museum (ChM), through E. Milby Burton; University of Miami Ichthyological Museum (UMIM), through Luis R. Rivas; University of North Carolina Institute of Fisheries (UNC), through Earl E. Deubler; Stanford University Natural History Museum (SU), through George S. Myers and the late Margaret Storey; University of Miami Marine Laboratory (UMML), through C. Richard Robins; Cornell University (CU), through Edward C. Raney; California Academy of Sciences (CAS), which includes old Indiana University numbers (IUM), through W. I. Follett; U.S. Fish and Wildlife Service Ichthyological Laboratory, U.S. National Museum (USFWS Ich. Lab.), through Giles W. Mead; M/V *Delaware* collections, through Robert H. Gibbs (RHG); Academy of Sciences in Havana, Cuba (ASH), examined by P. P. Duarte Bello and Jose Suárez Caabro; Museum of the Naval Academy at Mariel, Cuba (MNAMC), examined by Duarte Bello and Suárez Caabro. In addition to these, I am particularly grateful to Winfield Brady, who is now, and J. B. Siebenaler, who was then, of Florida's Gulfarium, Fort Walton Beach; to F. G. Wood of Marine Studios, Marineland, Florida; and to Craig Phillips, who was then of the Miami Seaquarium, for specimens deposited for this study at this laboratory and at the University of Florida Collections.

Specimens examined and their present location are listed in table 1. Where available, data as to depth of capture for bottom-caught individuals and, in pelagic specimens, depth of water over which capture was made, are also included. Estimated depths are from hydrographic charts. Habitats are listed with question marks when data with the specimen were incomplete—the habitat being inferred either from the geographical location or physical appearance of the specimen as compared with that of specimens of known habitat.

TABLE 1.—*Location and date of capture, number, size range, habitat, metamorphic stage, and present location of 264 specimens of* Pseudopriacanthus altus *studied*

[Metamorphic stages, based on vertical fin coloration: Pretransformation (P), transforming (T), completely transformed (C)]

Location	Date captured	Number of specimens	Size (mm.)	Collection [1]	Habitat [2]	Metamorphic stage
ATLANTIC OCEAN:						
Massachusetts	No date	2	49.3-57.1	CNHM 55986	Pelagic (?)	T, P
Katama Bay, Mass	Aug. 30, 1899	1	41.1	USNM 49665	do	P
Do	do	1	48.2	USNM 49618	do	P
Do	Sept. 1, 1899	6	30.8-47.3	USNM 49664	do	P, T
Do	Sept. 16, 1899	1	49.0	USNM 126831	do	P
Do	do	1	(?)	CAS 20584 (IUM 9323)	do	
Do	Sept. 19, 1899	1	47.1	USNM 63928	do	P
Do	1900	4	34.5-55.9	USNM 68129	do	P, T
Do	No date	1	53.9	CNHM 7690	do	P
Do	do	8	27.9-45.6	USNM 58892	do	P
Do	do	22	26.4-52.0	USNM 58831	do	P
Woods Hole, Mass	Sept. 29, 1875	1	44.2	USNM 15583	do	P
Do	Sept. 26, 1877	1	32.8	USNM 20642	do	P
Do	October 1899	1	37.1	USNM 58832	do	P
Do	do	2	35.7-41.1	USNM 58833	do	T, P
Do	do	1	57.3	USNM 85780	do	T
Acushnet River, Mass	Nov. 1, 1890	3	25.6-53.5	USNM 43732	do	
Newport, R.I	No date	1	(?)	CAS 20583 (IUM 8919)	do	
Rhode Island	October 1875	1	23.5	USNM 37377	do	P
Outside New Haven Harbor, Conn.	Oct. 8, 1956	1	36.4	BOC 3738	Bottom, 3.3 fathoms	P
Fire Island Inlet, Long Island, N.Y.	Aug. 11, 1938	2	33.9-34.0	CU 27831	Pelagic (?)	P
Do	do	1	33.2	CU 33112	do	P
Long Beach, Long Island, N.Y	No date	1	26.1	ANSP 40220	do	P
Quoque, Long Island, N.Y	August 1952	2	22.9-24.2	CU 21482	do	P
Tomkinsville, N.Y	No date	1	52.3	USNM 10763	do	T
39°37′ N., 70°58′ W. to 39°34′ N., 70°54′ W.	Aug. 19-20, 1953	24	12.4-19.9	WHOI, *Blue Dolphin*	Pelagic, ca. 1,300 fathoms	P
Atlantic City, N.J	No date	1	57.9	ANSP 13315	Pelagic (?)	T
Ventnor, N.J	Aug. 29, 1931	1	23.2	ANSP 54634	do	P
Do	August-September 1931.	13	21.1-26.6	ANSP 54620-32	do	P
Lovelady Island, N.J	July 30, 1931	1	27.4	ANSP 54633	do	P
Corson Inlet, N.J	Sept. 17, 1928	1	38.8	ANSP 51398	do	P
39°07′ N., 65°58′ W	Sept. 21, 1957	1	10.2	RHG, *Delaware*	Pelagic, ca. 2,500 fathoms	P
38°37′ N., 68°14′ W	July 13, 1958	3	11.3-13.9	do	Pelagic, ca. 2,000 fathoms	P
38°25′ N., 72°40′ W	1885	1	19.9	USNM 155627, *Albatross*	Pelagic (?)	P
38°10′ N., 68°10′ W	June 11, 1957	1	13.8	WHOI, *Delaware*	Pelagic, ca. 2,320 fathoms	P
Off Ocean View, Va	Sept. 26, 1922	1	54.3	USNM 155612	Pelagic	T
34°55′ N., 75°31′ W. to 34°55.5′ N., 75°32′ W.	June (?) 3, 1885	1	196.9	USNM 151917, *Albatross*	Bottom, ca. 25 fathoms	C
34°46′ N., 76°23′ W	Sept. 10, 1959	1	44.4	BLBG, *Silver Bay* 1263	Bottom, 4-6 fathoms	P
34°46′ N., 76°04′ W	Sept. 12, 1959	1	62.5	BLBG, *Silver Bay* 1273	Bottom, 17 fathoms	T
34°38′ N., 76°49′ W	Sept. 22, 1959	1	42.9	BLBG, *Silver Bay* 1291	Bottom, 8-10 fathoms	P
34°36′ N., 75°53′ W	Aug. 12, 1953	3	3.2-3.9	BLBG, *Gill* Cr. 3, reg. 75	Pelagic, 22 fathoms	P
Ca. 34°35′ N., 75°52′ W	Oct. 18, 1885	1	16.1	USNM 83884, *Albatross* (sta. 2606?).	Pelagic, ca. 25 fathoms	P
34°32′ N., 75°53′ W	Sept. 11, 1959	1	58.9	BLBG, *Silver Bay* 1268	Bottom, 30-31 fathoms	T
18 mi. SW of Cape Lookout, N.C	Feb. 8, 1956	1	225.4	UNC 132, *William J.*	Bottom, 50 fathoms	C
Off Cape Lookout, N.C	Sept. 2, 1914	1	3.4	USNM 111796, *Albatross*	Pelagic	P
Off Cape Lookout Light Ship, N.C.	do	2	5.2-5.8	USNM 111795, *Fish Hawk*	do	P
34°21′ N., 76°34′ W	Sept. 23, 1959	2	48.6-49.4	BLBG, *Silver Bay* 1299	Bottom, 14 fathoms	T, P
34°09′ N., 76°02′ W	Oct. 19, 1885	2	10.5-11.2	USNM 111797, *Albatross*	Pelagic, ca. 250 fathoms	P
33°57′ N., 77°01′ W	Sept. 4, 1959	1	15.0	BLBG, *Silver Bay* 1222	Pelagic, 16-17 fathoms	P
33°44′ N., 77°00′ W	Aug. 11, 1953	2	2.6-2.7	BLBG, *Gill* Cr. 3, reg. 65	Pelagic, 21 fathoms	P
33°40.5′ N., 76°59.5′ W	Dec. 9, 1959	1	213.2	BLBG, *Silver Bay* 1506	Bottom, 21-22 fathoms	C
33°39′ N., 76°48′ W	do	5	86.2-208.6	BLBG, *Silver Bay* 1505	Bottom, 55-58 fathoms	C
33°35′ N., 76°50′ W	June 16, 1957	1	210.7	UNC 1324, *La Gatita*	Bottom, 37.5 fathoms	C
33°29′ N., 76°40′ W	Aug. 11, 1953	1	2.7	BLBG, *Gill* Cr. 3, reg. 64	Pelagic, 210 fathoms	P
33°11′ N., 77°31′ W	Feb. 27, 1960	1	ca. 250	BLBG, *Silver Bay* 1672	Bottom, 30-32 fathoms	C
33°04′ N., 77°59′ W	Mar. 7, 1960	2	90.5-133.4	BLBG, *Silver Bay* 1738	Bottom, 20-21 fathoms	C
33°03′ N., 78°21′ W	Sept. 26, 1954	1	15.0	BLBG, *Gill* Cr. 8, reg. 54	Pelagic, 17 fathoms	P
Off Cape Romain, S.C	Jan. 5, 1937	1	166.5	ChM 37.3.6, *Richard and Arnold*.	Bottom, 20 fathoms	C
32°51′ N., 78°32′ W	Oct. 20, 1959	1	179.3	BLBG, *Silver Bay* 1360	Bottom, 19-21 fathoms	C
32°58′ N., 78°15′ W	Sept. 26, 1954	1	ca. 15	BLBG, *Gill* Cr. 8, reg. 53-54.	Pelagic(?) [3]	
32°40′ N., 76°46′ W	July 6, 1954	2	8.6-8.7	BLBG, *Gill* Cr. 7, reg. 62	Pelagic, 445 fathoms	P
32°37′ N., 78°49′ W	Mar. 8, 1960	1	103.1	BLBG, *Silver Bay* 1743	Bottom, 18-21 fathoms	C
32°32′ N., 78°40′ W	Oct. 26, 1959	32	161.0-261.8	BLBG, *Silver Bay* 1393	Bottom, 40-50 fathoms	C
32°32′ N., 79°01′ W	June 25, 1957	1	79.5	UMIM 1985, *Combat* 427	Bottom, 35 fathoms	
32°12′ N., 78°26′ W	Aug. 9, 1953	2	4.4-6.6	BLBG, *Gill* Cr. 3, reg. 49	Pelagic, 190 fathoms	P
31°57′ N., 79°16′ W	Aug. 6, 1953	1	8.3	BLBG, *Gill* Cr. 3, reg. 42	Pelagic, 72 fathoms	P
31°36′ N., 79°52′ W	July 2, 1954	1	12.1	BLBG, *Gill* Cr. 7, reg. 38	Pelagic, 27 fathoms	P
31°35′ N., 79°51′ W	Aug. 5, 1953	2	2.4-5.3	BLBG, *Gill* Cr. 3, reg. 38	Pelagic, 25 fathoms	P
Charleston, S.C	No date	1	227.0	SU 10409	Bottom	C
18 mi. SE. of Charleston, S.C	Apr. 4, 1939	1	167.5	ChM 50.136.32, *Holokai*	Bottom, ca. 7 fathoms	C
Off Charleston, S.C	Oct. 9, 1931	1	215.6	ChM 31.237.3	Bottom	C
Commercial trawling area, Brunswick, Ga.	Sept. 18-19, 1956	1	24.1	BLBG	Bottom, ca. 3 fathoms	P
31°02′ N., 80°00′ W	July 30, 1953	2	4.8-8.2	BLBG, *Gill* Cr. 3, reg. 31	Pelagic, 29 fathoms	P
30°11′ N., 80°17′ W	Aug. 31, 1956	1	84.5	USFWS Ich. Lab., *Combat* 72.	Bottom, 32 fathoms	C
30°01′ N., 80°32′ W	Jan. 14, 1957	1	92.7	USFWS Ich. Lab., *Combat* 203.	Bottom, 22 fathoms	C
Off St. Augustine, Fla	Oct. 3, 1956	1	47.2	BLBG	Bottom, ca. 10 fathoms	T

See footnotes at end of table.

TABLE 1.—*Location and date of capture, number, size range, habitat, metamorphic stage, and present location of 264 specimens of* Pseudopriacanthus altus *studied*—Continued

[Metamorphic stages, based on vertical fin coloration: Pretransformation (P), transforming (T), completely transformed (C)]

Location	Date captured	Number of specimens	Size (mm.)	Collection [1]	Habitat [2]	Metamorphic stage
ATLANTIC OCEAN—Continued						
29°43′ N., 80°25′ W	May 4, 1960	1	129.8	BLBG, *Silver Bay* 2079	Bottom, 20–22 fathoms	C
29°40′ N., 80°22′ W	July 28, 1953	1	4.0	BLBG, *Gill* Cr. 3, reg. 19	Pelagic, 25 fathoms	P
29°00′ N., 80°11′ W	July 27, 1953	1	Head only	BLBG, *Gill* Cr. 3, reg. 14	Pelagic, 36 fathoms	------
28°21′ N., 80°09′ W	Sept. 12, 1954	1	3.5	BLBG, *Gill* Cr. 8, reg. 10	Pelagic, 23 fathoms	P
27°00′ N., 79°18′ W	July 25, 1953	1	2.2	BLBG, *Gill* Cr. 3, reg. 1	Pelagic, 370 fathoms	P
Off W. tip Grand Bahama Island	Oct. 3, 1953	1	Ca. 19	BLBG, *Gill* Cr. 4	Pelagic (?) [4]	------
26°31′ N., 80°01′ W	Mar. 25, 1956	2	59.0–72.0	UMIM 1191, *Pelican* 15	Bottom, 30–35 fathoms	------
Baker's Haulover, Miami Beach, Fla.	Nov. 28, 1955	1	137.2	UMIM 1847	Bottom	C
Near Cutler, Biscayne Bay, Fla	July 26, 1958	1	43.5	BLBG	do	T
Soldier Key, near Miami, Fla	Ca. August 1954	1	73.2	do	Bottom, 3 fathoms	T
25°10′ N., 80°02′ W	Sept. 22, 1957	1	16.9	BLBG, *Combat* 438	Pelagic, 200 fathoms	P
Bermuda	1911	1	23.8	CNHM 48584	Pelagic(?)	P
"Bermuda?"	No date	1	236.0	CNHM 48608	Bottom(?)	C
GULF OF MEXICO:						
Deadman's Bay, Fla	do	1	37.6	USNM 73063, *Fish Hawk*	do	P
24°25′ N., 81°46′ W	1885 (Jan. 15?)	1	96.3	USNM 37772, *Albatross*	Bottom, ca. 75 fathoms	C
Do	Jan. 15, 1885	4	63.2–106.0	USNM 84498, *Albatross*	do	C
24°25′ N., 81°47′ W	do	1	66.1	USNM 134165, *Albatross*	Bottom(?), ca. 75 fathoms	C
Dry Tortugas, Fla	No date	1	39.9	USNM 117086	Bottom(?)	P
10 mi. N. of Loggerhead Key, Dry Tortugas, Fla.	Sept. 26, 1958	1	50.5	UMIM 2370	Bottom, ca. 20 fathoms	------
20 mi. NE. of Dry Tortugas, Fla	March 1950	1	92.4	UMIM 209	Bottom, ca. 18 fathoms	C
25 mi. NNE. of Dry Tortugas, Fla	Mar. 1–6, 1950	2	87.2–94.3	UG 161	Bottom, 17–18 fathoms	C
30 mi. NE. of Loggerhead Key, Dry Tortugas, Fla.	No date	2	67.3–77.9	UF 1434	Bottom	C
24°59′ N., 83°35′ W	Apr. 19, 1954	1	65.2	CNHM 59894, *Oregon* 1022	Bottom, 39 fathoms	T
Do	do	2	78.2–90.4	USFWS Ich. Lab., *Oregon* 1022.	do	C
Do	do	1	70.8	TU 13201, *Oregon* 1022	do	C
Lemon City, Fla	No date	1	47.2	USNM 181345	Bottom(?)	P
27°07′ N., 83°19′ W	Apr. 4, 1954	1	45.2	CNHM 59893, *Oregon* 963	Bottom, 23 fathoms	T
27°36′ N., 83°41′ W	Jan. 27, 1951	1	92.1	TU 2694, *Oregon* 255	Bottom, 25 fathoms	C
Anclotte Key, Pasco County, Fla	August 1929	1	204.3	UF 4214	Bottom(?)	C
28°47′ N., 84°37′ W	Mar. 15, 1885	1	63.4	USNM 84511	Bottom(?), ca. 24 fathoms	T
Do	Nov. 15, 1885	1	63.7	USNM 132201, *Albatross*	Bottom, ca. 24 fathoms	C
28°50.8′ N., 85°28′ W	Dec. 17, 1952	1	106.1	CNHM 45488, *Oregon* 732	Bottom, 57 fathoms	C
28°56.5′ N., 85°18′ W	Dec. 16, 1952	1	79.2	CNHM 45486, *Oregon* 731	Bottom, 40 fathoms	C
29°21′ N., 84°49′ W	July 26, 1958	1	82.7	BLBG, *Silver Bay* 587	Bottom, 15 fathoms	C
Ca. 25 mi. SW. of Panama City, Fla.	Apr. 19, 1958	1	196.5	BLBG	Bottom, ca. 20 fathoms	C
Inlet at Destin, Fla	November 1955	1	149.2	UF 5582	Bottom, 2.5 fathoms	C
Ca. 1 mi. off Destin, Fla	Mar. 30, 1956	1	165.8	UF 5593	Bottom, 16 fathoms	C
Off Destin, Fla	No date	1	183.6	UF 3950	do	C
Do	Ca. June 1958	1	201.7	BLBG	do	C
Near Destin, Fla	Summer 1958	1	176.9	do	Bottom, 17 fathoms	C
Fort Walton Beach, Fla	August 1958	2	23.3–40.7	do	Bottom, ca. 1 fathom	P
[Off] Pensacola, Fla	No date	1	161.1	SU 2800	Bottom	C
Pensacola, Fla	do	2	------	CAS 20585 (IUM 8570)	Unknown	------
30°17′ N., 87°13′ W	Jan. 23, 1957	1	167.0	CNHM 64180, *Oregon* 1647	Bottom, 7 fathoms	C
12 mi. SSW. of Horn Island, Miss	Nov. 3, 1931	1	52.6	USNM 155625	Bottom, ca. 10 fathoms	T
28°08′ N., 94°35′ W	June 29, 1957	1	169.9	TU 16282, *Silver Bay* 10	Bottom, 31 fathoms	C
Within 50 mi. of Corpus Christi, Tex.	1920–40	1	24.0	CNHM 40326	Unknown	------
19°48′ N., 91°20′ W	Aug. 25, 1951	1	40.9	CNHM 46507, *Oregon* 440–445.	Bottom, 14 fathoms	P
20°20′ N., 91°28′ W	Dec. 11, 1952	1	55.6	UMIM 1848, *Oregon* 721	Bottom, 17 fathoms	T
22°15′ N., 88°55′ W	Dec. 13, 1952	1	46.6	CNHM 45487, *Oregon* 725	Bottom, 25 fathoms	P
22°32′ N., 88°47′ W	Jan. 11, 1951	1	71.7	CNHM 46506, *Oregon* 222	Bottom, 29 fathoms	C
WEST INDIES:						
Vedado (Havana), Cuba	1944	1	Ca. 260	MNAMC (mounted)	Bottom	C
"Cuba"	No date	1	Ca. 250	ASH (mounted)	Unknown	C
18°37.5′ N., 64°57′ W	Sept. 26, 1959	1	108.3	BLBG, *Oregon* 2608	Bottom, 42 fathoms	C

[1] Collections listed in text, p. 104.
[2] Depths and questioned habitats discussed in text.
[3] Stomach contents: *Euthynnus alletteratus* (Rafinesque).
[4] Stomach contents: *Thunnus atlanticus* (Lesson).

TABLE 2.—*Reliable records of 7* Pseudopriacanthus altus *which were not studied*

[Collected by M/V *Oregon;* first 2 specimens listed by Springer and Bullis (1956: p. 80)]

Station	Locality	Date	Depth (fathoms)
263	29°22′ N., 88°06′ W	Feb. 16, 1951	45
531	28°25.5′ N., 92°33.5′ W	Apr. 10, 1952	29
1639	29°49′ N., 87°19′ W	Jan. 10, 1957	30
1705	29°57′ N., 86°13′ W	Feb. 12, 1957	25
1786	28°05′ N., 94°54′ W	Mar. 13, 1957	31
1789	28°07′ N., 95°03′ W	Mar. 14, 1957	31
1790	28°06′ N., 95°08′ W	Mar. 14, 1957	31

A few records based on apparently reliable sight identifications of trawled or dredged bottom forms are included in table 2.

GEOGRAPHICAL DISTRIBUTION

Pseudopriacanthus altus has been considered by most authors to be a West Indian species that regularly occurs north to South Carolina on the Atlantic shores of the United States, and to Pensacola, Florida, in the northeastern Gulf of

Mexico (Breder, 1948: p. 168; Bigelow and Schroeder, 1953: p. 410; Boulenger, 1895: p. 359; Hildebrand and Schroeder, 1928: p. 255; Jordan and Evermann, 1896: p. 1240; Jordan, Evermann, and Clark, 1930: p. 323; and Smith, 1907: p. 285). They further noted that this species is found as a straggler in the Gulf Stream as far north as Massachusetts.

Based on available material, recent field work, and the literature, the geographical range of the short bigeye can be stated as extending from Southport, Me. (Scattergood and Coffin, 1957: p. 156), to Horn Island, Mississippi, and scattered localities in the western and southern parts of the Gulf of Mexico (table 1 and fig. 1). It is also known from Bermuda (Beebe and Tee-Van, 1933: p. 141), Cuba (Fowler, 1942b: p. 75; Duarte Bello, 1959: p. 71), and from the vicinity of the Virgin Islands (*Oregon* station 2608). This distribution is similar to that given by Briggs (1958: p. 275), with ecological restrictions to be discussed later.

It is difficult to explain why the short bigeye has almost always been considered a West Indian species, except that early published and perhaps erroneous ranges for fishes from poorly known areas are often copied blindly without reference to faunal studies for specific localities. Evidence for the apparent rareness of *P. altus* in the West Indies, the Caribbean, and from northeastern South America (where the fishes are often very similar to those of the West Indies and the Caribbean) is found in a number of faunal lists which cover these areas and which fail to include the short bigeye. Some of these are Evermann and Marsh, 1902 (Puerto Rico); Cockerell, 1892 (Jamaica); Metzelaar, 1919 (Dutch West Indies), 1922 (Lesser Antilles); Meek and Hildebrand, 1925 (Panama); Bean, 1890 (Cozumel, Yucatan); Fowler, 1919 (Panama, Brazil, Surinam, St. Martin, St. Croix, St. Christopher, Jamaica, Haiti, Bahamas), 1928 (Bahamas, Haiti, Puerto Rico, St. Lucia, Dominica), 1937 (Haiti), 1941 (Brazil), 1944 (numerous Antillean islands and banks, Central America, Cayman Islands), 1951 (Brazil, Patagonia), 1952 (Hispaniola), 1953 (Colombia); Beebe and Tee-Van, 1928 (Haiti, Santo Domingo), 1935 (Haiti, Santo Domingo); Nichols, 1929 (Puerto Rico, Virgin Islands); Herre, 1942 (Antigua, Barbados); Beebe and Hollister, 1935 (Grenadines); Schultz, 1949 (Venezuela); Erdman, 1956 (Puerto Rico); Cope, 1871 (St. Martin, St. Croix, St. Christopher, New Providence); Puyo, 1949 (French Guiana); Miranda-Ribeiro, 1915 (Brazil); Nichols, 1912 (Cuba), 1921 (Turks Island); and Parr, 1930 (Bahamas, Turks Island).

Recent trawling operations by the U.S. Fish and Wildlife Service M/V *Oregon* in the West Indies (where hauls were made over rough bottom which is good habitat for *P. altus*) yielded but one specimen, and extensive trawling off the northeastern coast of South America yielded none.

The species is often taken by handline and in traps in the waters of Florida and the two Carolinas, and both of these methods are and have long been regular forms of commercial fishing throughout the West Indies (often conducted in deep water around rocks—where the species occurs in the United States). Markets where all species so caught are sold also have long been a regular source of specimens for ichthyologists in the West Indies. My own collections in the field and in the markets of Nassau, Havana, and Jamaica have failed to produce *P. altus*. Thus, *P. altus* either must be rare in the West Indies or must occupy a habitat which makes it extremely difficult to collect.

I doubted the presence of *P. altus* in the West Indies—on the lack of records as previously noted—until I enlisted the help of Dr. P. P. Duarte Bello and Dr. Jose Suárez Caabro of the Laboratorio de Biologia Marina of the Universidad Catolica de Santo Tomas de Villanueva at Havana, and until the recent collection of a single specimen by the *Oregon* (station 2608) off the Virgin Islands (table 1). Poey (1856–58, 1866, 1868) did not list this species for Cuba, and it was not until 1875 (p. 114) that he listed a 52-mm. fish as "*Priacanthus*?" and stated that it was like *P. altus* except for color. His specimen could not be located to clarify this record. Fowler listed the species in the collections of the Academy of Sciences in Havana (1942b: p. 75) and a specimen (presumably mounted) at the Instituto de Matanzas (1942a: p. 65). In August 1958, Dr. Duarte Bello told me that the specimen at the Academy of Sciences was actually *P. altus*, though labeled *Pempheris mulleri* Poey, and was approximately 250 mm. in standard length (mounted). The label read only "Cuba." He and Dr. Suárez Caabro found a second mounted specimen, 260 mm. standard length, in the museum of the Naval

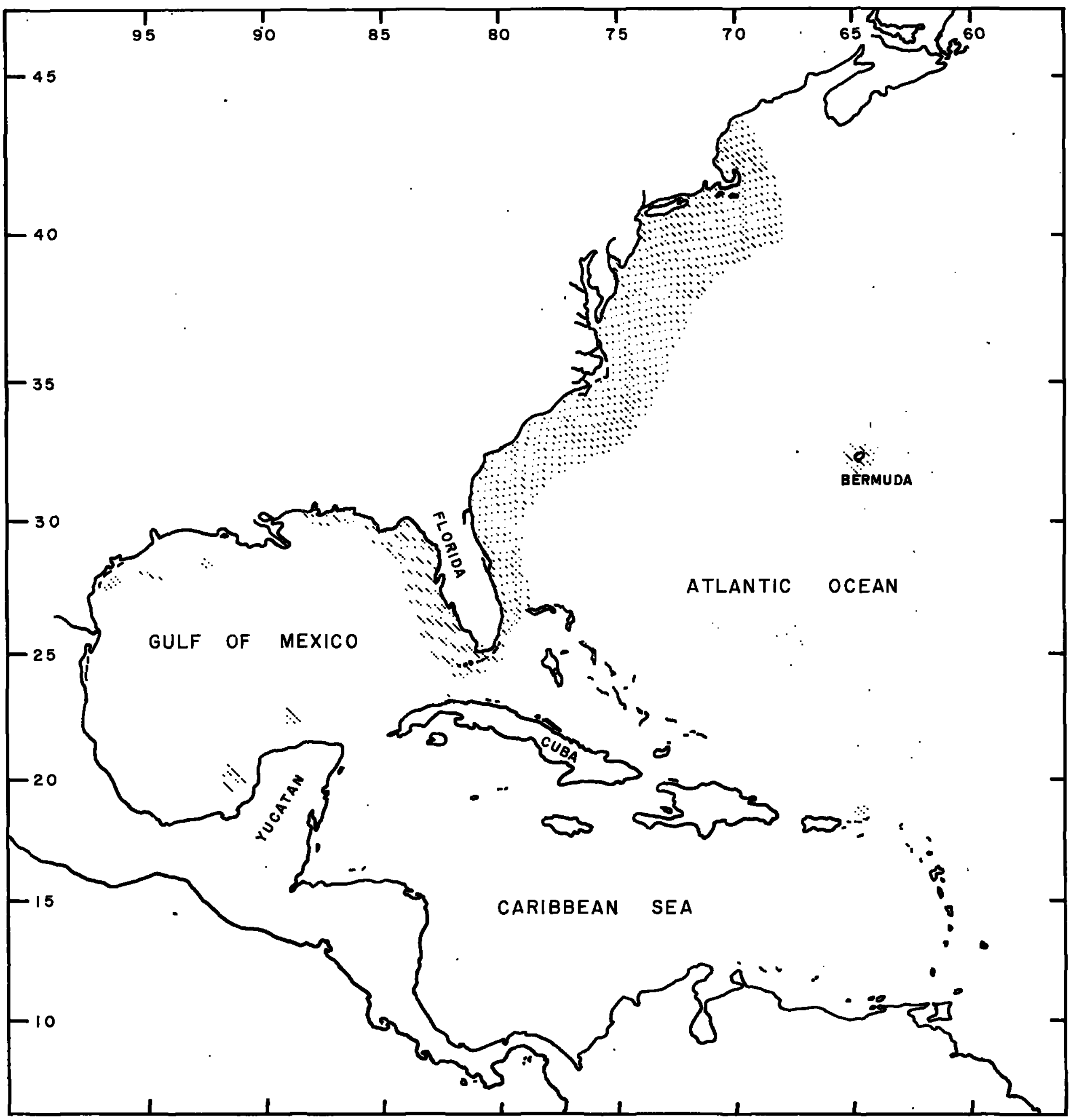

FIGURE 1.—Geographical distribution of *Pseudopriacanthus altus*.

Academy in Mariel, Pinar del Rio Province. The example was labeled as having been taken about 1944 at Vedado (Havana), and their conversation with the former curator of that museum confirmed the locality and included the fact that the specimen came from deep waters, "maybe more than 60 fathoms." The data which Duarte Bello sent me from these specimens substantiate his determinations. The following records were received in a later letter from Dr. Duarte Bello, dated September 19, 1960. I have not seen his specimens, which were being maintained alive in the Cuban National Aquarium, but presume his identifications are correct as he is familiar with the species. The records further substantiate a permanent Cuban population of *P. altus*—at least in the Havana region. The two additional captures are a 134-mm. individual from Jaimanitas, Mariano, La Habana, taken with hook-and-line using squirrelfish as bait on June 18, 1960, in 110 fathoms; and a 196-mm. specimen taken in the same manner at the same depth and locality on August 8, 1960, with grunt as bait.

Duarte Bello (1959: p. 71) listed this species from Vedado (presumably the 260-mm. specimen) and cited Jordan and Evermann (1896: p. 1239) and Jordan, Evermann, and Clark (1930: p. 323) for a Cuban distribution. Larger fishes in collections from the Havana region usually must be questioned as to locality of capture, especially when they are old or when no data other than "Havana" or "Cuba" are given. They may have come from the market, and market fishes sold in Havana were often collected in Florida or Yucatan waters (see Caldwell, 1957: p. 97) which is within the known range of *P. altus*. In view of the findings by Duarte Bello and Suárez Caabro, at least one of the mounted Cuban specimens and the two living individuals must be viewed as adults having valid locality data, and a permanent population may occur there.

With the Cuban and Virgin Islands records, there can be no doubt that *P. altus* occurs, at least occasionally, in the West Indies. An examination of general current systems as outlined by Sverdrup, Johnson, and Fleming (1942: chart VII), Galtsoff (1954: p. 29), and Leipper (1954: p. 121–122) shows that apparently no countercurrents originate in continental waters north of the Caribbean or in Bermuda waters and flow to the Bahamas, Antilles, or the Caribbean in general, that could carry larval *P. altus* to these areas from the north. The Virgin Islands specimen is 108 mm. in length, and presumably nearly adult. The Virgin Islands and Cuban populations of adults undoubtedly contribute to the Gulf Stream (Florida Current) population of larvae and prejuveniles as that current flows through the Straits of Florida. A 19-mm. prejuvenile taken from the stomach of a *Thunnus atlanticus* (Lesson) collected in the vicinity of the western tip of Grand Bahama Island (*Gill* cruise 4, table 1) might have been captured along the eastern edge of the current flowing by Grand Bahama. This bigeye almost certainly came from the Bahamas, Cuba, or the Antilles, as it is unlikely that so small a specimen spawned in the Gulf of Mexico or in Atlantic waters of southern Florida could have made its way across the Gulf Stream. A 2.2-mm. larva was captured in a plankton net at regular station 1 on *Gill* cruise 3 on the eastern side of the Gulf Stream. Presumably the specimen, though probably just hatched, rode the fast flow of the Stream to this point from somewhere in the Bahamas or northern Antilles.

If the West Indian population of adults extends much to the south of the Virgin Islands, its larvae might be expected to the eastward of the Bahamas as well, as certain portions of the North Equatorial Current flow from the Lesser Antilles up along the outside (east) of the Bahamas.

It is likely that the Bermuda population was based originally, and is perhaps in part maintained, on recruitment from the continent or from the West Indies, via branches of the Gulf Stream (see Sverdrup, Johnson, and Fleming (1942: chart VII).

ECOLOGICAL DISTRIBUTION

FACTORS INFLUENCING DISTRIBUTION

Pseudopriacanthus altus may occupy two separate habitats, depending on its stage of development. The larvae and prejuveniles up to approximately 60 mm. standard length are pelagic or have just left this niche, and these stages frequently are taken offshore by dip-net and in plankton or other surface-fishing nets. With one exception, possibly based on adults (a comment by Fowler, 1940: p. 13, that the species was taken in the fall by trawlers working off Cape May, N.J.), all of the specimens that I have seen, and inferences in the literature for others, indicate that *P. altus* is a straggler, through the medium of the Gulf Stream, north of about Cape Hatteras, N.C. I found no large specimens from north of that point in museums, although very small specimens were quite numerous. In continental waters south of Cape Hatteras and in the Gulf of Mexico, large adults were taken by U.S. Fish and Wildlife Service explorations and sport-fishing and commercial boats of various kinds. Large specimens also were seen in museums. Larvae and prejuveniles from southern waters also were collected or were seen in museums.

Larvae are found at or near the surface in or near the edge of the Gulf Stream (fig. 6), which undoubtedly influences their distribution.

Many small specimens, approximately 23 to 58 mm., from the coasts of New Jersey, Long Island (N.Y.), and from the south shores of the Cape Cod region were examined (table 1). As their appearance resembled that of offshore-caught specimens (and from partial data provided with some), it was presumed that these specimens actually were stragglers washed inshore from and by the northward-flowing currents. In fact, *P. altus* was originally described from a 1.2-inch specimen which, according to the author (Gill, 1862: p. 133), probably arrived in Narragansett Bay, R.I., the type locality, via the Gulf Stream. Recently, Scattergood and Coffin (1957: p. 156) and Morrow (1957: p. 241) noted small specimens taken under conditions which indicated that they were settling to the bottom (the one record in a trap set at 10 fathoms, the other in an oyster dredge in 3.3 fathoms). As no adults have been recorded from these waters, it is presumed that these specimens, too, would not have survived. I have examined Morrow's specimen (BOC 3738, table 1), and find that it resembles the pelagic forms. The specimen reported by Scattergood and Coffin unfortunately disappeared from a public display tank (Scattergood, personal communication). The color they describe suggests a pelagic form. Both of these specimens had probably just settled to the bottom after arrival inshore. Offshore, prejuveniles have been taken by dip-net or other nets at or near the surface. One collection examined indicates that at least the prejuveniles may occur in considerably deeper waters (though they are still pelagic). A series of 24 specimens, 12.4 to 19.9 mm., was collected in an Isaacs-Kidd midwater trawl at 24 fathoms over a depth of approximately 1300 fathoms (see table 1, WHOI collection, Aug. 19–20, 1953). Dr. Richard H. Backus wrote me in August 1958 that this is not a closing net and that "there is no assurance that the catch actually came from 24 fathoms but statistically speaking the chances are great that it did."

South of Cape Hatteras, juveniles and adults are apparently bottom dwellers and show a preference for hard, especially coral or rock, bottoms in depths up to about 60 fathoms (rarely to 110 fathoms). The adults are frequently taken by handlines or traps from in or near rocky areas or hard bottoms. This is particularly true of the larger specimens. It may be that the juveniles just arriving at the bottom from the pelagic habitat may be less restricted in their preferences, as most specimens taken from other than a rock bottom (or one with limited spots for the fish to hide in) were the smaller bottom forms.

The juveniles and adults apparently are very secretive. I have observed this in aquarium specimens, and Winfield Brady of Florida's Gulfarium, Fort Walton Beach, found this to be the case in his observations of wild specimens at depths of about 100 feet. Brady further stated that the fish would remain perfectly motionless in a niche in the rocks while he captured it without the aid of a net.

The preference of *P. altus* for a hard rocky bottom is well illustrated by its distribution in the Gulf of Mexico. The known Gulf distribution of *P. altus* is spotty (fig. 1; tables 1 and 2), as shown through extensive fishing by the U.S. Fish and Wildlife Service throughout most of the Gulf in all depths, in all seasons, and on all types of bottoms. Other collectors' findings substantiate this (table 1). When a chart of this distribution (fig. 1) is compared with the chart of the sedimentary provinces of the Gulf of Mexico as provided by Lynch (1954: p. 79), a similarity is shown (particularly where coral and limestone occur).

The short bigeye probably occurs on the entire Campeche Bank off the north and west coasts of Yucatan and in limited areas in the vicinity of Tampico and Vera Cruz, Mexico (areas of coral and limestone). *P. altus* is known from the entire Gulf coast of Florida, some Alabama and Mississippi waters, and certain areas in the northwestern Gulf (fig. 1)—all areas of hard bottom on Lynch's chart. Off the south Atlantic coast of the United States the bottom in areas where *P. altus* has been most regularly taken is also hard (see Moore and Gorsline, 1960: p. 18). Breaks in the range of *P. altus* in the Gulf correspond to Lynch's charted areas of soft mud bottom. Hildebrand (1954, 1955) did not list this species from shrimp fisheries conducted on soft bottoms in the western Gulf and western Yucatan areas. The West Indian specimens (table 1) were taken in areas where coral and rock are abundant.

Bermuda also furnishes abundant coral or rock substrate.

Temperature is possibly the most basic limiting factor in the distribution of *P. altus*, as the short bigeye is a subtropical or tropical species. Whereever conditions of temperature are suitable, however, the bottom type seems to be especially important in the success of permanent populations of adults.

Specimens are usually taken singly or in twos or threes, but it is not known whether this seeming rarity is a real phenomenon or a false impression gained from the secretive habits of the species as juveniles and adults and from the limited collections of pelagic forms. The collection of a large group of prejuveniles (24 specimens, WHOI collection, Aug., 19–20 1953, table 1) and an even larger series of adults in a single trawl haul (32 specimens, BLBG, *Silver Bay* station 1393, table 1) suggest the latter premise to be correct. Other museum collections from northern waters (table 1) indicate aggregations also, though in these instances data are not specific and complete enough for certainty.

EFFECT OF HABITAT ON METAMORPHOSIS

Results of recent studies (Parr, 1930: p. 58; Hubbs, 1941: p. 184, 1958: p. 282; Breder, 1949: p. 296; and M. C. Caldwell, in press) make it obvious that a wide variety of marine fishes which as adults occupy a bottom habitat have pelagic larvae and prejuveniles which undergo considerable change in appearance in their transition from the pelagic to the bottom habitat. Such stages have frequently been described as separate species or genera (Hubbs, 1958). Furthermore, it has been shown (Breder, 1949) that the specific size (or age) of the individual does not dictate time of change in form, but rather that the environmental change seems to trigger the metamorphosis after the delayed development. The fish maintains its prejuvenile appearance while continuing to grow until, probably within limits, the attainment of suitable conditions of environment. Such an arrested development is known for invertebrate marine animals (Thorson, 1957: p. 482) as well as for fishes (Breder, 1949: p. 296; M. C. Caldwell). As a consequence, a prejuvenile still in its pelagic environment may actually be larger than another of its kind which is in the proper habitat. It is this phenomenon that has resulted in confusion leading to the description of the larger or equally sized prejuvenile of a well-known adult as a separate form.

Pseudopriacanthus altus exhibits such a change of appearance and shows this differential or delayed development related to time of settling to the bottom.

Metamorphic stages in *P. altus* are quite different, and several fisherman told me that there were possibly two species of *Pseudopriacanthus* in the western North Atlantic. One was said to be a "dwarf," which was immediately suspect. The "dwarf" form proved to be merely the prejuvenile stage of *P. altus*. With the differential development in relation to habitat, the "dwarf" form had been seen that was larger than the "normal" form. No large specimens of the "dwarf" form were known simply because they either transformed if the proper habitat was attained or died if it was not. Although a simple method of detecting transitional stages, based on color pattern, was later found, the color pattern would not be particularly noted on casual observation. Hubbs (1958: p. 282) noted that "prejuveniles metamorphose very rapidly into the juveniles, which are much more like the adult. For this reason, transitional specimens are seldom encountered."

Thus, the fishermen had seen either large prejuveniles or transformed specimens of a similar or greater size—the two having quite different appearances. None of the form with the adult appearance was found smaller than about 50–55 mm., which made the validity of the "dwarf" form even more suspect, since this is about the maximum size for the latter. Figure 2 illustrates the two forms in question. They look very different, and as the difference in their standard lengths is only 2 mm., the possibility of two species was reasonable, if one had only these specimens. Note the differences in overall body color, spinous-fin membranes, and especially eye size. These two specimens are extremes of a gradient of general appearance.

It was necessary to find an obvious character, showing the extremes as well as indicating integration, in order to separate the three groups (pretransformed, transforming, and transformed) with relation to size and habitat. The color pattern of the caudal and soft parts of the vertical fins proved useful in this respect. The prejuvenile pattern consists of immaculate or spotted

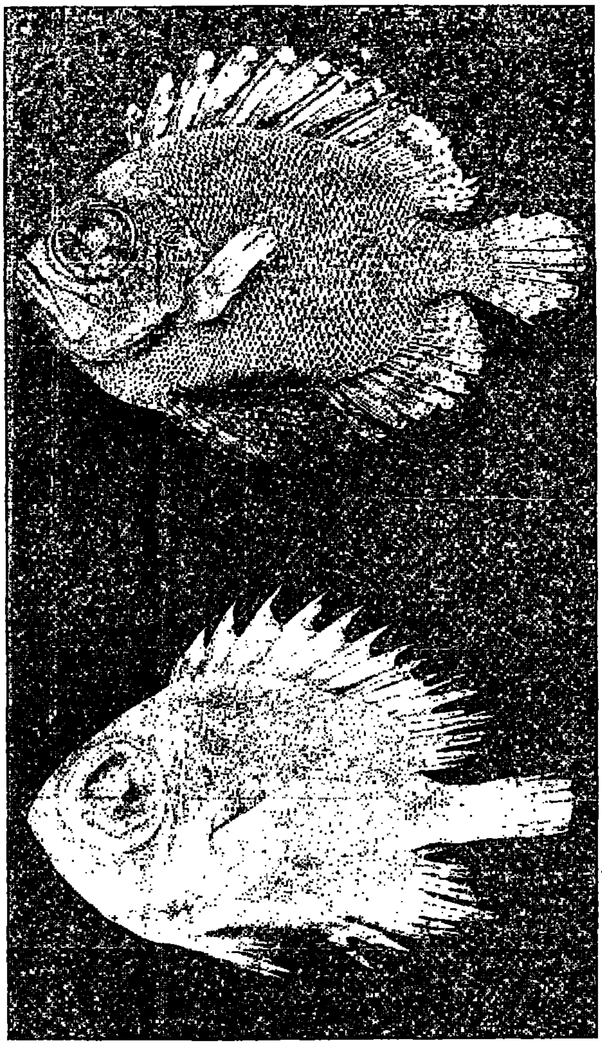

FIGURE 2.—Upper: Large pelagic prejuvenile *Pseudopriacanthus altus* from Massachusetts, showing early metamorphic characteristics (49.3 mm. standard length, CNHM 55986). Lower: Small bottom-dwelling *P. altus* from off St. Augustine, Fla., showing late metamorphic characteristics (47.2 mm. standard length, BLBG).

fins (figs. 16, 17, and 24), while the transformed juvenile and adult pattern shows an immaculate fin with a distinct dark edge (figs. 19–23). Fins on larvae and early prejuveniles are immaculate, and there is no dark edge on fins of a nontransforming late prejuvenile. The transition in color pattern appears to be a migration of the spot-forming pigment to the edge of the fin, where it accumulates to form the dark border. The transition pattern is shown in the two specimens illustrated in figure 2. In figure 3 the specimens which appear as intergrades in fin coloration lie between the specimens showing the extremes in color pattern, and the entire group forms an integrated, though overlapping, series. The individuals from north of Cape Hatteras (table 1) with an integrated fin coloration were taken inshore, and even if washed there, they could have begun the rapid transformation (Hubbs, 1958: p. 282). Most of the individuals from north of Cape Hatteras had the pure pelagic fin coloration (immaculate or spotted, depending on their size), however large they were, further evidence of arrested development (other than increase in size) with maintenance of the pelagic environment. The transforming specimens from the geographical range of the adult usually were trawled or were from inshore situations and thus were probably undergoing successful transformation. Some small spotted-fin bottom specimens, all from the geographical range of the adult, probably had just reached the bottom habitat when collected.

Even within the geographical range of the adult, the size at which the prejuveniles settle to the bottom varies (perhaps based on their geographical origin), for of two specimens collected at the same time (*Silver Bay* station 1299, table 1) the larger (49.4 mm.) retained the pretransformation (spotted) fin coloration, while the smaller (48.6 mm.) exhibited the transitional coloration.

This phenomenon is exhibited in four other collections also, all from Massachusetts. These collections are old, taken without complete and precise ecological and locality data, which precludes definite conclusions as to transitional relationships. The four collections, indicated in table 1, are—

(1) CNHM 55986, 2 specimens, the larger (57.1 mm.) with the pretransformation fin pattern and the smaller (49.3 mm.) with the transforming fin color. (2) USNM 49664, 6 specimens, one of the middle-sized ones (42.4 mm.) with the transforming fin color and the others (30.8, 39.3, 42.9, 44.9, and 47.3 mm.) with the pretransformation pattern. (3) USNM 68129, 4 specimens, the largest and smallest (34.5 and 55.9 mm.) with the transforming fin color and the two middle-sized ones (49.3 and 50.8 mm.) with the pretransformation pattern. (4) USNM 58833, 2 specimens, the larger (41.1 mm.) with the pretransformation fin color and the smaller (35.7 mm.) with the transforming color.

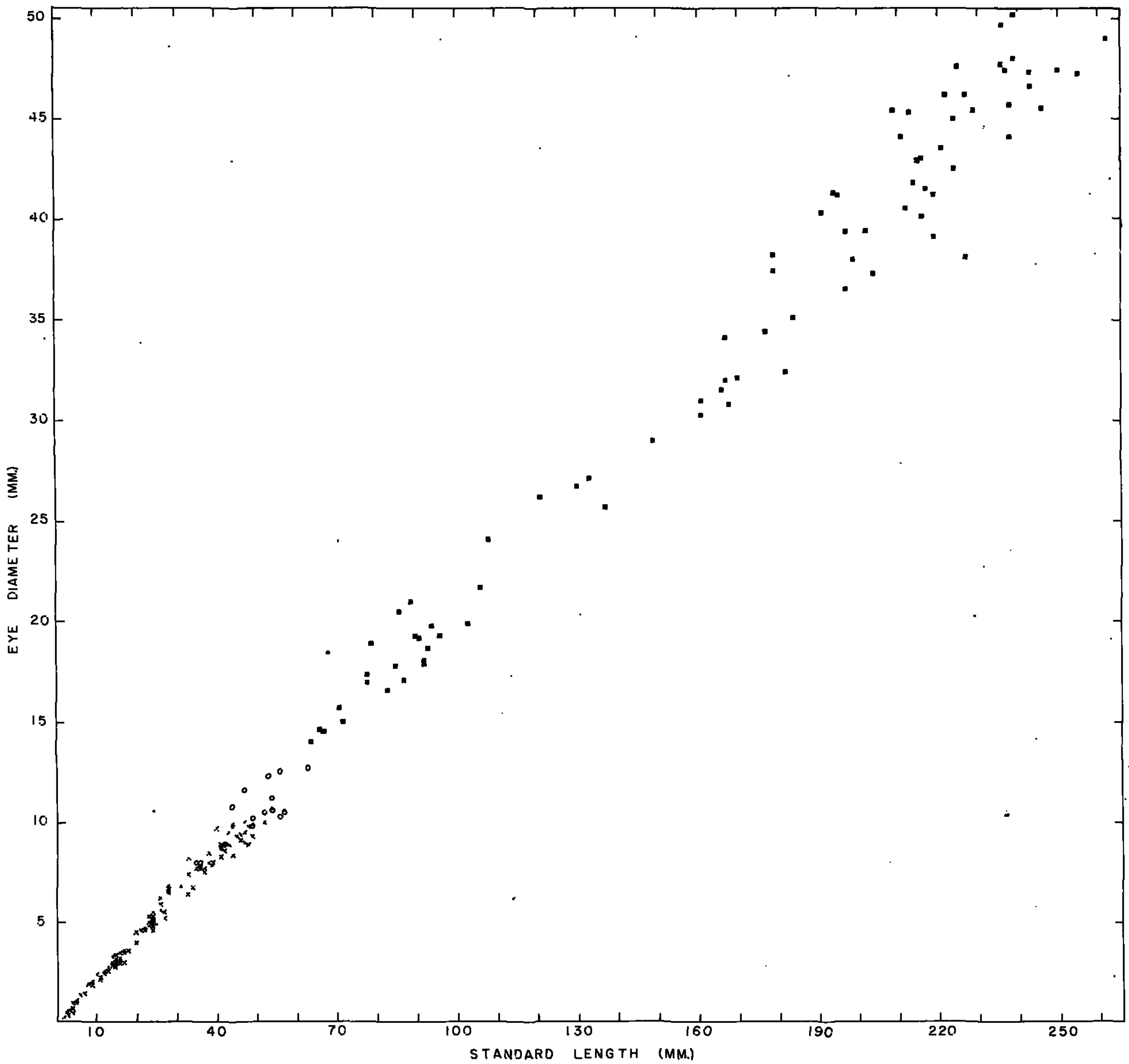

FIGURE 3.—Relation of eye diameter to standard length in *Pseudopriacanthus altus*. (Untransformed larvae and prejuveniles represented by crosses, transforming prejuveniles by open circles, and transformed juveniles and adults by squares.)

No series contained both metamorphosing and metamorphosed specimens.

The largest specimen with the transitional coloration was trawled from 3 fathoms off Soldier Key, Florida (table 1). According to the label, it was estimated to be 2 inches (about 50 mm.) total length at capture (about 40 mm. standard length). The transitional (or transformed) coloration would be expected under those conditions unless the fish had just settled to the bottom when captured. It was then kept in an aquarium at Marineland, Florida, for about 2½ months, and during this time it grew to a total length of 93 mm. (73 mm. standard length). At 73 mm. the fins still retained the transitional coloration, the body remained dark, and the eye was still relatively small. How long the specimen would have retained these transitional features is unknown, but they were retained, under these unnatural conditions, on this much larger speci-

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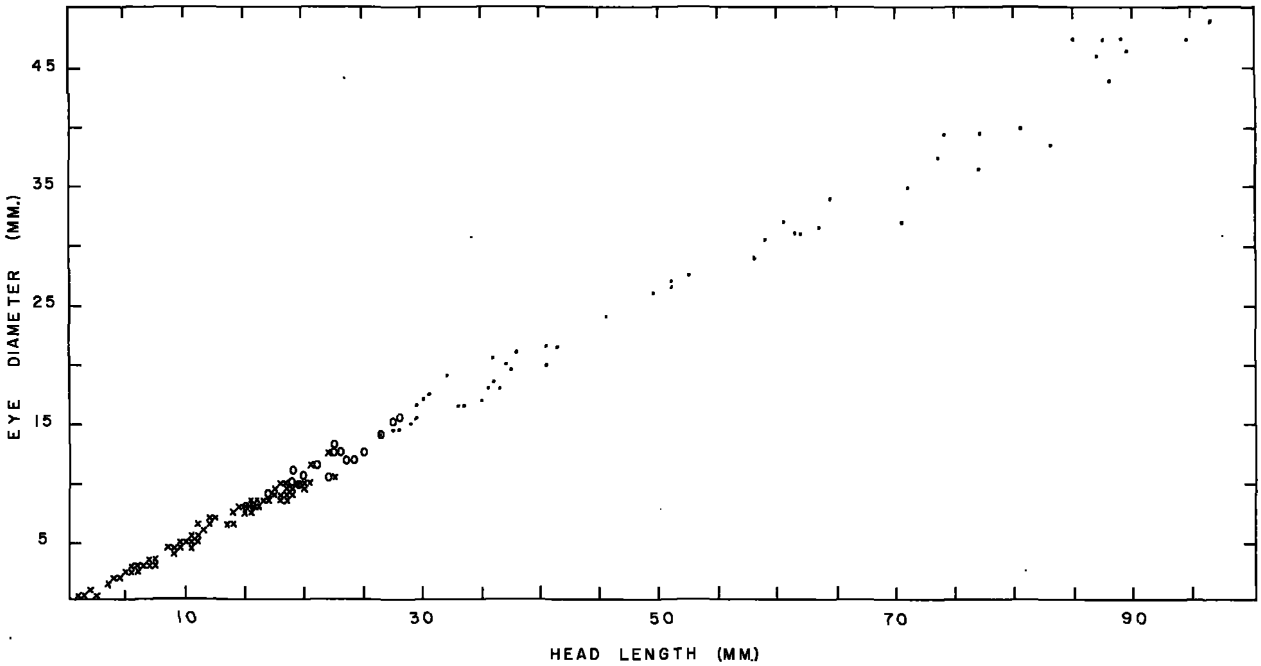

FIGURE 4.—Relation of eye diameter to head length in *Psuedopriacanthus altus*. (Untransformed larvae and prejuveniles represented by crosses, transforming prejuveniles by open circles, and transformed juveniles and adults by small dots.)

men than any found in nature (ca. 65 mm. the largest). The fish was found dead on the floor beside the aquarium, which might suggest that some force drove the transitional individual to seek a more suitable habitat, and that its only method of escape was to leap.

In relation of eye diameter to standard length, there often is a striking difference between the pelagic and bottom forms—the latter having a relatively larger eye at comparable sizes. Also, regression lines estimated visually show that the increase in eye diameter per unit of increase both in length of fish (fig. 3) and in length of head (fig. 4) is greater in the smaller (pelagic) fishes than it is in the larger (bottom) forms. Rather than there being an inflection in the zone of transformation (about 35 to 65 mm.), there appears to be a step, the result of a very rapid and apparently sudden increase in relative (as well as actual) eye size during transformation. The fish assume the bottom habitat at different sizes, and it is in the size range of the transformation that *P. altus* changes from a pelagic to a bottom habitat. Once the relative size of the eye reaches its maximum—in the size range (35–65 mm. standard length) at which the bottom habitat is assumed—it maintains a constant rate of increase (but lower than initially) to the largest size, though the eye diameter may be relatively smaller in larger fish than in the pelagic young.[1]

Figure 5 demonstrates the relation of eye size to habitat, length of the fish, and stage of development suggested by fin coloration. The open circles represent specimens dip-netted, surface-netted, or washed ashore. The solid squares represent specimens either demonstrated or suggested to have come from a bottom habitat. A few nontransformed specimens taken from a bottom habitat are indicated by open squares. Transitional stages from each habitat, as determined on fin color pattern, are represented by half-solid symbols. The dashed line suggests the dividing line between pelagic and bottom-dwelling specimens, with a few exceptions among bottom forms.

It is evident that pelagic individuals not finding suitable habitat continued to grow and may exceed in length the bottom-dwelling in-

[1] Some of the smallest larvae (fig. 5) have a much smaller eye in relation to standard length than most of the adults, but as they differ so from the adults in many features they are omitted from this discussion.

dividuals, as discussed earlier. Despite a wide range of eye diameters, particularly in the larvae (about 5 mm. or less), in which they may be influenced by physical distortion of the specimens, the eyes of pelagic specimens generally are relatively smaller than those of bottom-living ones. Transforming bottom forms plot generally lower on the graph than pelagic forms of the same size. Whether this increase in relative eye size with change of habitat is cause or effect is not known, though I favor effect (or the need for a larger eye in the dimly lit zone which the adult usually inhabits as compared with the brightly lit surface waters occupied by the larvae and prejuveniles). It is not clear what processes trigger the descent of the fish to the bottom.

These offshore-caught forms were taken at or near the surface (both the larvae and prejuveniles), except for a group taken by a midwater trawl set at 24 fathoms over 1,300 fathoms (table 1). These individuals, well north of the range of the adult (fig. 1), might have been seeking the bottom. Perhaps the stimulus in this case is light—with the fish changing from a positive to a negative phototropic response. This might also initiate the increase in relative eye size, to compensate for the reduced illumination. A change in dietary requirements and the pursuit of food also may influence the change of habitat in that the new requirements are met only in the bottom habitat.

The differential rate of growth (previously noted) related to habitat is well illustrated by the material examined. The largest actual or inferred pelagic forms (up to 58 mm.) were taken in northern Atlantic waters (table 1), which suggests they continued to grow without changing form as they were carried north by the Gulf Stream. The large pelagic form illustrated in figure 2, from Massachusetts, is one of these; while the small, nearly transformed bottom form is from about 10 fathoms, off St. Augustine, Florida, or well within the range of the adult.

The smaller pelagic forms taken in northern Atlantic waters could easily have been spawned in the northern part of the range of the adult and not yet had time to reach a large size. Prejuveniles taken in southern latitudes in the Atlantic (table 1) are all small (maximum size about 20 mm.), suggesting that they had been spawned from nearby adults or had found their way to an inshore bottom to transform rather

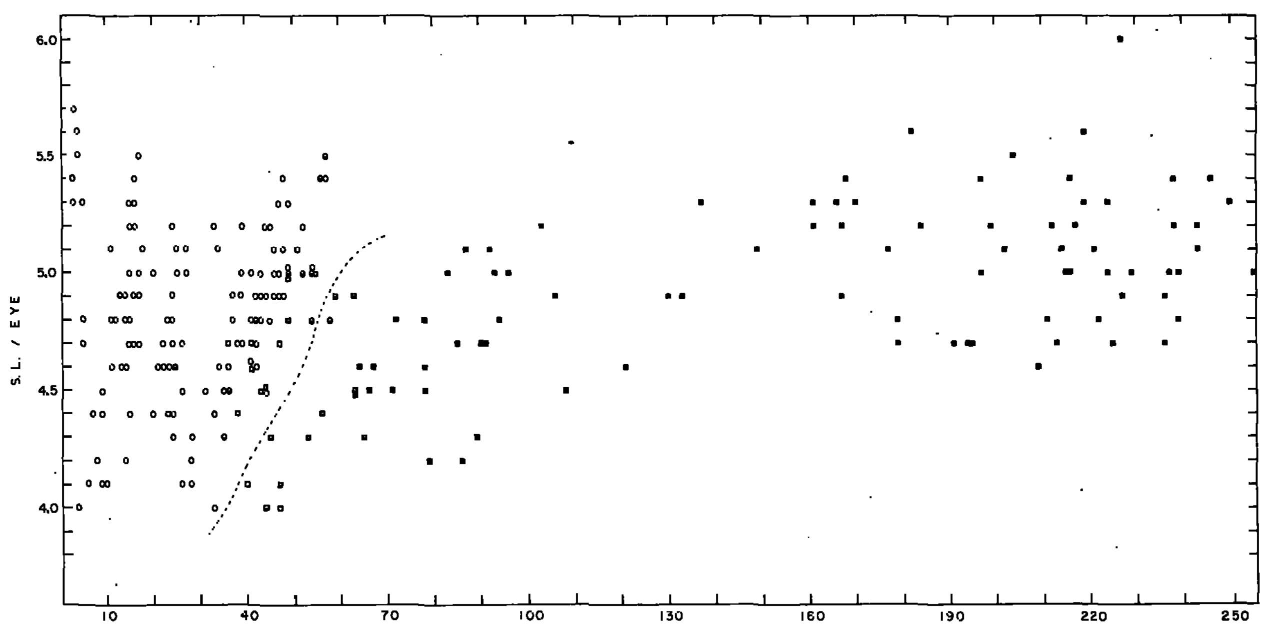

FIGURE 5.—Relation of ratio of eye diameter in standard length to standard length in *Pseudopriacanthus altus*. (Untransformed pelagic larvae and prejuveniles represented by open circles, untransformed bottom-living prejuveniles by open squares, pelagic transforming prejuveniles by half closed squares, and transformed juveniles and adults by closed squares.)

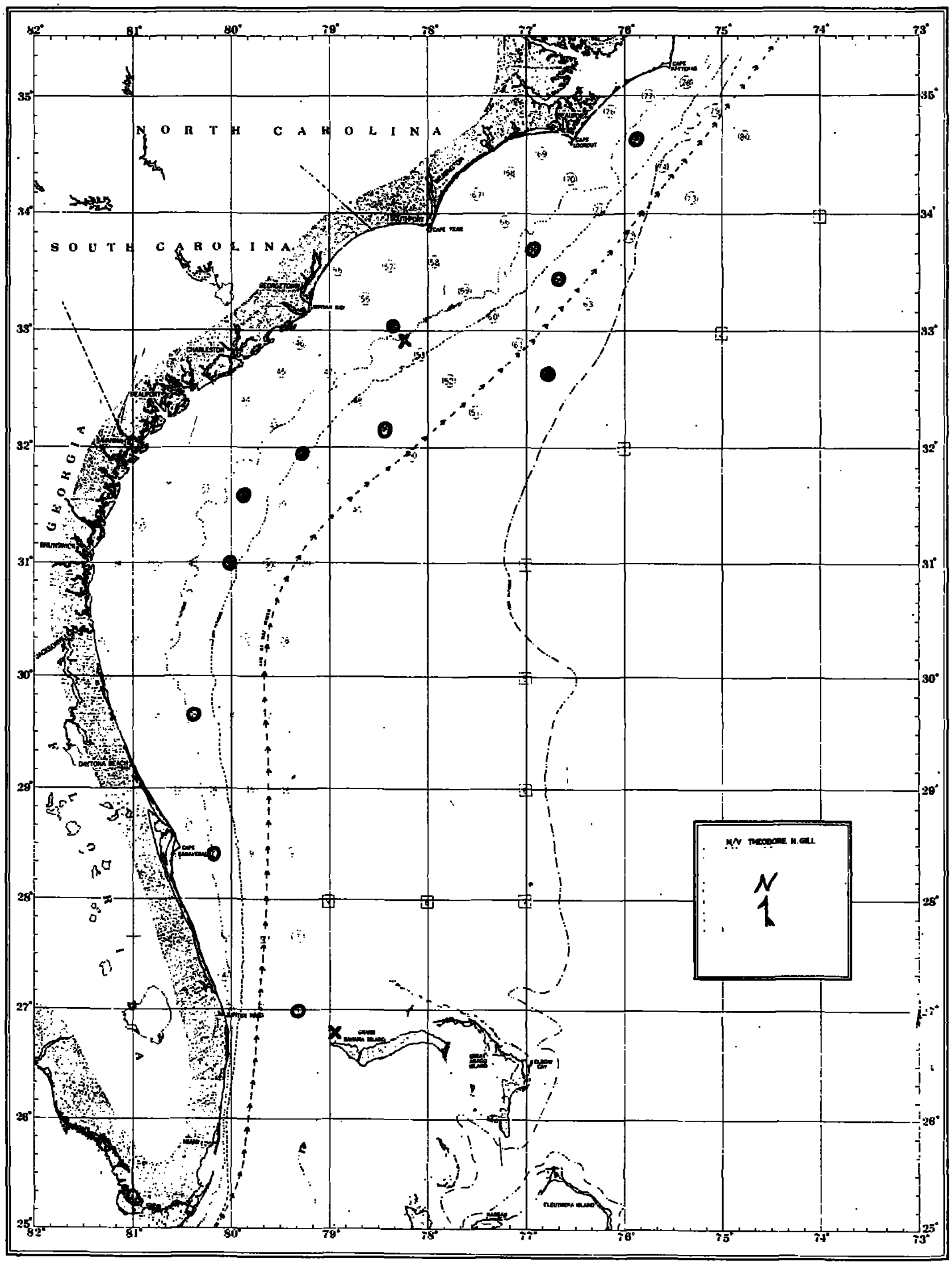

FIGURE 6.—Locations of capture of larval and small prejuvenile *Pseudopriacanthus altus* from operations of the M/V *Theodore N. Gill* off the southeastern Atlantic coast of the United States. Indicated to the seaward off the central coastline are the 20-fathom contour, the 100-fathom contour, the approximate axis of the Gulf Stream, and the 1,000-fathom contour. Open circles represent captures of one or more larvae, closed circles, one or more 15-mm.-or-less prejuveniles, and crosses prejuveniles from stomach contents. See table 1 for exact locations, numbers, and sizes of *Gill*-caught material.

than be swept north of the range of the adult. Once north of Cape Hatteras, they would find themselves generally in too deep water to transform until they reached the coasts of New Jersey, Long Island, or Cape Cod. There, prolonged life is probably impossible due to temperature. Likewise, pelagic forms taken in the Gulf of Mexico are small; however, there is much suitable habitat within this semienclosed area to provide proper temperature, depth, and substrate for the prejuveniles to settle in and transform successfully.

SPAWNING

TIME OF SPAWNING

Larvae collected during the *Gill* operations give some indication of the time of spawning of *P. altus*. The smallest specimen (2.2 mm.) was taken on July 25 off the east coast of southern Florida at regular station 1 on *Gill* cruise 3 (table 1; figs. 6 and 7). Individuals of comparable size were taken at other stations and on subsequent cruises through the middle of September (table 1; fig. 7). Such small specimens must have been only a few days old at most, and probably only a day or so. While they indicate that the spawning season for this species must extend for at least 2 months, from mid-July to mid-September, 8.6- and 8.7mm. specimens taken July 6 off North Carolina at regular station 62 on *Gill* cruise 7 indicate an even more extended season. To reach this size probably took at least several days, which extends the spawning season back to early July or perhaps late June. Gordon (1960: p. 61) noted the collection of a 62-mm. total length individual in Rhode Island in July, indicating a still somewhat earlier initial spawning, at least in some years, for this specimen to have reached this size by even late July (fig. 7). Specimens taken after mid-September were 10 mm. or more (table 1; fig. 7), indicating completion of the spawning season. Further evidence for a midsummer to late summer or early fall spawning in southern latitudes is seen in table 1.

Several 20- to 30-mm. specimens were taken in northern latitudes in the late summer and early fall. These were not included in figure 7 because only partial data, such as a month or spread of 2 months, were given on labels. There are also numerous references in the literature to late summer and fall collections of small (prejuvenile) specimens in New England and slightly more southern waters and to their apparent arrival there via the Gulf Stream.

Still further evidence that spawning is completed by mid-September at the latest is given by a

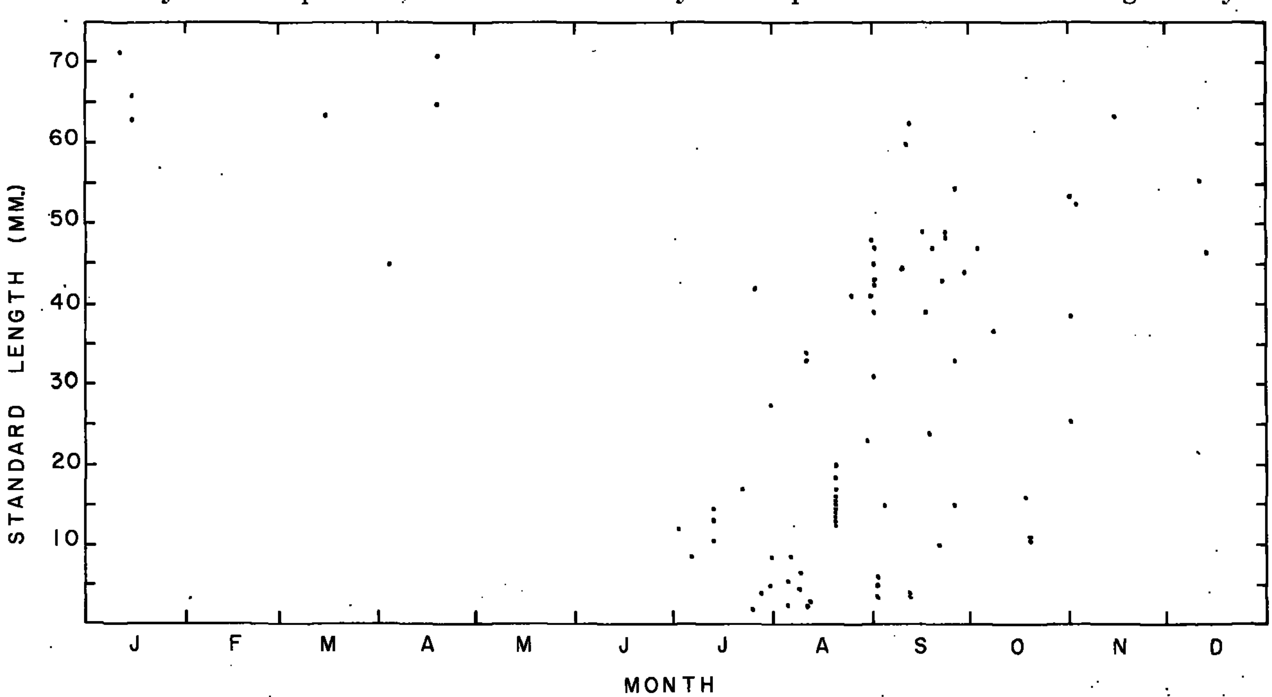

FIGURE 7.—Size distribution, by months, of specimens of *Pseudopriacanthus altus*, 75 mm. standard length or less.

series of 32 presumably spent adult specimens (161.0–261.8 mm.) taken at *Silver Bay* station 1393 on October 26 (table 1).

PLACE OF SPAWNING

From all evidence, *P. altus* is a very secretive and sedentary species unlikely to undertake major spawning migrations, if it moves at all. The adults seemingly spawn where they spend their mature life, in waters of about 60 fathoms or less (table 1), rarely to 110 fathoms. Collections from the *Gill* show that the larvae are pelagic. Although sampling was conducted from near the shore out into the approximate axis of the Stream (Anderson, Gehringer, and Cohen, 1956), most of the larvae were taken westward of the Gulf Stream (fig. 6) over depths of less than 100 fathoms, mostly 20–30 fathoms (table 1). Likewise specimens dip-netted in southern latitudes (below Cape Hatteras) were taken to the shoreward, except for those taken nearer the middle of the Gulf Stream in higher latitudes south of Cape Hatteras and one taken on the eastern side of the Stream northwest of Grand Bahama Island (table 1; fig. 6). The latter individual could have been spawned along the western edge of the Bahama Islands, or even in the northern Antilles, and reached its point of capture, despite its small size (2.2 mm.), in the fast flow of the Gulf Stream in this region (Leipper, 1954). The larvae taken in the main Stream off the Carolinas (table 1; fig. 6) from farther offshore could have had a similar origin, or could have originated in inshore continental waters and been transported much farther offshore after spending several days in the vagaries of the flow. Prejuveniles taken well offshore north of Cape Hatteras presumably could have had either a southern inshore continental origin or one in the West Indies or Bahamas.

MORPHOLOGY

Detailed descriptions of morphological features not discussed in this paper may be found in Jordan and Evermann (1896: p. 1239), Smith (1907: p. 285), Hildebrand and Schroeder (1928: p. 254), and Morrison (1890: p. 163).

Larvae of other Priacanthidae were taken in *Gill* tows, and series of these (*Priacanthus*) were distinguished from *Pseudopriacanthus altus*. Larval *P. altus* (see figs. 8-10 and descriptions of larvae in following section) could be distinguished from larval *Priacanthus* of comparable size by the presence of heavy pigment on the dorsal aspect of the brain and on the dorsal surface of the gut, a series of many small dark spots on the ventral midline as opposed to series of only a few spots (less than 10 at the smallest sizes) on *Priacanthus*, pigmented gill arches at certain sizes, and by shorter preopercular spines (half the length of those in *Priacanthus*).

As with most marine fishes having truly pelagic larvae distributed by ocean currents (a phenomenon which permits free exchange of genes), *Pseudopriacanthus altus* exhibits no measurable or significant geographical variation, but apparently is constant throughout its range. As a partial exception, the 108.3-mm. specimen from the Virgin Islands (table 1; appendix table A–1), representing a population so placed geographically that it receives little or no gene influence from other areas, exhibited characters which fell within the range of meristic values for the species, but approached the extremes of several specimens (low gill-raker count of 6+17; high lateral-line scale count of 37; high vertical scale-row count of 41; and a high pectoral-ray count of 19 left and 18 right). In body proportions it appeared normal.

MERISTIC CHARACTERS

Counts were recorded only on prejuveniles, juveniles, and adults. As, by my definition, the full complements of all fin rays are not formed in larvae, the numbers of spines and soft-rays were not recorded for larvae. The progression of development, however, is discussed under each character—scale, fin-ray, and gill-raker formation was very rapid, once initiated. The smallest specimen for which counts were recorded and included in the tables was 8.2 mm. It was considered the earliest prejuvenile. The next smaller specimen available, 6.6 mm., although complete in complement of other fin-rays, did not have a full complement of secondary caudal rays. This specimen was considered the largest larva of the study. The point of division between larvae and prejuveniles, by my definition, lies between 6.6 and 8.2mm.

Fin and Fin-Ray Development

Parts of the rays of many fins of critical-sized specimens were missing. Therefore, the terms "at least" and "about" are used in the following discussions, as the precise size at which a character developed could not be determined. Complete segmentation and complete branching indicate at least one segmentation line or one branch in each ray (which segments or branches) of the fin.

Caudal fin.—Development of the hypural complex began at about 3.5 mm. The turned-up urostyle was still obvious at 6.6 mm. and development of the hypural was complete before 8.2 mm. Ossification was first noted in a 4.0-mm. individual.

In the development of the caudal fin, a finfold was present in the smallest larva (2.2 mm.; see fig. 8), and rays apparently were forming, although no ossification of rays was noted in stained specimens until a size of 3.5 mm. Ossification proceeded anteriorly, and the full complement of 16 principal rays was evident in a stained 4.4-mm. larva. Segmentation, beginning with the innermost rays, had begun by at least 4.4 mm., and was completed by at least 8.2 mm. Branching had begun at 10.2 mm., and was complete at 16.8 mm. Four dorsal and four ventral ossified secondary rays were present for the first time at 8.2 mm. Large adults showed, by gross microscopic examination, all secondary rays to be segmented.

All 121 caudal fins so examined had 14 branched principal soft-rays and two unbranched principal soft-rays (the most-dorsal and-ventral principal rays of the fin). The principal rays are divided equally between the two caudal lobes.

Pectoral fins.—A pectoral-fin membrane (fold) with forming rays was present in the smallest larva (2.2 mm.; see fig. 8). Ossification, shown by staining, began ventrally at about 3.5 mm. There were 13 rays in the pectoral fin of a 4.4-mm. larva, 15 in one of a 4.8-mm. larva, and 17 were seen in a 5.3-mm. individual. Segmentation had begun by at least 6.6 mm., starting with the uppermost rays, and was complete by about 8.2 mm. Neither the size at which branching began, nor the sequence, could be determined, but it was complete by 8.2 mm. In large individuals the most-dorsal and two most-ventral rays are unbranched.

The variation in number of pectoral rays of the full complement is shown in table 3. In addition, three other individuals had 17 left pectoral rays (the right rays were not counted). Large series of specimens contained individuals with both the 17–17 and 18–18 counts, as well as ones with unlike combinations. Some juvenile and adult fish had 17 or 19 rays, but the usual count was 18, while the predominant count for prejuveniles was 17, with two specimens having 16.

TABLE 3.—*Variation in pectoral fin-ray counts for 138 pairs of fins in* Pseudopriacanthus altus

[The upper number in each block is the count obtained for that combination, and the number in parentheses below is the approximate percentage of that count in the total sample]

LEFT \ RIGHT	16	17	18	19	Total
16	1 (0.7)				1 (0.7)
17	1 (0.7)	81 (58.7)	7 (5.1)		89 (64.5)
18		3 (2.2)	43 (31.2)		46 (33.3)
19			1 (0.7)	1 (0.7)	2 (1.4)
Total	2 (1.4)	84 (60.9)	51 (37.0)	1 (0.7)	138

Dorsal fin.—A finfold was present posteriorly at 2.6 mm., and there was a complete fold in a 2.7-mm. specimen. No ossified rays were found in stained specimens until 3.5 mm.; and ossification proceeded posteriorly. A full complement of ossified rays, distinguishable as pro-spines and pro-soft-rays, was present in a 4.4-mm. stained specimen. Segmentation of pro-soft-rays began at about 6.6 mm., starting with the posteriormost rays, and was complete by at least 8.2 mm. No soft-rays were branched at 15.0 mm., but some posterior ones were branched at 16.8 mm., and branching was apparently complete at 20 mm., and certainly at 34.0 mm.

The full complement of dorsal spines, 10 (X), found in all 233 prejuvenile, juvenile, and adult specimens so examined, was present by 8.2 mm. (the earliest prejuvenile of the study), when segmentation of the soft-rays was complete. Variation in the number of fully developed soft-rays is summarized in table 4.

TABLE 4.—*Variation in dorsal and anal fin-ray counts for 233 specimens of* Pseudopriacanthus altus

[The upper number in each block is the count obtained for that combination, and the number in parentheses below is the approximate percentage of that count in the total sample]

COMBINATIONS OF FIN-RAY COUNTS (DORSAL; ANAL)

	X, 10; III, 10	X, 11; III, 9	X, 11; III, 10	X, 11; III, 11	X, 12; III, 11
NUMBER	12 (5.2)	3 (1.3)	216 (92.7)	1 (0.4)	1 (0.4)

Anal fin.—A finfold was present at 2.6 mm., and a full complement of rays was seen at 4.4 mm. (pro-spines and pro-soft-rays distinguishable). The first ossified rays were seen in stained specimens at 3.5 mm.; and ossification proceeded posteriorly. Segmentation of pro-soft-rays was first seen at 5.3 mm., and was complete by about 8.2 mm. There was no branching of anal rays in a 13.9-mm. individual, but branching had begun with the most posterior rays at 15.0 mm., and was complete by 16.8 mm.

The full complement of anal spines, three (III), found in all 233 prejuvenile, juvenile, and adult specimens so examined, was present by 8.2 mm., when segmentation of the soft-rays was complete. Variation in the numbers of fully developed soft-rays is shown in table 4. The anal fins of individuals with a dorsal count other than the modal X, 11 show the modal anal ray count of III, 10 in all but one instance (a specimen with a dorsal-ray count of X, 12 and an anal-ray count of III, 11).

Pelvic fins.—This was the last fin to form, there being no evidence of it until a bud appeared in a 3.9-mm. specimen. Ossified rays were first formed in a 4.0-mm. specimen, but the full complement of 6 (distinguishable as 1 pro-spine and 5 pro-soft-rays) was not present until 4.8 mm. Segmentation was first noted by about 6.6 mm., and was complete by about 8.2 mm. Branching had started by 8.2 mm., and was complete at 8.7 mm.

All pelvic fins so examined, 147 pairs, had a count of 1 spine and 5 soft-rays, except for the right fin of a 45.5-mm. specimen (from USNM 58831), which had a I, 4 count. Such a variant is extremely unusual in this constant-rayed fin, and the low count was possibly due to an injury to the embryo.

Scales

Although the smallest prejuvenile (8.2 mm.) was completely covered with scales, the smallest individual on which vertical scale rows were counted was 23.8 mm., and the smallest on which lateral-line scales were counted was 26.4 mm. The full range of adult complement of vertical scale rows and pored lateral-line scales was present at approximately these sizes. On the basis of a previous discussion of the phenomenon (Caldwell, 1957: p. 105), I presume that once the scales are formed in *P. altus*, the number for that individual remains unchanged. The variation in combinations of numbers of vertical rows and pored lateral-line scales is shown in table 5.

TABLE 5.—*Variation in counts of pored lateral-line scales and vertical scale rows in 145 specimens of* Pseudopriacanthus altus

[The upper number in each block is the count obtained for that combination, and the number in parentheses below is the approximate percentage of that count in the total sample]

VERTICAL SCALE ROWS	PORED LATERAL-LINE SCALES									
	31	32	33	34	35	36	37	38	39	Total
35	1 (0.7)	1 (0.7)	1 (0.7)	2 (1.4)						5 (3.4)
36		2 (1.4)	1 (0.7)	3 (2.1)						6 (4.1)
37	1 (0.7)	3 (2.1)	4 (2.8)	9 (6.2)	4 (2.8)	2 (1.4)	1 (0.7)			24 (16.6)
38	1 (0.7)	2 (1.4)	10 (6.9)	5 (3.4)	14 (9.7)	4 (2.8)	3 (2.1)			39 (26.9)
39			9 (6.2)	8 (5.5)	8 (5.5)	6 (4.1)	2 (1.4)	1 (0.7)		34 (23.4)
40			2 (1.4)	11 (7.6)	5 (3.4)	1 (0.7)	4 (2.8)		1 (0.7)	24 (16.6)
41			1 (0.7)	1 (0.7)	3 (2.1)	1 (0.7)	1 (0.7)	2 (1.4)		9 (6.2)
42		1 (0.7)		1 (0.7)	1 (0.7)					3 (2.1)
43					1 (0.7)					1 (0.7)
Total	3 (2.1)	9 (6.2)	28 (19.3)	40 (27.6)	36 (24.8)	14 (9.7)	11 (7.6)	3 (2.1)	1 (0.7)	145

No scales had formed at 4.8 mm. At 5.3 mm., there were small patches on the lower flank of the belly on each side in the region anterodorsal to the anus, and a small patch near the anterior end of the isthmus. A 6.6-mm. individual was covered with scales except for areas just ventral and posterior to the base of the pectoral fins, on the lower half of the caudal peduncle, and the lower half of the flank of the body above the anal fin and behind the anus. The scales appeared to form first as widely spaced bristles. These soon developed into the upstanding ctenii of the prejuvenile, and in final development they were strongly ctenoid scales firmly anchored in the scale pockets.

The lateral-line scales did not form until about 25 mm. There was an open channel between the other scales (seen in an 8.2-mm. individual) to mark its course in the smaller fish. The scales adjacent to this channel appeared to join to cover the open area as they enlarged, meanwhile developing the pores.

Gill Rakers

The smallest specimen in which gill rakers were counted was 19.9 mm. The count obtained, 8 + 19, falls at the mode of the range for the adults. Variation in combinations of upper-limb and lower-limb gill rakers is summarized in table 6.

Although the size at which gill rakers first form was not determined, they were well-developed in the smallest prejuvenile of 8.2 mm.

TABLE 6.—*Variation in upper- and lower-limb gill-raker counts for 112 specimens of* Pseudopriacanthus altus

[The upper number in each block is the count obtained for that combination, and the number in parentheses below is the approximate percentage of that count in the total sample]

LOWER LIMB	UPPER LIMB 6	7	8	9	Total
17	1 (0.9)	3 (2.7)	2 (1.8)		6 (5.4)
18		11 (9.8)	10 (8.9)		21 (18.8)
19		7 (6.3)	27 (24.1)	2 (1.8)	36 (32.1)
20	1 (0.9)	3 (2.7)	32 (28.6)	9 (8.0)	45 (40.2)
21		1 (0.9)	1 (0.9)	2 (1.8)	4 (3.6)
Total	2 (1.8)	25 (22.3)	72 (64.3)	13 (11.6)	112

Bony Cranial Crest

A single prominent, medial, cranial crest, armed throughout its length with 8 strong dorsomedial serrations, and with a sharply upturned (about 40°) backward projection, was present on a 2.2-mm. individual (fig. 8). At 2.4 mm., the serrations had increased in number and become less prominent, while the backward projection had begun to decrease its angle and lie flatter against the head and body. By 2.6 mm., the serrations were lost on the anterior part of the crest and were weak on the backward projection

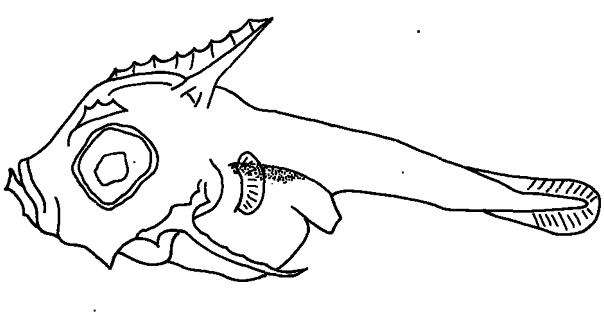

FIGURE 8.—Larval *Pseudopriacanthus altus*, 2.2 mm. standard length (BLBG, *Gill* Cr. 3, Reg. 1), Semidiagrammatic.

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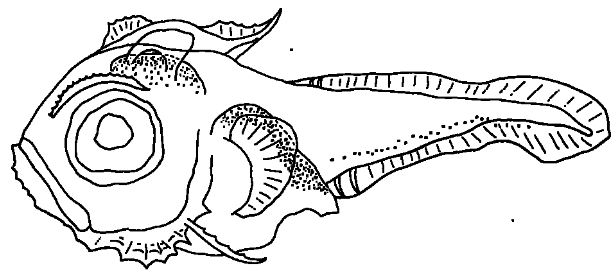

FIGURE 9.—Larval *Pseudopriacanthus altus*, 3.2 mm. standard length (BLBG, *Gill* Cr. 3, Reg. 75). Semidiagrammatic.

(which by this size was flat against the dorsal surface of the body except for its still-upturned tip). At 3.2 mm. (fig. 9), a small, weakly serrate, secondary crest had appeared on the anterior median surface of the original crest. A compressed secondary crest also had formed at the angle made by the upturned projection. By 6.6 mm. (fig. 10) this crest had expanded to include the entire length of the original crest. Strong serrations, each supported by a thickening to the foundation formed by the original crest, extended along the top of this secondary crest (fig. 10). By 8.2 mm.,

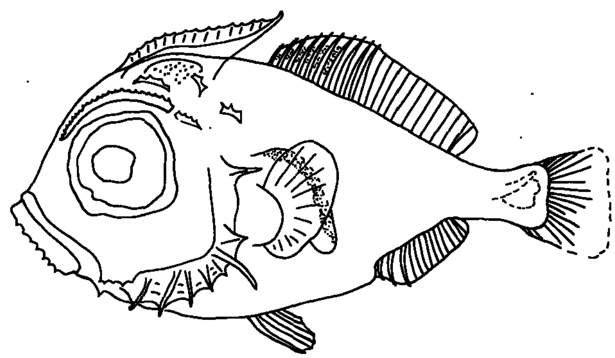

FIGURE 10.—Larval *Pseudopriacanthus altus*, 6.6 mm. standard length (BLBG, *Gill* Cr. 3, Reg. 49). Semidiagrammatic.

the serrations had become weaker, and the entire crest had begun to be absorbed by overgrowth of the dorsal surface of the head. Only a row of weak serrations in the midline of the forehead remained in a 16.8-mm. specimen, an outline only by 19.9 mm., and all trace had disappeared in a 34.0-mm. individual.

Supraocular Crest

Larval and early prejuvenile *P. altus* possess an eyebrowlike serrate bony crest over each eye.

In the smallest larva, 2.2 mm. (fig. 8), this crest bore three heavy serrations and extended over only the anterior half of the supraocular region. At 2.7 mm., this crest extended both posteriorly and anteriorly over the entire top of the eye and beyond. The serrations had increased in number but decreased in strength. By 3.9 mm., the crest extended farther around the eye to shield its anterodorsal and posterodorsal arcs. By 6.6 mm. (fig. 10), the serrations and the ridge itself were becoming decreasingly prominent, and additional serrate ridges were forming lateral to the medial cranial crest. By 8.2 mm., the supraocular crest had become more finely serrate and the additional ridges were more prominent. By 12.1 mm., (fig. 11) all of these crests and ridges were disappearing (probably being overgrown as they ceased to grow), and by about 35 mm. only vague outlines could be seen. These, too, were lost by 40 mm.

Preopercular Spines

Larval *P. altus* possess a strong, conspicuous, ridged, and serrate spine at the angle of the preopercle, flanked by two spines that are shorter and less prominent (but also ridged). In the 2.2-mm. larva (fig. 8), the angle spine reached nearly to the anal opening. It became progressively shorter in relation to the head length as the size of the fish increased (actually it appeared to be overgrown as the preopercle enlarged), until in individuals of about 75 mm., it remained only as a heavy, pointed projection, little more conspicuous by its length than its immediate neighbors above and below. Although its outlines were still discernible in the largest adult examined (261.8 mm.), it lost its significance as a spine in fish above about 75 mm. Beginning with the largest larvae, and as the fish enlarged, other spines also developed as strong serrations on both limbs of the preopercle, including the two shorter spines which originally flanked the angle spine. The serrations increased in numbers and strength with length of fish to about 200 mm., after which they decreased. The preopercle of the largest adults is only finely serrate and the larger angle spines are overgrown and visible only as outlines.

Nostrils

Formation of the paired nostrils was complete (including a tube surrounding the opening of the more anterior one of a pair on each side) in an 8.2-mm. specimen. No external openings were discernible in a 6.6-mm. individual.

Teeth

Adults of *P. altus* possess irregular rows of small canine or sharp-pointed peglike teeth on the premaxillaries and dentaries. Similar small peglike teeth also occur on the tongue, vomer, and palatines. The size at which these teeth form was not determined, but all teeth were present and obvious in a 19.9-mm specimen.

At about 35 mm., a single row of rather widely spaced canines, several times the size of their neighbors, began to develop on the outer edge of the premaxillaries and dentaries. As they first appeared at about the size metamorphosis begins, before the bottom habitat is assumed, and persisted through the largest specimens examined, their appearance may be related to a new diet.

Fin-Ray Serrations

The spines of the dorsal, anal, and pelvic fins of the smallest prejuveniles develop ridges which become rough due to small irregular projections. These projections develop on the leading edge of the single pelvic spine, and on alternate lateral aspects of the dorsal and anal spines. The dorsal and anal spines are heteracanthus (staggered) in their insertions, and a spine that is heavy and rough on its left side is more delicate and smooth on its right. The next spine following is rough on its right side and smooth on its left. In the larger adults, the roughness tends to disappear, though the alternating rough and smooth appearance persists.

The dorsal, anal, and pelvic soft-rays in the smallest prejuveniles also develop the rough surface on both sides, and this character persists in lessening degree in the larger specimens examined, though it is never completely lost.

Branchiostegals

A full complement of six branchiostegal rays on each side was evident on a 2.7-mm. specimen, the smallest stained.

Vertebrae

Ossification was first noted in the anteriormost vertebrae in the smallest specimen (2.7 mm.) stained. All vertebrae in a 4.8-mm. individual showed some degree of ossification, which progressed posteriorly.

BODY PROPORTIONS

Twenty-five body parts were measured on a complete size range of specimens from the largest larva (6.6 mm.) to the largest adult (261.8 mm.) and the data presented in table A-1. Selected measurements were made on 158 additional specimens from the smallest larva (2.2 mm.) to a 254.9-mm. individual (table A-1). These measurements were plotted relative to standard length, and the resulting scatter diagrams are included in figures 3 and 25 to 32. Regression lines were eye-fitted to the data with a straight-edge for discussion purposes, but were not included in the figures. All proportions of larvae were not measured because most of the characters included here are based on parts not present in larvae or because the larvae are so unlike the prejuveniles that to include them would be of little value. The larvae are illustrated in figures 8 to 10.

The distances from pelvic-fin insertion to snout and to midcaudal base were not measured, as the insertion of this fin remained constant in position with that of the pectoral.

Eye diameter in relation to head length and to standard length was discussed in detail in an earlier section on metamorphosis in relation to change of habitat. The eye diameter initially has a higher rate of increase than in sizes greater than about 35–65 mm., the zone of transformation (fig. 3). The relation of eye to head remains constant at all sizes, after an upward step at metamorphosis (fig. 4).

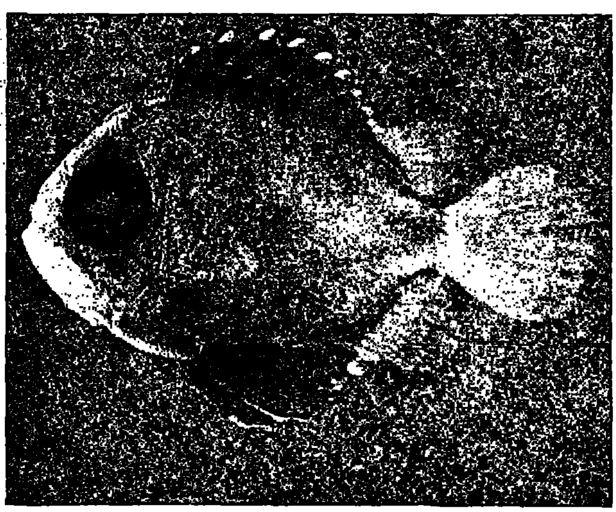

FIGURE 11.—Pelagic prejuvenile *Pseudopriacanthus altus*, 12.1 mm. standard length (BLBG, *Gill* Cr. 7, Reg. 38).

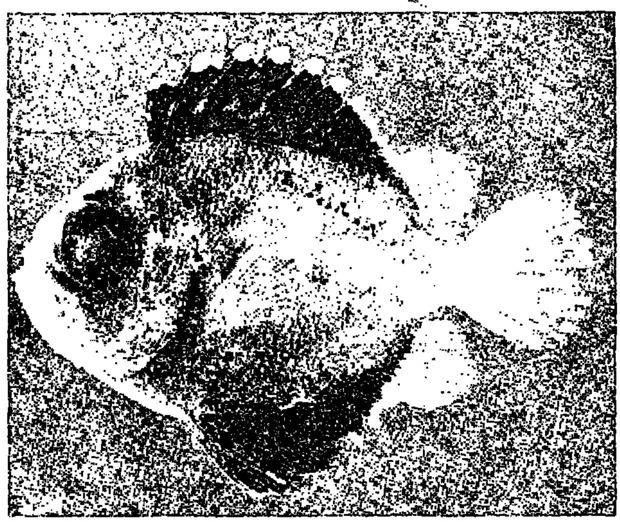

FIGURE 12.—Pelagic prejuvenile *Pseudopriacanthus altus*, 15.0 mm. standard length (BLBG, *Gill* Cr. 8, Reg. 54).

Many of the regression lines eye-fitted to the body proportions in standard length show inflections at various sizes (step indicated in parentheses); some show no inflection. The body proportions are as follows:

Body depth at pelvic-spine base, down (75–85 mm.), figure 25; body depth at third anal-spine base, down (75–85 mm.), figure 25; head, down (125–135 mm.), figure 32; snout to dorsal-fin origin, down (120–130 mm.), figure 30; snout to dorsal-fin termination, down (75–85 mm.), figure 30; snout to anal-fin origin, no inflection, figure 30; postorbital, down (80–90 mm.), figure 32; least depth of caudal peduncle, down (150–160 mm.), figure 29; dorsal-fin origin to midcaudal base, down (95–105 mm.), figure 29; anal-fin origin to midcaudal base, down (95–105 mm.), figure 29; dorsal-fin base, down (65–75 mm.), figure 32; anal-fin base, down (80–90 mm.), figure 32; bony interorbital, down (50–60 mm.), figure 31; pectoral fin origin to snout, down (110–120 mm.), figure 31; pectoral fin length, down (95–105 mm.), figure 31; pelvic-fin spine length, down (150–160 mm.), figure 28; second pelvic-fin soft-ray length, down (100–120 mm.), figure 28; maxillary, down (120-130 mm.), figure 30; third dorsal-fin soft-ray, down (step at 70–80 mm.), figure 27; third anal-fin soft-ray, down (70–80 mm.), figure 27; snout, up (50-60 mm.), figure 30; dorsal-fin termination to midcaudal base, up (110–130 mm.), figure 26; anal-fin termination to midcaudal base, up (110–130 mm.), figure 26; and pectoral fin

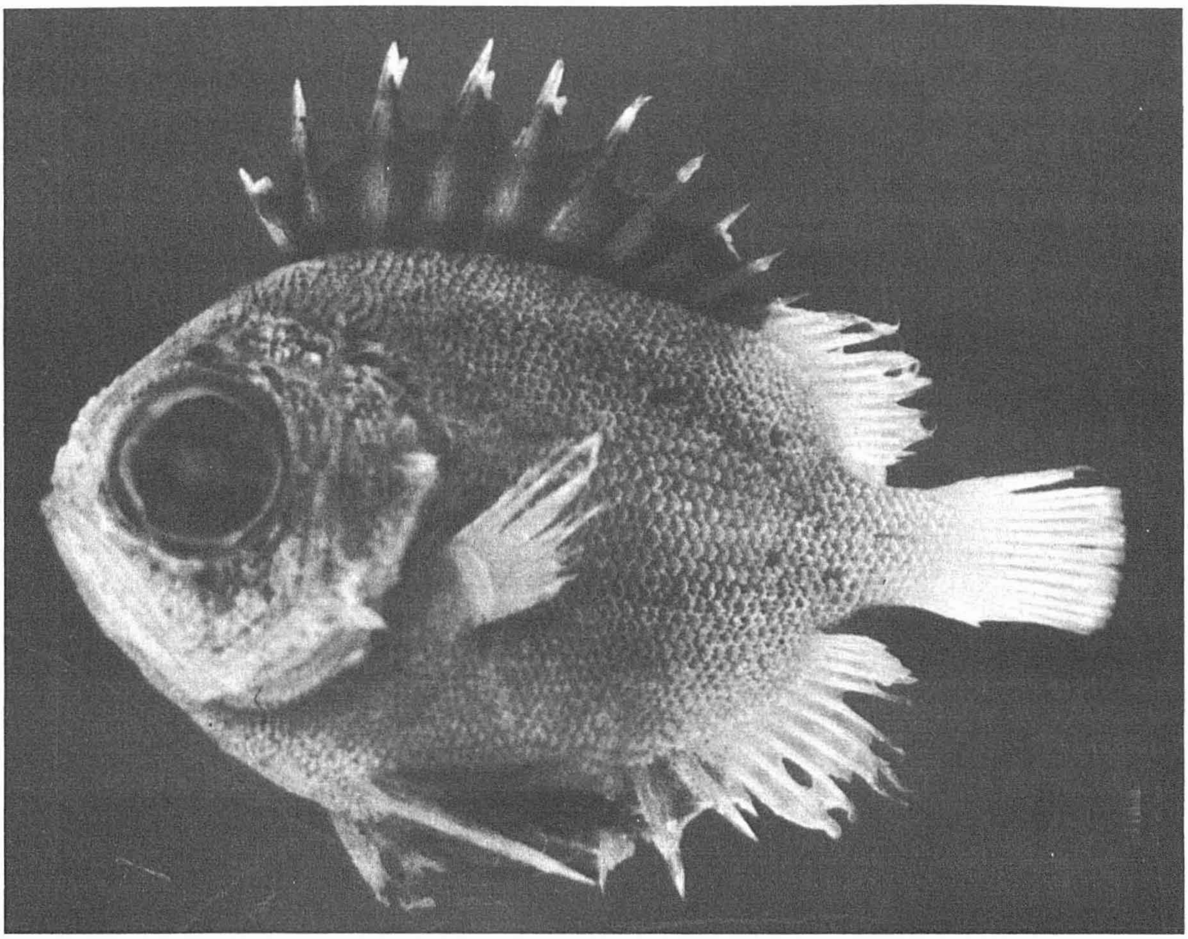

FIGURE 13.—Pelagic prejuvenile *Pseudopriacanthus altus*, 16.8 mm. standard length (WHOI).

origin to midcaudal base, up (130–140 mm.), figure 29.

Although the data are not sufficiently strong to support a positive statement, I believe from examination of a size series of specimens (figs. 11 to 23) that the inflections in relations of body proportions to standard length are, at least in part, a function of a general postcranial elongation of the larger fish, particularly in the region of the caudal peduncle, brought about by a disproportionately greater rate of increase in length in comparison with increase in body part—rather than a slowing down of growth in the body part and a constant rate of increase in the length.

PIGMENTATION

PIGMENTATION OF PRESERVED SPECIMENS

The following descriptions are based on pigmentation of formalin- and alcohol-preserved specimens. In the discussion which follows, the word "pigmentation" refers only to dark chromatophores, which appear brown or black. These chromatophores remain, though varying in intensity with type and duration of preservation, for an indefinite, usually a long period of time and to systematists are the most useful of all pigment characters.

The eye remains dark throughout life.

Body Pigmentation

Pigmentation in the smallest specimen examined, 2.2 mm. (fig. 8), consisted only of (1) a few internal scattered chromatophores either on the upper exterior surfaces of the gut, or on the lining of the abdominal cavity, and (2) dark areas extending either across the anterior and posterior portions of the optic lobes or on the brain case, forming a pigmented area under the single cranial spine. In addition, a small patch of pigment extended between the eyes, across the surface of the forebrain, anterior to the optic-lobe pigmentation.

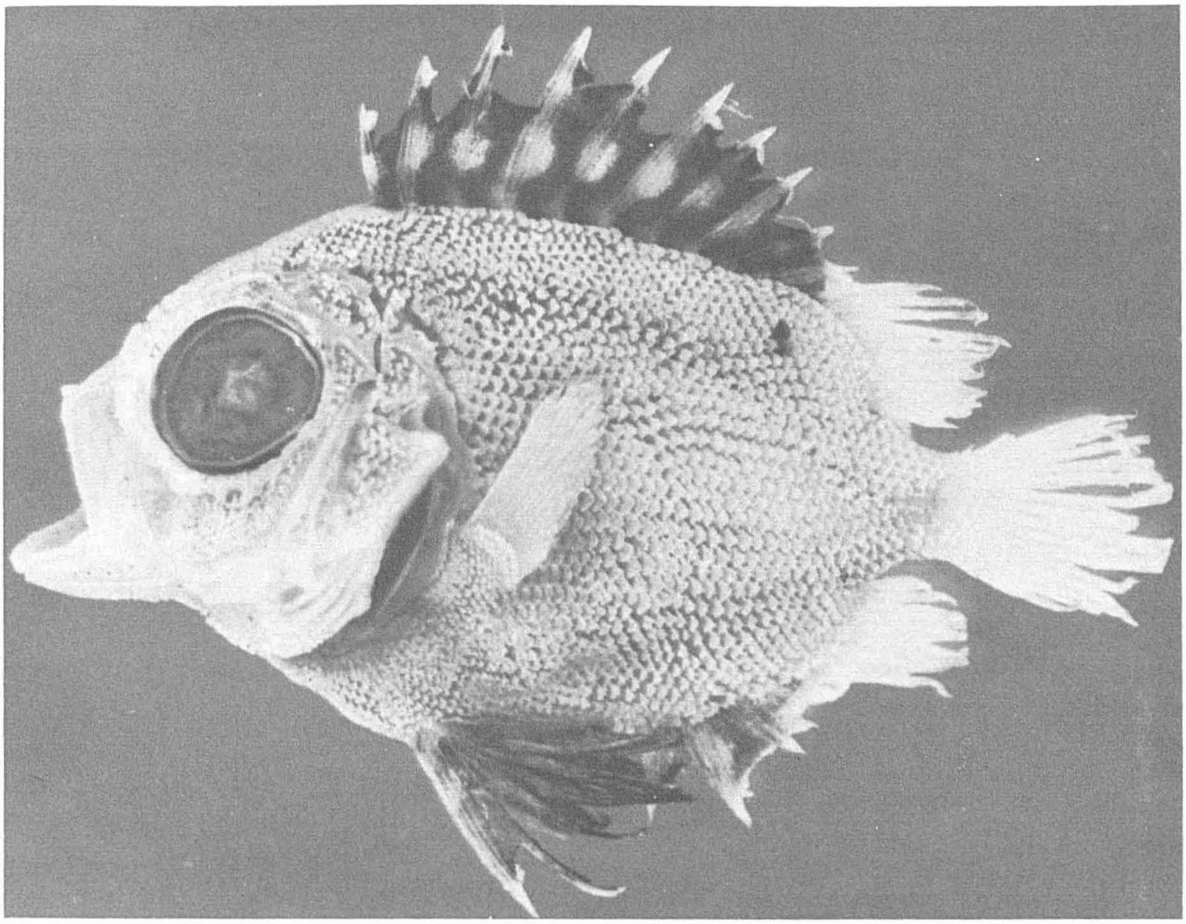

FIGURE 14.—Pelagic prejuvenile *Pseudopriacanthus altus*, 19.9 mm. standard length (WHOI).

By 2.4 mm., a single series of closely arranged chromatophores had developed along the ventral midline of the postanal region, and very light pigmentation had appeared at the angle of the preopercle.

By 2.6 mm., pigmentation on the preopercle had spread to cover the basal two-thirds of the spine at the angle. In addition, pigment seemingly on the dorsal surface of the gut had intensified very noticeably and had begun to spread down over the sides of the gut. A 2.7-mm. individual also had several dark spots along the edge of the isthmus, the gill arches were darkening, a patch of small chromatophores was evident at the point where the tubular and bulky parts of the gut join within the dorsal region of the body cavity, and a single large chromatophore was present at the anal opening. In a second 2.7-mm. specimen the patch of pigment at the junction of the two sections of the gut extended along the apparent dorsoposterior surface of the tubular gut nearly to the anus. In both of these 2.7-mm. specimens there was a general darkening of the body, although individual chromatophores were not evident. At 3.2 mm. (fig. 9), a few small pigment spots were present on the caudal finfold. The chromatophores on the optic lobes or on the brain case had descended laterally.

The chromatophores on the optic lobes of the brain or on the brain case had descended farther by 3.9 mm., and the cleithrum had pigment along its inner edge—the only changes since 3.2 mm. By 4.0 mm., the spots on the developing caudal fin and those on the ventral midline had disappeared. In addition there was loss of some pigmentation on the preopercle, cleithrum, and gill arch. This loss was complete at 6.6 mm., except on the base of the preopercle-angle spine (fig. 10).

Other than a general darkening of the entire outer surface, which obscured the internal pigmentation, no further changes were noted until

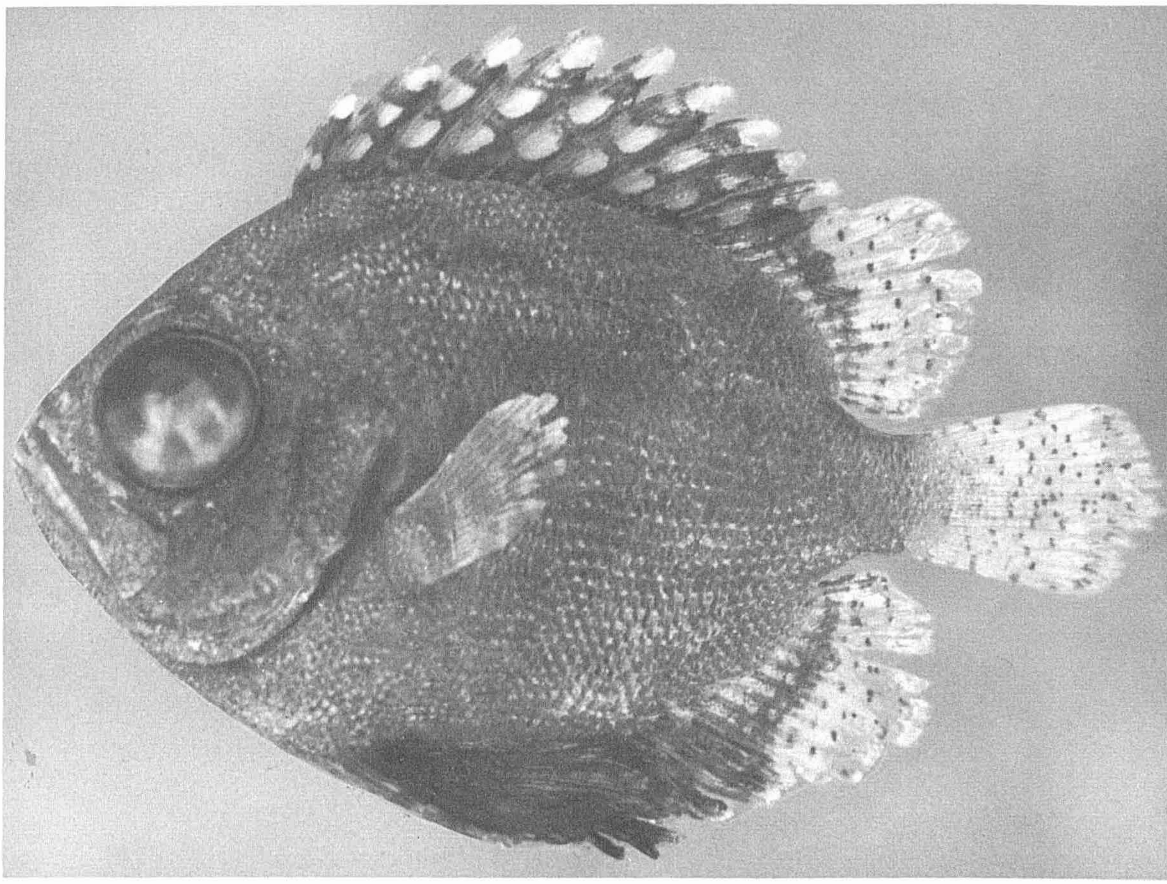

FIGURE 15.—Pelagic prejuvenile *Pseudopriacanthus altus*, 34.0 mm. standard length (CU 27831).

8.2 mm., when small, very dark chromatophores were evident over most of the head and body. At 10.2 mm. these chromatophores had darkened the entire external surface. In addition, a series of many sharply defined dark spots had appeared on the future course of the lateral line. Above this series was a second row of about 10 evenly spaced, larger dots (these were still evident at 48.6 mm.; see fig. 17). No further changes in body pigment occurred by 15.0 mm. except for the reappearance of isolated dark spots in the region of the cleithrum (fig. 12). This color pattern persisted from about 20 to 30 mm., with the exception of a lightening of the skin and scales covering the bases of the caudal rays. At this approximate size, dark chromatophores began to outline the scales just anterior to their ctenii and to cover the scale pockets (see fig. 15). By 58.9 mm., the dark chromatophores covered only the pockets and gave the scales the appearance of having dark centers (fig. 18). Suggestions of three or four wide, poorly defined, incomplete vertical bars also appeared on the 34.0-mm. specimen illustrated in figure 15. These bars may persist to adulthood and are especially noticeable when the fish is alive. The chromatophores appearing over the center of those scales in the regions of the bars were more expanded and intense. This pigmentation persisted, especially above the lateral line, to the largest specimens.

Fin Pigmentation

Pectoral fins.—Immaculate at all sizes.

Pelvic fins.—All specimens up to 6.6 mm. had immaculate pelvic fins (figs. 8–10). By 8.2 mm., these fins had a scattering of small dark chromatophores along the rays and onto the membranes connecting them. These chromatophores spread and increased in number until the fins, with the exception of their immaculate tips, were completely covered with dark pigment by 10.2 mm. The tips also were covered by 15.0 mm. (fig. 12). In specimens larger than 10.2 mm., the pigment was progressively less intense on the rays than on

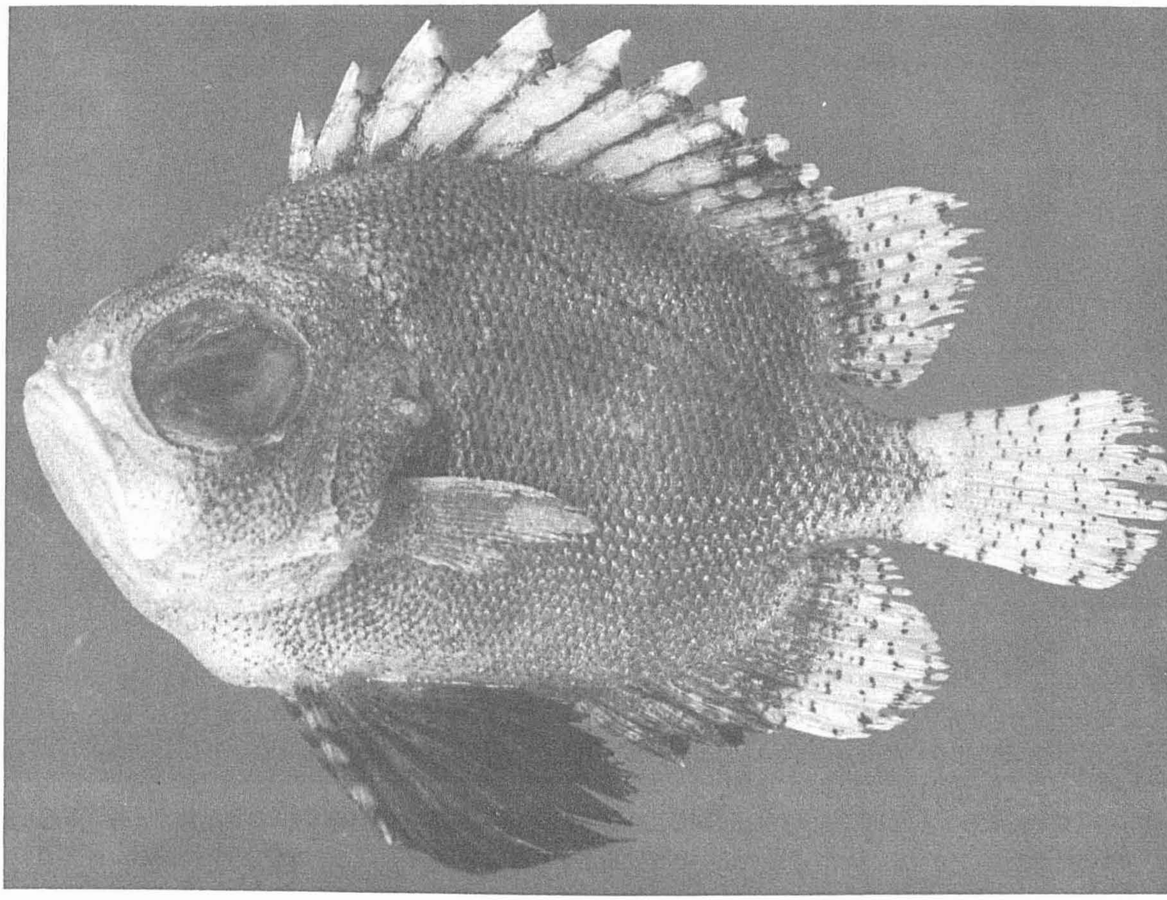

FIGURE 16.—Bottom-living prejuvenile *Pseudopriacanthus altus*, 40.7 mm. standard length (BLBG).

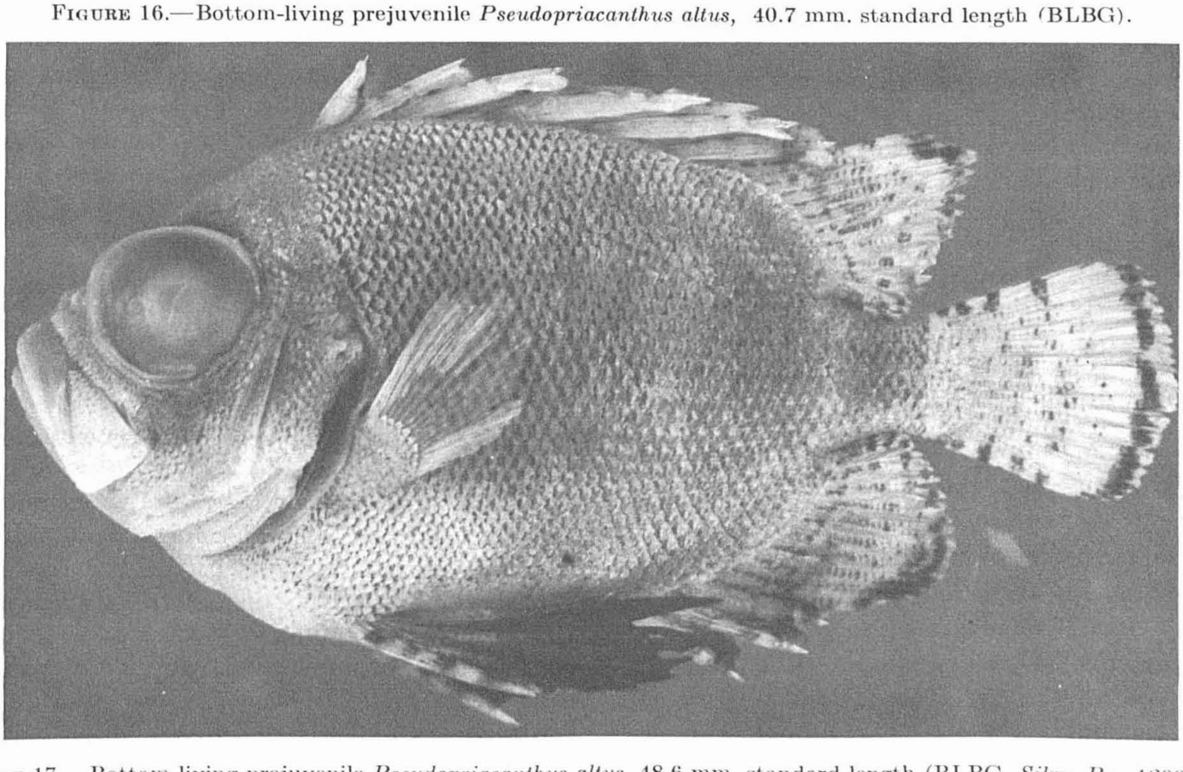

FIGURE 17.—Bottom-living prejuvenile *Pseudopriacanthus altus*, 48.6 mm. standard length (BLBG, *Silver Bay* 1299).

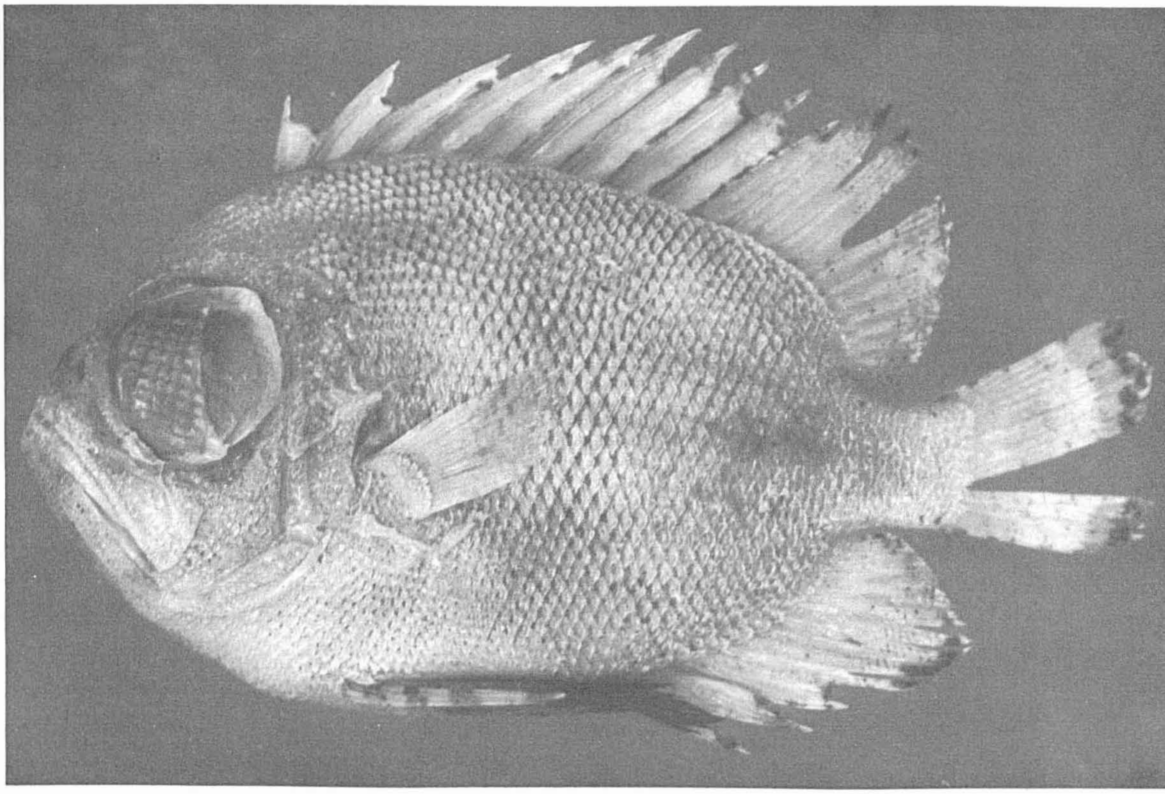

FIGURE 18.—Bottom-living prejuvenile *Pseudopriacanthus altus*, 58.9 mm. standard length (BLBG, *Silver Bay* 1268).

the membranes, until about 65 mm. (see fig. 19, 67.3 mm.) when, in the pigmented parts of the fin, it was concentrated almost entirely on the membranes. This pigmentation persisted through the largest sizes.

During the above sequence, beginning in a 16.8-mm. specimen (fig. 13), the basal parts of these fins began to lose pigment, although it persisted here in some specimens to about 50 mm. (see fig. 17, 48.6 mm.). Loss of pigment progressed distally (figs. 18 through 22) until in the largest examples (fig. 23, 261.8 mm.), only dark tips remained, with streaks of less intense pigment along the inner edges of some soft-rays. In the adults, the rays nearest the spine were the most heavily pigmented, and the rays became progressively less pigmented away from the spine.

In some specimens as small as 12.8 mm., the pigment on the single spine formed a pattern of three or four bars across the spine. After about 19.9 mm. (fig. 14), all specimens up to about 75 mm. (figs. 15 through 19) had this pattern. It was most intense at about 50 mm., and gradually diminished until the spine became immaculate after about 75 mm.

Caudal fin.—All specimens up to about 19.9 mm. (figs. 8–14) had immaculate caudal fins. A 22.9-mm. specimen also appeared to have an immaculate fin—a part of the fin was missing. A 23.2-mm. specimen bore small dark specks arranged in several irregular vertical rows along the caudal rays. This pigment pattern persisted until metamorphosis had begun. Unmetamorphosed specimens as large as 57.1 mm. showed this coloration, and one of them, 40.7 mm., is illustrated in figure 16. During metamorphosis (seen in specimens 34.5 to 65.2 mm.) the fin was specked, and the tips of the rays were nonpigmented. As metamorphosis progressed, these specks appeared to migrate distally along the rays and accumulate near the border of the fin, forming a band of black of varied intensity proximal to the light tips (figs. 16, 17, and 18). After metamorphosis was complete (in some specimens as small as 63.2 mm.) the fin was again immaculate except for the dark band, which from this stage onward appeared as a border on the fin (figs. 19 through 23).

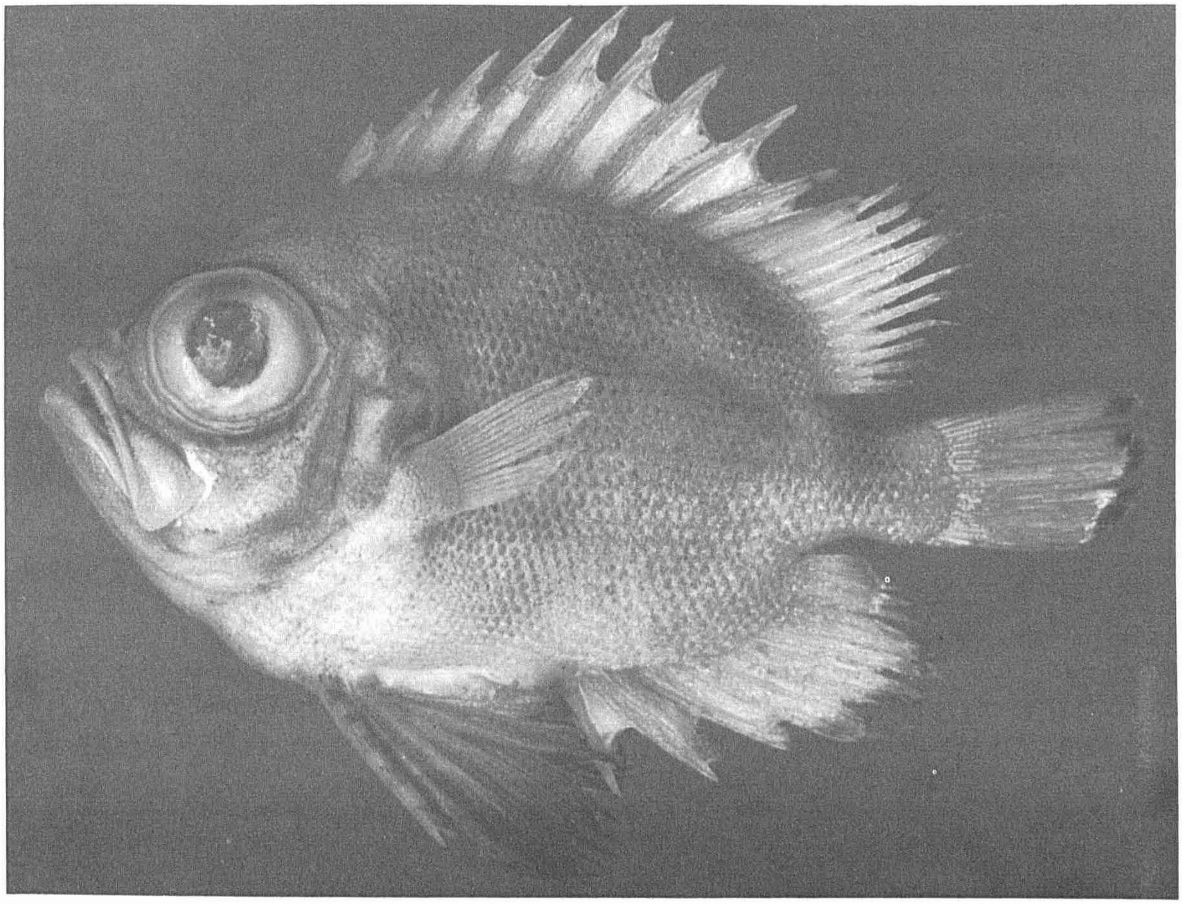

FIGURE 19.—Juvenile *Pseudopriacanthus altus*, 67.3 mm. standard length (UF 1434).

Dorsal fin.—The dorsal fin was immaculate in specimens up to 5.3 mm. The soft part of this fin continued immaculate in specimens up to 12.1 mm. (fig. 11) and in some to as large as 16.5 mm.

The interspinous membranes received pigment the earliest, and this was first noted in a 6.6-mm. specimen (fig. 10). The numerous pigment spots occupied the middle half of the membranes connecting the first seven spines of the fin. At 8.2 mm. pigment was present over the entire spinous fin, with the exception of the tips.[2] This pigment pattern intensified, especially along the edges of the spines, until in a 10.2-mm. specimen the fin appeared very dark.

In a 12.1-mm. individual, unpigmented disk-shaped areas had begun to form on the spines and adjacent membranes, half on spine and half on membrane, about midway of each spine (fig. 11). These clear areas, seemingly formed by the migration of pigment, formed a row of spots parallel to the base of the fin. The pigmented edges of these light spots were darker than the adjacent membrane, probably due to the migration and consequent crowding of the pigment as it retreated to form the unpigmented area. Also at about 12 mm. pigment had begun to appear at, and adjacent to, the base of the soft part of the dorsal, covering progressively less of the posterior soft-rays and their membranes (fig. 11).

At 15.0 mm. (fig. 12), the unpigmented spots in the initial row on the spinous dorsal had become more prominent and a second series of spots had begun to form distally and parallel to them. The tips of the spines and membrane at the tips remained unpigmented. Also at 15.0 mm. single chromatophores had begun migrating along the soft rays (but not along the membranes) from the pigment at the base of the soft fin.

[2] In preserved material the clear tips of the interspinous membranes often were torn away, giving the impression of color extending to the edge of the fin—not to be confused with the apparently normal loss of the membranous flaps at the tips of the spines, which occurs with change of habitat, or at approximately 50-60 mm.

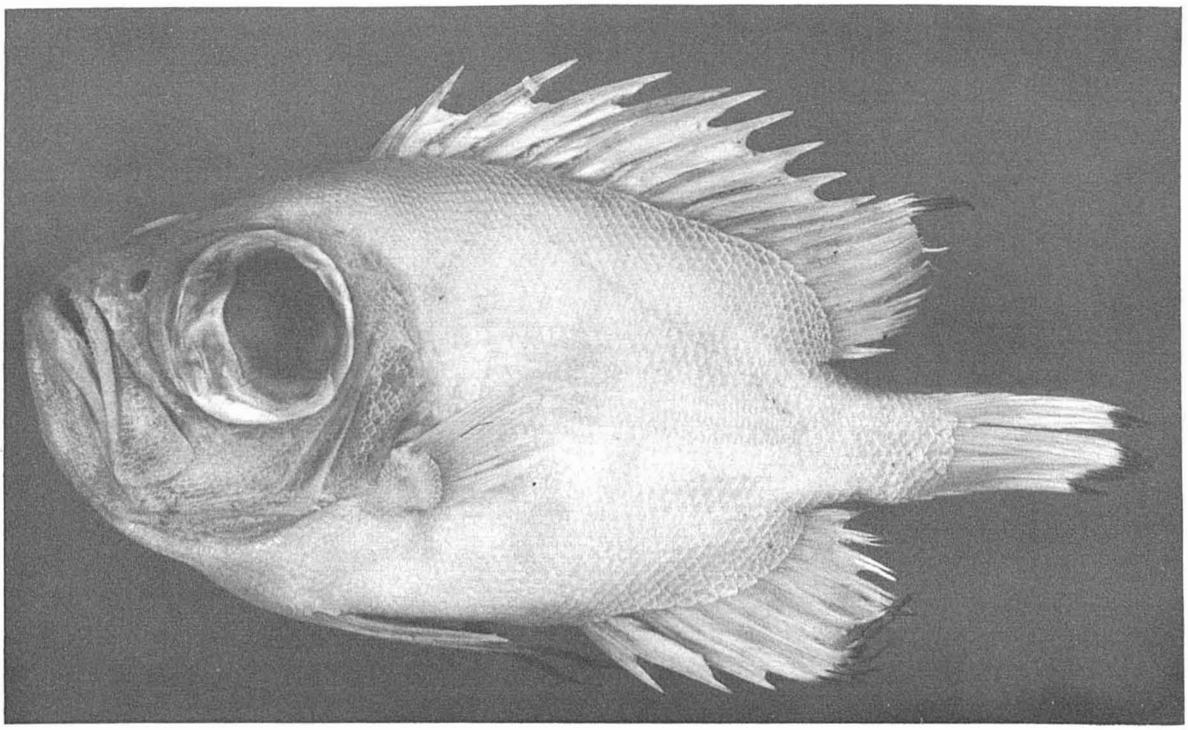

FIGURE 20.—Juvenile or adult *Pseudopriacanthus altus*, 108.3 mm. standard length (BLBG, *Oregon* 2608).

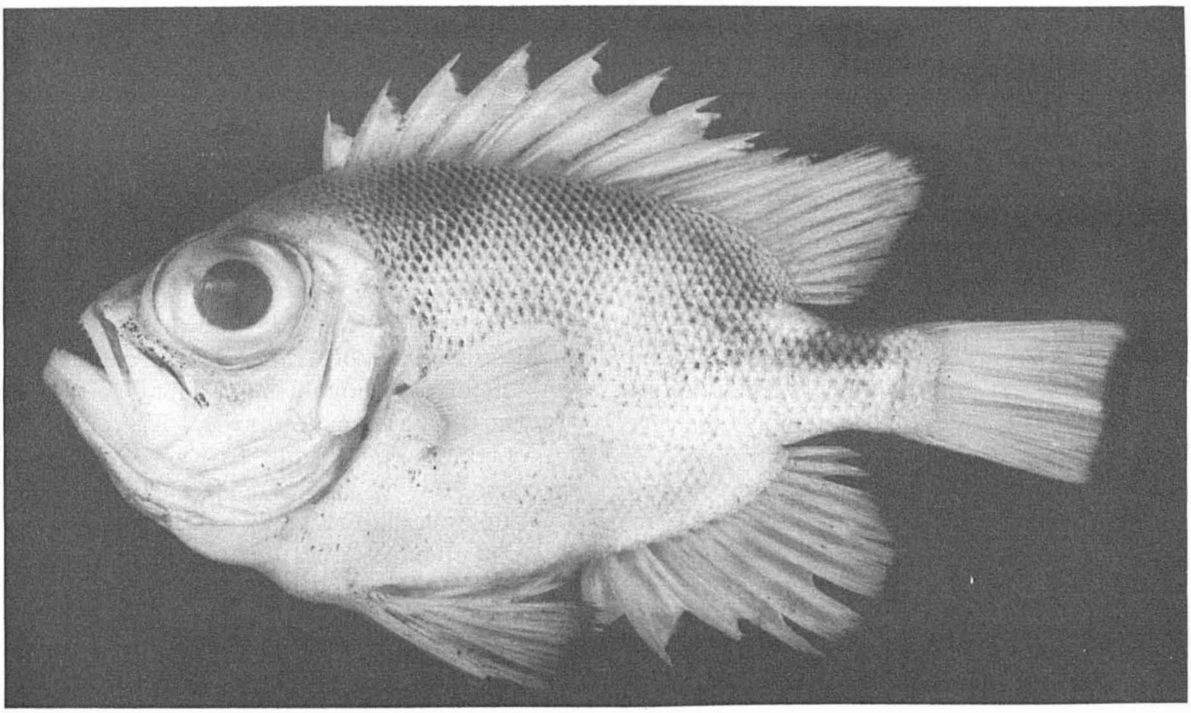

FIGURE 21.—Juvenile or adult *Pseudopriacanthus altus*, 129.8 mm. standard length (BLBG, *Silver Bay* 2079).

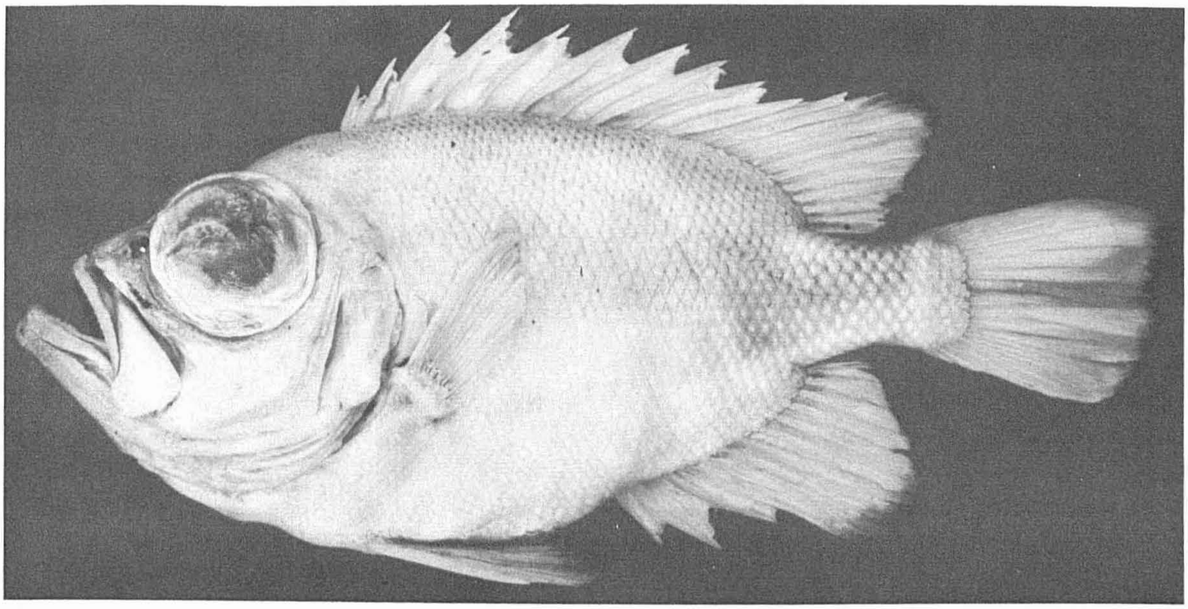

FIGURE 22.—Juvenile or adult *Pseudopriacanthus altus*, 236.6 mm. standard length (BLBG, *Silver Bay* 1393).

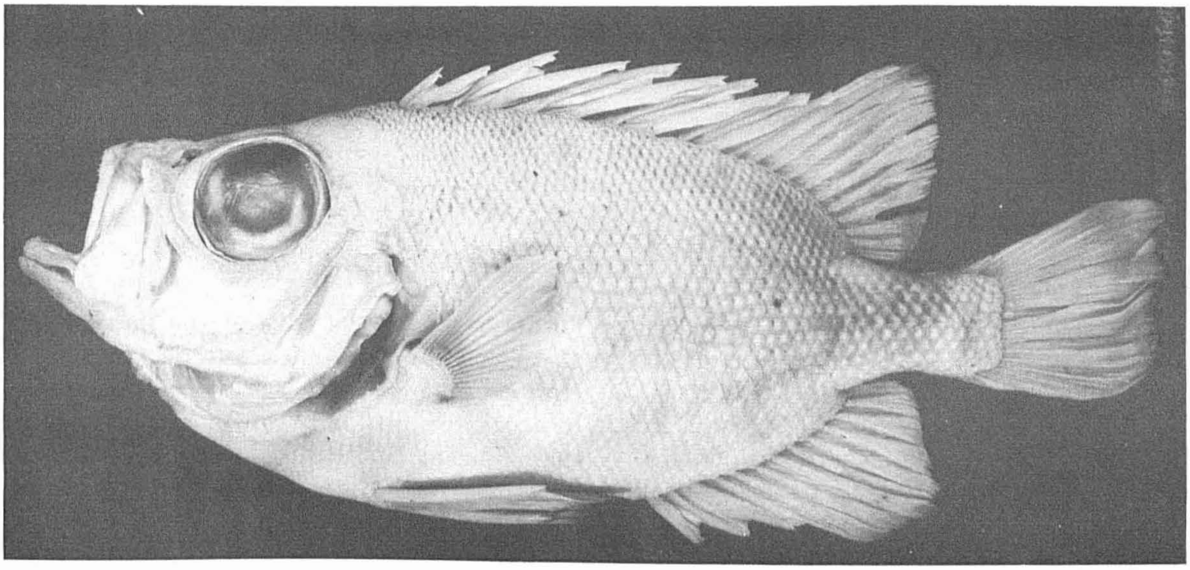

FIGURE 23.—Juvenile or adult *Pseudopriacanthus altus*, 261.8 mm. standard length (BLBG, *Silver Bay* 1393).

In a 16.8-mm. individual (fig. 13), a third row of light spots had begun to form at the base of the spinous dorsal, and pigment had just begun to form on the anteriormost inter-soft-ray membranes. This same dorsal-fin pigmentation was present in a 19.9-mm. individual (fig. 14).

By 34.0 mm. (fig. 15), three rows of unpigmented spots were prominent, and some of the spots extended anteriorly across the spine to the next interspinous membrane. A fourth row of spots had begun to form at the base of some spines. The pigment mass at the base of the rays and membranes of the soft dorsal fin had separated slightly from the base of the fin—a few isolated chromatophores remained on both the rays and their intermembranes. Scattered chromatophores were present on the soft-dorsal rays, between the pigment mass and the edge, forming several irregular rows parallel to the base of the fin. It seemed that a migrating chromatophore split upon reaching a branch in a soft-ray. In specimens of this size, about 34 mm., several light spots, similar to

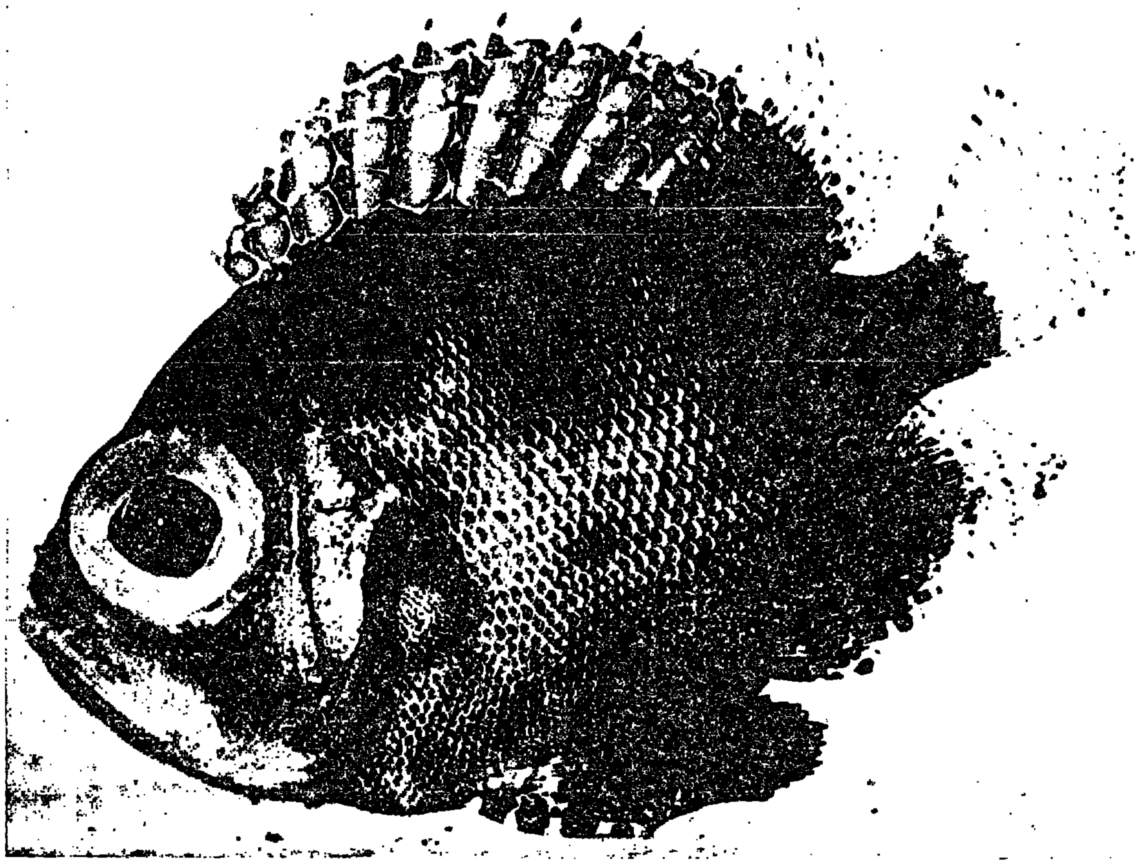

FIGURE 24.—Living prejuvenile *Pseudopriacanthus altus* (estimated 50 mm.).

those of the spinous part of the fin, were also present in the pigment mass at the base of the soft part of the fin.

On a 40.7-mm. specimen (fig. 16), the light spots on the spinous part of the dorsal fin had enlarged until there was only a suggestion of spots. The membrane bordering the anterior edge of each spine bore a line of dark pigment, and the spines retained a few chromatophores. The pigment mass near the base of the soft fin had moved farther distally, and the membranes were pigmented only at the base. The pigment mass was broken up by light spots. Distal to the mass, individual chromatophores were arranged in irregular rows, along the rays only, to the edge of the fin.

By 48.6 mm. (fig. 17), the spinous part of the fin was essentially unpigmented, except for a few scattered chromatophores near the anterior and posterior edges of the membranes. Some of the migrating pigment on the soft part of the fin had accumulated on the edge of the fin, particularly at the ends of the most anterior rays, and the chromatophores near the tips of the rays had broken into a mass of smaller spots extending onto the adjacent membranes. Of the original pigment mass at the base of the soft fin, only scattered chromatophores remained on the membranes and bands of pigment on the rays. In the basal area of the fin only the membranes retained pigment.

In a 58.9-mm. specimen (fig. 18) the lines of pigment on the membranes, parallel to the spines, were less intense, and all traces of the light spots on the spinous fin were gone. Some pigment remained at the distal edge of the interspinous membranes, especially on the most posterior spines, connecting the spines with a thin dark line. The basal half of the soft fin was immaculate and only a few scattered migrating chromatophores remained proximal to the dark anterior edge. The chromatophores on the posterior edge of the fin had nearly disappeared.

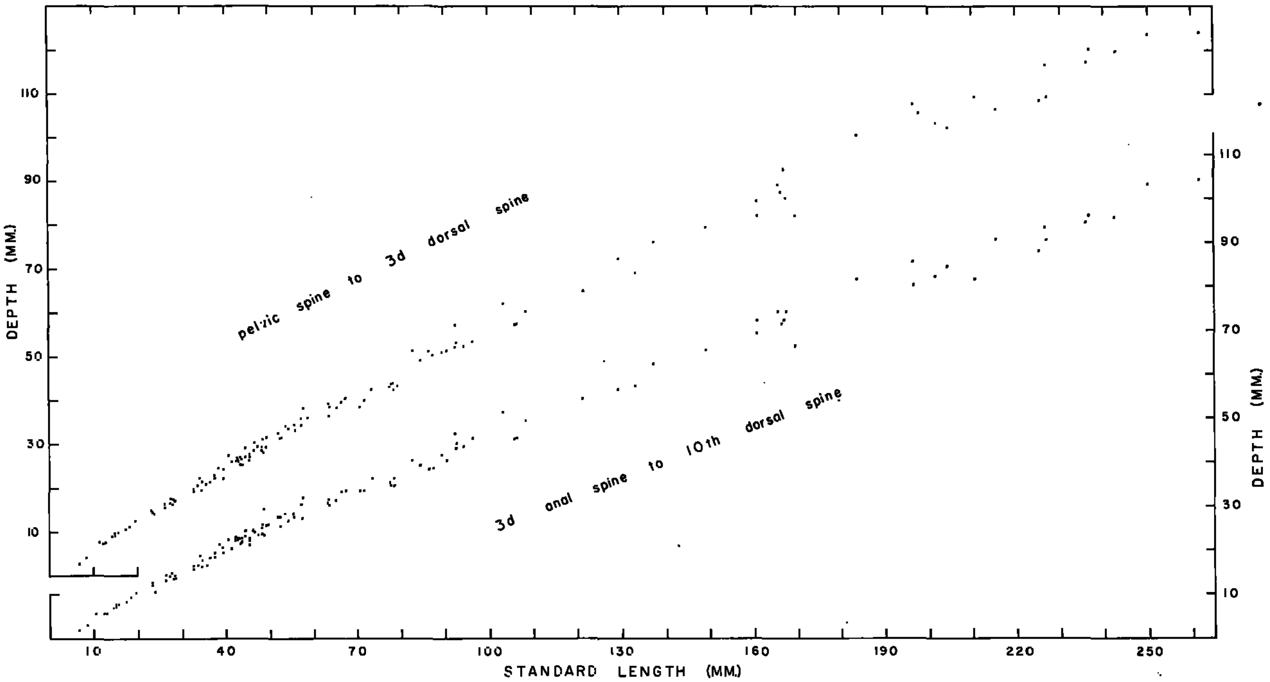

FIGURE 25.—Relation of body depth from pelvic spine insertion to 3d dorsal spine base and of body depth from 3d anal spine base to 10th dorsal spine base to standard length in *Pseudopriacanthus altus*.

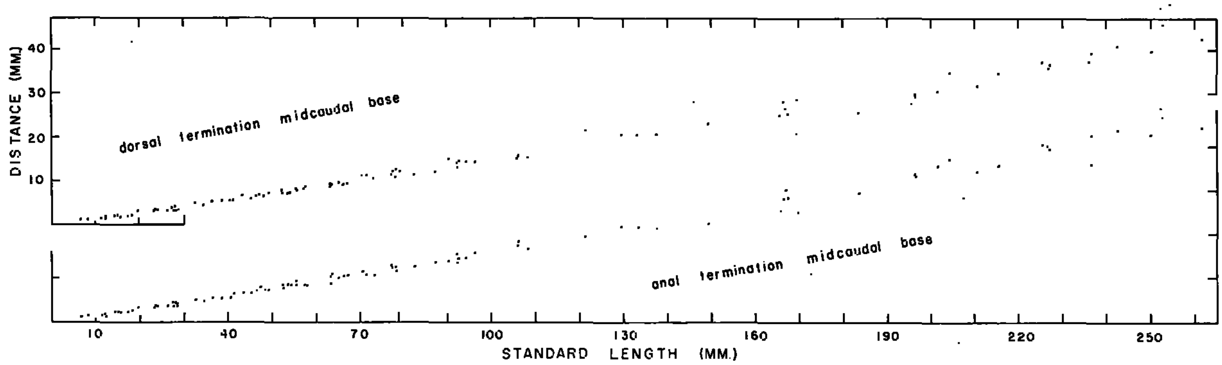

FIGURE 26.—Relation of distance from dorsal- and from anal-fin terminations to midcaudal base to standard length in *Pseudopriacanthus altus*.

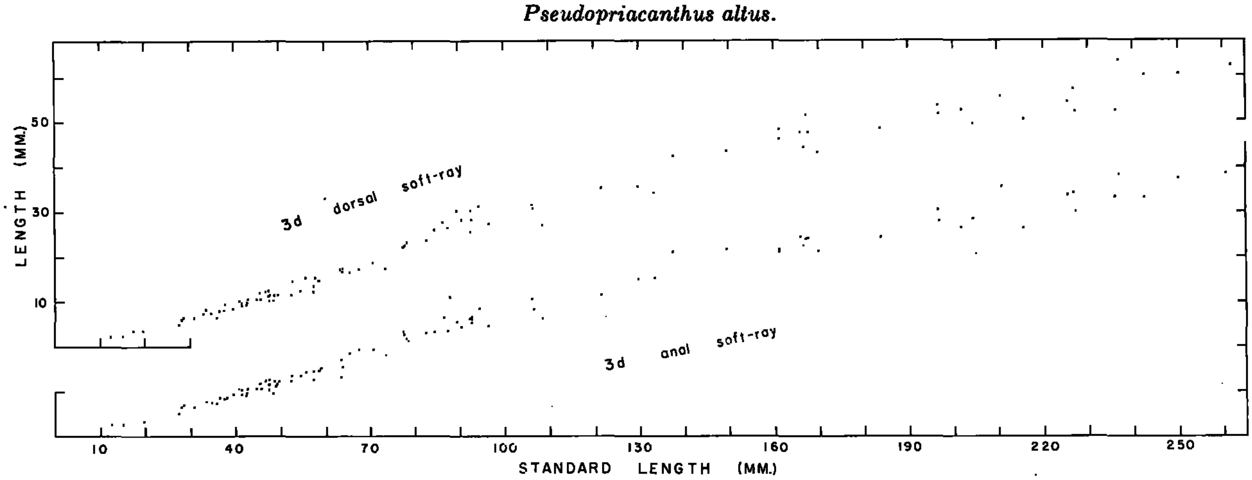

FIGURE 27.—Relation of lengths of 3d dorsal and 3d anal soft-ray to standard length in *Pseudopriacanthus altus*.

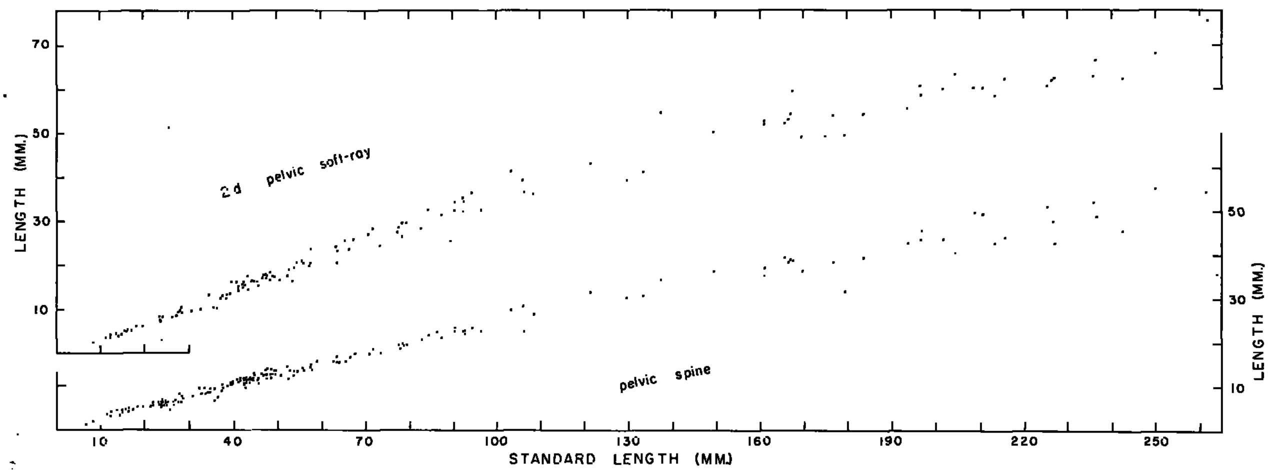

FIGURE 28.—Relation of length of pelvic spine and of 2d pelvic soft-ray to standard length in *Pseudopriacanthus altus*.

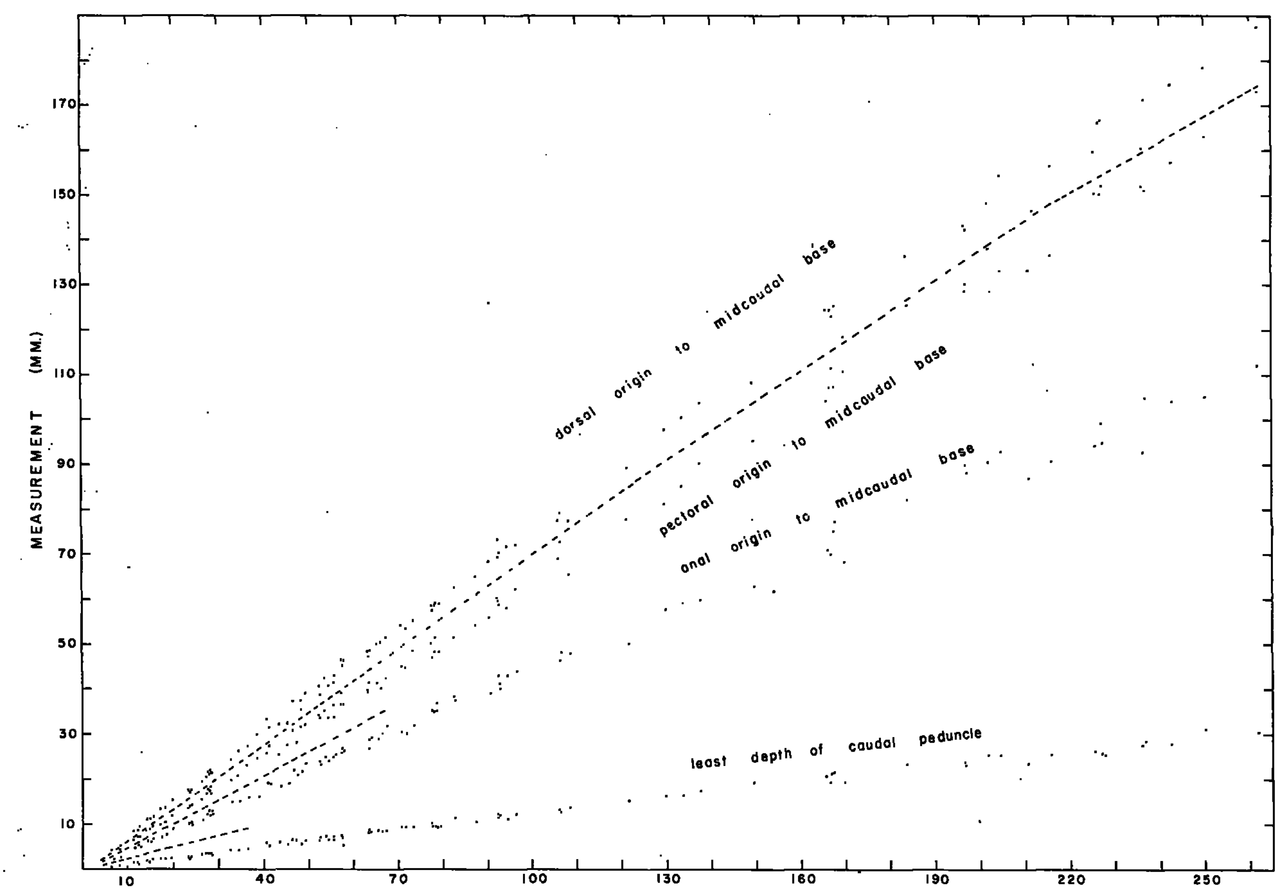

FIGURE 29.—Relation of least depth of caudal peduncle, of distance from origin of dorsal fin and from anal fin to midcaudal base, and of distance from origin of pectoral fin to midcaudal base to standard length in *Pseudopriacanthus altus*. (Dashed lines serve as guides in the separation of series of dots.)

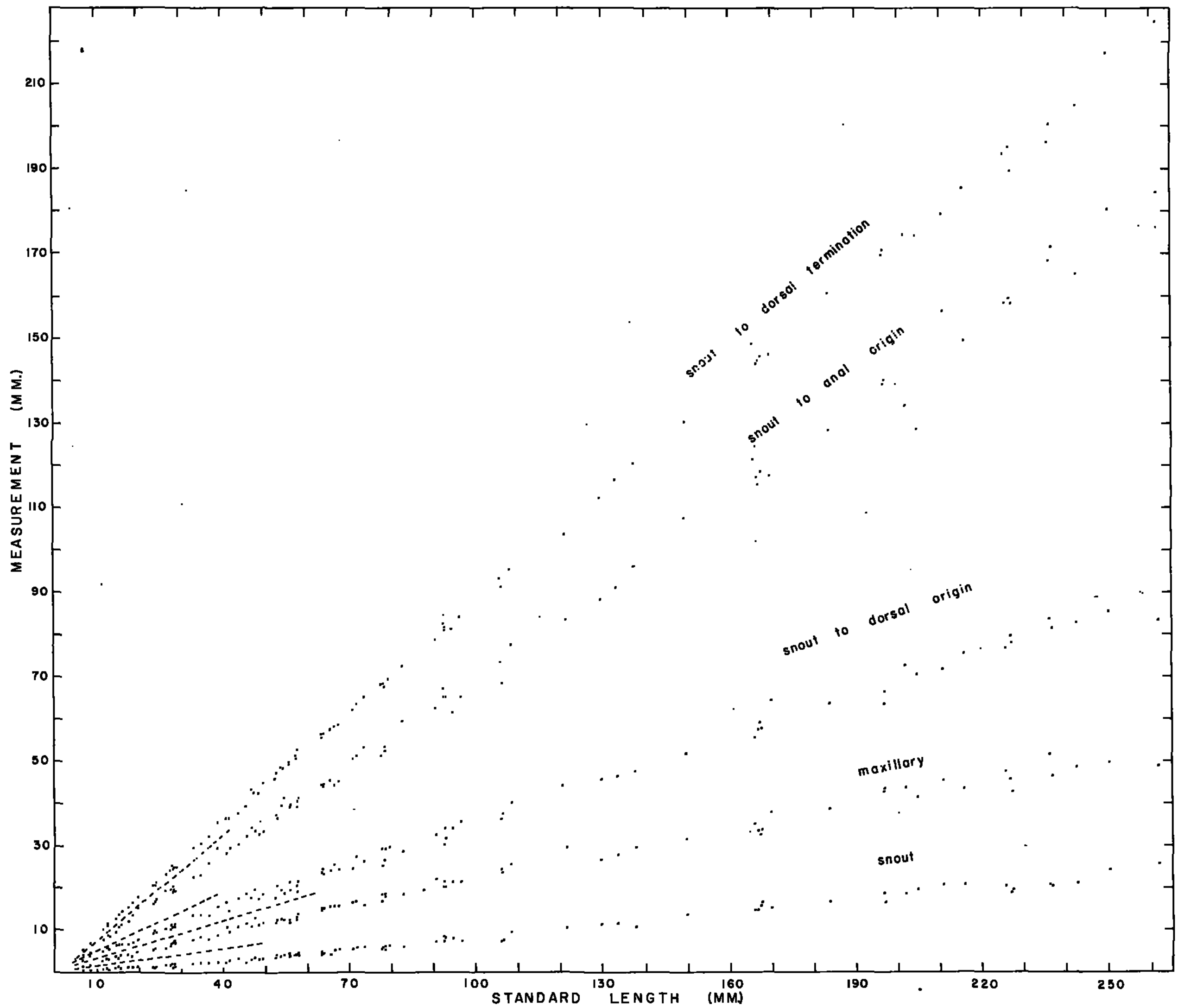

FIGURE 30.—Relation of snout length, of maxillary length, of distance from tip of snout to origins of dorsal and anal fins, and of distance from tip of snout to dorsal-fin termination to standard length in *Pseudopriacanthus altus*. (Dashed lines serve as guides in the separation of series of dots.)

In a 67.3-mm. individual (fig. 19), pigment of the dorsal fin consisted of only the black tips of the anteriormost soft-rays and traces of the lines parallel to the spines. In larger individuals, through the largest (261.8 mm.; see fig. 23), the lines of pigment parallel to the spines persisted in ever lessening degrees of intensity. The dark edge of the soft fin persisted without loss of intensity, and was broadest on the most anterior rays; it was never observed on the tips of the one or two most posterior soft-rays.

Anal fin.—The pigment pattern and its development on the anal fin were so similar to those of the dorsal fin, both in sequence and in size of fish at which the pattern developed, that it is unnecessary repetition to describe them here, other than to note a few minor differences.

Pigment on the anal fin was first observed on an 8.2-mm. specimen. Two rows of light spots, plus the light tips, appeared to be the maximum development of this pattern on the spinous fin, as seen at 34.0 mm. (similar to the maximum spotting on the spinous dorsal fin; see fig. 15). Lines of pigment parallel to the spines developed subsequent to the spots. The line anterior to the second spine persisted to about 65 mm., whereas

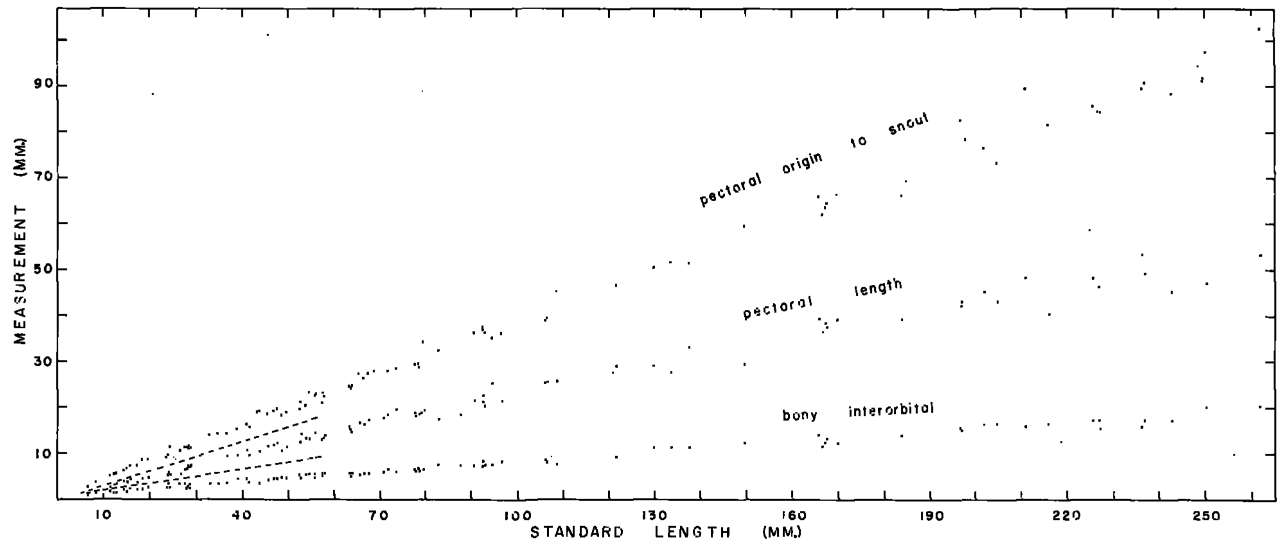

FIGURE 31.—Relation of interorbital width, of pectoral-fin length, and of distance from pectoral-fin origin to tip of snout to standard length in *Pseudopriacanthus altus*. (Dashed lines serve as guides in the separation of series of dots.)

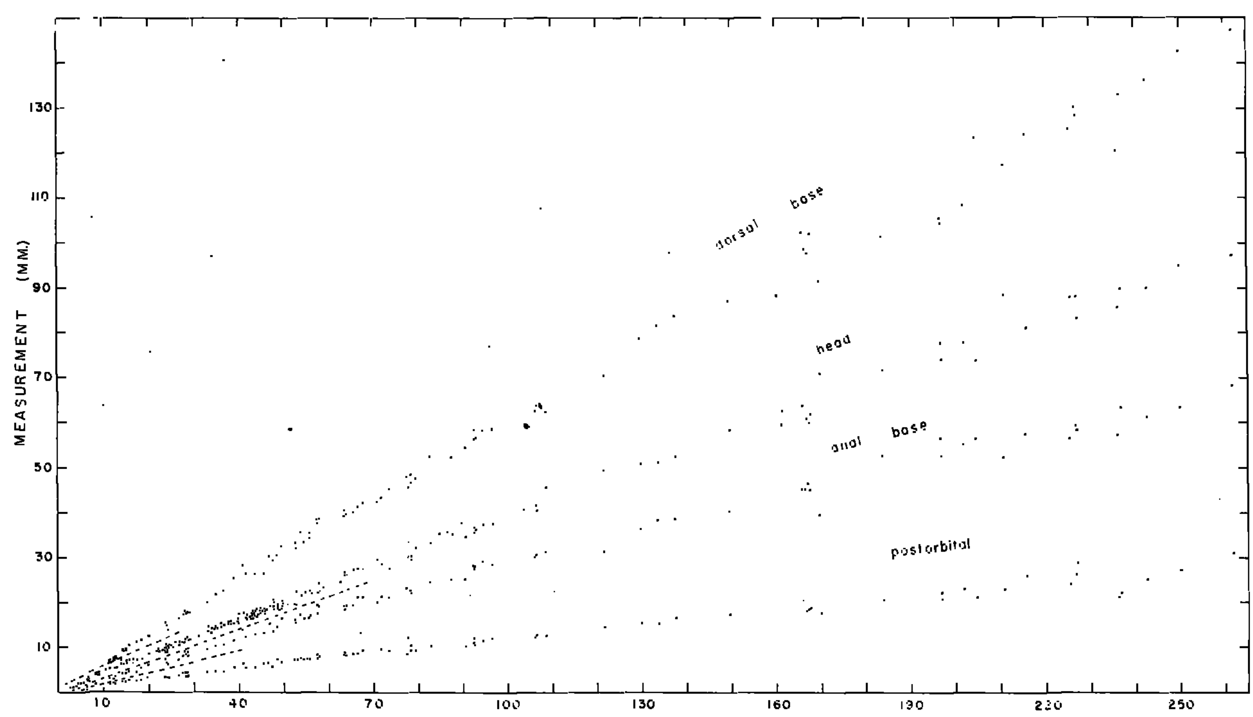

FIGURE 32.—Relation of postorbital length, of dorsal-fin and of anal-fin bases, and of head length to standard length in *Pseudopriacanthus altus*. (Dashed lines serve as guides in the separation of series of dots.)

the line adjacent to the third spine persisted to the largest size.

PIGMENTATION OF LIVING AND FRESHLY PRESERVED SPECIMENS

The following color notes were made on a 196.5-mm. specimen of *P. altus* collected by handline in 25 fathoms off Panama City, Florida, on April 19, 1958. The notes on live color were made from the fish just before preservation and from a Kodachrome transparency made of the specimen before preservation. The notes after preservation were made on April 21, after the fish had been killed and preserved in 10-percent formalin and not exposed to light beyond the first few hours.

In Life

Alive, and just after capture, the specimen was bright carmine with the exception of the black edges on the soft-dorsal and anal fins, and on the caudal and pelvic fins.

When the live fish was handled before preservation, its color faded into carmine bars and very light pink interspaces (see body pigmentation of preserved adult). The dorsal fin was yellow-orange below milky white tips. The iris of the eye was golden, and the surrounding areas carmine.

Two Days After Preservation

The interspinous membranes of the dorsal and anal fins were yellow except for milky areas in the shape of right triangles near the spine tips. The base of the triangle was parallel to the body of the fish, and the perpendicular side was against the anterior of the two spines. The leading edges of the dorsal spines were dark carmine except for their tips. The caudal, soft-dorsal, and soft-anal fins were light, mottled carmine with black edges. In the soft dorsal these mottled areas formed four alternating light and dark bands directed obliquely dorsoventrally, beginning with a dark anterior band. The pelvic fin was light carmine with a black edge, and the pectoral was light carmine.

These descriptions agree with the usual descriptions of color in the literature; i.e., a crimson fish with black markings on vertical and pelvic fins. The pattern of black, as noted in the description of preserved color, varies with the size of the fish. The brief color descriptions by Smith (1907: p. 285) and Jordan and Evermann (1896: p. 1240) apparently are from a large fish; that of Hildebrand and Schroeder (1928: p. 255) from a transforming prejuvenile.

The color of the live pelagic prejuvenile has not been described. That of a close relative, *Priacanthus cruentatus* (Lacépède), has been described elsewhere (D. K. Caldwell, in press) and consisted of blues and silvers—as expected in most pelagic prejuveniles (Hubbs, 1941: p. 184). The coloration of pelagic *Pseudopriacanthus altus* may be similar, with the red hue assumed almost immediately on arrival inshore.

The usual reference to color of specimens caught in tidepools—all such references seen were from the northern latitudes—is "bright red" (see for example, Nichols and Breder, 1927: p. 83). Scattergood and Coffin (1957: p. 156), in a more detailed description, said of the color of a 28-mm. individual collected in a trap set at 10 fathoms—

> The body color in life was orange red; the spiny dorsal fin had two rows of orange spots, two on each spine; the ventral spine had two orange spots; the iris had four white spots; and immediately above the lateral line was a row of 12 black blotches.

The lateral-line spots of my prejuvenile *Pseudopriacanthus altus* were discussed in the section on body pigmentation of preserved specimens. The orange spots on the spinous dorsal of Scattergood and Coffin's specimen apparently are the light spots I described for preserved specimens.

These spots on the spinous dorsal do appear dark in a black and white photograph of a living specimen of unstated size (fig. 24), taken through an aquarium glass at Marine Studios, Florida; I did not see the living fish. This fish is probably the same metamorphosing specimen I referred to earlier as being about 40 mm. at capture and 73 mm. at death. The date of capture was August 7, and that on the photograph, "Sept." In the photograph of the living fish the dark areas on the spinous fin are edged with black, as are the light areas on the same fin after preservation. The spaces between these black-edged disks are light on the living fish, while in a preserved specimen of slightly smaller size they are dusky (fig. 15). The spots Scattergood and Coffin referred to on the ventral spine are probably the light areas I referred to on the pelvic spine. Gordon (1960: plate 49) showed a photograph of an apparently freshly killed pretransformation prejuvenile exhibiting coloration similar to that of this living specimen. He described the color of the specimen as brilliant red (p. 61). However, he indicated the specimen was collected inshore. A color transformation from blue-silver hues to red may be very rapid with change of habitat.

P. altus lives primarily in deeper water in dark crevasses of rocks. As pinks and reds become invisible in deep water, the short bigeye may possibly take on this coloration as camouflage. Dr. John E. Randall, first in conversation with Jack W. Gehringer in June 1960, and later by letter dated September 16, 1960, stated that closely related *Priacanthus arenatus* Cuvier seen just off the bottom in 60 feet of water on a reef at St. John, Virgin Islands, appeared a neutral gray to the eye and in a color motion picture film. Randall stated that on transport to the surface, the fish was a deep red, but that this change was an artifact of the loss of the red end of the spectrum at 60 feet and that a flash photograph of the fish at that depth in reality shows them to be dark red at all times.

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APPENDIX

The measurements taken which were only discussed and graphed, but otherwise not indicated by empirical values, are of considerable value to systematists, and have been included here in table A–1. Those measurements discussed in some degree are also included for completeness.

TABLE A–1.—*Empirical measurements (mm.) of selected body parts for 248 specimens of* Pseudopriacanthus altus *from throughout its range*

[See Definitions, p. 104 for method of taking measurement]

Body part measured	Standard length (mm.) of specimen																	
	2.2	2.4	2.6	2.7	2.7	3.2	3.2	3.4	3.5	3.9	4.0	4.4	4.8	5.2	5.3	5.8	6.6	8.2
Depth from pelvic spine base to 3d dorsal spine base																	2.8	4.1
Depth from 3d anal spine base to 10th dorsal spine base																	1.9	3.0
Head length				1.2		1.2	1.3			1.7	1.8	2.1	2.1		2.3		3.2	4.1
Snout–dorsal-fin origin																	2.9	3.9
Snout–dorsal-fin termination																	5.1	6.9
Snout–anal-fin origin																	4.1	4.7
Snout length																	0.7	0.7
Postorbital length																	0.8	1.6
Least depth of caudal peduncle																	0.7	0.9
Dorsal-fin origin–midcaudal base																	3.8	5.1
Dorsal-fin termination–midcaudal base																	1.1	1.1
Anal-fin origin–midcaudal base																	2.4	2.9
Anal-fin termination–midcaudal base																	1.1	1.3
Dorsal-fin base																	2.8	4.0
Anal-fin base																	1.2	1.9
Pectoral-fin origin–snout																	2.9	3.8
Pectoral-fin origin–midcaudal base																	3.3	4.1
Pectoral-fin length																		
Pelvic-spine length																	1.1	2.0
2d pelvic ray length																		2.5
Eye diameter	0.3	0.3	0.4	0.4	0.5	0.6	0.5	0.6	0.5	0.7	1.0	.0.8	1.0	1.1	1.0	1.4	1.3	1.6
Interorbital width																	0.8	1.2
Maxillary length																	1.2	1.6
3d dorsal ray length																		
3d anal ray length																		

Body part measured	Standard length (mm.) of specimen																	
	8.3	8.6	8.7	10.2	10.5	11.2	11.3	12.1	12.4	12.8	12.8	13.7	13.8	13.9	14.2	14.3	14.5	14.8
Depth from pelvic spine base to 3d dorsal spine base							7.4	7.7	7.8						9.0			
Depth from 3d anal spine base to 10th dorsal spine base							5.6	5.8	5.9						7.0			
Head length	4.0	4.1	4.5	5.0			5.5	5.7	5.9	5.8			6.5	7.1	6.5			
Snout–dorsal-fin origin							5.0	5.8	5.9						6.4			
Snout–dorsal-fin termination							10.0	11.0	11.4						12.8			
Snout–anal-fin origin							7.7	8.7	8.6						9.5			
Snout length							1.0	1.1	0.8						1.1			
Postorbital length							2.0	2.1	2.0						2.2			
Least depth of caudal peduncle							1.7	1.6	1.6						2.0			
Dorsal-fin origin–midcaudal base							8.4	8.8	9.7						11.0			
Dorsal-fin termination–midcaudal base							1.5	1.8	2.0						2.0			
Anal-fin origin–midcaudal base							5.0	5.6	5.4						6.5			
Anal-fin termination–midcaudal base							1.7	1.9	1.8						2.1			
Dorsal-fin base							6.8	7.2	7.5						9.2			
Anal-fin base							3.4	3.3	3.6						4.2			
Pectoral-fin origin–snout							5.1	5.5	5.7						6.4			
Pectoral-fin origin–midcaudal base							6.5	7.0	7.0						8.5			
Pectoral-fin length							2.5	3.0	3.2						3.7			
Pelvic-spine length							3.4	3.3	4.2				4.6		3.3			
2d pelvic ray length							3.7	3.9	4.3				4.7		4.0			
Eye diameter	1.8	1.8	2.0	2.5	2.2	2.2	2.6	2.5	2.6	2.8	2.6	3.0	3.0	3.3	2.9	3.0	2.8	2.8
Interorbital width							1.8	1.5	1.5						2.0			
Maxillary length							2.7	3.0	3.0						3.4			
3d dorsal ray length								2.4										
3d anal ray length								2.6										

TABLE A-1.—*Empirical measurements (mm.) of selected body parts for 248 specimens of* Pseudopriacanthus altus *from throughout its range*—Continued

Body part measured	Standard length (mm.) of specimen																	
	14.9	15.0	15.0	15.1	15.1	15.6	15.7	15.8	16.1	16.1	16.4	16.5	16.8	16.9	16.9	17.1	17.3	18.4
Depth from pelvic spine base to 3d dorsal spine base		9.4	9.6					10.0									10.8	11.2
Depth from 3d anal spine base to 10th dorsal spine base		7.3	7.1					7.9									8.4	9.1
Head length		7.0	6.8					7.4	6.8		7.3						7.4	7.6
Snout-dorsal-fin origin		6.5						6.7									6.6	7.0
Snout-dorsal-fin termination		13.7						14.2									15.2	16.3
Snout-anal-fin origin		10.9						11.1									12.0	13.3
Snout length		1.5						1.3									1.3	1.4
Postorbital length		2.3						2.6									2.6	2.9
Least depth of caudal peduncle		1.9						2.2									2.3	2.4
Dorsal-fin origin-midcaudal base		11.3						11.9									13.2	13.9
Dorsal-fin termination-midcaudal base		2.1						1.9									2.0	2.4
Anal-fin origin-midcaudal base		6.3						7.0									7.2	8.0
Anal-fin termination-midcaudal base		2.2						2.1									2.2	2.6
Dorsal-fin base		9.5						10.3									11.0	11.8
Anal-fin base		4.2						4.8									4.8	5.6
Pectoral-fin origin-snout		6.9						7.3									7.5	8.6
Pectoral-fin origin-midcaudal base		8.6						9.2									9.9	10.1
Pectoral-fin length		3.6						4.1									3.5	4.4
Pelvic-spine length		4.1	4.6					4.9	4.2		5.0						4.8	5.4
2d pelvic ray length		4.7						5.1	5.1		5.3						5.3	6.1
Eye diameter	3.4	3.1	3.2	2.9	3.0	3.0	3.2	3.0	3.0	3.1	3.5	3.0	3.4	3.4	3.6	3.4	3.5	3.6
Interorbital width		1.6						2.1									2.0	2.2
Maxillary length		3.1						4.0									4.0	3.9
3d dorsal ray length		2.8															3.6	
3d anal ray length		2.7																

Body part measured	Standard length (mm.) of specimen																	
	18.4	19.9	19.9	21.1	21.7	21.8	22.9	23.2	23.3	23.5	23.5	23.5	23.5	23.6	23.7	23.8	23.9	24.0
Depth from pelvic spine base to 3d dorsal spine base		12.7						15.0								14.8		14.2
Depth from 3d anal spine base to 10th dorsal spine base		10.1						12.3								12.1		10.5
Head length		8.8	8.5	9.2	9.7	9.4	9.5	9.8		10.7	10.0	9.9	10.0	10.0	9.8	9.8	10.1	10.5
Snout-dorsal-fin origin		7.7						9.3								9.9		9.8
Snout-dorsal-fin termination		17.8						20.7								20.8		21.1
Snout-anal-fin origin		15.0						16.4								16.7		17.1
Snout length		1.7						1.7								1.4		1.6
Postorbital length		3.3						3.5								3.5		3.5
Least depth of caudal peduncle		2.4						2.9								2.9		2.9
Dorsal-fin origin-midcaudal base		15.3						17.9								17.4		17.3
Dorsal - fin termination-midcaudal base		3.3						3.2								3.7		3.6
Anal-fin origin-midcaudal base		9.4						10.6								10.8		10.1
Anal-fin termination-midcaudal base		3.3						3.4								3.6		3.7
Dorsal-fin base		12.4						15.4								14.9		13.8
Anal-fin base		6.2						7.5								6.9		6.6
Pectoral-fin origin-snout		8.7						9.2								9.9		11.2
Pectoral-fin origin-midcaudal base		11.6						13.4								13.8		14.0
Pectoral-fin length		4.6						5.1								5.8		5.2
Pelvic-spine length		5.3		5.4	5.7	6.1	6.3	6.4		5.1	5.9	6.3	6.0	5.7	6.6	5.8	15.8	5.8
2d pelvic ray length		6.1						8.4		7.3						7.2		8.4
Eye diameter	3.6	4.0	4.5	4.6	4.7	4.6	4.8	5.0	5.3	5.5	4.9	5.3	4.8	5.0	4.8	4.9	4.6	5.2
Interorbital width		2.7						2.9								3.2		2.6
Maxillary length		4.7						5.1								5.2		
3d dorsal ray length		3.6																
3d anal ray length		3.3																

TABLE A-1.—*Empirical measurements (mm.) of selected body parts for 248 specimens of* Pseudopriacanthus altus *from throughout its range*—Continued

Body part measured	Standard length (mm.) of specimen																	
	24.1	24.2	24.4	24.5	25.0	25.6	26.1	26.4	26.6	27.4	27.9	28.0	28.1	28.4	30.8	32.7	32.8	33.2
Depth from pelvic spine base to 3d dorsal spine base	-----	-----	-----	-----	-----	-----	15.8	16.7	-----	16.9	17.9	16.6	17.7	17.3	-----	19.9	19.5	-----
Depth from 3d anal spine base to 10th dorsal spine base	-----	-----	-----	-----	-----	-----	13.2	14.5	-----	14.1	14.8	13.8	14.1	13.9	-----	16.3	15.6	-----
Head length	10.8	10.4	10.6	10.3	10.4	11.2	10.9	11.5	11.1	11.2	12.0	12.1	11.8	11.9	12.7	13.8	14.5	13.5
Snout-dorsal-fin origin	-----	-----	-----	-----	-----	-----	10.2	-----	-----	10.2	11.3	10.9	11.0	11.4	-----	-----	13.6	-----
Snout-dorsal-fin termination	-----	-----	-----	-----	-----	-----	23.3	-----	-----	24.1	25.4	24.6	25.0	25.0	-----	-----	29.7	-----
Snout-anal-fin origin	-----	-----	-----	-----	-----	-----	19.5	-----	-----	19.8	20.1	19.0	19.6	19.2	-----	-----	22.7	-----
Snout length	-----	-----	-----	-----	-----	-----	2.0	-----	-----	2.0	2.1	1.8	1.7	2.2	-----	-----	2.2	-----
Postorbital length	-----	-----	-----	-----	-----	-----	3.8	-----	-----	4.2	4.2	3.9	4.2	3.9	-----	-----	4.4	-----
Least depth of caudal peduncle	-----	-----	-----	-----	-----	-----	3.3	-----	-----	3.6	3.7	3.6	3.6	3.7	-----	-----	4.1	-----
Dorsal-fin origin-midcaudal base	-----	-----	-----	-----	-----	-----	19.5	-----	-----	20.6	21.8	21.8	22.0	21.5	-----	-----	24.5	-----
Dorsal-fin termination-midcaudal base	-----	-----	-----	-----	-----	-----	3.3	-----	-----	4.0	3.5	4.1	3.5	3.7	-----	-----	5.0	-----
Anal-fin origin-midcaudal base	-----	-----	-----	-----	-----	-----	11.2	-----	-----	12.8	13.3	12.5	13.1	12.6	-----	-----	15.1	-----
Anal-fin termination-midcaudal base	-----	-----	-----	-----	-----	-----	3.9	-----	-----	4.3	3.7	4.2	4.0	3.8	-----	-----	5.0	-----
Dorsal-fin base	-----	-----	-----	-----	-----	-----	16.4	-----	-----	17.1	18.0	17.5	17.9	17.9	-----	-----	20.0	-----
Anal-fin base	-----	-----	-----	-----	-----	-----	7.3	-----	-----	8.4	9.1	8.6	9.0	8.4	-----	-----	9.8	-----
Pectoral-fin origin-snout	-----	-----	-----	-----	-----	-----	10.6	-----	-----	11.5	11.5	11.4	11.3	11.6	-----	-----	14.0	-----
Pectoral-fin origin-midcaudal base	-----	-----	-----	-----	-----	-----	15.4	-----	-----	16.7	17.6	17.4	18.1	16.9	-----	-----	19.7	-----
Pectoral-fin length	-----	-----	-----	-----	-----	-----	5.5	-----	-----	6.5	6.9	7.1	7.1	7.0	-----	-----	-----	-----
Pelvic-spine length	6.3	6.7	6.4	6.2	6.2	4.9	6.3	5.7	6.9	6.4	8.0	6.5	7.6	7.2	7.7	9.1	8.1	9.6
2d pelvic ray length	-----	-----	-----	-----	-----	-----	8.4	-----	-----	8.9	9.5	9.7	9.1	10.4	9.9	-----	10.0	-----
Eye diameter	5.2	5.2	5.1	4.9	4.9	6.2	5.6	5.9	5.2	5.5	6.8	6.6	6.5	6.7	6.8	7.4	8.2	6.4
Interorbital width	-----	-----	-----	-----	-----	-----	3.2	-----	-----	3.4	2.4	2.8	2.2	3.1	-----	-----	3.1	-----
Maxillary length	-----	-----	-----	-----	-----	-----	5.8	-----	-----	6.1	6.9	7.0	7.0	7.4	-----	-----	7.9	-----
3d dorsal ray length	-----	-----	-----	-----	-----	-----	-----	-----	-----	5.0	-----	6.2	-----	6.5	6.7	-----	7.2	8.1
3d anal ray length	-----	-----	-----	-----	-----	-----	-----	-----	-----	5.0	-----	6.8	-----	7.0	6.6	-----	-----	7.6

Body part measured	Standard length (mm.) of specimen																	
	33.9	34.0	34.5	34.8	35.7	35.7	36.4	37.1	37.3	37.5	37.6	38.4	38.8	39.2	39.2	39.2	39.9	40.7
Depth from pelvic spine base to 3d dorsal spine base	20.9	22.3	19.8	21.5	-----	21.0	21.5	-----	23.0	22.1	-----	-----	24.2	22.3	24.3	-----	-----	-----
Depth from 3d anal spine base to 10th dorsal spine base	16.9	18.8	16.4	17.7	-----	16.7	18.1	-----	18.3	19.3	-----	-----	21.2	19.4	20.5	-----	-----	-----
Head length	14.2	14.2	14.8	14.2	15.3	14.8	15.0	15.3	15.5	15.5	15.8	15.1	15.3	15.8	16.5	15.6	17.6	-----
Snout-dorsal-fin origin	-----	-----	13.7	-----	-----	-----	13.3	-----	-----	-----	-----	-----	15.2	-----	-----	-----	-----	-----
Snout-dorsal-fin termination	-----	-----	30.7	-----	-----	-----	32.3	-----	-----	-----	-----	-----	35.7	-----	-----	-----	-----	-----
Snout-anal-fin origin	-----	-----	23.0	-----	-----	-----	26.0	-----	-----	-----	-----	-----	29.3	-----	-----	-----	-----	-----
Snout length	-----	-----	2.6	-----	-----	-----	2.7	-----	-----	-----	-----	-----	2.6	-----	-----	-----	-----	-----
Postorbital length	-----	-----	4.8	-----	-----	-----	4.7	-----	-----	-----	-----	-----	5.4	-----	-----	-----	-----	-----
Least depth of caudal peduncle	-----	-----	4.2	-----	-----	-----	4.8	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Dorsal-fin origin-midcaudal base	-----	-----	26.3	-----	-----	-----	27.5	-----	-----	-----	-----	-----	30.0	-----	-----	-----	-----	-----
Dorsal-fin termination-midcaudal base	-----	-----	4.5	-----	-----	-----	5.4	-----	-----	-----	-----	-----	5.5	-----	-----	-----	-----	-----
Anal-fin origin-midcaudal base	-----	-----	15.5	-----	-----	-----	16.3	-----	-----	-----	-----	-----	16.5	-----	-----	-----	-----	-----
Anal-fin termination-midcaudal base	-----	-----	4.9	-----	-----	-----	5.4	-----	-----	-----	-----	-----	5.1	-----	-----	-----	-----	-----
Dorsal-fin base	-----	-----	21.7	-----	-----	-----	22.7	-----	-----	-----	-----	-----	25.3	-----	-----	-----	-----	-----
Anal-fin base	-----	-----	10.4	-----	-----	-----	10.8	-----	-----	-----	-----	-----	11.7	-----	-----	-----	-----	-----
Pectoral-fin origin-snout	-----	-----	14.1	-----	-----	-----	14.1	-----	-----	-----	-----	-----	15.2	-----	-----	-----	-----	-----
Pectoral-fin origin-midcaudal base	-----	-----	20.7	-----	-----	-----	23.0	-----	-----	-----	-----	-----	24.6	-----	-----	-----	-----	-----
Pectoral-fin length	-----	-----	-----	-----	-----	-----	9.1	-----	-----	-----	-----	-----	9.6	-----	-----	-----	-----	-----
Pelvic-spine length	8.2	8.6	8.7	9.3	6.7	9.2	7.5	10.2	9.0	10.2	9.8	-----	10.0	10.3	10.3	10.6	11.0	-----
2d pelvic ray length	-----	-----	13.1	-----	10.9	-----	10.2	12.8	-----	-----	13.0	12.5	13.5	-----	-----	13.8	-----	-----
Eye diameter	7.3	6.7	8.0	7.7	8.0	7.8	7.7	7.5	7.7	8.0	8.5	8.2	8.3	7.9	8.0	7.6	9.7	8.8
Interorbital width	-----	-----	3.3	-----	-----	-----	3.5	-----	-----	-----	-----	-----	4.2	-----	-----	-----	-----	-----
Maxillary length	-----	-----	8.1	-----	-----	-----	7.9	-----	-----	-----	-----	-----	8.9	-----	-----	-----	-----	-----
3d dorsal ray length	-----	-----	7.5	-----	6.8	-----	8.0	8.2	-----	-----	9.6	-----	-----	-----	-----	8.9	-----	-----
3d anal ray length	-----	-----	7.7	-----	7.3	-----	8.7	8.2	-----	-----	8.4	-----	-----	-----	-----	9.1	-----	-----

TABLE A-1.—*Empirical measurements (mm.) of selected body parts for 248 specimens of* Pseudopriacanthus altus *from throughout its range*—Continued

Body part measured	Standard length (mm.) of specimen																	
	40.9	41.1	41.1	41.1	42.1	42.2	42.4	42.4	42.6	42.7	42.9	42.9	43.4	43.5	43.6	43.7	44.2	44.4
Depth from pelvic spine base to 3d dorsal spine base	27.7	26.0	------	------	------	26.2	------	------	26.4	26.7	26.4	------	27.0	25.4	25.2	26.6	------	29.1
Depth from 3d anal spine base to 10th dorsal spine base	22.5	20.3	------	------	------	22.1	------	------	22.3	22.4	22.4	------	22.9	21.6	21.9	22.9	------	24.3
Head length	17.8	16.6	17.3	16.3	16.9	17.8	16.9	17.2	17.0	17.2	17.5	17.0	18.2	18.8	17.0	17.4	17.9	18.4
Snout–dorsal-fin origin	16.4	14.5	------	------	------	------	------	------	------	------	------	------	------	17.2	------	------	------	------
Snout–dorsal-fin termination	36.8	36.6	------	------	------	------	------	------	------	------	------	------	------	37.8	------	------	------	------
Snout–anal-fin origin	28.4	29.7	------	------	------	------	------	------	------	------	------	------	------	30.5	------	------	------	------
Snout length	2.7	3.0	------	------	------	------	------	------	------	------	------	------	------	3.5	------	------	------	------
Postorbital length	6.2	5.4	------	------	------	------	------	------	------	------	------	------	------	5.6	------	------	------	------
Least depth of caudal peduncle	6.0	5.1	------	------	------	------	------	------	------	------	------	------	------	6.0	------	------	------	------
Dorsal-fin origin–midcaudal base	33.2	31.8	------	------	------	------	------	------	------	------	------	------	------	32.3	------	------	------	------
Dorsal-fin termination–midcaudal base	5.6	5.8	------	------	------	------	------	------	------	------	------	------	------	6.9	------	------	------	------
Anal-fin origin–midcaudal base	19.8	19.1	------	------	------	------	------	------	------	------	------	------	------	18.8	------	------	------	------
Anal-fin termination–midcaudal base	5.6	6.4	------	------	------	------	------	------	------	------	------	------	------	6.6	------	------	------	------
Dorsal-fin base	28.2	26.2	------	------	------	------	------	------	------	------	------	------	------	26.1	------	------	------	------
Anal-fin base	14.2	12.5	------	------	------	------	------	------	------	------	------	------	------	13.0	------	------	------	------
Pectoral-fin origin–snout	16.1	15.8	------	------	------	------	------	------	------	------	------	------	------	19.2	------	------	------	------
Pectoral-fin origin–midcaudal base	25.6	27.2	------	------	------	------	------	------	------	------	------	------	------	25.2	------	------	------	------
Pectoral-fin length	10.7	9.7	------	------	------	------	------	------	------	------	------	------	------	10.4	------	------	------	------
Pelvic-spine length	11.7	11.1	11.5	11.2	11.1	10.3	10.7	11.6	10.9	11.4	9.6	11.9	11.6	10.9	11.4	11.8	11.7	11.3
2d pelvic ray length	16.4	14.6	14.9	15.4	15.6	------	15.4	16.1	------	------	------	15.7	17.7	14.6	------	------	16.5	------
Eye diameter	8.7	8.6	8.9	8.3	9.2	8.9	8.9	8.6	8.9	8.9	9.5	8.5	8.9	10.8	8.4	9.0	9.9'	9.8
Interorbital width	4.1	3.9	------	------	------	------	------	------	------	------	------	------	------	3.5	------	------	------	------
Maxillary length	10.7	9.3	------	------	------	------	------	------	------	------	------	------	------	10.5	------	------	------	------
3d dorsal ray length	10.4	9.1	9.1	------	9.4	------	9.9	------	------	------	------	10.7	------	------	------	------	------	------
3d anal ray length	10.5	9.3	10.1	------	9.7	------	9.5	------	------	------	------	10.6	------	------	------	------	------	------

Body part measured	Standard length (mm.) of specimen																	
	44.5	44.9	45.2	45.5	45.5	45.6	46.5	46.6	47.1	47.2	47.2	47.3	48.2	48.3	48.4	48.6	49.0	49.3
Depth from pelvic spine base to 3d dorsal spine base	27.2	------	26.5	27.2	27.5	------	28.7	30.1	------	29.1	------	------	28.9	31.0	29.5	28.4	------	29.1
Depth from 3d anal spine base to 10th dorsal spine base	23.3	------	21.2	22.2	22.2	------	24.3	24.2	------	23.1	------	------	23.8	25.6	25.1	23.7	------	25.8
Head length	18.5	18.3	18.7	17.8	18.5	18.6	19.1	19.4	19.1	20.8	20.3	18.7	19.0	19.8	19.4	18.8	18.9	19.4
Snout–dorsal-fin origin	------	------	18.4	------	------	------	------	17.5	------	19.4	------	------	17.1	------	------	------	------	18.1
Snout–dorsal-fin termination	------	------	39.1	------	------	------	------	43.1	------	42.2	------	------	42.3	------	------	------	------	44.8
Snout–anal-fin origin	------	------	32.2	------	------	------	------	34.1	------	33.5	------	------	32.7	------	------	------	------	33.5
Snout length	------	------	2.8	------	------	------	------	3.2	------	3.6	------	------	3.4	------	------	------	------	3.5
Postorbital length	------	------	6.2	------	------	------	------	6.7	------	5.9	------	------	7.1	------	------	------	------	6.9
Least depth of caudal peduncle	------	------	5.8	------	------	------	------	6.1	------	6.5	------	------	5.9	------	------	------	------	6.4
Dorsal-fin origin–midcaudal base	------	------	32.6	------	------	------	------	37.2	------	35.2	------	------	37.5	------	------	------	------	39.0
Dorsal-fin termination–midcaudal base	------	------	6.0	------	------	------	------	6.7	------	6.8	------	------	6.7	------	------	------	------	7.3
Anal-fin origin–midcaudal base	------	------	19.4	------	------	------	------	22.4	------	21.3	------	------	22.0	------	------	------	------	23.8
Anal-fin termination–midcaudal base	------	------	6.4	------	------	------	------	7.0	------	7.9	------	------	7.3	------	------	------	------	7.2
Dorsal-fin base	------	------	26.5	------	------	------	------	30.4	------	29.2	------	------	30.7	------	------	------	------	32.8
Anal-fin base	------	------	13.1	------	------	------	------	15.3	------	13.7	------	------	14.6	------	------	------	------	16.8
Pectoral-fin origin–snout	------	------	18.7	------	------	------	------	19.4	------	19.8	------	------	18.3	------	------	------	------	19.0
Pectoral-fin origin–midcaudal base	------	------	27.3	------	------	------	------	30.6	------	28.0	------	------	31.6	------	------	------	------	32.0
Pectoral-fin length	------	------	11.7	------	------	10.5	------	11.8	------	12.2	------	------	10.5	------	------	------	------	11.2
Pelvic-spine length	12.7	12.4	------	11.6	11.3	12.6	12.6	12.4	13.6	11.7	12.4	13.6	12.9	11.8	13.9	12.8	13.1	12.7
2d pelvic ray length	------	16.3	16.3	------	------	15.3	------	17.0	17.7	17.5	17.5	17.8	16.8	18.1	------	------	17.8	17.4
Eye diameter	9.3	8.6	10.4	9.1	8.9	9.4	9.4	10.0	9.5	11.6	11.7	9.0	8.9	9.4	9.8	10.2	9.3	9.8
Interorbital width	------	------	4.0	------	------		------	4.5	------	4.7	------		4.7	------	------		------	4.8
Maxillary length	------	------	11.2	------	------	------	------	10.9	------	12.9	------	------	11.0	------	------	------	------	11.5
3d dorsal ray length	------	10.6	12.0	------	------	10.6	------	12.1	11.3	12.3	10.1	11.2	10.1	------	------	11.9	------	------
3d anal ray length	------	10.8	11.7	------	------	10.8	------	12.4	------	12.7	10.2	11.7	9.7	------	------	12.1	11.7	11.6

TABLE A-1.—*Empirical measurements (mm.) of selected body parts for 248 specimens of* Pseudopriacanthus altus *from throughout its range*—Continued

Body part measured	Standard length (mm.) of specimen																	
	49.3	49.4	50.8	52.0	52.3	52.6	53.5	53.9	54.3	55.6	55.9	57.1	57.3	57.9	58.9	62.5	63.2	63.4
Depth from pelvic spine base to 3d dorsal spine base	------	31.7	------	32.8	31.5	31.5	------	34.0	33.7	34.5	33.1	36.0	34.5	38.1	36.0	------	39.4	38.4
Depth from 3d anal spine base to 10th dorsal spine base	------	25.9	------	27.7	27.7	25.4	------	28.4	26.8	28.4	27.5	30.5	27.4	32.0	29.3	------	31.5	30.9
Head length	20.4	19.6	19.7	19.8	19.8	22.6	19.9	21.8	22.3	22.8	22.1	22.3	22.2	24.1	23.3	24.8	26.3	26.4
Snout-dorsal-fin origin	------	------	------	------	17.6	20.2	------	19.3	18.6	21.4	19.3	20.3	19.0	21.7	------	------	23.7	24.2
Snout-dorsal-fin termination	------	------	------	------	45.8	47.2	------	48.7	48.4	49.2	49.2	51.5	50.7	52.8	------	------	55.8	56.3
Snout-anal-fin origin	------	------	------	------	37.1	36.8	------	39.9	41.2	39.4	39.6	39.2	40.9	41.2	------	------	44.4	44.6
Snout length	------	------	------	------	3.9	4.2	------	4.0	4.1	4.9	4.2	4.4	4.2	4.5	------	------	5.0	4.9
Postorbital length	------	------	------	------	7.3	7.1	------	7.5	7.3	7.5	7.5	8.4	7.9	8.0	------	------	8.3	8.6
Least depth of caudal peduncle	------	------	------	------	6.6	7.0	------	7.1	6.8	7.1	6.8	7.7	7.1	8.3	------	------	8.3	8.9
Dorsal-fin origin-midcaudal base	------	------	------	------	40.8	38.8	------	42.5	40.7	41.5	43.0	46.6	45.1	46.5	------	------	48.9	47.3
Dorsal-fin termination-midcaudal base	------	------	------	------	8.0	7.1	------	7.1	7.6	8.1	8.0	8.3	8.1	8.8	------	------	8.9	9.5
Anal-fin origin-midcaudal base	------	------	------	------	24.3	23.8	------	25.4	24.1	25.7	25.9	27.2	26.1	26.7	------	------	29.4	27.1
Anal-fin termination-midcaudal base	------	------	------	------	8.2	7.6	------	8.3	8.3	9.1	8.1	8.5	8.7	8.6	------	------	10.2	8.8
Dorsal-fin base	------	------	------	------	33.4	32.0	------	35.6	33.3	34.2	35.5	38.6	37.6	38.7	------	------	40.6	39.2
Anal-fin base	------	------	------	------	16.1	15.8	------	17.3	16.5	16.9	17.0	19.5	17.8	19.0	------	------	18.7	19.2
Pectoral-fin origin-snout	------	------	------	------	19.6	21.2	------	20.6	23.2	22.7	22.9	21.0	23.1	22.2	------	------	24.8	24.6
Pectoral-fin origin-midcaudal base	------	------	------	------	34.0	33.1	------	35.0	33.3	36.1	33.8	39.0	36.5	36.5	------	------	39.8	39.6
Pectoral-fin length	------	------	------	------	12.3	14.1	------	13.3	13.0	14.4	------	13.2	13.0	13.9	------	------	15.7	15.6
Pelvic-spine length	13.3	13.2	12.1	14.4	11.6	13.5	12.2	13.2	13.2	14.0	13.6	14.6	14.8	13.6	15.6	15.8	16.8	15.4
2d pelvic ray length	------	------	16.8	------	17.9	19.0	16.5	19.7	20.4	21.0	20.6	20.0	20.1	23.8	------	------	24.3	23.3
Eye diameter	9.8	9.9	9.9	10.0	10.5	12.3	10.6	10.7	11.2	12.5	10.3	10.6	10.5	12.0	12.0	12.7	14.0	14.0
Interorbital width	------	------	------	------	5.1	4.7	------	5.2	5.1	4.9	5.4	5.8	5.4	5.8	------	------	5.0	5.8
Maxillary length	------	------	------	------	11.6	12.3	------	12.6	12.3	12.3	11.8	13.0	12.8	13.8	------	------	15.0	14.7
3d dorsal ray length	------	11.9	------	------	11.9	14.7	------	------	12.7	15.3	------	13.7	12.3	15.7	14.8	------	17.1	17.0
3d anal ray length	------	12.0	------	------	12.4	13.7	------	------	13.7	14.4	------	14.7	12.8	14.9	15.0	------	18.1	17.0

Body part measured	Standard length (mm.) of specimen																	
	63.7	65.2	66.1	67.3	70.8	71.7	73.2	77.5	77.9	78.2	78.3	79.2	82.7	84.5	86.2	87.2	89.4	90.4
Depth from pelvic spine base to 3d dorsal spine base	36.4	38.1	30.8	40.5	38.9	40.0	42.8	43.3	43.9	44.0	42.3	43.5	51.9	49.1	51.1	50.5	51.2	51.6
Depth from 3d anal spine base to 10th dorsal spine base	30.4	31.5	33.1	33.6	33.8	33.7	36.1	35.3	34.8	36.2	34.8	------	40.4	30.2	38.4	38.9	41.7	40.5
Head length	26.3	27.3	27.7	27.9	29.6	28.8	27.8	30.2	33.5	30.4	29.7	32.1	33.2	35.3	35.8	35.2	37.8	34.8
Snout-dorsal-fin origin	23.1	24.0	25.7	24.2	24.6	27.3	26.2	29.1	25.1	26.6	29.1	29.8	28.6	------	------	------	------	32.6
Snout-dorsal-fin termination	56.1	57.8	58.2	58.7	62.1	63.6	65.0	68.2	------	68.0	67.9	69.5	72.5	------	------	------	------	78.9
Snout-anal-fin origin	44.3	45.8	44.3	45.2	59.9	51.2	53.4	51.3	------	52.6	53.7	------	59.8	------	------	------	------	62.7
Snout length	4.9	4.4	5.3	5.7	5.8	6.0	6.0	5.9	5.9	6.2	5.5	6.1	6.2	------	------	------	------	7.1
Postorbital length	8.3	8.6	8.9	9.4	9.6	9.9	9.1	8.8	12.4	10.1	9.1	9.4	10.4	------	------	------	------	10.2
Least depth of caudal peduncle	8.5	8.9	8.6	8.9	9.5	9.4	9.6	10.2	9.7	9.7	9.9	9,9	11.6	------	------	10.9	------	11.1
Dorsal-fin origin-midcaudal base	48.9	50.2	50.5	51.6	54.3	53.3	55.1	58.7	57.4	58.9	59.0	59.0	62.6	------	------	65.0	------	68.3
Dorsal-fin termination-midcaudal base	9.2	9.8	9.4	9.6	11.1	11.3	10.6	11.6	12.3	11.0	12.7	12.2	11.5	------	------	12.2	------	15.0
Anal-fin origin-midcaudal base	29.4	29.4	30.6	32.4	31.0	30.5	32.1	35.9	35.3	37.0	35.4	------	37.7	------	------	38.8	------	39.2
Anal-fin termination-midcaudal base	10.6	10.0	10.3	10.6	11.1	10.6	10.9	12.8	12.4	11.3	12.5	------	12.6	------	------	13.9	------	13.9
Dorsal-fin base	39.7	40.0	41.2	42.2	42.5	43.7	45.1	48.0	45.7	48.7	46.8	47.5	52.1	------	------	52.2	------	54.8
Anal-fin base	19.2	19.3	21.2	21.3	20.3	21.5	21.1	23.5	23.4	22.9	22.3	------	24.7	------	------	25.1	------	25.5
Pectoral-fin origin-snout	24.6	27.3	26.3	27.4	28.0	28.0	28.9	29.6	------	29.6	28.9	34.5	32.4	------	------	------	------	36.5
Pectoral-fin origin-midcaudal base	41.1	41.2	40.0	42.4	45.0	44.6	48.5	50.0	47.0	48.1	51.4	48.1	51.6	------	------	54.0	------	56.0
Pectoral-fin length	14.6	16.7	16.4	17.1	17.9	18.6	14.9	18.3	18.5	18.7	18.8	19.3	17.5	------	------	18.5	------	21.7
Pelvic-spine length	15.3	15.8	16.6	17.3	17.3	18.4	17.6	19.4	18.7	19.9	19.2	19.5	20.7	21.9	22.4	21.0	------	22.1
2d pelvic ray length	20.7	25.4	23.8	26.0	27.0	28.2	24.2	27.7	28.7	29.8	26.8	29.7	28.2	32.6	------	31.5	25.7	32.7
Eye diameter	14.0	15.1	14.6	14.5	15.7	15.0	15.6	17.0	16.4	17.4	16.3	18.9	16.6	17.8	20.5	17.1	21.0	19.3
Interorbital width	5.5	5.3	5.6	5.9	6.0	6.7	6.0	6.6	6.2	6.1	6.4	6.4	7.8	------	------	7.4	------	7.4
Maxillary length	15.0	15.5	15.5	15.6	16.5	------	15.6	18.1	16.9	18.2	17.7	------	18.4	19.5	------	19.1	------	22.0
3d dorsal ray length	16.3	16.7	------	17.1	18.8	------	17.5	22.1	22.5	23.1	17.3	------	23.7	26.0	27.9	26.6	30.4	28.3
3d anal ray length	15.2	18.6	------	19.2	19.4	------	18.0	23.1	22.6	21.9	21.3	------	23.0	23.3	26.5	23.2	25.7	24.4

TABLE A-1.—*Empirical measurements (mm.) of selected body parts for 248 specimens of* Pseudopriacanthus altus *from throughout its range*—Continued

Body part measured	Standard length (mm.) of specimen																	
	90.5	92.1	92.4	92.7	94.3	96.3	103.1	106.0	106.1	108.3	121.3	129.8	133.4	137.2	149.2	161.0	161.0	165.8
Depth from pelvic spine base to 3d dorsal spine base	------	57.4	52.1	53.2	52.8	53.7	62.1	57.1	57.4	60.3	65.0	72.6	69.2	76.4	79.8	82.4	85.9	89.5
Depth from 3d anal spine base to 10th dorsal spine base	------	46.6	43.1	44.4	43.8	45.8	51.4	45.2	45.3	49.3	54.5	56.6	57.2	62.4	65.8	69.1	72.4	74.1
Head length	------	36.6	35.7	36.1	37.2	37.5	40.7	41.5	40.5	45.7	49.3	50.9	51.0	52.3	58.1	59.3	62.2	63.6
Snout-dorsal-fin origin	------	34.0	30.1	31.6	34.0	35.9	------	41.2	37.8	40.0	44.0	45.9	46.1	47.5	51.9	------	------	55.1
Snout-dorsal-fin termination	------	82.7	81.0	81.1	81.3	84.0	------	93.4	91.2	95.5	103.7	112.1	116.9	120.2	130.1	------	------	148.6
Snout-anal-fin origin	------	65.1	67.4	65.1	61.7	65.4	------	73.5	68.7	77.6	83.8	88.1	91.4	96.1	107.8	------	------	121.5
Snout length	------	8.6	7.4	8.4	8.0	7.3	------	7.6	7.6	9.7	10.5	11.2	11.5	10.8	13.6	------	------	14.6
Postorbital length	------	12.0	11.0	10.9	11.8	12.0	------	12.2	12.9	12.8	14.5	15.5	15.2	16.7	17.5	------	------	20.6
Least depth of caudal peduncle	------	12.2	11.9	12.0	11.9	12.4	------	13.1	12.8	13.9	15.2	16.1	16.5	17.6	19.3	------	------	20.7
Dorsal-fin origin-midcaudal base	------	73.1	69.4	70.1	71.8	72.0	------	77.8	79.2	77.5	89.4	97.9	100.3	103.8	108.1	------	------	124.5
Dorsal-fin termination-midcaudal base	------	14.1	13.1	14.6	14.4	14.3	------	15.3	15.7	15.5	21.5	20.6	20.6	20.8	23.0	------	------	25.0
Anal-fin origin-midcaudal base	------	43.4	40.5	41.6	43.5	44.5	------	46.9	48.7	48.3	50.6	58.0	59.6	60.3	63.2	------	------	71.1
Anal-fin termination-midcaudal base	------	15.2	13.3	14.4	14.8	15.8	------	17.1	18.1	16.8	19.2	21.7	21.5	21.3	22.5	------	------	25.3
Dorsal-fin base	------	58.8	56.6	56.5	58.2	58.7	------	62.5	63.9	62.1	70.2	78.8	81.2	83.6	87.0	------	------	102.2
Anal-fin base	------	28.5	28.3	27.6	29.5	28.4	------	30.2	30.6	31.1	31.4	36.5	38.4	38.9	40.5	------	------	45.4
Pectoral-fin origin-snout	------	37.2	37.6	36.3	35.4	36.3	------	39.0	39.8	45.2	46.9	50.6	51.6	51.5	59.8	------	------	66.0
Pectoral-fin origin-midcaudal base	------	60.2	59.7	58.7	58.0	62.2	------	69.0	72.8	65.1	78.0	81.2	85.1	90.3	95.3	------	------	104.2
Pectoral-fin length	------	22.8	21.1	20.2	25.3	21.8	------	25.2	25.2	25.9	29.0	29.0	27.8	33.1	29.7	------	------	39.2
Pelvic-spine length	23.1	22.8	22.9	22.0	23.2	22.7	27.6	28.1	22.9	26.2	31.5	30.1	30.6	34.1	36.2	35.1	37.0	39.1
2d pelvic ray length	34.2	32.2	35.3	34.3	36.8	32.5	41.5	39.3	36.8	36.3	43.2	39.5	41.2	54.9	50.4	52.8	52.0	52.3
Eye diameter	19.2	17.9	18.0	18.7	19.8	19.3	19.9	21.7	21.7	24.1	26.2	26.7	27.1	25.7	29.0	30.3	31.0	31.5
Interorbital width	------	8.3	7.2	7.3	7.6	8.4	------	8.7	8.0	7.8	9.3	11.1	11.1	11.4	12.5	------	------	14.4
Maxillary length	------	21.3	20.0	20.0	21.4	21.2	------	24.2	23.5	25.5	29.5	26.9	27.9	29.7	31.5	------	------	35.0
3d dorsal ray length	------	25.6	30.3	28.4	31.2	27.2	------	31.9	30.8	27.0	35.2	35.7	34.3	42.3	43.8	48.3	46.3	47.6
3d anal ray length	------	26.1	26.5	25.4	28.9	24.6	------	30.9	28.2	26.1	31.5	35.0	35.1	41.0	41.9	41.1	41.9	44.7

Body part measured	Standard length (mm.) of specimen																	
	166.5	167.0	167.5	169.9	176.9	179.2	179.3	182.1	183.6	190.9	193.8	195.3	196.5	196.9	198.9	201.7	204.3	208.6
Depth from pelvic spine base to 3d dorsal spine base	87.9	93.0	86.4	82.2	------	------	------	------	100.6	------	------	------	107.8	100.7	------	103.2	102.4	------
Depth from 3d anal spine base to 10th dorsal spine base	71.8	72.5	74.1	66.6	------	------	------	------	81.8	------	------	------	85.9	80.4	------	82.2	84.6	------
Head length	60.6	64.7	61.6	70.5	------	------	------	------	71.2	------	------	------	77.1	73.9	------	77.2	73.4	------
Snout-dorsal-fin origin	57.3	59.0	57.6	64.1	------	------	------	------	63.9	------	------	------	63.5	66.4	------	72.6	70.3	------
Snout-dorsal-fin termination	144.0	144.8	145.7	146.1	------	------	------	------	160.6	------	------	------	169.8	170.9	------	174.4	174.4	------
Snout-anal-fin origin	117.2	115.8	118.9	117.8	------	------	------	------	128.6	------	------	------	139.4	140.3	------	134.2	128.8	------
Snout length	14.6	15.3	16.2	15.0	------	------	------	------	16.5	------	------	------	18.5	16.4	------	18.3	19.1	------
Postorbital length	18.2	18.9	19.0	17.8	------	------	------	------	21.8	------	------	------	22.5	21.0	------	23.2	21.5	------
Least depth of caudal peduncle	19.1	21.1	21.5	19.4	------	------	------	------	23.2	------	------	------	23.6	23.2	------	25.1	25.1	------
Dorsal-fin origin-midcaudal base	124.5	123.0	125.4	118.5	------	------	------	------	136.4	------	------	------	143.1	142.1	------	148.2	154.5	------
Dorsal-fin termination-midcaudal base	28.0	26.7	25.4	28.9	------	------	------	------	25.7	------	------	------	29.6	29.7	------	30.4	34.7	------
Anal-fin origin-midcaudal base	70.3	75.5	72.9	68.7	------	------	------	------	82.6	------	------	------	90.3	88.7	------	91.0	93.2	------
Anal-fin termination-midcaudal base	28.0	30.1	28.4	25.0	------	------	------	------	29.5	------	------	------	33.8	33.3	------	35.9	37.0	------
Dorsal-fin base	98.9	97.8	102.0	91.4	------	------	------	------	111.4	------	------	------	115.5	114.2	------	118.4	123.2	------
Anal-fin base	45.2	46.6	45.0	39.8	------	------	------	------	52.6	------	------	------	56.7	52.7	------	55.1	56.7	------
Pectoral-fin origin-snout	62.0	63.9	64.6	66.5	------	------	------	------	66.2	------	------	------	82.7	78.2	------	76.7	73.1	------
Pectoral-fin origin-midcaudal base	107.2	111.9	107.5	111.0	------	------	------	------	125.9	------	------	------	128.9	130.3	------	138.2	133.5	------
Pectoral-fin length	36.8	38.6	37.8	39.1	------	------	------	------	39.1	------	------	------	42.1	43.2	------	45.5	43.5	------
Pelvic-spine length	38.4	39.0	38.8	36.2	38.2	39.6	31.8	39.2	39.4	41.6	42.6	45.0	43.3	45.4	42.0	43.6	40.6	49.8
2d pelvic ray length	53.3	54.5	59.7	49.1	54.0	56.2	49.7	60.5	54.2	54.5	55.9	62.7	60.8	58.7	54.2	60.0	63.4	60.2
Eye diameter	32.0	34.1	30.8	32.1	34.4	38.2	37.4	32.4	35.1	40.3	41.3	41.2	36.5	39.4	38.0	39.4	37.3	45.4
Interorbital width	11.9	12.6	13.2	12.2	------	------	------	------	14.0	------	------	------	15.7	15.3	------	16.5	16.8	------
Maxillary length	33.5	37.4	33.8	37.6	------	------	------	------	38.6	------	------	------	42.6	43.1	------	43.7	41.3	------
3d dorsal ray length	44.2	51.6	47.6	43.2	------	------	------	------	48.7	------	------	------	53.8	51.8	------	52.8	49.5	------
3d anal ray length	42.6	44.0	44.1	41.2	------	------	------	------	44.2	------	------	------	50.4	48.0	------	46.6	48.7	------

TABLE A-1.—*Empirical measurements (mm.) of selected body parts for 248 specimens of* Pseudopriacanthus altus *from throughout its range*—Continued

Body part measured	Standard length (mm.) of specimen																	
	210.7	211.5	213.2	214.0	214.7	215.6	215.6	216.8	217.1	218.5	219.4	220.6	221.5	223.7	223.8	225.4	226.8	227.0
Depth from pelvic spine base to 3d dorsal spine base	109.1					106.5										108.7	116.7	109.5
Depth from 3d anal spine base to 10th dorsal spine base	81.8					90.9										88.0	93.5	90.7
Head length	88.0					80.8										87.4	87.1	82.8
Snout-dorsal-fin origin	71.8					75.2										76.5	79.5	77.7
Snout-dorsal-fin termination	179.5					185.7										193.8	195.2	189.8
Snout-anal-fin origin	156.9					149.7										158.9	159.3	158.6
Snout length	20.5					20.6										21.3	18.8	19.5
Postorbital length	23.1					26.2										24.7	26.4	29.0
Least depth of caudal peduncle	23.4					25.2										26.0	27.1	25.6
Dorsal-fin origin-midcaudal base	146.9					156.7										159.8	166.1	166.9
Dorsal-fin termination-midcaudal base	31.7					34.5										37.0	35.9	36.6
Anal-fin origin-midcaudal base	87.6					91.0										94.9	99.8	95.4
Anal-fin termination-midcaudal base	34.4					35.6										40.2	40.0	39.2
Dorsal-fin base	117.3					124.2										125.5	130.3	128.4
Anal-fin base	52.2					57.6										56.7	59.4	58.4
Pectoral-fin origin-snout	89.5					81.6										85.6	84.5	84.5
Pectoral-fin origin-midcaudal base	133.5					136.9										150.6	150.4	152.3
Pectoral-fin length	48.5					40.8										48.4	46.6	
Pelvic-spine length	49.2	43.2	42.8	44.6	47.3	44.0	46.5	45.5	45.4	43.9	43.6	45.0	43.3	46.0	47.3	51.0	47.8	42.9
2d pelvic ray length	60.2	60.6	58.6	60.4	66.9	62.3	62.4	62.7	60.7	59.2	63.1	62.4	58.8	63.1	62.1	60.9	62.0	62.1
Eye diameter	44.1	40.5	45.3	41.8	42.9	40.1	43.0	41.5	41.5	39.1	41.2	43.5	46.2	42.5	45.1	47.6	46.2	38.1
Interorbital width	16.0					16.8										17.1	17.4	15.7
Maxillary length	45.2					43.1										47.3	45.6	42.9
3d dorsal ray length	55.7					50.4										54.3	57.1	52.0
3d anal ray length	55.9					46.4										53.8	54.1	50.0

Body part measured	Standard length (mm.) of specimen													
	228.6	235.6	236.0	236.6	238.2	238.4	239.0	239.3	242.5	242.7	245.5	250.0	254.9	261.8
Depth from pelvic spine base to 3d dorsal spine base			117.4	120.3					119.9			123.8		124.0
Depth from 3d anal spine base to 10th dorsal spine base			94.6	96.0					95.6			103.2		104.4
Head length			85.0	89.0					89.4			94.3		96.7
Snout-dorsal-fin origin			83.8	81.1					82.8			85.4		83.0
Snout-dorsal-fin termination			196.4	200.2					205.0			217.8		225.0
Snout-anal-fin origin			168.3	161.9					165.7			180.6		184.8
Snout length			20.8	20.1					21.0			24.0		25.5
Postorbital length			21.7	27.5					25.3			27.5		31.2
Least depth of caudal peduncle			27.5	28.2					27.9			31.0		30.1
Dorsal-fin origin-midcaudal base			160.5	171.4					174.6			178.4		187.5
Dorsal-fin termination-midcaudal base			32.1	39.4					40.8			39.8		42.4
Anal-fin origin-midcaudal base			93.1	105.4					104.4			105.6		112.7
Anal-fin termination-midcaudal base			36.5	42.8					43.9			42.6		44.1
Dorsal-fin base			120.5	133.0					136.3			142.8		147.5
Anal-fin base			57.5	63.1					61.1			63.5		68.4
Pectoral-fin origin-snout			89.6	90.9					88.5			97.9		102.6
Pectoral-fin origin-midcaudal base			152.3	151.4					157.8			163.5		173.5
Pectoral-fin length			53.8	49.2					45.5			47.5		53.6
Pelvic-spine length	47.8	51.0	52.0	48.9	48.1	46.3	49.1	50.3	45.6	51.1	45.1	55.1	49.1	54.8
2d pelvic ray length	61.8	66.1	63.0	66.6	67.9	69.7	64.3	67.6	62.5	66.6	66.3	68.0	65.4	75.5
Eye diameter	45.4	49.7	47.7	47.4	45.7	44.1	48.1	50.2	46.6	47.3	45.5	47.4	47.2	49.0
Interorbital width			16.0	17.2					17.3			20.1		20.8
Maxillary length			51.7	46.4					48.5			49.6		48.7
3d dorsal ray length			52.3	63.6					60.3			60.7		62.5
3d anal ray length			53.2	58.3					53.3			57.8		58.5

ADDENDUM

After the manuscript for this paper had gone to press, a recent paper by Paulo de Miranda Ribeiro came to my attention (Alguns peixes pouco conhecidos ocorrendo na costa Brasileira, *Boletim do Museu Nacional, Rio de Janeiro, nova serie, zoologia*, no. 224, p. 1–11, 1961). In this paper, Miranda Ribeiro described and figured a specimen, apparently a priacanthid, which he designated as *P. altus*. The specimen was collected far offshore between Florianopolis and Laguna, Brazil (at latitude 28°45′ S., longitude 47°50′ W.), and is thus so far out of the geographical range given in the present paper for this species that it requires comment.

The specimen clearly is not *P. altus*. The reasons for this become evident when Miranda Ribeiro's description and figure are compared with my data and figures presented in this paper. Miranda Ribeiro did not include many pertinent facts which would positively identify his specimen, but it most closely resembles *Cookeolus boops* (Bloch and Schneider) and is from within the recorded range of that species. Although coming from within or near the ranges of the two western Atlantic species of the genus *Priacanthus*, it does not fit the descriptions of these two species. I have recently treated the four western Atlantic priacanthids with illustrations and a key (Caldwell, in press).

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